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State of Geodesy 2026

A baseline maturity
assessment



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State of Geodesy 2026: A baseline maturity assessment

United Nations Global Geodetic Centre of Excellence (2026)

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Responsibility for the findings, interpretations, and any errors in this report rests with the UN-GGCE.

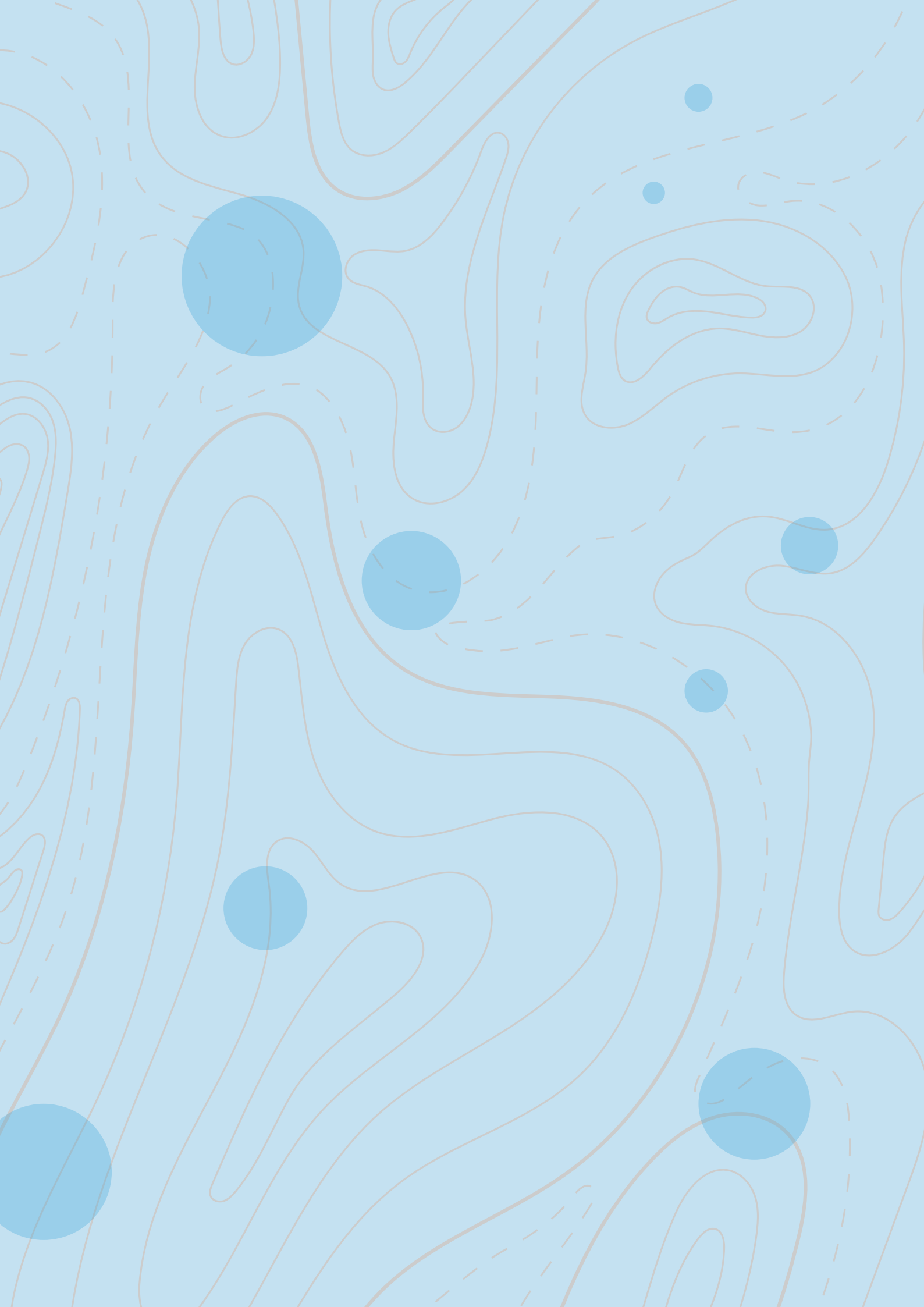
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Acronyms and Abbreviations

BKG	Federal Agency for Cartography and Geodesy (Germany)
CDDIS	Crustal Dynamics Data Information System
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite
EOP	Earth Orientation Parameters
FAIR	Findable, Accessible, Interoperable, and Reusable (data principles)
FIG	International Federation of Surveyors (Fédération Internationale des Géomètres)
GGSC	Global Geodesy Supply Chain
GGOS	Global Geodetic Observing System (of the IAG)
GNSS	Global Navigation Satellite Systems
IAG	International Association of Geodesy
ICRF	International Celestial Reference Frame
ISO	International Organization for Standardization
ITRF	International Terrestrial Reference Frame
JDP	Joint Development Plan for Global Geodesy
MoU	Memorandum of Understanding
OGC	Open Geospatial Consortium
PPP	Precise Point Positioning
SCoG	Subcommittee on Geodesy (UN-GGIM)
SLR	Satellite Laser Ranging
SoG	State of Geodesy
UN	United Nations
UN GA	United Nations General Assembly
UN-GGCE	United Nations Global Geodetic Centre of Excellence
UN-GGIM	United Nations Committee of Experts on Global Geospatial Information Management
VGOS	VLBI Global Observing System
VLBI	Very Long Baseline Interferometry



Executive Summary

From mandate to action

In February 2015, the United Nations General Assembly adopted Resolution 69/266, “A Global Geodetic Reference Frame for Sustainable Development.” This landmark resolution serves as the strongest international mandate for geodesy, formally recognising that no single nation can maintain the Earth’s positioning and reference frame infrastructure alone.

To act upon this mandate, the international community is now focused on securing a robust Global Geodesy Supply Chain (GGSC), which comprises the end-to-end system of observatories, data centres, and expert analysis that generates the geodetic products essential for satellite operations, positioning services, timing synchronisation, and Earth observation. By strengthening this supply chain, the UN-GGCE directly addresses the “hidden risk” of systemic infrastructure failure, ensuring that the geodetic foundation remains stable for the benefit of global safety, economic prosperity, and sustainable development.

What is geodesy and why does it matter?

Geodesy is the science of measuring Earth’s shape, orientation, gravity field, and changes over time. Satellites depend on constant updates about their position in space and Earth’s position and orientation. These geodetic products enable:

- Global Navigation Satellite Systems (GPS, Galileo, GLONASS, BeiDou) to provide accurate positioning to billions of users.
- Telecommunications networks to synchronise time across cell towers with microsecond precision.
- Financial systems to timestamp transactions for regulatory compliance and fraud detection.
- Energy grids to monitor and control power distribution in real-time.
- Climate science to track millimetre-scale sea level rise and centimetre-scale land subsidence.
- Space operations to manage satellite orbits and avoid collisions.

In October 2024, operators of the world’s Global Navigation Satellite Systems (GNSS) issued an unprecedented joint statement acknowledging that weaknesses in the GGSC pose risks to continuous satellite services—underscoring both the interdependence between satellites and geodesy, and the urgency of understanding supply chain vulnerabilities.

Purpose and context

This document presents the first comprehensive maturity assessment of the GGSC. Despite geodesy’s critical role in modern infrastructure – from telecommunications and financial systems to climate monitoring and navigation – the supply chain has never been systematically evaluated as an integrated system.

Methodology

The assessment evaluated 58 capabilities across six domains using a five-level maturity scale (Level 1 = Undefined / Basic / Ad-hoc / Siloed, Level 5 = optimised). Capabilities were assessed across four dimensions: People, Processes, Technologies, and Data. The framework integrated best practices from data management, asset management, and enterprise architecture standards, adapted specifically for geodetic infrastructure.

Assessment scores were developed through:

- Analysis of the 2024 Global Geodesy Needs Assessment (500+ stakeholders across 110 countries).
- Consultation with 130+ leaders from the International Association of Geodesy (IAG), UN Committee of Experts on Global Geospatial Information Management Subcommittee on Geodesy, and UN Global Geodetic Centre of Excellence.

Each score includes a confidence level (high, medium, low) acknowledging the pioneering nature of this work and inherent limitations in available evidence.

Domain-level performance

The GGSC achieved an overall average maturity score of 2.3 out of 5, placing it between Level 2 (“Repeatable”) and Level 3 (“Defined”). This indicates a system with established operational capabilities and some standardised processes, but significant variation across functional areas.

Critical Pattern: Governance as cross-cutting constraint

The assessment identified governance and financial management capabilities receiving Level 1 scores (the lowest level), indicating these functions are largely absent or operate ad-hoc without formal structures. Specifically:

- Mandate development (1.0): Despite over ten years since the UN General Assembly Resolution 69/266, no international organisation has formal authority to develop, implement, or enforce policies for the GGSC.

- Strategic planning (1.0): Plans exist but lack governmental authority for implementation.
- Financial management (1.0): No coordinated mechanisms for assessing needs, developing investment strategies, or allocating resources across the supply chain.
- Risk management (1.0): No systematic risk assessment or mitigation at supply chain level.

The IAG provides effective scientific and technical coordination within its scope, with well-defined processes and strong compliance at IAG-affiliated observatories (score 3.0). However, as a scientific membership organisation, the IAG operates without governmental authority to direct Member State actions, mandate resource contributions, or enforce operational requirements beyond its member institutions.

At the intergovernmental level, UN General Assembly resolution 69/266 represents the strongest mandate for geodesy, but as a non-binding resolution, it encourages voluntary action without implementation mechanisms or accountability structures.

Domain	Score	Interpretation
Data Management	2.7	Relatively mature data acquisition and processing for established techniques, but gaps in governance, quality management, and preservation.
Data Products & Software	2.3	Reasonable capability in reference frames and product generation, but vulnerabilities in software development and service delivery.
Asset & Infrastructure Management	2.3	Adequate equipment maintenance when resourced, but fundamental gaps in network oversight and supply chain modelling.
Engagement & Collaboration	2.2	Effective scientific coordination, but weak policy communication and minimal public awareness.
Innovation & Development	2.1	Active research prototyping, but ad-hoc and uncoordinated, with poor knowledge management.
Governance & Strategy	1.8	Multiple Level 1 capabilities in mandate, policy, strategic planning, and all financial management functions.

Observable effects of governance constraints

The governance gaps correlate with lower maturity in several areas:

Risk and Continuity (scores 1.0-1.7):

- No systematic supply chain risk assessment or disaster recovery planning.
- Single points of failure identified (e.g., CDDIS¹ as sole comprehensive archive for some datasets; specific analysis centres without redundant backup).
- Limited coordinated strategies for extended observatory outages.

Workforce Development (score 1.7):

- Declining university geodesy programs in multiple regions.
- Aging workforce without proportional new professional development.
- Concentration of specialised expertise among individuals approaching retirement.
- Poor knowledge management (score 1.3) with limited documentation and no centralised repositories.

Public and Policy Awareness (score 1.3):

- Minimal systematic outreach to policymakers or public.
- Geodesy unfamiliar to most decision-makers despite its critical infrastructure role.
- Few evidence-based materials explaining geodesy's societal importance.

Financial Sustainability:

- Significant reliance on voluntary in-kind contributions.
- Personnel seeking competitive grants to supplement operational funding.
- Over half of the Very Long Baseline Interferometry (VLBI) and Satellite Laser Ranging (SLR) stations are aging or degrading without clear modernisation funding.

- Staff contributing to critical functions (e.g., standards development) on personal time.

Strengths within current structure

Despite structural constraints, the assessment identified strong technical performance in several areas:

- GNSS data acquisition and analysis (scores 3.5-3.8): Extensive global network with good coordination through International GNSS Service.
- DORIS system (score 4.0): Well-distributed network with consistent institutional support from France.
- Equipment calibration and maintenance (score 3.3): Strong technical expertise and established procedures at IAG facilities.
- Standards development (score 3.0): Active participation in International Organization for Standardization (ISO), Open Geospatial Consortium (OGC), and other technical bodies.
- Reference frame maintenance (score 3.0): Established processes with multiple software tools available globally.

Areas Requiring Further Investigation

The assessment identified several areas where available evidence was insufficient for confident evaluation:

- 1 Supply chain architecture: No comprehensive technical specification exists defining the design of an accurate and reliable GGSC needed to meet user requirements.
- 2 Security requirements: Low confidence in physical and cyber security assessments. A systematic evaluation is needed if geodesy is designated as critical infrastructure.
- 3 Data centre coordination: Conflicting accounts of mirroring practices, backup arrangements, and disaster recovery capabilities require systematic documentation.
- 4 Software sustainability: Insufficient evidence on software quality standards, security audits, dependencies on individual developers, and succession planning.

¹ NASA's Crustal Dynamics Data Information System (CDDIS) provides data and information to support the international space geodesy community.

- 5 Quantitative workforce trends: Anecdotal reports of decline lack systematic data on program numbers, enrolment rates, age demographics, and skill gaps.
- 6 Economic analysis: Current investment levels unknown, required resources unquantified, and cost-benefit comparisons not performed.

Limitations

This assessment has inherent limitations as it is the first systematic evaluation of the GGSC:

- Evidence base: Primarily from IAG-affiliated experts; consequently, perspectives from commercial networks, non-IAG agencies, and private users may be underrepresented.
- Temporal snapshot: Reflects status as of May 2025; conditions at individual facilities may change over time.
- Framework: The 58-capability model represents a first attempt; alternative taxonomies might yield different insights.
- Scoring methodology: Reflects expert judgment rather than quantitative measurement; different assessors might assign different scores.
- Geographic coverage: Stronger evidence from regions with active IAG participation than from developing countries or emerging programs.
- Confidence levels: Qualitative subjective assessments rather than quantitative measures.

Interpretation

The maturity assessment describes a GGSC that currently operates and produces geodetic products supporting numerous applications, while exhibiting significantly lower maturity in governance, strategic planning, financial management, and coordination functions that typically require authority and resources at the international level.

The variation in scores reflects historical development through in-kind scientific collaboration that has produced strong technical capabilities within geodetic technique communities, but has not established overarching governance, strategic planning, and coordination mechanisms characteristic of mature critical infrastructure systems.

Current operational performance reflects the technical expertise and institutional commitment of participating organisations, functioning within resource constraints and organisational structures evolved for scientific collaboration. The concentration of Level 1 scores in foundational governance and financial management capabilities, combined with widespread reliance on in-kind contributions across multiple domains, raises questions about whether current structural arrangements provide adequate resilience, sustainability, and coordination capacity given the supply chain's role supporting critical infrastructure and societal applications.

The assessment findings establish a baseline for understanding the current state of geodesy –with both strengths in technical operations and gaps in strategic coordination. This lays the foundation for future decisions about international cooperation, resource allocation, and governance arrangements for global geodesy.

Note: This assessment is descriptive, establishing baseline understanding of current state. It does not provide recommendations for action. Subsequent policy analysis from the UN-GGIM Subcommittee on Geodesy with support from UN-GGCE will examine options for addressing identified gaps and vulnerabilities.

1. Introduction

Modern society relies on satellites. Satellite information is essential for economic growth, the operation of critical infrastructure, and is a cornerstone of national defence forces. But have you ever stopped to think about what satellites rely on?

Satellites are reliant on constant updates about their place in space (satellite orbit information) and the Earth's place in space (shape, orientation, gravity field, and coordinate reference frame). This Earth and satellite place in space information are collectively known as geodetic products. Constant updates to the geodetic products are needed because the Earth and satellites are always moving.

Geodesy is the science of measuring and understanding Earth's shape, orientation in space, and gravity field and it is performed every day, by people all around the world to ensure geodetic products, and satellite services are accurate and reliable.

As digital technologies increasingly rely on precise positioning and timing information, and as Earth observation becomes critical for understanding environmental change, geodesy has evolved from a specialised scientific concern into essential public infrastructure comparable to communication networks or power grids.

Despite its critical importance, the global geodesy supply chain has never been comprehensively assessed. Individual components have been evaluated. Technical capabilities have been documented. But critical questions remain unanswered:

- How well do these elements function together?
- Where do vulnerabilities exist?
- Does the current architecture meet the demands being placed upon it?

This report addresses that gap. It presents the first comprehensive maturity assessment of the global geodesy supply chain.

The assessment comes at a pivotal moment. Demand for geodetic services is accelerating across sectors— from autonomous vehicles requiring centimetre-level positioning to climate scientists tracking millimetre-scale sea level rise. Simultaneously, the infrastructure delivering these services faces mounting challenges: aging ground networks, funding uncertainties, fragmented governance, and increasing complexity as new technologies and user requirements emerge.

1.1 Purpose and scope

This assessment aims to provide government officials and policymakers with a clear understanding of the current state of global geodesy, the maturity of its supply chain, and the structural weaknesses that threaten its ability to meet present and future demands. The analysis is intentionally comprehensive, examining not only technical capabilities but also the organisational, governance, and sustainability dimensions that determine whether the system can reliably deliver critical services.

1.2 What is the global geodesy supply chain?

The global geodesy supply chain (GGSC) refers to all components for establishing geodetic products:

- **ground station observatories and observers** who monitor the movement of Earth and satellites. These observatories use geodetic measurement techniques such as Global Navigation Satellite Systems (GNSS), Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS), and gravity measurements from several Earth observation missions;
- **data centres and data centre operators** who collect, quality check, store, archive and distribute the data from observatories and make it available to the global analysis community; and
- **analysis centres, correlation centres, and analysts** who translate the data into geodetic products including Earth Orientation Parameters, Global Coordinate Reference Frames, satellite orbits, clock corrections, and models of the Earth's gravitational field.

Figure 1. Simplified schematic of the global geodesy supply chain



It is a *global* geodesy supply chain because the observatories and highly qualified people need to be distributed around the world to achieve the required accuracy and reliability of the geodetic products. Figure 1 illustrates this start-to-end process of the GGSC, from ground observations to usable geodetic products that keep satellites operational and accurate.

The GGSC is comprised of *structural* (i.e., material) and *operational* (i.e., non-material) elements. The GGSC structural elements are the physical infrastructure involved in the production, storage, and distribution of geodetic products including, but not limited to, ground observatory equipment, hardware at data centres, and data distribution networks (e.g., optic fibre).

The operational elements perform supporting functions for structural elements, ensuring they function efficiently and effectively. Operational GGSC elements include strategic and operational planning, risk management, financial management, cyber security, human resources, quality management and standards.

2. Geodesy's role in society

Geodesy provides the invisible foundation upon which countless modern services and technologies depend. While the discipline itself remains unfamiliar to most policymakers and the public, its outputs—accurate positioning, precise timing, and stable reference frames—have become as essential to contemporary society as electricity or the internet. The global geodesy supply chain (GGSC) delivers these critical services through an integrated network of ground stations, satellites, analysis centres, and data systems that operate continuously to maintain services used worldwide.

The strategic importance of geodesy has gained increasing recognition in recent years. At the 18th meeting of the International Committee on GNSS (ICG) in October 2024, GNSS providers—including GPS, GLONASS, Galileo, and BeiDou—acknowledged risk to GNSS satellite operations stemming from weaknesses in the GGSC. In a joint statement, ICG members emphasised that strengthening the GGSC should be prioritised to ensure continuous and reliable GNSS services.² This unprecedented acknowledgment from the world's major position, navigation and timing system operators underscores both the interdependence between the GGSC and satellite systems, and the urgency of addressing vulnerabilities in the supply chain.

2.1 The foundation of satellite services

Satellites cannot function without geodesy. For example, the GNSS satellites which broadcast signals that devices use to calculate position, must themselves know their own positions with extraordinary precision—typically within a few centimetres. This is where geodesy becomes indispensable. The global network of geodetic ground stations continuously tracks satellites, and geodetic analysis centres process these observations to determine precise satellite orbits and clock corrections satellites constantly need to deliver accurate and reliable satellite services to billions of users.

Without a robust GGSC, the accuracy of satellite services will degrade. The reference frame that defines “where” a position is located, the precise ephemerides that describe satellite orbits, and the clock corrections that enable timing services—all depend on the continuous operation of geodetic networks and processing facilities. A failure or degradation in the GGSC directly translates to reduced satellite performance, affecting every service and application that depends on GNSS services.

2.2 Historical context

The GGSC emerged organically from scientific collaboration that began in the 19th century with the International Association of Geodesy (IAG) tracing its origins to 1862. For over a century, geodesy was primarily an academic and national mapping concern, with countries conducting surveys independently using terrestrial techniques. The modern GGSC began to take shape in 1988 when the International Earth Rotation and Reference Systems Service (IERS) was established by the International Astronomical Union and International Union of Geodesy and Geophysics, marking the first systematic effort to create and maintain global reference frames. The launch of the first GPS satellite in 1978 and the system's full operational capability by 1993 proved transformative, making precise positioning accessible on a global scale and fundamentally changing geodesy from a specialised scientific discipline into essential infrastructure.

By establishing the International GNSS Service, the IAG pioneered a collaborative model where over 200 self-funding agencies, universities, and research institutions voluntarily contribute ground tracking stations, data centres, and analysis capabilities to produce high-precision GNSS products. However, governance for geodesy developed differently than for comparable global infrastructure systems. While civil aviation created the International Civil Aviation Organization with binding standards, and meteorology established the World Meteorological Organization

2 ICG-18 Joint Statement, https://www.unoosa.org/documents/pdf/icg/2024/ICG-18/ICG-18_Joint_Statement.pdf, accessed 21 August 2025.

with coordinating authority, geodesy evolved through scientific cooperation under the IAG without formal international governance mechanisms.

The IAG Services structure emerged organically to coordinate technique-specific activities (GNSS, VLBI, SLR, DORIS), but no overarching governance body was created with authority to set binding policies, allocate resources strategically, or ensure supply chain resilience. This governance gap persisted even as geodesy's importance grew exponentially—from supporting a few thousand researchers to underpinning billions of daily positioning transactions and critical infrastructure operations worldwide. The absence of formal governance structures, despite increasing societal dependence, reflects geodesy's historical evolution as a scientific collaboration rather than its current reality as critical global infrastructure.

Recognising the importance of the GGSC, the United Nations General Assembly adopted resolution 69/266 in February 2015, entitled 'A Global Geodetic Reference Frame for Sustainable Development' which encourages Member States to work together to sustain and enhance the GGSC.

2.3 Socio-economic development

The dependence on geodesy extends far beyond navigation. While GNSS is predominantly known for positioning and navigation, it has also become the primary source of accurate timing for critical infrastructure operations worldwide, including telecommunication services, energy grids, and financial systems.^{3,4,5,6,7} This timing function relies entirely on the supply chain to accurately measure time and enable GNSS satellites to synchronise precise time globally.

The downstream markets enabled by geodesy are substantial. Between 2022 and 2031, revenue from GNSS services alone is expected to grow at a compound annual growth rate (CAGR) of 9.2 percent, reaching a total of €492 billion (US\$573 billion) by 2031.⁸ In the same period, Earth observation market revenues are set to double from roughly €2.8 billion (US\$3.3 billion) to over €5.5 billion (US\$6.4 billion).⁸ The satellite communications market size is estimated at €166 billion (US\$193 billion) in 2024, and is expected to reach €253 billion (US\$297 billion) by 2029, growing at approximately 9% CAGR between 2024-2029.⁹ Yet this economic dependence creates vulnerability: disruptions to the GGSC that degrade GNSS performance would ripple through multiple sectors simultaneously, potentially causing cascading failures across interconnected systems.

2.3.1 Telecommunications

Telecommunication services, including mobile and satellite networks, are heavily dependent on precise timing. GNSS is the sole technology capable of providing the time synchronisation required for accurate data transmission (e.g., via internet on mobile devices) and seamless 'handovers' from one cellular phone tower to another as a mobile user roams. Of all critical infrastructure sectors, telecommunications are the most vulnerable to GNSS disruptions due to their stringent time synchronisation requirements.

Modern telecommunications networks require time synchronisation accurate to within microseconds or even nanoseconds. When a mobile phone connects to a network, multiple cell towers must coordinate precisely to avoid interference and ensure continuous service as the user moves. This coordination depends on all towers maintaining a common time reference, which is

3 John Garamendi et al., 2015, Letter to Congress of the United States, <https://rntfnd.org/wp-content/uploads/Congressional-Letter-to-PNT-Executive-Committee.pdf>, accessed 21 August 2025.

4 London Economics, 2023, The economic impact on the UK of a disruption to GNSS, https://assets.publishing.service.gov.uk/media/652eb0446b6fbf000db7584e/20231018_London_Economics_Report_GNSS.pdf, accessed 28 May 2024.

5 UK Government, 2023, National Risk Register, https://assets.publishing.service.gov.uk/media/64ca1dfe19f5622669f3c1b1/2023_NATIONAL_RISK_REGISTER_NRR.pdf, accessed 28 May 2024.

6 Monty Graham, 2012, GPS Use in U.S. Critical Infrastructure and Emergency Communications, <https://www.gps.gov/multimedia/presentations/2012/10/USTTI/graham.pdf> accessed 28 May 2024.

7 Michael A. Lombardi, 2021, An Evaluation of Dependencies of Critical Infrastructure Timing Systems on the Global Positioning System (GPS) <https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2189.pdf> accessed 28 May 2024.

8 EUSPA, Market Report 2022, https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf, accessed 28 May 2024.

9 Mordor Intelligence, 2024, Satellite Communications Market Size Source: <https://www.mordorintelligence.com/industry-reports/global-satellite-communication-market>, accessed 23 October 2025.

provided by GNSS receivers at each tower site. These receivers, in turn, depend on the precise satellite orbit and clock information generated by the GGSC.

Without the GGSC that enables GNSS timing services, the operation of mobile phone networks would be impossible. The social and economic implications are profound: telecommunications underpin not only personal communication but also emergency services, Internet connectivity, remote work, e-commerce, and countless other aspects of modern life.

2.3.2 Financial systems

Financial systems have used GNSS for timekeeping and time synchronisation for decades. As GNSS provides a globally consistent timestamp of when a transaction occurs with traceability to Universal Coordinated Time (UTC) for regulatory compliance, it became critical across various sectors – from stock exchanges and banking systems to local shop credit-card machines.¹⁰

In financial markets, accurate timestamps are essential for transaction ordering, regulatory compliance, fraud detection, and high-frequency trading. When multiple transactions occur in rapid succession, knowing their precise sequence can determine which is executed first—potentially affecting prices and trading outcomes. Regulatory frameworks in major markets now require timestamps accurate to within microseconds, a standard achievable through GNSS-based timing systems supported by geodetic infrastructure.

Without GNSS and its underlying geodetic foundation, some stock exchanges would likely continue to operate using alternative timing sources, albeit with reduced accuracy and protection for investors. Markets might revert to less precise timing systems, potentially creating opportunities for timing arbitrage and making it more difficult to detect certain types of market manipulation. Banking systems and other businesses without backup timing solutions would face more severe disruptions, potentially affecting payment processing, ATM operations, and point-of-sale transactions.

2.3.3 Energy grid systems

The energy sector relies on GNSS-derived timing for synchronisation in power distribution, with this timing capability ultimately dependent on the GGSC. Modern electrical grids operate as complex, interconnected systems where maintaining stable frequency and phase relationships is critical for reliability. Continuous measurements are conducted at a variety of strategic locations throughout the grid—such as power plants, substations, and transmission lines—to support planning, control, automated protection, and real-time operational optimisation of energy systems.

Phasor Measurement Units (PMUs), which monitor the electrical state of the grid in real time, require time synchronisation accurate to within microseconds to compare measurements from different locations. This synchronisation enables grid operators to detect disturbances, predict failures, and respond to problems before they cascade into widespread outages. GNSS timing, enabled by the supply chain, is the standard solution for providing this synchronisation across geographically distributed facilities.

Without GNSS and supporting geodetic services, power grid operations would become significantly more labour-intensive and challenging, with reduced effectiveness of diagnostic tools. Grid operators would lose the ability to conduct real-time wide-area monitoring, making it more difficult to prevent blackouts or restore service after outages. This would cause financial stress on Member States and energy operators facing increasing electricity demand.

2.4 Earth observation and environmental monitoring

Beyond its role in enabling positioning, navigation and timing services, geodesy provides the reference framework essential for understanding Earth system changes. Climate scientists tracking sea level rise, glaciologists monitoring ice sheet loss, seismologists assessing earthquake hazards, and meteorologists improving weather forecasts all depend on geodetic observations and reference frames.¹¹

¹⁰ EUSPA, Report on Time & Synchronisation User Needs and Requirement, 2019, https://www.gsc-europa.eu/sites/default/files/sites/all/files/Report_on_User_Needs_and_Requirements_Timing_Synchronisation.pdf, accessed 28 May 2024.

¹¹ UN-GGCE, 2025, Geodesy is critical to climate science, https://ggim.un.org/UNGGCE/documents/Policy_Brief_Geodesy_is_critical_to_climate_science.pdf, date accessed: 30 January 2026.

Satellite Earth observation missions—which monitor everything from atmospheric composition to ocean currents to land subsidence—require precise knowledge of the satellite position to convert measurements into meaningful information about Earth’s surface. This positioning comes from geodetic tracking networks. Similarly, combining observations from multiple satellites or tracking changes over time requires a stable reference frame that defines positions consistently across space and time. The International Terrestrial Reference Frame (ITRF), maintained through international geodetic collaboration, serves this function and is fundamental to virtually all Earth observation activities.

As concerns about climate change intensify, the importance of the GGSC for monitoring environmental change has grown. Measuring millimetre-scale sea level rise, tracking centimetre-scale land subsidence in coastal cities, or detecting subtle ground deformation preceding volcanic eruptions all require the precision and stability that only geodesy can provide. The accuracy of climate projections, the effectiveness of natural hazard early warning systems, and the ability to verify international environmental agreements increasingly depend on an accurate and reliable GGSC.

2.5 Infrastructure development and disaster response

Geodesy supports infrastructure development and management across multiple sectors. Construction of bridges, tunnels, dams, and other major structures requires precise surveying and monitoring to ensure safety and performance. Land administration and cadastral systems depend on geodetic reference frames to define property boundaries and manage land use. Transportation systems—from aviation to maritime shipping to autonomous vehicles—rely on positioning services with geodetic foundations.

When disasters strike, geodetic observations become critical for response and recovery. Following major earthquakes, geodetic networks can rapidly measure ground deformation, helping scientists assess aftershock risks and structural engineers evaluate building safety.

Satellite positioning enables emergency responders to navigate damaged areas and coordinate rescue operations. Geodetic monitoring helps track volcanic unrest, landslide movement, and flood extent, supporting evacuation decisions and damage assessment.

2.6 Scientific research and space operations

The scientific community depends extensively on geodetic infrastructure for research spanning multiple disciplines. Understanding Earth’s rotation variations, gravity field changes, plate tectonics, and the interaction between solid Earth, oceans, ice sheets, and atmosphere all require high-precision geodetic observations. These measurements contribute to fundamental scientific questions while also providing practical information for applications from resource exploration to navigation safety.

Space agencies and satellite operators rely on geodetic services for mission planning, satellite tracking, and collision avoidance.

As low Earth orbit becomes increasingly crowded with satellites, the need for accurate orbit determination—based on geodetic tracking—becomes ever more critical for space sustainability and safety.

2.7 The vulnerability of an invisible infrastructure

Despite its critical importance across these diverse domains, geodetic infrastructure remains chronically underfunded and institutionally fragmented. Many organisations and governments that depend heavily on geodetic services are unaware of this dependence, viewing GNSS as a standalone system rather than recognising it as one component of a broader GGSC. This invisibility creates a dangerous vulnerability: critical services rest on infrastructure that lacks the governance, resources, and public awareness necessary to ensure long-term sustainability.

The weaknesses in the GGSC acknowledged by GNSS providers at ICG-18² are not merely technical concerns—they represent systemic risks to the functioning of modern society. Understanding geodesy’s pervasive role across telecommunications, finance, energy, Earth observation, infrastructure, and scientific research is essential context for appreciating both the urgency of this assessment and the importance of the governance and sustainability challenges it identifies.



3. Methodology to develop a comprehensive maturity assessment

This section describes the process of developing a comprehensive assessment framework to assess the maturity of the GGSC. Subsection 3.1 introduces key concepts and definitions, subsection 3.2 provides an overview of the existing assessment frameworks that formed the basis of the chosen approach, and subsection 3.3 outlines how the frameworks were used to create the GGSC maturity assessment.

3.1 Definitions

3.1.1 Global geodesy supply chain maturity and capabilities

In general terms, **mature** refers to a “very advanced or developed form or state” and reflects the degree to which something has evolved toward a fully functional, effective, and sustainable condition.^{12,13}

Adopting this concept to the GGSC, we define **GGSC maturity** as the extent to which necessary capabilities are fully developed to produce and deliver geodetic products with the required properties (e.g., accuracy, robustness, integrity) to fully meet end-user needs. A highly mature supply chain has well-developed, reliable, and sustainable capabilities; a less mature supply chain has capabilities that are incomplete, fragmented, or vulnerable.

In this context, **GGSC capabilities** are the functions, processes, resources, or competencies required for the effective GGSC operation. **Strengthening GGSC maturity** refers to the progressive development of GGSC capabilities from their current state toward higher levels of effectiveness, reliability, and sustainability.

3.1.2 Global geodesy supply chain capability model

A **capability model** is a hierarchical representation of the core functions of an organisation, company, or enterprise (hereafter collectively referred to as entity) that are required to deliver value.

The **GGSC capability model** is a simplified representation of the GGSC through its capabilities, which are grouped into domains and subdomains corresponding to specific GGSC functional areas.

3.1.3 Global geodesy supply chain maturity assessment framework

A **maturity assessment framework** is a structured framework used to evaluate the overall maturity level of an entity's capabilities. It includes a set of diagnostic tools and guidance on their use for evaluating the overall maturity level of an entity. As the development of the entity's capabilities is a continuous process, regular monitoring is essential to track progress and implement adjustments when necessary.¹⁴

The **GGSC maturity assessment framework** incorporates the GGSC capability model and the assessment measures. It is designed to conduct systematic qualitative assessments of the GGSC maturity.

3.2 Summary of frameworks used to develop the global geodesy supply chain assessment framework

Several frameworks and capability models were used as guidance to develop the GGSC maturity framework and capability model (Table 1).

12 Cambridge Dictionary, 2025, Meaning of maturity in English. Retrieved from Cambridge Dictionary: <https://dictionary.cambridge.org/us/dictionary/english/maturity>

13 Mettler, T., 2011, Maturity assessment models: a design science. *International Journal of Society Systems Science*, 3(1/2), 81-98. Retrieved from <https://www.inderscience.com/offers.php?id=38934>

14 Christoph Stoiber, M. S., 2023, Keeping Your Maturity Assessment Alive. *Bus. Inf. Syst. Eng.*, 65, 703-721. doi:10.1007/s12599-023-00805-y

Table 1. Frameworks used to develop the global geodesy supply chain maturity assessment

Framework type	Framework / model	Acronym	Concept and application area
Data management frameworks	Data Management Body of Knowledge	DMBOK	Defines best practices for managing data across its lifecycle. Positions data as a strategic asset within an organisation.
	Data Management Capability Assessment Model	DCAM	Defines key data management capabilities and their maturity levels. Used to assess organisational data management maturity.
	Data Management Maturity Model of the Capability Maturity Model Integration	CMMI-DMM	Defines key data management practices and their maturity levels. Used to assess the maturity of the implementation of data management practices.
Asset management frameworks	ISO standard for asset management	ISO 55001	Specifies requirements for establishing, implementing, maintaining, and improving an asset management system. Helps manage assets to deliver value.
Enterprise architecture frameworks	Open Group Architecture Framework	TOGAF	Describes enterprise architecture across several layers, including business, data, application, and technology. Used to design, plan, implement, and govern enterprise systems.
	Business Architecture Body of Knowledge	BIZBOK	Defines principles and practices for managing business architecture. Used to design and improve processes and capabilities of business models.
	International Development Organizational Business Architecture Reference Model	IDO	Provides a structured approach (i.e., a model) to business architecture for international development organisations. Used to standardise processes and capabilities across multiple organisations and stakeholders.

Table 2. Relationship between the components of the GGSC maturity assessment and other adopted frameworks; see also Table 1.

Structural components of the GGSC maturity assessment framework		GGSC-specific	DMBOK	DCAM	CMMI-DMM	ISO 55001	TOGAF	BIZBOK	IDO
GGSC capability model			X	X	X		X	X	X
Capabilities	Engagement and collaboration	X					X	X	X
	Governance and strategy	X				X	X	X	X
	Data management	X	X	X	X		X		X
	Data products and software	X	X	X	X		X		X
	Asset and infrastructure management		X			X		X	X
	Innovation and development	X							X
Assessment measures									
Dimensions	People	X							
	Technologies						X		
	Processes		X		X		X		
	Data	X	X	X	X		X		
Maturity Scale		X		X	X		X	X	X

3.2.1 Data management frameworks

To account for the data-related aspects of the GGSC, elements from the Data Management Body of Knowledge (DMBOK)¹⁵, Data Management Capability Assessment Model (DCAM)¹⁶, and Data Management Maturity Model of the Capability Maturity Model Integration (CMMI-DMM)¹⁷ were included. These data management frameworks were however unable to capture other GGSC dimensions such as people, technologies, and processes.

3.2.2 Asset management standard

Elements from ISO 55001:2024 Asset management – Asset management system – Requirements, which refers to “the establishment, implementation, operation, maintenance and improvement of a management system for asset management”¹⁸ were used to ensure consideration of asset management components of the GGSC.

3.2.3 Enterprise architecture frameworks

Components from enterprise architecture (i.e., organisation-wide) frameworks, namely the Open Group Architecture Framework (TOGAF)¹⁹ and the Business Architecture Body of Knowledge (BIZBOK)²⁰ were also

considered. While these frameworks are primarily used within public and private sectors, they have also demonstrated relevance for intergovernmental and multi-stakeholder organisations.

For example, the International Development Organizational (IDO) Business Architecture Reference Model²¹ was developed by the Business Architecture Guild²² as an implementation of BIZBOK and was originally intended for industry use. However, it also proved to be valuable for unifying processes and strategies across international development organisations (e.g., World Bank, World Food Program, United Nations Development Programme), which is also relevant in the GGSC context.

To summarise, none of the above-mentioned frameworks and models can holistically describe and assess all GGSC dimensions. Therefore, we combined selected elements from them to create the new GGSC maturity assessment framework.

¹⁵ <https://dama.org/learning-resources/dama-data-management-body-of-knowledge-dmbok/>

¹⁶ <https://edmcouncil.org/frameworks/dcam/>

¹⁷ <https://cmminstitute.com/cmmi>

¹⁸ <https://www.iso.org/standard/83054.html>

¹⁹ <https://www.opengroup.org/togaf>

²⁰ <https://www.businessarchitectureguild.org/general/custom.asp?page=002>

²¹ <https://www.prnewswire.com/news-releases/business-architecture-guild-releases-international-development-organization-reference-model-v1-0--302392594.html>

²² <https://www.businessarchitectureguild.org/>

4. The global geodesy supply chain maturity assessment framework

The GGSC maturity assessment framework was developed by integrating the components from the existing assessment frameworks (see Table 1) and aligning them with the GGSC specific context. Such an approach ensures a more realistic evaluation of the GGSC maturity.

The GGSC maturity assessment framework encompasses the GGSC capability model and the associated assessment measures (Figure 2, Table 2). The IDO reference model, with its defined set of capabilities for international development organisations, serves as the foundation for the GGSC capability model. In addition, the GGSC-specific capabilities were incorporated based on the GGSC functionality and requirements identified in the Global Geodesy Needs Assessment report.²³ The resulting capabilities are grouped into six domains, with data-related domains constituting the core, complemented by Governance and Strategy, Asset and Infrastructure Management, Engagement and Collaboration, and Innovation and Development.

Within the framework, the GGSC capabilities were assessed across four dimensions – People, Technologies, Processes, and Data, where each dimension has a maturity scale ranging from Level 0 to Level 5.

The GGSC maturity assessment framework represents a first attempt and will likely require refinement. Furthermore, future assessments may identify more appropriate metrics or different capability groupings.

4.1 Global geodesy supply chain capability model

The GGSC capability model is a three-tiered hierarchical framework comprising 58 capabilities (Figure 3). The three tiers are:

- Tier 1: Domains

Functional areas that encompass core operations of the GGSC.

- Tier 2: Subdomains

More specific categories within each domain.

- Tier 3: Capabilities

Set of functions, processes, resources, or competencies required for effective GGSC operations within each subdomain.

For example, the **Data Products and Software** domain includes two subdomains, namely **Product Development and Maintenance** and **Delivery and Support**. In turn, the subdomains have several capabilities, such as Reference Frames, Geodetic Data Products, Geodetic Software and Tools, Geodetic Services, and Training and Education.

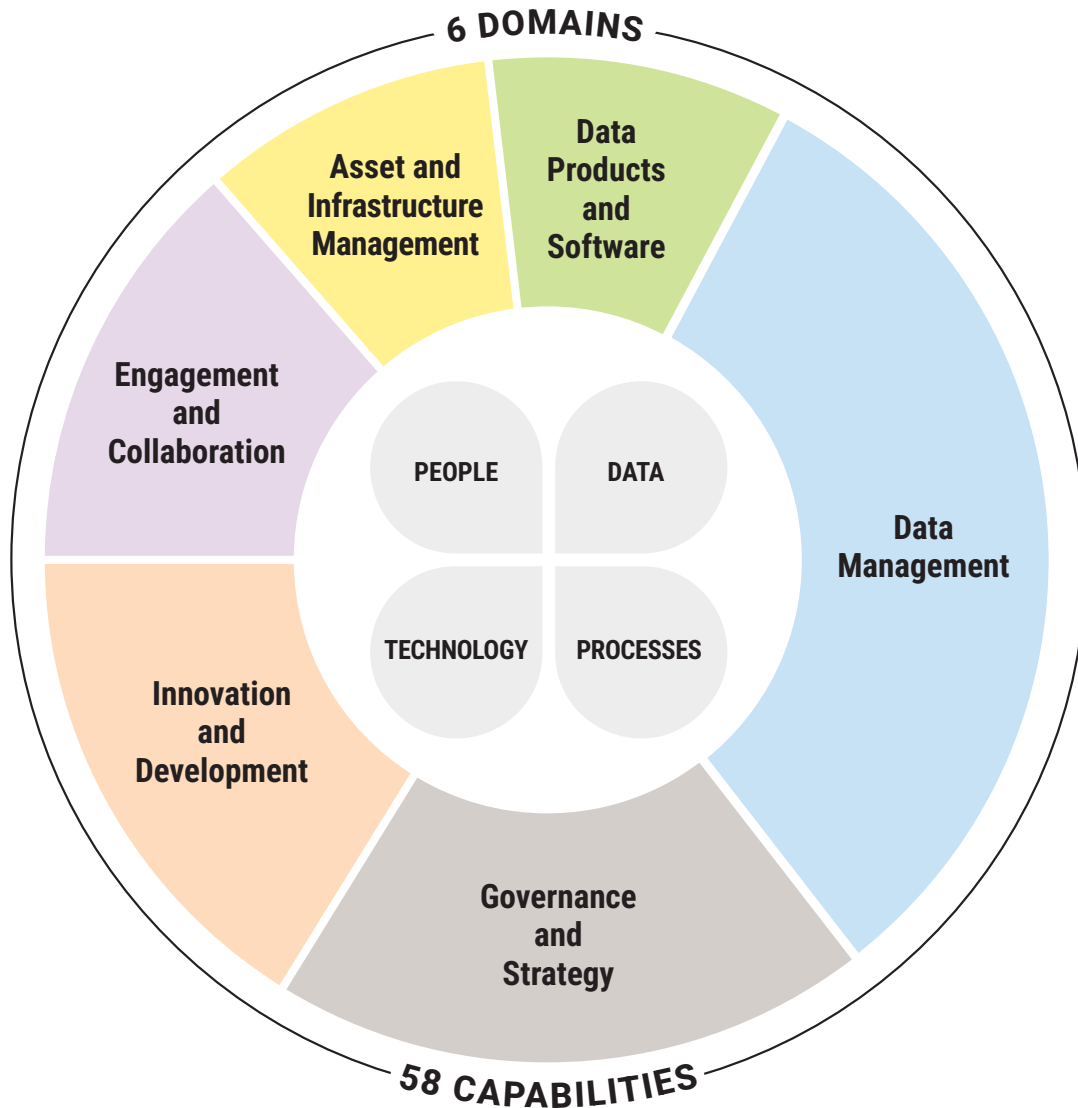
4.2 Assessment dimensions and maturity scale

The maturity of GGSC capabilities is assessed across several dimensions to provide a comprehensive overview of the GGSC state. These dimensions include:

- People: Human capital necessary for effective GGSC governance, strategy and operations, including skills, competencies, experience, clearly defined roles and responsibilities, training programs, capacity development, knowledge management, and organisational culture that supports collaboration and innovation.
- Processes: Documented, standardised practices, procedures, and governance mechanisms that guide, control, and continuously improve GGSC governance, strategy and operations, including decision-making frameworks, quality assurance, risk management, and stakeholder engagement.
- Technologies: Digital and physical infrastructure, platforms, systems, and tools that enable, automate, and support effective GGSC governance, strategy and operations, including hardware, software, networks, and emerging technologies.

²³ Global Geodesy Needs Assessment, https://ggim.un.org/UNGGCE/documents/20240509-Global_Geodesy_Needs_Assessment.pdf

Figure 2. Schematic representation of the GGSC maturity assessment framework.



- Data: Information assets and products that inform and result from GGSC governance, strategy and operations, including geodetic data products, meta-data, quality metrics, and documentation that meet user requirements and support evidence-based decision-making.

Each assessment dimension has a maturity scale ranging from Level 0 to Level 5 (Tables 3 – 7). Level 0 indicates a no maturity for a particular capability within the GGSC, while Level 5 represents a highly mature state.

In this work, we define the Level 5 state for each dimension as follows:

- People: Have dedicated funding, clearly defined roles and responsibilities, and relevant skills and training for effective GGSC operation.
- Processes: Are formalised, documented, communicated, and adhered to.
- Technologies: Are interoperable, maintained, scalable, fit-for-purpose.
- Data: Follows FAIR principles²⁴ (i.e., findable, accessible, interoperable, reusable) and undergo regular quality checks.

Note that **Not Applicable (NA)** is applied in instances, where assigning a numerical value is not meaningful, for example, for the Technology dimension of Strategic Planning.

²⁴ <https://www.go-fair.org/fair-principles/>

PEOPLE

Table 3. Maturity levels of the People dimension

Level	Meaning	Description
1	Undefined	Capacity funding is lacking or unknown, roles and responsibilities are undefined, skills are unassessed, and training is ad-hoc or absent.
2	Managed	Capacity funding is predominantly in-kind, roles and responsibilities are not well defined or reactive, skills of the people involved are assessed as inconsistent, and training is informal and unstructured.
3	Defined	Capacity funding limited and not long-term, inconsistent and / or partially in-kind, roles and responsibilities are partially defined for key functions, skills of the people involved are assessed as relevant, and training is available through formal channels for some needs.
4	Capable	Capacity funding is available for long-term contracts and a low dependence on in-kind support for critical functions, roles and responsibilities are well defined with clear accountability, skills of the people involved are assessed as strong and relevant, and training is available through formal channels and structured programs.
5	Empowered	Capacity funding is available for long-term contracts and there is no dependence on in-kind support for critical functions, roles and responsibilities are well defined with clear accountability and optimised to enhance collaboration, skills of the people involved are assessed as strong, relevant and continuously developed, and training is proactive through formal channels and structured programs.

TECHNOLOGIES

Table 5. Maturity levels of the Technologies dimension

Level	Meaning	Description
1	Basic	Uncoordinated and incompatible, often not fit for purpose, poorly supported, difficult to scale, and only usable by experts.
2	Available	Ad-hoc network with minimal compatibility, is sometimes fit for purpose, has basic support and scalability, and is only usable by experts.
3	Standardised	A network with good compatibility and international discussions on enhancing compatibility, is fit for purpose most of the time, is mostly supported and scalable, and is only usable by experts.
4	Managed	A network with strong compatibility and investment based on operational user requirements, is well supported and scalable, and is usable by science users.
5	Strategic	A robust network with strong compatibility and investment based future needs, is proactively supported, optimised for scalability, and is usable for innovation.

PROCESSES

Table 4. Maturity levels of the Processes dimension

Level	Meaning	Description
1	Ad-hoc	Processes are not often formalised, documentation is limited or does not exist, communication of processes is inconsistent or absent, and the use of processes varies significantly between individuals or situations and not consistently followed.
2	Repeatable	Processes are typically informal and localised to a small number of applications, documentation may be available for some processes may be documented, but not in a standardised format or central repository, communication of processes is ad-hoc, usually verbal or within small groups and the use of processes are followed inconsistently, with a high dependency on individual or team knowledge.
3	Defined	Processes are often formal and regularly used, documentation is available in a standard format and stored centrally, communication of processes is formally communicated to relevant stakeholders, often through training or accessible repositories and the use of processes are expected but monitoring and enforcement are inconsistent.
4	Managed	Processes are formal and a standard part of the process lifecycle and is consistently applied, documentation is comprehensive including procedures, roles, and performance metrics, communication of processes is systematic and includes structured training and updates on process changes, and the use of processes are consistently followed, and adherence is monitored and measured quantitatively.
5	Optimised	Processes are streamlined and efficient, supporting rapid adaptation and improvement cycles, documentation is dynamic, continuously updated to reflect optimisations and integrates best practices, communication of processes is highly effective and proactive, ensuring all stakeholders are fully engaged in process performance and improvements, and the use of processes are consistently followed with a strong focus on optimising execution, informed by continuous analysis of performance data and feedback.

DATA

Table 7. Maturity levels of the Data dimension

Level	Meaning	Description
1	Siloed	Very little of the data is FAIR and the quality attributes of the data (e.g. timeliness, accuracy) are not well defined.
2	Aware	Little of the data is not FAIR and some of the quality attributes of the data (e.g. timeliness, accuracy) are not well defined.
3	Standardised	Some of the data is not FAIR and the quality attributes of the data (e.g. timeliness, accuracy) are mostly defined.
4	Governed	Most of the data is FAIR and the quality attributes of the data (e.g. timeliness, accuracy) are well defined.
5	Strategic	Most of the data is FAIR and the quality attributes of the data (e.g. timeliness, accuracy) are defined and monitored.



5. State of Geodesy 2026

5.1 Global geodesy supply chain maturity assessment

An initial maturity assessment of the GGSC was undertaken by staff of the UN Global Geodetic Centre of Excellence (UN-GGCE) in consultation with the President of the IAG, Dr Richard Gross, in May 2025. The assessment team assigned maturity scores based on evidence presented in the Global Geodesy Needs Assessment²⁵, which captured perspectives from over 500 stakeholders across 110 countries.

These preliminary results underwent extensive consultation with over 130 people holding leadership or coordination positions within the IAG, the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM) Subcommittee on Geodesy, and the UN-GGCE International Advisory Committee. Based on feedback from this consultation process, both the supporting evidence and maturity scores were refined and are reflected in this document.

Each maturity score is accompanied by a “confidence level” that acknowledges inherent limitations in the assessment. Despite drawing on extensive details from the Global Geodesy Needs Assessment and consultation with subject matter experts, there are knowledge gaps and uncertainty about specific aspects of the supply chain. Three confidence levels are used throughout the analysis—high, medium, and low.

Readers should note that even scores with high confidence levels do not represent absolute certainty. This reflects the pioneering nature of this work as the first comprehensive maturity assessment of the GGSC. Consequently, much of the evidence underlying this assessment is qualitative rather than quantitative in nature. As more robust monitoring systems are developed, future assessments will benefit from stronger quantitative evidence, enabling more precise and confident evaluations of supply chain maturity.

5.2 Summary of maturity assessment

The maturity assessment of the GGSC yielded an overall average score of 2.3 across all assessed capabilities. This score places the GGSC between Level 2 (“Managed” or “Repeatable”) and Level 3 (“Defined” or “Standardised”) on the maturity scale, indicating a system that is operational but fragile (Table 8). A Level 2.3 supply chain can produce accurate geodetic products but not reliably. In practice, this means the supply chain delivers products that are generally adequate for routine scientific users, but with reliability that depends heavily on individual commitment and institutional goodwill rather than formal arrangements. It cannot systematically detect emerging risks, respond to disruptions, or guarantee continuity of services which is important for geodetic products which are inputs for critical infrastructure operations.

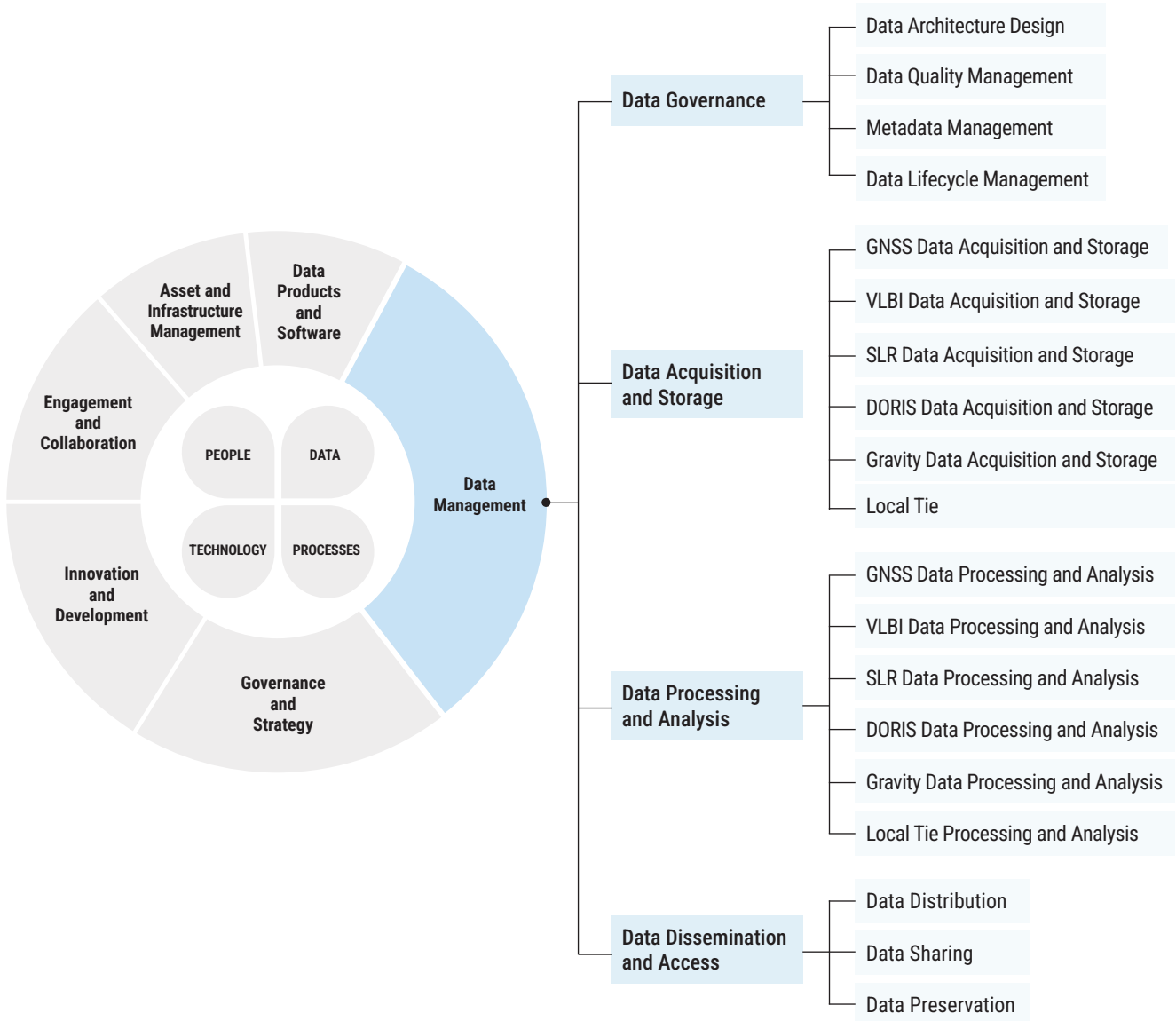
Table 8: Average maturity scores across the domains of the global geodesy supply chain

Domain	Average Score
Data Management	2.7
Data Products and Software	2.3
Asset and Infrastructure Management	2.3
Engagement and Collaboration	2.2
Innovation and Development	2.1
Governance and Strategy	1.8

²⁵ https://ggim.un.org/UNGGCE/documents/20240509-Global_Geodesy_Needs_Assessment.pdf

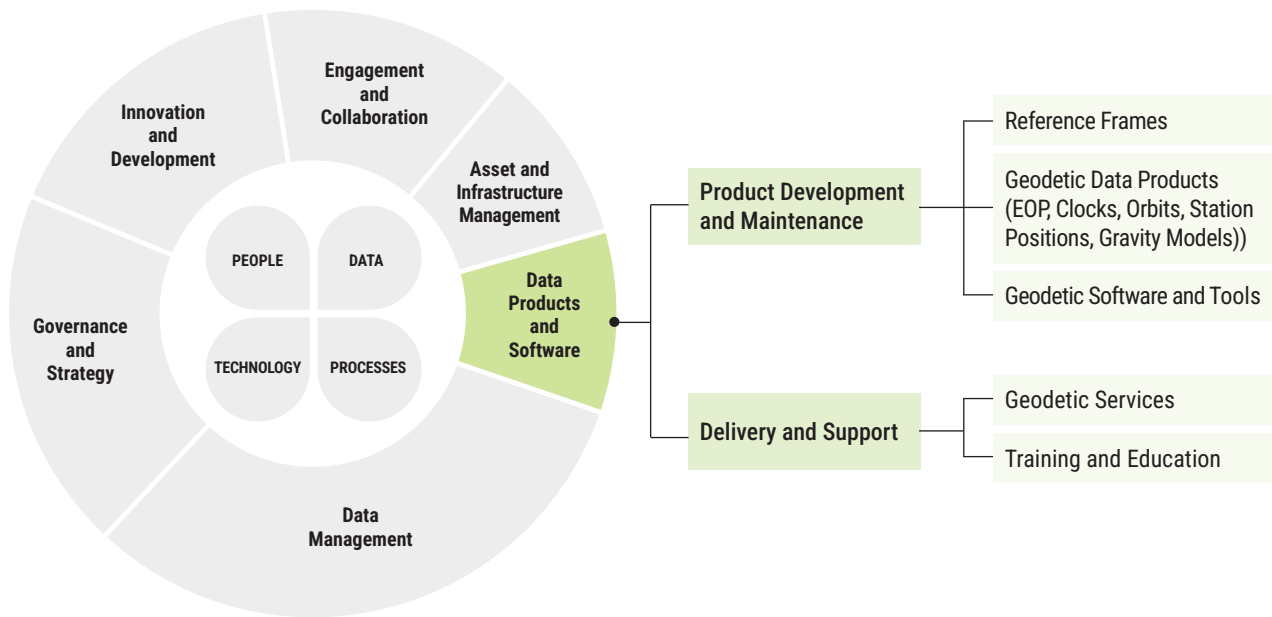
DATA MANAGEMENT

Maturity scores varied considerably across the six assessed domains, with a 0.9-point spread between the highest and lowest performing areas. The **Data Management domain** achieved the highest average score at 2.7, reflecting relatively mature capabilities in data acquisition, processing, and analysis for established geodetic techniques. Within this domain, GNSS data acquisition and storage scored particularly well (3.5), supported by an extensive global network of stations and well-established protocols through the International GNSS Service. DORIS data collection also demonstrated strong performance (4.0), benefiting from consistent institutional support and a well-distributed global network. However, even within this highest-performing domain, significant gaps exist in data governance capabilities, including data quality management (2.0), metadata management (2.0), and data preservation (2.0), where limited personnel capacity and absence of coordinated redundancy protocols constrain effectiveness.



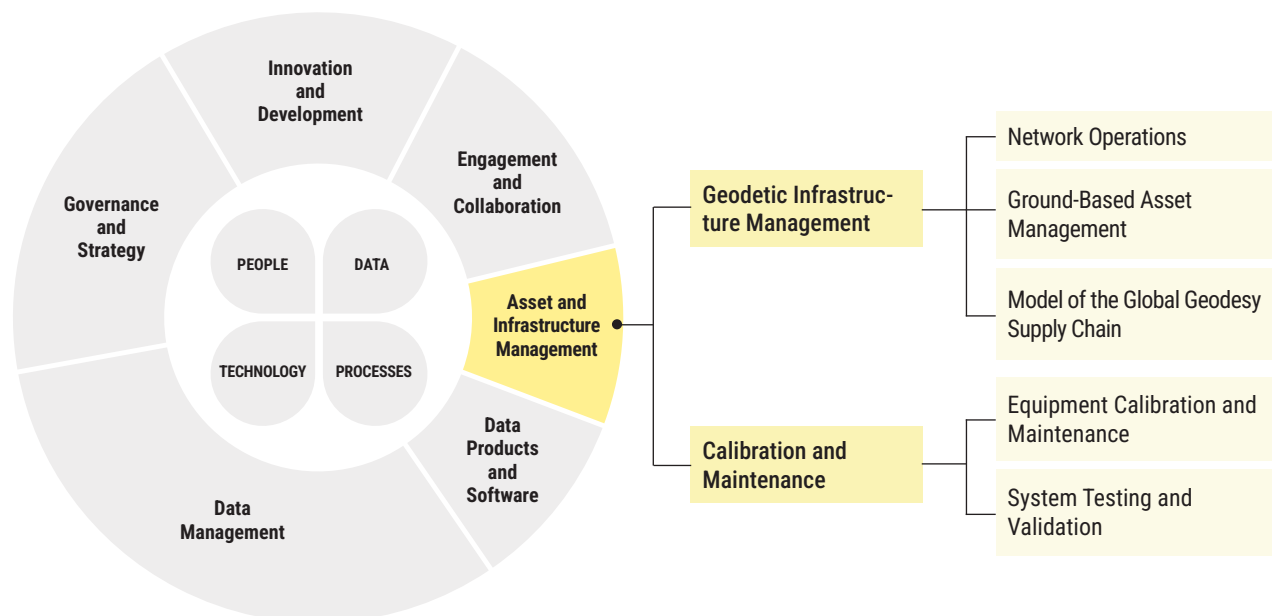
DATA PRODUCTS AND SOFTWARE

The **Data Products and Software domain** (2.3) and **Asset and Infrastructure Management domain** (2.3) both scored at the overall average. Data Products and Software showed reasonable capability in reference frame maintenance (3.0) and geodetic data product generation (2.8), with established processes documented in scientific literature and multiple software tools available to the global community. However, this domain faces challenges in geodetic software development (2.0), where dependencies on individual developers and incomplete documentation create vulnerabilities, and in geodetic services delivery (2.0), where limited resources affect the implementation of FAIR principles and service reliability.



ASSET AND INFRASTRUCTURE MANAGEMENT

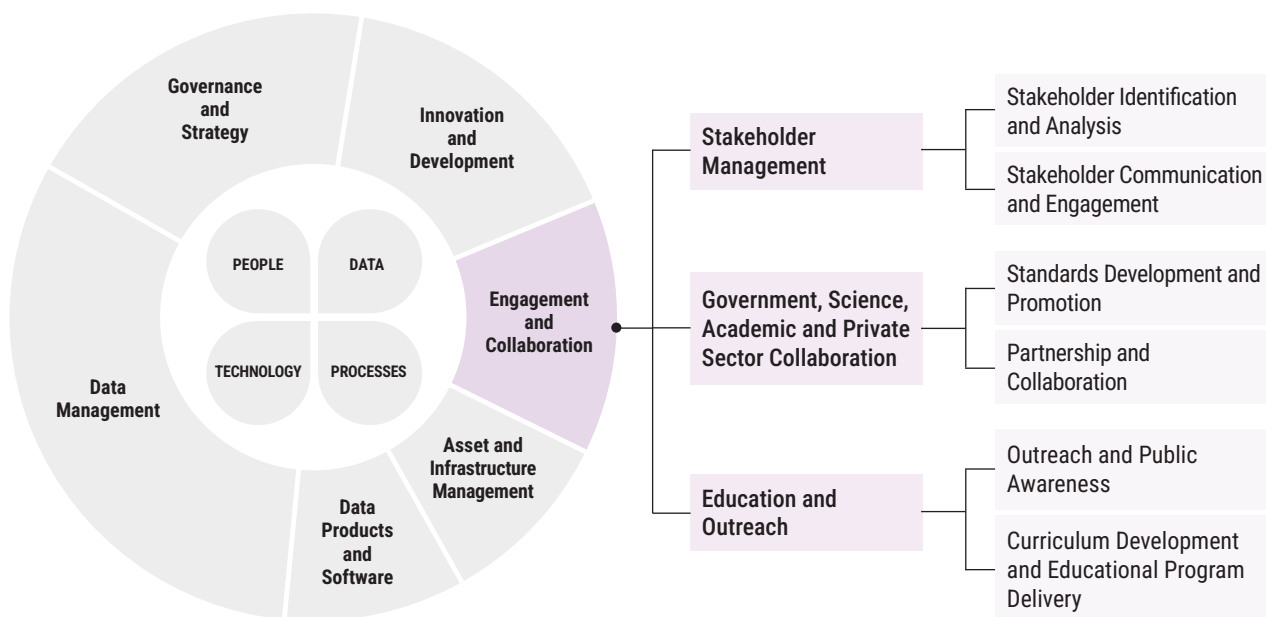
Asset and Infrastructure Management similarly present a mixed picture, with adequate equipment calibration and maintenance capabilities (3.3) when resources are available, but fundamental gaps in network operations oversight (2.0) and the complete absence of comprehensive supply chain modelling (1.0), reflecting the lack of end-to-end visibility across the system.



ENGAGEMENT AND COLLABORATION

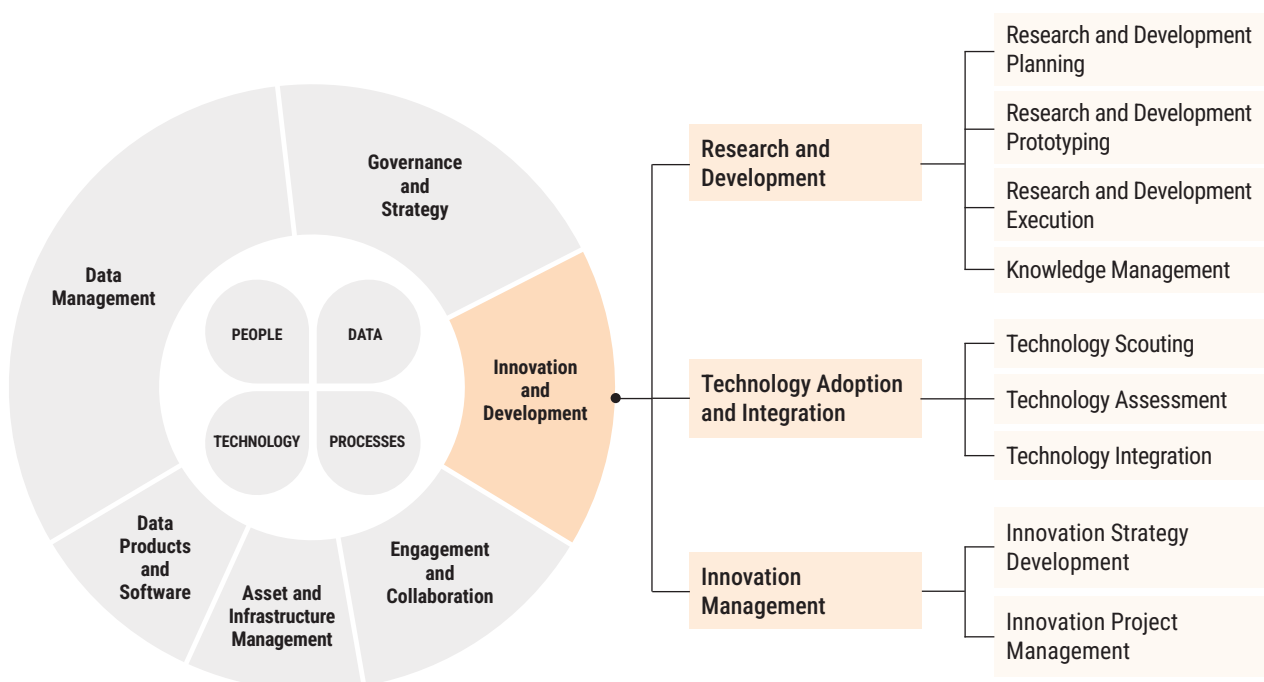
Engagement and Collaboration (2.2) and **Innovation and Development** (2.1) domains scored slightly below the overall average. The Engagement and Collaboration domain demonstrates reasonable capability in stakeholder identification within the scientific community (2.5) and standards development (3.0), supported by active participation in technical bodies such as ISO and OGC. However, this domain faces significant challenges in stakeholder communication beyond the geodetic community (2.0), where inadequate mechanisms exist to engage policymakers

and end-users, and in public awareness activities (1.3), where extremely limited resources and absence of coordinated outreach platforms constrain effectiveness. Partnership and collaboration capabilities (2.0) are hindered by the absence of formal intergovernmental coordination mechanisms beyond UN-GGIM.



INNOVATION AND DEVELOPMENT

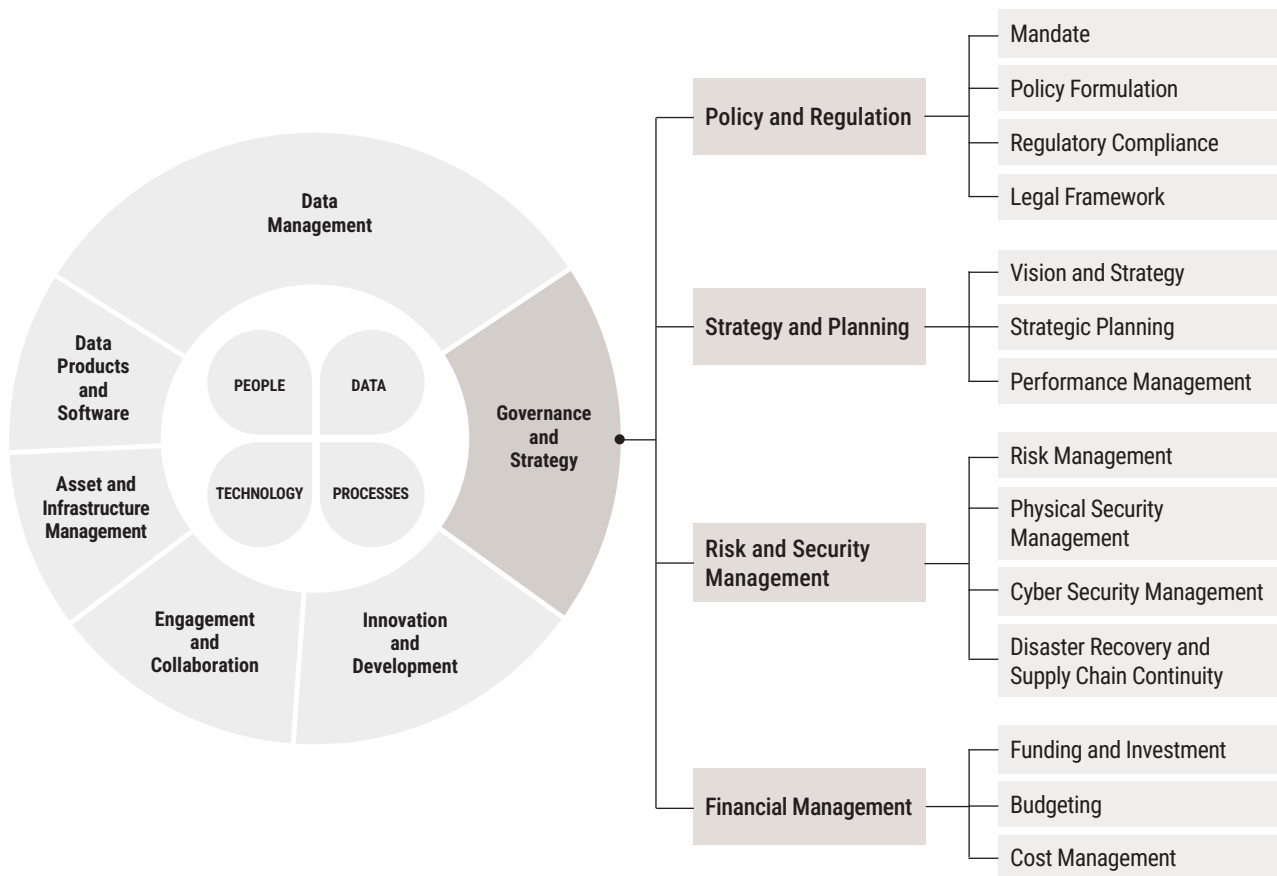
The Innovation and Development domain shows active research and development prototyping (3.0) occurring primarily in academic institutions and space agencies, but this activity remains ad-hoc and uncoordinated due to the absence of formal governance structures. Knowledge management in this domain is particularly weak (1.3), with critical dependencies on individual experts, limited documentation, and lack of systematic processes to capture and transfer institutional knowledge as senior specialists retire.



GOVERNANCE AND STRATEGY

The **Governance and Strategy** domain received the lowest average score at 1.8, with multiple capabilities scoring at Level 1, the lowest point on the maturity scale. This domain encompasses foundational capabilities that affect the entire supply chain, including mandate development (1.0), policy formulation (1.0), strategic planning (1.0), and all three financial management capabilities—funding and investment (1.0), budgeting (1.0), and cost management (1.0). The Level 1 scores in these areas reflect the absence of an international governance structure with visibility, authority, and accountability across the GGSC. While UN General Assembly resolution 69/266 provides the strongest existing mandate, it is non-binding and encourages voluntary action without implementation mechanisms. Risk management capabilities also scored at Level 1, indicating that no organisation systematically identifies, assesses, and mitigates supply chain risks, despite acknowledged dependencies on small numbers of experts and single-jurisdiction control of critical components. The higher-scoring capabilities within this domain—regulatory compliance (3.0) and physical security management (3.0)—reflect adequate local-level compliance and security at individual observatories, though confidence in these assessments is noted as low without comprehensive evaluation from a critical infrastructure perspective.

The significant variation in scores across domains reveals that operational and technical capabilities (particularly in data management) function at moderate maturity levels, while strategic, governance, and coordination capabilities remain largely undeveloped. This pattern suggests a system that evolved organically through scientific collaboration, developing strong technical expertise and established operational practices within individual geodetic technique communities, but lacking the overarching governance, strategic planning, and coordination mechanisms that would typically characterise mature critical infrastructure systems. The concentration of Level 1 scores in foundational governance and financial management capabilities, combined with widespread reliance on voluntary contributions and in-kind support across multiple domains, indicates structural constraints that affect the long-term sustainability of even those capabilities that currently demonstrate adequate operational performance.





6. Observations

6.1 Governance and financial capabilities as cross-cutting constraints

The overall average maturity score of 2.3 for the GGSC represents an aggregate across capabilities with highly variable performance. Within this average, the assessment identified a concentration of Level 1 scores in governance and financial management capabilities, which represent foundational functions that affect the operation of other capabilities throughout the supply chain. Specifically, the capabilities of mandate development, policy formulation, strategic planning, funding and investment, budgeting, and cost management all received Level 1 scores, indicating that these functions are largely absent or operate on an ad-hoc basis without formal structures.

The assessment identified governance as a cross-cutting constraint affecting multiple domains. No international organisation currently possesses combined visibility, authority, and accountability across the entire GGSC to develop coordinated policies, facilitate strategic resource allocation, or establish binding operational standards. The IAG coordinates scientific and technical activities effectively within its scope but operates as a scientific body without governmental authority or mandate to direct Member State actions. At the intergovernmental level, UN General Assembly resolution 69/266 represents the strongest existing mandate for geodesy, but as a non-binding resolution, it encourages voluntary action without establishing implementation mechanisms, enforcement provisions, or accountability structures.

No international organisation currently possesses combined visibility, authority, and accountability across the entire GGSC.

This absence of coordinating governance structures at the international level has implications for how critical infrastructure sectors that depend on geodetic

services ensure continuity of those services. Without an international entity responsible for overseeing supply chain resilience, coordination functions such as risk assessment, contingency planning, and strategic investment allocation occur in fragmented ways, if at all. The governance structure that exists—primarily through in-kind scientific collaboration coordinated by the IAG and periodic engagement through UN-GGIM processes—has enabled the supply chain to develop and operate, but consultation evidence suggests it has not established the strategic planning, resource coordination, or accountability mechanisms that characterise governance structures in comparable international infrastructure systems.

The governance structure that exists has enabled the supply chain to develop and operate, but has not established the strategic planning, resource coordination, or accountability mechanisms that characterise governance structures in comparable international infrastructure systems.

At the national level, consultation respondents reported that responsibility for geodesy in many countries is distributed across multiple government agencies (including those responsible for mapping, science, defence, space, and environment) without a designated lead authority or formal coordination mechanism. This organisational fragmentation creates challenges for coherent national strategy development, consistent international representation, and effective response to supply chain vulnerabilities that require cross-agency coordination. The absence of unified national coordination structures in many countries compounds the challenges of establishing effective international governance, as there may be no single national entity with comprehensive responsibility for geodesy matters.

Responsibility for geodesy in many countries is distributed across multiple government agencies without a designated lead authority or formal coordination mechanism.

The Level 1 scores in financial management capabilities reflect the absence of coordinated mechanisms for assessing funding needs, developing investment strategies, or allocating resources strategically across the supply chain. No international body currently performs systematic analysis of operational costs, capital requirements, or funding gaps across the global network of observatories, data centres, and analysis facilities. Consultation evidence indicates that funding for geodetic activities comes primarily from individual institutional budgets, with significant reliance on voluntary in-kind contributions where staff and facilities are provided by organisations without dedicated geodesy budgets. Evidence from the Global Geodesy Needs Assessment indicates that personnel at some observatories and analysis centres must seek competitive research grants to supplement operational funding, with time spent on grant applications reducing capacity for core geodetic functions.

Funding for geodetic activities comes primarily from individual institutional budgets, with significant reliance on voluntary in-kind contributions where staff and facilities are provided by organisations without dedicated geodesy budgets.

The absence of coordinated funding mechanisms has observable effects on supply chain operations. Consultation respondents reported instances where ground observatories do not consistently meet technical standards established by IAG Services, where personnel contribute time to critical functions such as standards development outside their formal work responsibilities, and where academic staff working on geodetic analysis or software development operate

under short-term contracts that create uncertainty about long-term capability continuity. The assessment identified aging infrastructure at multiple observatories without clear funding pathways for modernisation, reliance on individual software developers without institutional sustainability plans, and declining numbers of higher education programs training new geodesists—all of which respondents connected to resource constraints and absence of strategic funding coordination.

These observations suggest that while the GGSC operates and produces geodetic products that support numerous applications, the foundational capabilities required for strategic planning, coordinated investment, and systematic risk management remain underdeveloped. The current operational performance reflects the technical expertise and institutional commitment of participating organisations but occurs without the governance and financial coordination structures that would typically support long-term sustainability and resilience in systems of comparable societal importance.

6.2 Governance constraints and associated capability patterns

The assessment identified patterns where capabilities in risk management, workforce development, infrastructure resilience, and stakeholder engagement scored at lower maturity levels, with consultation evidence suggesting connections to the governance constraints described in Section 6.1.

Risk and continuity management capabilities received scores reflecting limited organisational development. Formal risk management scored 1.0, disaster recovery planning scored 1.7, and performance management scored 2.0. Consultation respondents indicated that no international organisation currently conducts systematic risk assessment, maintains comprehensive continuity plans, or monitors performance metrics across the entire supply chain. Individual IAG Services and observatories manage risks within their operational scope, but end-to-end supply chain risk visibility and coordinated contingency planning remain limited. The assessment identified several concentration points where disruption to single facilities or small numbers of personnel would significantly affect product availability. For example, the NASA Crustal Dynamics Data Information System (CDDIS) serves as the most comprehensive archive for multiple geodetic datasets,

though other data centres maintain partial archives. Similar dependencies exist in product generation, where specific analysis centres produce particular geodetic products without fully redundant backup facilities. Consultation evidence indicates that formal disaster recovery protocols and geographic redundancy arrangements are not systematically implemented across data centres and analysis facilities. Additionally, limited coordinated strategies exist to address potential extended outages at critical observatories, particularly those in the southern hemisphere where station density is already lower than in northern latitudes.

Specific analysis centres produce particular geodetic products without fully redundant backup facilities.

Workforce and knowledge management capabilities also received lower maturity scores, with consultation evidence indicating challenges in both developed and developing countries. The assessment of training and education capability (score 1.7) reflected reports from multiple regions of declining numbers of university geodesy programs, reduced formal training opportunities, and an aging workforce without proportional replacement by new professionals entering the field. Consultation respondents from academic institutions noted that geodesy courses are increasingly difficult to sustain under current university operating models, and that specialised expertise in certain geodetic techniques is concentrated among small numbers of individuals approaching retirement age. The knowledge management capability scored 1.3, with evidence indicating limited systematic documentation of specialised procedures, absence of centralised repositories for technical knowledge, and dependencies on individual experts for specific software tools and analysis workflows. These patterns suggest challenges in maintaining and transferring institutional knowledge across generations of practitioners, though the extent and geographic distribution of these challenges vary across different geodetic techniques and regions.

Public and policy awareness received the lowest scores in the Engagement and Collaboration domain. The outreach and public awareness capability scored 1.3, reflecting minimal personnel capacity dedicated to this function, absence of coordinated outreach

platforms, and limited systematic efforts to communicate geodesy's role to non-technical audiences. Consultation respondents consistently reported that geodesy remains unfamiliar to most policymakers and the public, with few evidence-based materials available that explain geodesy's connections to everyday technologies and critical infrastructure in policy-relevant terms. Respondents from adjacent scientific disciplines noted limited awareness of dependencies on geodetic reference frames and products. The assessment identified this awareness gap as a structural constraint, as strategic planning and resource allocation decisions for infrastructure typically require understanding among decision-makers of the infrastructure's function and importance. Without mechanisms to systematically communicate geodesy's role, consultation evidence suggests that geodetic requirements may not be adequately represented in relevant policy processes, funding decisions, or critical infrastructure planning.

These patterns across risk management, workforce development, continuity planning, and stakeholder engagement capabilities share a common characteristic: they represent coordinating and strategic functions that typically require organisational structures with supply chain-wide visibility and convening authority. The assessment found that while individual organisations and IAG Services manage these functions effectively within their operational scope, coordinated approaches at the supply chain level remain limited, consistent with the governance and strategic planning capability assessments described in Section 6.1.

6.3 The role of the International Association of Geodesy

The assessment identified the IAG as providing essential coordination for scientific and technical functions within the GGSC. Scientists participating in IAG Service structures collaborate effectively to coordinate observations, share data, develop analysis methods, and generate geodetic products. The assessment found that IAG Services have established well-defined technical processes and procedural frameworks that enable this coordination. IAG-affiliated ground observatories demonstrated strong compliance (score 3.0) with applicable laws, regulations, and technical standards in their respective host countries. The assessment also found strong capabilities for equipment calibration and maintenance at IAG-affiliated facilities, reflecting both

technical expertise among personnel and established procedural frameworks for maintaining measurement accuracy.

Current operations depend substantially on the IAG's scientific coordination role while lacking complementary governmental coordination mechanisms that could address strategic planning, resource allocation, and policy implementation functions.

The IAG's coordination role operates within the scope of a scientific membership organisation, facilitating voluntary collaboration among researchers and institutions that contribute observatories, data centres, analysis facilities, and expertise to the supply chain. This model has enabled the development and operation of the geodetic techniques and product generation capabilities that currently support numerous applications. However, as a scientific body, the IAG operates without governmental authority to direct Member State actions, mandate resource contributions, establish binding operational requirements, or enforce compliance with standards beyond its member institutions. The effectiveness of IAG coordination in scientific and technical domains, combined with the governance capability scores described in Section 6.1, suggests that current supply chain operations depend substantially on the IAG's scientific coordination role while lacking complementary governmental coordination mechanisms that could address strategic planning, resource allocation, and policy implementation functions.

6.4 Interpretation of Assessment Findings

The maturity assessment documented a GGSC that currently operates and produces geodetic products supporting numerous applications, while exhibiting lower maturity levels in governance, strategic planning, financial management, and several coordination functions. The assessment found an average maturity score of 2.3 across all capabilities, with significant variation

across domains (ranging from 1.8 to 2.7) and even greater variation among individual capabilities (ranging from 1.0 to 4.0).

This variation in maturity scores reflects the supply chain's historical development through voluntary scientific collaboration coordinated by the IAG, which has produced strong technical capabilities and established operational procedures within individual geodetic technique communities. The assessment found well-developed capabilities in areas such as GNSS and DORIS data acquisition (scores 3.5 and 4.0 respectively), data processing and analysis for established techniques (scores generally 2.8 to 3.8), and equipment calibration and maintenance (score 3.3). These operational and technical capabilities function effectively within current resource constraints.

The lower maturity scores concentrated in governance, strategic planning, financial management, risk management, and supply chain-wide coordination capabilities (multiple Level 1 scores) indicate that functions requiring authority, accountability, and resources at the international supply chain level remain largely undeveloped. The assessment found that strategic planning, resource allocation, risk assessment, and coordination decisions occur in fragmented ways through individual institutions and voluntary collaboration rather than through formal governance structures with supply chain-wide visibility and authority.

The assessment documented several structural characteristics that may affect long-term supply chain sustainability:

- **Resource models:** Significant reliance on voluntary in-kind contributions, with personnel and facilities provided by institutions without dedicated geodesy budgets, and evidence of staff seeking competitive grants to supplement operational funding.
- **Infrastructure condition:** Consultation evidence indicating that over half of VLBI and SLR stations are aging or experiencing degradation, with uncertain funding pathways for modernisation or replacement.
- **Workforce trends:** Reports from multiple regions of declining university geodesy programs, reduced training opportunities, and concentration of specialised expertise among personnel approaching retirement age.

- Concentration points: Dependencies on single institutions or small numbers of personnel for certain critical functions, including comprehensive data archives, specific product generation, and specialised software maintenance.
- Coordination mechanisms: Effective scientific and technical coordination through IAG Services operating on voluntary collaboration, without complementary governmental coordination structures for strategic planning, resource allocation, or policy implementation.

These characteristics indicate that current operations depend substantially on the technical expertise, institutional commitment, and voluntary contributions of participating organisations and individuals, functioning within resource constraints and organisational structures that evolved for scientific collaboration rather than critical infrastructure management. The assessment findings suggest examining whether the current structural arrangements provide adequate resilience, sustainability, and coordination capacity given the supply chain's role in supporting critical infrastructure and numerous societal applications.

6.5 Limitations of this assessment

This assessment represents the first comprehensive maturity evaluation of the GGSC and has several inherent limitations that should be considered when interpreting findings:

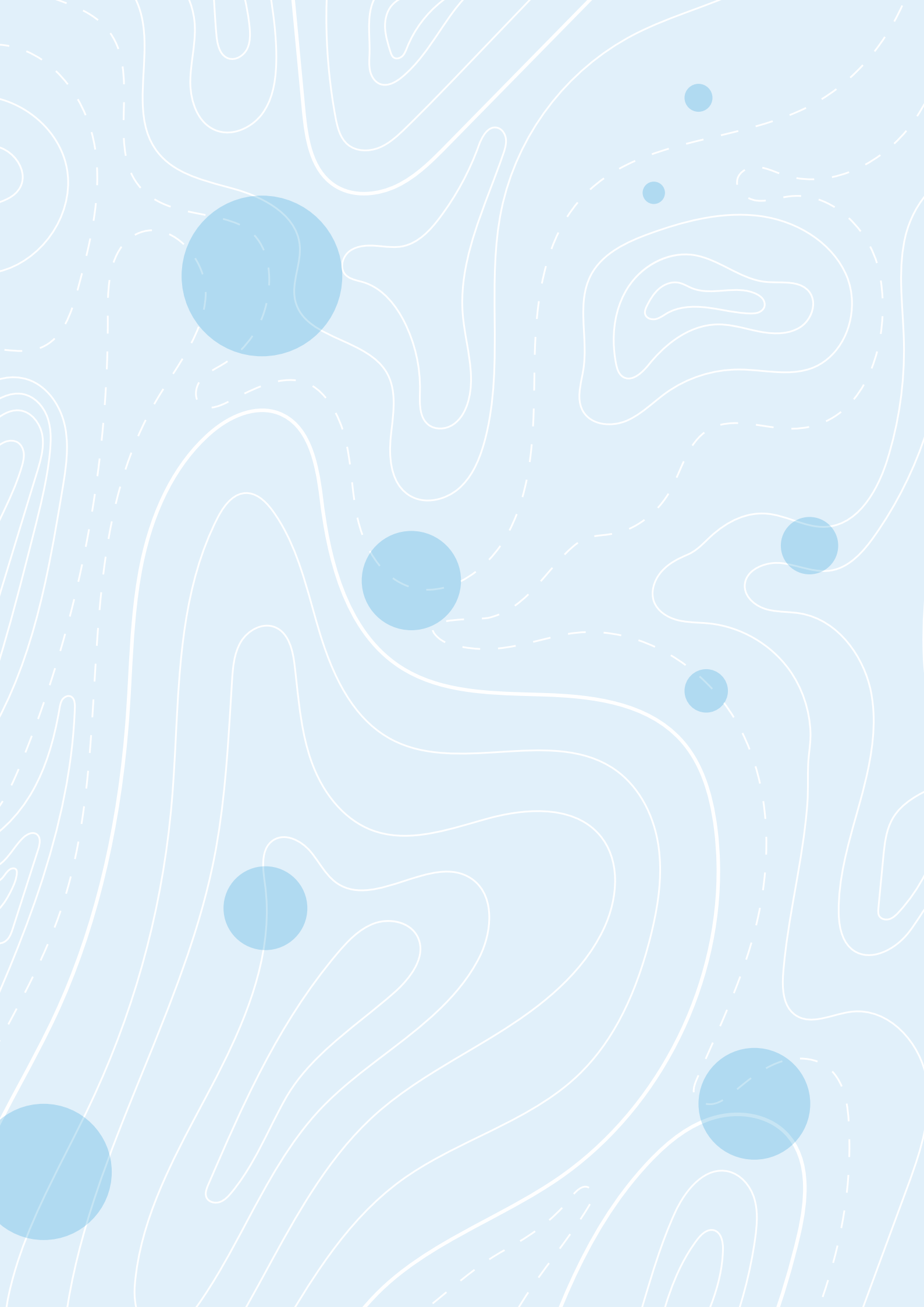
- Sampling and consultation limitations: Evidence came primarily from experts affiliated with the IAG and its Services, who possess deep technical knowledge of geodetic operations but may have perspectives shaped by their roles within the scientific community. Perspectives from non-IAG affiliated networks (including commercial GNSS networks, national mapping agencies operating independently of IAG Services, and private sector users of geodetic products) may be underrepresented in the assessment evidence base. Additionally, the consultation process reached leadership and coordination roles more effectively than operational staff at individual facilities, potentially affecting the comprehensiveness of operational-level evidence.
- Temporal constraints: The assessment reflects the status of the GGSC as understood in May 2025

based on the Global Geodesy Needs Assessment conducted in 2024 and subsequent consultations. Conditions at individual facilities, institutional arrangements, personnel situations, and technical capabilities change over time. The assessment provides a snapshot rather than continuous monitoring, and some specific details may have changed since consultation activities concluded.

- Framework and scope limitations: The 58-capability model developed for this assessment represents a first attempt to systematically categorise GGSC functions. Alternative capability taxonomies might organise functions differently or identify capabilities not captured in this framework. The maturity scale definitions (Levels 1-5) were adapted from existing frameworks but applied to geodesy for the first time, and alternative maturity criteria or scale definitions might yield different assessments. The assessment focused on the supply chain producing geodetic reference frames and products, with less detailed evaluation of end-user requirements, application-specific performance needs, or the full range of commercial and national networks operating outside IAG coordination.
- Evidence quality variations: Evidence quality varied across capabilities based on available documentation, consultation response patterns, and the inherent observability of different functions. Some capabilities (particularly those with quantitative operational metrics) could be assessed with higher confidence than others (particularly those involving strategic or organisational functions where evidence is primarily qualitative). The confidence levels assigned (high, medium, low) acknowledge this variation but represent subjective judgments rather than statistically derived measures. Capabilities assessed with low confidence should be considered preliminary findings requiring validation through more detailed investigation.
- Scoring methodology limitations: Maturity scores reflect expert judgment based on available evidence and consultation feedback. No standardised measurement instruments or quantitative thresholds define the boundaries between maturity levels. Different assessors reviewing the same evidence might assign different scores based on their interpretation of maturity level definitions and weighting of evidence types. The assessment process included consultation with over 130 experts to refine scores, but inter-rater reliability was not formally

quantified. The scoring represents a reasonable interpretation of available evidence rather than definitive measurement.

- Geographic and institutional coverage: Evidence collection achieved stronger coverage in regions with active IAG Service participation and institutions with established geodetic programs. Evidence from developing regions, countries with emerging geodetic capabilities, and institutions with limited international collaboration may be less comprehensive. This may affect the representativeness of findings, particularly for capabilities related to global coverage, capacity development, and regional variations in infrastructure and expertise.
- Future assessments could address these limitations through expanded consultation with diverse stakeholder groups, systematic quantitative data collection where feasible, refinement of the capability model and maturity scales based on lessons learned, and development of standardised assessment protocols with explicit scoring criteria.



7. Recommendations for Further Investigation

This assessment identified several areas where available evidence was insufficient to support confident maturity assessments, where consultation participants expressed divergent views, or where systematic data collection has not yet occurred. These areas represent priority topics for future investigation to support more comprehensive understanding of the GGSC.

7.1 Supply chain architecture and requirements definition

The assessment found no comprehensive technical specification defining the optimal configuration of the GGSC. While individual IAG Services maintain requirements for their respective techniques, no integrated analysis documents the number, geographic distribution, technical specifications, and redundancy arrangements of observatories, data centres, and analysis facilities needed to reliably produce geodetic products meeting current and projected user requirements. This gap extends to several specific questions:

- **Observatory network design:** What constitutes adequate global coverage, station density, and geographic redundancy for each geodetic technique (GNSS, VLBI, SLR, DORIS) to achieve required product accuracy and reliability? What are the minimum network configurations that will maintain acceptable product quality if individual stations experience extended outages?
- **Data centre architecture:** How many data centres with what geographic distribution and redundancy arrangements are required to ensure data availability, integrity, and preservation? What standards for synchronisation, replication, backup, and disaster recovery should apply?
- **Analysis capacity requirements:** What analysis centre capacity, distribution, and backup arrangements are needed to maintain continuous product generation? How should analysis functions be distributed to ensure resilience against institutional disruptions or geopolitical access restrictions?

- **Performance metrics and thresholds:** What quantitative accuracy, latency, availability, and reliability requirements do different user communities have for geodetic products? How do current supply chain capabilities compare to these requirements, and where do gaps exist?

No comprehensive technical specification exists defining the optimal configuration of the GGSC.

Further investigation in this area would establish technical baselines against which current capabilities and future investment decisions could be evaluated. This work would require engagement with both the geodetic community to assess technical requirements and user communities to document application-specific needs.

7.2 Security requirements and critical infrastructure classification

The assessment assigned maturity scores of 3.0 for both physical security management and cyber security management at geodetic facilities, but confidence in these assessments was noted as low. Consultation participants indicated that existing security measures appear adequate for current operations under present institutional arrangements, but systematic evaluation has not been conducted to determine whether security measures align with the strategic importance of geodetic infrastructure to critical services.

Several specific questions require investigation:

- **Current security baseline:** What physical security measures (access control, perimeter protection, surveillance, personnel vetting) are currently implemented at geodetic observatories, data centres, and analysis facilities? How do these measures vary across institutions, countries, and facility types?

- **Cyber security posture:** What cyber security controls (network security, access management, intrusion detection, incident response, security testing) are implemented across the supply chain? Are geodetic systems subject to the same security requirements as other critical infrastructure systems within their host institutions?
- **Critical infrastructure implications:** If geodetic infrastructure components were formally designated as critical infrastructure—as has occurred for GNSS ground control segments in some jurisdictions—what additional security requirements would apply? What gaps exist between current security measures and standards typically required for critical infrastructure systems?
- **Threat assessment:** What are the realistic threat scenarios (physical intrusion, cyber attack, insider threats, supply chain compromise) affecting geodetic infrastructure? What would be the consequences of successful attacks on key facilities or systems?
- **Security coordination:** Are security incidents, vulnerabilities, or threats shared systematically across the geodetic community? Do coordinated security monitoring or incident response mechanisms exist?

This investigation would require security expertise beyond the geodetic community's current scope and would need to respect operational security considerations that may limit public documentation of specific security measures.

7.3 Data centre coordination and redundancy

The assessment identified data centres as critical infrastructure for geodetic data management but found limited evidence regarding coordination, standardisation, and redundancy arrangements across data centres. Consultation participants provided conflicting accounts of data mirroring practices, backup arrangements, and coordination protocols. Several specific areas require systematic investigation:

- **Current data holdings and distribution:** Which data centres maintain which geodetic datasets, at what completeness levels, and with what update frequencies? Are complete redundant copies of all

critical datasets maintained at multiple geographically distributed locations?

- **Coordination mechanisms:** What formal and informal coordination exists among data centres? Are there agreements, protocols, or standards governing data exchange, synchronisation, quality control, and version management across centres?
- **FAIR principles implementation:** To what extent do current data management practices align with Findability, Accessibility, Interoperability, and Reusability (FAIR) principles? Where do gaps exist, and what would be required to achieve full FAIR compliance?
- **Quality assurance:** What quality control procedures are implemented at different data centres? Are file integrity checks, metadata validation, and completeness verification performed systematically? How are data quality issues identified and resolved?
- **Disaster recovery capabilities:** What backup, replication, and recovery procedures exist to restore data services following facility outages, equipment failures, or data loss events? Have these procedures been tested, and what recovery time objectives apply?
- **Single points of failure:** The assessment noted that CDDIS serves as the most comprehensive archive for multiple geodetic datasets. What would be the impact of extended CDDIS unavailability? What alternative access pathways exist, and how long would it take to establish them?

Further investigation should systematically document current data centre operations, test coordination and recovery procedures, and identify gaps relative to best practices for critical data infrastructure management.

7.4 Software quality, security, and sustainability

The assessment identified geodetic software as essential supply chain infrastructure but found insufficient evidence to confidently assess software quality, security, documentation, and maintenance sustainability. Consultation participants noted that specialised geodetic software may be developed and maintained by small numbers of individuals, sometimes outside formal institutional frameworks, raising questions

about long-term sustainability and compliance with contemporary software engineering standards.

Specific investigation areas include:

- **Software inventory and dependencies:** What software tools are critical for geodetic data processing, analysis, and product generation? Which of these are proprietary versus open source? What dependencies exist between different software tools and versions?
- **Development and maintenance models:** Who develops and maintains critical geodetic software? Are development activities supported through formal institutional commitments, or do they rely on individual contributions? What succession planning exists for software maintained by individuals approaching retirement?
- **Code quality and standards:** Do geodetic software tools comply with contemporary software engineering standards for code quality, testing, documentation, and version control? Have security audits been conducted? Are software development practices consistent with those used in other critical infrastructure applications?
- **Security vulnerabilities:** Have geodetic software tools been assessed for security vulnerabilities, including input validation, access control, cryptographic implementations, and dependency vulnerabilities? Are security updates applied systematically?
- **Documentation adequacy:** Is documentation sufficient to enable new users to operate software effectively and new developers to maintain and extend codebases? Is documentation kept current as software evolves?
- **Data centre IT security standards:** Do geodetic data centres implement standardised IT security practices, including network segmentation, access controls, logging and monitoring, patch management, and incident response? Are these practices audited regularly?

Investigation in this area would require software engineering and cyber security expertise to conduct code reviews, security assessments, and documentation evaluations. Findings would inform development of software quality and security standards appropriate for geodetic infrastructure.

7.5 Quantitative workforce trends

The assessment noted consultation evidence of declining geodesy programs and aging workforce, but systematic quantitative data does not exist to characterise workforce trends comprehensively. Further investigation should establish:

- **Academic program trends:** How many universities globally offer geodesy degree programs at undergraduate, masters, and doctoral levels? How have these numbers changed over the past 10, 20, and 30 years? What are projected trends?
- **Enrolment and graduation rates:** How many students enrol in and complete geodesy programs annually? What are trends in student interest, and how do geodesy programs compare to related geoscience disciplines?
- **Workforce demographics:** What is the age distribution of professionals working in geodetic research, education, and operations? What is the expected rate of retirement over the next 5, 10, and 15 years?
- **Skill gaps and specialisations:** Which specialised skills (e.g., VLBI correlation, geoid modelling, reference frame computation) show the most acute personnel shortages? Where are these shortages geographically concentrated?
- **Career pathways:** What career pathways exist for geodesy professionals? How competitive are geodesy positions compared to adjacent fields? What factors influence career choices among students considering geodesy?

Specialised expertise is concentrated among individuals approaching retirement age.

Systematic data collection through surveys, institutional records, and labour market analysis would support evidence-based workforce planning and inform educational capacity development strategies.

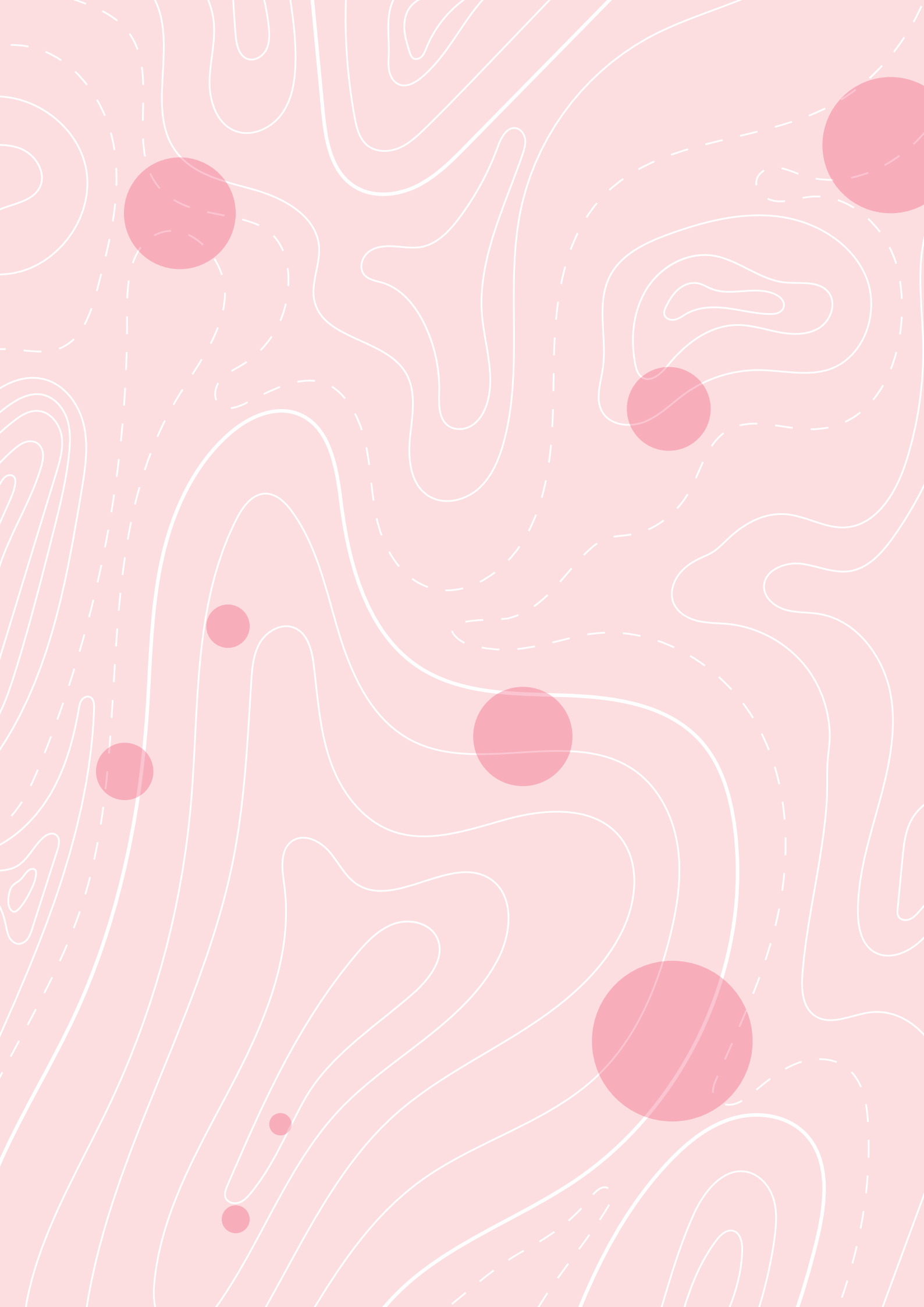
7.6 Economic analysis

The assessment identified funding as inadequate (maturity score 1.0) but did not quantify current investment levels or estimate required resources. Economic analysis should address:



















- Current global investment: What is the total annual expenditure on geodetic observatories, data centres, analysis facilities, and coordination activities globally? How is this investment distributed across countries, institutions, and functions?
- Full cost accounting: What are the actual costs of operating the GGSC when in-kind contributions are quantified at market value? What are the opportunity costs of relying on voluntary contributions?
- Investment gaps: What additional investment would be required to address identified infrastructure deficiencies, implement redundancy and security improvements, and support workforce development? What are the costs of different improvement scenarios?
- Economic value and return on investment: What is the economic value generated by geodetic services across different application sectors (positioning services, Earth observation, critical infrastructure timing, scientific research)? How does this compare to investment in geodetic infrastructure?
- Cost of disruption: What would be the economic costs of degraded geodetic service accuracy, extended outages, or supply chain failures? How do these costs compare to investment in resilience improvements?

Current investment levels are unknown, required resources are unquantified, and cost-benefit comparisons have not been performed.

Economic analysis would provide evidence for resource allocation decisions and support cost-benefit evaluation of alternative investment strategies.














Appendix

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Engagement and Collaboration	Stakeholders Management	Stakeholder Identification and Analysis	Identifying and classifying the stakeholders of the GGSC	3 	2 	3 	2 
Engagement and Collaboration	Stakeholders Management	Stakeholder Communication and Engagement	Communicating and engaging with stakeholders effectively.	2 	2 	2 	2 
Engagement and Collaboration	Government, Science, Academic and Private Sector Collaboration	Standards Development and Promotion	Developing and promoting standards required for the GGSC	3 	3 	3 	3 
Engagement and Collaboration	Government, Science, Academic and Private Sector Collaboration	Partnership and Collaboration	Establishing and managing collaborations across government, science, academia, and private sector.	2 	2 	NA	NA
Engagement and Collaboration	Education and Outreach	Outreach and Public Awareness	Public awareness about the importance of geodesy and engaging in outreach activities.	2 	1 	1 	1 




















Average	Evidence
2.5	<p>The IAG demonstrates reasonable capacity (score 3) to identify stakeholders within the geodetic and geospatial communities, evidenced by well-attended science and technology conferences and effective engagement through UN-GGIM structures. However, some gaps in stakeholder identification processes were reported, which reflect gaps in capturing end-users such as climate scientists, weather forecasters, satellite operators, and policy officials. The assessment identified reliance on manual and non-shareable data capture methods, which may limit scalability and coordination across parts of the supply chain. Technology and software for stakeholder identification are moderately developed (score 3) but lack integration with the stakeholder engagement platforms through the geodetic community (e.g. IAG, FIG).</p>
2.0	<p>Communication on technical topics amongst people within the geodetic community is done reasonably well, however broader strategic and policy communication is weak across all dimensions. A major deficiency identified in the Global Geodesy Needs Assessment is insufficient evidence-based materials explaining geodesy to policymakers and the public. Outside the geodetic community, there is limited awareness among adjacent scientific disciplines and the private sector about their dependency on geodesy. Communication processes score 2 with high confidence, reflecting that although some processes are in place to communicate to people inside the geodetic community exist (e.g. IAG newsletters), inadequate mechanisms exist to communicate with government policy makers and users of geodetic products. The lack of coordinated technology platforms and channels to communicate between scientists, policy makers and the private sector constrain engagement effectiveness, resulting in inconsistent messaging and limited reach beyond the scientific community.</p>
3.0	<p>A small, dedicated community demonstrates reasonable technical capability (people score 3) in developing geodetic standards, but capacity is severely insufficient given the proliferation of standards requiring geodetic input across modern society. The processes for standards development are well-established (score 3) through technical bodies such as ISO and OGC however there is an over-reliance on in-kind contributions, with many experts contributing to standards work in their personal time despite the critical importance of this function. Technology and methodologies for standards development are reasonable mature (score 3), but there is low confidence (confidence 1) in the data supporting standards promotion effectiveness, indicating limited tracking of adoption and impact across user communities.</p>
2.0	<p>Scientists engage and collaborate effectively through established IAG meetings and IAG Service structures; however, this engagement and collaborate does not extend to government and the private sector. There is a deficiency in engagement and collaborations at national and international governmental levels, likely stemming from absent national and international governance structures. Very few countries have geodesy committees with cross-government representation or include geodesy on inter-agency agendas. Formal intergovernmental coordination is largely absent outside UN-GGIM, whose decisions lack legal force. Where intergovernmental collaboration exists, it tends to be project-specific rather than systematic. A concerning weakness is deteriorating cross-domain engagement between astronomy and geodesy communities, potentially due to VGOS network separation, resulting in the celestial reference frame being orphaned between disciplines.</p>
1.3	<p>Outreach and public awareness capability is assessed at low maturity (score 1.3). Consultation responses indicate limited public and policy awareness of geodesy relative to its technical role. Outreach activities appear to be conducted by a small number of contributors, often on an in-kind basis. No centrally coordinated outreach platform or shared engagement metrics were identified. Respondents noted recent improvements linked to UN-GGCE policy outreach activities. Comparisons were made with other large science initiatives as potential reference models for communication approaches.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Engagement and Collaboration	Education and Outreach	Curriculum Development and Educational Program Delivery	Developing and executing educational programs and trainings	2 	2 	2 	NA
Governance and Strategy	Policy and Regulation	Mandate	Developing the formal authority to develop, implement, and enforce policies and regulations in alignment with its defined objectives and legal framework.	1 	1 	NA	NA
Governance and Strategy	Policy and Regulation	Policy Formulation	Defining and establishing the high-level principles, rules, and guidelines that govern the GGSC.	1 	1 	NA	NA
Governance and Strategy	Policy and Regulation	Regulatory Compliance	Ensuring adherence to relevant laws, regulations, and standards related to ground observatories	3 	3 	NA	NA
Governance and Strategy	Policy and Regulation	Legal Framework	Establishing the legal structures and agreements that underpin geodetic operations.	2 	2 	NA	NA


Average	Evidence
2.0	<p>Educational content and training capacity is lacking across the dimensions of people and processes, with high confidence in this assessment. Representatives from both developed and developing countries report declining numbers of higher education programs, an aging workforce, and insufficient qualified staff. Developing countries face disproportionate impacts due to lower baseline capacity. The scores reflect both the small number of people creating educational programs and the challenges academic institutions face in maintaining existing geodesy courses, which are perceived as expensive to run under current university operating models. There is a notable absence of high-quality online geodetic training courses. The systematic processes for curriculum development and program delivery are underdeveloped, resulting in ad hoc rather than strategic approaches to addressing the workforce crisis in geodesy.</p>
1.0	<p>The assessment indicates low maturity (score 1) in the people and processes supporting mandate development for geodesy. The strongest existing international mandate identified is UN General Assembly resolution 69/266, which is non-binding and encourages Member States to sustain geodesy within existing resources. Consultation evidence indicates that international governance arrangements are limited in their ability to develop, implement, or enforce policies and regulations related to geodesy. At national level, responsibilities are often distributed across multiple departments without a designated lead authority or formal coordination mechanism. Respondents reported that this distribution is associated with variation in international representation and interdepartmental coordination. Assessment evidence suggests that limited formal mandate structures reduce the consistency with which scientific recommendations are translated into governmental policy actions.</p>
1.0	<p>The assessment indicates low maturity (score 1) in policy formulation capability across the GGSC. Evidence reviewed did not identify a comprehensive, formalised, and enforceable set of high-level principles or rules at the international level. The UN-GGIM Committee of Experts was identified as the primary formal coordination mechanism, with non-legally binding decisions. While individual IAG Services demonstrate governance practices within their operational scope, no overarching supply-chain-level governance structure with governmental authority was identified. Respondents reported that policy development activities are primarily science-driven and consensus-based rather than embedded in formal governmental policy frameworks. This condition is associated with limited ability to establish binding cross-supply-chain policy instruments.</p>
3.0	<p>IAG-affiliated ground observatories demonstrate reasonable compliance with laws, regulations, and standards in their host Member States. However, significant challenges exist in translating IAG recommendations, infrastructure requirements, and standards into national policies and laws. This highlights a structural weakness: IAG representatives cannot make binding decisions implementable upon return to their countries, requiring translation of scientific language into policy-appropriate terms to secure investment. For non-IAG and privately owned GNSS networks, regulatory compliance is more variable, with some networks operating beyond recognised regulatory or technical oversight. Regional disparities are pronounced, with robust compliance frameworks in Europe, North America, and Asia-Pacific, but limited capacity, uneven modernisation, and outdated infrastructure across Africa and developing countries. Even well-intentioned operators in developing regions often lack resources to maintain compliance with evolving standards.</p>
2.0	<p>Legal structures and agreements supporting geodetic operations are underdeveloped at national, regional, and international levels. The absence of international governance for geodesy means no legally binding framework ensures the supply chain can accurately and reliably create geodetic products. Member States frequently lack authority to implement supply chain requirements proposed by the scientific community. Much of the supply chain operates on goodwill and informal contributions rather than formalised agreements, creating vulnerability and unpredictability. There is no formal recognition of geodesy components within critical infrastructure legal frameworks for essential services like power grids, financial transactions, and communications systems. This legal vacuum prevents the establishment of enforceable obligations, liability frameworks, and sustainability mechanisms that would normally apply to infrastructure of such systemic importance.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Governance and Strategy	Planning and Strategy	Vision and Strategy	Developing a long-term vision and strategic direction for the GGSC	3 	3 	NA	NA
Governance and Strategy	Strategy and Planning	Strategic Planning	Creating plans and roadmaps to achieve the strategic objectives of the GGSC.	1 	1 	NA	NA
Governance and Strategy	Strategy and planning	Performance Management	Monitoring, evaluating, and improving the performance of the GGSC and its stakeholders.	2 	2 	NA	NA
Governance and Strategy	Risk and Security Management	Risk Management	Identifying, assessing, and mitigating risks that could impact the GGSC	1 	1 	NA	NA
Governance and Strategy	Risk and Security Management	Physical Security Management	Protecting geodetic observatories and access, and operation.	3 	3 	3 	NA

















Average	Evidence
3.0	Capability to develop strategic vision exists but is constrained by governance limitations. The UN-GGCE has developed the 1st Joint Development Plan for Global Geodesy, providing guidance for Member States, UN-GGCE, and partners on actions to sustain the supply chain. However, this plan was developed largely within the scientific community without substantial input from policymakers and the private sector. The absence of international governance means no legally binding long-term strategy exists. While the people working on strategic vision (primarily through UN-GGCE) demonstrate capability and the processes are replicable, the lack of governmental authority limits implementation.
1.0	Strategic planning capability is critically insufficient. Although the UN-GGCE has developed the 1st Joint Development Plan outlining strategic objectives and phased actions, the absence of international governance means plans are developed primarily by the scientific community without formal authority to implement or fund recommendations. International governance with visibility, authority, and accountability for the entire supply chain does not exist. Consequently, the strategic direction set by the science community cannot be effectively implemented to mitigate supply chain risks. The people involved in planning lack governmental mandate, processes are informal and non-binding, and there is no mechanism to ensure Member State alignment with strategic plans. This creates a fundamental disconnect between scientific strategic planning and governmental implementation capacity.
2.0	Performance management within individual IAG Services functions reasonably well to meet immediate stakeholder needs. However, as satellite-based services and user communities rapidly expand, insufficient attention is paid to identifying, monitoring, evaluating, and improving performance across the entire supply chain. An assessment framework exists for some performance criteria, but this is limited by insufficient data and lack of available information. The fundamental constraint is the absence of overall governance for the supply chain, meaning no organisation has complete visibility, authority, or accountability necessary for effective monitoring and evaluation functions. Performance management remains fragmented across individual services and organisations without end-to-end supply chain perspective. The people and processes for comprehensive performance management are inadequate, and there is no systematic data collection enabling holistic supply chain performance assessment.
1.0	Formal risk management capability is assessed at low maturity (score 1). The assessment did not identify an organisation with responsibility for systematic identification, assessment, and mitigation of risks across the entire supply chain. Risk management activities appear to occur primarily within individual organisations or services. Consultation evidence indicates dependencies on small numbers of experts and facilities in certain functions, which respondents identified as potential concentration risks. Geopolitical and institutional disruptions were reported to have affected collaboration and data continuity in some cases. Further investigation would be required to determine the extent of distributed governance arrangements, mirrored data centres, and regional redundancy planning.
3.0	Most IAG observatories report adequate physical security for current operations, with measures in place to protect equipment and staff from immediate threats. Representatives indicate site protection and access do not significantly impact operations under current conditions. However, confidence in this assessment is low because more investigation is needed to determine whether security measures would be sufficient if infrastructure were classified as critical infrastructure in the future, which would trigger higher security standards. The processes for physical security exist and function adequately at individual observatories, but there is no systematic assessment of whether security measures are commensurate with the strategic importance of geodesy to national and global infrastructure dependencies. This gap in comprehensive security assessment represents an unquantified risk.

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Governance and Strategy	Risk and Security Management	Cyber Security Management	Protecting geodetic assets, data, and systems from unauthorised access, use, disclosure, disruption, modification, or destruction.	3 	3 	3 	NA
Governance and Strategy	Risk and Security Management	Disaster Recovery and Supply Chain Continuity	Planning for and responding to disruptions to geodetic operations caused by disasters or other unforeseen events.	2 	2 	1 	NA
Governance and Strategy	Financial Management	Funding and Investment	Securing and managing the financial resources required to support geodetic activities.	1 	1 	NA	1 
Governance and Strategy	Financial Management	Budgeting	Developing and managing budgets for geodetic programs and projects.	1 	1 	NA	1 
Governance and Strategy	Financial Management	Cost Management	Controlling and optimising the costs associated with geodetic operations.	1 	1 	NA	1 
Data Management	Data Governance	Data Architecture Design	Designing the structure for organising and managing data.	2 	2 	2 	3 












Average	Evidence
3.0	<p>Most IAG Service representatives report adequate cyber security and adherence to national-level government or university cyber security protocols. Current security measures appear sufficient for present operational conditions, however, confidence in this assessment is low because existing protocols are based on hardware and software not being classified as critical infrastructure systems. Should geodetic systems be designated as critical infrastructure in the future, current cyber security measures may prove insufficient to meet elevated requirements. The absence of international governance means no coordinating body assesses cyber security risks across the entire supply chain or establishes minimum security standards. There is no evidence of systematic cyber security auditing, threat modelling, or incident response planning at the global supply chain level. Individual organisations maintain adequate security within their contexts, but supply chain-wide cyber resilience remains unassessed and uncoordinated.</p>
1.7	<p>Disaster recovery and continuity planning capability is assessed at low maturity (average score 1.7). No international body was identified as responsible for coordinated continuity analysis across the supply chain. Evidence suggests that disaster recovery practices vary across facilities. Some observatories reported successful recovery from past disruption events, while others reported limited insurance coverage or redundancy. Consultation responses indicate limited availability of supply-chain-level continuity frameworks and uneven implementation of redundancy measures.</p>
1.0	<p>Assessment evidence indicates that financial resources across the GGSC are limited relative to identified needs (score 1). Consultation responses report significant reliance on in-kind and voluntary contributions. Funding is reported to vary across institutions and regions, with mixed coverage of both capital and operational requirements. Respondents noted limited consolidated visibility of current investment levels across the supply chain, which constrains coordinated forward planning. In several cases, personnel at observatories and analysis centres reported reliance on competitive grants outside operational budgets, which may affect available time for core functions. No coordinated international funding allocation or investment prioritisation mechanism was identified.</p>
1.0	<p>Budgeting capability is assessed at low maturity (score 1). No international body was identified that systematically assesses short-term and long-term operational and capital budget requirements across the full supply chain. Consultation evidence indicates reliance on institution-level budgeting processes and in-kind contributions. Governance arrangements were reported as fragmented across jurisdictions, with limited mechanisms for coordinated financial planning or cross-supply-chain resource allocation. Available data on current expenditures and projected budget needs is incomplete, which limits evidence-based global budget planning.</p>
1.0	<p>Cost management capability is assessed at low maturity (score 1). Consultation responses indicate that cost control and optimisation are primarily undertaken at the organisational level rather than coordinated across the supply chain. Aging infrastructure was frequently cited as contributing to rising maintenance costs. No global mechanism was identified for coordinated cost tracking or optimisation across facilities and services. While options such as shared infrastructure and public-private partnerships have been discussed in expert forums, no supply-chain-wide cost optimisation framework was identified.</p>
2.3	<p>Some data architecture has been developed but with improvement opportunities. Data centres exist for various geodetic techniques to host multiple data levels (raw, level 1, level 2) with quality checking, archiving, and distribution functions. The scientific community conducts unified analysis workshops to prevent architectural decisions from resulting in incorrect products. From an IAG Services perspective, data architecture could be operationalised more effectively, though performance is strong considering resource limitations and reliance on in-kind contributions. Interoperability challenges exist between IAG Services data and non-IAG networks (commercial, national, private-sector GNSS streams), with architectural differences between scientific and private sector communities creating user difficulties. The architecture is designed primarily for specialist users rather than emerging user communities, making it challenging for non-experts to understand, access, and use geodetic data effectively.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Data Management	Data Governance	Data Quality Management	Ensuring data is accurate, reliable, complete and timely	2 	2 	1 	3 
Data Management	Data Governance	Metadata Management	Managing information about the data itself for aspects like discoverability and lineage	2 	2 	1 	3 
Data Management	Data Governance	Data Lifecycle Management	Managing data from creation through usage to disposal.	2 	2 	1 	3 
Data Management	Data Acquisition and Storage	GNSS Data Acquisition and Storage	Collecting data from GNSS receivers.	3 	4 	4 	3 













Average	Evidence
2.0	<p>Data quality management capability averages 2.0 but with notable weaknesses and low confidence in multiple areas. Regional and international data centres are the primary quality management infrastructure but operate with limited staffing allocating only fractions of time to quality activities. While personnel perform scientific quality management well, it cannot be verified whether all geodetic data required for geodetic products are available in multiple data centres, meet FAIR principles, completeness, and timeliness standards. This verification gap is most acute for international data centres on which there is a strong reliance on the CDDIS archive. This creates a potential single-point-of-failure risk. Technology and data scores are higher as quality assessment tools and standards exist, but low confidence indicates insufficient evidence of systematic deployment and effectiveness. The processes dimension score is particularly weak due to lack of coordinated quality management protocols across distributed centres and absence of binding quality standards enforceable across contributing organisations.</p>
2.0	<p>Metadata management capability averages 2.0 with significant limitations and low confidence in multiple dimensions. Regional and international data centres maintain reasonably good scientific metadata, but limited staffing dedicating only partial time to metadata activities constrains systematic management. It cannot be verified whether all geodetic metadata required for geodetic products are available in multiple data centres, meet FAIR principles, completeness, and timeliness standards. This verification gap is most acute for international data centres on which there is a strong reliance on the CDDIS archive. Examples demonstrate that while scientific metadata may meet quality standards for specialist users, non-specialist users find geodetic data difficult to locate and interpret, indicating metadata inadequacy for broader user communities. Technology and data capabilities for metadata management exist but there are questions outstanding regarding deployment effectiveness. The processes for coordinated metadata management are weak due to lack of standardised protocols across distributed centres.</p>
2.0	<p>Data lifecycle management reveals gaps across the continuum from acquisition through preservation and long-term curation. Regional and international data centres represent primary infrastructure but operate with minimal dedicated staffing, with personnel allocating only fractions of time to lifecycle management within government or academic institutions. This limited resource allocation raises sustainability concerns. Critically, no coordinated lifecycle management protocols exist among centres. Essential practices such as distributed redundancy, synchronised replication across geographic regions, and standardised data versioning are absent. Such coordination is fundamental to robust lifecycle governance and necessary for data integrity, continuity, and disaster recovery.</p>
3.5	<p>GNSS data acquisition and storage demonstrates the strongest capability in the supply chain. An extensive global network of GNSS stations operates with good coordination through the IGS, providing capacity for continuous data collection from permanent reference stations worldwide. However, capability is unevenly distributed geographically. Open access to GNSS data and services remains limited in certain areas, particularly developing countries, resulting in coverage gaps affecting both station density and dataset completeness. Workforce expertise shows marked regional variation, with developed countries exhibiting high technical competency and adequate staffing, while developing countries demonstrate notable deficiencies in specialised expertise for receiver operation, data management, and quality control. Established protocols are well-defined and documented, with minimal operational challenges. Available GNSS receiver technology demonstrates high quality across manufacturers, with competitive pricing, diverse options, and fit-for-purpose solutions supporting flexible deployment strategies while maintaining data quality.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Data Management	Data Acquisition and Storage	VLBI Data Acquisition and Storage	Collecting data from VLBI telescopes.	3 	3 	3 	3 
Data Management	Data Acquisition and Storage	SLR Data Acquisition and Storage	Collecting data using satellite laser ranging.	2 	4 	3 	3 
Data Management	Data Acquisition and Storage	DORIS Data Acquisition and Storage	Collecting data from DORIS tracking stations.	4 	4 	4 	4 
Data Management	Data Acquisition and Storage	Gravity Data Acquisition and Storage	Measuring the Earth's terrestrial gravitational field.	2 	4 	4 	3 

Average	Evidence
3.0	<p>VLBI data acquisition and storage capability averages 3.0 but with low confidence across most dimensions. There is uncertainty about whether sufficient staff work on VLBI operations. Some indication suggests workforce may have decreased due to divergence between VGOS and astronomy VLBI technology, potentially impacting ICRF products. Data collection occurs through a sparse telescope network with particularly limited southern hemisphere coverage. Over half of VLBI stations are aging or degrading, impacting data quality and reliability. Restricted bandwidth at remote sites delays data transmission, potentially preventing real-time product generation. VLBI technology has mixed performance with some systems aging and degrading while others are performing well. Data quality currently meets accuracy requirements but with low confidence, as qualitative evidence suggests the network may lack sufficient reliability and redundancy. There is a concern that closure of a few southern hemisphere stations due to maintenance or failure could significantly impact geodetic product accuracy and reliability.</p>
3.0	<p>SLR data acquisition and storage capability averages 3.0 but with moderate confidence and significant concerns about network sustainability. Data collection uses a sparse station network, particularly in the southern hemisphere. Over half of SLR stations are aging or degrading, affecting data quality and reliability. Network infrastructure has not kept pace with growing demand, and limited continuous tracking capability reduces derived product accuracy. There are some questions regarding whether or there are sufficient staff working on SLR operations, with suggestions that some staff now dedicate time to other projects such as space debris tracking instead of geodetic tracking due to financial pressures. The ILRS maintains well-defined work programs with good member communication. Technology demonstrates mixed performance with some systems aging and degrading while new systems are being installed, though more investigation is needed to determine required network configuration required for accurate and reliable geodetic products.</p>
4.0	<p>DORIS data collection operates over a strong network of stations distributed around the world (around 60 DORIS stations). The current network is quite well distributed globally, though geopolitical issues cause some coverage gaps. Most work related to DORIS is undertaken by the French government and is well supported, providing strong personnel capacity. The IDS maintains a well-defined program of work with good communication amongst members, demonstrating mature procedural frameworks. The IDS systems function well and are fit for purpose, representing strong technological capability. Indications are that data quality currently meets accuracy and reliability requirements, with consistent high-quality data output. One of the key strengths of the DORIS network and system is that it is strongly supported by the French government, ensuring sustained operations and maintenance. However, this strength is simultaneously a risk, as any reduction in French government support for DORIS would cause the system to suffer significantly, creating a single-jurisdiction dependency that could impact data continuity and long-term sustainability.</p>
3.3	<p>The Earth's gravity field is modelled using satellite and surface (terrestrial, shipborne and airborne) gravity data. Surface gravity data is essential for increasing the resolution and accuracy of satellite data, yet this surface gravity data is limited in number and unevenly distributed globally, with particularly sparse coverage in developing regions. This uneven distribution hinders accurate modelling of the geoid in less-monitored areas. There are a limited and decreasing number of professionals who have the capability to perform geoid model development, with this capacity challenge particularly acute in developing countries. Well-documented processes exist for performing measurements and creating models of the Earth's gravity field, traditionally recorded in scientific journals, demonstrating strong procedural maturity. Strong satellite-based systems are available to measure the time-dependent and static gravitational field, and good quality air, ship and land-based systems are available for surface measurements. Data quality shows variation, with good quality space-borne data but variable airborne, shipborne and terrestrial gravity data archives around the world, reflecting the uneven global distribution and capacity challenges in developing regions.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Data Management	Data Acquisition and Storage	Local Tie	Surveying to connect different geodetic instruments on site.	2 	2 	1 	3 
Data Management	Data Processing and Analysis	GNSS Data Processing and Analysis	Analysing collected GNSS data.	4 	4 	3 	4 
Data Management	Data Processing and Analysis	VLBI Data Processing and Analysis	Analysing collected VLBI data.	2 	2 	2 	3 
Data Management	Data Processing and Analysis	SLR Data Processing and Analysis	Analysing collected SLR data.	3 	4 	3 	4 
Data Management	Data Processing and Analysis	DORIS Data Processing and Analysis	Analysing collected DORIS data.	4 	4 	3 	4 

Average	Evidence
2.0	<p>There are a limited number of people with the knowledge and capability to perform high quality local tie surveys, creating a significant capacity constraint in personnel. These surveys are being conducted less frequently worldwide, indicating a declining trend in data collection activity. There is a lack of clear processes and software to assist people in performing local tie surveys and subsequent analysis, representing a significant procedural gap. Although the data that is available globally is generally of good quality, the other areas of people, processes and technology are lacking. The limited capacity, declining survey frequency, and absence of standardised processes and supporting software collectively weaken this critical capability for connecting different geodetic instruments on site, despite the reasonable quality of the limited data that is collected.</p>
3.8	<p>GNSS data analysis is performed by dedicated analysis centres and a combination centre within the IGS. Current capability within the centres is relatively strong compared to other geodetic techniques, with adequate personnel capacity. A range of different processes can be used to analyse GNSS data and they are well documented, providing strong procedural frameworks. The technology to analyse GNSS data is mature, with a range of different software available including proprietary and open-source options, offering flexibility and redundancy in analytical capabilities. The data produced from this analysis is high quality and used for a wide range of applications, demonstrating strong output quality and utility. The combination of strong personnel capacity, well-documented processes, mature technology platforms, and high-quality data outputs makes GNSS data processing and analysis one of the most robust capabilities within the GGSC.</p>
2.3	<p>For IAG-affiliated (IVS S/X and VGOS networks) VLBI data, analyses are carried out by analysis and correlation centres as part of the IVS. Current capability within the centres relies significantly on in-kind support and is therefore inadequately funded, creating sustainability concerns. A bottleneck exists associated with the correlation of VLBI data due to the limited number of correlators operating worldwide, constraining processing capacity. However, a substantial and growing volume of astrometric and high-frequency (X/Ka, K-band) VLBI data is processed and correlated outside the IVS analysis framework. These networks contribute directly to Celestial Reference Frame and geodetic products but operate under different institutional arrangements and funding models, creating implications for fragmented governance and uneven interoperability standards between them and the IVS system. This fragmentation introduces coordination challenges and potential data quality variations across different processing pathways.</p>
3.5	<p>SLR data analysis is performed by dedicated analysis centres within the ILRS. These activities are hindered by reliance on unsustainable in-kind contributions and overall inadequate funding, creating personnel and resource sustainability concerns. A range of processes can be used to analyse SLR data and they are well documented, demonstrating strong procedural maturity. The technology to analyse SLR data is mature, with a range of different software available including proprietary and open-source options, providing flexibility in analytical approaches. The data produced from this analysis is high quality and used for a wide range of applications, demonstrating strong output quality despite the funding and sustainability challenges facing the analysis centres.</p>
3.8	<p>DORIS data analysis is conducted by Analysis and Associate Analysis Centres within the IDS. This process, like others, relies heavily on in-kind support from France. Most work related to DORIS is undertaken by the French government and is well supported, providing strong and consistent personnel capacity. The IDS maintains a well-defined program of work with good communication amongst members, demonstrating mature procedural frameworks for analysis activities. The IDS systems function well and are fit for purpose, representing strong technological capability for data processing. Indications are that data quality currently meets accuracy and reliability requirements, with high-quality analytical outputs. One of the key strengths of the DORIS network and system is that it is strongly supported by the French government, ensuring sustained analysis operations. However, this strength simultaneously represents a risk, as any reduction in French government support for DORIS would cause the system to suffer significantly, creating a single-jurisdiction dependency for this critical analysis capability.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Data Management	Data Processing and Analysis	Gravity Data Processing and Analysis	Analysing collected terrestrial gravity data.	3 	3 	2 	3 
Data Management	Data Processing and Analysis	Local Tie Processing and Analysis	Analysing local tie survey data.	2 	3 	1 	2 
Data Management	Data Dissemination and Access	Data Distribution	Sharing data and products with users.	2 	2 	1 	3 
















Average	Evidence
2.8	<p>With respect to the global geoid, analyses are based on satellite gravimetry (data available from NASA and ESA) and the capacity to process this data demonstrates strong capability but suboptimal capacity. Many developed countries have good distribution of gravity data and have the capacity to calculate the geoid with an accuracy of a few centimetres. This capacity is ensured by national agencies in charge of geodetic reference frames. In many developing countries, there is no gravity data or geoid calculation capacity, and the importance of the geoid is not recognised by national governments, creating significant geographical gaps in analytical capability. The Earth's gravity field is modelled using satellite and surface (terrestrial, shipborne and airborne) gravity data. Surface gravity data is essential for increasing the resolution and accuracy of satellite data, yet is limited in number and unevenly distributed globally, with particularly sparse coverage in developing regions hindering accurate geoid modelling. There are a limited and decreasing number of professionals who have the capability to perform geoid model development, particularly problematic in developing countries. Well-documented processes exist for performing measurements and creating models of the Earth's gravity field, traditionally recorded in scientific journals. Strong satellite-based systems measure the time-dependent and static gravitational field, and good quality air, ship and land-based systems are available. Data quality shows good quality space-borne data but variable airborne, shipborne and terrestrial gravity data archives around the world.</p>
2.0	<p>The analysis relies significantly on in-kind contributions, with limited capacity and limited capability across the personnel dimension. There are a limited number of people with the knowledge and capability to perform high quality local tie surveys and their subsequent analysis, creating significant capacity constraints. These surveys are being conducted less frequently worldwide, resulting in declining data availability for analysis. There is a lack of clear processes and software to assist people in performing local tie surveys and the subsequent analysis, representing a major procedural and technological gap. Although the data that is available globally is generally of good quality, the other areas of people, processes and technology are lacking. This creates an overall weak capability despite reasonable data quality, as the limited personnel capacity, declining survey frequency, absence of standardised analytical processes and supporting software collectively undermine the effectiveness of local tie processing and analysis.</p>
2.0	<p>In general, geodetic data handled by IAG services is open and free. However, examples exist around the world where some Member States do not share data or make it available only for restricted use. Data sharing technologies and protocols are well established for CDDIS and some regional data centres, but consistency across all data centres is lacking. Regional and international data centres represent the primary infrastructure for geodetic data distribution. Different data centres often host only subsets of geodetic data and products and operate with minimal dedicated staffing. Personnel typically allocate only a fraction of their time to data stewardship activities within government agencies or academic institutions, raising concerns about the sustainability of data management practices. Limited evidence exists of coordinated distribution or mirroring among these centres. Essential practices such as distributed redundancy, synchronised replication across multiple geographic regions, and standardised data versioning appear absent. Such coordination would be fundamental to robust data lifecycle governance frameworks and is particularly necessary for ensuring data integrity, continuity, and disaster recovery capabilities under international governance mechanisms. Consequently, verification of whether geodetic datasets adhere to FAIR principles throughout their lifecycle, or whether data completeness and timeliness standards are consistently maintained, remains impossible. This verification gap is most acute regarding international data centres, where a single-point-of-failure risk exists with only one known centre hosting the complete geodetic dataset, creating vulnerabilities in data preservation, accessibility, and long-term stewardship.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Data Management	Data Dissemination and Access	Data Sharing	Allowing others to use geodetic data (from data centres and real-time streams) under defined rules	3 	4 	2 	3
Data Management	Data Dissemination and Access	Data Preservation	Keeping geodetic data accessible and usable long-term.	2 	2 	1 	3
Data Products and Software	Product Development and Maintenance	Reference Frames	Ensuring the determination and maintenance of reference frames.	3 	3 	3 	3

















Average	Evidence
3.0	<p>There is a call for open data sharing, with data from IAG Services being generally available, often for free. However, open access to geodetic data is limited in some regions. Personnel are limited, typically allocating only a fraction of their time to data sharing activities within government agencies or academic institutions, creating resource allocation concerns. No legally binding requirements exist for countries to share data; all sharing is done on a voluntary basis under the recommendations and guidelines of the IAG Services. No evidence exists of coordinated distribution or mirroring among data centres, which are essential practices to have distributed redundancy, synchronised replication across multiple geographic regions, and standardised data versioning. Such coordination would be fundamental to robust data lifecycle governance frameworks and is particularly necessary for ensuring data integrity, continuity, and disaster recovery capabilities under international governance mechanisms. The voluntary nature of data sharing combined with the lack of coordinated governance creates sustainability and reliability concerns despite general availability of IAG Services data.</p>
2.0	<p>There is very little geographical redundancy for data storage and archiving, with CDDIS being the only single point of truth for some geodetic datasets. Although other data centres around the world host subsets of the information stored in CDDIS, none hold an archive of IAG service data as extensive as CDDIS does, creating significant single-point-of-failure risk. There is a call for open data sharing, with data from IAG Services being generally available, often for free, though open access to geodetic data is limited in some regions. Personnel are limited, typically allocating only a fraction of their time to data sharing activities within government agencies or academic institutions, raising concerns about long-term sustainability of preservation efforts. No legally binding requirements exist for countries to share data; all sharing is done on a voluntary basis under the recommendations and guidelines of IAG Services. Limited evidence exists of coordinated distribution or mirroring among data centres, which are essential practices to have distributed redundancy, synchronised replication across multiple geographic regions, and standardised data versioning. Such coordination would be fundamental to robust data lifecycle governance frameworks and is particularly necessary for ensuring data integrity, continuity, and disaster recovery capabilities under international governance mechanisms. The lack of geographical redundancy combined with voluntary participation and absence of coordinated preservation protocols creates significant vulnerabilities for long-term data accessibility and usability.</p>
3.0	<p>Maintaining a stable reference frame relies on continuous observation with a stable observatory network, yet more than half of the stations needed for this are aging and degrading, threatening the accuracy of future terrestrial reference frames. Furthermore, a risk exists associated with the limited expertise available worldwide capable of performing accurate reference frame computations. For the International Terrestrial Reference Frame, people work on this across the world with specialists located in France, Germany and USA. Processes are documented in scientific journals and discussed at numerous scientific conferences. Several different techniques and software packages are available to the global community. The data is open and accessible to the global community. For the International Celestial Reference Frame, CRF maintenance is equally dependent on long-term stability of VLBI infrastructure and directly coupled through Earth Orientation Parameters. People work on this across the world and their efforts are coordinated through the IAG and International Astronomical Union. Processes are documented in scientific journals and discussed at scientific conferences. Several different techniques and software packages are available to the global community. The data is open and accessible to the global community, though some have expressed concerns that less data may be available following a divergence in activities between the astronomy and geodetic communities due to the transition to VGOS.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Data Products and Software	Product Development and Maintenance	Geodetic Data Products (EOP, Clocks, Orbits, Station Positions, Gravity Models)	Creating standardised geodetic products.	2 	3 	3 	3
Data Products and Software	Product Development and Maintenance	Geodetic Software and Tools	Developing and maintaining software for the creation of geodetic products	2 	2 	1 	3
Data Products and Software	Delivery and Support	Geodetic Services	Providing access to and support for geodetic data and products.	2 	2 	2 	2













Average	Evidence
2.8	<p>Standards are critical for using geodetic data and accessing products, and while detailed product development practices and standards inventories exist, such as those from GGOS/IAG Services, their maintenance relies heavily on in-kind contributions. Weak and fragmented governance limits the implementation of standards and protocols. Improvements are needed for data and metadata to be Findable, Accessible, Interoperable, and Reusable (FAIR). People work on this across the world and their efforts are coordinated through IAG Services. However, in many cases people are working on these essential products based on in-kind contributions from national agencies, or work is being undertaken by academic staff and students, creating sustainability concerns. Processes are documented in scientific journals and discussed at numerous scientific conferences, demonstrating procedural maturity. Several different techniques and software packages are available to the global community, providing technological diversity. The data is open and accessible to the global community. However, the reliance on in-kind contributions combined with weak governance structures limits the consistency and long-term sustainability of standardised product development despite the availability of appropriate processes, technology, and data.</p>
2.0	<p>Software is a material element of the supply chain, however, some of the important software which is used is bespoke. People work on this across the world and their efforts are coordinated through IAG Services, yet the specialised nature of the software means development may depend on a single person, and that person may be contributing time based on in-kind contribution or be on a short-term contract at a university. Many of these risks are not being monitored because there is no global governance for geodesy performing a start-to-end risk assessment. Some processes are documented in scientific journals or GitHub libraries, but not all, indicating incomplete documentation. More evidence is needed on this topic. The specialised nature of this software means it may not be written to comply with all cyber security requirements needed or may not meet current computer programming standards. More evidence on this is needed. The data is open and accessible to the global community, though more information is needed to know how vulnerable data quality is to the other issues described regarding personnel, processes, and technology. The single-person dependency risks combined with incomplete documentation and uncertain security standards create significant vulnerabilities in this critical software development capability.</p>
2.0	<p>Data centres collect and distribute geodetic products that are made available through websites of the IAG Services and GGOS. Improving Findability, Accessibility, Interoperability, and Reusability (FAIR principles) is vital for broader use, yet limited resources impact the geodesy community's ability to carry out this work. Personnel are limited, typically allocating only a fraction of their time to data sharing activities within government agencies or academic institutions, raising sustainability concerns. No legally binding requirements exist for countries to share geodetic products; all sharing is done on a voluntary basis under the recommendations and guidelines of IAG Services. No evidence exists of coordinated distribution or mirroring among data centres, which are essential practices to have distributed redundancy, synchronised replication across multiple geographic regions, and standardised data versioning. More information about this coordination challenge is needed. Access to geodetic products is expected to be very important for several satellite platform providers. Currently, insufficient evidence exists which describes the way in which data flows through the IAG services and ultimately is used to produce geodetic products. It is also unclear if or how these products are mirrored across different servers around the world, which is important for reliability. The combination of limited personnel, voluntary participation, lack of coordination, and insufficient evidence of data flow and mirroring creates significant concerns about the sustainability and reliability of geodetic service delivery.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Data Products and Software	Delivery and Support	Training and Education	Offering training and education on geodetic principles and tools.	2 	1 	NA	2 
Assets and Infrastructure Management	Geodetic Infrastructure Management	Network Operations	Managing and operating geodetic station networks.	2 	3 	1 	2 
Assets and Infrastructure Management	Geodetic Infrastructure Management	Ground-Based Asset Management	Managing physical geodetic equipment on the ground at observatories.	3 	2 	2 	3 
Assets and Infrastructure Management	Geodetic Infrastructure Management	Model of the Global Geodesy Supply Chain	Modelling, monitoring and analysing the GGSC processes and vulnerabilities.	1 	1 	1 	1 

















Average	Evidence
1.7	<p>There is a clear decline in the number of academic courses and formal training programs offered, leading to a shrinking pool of geodesy professionals globally. This is a significant concern, particularly for developing countries needing more training opportunities. The decreasing number of formal education programs worldwide represents a significant risk to long-term capacity. No clear strategy or implementation plan exists to rectify this issue, and no evidence suggests where something has been tried to reverse this trend and been successful, indicating weak procedural frameworks for addressing the decline. A lack of evidence exists which shows the real reduction in courses worldwide, with much of the evidence being anecdotal rather than systematically documented. The declining availability of training and education combined with the absence of coordinated strategies to address this trend creates a critical threat to the future sustainability of geodetic expertise globally, particularly affecting developing countries that already face greater challenges in accessing quality training opportunities.</p>
2.0	<p>Managing and operating geodetic networks is fragile due to insufficient resources, aging infrastructure, geographical gaps, heavy reliance on in-kind contributions, and a lack of coordinated governance and recognition as critical infrastructure. This situation puts the accuracy and reliability of geodetic products and the many applications that depend on them at risk. There is overreliance on in-kind contributions and staff in academic institutions, creating sustainability concerns for personnel capacity. Within each of the IAG Services, the processes are clear and well-defined, demonstrating strong procedural frameworks at the service level. However, there is a lack of processes for broader strategic and operational components of the GGSC due to a lack of governance. There is no oversight or start-to-end visibility of the supply chain. Also, there is no design of what a mature and robust network for a GGSC looks like, including the ground observatories, data centres and analyses needed to create geodetic products. Regarding technology, some infrastructure is aging and degrading while other components are sufficient. The biggest risk is loss of VLBI and SLR ground observatories and VLBI correlation centres, which would significantly impact network operations and data quality.</p>
2.5	<p>The management of physical geodetic equipment at ground observatories is generally done well by the people who are working at the observatories. However, evidence points to a critical situation characterised by significant under-resourcing, aging infrastructure, operational unreliability, and weak governance frameworks. This points to a lack of processes for broader strategic and operational components of the GGSC due to a lack of governance. There is no oversight or start-to-end visibility of the supply chain. Also, there is no design of what a mature and robust network for a GGSC looks like, including the ground observatories, data centres and analyses needed to create geodetic products. A possible exception is the NASA network of SLR and VLBI stations, with the accompanying GNSS receivers. Here, the central Operations Centre can take an overview and direct resources to solve operational problems as they arise, demonstrating effective centralised management. The non-NASA observatories have the potential to be innovative and frequently are but often have to juggle capital funding with that needed for operations, creating resource allocation challenges that impact equipment management effectiveness.</p>
1.0	<p>There is no international governance for geodesy, which means there is no start-to-end visibility, model, or digital twin of the GGSC. The foundational processes required for effective GGSC modelling are largely missing or fragmented, and there are significant open questions and identified needs regarding the required vulnerability analysis and simulation. This collectively implies that this area is not currently being managed or operated well enough to provide the required understanding and robustness for the supply chain. No one is currently working on this at the level of detail required to develop a realistic model of what a mature GGSC is. The UN-GGCE is developing high-level guiding principles; however, a thorough quantitative description is not expected in the short term. A considered effort would need to be put into this with support from the scientific and policy communities. This points to a lack of processes for broader strategic and operational components of the GGSC due to a lack of governance. There is no oversight or start-to-end visibility of the supply chain. Also, there is no design of what a mature and robust network for a GGSC looks like, including the ground observatories, data centres and analyses needed to create geodetic products. The absence of modelling capability represents a fundamental gap in understanding and managing supply chain risks and dependencies.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Assets and Infrastructure Management	Calibration and Maintenance	Equipment Calibration and Maintenance	Calibrating and maintaining geodetic equipment for accuracy.	3 	4 	3 	3 
Assets and Infrastructure Management	Calibration and Maintenance	System Testing and Validation	Testing and confirming the functionality and performance of geodetic systems and software.	2 	3 	3 	2 
Innovation and Development	Research and Development	Research and Development Planning	Strategic and operational preparation of research projects to analyse, monitor, and enhance the GGSC or its components.	2 	1 	2 	1 
Innovation and Development	Research and Development	Research and Development Prototyping	Developing and testing new concepts, theories, models, or new technology.	3 	3 	3 	3 

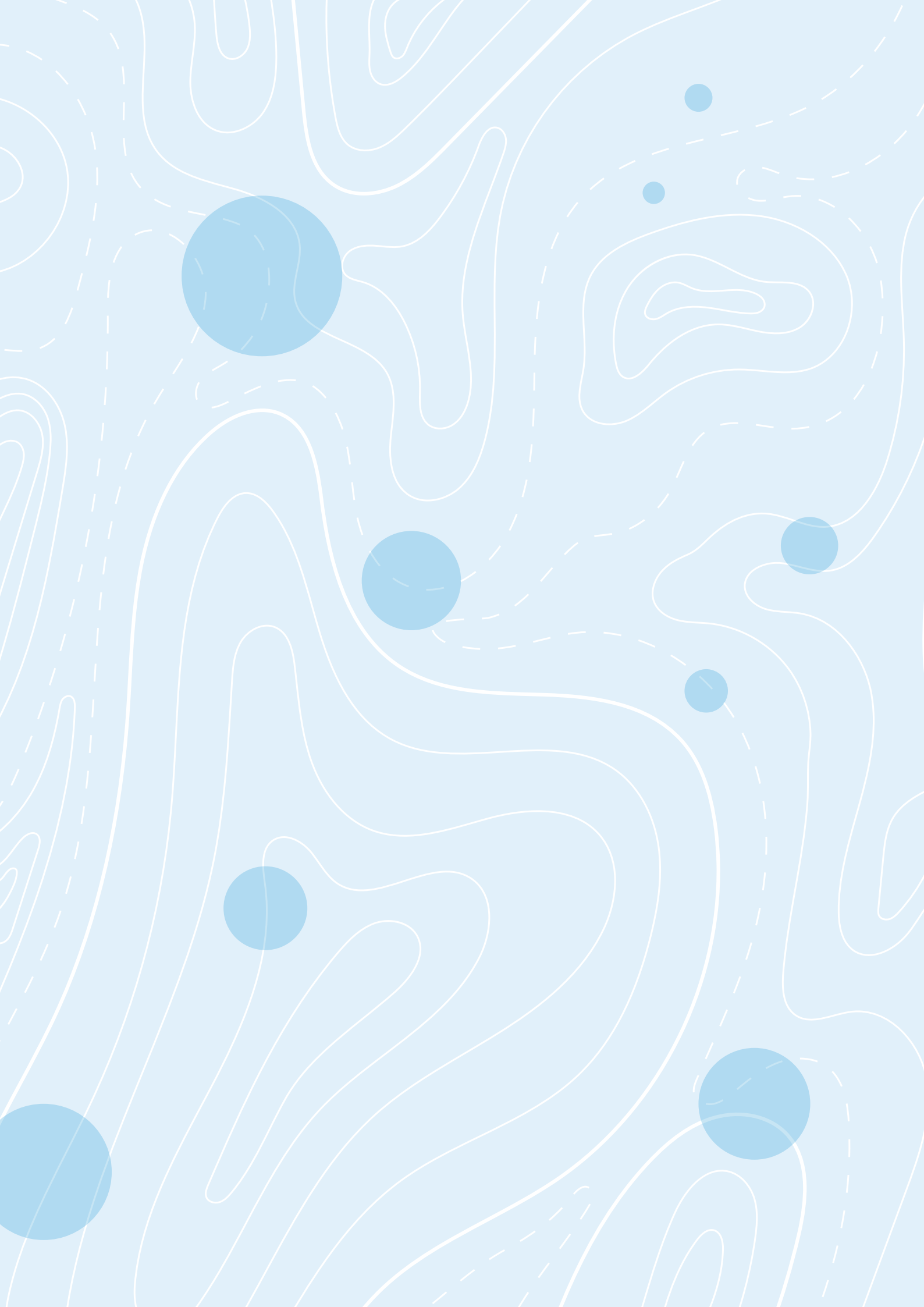
Average	Evidence
3.3	<p>Equipment calibration and maintenance are critical for accuracy, but maintenance is a growing cost due to aging infrastructure. More than half of the observing stations are degrading in terms of accuracy and reliability, creating significant operational challenges. Resource limitations lead to longer outages and unreliability, and the specialised nature of hardware with limited supplier support adds difficulty to maintaining accuracy. IAG services perform calibration and maintenance well for the infrastructure used by IAG Services, demonstrating strong personnel capability and expertise. IAG Services have well-defined processes to perform these calibrations, showing procedural maturity. However, the aging infrastructure, resource constraints, and limited supplier support for specialised equipment create ongoing challenges that impact the effectiveness and sustainability of calibration and maintenance activities despite the strong capabilities within IAG Services.”</p>
2.5	<p>System testing and validation are necessary to confirm functionality and performance. However, outdated software contributes to products not meeting required quality, and quality control and validation efforts are hindered by limited resources. While important, these validation processes do not receive adequate attention relative to their criticality. IAG services perform testing and validation well for the infrastructure used by IAG Services, demonstrating capable personnel. IAG Services have well-defined processes to perform these validations, showing procedural frameworks are in place. However, the combination of outdated software, resource limitations, and insufficient attention to validation activities creates gaps in ensuring that geodetic systems and software consistently meet performance requirements. The limited resources allocated to this critical function, combined with aging software systems, undermines the effectiveness of validation efforts despite the presence of capable personnel and defined processes within IAG Services.</p>
1.5	<p>Research and development planning is addressed in the 1st Joint Development Plan for Global Geodesy; however, it is a component which is currently under-funded. Furthermore, due to the issues related to a lack of formal governance mechanisms at a global level, this effort is not formal and not coordinated. Notwithstanding the loss of formal geodetic departments in higher education institutions, there are several R&D projects being undertaken and published. Examples include tests of the Theory of General Relativity from SLR and VLBI observations, improvements in estimations of the global geoid, improvements in tidal models using many of the geodetic techniques including gravity, and groups experimenting with MHz laser ranging and with small, inexpensive laser ranging systems. On the other hand, there is cultural and procedural inertia that affects innovation within some geodetic techniques. In the case of VLBI, for example, innovation can be slow to be adopted due to entrenched legacy practices and conservative governance structures. This limits methodological progress, discourages younger researchers, and slows the transition toward modernised, higher-precision geodetic operations. The lack of formal governance, inadequate funding, and cultural barriers to innovation collectively constrain effective R&D planning despite ongoing research activities.</p>
3.0	<p>Deploying production-ready technologies to support geodesy is undertaken on an ad-hoc basis, predominantly within the academic sector. Due to the issues related to a lack of formal governance mechanisms at a global level, this effort is not formal and not coordinated. Geodesists also have a challenge to convert research results into operational services that support everyday societal needs. Much of global geodesy still depends on a small number of experts and bespoke workflows. Limited documentation, absence of open repositories, and the retirement of senior specialists create single-person dependency risks that threaten institutional memory and long-term innovation capacity. Despite these coordination and documentation challenges, there are active prototyping efforts occurring within the research community, particularly in academic institutions and space agencies. Examples of prototyping activities include development of new laser ranging systems, improvements in tidal models, and enhancements to geoid estimation techniques. However, the ad-hoc nature of these efforts, limited documentation, and single-person dependencies create sustainability risks that undermine the effectiveness of prototyping activities.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Innovation and Development	Research and Development	Research and Development Execution	Deploying production-ready technologies to support geodesy.	3 	2 	2 	2 
Innovation and Development	Research and Development	Knowledge Management	Collecting, organising, sharing, and effectively using knowledge obtained because of research and development.	1 	2 	1 	1 
Innovation and Development	Technology Adoption and Integration	Technology Scouting	Finding and evaluating new technologies relevant to global geodesy.	2 	1 	2 	2 

Average	Evidence
2.3	<p>Deploying production-ready technologies to support geodesy is undertaken on an ad-hoc basis, predominantly within the academic sector. Due to the issues related to a lack of formal governance mechanisms at a global level, this effort is not formal and not coordinated. Geodesists also have a challenge to convert research results into operational services that support everyday societal needs, representing a significant gap between research and operational implementation. Much of global geodesy still depends on a small number of experts and bespoke workflows. Limited documentation, absence of open repositories, and the retirement of senior specialists create single-person dependency risks that threaten institutional memory and long-term innovation capacity. While there are examples of successful technology deployment, particularly within space agencies and some academic institutions, the overall execution capability is constrained by the lack of coordinated governance, formal processes for transitioning research to operations, and sustainable funding models. The ad-hoc nature of deployment combined with personnel dependencies creates vulnerabilities in ensuring that new technologies are effectively integrated into operational geodetic services.</p>
1.3	<p>Much of global geodesy still depends on a small number of experts and bespoke workflows. Limited documentation, absence of open repositories, and the retirement of senior specialists create single-person dependency risks that threaten institutional memory and long-term innovation capacity. This represents a critical weakness in knowledge management across the research and development dimension. There is no formal governance structure or coordinated approach to systematically collect, organise, and share knowledge obtained from research and development activities. Knowledge is often held by individual experts, documented in scattered scientific publications, or maintained in personal repositories rather than centralised, accessible knowledge management systems. The absence of open repositories and standardised documentation practices means that valuable knowledge may be lost when senior specialists retire or move to other positions. This single-person dependency creates significant vulnerabilities in institutional memory and threatens the continuity and accessibility of critical geodetic knowledge. Without coordinated knowledge management processes and technology platforms, the global geodesy community faces ongoing challenges in effectively capturing, preserving, and disseminating research and development knowledge across generations of researchers and practitioners.</p>
1.8	<p>There are some examples of new technology being scouted and evaluated, particularly within the university sector and within space agencies. This is not often done purely for geodesy purposes; however, geodesy is a beneficiary of broader technology scouting efforts in related fields. The technology scouting activities that do occur are typically undertaken on an ad-hoc basis rather than through systematic, coordinated processes. Due to the lack of formal governance mechanisms at a global level, technology scouting efforts are not formally organised or coordinated across the global geodesy community. This results in fragmented awareness of emerging technologies and potential missed opportunities for adopting innovations that could benefit geodetic operations. Space agencies such as NASA and ESA conduct technology scouting as part of their broader mission portfolios, and geodetic applications benefit from these activities. Similarly, university research groups explore new technologies as part of their academic research programs. However, the absence of a dedicated, coordinated technology scouting function specifically for global geodesy means that the community may not systematically identify and evaluate all relevant emerging technologies. The ad-hoc nature of current technology scouting combined with limited coordination creates gaps in the community's ability to proactively identify and assess new technologies that could enhance geodetic capabilities.</p>

Level 1	Level 2	Level 3	Description	People	Processes	Technologies	Data
Innovation and Development	Technology Adoption and Integration	Technology Assessment	Evaluating the potential impacts, risks, and benefits of new technologies on the GGSC.	3 	2 	3 	2 
Innovation and Development	Technology Adoption and Integration	Technology Integration	Adopting and integrating new technologies into the GGSC.	2 	3 	3 	3 
Innovation and Development	Innovation Management	Innovation Strategy Development	Creating a plan for fostering innovation to enhance the GGSC.	1 	1 	1 	1 
Innovation and Development	Innovation Management	Innovation Project Management	Managing projects focused on developing and implementing innovative geodetic solutions.	2 	3 	3 	3 

Average	Evidence
2.5	<p>There are some examples of new technology being assessed. One example of great benefit to the geodetic community is the Genesis mission being developed by ESA, which demonstrates that technology assessment activities do occur. However, like technology scouting, these assessment activities are typically undertaken on an ad-hoc basis rather than through systematic, coordinated processes. Due to the lack of formal governance mechanisms at a global level, technology assessment efforts are not formally organised or coordinated across the global geodesy community. This results in fragmented evaluation of potential impacts, risks, and benefits of new technologies for the supply chain. Space agencies conduct technology assessments as part of their mission development processes, and these assessments consider geodetic applications and impacts. Research institutions also evaluate new technologies through academic research and pilot projects. However, the absence of a comprehensive, coordinated technology assessment framework specifically for the GGSC means that potential impacts, risks, and benefits may not be systematically evaluated from a holistic supply chain perspective. The ad-hoc nature of assessments combined with limited coordination creates gaps in understanding how new technologies might affect the entire supply chain, including potential risks, dependencies, and opportunities for enhancement.</p>
2.8	<p>Adopting and integrating new technologies into the GGSC is being undertaken on a limited basis, predominantly within space agencies. Due to the issues related to a lack of formal governance mechanisms at a global level, this effort is not formal and not coordinated. The absence of coordinated governance means there is no systematic process or authority for evaluating, prioritising, and integrating new technologies across the global supply chain. Technology integration occurs in fragmented ways, often driven by individual agencies, research institutions, or projects rather than through coordinated supply chain planning. Space agencies such as NASA and ESA integrate new technologies as part of their mission development, and these efforts benefit geodetic capabilities. However, the integration is typically focused on specific agency objectives rather than holistic supply chain needs. The lack of formal coordination means that technology integration decisions may not consider interdependencies across the supply chain, potential impacts on data compatibility and interoperability, or opportunities for shared infrastructure and standardisation. Cultural and procedural inertia within some geodetic techniques also affects the rate of technology adoption, with entrenched legacy practices and conservative governance structures slowing the integration of modernised, higher-precision technologies. The limited, uncoordinated nature of technology integration combined with cultural barriers creates significant constraints on the GGSC's ability to systematically adopt and benefit from technological advances.</p>
1.0	<p>There is no formal innovation strategy for geodesy. This is largely since there is no international governance for geodesy. Without governance structures to provide oversight, accountability, and coordination, there is no entity responsible for developing, implementing, or monitoring an innovation strategy for the GGSC. The absence of an innovation strategy means there is no coordinated vision for how innovation should be fostered, what priorities should be established, how resources should be allocated to support innovation, or how innovation efforts should be evaluated and adjusted over time. While individual organisations, research groups, and space agencies may have their own innovation strategies that include geodetic components, these are fragmented and not coordinated at a global supply chain level. The lack of governance also means there is no mechanism for bringing together stakeholders from across the supply chain—including government agencies, research institutions, private sector, and international organisations—to collectively develop and agree upon innovation priorities and strategies. Without a formal innovation strategy, the global geodesy community faces challenges in systematically identifying innovation needs, coordinating innovation efforts, avoiding duplication, sharing innovation results, and ensuring that innovation activities align with and support the overall sustainability and enhancement of the GGSC.</p>
2.8	<p>Managing projects focused on developing and implementing innovative geodetic solutions is being undertaken on a limited basis, predominantly within space agencies. Due to the issues related to a lack of formal governance mechanisms at a global level, this effort is not formal and not coordinated. Space agencies such as NASA, ESA, and others manage innovation projects as part of their broader mission portfolios, and these projects often include geodetic components or applications. Research institutions and universities also manage innovation projects through research grants and academic programs. However, the absence of coordinated governance means there is no systematic oversight of innovation project management across the GGSC.</p>





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