UNITED NATIONS **E/C.20/2022/17/Add.1**

Economic and Social Council

22 July 2022

Committee of Experts on Global Geospatial Information Management
Twelfth session
New York, 3–5 August 2022
Item 15 of the provisional agenda*
Implementation and adoption of standards for the global geospatial information community

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Note by the Secretariat

Summary

The present paper contains the report prepared jointly by the Open Geospatial Consortium (OGC), Technical Committee 211 of the International Organization for Standardization (ISO/TC 211) and the International Hydrographic Organization (IHO) on the implementation and adoption of standards for the global geospatial information community for consideration by the Committee of Experts on Global Geospatial Information Management.

At its eleventh session, held virtually on 23, 24 and 27 August 2021, the Committee of Experts adopted decision 11/111, in which it expressed its appreciation for the collaborative efforts and work of the standards development organizations in developing and preparing standards for the measurement and monitoring of the Sustainable Development Goals, advancing data access and data sharing, including towards the ongoing response to the coronavirus disease (COVID-19) pandemic, disaster risk reduction and management, and the continuing development of the open application programming interface standards, the ISO 19152 Land Administration Domain Model and the S-100 suite of marine data product specifications. The Committee also welcomed and endorsed the third edition of the "Guide to the role of standards in geospatial information management", the purpose of which was to promote the recommendations regarding the use of standards for geospatial information management. In this regard, the Committee urged Member States and as a living online resource aligned with the Integrated Geospatial Information Framework and to actively use the guide for standards-based geospatial solutions.

In the report, the three organizations elaborate on their collective efforts to advance the uptake and use of geospatial standards. They provide details of the work of the Open Geospatial Consortium on the development of modernized open application programming interface standards and the integration of geospatial information, statistics and other data to address the access to and integration of location information related to Earth observations, disaster preparedness and response, health, marine spatial data interoperability, the environment and climate change. The work of Consortium's community includes a strong focus on improving connections with Consortium standards (e.g. the Features and Environmental Data Retrieval application programming interfaces), International

* E/C.20/2022/1

Hydrographic Organization standards (e.g. S-122) and International Organization for Standardization standards (e.g. ISO 19152, including the proposed marine part).

They also describe the work of technical committee 211 and its continued progress in the development of the multi-part standards ISO 19152 Land Administration Domain Model, the ISO 19144 series on land cover and ISO 19160 on addressing, and discusses the increased use of the ISO Geodetic Registry. Lastly, they present the advances made by the International Hydrographic Organization on the S-100 Universal Hydrographic Data Model to support the creation and maintenance of interoperable maritime data product services that are compliant with the ISO 19100 series of geographic information standards. This includes the projected work with some littoral states to use the Integrated Geospatial Information Framework Marine Spatial Data Infrastructure maturity road map currently being discussed for real-world Marine Spatial Data Infrastructure development.

The organizations also provide an overview of their work regarding the use of geospatial standards in supporting the measurement and monitoring of the Sustainable Development Goals; discuss the role of standards in the continued response to the global COVID-19 pandemic; present information on how the organizations are working to practically strengthen their interlinkages with the regional committees, functional groups and thematic groups of the Committee of Experts; highlight their continued support to the standards pathway for the Implementation Guide of the Integrated Geospatial Information Framework; detail the activities undertaken to promote and raise awareness of the "Guide to the role of standards in geospatial information management" as a living online resource aligned with the Framework; and discuss practical examples of the implementation of geospatial standards that help further strengthen the guide, as a means to ensure standards accountability and compliance of practice and to demonstrate the benefits of implementing geospatial standards.

I. Introduction

1. In making decision 11/111 at its eleventh session in August 2021, the Committee of Experts expressed its appreciation for the collaborative efforts and work of the standards development organizations in developing and preparing standards for the measurement and monitoring of the Sustainable Development Goals (SDGs), advancing data access and data sharing, including towards the ongoing response to the COVID-19 pandemic, disaster risk reduction and management, and welcomed continuing development of the open application programming interface (API) standards, the ISO 19152 Land Administration Domain Model and the S-100 suite of marine data product specifications. The Committee also endorsed the third edition of the 'Guide to the role of standards in geospatial information management' and encouraged Member States and relevant stakeholders to contribute practical examples on the implementation of geospatial standards to further strengthen the Standards Guide.

2. During the intersessional period, the three Standards Development Organizations (SDOs), OGC, ISO/TC 211, and IHO, worked in partnership to leverage our respective missions and membership expertise to advance Findable, Accessible, Interoperable and Reusable (FAIR) principles and standards to meet the goals and objectives of the Committee of Experts. We continue to increase cooperation through our formal liaison agreements and joint program initiatives to produce standards and good practice recommendations that could not be fully achieved by working in isolation.

3. This present report details the collective efforts of the SDOs in the intersessional period since the tenth session. In the report, the three SDOs elaborate on their joint efforts, including:

(a) OGC is examining its work on the development of modernized open application programming interface standards and the integration of geospatial information, statistics and other data to address access to, and integration of, location information related to Earth observations, disaster preparedness and response, health, the environment and climate change;

(b) ISO/TC 211 discusses their progress in the development of the multi-part standards ISO 19152 Land Administration Domain Model, the ISO 19144 series on land cover and ISO 19160 on addressing, and how increased use of the ISO Geodetic Registry collectively demonstrate the use of standards; and,

(c) IHO discusses the advances made on the S-100 Universal Hydrographic Data Model to support the creation and maintenance of interoperable maritime data product specifications that are compliant with the ISO 19100 series of geographic information standards.

4. The Committee of Experts is invited to take note of the report and to express its views on the way forward for the implementation and adoption of standards for the global geospatial information community. Points for discussion and decision are provided in paragraph 38.

II. Update on the work of the Standards Development Organisations

Update from the Open Geospatial Consortium

5. OGC and its more than 560 members from across the private and public sectors have guided the advancement of standards and associated good practices to make geospatial

information FAIR in support of global requirements. Through its member meetings, workshops, forums, summit events, and practical results demonstrated via its Innovation program, OGC is helping advance work in an expanding range of geospatial interoperability challenges facing the international community. OGC is leading the dialogue on the implications of fast-changing technology and community trends. Over the past year, OGC has focused on a range of topics relevant to the Sustainable Development Goals, including the development of a common health emergency data model as part of a Health Spatial Data Infrastructure (SDI) initiative in response to the COVID-19 pandemic; its continued focus on improved support to disaster response; increased coordination within the Marine domain; and has created a global forum on climate services. The OGC is continuing with its advancement of an open API standards suite offering a modernization of OGC's Web Services standards designed to simplify development and deployment, increase the flexibility of mobile applications, and more efficiently leverage big data and cloud-native infrastructure.

6. **Adoption and Implementation of OGC General Purpose geospatial standards**. A program to modernize OGC Web Services into more easily implementable Open API Standards is currently underway. The OGC Environmental Data Retrieval Open API, recently approved, provides greater capability to discover and query big data sources in a location and time context. This Standard has broad applicability and is being implemented in major national and international hydro-meteorological offices to help reduce the complexity of discovery and access to critical data supporting weather and climate analyses and forecasts. Further, OGC Open API-Features are currently being implemented in major commercial and open-source geospatial technologies underpinning the global geospatial information management community.

7. **The OGC Web Services and OGC Sensor Web Enablement (SWE) Services** continue to be implemented in hundreds of commercial, open-source, and custom-designed geospatial technologies and Internet of Things deployments worldwide. These implementations support greater understanding and decision-making related to water resource management, emergency and disaster management, meteorology and ocean science; smart, safe, and resilient cities, communities and infrastructure; and many other areas of high relevance to realizing the ambition of the 2030 Agenda.

8. **GeoPackage**, an OGC standard designed to manage and use large amounts of geospatial data on a mobile device in connected, limited connectivity, or disconnected environments, are rapidly becoming an alternative to vendor-specific formats. GeoPackage is being used in various applications, including disaster response through efforts such as the Humanitarian OpenStreetMap program[1]. New work on GeoPackage results in platform agnostic implementations, which greatly broaden the ability to store and publish GeoPackage datasets from most modern software environments.

9. **Adoption and Implementation of OGC Domain Specific Standards**. OGC continues to support the SDGs related to resilient infrastructure and livable cities through expanding implementations of OGC CityGML and associated Application Domain Extensions, IndoorGML, and the Indoor Mapping Data Format (IMDF) Community Standard. These standards allow the creation of detailed 3D city models or digital twins with indoor navigation capabilities that support a range of urban planning, energy efficiency, public safety, accessibility, city service provision, and other applications. These standards have been implemented in commercial and open-source products and are in active implementation across municipalities in Asia, Europe, and North America.

[1] www.hotosm.org

10. **Addressing Health and Disaster Events.** OGC concluded an international Health SDI Concept Development Study in early 2021, polling health and geospatial experts on the essential location-relevant information needed to support more effective preparation and response to future pandemics and other health emergencies. From this effort, an initial common Health SDI data model has been developed and is being tested as part of a multi-year OGC Disaster Pilot currently underway.

11. **Increasing Engagement with Regional Committees and other International Bodies**. In concert with the OGC Disaster Pilot[2], OGC has implemented a Stakeholder Coordination process to directly engage the global stakeholder community, including the regional committees and functional groups of the Committee of Experts, the Group on Earth Observations (GEO), involved in health and disaster response to integrate stakeholder expertise, requirements, and use cases into the pilot process. This coordination process also allows stakeholders to field test standards-based capabilities produced by OGC initiatives. Through this stakeholder engagement process, OGC is working to accelerate the transfer of relevant standards-based approaches into community use.

12. **Compliance Testing Resources**. As part of OGC's compliance testing and certification program[3], OGC implemented several new online compliance tests. Technology developers and organizations implementing OGC standards can use this facility without charge to test for correct implementation of the SensorML 2.0 and GeoTIFF 1.1 and CDB standards and seventeen additional approved OGC standards. The OGC test engine and test scripts are available under an open-source license. They can be implemented locally by organizations wishing to test for the correct implementation of OGC standards in their legacy systems and internally developed software.

13. **Innovation and Standards Development.** Unique to OGC is its Innovation program, which brings sponsors and participants together to collectively work on solving common problems across multiple domains. The Innovation program uses real-world scenarios and demonstrations of results and is closely connected to the standards program. Through testing OGC (and IHO and ISO) standards using practical use cases, the SDOs can individually and collectively improve their standards based on real-world implementations, shortening the adoption cycle of new and existing standards.

14. In 2021 and carrying on into 2022, OGC leads or participates in the following initiatives:

(a) **Climate Resilience Initiative**. Works to accelerate our collective readiness for accessing, fusing, and analyzing data from the climate change modelling community with earth observation and social science data to contribute to the global push for strengthening climate resilience;

(b) **CLINT**. Aims to advance an Artificial Intelligence framework for Climate Intelligence (CLINT) which builds on Machine Learning techniques and algorithms to process big climate datasets for improving Climate Science in the detection, causation, and attribution of Extreme Events;

(c) **CYBELE[4]**. Helps develop large-scale High-Performance Computing enabled test beds in the domain of agri-food and delivers a distributed big data management

[2] www.ogc.org/projects/initiatives/disasterpilot
[3] http://cite.opengeospatial.org/teamengine/
[4] CYBELE is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 825355

architecture and a data management strategy for Precision Agriculture and Precision Livestock Farming;

(d) **DEMETER**[5]. Works to deploy farmer-centric interoperable smart farming-IoT-based platforms delivered through a series of 20 pilots across 18 countries (15 States in the EU);

(e) **Disaster Pilot 2021.** Prototypes of online and offline service provision of Earth observations, health, and other critical data for First Responders. A multi-year effort, the OGC Disaster Pilot 2022 continues focusing on the provision of analysis-ready data and decision-ready indicators;

(f) **EO Cloud Platform CDS.** The scope of this study is the evaluation of EO cloud platform architectures and alignment with open standards and documentation of their readiness to support the Disaster Pilot 2021 disaster response exercise scenario;

(g) **IHO-OGC Federated Marine SDI**. The Federated Marine SDI Demonstration Pilot demonstrates how implementing a Marine SDI can unlock far more valuable data and insights than the traditional providers and consumers of hydrographic data alone. Specifically, the Pilot includes one or more land and sea interface scenarios to demonstrate how a federated Marine SDI can provide simple, secure access across borders and domains and improve the connections between terrestrial and marine foundational communities based on exercising both IHO´s S-1XX and OGC API Standards;

(h) **Geotech IE.** Helps contribute to improving the connectivity between Geospatial Information Systems (GIS) and Building Information Modelling to exploit the standardization resources already available from the OGC and other organizations as an input for OpenBIM resources to share geotechnical engineering data in the appropriate context for users;

(i) **Health Spatial Data Infrastructure CDS**. Offers a common, standardized health geospatial data model and schema that will establish a blueprint to better align the community for early warning, response to, and recovery from future health emergencies. Such a data model will help to improve support for critical functions and use cases;

(j) **OGC Sprints.** OGC Sprints are collaborative events driven by rapid code development to implement and test specific capabilities of a technical approach or standard. Most OGC API Standards are refined and tested via these Sprints so that each final Standard is proven to be implementable and useful;

(k) **OGC Testbed-17**. OGC Testbeds are OGC's largest Innovation Program initiatives. Testbeds boost research and development to make location data and information more FAIR Testbeds provide a unique opportunity for sponsors to tackle location data and processing challenges together with the world's leading geospatial IT experts; and,

(l) **UxS Command and Control IE.** Tests the suitability of Command and Control for Unstaffed Systems (UxS) in a real-world environment. This initiative aims to assess

[5] DEMETER is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 857202

whether the data model is suitable for multi-domain, multi-heterogenous vehicle use and demonstrate the exchange of command-and-control information.

Update from the technical committee 211 of the International Organization for Standardization (ISO/TC 211)

15. ISO/TC 211 Geographic information/ Geomatics[6] is ISO's entry point to geospatial standards and works to develop and maintain an aligned set of Standards focused on the geospatial context. A goal is to provide and recommend geospatial standards accepted and applicable for integration with other standards without re-modelling for use in domains needing location. ISO/TC 211 consists of 37 Participating and 33 Observing members, with members being national standards bodies. ISO/TC 211 collaborates and liaises with many ISO committees and external organizations. Key internal ISO liaisons include integrated transport, building information modelling, and smart cities. Freely available resources such as UML models and XML schemas for supporting standards implementations are also found on ISO/TC 211 website. The Committee is active in the ISO pilot work on machine-readable standards and the ISO online standards development tool pilot.

16. **The Sustainable Development Goals.** Geospatial standards support the broader objectives of the 2030 Agenda for Sustainable Development: both general purpose geospatial standards that are important for industry and infrastructure, and those standards in direct support of the Committee of Experts, specifically in the areas of Geodetic Referencing, Land Administration, Land Cover Land Use, and Addressing. ISO provides tools to help technical committees to map their projects to the SDGs[7]. As reported to the Committee at its previous sessions, several countries report the use of the ISO 19160-1 standard of how Addresses are vital in the fight against COVID-19 by enabling monitoring of the contagion chain of the disease.

17. **General purpose geospatial standards and aligning with the business environment**. Several geospatial standards are so basic that users are not always aware of them being implemented. Standards that uniformly describe data (specifications, metadata and quality, and geographic point location by coordinates) are widely used. Other examples of these hidden standards cover the process of relating national coordinate reference systems to global geodetic reference systems (so that two or three numbers can represent a place on the earth) and the calibration of remote sensing devices.

18. **Participation in standardization and advancing implementation**. The requirements for standardization are identified by the user community, and therefore stakeholder participation is essential. The ISO/TC 211 User Story collection[8] is a response to the need to demonstrate that standards are not only adopted in legislation and national frameworks but are also implemented. The ISO/TC 211 website provides some twenty stories examining the role of standards. The metadata standard ISO 19115 and the OGC Web Mapping Service (WMS) (also ISO 19128) are the most common standards detailed in the ISO/TC 211 User story collection. Yet, this is just the tip of the iceberg. The Defence Geospatial Information Working Group (DGIWG) and IHO standards are based on standards from ISO/TC 211 and OGC. ISO/TC 211 continues to look and listen outwards, for example, by presenting at the United Nations World Geospatial Information Congress and convening joint workshops with ISO and IEC committees on Smart Cities and Digital Twins. Our 2022 Standards in Action seminar attracted a dozen presentations on 'Governmental Services based on GIS standards' and

[6] https://committee.iso.org/home/tc211
[7] https://www.iso.org/sdgs.html
[8] https://committee.iso.org/sites/tc211/home/standards-in-action/user-story-challenge.html

'scientific projects concerning GIS standards'; the presentations are available on the ISO/TC 211's website.

19. **Increasing engagement with the Committee of Expert's Regional Committees**. ISO/TC 211 is in conversation with the Committee of Expert's Regional Committees for Africa (UN-GGIM Africa), Arab States (UN-GGIM Arab States) and Europe (UN-GGIM Europe) to help facilitate the engagement of Member States in the development of national standards. ISO/TC 211 already has liaison relations with the Committee's Regional Committees of the Americas (UN-GGIM Americas) and of Asia and the Pacific (UN-GGIM-AP).

20. **Coordinate Reference Systems**. ISO/TC 211 supports the implementation of the Global Geodetic Reference Frame (GGRF) by developing standards, e.g., ISO 19111 "Referencing by coordinates", ISO 19127 "Geodetic Register", and ISO 19161-1 "ITRS"; and through a long-term sustainable ISO Geodetic Register (ISOGR)[9] and its associated Control body which consists of convenors nominated by the International Association of Geodesy (IAG) and of international geodetic experts. The register is accessible through an online system and is freely available. We continue our conversation with the Committee of Expert's Subcommittee on Geodesy, where ISO/TC 211 participates as an invited observer. Moreover, the SDOs welcome progress toward the United Nations Global Geodetic Centre of Excellence.

21. Many geospatial users today are familiar with the European Petroleum Survey Group (EPSG) Dataset and Registry managed by the International Association of Oil and Gas Producers (IOGP) and the OGC CRS registry. The existence of three "official" registers and several others has caused some confusion. Thus, ISO/TC 211, OGC, and the IOGP are working on a joint statement that aims to describe the interactions between these registers and help users determine when to use each of them.

22. **Land Administration**. Having engaged OGC, IHO, International Federation of Surveyors (FIG), United Nations Office of Legal Affairs' Division for Ocean Affairs and Laws of the Sea (DOALOS), the World Bank, the United Nations Food and Agriculture Organization (FAO), and UN-Habitat, we have initiated an extensive revision of ISO 19152:2012 "Land Administration Domain Model" with confidence that the proposed new parts to this standard will cover the organizational requirements. The result of the consultation is an agreement on a multi-part standard: 1) General Conceptual Model; 2) Land Registration; 3) Marine Georegulation; 4) Valuation Information; 5) Spatial Planning; and 6) Implementations. Parts 1, 2, 3, 4 and 5 have been initiated and are part of the ISO/TC 211 work programme. Parts 1 and 3 should be available for public comment in the coming year (ISO Enquire Stage). A proposal for Part 6 is under preparation.

23. **Land Cover and Land Use (LCLU)**. LCLU is an essential and fundamental data theme that millions of professional users use globally across various applications. While the explosion of Location Intelligence tied to these essential data layers continues at a pace, the growing need for an agreed-upon LCLU meta language is vital to facilitate international analysis. ISO 19144-2:2012 "Geographic information - Classification systems -- Part 2: Land Cover Meta Language (LCML)" was developed under the leadership of FAO, and FAO are engaged in the revision and development of ISO 19144-3, a similar meta language standard for Land Use. A revised text of ISO 19144-2 should be available for public comment in the coming year (ISO Enquiry Stage). We plan a part 4 to establish a register of land cover and land use classifications. The ISO/TC 211 advisory group for Land Cover and Land Use comments on the draft recommendations for these core data themes, as requested by UN-GGIM Europe's Working Group on Core Data.

[9] https://registry.isotc211.org/

24. **Addressing**. An address provides structured information for the unambiguous determination of an object, such as a house or apartment building. Addresses are essential for managing cities, for governance and public administration generally, for service delivery in the public and private sector, and they can give people status or (legal) identity in society. ISO 19160-2 supports the Universal Postal Union's initiative, 'Addressing the World – An Address for Everyone', which promotes the establishment of national addressing infrastructures for the benefit of all. The multi-part ISO 19160, Addressing, provides the standards required for a country's addressing infrastructure, such as a conceptual data model; terminology; good practices for assigning and maintaining addresses; how to measure the quality of address data; and international postal addressing, the latter jointly developed with the Universal Postal Union (UPU). During the inter-sessional period, the following progress was made:

(a) A public Enquiry Draft of ISO 19160-2 Addressing -- Part 2: Assigning and maintaining addresses for objects in the physical world should be available by this present session. ISO 19160-2 specifies how to plan, implement, and maintain addresses and corresponding address data to gain maximum benefits for governance and society in the long run. It is a tool against which Governments could measure the objectives, principles and goals conformance of their addresses policies for a good practice and governance framework. This standard supports the implementation of the Integrated Geospatial Information Framework (IGIF), namely, enabling geospatial (address) information governance, policy and institutional arrangements that ensure effective geospatial (address) information management, accommodate individual, organizational requirements and arrangements, and are aligned to national and global policy frameworks. The standard is also useful for those involved in slum upgrading, as addresses are often assigned when settlement housing conditions are being improved.

(b) Public enquiry on a revised text for ISO 19160-4 International postal address components and template language closed in May 2022, and the revised edition should be published later this year. The UPU has led this revision.

Update from the International Hydrographic Organisation (IHO)

25. **Marine Geospatial Framework**. The IHO continued to work on its S-100 *Universal Hydrographic Data Model* framework to support creating and maintaining interoperable maritime data product specifications compliant with the ISO-19100 series of geographic information standards. The S-100 infrastructure includes the Geospatial Information Registry[10]. Feature Catalogue and Portrayal Catalogue builder have been developed and are now embedded into developing and maintaining data product specifications. S-100 based product specifications assigned to IHO, the International Association of Light Authorities (IALA), the Intergovernmental Oceanographic Commission (IOC), the Inland ENC Harmonization Group (IEHG), the World Meteorological Organization (WMO), the International Electrotechnical Commission (IEC) and NATO are being maintained on the IHO website[11].

26. The new edition 5.0.0 of S-100 represents the cumulation of experiences of the past four years in testing and development against S-100. Several extensions have been incorporated to support the enhancement of standards based on the S-100 framework with requirements from stakeholders to meet safety and efficiency in digital marine. Major extensions are Real-Time Functionality to implement temporal extent to facilitate time-sensitive representations of data

[10] http://registry.iho.int/

[11] https://iho.int/en/s-100-universal-hydrographic-data-model

such as water level; Encryption to increase security to better align with e-Navigation frameworks of IMO; Interoperability Framework and Harmonized Portrayal; Metadata Discovery to improve the functionality for data discovery and Language Packs to support multilingual for S-100.

27. **Interoperability in navigation systems**. IHO has developed the S-98 specification for data product interoperability in S-100 navigation systems to de-clutter displays; reduce information overload; resolve conflicts; and improve the overall quality and clarity of information presentation to mariners when multiple S-100 based data products are simultaneously displayed on-screen data product. The specification describes interoperability for S-100 based product specifications - S-101 Electronic Navigational Chart, S-102 Bathymetric Surface, S-104 Water Lever Information, S-111 Surface Current and S-129 Under Keel Clearance Management.

28. **Product standards development**. S-100 based product specifications have been developed and tested according to the S-100 Implementation Decade (2020-2030) roadmap. The first edition of the S-104 Water Lever Information and the S-128 Catalogue of Nautical Publication was published in April and May 2022, respectively, for initial implementation, testing and evaluation, and further stakeholder review. A new product specification is S-130 Polygonal Demarcations of Global Sea Area, which is primarily intended for encoding the extent of global sea area using a system of unique numerical identifiers. S-164 Test Data Sets for the S-100 navigation system are now under development.

29. **Testbed and Innovation Program**. IHO operates a project named S1OOP - S-100 Open Online Platform that is aimed to be the foundation for a digital ocean and accelerate the wide adoption of the S-100 hydrographic framework by jointly developing and making available the technical requirements needed to overcome any S-100 implementation barriers. The project installed four themes, Theme 1 - Online viewer; Theme 2 – Data Production and Protection; Theme 3 – Open source management; and, Theme 4 – Knowledge and Capacity. The new Joint IHO-Singapore Innovation and Technology Laboratory (IHO Lab), established in Singapore in October 2021, is aimed to accelerate innovation in the field of hydrography through sandbox implementation of new S-100 standards under construction. The IHO Lab embarked on two pilot projects: Automated conversion of S-57 Electronic Navigation Chart (ENC) to S-101 next-generation ENC and developing a digital infrastructure for S-131 marine harbour infrastructure.

30. **Marine Spatial Data Infrastructure (MSDI)**. MSDI has been highlighted as an important component of the future development of hydrographic offices. There is either no, or very little, basic teaching material is available for MSDI training that is free of charge for IHO Member States. IHO has established basic MSDI training material for IHO Member States and their respective Regional Hydrographic Commissions to conduct basic MSDI education and training. The MSDI training material is now free and available on the IHO webpage under the IHO MSDI Working Group Body of Knowledge[12]. An MSDI e-learning program has also been developed to enable people access to MSDI teaching externally and even receive the teaching online. The MSDI teaching material is available on the IHO's website for free. The interactive e-learning material can be downloaded or viewed on YouTube.

31. The FAIR principles are used widely in the geospatial community, promoting and supporting knowledge discovery and innovation as well as data and knowledge integration and sharing and reuse of data. The FAIR principles do not strictly define how to achieve a state of 'FAIRness'. Rather they describe a continuum of features, attributes, and behaviours that will

[12] https://iho.int/en/body-of-knowledge

move a digital resource closer to that goal. The principles help data and metadata be 'machine readable', supporting new discoveries through harvesting and analysing multiple datasets. To foster a 'Hydrographic Offices' approach to the FAIR Data Principles, IHO will establish guidelines on how IHO Member States can use the FAIR principles in their work with their national and regional MSDIs and, together with the OGC's Marine Data Working Group to establish an MSDI FAIR principles checklist.

32. The concept of Digital Twins is now widely used, and in the marine community, the application of Digital Twin of the Ocean or Digital Twin of the Sea is now under development. Digital Twins provide a framework for creating a digital truth about the physical environment. Through simulations that show the cause and effect of an event happening, Digital Twins help policymakers and decision-makers make informed decisions to prevent incidents from occurring or mitigate the event's impacts. A digital twin should be seen as a digital replica of a living or non-living physical entity. By combining the physical and virtual worlds, data is provided, enabling the virtual entity to exist simultaneously as the physical entity. As seen from an MSDI perspective, this has to be an important component in a marine Digital Twin application. The MSDI will be able to provide the datasets to create a highly complex virtual model that is the exact counterpart (or twin) of a physical thing. For example, the 'thing' could be a harbour or a sailing route marine protected area. Connected sensors on the physical asset collect data that can be mapped onto the virtual model. Anyone looking at the marine digital twin can now see crucial information about how the physical thing is doing in the real world. A marine digital twin will be a vital tool to help operators understand how products and initiatives are performing and how they will perform in the future. Analysis of the data from the connected sensors, combined with other sources of marine information, will allow agencies to make predictions. In order to have a Hydrographic Office approach to the marine Digital Twins, IHO will establish recommendations to IHO Member States on how MSDI and Hydrographic Offices can be part of Digital Twins in the future.

33. **Global coverage of seabed topography**. To improve the incomplete image of the ocean's seabed topography from all available data resources, IHO has continued to develop its "Crowdsourced Bathymetry campaign" and its supporting guidance document (IHO B-12). In addition, significant developments have been undertaken to the IHO´s Data Centre for Digital Bathymetry (DCDB) to enhance uploading, data viewing and download functionality. This results in a "General Bathymetric Chart of the Oceans" (GEBCO) grid of global ocean seabed topography, which is now publicly available under open data policy terms for download and reuse. The grid is updated annually; the 2021 grid now has 20.6% coverage, an increase of more than 14% over the past four years.

III. Supporting the implementation of the Integrated Geospatial Information Framework

34. After the third edition of the standards guide was endorsed at the Committee of Expert's eleventh session, the SDOs have worked to make it available as a web publication[13] and continue to receive and act on feedback.

35. The SDOs welcome the advancements of the IGIF and its implementation for the marine domain "IGIF-Hydro" as a practical means for ensuring a uniform approach to data integration and management between the land and sea domains. There are numerous common elements within the IGIF and the IGIF-Hydro with work on MSDI; hence simple connections can now be made to bring the definitions section up to date. Thus, IHO has now initiated a process for updating and modifying the IHO publication C-17 in response to these two IGIF initiatives.

[13] http://standards.unggim.ogc.org/index.php

The focus of a new version of C-17 will be on how Hydrographic Offices can act in response to the IGIF and IGIF-Hydro and the broader global perspective, and will focus on operational issues, like data consistency, data quality, multiple-use best practices, business models, the FAIR principles, maritime digital twins and other relevant initiatives leaving the IGIF and IGIF-Hydro to define broader use cases.

IV. Geospatial Standards in Measuring and Monitoring the Sustainable Development Goals

36. The SDOs continue to maintain and advance a framework of geospatial standards and good practices that support the mapping, visualization, analysis and forecasting related to the SDGs. The geospatial standards advanced by the SDOs continue to be adopted by technology suppliers worldwide to make it easier for the user community to implement FAIR solutions that are broadly compatible with collaboration and data sharing. Moreover, the development of domain-specific standards is helping to address specific SDG goals such as hunger, health, and sustainable communities.

37. Some specific examples of SDO support to SDGs over this past year include Goal 2: Zero Hunger (ISO/TC 211 Land Cover/Land Use); Goal 3: Good Health and Well Being (OGC Health Spatial Data Infrastructure Data Model); Goal 9: Industry, Innovation and Infrastructure (All SDO general-purpose standards apply); Goal 11: Sustainable Cities and Communities (implementation of OGC CityGML, OGC Indoor Mapping Data Format Community Standard); Goal 13: Climate Action (SDO General Purpose Standards, OGC Open API: Environmental Data Retrieval); Goal 14: Life Below Water (IHO Electronic Navigational Chart, S-102 – Bathymetric Surface, S-111 – Surface Currents, and S-129 – Under Keel Clearance).

VIII. Points for discussion

38. **The Committee of Experts is invited to:**

(a) Take note of this present report of the SDOs and express its views on their progress, work and plans.

(b) Encourage broad use of the Standards Guide to support the implementation of standards-based solutions that ensure interoperability, data sharing, and flexibility to adapt to changing data sources and technologies.

(c) Urge Member States and other relevant entities of the United Nations system to participate, through membership and resource provision, in the international geospatial standards development processes and meetings of the OGC, ISO/TC 211, and IHO to follow, provide scenario and use case-based input into, and review in-work standards as they are developed, finalized and approved.