GGC GGC33/4/1
Meeting 33 4 October 2016
Agenda Item 4.1

Report on the Forum for Future Ocean Floor Mapping

Submitted by Chair Forum Organizing Committee

SUMMARY

Executive Summary: This document provides details on the Forum for Future Ocean Floor Mapping held in Monaco 15 to 17 June 2016 as well as information on the initial outcomes from the Forum, which will be discussed under agenda item 7.1.2.

Action to be taken: See paragraph 3

Related documents: See attachments

1. Forum for Future Ocean Floor Mapping event

1.1 The Forum for Future Ocean Floor Mapping was held in the Principality of Monaco Wednesday 15 June through Friday 17 June 2016. The Forum was a joint effort of Nippon Foundation and GEBCO. Initially conceived as a celebration of 10 years of the GEBCO-Nippon Foundation training programme at the University of New Hampshire, it was widened at Nippon Foundation's initiative to be a Forum to set out the goals for the future of seafloor mapping for at least the next decade.

1.2 The Nippon Foundation funded all of the Forum including all venues and events, travel and accommodation for keynote and other special invitees, all expenses of the 48 scholars from the GEBCO-Nippon Foundation training programme and organizational support.

1.3 Day One consisted of keynote addresses at the Monaco Oceanographic Museum at which approximately 210 attendees (including all Forum participants, local organizations and Forum accompanying persons) participated in an interesting and inspirational programme. See Forum Programme as attachment 1.

1.4 On Day One the Forum was opened by HSH Prince Albert II of Monaco. Nippon Foundation chairman Mr Yohei Sasakawa announced that an Association of Alumni from the GEBCO/NF University of New Hampshire Training Programme would be formed. He also announced that the Nippon Foundation would support the new GEBCO project, Seabed 2030, to map the seafloor properly by 2030. This will a major initiative for GBCO.

1.5 Days Two and Three were held at Novotel Hotel and were comprised of panel discussions. There were 166 attendees from 48 countries who participated in these

moderated panels. Included in this total were the forty eight GEBCO–Nippon Foundation scholars from 28 countries.

1.6 The Forum Panel discussions (See Attachment2) on Day Two and Three lead to many suggestions of key needs for Seafloor 2030.

1.7 In association with the Forum a workshop on the Arctic and Antarctic seafloor mapping was held on 12 and 13 June. It was attended by about 35 scientists many of whom also attended the Forum.

1.8 At the IHB on Tuesday 14 June all of the Nippon Foundation scholars met with Nippon Foundation personnel, including Mr Sasakawa, to discuss interactions among the Scholars and to propose potential joint projects.

2. Outcomes

2.1 The primary outcome of the Forum is the Seabed 2030 Roadmap, which is reported on separately.

2.2 Shortly after the Forum a communique (Attachment 3) summarising key Forum conclusions was distributed to all attendees and over 500 media outlets.

2.3 A series of media releases have been written and distributed under the leadership of Forum media consultant Patrick Orr. These have generated a series of follow-on media enquiries and reports. We are now providing ongoing media releases to a list of over 500 journals, science writers and websites. Publicity for the Forum and the ultimate challenge of Seabed 2030 has been positive and widespread, culminating in a feature in Newsweek (7 October) spread over four pages. The BBC Science Correspondent attended the Forum and interviewed participants over a several days. There was a preview in the Economist and follow-up articles in the Sunday Times (UK), the New York Post, the Daily Telegraph (Australia), and a range of technical publications and websites. A regular 'News from GEBCO' is being distributed monthly, recycling the press releases for those who attended or were invited to the Forum. The strapline 'Towards Seabed 2030' is being added with the GEBCO logo to all printed material.

2.4 A six page special spread on Seabed 2030 is to be published in Hydro International in early 2017. There is a close working relationship with this important publication which, next year, will be offering GEBCO a free page for comment and news in every other published edition.

2.5 A video of the Forum is in final stages of completion. An early draft of parts of it was provided to Nippon Foundation and they have used it internally and put it on YouTube with Japanese subtitles.

2.6 As a result of the keynote presentation of Jyotika Virmani of XPRIZE, a team, GEBCO-Nippon Foundation, based on Nippon Foundation scholars has been entered for the Shell Ocean discovery XPRIZE completion. A press release providing details is attached (Attachment 4).

3. Action

The GGC is requested to:

a. **Note** the information provided; and
b. **Take** any other action deemed appropriate.

Attachments:

1. Forum Programme
2. Forum Panel Reports
3. Forum Communiqué
4. XPrize Press Release

Attachment 1 - Forum Programme

Final Version

Sunday, 12 June Novotel Monte Carlo Hotel
10:00 – 14:00 Registration –Hotel lobby

Monday, 13 June Novotel Monte Carlo Hotel
10:00 – 14:00 Registration – Hotel lobby

Tuesday, 14 June, 2016 Novotel Monte Carlo Hotel
09:00 – 17:00 Registration – Hotel lobby
18:00 – 21:00 Icebreaker – Novotel Monte Carlo Hotel Terrace, 7th floor

Wednesday, 15 June Monaco Oceanographic Museum
08:00 Departure by bus from Novotel Monte Carlo Hotel to Monaco Oceanographic Museum
8:15 – 08:45 Registration Monaco Oceanographic Museum Lobby
09:00 All seated – await arrival of HSH Prince Albert II
09:35 Address by the Chair of the GEBCO Guiding Committee – VAdm (ret) Shin Tani
09:45 Address by the Chair of the Nippon Foundation – Mr Yohei Sasakawa
09:55 Address and Forum opening by HSH Prince Albert II
10:15 - 11:00 Posters. Tea/Coffee Break
11:00 - 11:10 IHO opening address Robert Ward, International Hydrographic Bureau
11:10 - 11:20 IOC opening address Vladimir Ryabinin, Intergovernmental Oceanographic Commission of UNESCO
11:20 - 11:50 Keynote speaker 1 - Robert Ballard, Center for Ocean Exploration, Graduate School of Oceanography/URI and Ocean Exploration Trust
11:50 - 12:20 Keynote speaker 2 - Larry Mayer, Center for Coastal and Ocean Mapping/ Joint Hydrographic Center UNH
12:20 - 12:50 Keynote speaker 3 - David Heydon, DeepSea Metals
13:00 - 14:00 Lunch, provided by Forum. Posters
14:00 – 14:30 Keynote speaker 4 - Kristina M. Gjerde, IUCN (International Union for Conservation of Nature)/Wycliffe Management
14:30 - 15:00 Keynote speaker 5 - Jyotika Virmani, XPRIZE Foundation
15:00 – 15:30 Posters. Tea/Coffee Break
15:30 – 16:00 Keynote speaker 6 - Bjorn Jalving, Kongsberg Maritime, Subsea Division
16:00 – 16:30 Keynote speaker 7 - Simon Winchester, Author
16:45 Departure by bus from Monaco Oceanographic Museum to Novotel Monte Carlo Hotel
19:00 Departure by bus from Novotel Monte Carlo Hotel to Monaco Yacht Club
19:30 Gala Function at Monaco Yacht Club
22:00 Departure by bus to Novotel Monte Carlo Hotel from Monaco Yacht Club
22:30 Departure by bus to Novotel Monte Carlo Hotel from Monaco Yacht Club

Thursday, 16 June Novotel Monte Carlo Hotel
09:00 - 10:30 Panel 1 – Use of bathymetry: The deep ocean perspective
Moderators:
Asahiko Taira, JAMSTEC, Japan

Vicki Ferrini, GEBCO, USA
10:30 - 11:00 Posters. Tea/Coffee Break
11:00 - 12:30 Panel 2 – Use of bathymetry: The coastal perspective
Moderators:
Larry Mayer, CCOM, USA
Marzia Rovere, GEBCO, Italy
12:30 - 13:30 Lunch Provided by Forum at Hotel. Posters
13:30 - 15:00 Panel 3 – New tools and techniques in ocean mapping
Moderators:
Dawn Wright, ESRI, USA
Martin Jakobsson, GEBCO, Sweden
15: 00 - 15:30 Posters. Tea/Coffee Break
15:30 - 17:00 Panel 4 – Mapping the world ocean floor
Moderators:
Craig McLean, NOAA, USA
Lisa Taylor, GEBCO, USA
17:00 – 17:15 Workshop organization session
19.00 Prearranged Dinner at Novotel Monte Carlo Hotel, provided by Forum

Friday, 17 June Novotel Monte Carlo Hotel
Concurrent Workshop Sessions.

Workshop 1 - – Use of bathymetry: The deep ocean perspective
Facilitators: Asahiko Taira, JAMSTEC, Japan; Vicki Ferrini, GEBCO, USA

Workshop 2 - Use of bathymetry: The coastal perspective
Facilitators: Larry Mayer, CCOM, USA; Marzia Rovere, GEBCO, Italy

Workshop 3 - New tools and techniques in ocean mapping
Facilitators: Dawn Wright, ESRI, USA, Martin Jakobsson, GEBCO, Sweden

Workshop 4 - Mapping the world ocean floor
Facilitators: Craig McLean, NOAA, USA, Lisa Taylor, GEBCO, USA

09.00 - 10:00 Concurrent Workshop Sessions. Breakout into focus groups with pre-identified
leaders from industry and academia. All participants will be assigned to specific focus groups.
10:00 - 10:30 Posters. Tea/Coffee Break
10:30 - 11:30 Concurrent break-out Sessions.
All participants will rotate to next concurrent Workshop session.
11:30 – 11:45 Break for transition
11.45 - 12:45 Concurrent break-out Sessions.
All participants will rotate to next concurrent Workshop session
12.45 - 14:00 Lunch, provided by Forum at Hotel. Posters
14:00 - 15:00 Concurrent break-out Sessions.
All participants will rotate to next concurrent Workshop session.
15.00 - 15:45 Posters. Tea/Coffee Break
15.45 - 17:00 Plenary: Way-forward session. Closing of the Forum
19:00 Informal Dinner at Novotel Monte Carlo Hotel, provided by Forum

Attachment 2 – Forum Panel Reports

FOFM Panel 1: Deep Ocean Perspective

Co-moderators: Vicki Ferrini (Lamont-Doherty Earth Observatory/Columbia Univ., USA), Asahiko Taira (JAMSTEC, Japan)

Panelists: Razali Ahmed (PETRONAS, Malaysia)
Boris Dorschel (Alfred Wegner Institute, Germany)
Jennifer Jencks (NOAA, USA)
Brian Perratt (Global Marine Systems/ICPC, UK)
Juvenal Shiundu (International Maritime Organization)

Initial High-level Points for Communique

- Fully inventory/display footprint of existing data (+ metadata) and identify collaborations/incentives to gain public access to existing data that are not yet available.
- Develop a marketing strategy/plan to raise awareness about ocean mapping and its broad relevance to better engage the community of stakeholders (data producers, data consumers, governments, general public).
- Further develop relationships and collaborations between Scholars and other GEBCO members to fully activate and utilize the network already built through the Nippon Foundation Programme
- Develop a clear vision of GEBCO's role in future ocean mapping (including its products and role in facilitating international coordination/cooperation), and formalize the efforts GEBCO members (including developing mechanisms to help support them appropriately).

Grand Ocean Mapping Vision - Deep Water Perspective

- Increased resolution and efficiency of acquisition
- New visualization
- Broader engagement
- Improved documentation of data quality
- Improve data quality

Deep Water Bathymetry – Definition, Products, Resolution

- We want to map the entire surface of the earth seamlessly
- There are many ways to define "deep ocean." Practical definitions include:
    - Could be based on technological limitations of systems/platforms being used (e.g. ship-based multibeam vs AUV).
    - Could be based on assumed frequency of bathymetric change that would require re-mapping.
    - Could be based on a static depth (e.g. 200m) or feature boundary (e.g. shelf break)
    - Maybe include distinction between national and international since the coordinated approaches based on this definition will have different strategies?
- The deep ocean is at the frontier of science

- **Products**
    - Majority of users will not necessarily be bathymetrists/hydrographers – need data in a form for more general users. Need to be sure that we have clear annotation of quality description.
    - Needs:
        - Variable resolution unstructured grids
        - Common formats (e.g. GDAL-compliant grids)
        - Point cloud representations
        - New ways to visualize
        - GEBCO can promote acquisition/sharing of complementary data types (e.g. backscatter, water column) by facilitating pre-cruise communication and coordination.
    - *Gridded data is unlikely to be what the world will be asking for in 2030* so we need to be sure that we all preserve the full resolution data set (input points) – not just the grids. Uncertainty of points will need to be addressed. Cloud computing is ripe to help address these needs and we should start moving toward sharing points in the near-term
    - *First step is to develop and populate metadata viewer to help find existing data.*
- **Resolution**
    - The deep-sea floor is more dynamic than we ever thought, *100-m horizontal grid resolution should be the baseline for deep ocean bathymetry but in many areas higher-resolution is warranted.*
    - We aspire to reach the highest resolution the technology can give us. “Goal of GEBCO is to make the seafloor public.”
    - The features themselves propose an appropriate data density. The frequency of resurvey and higher resolution needs will be defined by environment, processes, and specific use-cases
- **Mapping the Gaps**
    - The ocean should not be a curtain that hides the seafloor.
    - We need to gain access to existing (meta)data. The first step is to share metadata about what data have been acquired and how they might be accessed. There is a lot of work that can be done here in terms of developing collaborations, providing technical resources and training, deploying new web services and developing collaborations to access “dark data”
    - ***Collaborations*** between industry, academia and governments are critical. This requires that we improve ***marketing*** within the ocean sector, with the public with governments.
    - ***Coordination*** to optimize efficiency and coverage with new data acquisition. This can include mapping campaigns
    - GEBCO can play a big role in terms of facilitating communication, helping with the development and implementation of web services, and working to ensure that many flavours of data/metadata can be made available.

Roadmap

- Develop guidelines, templates, technical support to help share metadata about existing bathymetry data.
    - Set up GEBCO map interface that aggregates metadata about existing bathymetry data via web services
- Communication:
    - Develop strategic partnerships with data producers – many don't know that they can contribute to GEBCO, many don't know they can use GEBCO products
    - Global publicity
    - Crowd-Funding

FOFM Panel 2 - Use of bathymetry: The coastal perspective

Moderators:

- Larry Mayer, Center for Coastal and Ocean Mapping/UNH, USA
- Marzia Rovere, GEBCO, Istituto di Scienze Marine/CNR, Italy

Panel members:

- Nadia Pinardi, Bologna University, Italy
- Thomas Furey, INFOMAR, Marine Istitute, Ireland
- Shep Smith, Office of Coast Survey/NOAA, USA
- Peter Harris, GRID-Arendal, Norway
- Sjoerd van den Brom, Boskalis, The Netherlands

Facilitators for day 3:

- Marzia Rovere, GEBCO, Istituto di Scienze Marine/CNR, Italy
- Thomas Furey, INFOMAR, Marine Istitute, Ireland

Rapporteurs for day 3:

- Walter Reynoso Peralta, Servicio de Hidrografía Naval, Argentina
- Amon K. Kimeli, Kenya Marine & Fisheries Research Institute, Kenya

1. What is meant by coastal seafloor mapping

- Marine waters down to 200 m depths as suggested in the United Nations Convention on the Law of the Sea (UNCLOS) which defines the outer limit of the legal continental shelf by reference to the 200 metre isobath and the criteria of exploitability. The outer limit of the legal continental shelf in UNCLOS is also determined by reference to a distance of 200 nautical miles or to the outer edge of the geological continental margin, wherever there is geological evidence that the margin extends beyond that limit. There is tendency among coastal States to use article 76 of UNCLOS, instead. Article 76 cites that when the continental margin extends beyond 200 nm, States must apply a formula where the outer limit must be located up to: i. a distance of 60 nm from the foot of the continental slope or a line where the ratio of sediment depth to its distance from the foot of the continental slope is 1/100; ii. a distance of 350 nm from the baselines from which the territorial sea is measured; iii. 100 nm from the 2,500 m isobaths. The implementation of the above rules or other rules implies knowledge of marine geomorphology and geology of the margin.
- Outer boundary - 200 m depth because tides are not obligatory applied beyond this depth.

- Geomorphologic approach, the shelf break, which can range from 120 to 300 m should be considered a dynamic layer rather than a fixed depth.
- Inshore boundary of what is achievable mapped by 2030 – 10 m contour or 10-50 m interval or the distance from the coast, 12 nm, territorial waters limit.
- Hydrographers: targeting 0 – 50 m for safe navigation, these body of waters may be prohibited in certain areas of the world for safety and security reasons by defence authorities.
- Defined by the resolution and capability of the multibeam systems.

Conclusions
Seafloor mapping of coastal areas is key to all activities that impact the coastline or have a direct relationship with the coastline. Although scientists perceive the ocean floors as a continuum from the coastline down to the deepest abyssal plains and the principle of Marine Spatial Data Infrastructure is to have a smooth access of authoritative and accurate data, there is still a general requirement to have a distinction between "bathymetry" (deep ocean) vs. "hydrography" (less than 50 m water depth for safe navigation). Furthermore, the costs and times for mapping the seas shallower than 50 m increase logarithmically.

2. Who are the users of coastal bathymetry?

- Industry: aquaculture, renewable energy, oil and gas (30 % of global production on continental shelves), shipping, fishery (90 % of the fishing grounds occur in 200-400 m and need habitat mapping for fishing grounds predictions for better economics and sustainable fisheries), transport of energy (pipelines), communication (cables), mining mostly for aggregates, phosphates, iron ores.
- Safety of navigation and Security Authorities: Hydrographers, Navy.
- Scientists: Geologists, Biologists, Oceanographers.
- Forecasting, oceanographic and hydrodynamic modelling, tsunami and marine hazard modelling/forecasting, inundation maps particularly at ocean inlets and outlets, tides and currents modelling. Oceanographic models - not only physics but also chemistry and biology.
- Governments, regional authorities and United Nations (FAO, UNEP, IMO, IOC-UNESCO etc.) responsible for a sustainable management of the marine resources: they need seafloor and habitat mapping as a decision tool and risk assessment baseline.
- Coastal engineers, port and harbour managers, also for identification of dumping sites.
- Coastal erosion mitigation: sediment budget estimation and management, especially where human infrastructures are present.
- Education sector.
- Recreational users: recreational boaters, divers, surfers.
- Conservation community: marine protected areas definition, archaeological and historical sites detection and preservation. Submerged archaeological remains are also important to constrain sea level curves.

- Bird life and marine mammals monitoring, both influenced by bathymetric features (canyons, seamounts).

Conclusions
Bathymetry, especially in the coastal areas, underpins marine and maritime spatial planning and decision-making by governments on access to seabed space. The bathymetry of the coastal areas serves a wide community of stakeholders. The public access to shallow water bathymetry imply that there are unidentified users, because the value of having mapped the seabed is still underestimated. Furthermore, the dynamic nature of shallow water environments need to consider temporal components (4D datasets) and repeated measurements, for proper risk management and sustainable use of the seas, through marine spatial planning. The new technologies fully comply with this necessity. How we distribute data may be critical as this links completely unexpected utilization, collaborations and outcomes.

3. What resolution needed depending on the uses?

- Seafloor geomorphic features have biological/ecological significance, because biological communities are associated to certain specific physical habitats. Their mapping does not required the highest possible resolution, 20-30 m is sufficient. For general-purpose usage, 20 m resolution will be sufficient.
- For a global scale, we need an accurate 500 m grid for storm surge, storm wave and tsunami modelling for the entire continental shelf (0-250 m). However, with regard to detailed tsunami prediction/mitigation, data resolution should be set depending on the tsunami wavelength, as theoretically inferred. Tsunami wavelength, in turns, depends on the water depth. Therefore required data resolution should change with water depth.
- Engineering and shipwreck search & rescue need sub-meter resolution regardless of depth (0.1 m). In certain cases, industry needs to make repeated surveys, depending on the objectives. For example in ripple/dune environments twice a year is sufficient, while during dredging operations of gigantic infrastructures, such as Suez, the entire stretch has been surveyed twice a day.
- 0.1 meter real-time accuracy is feasible worldwide, through certain GPS services, but this is not necessary for a general baseline for all world oceans. First, the big picture, then we can go into higher resolution in specific areas where repeated surveys and temporal monitoring are required for highly dynamic environments, such as inlets, outlets, coastal areas prone to storm surges and coastal erosion, areas of particular ecological significance etc.
- For hazard detection of meter-scale objects in navigation depths, the measurement resolution needs to be finer than 1 m. This is achievable with modern multi beam systems and LIDAR systems are getting close in very shallow clear water. More than that, the identification of hazard is key and non-dependent of resolution.
- Horizontal and vertical resolution should be homogenous.
- Coastal modellers will become major users of bathymetry data. They need accurate and high resolution bathymetry for coastal inundation, biogeochemical forecasting and all anomalies in coastal circulation and ecosystem structure. The 10-100 m horizontal mapping grid resolution is an urgent requirement as well as the accuracy

of the retrieved depth data which should be within few tens of cm (tidal elevations in several world ocean areas are of the order of 50 cm). Estimates of temporal scales of change of bathymetry in the coastal areas is also an urgent requirement, as well as the size of these changes.

- More than resolution itself, there is the need for oceanographic modellers to have assigned uncertainties to the different kind of data sources/technologies; this applies especially for crowd sourced information.
- There is the urgent need to establish a global Vertical Datum (could be WGS-84 Mean Sea Level). A non-tide datum may be helpful also for developing nations which cannot afford a network of tide gauges. Open Geospatial Consortium (OGC) – Marine Domain Working Group will discuss relevant marine data management and geodetic issues (Marine DWG Charter document).
- The IHO S-44 standards provide the regulations in terms of accuracy and resolution for vertical and horizontal in hydrographic surveys. The Special Order and order 1A apply for coastal hydrographic surveys. Thus the uncertainty and accuracy reference is assigned. Anyhow, leading edge technology of multibeam systems may achieve better resolution and accuracy than current IHO standards.

Conclusions
Resolution is utterly important, but so are uncertainty and repeatability of the measurements. Depth accuracy of few tens of cm and horizontal resolution of 5-10 m, globally, would be desirable. Notwithstanding, most of our coastal waters are not even mapped to 100 m resolution, it is reasonably better to obtain the big picture by 2030, i.e. much wider coverage at medium resolution. Dynamic coastal areas mapped at highest resolution require continuous and repeated surveys, this task will employ the future generations. The data have to be collected referenced to geodetic datum, tides corrections have lower priority, being important for the safety of navigation and inundation maps. Need to be cautious in terms of defining figures of resolution, because technology, products and requirements are ever changing.

4. What kind of data and data products are needed by the users?

- Data sets should be have enough quality and density in order to extract from them many different products to cover a wide range of applications. Interactive electronic/digital map/chart for different purposes is better instead of a particular single product. It is important that data are described and provided in open standards. The specific communities will create tools, applications, software to achieve their best products, also through crowd-funding (recreational users – as there are many – can contribute to some kind of crowd-source to support applications they like).
- Develop an open-data format standardized – can be used by people without hydrographic knowledge.
- Marine Spatial Data Infrastructure is critical: interoperability, accurate metadata, data format description, data exchange with other geospatial data systems is a priority.
- Seamless topography between land and sea. Only navigators need nautical charts with their shoal bias; most users need DTMs in GIS formats with no shoal bias.

- Coastal engineers require cleaned soundings data to create their own gridding.
- Time series products are needed– e.g. migrating sand dunes, time-varied distribution of fish and biomass.
- Interpreted and informed layers for the decision-making processes, e.g. benthic habitat maps / seabed types, hazards, conflicting and overlapping uses of the sea.
- Gridded products may have different resolutions depending on the water depth: multiple resolution surfaces, this is also included as new tool in some commercial software.
- Statistical maps with uncertainty and accuracy estimation.
- Inventory of the bathymetric gaps.
- Undersea features polygons in shallow waters, as well as, harmonization of their terms and definitions.
- BAG files are very helpful (but to hydrographers) – include uncertainty information.
- Standards for non-hydrographic community are more appropriate / S100 is not specifically for hydrographic community.
- GEBCO products are appropriate for a large base of users– (netcdf, ascii & geotiff), but netcdf is specific to the scientific community.
- GEBCO Digital Atlas – baseline product collated, and one stop shop for data discovery, data repositories could be supported.

Conclusions
Effective Marine Spatial Data Infrastructures need interoperability, accurate metadata, data format description, data exchange with other geospatial data systems. Instead of providing a set of products, GEBCO will consider ensuring raw data or cleaned XYZ access and associated tools. This requires a suitable cloud based storage and related applications, where users have access and can select areas of interest. In the light of the emergence of a new OGC standard, GEBCO should consider the option of providing products as Discrete Global Grid Systems (DSSG), which represents the Earth with a tessellation of nested cell. DSSG as a whole consists in the conversion of traditional data archives into standardized data architectures that support parallel processing in distributed and/or high performance compute environments.

5. What are the emerging conflicting uses?

- In many European countries, there is opposition to offshore oil&gas exploration and exploitation, due to fears for the fishing and leisure industry, landscape concerns and environmental impacts. But in most cases that fishing boats are closely circling the oil rigs in the southern North Sea, evidently because the rigs attract fish. Bathymetry may thus alleviate the fears.
- Offshore energy vs shipping and fishing; fishing and sometimes leisure vs marine protected areas.
- Mapping of traffic patterns and infrastructure (energy, cables) helps identify conflicting uses early so they can be reconciled.
- Government decision-making is often about trade-offs. An example is the increasing need to design marine protected areas to set aside and protect representative

habitats. So the kind of seabed areas used for fishing need to be mapped and understood so that some of these areas can be set aside in MPAs.
- This is not specific to bathymetry, knowledge of the marine environment in general will mitigate conflicts hopefully toward sustainable development.
- Bathymetry data will allow a better understanding of the context of decision making in conflict like drilling vs fishery, artisanal fishery vs industrial fishery.

6. How poor is our knowledge of the continental margins?

- There are large gaps in our bathymetric knowledge of many continental margins even at 1 mile grid spacing. Margins of Africa, parts of Asia, Greenland and Antarctica are very poorly mapped. In some places poor data quality makes geomorphic mapping impossible even at broad spatial scales.
- Setting of MPAs and zoning for management of the sea is demanding a network of well qualified technicians and robust data. In terms of bathy being effectively used to identify MPAs in areas beyond national jurisdiction, GEBCO should better coordinate with the non-profit/NGO community. There is great engagement among academia, government, and industry, but not with GEBCO, and there is a good assessment of where bathy is needed for MPAs, reserves and the like (e.g., MPA Atlas of Marine Conservation Institute, IUCN, The Nature Conservancy, Conservation International).

7. How do we map the coastal areas? (+ criteria to address priorities)

- An integrated technology approach is favoured in the coastal areas. LIDAR, satellite imageries, multibeam, singlebeam, open ROV data.
- Start with an inventory / gap analysis (what can we get access to in short term): presence / absence of data.
- Military & industry. Negotiations needed. Encourage more and more HO's drawing into data sharing initiative. GEBCO should engage furthermore with HOs through IRCC and regional hydrographic commissions. Persuade more HOs to include shallow water bathymetry from ENCs (Electronic Nautical Charts) into GEBCO. Some lessons learnt (i.e. EMODnet) unfortunately indicate that some HO's are stepping back in the participation and active involvement in data sharing projects.
- Recommend permitting regulation to ensure data are provided to national data centres (standard approach will not be feasible between different States). Call for this has to be enforced. Highlight resourcing & infrastructure requirement of national marine data centres, IOC and IHO have capacity building initiatives that may support this.
- Encourage crowd sourcing and funding, particularly in the context of monitoring costal dynamic systems, and raising public awareness.
- Convince coastal and developing member States – marine data is important and baseline requirement for society.
- Encourage crowd sourcing from scientific communities (for example whale watchers).
- Consider mobilising GEBCO scholars for extracting grids from Hydrographic Office data / digitising fair sheets (not feasible on large HO's due to data volumes). In Australia, the HO outsourced the digitalization of the nautical charts to the National

Geoscience Agency. Consider similar efforts and engage society through Citizen Science Actions and crowd source digitisation of data (X-Prize) (consider gamifying it – however needs significant technical knowledge – is not straightforward). Digitising is mechanical, phase approach could be taken to get it to a certain level.

- Consider mobilising GEBCO scholars + research institutions to build a global coastal model using satellite-derived (imagery) bathymetry (human capacity for data processing as a global initiative). Draw a plan for addressing the variable uncertainty that is inherent in SDB data.
- Facilitate technology & knowledge transfer mechanisms for data centres, particularly in developing countries of Western Africa, where oil&gas industry acquired great amount of data in the last 20 years and coastal States secured agreements for data delivery.
- GEBCO should continue to work with regional / coastal initiatives (e.g. Oceanwise – EMODnet, IBCAO, IBSO etc), and supporting best practice, but should not compete / try and be product supplier.
- GEBCO portal should be global data source page, while pointing to alternative higher resolution sources, GEBCO should be host of a baseline dataset.
- GEBCO should promote cultural change, sharing of data, investment in HO people infrastructure to develop the grids, over and above the nautical charting which is shared by the Hydrographic Offices.
- Encourage countries that acquired data for application of extension of continental shelf under UNCLOS to submit their data to GEBCO through DOALOS. The challenge is to build a trust to share datasets for the benefit of the mankind.
- Encourage contractors that acquired bathymetric data in The Area for mineral resources exploration to submit their data to GEBCO, at least at low resolution.
- GEBCO may more actively acknowledge data contributions in new releases.
- GEBCO should provide more intuitive information on how to contribute with new data sets via the web site.
- GEBCO should disseminate the value of seafloor mapping through dedicated outreach programmes.
- GEBCO may liaise with the GeoHab group on delivery of better outputs of ancillary data (backscatter) in long term. GEBCO Science day could be a mechanism to update community on GeoHab activity.
- GEBCO should coordinate with deep ocean ship surveys like GO-SHIP http://www.go-ship.org/.
- Consider creating a GEBCO app that is tailored for the layman and policymakers.
- Consider providing a link to a crowdfunding website, where satisfied users could provide contributions to future GEBCO updates and maintenance.

General Recommendations

- Encourage political support (UN and G7) for increased resources for seafloor mapping to achieve the 2030 goal. IHO & IOC communication of requirement for global ocean floor mapping to United Nations (71st Assembly 13th - 26th Sept. 2016) within goal 14, to conserve and sustainably use the world's oceans, seas and marine resources. Ocean mapping could complement the United Nations Atlas of the Oceans. Take that message forward to UN to get sanction for the initiative of global mapping.

- 2 topics have been chosen as high level issues for G7 coordinated action and research investment in 2015 (Future of the Ocean and its Seas: a non-governmental scientific perspective on seven marine research issues of G7 interest). These are marine plastic litter and deep-sea mining. Mapping of the seafloor as high level issue is never mentioned in the latter one.
- In the UN First Global Integrated Marine Assessment (World Ocean Assessment I), seafloor mapping is not mentioned as a knowledge gap for the oceans.
- Engage with a campaign, need a strategy to find the resources– develop a position paper on rational of why bathymetric data should be gathered, reinforce the need for a physical habitat description highlighting the difference between full-resolution data and downsampled gridded data, as well as the global benefits of data sharing. In current position papers, the need for a complete mapping of the ocean floors by 2030 is not adequately addressed. Bathymetric surveys by multibeam systems not only map the seabed, but acoustically image the physical water column, biomass, fish populations and hydrocarbon plumes. Furthermore, multibeam surveys require the periodic sampling of temperature, salinity and density of the water column, by means of CTD probe deployments or deep-towed profilers, while in the Ship-of-Opportunity Programme (SOOP) XBT casts measure only temperature.
- The key to mapping the oceans is greater international coordination of scientific research by industry and scientific institutions; capacity building through active engagement of developing States in research is also required.

FOFM Panel 3 - New tools and techniques in ocean mapping

Synopsis

Do we have the tools and techniques to map the world ocean?

It is not only the available technology to directly measure seafloor depths that matters for GEBCO since the task to map the ocean floor also involves bringing all available depth measurements together into a database for the compilation a coherent bathymetric portrayal of the world ocean floor. Therefore, bathymetric post-processing and analyses software, database technology, computing infrastructure and gridding techniques must be brought into the discussion regarding available tools and techniques in ocean mapping along with the latest development of seafloor mapping methods. This is reflected by the four main topics that were in specific focus for the discussion in Panel 3:

1. Mapping technologies
    a. *Sonars and mapping platforms*
    b. *Crowd source technologies*
    c. *Satellite-derived bathymetry*
2. Cloud computing and database infrastructures
3. The gridding concept and formats
4. Auxiliary parameters to bathymetry

Mapping technologies

Sonars and mapping platforms

The technological development constantly improve the accuracy, resolution and seafloor coverage for echo-sounding methods. The modern most widely used acoustic mapping technology is based on the multibeam echo sounder with the capability of mapping a swath underneath the vessel. The width of a mapped swath of the seafloor is for a modern multibeam around five times the water depth and sometimes better. Interferometric sonars exist and are being developed with much wider swath widths, specifically suited for shallow water mapping or installation in AUVs due to their smaller size. However, the quality of depth measurements of interferometric sonars are not yet at the level of conventional multibeam echo sounders, although the side-scan information they collect are of superb quality. Next in line we might see sonars based on a mix between the interferometric and more conventional multibeam technology.

While the echo sounding technique is constantly being improved, both with respect to performance and availability, the mapping of the world's ocean floor is increasing only slowly. This is particularly true for the sea-ice covered and iceberg infested portions of the oceans and the most remote areas with sparse ship traffic such as the south Pacific. The panel discussion therefore converged to discuss the development of unmanned vehicles of various sorts. The discussion is here summarized with the following conclusions:

- Available commercial and custom developed AUVs are optimal for high-resolution mapping of smaller areas, but limited with respect to range preventing longer (weeks) missions.
- Gliders equipped with multibeam sonars would extend the range substantially compared to traditional AUVs, but available multibeam sonars are not small enough to be installed on gliders.
- Fleets of low maintenance autonomous surface or underwater vehicles may provide a solution of mapping remote areas.
- An unmanned mapping barge, steered by satellite communication and equipped with an ultra-narrow beam deep-water multibeam would permit systematic high-resolution mapping of the deep world ocean. This is one idea raised to reach the goal of map the entire world ocean floor at resolution substantially better than 100 x 100 m.

The Shell ocean discovery XPRIZE is currently challenging teams to develop new deep-sea technologies for autonomous, fast and high-resolution ocean mapping. The price of $7 million is designed to bring the target of a fully mapped world ocean seabed closer, fully in line with GEBCO goals.

Crowd source technologies

Using crowd sourced bathymetry is not new to GEBCO. Bathymetry provided by the Norwegian company Olex comprised a significant source for the compilation of the International Bathymetric Chart of the Arctic Ocean (IBCAO) Version 3.0 grid released 2012. The Olex depth measurements originate from their automatic charting system installed primarily on fishing vessels. The Olex database is growing fast because the fishing vessels share their logged depths in order to collectively build better seafloor maps. Bathymetric data from Olex also played a major role in the GEBCO 2014 grid. Several additional companies based on the crowd source philosophy exist on the market. Small and easy to install NMEA-loggers storing depths from any ship echo sounder already exist and are being further developed. IHO has a crowd source working group with substantial GEBCO engagement. This working groups is tasked to draft recommendations for the minimum metadata to be

provided along with depth measurements and discuss available technologies, and online upload technologies and storage. Panel 3 discussed the crowd source technology which is spreading beyond installing loggers on conventional echo sounders. One such example is SmartFin, a collaboration between researchers at the Scripps Institution of Oceanography that has developed surfboard fins that record ocean temperature, pH, salinity, location, and wave characteristics. The fin broadcasts data straight to phones using the Bluetooth wireless technology. Even if the SmartFin not is logging depths, it highlights innovative thinking out of the box. A major conclusion from the discussion on crowd source technology was:

- Crowd sourcing is a powerful concept in ocean mapping that has a huge potential to substantially boost the targeted mapping, specifically in shallow water.

Satellite-derived bathymetry

The gap between the coastline and where depth measurements exist on the continental shelf is large in several vast remote areas on Earth. Surveying of the areas using conventional methods from ships, and even with AUVs, may be enormously challenging and expensive. Furthermore, LIDAR is expensive and limited to clear water. In such remote areas, where other means of seafloor mapping not is easily feasible, bathymetry derived from satellite imagery may provide a specifically promising method. Freely available imagery, such as Landsat 8, as well as commercial higher-resolution satellite images comprise vast data sources with global coverage. The development of satellite derived bathy methods that are not based on only the optical spectrum may overcome the non-clear water issue. The discussion in Panel 3 on the use of satellite-derived bathymetry is summarized in the following conclusions of importance for the GEBCO task of mapping the world ocean from the coast to the deepest parts of the oceans:

- Shallow water bathymetry derived from satellite imagery constitute a promising technique that may be particularly useful in remote areas where other available mapping methods not are feasible. Derived depths from satellite imagery are not as high quality and accurate as from other conventions mapping methods, but it is a source better than nothing with huge spatial coverage.

A pilot project between GEBCO and Google will be initiated to further investigate the application of satellite derived bathymetry on global scale. Ongoing projects aiming towards the development of the satellite image derived bathymetry mapping method exist within the GEBCO that involves the University of Minnesota Polar Geospatial Center.

Cloud computing and database infrastructures

The present GEBCO central bathymetric database as well as databases of regional mapping projects under GEBCO resides on servers at the host organizations. While the underlying bathymetric source data from mapping campaigns amounts to vast amounts of terabytes, the amount of data cleaned and ready to go into a regional bathymetric database, or directly to GEBCOs central repository, is more on the order of gigabytes. The sizes of these databases will naturally increase once GEBCO targets a higher resolution global coverage, but will remain far from the amount of raw ship soundings collected at sea. This together with that GEBCO moves towards establishing more regional projects at host organization around the world, points towards several potential benefits of using a cloud based infrastructure for the regional mapping projects under GEBCO and for its central repository as well as for gridding

and processing routines. Several potential hinders and questions were identified during the Panel 3 discussion:

- Will it be possible to efficiently handle different access levels to such a cloud based database and computing infrastructure?
- The productions of a coherent bathymetric gridded compilation from a broad range of data sources involves an iterative process where depth data cleaning is alternated with gridding and analyses. Will a cloud based database permit efficient work on data with a suite of software?
- Will the network speed restrict the use of such cloud based database structure to only the most technologically developed countries?

In order the address these questions a pilot project was initiated between Esri and the GEBCO regional mapping project IBCAO.

The gridding concept and formats

The GEBCO 2014 grid, as well as the grids produced by linked regional mapping projects (e.g. IBCAO, IBCSO), are based on vastly heterogeneous source data implying that some areas are well mapped while others are extremely poorly mapped. In some areas of the world ocean much higher resolution final grids would be possible to produce than the GEBCO 2014 (0.5 x 0.5 min), IBCAO (500 x 500 m) and IBCSO (500 x 500 m) grid. But since no there is no widely spread grid-format for variable sized grids that common software read, GEBCO as well as regional mapping projects have stuck to produce grids with one set cell-size resolution, even if the applied gridding approaches lend themselves well to produce variable sized grids with resolution steered by the density of the source data. The BAG (Bathymetry Attributed Grid) is however a grid format that Esri, Caris, QPS and several other software producers have begun to implement, which may be suitable to store variable sized grid. In Panel 3 there was a technical discussion on variable sized grids and the general conclusions were:

- Variable grids will be more in demand as the end-user community begin to realize that this is an option to get bathymetric overviews of large areas and details of smaller areas in one convenient database.
- GEBCO could drive the community of software vendors toward a solution, but it must be kept in mind that software vendors often do not make open standards, the Open GIS Consortium (OGC) does and then software vendors adopt/promote those.

Auxiliary parameters to bathymetry

Along with bathymetry information about the seafloor composition is widely asked for by the end user community. Panel 3 discussed other efforts such as GEOHABs (Marine Geological and Biological Habitat Mapping).

Raw comments

Backscatter Working Group capacity and affordability to access are important but regarding the data acquired by these different platforms, a focus on **backscatter** information is needed; Backscatter to identify the bottom, and what kind of resources can be exploited or protected

- Variable resolution issues here too
- Dawn shares GEOHABs Backscatter Working Group efforts and working document; shares that special issue of Marine Geophysical Researches

- For the GEBCO road map they might want to coordinate with GEOHAB working group; shake hands between communities; draping

- Is it GEBCO's role to push into this arena? Sometimes it is too hard to reconcile; can we get Backscatter for the entire world even? it might be too early at the present to talk about Backscatter within GEOHAB but a possibility for the future road map; Backscatter on top of GEBCO grid is one specific use case.

FOFM Panel 4 - Mapping the World's Ocean

Moderators:
Craig McLean, Office of Oceanic and Atmospheric Research/NOAA USA
Lisa Taylor, GEBCO, National Centers for Environmental Information/NOAA USA
Panel members:
Dick Schaap, Mariene Informatie Service, Netherlands
David Millar, Fugro Pelagos, USA
Peter Heffernan, Marine Institute, Ireland
Paul Holthus, World Ocean Council, USA
Thierry Schmitt, Naval Hydrographic and Oceanographic Service/SHOM, France

Original Questions:

- *How can we best identify current gaps in bathymetric coverage based on geography, depth, and resolution?*
- *How can we engage more mariners to contribute crowd-sourced bathymetry?*
- *What is the potential for campaign type efforts to map areas of the ocean floor? Crowd-sourced bathymetry?*
- *What are the barriers to sharing bathymetric data and how can we overcome them?*
- *How is industry tackling this challenge?*
- *What processes and practices are working well and how can we build upon them?*
- *How can we leverage satellite-derived bathymetry for mapping sensitive coastal areas?*
- *What partnerships can we foster with governments, industry, NGO's and institutes to get*
- *this done?*

****

In order to achieve the 2030 vision to map the entire ocean floor, we must:

1. Identify and access existing bathymetric data from hydrographic offices, industry, research organizations, and individual mariners.
2. Map the bathymetric gaps using crowdsourcing, coordinated basin scale campaigns, satellite derived bathymetry, regional compilations and innovations in remotely controlled collection technology.
3. Produce a 'startup' style prospectus that lays out the vision of mapping the seafloor by 2030 that resonates intellectually and emotionally with the public and clearly answers the question "Why should we care?".

4. Create strong partnerships for collecting, sharing and compiling data.
5. Internally restructure the way GEBCO operates to include a range of sector specific ambassadors (e.g., oil and gas) and enough 'connectors' to open the door to new partnerships. Hire a full time person to orchestrate all the moving pieces involved with the 2030 vision.

****

1. Identify and access existing bathymetric data

Accessing existing bathymetric data will go a long way toward filling the gaps in our world ocean coverage. At the moment, however, there is no mechanism in place to identify or access these bathymetric datasets. Current barriers (real or perceived) to sharing these data include concerns about national security, sovereignty, liability, loss of profit potential, comprise of strategic or competitive advantage, technical challenges, lack of coordination, desire for anonymity and a lack of understanding of the overall benefit to the well-being of our planet and the people on it. At the moment, there are probably dozens, if not hundreds of individual databases of bathymetric data in existence. These are largely held by national governments, national oil companies, international oil companies and survey companies, but also include submarine cable companies, deep sea mining companies, research organizations and individual mariners. In many cases, these data are treated as proprietary and not shared or even visible. As a result, to identify and access existing bathymetric data holdings, it is critical that those who hold the data are convinced to share it, even if at a decimated level. To this end, GEBCO needs to develop a strategy for identifying and accessing existing bathymetric data. This strategy needs to include identification of the potential contributors and a standard message / communication that clearly states the project vision, the need (including maps showing the real gaps in coverage), the goals, the resolution requirements (acceptability of decimated data), potential tax benefits and mitigations to barriers. GEBCO needs to de-commission the mind-set that these data are proprietary and can't be shared.

Part of the strategy probably needs to include a determination of who will engage the various potential contributor groups. For example, is it best for GEBCO to engage all potential contributors or is it best for GEBCO to provide the support material for others (national governments, industry associations and/or survey companies for example) to engage a portion of the potential contributors. Some nations and some regions already have databases or systems in place that make bathymetric data publically available. These also need to be identified and in such cases, those databases need to be exploited versus going back to the source data. In the case of commercial survey companies, most of the data they collect, hold and manage (often in databases) are owned by their customers and not by the survey companies. In such cases, customer approval would be required before such data could be accessed and in those cases, maybe it makes sense for the survey company, with the support of GEBCO to engage their customers. Many nations have successfully incorporated bathymetric data into their regulatory framework. For example, is the requirement of a lease block sale or the issuance of environmental permit that bathymetric data acquired at that site and/or in support of that activity be provided to the government granting the rights? Those nations not currently implementing such a strategy could possibly learn from those that are currently using it with success.

Given the global nature of this issue, its importance to global resilience and sustainability and its significance to humanity in general, it would probably be appropriate and helpful to

engage the United Nations on this issue. Maybe this can best be accomplished through the IHO, the regional hydrographic commissions and/or key member states. In addition to urging member states to share data, they may be able to assist in promoting the concept of making survey data associated with UNCLOS submittals available to GEBCO, even if at a decimated level. There is probably a role for the World Ocean Council (WOC) in this effort as well. Billed as "The International Business Alliance for Corporate Ocean Responsibility", the WOC could promote this issue within its members and its membership communities. They have the ability to potentially create a working group on this subject and also promote at their annual World Ocean Summit.

Another source of existing data could also be crowd-sourced bathymetry. Crowd-source efforts to date have largely been regional and focused on the fishing communities, but with the IHO's recent crowd-sourced bathymetry initiative and portal, there is a mechanism to expand this concept to a much broader community. Through outreach via the UN, international governments, the WOC, industry associations, the survey industry and others this concept could be expanded to include many more contributors. Various levels of crowd-sourced bathymetry are possible. These could range from consumer grade fathometer data acquired by recreational boaters to single beam data acquired by cruise ships, container ships, tankers and bulk carriers, to multibeam data acquired by commercial survey and oceanographic research ships as they transit and move from project.

Key to all of the above is a communication strategy that emphasizes the corporate social responsibility and corporate ocean responsibility of sharing data for this purpose. This communication strategy must also educate potential stakeholders about the benefits of contributing, including potential tax benefits, while alleviating stakeholder concerns about liability.

2. Map the bathymetric gaps

After accessing the existing data and identifying the remaining gaps in coverage, we need to fill in the gaps by crowdsourcing, conducting coordinated basin scale mapping campaigns and regional compilations, using satellite derived bathymetry, and fostering innovation on technologies for remotely controlled data collection.

- Resource mapping the gaps with crowdfunding.
- To connect industry with the developing countries to help them map their EEZs to benefit from it.
- Fund capacity building for developing countries
- Good maps "de-risk investments" upstream – from environmental to exploration etc.
- We have technology to do the mapping but not enough funding. It's a social issue.
- Governance is a big road block.
- Piggyback on projects funded for other oceanographic work
- CSB:
    - Potential is BIG- 10 million single beam vessels potential. Need to show benefit of giving data in terms of global coverage
    - CSB is a spectrum so we should not get locked into any one model.
    - Have to overcome the mind-set that CSB is bad and has liability issues.
    - For CSB – biggest costs is keeping people involved and engaged in CSB projects

    - Is illegal now to collect data in territorial waters, but it is being done anyway, so we can't be like ostriches and keep our heads in the sand. There will be data at some point so this must be accepted.
    - OLEX commented that Liability has never been an issue.
    - National hydrographers are negative about crowdsourcing, especially for MSDI risk management.
    - Get data from everybody / a community that is co-ordinated and shares is a good incentive
    - People want to be part of something big, so must close loop: to engage people, they must see what they have done…..immediate feedback essential (buy square km of seafloor)
    - 2 pilot models: 1) trusted nodes to serve as do liaisons with a mariner group (olex, sea-id), 2) Working with makers of ENC and navigating software (Rosepoint)
    - Add echo sounders to other vessels that could be collecting
    - Flag-state nations should require data as part of registration. (e.g., SOLAS regulations with IMO to add loggers.
    - Cruise industry wants better data
    - Get countries to invest so more likely then to get involved
    - Make HOs do something to make people buy-in.
    - General level crowd-sourced data participants should be able to get compiled data back into their system, like TeamSurv and OLEX, and in best available resolution.
    - IMO to engage in crowdsourcing
    - Allow people see where there's a gap so they can have a choice of where they can pass and share data.
    - Need positive feedback loop to make people see it and get them involved.
    - Engage powerful groups. Get more volunteers.
    - Hydrographic offices may think that crowd-sourced data is useless for charting, but GEBCO can't think this way and it should establish some rules for the mariners who are willing to gather the data and share it.
    - Create a market of innovation and instrumentation for crowdsourcing
    - Need more ideas on how to engage the crowd
    - We have to overcome the fear that hydrographic offices have that CSB will be used for navigation
    - Territorial waters and military restrictions are a barrier to crowdsourcing, but it will happen anyway.
- Basin scale campaign mapping:
    - Strong buy-in and commitment from top-levels. Need political agreement with strong scientific collaboration and support underpinning political commitment.
    - Take advantage of vessels of opportunity and get surveyor on board – travel slower so use less fuel and get data – win win and grow it exponentially
    - Number of commercial vessel and multibeams are limited, especially for deep ocean surveying.

    - Get companies involved in the global drifter programme. Identify the campaign areas and the gaps and look for companies who want to be involved. Create a more standardized system or package.
    - Campaign mapping for every country to concentrate on particular big region and map it.
    - Effective cooperation is required. Even the cooperation between US and Canada has just begun.
    - How do we choose the areas? Think Galway initiative, collecting transit data, etc.
    - Look at horizon 2020 : https://ec.europa.eu/programmemes/horizon2020/
    - Galway project Canada US Europe political agreement to engage organizations to map the North Atlantic. Established a fellowship to map the gap
    - How much it will cost? - 1 billion on international scale it's not a lot
- Regional mapping projects
    - Think success of IBCAO ® communication and get people to be part of project and community. Also need academic (research) component, one of reasons that IBCAO successful
- Satellite Derived Bathymetry

3. Produce a 'startup' style prospectus

Produce a 'startup' style prospectus that lays out the vision of mapping the seafloor by 2030 that resonates intellectually and emotionally with the public and clearly answers the question "Why should we care?".

- Produce a prospectus that would make a case for everyone (policymakers, academia, industry) to come on board.
- Hire professional communicators, marketers, business coach, etc.
- Articulate the return of the investment
- Prospectus needs to be a living document
- Explain to the airline industry that bathymetry would help reduce the cost of airplane search offshore
- Need to be explicit in our vocabulary to address different audiences about what exactly we want
- Need coordination and a plan of communication: IHO and IOC have point of contact which is a good start – think IMO and UN (all different groups reached!) also explain what you mean by data (be specific about exactly what you want)
- Speak to multiple audiences to engage in GEBCO vision
- Entertainment to make people interested enough to engage
- Need to elevate recognition of GEBCO
- Include background data to feed the media
- Business plan to get a lot of people on the same page
- Story that paints the picture and answers the question WHY should we care?
    - need a video summarizing how little we know! What will we gain by having a better map?

    - We need to connect both with people's' intellect and hearts in order to engage the right organizations and individuals to map the ocean floor.
    - Politically – public monies aspect ® huge benefit to people ® if society understands how nb ocean is the might change mind-set – think about Food and food security (if no food – think disaster) GOING TO NEED ACTIVISM
    - One ocean – one planet – so remember this!
    - Need a document outlining what we want to do – something to send out! See what EMODNET did as marketing tool – must be pretty and multiple perspective and motivations and professionally done. Prospective must give context and destination so managers know why they give data and what benefit will be in long term.
    - Make a study on the economic impact (ROI) to show the government (worked for Ireland)
    - Must be polished
    - Target an audience. Market the idea. Ad campaign with a catchy way to make people curious to know about GEBCO processes on how data is being shared.
    - Make the prospectus like a business plan. Be specific. What data do we need? Be realistic with the plan.
    - The ocean is the food for next generation make politicians understand this
    - A prospectus to share globally to many groups (government, industry, media, academia) is critical
- Change the mind-set:
    - We need to decommission our polarized mind-set about mapping the ocean floor and excite those in charge of the purses. We need a real map of the ocean, like *The Real Map of Ireland* that changed the public's perception of oceans.
    - We tend to always end up with what's good for the company / person. How can you change this mind-set? What is the role of this community to drive people to share data?
    - We need images that show where we need data.
    - Make the case – why what is it useful for – how will it help society : articulate rationale
- Present the GEBCO project to potential data contributors and engage them with our objectives. As Dave Monahan said, inviting them to participate rather than merely contribute is a better way to get their interest.
- We have to concentrate on the data and not on products
- Mapping the gaps is not enough for public – but environmental application with particular examples would resonate
- List successes
- Storytelling through ESRI and Google made by general public also
- Articulate why people should care about bathymetry. Need a study on value of bathymetry (see Ireland and Norway studies)
- Focus on the emotive nature of the ocean and its deep and numerous connections to the general public in addition to the scientific community
- Individual Stories: (Doug from newsweek; Esri story boards, Google, videos)

- Clear definitions of terms like ‘data’
- Create marketing, social media, PR and communication plans that utilize various media channels to communicate the importance of GEBCO
- Must be correct in terminology
- Define communication tools… brochure plus ppt……. need PR videos
- Don’t have to know everything now to start…doesn't have to be perfect
- Need maybe two prospectuses: 1) industry (head) and 2) people (heart)
- PR and education to get the politicians to understand that it’s beneficial for them
- Education in developing countries about what bathymetry is and why it is important

4. Create strong partnerships

The success of GEBCO’s 2030 vision depends on creating and fostering strong partnerships for collecting, sharing and compiling data, as well as financial support to maintain the needed infrastructure, coordination and innovation for mapping the ocean floor.

- Connect with international bodies (IMO, IOC, IHO, WMO) to discuss funding and governance and policy changes
- Cruise industry in Caribbean and Canadian Arctic
- Celebrity community, development community, outreach community, technology community
- Approach licensing block authorities; environmental agencies; ISA; HOs, etc.
- Engage regional and national initiatives, plus other working groups in IHO, e.g. the Marine SDI Working Group and UN-IOC regional atlas programmes.
- Activist community
- Start with ministries and high level states: get images…. Also heads of research institutions
- Oil and gas overseeing bodies must be approached by GEBCO ambassador
- Approach marine environmental protection agencies

5. Restructure GEBCO operations

To meet the 2030 challenge, GEBCO needs to change the way it operates to maximize coordination and to engage as many sectors as possible. One model is to have an array of sector specific ambassadors (e.g., oil and gas) and others to serve as 'connectors' to foster new partnerships and projects. A full time executive officer is needed to orchestrate all the moving pieces involved with the 2030 vision.

- Present GEBCO vision at IHO conference with politicians and hydrographers
- Group of ambassadors of GEBCO to connect with the wider groups and industry to tell the story
- Duncan Mallace QPS – ambassador to oil/gas industry
- Develop a robust advertising and ambassador campaign, and increase visibility at international intergovernmental organizations, such as the UN.
- Fund a full-time person to coordinate the approach
- Develop, initiate and implement: 1- a group of committed GEBCO Ambassadors with a mandate; 2- list international venues and organizations where the Ambassadors will

go to promote and present GEBCO value proposition 3- a short promotional video on what is GEBCO and what it is NOT for societal benefits on the IHO\IOC - GEBCO Website 4- a recognition process and IHO/IOC - GEBCO programme to acknowledge formally the model contributing organizations to identifying data gaps and communication and coordination within the data collecting and mapping communities.

- Venue where GEBCO ambassador could speak
- Understand the strengths and skill sets of GEBCO members as well as limitations
- Ambassador network to target specific stakeholder groups and regions
- Connectors and Networkers
- Learn from our wise decision to hire professionals to handle meeting logistics and PR for the Forum….Employ full time coordinating, communication and marketing professionals

Attachment 3 – Forum Communiqué

Post Forum Communiqué
29 June 2016

Forum for Future Ocean Floor Mapping

Mapping the ocean floor by 2030

A meeting in Monaco of over 150 senior representatives, scientists, scholars and business associates from major ocean related organisations has endorsed the objective of Seafloor 2030 – that the comprehensive mapping of the entire ocean floor was possible by the year 2030. More than 85 per cent of the world ocean floor remains unmapped with modern mapping methods.

Tasked with the responsibility of developing a Roadmap for the Future of Ocean Floor Mapping, the meeting, held under the auspices of the General Bathymetric Chart of the Oceans (GEBCO), the world's only international organisation mandated to map the ocean floor, called for the sharing of bathymetric information to create, for GEBCO, a global baseline bathymetric database. It also called for greater access to the tools and technology, particularly for developing and coastal nations, to make a comprehensive database possible, for the sharing of data to achieve this ultimate objective.

The Forum for Future Ocean Floor Mapping (15 to 17 June) was formally opened by Prince Albert II of Monaco, great-great-grandson of Prince Albert I, who founded GEBCO in 1903. Keynote addresses were given by Robert Ward, President of the Secretariat of the International Hydrographic Organisation (IHO) and by Thorkild Aarup, representing the Intergovernmental Oceanographic Commission of UNESCO. GEBCO is a joint project of both organisations.

Addresses were also given by Bob Ballard, who discovered the wreck of the Titanic, and Simon Winchester, author of books on the Atlantic and Pacific oceans. Other keynote speakers included Larry Mayer, Director of the Center for Coastal and Ocean Mapping at the University of New Hampshire, David Heydon, Founder of DeepGreen Resources & Nautilus Minerals, Kristina Gjerde, Senior High Seas Advisor at the International Union for the Conservation of Nature (IUCN), Jyotika Virmani, Senior Director, Energy and Environment,

at XPRIZE, and Bjorn Jalving, Executive Vice President of the Kongsberg Maritime's Subsea Division.

Yohei Sasakawa, Chairman of The Nippon Foundation, which sponsored the Forum, called for collaboration for the protection and sustainable use of the world's oceans. He called for strong international support for mapping the ocean floor.

In his welcome speech, Vice Admiral Shin Tani, Chairman of GEBCO's Guiding Committee, said that the world "knows more about the topography of Mars than the Earth's seafloor".

Mr Sasakawa also announced the formation of an alumni association for the 72 GEBCO scholars from 34 countries, who have gained their Postgraduate Certificates in Ocean Bathymetry at the University of New Hampshire, to be joined by a further six scholars in September. The programme, sponsored by The Nippon Foundation, is designed to build human capacity in key coastal states by supporting the development of future maritime leaders.

After two days of intensive panel discussions and breakout sessions, participants concluded that the task of mapping the ocean floor involved a new structure for global coordination of mapping activities and gathering of all available depth measurements into a database for the compilation of a coherent bathymetric portrayal of the world's ocean floor. Thus bathymetric post-processing and analysis software, database technology, computing infrastructure and gridding techniques should be brought into the equation along with the latest developments in seafloor mapping methods.

In terms of mapping technologies, Forum delegates agreed that while echo sounding techniques were being constantly improved, the mapping of the ocean floor is only slowly increasing. This was particularly true for sea-ice covered and iceberg infested portions of the oceans – and other remote areas with sparse ship traffic such as the South Pacific. The development of unmanned vehicles was discussed. Available commercial and custom developed drones, gliders equipped with multi beam sonar, fleets of low maintenance autonomous surface or underwater vehicles and unmanned mapping barges, steered by satellite communication and an ultra-narrow beam deepwater multi beam, could all be used for different situations.

The Shell Ocean Discovery XPRIZE was currently challenging teams to develop new deep-sea technologies for autonomous, fast and high-resolution ocean mapping.

The meeting agreed that crowd sourced bathymetry – not new to GEBCO – was a powerful concept in ocean mapping with a huge potential of substantially boosting targeted mapping, specifically in shallow water. Shallow water bathymetry, derived from satellite imagery, constituted a promising technique that could be useful in remote areas where other available mapping methods are not feasible.

A pilot project between GEBCO and Google will be initiated to investigate further the application of satellite imagery derived bathymetry on a global scale, utilising GEBC0's human capacity outreach.

The present GEBCO central bathymetric database, as well as regional mapping projects under GEBCO, resides on servers of the host organisations. The sizes of these databases would increase once GEBCO targets a higher resolution global coverage, but will remain far

from the amount of raw ship soundings collected at sea. As GEBCO moves towards establishing more regional projects with host organizations, there would be benefits from using a cloud based infrastructure for regional mapping projects under GEBCO.

The guiding concept and formats were discussed – with the opinion that variable grids will be more in demand as the end-user community begins to realize the option of placing bathymetric overviews of large areas – and details of smaller areas – onto one convenient database. A resolution minimum one hundred metre grid was achievable.

In essence, to achieve seafloor 2030, existing data must be identified and the remaining gaps mapped. The key to achieving this target would be greater institutional coordination between scientific research and industry combined with capacity building through the effective engagement of developing states. Political support through UN organizations and the G7 was required to increase resources for this task. Ocean mapping could complement the United Nations Atlas of the Oceans and Goal 14 of the Sustainable Development Goals (SDGs) – to conserve and sustainably use the world's oceans, seas and marine resources.

Ends

For more information contact:

Robin Falconer
robinfalconerassociates@paradise.net.nz
David Clark
david.m.clark@noaa.gov

Notes to editors:

GEBCO is a joint project of the International Hydrographic Organization (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO – the United Nations Educational Scientific and Cultural Organization – which was founded by Prince Albert I of Monaco in 1903.

The International Hydrographic Organization (IHO) was established in 1921 as the International Hydrographic Bureau (IHB). The present name was adopted in 1970 as part of a new international Convention on the IHO adopted by the then member nations. The former name, International Hydrographic Bureau, was retained to describe the IHO Secretariat, which coordinates and promotes the IHO's programmes and provides advice and assistance to Member States. The IHO has 85 member states with 8 others in various stages of applying to join.

The UNESCO's Intergovernmental Oceanographic Commission (IOC) was established by the General Conference of UNESCO in 1960. It first met in Paris at UNESCO Headquarters in 1961. There are currently 148 Member States. The IOC promotes international cooperation and coordinates programmes in marine research, services, observation systems, hazard mitigation and capacity development in order to understand and effectively manage the resources of the ocean and coastal areas.

The Nippon Foundation, a private, non-profit foundation, was established in 1962 for the purpose of carrying out philanthropic activities, using revenue from motorboat racing. The Foundation's overall objectives include social innovation, assistance for humanitarian activities and global ocean management. Its philanthropic ideals embrace social development

and self-sufficiency, and it pursues these principles by working to improve public health and education, alleviate poverty, eliminate hunger and help the disabled.

Attachment 4 – XPRIZE Press Release

News from GEBCO

29 September 2016

GEBCO team enter Shell Ocean Discovery XPRIZE to advance breakthrough technologies in ocean floor mapping

A team of graduate fellows from The Nippon Foundation's GEBCO Postgraduate Certificate in Ocean Bathymetry Training Programme, run at the Center for Coastal and Ocean Mapping at the University of New Hampshire, will be taking part in the $7million Shell Ocean Discovery XPRIZE. The GEBCO-NF team have entered this three year global competition aimed at challenging teams to advance breakthrough technologies for autonomous, fast and high-resolution ocean exploration. The new competition is part of XPRIZE's 10-year ocean initiative in a commitment to launch five multi-million dollar prizes by 2020 "to address critical ocean challenges and help make the oceans healthy, valued and understood".

The GEBCO (General Bathymetric Chart of the Oceans) team will address the key elements of the challenge: seabed mapping first at 2,000 metres, then at 4,000 metres with a five metre and 0.5 metre vertical resolution. The deadline for submission of documents is 15 December, with field tests taking place late next year. Results will be announced in December 2018.

The inspiration to enter a team for the challenge came last June from the NF-GEBCO Forum for Future Ocean Floor Mapping, held in Monaco and attended by 150 senior representatives, scientists and scholars from major ocean-related and international organisations. A key aspect of the Forum was the celebration of 12 years of the Ocean Mapping Training Programme, funded by The Nippon Foundation, and 48 graduate fellows were in Monaco for the event. The GEBCO-NF team entering the competition comprises graduate fellows from Israel, Poland, Russia, the UK, USA, Japan and Malaysia, as well as technical advisers from Norway, the USA, UK, The Netherlands and New Zealand.

"The core group currently represents six different years of the programme and seven

different coastal states", says Rochelle Wigley, Director of the New Hampshire Ocean Mapping Course and a member of the team. "The seven alumni leading this initiative come from diverse backgrounds in industry, the Navy and research, and it is this diversity which gives the team its strength. These alumni are part of the future of ocean mapping and the networks they are building across national borders and bring together diverse people with a passion for the ocean".

Her views are endorsed by Hadar Sade, a graduate fellow from Israel, who is also part of the team. "We have all taken up the challenge that our oceans and seas are our future – the common heritage of mankind," he says.

The Monaco Forum endorsed NF-GEBCO's vision for mapping the ocean floor by the year 2030, or Seabed 2030 – with the creation of "a high resolution digital map, from the coast to the deepest trench of the ocean that enables scientists to explore and understand how the oceans work, shaping maritime policy and supporting the management of natural marine resources for a sustainable Blue Economy".

A joint comment from Jyotika Virmani, Senior Director of Energy and Environment for XPRIZE, and Dawn Wright, Chief Scientist at Esri, the mapping software platform that will support the XPRIZE, remarked that "over 60% of the Earth's surface has not yet been mapped. The ocean covers 70% of our planet's landmass, and of that, less than 15% of the seafloor has been mapped at a resolution finer than 5kms. In fact, we have higher resolution maps of the entire surface of the Moon, Venus and Mars than we do of our own Earth. But this situation can be changed". .

Bob Anderson, technical adviser to the GEBCO-NF team, and a former US Navy submarine electrical engineer, says that the competition "is comprised of a number of technical challenges which individually are achievable using current technologies but, in combination, present a very difficult problem. Swath survey systems are common, but the requirement for high resolution means the survey system needs to operate near the seafloor. This presents multiple requirements: the system must be mounted to an underwater vehicle and capable of being launched and retrieved without the support of a manned surface ship".

He adds: "operating a vehicle near the seafloor represents the risk of collision in rough terrain. The underwater vehicle position must be determined accurately, and GPS does not work underwater, so a positioning system must be incorporated which combines a satellite positioning system at the surface and an acoustic positioning system underwater.

"The system must be deployable from a shore site to an offshore location and then returned to shore where the results of the survey must be delivered within 48 hours. And the entire system must fit within the confines of an ocean shipping container".

Further technological support is being provided by Kongsberg Maritime, one of the world's leading sonar and AUV manufacturers.

Describing the team's task, Robin Falconer, Chairman of the NF-GEBCO Forum's organising committee, who has coordinated the GEBCO-NF challenge, remarked

"almost all the key elements required for the challenge already exist but are used in other applications. Putting them together to meet the XPRIZE application is what we will do".

-ends-

For more information contact:

Robin Falconer
robinfalconerassociates@paradise.net.nz

Patrick Orr
Patrick@raittorr.co.uk

About GEBCO:

GEBCO (The General Bathymetric Chart of the Oceans) s a joint project of the International Hydrographic Organisation (IHO) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO – the United Nations Educational Scientific and Cultural Organization. It has its origins in the GEBCO chart series initiated in 1903 by Prince Albert I of Monaco. GEBCO is the only international project with a mandate to map the floors of the global oceans.

The **International Hydrographic Organization** (IHO) was established in 1921 as the International Hydrographic Bureau (IHB). The present name was adopted in 1970 as part of a new international Convention on the IHO adopted by the then member nations. The former name, International Hydrographic Bureau, was retained to describe the IHO Secretariat, which coordinates and promotes the IHO's programmes and provides advice and assistance to Member States. The IHO has 85 member states with 8 others in various stages of applying to join.

UNESCO's **Intergovernmental Oceanographic Commission** (IOC) was established by the General Conference of UNESCO in 1960. It first met in Paris at UNESCO Headquarters in 1961. There are currently 148 Member States. The IOC promotes international cooperation and coordinates programmes in marine research, services, observation systems, hazard mitigation and capacity development in order to understand and effectively manage the resources of the ocean and coastal areas.

The **Nippon Foundation**, a private, non-profit foundation, was established in 1962 for the purpose of carrying out philanthropic activities, using revenue from motorboat racing. The Foundation's overall objectives include social innovation, assistance for humanitarian activities and global ocean management. Its philanthropic ideals embrace social development and self-sufficiency, and it pursues these principles by working to improve public health and education, alleviate poverty, eliminate hunger and help the disabled.