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THE SHELL OCEAN DISCOVERY XPRIZE COMPETITION IMPACT ON THE DEVELOPMENT OF OCEAN MAPPING POSSIBILITIES

ABSTRACT

The paper presents the impact that the XPRIZE Foundation competition, the Shell Ocean Discovery XPRIZE, has had on the development of current ocean mapping possibilities. A race for the prize has accelerated the development of innovative seabed mapping approaches that concentrated on new systems engineering or cutting-edge and innovative methods of existing equipment exploitation. The GEBCO - Nippon Foundation (NF) Alumni Team’s entry is presented in details as a state of the art example of mature and robust ocean-mapping solution utilizing a high degree of autonomy and providing the possibilities of deep-ocean mapping that were unattainable before.

Keywords: ocean mapping, bathymetry, AUV, USV, echosounder, hydrography, autonomous systems

OVERVIEW OF THE COMPETITION RUN

The Shell Ocean Discovery XPRIZE is one of the competitions organized by the XPRIZE Foundation. The aim of the Foundation is to motivate groups of individuals to face global challenges of different types, including water abundance technologies, enhancing women's safety or providing news ways to provide education where conventional learning is challenging. The Shell Ocean Discovery XPRIZE focuses on the deep ocean, initiating the race among ocean mappers and ocean engineers, representing various scientific and academic organizations and enterprises.

The initial competition rules, released in 2015, split the competition into two Rounds. In both Rounds, the participating Team were to demonstrate a ocean mapping system capable of producing a high-resolution bathymetric map of the designated area, and images of seabed objects that could be of archeological, biological or geological features.

The mapping system construction and its use is restricted by the competition rules. The complete solution must be portable enough to fit into one standard 40-feet container. The technology used must ensure autonomous or remote-controlled operations in the offshore survey area. Restricted survey and data processing time (24 hours of data collection and 48 hours for map production in Round 2) forces the Teams to push the boundaries of current available surveying methodologies.

The state of ocean mapping technology possibilities prior to the competition, in the view of the XPRIZE rules is described in [11]. This paper describes how the competition has accelerated the efforts to increase the potential for exploring the deep oceans.

THE FOUNDATIONS OF THE SELECTED COMPETITION ENTRIES RELEASED UP TO THE CURRENT DATE

Teams participating in the competition present two main approaches to the deep ocean mapping. The first one can be treated as a reliable approach, based on the verified foundations of hydrographic surveying, but pushed to the boundaries of data collection effectiveness. The second approach is innovative engineering, aiming on new techniques of data collection or non-conventional ways of handling with the surveying equipment.

Team Tao is an example of the revolutionary engineering approach. This British group of marine engineers propose using a new type of underwater vehicles, transported in a group of 12 under the deck of an unmanned catamaran. These underwater vehicles, called BEMs, are released one by one, descending vertically and halting at a fixed height above the seafloor in order to scan the seabed acoustically while rotating around their vertical axis. With some freedom to move horizontally, they are able to cover a designated portion of the seafloor before ascending to recharge, while the next BEM is surveying [6]. Fig. 1 shows the concept of deep-sea surveying according to Team Tao.

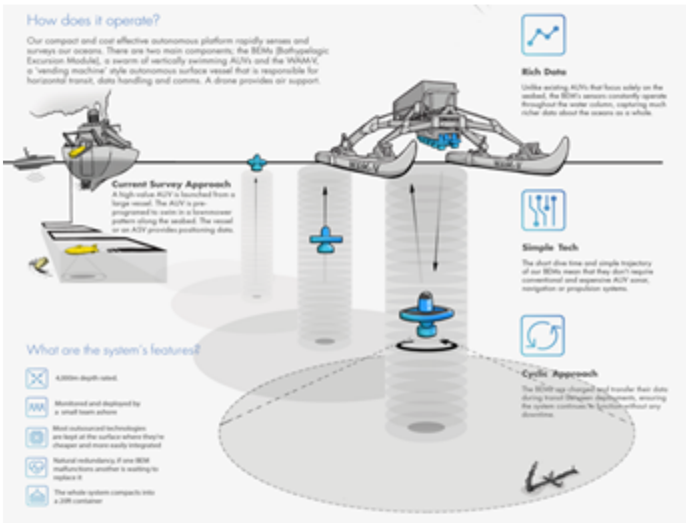

Fig. 1. The concept of deep sea surveying according to Team Tao (source: http://www.team-tao.org, access 09.07.2018.).

Final Round results will verify the success of this innovative approach. Because of their compact sizes, BEMs are promising devices for seabed mapping, especially for smaller platforms.

The German Arggonauts focuses on the idea of swarm mapping. The growing popularity of this approach reflects higher coverage rates when compared to a single device. Portable AUVs (Autonomous Underwater Vehicles) will be towed by USVs (Unmanned Survey Vehicles) to the survey site, map the designated area and then return to the surface. An innovative recovery method, based on using the floating tow lines, after comprehensive testing, can become an affordable method of bringing the survey equipment back to shore, although its robustness for the rough sea conditions must be proven. The AUV and surface vessel are presented in Fig. 2.

Fig. 2. Main components of the Arggonauts' mapping system (source: https://www.instagram.com/arggonauts/, access: 10.07.2018.)

Team Kuroshio, representing Japan, merged the innovative concept of a swarm of underwater devices with the classic approach of a surface vessel to position the underwater components (Fig. 3). The surface vessel based on the RIB-type hull will acoustically communicate with a set of autonomous underwater vehicles. AUVs employed by this Team are 3 m long, 300 kg AE2000a vehicles from the Institute of Industrial Science, The University of Tokyo (Fig. 4). Their declared cruising speed is 2 kn [5].

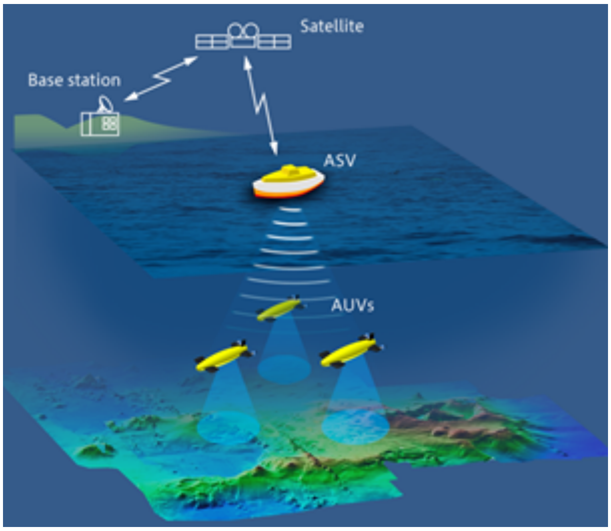

Fig. 3. The overview of the idea of the Team Kuroshio's entry (source: https://team-kuroshio.jp/en/technology/, access: 11.09.2018.)

Fig. 4. The Team Kuroshio's mapping system components (source: https://team-kuroshio.jp/en/technology/, access: 11.09.2018.)

The configuration proposed by the Team Kuroshio has the potential for large area mapping capabilities, which is not only be a significant for the Shell Ocean Discovery XPRIZE, but also for all Japanese ocean mapping activities, underlying this country's effort to map the ocean floor.

GEBCO - NIPPON FOUNDATION ALUMNI TEAM IN THE COMPETITION

The GEBCO-NF Alumni (GNFA) Team is a unique participant of the SHELL Ocean Discovery XPRIZE Competition, in that the team is an international group with diverse backgrounds, education and profession. The mapping system proposed by the Team is based on the proven technology of the AUV HUGIN by Kongsberg Maritime, with the addition of a new class of USV that has been designed and built through the Team's effort.

The origin of the Team comes from the Forum for Future Ocean Floor Mapping in Monaco, organised by the Nippon Foundation and GEBCO in June 2016. The Forum gathered some of the most accomplished professionals in the industry, academia and governmental institutions from around the world to discuss the future of ocean mapping. Two important initiatives that will be crucial for a better understanding of our oceans emerged at the Forum. The first one is the program called Seabed 2030, launched by GEBCO and Nippon Foundation, that sets a goal of thoroughly mapping the seafloor by 2030 through joint efforts from industry, academia and governmental institutions from all the world [3]. Such a challenging goal required a focus on emerging technology developments, which leaded to the next initiative, also initiated at the Forum for Future Ocean Floor Mapping. The Shell Ocean Discovery XPRIZE competition has become a propeller that will ultimately help enable the achievement of the goal set by Seabed 2030 through encouraging technological development that will advance the autonomy, scale, speed, depths and resolution of ocean exploration.

A team of 15 Nippon Foundation / GEBCO training program alumni from 12 nations accepted the challenge and developed a unique and innovative concept, while being advised and mentored by selected GEBCO and industry experts. The team is now operating the autonomous surface ship capable of the launch and recovery of an autonomous underwater vehicle. The SEA-KIT vessel, designed and built within the team, opens up endless possibilities for water bodies exploration without exposing people to the harsh offshore environment. The GEBCO-Nippon Foundation Alumni Team, together with an international team of volunteers, scholars, industry experts, advisors, partners and suppliers has integrated existing technology with new ideas to build an innovative, unique and competitive system for acquiring data and making value-added sea-floor information easily accessible. Beyond the Shell Ocean Discovery XPRIZE Competition, the team envisions its concept playing an active role in achieving the goals set by Seabed 2030.

SURVEYING PERFORMANCE AND ITS IMPACT ON OCEAN MAPPING POSSIBILITIES

Bathymetry and acoustic imagery data in the GNFA's mapping system is collected by the AUV HUGIN. Ocean Floor Geophysics' HUGIN *AUV Chercheur* was used for Round 1 of the Competition – the Technology Readiness Test. The vehicle was equipped with the deep-water interferometric synthetic aperture sonar, providing the data from two channels on the either side of the vehicle, and EM2040 multibeam echosounder, filling the nadir gap (Fig. 5).

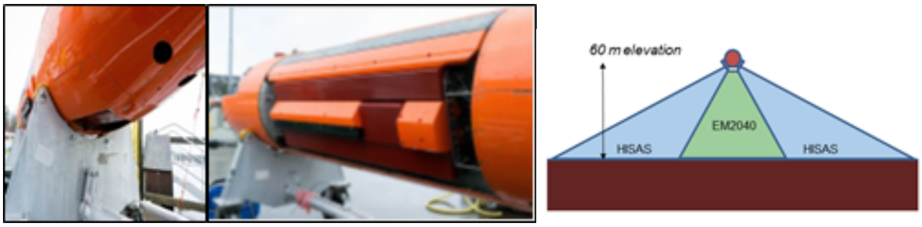

Fig. 5. The GNFA data collection equipment (EM 2040 and HiSAS) and basic geometry. 60 m altitude and Wide Area Mode configuration ensure 780 m swath width [8] in the Technology Readiness Tests. (Photo credits: Kelly Duncan/OFG)

The AUV is transported to the survey area by the unmanned surface vessel (USV). The USV also provides the positioning through an underwater acoustic link (HiPAP) and ensures communication with onshore mission control station during data collection. The USV serves as a mothership to the AUV and a new class of vessel has been designed and built (Fig. 6) by the team to accomplish these tasks. SEA-KIT meets all the expectations of a seaworthy vessel to supply surveying and surveillance operations. For the purpose of the competition, SEA-KIT has been designed to cooperate with the HUGIN AUV, but it can be easily modified to fit other similar types of AUVs [4].

Fig. 6. Visualization of the SEA-KIT in water and with HUGIN onboard. (Source: [12]. Figure by B. Simpson. All rights /registered drawings / patents pending all reserved to Hushcraft Ltd.)

The mapping system developed by GNFA presents a high level of autonomy in all aspects of its operation. The main mapping component – the HUGIN AUV is a fully autonomous device, acting according to the preprogrammed mission with obstruction avoidance capabilities. No outside intervention is needed during its mission. Navigation estimates are generated based on information from the Inertial Navigation System, Doppler Velocity Log and depth sensor with the use of an extended Kalman filter incorporated into NavP solution by Kongsberg. This allows the AUV to perform a mission from waypoint to waypoint, although it is important to clarify that in the purely autonomous operation the position estimate will drift over time resulting in an increasing position uncertainty. To reduce this problem, the positioning updates from the surface vehicle are provided by the Ultra Short Base Line system (USBL). In our case, a Kongsberg HiPAP 351P-MGC USBL was used to update the AUV positioning, during the Technology Readiness Tests. The cooperation with a surface vessel is therefore an essential part of accurate surveying using the autonomous underwater vehicle [8].

The surface component – SEA-KIT – can be operated in 4 modes. A physical helm can be used by the crew, allowing the vessel to be handled like a manned boat. Remote-control mode is conducted by the vessel controller handset. There are also two types of autonomous mode, that are the main methods for SEA-KIT operations. In Autonomous Remote mode, the K-MATE interface is used to set the speed and heading. Fully Autonomous mode is based on waypoint following. In this mode, the vessel is fully controlled by K-MATE [8].

K-MATE is an autonomous surface vehicle control system supplied by Kongsberg Maritime. It can be integrated with different types of vessels through an electrical interface, providing waypoint following and collision avoidance, if accepting sensors data about scene analysis. In addition, it provides a virtual anchor function reacting on changes in external environmental conditions that keeps the vessel on position [2].

A huge step towards unmanned surveying is a newly developed procedure of launch and recovery of the AUV onboard the USV. The process is supervised from the control station using CCTV cameras onboard SEA-KIT, but there is no direct human interference. Launch and recovery tests conducted in Norway, were probably the first successful attempts in the world of starting and completing an offshore AUV operation with no human handling of the mapping equipment when at sea (Fig. 7).

Fig. 7. Aerial view of SEA-KIT during HUGIN retrieval operations.
(credit: Lew Abramson, Inner Space Center)

A NEW STYLE OF OCEAN MAPPING PROJECTS ORGANISATION. A TURN TOWARDS CLOUD-BASED TECHNOLOGY

GNFA is a Team lead by the Alumni of The Nippon Foundation/GEBCO Training Program at the University of New Hampshire, supported and advised by the GEBCO community members. The Nippon Foundation is the main partner in this extraordinary project and the Team have established cooperation with companies and organizations providing certain services. The project is hosted at the Center of Coastal and Ocean Mapping / Joint Hydrographic Center at the University of New Hampshire. A list of partners and industry suppliers includes Kongsberg Maritime, Hushcraft, Ocean Floor Geophysics, Earth Analytic, Esri and Teledyne Caris. In this way, a unique network entwining literally the whole world has been established. All the initial ideas, first attempts and initial documentation have been created remotely, by close co-workers, most whom had never met before the project.

System preparation and sea trials required the presence of the Team members on site, but the vast majority of organizational aspects of the project, including decision making and sub-teams management were conducted remotely. This includes also parts of the collected data processing. The Team developed autonomous and cloud-based data processing with advanced algorithms for the fusion of high-resolution bathymetry and seafloor imagery to turn data easily into information (Fig. 8). This enables the team to work more cost-efficiently, considering that the members are based in different locations around the world.

Fig. 8. Data processing workflow utilizing automated processing routines and cloud technology (source: [7]).

Data collected by mapping sensors are first precisely georeferenced by the NavLab algorithms utilizing data recorded by the acoustic underwater navigation system. HiSAS data are then processed by the FOCUS machine. Bathymetric data from interferometric sonar and from multibeam echosounder, both mounted on AUV, are then processed by Caris. Bathymetric data from two types of data collection devices are combined together and corrected for tides, leading to the product grids generation. This process is automated, although this is currently desktop machine processing.

Cloud-based technology is introduced at the stage of product storage and data /information sharing. Mosaics datasets are stored on the ArcGIS Server Geodatabase and imagery data in the file servers. This enables their usage on the ArcGIS portal. Web maps created this way allow permitted users to view, analyze or download the value-added products.

The successful experience of remote organization and cooperation between people from distant locations shows that cloud technology could be incorporated in earlier stages of the data processing workflow. In this case, the Caris processing, now performed on the desktop machine, would be transferred to the cloud. The concept could be a turning point to push forward Seabed 2030, considering the data is being contributed from around the world and processed in different regional centers.

CONCLUSIONS

The Shell Ocean Discovery XPRIZE competition has been designed to accelerate the development of ocean mapping technologies, which has certainly been achieved. The eight final teams have already creatively presented innovative and exciting world-class ocean engineering and hydrographic surveying possibilities. The true achievements of the competition participants will probably emerge in the Final Round, beyond what was released in the public domain during the competition.

The great collaborative effort undertaken by the GEBCO Nippon Foundation Alumni Team led them not only to being exposed to and joining the community of industry leaders, but also puts them in the position to aid the accomplishment of the main goal of their supporting organizations, namely GEBCO (General Bathymetric Chart of the Oceans) and the Nippon Foundation : mapping the entirety of the world's ocean floor.

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