for the

Shell OCEAN DISCOVERY XPRIZE®

On behalf of the GEBCO-NF Alumni Team
Jaya Roperez

Modified presentation of Dr Rochelle Wigley
The inspiration to enter as a team for the challenge:

- Opening speech by Mr Sasakawa – Argued for ongoing alumni development & projects
- Jyotika Virmani, Senior Director in Prize Operations, at XPRIZE said at the Forum “NF GEBCO training program is probably the most successful unknown capacity-building global initiative”

Mr Sasakawa, Chairman of the Nippon Foundation
Proposed ‘…to map 100% of the topography of the World Ocean by 2030’

Nippon Foundation - GEBCO
Seabed 2030 Project announced
A $7 million global competition challenging teams to advance deep-sea technologies for autonomous, fast and high-resolution ocean exploration.

Create solutions that advance the autonomy, scale, speed, depths and resolution of ocean exploration

https://oceandiscovery.xprize.org
The key elements of the challenge

1. Create an autonomous solution to collect data
2. All components used for data gathering must fit within a standard 40 ft shipping container
3. Produce a high-resolution bathymetric map of an area of 100 km$^2$ (5 m horizontal and 0.5 m vertical resolution)
4. Produce images of a specified object
5. Identify and image five archeological, biological or geological features

Data collection must be completed in 16 hours with 48 hours for product generation
Meeting global challenges

Nippon Foundation - GEBCO Seabed 2030

**Produce:** Bathymetric grids where no features of the accessible parts of the World Ocean floor larger than 100 m remains to be portrayed.

**Challenges:** Keeping up with technology
The Postgraduate Certificate in Ocean Bathymetry

Designed to train a new generation of scientists and hydrographers in ocean bathymetry

The Center for Coastal and Ocean Mapping /Joint Hydrographic Center
University of New Hampshire, USA

84 scholars from 37 coastal states over last 14 years
GEBCO-NF Alumni Team: 12 active alumni

10 different coastal states & 8 years of training program

Industry Partners:
- Kongsberg Maritime
- Ocean Floor Geophysics
- Hushcraft Ltd
- University of New Hampshire
- OceanAero
- Teledyne CARIS

http://gebco-nf.com

4 technical advisors from within GEBCO
The GEBCO-NF Alumni Team concept
Integrates existing technology with innovative new ideas

Hushcraft Limited USV
- Sea-Kit XP with KM HiPAP 351P-MGC
- Unmanned operations by KM

Kongsberg Maritime HUGIN 1000 AUV
- OFG Chercheur AUV (3,000 m)

High quality seafloor bathymetry and imagery
- Combination of EM2040 MBES, HISAS side-scan wide-area and HISAS bathymetry & spot-focused HiSAS imagery
<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decision to register a XPRIZE team</td>
<td>June</td>
</tr>
<tr>
<td>First discussion with boat designer</td>
<td>17 Dec</td>
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<tr>
<td>Shell Ocean Discovery XPRIZE summit</td>
<td>11-14 Nov</td>
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<tr>
<td>Submission of technical documents</td>
<td>17 Dec</td>
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<tr>
<td>Through to Round 1</td>
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<tr>
<td>Submission to Nippon Foundation</td>
<td>5 Oct</td>
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<tr>
<td>Round 1 funded by NF / SPF - $3.25M</td>
<td>3 Nov</td>
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<tr>
<td>Meeting</td>
<td>11-14 Nov</td>
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<tr>
<td>First conversation with boat designer</td>
<td>7 Feb</td>
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<tr>
<td>Meeting</td>
<td>27 Feb</td>
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<tr>
<td>Meeting</td>
<td>16 March</td>
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<td>Meeting</td>
<td>22 March</td>
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<td>Meeting</td>
<td>6 April *</td>
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<td>Meeting</td>
<td>11-14 April</td>
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<td>Meeting</td>
<td>21 April</td>
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<td>Meeting</td>
<td>22 April</td>
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<td>Meeting</td>
<td>26 April</td>
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<td>Meeting</td>
<td>15-16 May</td>
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<td>2 June</td>
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<td>30 June</td>
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<td>Meeting</td>
<td>24 July</td>
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<td>7 Aug</td>
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<td>14 Aug</td>
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<td>Meeting</td>
<td>19 Aug</td>
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<td>Meeting</td>
<td>24 Aug</td>
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<td>Meeting</td>
<td>1 Sept</td>
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<td>Meeting</td>
<td>2 Sept</td>
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<td>Meeting</td>
<td>14 Sept</td>
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<td>Meeting</td>
<td>18 Sept *</td>
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<td>Meeting</td>
<td>27 Sept</td>
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<td>Meeting</td>
<td>3 Oct</td>
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<tr>
<td>Meeting</td>
<td>3 Nov</td>
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<tr>
<td>Meeting</td>
<td>20 Nov</td>
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<tr>
<td>Metal cut for Boat Build</td>
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<tr>
<td>First installment of funds</td>
<td></td>
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<tr>
<td>K-MATE contract</td>
<td></td>
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<tr>
<td>SEA-KIT delivered</td>
<td></td>
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<tr>
<td>2nd installment of funds ($2,741,500)</td>
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<tr>
<td>Data Group: 2 week visit</td>
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<td>AUV arrives in Norway</td>
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<td>AUV tests with chase boat Storm</td>
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<tr>
<td>AUV &amp; Data Team sea-trials in Norway</td>
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<tr>
<td>OFG contract</td>
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<tr>
<td>SEA-KIT christened USV Maxlimer</td>
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<tr>
<td>USV Maxlimer’s first wet test</td>
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<td>USV Maxlimer in Norway</td>
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<td>USV Maxlimer K-Mate development &amp; trials</td>
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<td>First USV– AUV trials: Testing HiPAP</td>
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<td>First AUV retrieval</td>
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<td>Start of final sea trials</td>
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<td>Technology readiness test</td>
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<td>Project Ocean Discovery XPRIZE Summit</td>
<td>2016</td>
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<td>Project Time Line</td>
<td>2017</td>
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</table>
The GEBCO-NF Alumni Team concept
Integrates existing technology with innovative new ideas

- Hushcraft Limited USV
  - Sea-Kit XP with KM HiPAP 351P-MGC
  - Unmanned operations by KM

- Kongsberg Maritime HUGIN 1000 AUV
  - OFG Chercheur AUV (3,000 m)

- High quality seafloor bathymetry and imagery
  - Combination of EM2040 MBES, HISAS sidescan wide-area and HISAS bathymetry & spot-focused HiSAS imagery
USV SEA-KIT: Unmanned surface utility craft

- Designed as mother vessel for AUV – fitting in 40 ft container
- Exclusion area safety vessel
- Border Safety / Patrol vessel
- Rapid survey deployment
- Passive Acoustic Monitoring
- Acoustic positioning USBL
- Ocean Data Collection Platform
- Communications Repeater Station
The start of construction with metal for the hull being cut (21 April 2017)

Delivery of completed hull (28 June 2017)

USV at workshop ready for wet test (31 August 2017)
FIRST WET TESTS IN UK

Christened USV Maxlimer - 1 Sept 2017
<table>
<thead>
<tr>
<th><strong>SEA-Kit Dimensions:</strong></th>
<th><strong>Fully redundant propulsion and communication systems</strong></th>
<th><strong>Two independent power supplies and power charge</strong></th>
</tr>
</thead>
</table>
| • Length: 11.75 m (38.55 ft)  
• Beam: 2.2 m (7.22 ft)  
• Transport Height: 2.0 m (6.56 ft) - Operational Height: 7 m (22.97 ft)  
• Weight: 11,200 kg (estimated) | • Propulsion: 2 X 10 kW / 1200 rpm electric directional thrust motors  
• Communication: Wi-Fi, Radio, Satellite (Iridium and Inmarsat) and Kongsberg Maritime Broadband Radio (<45 km offshore)  
• CCTV: 2 interior and 6 fore and aft cameras, 1 night-vision camera | • Generator 2 X 18 kW 48 V DC  
• Fuel 2,000 L  
• 56 Gel and Absorbent Glass Mat (AGM) types of valve-regulated lead-acid battery (VRLA) Marine Batteries, 12 V – 214 Ah capacity  
• 4 dry cell Absorbed Glass Matt (AGM) VRLA 12 V 100 Ah Marine Dual Purpose Batteries for the engine and propulsion |
SEA-KIT Communication & Navigation

Remote control antennae
Kongsberg Seapath 130 GPS antenna
Wind Sensor & AIS antenna
Kongsberg MBR
Wifi and Radio antennae for AUV (OFG) & Iridium antenna
HS70 GPS compass
Simrad 4G radar & GPS for Iridium
Loud hailer: anti-hijack!
Inmarsat SAILOR 500
FleetBroadband

HIPAP 351P-MGC
Transducer
Modes of Operation
1. Unmanned, partly autonomous
   (Kongsberg Maritime AS K-MATE)
2. Remote control (joystick)
3. Manned
USV Maxlimer on her way to Norway

Unpacking SEA-KIT container in Horten, Norway

8 Sept 2017

14 Sept 2017
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Ocean Floor Geophysics Capabilities:

➢ Deep water **AUV** operations and data acquisition for **infrastructure inspection and survey**

* Route and Site Surveys  * Pipeline Inspection  * Mineral Exploration
  * Decommissioning Survey  * Archeology and Salvage
  * Seafloor Search  * Environmental Baseline Studies
  * Seafloor Classification  * Unexploded Ordinance  * Physical Oceanography

➢ Electromagnetic mapping and Magnetic 2D & 3D surveys
➢ Geo-chemical prospecting and mapping surveys
➢ Gravity and inversion post processing (ROV/AUV borne)
➢ Sensor Development - Self Compensating Magnetometer (SCM) System for **real-time** compensated magnetic data.
WHY OFG:

➢ OFG Personnel have diverse AUV Experience - Operations, System Integration and Design

➢ Mission Planning

➢ Selection, Design, and Integration of Sensors

➢ R&D background

➢ Similar philosophical approach
### “Chercheur” HUGIN 1000 AUV Specs

| General | • Rating: 5 - 3,000 m  
|         | • Length: 5.5 m  
|         | • Weight in Air: 1,200 kg  
|         | • Neutrally buoyant  
| Sensors | • SAS: Kongsberg Maritime HISAS 1032  
|         | • MBES: EM2040 200-400 kHz (0.7° x 0.7° beam width)  
|         | • Sub-Bottom Profiler: EdgeTech DW 106 SBP  
| Navigation Sensors | • IMU: Honeywell HG9900  
|         | • Compass: Leica DMC  
|         | • DVL: Teledyne RDI Workhorse Navigator 300 kHz  
|         | • Altimeter: Kongsberg Mesotech 675 kHz down looking  
|         | • Forward Looking Sonar: Imagenex MBES sonar  
|         | • CTD: SAIV CTD  
|         | • USBL: HiPAP Transponder  
|         | • Depth Sensor: DigiQuartz 8CB4000  
|         | • GPS Receiver: Novatel  
| Power | • 3 batteries (24 kWh)  
|       | • Endurance estimates: 37 hrs @ 3 kts & 27 hrs @ 4kts  

THANK YOU to Kongsberg Maritime in Horten, Norway for supporting us through 2 months of sea-trials.
Data group and OFG operators acquired bathymetric and side-scan data, as well as sub-bottom profiles. The data was collected during 12 dives in 4 weeks.

Included:

• DVL calibrations
• Patch tests separately for EM2040 and HISAS 1032
• Various operational modes: getting wide-area side scan bathymetry operational (KM input), testing standard HISAS bathymetry and HISAS imagery
• Data collection different altitudes and speeds
Focus on Automated Data Flow

- Masa worked with Teledyne CARIS to understand:
  1. AUV work flow in processing HISAS data & EM2040 data (Ms. Fernanda Viana Da Conceicao)
  2. Developed automated work flow based on CARIS processing tools
- Fine-tuned and further developed during sea trials at Kongsberg Maritime
- CARIS output will be imported into ArcGIS
  1. Analysis of bathymetric data (contours, slope etc.)
  2. Publishing of image services in ArcGIS Online
  3. Collection of bathymetric data available from internet sources
HUGIN 1000 with HISAS 1032
Data Collection

STANDARD HISAS MODE:
Distance-triggered
• Swath width: ± 200 m (400 m)
• Side scan image: = ~ 4 cm
• HISAS Bathymetry Resolution: = 1 m
• HISAS Spot Bathymetry Resolution: = 10 cm
• Speed: = 3.9 knots (2.0 m/s)

WIDE-AREA (SIDE-SCAN) MODE:
Time-triggered
• Swath width: ± 375 m (750 m)
• Side scan image: = ~ 1 - 2 m
• Bathymetry Resolution: = ~2 m
• Speed: = 4.3 knots (2.2 m/s)
WIDE AREA MODE
Bathymetric Side-Scan Method

Standard HISAS MODE
Synthetic Aperture Sonar (SAS) Method

Wider Swath Width: 750 m

Physical beam width is worse at outer beam: ~1-2 m resolution

Narrower Swath Width: 400 m

SAS Physical beam (yellow) width is homogeneous: ~4 cm resolution

Virtual Long Array = Synthetic Aperture Array

For wide area bathymetry

60 m elevation

Wide Area Mode

EM2040

For seafloor feature detection

40 m elevation

HISAS

EM2040

HISAS
### AUV “Chercheur” Data types

<table>
<thead>
<tr>
<th>Sonar</th>
<th>File type</th>
<th>Data</th>
<th>Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>EM2040</td>
<td>*.all</td>
<td>Bathymetry &amp; Imagery</td>
<td>&lt;1 m</td>
</tr>
<tr>
<td>HISAS (Standard)</td>
<td>*.all</td>
<td>Port and Starboard Bathymetry</td>
<td>1 m</td>
</tr>
<tr>
<td>HISAS (Standard)</td>
<td>*.xtf</td>
<td>Imagery</td>
<td>4 cm</td>
</tr>
<tr>
<td>HISAS (Standard)</td>
<td>*.all</td>
<td>Port and Starboard Spot Bathymetry</td>
<td>10 cm</td>
</tr>
<tr>
<td>HISAS (Standard)</td>
<td>raw data</td>
<td>Port and Starboard Spot Imagery</td>
<td>~2-4 cm</td>
</tr>
<tr>
<td>HISAS (Wide-area)</td>
<td>*.all</td>
<td>Port and Starboard Bathymetry</td>
<td>2 m</td>
</tr>
<tr>
<td>HISAS (Wide-area)</td>
<td>*.xtf</td>
<td>Imagery</td>
<td>1-2 m</td>
</tr>
</tbody>
</table>
Kongsberg Proprietary software FOCUS & REFLECTIONS takes raw HISAS data and produces .all & .xtf for input into CARIS.
Import PORT *.all files
Import STBD *.all files
Import NavLab files for TPU only

DETAILED EXAMPLE:
HISAS wide-area mode work flow

Want to know more… speak to Masanao Sumiyoshi
• Nadir fill
• Approximate total swath width = 200 m
  (120° swath & 400 beams at 60 m altitude)
• Data resolution ≤1 m
HISAS Wide-Area Test

30 m AUV altitude

60 m AUV altitude

Better S/N

60 m AUV altitude

+/- 390 m (780 m full swath)
Patch Test for HISAS Wide-Area

[PORT] Roll: +0.225 degree

[STBD] Roll: +0.185 degree
Data density: Different HISAS modes

**Standard HISAS**
0.5 m along track spacing

**Wide-area mode**
~1.5 m along track spacing

Both modes:
1 m across track spacing
HISAS wide-area mode with EM2040 nadir gap filling
Coverage Estimates

- Standard HISAS: 2.7 km²/hour
- HISAS wide-area side-scan: 6.2 km²/hour

*This includes EM2040 nadir gap data*

The Team plan for XPRIZE was to run various AUV modes:

- 13 hours of HISAS wide-area mode (80.3 km²)
- 2 hours of standard HISAS mode (5.4 km²)

= ~86% of required coverage
EM2040 backscatter vs. HISAS imagery
Only wreck covered using HISAS mode – more to come.....

HISAS Imagery

HISAS Spot Imagery

Shipwreck 20 m Length; 5 m Beam in ~200 m water depths
Dive 12 surface (1 m resolution) based on HISAS wide area, HISAS and EM2040 data
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More pictures to follow

On hard drive at home
THANK YOU