UDT
Undersea Defence Technology
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Future Underwater Enablers; learning from other operators within the marine sector

Sonardyne SOUND IN DEPTH

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Contents

Introduction & Approach

- A joint investigation by BAE Systems Submarines and Sonardyne International, the approach to the paper started with a set of meetings to understand the possible synergies between the two 'sectors' before conducting research into, primarily, the non-defence sector

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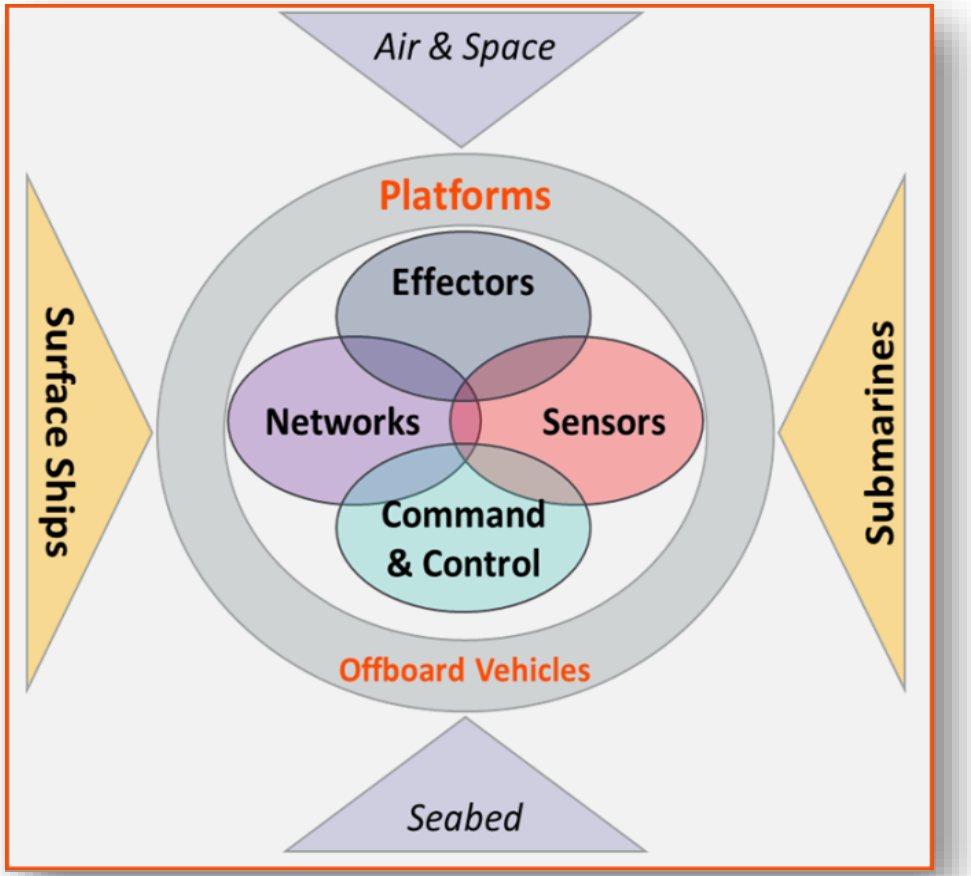
Sector Overview & Analysis

Underwater Defence Sector

- The defence sector in the underwater domain can be described as any platform or system that enables military capability to be delivered from within, into or outside of the underwater environment.
- Not all of this capability operates within the underwater battlespace which is both temporal and spatial in terms of the scale of the battlespace with reference to a military campaign ie. defence may use systems in peacetime or for benign data collection in the environment.
- The systems that may be considered as enablers to achieving such underwater capability cover everything **'from seabed to space'** in order to achieve overall situational awareness and command & control (C2).
- Capability comprises not just technology or systems but the policy, people, training and tools to deliver it.



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Sector Overview & Analysis

Underwater non-Defence Sector

- Hereafter referred to as the 'marine sector' describes broadly the application of technology for research or operational programmes in the following areas:
  - Oil & Gas and Renewables/Energy (both including supporting offshore installations in the subsea), Exploration and Survey, Marine/Ocean Science
- The marine sector operates systems within and on top of the underwater environment, primarily ships and submersibles, tethered ROVs and subsea/seabed infrastructure.
- Many challenges and technology solutions are similar to defence albeit defence has more challenging operational constraints most primarily the need to operate in an underwater battlespace and the operational mission security that entails
- Many new systems are being developed to help automate and simplify marine operations, in particular the more challenging operations where persistent monitoring is required. This is especially true for seabed and critical infrastructure operations.

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Sector Overview & Analysis

Challenges and Comparisons

- Probably the most important challenge will be at the enterprise level. This covers:
  - Systems architecture understanding and development;
  - Software development; modelling and simulation, training and distributed control systems;
  - Security accreditation for new systems across the underwater domain;
  - Unmanned systems and autonomous technologies skills development;
  - Infrastructure to support through-life management of systems;
  - Advanced manufacturing and in-service support solutions;
  - Platform / payload agnostic integration;
  - Energy harvesting, docking and 'garaging';
  - Sensing and response to seabed infrastructure faults;
  - Seabed intervention and repair;

- Much of the above are challenges that are also faced by the Defence sector

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Sector Overview & Analysis

Challenges and Comparisons

- It can be extrapolated that certain operations in the ‘underwater battlespace’ will likely see demand for increased capability that requires pull-through from the marine sector.
- There are a number of similarities between the sectors operating in a common environment with similar platforms, operations and technical or environmental challenges.
- A deliberately simplified set of comparisons are summarised in the tables below which should indicate the commonality between the sectors
- Note. The following doesn’t detail the security definitions between the sectors. Marine still needs to maintain operational security, it’s merely driven by different levels of threat and tempo

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Sector Overview & Analysis

Challenges and Comparisons

Platforms	Defence	Marine
Submarines	Y	N
Surface Ships	Y	Y
Aircraft	Y	N
Satellites	Y	Y
Remote Vehicles	Y	Y
Autonomous Vehicles	Y	Y
Seabed Infra	Y	Y

Operations	Defence	Marine
Covert surveillance underwater	Y	N
Covert surveillance above water	Y	N
Environment Assessment	Y	Y
Geospatial Assessment	Y	Y
Under Ice & Arctic	Y	Y
Seabed	Y	Y

Challenges	Defence	Marine
Data Integrity	Y	Y
Asset Integrity	Y	Y
Operational Safety	Y	Y
Operational Security	Y	N – less so
Ambient Noise	Y	Y
Environment Assessment	Y	Y
Marine Mammals	Y	Y
Marine Fouling	Y	Y
Manned / Unmanned Teaming	Y	Y
Remote Sensing	Y	Y
Comms	Y	Y

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Results & Discussion

Programmes & Technology

Oil & Gas technology drivers

- Connectivity
- Autonomous activities – inspection, light intervention and near real-time information gathering.
  - Seabed resident ROVs or AUVs
  - Autonomous Surface Vessels
- Edge computing – Information not Data
  - Change or Feature detection – Machine Vision
  - Event Categorising – Deep learning
  - Decision making – Artificial Intelligence
- Reduce offshore people – risk and cost
- Improve operational efficiency – cost and time

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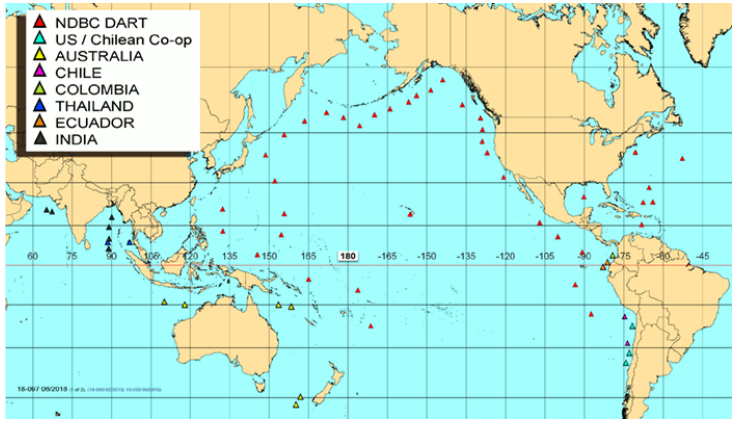
Results & Discussion

Programmes & Technology

- The technology that is used today in the offshore (marine) sectors could potentially provide significant benefits to the Defence sector.
- In particular, passive monitoring and more 'active' systems. The ability to have instruments that can navigate to pre-determined positions on the seabed and observe for an extended period of time, communicate an alert through a network of subsea assets to an autonomous vehicle, which in turn alerts the control station has been demonstrated outside of defence.



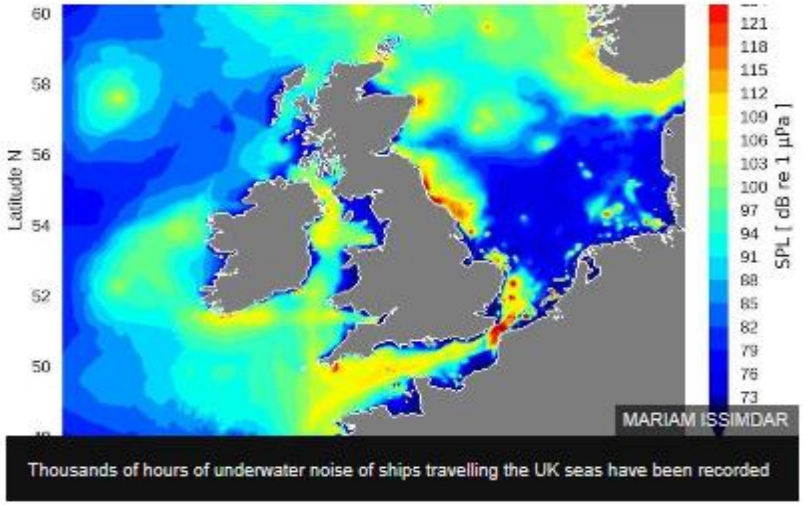
Observatories

Note. Image References contained within paper

Results & Discussion

Programmes & Technology

- There is considerable Oil & Gas seabed/subsea infrastructure, which if paired with compatible communication and navigation instrumentation, it could be utilised for defence purposes, security accreditation and correct geographical coverage notwithstanding
- Collecting real-time information on the underwater environment, in far greater fidelity and higher density coverage zones, is becoming increasingly important for modelling & simulation and also real-time prediction for optimising / calibrating sensors and communications equipment in the field



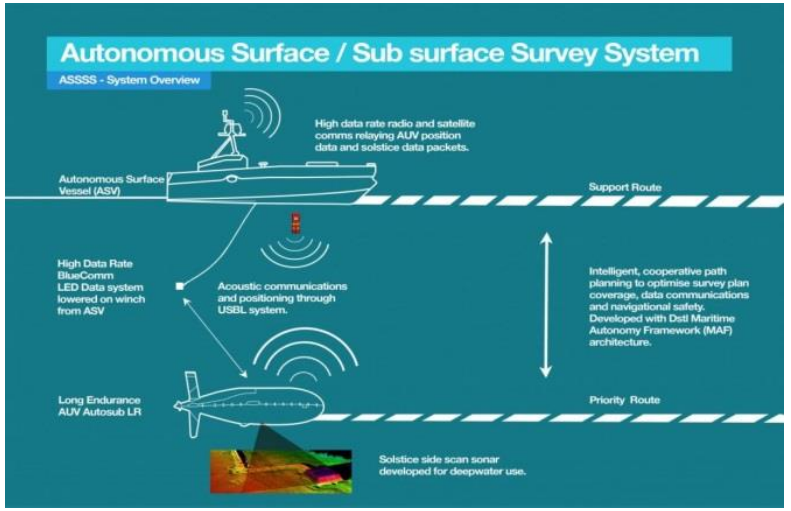
The first UK-wide map of underwater noise made by ships has been created, marine scientists have said.

Note. Image References contained within paper

Results & Discussion

Programmes & Technology

- To remove the need to deploy reference acoustic transponders, hybrid navigation solutions are using natural and manmade seabed features as absolute references
- UK Government, through Innovate UK, is funding a number of projects in the marine sector, a particular highlight is the Autonomous Surface Sub-surface Survey System
- The development of so-called E-Robotics or seabed Resident Systems is being rapidly developed to aid persistent and repeatable underwater inspection and intervention activities using AUV/ROV platforms paired with supporting infrastructure



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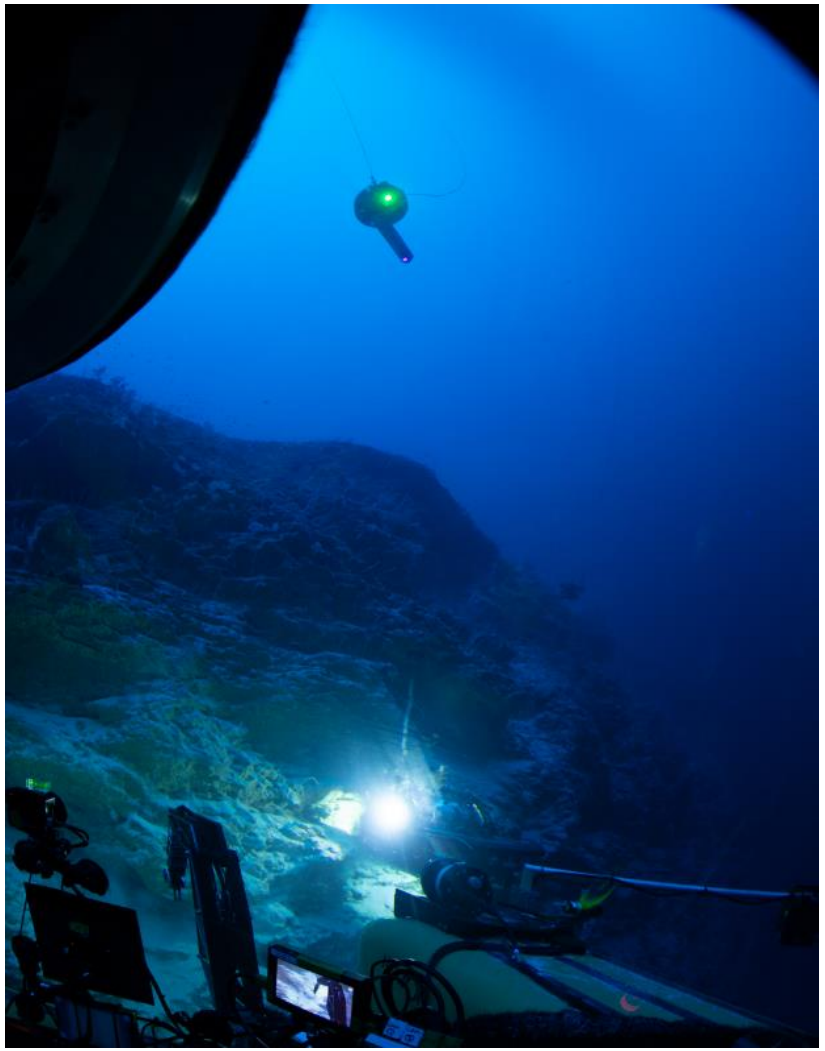
Results & Discussion

Programmes & Technology

- Optical Comms in the Seychelles!



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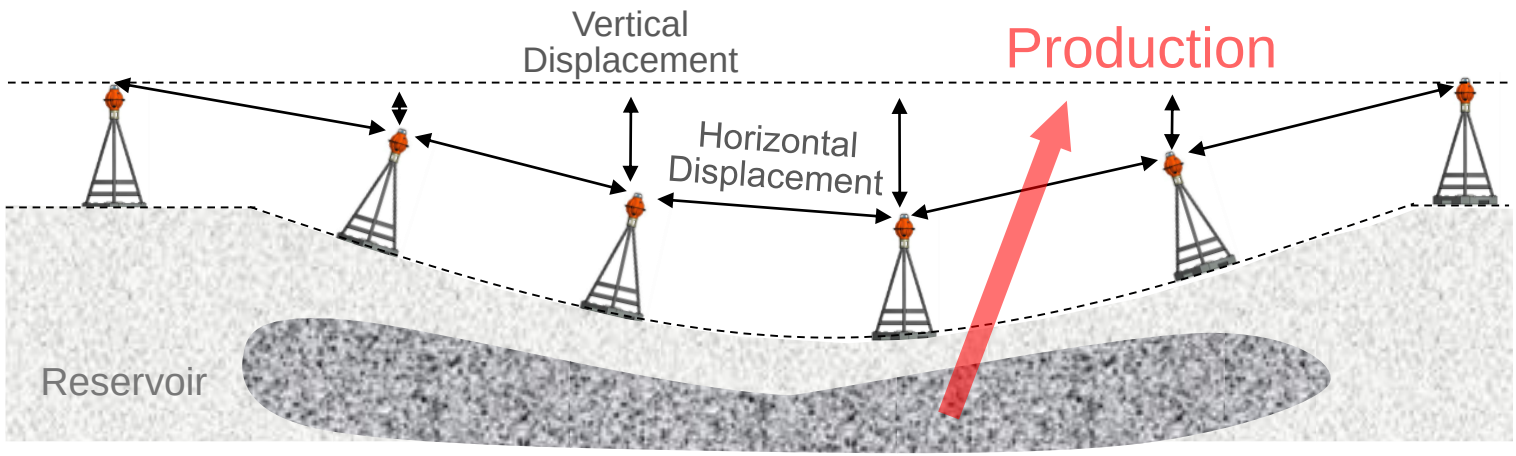
Non – Defence example project

- Purpose – Seabed Settlement Monitoring
- On-going requirement to monitor the seabed settlement around a producing Oil or Gas reservoir
- Past, Present and Future



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Past - Acoustic Seabed Network - ASN

- Example site - 203 Autonomous Monitoring Transponders covering an area of about 400 km^2
- Deployed at depths between 800 to 1100m
- Pre-deployment seabed location planning
- Accurate positioning of the transponders
- Logging pressure, temperature, inclination & sound speed
- Communicating and measuring acoustic ranges to neighbouring nodes
- Optimised data recovery and vessel routing

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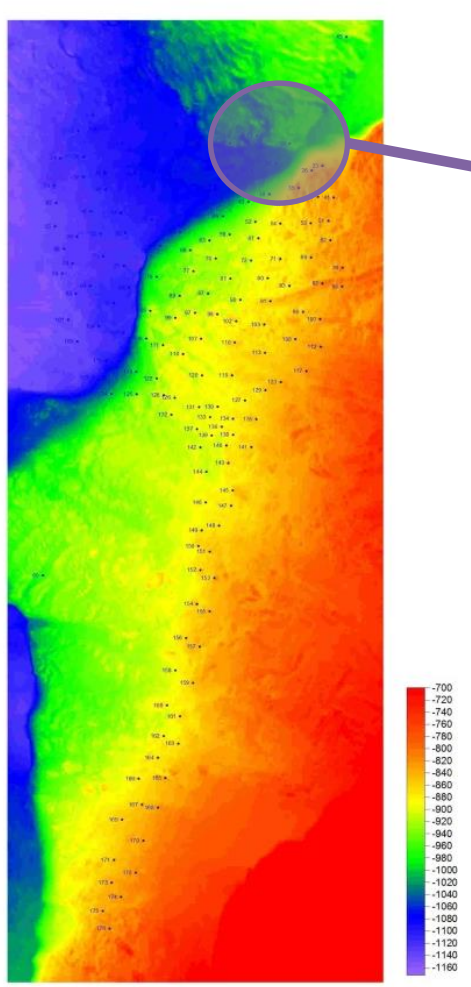
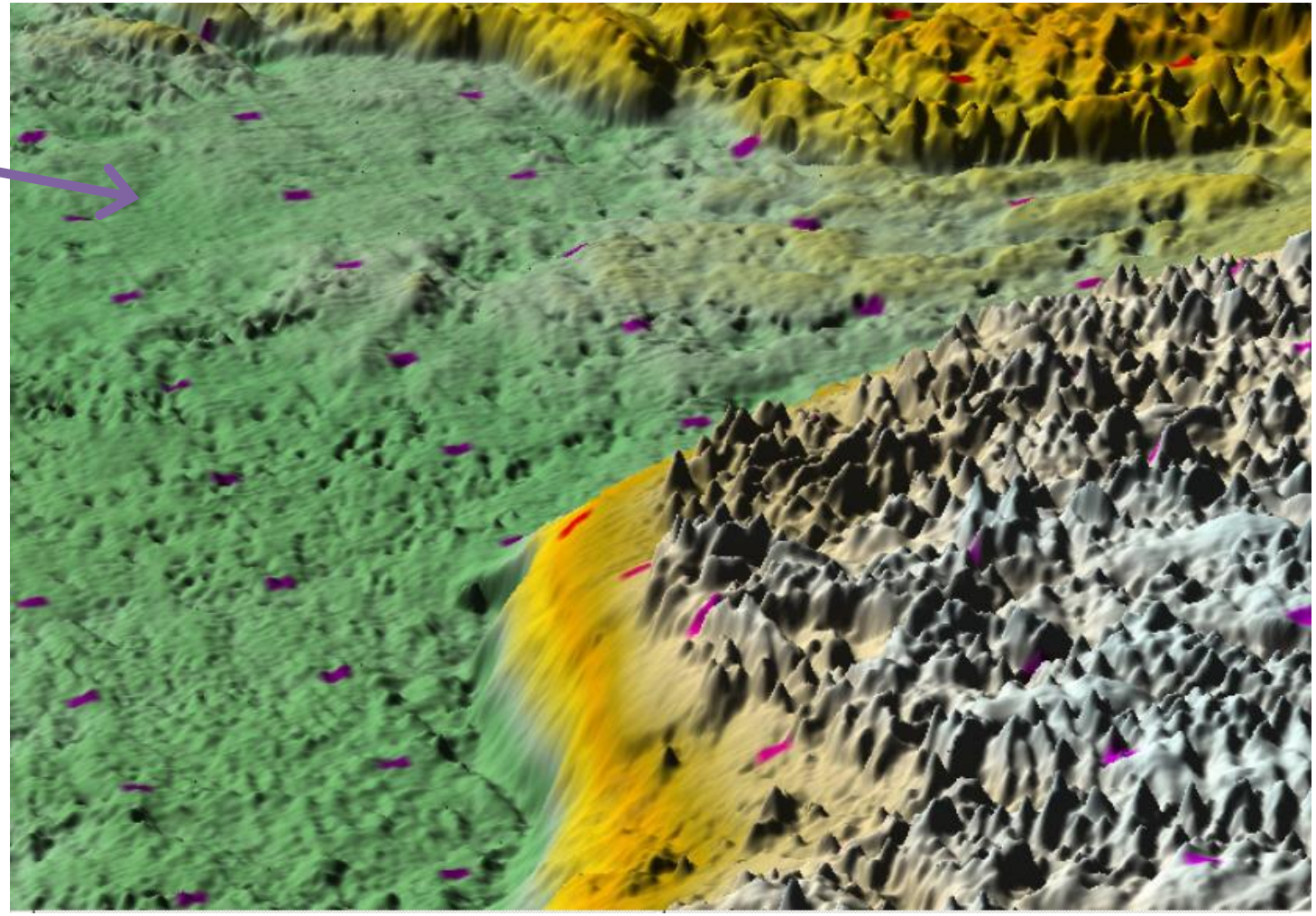
ASN - Planning





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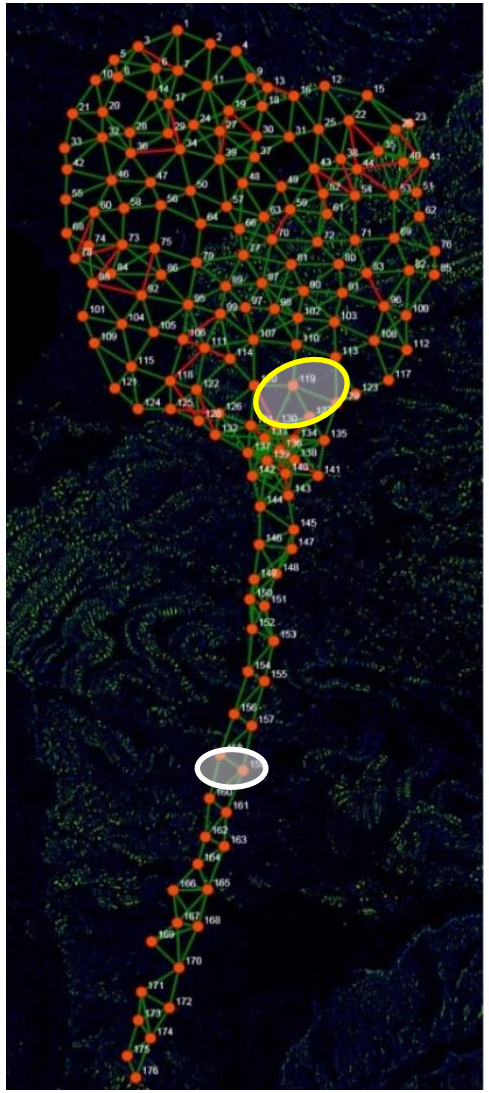
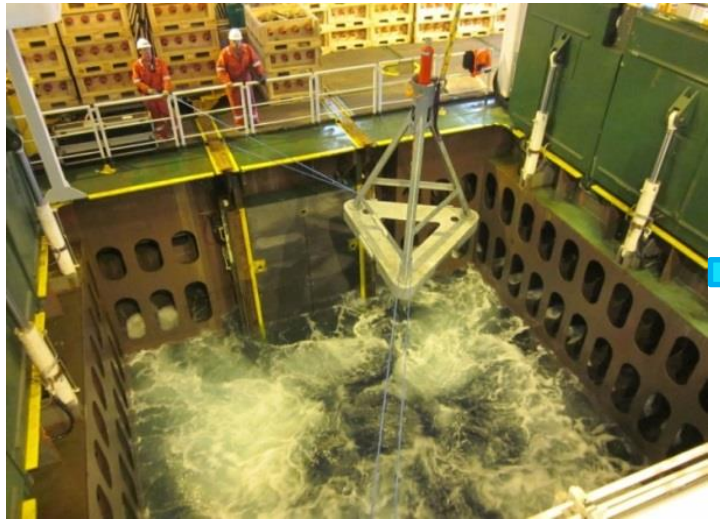
ASN – Deployment





Past - ASN – Data Collection

- For 6 years all the nodes logged pressure, temperature, inclination and sound speed every 6 hrs
- Acoustic ranges measured every 3hrs
- The measurement schedule was modified as more information was gathered to optimise the measurement strategy
- Approx. 3MB of data logged per node
- All logged data was download using up to 9kbps acoustic telemetry to a vessel mounted or dunking transceiver.
- Data harvested every 6 months; 250kB data; 6mins
- Time synchronised and drift measured to ppm
- The transit time between nodes was 10 mins
- >600MB downloaded acoustically

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Past - ASN – Recovery

- 6 years later…

- With the latest technology the battery life for this transponder is now heading towards 15 years
- New sensors option include:
  - Acoustic Doppler Current Profiling (ADCP) for turbulence
  - Pressure Inverted Echo Sounder (PIES) for average sound speed and estimation of Sound Speed Profile (SSP)
  - Ambient Zero Ambient (AZA) high accuracy pressure recording (mm)
  - 4Component Seismic (3 geophones, 1 hydrophone)
  - Physical, Chemical, Biological sensors
- LASER high bandwidth optical communications
- Acoustic data routing throughout the network

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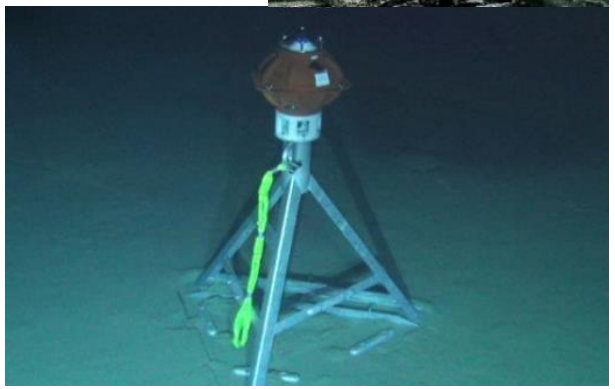
Present - ASN – Data Collection

- Autonomous Surface Vessels fitted with Sonardyne 6G modem and GPS-A technology is used routinely to harvest data at up to 9kbps
- Acoustic sensor node positioning using GNSS and acoustic ranges to “box-in” the node.
- On-shore real-time remote access via satellite for control and data
- More frequency pre-determine data harvesting routes



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Near Future - ASN – Data Collection

- Seabed Resident AUV used to periodically harvest sensor data, time synchronise nodes, map the seabed and position seabed nodes.
- 600Mbps LASER based optical communications
- 3D seabed reconstruction and change detection
- Feature based aided inertial navigation
- Intelligent routing and data gathering

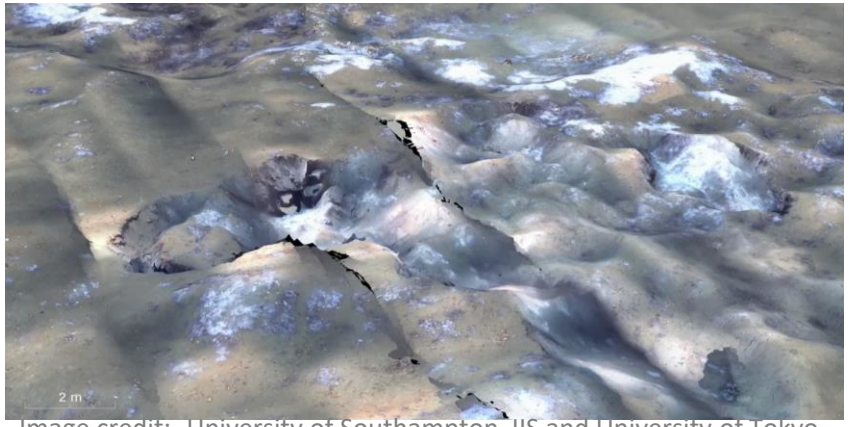
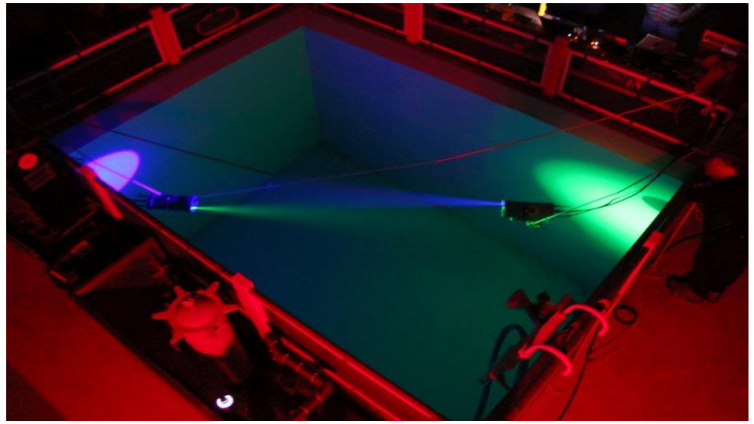


Image credit:- University of Southampton, IIS and University of Tokyo



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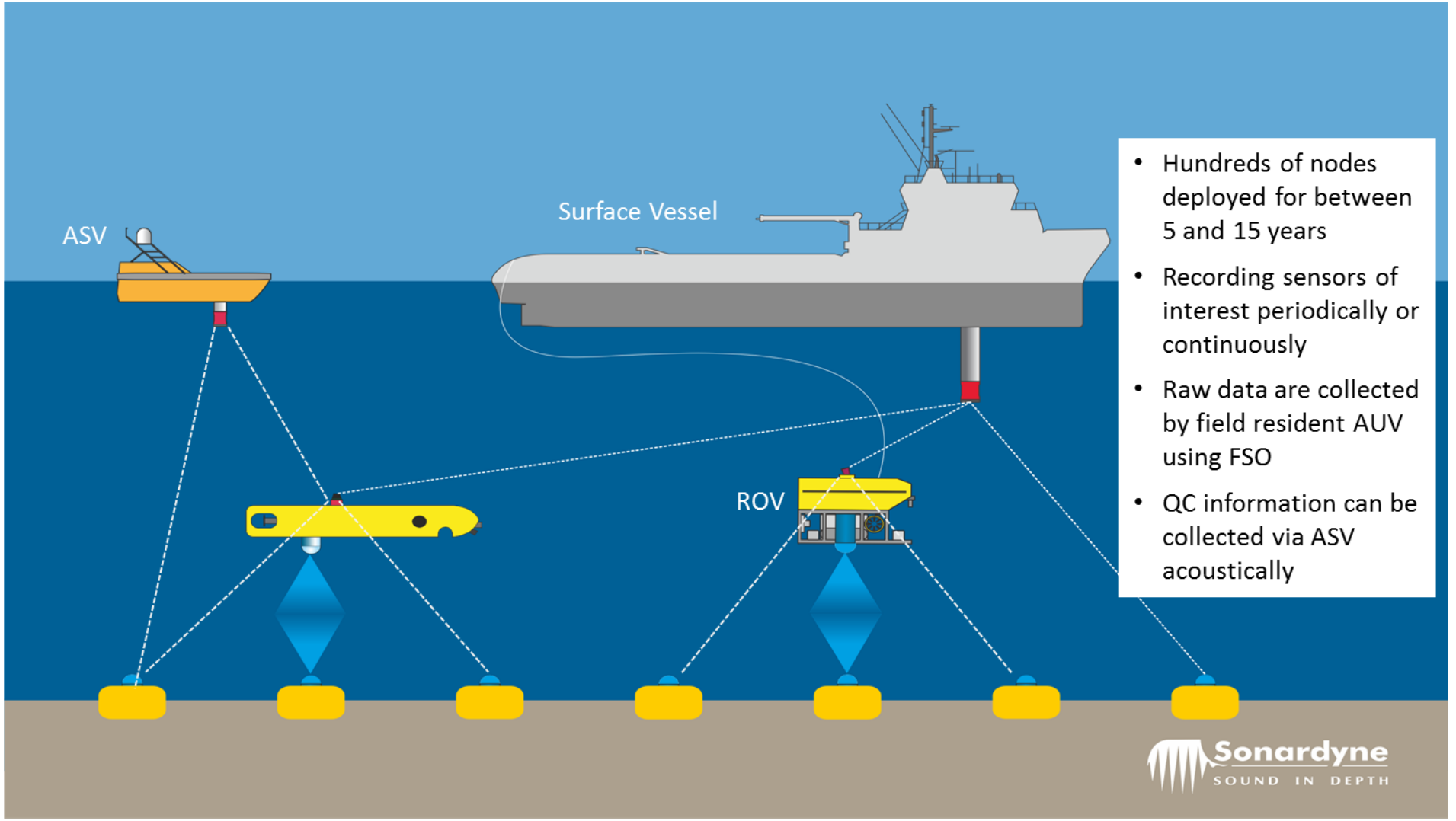
Near Future - ASN – Data Collection



- Hundreds of nodes deployed for between 5 and 15 years
- Recording sensors of interest periodically or continuously
- Raw data are collected by field resident AUV using FSO
- QC information can be collected via ASV acoustically

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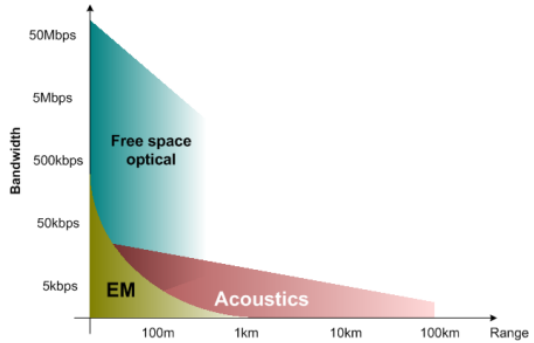
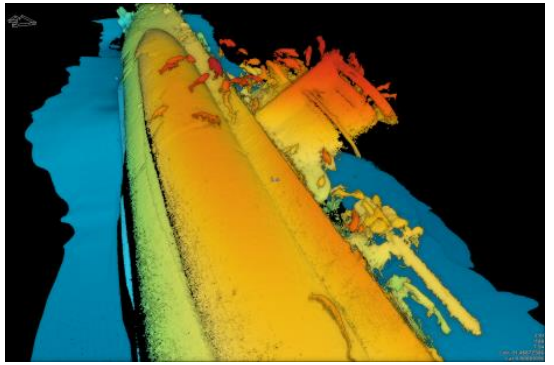
Conclusions

Cross-sector Considerations

- Common requirements:-
  - Communications
    - Free Space Optical
    - Acoustic
    - EM
  - Navigation
    - Tightly coupled Doppler inertial (0.01% distance travelled*)
    - Acoustic navigation, USBL, LBL, Sparse LBL, Collaborative
    - Feature, terrain, gravity and magnetic mapping and localisation
  - Autonomy
    - Autonomous Surface Vessels
    - Seabed resident tether-less vehicles
    - Long-term Autonomous Monitoring System
  - Machine learning
    - Feature detection and classification
    - Edge computing and decision making





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* Typical survey

Conclusions

Cross-sector Considerations

- This paper has examined the similarities between the defence and non-defence sector referred to as marine, herein.
- There is evidence that supports the argument that deeper examination and considerations should be made towards the more formal collaboration between the sectors.
- Whether this can be done through design or by inevitable convergence is a matter of choice, however, clearly a more focussed campaign to drive cross-sector innovation, transfer of technology and development of skills and shared manufacturing or test & evaluation capabilities can only be achieved if advocated by sector leadership at the highest level in government and industry.

Conclusions

Recommendations

- Access to global environmental datasets for use within underwater modelling & simulation toolsets – noting a lot of this is becoming more widely open source
- Provision of 'anonymous passive detection' from nascent deployed systems in the marine sector such as through the proliferation of sensors and new underwater infrastructure eg. ocean observatories, Argo floats and other similar sensor systems
- In addition to the above sensor data, access to 'old data-sets' for data analytics and improved predictive pattern of life analysis
- Agreement on the protection and responsibilities of critical seabed infrastructure or the techniques to sense and respond to failures, innocent or malicious, physical or electronic
- Collaboration on common challenges that aren't too 'sector specific' such as: seabed mapping, seabed intervention, energy harvesting, marine bio-fouling, advanced manufacturing and test & evaluation of agreed technology areas
- Underwater communications, navigation and positioning techniques is another area where there will be some similarities in the skills base but not in the specific solutions

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Thank you

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