National Marine Facilities

Technology Roadmap

2019/20

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

noc.ac.uk

NERC SCIENCE OF THE ENVIRONMENT

Introduction

Against a backdrop of tight budgets, rapid technical development, big data and the increasing use of Marine Autonomous Systems (MAS) platforms, National Marine Facilities (NMF) is committed to delivering the best possible support and value for money to the UK science community. We will constantly strive to develop equipment and improve processes to deliver more efficient and effective support to the Natural Environment Research Council's (NERC) Marine Facilities Programme (MFP). The direction of this progression is necessarily driven by future science needs and relies heavily on the input of the UK science community. The Roadmap is updated annually to reflect science priorities communicated via the Marine Facilities Advisory Board or other forums and/or advances in technology.

The environmental impact of NMF's activities at sea will be assessed from 2019 onwards with actions taken to mitigate the impact wherever possible.

The Roadmap is structured to present sequentially each area of capability, categorized as follows:

i) **Current Capability** – a description of the current capability in that area

ii) **Science Drivers** – an overview of the science pulls requiring new technology developments

iii) **Future Capability** – developments that are planned and have associated funding in place

iv) **Aspirations** – potential future capabilities for which funding will be sought

v) **2018/2019 Update** – brief overview of progress developing enhanced capabilities since the previous issue of the technology Roadmap.

Contents

Seismics

Current Capability

Airgun deployment during seismics operations

- Bolt 1500-LL airguns
- Sercel GI 250 airguns
- 2.4 km multichannel streamer, extended to 3 km where required through hire of remaining 600m length
- Big Shot fire control system
- Avalon RSS-2 array source control system

The current seismic source arrangements are outdated and optimized for operations on previous classes of research ships. There are limitations with the volume of source that can be deployed and streaming and recovery are slow.

Science Drivers

- Reduce costs – Long mobilisation periods are required to assemble and commission equipment taking up valuable ship time. Age, complexity and lack of reliability mean that costly sea trials are often required prior to science to provide equipment assurance and staff training. A containerised, ready- assembled system delivered to the ship with minimal set up time and low maintenance overhead will cut mobilisation periods and require less technical support.

- High performance source – The aged fleet of bolt 1500-LL airguns and associated compressors do not provide the energy or fidelity of signal to make full use of the NMEP modern multi-channel streamer to deliver high resolution 3D images. GI guns deliver a much sharper waveform via a 2-stage firing process.

- Improved reliability – The system of beam deployed airgun arrays with pneumatic umbilicals is unreliable and can incur failures while firing often resulting in a change of source level while in mid seismic line. Airgun repair then requires a break in science to recover and fix. A J-rail deployment system and buoy mounted gun arrays coupled with the much smaller recoil of GI guns would greatly reduce the mean time between failures and enable faster repairs.

- Reduce wake interference – The twin propulsion designs of RRS *James Cook* and RRS *Discovery* produces a much greater wake profile than previous research ships. Airguns are fired while being towed through this aerated water seriously affecting source level and consistency. Modifications to the after deck of both ships would allow sources to be towed much wider from the ship's centreline and reduce this problem.

- Flexibility – Bolt 1500-LL airguns can only be reconfigured by changing the entire chamber. Chambers are large, unwieldy and expensive and NMF only holds a limited amount of each size therefore limiting the options for reconfiguring array size at sea. GI 250 airguns can be reconfigured quickly by the use of an inexpensive plastic insert giving a Principal Investigator an almost unlimited choice of source configurations.

Future Capability

A seismics working group was set up to consider in more detail what future capability is required to support the geophysics community; its findings were presented to the September 2018 Cruise Programme Executive Board and are detailed below):

- To upgrade through investment in a new commercial off-the-shelf capability, and develop a containerised, modular system with reduced through life costs, mobilisation/ demobilisation times, and maintenance and technical support are required ashore and at sea.

A structured procurement strategy is proposed over the next two to three years to purchase the following (dependent upon additional funding):

- A versatile, highly configurable seismic airgun source comprising up to 24 individual airguns
- A source tow depth and geometry control system capable of supporting different scientific applications
- A versatile and adaptable seismic source deployment system, deployable from Ocean Facilities Exchange Group partner research vessels as well as NERC's fleet, in full or in part
- A full suite of potential field sensing systems, appropriate to fixed and mobile installation on any of the global fleet of scientific research vessels
- A high resolution, short streamer shallow sub-seabed imaging capability.

Aspirations

A multichannel streamer capability greater than 3000m.

Coring

Current Capability

The NMEP has eight different types of corer with both tubular and box varieties available.

- Tubular Corers
  - Gravity Corer (Sample tubes 63.5mm OD, 1 to 4m depth)
  - Kasten Corer (Sample 150mm square, up to 5m depth)
  - Piston Corer (Sample tubes 90mm or 110mm OD, up to 25m depth)
  - Multi Corer (Up to 12 sample tubes 56mm OD, 0.6m depth)
  - Mega Corer (Up to 12 sample tubes 100mm OD, 0.6m depth)

Multi corer

- Box Corers
  - SMBA Corer (Sample 600mm square, 0.45m depth)
  - NIOZ (haja) Corer (sample 500mm square, 0.5m depth)
  - Day Grab (10kg surface sample)

Science Drivers

- Enduring requirement for deep sea benthic sampling.
- Accuracy of sampling. A lot of time is taken lowering sampling systems with no accurate inspection of the sampling site.

Future Capability

- A wire mounted camera system to view and record sampling sites.

Aspirations

- A 40m piston corer utilising a bespoke handling and deployment system.
- Potential development of a precision coring system deployable using Hybis platform.

Conductivity, Temperature and Depth CTD

Current Capability

The National Marine Equipment Pool (NMEP) has both stainless steel and Ti CTD frames and is capable of completely trace metal free sampling (in conjunction with portable MFCTD winches). CTD frames can be fitted with 10 and 20 litre sample bottles (24 of each). The frame can carry sensors to measure conductivity, temperature, pressure, turbidity (transmissometer and back scatter), oxygen, chlorophyll, and water velocity. They can be deployed to full ocean depth (6000m).

CTD sample recovery

Science Drivers

Data from CTDs and the associated sensors are fundamental and contributes to 75% of the biogeochemistry science delivered. The incorporation of state of the art sensors, or the capability to incorporate state of the art sensors above and beyond the current technology is key.

CO_2 and pH sensors are critical to enhance the understanding of ocean acidification and the role of the ocean in modifying atmospheric CO_2. The rapid optical imaging of macroscopic particles and zooplankton in vertical profiles is relevant to NERC programmes investigating carbon export such as NERC COMICS, AMT and WCB

Future capability

- The incorporation of full ocean depth CO_2 and PH sensors with rapid response times into CTD frames.
- An Underwater Vision Profiler incorporated into CTD frames by either adapting existing SeaSoar instrument or purchase of a new one.

Fixed and Towed Body Sampling

Current Capability

Full ocean depth mooring systems capable of 24-month time series observations. Vertical Microstructure Profiler (VMP), Sea Soar and Scanfish delivery systems.

Science Drivers

A fixed point mooring being deployed

- There is an ongoing requirement for fixed, low cost, observation systems.
- There is an increasing demand for larger sensor payloads on all platforms.

Future Capability

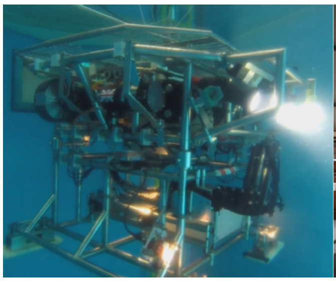
- Develop real time telemetry of data from moored observatories using underwater acoustics and satellite technologies.
- Develop a suitable smoke beacon that will withstand full ocean depth and activate on return to surface, either by pressure or conductivity, to provide a clear locator (better than a flag or strobe in daylight)
- Design syntactic float collars for specific and individual items that would reduce the use of inline glass in moorings for reducing mooring length in certain situations
- Develop a current meter for use on the freefall VMP
- Evaluate the feasibility of the use of synthetic conducting ropes for the towed vehicle fleet (Seasoar and Scanfish).

Aspirations

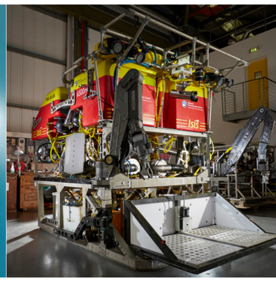
- In collaboration with MARS, investigate the benefits and feasibility of the development of *in-situ* moored power sources to enable recharging of AUVs and prolong their deployment duration.

Remotely Operated Platforms (ROP)

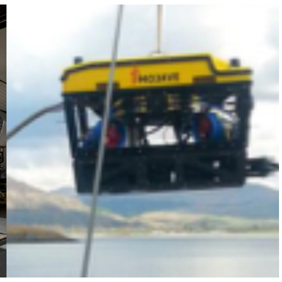
Current Capability



HyBIS RUV



Isis ROV



Mojave ROV

- *Isis* Remotely Operated Vehicle (ROV) – The *Isis* ROV is a well-established and mature system. Over the years it has gone through a number of upgrades to improve the instrumentation and systems, and this incremental upgrade of the vehicle is likely to continue over the next five years.
- HyBIS Robotic Underwater Vehicle (ROP) – HyBIS is a modular remotely controlled vehicle. It is very similar to a remotely operated vehicle, but lacks syntactic foam and so is directly coupled to the ship. The HyBIS system comprises a ship side power and control system, a bottom end command module with cameras and lights, and interchangeable payload modules. This set-up allows each payload module to be precisely located and oriented on the seabed and thus precision seabed sampling is possible to achieve. HyBIS's heavy lift capability also makes it an ideal platform for precision placement and recovery of seabed experiments, thus potentially changing the deployment approach for seabed landers.

- Mojave ROV – The Mojave ROV is a small shallow water (300m) rated system. It is equipped with lights, cameras, and a three function manipulator arm.

Science Drivers

- Reduce operating costs (*Isis*) – *Isis* is a large complex deep-water ROV system, and, although highly efficient compared to similar systems used by other institutes, is expensive to run both in terms of consumables and labour. To maximise the utility of the vehicle to the community, these costs should ideally be reduced.

- Enhanced scientific interaction – Currently, the number of people who can guide the ROV / HyBIS operations are limited to the people on the cruise. By having the capability to create a virtual control room, the number of people who can engage with and potentially guide the vehicle deployments can be increased. A virtual control room would also provide out-reach opportunities and could be supported in the operations room within the Innovation Centre at NOC.

- Obsolescence management and system upgrades (*Isis*) – Although *Isis* has been upgraded significantly over the years not all the systems have been changed. Thus, there is an ongoing need to upgrade systems as they break or become obsolete.

- Improve the operational reliability of the system (HyBIS) – The existing HyBIS platform, although highly capable, is still immature and has a number of design issues which makes it hard to maintain and operate. These issues need to be addressed to make the system more reliable and operationally effective.

- Extend operational capabilities (HyBIS) – The payload modules for HyBIS provide a limited set of options to the community. By developing new payload modules (e.g. precision push cores) the utility of the platform will increase.

Future Capability

- ROV virtual control room –Currently, it is possible to create a virtual control room, but this requires significantly higher bandwidth which is expensive. However, as it is intended to upgrade the ship’s data link to 2MB/s by 2019 this should provide enough bandwidth to create a simple virtual control room. As the ship’s up-link (ship to shore) is not utilised to the same level as the down-link, streaming live data from the ROV to shore should be achievable. This work will be done in collaboration with the Scientific Ship Systems group.

- ROV power supply replacement – The ROV (Jetway) power supply unit is the original system acquired for the ROV, and is coming to the end of its life. The replacement unit will be looked at in the broader context of power supplies for the remotely operated platforms supported by the group, and operated from the ship.

- ROV control software upgrades – The existing ROV software is still based on the early Jason 2 code from WHOI. This code makes interfacing new sensors into the control system difficult. This upgrade will look at modernising the control architecture and will also attempt to reduce the operator load when piloting the ROV.

- HyBIS command module upgrade – The existing HyBIS command module is unreliable, expensive to maintain and has limited upgradeability. To enhance the capability of the system a new command module will be developed. This will include both the physical hardware and the associated control software, and will significantly enhance the capability of the system. Due to the complete redesign of the module, the system has been renamed the Modular Payload Underwater Sytems (MPUS).

- Heave compensation for HyBIS – MPUS is an extremely flexible platform and allows precise control at the seabed; however, as it is directly coupled to the ship it is affected by the ship's motion. Heave compensation on the deep tow winch would greatly reduce this effect and would make the system more broadly useable.
- HyBIS recovery payload module – There are times when equipment is lost at sea, e.g. CTD frames, landers, and AUVs. Generally, it is possible to approximately locate the equipment, but there is usually no capability to recover the items. Under these circumstances either a highly expensive rescue mission is required or the equipment is written off. A suitably configured MPUS recovery module could be used to recover the lost equipment at minimal cost. Such a module could also be used for the recovery of landers in highly fished areas.
- Common interface module – Part of MPUS's flexibility is the ability to integrate different sensor payloads onto a mission specific payload module. Currently this involves considerable input from the ROV team which is costly. To simplify this process a generic payload module will be created with the associated detailed interface document. This will be produced to enable custom payload designs to be created by external users

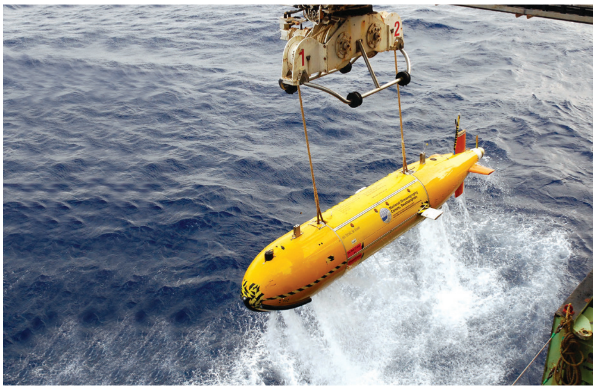
Aspirations

- Further enhance the ROV control software – Although we intend to upgrade the existing ROV control software as part of the obsolescence management of the vehicle, this upgrade will not focus specifically on reducing and simplifying the piloting load. Using autonomous behaviours has the potential to make piloting easier. This would reduce the training requirements for new pilots and the number of fully trained technicians required for the operations. Background research for these upgrades will be undertaken over the next five years.
- Create new payload modules and refine the concept of operations for MPUS – There are likely to be other MPUS modules which would significantly benefit the science community, and new modes of operation which can be exploited. The aspiration is to work with the science community to explore and develop these modules and modes of operations as and when resources and science priorities allow.

2018/2019 Update

- MPUS (HyBIS) Command Module Upgrade – The MPUS command module upgrade is progressing well. The system has been designed and the majority of the hardware has been purchased. The next phase will be assembly and software development
- Heave Compensation – The heave compensation was briefly tested on HyBIS as part of the DY094 cruise but proved ineffective. It is intended to test the heave compensation of the RRS *Discovery* as part of the 2019 vessel trials.
- ROV Virtual Control Room – Live streaming data from the vessels has been tested during JC165 and JC166 cruises. This demonstrated that there is sufficient bandwidth from the ship to be able to do this. The next steps will be to develop the concept further, and refine the hardware and software. We will then undertake more trials to test these refinements

High Power MAS Platforms



Current Capability

The high-powered Autonomous Underwater Vehicle (AUV) fleet developed by NOC is becoming routinely used for scientific data collection. The vehicles are particularly well suited to high-resolution acoustic surveys and under ice operations. However, they are now being requested to perform photographic surveys very close to the seabed. These photographic surveys are considerably more challenging and significantly increase the risk of loss or damage to the vehicle, and this trend in pushing the operational envelope of the vehicles and is expected to continue. Thus, the vehicles will need to continue to be developed.

- Autosub6000 AUV – The Autosub6000 AUV is an established vehicle, which has been continually upgrades since its first deployment in 2007. It is 6000m depth rated and has rechargeable batteries. This high-powered AUV, developed by NOC, is becoming routinely used for scientific data collection. It is particularly well suited to high-resolution deep water acoustic surveys.

- C-Worker 4 – MARS purchased a C-Worker 4 Unmanned Surface Vehicle in 2018 for use as part of the fleet. Although not a high power AUV, it has been purchased to support the high power AUV work. It has a modular payload bay and so will fulfil a number of roles. These include:
    - Tracking and communications with subsurface assets – The C-Worker will be equipped with a Sonardyne USBL beacon which will allow the USV to track and communicate with Autosub6000, ALR6000, and seabed landers. This tracking should significantly improve the AUV navigational accuracy, and reduce the ship monitoring time.
    - Shallow bathymetry surveys – The modular payload allows an EM2040 multibeam system to be fitted for high resolution bathymetric surveys.
    - Sensor testing – The C-Worker can also be used for testing oceanographic sensors, e.g. the sensors being developed as part of the Oceanids programme

Science Drivers

- Improved system reliability – The Autosub6000 has had significant issues with reliability as identified by the PCAs associated with JC120, JC132, DY021, DY030, & DY034. This is compounded by the internal lonworks control system being obsolete.

- Reduce ship monitoring time – The time required to monitor Autosub6000 to dive to depth, and to track it back to the surface has been highlighted as an issue by various scientists. Professor Russell Wynn commented on this during the first science cruise of Autosub6000 (JC027) and this was reiterated by the PCA for JC132.

- **Improve the obstacle avoidance system and AUV situational awareness** – The AUV is being tasked more to undertake photographic surveys close to the seabed (DY021,30,34 & JC136) and to perform surveys in extreme terrain (JC125). To make this more robust and to extend the operating envelope, it will be necessary to improve the AUV's obstacle avoidance system and situational awareness.
- **Improved vehicle autonomy** – The higher level of autonomy will be driven by:
  - The requirement for an improved obstacle avoidance system
  - A likely increased demand for adaptive mission planning of the AUV
  - Improved system health monitoring
- **Improve Autosub6000 navigational accuracy** – Autosub6000 has experienced problems with high-resolution navigation and attitude measurement. These problems have been seen in the camera survey work DY034, and the sonar surveys in JC044 and JC125. Resolving these issues would significantly enhance the quality of data collected by the AUVs. This improved navigational accuracy has been highlighted as a specific need for surveys of Marine Protected Areas where longitudinal studies need to survey the exact same area repeatedly
- **Replace Autosub3 under ice capability** – The retirement of Autosub3 removed the capability to make high power acoustic sonar measurements under the ice. Developments as part of the Oceanids project will provide an enhanced under ice capability from 2021 onwards.

Future Capability

- **Autosub6000 mid-life refit** – This refit will involve the redesign of a number of internal electronics systems to improve reliability and deal with obsolescence issues. The work will also create: a full set of system level spares; a system simulator to simplify the diagnostics of system level faults; and a new control container to reduce mobilisation time, and improve installation reliability.
- **Build Autosub2KUI to replace Autosub3** – The Oceanids project is funding the development of a fourth generation Autosub2000 which will be built to replace Autosub3. This will integrate the development work described below, and will incorporate a 2000m rated foam centre section to allow the AUV to carry double the energy of Autosub6000. This will allow the AUV to operate under ice in a similar fashion to Autosub3.
- **Develop a new on-board control system –** The on-board control system (OCS) of Autosub6000 is based around Lonworks, a mid-90s distributed computing system. This has served the AUVs well, but is now obsolete and is becoming difficult to support. Coupled to this, the internal control and electronics systems have evolved as different requirements arose and are now poorly documented and difficult to maintain. This has also resulted in a diverse range of software tools being required to run the AUV which has produce a complex and error-prone system. To alleviate these issues a new onboard control system will be developed. This will improve the system reliability, make it simpler to integrate new sensors, and will provide a modern and future-proof system for ongoing development. This development is funded as part of Oceanids and will be integrated into Autosub2KUI. Once fully proven it will be retrofitted to the existing Autosub6000.
  The OCS development will also be integrated into the Autosub Long Range control system upgrade. There will also be new under ice behaviours developed to allow the AUV to operate safely under ice. These behaviours will build on the original Autosub3

work, and couple this to the new OCS and OAS system to further enhance the under-ice capabilities

- Front seat / back seat architecture – MARS aims to adopt the OCS software architecture to enable science users to deploy deployment specific algorithms on board the OCS controlled vehicles using the front seat / back seat paradigm. For example, an externally written front following algorithm could be added to the backseat to enhance the science utility of the campaign

- Upgrade the Obstacle Avoidance and Situational Awareness –The current Autosub6000 obstacle avoidance system was developed in 2009 for work in the mid-Caymen rise as part of JC044. The system is optimised for operation in the rugged terrain seen around mid-ocean ridges. The design was constrained by the available deep rated sensor system and the processing power of the Lonworks systems. However, the AUV is now operating in more complex terrain (e.g. Canyons JC125) and close to the seabed for camera surveys (JC136). The current system will be upgraded as part of the Oceanids Autosub2KUI development to provide better situational awareness and will be coupled to the new OCS to enhance the operational envelope of Autosub2KUI. Once fully test the new obstacle avoidance system will be retrofitted to Autosub6000

- Monitoring of Autosub6000 / Autosub2KUI via a USV – A C-worker 4 unmanned surface vehicle will be used to monitor and track the AUVs using an integrated USBL. This monitoring will significantly reduce the ship time required to track the AUV at the start and end of the mission. It will reduce the navigation error of the vehicle as it won't be subject to the 0.1% of distance travelled error build up associated with dead reckoning as the USV will continually send down USBL position updates. The continual monitoring will also reduce the risk of vehicle loss, and so any deviation from course or collision with the seabed will be seen. The constant communication will also enable the use of more complex adaptive mission planning as the vehicle plan can be continually monitored as the plans evolve and so the risk of poorly adapted plans is reduced

Aspirations

- New sensor integration – The scientific requirements of an operational AUV continually evolve as research develops. For an operational AUV to remain useful its payload must keep pace with requirements. Continued close collaboration with the scientific user community will lead to improvements in sensors and keep our technology at the leading edge. Current scientific requirements include improved resolution camera systems and the use of a 3D camera for the Biocam project.

- Enhance inter vehicle co-operation – As we move towards multi-vehicle missions the systems will need to be developed so that they operate as a co-ordinated fleet. This will tie into the work associated with the long-range fleet command and control, but will be local to the existing vehicles.

- Enhanced vehicle Autonomy – As part of the new Onboard Control System development we will be producing a strong basic control system for the AUV. We intend to utilise this base platform and enhance it by layering on high level autonomy behaviours thereby increasing the utility of the vehicles to the science community. The goal is to build a broad library of behaviours which will support the data collecting. This will be achieved by developing specific, broadly applicable behaviours as part of defined science campaigns. This will allow us to test and prove the behaviours before they are added to the behaviour library.

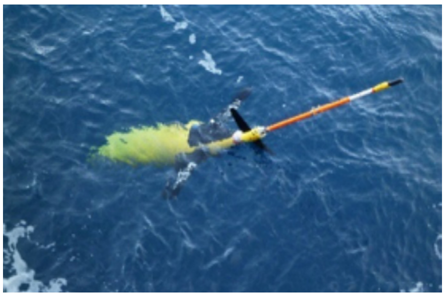
- Development and curation of data processing tools – As part of the NMF support to the science community we intend to create and curate tools to allow rapid processing of data, which can produce operational data products. These operational data products will not be publication quality but enable rapid assessment of the quality of the data gathered, and highlight areas of interest in the data which would require further investigation.
- Hover capable Autosub – Autosub6000 is only capable of conducting photographic survey in flat terrains. A hover capable AUV has the potential to be able to operate in close proximity to canyon walls, seamounts and other rough terrain.

2018/2019 Update

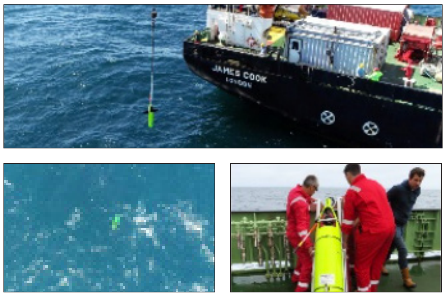
- Design of Autosub2KUI – Development of Autosub2KUI has entered the detailed design phase, initial trials are expected Q1 2020.
- Innovate UK A2I2 project – As part of a collaborative research and development project MARS will be developing a prototype hover-capable AUV.
- Autosub6000 mid-life refit – Following a number of reliability issues with Autosub6000 it was clear that the vehicle needed a mid-life refit and this could not be achieved while still supporting science. This refit started Q4 2018, and will complete Q3 2019 for the upcoming DY108/9 expedition.
- C-Worker 4 commissioning – Following the purchase of the C-Worker 4 it was trialled as part of the JC166/7 expedition. Unfortunately a number of issues were identified during this trial which needed to be rectified by the manufacturer. These are being undertaken and all being well we expect the vehicle to be operational within the NMEP by the end of 2019.
- Low Cost AUV Technology (LCAT) Project – The LCAT project is focused on developing smart networks of vehicles to improve navigational accuracy. It builds on the aspiration to develop inter vehicle co-operation.

Underwater Glider Platforms

Slocum glider



Seaglider



Deepglider

Current Capability

The underwater gliders within the MARS long-range fleet are listed below. However, these vehicles can be equipped with a variety of different sensors, and ancillary systems which will enhance their basic capabilities. For a full understanding of these capabilities it is necessary to speak to the engineering manager responsible for the relevant platform:

- 10 x Seagliders
- 23 x Slocum gliders (200m & 1000m)
- 1 x University of Washington Deepglider (6000m).

Science drivers

- Reduction in operational cost – Reducing these costs will allow a higher utilisation of the fleet and thereby increased science impact.
- Improve system reliability – The gliders, although commercial systems, still have reliability issues. Improving process control will enhance reliability and thus science delivery
- Under ice capabilities – Surveying under the Arctic and Antarctic ice shelves is of growing scientific importance. Gliders could in theory collect data from beneath the ice and a long way from the ice front, but there are a number of challenges which need to be overcome before this can be practically achieved.
- Improve navigational accuracy – The sub-surface navigational accuracy of gliders is poor. For many applications this is not an issue, however for long duration sub-surface missions (i.e under ice) improvements are required.
- Deeper operations (gliders) – Current gliders are limited to 1000m depths. This is insufficient for a number of applications, and hence deeper gliders are desirable
- Instrument calibration (gliders) – Pre- and post-deployment calibrations are currently time consuming, potentially removing the vehicle from the fleet for several months at a time.

Future Capability

- Deep gliders – Deeper operation of the glider fleet will become available through the purchase of a University of Washington Deepglider. In addition, NOC is involved in the development of a deep glider as part of the Horizons 2020 BRIDGES project. The H2020 glider project will be completed by the end of 2019.

BRIDGES glider project

- Rechargeable batteries Slocum gliders – Glider currently use single use (primary) cells to maximise the energy for a deployment. However, for shorter or higher power deployments a rechargeable pack is more appropriate – These packs would significantly reduce the deployment costs as no battery purchase is needed. MARS has undertaken an evaluation of the benefits of these rechargeable packs, and has recently purchased a set for evaluation.
- Under Ice Operations – It is desirable for the glider fleet (both Slocum and Seaglider) to be able to operate under the ice in both the Arctic and Antarctic. Currently these have little if any specialised capabilities to do this. We will endeavour to upgrade the glider software to integrate the ice-avoidance behaviours into the glider fleet software to minimise the danger of operating in ice-covered regions. Finally, RAFOS infrastructure is being purchased as part of Oceanids to enable navigation under ice using long range acoustic beacons. The technique requires a number of low frequency sound sources at known locations transmitting at known times. The receivers on the vehicle pick up these signals and by knowing the time offset can estimate their position. The sound sources have been purchased and the receiving element will be developed over the next few years.
- Sensor Integration – New sensors are continuing to come on stream and will need to be integrated into the long-range fleet. As part of the Oceanids Sensors programme the long-range fleet will have a common sensor interface developed which should simplify the integration of new sensors in the future.
- Improved system reliability – Process control will continue to improve, and new checks will be introduced to catch errors early. For example a helium leak detector is being used to fine micro leaks before the glider is deployed.

Aspirations

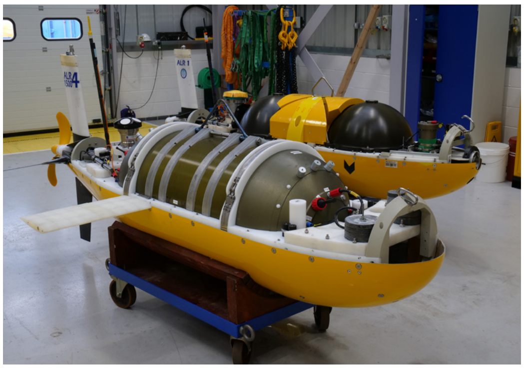
- New lower cost primary packs for gliders. Current glider packs typically use Electrochem Lithium Sulfuryl Chloride cells. These cells are highly expensive and the battery packs form a large portion of the battery deployment cost. Other cell chemistries are available and we are looking at the potential of developing a lower cost battery pack with similar energy density. If successful, this would significantly reduce the deployment cost for the gliders without impacting the survey range.

2018/2019 Update

- Trials of Deepglide – The Deepglider was successfully trialled as part of JC166/7 expedition in June 2018 (https://www.noc.ac.uk/news/new-deepglider-ocean-robot-successfully-trialled-southwest-uk), and we are currently purchasing a second Deepglider for the NMEP
- New helium leak detector – A new helium leak detector is being used to test for leaks in the glider prior to deployment. This should capture some micro-leaks which would not normally show up and so should improve the reliability of the gliders in the field
- New rechargeable Slocum packs – As part of the fleet upgrade we have purchased a rechargeable battery pack for the Slocum gliders

Long Range AUV Platforms

Current Capability


ALR6000 Front ALR15000 back

The long range AUVs under development for the MARS long-range fleet are listed below. These vehicles can be equipped with a variety of different sensors, and ancillary systems which will enhance their basic capabilities. These novel vehicles are not yet fully supported in the NMEP but may be accessed by the science community through collaboration with the MARS Development Group:

- 3 x Autosub Long Range 6000 (ALR6000)
- In Development 3 x ALR15010

Science Drivers

- Increase system energy (ALR) – The current 6000m rated system does not have the necessary energy for some of the applications currently being proposed. This is because these applications have higher sensor loads, and require increased operational speed.
- Improved on-board control system (ALR) – There is a trend to deploy large mixed fleets of long range MAS for large area data collections. Thus, the ALR needs to be capable of being integrated into these fleets, as described in the Long Range C2 section.
- Hibernation capability (ALR) – There are a number of applications which require long-term periodic monitoring. This monitoring could not be accomplished in one ALR mission but the ability to hibernate on the seabed would allow these missions to be undertaken.

Future Capability

- ALR1500 – To increase the payload power capacity and operational speed of the ALR6000, extra energy is required. To achieve this increase in energy, a shallower rated (1500m) ALR variant is being developed as part of the Oceanids ALR1500 project. This will use a single central pressure vessel which will be more buoyant than the current 6000m rated system and hence will allow more batteries to be installed into the vehicle. The ALR1500 vehicle will be developed for under ice operations, but could also be used in other areas such as carbon capture and storage monitoring
- Improve ALR Control System – The existing ALR control system has been tailored to a specific deployment programme. Thus, the system needs to be further developed to create a more general system for future deployments. To simplify this development the ALR control scheme will be integrated to the OCS development mentioned for the high power AUVs. This approach will maximise the benefits of the software development efforts with MARS. The ALR OCS variant will also include the front seat / back seat paradigm to allow users defined algorithms to be installed on the ALR vehicles.
- Under Ice Operations – It is desirable for the ALRs to be able to operate under the ice in both the Arctic and Antarctic. Currently these have little if any specialised capabilities to do this. Over the next five year we will build detailed under-ice behaviours for the ALR based around the new on-board control system. This will include using terrain-aided navigation techniques to allow arctic basin crossings. Finally, RAFOS infrastructure is being purchased as part of Oceanids to enable navigation under ice using long range acoustic beacons. The technique requires a number of low frequency sound sources at

known locations transmitting at known times. The receivers on the vehicle pick up these signals and by knowing the time offset can estimate their position. The sound sources have been purchased and the receiving element will be developed over the next few years.

- Rechargeable packs for ALR – Currently the ALR (both 6000 and 1500) uses lithium primary packs for their operations. However, for certain higher power shorter duration missions this approach is expensive. A high capacity lithium rechargeable pack would enable the vehicle to undertake shorter duration, higher power missions in a more cost-effective fashion. We intend to explore options for the development / purchase of a suitable pack for the ALR

- Improving Navigational Accuracy – There are a number of areas where improvements in navigational accuracy will be introduced into the long-range AUVs. These developments include:

  - Integration of a high precision AHRS into the ALR
  - Developing improved navigation techniques as part of the Innovate UK funded P3Nav project.

- Simulation Environment – MARS will develop tools to accurately simulate ALR missions prior to deployment to help identify bugs in the software system.

Aspirations

- ALR hibernation capability – To allow the ALR6000 to increase its endurance and to perform period monitoring of a specific area, techniques will be developed to allow the ALR to hibernate while still maintaining navigational accuracy

- General AUV improvements – As with the higher power vehicle aspirations we also intend to:

  - Enhance inter vehicle co-operation
  - Enhanced vehicle autonomy
  - Develop new concepts of operational and undertake application- specific developments
  - Develop and curate operational data processing tools.

2018/2019 Update

- ALR1500 – The first ALR1500, ALR4, has been manufactured and is undergoing factory acceptance testing (FAT), and should complete harbour acceptance testing (HAT) in Q1 2019. ALR5 and ALR6 will follow throughout 2019.

- Improve ALR Control System – A new onboard control system has been developed for ALR based on the ROS middleware. This software will be tested as part of the ALR4 FAT and HAT.

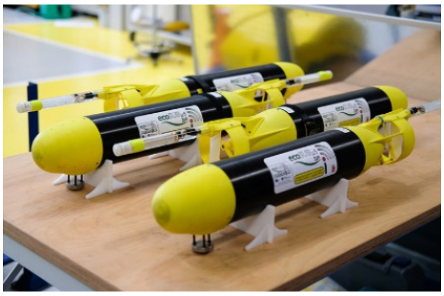
- USV/LRAUV Tracking – A prototype system demonstrating USV tracking of ALR was trialled in Loch Ness in May 2018 as part of the Innovate UK Autonomous Surface / Subsurface Survey System project.

- P3NAV – Initial trials of an ALR fitted with a novel hybrid INS/MEMS/DVL navigation system were conducted with Sonardyne in Loch Ness in December 2018. This work will continue in 2019/20.

- **Simulation Environment** – A high fidelity physics based simulation of ALR has been developed and is actively being used to de-risk HAT activities.

Low Infrastructure AUV Platform

Gavia AUV



ecoSUB AUVs

Sparus2

Current Capability

- **Gavia AUV** – The Gavia AUV Freya is a small, lightweight system which can be operated from a small boat. It has a 500m depth rating and is equipped with a GeoSwath+ sonar (bathymetry and sidescan) and camera system

Science Driver

- **Inshore deployments** – The current NMEP fleet is predominately targeted at open ocean operations. Smaller man-portable platforms have a role to play in monitoring of near shore Marine Protected Areas

- **Low infrastructure vehicles** – Global Challenges Research Fund projects such as SOLSTICE have highlighted a requirement for low cost and low infrastructure vehicles for work with developing nations

- **Surrogate vehicles for de-risking trials** – The large AUVs in the NMEP are expensive to trial and hence new functionality is often tested in the field on science campaigns. For some developments it is feasible to de-risk these developments through the testing of lower cost surrogate vehicles

Future Capability

- Low Cost Platforms – MARS have been working in partnership with Planet Ocean to develop the ecoSUB range of very low cost AUV platforms

- Surrogate vehicles – A Sparus2 AUV has been purchased by the MARS development group for the testing of collision avoidance behaviours.

Aspirations

- The intent is to further enhance the NMEP with low logistics platforms (for example ecoSUBs), subject to available funding.

2018/2019 Update

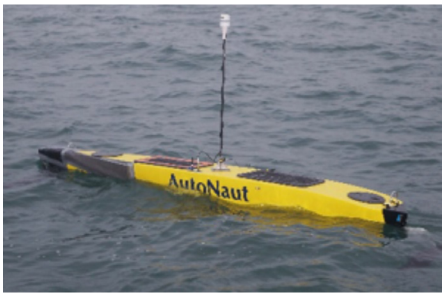
- **ecoSUBs in the North Sea** – Two ecoSUB AUVs were deployed in the North Sea as part of MASSMO5b where they successfully collected and transmitted vertical profiles of speed of sound

- **Low Cost AUV Technology (LCAT) Project** – A fleet of six ecoSUBs was deployed in Loch Ness in January 2019 as part of the Innovate UK funded LCAT project which demonstrated collaborative operation and localization of a fleet of vehicles

- **Gavia Upgrades** – As part of the upcoming use of the Gavia on the JC180 expedition a new Sub-Bottom Profiler module has been purchased along with a science bay and new battery pack. The science bay can be installed with sensors from the NMEP to increase the measurement capabilities of the Gavia.

Long Range Unmanned Surface Vehicles

Waveglider SV3



Autonaut

C-Enduro

Current Capability

The long range unmanned surface vehicles currently available in the MARS are listed below. They are split into proven platforms, which have demonstrated their ability to reliably deliver scientific data, and experimental platforms which show promise, but are still immature. All of these vehicles can be equipped with a variety of different sensors, and ancillary systems which will enhance their basic capabilities. For a full understanding of these capabilities it is necessary to speak to the Engineering Manager responsible for the relevant platform.

Proven Platforms

- 2 x Waveglider SV3

Experimental Platforms – not recommended for science

- 1 x AutoNaut
- 1 x C-Enduro.

Science Drivers

- **Acoustic gateway for data harvesting** – Unmanned surface vehicles are an ideal platform to act as an acoustic gateway to harvest data from subsea moorings and landers. For example this would be very useful for the RAPID Array as it would allow period collection of the moorings data between the mooring turn around expeditions

- **Acoustic gateway and navigational aiding** – Unmanned surface vehicles are also an ideal platform to act as an acoustic gateway and navigational aid to long range sub-surface vehicles

- **Measuring air sea pCO_2 gas exchange** – Measuring the air/sea pCO_2 gas exchange is vital to understanding how the oceans and atmosphere interact. USVs provide an ideal platform for directly monitoring this gas exchange.

Future Capability

- Acoustic gateway and navigational aid (USVs) – The USV fleet provides an ideal method of gathering data from fixed sea-bed arrays acoustically, and also providing a navigational aid to sub-surface vehicles. To develop these capabilities MARS is part of the ACSIS trial which will be using a waveglider to acoustically harvest data from the RAPID array; and the Innovate UK ASSS project which will couple a long-range surface vehicle to the ALR to act as an acoustic gateway and a navigational aid. These techniques will continue to be developed and it is anticipated that these capabilities will be available to the community for routine operations within the next few years
- Measuring air sea gas exchange – Measuring the air/sea gas exchange is vital to understanding how the oceans and atmosphere interact. USVs provide an ideal platform for directly monitoring this gas exchange. MARS will work with the science community to adapt the USVs so that they can provide a platform to measure this gas exchange. The CaPASOS projects will measure pCO_2 from USVs.

Aspirations

- Develop the AutoNaut USV for use in the NMEP – The AutoNaut vehicle 'Gordon' has proved to be unreliable, and although in principle a competent platform, is not fit for long-term science. There is an aspiration to upgrade the platform to resolve existing reliability issues and to closely integrate the system into the C2 architecture. Once this work is complete the approach could be extended to the large AutoNaut platforms
- Review the use of the C-Enduro – The user case for the C-Enduro will be evaluated to understand where it adds value in the NMEP. If it cannot be shown to be of benefit we will recommend that it is removed from the pool.

2018/2019 Update

- Waveglider Acoustic Modem Trials – The Sonardyne Acoustic modem was tested during the JC166/7 expedition, and demonstrated that it could reliably communicate down to 4000m. The results also suggested that 5000m could be reasonably expected

Long Range MAS Platforms Command and Control (C2)

Due to the different control infrastructure for each vehicle, there is currently no way to run a large mixed fleet of vehicles in a simple co-ordinated fashion. To maximise the effectiveness of the MARS fleet it is necessary to develop a unified control system to support mixed fleets and to tightly integrate this with automated data ingestion into the British Oceanographic Data Centre (BODC). The development efforts for this is funded by the Oceanids C2 project.

Current Capability

The current command and control system for the long range fleet consists of the following components:

- ALR control interface
- Slocum control interface
- Seaglider control interface
- Waveglider control interface

- Autonaut control interface
- C-Enduro control interface
- MARS piloting portal (http://mars.noc.ac.uk)

Science Drivers

- Simplify the piloting process – The current piloting system consists of a different user interface for each different platform. This results in significant pilot training costs, and makes operating a fleet of diverse vehicles difficult.
- Semi-automate / Automate vehicle piloting – To reduce the piloting demand semi-automated piloting should be developed, both to reduce the deployment cost and to optimise the data collection
- Reduced data processing overhead – The overhead in time and money of ingesting the data from the long-range MAS platforms into BODC is considerable, and can be significantly reduced through automation.
- Improved deployment visibility and outreach – The current deployments for the long-range MAS fleet are not clearly visible to the science community and the wider public. Improving this visibility will assist with outreach and show UK science in action

Future Capability

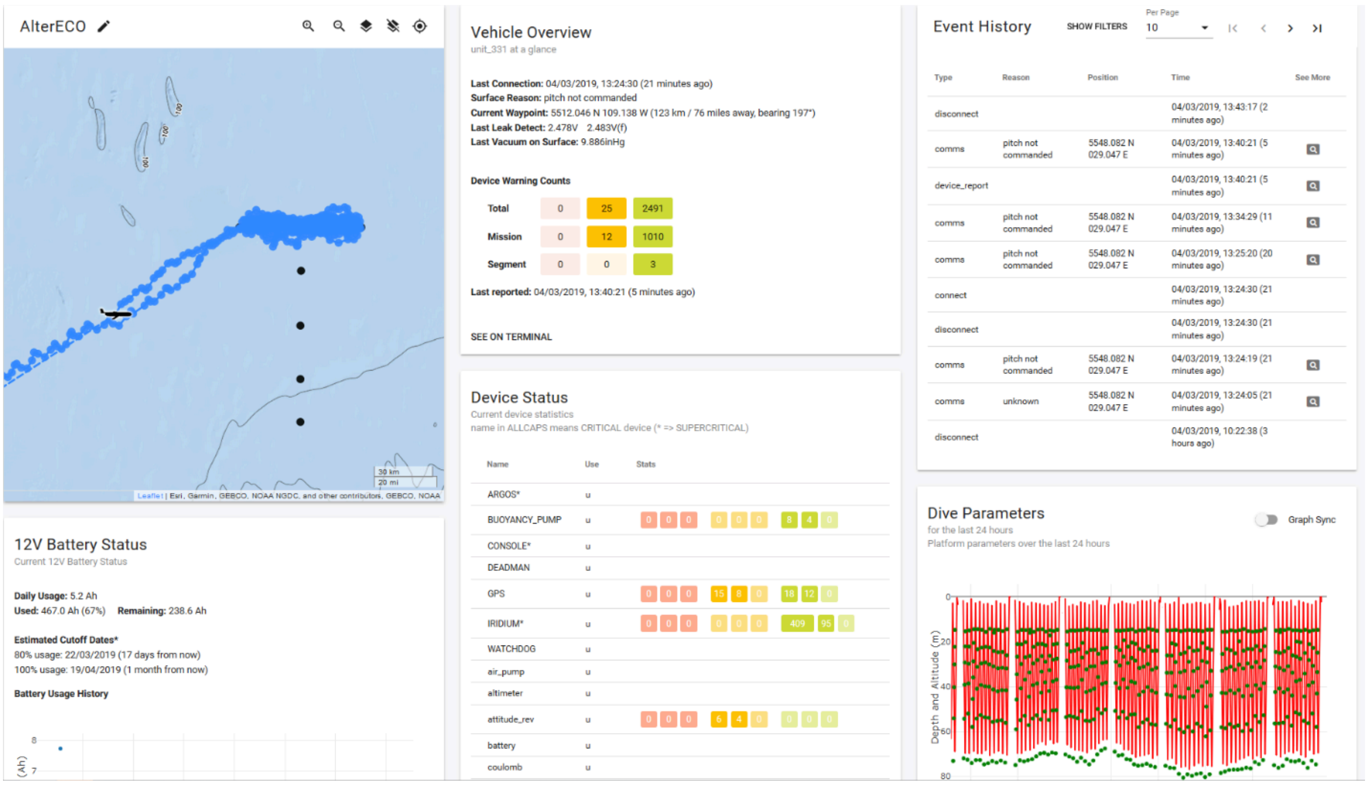
- Unified control interface – A unified control interface will be developed to simplify the deployment of mixed fleets of vehicles. This interface will be simple, intuitive, yet powerful enough to allow the pilot to create complex mission plans. The interface will build on the investment that has already taken place in this area, and will be integrated into all of the long-range fleet. The development will be undertaken using an agile approach and so iterative upgrades to the system will occur throughout the project duration. The control interface will be available to the wider UK community for piloting and monitoring of the assets
- Vehicle Data Processing, Curation & Availability – The near real time data generated by the vehicle needs to be automatically gathered, processed, QC'd and ingested into BODC or a similar curation facility. This should be done as close to real time as possible so that it is available for the pilot (human or computer) and can be ingested into forecasting models. The data will be stored in a standard format (e.g. EGO NetCDF) for simplified distribution. The data gathered will also be available via the Piloting Website in real time
- Automated piloting infrastructure – To reduce the piloting load required for mission, an automated piloting infrastructure will be created. This will allow rapid development of automated piloting routines / integration of third party piloting algorithms for applications using a variety of vehicles
- Scientific data fusion – This part of the C2 development will generate data products from the long-range MAS platforms from the near real time data. These data products can be combined with data from other sources to both validate the data gathered, and also to guide the platform to optimise the data collected
- Engineering data fusion – This aspect of the work will develop approaches for automatic fleet heath monitoring and mission risk evaluation to better inform human pilots or automated fleet controllers

- MAS Control Room – A bespoke MAS control room will be developed at NOC for stakeholder engagement around ‘over-the-horizon’ operations.

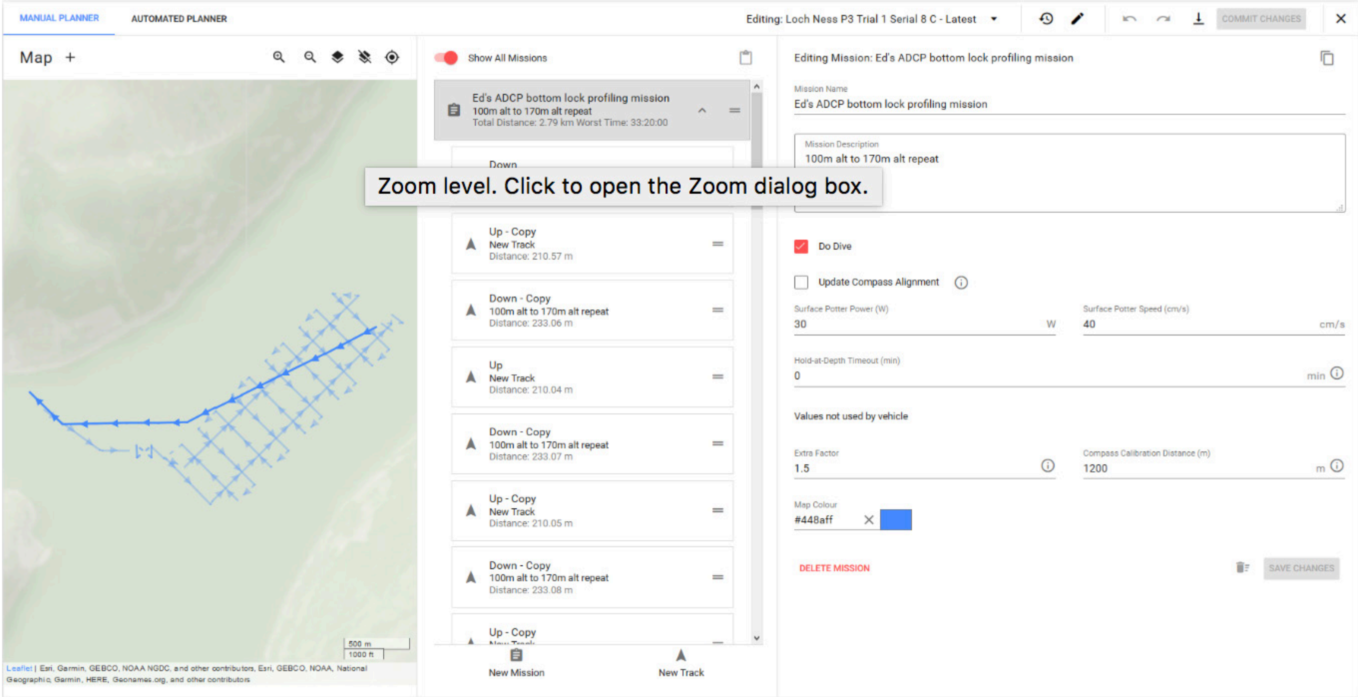
Aspirations

- Extend the C2 infrastructure to other NMF assets – The development of the website tool provides real time data to the vehicle pilots and will be useable by the wider science community. We intend to investigate using this functionality in other aspects of NMF, specifically the website front end and associated back end ingestion system into BODC. These could be applicable to near real time data from moorings and the NOC research vessels.
- C2 continued development – The Oceanids C2 development will significantly enhance the operations of the fleet, but it will not cover all requirements. Thus, we intend to further enhance the command and control as and when new requirements and resources become available
- Integration with the OCS – The ambition is to more tightly integrate the C2 infrastructure with the OCS, thereby improving the control and autonomy of the long range fleet.

2018/2019 Update



- Oceanids piloting tools – The unified Oceanids web portal has been rolled out to beta testers for piloting of Slocums, Seagliders and ALRs (see images above)
- Glider near real-time data processing – Near real-time data from MARS gliders can now automatically be engested into BODC and provided in EGO net-cdf format
- Automated piloting framework – A prototype of the automated piloting framework will be trialled alongside an alterEco deployment near Dogger Bank in February 2019
- Newly commissioned control room – The MAS control room has recently been commissioned, and will be used for upcoming large scale deployments.



Gravimeter

AT1M Gravimeter

Current Capability

- The AT1M-12U gravimeter was added to the NMEP in 2018 as an upgrade to the obsolete S040 meter
- The S084, also now approaching end-of-life, and whose component parts are becoming harder to replace or support, remains to be upgraded
- Both generations of the meter are zero-length spring gravimeters which are mounted within a gyro-stabilised platform

Science Drivers

- To counter increasing reliability issues with ageing hardware, the decision was made in 2017 to upgrade our S-Series meters to the AT-Series
- Feedback from our scientific users pertaining to the first upgrade indicates that it would be desirable to run trials to compare the performance of the AT1M-12U meter with our S084 meter.

Future Capability

- In 2019/2020, the aim will be to restore the S084 to working order in order to run it alongside the AT1M-12U in the summer trials period. Their performance will be evaluated by NMF Scientific Ship Systems working with a marine geophysics user group. The conclusions from this analysis will be used to specify the upgrade or replacement of the S084 for introduction into service in 2020/2021.

Aspirations

- To work in partnership with the marine geophysics community to operate and support two, state-of-the-art marine gravimeters
- To explore the possibility of integrating gravimeters into AUVs and ROVs.

2018/2019 Update

- The AT1M-12U gravimeter was tested on the RRS *James Cook* trials cruise and RAPID to collect data about its performance.

Magnetometers

Current Capability

- NMF Ship Scientific Systems operates three, older-generation SeaSpy1 magnetometers and one new SeaSpy2 magnetometer.

SeaSpy being prepared for deployment

Science Drivers

- The two generations of magnetometer have incompatible component parts. This raises difficulties when magnetometers are required to be mobilised at the same time: changing from one to the other requires spooling a new cable onto the winch drum and faulty parts cannot be swapped out at sea.
- The newer generation is lighter, easier to handle on deck, and has better absolute accuracy

Future Capability

- In 2020/2021 (or earlier, if possible), the aim will be to purchase a new SeaSpy2 to give us two consistent mobilisation kits
- In 2021/2022 (or earlier, if possible), the aim will be to replace the two remaining SeaSpy1 magnetometers with SeaSpy2s.

Aspirations

- To work in partnership with the marine geophysics community to integrate magnetometer acquisition into the shipboard acquisition and quality assurance systems.

2018/2019 Update

- Due to other commitments, purchasing another SeaSpy2 was deferred to 2019/2020
- A module was implemented in a trial Techsas system to collect SeaSpy data and thus integrate it with the shipboard data acquisition system. Providing magnetometer data in the NetCDF data products enables our partners in the marine geophysics community to start developing quality checking tools for this dataset.

Ship-fitted hydroacoustic suite

Current Capability

- NMF Ship Scientific Systems operates on each ship, a hydroacoustic suite consisting of: Kongsberg EM122 Deep Water Multibeam, Kongsberg EM710 Multibeam, Kongsberg EA640 Singlebeam, Kongsberg SBP120 Sub-bottom profiler, Kongsberg EK60 Fisheries Echosounder, Teledyne RDI OS75 Acoustic Doppler Current Profiler, Teledyne RDI OS150 Acoustic Doppler Profiler, Sonardyne Ranger2 USBL Underwater Positioning System.

Science Drivers

- Kongsberg. The Kongsberg SBP120 is approaching end-of-support with obsolescence due in 2021
- OS-Series ADCP. Our Ocean Surveyor (OS) ADCPs are operated with Teledyne VMDAS with analysis undertaken with Teledyne WinADCP. There is strong support in the scientific community to integrate the University of Hawaii's ADCP control, acquisition and analysis package UHDAS + CODAS, as these have become part of the standard suite of analysis tools in the field of ocean currents

Future Capability

- Kongsberg – In 2019/2020, it is planned that the SBP120 will be upgraded to SBP27 on both ships. This will involve the replacement of the topsides amplifier and processing units followed by deep-water commissioning. This upgrade will only proceed if there is the opportunity to undertake commissioning
- OS-Series ADCP. In 2019/2020, the topsides computer system for the ADCPs will be augmented on both ships to provide the option for scientists to use UHDAS + CODAS.

Aspirations

- To work with manufacturers to manage the upgrades to obsolescence in our ship-fitted hydroacoustic suite.
- To work in partnership with the scientific community to explore ways we can adapt our capabilities to best meet their needs.
- To work with manufacturers to trial new technologies.

2018/2019 Update

- No updates from last programme year.

Ocean and atmosphere monitoring

Current Capability

- NMF Ship Scientific Systems supports and operates ocean and atmosphere monitoring stations on each ship. These measure wind speed, wind direction, air temperature, humidity, solar irradiance, air pressure, salinity, conductivity, water temperature, flow rate, water fluorescence and transmittance through water. A Near-Real-Time (NRT) processing system automates the transmission of regular summaries of this data to the BODC to support near-real-time continuous ocean monitoring. Another automated processing system takes recent CTD cast data, summarises this and transmits it to the Met Office for ingestion into forecast models.

Science Drivers

- In order to support BODC's drive towards robust, NRT monitoring of essential ocean variables (EOV) upgrades will be developed and implemented to streamline the data acquisition pipeline and the integration of metadata. The aim is to be able to easily scale our ocean and atmosphere monitoring to take on new sensors to collect the full range of EOVs. This work is closely linked to the work being undertaken with our data acquisition systems.

Future Capability

- The aim is to develop and implement a system control and data acquisition (SCADA) standalone ocean and atmosphere monitoring station, with an integrated database and configuration interface leveraging the latest web-based technologies, such as Influx, NodeRED and Python. This shall interface with the ship's data acquisition system, metadata manager and NRT transmission modules to provide an extensible, robust pipeline for the measurement of EOVs.

Aspirations

- To work in partnership with BODC and C2 Developers to develop applications which integrate with BODC's data ingestion services.
- To work with PML to increase underway use of the pCO_2 system fitted to RRS *Discovery* and RRS *James Clark Ross*, to take advantage of opportunities to fill in some of the gaps in data from areas less surveyed.

2018/2019 Update

- The old LabView-based acquisition system was replaced with Python and augmented with the Influx database to provide local storage of collected data for onwards transmission. NodeRED was explored as a technology to permit easier configuration of NUDAMs (a type of A2D converter). Two-monthly meetings were arranged with BODC and developers in MARS to help co-ordinate and feedback on development. The flow rate sensor for the water sampling system was introduced, along with updates to the acquisition software to enable the acquisition of flow rate data.

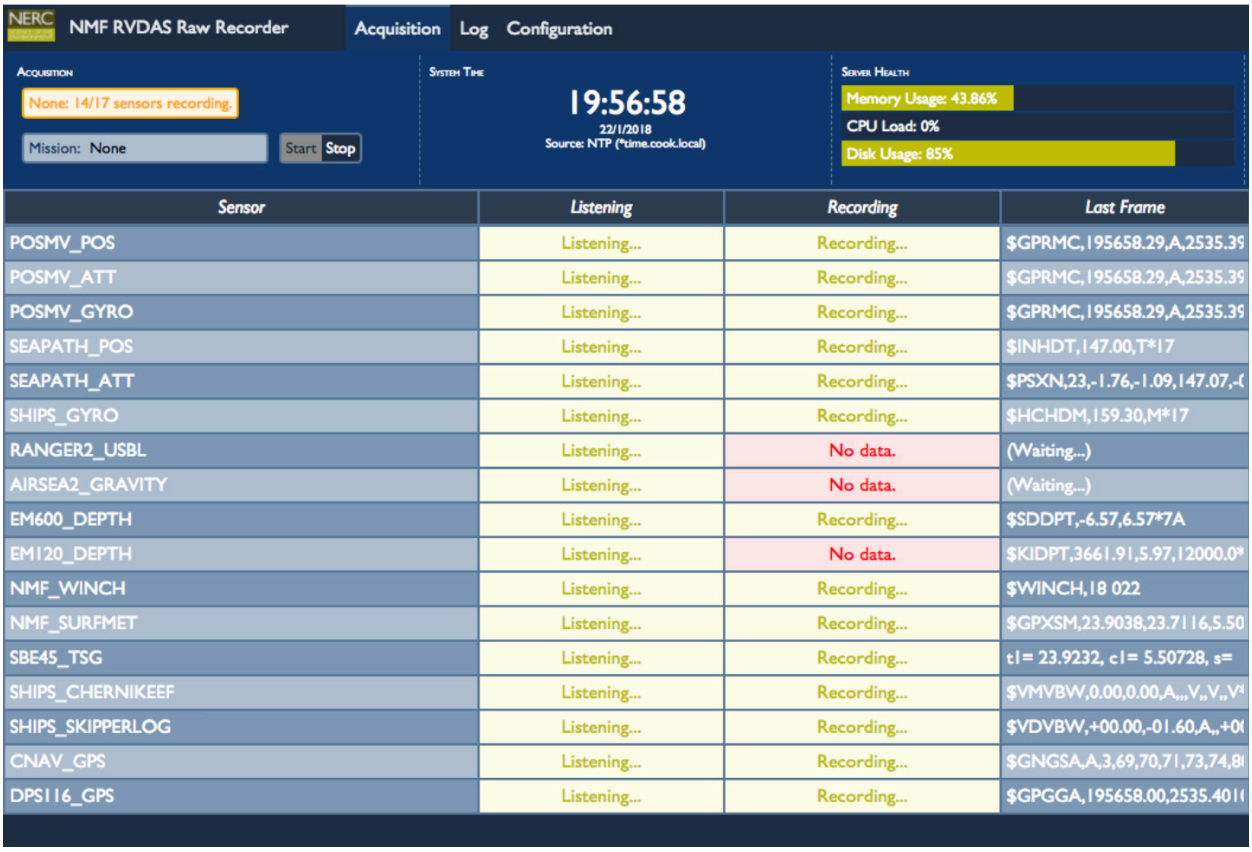
Data acquisition systems

Current Capability

NMF Ship Scientific Systems supports an acquisition network which collects serial and UDP messages from our suite of sensors for acquisition by Ifremer TECHSAS and NMF RVDAS. Position, attitude, heading, ocean and atmosphere, depth, gravity, wave radar and USBL fixes are collected by our acquisition systems.

Science Drivers

- Developments to our acquisition systems are organised into themes of collection, evaluation, organisation and dissemination:



The NMF Research Vessel Data Acquisition System (RVDAS) front-end

- ### Collection

  Developments in this area target data security, sensors, network infrastructure and metadata. The growing requirement to transmit and share near-real-time data to a number of consumers both onboard and ashore requires better integration of metadata. The increasing importance of the data products to a wide range of end-users also requires measures to be taken to ensure the security of data through redundant storage and parallel acquisition networks that eliminate single-point failures.

- ### Evaluation

  The growing requirement to transmit and share near-real-time data requires quality checking (QC) to be expanded to include automated engineering QC, which processes and flags data which fails basic integrity checks. Furthermore, in working in partnership with the scientific community, it is desirable to integrate specialist community-developed QC processes which can evaluate datasets such as gravity and magnetics.

- ### Organisation

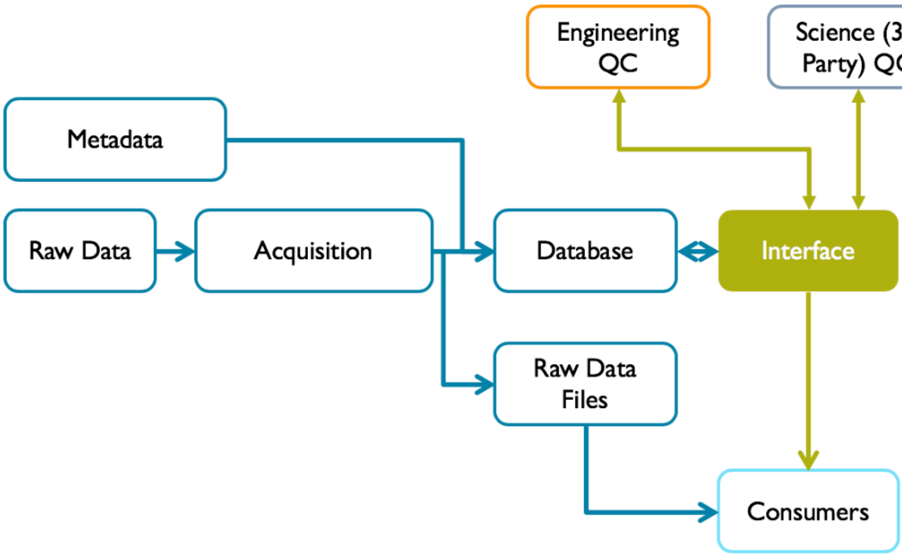
  In order to transmit meaningful data to the wide range of consumers onboard and ashore, it becomes necessary to structure the data storage into databases, with the ability to apply metadata at the creation of data products.

- ### Dissemination

  Providing access for people and processes to structured data and metadata requires suitable interfaces to be developed to the databases. Such interfaces would enable the development of modular 'post-processors' which would query the database and produce specific data products, such as NRT streams to BODC, onboard data servers or post-processed bespoke data products.

Future Capability

The aim is to build a comprehensive, modular, interface-driven system which enables extensible acquisition and collection of events and other metadata, plug-in QC routines, the storage of structured data and the scalable dissemination of data products to a range of consumers.



Concept of a modular acquisition system with a unified interface to consumers

In the short term:

- a free-form event logger will be developed, following BAS's design to provide contextual metadata. In the longer term, this will be extended to integrate with BODC vocabularies and to provide deployment metadata with NetCDF data products.
- a basic metadata system will be developed to store the information associated with the ship's sensors in a machine-readable way. This will provide the parsing instructions to convert raw data into database rows. In the longer term, this will be integrated with the BODC sensor library.

In the medium term:

- an interface will be developed to allow machine readable access to the database (as an application programming interface (API)).

In the longer term:

- a series of post-processing modules will be developed to interact with this interface and provide particular services, such as an onboard data server, NetCDF generation, NRT streams and data monitoring.

Aspirations

- To work with BODC and the British Antarctic Survey to align our developments to the needs of our data centres and scientific stakeholders
- To work with BODC to develop applications which integrate into BODC's data ingestion services.

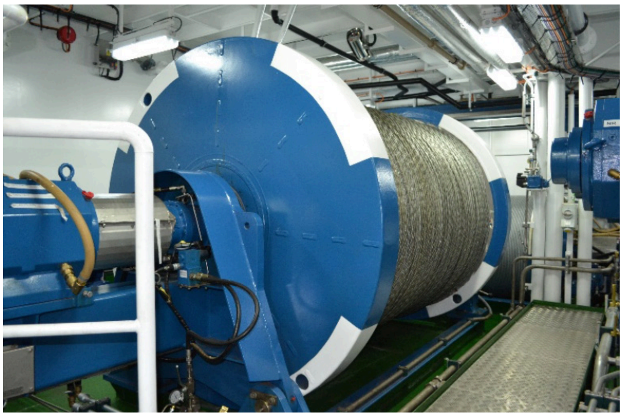
2018/2019 Update

- At the 2018 refit, the ship's VM server infrastructure was replaced with new, supported hardware. The acquisition network was duplicated to eliminate the serial-to-UDP converter (Moxa) as a single point vulnerability. NMF RVDAS, which logs raw NMEA, was updated to rebroadcast acquired data to permit downstream ingestion into a database. An event logger, working to the same design as BAS, was developed to be compatible with our VM systems, to serve as a starting point for later integration with BODC vocabularies
- Two-monthly meetings were arranged with BODC and developers in MARS to help coordinate and feedback on development
- Several meetings between BAS and NMF took place to explore avenues of cooperation.

Winches

Current Capability

- The NMEP includes a comprehensive suite of deck winches including: 1 tonne – 5 tonne rated general purpose winches, 5 tonne rated North Sea winches and a 10 tonne GPC winch as well as winches specific to mooring deployment, VMP/SeaSoar/scanfish platforms and seismic operations
- In addition, the NMEP has two metal free portable winches, one electrical and one electro-optic. After repair, both require trials to return to service in 2019.



Winch drum on RRS Discovery

Science Drivers

- Reliable winches that can be operated in all conditions by NMF technicians or, where appropriate, NMF mariners. There will always be a trade-off between the use of general-purpose winches which are easier to maintain and operate and bespoke winches which can be more complicated to operate and more expensive to maintain.

Future Capability

- An analysis of winch usage from 2015 onwards will be undertaken by NMF in 2019. This will inform a review of the winches held within the NMEP.

Ancillary Equipment and facilities

Calibration Laboratory

Current Capability

- NMF currently has a bespoke ocean instrument calibration facility open to internal and external customers capable of high quality temperature, conductivity, salinity and pressure calibrations.

Science Drivers

- The integrity of any scientific endeavour is dependent upon the accuracy of measurements. Calibration can be an expensive and time consuming business. This in-house facility allows us to offer a competitive, fast service to scientists and technical groups. We work closely with the Ocean Technology and Engineering Group to test their development sensors.

Future Capability

- Develop a glider calibration facility for the full sensor bay including a Seabird 911+
- Design and build a temperature calibration bath
- The NMF Calibration Lab is fully traceable to National Standards. In addition, we aim to achieve full ISO9001 accreditation by MFAB 2020.

Aspirations

- Undertake a review of NMF sensors to determine if this facility should be expanded.
- Maximise the use of the Calibration Laboratory by NOC teams, and reduce the volume of equipment calibration subcontracted outside of NMF within the resource capacity of the facility.

Container Laboratories

Current Capability

The current fleet of container laboratories includes radionuclide, clean chemistry, constant temperature and general purpose containers.

Science Drivers

These container laboratories will continue to supplement the laboratory facilities onboard the RRS *James Cook* and RRS *Discovery* as well as other ships.

Future Capability

As part of the five-year rolling plan NMF will purchase one new ‘clean chemistry’ lab and one new radionuclide lab over the next two years.

Acronyms

ADCP	Acoustic Doppler Current Profiler
AHRS	Attitude-Heading Reference System
ALR	Autosub Long Range
AMT	Atlantic Meridional Transect
AUV	Autonomous Underwater Vehicle
BAS	British Antarctic Survey
BODC	British Oceanographic Data Centre
CaPASOS	Calibrated pCO2 in Air and Surface Ocean Sensor
CODAS	Common Ocean Data Access System
COMICS	Controls over Ocean Mesopelagic Interior Carbon Storage
CTD	Conductivity, Temperature and Depth
EOV	Essential Ocean Variable
FAT	Factory Acceptance Testing
HAT	Harbour Acceptance Testing
HyBIS	Hydraulic Benthic Interactive Sampler
ICOS	Integrated Carbon Observation System
INS/MEMS /DVL	Inertial Navigation System / Micro-electromechanical Systems / EMS / Doppler Velocity Log
MARS	Marine Autonomous and Robotic Systems
MPUS	Modular Payload Underwater Systems
NetCDF	Network Common Data Form
NMEP	National Marine Equipment Pool
NMF	National Marine Facilities
NOC	National Oceanography Centre
NRT	Near-Real-Time
OCS	On-board Control System
OS	Ocean Surveyor
PCA	Post-Cruise Assessment
RINGO	Readiness of ICOS for Necessities of Integrated Global Observations
ROP	Remotely Operated Platform
ROS	Robot Operating System
ROV	Remotely Operated Vehicle
SBP	Sub bottom profiler
SOLSTICE	Sustainable Oceans, Livelihoods and food Security Through Increased Capacity in Ecosystem research in the Western Indian Ocean
UDP	User Datagram Protocol
UHDAS	University of Hawaii Data Acquisition System
USBL	Ultra Short BaseLine
USV /LRAUV	Unmanned Surface Vehicle/ Long Range Autonomous Underwater Vehicle
WCB	Western Core Box
WHOI	Woods Hole Oceanographic Institution

The National Oceanography Centre
National Marine Facilities