Marine Facilities Advisory Board

National Oceanography Centre, Southampton

Tuesday 26th and Wednesday 27th March 2019

Day One: Tuesday 26th March 2019: Seminar Room

Time	#	Item	Lead		Page
14:00		Welcome	Mark Inall		
14:10	1	Introductions from current members and new members	All	Paper 1	3
14:30	2	Overview of MFAB – history and future	Mark Inall		
14:50	3	Discussion - opportunity for new members to raise questions			
15:15		Refreshment break			
15:30	4	Standing item: Update on new medium/large equipment/technologies	Carol Robinson	Paper 2	6
15:45		Optional tour of the National Oceanography Centre.	Jackie Pearson		
17:00		Transfer to Jury's Inn by Unilink Bus – Travel guidance is in the papers for information.			
19:00		Dinner at Jury's Inn			
		B & B has been arranged for: Professor Carol Robinson Professor Nick Wright Dr Chris McGonigle Dr Jo Hopkins Dr Kate Hendry Dr Erica Koning Dr Sophie Fielding Dr Adrian Baker Dr Andy Rees Professor Mark Inall at Jury's Inn, Southampton			

Day Two: Wednesday 27th March 2019: Seminar Room

Time	#	Item	Lead		Page
09:00		Welcome	Carol Robinson		
09:05	5	Minutes and actions, March 2018	Carol Robinson	Paper 3	9
09:20	6	Update from the Cruise Programme Executive Board	Carol Robinson/ Leigh Storey		
09:30	7	National Marine Equipment Pool	Leigh Storey		
09:40	8	Technology Road Map – amendments	Maaten Furlong	Paper 4	21
09:50	9	Comment and feedback from the Board	Carol Robinson		
10:20	10	MFAB working groups	Leigh Storey		
10:30	11	Innovation – how rocess/systems have been improved e.g. ballasting of AUVs/gliders	Maaten Furlong & Alex Phillips		
10:40		Refreshment break			
11:00	12	Reliability analysis (incl. glider policy)	Alex Phillips, Maaten Furlong		
11:10	13	Ship fitted equipment	Colin Day		
11:20	14	Update on Marine Facilities Programme website	Colin Day		
11:30	15	Oceanids I – current progress	Alex Phillips, Maaten Furlong		
11:40	16	Oceanids II – proposed areas for development	Alex Phillips, Maaten Furlong		
12:00		Lunch break			
13:00	17	Responses to call for Capital Expenditure Proposals	Carol Robinson/ Leigh Storey	Paper 5	58
13:20	18	MARS Chief Scientist	Leigh Storey		
13:45	19	Any other business			
14:00		Close			
Papers for information: *Annual report to CPEB* (*page 81*) *Capital Expenditure Proposal Form, (page 83), Terms of reference, (page 84), Public transport details to Jury's, (page 92)*					

Membership of the Marine Facilities Advisory Board 2019
Professor Carol Robinson, Chair, University of East Anglia **Start: March 2019 End: February 2022**
The role of marine bacteria, phytoplankton and zooplankton in global cycling of carbon and oxygen in temperate, tropical and polar oceans. The influence of nutrient supply, increasing temperature and carbon dioxide and decreasing dissolved oxygen on the cycling of carbon through the marine microbial food web. Determination of plankton production and respiration using analytical chemistry, remote sensing, numerical models, water mass tracers, gliders and time series datasets. Latitudinal variability in the balance between phytoplankton uptake of CO_2 and bacterial production of CO_2 to develop empirical and remote sensing models to derive global plankton production.
Dr Adrian Baker, dstl (External equipment specialist) **Start March 2019 End: February 2022**
Science strategy, planning and management, review of scientific programmes and deliverables, capability and capital equipment planning, technical leadership of environmental, autonomous systems, radiological and oceanographic research and consultancy, communication and presentation of technical information. Development of methods to process and interpret oceanographic data sets from autonomous submarine vehicles. Environmental and sustainability issues. Member of NERC Innovation Advisory Board and Science and Technology Facilities Council Ethics Committee. Former Dstl Chief Scientist, former member of NERC Science and Innovation Strategy Board (SISB) and NERC Capital Advisory Group.
Professor Mike Elliott, University of Hull **Start March 2019 End: February 2022**
Science and management of estuaries and coastal areas, marine and estuarine pollution, effects of human activities on biological systems; policy and legislative aspects of estuaries and coasts. Knowledge of surveys using all-terrain vehicles, ROVs, vessels, aeroplanes. Former lecturer in marine biology, physical, chemical, biological oceanography, threats in aquatic systems, and governance of estuaries and coasts. Knowledge of seabed scanning, terrain mapping, drones, satellite information, LIDAR. Health and Safety. Independent non-Executive member of the MSCC and member of Marine Scotland Science Advisory Board.
Dr Kate Hendry, University of Bristol **Start March 2019 End: February 2022**
Modern biogeochemical cycling and past ocean processes, biogenic opal and silicon cycling in seawater, ocean chemistry and paleoclimate, Antarctic sea-ice environment. Nutrient cycle, isotope cycling, barium cycling, carbon cycle, role of ocean circulation on the marine silicon cycle and global climate, Southern Ocean sponges. Kate teaches in the following topic areas: environmental geosciences, climates and ecosystems, climate modelling, oceanography, isotope geochemistry and palaeoceanography. Kate is a director of Antarctic Science Ltd, and sits on the UK National Committee of Antarctic Research.

Dr Jo Hopkins, National Oceanography Centre **Start March 2019 End: February 2022**
Physical oceanographer. Knowledge of ship-based observations, moored and autonomous platforms, remote sensing and modelling approaches used to understand how the physical environment helps shape and sustain productivity and biogeochemical cycling within the ocean. Recent work focuses on physical shelf sea dynamics and ocean-shelf exchange processes and their importance for the cycling of carbon and nutrients; dynamics and frontogenesis in regions of fresh water influence; ocean front and fresh water plume detection, monitoring from satellite data; coupling of remote sensing and in-situ observations.
Dr Kerry Howell, Plymouth University **Start March 2019 End: February 2022**
Sustainable management of the deep-sea ecosystem, population connectivity on depth-dependent diversity of deep-sea marine benthic biota, predictive habitat mapping and modelling. Specialist skills in deep-sea biology including: species identification and distribution, species diversity, habitat distribution, human impacts and conservation concerns. MPAs and impacts of deep-water fisheries. Marine spatial planning associated with deep-sea mining. Member of the NERC Cruise Programme Review Group, Member of the International Council for the Exploration of the Sea's Working Group on Deep-Sea Ecology. Lecturer in marine ecology.
Dr Chris McGonigle, Ulster University **Start March 2019 End: February 2022**
Acquisition and processing of marine geophysical data (multibeam echosounder, side scan sonar, sub- bottom profiler), physical sampling (grabs, corers) and the use of underwater imagery (stills, video) for validation and interpretation. Use of acoustic techniques to understand biotic and abiotic resources and processes in a range of marine environments, with application to community ecology, benthic habitat mapping and fisheries science. Working at the interface of marine ecology, acoustics, spatial analysis and numerical modelling for the sustainable development of marine resources and conservation of marine biodiversity.
Professor Mark Moore, University of Southampton **Start March 2019 End: February 2022**
Marine phytoplankton ecophysiology and biogeochemistry, nutrient limitation in the modern ocean, chlorophyll fluorescence, nutrient limitation of oceanic nitrogen fixation including iron stress physiology, interactions between nutrient biogeochemistry and ocean circulation, from turbulence, through fronts and mesoscale eddies to global scales. Knowledge of sampling equipment (e.g. CTD and underway sampling systems), microstructure profilers, towed instrumentation (e.g. SeaSoar), trace metal clean sampling equipment (Titanium CTD systems, Go-Flo samplers, towed fish), moored equipment (e.g. ADCPs, thermistor chains), containerised laboratories and Fast Repetition Rate fluorometers.
Randolph Sleister, British Antarctic Survey (BAS) **Start April 2015 – March 2021**
Ship Operations Manager for BAS
Dr Tim Smyth, Plymouth Marine Laboratory **Start March 2019 End: February 2022**
Head of Science for Marine Biogeochemistry and Observations group; includes oversight of AMT and Long-Term Science Multiple Centre projects including ORCHESTRA, ACSIS and LOCATE. Has led NERC NC funded (now CLASS)

Western Channel Observatory (autonomous moorings, research vessels and in-water technology and equipment). Involved in the RAPID ABC-Fluxes project and JSR Autonomy projects AlterEco and CAMPUS (marine autonomy). Member of NCAS Atmospheric Measurement Facility steering group, advisor to NERC Moorings Advisory Group. Served on UK Integrated Monitoring and Observation Network and National Centre for Ocean Forecasting executives.
Professor Nick Wright, Newcastle University **Start March 2019 End: February 2022**
Engineer with experience of collaboration with marine, geo and environmental scientists through providing technology. Networked with industries that work in marine environment; familiar with likely developments of technology in the future. Works at interface of materials engineering with electronics and computing to develop sensor systems and robotics. Knowledge of use of data science techniques in maximising the impact of marine measurements and knowledge of development of AI for subsea robotics. On-going activities include turbidity currents, dolphin recognition using AI image analysis, marine sensor networks, subsea power technology and others.
International Barter Partner - vacant
Member – one post vacant
National Oceanography Centre staff - Advisory Roles
Dr Graham Allen, Head of the British Oceanographic Data Centre
Colin Day, Programme Management Group Head, National Marine Facilities
Dr Maaten Furlong, Head of Marine Autonomous and Robotic Systems, National Marine Facilities
Professor Angela Hatton, Director of Science and Technology
Helen Oldridge, Head of Scientific Engineering, National Marine Facilities
Julie Pringle Stewart, Chief Operating Officer
Leigh Storey, Associate Director, National Marine Facilities
Dr Mike Webb, Head of Science, Natural Environment Research Council

Secretary: Jackie Pearson, International and Strategic Partnerships Office

NERC Capital Update for MFAB

Date compiled: 4 February 2019, Author Oliver Knevitt, UKRI NERC

NERC Capital awards to marine research organisations 18/19

- £700,000 was awarded to the Marine Biological Association approved in August 2018 for spending in 2018/19. This capital award will support refurbishment for a vented formalin sample store, freezer bank and/or MVE cryotank room, fully equipped molecular microbiome laboratory, microbiology/phycology laboratory, shipping/receiving station, IT and office space as part of refurbished laboratories.
- £76,000 was awarded to SMRU in December 2019 for replacement of the Selkie boat engine
- £155,000 was awarded to SAMS for upgrade work to the SAMS AUV (Gavia), which was approved in Nov/Dec 2018. This included the purchase of a sub bottom profiler and a science bay module for the AUV.
- £168,000 was awarded to NOC for onward payment to SAMS for a Turbulence sensor package, approved in Jan 2019. It was thought that this sensor package would benefit the Ellet Line Array work funded through the NC Science award (CLASS) for the next couple of years, thus benefitting both NOC and SAMS, and might revert back into the NMEP potentially for deployment on the new deep gliders in the future.

Other current capital activities

NERC has provided sustained capital funding for marine robotic systems and sensors in recent years (with £13.3m invested between 2012 and 2015). In 2016, a further £16m of Industrial Strategy Challenge Fund (ISCF) capital investment (2016-2022) was announced to develop new marine robotic vehicles and their command and control systems, and the development of marine sensors (http://www.nerc.ac.uk/funding/application/outcomes/awards/2016/marine-sensor/).

In addition, BEIS invested £75m in the now operational research ship, RRS Discovery, and £225m in a new polar research ship, RRS *Sir David Attenborough*, which should come into service in 2020. The new vessel will be designed to undertake leading edge multi-discipline science in both Polar Regions with new capabilities, such as a scientific moon pool (i.e. a 4m2 opening in the vessel's hull giving access to the water below) to allow for the safe deployment and recovery of marine equipment and autonomous systems whilst amongst sea ice.

Strategic research programme equipment on grants during 18/19
All equipment is directly incurred unless stated otherwise.

Open Ocean and polar waters research programmes
Ice Sheet Stability (2010 – 2017)
http://www.nerc.ac.uk/research/funded/programmes/icesheet/
Budget: £7.5m (incl. £800k investment in tractor train and £650k in shelf sea moorings)

The programme's research is focused on the causes of the rapid ice loss from Pine Island Glaciers (on the West Antarctic Ice Sheet)

- NE/J005681/1 £6,149 was awarded to Andrew Shepherd at University of Leeds for purchase of equipment on "ISTAR-D - The contribution to sea-level rise of the Amundsen Sea sector of Antarctica"

- NE/J005789/1 £40,000 for directly incurrent equipment and £29,272 for other equipment was awarded to Peter Clarke at Newcastle University for purchase of equipment on "iSTAR-D: The contribution to sea-level rise from the Amundsen Sea sector of Antarctica"

Changing Arctic Ocean (2017 – 2022)
http://www.nerc.ac.uk/research/funded/programmes/arcticocean/

Budget: £16m (plus German contribution from BMBF of ~£3m towards joint German-UK projects)

The over-arching goal of this programme is to understand how change in the physical environment (ice and ocean) will affect the large-scale ecosystem structure and biogeochemical functioning of the Arctic Ocean, the potential major impacts and provide projections for future ecosystem services.

- NE/P006280/1 £35,400 was awarded to David Pond at the University of Stirling/Scottish Association For Marine Science for purchase of equipment on "Mechanistic understanding of the role of diatoms in the success of the Arctic Calanus complex and implications for a warmer Arctic"

- NE/P006302/1 £26,797 for directly incurred equipment and £10,250 for other equipment was awarded to Finlo Cottier at Scottish Association For Marine Science on "Arctic PRoductivity in the seasonal Ice ZonE (Arctic PrIZE)"

- NE/P006426/1 £16,750 was awarded to Martin Solan at University of Southampton for equipment on "The Changing Arctic Ocean Seafloor (ChAOS) - how changing sea ice conditions impact biological communities, biogeochemical processes and ecosystems"

The Role of the Southern Ocean in the Earth System (2018 – 2023)
http://www.nerc.ac.uk/research/funded/programmes/roses/
Budget: £7m

The Role of the Southern Ocean in the Earth System (RoSES) programme will provide the scientific basis to inform international climate policy on the role of the Southern Ocean carbon system in 21st century global climate change.

- NE/P021379/1 £56,251 was awarded to Michael Fedak at University of St Andrews for equipment on "Processes Influencing Carbon Cycling: Observations of the Lower limb of the Antarctic Overturning (PICCOLO)"

- NE/P021395/1 £45,219 was awarded to Karen J. Heywood at University of East Anglia for equipment on " Processes Influencing Carbon Cycling: Observations of the Lower limb of the Antarctic Overturning (PICCOLO)"

Innovation

UK Aquaculture Initiative (2016-2021)
http://www.nerc.ac.uk/innovation/activities/sustainablefood/aquaculture/ukai/
Budget £6m (plus co-funding from BBSRC and Cefas)

Joint NERC and BBSRC initiative to support high-quality, innovation and research translation that will enable the development of a healthy, safe and sustainable UK aquaculture system.

- NE/P010970/1 £10,000 was awarded to Professor Matt Mowlem, National Oceanography Centre, Science and Technology for equipment on "Improving Biosecurity in Aquaculture using High Speed, Low cost, Lab on a Chip Micro-Cytometry for the Surveillance of Harmful Algal Blooms"

Marine Facilities Advisory Board
(Draft meeting note)
National Oceanography Centre, March 23rd 2018

Prof Mark Inall, SAMS – Chairman (MI)

Dr Sophie Fielding, British Antarctic Survey (SF)
Dr Maarten Furlong, National Oceanography Centre (MF)
Prof Angela Hatton, National Oceanography Centre (ADH)
Mr Andy Henson, National Oceanography Centre (AH)
Prof Karen Heywood, University of East Anglia (KH) by VC
Dr Erica Koning, Royal Netherlands Institute for Sea Research (EK) by VC
Mr Randolph Sliester, British Antarctic Survey (RS)
Mr Leigh Storey, National Oceanography Centre (LS)
Dr Andy Rees, Plymouth Marine Laboratory (AR) by VC
Professor Carol Robinson, University of East Anglia (CR) by VC
Dr Mike Webb, Natural Environment Research Council (MW)
Prof Russell Wynn, National Oceanography Centre (RW)

Secretariat: Jackie Pearson, National Oceanography Centre (JP)

Observing: Dr Natalie Clark, Natural Environment Research Council (NC)

Apologies
Dr Graham Allen, British Oceanographic Data Centre
Mr Robert Gatliff, British Geological Survey (RG)
Professor Matt Mowlem (NOC)
Dr Phil Nightingale (PML)
Prof Christine Peirce, University of Durham (CP)
Ms Julie Pringle-Stewart, National Oceanography Centre (JPS)

Item 1 Welcome and matters arising from meeting minutes from May 2017

1.1 MI advised the Board that Professor Carol Robinson (CR) would be joining this meeting as the incoming Chair, as this would be MI's last meeting as Chair. CR will be taking over as the Marine Facilities Advisory Board (MFAB) Chair in April 2019.

1.2 The minutes are to be issued as a draft, and posted on-line, as soon as possible. Amendments were noted as follows:

- Page 1, 1.3 – the business case is referring to the OCEANIDS business case so this should be changed.
- Recheck document for instances when names have been used rather than initials and correct.
- P 6, 5.5 - Ray Leakey is the science lead on the polar vessel so this should be added, in brackets.

Once the changes are complete, the draft minutes can be published.
Action: MFAB Secretariat

1.3 MI went through the actions list. SF asked if the visibility of the MFAB website could be enhanced. RW agreed to help with this as he now has oversight of the NOC website. Damion Cook is now the Communications Officer who is the lead for technology and has this all in hand. MI confirmed that the link about the capital expenditure was now available. NERC's pages on MFAB need to mirror the NOC MFAB pages. **Action: Secretariat**

1.4 Regarding the action at 6.2, Dr Leigh Marsh updated the National Marine Equipment Pool (NMEP) web pages so these are community facing and there is more information available now.

Item 2 Membership

2.1 AH asked if it would be possible for information to be made available about what science areas members represent, e.g. in terms of types of equipment used and about their science areas.

2.2 We are at a stage when many members are due to end their term. MI will continue through this year but CR will take over as Chair at the next meeting. There is a need for an influx of new scientists onto the MFAB. How do we achieve this? The opportunity could be advertised to the community? Previously, we have taken a selected approach amongst ourselves but perhaps we should ask the wider community now, as an open call. This was agreed but it would be best to try to stagger the points at which members leave. CR suggested keeping four members on the Board for one more year. Next year's meeting would see a mix of new members joining as others leave. MI had received some suggestions. It is important to be clear about what areas of marine science should be represented.

2.3 There should be a call for new members as soon as possible. MI will draft some text and circulate to the board for comment and input. The call should be linked to the Terms of Reference, the NMF Technology Road Map and the NMEP inventory list. We need to think about the primary equipment users, and those who are knowledgeable about certain pieces of equipment. **Action: MI**

2.4 RW asked if there were still gaps, whether members still target individuals. MI had already had some suggestions from existing members and agreed to ask members if they would also like to suggest colleagues to apply.

2.5 LS asked for clarity on the roles of members. For example, Professor Matt Mowlem (MM) – is Matt's role that of an advisor? Also, is RS attending as an observer? ADH confirmed that MM is on the Board to advise about what is needed. Is there categorization within the NOC core group in terms of science area or equipment? It was suggested that there should be representation on the Board from other operators of large NERC assets. There needs to be definition of the group that is non-NOC core membership e.g. BAS, BGS etc. SF asked whether MFAB is a NOC or NERC Board. MW advised that the board reports both ways. The authority on capital is under NOC. As NOC is still within NERC at the moment, NERC retains an interest

which is why MI attends the Cruise Programme Review Group meetings. This is reflected in the first paragraph of the MFAB ToR. MI suggested that in future, NERC may take ownership of the MFAB completely although this is not for this Board to decide. [Post meeting note: The MFAB is run by the NOC on behalf of the NERC marine science community]

2.6 BAS and BGS operate large capital assets on behalf of NERC. BAS is a user of the equipment pool and contributes to discussion on the contents. MI commented on the value of MFAB to enable discussion about when new equipment is purchased. LS added that it is helpful to understand who attends and what advice they can offer. It is important to match people to capability and we must be careful also not to miss off science groups. Every part of the science community must be represented. It is important to get a broad spectrum of representation and for us to be aware of what expertise members can bring.

2.7 MW said that canvassing the community has sometimes been done well but sometimes colleagues have not always had the time to review equipment needs. For example, we might have got more feedback if there had been an open call on the new Autosub 3 but we didn't do this. This group should receive evidence and provide advice rather than canvassing and providing a steer. At the moment, we are dependent on one person to represent a section of the community. For example, if National Marine Facilities advises MFAB that there is a challenge on the horizon, this might start an exchange of information with wider community. MI commented on how we reach the 'wider community': there is the NERC marine listserver and the NOC Association listing. MW added that when there is a big decision to be made, for example, if there needs to be a decision on what to deprioritize, then we may need to adopt a more rigorous process.

2.8 SF said that submitting evidence independent of collating is the starting point. LS commented on the need to review data. For example, has the equipment been requested in the last five years, how often has it been used, can this capability be bartered, etc.

2.9 MW mentioned an IODP survey that Professor Damon Teagle of the University of Southampton had conducted. He went to each department with an interest and the onus was on each person to respond. SF added that she canvasses input by contacting everyone on their email and following up for feedback. She added that the marine listserver is a good method of contacting the community. If we give the community an opportunity to respond then the onus is on them to respond. There may be a risk that we may not know everyone with an interest. ADH advised that NERC can provide data on who has worked in certain areas. KH suggesting using the NERC Marine Listserver and the Challenger Society. MI asked for any ideas about suggestions for new items of equipment to be sent to the Secretariat who could then circulate via the NERC marine list server* (see point 2.9.2), the Challenger Society and the NOC Association. **Action: All and Secretariat**

2.9.1 There is no reference in the ToR as to how we connect with the community. ADH added that whilst it is good to circulate information, there is a responsibility on the community to contribute too. CR asked whether we could include a paragraph in *Challenger Wave*. For example, a note about this MFAB meeting and advise to sign up to the NERC Marine Listserver in order to get updates. Write a note about this for Challenger Wave. **Action: Secretariat**

2.9.2 NC advised that there is no longer a marine listserver as the format has changed recently. *Post meeting note: the Secretariat checked on this with NC.* There was a concern that the UKRI/NERC listserver that has replaced the marine listserver is too generic and no longer focussed on the marine community.

Item 3 RRS *Discovery* and RRS *James Cook* update

3.1 RRS *Discovery* – the business case for RRS *Discovery* required endurance for 50 days. Currently, this is between 40 and 45 days. Endurance depends on fuel usage and the amount of equipment on board. The community needs to be reminded to plan on a maximum speed of 10 knots (and potentially slower in Southern waters). **Action: advise community of speed and duration LS/NMF**

3.2 The number of berths on RRS *Discovery* has been an issue but we are adding another cabin this summer. There may be 30 scientific berths. LS mentioned that RRS *Discovery* was now compliant for operating in Polar Waters with the RRS *James Cook* to follow this year. The bandwidth on the ships has now been increased in response to feedback from PIs.

3.3 RS advised that the launch of the RRS *Sir David Attenborough* (SDA) will take place on 17th May 2018 and the acceptance date will be 31st October after which BAS will undertake one year of engineering trials followed by three scientific trials, then the ship will travel down south and undertake a 40 day Arctic rehearsal expedition. BAS will go to the Arctic for a rehearsal expedition after which the ship will be considered fully commissioned. MI noted that for the Arctic trials expedition, there had been a request for input from the community, announced by NERC this week. The Arctic rehearsal will include geophysical, geological and geochemistry components.

Item Four Working Groups

4.1 MI advised that we have adopted the Seismic Capability Working Group which is on-going and rebranded as a MFAB working group. LS said that it was a shame that Professor Christine Peirce (CP) was unable to attend the meeting as she had been the driving force behind this.

4.2 There are five options for review. 1.) remove capability 2.) retain current capability 3.) barter with Ocean Facilities Exchange Group (OFEG) partners 4.) charter or 5.) put together a business case to invest in it. CP has done a lot of work in looking at the capital on this and AH has been looking at the on-

going costs. We need to establish whether we have achieved some of the savings that we anticipated. We want to deliver the report to the next Cruise Programme Executive Board (CPEB) and will forward to MI beforehand. The MFAB Secretariat will circulate the r2eport to the membership before it goes to the October CPEB meeting. **Action: MI and Secretariat**

4.4 MI had asked the MFAB for suggestions of new working groups and we received the nomination for the Data within the Marine Facilities. CP sparked the initial decisions with some colleagues outside this Board.

4.5 MI said that he would like to discuss membership of this board. There is a list of on-going initiatives and it would be good to invite discussion. SF spoke about a review of the Techsas data logging software for the NERC ships, including the SDA. There are different systems which may not be capturing all the information needed. There is a need to look at data flow throughout. There may be a need to identify more training. There needs to be a review of existing systems to review their efficacy to check that they are fit for purpose. SF said that some of this may occur because of the SDA but there needs to be request out to the community to check that all is well.

4.6 MF asked if the work on SDA is linked into what NOC is doing currently? He is concerned that we may build a system that works well for the SDA but will it work for the RRS *James Cook* and RRS *Discovery*? Any system will need to ensure that the needs of the entire fleet are met. AH said that NOC had approached Techsas originally because this was the preference of the OFEG.

4.7 RS added that on the SDA, BAS is delaying adding the IT kit until there is more certainty. BAS will wait to add until before the trials begin. SF explained that BAS is trialling Techsas at the moment to be certain that this is the system that they want. AH noted that this is what the data group could help determine.

4.8 LS said that the notes from the WG should complement and not duplicate other documentation. The first meeting should say what the WG is intending to look at and MFAB is the right place to present this. This is a huge area and there is a lot of work going on. MI agreed that there is more than just ship-side issues to consider. For example, we need to think about the flow of data management both across ships and beyond the ships. We need to gauge whether there are sufficient concerns in our community to make a change. RS advised that in terms of the SDA, the entire server and network system is mocked up in Cammell Laird. He suggested gathering some targeted information on vessels with a section in the post expedition assessment form as this might be a good way of targeting the ship's users? Is there a post-user survey on the MARS platforms? Is this data logging system working for you? All of this leads back to the Cruise Programme Review Group.

4.9 SF advised that BAS is writing a data logging specification and this will be reviewed by scientists and engineers so that they can review and make suggestions. We will look at the specification alongside the programmes to check that this will work. There is an onus to go out to the community to get

more knowledge to see what else should be added. RS suggested that we need to engage with the other NERC vessel operators so that we don't just have a bespoke system that will only work on one vessel. MF asked whether this discussion was about hardware or software. It is important to be clear about the terminology. If the hardware is in, and there is then a need to change it, this is painful!

4.9.1 MI asked about membership of the Data Working Group. He suggested that Dr Graham Allen should lead and that we should include Dr Ray Leakey. AR asked for clarification on the nature of the problem on data. Is it the case that data is not being transferred correctly? It is important to involve BODC from the start. SF added that there have been issues around the quality control (QC) of the data. LS agreed we need to know if the systems are fit for purpose. Data needs to flow in, in the right format and then be archived. MI suggested involving someone on the group who has experience in this and nominated Andy Rees who agreed to join. At this point MI said it was also important not to lose sight of the great stuff we do; let's not be too negative. MI asked for a nomination of a contact to be involved, from the Marine Autonomous and Robotic Systems team and MF nominated Alvaro Lorenzo Lopez. AH suggested Juan Ward who is Head of Scientific Systems and manages the Techsas systems. SF added that there are others in the community whom it would be good to involve. SF added that there is no criticism, simply an awareness of certain issues and we just need to find out how we fix them. Data collection should be standardised across the three platforms. Dr Graham Allen needs to be approached to set up a working group. **Action: MI**

Item 5 Marine Capital Equipment

5.1 MF spoke to this item which concerns non-MEP capital that will work its way into the NMEP by 2021. **Autosub Long Range 1500m Rated Platform** – There have been problems with the vehicle's pressure vessels. The specification of the ALR 1500 is similar to Autosub6000 but will have 2.5 times the energy. We will be building terrain navigating capability into the vehicle which will be able to stay subsurface for longer periods of time that will enable, for example, polar crossings. We will be updating the control system and are looking to upgrade both the hardware and software and should be able to integrate sensors more easily. The vehicle will be fitted with a turbulence probe and will have options to integrate low power sensors within the MEP.

5.2 **Autosub 2000 Under Ice (A2KUI)** will enhance our under ice capability and will be available in 2021. The vehicle's sensors will be similar to Autosub6000 and will have an improved obstacle avoidance system. We are upgrading the on board control systems which will have the same code base as the Autosub Long Range 6000. It will be easy to integrate sensors onto this vehicle.

5.3 **C-Worker 4** has been designed to be launched and recovered from our ships. The USBL system will enable us to track the AUV 6000 thereby saving ship time. The continuous tracking capability will enable us to improve navigational

accuracy. We will leverage capability within the NMEP to integrate sensors onto the vehicle and it will be possible to use the C-Worker for testing sensors.

5.4 The **C2 (MAS Platform Command-Control System)** project is using agile development techniques and software system in stages. Two phases: 1.) build a standardised piloting interface and 2.) stream-line data flow into the BODC. This will be integrated into the Marine Facilities Portal and we will be developing an autonomous deployment form. We are looking to pull the data through to the BODC. We are building the infrastructure and will be looking at automated piloting. There will also be a simulation capability.

5.5 There are five marine sensor projects but these may not end up in the NMEP. We will integrate the sensors into the fleet and there is a trials plan and ultimately, they will be integrated into the vehicles.

5.6 MI noted that there needs to be a dissemination communications plan for OCEANIDS. RW explained that NOC is looking to target a number of events when we can highlight these developments. There is a poster that is ready to go onto the NOC web site. The NOC is developing a trials plan and hopes to share elements of this with the community. There will be an anticipated timeline for when all of these new assets become available.

Item 6. Capital Expenditure Proposal Form

6.1 There will be an announcement via the marine list server and through the NOC Association. **Action: Secretariat**

6.2 Whilst there are standard funds available annually to support this, the vast majority of those funds are needed to replace and/or maintain existing equipment. It will be made clear that this is the case, and that the list will exist primarily to be used in the event of unpredictable injections of capital cash by NERC, UKRI or other Government agency. If there is a request for an item that isn't funded in one round, the application won't be discarded but will be carried forward to the next round. It will be useful to have a ready to go list of items that have been requested.

6.3 KH asked why the form only refers to RRS *Discovery* and the RRS *James Cook.* What about the RRS *James Clark Ross*? What about barter ships? There may be scientists who have glider campaigns who are not on ships at all. MI advised that this is unintentional and the form should be for any users of the NMEP. This needs to be corrected. **Action: Secretariat**

6.4 KH queried the reference to ship-based equipment – does this mean items that are permanently attached? MI confirmed that the reference means anything that is in the pool. SF noted that this should be amended to 'marine equipment'. This does not only refer to equipment that is permanently attached. These corrections need to be made and then advertise its availability. **Action: Secretariat**

7. NMF Technology Road Map

7.1 We are at a point when we are looking for final comments before publishing. AH advised that the seismic section has been revised and one of the NMEP gravimeters has been upgraded. There was a plan to try these on the SDA. It was not known whether the SDA has a gravimeter as we thought the purchase had fallen through. RS advised that the gravimeter has been ordered and there have been no issues. AH commented that NMF will try the gravimeter on the RRS *James Cook*.

7.2 AH advised that NOC is trying to upgrade/modernise the lab containers which are expensive. The Calibration Laboratory is an up and running facility. We have space capacity and this is quick and more economical than going elsewhere. On HyBis, the command model is due to be upgraded.

7.3 MF advised that NMF is looking to develop a virtual control room for the ROV. This will use increased bandwidth on the ship.

7.4 We are trialling a deep glider from the University of Washington. There will be rechargeable batteries for the Slocum gliders.

7.5 MI advised that he has some feedback from CP. We need to get the document signed off and make it available. With reference to ACSIS, RW asked if it would be possible to add depth capability to projects using a USV to harvest data from moorings.

7.6 RS advised waiting to see how the 40m corer works on the SDA first because the Japanese had used the same system and lost it on the first deployment. We should resolve this on the SDA first before we invest again.

7.7 AR queried the fact that there is no mention of CTD systems. AH explained that we haven't identified growth areas for CTD systems. SF said that she was aware of some and would pass these on. **Action: SF** AR added that it is important to mention the capabilities and packages that available for the CTDs as this will be of interest to the community.

7.8 EK mentioned the coring systems. A couple of years ago, NMF bought a sensor system from Ifremer to take care of corings so that it would be more reliable. EK asked if this has ever been implemented as it is not in this document. It was intended to ensure that sediment samples are uniform. AH agreed to check this. **Action: AH**

7.9 With respect to the section on gliders, RW asked if it will be possible to have a micro AUV.

7.9.1 SF advised that BAS has just bought some containers that have been designed to fit the SDA. It might be worth the NOC looking at this specification to help with future purchases, noting that the SDA runs on different power. (Previously NOC gave BAS the specifications for the RRS *Discovery* containers).

7.9.2 RW referred to integrating unmanned aerial vehicles with ships and Marine Autonomous Systems noting that we don't have this capability in NMFP but it is in BAS and SAMS, and asked for views from the Board. MI said that if there is a future investment in MAS, we should look at unmanned aerial vehicles. MF added that NOC is looking at exploring the use of quadcopters. The Schmidt Ocean Institute has a system that had a vertical take-off capability with 12 hours endurance. MI suggested that we will look at the capabilities of aerial vehicles and in the future, these will be part of the drop down menu for when colleagues are planning research expeditions. RS added that NOC has an extended range of fixed wing vehicles that are being adapted. There is also a group in BAS that is dedicated to developing unmanned aerial vehicles. MF added that there is a lack of science drivers – for example, what are the applications? We are clear on the use of the quadcopter but what are the science users? RS suggested talking to BAS as we can talk about the science applications of the unmanned fleet. MI added that the document just needs a pointer about the aspirations. MI advised that SAMS has a small ROV and two AUVs and agreed to send a list of equipment to **AH. Action: MI**

7.9.4 MI wrapped up this section by asking that further comments are received two weeks from today. After that, the Roadmap will be published. JP to send reminder. **Action: Secretariat**

7.9.5 CP has communicated details of some errors to MI, including that the Roadmap is lacking of imagination and inspiration and that it could be business damaging if made publically available. MI asked for a view from the Board. Does this relate to commercially sensitive information? MF said that there was already information about vehicles on-line. No members present agreed that publication of the roadmap would be business damaging. Once updated with final comments, the Technology Roadmap needs to be advertised to the community. AR suggested adding it to the Marine Facilities Portal. The Roadmap will be a useful reference in terms of completing the Ship-time and Marine Equipment *(*SME) forms. **Action: AH**

Item 8. Marine Environmental Interaction Policy

8.1 CP and Rob Larter (BAS) were the driving power behind this. NERC and the CPEB has adopted the policy which will be published shortly on the NERC policy web page. It provides for an environmental impact assessment (EIA) to be undertaken each time a NERC ship goes to sea. There are two types of EIA, standard and enhanced. The policy indicates what sort of expedition requires an 'enhanced' assessment. Most expeditions require a standard assessment.

8.2 The intention is to start completing EIAs for the RRS *James Cook* and RRS *Discovery* from 2019 onwards. The EIAs will be presented at the six monthly planning meeting and any mitigating actions discussed. There is an intention to kick this off with the SDA this year although this may not fit in with the initial ship trials. There will be a recruitment process to provide for one person to be designated as an assessor to support P.Is and we have had an initial discussion with BAS as to how this would work. This is good for us and for

NERC. In theory, the first meeting for these may take place Oct/Nov this year. SF added that this will mean an EIA for every expedition, whereas before these were only required for those expeditions where the type of work was deemed to be more sensitive. For BAS there is an EIA for everything south of 60º and for cruises around South Georgia.

Item 9. The National Marine Facilities Portal

9.1 MI talked through Colin Day's paper about the updates on the Portal that weren't there this time last year. SF asked whether BAS will be able to cache the portal on the JCR and the SDA? LS agreed to check this with Colin Day **Action: LS**

9.2 MI advised that autonomous vehicles are now in the portal. The link to the NMEP listing is being delivered this week. We are now allocating equipment to expeditions via the NMFP. MI suggested that to save him time, should there be some costings functionality added? EK agreed that it is helpful if scientists, in planning an expedition, can have a costing running alongside their application, in real time, to see how the costs build. This would be useful functionality, especially with large, expensive items of equipment.

Item 10. Any other business and date of next meeting

10.1 SF spoke about the assessment of noise that had been raised during the last MFAB meeting and asked if there has been any movement on this? The query concerned RRS *Discovery*. LS advised that NOC was not able to match the comment against anything seen although it has occurred on the RRS *James Cook*. NMF can't replicate the noise on RRS *Discovery* so the source of the reported noise issue cannot yet be determined. There isn't an identified 'electrical noise problem' on RRS *Discovery.* SF added that there was an issue identified but the cause isn't known. The way to find out what it is would be to undertake a testing. AH said that if there is a strong science driver to do this, we can put forward a business case to do this. We do need to justify it. MI asked that the CPRG to keep an eye on this. SF added that Dr Steve Boharty has just done an expedition and presumably this would have been picked up. RS added that BAS will be doing noise range on the SDA, querying if this might be helpful for NOC, assuming the RRS *Discovery* could be in the same place. Unfortunately, the ship will not be in the right place to do this. The conclusion was that no present or reproducible electronic noise problem is known to exist on *Discovery* at the present time.

10.2 Membership

Three years ago, we switched from six monthly meeting to annually. MI considered that the frequency of meetings is about right but perhaps it would be an idea to have the meeting over two days as this may enable opportunity for more input. RW suggested that if we have a meeting with large number of members next time, we may need extra time. MI added that useful connections are often made 'in the margins'. Perhaps the next meeting could include an evening component? LS suggested that it would be good to focus

on the Technology Road Map, say 30 minutes on each section. In going through each section in this way, we can be certain that the drivers are relevant? RS added that a Technology Roadmap workshop could feed back into the MFAB. RS suggested that we invite the community to comment on the roadmap. LS was pleased that WGs are being set up. CR suggested perhaps having a two hour session at the Challenger conference every two years? MI agreed that the TRM might benefit from input from a wider group. There is also the issue of new membership. Perhaps the next meeting should have an evening element as this may help initiate the new membership, when CR will be chairing. It was agreed to have start with an afternoon session, then an evening and then part of the next morning. AH said that when NOC has new members in the Science Directorate, they have a half day induction. It would be good to have something similar for new members of MFAB. MI volunteered to be part of this induction process. Induction is a good idea as it goes hand in hand with new membership. An invitation to the community to become members should be done with a month of this meeting. **Action: MI and Secretariat.**

10.3 KH suggested not having the meeting in Southampton, however, JP noted that when the MFAB had been held in Birmingham, physical attendees were NOC staff and Mike Webb from NERC. (*Post meeting correction: also attended: George Wolff, Chair, University of Liverpool, Bob Gatliff, BGS*)

10.4 KH Thanked NOC IT for the Skype link up as it had worked well. Thanks to be forward to Rob Jones, NOC IT. **Action: Secretariat**

Actions

Item number	Action	Allocated to
1.2	Make amendments to May 2017 minutes and post on-line	Secretariat
1.3	NERC's pages on MFAB to mirror NOC MFAB pages	Secretariat
2.3	Draft text for a call for new members for MFAB	Mark Inall
2.9	Suggestions for new items of equipment to be sent to the Secretariat for circulation to community via NERC's research community news, events and jobs listing, Challenger Society and NOC Association.	Members of the Board/Secretariat
2.9.1	Write note about MFAB to be included in *Challenger Wave* with advice to sign up for the NERC's research community news letter to receive updates.	Secretariat
3.1	Advise community about the speed and duration of RRS *Discovery*	LS/NMF
4.2	Circulate seismics working group report to membership before it goes to October CPEB meeting.	Secretariat

4.9.1	Approach BODC's Graham Allen to set up a working group	Mark Inall
6.3 and 6.4	Make revisions to capital expenditure proposal form and advertise.	Secretariat
7.7	Advise growth areas for CTD systems to Andy Henson	Sophie Fielding
7.8	Check if the sensor system purchased from Ifremer has been implemented.	Andy Henson
7.9.2	Send list of SAMS equipment to Andy Henson	Mark Inall
7.9.4	Remind Board about need to submit final comments on TRM	Secretariat
7.9.5	Update TRM with final comments and advertise	Andy Henson
9.1	Check whether BAS will be able to cache the portal on the JCR and the SDA	Leigh Storey
10.2	Invite members of the community to apply for membership of the MFAB	Mark Inall and Secretariat
10.4	Thank Rob Jones of NOC IT for assistance in meeting	Secretariat

National Marine Facilities Technology Roadmap - 2019/20

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.

Seismics

Airgun deployment during seismics operations

Current Capability

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

Multi corer

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

CTD sample recovery

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).

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

A fixed point mooring being deployed

Current Capability

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

Science Drivers

- 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

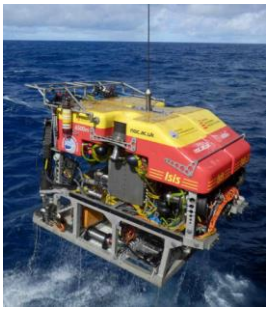
- Develop real time telemetry of data from moored observatories using underwater acoustics and satellite technologies
- Develop a suitable smoke beacon that will withstand full ocean depth and activate on return to surface, either by pressure or conductivity, to provide a clear locator (better than a 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).

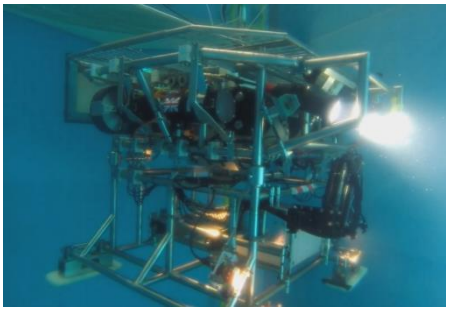
Aspirations

- 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)



Isis *ROV*



HyBIS RUV

Mojave ROV

Current Capability

- ***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 (RUV).** 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
- **MPUS (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 MPUS (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
- **MPUS (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 Marine Autonomous Systems (MAS) Platforms

Autosub6000

C-Worker 4

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 & 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 need for higher levels 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 Deepglider**. 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.

Teledyne Webb Research Slocum lithium ion rechargeable battery pack.

Long Range AUV Platforms

ALR6000 Front ALR15000 back

Current Capability

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 Platforms

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 Drivers

- **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

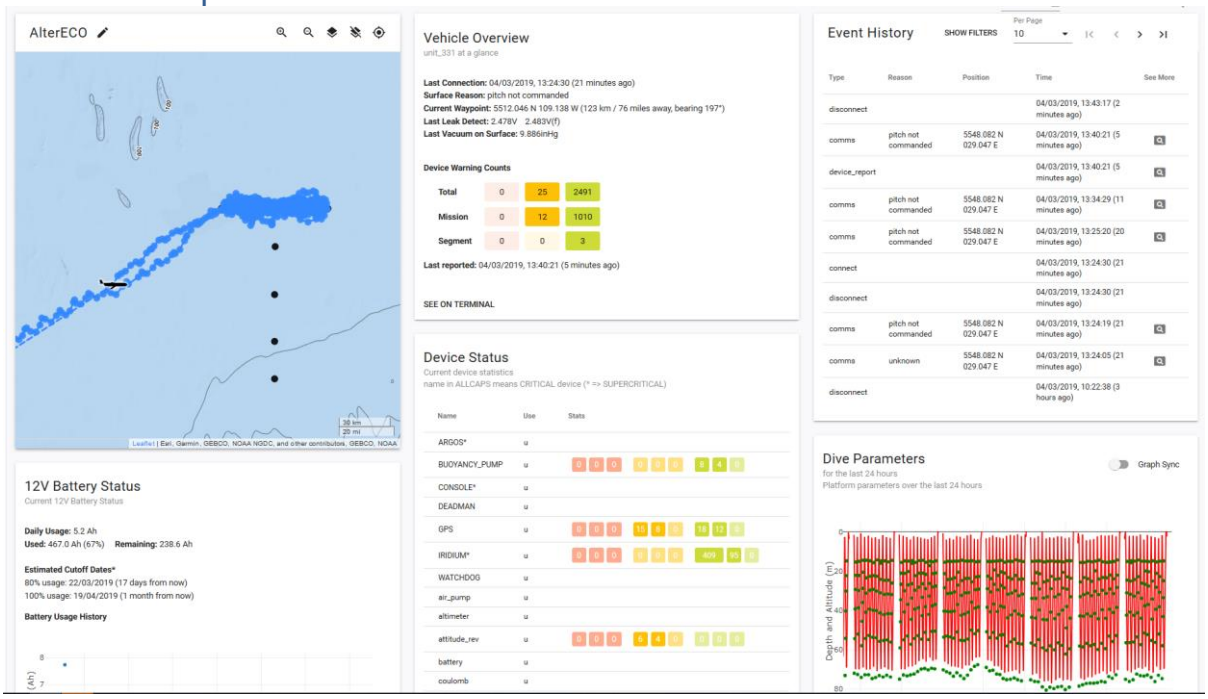
- **Unified control interface**. A unified control interface will be developed to simplify the deployment of mixed fleets of vehicles. This interface will be simple, intuitive, yet powerful enough to allow the pilot to create complex mission plans. The interface will build on the investment that has 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.

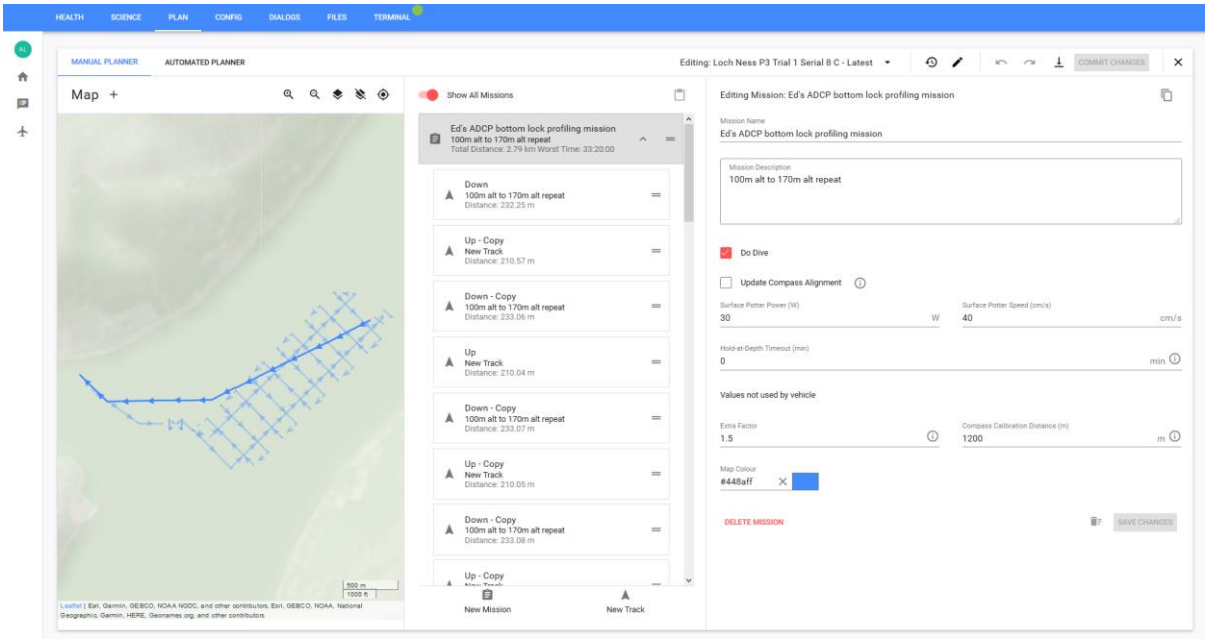
Aspirations

- **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



C2 Portal vehicle overview tab



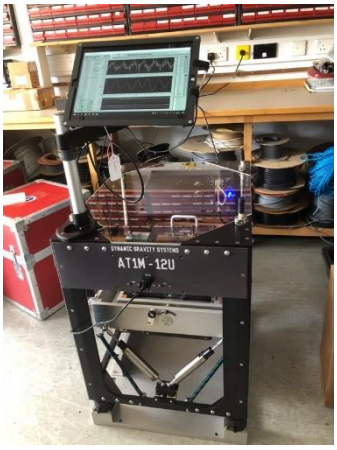
C2 Portal mission planning tab

- **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

SeaSpy being prepared for deployment

Current Capability

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

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.

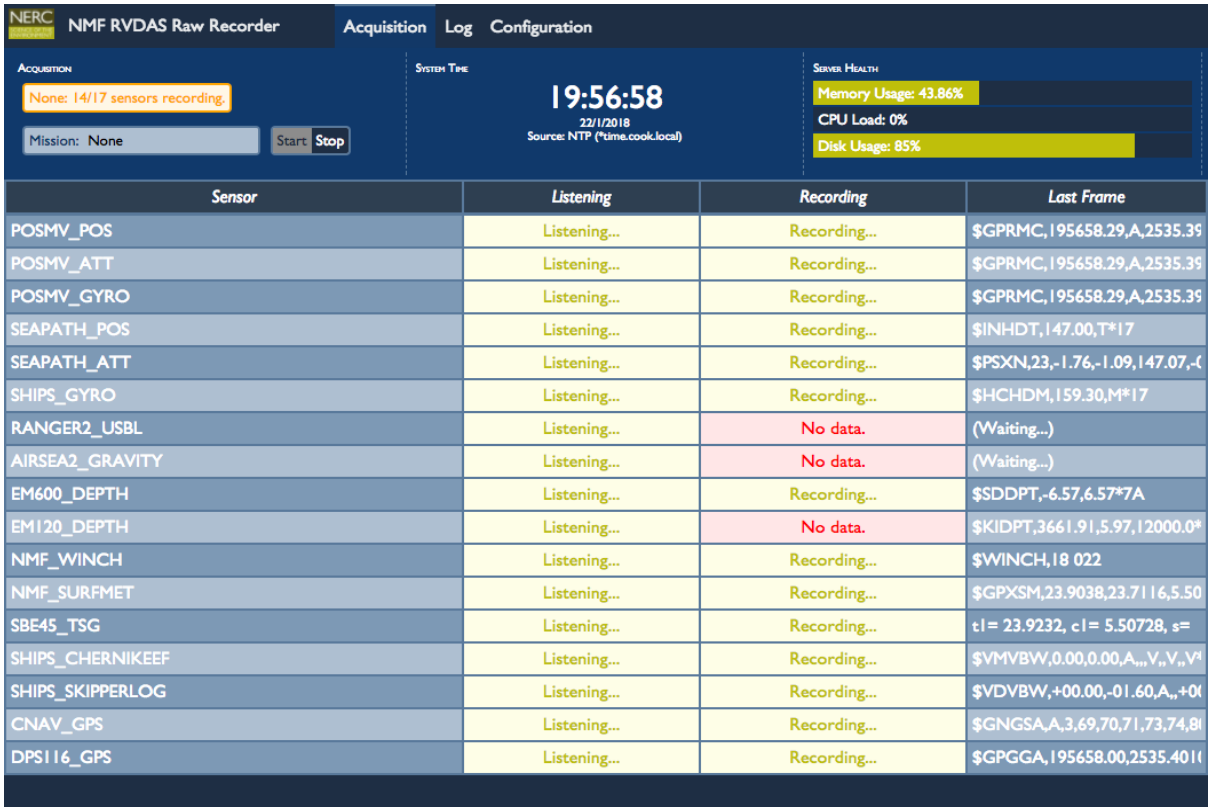
2018/2019 Update

- 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.



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

Science Drivers

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

    - ### 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

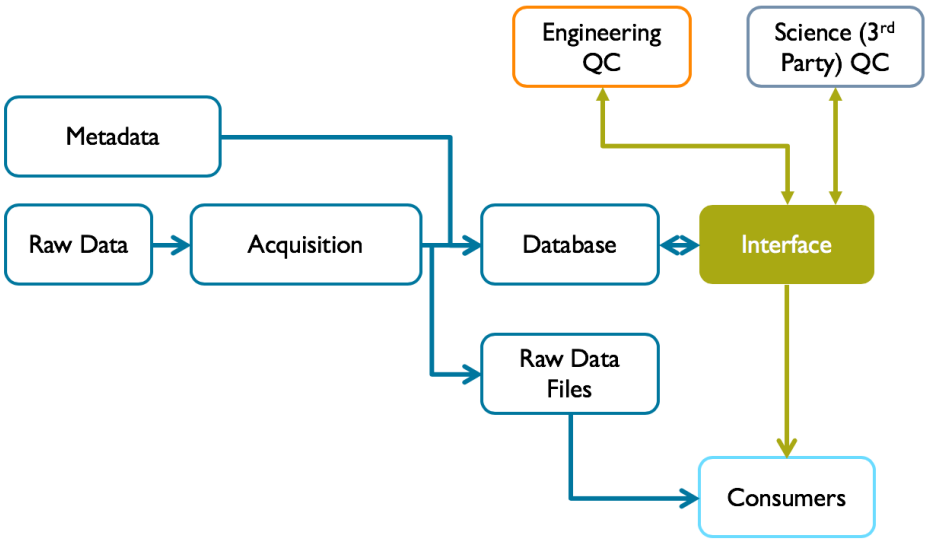
      In order to transmit meaningful data to the wide range of consumers onboard and ashore, it becomes necessary to structure the data storage into databases, with the ability to apply metadata at the creation of data products.

    - ### 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

Winch drum on RRS Discovery

- 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.

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.

The National Oceanography Centre

National Marine Facilitie

Capital Expenditure Proposal Form: IN CONFIDENCE

1. In August 2018 we advertised the first call for submission for new items for the NMEP, via the Capital Expenditure Proposal Form. The background to the call is included in the papers for information. Four proposals were received, the titles of which are given below. Working with the MFAB Secretary, Carol Robinson allocated members of the Board as assessors.

Applicant/s	Institution	Item
Eleanor Frajka-Williams, Nicholas Harmon	National Oceanography Centre and University of Southampton	Paros Scientific Seismic + Ocean Sensors-Absolute Pressure Gauge
Bramley Murton	National Oceanography Centre	Full heave compensation for the deep-tow conducting f/o winch
Adrian Martin	National Oceanography Centre	Trace metal clean snowcatcher
James Thorburn	University of St Andrews	National Acoustic Network

2. Anonymised feedback from assessors is appended to copies of the proposals, below and grades received are in the table below. The Board is invited discuss and rank the proposals which will then be moved onto the National Marine Equipment Proposal Five Year Capital Expenditure Plan, for consideration by the National Marine Facilities, alongside other capital expenditure. **Action: All**

Applicant	Assessor One	Assessor Two	OVERALL
J Thorburn University of St Andrews	3	4	7

Note for NOC colleagues…grades for NOC proposals have been removed

Capital Expenditure Proposal Forms

Proposal One

CAPITAL EXPENDITURE PROPOSAL FORM: Dr Adrian Martin

1	Date	28 September 2018
	Name	Adrian Martin
	Institution	National Oceanography Centre
	Email address	adrian.martin@noc.ac.uk
2	Capital Item - brief description	Trace metal clean snowcatcher: The Marine Snowcatcher is an increasingly used piece of equipment for investigating the downward flux of organic material in the ocean. The new trace metal version (MkII) comprises a ~2m long, ~100l tube with a small settling compartment at the bottom. The tube is deployed open and shut remotely via a signal through a conducting wire. The water trapped inside will contain sinking organic material which can be segregated by sinking speed through settling into the lower chamber. The current non-TM-clean version is triggered by messenger. Inside the UK it is already a key tool in a variety of projects (COMICS, CUSTARD) and outside the UK it is being purchased by Norwegian and Icelandic groups to form part of large EU proposals. At present though it is not trace metal clean and so cannot be used to explore the role of metals such as iron influencing the downward flux. NOC have a design for a snowcatcher Mk II which could be built as a trace metal clean version.
3	Institute/ science area	Pelagic biology/biogeochemistry
4	Total Capital Cost (inc. VAT, if applicable) Please note that the minimum cost requirement is £10k and the item should have a minimum two year life.	£43k
5	New/Replacement/Maintenance of existing (select one)	New
6		

	How the asset will be used (inc. project name from box 20)	The TM clean Snowcatcher MkII will be used to collect sinking organic material on the CUSTARD 2019 cruise in the S.Ocean. By deploying it at a sequence of depths, vertical profiles of the composition of sinking flux can be collected. This will allow the scientists for the first time to examine how metals such as iron are remineralised out of different fractions (by sinking speed) of the sinking marine debris. This is important to determine how and why the remineralisatoin depth of metals, carbon and nutrient elements (N, Si, P) differ and the role this plays in controlling uptake of atmospheric carbon by S.Ocean marine life.
7	Annual maintenance costs	10% of capital at a very rough estimate
8	What is the anticipated duration of service?	5 years
9	Estimated disposal costs	Nominal. It is a high density plastic tube ~2m long with largely kevlar/titanium fittings
10	What commissioning or setting to work will be required prior to first use?	Additionally requires 10 month staff time to build from current design. The work could be done by the OTE group at NOC who have designed it.
	Justification for Acquisition	
10	Key science driver	Examining the role of metal biogeochemistry in controlling the function of the mesopelagic zone, the region spanning depths of 100m-1000m where the majority of organic carbon arising from photosynthesis by marine organisms is respired. Mesopelagic biogeochemistry is the focus of major current UK (CUSTARD, PICCOLO) and international (EXPORTS, WHOI Audacious) projects with UK involved in two further large EU H2020 proposals under review (MEESO and SUMMER to BG-03)
11	Value for Money	Viewed as a replacement to one of the current MkI snowcatchers this would add a new capability in trace metal analysis for a net cost of ~£23k. It's addition to the NMEP is already supported by the wider UK marine science community - see below.

12	Resource Budget Impact (is this spend to save?)	Could be used as a replacement for standard Snowcatcher MkI when it reaches end of service. The cost of purchasing a new MkI is ~£20k
13	Alternatives	None currently available. Hence the recent work designing it.
14	**Environmental impact** - 1) Are there any hazardous substances associated with running/operating this equipment (e.g. lithium batteries, calibration gases, radioactive substances, COSHH related substances)	No
15	**Environmental impact** - 2) Are there any specific environmental impacts associated with running/operating this equipment (e.g. underwater radiated noise associated with echosounders and seismic equipment, radioactive waste disposal)	No
	Timing	
16	**Year:**	Funded 2018 to be first deployed 2019
17	**Procurement Lead Time:**	Main constraint is staff time for the build. This could begin in spring 2018 and it would be advantageous to have purchased components in advance.
18	**Full Implementation Time:**	NOC design would have one ready for deployment on the CUSTARD cruise provisionally scheduled for Nov-Dec 2019
19	**Timing Constraints:**	Staff time - see above
20	**Project Details (please include: name, funders, reference number, duration, science objective)**	
	1. CUSTARD, NERC, NE/P021247/1, 4 years (2018-2022), investigation of how physical circulation and biogeochemistry (particularly iron and silicate availability) interact to control the uptake and storage of atmospheric carbon by marine life in the Southern Ocean - https://roses.ac.uk/custard/ 2. At the 2018 Challenger meeting AMBIO workshop there was also community wide support for this to be added to NMEP to be part of future science proposals. As examples of this support Prof Alessandro Tagliabue of U.Liverpool, Prof Mark Moore of U.Southampton and Prof Maeve Lohan have all given their support for this request.	

Additional information provided by applicant, on request by one of the assessors:

Assessor request to know how the trace metal free unit will be kept and operated in a clean fashion: "The use of these systems is not straightforward and generally involves them rolling around on a ships deck prior to deployment and being stored in the open atmosphere. Other trace metal free systems (e.g. niskin bottles) are cleaned thoroughly and stored when not being used in clean laboratories and then handled using clean procedures. I would like to see some detailed description of how this system is to be operated cleanly and how some electronics will be incorporated into the system to ensure that the depth of firing is known (currently this is solely reliant on wire measured out from the winch)."
The assessor is right that the current snowcatcher has been used a in a rather relaxed manner in terms of storage and this would be inappropriate for a TM-clean version. There are a number of options for storage. The first is for it to be stored in a TM-clean container; it is only 2m tall and the end cap is ~10-20cm and can be detached. Second, to obtain/build a plastic box, or plastic-lined metal box, with a door and fittings to secure the box to the ship. Third, to encase it in plastic sheeting, effectively building a bubble round it, in the hangar. Concerning usage, it will be deployed open and hence flushed with seawater as it descends. This is the same method used for maintaining clean standard TM clean rosettes. Once again in analogy to existing TM rosette protocol, sensitive parts can be covered with plastic gloves or equivalent until just prior to deployment. The triggering of the snowcatcher to close will be done using a messenger, in the same way that TM clean sampling is done using GoFlo bottles e.g. recent cruise DY096. Hence, aside from the storage discussed above we foresee no issues other than those currently addressed by the TM rosette sampling and clean GoFlo protocols. Depth will be judged either by length of wire out or by using a reversing thermometer. As stated in the application, as a contribution to the cost we have secured funds for the necessary staff time for constructing the TM clean snowcatcher. The quoted cost of £43k in this application is for components. Please note that there was a typo in the application. Under “lead time” it should have stated that work on building the prototype could begin in spring 2019. This is still to deliver the MkII in time for the DY111 CUSTARD cruise at the end of the 2019.

PROPOSAL TWO **CAPITAL EXPENDITURE PROPOSAL FORM: Professor Bramley Murton**		
1	Date	20th July 2018
	Name	Bramley Murton
	Institution	National Oceanography Centre
	Email address	bramley.murton@noc.ac.uk
2	Capital Item - brief description	Full heave compensation for the deep-tow conducting f/o winch
3	Institute/ science area	NOC/Marine Geosciences
4	Total Capital Cost (inc. VAT, if applicable)	unknown, last enquiry was about £50k to implement software (Rolls Royce) to control the deeptow winch
5	New/Replacement/Maintenance of existing (select one)	New
6	How the asset will be used (inc. project name from box 20)	All projects requiring the use of HyBIS or equivalent near-seafloor platforms.
7	Annual maintenance costs	unknown - probably a few £k
8	What is the anticipated duration of service?	life of the vessel
9	Estimated disposal costs	N/A
10	What commissioning or setting to work will be required prior to first use?	Seagoing trials and crew training to operate the system
	Justification for Acquisition	
10	Key science driver	Near seafloor observation and sampling platforms that are suspended by the deep-tow cable and lack their own buoyancy are subject to vessel heave. This creates disturbance of the seafloor, and endangers the platform. For example, the HyBIS system is capable of visual surveying and sampling of the seafloor, but is restricted by sea state and the resulting heave adversly affects the data quality. Similarly, deployment of instruments by wire are also affected by

		heave, as are other instruments such as electromagnetic imaging platforms.
11	Value for Money	The currently installed deep-tow winches on the RRS JC and Disco are designed to accommodate active heave compensation. This is also a standard on many commercial ROV and survey vessels. A modest investment in upgrading these winches will decrease the seastate downtime for near-bottom platforms, enable better quality data, reduce damage to those systems, and enable new platforms and sensors to be deployed.
12	Resource Budget Impact (is this spend to save?)	yes, reduced damage and expand operational window.
13	Alternatives	none
14	**Environmental impact** - 1) Are there any hazardous substances associated with running/operating this equipment (e.g. lithium batteries, calibration gases, radioactive substances, COSH related substances)	none
15	**Environmental impact** - 2) Are there any specific environmental impacts associated with running/operating this equipment (e.g. underwater radiated noise associated with echosounders and	none

	seismic equipment, radioactive waste disposal)	
	Timing	
16	**Year:**	
17	**Procurement Lead Time:**	
18	**Full Implementation Time:**	
19	**Timing Constraints:**	
20	**Project Details (include: name, funders, reference number, duration, science objective)**	

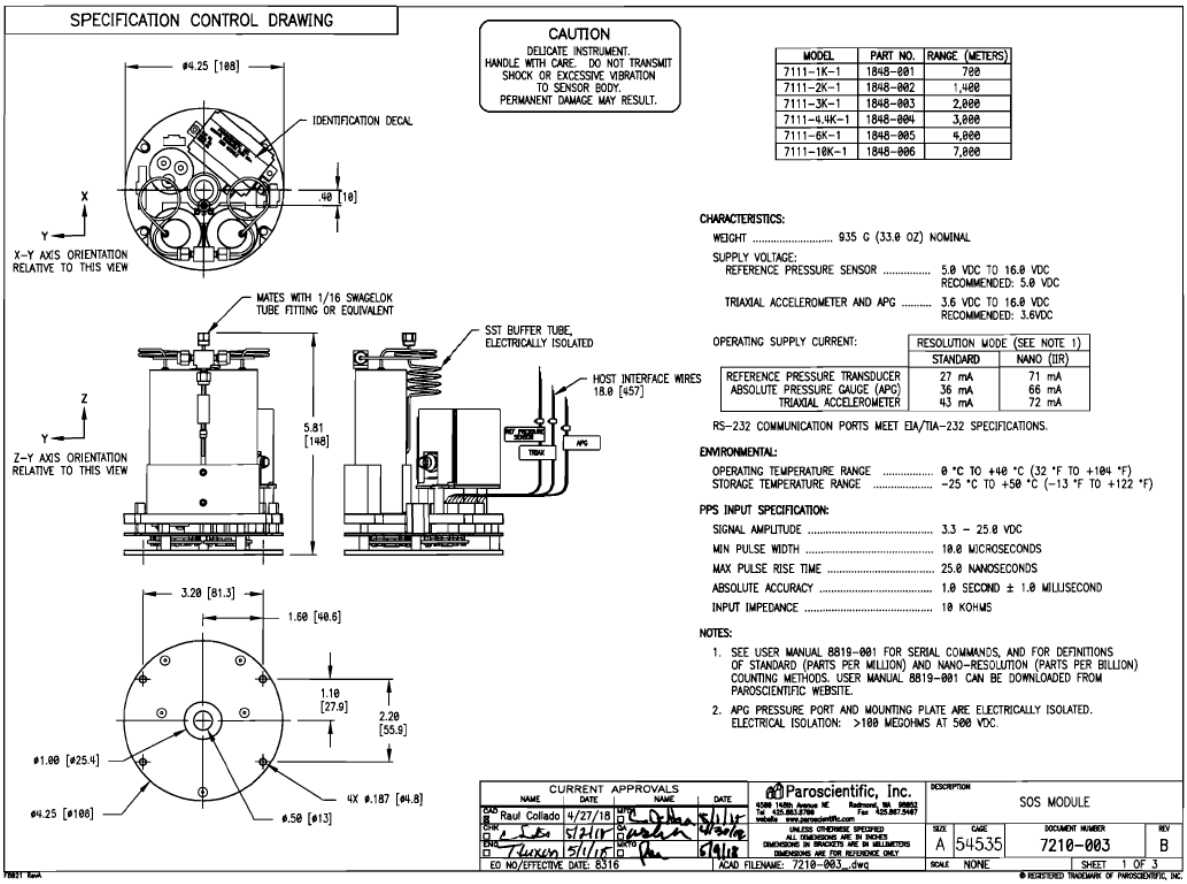
PROPOSAL THREE

CAPITAL EXPENDITURE PROPOSAL FORM: Dr Eleanor Frajka-Williams & Dr Nicholas Harmon

1	Date	24 September 2018
	Name	Eleanor Frajka-Williams, Nicholas Harmon
	Institution	National Oceanography Centre, University of Southampton
	Email address	eleanor.frajka@noc.ac.uk, n.harmon@soton.ac.uk
2	Capital Item - brief description	Paros Scientific Seismic + Ocean Sensors- Absolute Pressure Gauge
3	Institute/ science area	Oceanography/Geophysics
4	Total Capital Cost (inc. VAT, if applicable)	$57,375.00/per instrument - minimum 4
5	New/Replacement/Maintenance of existing (select one)	New technology for ocean bottom pressure measurement that is less subject to drift of the sensor
6	How the asset will be used (inc. project name from box 20)	4-5 RAPID AMOC mooring deployments
7	Annual maintenance costs	~£10,000-based on estimated costs for batteries and other consumables
8	What is the anticipated duration of service?	10 years
9	Estimated disposal costs	unknown
10	What commissioning or setting to work will be required prior to first use?	Calibration is required but performed with assistance of Paros.
	Justification for Acquisition	
10	Key science driver	Absolute pressure measurements at the ocean bottom are fundamental to diagnosing deep ocean circulation, for understanding changes in water depth and for acoustic energy propagating through the water column. The previous state-of-the-art bottom pressure sensors, however, were all subject to drift on the timescale of the deployment, meaning that e.g., low frequency variability could not be assessed. With the parts per billion scale resolution and calibration of the Paros scientific absolute pressure gauges, drift-free measurements of ocean bottom pressure are

		now possible. With this equipment, accurate deep ocean circulation can be calculated, as well as geodetic (vertical) changes in seafloor elevation, and recording of seismic and ocean gravity wave energy propagation near the deployment location. These sensors would provide a powerful multidisciplinary sensor, maximizing the scientific output of each mooring.
11	Value for Money	These sensors are an upgrade to currently deployed equipment on the RAPID moorings. The new sensors will provide superior measurements to the current for studies of ocean circulation (see Chris Hughes et al., 2018 on "A window on the deep ocean") and will also provide a rich data set for use by geodesists and seismologists. The cost for a stand alone ocean bottom seismometer is £30,000 and for a bottom pressure recorder is $24,000.
12	Resource Budget Impact (is this spend to save?)	unknown. This is not a spend-to-save case, but a spend-to-deliver new science (seismic) and reduced uncertainty on current observations (RAPID).
13	Alternatives	Paros produces the instrumentation. Data loggers etc. can be purchased from Columbia University or other universities Paros has worked on development with.
14	**Environmental impact** - 1) Are there any hazardous substances associated with running/operating this equipment (e.g. lithium batteries, calibration gases, radioactive substances, COSH related substances)	Lithium batteries are required to power the system.
15	**Environmental impact** - 2) Are there any specific environmental impacts associated with running/operating this equipment (e.g. underwater radiated noise associated with echosounders and seismic equipment, radioactive waste disposal)	No.
	Timing	
16	**Year:**	2018
17	**Procurement Lead Time:**	9 months
18	**Full Implementation Time:**	1 year
19	**Timing Constraints:**	none

20	**Project Details (include: name, funders, reference number, duration, science objective)**
	RAPID AMOC (NERC-funded under a service level agreement): The aim of the RAPID programme (2004-2020) is to monitor the variability of the Atlantic Meridional Overturning Circulation, its structure and associated heat and freshwater transports. The observations included in this programme include temperature and salinity, ocean velocities, and bottom pressure measurements on moorings across the Atlantic around 26N. The results from these observations are widely used by the scientific community (oceanographers, climate scientists, atmospheric scientists) to answer questions about ocean circulation variability, as well as to evaluate numerical and climate models. One of the greatest sources of uncertainty in the RAPID calculation arises from our inability to measure ocean bottom pressure in a way that is not subject to low frequency drift (Worthington, Frajka-Williams, McCarthy - Estimating the Deep Overturning Transport Variability at 26N Using Bottom Pressure Recorders, in revision at Journal of Geophysical Research-Oceans). The ability to measure bottom pressure without drift would reduce uncertainty on the MOC estimates produced by RAPID and used by the wider community.



EDITED EMAIL TRAIL BETWEEN DR HARMON AND PAROSCIENTIFIC

From: Harmon N.
Sent: 04 January 2019 10:45
To: Pearson, Jackie F. <jfpea@noc.ac.uk>
Subject: FW: {Spam?} RE: Contact form response for Paroscientific Inc

Dear Jackie,

Please find attached information from Tyler. In addition there may be some opportunity for some matching funds from Paros Scientific/Columbia University to provide additional sensors for deployment on the Rapid Programme if that factors into the equation at all. I can request a letter from them if it helps.

Sincerely,

Nick

On 17/08/2018, 18:21, "Tyler Cronk" wrote:

Hi Nick,

So, I've spent a lot of time sifting through the link and sub-links that you sent. This is a fantastic project and we're very excited to be talking to you about possibly applying SOS modules to help. They would add tremendous research data to the project in addition to geophysics, oceanography, seismology, etc.

First, here is a link to our overall SOS presentation:
http://paroscientific.com/pdf/P20_Seismic_Oceanic_Sensors_(SOS).pdf

There are three main parts of this technology -

1) Nano Resolution (parts per billion resolution):
http://paroscientific.com/pdf/20_Oceans_2012_Tsunami_MARS.pdf

2) A-0-A In-Situ Calibration: http://paroscientific.com/pdf/G8085_Configuring_A-0-A_System.pdf

3) Pressure Sensors and Accelerometer:
http://paroscientific.com/pdf/G8096_Triaxial_Accelerometer.pdf

As you know, we've been working with multiple universities and OEM's on deployment and data collection. The graph in the above SOS presentation is the clearest representation of how successful it’s been so far.

I have attached SCD 7210-003 for the specifications of the SOS. There are two different development routes that we see: 1) purchasing SOS module from us and developing the rest of the system OR 2) purchasing a system already developed through another source (for instance, Columbia University). We can help you figure out what the best route would be.

A few questions:

Can you please provide us detailed information on the moorings? How are they installed? How do you gather information form the sensors (Log? Subsea modem? Satellite?)? Where are the sensors and how are they installed? How do you communicate with the moorings/sensors? The more information you can provide, the more guidance we can provide.

What technical and design/development capabilities are at hand for you and your team? From looking through the links, it appears there are plenty of custom setups but we don't want to make assumptions. The capabilities we're curious about include software, mechanical design, electrical, etc.

Where would the SOS be installed? How would it be installed? How would you communicate with it? How would you gather data?

_____

The initial quote I can send you is $57,375.00 ea. The lead time would be 9 months ARO.

Once again Nick, I enjoyed talking with you. Have a nice weekend and I look forward to your response.

Tyler

Tyler J. Cronk
Application Engineer
Paroscientific, Inc.
Redmond, WA 98052, USA
www.paroscientific.com

From: Harmon N.]
Sent: Thursday, August 16, 2018 1:43 PM
To: Tyler Cronk <
Subject: Re: Contact form response for Paroscientific Inc

Dear Sir or Madam:

I'm interested in obtaining a quote for 5 absolute pressure gauges for seismic and physical oceanographic purposes as part of a long term deployment of moorings across the atlantic. Perhaps it would be good to arrange a phone call to discuss specifications? I'm available after 4 pm UK time today and tomorrow and a good part of next week. Thank you in advance for your assistance.

Sincerely,

Nick

PROPOSAL FOUR

CAPITAL EXPENDITURE PROPOSAL FORM: Dr James Thorburn

1	Date	10 January 2019
	Name	James Thorburn
	Institution	St. Andrews University
	Email address	jat21@st-andrews.ac.uk
2	Capital Item - brief description	Acoustic telemetry equipment (receivers) for the provisioning of Passive Acoustic Telemetry projects.
3	Institute/ science area	Marine spatial ecology/animal tracking.
4	Total Capital Cost (inc. VAT, if applicable) Please note that the minimum cost requirement is £10k and the item should have a minimum two year life.	This proposal is using the VEMCO equipment. There are other manufactures, but VEMCO has been shown to be one of the most reliable manufacturers of Acoustic Telemetry equipment. It is also one of the most widely used manufacturer in the UK. There are several different types of receiver, each with its own cost/use benefit depending on the research species and study environment. Ideally, having a pool of acoustic equipment that researchers could use and adapt to suit their needs would be ideal. Total cost is dependent and can easily be adapted to suite available budget. All come with new batteries. • Standard VR2W: £1205 • Acoustic release VR2AR: £3010 o ARC Acoustic Release Canister, holds approx. 130-160 m x 4 mm dyneema: £930 o ARC Acoustic Release Canister, holds approx. double above x 4 mm dyneema: £1240 • Acoustic modem communication setup: o Receiver VR4 £14500 – Underwater modem is included. o Top side modem £12500 • Surface comms box for active tracking or communication with AR unit. VR100: £4545 • Hydrophones to use with VR100 o VHTx (transponding hydrophones for arming VR2AR): £1665 o Directional hydrophone for active tracking VH180-D: £1245 • Range test tags cost £262 (UK delivered, ex VAT).
5	New/Replacement/Maintenance of existing (select one)	New
6		

	How the asset will be used (inc. project name from box 20)	These receivers will form a pool of Passive Acoustic Telemetry (PAT) equipment in the UK that researchers can bid to use in order to develop new research or extend existing projects. This will add significant value to PAT research by increasing the number of receiver's projects can use, widening the spatial coverage of each project, helping to link multiple projects together and help0ing to provide movement data for mobile species within UK waters. There is also the hope that this resource could form a platform from which to develop a National Acoustic Array within the UK.
7	Annual maintenance costs	The battery needs to be repaced each year (£13.45 + vat per unit). When this is done, a new O'ring should be used to seal the unit (£10 per unit)
8	What is the anticipated duration of service?	The receiver units can communicate with transmitter on multiple code maps, so newly developed transmitters could still be used with these receivers. The expected work life of a receiver is in excess of 10 years with suitable servicing.
9	Estimated disposal costs	Battery disposal should be undertaken by the research project using the units.
10	What commissioning or setting to work will be required prior to first use?	Each unit is automatically started in record mode. The set up of each unit would be the responsibility of the research team deploying and using the receivers.
	Justification for Acquisition	
10	Key science driver	Increase knowledge on the spatial ecology of mobile species throughout UK waters.
11	Value for Money	Acoustic receivers, as part of a wider project, offer excellent value for money. Given that individual research project would be expected to meet the cost of tags.
12	Resource Budget Impact (is this spend to save?)	
13	Alternatives	There are no alternatives. Alternative tracking methods would include satellite tags, but they are known to have poor resolution, especially in coastal waters.
14	**Environmental impact** - 1) Are there any hazardous substances associated with running/operating this equipment (e.g. lithium batteries, calibration	Each receiver is powered by a 3.6 volt Lithium battery. The units them selves are sealed and there is a very low risk of the batteries coming into contact with sea water.

	gases, radioactive substances, COSHH related substances)	
15	**Environmental impact** - 2) Are there any specific environmental impacts associated with running/operating this equipment (e.g. underwater radiated noise associated with echosounders and seismic equipment, radioactive waste disposal)	The receivers themselves produce no noise. There is the potential for small scale benthic disturbance at the deployment site of new receivers. This equates to approximately 2m^2 per unit. Each unit runs off a lithium battery, which needs to be replaced every year. These batteries require appropriate disposal.
	Timing	
16	**Year:**	2019 onwards
17	**Procurement Lead Time:**	NA
18	**Full Implementation Time:**	NA
19	**Timing Constraints:**	NA

20 Project Details (include: name, funders, reference numbers, duration, science objective

National UK Acoustic Network (UKAN)	A National Acoustic network could provide a wealth of information on the movements of migratory species and provide a strong framework to support future acoustic studies.

Data on movement for larger marine animals is limited. Fully aquatic species that do not break the surface often have movement predicted from environmental variables recorded on an archival tag, such as light, depth and temperature. Geo-location is post-processed from these variables to give an estimated of movement for the tagged animal. However, these often have large errors associated with them, especially in coastal areas. Acoustic telemetry, a system involving a receiver and transmitter pairing, are being increasingly used to monitor the movements of study species in relation to localised areas. The transmitter produces a unique ID code which is transmitted at a pre-determined time interval, if the transmission is close enough to a receiver unit (approximately 500 m) it records the ID code as well as a time-date stamp. The transmitters, which can be fitted with other sensors (such as depth or temperature), to provide additional information on the environment the tagged animal has experienced, can either be attached to or inserted in the study

animal. Most commonly used in the format of Passive Acoustic Telemetry (PAT) arrays involving a static receiver network to map movement through detections, this system is ideal for studying the spatial ecology of an aquatic animal within a localised area. The advantage to this system is that the tagged animal does not need to be recaptured to retrieve data as the receiver records presence. Early studies typically deployed small numbers of receivers to detect the presence of a few tagged individuals. Now, in some parts of the world, large numbers of acoustic receivers are deployed in static arrays for extended periods of time. Extensive, permanent arrays have created baseline systems to which researchers can add too in order to investigate specific research questions and for wider biodiversity monitoring. For example, as part of the LifeWatch European programme to develop automated biodiversity monitoring, a permanent acoustic array comprising 117 receivers has been deployed in the North Sea off Belgium, the Western Scheldt estuary and several rivers/canals. The establishment of permanent arrays, their low cost and longevity are expected to continue to drive growth use of PAT to address questions in spatial ecology. Due to this, having a national pool of PAT equipment that researchers could utilise to either develop new or extend existing PAT projects would be of great benefit and encourage collaborative projects as there would be sufficient equipment to link several research areas which would provide wider movement data. There is also the potential that this equipment could form the core of a National Acoustic Array. The map detailed in Figure 1 shows the location of all known acoustic arrays, that have been deployed in the last 5 years. These studies involve 37 different research institutions and government agencies throughout the UK, so this resource has the potential to benefit many different research organisations UK wide.

Figure 1: Map showing acoustic study sites in the UK and Ireland.

The proposal is for a national acoustic resource that will:

1) Initially provide a pool of acoustic receivers:

Researchers working with PAT in UK waters could bid to use this resource in order to develop new or expand existing projects taking place in UK waters. The equipment would be loaned to projects in order to increase the spatial remit of each project, helping to provide more information on the spatial ecology of the study species. This has significant implications for studies researching the movements of mobile species. The project would purchase a range of acoustic receivers and range testing tags (to allow for detailed ranges testing to be undertaken) that UK based researchers could apply to borrow for their own research. This will allow projects to install larger and more comprehensive acoustic arrays, enhancing the research potential of individual projects, promoting the UK as a centre of excellence for acoustic studies. A model for this does exist in the form of the Ocean Tracking Network (OTN) based in Canada. They loan equipment to acoustic projects around the world. However, one drawback is that researchers must cover import duty on all borrowed equipment, this is recoverable upon return, but can still place a strong financial burden on a project.

Furthermore, receivers could be attached to automated vehicles to provide coverage, perhaps using such vehicles to undertake surveys for acoustics tags in areas where moorings are not feasible. At this stage, any acoustic detections could be submitted to a centralised database, such as that held by RS Aqua, the UK contact for VEMCO equipment, who could pass detections on to the research project associated with the ID of the tags (although as detailed below, we would hope to develop a centralised data repository to enable the dissemination of acoustic data). This would have the potential to drastically increase the range of localised acoustic projects by having remote receivers with the ability to detect tags. The inference on movement that such detections could provide would help identify the connectivity of coastal regions

2.) Create a platform for which to develop a national acoustic array that all researchers could use:

It is hoped that this pool of receivers could form a platform from which to develop a UK Acoustic Network (UKAN). This would be a network of receivers around the UK coast that that will have the capability of recording any deployed acoustic tags used for individual research projects. As can be seen from Figure 1, there are already a significant number of receiver arrays throughout UK waters, the UKAN project could fill in the gaps between these projects to provide a comprehensive network of receivers that have the potential to benefit all UK project on studying the movements of mobile species. UKAN will also provide a platform where researchers would register their individual acoustic research projects, showing the project location, species being worked on, what the tag IDs they are deploying will be and dates of deployment. This will help other researchers plan their work, maximising the potential of each project while ensuring no cross over of tag IDs. A national array would substantially increase the potential of acoustic studies to be undertaken on migratory species. As well as a central platform to help researchers plan their projects the network would also act as a central data repository for all data collected

by its equipment, helping researchers find out if their tags have been detected in other areas. UKAN would lend great understanding to the movements of aquatic animals around the UK and acoustic platforms could be added to with other environmental recorders to enhance the functionality of the network.

James Thorburn, St Andrews University, Coastal Resource Management Group

One pager summary:

Dear Jackie

Please find attached a one pager outlining the concept of a national acoustic array. This is, of course, a brief outline of the idea and I will provide a more detailed project if it is deemed of interest to carry forward. I am more than happy to provide this whenever you need it.

I do apologise for only providing a brief synopsis at this stage. I hope this is at least enough information to give an outline on the idea I am proposing.

Please do ask as many questions as needed.

Kind regards

James

National UK Acoustic Network (UKAN)

A National Acoustic network could provide a wealth of information on the movements of migratory species and provide a strong framework to support future acoustic studies.

BACKGROUND

Acoustic telemetry is increasingly being used to track the movements of aquatic animals. The system works around a receiver unit and a transmitter pairing. The transmitter produces a unique ID code which is transmitted at a pre-determined time interval, if the transmission is close enough to a receiver unit (approximately 500 m) it records the ID code as well as a time-date stamp. The transmitter is in the form of a small tag that can either be attached to or inserted in the study animal. The advantage to this system is that the tagged animal does not need to be recaptured to retrieve data as the receiver records presence. The transmitters can be fitted with other sensors, such as depth or temperature, to provide additional information on the environment the tagged animal has experienced. The system is ideal for studying the spatial ecology of an aquatic animal within a localised area.

The proposal is for a national acoustic resource that will aim to:

1) **Provide a loan of hardware to projects to reduce financial restraints:**
UKAN would purchase a range of acoustic receivers that UK based researchers could apply to borrow for their own research. This will allow UK based research projects to install more comprehensive acoustic arrays, enhancing the research potential of individual projects, promoting the UK as a centre of excellence for acoustic studies.
A model for this does exist in the form of the Ocean Tracking Network (OTN) based in Canada. They loan equipment to acoustic projects around the world. However, one drawback is that researchers must cover import duty on all borrowed equipment, this is recoverable upon return, but can still place a strong financial burden on a project.

and

2) Install a national acoustic array that all researchers could use:

UKAN would install and manage a nationwide acoustic array that will have the capability of recording acoustic tags used for individual research projects. UKAN will also provide a platform where researchers would register their individual acoustic research projects, showing the project location, species being worked on, what the tag IDs they are deploying will be and dates of deployment. This will help other researchers plan their work, maximising the potential of each project while ensuring no cross over of tag IDs. A national array would substantially increase the potential of acoustic studies to be undertaken on migratory species. There is also the possibility of utilising more state of the art technology by attaching receivers to automated vehicles to provide coverage, perhaps using such vehicles to undertake surveys for acoustics tags in areas where moorings are not feasible.

As well as a central platform to help researchers plan their projects the network would also act as a central data repository for all data collected by its equipment, helping researchers find out if their tags have been detected in other areas. UKAN would lend great understanding to the movements of aquatic animals around the UK and acoustic platforms could be added to with other environmental recorders to enhance the functionality of the network.

This proposal has been submitted by the Coastal Resource Management Group at the University of St. Andrews. Please direct all correspondence to Dr. Mark James maj8@st-andrews.ac.uk and Dr. James Thorburn. jat21@st-andrews.ac.uk

Responses from assessors: Proposal from Dr James Thorburn

Assessor One

This is an interesting note, but it does not seem as much a proposal as a concept. As a concept, the idea has considerable merit. As a proposal is more difficult to evaluate based on the lack of specific detail. There is a good case made for the relative merits of Passive Acoustic Telemetry (PAT) as a technology, what it means and why it is useful.

It is not clear how much money is being bid for here – the proposal is written as if for one receiver (standard or acoustic), but presumably it is suggesting the acquisition of an array. This comes in at a cost of £41, 1102). How many are suggested as a minimum to make up a useful number for the PAT pool? This would be critical to the effectiveness of a national array, as it would need a critical mass of receivers to really be of best use at a national level. Dr. Thorburn has indicated the following in his correspondence: "*stress to the reviewers that there are no estimated total spend as, due to the nature of the equipment, it is fully flexible and can be adapted to suit a budget. If required, I can provide total estimates based on number of units purchased*". The suggestion is that it could be scaled up or down in cost depending on how much funding was available. This is fair enough in and of itself, but lacks the specific detail to make an informed decision about value for money. What would be helpful would have been several indicative costings, based on theoretical examples, for instance: small £20 k), medium (£100 k) and large array (>£250 k), how many units this would comprise etc. and what the effect would be in terms of the additional items? Are all the costs that are listed per receiver; presumably, some of these would only need to be procured once.

Further, it is not clear the scale of what is being proposed here – is this for a smaller array for site specific deployment, or is it for a national array? The title of the proposal would suggest a national array, but the content of the proposal suggests a much more modest affair. From the front matter on the form, this proposal is not for a national array, but a smaller set of PAT equipment that researchers would bid for as part of other applications to NERC. The real value of this concept would be for a permanent array with national coverage. How many units would be needed to make this feasible and what would the maintenance and servicing costs in the longer term? The maintenance costs here are based on changing the batteries on the units that are recovered on an application to application basis. If it was a permanent installation this would be a very different situation with much higher overheads. If we take the LifeWatch programme as an example in the North Sea. This network appears to consist of The Permanent Belgian Acoustic Receiver Network (PBARN); C-PODs in the Belgian Part of the North Sea. There are quite a lot of sensors in a relatively small area – how would this translated into a national pool to achieve a comparable level of resolution? What would the associated costs be? This kind of detail would give a much clearer indication of what it would cost and the labour necessary to emulate something comparable.

It is difficult to know whether it will provide value for money – as it is contingent upon sufficient researchers that would be able to utilise this functionality, and there being tags on the organisms for the receivers to receive. Maybe a review of the number of

publications using PAT or acoustic tags in UK waters would develop this as a concept and afford some reassurance that there is sufficient demand? As indicated by Figure 1, there are 37 different organisations; government and research institutes that have deployed acoustic arrays in the last 5 years. How has this translated into demonstrable output or policy change that would show value for money? Maybe an example of where this kinds of a resource would make a difference or addition to existing infrastructure would help to make a convincing case.

In terms of deployment options, it is acknowledged that this technology could interface with AUVs to give coverage in areas where moorings are not feasible. That said, another potential issue with this equipment would be that it may likely be deployed for a considerable period of time on any individual project – during which time it would not be available to other researchers unless they were already working in that location. It would not be difficult to imagine a 3-5 year project that would utilise this array as an in-kind contribution to reduce the costs associated and improve the value for money. In this kind of situation, this would result in 3-5 such deployments in the lifetime of the equipment – which would not represent good value for money in my opinion. This may be more or less of a problem, but it is difficult to know how it could be affected in advance of applications seeking to make use of it.

Where are the suggested deficiencies in the current national coverage (Figure 1), and where does this relate to the institutes that are currently engaged in marine telemetry work – are these permanent installations, or organisations that have access to PAT equipment? More detail would help to make a stronger case.

Again, related to Section 2 - the implication here is that this could be used to fill the gaps and create a UKAN. This is a nice idea, and would certainly have considerable merit. But this muddies the water in terms of what is being requested. Is this a bid for a small set array for multiple site-specific deployments, or the beginnings of a national array?

Overall, what is being requested is not particularly clear. There is merit in this as an idea for PAT; as both a smaller mobile array and as a national network (UKAN), but my feeling is that it needs substantial development as one or the other of these things before it could be given further consideration, and certainly before it was mature enough to warrant funding.

Grade: 3

Assessor Two

1. This seems to be a sensible thing to invest in, providing that there is a real requirement from the community for such fish/ marine mammal tracking. The proposer has given no real feel for the numbers of institutions/ research projects that might want to use such equipment – so this probably warrants discussion at the MFAB.

2. Clearly the approach is limited in that (1) the animals must be tagged; and (2) they must then swim within a short distance of a receiver. So planning of projects and a good prior knowledge will critical to get the required detections. Should the

equipment be funded it would be worth considering how one assesses which projects would make the best use of it.

3. The costs are not precisely defined in the proposal – with unit prices being given. I would have rather that the proposer had said that an appropriate monitoring scheme/ network would ideally require X, Y and Z, at a total cost of ****. Having said this clearly a number of receiver units could be purchased for a cost of say £10-30k, so the overall cost is not high, unless one wanted to go for large numbers of the receiver variant with the acoustic modem.

4. These could have other applications – we have used VEMCO tags before on autonomous vehicles.

Overall, my view is that purchase of some of this equipment might be a good addition to the marine equipment pool. However, I should point out that I am stating this without a good knowledge of what already exists along these lines within the pool.

Grade: 4

Paper for information:

MFAB: Annual report to CPEB – report by Professor Mark Inall

1. Procedural activities

New Chair

Professor Mark Inall comes to the end of his 3-year term as chair of MFAB in November 2018. Professor Carol Robinson as incoming chair has been shadowing Mark since the March 2018 meeting of MFAB. Handover will be completed at the MFAB meeting in March/April 2019.

New Members

Working closely with Leigh Storey and MFAB secretary, both incoming and outgoing chairs are pleased to announce a refreshed MFAB membership, achieved through an open-call process to the UK marine science community. Response was excellent, with high quality applicants, exceeding demand. A short list from the selection group has been approved by NOC Executive Director (Professor Ed Hill), and included in Annex A for information (This information is given at paper one). With a relatively high number of new members, an induction/handover session has been planned, to take place immediately prior to the next full meeting of MFAB.

Of note to CPEB is that the principles followed during selection were ones of: excellence of candidates; coverages of discipline area; gender and diversity balance. We did not explicitly consider institutional representation for selecting the new "science expert" members of MFAB.

2. Working Groups: Seismics Working Group

Over the last 12 months an MFAB working group on Seismics capability has been active. The group comprised Professor Christine Pierce (MFAB member, U. Durham), Mr Leigh Storey (MFAB, NOC) and Dr Rob Larter (BAS). The working group report is on the CPEB agenda for discussion. Issue and recommendations are repeated here for completeness.

Seismics Working Group: Issue and Recommendation:

Improvements in multichannel seismic data logging capability within the NMEP over recent years have identified that the operating characteristics exhibited by the RRS *James Cook* and RRS *Discovery*, specifically their increased wake width, are having a significant impact upon the output of the NMEP seismic source. As a result, a MFAB working group has reviewed the following options: i) remove seismic capability from the NMEP, ii) retain current capability, iii) barter, iv) charter, and v) invest to upgrade. The recommendation is to invest in new capability to take advantage of the latest Commercial Off The Shelf (COTS) equipment to develop a modular system that will reduce through-life costs by standardising and minimising maintenance, containerising all parts of the system for ease of use, cost-effective shipping and reduction of de/mobilisation time in port and ashore, while at the same time reducing the technical support required to operate the system at sea.

Data handling: Deck to Desktop

MAFB has initiated a new working group on data management ("From deck to desk-top"), to be led by Dr Graham Allen (Head of BODC). This now seems particularly timely given the statements and recommendations in the independent LRI commissioning panel report: "The Panel agreed that additional posts to allow the direct automatic ingestion of data into BODC would be very beneficial, and noted that this should also improve communications between Principal Scientists and the data centre, which have suffered some difficulties in the past, and could start to approach the use of near real-time data for multiple end-users."

At the time of writing the working had not yet convened their first meeting, but it is actioned to provide a draft report to the next MFAB meeting (Spring 2019).

3. Community Communications

As an opening comment, attention is drawn to the LRI commissioning panel's report statement: "The MFAB and CPRG provide well-established mechanisms to consult with user groups and should be continued in the same vein."

Open Calls

Open calls on MFAB membership and on capital equipment requests have demonstrated a good level of awareness of MFAB, CPRG and CPEB in the marine community. MFAB should be encouraged to consult openly more often on matters relating LRI assets principally with NMF's Engineering Managers and/or with the Head of SE or MARS. Particularly regarding significant 'retirals' (e.g. Autosub3, geophysics arrays), major updates on new assets (e.g. new assets entering NMEP, SDA trials programme).

NMEP Technology Roadmap

Publication of the NMEP Technology Roadmap provides a step change in the provision of information to the UK marine community on present and potential future capabilities of the NMEP. MFAB Chair thanks Mr Andy Hensen (Head of SE) and Dr Maaten Furlong (Head of MARS) for their work in producing this document, and encourage the production and dissemination of an annual update to this 'living document'. One particular benefit of publishing the Roadmap will be to illicit community response to help shape future MAS development and/or investment opportunities.

National Marine Facilities Portal

Updating of the portal, with active links to the NMEP inventory and inclusion of MAS assets marks a step change in service for the UK marine science community who use the ships and pooled equipment. At an anecdotal level, feedback form the community has been singularly positive regarding this development.

4. Recommendations

In addition to the activities summarised above, of which Exec Director NOC and CPEB automatically have sight, specific recommendations from MFAB working group on seismics come directly to CPEB is a separate paper.

Paper for information: Capital Expenditure Proposal Form

Members of the NERC-funded marine science community, who are involved in research expeditions which utilize National Marine Equipment Pool (NMEP) equipment, are invited to submit proposals, by completing a **Capital Expenditure Proposal Form,** for sensors, systems or platforms to enhance the NMEP.

A note on Expectation: The purpose of this exercise is that, when opportunities arise at short notice, National Marine Facilities (NMF) will have an up-to-date, rank-ordered openly-generated priority list of proposed capital purchases that will be used to inform how the National Marine Equipment Pool (NMEP) Capital Funding is used.

Please note that, in a typical year, one without exceptional and unpredictable capital purchase opportunities, funding is used to replace equipment which is lost, damaged or obsolete, or to fund development work on current items within the NMEP.

Submission and review process

There will be two rounds of proposal reviews each year. Applicants are asked to submit proposals by the due dates given below. Proposals received after the next available due date will be held over until the next round.

- Email proposals to Jackie Pearson of the Marine Facilities Advisory Board (MFAB) Secretariat: jfpea@noc.ac.uk
- The MFAB Chair will nominate members of the Board with relevant expertise, to review and rank proposals.
- Reviews will be drawn together by the MFAB Chair, and given a final rank ordering.
- The rank ordered list will be merged with existing list by the MFAB Chair in discussion with the Associate Director, National Marine Facilities, National Oceanography Centre.
- Proposals will be reviewed against the availability of NMF technicians to maintain and operate equipment over its expected lifetime.
- Feedback will be given for all proposals submitted.

Due dates for 2018/19

Round one: 30 September 2018
Round two: 31 March 2019

Paper for information:

Terms of Reference

Marine Facilities Advisory Board

Purpose

The purpose of the Marine Facilities Advisory Board (MFAB) is to acquire views from the whole of the UK marine science community and then provide advice to the Executive Director of the National Oceanography Centre (NOC) on current capability and future development of the Natural Environment Research Council (NERC) National Marine Equipment Pool (NMEP) including the Marine Autonomous and Robotic Systems (MARS) autonomous equipment. The NMEP is co-ordinated through, and lead, by NOC on behalf of NERC and MFAB sits within a governance framework which reviews the performance of NOC (see Annex A). The chair of MFAB sits on the assurance group the Cruise Programme Executive Board (CPEB) in order to inform the NERC Director of Science and Innovation (DSI), and to provide assurance that the strategic investments being made by NOC reflect the wider UK marine science community views and are prioritised on the basis of benefits to the whole of the UK marine science community.

Remit

MFAB will provide advice to the Executive Director of NOC in developing a medium to long-term holistic strategy for future equipment requirements in UK marine science. This will respond to and reflect the community's needs and current and future funding.

A medium to long-term holistic approach to future equipment requirements is vital in an environment of growing cost and technical complexity of equipment and unpredictable Government funding opportunities, especially where funding constraints are likely to become even more challenging and/or focussed in the future.

MFAB's remit must involve a continuous assessment of the NMEP:

• What is there?
• What state is it in?
• What has the usage been over the past five - ten years?

This assessment feeds into NOC's baseline annual service provision, based on what can be maintained, at what level of readiness, within the annual resource 'flat cash' National Capability Marine Large Research Infrastructure allocation which funds owner and 'ready to go' costs.

MFAB will be cognisant of the needs and expectations of the UK marine science community, the requirements of NERC strategic science programming, and emerging technological advances in marine observing equipment and the need for

long term availability of NERC-funded data in a NERC Data Centre (see NERC Data Policy - http://www.nerc.ac.uk/research/sites/data/policy/). In terms of:

- prioritising replacement for wear and tear and losses annually and managing obsolescence

- investment to develop new capability and capacity.

This is essential information, both for supporting the current portfolio of NERC-funded marine science (including Discovery, Strategic Programmes, and NC Science), but also to anticipate the likely requirements for NERC-funded and other equipment facilities relevant to NERC sea-going science delivery in the near to medium future. Ultimately, MFAB will advise and assist NOC in the development of a strategy that prioritises the equipment portfolio with regard to emergent and declining scientific requirements.

National Marine Facilities

The remit of National Marine Facilities (NMF) is to develop, co-ordinate and provide major platforms, observing systems and technical expertise required by the UK's marine science community - the NC LRI grant pays for the National Marine Equipment Pool (NMEP) to be maintained in a '*ready to go*' state and available for use by the UK marine science community - the grant covers technicians, workshops, test and calibration facilities, storage facilities, spare parts and consumables.

Responsibilities

MFAB needs to achieve the overall purpose and remit set out above by:

- transparency and ensuring that functional engagement and communication between NERC, NOC, and science community are clear and understood

- engaging and consulting with the UK marine scientific user community[1]

- demonstrating the success of investment consultation for UK marine science

- changing behaviour and/or perceptions where necessary.

An annual statement of consultation undertaken and replacement/development investment decisions made is to be drawn from the MFAB papers and five year NMEP capital plan. This should be drawn up by the Associate Director National Marine Facilities and the MFAB Chair. This should also summarise equipment to be mothballed and/or scrapped. The report should be circulated widely (via the NOC Association) and form part of the process of reporting to CPEB.

[1] The marine science community is defined as that established by the NOC Association: a network of identified, institutional representatives of Universities and research centres. Membership of the NOC Association as at January 2019 is detailed in Annex B.

Methods of Working

The Advisory Board will meet once a year in April. An exceptional, additional meeting may be held if required. It will also be possible to hold special working group meetings.

At each meeting each member will report back on the views and advice of their section of the community.

Reports produced for consideration by NOC Executive after each meeting

Report collated and agreed for CPEB meetings.
Meeting agendas will normally be agreed with NERC Head of Marine Science (on behalf of DSI), NOC COO and NOC AD NMF and usually take the form of:

1. Minutes and matters arising
2. Report on community engagement undertaken
3. Report and discussion on collated community views
4. Reports and discussions on equipment condition and maintenance lists provided by NOC annually
5. Recommendations for retirements
6. Future recommendations for investment
7. Specific Issues as they arise.

The draft agenda is to be circulated two to three weeks prior to meeting with all papers and final agenda to be circulated two weeks prior to the meeting.

The following actions will be taken to elicit specific input from the user community prior to each meeting:

1. A call for input via an internet portal; call made via the NOC Association members to alert individuals in their institutions.

2. Call from named ‘science users’ on MFAB to elicit input from their network, either via the web portal, to directly to the Board member

Membership

Membership should be kept under review to ensure it is relevant and representative of the whole community although it should include:

A chair that is independent of NOC
An external equipment specialist
An international barter partner
NERC Head of Marine Science
NOC COO
NOC AD NMF
Head of BODC (NOC CIO)

At least ten members from the UK marine scientific user community [2]

Members will be appointed for a three-year term. The Chair may invite members to renew their membership at the end of the term.

If members are unable to attend more than two meetings in succession, the Chair reserves the right to appoint an alternative member.

Members may nominate a delegate to attend a meeting they are unavailable.

Membership of MFAB is at Annex C.

Expenses

NOC will pay all reasonable T & S expenses of the members of the Board in attending meetings of the MFAB. Reimbursement will be in accordance with UKRI policy.

Annex A

Ship Governance arrangements: A new governance board will be convened and will be chaired by the NERC Director, Science & Innovation. The board's membership will also include –

NERC Director, Finance
Chair of the NERC Cruise Programming Review Group*
Chair of the NERC Marine Facilities Advisory Board*
NOC Director of the National Marine Facilities
NOC Director, Finance and Operations

(* - These two NERC advisory groups (whose membership includes 17 member of the seagoing science community) advises on all aspects of the cruise programme (including current/future marine facility and equipment requirements) and are chaired by senior members of the seagoing science community (Professor Paul Tyler, University of Southampton and Professor Mark Inall, SAMS).

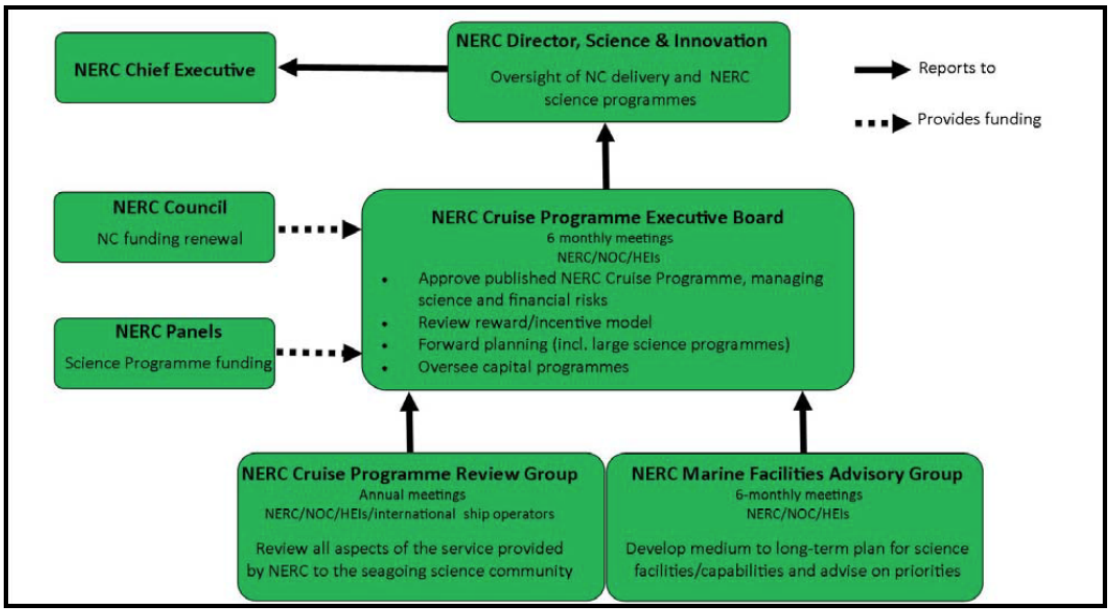
The BAS Director of Operations may attend for discussions pertaining to BAS-operated ships and aircraft.

The new governance board's Terms of Reference includes –

- Approving the published cruise programme, managing association science and financial risks
- Forward planning (including large science programmes)
- Reviewing the rewards/incentive model

[2] The marine science community is defined as that established by the National Oceanography Centre (NOC) Association: a network of identified, institutional representatives of Universities and research centres. Membership of the NOC Association as at January 2019 is detailed in Annex B.

- Overseeing the capital programme



Annex B

Membership of the National Oceanography Centre Association at January 2019

British Antarctic Survey
British Geological Survey
Heriot Watt University
Imperial College/Grantham Institute
Marine Biological Association
Plymouth Marine Laboratory
Queen's University Belfast
Scottish Association for Marine Science
Sea Mammal Research Unit
University College London
University of Aberdeen
University of Bangor
University of Bristol
University of Cambridge
University of Cardiff
University of Dundee
University of Durham
University of East Anglia
University of Edinburgh
University of Essex
University of Exeter
University of Glasgow
University of Hull
University of Leeds
University of Leicester
University of Liverpool

University of Newcastle
University of Nottingham
University of Oxford
University of Plymouth
University of Portsmouth
University of Reading
University of Sheffield
University of Southampton
University of St Andrews
University of Stirling
University of Strathclyde
University of Swansea
University of York

Clusters and societies

The Challenger Society
The Marine Alliance for Science and Technology for Scotland (MASTS)

Annex C

Membership of the Marine Facilities Advisory Board - 2019

***Identified UK marine scientific user community members**

NAME	**Affiliation**
Dr Adrian Baker	Defence Science and Technology Laboratory
Professor Mike Elliott	University of Hull
Dr Kate Hendry	University of Bristol
Dr Joanne Hopkins	National Oceanography Centre
Dr Kerry Howell	Plymouth University
Dr Chris McGonigle	Ulster University
Professor Mark Moore	University of Southampton
Professor Carol Robinson, Chair	University of East Anglia
Randolph Sliester	British Antarctic Survey
Dr Tim Smyth	Plymouth Marine Laboratory
Dr Mike Webb	Natural Environment Research Council
Professor Nick Wright	Newcastle University
Advisory Role	**National Oceanography Centre**
Dr Graham Allen	Chief Information Officer, British Oceanographic Data Centre
Colin Day	Programme Management Group Head, National Marine Facilities (NMF)
Dr Maaten Furlong	Head of Marine Autonomous and Robotics Systems, NMF
Professor Angela Hatton	Director of Science and Technology
Helen Oldridge	Head of Scientific Engineering, NMF

Julie Pringle Stewart	Chief Operating Officer
Leigh Storey	Associate Director, NMF
Jackie Pearson, Secretary	International and Strategic Partnerships Office

Data Protection

Members are advised that your data will only be used to make you aware of:

1.) dates, content and outputs for meetings of the Marine Facilities Advisory Board
2.) requests for your input on Marine Facilities Advisory Board-related participation in future events.

Your data will not be shared with any third party individual or organisation without your prior permission being granted.

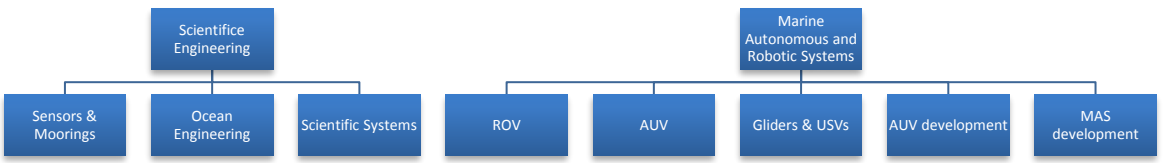
Annex D

The National Marine Equipment Pool (NMEP)

The NMEP is the UK's central equipment pool for Marine Science and is available to the UK's marine science community. It is supported by an annual grant from NERC and the majority of it is kept within a Customs Warehouse. It is maintained and operated by the engineers and technicians within the NMF group based at the NOC. The NMEP includes equipment developed or purchased to support the following capabilities:

a. Seismic Source and Recording
b. Deployed Sensors
c. Ship-borne Sensors
d. Benthic Sampling
e. Fixed and Towed-body Sampling
f. Laboratories and Equipment
g. Long-range Marine Autonomous Systems (MAS) Platforms
h. Ship-deployed MAS Platforms and ROVs

The Engineering groups within NMF are arranged as per the organisational chart below. There are 'operationally focussed' teams and 'development focussed' teams who interact closely in the development of specific equipment/platforms and their subsequent adoption into the NMEP for use by the wider community. The operational teams are funded by NERC via a National Capability-large-scale research infrastructure (NC LRI) grant however the development groups are self-funded.

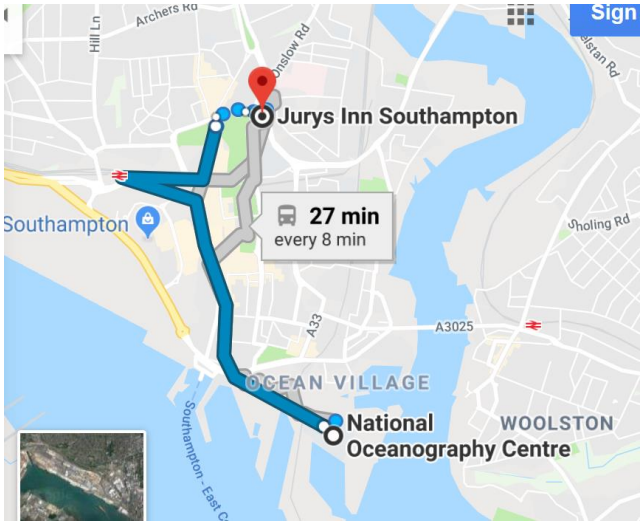


Papers for information: **LOGISTICS**

If you have requested B & B, this has been booked for you at Jurys Inn:

Jury's Inn, 1 Charlotte Place, Southampton, SO14 0TB
DD: 023 803 71213 Fax: 023 803 71100

Directions from the National Oceanography Centre to Jurys Inn

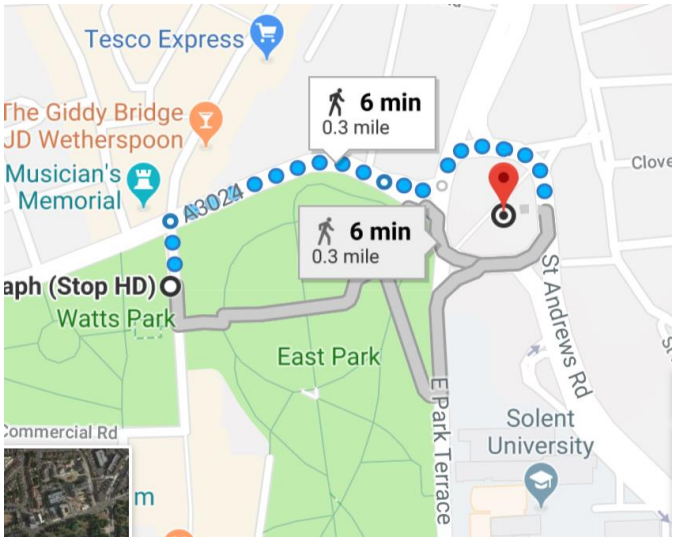


From the Cenotaph stop, Jury's Inn is a six minute walk across the park.

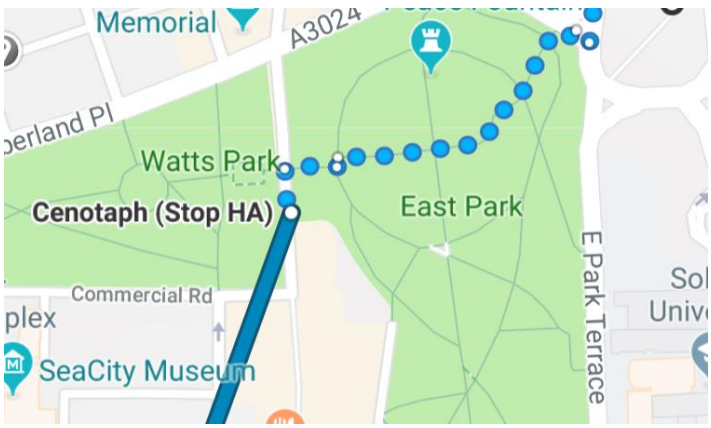
The pick-up point for the Unilink Bus service is in the car park in front of the National Oceanography Centre.

Take either U1A or U1W Unilink Bus eight stops and alight at the Cenotaph Stop HD.

The Unilink Service runs every 8 minutes.



To return to NOCS



Return to the Cenotaph (Stop HA) and take the Unilink Bus U1C to City Centre & NOCS. Service runs every 8 minutes.

Fare: Single fare £2.00 (note return tickets are only useable on the day)