BIS long-term capital investment consultation

Response coordinator:

Dr. Jennifer Riley, International and Strategic Partnerships Office, NOC (jennifer.riley@noc.ac.uk) on behalf of the National Oceanography Centre.

About us:

The National Oceanography Centre[1] is part of the Natural Environment Research Council (NERC) and is the UK national focus for Oceanography. It undertakes large-scale, long-term oceanographic research from coast to deep ocean. It provides national capability in oceanographic sciences (including sustained ocean observing, integrated seafloor/risk/habitat mapping, large-scale ocean/self/ecosystem model development and technology innovation) and manages on behalf of NERC marine scientific research facilities, large research infrastructure and data assets - including the global-class research ships RRS James Cook and RRS Discovery, the National Marine Equipment Pool (NMEP), the Marine Autonomous and Robotics Systems Facility (MARS), the British Oceanographic Data Centre (BODC), the British Ocean Sediment Core Research Facility (BOSCORF) and the Permanent Service for Mean Sea Level (an international facility). About 500 staff are employed in NOC and it has an annual budget of £45 million plus a variable capital allocation. The NOC is based on two sites at Southampton (headquarters) and Liverpool where it is co-located with staff and students of the Universities of Southampton and Liverpool.

Declaration of interests:

NOC welcomes the opportunity to respond to the BIS Consultation on the long-term capital investment. The National Oceanography Centre (NOC) is a focal point for UK Marine Science and many of its programmes are funded through public money, accessed via NERC and ESPRC as well as other government departments such as DEFRA. This response presents the views of NOC and may not necessarily reflect those of our parent body NERC.

Contribution to collective view from environmental research centres

In addition to the points made in this consultation response the executive director of NOC has also contributed to a collective view, from the heads of six major environmental science national research centres. As such we recommend that you also refer to response dated 27th June 2014 from the directors of the National Oceanography Centre (NOC), British Antarctic Survey (BAS), British Geological Survey (BGS), Centre for Ecology and Hydrology (CEH), National Centre for Atmospheric Science (NCAS), National Centre for Earth Observation (NCEO).

[1] www.noc.ac.uk

National Oceanography Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

Consultation Questions:

We have provided answers to both of the key questions (numbers 1 and 5) and also provided responses to those questions set out which are relevant to the scientific capacity and interest of the National Oceanography Centre's (NOC) activity, and that of wider UK marine community from the perspective of NOC.

1. KEY QUESTION: What balance should we strike between meeting capital requirements at the individual research project and institution level, relative to the need for large-scale investments at national and international levels? (1000 words maximum)

The UK scientific community benefits from large capital investment at both the individual research project/institutional level, and national/international level investment.

Large scale national level capital investment into infrastructure, such as the two global class research ships, *RRS James Cook* (delivered 2007) and recently commissioned *RRS Discovery* (delivered in 2013), provide world-class facilities which would not otherwise be available to the national research community at an institutional level. These investments mean that, tonne for tonne, the UK has arguably the most advanced oceanographic fleet in the world. Such large- scale capital investments enable the UK to:

- ***Undertake world class science***
- ***Leverage access and collaborate*** with international partners and programmes not otherwise accessible solely by the UK research base.
- Ensure that it has a ***leading role in advancements in research capacity*** on an international stage.

However, such ***large-scale investments cannot be considered in isolation***, and require consideration and commitment to appropriate, on going staff and recurrent (resource) funding to operate them. As a Research Council institute, the ***National Oceanography Centre (NOC) is critically reliant on the Research Councils (NERC) for access to capital*** and consequently considers it important that the Research Councils have adequate levels of capital funding in their baselines to support:

- ***Essential upgrades, refits, repairs*** associated with large research infrastructure such as the research ships
- ***Smaller-scale investments that are associated with large research infrastructure***, such as the ship-deployable equipment in the National Marine Equipment Pool and the Marine Autonomous and Robotics Systems Facility

Additionally, the NOC is dependent on NERC allocations of capital for other basic aspects of its fabric and operations, such as ***building upgrades and laboratory refurbishments and local-scale IT equipment and infrastructure***.

The NOC not only ***delivers and supports short-term projects*** but also ***undertakes science of a long-term nature,*** which requires more continuous streams of capital (such as to support sustained ocean observing infrastructure). Moreover, the scientific facilities and pooled equipment resources ***support multiple projects by multiple Universities and Research Institutes*** on an ongoing basis.

The key message from all of these needs is, that ***it is important to be able to match these capital investments to ongoing operational needs and to align them closely with scientific priorities***. In our view this will be best achieved if there is substantial ability to ***allocate capital funding in close proximity to the resource funding for science programmes and facilities*** (i.e. within the Research Council baselines).

Capital investment at the institutional level is also crucial, ensuring:

- A broad ***depth and diversity of research capital investment*** across the UK science base
- ***Novel technology innovation*** between UK industry and individual institutions (Box 1)
- ***Sustained observations*** of the oceans (Box 2)

Box 1 - Novel technology innovation

The National Marine Equipment Pool (NMEP)[2] is the ***largest centralised marine scientific equipment pool in Europe*** and allows scientists from a range of disciplines to gain access to a wide range of re-usable equipment and skilled engineers, technologists and facilities through one central programme. In particular NMEP:

- Prevents unnecessary duplication of investments in capital by multiple Universities
- Recognises that the scale of investments (e.g. remotely operated vehicles) are beyond the capabilities of most single Universities in the UK,
- Enables critical mass and efficient deployment of the expert technical skills to support use of marine equipment at sea,
- Facilitates broad participation in oceanographic sciences.

One of the key components to NMEP is the Marine Autonomous Robotic Systems (MARS)[3] programme. ***MARS enables scientists to explore the deep ocean and under ice regions in ways that were previously not possible***. Most recently the MARS programme deployed the Autonomous Underwater Vehicle (AUV), Autosub[4] during a cruise on the James Cook in the Caribbean, and discovered the worlds deepest black smoker.

As set out in the "Eight Great Technologies" (Willets, 2013)[5] document, ***Marine Robotics is a key technology area in which the UK is and can continue to be a global leader***. As such continued investment into areas of novel technology innovation is critical for maintaining the UK at the forefront of this technological revolution.

[2] http://noc.ac.uk/research-at-sea/nmfss/nmep
[3] http://noc.ac.uk/research-at-sea/nmfss/mars
[4] http://noc.ac.uk/research-at-sea/nmfss/nmep/autosubs
[5] David Willetts (2013) Eight Great Technologies, Policy Exchange.
[Accessed from: www.policyexchange.org.uk/images/publications/eight%20great%20technologies.pdf, Access Date: 02/07/2014]

Box 2 – Sustained observations

The ***oceans are grossly under-sampled in space and time.*** Sustained observations[6] over multidecadal timescales are key to understanding change and variability at time-scales from days to decades and from local, to regional, ocean-basin, and global scales. Key examples of sustained observations in the ocean include the Porcupine Abyssal Plain (PAP) Observatory[7] and RAPID-WATCH[8].

- ***The PAP Observatory*** has provided key time series datasets for analysis of the effects of ***climate change on the open-ocean and deep-sea ecosystems***, and to ***inform policy***.
- ***RAPID-WATCH*** delivers a ***decade-long (2004-2014) time series*** of ocean temperature and current observations. These observations are critical for ***understanding how global warming could alter ocean circulation***, leading to changes in global climate.

In order to operate efficiently both PAP and RAPID-WATCH need a critical mass of researchers and support staff, who are focussed on full-time research, and have access to high levels of coordination and complex project management organisation. ***Research centres such as the National Oceanography Centre (NOC) are key to providing such support but require long-term capital investment in both strategically planned matched capital and resource investments.***

In NOC's view, capital investment should be ***more balanced toward institutional level capital***, which is more likely to:

i. Support and retain a ***broad and diverse research base***.
ii. ***Reduce lumpiness*** in associated resource funding (which is difficult during flat or reduced funding), so to maintain and maximise the use of the investment.
iii. Provide greater opportunity to work with UK technology SME's to ***advance the UK innovation agenda.***

A key aspect of ensuring resources are geared towards institutional level capital is to ensure that there is ***sufficient capital within Research Council baselines***, which research centres can access, in order to maximise the alignment and prioritisation of capital investments alongside the longer-term science resource funding.

2. How can we maximise collaboration, equipment sharing, and access to industry to ensure we make the most of this investment? (1000 words maximum)

From a marine science perspective, ***ensuring capital investment is maintained at the intuitional level*** in programmes such as the National Marine Equipment Pool (NMEP) and Marine Autonomous Robotic Systems (MARS), is key to maximising collaboration, equipment sharing and access to industry. It is ***through all of these facilities that the UK marine science community is able to undertake at sea research***. Investment in NMEP ensures that UK marine community has access to:

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[6] http://noc.ac.uk/ocean-watch/why-we-need-sustained-observations
[7] http://noc.ac.uk/ocean-watch/open-ocean/porcupine-abyssal-plain
[8] http://noc.ac.uk/ocean-watch/open-ocean/rapid-watch

- ***Sensors and moorings***[9], which are critical for determining the velocity and chemistry of the water column
- ***Deep platforms***[10] needed to operate the equipment such as autonomous underwater vehicles and remotely operated vehicles
- ***Base engineering***[11] which supports the winches and wires which are critical for deploying equipment into the water
- ***Ship scientific systems***[12] providing IT support and bottom profilers to map the sea floor
- ***MARS group*** which provide access to and development of underwater robotic vehicles, as well as providing ***strong links with industry*** (Box 3).

Box 3 – Links with industry

Investment in the ***Marine Autonomous Robotic Systems*** (***MARS) programme*** is a clear, key example of where ***links can be made between the research community and industry***.

- The development of new fleet of unmanned surface vehicles was facilitated through the investment of capital from NERC, Defence Scientific and Technology laboratories, and Technology Strategy Board SBRI (Small Business Research Initiative)[13].

The success of UK marine scientists in developing underwater robotics has enabled the MARS group to diversify and form the ***MARSIC (Marine Autonomous Robotic Systems Innovation Centre).*** The development of MARSIC will facilitate:

- ***Investment to expand NOC facilities*** to improve partnerships and business developments with UK SME's as a research and innovation hub.
- Greater emphasis to be placed on ***developing relationships with stakeholders*** (including those in local enterprises)
- The ***development of specialist forums and steering groups*** where knowledge and information can be exchanged between the science and industry sectors.
- ***Leverage of funding*** from other bodies, including the Technology Strategy Board as well as research councils including NERC and ESPRC.

The MARSIC ***will draw a vibrant research community together***, providing an opportunity to undertake ***world-class research and create start-ups***. Capital investment into programmes promoting links with industry such as MARSIC, will enable the UK to ***pioneer new state-of-the-art-science and technology*** for exploration and utilisation of the marine environment. This links well with the recently published UK Robotic Autonomous Systems Strategy (RAS2020, 2014)[14].

In order to ***maximise scientific output,*** from a National Oceanography Centre (NOC) perspective the NMEP is central to the UK's capacity to ***barter access to other international platforms***[15] within the international marine science community. Through bartering agreements NMEP equipment is used by a wide marine community beyond that of NOC in conjunction with a wide range of large capital infrastructures (Box 4).

[9] http://noc.ac.uk/research-at-sea/nmfss/scientific-engineering/sensors-moorings
[10] http://noc.ac.uk/research-at-sea/nmfss/scientific-engineering/deep-platforms
[11] http://noc.ac.uk/research-at-sea/nmfss/scientific-engineering/base-engineering
[12] http://noc.ac.uk/research-at-sea/nmfss/scientific-engineering/ship-scientific-systems
[13] https://sbri.innovateuk.org/
[14] RAS2020, 2014 [accessed from https://connect.innovateuk.org/documents/2903012/16074728/RAS%20UK%20Strategy?version=1.0]
[15] http://noc.ac.uk/research-at-sea/reasons-set-sail/international-working

In NOC's view, in order to ***maximise collaboration***, it is important to have an ***on-going commitment to a continued investment in capital for science at the institutional level***. Such capital investment is needed to ensure that we have a ***high-value science and technology output and innovation***, which is key for the scientific community as it ***enables leverage with UK industries and other international research centres***.

Box 4 - Bartering
The National Oceanography Centre (NOC) has been a pioneer in the international bartering of research ships and large marine equipment. Bartering is the means by which ship-time and access to other specialist facilities is exchanged between nations. It has multiple benefits including:

- ***Avoiding the expense and environmental impact*** of ship positioning costs,
- ***Opening access*** to a wider range of specialist facilities
- Enabling critical ***demand peaks to be managed***.

Bartering within the NMEP includes facilitating national and international access to:

- ***Vessel time*** - since 2006 NERC multi-purpose research ships have carried scientists from *34 UK universities, 10 other UK organisations, 51 European institutions, 24 United States institutions, 16 other institutions worldwide*
- ***Specialised equipment –*** including remotely operated vehicles (ROV's), multichannel seismic systems and multi-beam echo-sounders.
- ***Personnel time –*** needed to operate the highly specialised equipment

Bartering also facilitates:

- ***Greater communication*** between other major international marine institutes
- ***Knowledge Exchange***
- ***World class science*** through development of experience

3. What factors should we consider when determining the research capital requirement of the higher education estate? (1000 words maximum)

Research Centres such as the National Oceanography Centre (NOC) are ***key to the science and innovation landscape*** within the UK, complementing and working alongside UK universities. Together ***research centres and universities***:

- ***Provide the success and vitality*** of the UK's environmental science base
- Provide the UK with an ***edge in the global science*** race[16].

NOC is co-located with the Universities of Liverpool and Southampton. In Southampton the University has 25% of the interest in the Waterfront Campus and staff and students. Together with the University staff, NERC staff also occupy the campus and ***share key infrastructure*** including:

- Communal spaces,

[16] Commented upon in the 2008 RAE exercise

- Laboratories,
- Library facilities,
- IT facilities.

In order to facilitate the relationship between NERC and University of Southampton at the NOC, a ***campus development committee, and an operational management board oversee the common, efficient and effective use of space***.

Investments in the Waterfront Campus usually involve c***apital co-investment by both NERC and the University***. Current arrangements in which ***NERC can plan and allocate capital investment strategically from within its baseline,*** has worked well to enable NERC and the University to work together as effective partners, developing a shared approach to the management of the Waterfront Campus at Southampton.

However, ***Research centres have a highly distinctive role*** in the science and innovation landscape, separate to that which universities occupy. The entirely ***research focussed environment*** of centres such as NOC, enables:

- Novel ***technological innovation*** (Box 1)
- ***Sustained observations*** (Box 2)
- ***Bartering agreements*** (Box 4).

In order to occupy this unique role, research centres such as NOC require capital investment, which is different to the requirements of universities. ***NOC is critically dependent on Research Councils for funding*** unlike universities, which have access to Higher Education Council for England (HECFE) money, which covers infrastructure and overhead costs. The capital provided through research councils pays for:

- ***Periodic upgrades/refurbishments/refits*** of basic scientific equipment
- ***Buildings*** – NOC estates are shared by both the Universities of Southampton and Liverpool
- ***Laboratories***
- ***Ships***

In NOC's view, it is key that ***Research Councils continue to have sufficient capital to sustain capital funding to Research Centres in the longer term***.

4. Should - subject to state aids and other considerations - science and research capital be extended to Research and Technology Organisations and Independent Research Organisations when there are wider benefits for doing so? (1000 words maximum)

As a Research Council Institute, access to long-term capital is critical to ensure that scientific capacity of the National Oceanography Centre (NOC) is maintained. However, given a demonstrable need and appropriate continued research community access, then in NOC's view ***Independent Research Organisations should have access to science and research capital.***

This is especially the case given that NERC is ***considering the ownership and governance*** of its Research Centres (including NOC), in which one possible outcome is they become legally independent research organisations.

Although ***no decision has been made to date*** on the outcome of ownership and governance, NOC has identified that continuing ***access to capital funding from NERC and other Research Councils is a key issue***. This is especially the case for NOC given that ***marine science is a capital-intensive research field***, and that much of NOC's current capital supports the wider UK marine science community. This places NOC in a unique position, as the focus for enabling infrastructure and equipment access to the wider research community.

Were NOC to become a not-for-profit institution outside of the public sector then the centre would need to still be able to directly access capital funds through RCUK and bid for big capital items, in order to sustain the UK's national capability as an international player in marine science.

5. KEY QUESTION: What should be the UK's priorities for large scale capital investments in the national interest, including where appropriate collaborating in international projects? (1000 words maximum)

The major projects of direct interest to the UK Marine science community as laid out in the consultation document are:

- Environmental Observing Systems Research
- Jason Continuity of Service (Jason-CS) for sea level monitoring,
- Innovation and Environmental Big Data Research and Innovation.

Environmental Observing Systems Research

The £130 million investment into Environmental Observing Systems Research and Innovation is a ***crucial capital investment*** for the wider UK environmental observing community, including the UK marine science community. This proposed programme will help to:

- ***Develop a well-rounded view of the earth system***
- ***Promote, cross collaboration*** between disciplines.

Specifically, from a marine science perspective, such a programme will feed into ***strategic national programmes*** including***:***

- ***UK-IMON (UK-Integrated Marine Observing Network)***[17],
- ***NERC Shelf Seas Biogeochemistry (SSB) Research Programme***[18]
- ***FASTNEt (Fluxes Across Sloping Topography of the North East Atlantic)***[19]

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[17] http://www.uk-imon.info/
[18] http://www.nerc.ac.uk/research/funded/programmes/shelfsea/
[19] http://www.sams.ac.uk/fastnet

Environmental Observing Systems Research will also ***complement strategic international programmes*** such as:

- ***ICOS (International Carbon Observing System)***[20]
- ***GLOSS (Global Sea Level Observing System)***[21]
- ***GOOS (Global Ocean Observing System)***[22]

It would also contribute to the forthcoming ***UK shelf-observing programme*** led by NERC/NOC. This programme will comprise of a network of in situ seafloor and water column 'observatories' comprised of moorings, mobile and intelligent autonomous underwater vehicles, with real time data exchange and telemetry transmission.

Improving Environment Observations through such capital investment also ***underpins the science of the current DEFRA agenda***, which aims to devise more cost-effective technologies for ***UK Marine Planning***[23] and ***Marine Strategy Framework Directive (MSFD)***[24] monitoring.

This investment would also provide ***significant technology innovation,*** working with UK industry to develop:

- Real intelligence in autonomous vehicles.
- Low-cost sensor development particular in biogeochemical and genomic sensors.
- Real-time adaptive sensing.
- Real-time data telemetry.

Jason Continuity of Service (Jason-CS)

The £20 million investment in the Jason – Continuity of Service (Jason-CS) satellites for the continuation of accurate global mean sea level measurements is of vital importance to UK and international scientific efforts that are focussed on ***observing and predicting changes in sea level due to climate change.***

The Jason-CS satellite mission and associated data products deliver:

- ***High quality observations*** of a key integrated measure of climate change, which are the cornerstone of climate adaptation policy, providing cost avoidance benefits to society (Box 5).
- ***Higher accuracy and resolution data globally*** than can be achieved by any other means for this key climate variable.
- ***High precision radar altimetry***, which are essential for validating these model projections framed in the latest IPCC Assessment Report[25].

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[20] http://www.icos-infrastructure.eu/
[21] http://www.gloss-sealevel.org/
[22] http://www.ioc-goos.org/
[23] http://www.marinemanagement.org.uk/marineplanning/
[24] https://www.gov.uk/government/consultations/marine-strategy-framework-directive-measuring-progress-in-uk
[25] The latest IPCC Assessment Report projects accelerated sea level increases over this century for all greenhouse gas emissions scenarios.

- ***Improved operational weather (and ocean weather) forecasting and seasonal forecasts***.

The ***Jason-CS mission aligns with the National Oceanography Centre's (NOC) own long-term strategic investment*** in sea level science where NOC scientists are international leaders in the field.

Box 5 – Cost avoidance benefits

- To date, ***£150 billion assets and 4 million people are at risk from coastal flooding*** in the UK. Government spending on flood management and coastal defence (£3.2 billion over the past four years) is ***underpinned by reliable advice*** (e.g. though UKCP09) on the rates of sea level rise and any changes to those rates.

- Jason-CS can help to ***provide information for staged protection schemes*** such as the Environment Agency's TE2100 programme to deliver flood protection for the Thames region (including options for replacing the Thames Barrier).

Innovation and Environmental Big Data Research and Innovation

The £70 million investment into Environmental Big Data Research and Innovation is also of ***high importance to NOC and the wider UK marine science community*** and enables contribution to Earth System Science.

Big data is produced through:

- ***Large scale observations*** through Earth observation ***(e.g. Jason-CS) and ARGO***[26] (Box 8) programmes are a few of the limited examples of where observation data is assimilated and validated into large-scale modelling.
- ***Large scale modelling*** (of the atmosphere, oceans, land or biogeochemical cycles) using state of the art models such as ***NEMO (Nucleus for European Modelling of the Ocean)***[27].
- ***Marine bioinformatics*** (Box 6).

The current ability of the UK researchers to ***integrate large-scale modelling with complimentary large-scale observation datasets is not maximised*** for advancements in world-leading research and improvements in the predictive capability of scientific research. The ***key to crucial advances in predictive capability***, include:

- ***Improving down-scaling methodologies***, to enable models to be used for predictive capacity at societally relevant spatial scales.
- ***Increasing modelling and observation resolution***, so that truly effective predictive regional assessments can be made at scales of 5-20 km.

[26] http://noc.ac.uk/ocean-watch/open-ocean/argo

[27] http://www.nemo-ocean.eu/. NOC is a partner of the NEMO project, which is widely used across European research centres and by the UK Met Office for operational oceanography products.

Box 6 – Marine Bioinformatics

The technology now exists to carry out ***single cell metagenomics***, which will enable us for the first time, to ***unequivocally determine function at the cellular level***, rather than randomly over an undefined community level. This will aid ***advances in ecosystem modelling*** and our understanding of the marine environment as a whole as well as the possibilities of uncovering new materials and substances.

The UK is uniquely placed in Europe to make this advance, and it requires a relatively small investment (~£1m) to realise this in terms of investment in facilities, local scale computing and capital equipment.

Improved predictive capability will enable greater understanding of:

- ***High-productivity aquaculture practice,***
- ***Fisheries productivity (associated with ocean eddies),***
- ***Storm-surge and flooding risk,***
- ***Environmental change,***
- ***Hazard risk assessment***.

Such an increase in the knowledge base will ensure that appropriate mitigation and adaptation strategies to climate change are in place in the UK.

To realize such a goal ***requires significantly increased investment in big data capital*** to support the necessary architecture and capacity of integrating large scale, high-resolution observational datasets with nested high-resolution physical and biogeochemical models. Such an investment will have ***notable benefits for***:

- ***Government*** (e.g., transport infrastructure investment),
- ***Industry*** (e.g., environmental hazard re-insurance, changing food production practice),
- ***Wider society benefits*** for environmental resilience.

6. What should the criteria for prioritising projects look like? (1000 words maximum)

A key criteria for prioritising projects is the ability of the UK and/or international projects to ***support the on going resource cost of operating these capital investments***, which in some cases may have an expected operational life of >20 years (e.g. Research Ships).

The ***UK runs a real risk*** of making an aggregated investment of > £5.5 billion over the proposed five year period, but that the investment is then under-utilised because of a ***mismatch of, or insufficient resource funding***.

7. Are there new potential high priority projects, which are not identified in this document? (1000 word maximum)

One key area of investment worthy of note within the Environmental Observing Systems Research and Innovation proposed priority project is the research area of ***marine autonomous and robotic systems***. Mentioned in the recently published, Eight Great Technologies[5] (Willetts, 2013) Marine autonomous and robotics systems (including autonomous underwater vehicles, surface wave gliders and under-sea gliders) will in due course ***transform ocean measurements***, by:

- ***Providing continuous, autonomous and intelligent ocean monitoring services*** (continuous presence in the ocean), thereby reducing necessary ship time to take measurements
- ***Supporting science otherwise difficult or impossible to conduct*** from research ships (e.g. under ice oceanographic survey and monitoring)
- ***Reducing dependency on research ships***

Nevertheless, ***oceanographic science will remain dependent on research ships for the foreseeable future***, to ensure that science that cannot be conducted in other ways (e.g. where high power demand, bulky instrumentation and at sea analytical processing facilities are required) is still undertaken[28]. The advent of ***autonomous systems will enable the work of research ships to be focussed much more effectively on the most challenging observational science,*** involving parameters, processes and space-time scales for which ships are the optimal platforms.

The development of the UK marine robotics programme (e.g. ***the Marine Autonomous Robotic Systems, MARS programme***[29], Box 7), to date has enabled the UK to leverage a competitive advantage at an international level. Such marine robotics programmes ***demonstrate technological innovation in real world environments*** (RAS2020, 2014) [14], developing key exploratory tools capable of:

- ***Autonomous movements***
- ***Controlling movements*** to explore the marine environment
- ***Planning actions*** based on the surrounding environment (e.g. underwater topography)
- ***Interfacing (remotely) with people*** (e.g. data uploads via satellite networks)

However, it is ***only through further capital investment that that UK will be able to propel itself to be an international leader in the field.***

Research into the global variability and dynamism of ocean process beneath the sea surface are critical to understand, manage, and sustainably exploit the marine environment. ***Understanding such ocean processes at spatial*** scales of 1-50 km, and temporal scales of hours to months determine:

- Re-distribution of ocean heat;

[28] http://noc.ac.uk/f/content/downloads/2013/Scanning%20the%20Horizon-reduced.pdf
[29] http://noc.ac.uk/research-at-sea/nmfss/mars

- Rate of CO_2 uptake into the ocean;
- Biological productivity;
- Regional sea-level change;
- Freshening of the Arctic Ocean;
- Links between ocean state and seasonal climate variability;
- Optimising environmental and development decisions about exploiting ocean and seafloor resources.

Box 7 – The Marine Autonomous Robotic Systems (MARS) programme
The robotic equipment in the MARS programme allows scientists to explore the oceans in ways that previously were not possible, accessing areas that humans should not or cannot go. The MARS programme consists of:

- ***Autonomous underwater vehicles (AUV's)***
  - ***Autosub3*** – which can travel up to 400 km between charges, and dive to depths of 1600 m.
  - ***Autosub6000*** – which builds on the capacity of Autosub3, but is depth rated to 6000 m.
  - ***Autosub Long Range*** – is the newest development, currently undergoing trials, which has increased range of 6000km as well as a 6000 m depth rating.
- ***Gliders,*** which don't have conventional propulsion systems like Autosub, but alters their internal buoyancy to ***slowly glide through the water column***. Unlike Autosub gliders use little power and are inexpensive to operate, but cannot be used for energy intensive or rapid observations. Currently the MARS programme has a fleet of 11 gliders.

Single-point observing (e.g. ships and ocean observatories) will never provide a cost-effective solution to truly advance ocean observing at the necessary spatial and temporal scales. Recent advances in technology have demonstrated that ***marine autonomy is a tractable solution for ocean observing, if further innovation investment is made.*** This investment would support:

- ***Targeted sensor development*** for biological, (meta)genomic, and biogeochemical observing;
- Further ***development of un-manned sea-surface vehicles*** as "data gateways" from in-water data transmission from underwater vehicles, to shore in real-time via satellite telemetry;
- ***Assimilation and "intelligent" response of multiple data streams*** from in situ for autonomous reconfiguration of robotic platforms;
- ***Links between Research Centres and industry*** (Box 3).

8. Should we maintain a proportion of unallocated capital funding to respond to emerging priorities in the second half of this decade? (1000 word maximum)

In the National Oceanography Centre's (NOC's) view, the ***greatest imperative is to be able to strategically plan capital investments and the associated resource budgets with long-planning lead-times***. This is especially important for large oceanographic programmes, which often have major international cooperative elements. Therefore, generally speaking, ***holding back capital is less consistent with this long-term strategic planning approach.***

With such a long-term approach there is a ***need for sensible forward horizon scanning,*** in order to be able to allocate capital in the future to emerging priorities. Such priorities could include the need for:

- Strategic planning of ***contingency management at an operational level*** (best managed from within Research Council baselines)
- Ensuring capital availability to ***support national infrastructure projects***

Strategic planning and contingency management at an operational level

Whenever equipment is deployed in the ocean there is always a risk that it may not be retrieved, due to damage, failure or theft. At all phases of operational oceanography, from the planning to the execution of a project and deployment of scientific equipment, ***risk based management principles guide our operational capacity***. If such an eventuality were to happen and there is no capacity within the available capital funding to replace lost equipment, then this could implications for long-term sustained observations (Box 2) in the ocean or the ability of NOC to engage at an international level with other marine communities, through bartering (Box 4).

Therefore, it is critical that research centres such as NOC, have ***access to a high level capital within the baseline budgets of research councils***, which is closely aligned with the science priorities of its research centres. Access to such capital will enable contingencies to be managed at the operational level. In order to implement such access to baseline capital, ***strategic forward planning*** needs to be undertaken over sensible time horizons.

Ensuring capital availability to support national infrastructure projects

Amongst the marine scientific and business community there is an emerging view that there should be a ***programme of extensive, systematic mapping of the seafloor within the UK marine area*** (of which only 30-40% is mapped at high resolution with modern methods). Currently, the areal coverage of high-resolution mapping is increasing at about 2-3 % per year[30]. Such an endeavour is ***consistent with a wider European Commission aim to map the seas of Europe at high resolution by 2020.***

The outcome of such a mapping project would be a publicly available, ***national "big data" infrastructure asset, to support a diverse range of public and private sector users engaged in economic development and marine planning*** (including benefit as a key base data set for scientific applications). To undertake such a project would require participation from:

- ***Business*** (delivering much of the mapping effort, technology and key users of the data)
- ***Public sector*** (marine planning and regulatory authorities)
- ***Scientists*** (specialised analysis and interpretation, new mapping technologies).

[30] This has mostly resulted from the work of the UK Civil Hydrography Programme, with some further contributions coming from mapping efforts associated with specific scientific projects.
[30] http://www.bodc.ac.uk/projects/international/argo/

Given the diverse range of participants and beneficiaries, the work undertaken would be seen as a ***national infrastructure project***. In the view of NOC, ***such a project should not be conceived of as a scientific project per se because its primary motivation and beneficiaries are not scientific***. Nevertheless, a number of science investments (including the highly capable research ships already procured) and marine autonomous and robotic systems could make important contributions to such an endeavour. There therefore ***needs to be sufficient capital available to enable the scientific community to support and respond to emerging national infrastructure projects*** such as seabed mapping.

9. Are the major international projects identified in the consultation the right priorities for this scale of investment at the international level? Are there other opportunities for UK involvement in major global collaborations? (1000 words maximum)

Oceanographic science is inherently international, requiring cooperation at the global and basin scales. Such cooperation is facilitated through the Intergovernmental Oceanographic Commission (IOC) of UNESCO and its programmes such as the Global Ocean Observing Systems (GOOS).

Many of the science programmes of the National Oceanography Centre (NOC) take place within the context of larger international programmes, as such the resulting data return is highly levered. For example the UK (through the NOC/NERC and the Met Office) contributes to the international ***Argo float programme***[31] (Box 8).

In this response NOC has outlined several key areas where we recommend major capital investment. These include:

- ***National marine equipment pool***, facilitating bartering at the international level (Question 1 and Box 4)
- ***Sustained observations***, including long-term observational programmes such as RAPID-WATCH and the PAP sustained observatory (Box 2).
- ***Novel technology and innovation***, including the marine robotics (Box 7)
- ***Environmental Observing Systems Research*** (Question 5)
- ***Jason Continuity of Service (Jason-CS)*** for sea level monitoring (Question 5)
- ***Innovation and Environmental Big Data Research and Innovation*** (Question 5)

Each of these projects helps NOC to leverage the UK as a leader in international marine science. With the proposed capital investment, the research capabilities of NOC will enable the UK to be a lead player in transatlantic alliances between the EU, USA and Canada facilitated by high level agreements such as the ***'Galway Statement on Atlantic Ocean Cooperation'***[32].

[32] http://www.innovation.ca/sites/default/files/Rome2013/files/Canada-EU-US%20Galway%20Statement%20on%20Atlantic%20Research%20Cooperation%202013.pdf

Box 8 – Argo Float Programme

Argo floats are ***small autonomous drifting robots***, which measure the ***temperature and salinity (T-S)*** between the ***ocean surface of and 2000 m depth***. The Argo programme is so successful that it has collected more ocean T-S profiles, compared to the entire 20th centaury. The programme aims to:

- ***Provide a quantitative description of the state of the upper ocean***,
- ***Enhance the value of the Jason altimeter***
- ***Provide data for model initialisation and coupled ocean-atmosphere forecasts***
- ***Document the seasonal to decadal climate variability and predictability***

Argo floats have become an ***essential tool for understanding the global ocean***, particularly:

- ***Developing spatial and temporal data standards***
- ***Enhancing International collaboration***
- ***Developing data management systems***
- ***Changing the scientific rationale behind data collection***.

The UK's contribution to the global Argo array is mainly through ***ad hoc capital investments and the programme has generally suffered from the UK's inability to make long-term financial commitments*** to it. Currently UK investments constitute less than 2% of the global floats annually.

Despite this, the UK investment into the programme provides an open-access data set available for science and operational forecasting. ***Over 50% of research papers using Argo data have a UK co-author giving the UK excellent scientific leverage.*** Thus the Argo programme illustrates the desirability of being able to better plan long–term strategic investments.

Furthermore the ***work of the on going observational programmes***, such as RAPID-WATCH and PAP, UK-IMON, SSB Research Programme and FASTNEt, ***feed directly into international science coordination programmes*** such as GOOS, GLOSS and ICOS, which aim to:

- Address knowledge gaps within the international scientific research agenda;
- Facilitate collaboration between nations;
- Promote capacity development.

Furthermore, ***Future Earth[33] is a new 10-year international research initiative*** that will develop the knowledge for responding effectively to the risks and opportunities of global environmental change and for supporting transformation towards global sustainability in the coming decades. ***Investments in marine science***, as outlined in this response, at both ***national and institutional level will enable the UK to play a leading role*** in such a globally ambitious project.

Thus in NOC's view the projects highlighted in this response, are key priorities to facilitate the leveraging of UK science on an international stage, and also ensure that the investments UK government makes into large capital items ***ensure that data is not collected in isola***tion but feeds into a global scientific agenda, placing the ***UK at the forefront of marine science***.

[33] http://www.icsu.org/future-earth