NET ZERO OCEANOGRAPHIC CAPABILITY

NZOC

NEW TECHNOLOGY
NEW TECHNIQUES

Embedding NZOC in Digitally Enabled Ocean Science

Workshop Report (Nov'22)

UKRI Natural Environment Research Council

Foreword

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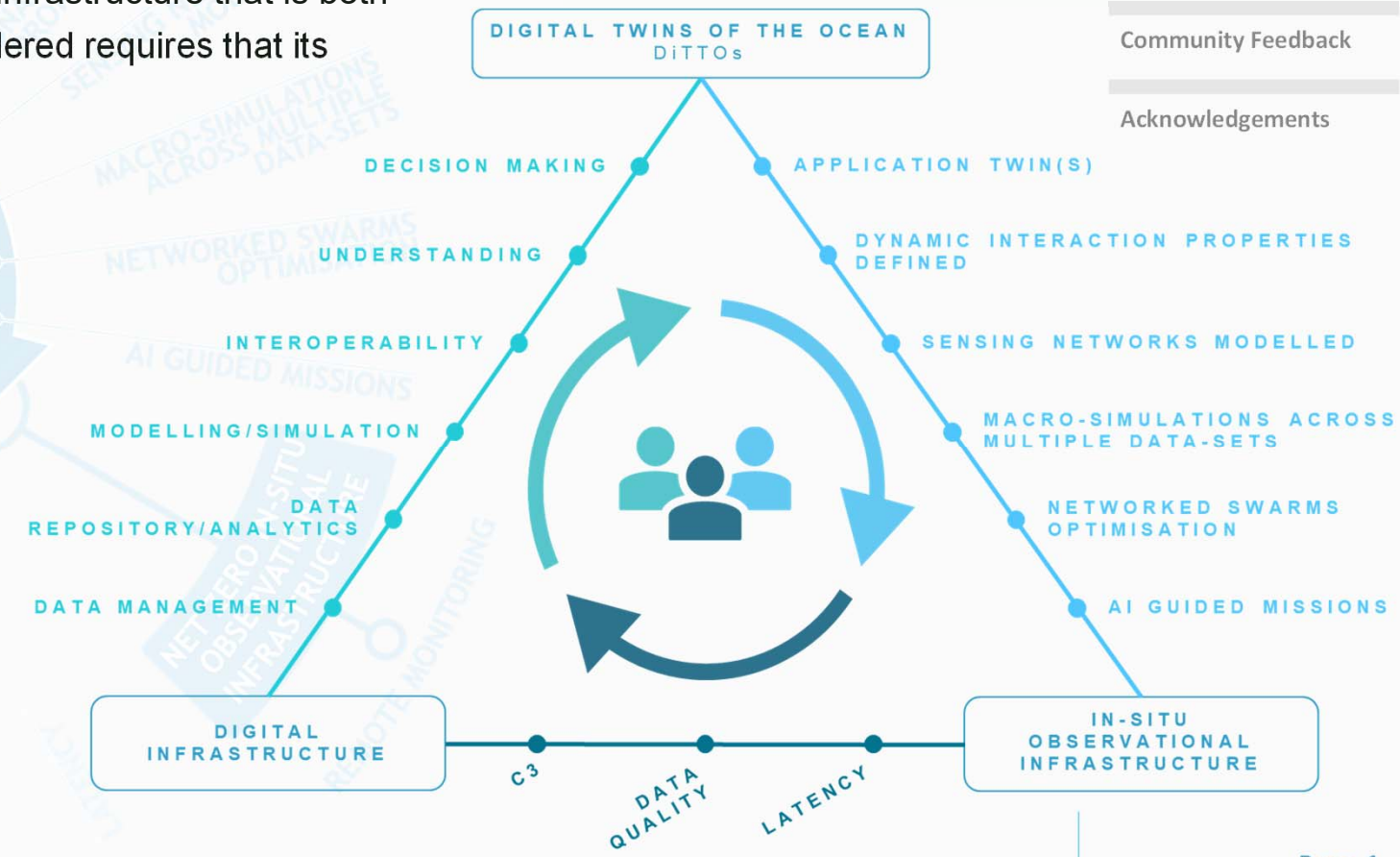
NZOC is founded upon two key precepts: there is an imperative to measure the ocean in ever greater detail if we are to understand, predict and mitigate the catastrophic changes we are precipitating; and there is a requirement to be part of the solution whilst we do it. Realising the opportunities presented by a research infrastructure that is both connected and distributed in ways not previously considered requires that its development:

a) Is explicitly linked to the digital infrastructure that will be in place in the future.

b) Is able to support and deliver new ways of managing data in accordance with FAIR principles.

c) Supports and takes advantage of innovations such as Digital Twins of the Ocean.

Understanding the links that enable a-c above was the objective of this activity.



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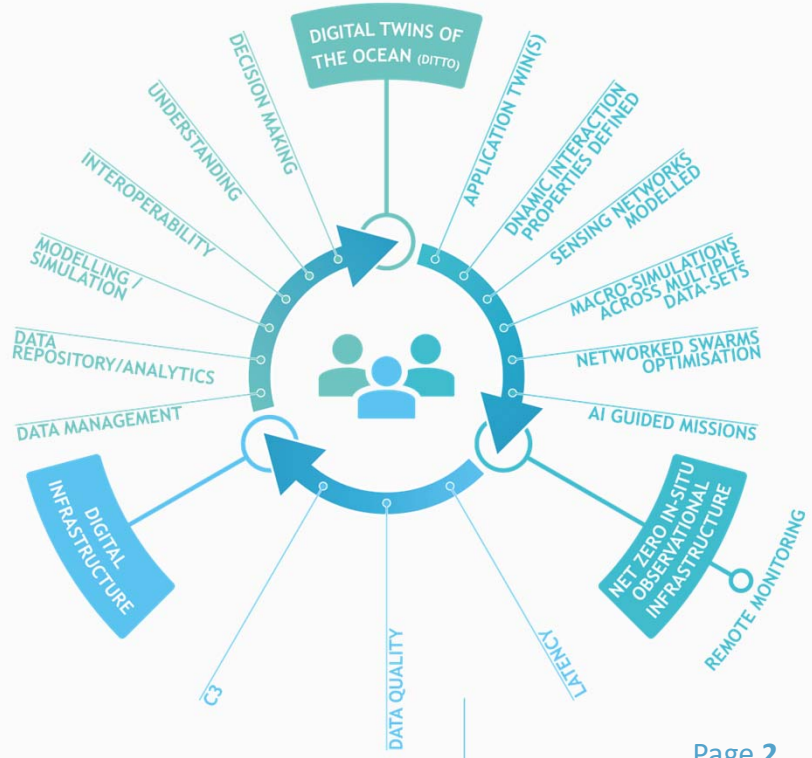
Introduction

To advance the Digital theme of the Net Zero Oceanographic Capability transformation, the Natural Environment Research Council funded the National Oceanography Centre to convene a workshop to examine the links between digital infrastructure, in-situ observing infrastructure and digital twins of the ocean.

Held in November 2022, the two-day workshop brought together a diverse set of digital experts and data users from academia, industry and marine providers. The outcomes of the workshop were then presented at an open event which took feedback from a wider range of science stakeholders.



This report summarises the findings of the workshop and community feedback session.

1. What is required to link in-situ observations to digital infrastructure?

Digitally enabled ocean observations will open new scientific opportunities by offering increased spatial and temporal resolution of data, enabling scientists across the world to collaborate in science missions. Early engagement of scientists with the emerging data ecosystem will be key to building a joined-up infrastructure that supports NERC's goal of delivering world class environmental research. To build trust in "the NZOC product", demonstrator science missions are urgently required. This could be supported by developing an NZOC control room / education space to showcase the power of remote participation and use of models in science missions, and to begin training the next generation of oceanographers.

The ability to track and verify data quality throughout the data management chain will be key to building confidence in new ways of working. Rapid upscaling of the observing network means that there will be extremely limited reference data for calibration of newly observable variables, and a new approach to Quality Control (QC) is therefore required.

The global ARGO programme offers key lessons about the importance of international collaboration and governance for delivering a global observing capability. There must be an international effort to define common standards (e.g. comms, data, QC and security) that will support collaborative ocean observing efforts and a diversified supply chain. The experiences of the ARGO programme have also exposed the length of time for the uptake of new sensors. A technology roadmap is required for rapid sensor development that provides for integration with platforms and the digital research infrastructure.

Funding is a key driver towards the NZOC model, and it is important that this includes the end-to-end chain of data collection, management, distribution and use. A cross-council approach is also needed if UKRI is to stimulate innovation in all of the required technologies.

The NZOC system must have clear ownership of the collection, management, distribution and use of data, identifying the communities responsible for each component of the chain. It must also integrate the approach to managing data from diverse assets.

NZOC will dramatically increase the role of automation, autonomy and AI. The system design needs to consider to always keep humans in the loop to guide the collection of scientific data.

Key Message 1.1

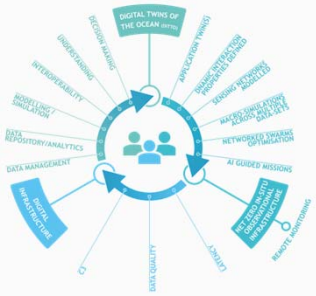
We need demonstrators to build trust and demonstrate the validity of the approach (fail fast, learn fast mentality).

Key Message 1.2

Uptake of new sensors can take 5+ years and we must seek to incorporate high-TRL / COTS technology to accelerate this.

Key Message 1.3

We need to learn lessons from the ARGO community.



2. What is required to link digital infrastructure to digital twins of the ocean?

Digital Twins of the Ocean (DiTTOs) have the potential to revolutionize how we observe and interact with the observing system, but DiTTOs are still on their infancy. It is also important to note there will not be a single DiTTO but multiple DiTTOs representing different scenarios. How to manage digital twins in general and make them interoperable is not a trivial question, but the UK is making good progress in this area thanks to the UKRI Information Management Framework project and BAS Antarctic Digital Twins activity.

DiTTOs represent a paradigm shift in how data gets used, enriching and mixing data from multiple sources, including models, to create information. Those datasets integrated and generated by the DiTTO must not be contradictory and need clear ownership, access models and authorship, driving requirements on the digital infrastructure to fulfil those needs.

Modelling and the seamless integration of in-situ observations are key components of DiTTOs, and they will have impact on the supporting digital infrastructure design.

The DiTTO data chain and infrastructure must integrate effectively with other infrastructures from other domains (for example the atmospheric domain to share atmospheric data).

User requirements are big and heterogeneous. There are different expectations from:

a. Different communities,

b. Individuals vs communities,

and

c. New vs emerging vs stablished users.

Key Message 2.1

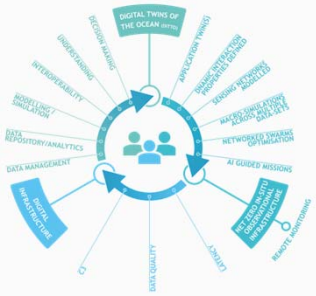
There will be lots of digital twins. An information management framework (IMF) is needed to ensure interoperability.

Key Message 2.2

There must be an integrated end-to-end chain built around data centres to feed multiple DiTTOs.

Key Message 2.3

Case studies and prototypes are required to demonstrate the approach.



3. What is required to link digital twins to in-situ observations?

Whilst we know that integrating digital twins into the NZOC model will open the possibility of more complex and better targeted operations that increase their scientific value, it remains the least understood piece of the digitally enabled ocean observing infrastructure. Funding a demonstrator would help to expose the challenges to adoption that will depend on specific applications with routine monitoring being a 'closer' technology and easier to automate than discovery science missions.

Mission monitoring and execution of the autonomous assets (the future observing system), sits outside of the DiTTOs, but the DiTTOs will facilitate the coordination of the autonomy. In delivering the NZOC we need to find ways to co-develop both systems.

Digital Twins of the Ocean (DiTTOs) can help to optimise networked fleets, using live feedback about potential energy savings, fault detection, better routes for scientific sampling, avoiding high-risk weather events *etc.* to inform decisions that might not be obvious to the user. However, this does not mean that humans should be removed from the picture, and the role of Principal Investigators and others must be clearly defined. The NZOC architecture also needs to be greater than just DiTTOs. It needs to integrate simulators and twins from other domains, for example: vehicle and sensor simulators.

A key area where further understanding needs to be developed is around how the ecosystem is interconnected:

- How do DiTTOs connect to the observing system, not just as consumers of data but also commanding and controlling it?
- What information is needed by the DiTTOs?
- How will the DiTTOs cope with the sparsity of data that is caused by the challenges of underwater communications to make decision?
- How will data move between the different digital twins?

There are other international initiatives doing similar work, coordination and sustained community engagement is required to achieve a global governance.

Key Message 3.1

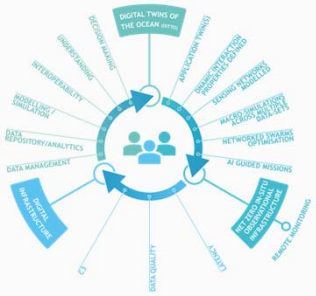
This is the least understood side of the triangle.

Key Message 3.2

A demonstrator would help communities to understand what this means.

Key Message 3.3

We must not lose sight of the objective: 'scientist in the loop' for better and more sustainable science.



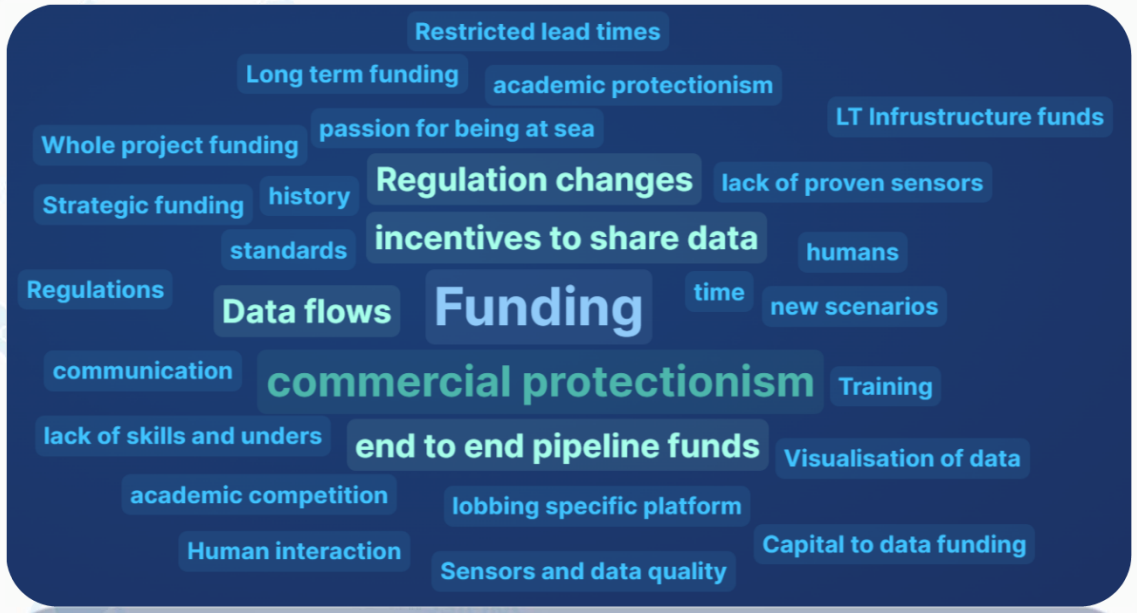
Community Feedback

Considering specific use cases, at the open session, stakeholders were invited to focus on two specific questions.

1. What are the opportunities for science?
2. What is needed to build trust in NZOC?

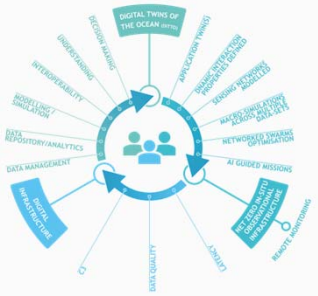
Much of the feedback was consistent with the themes identified as part of the workshop. The group emphasised the importance of transparency around objectives, vision and decision-making to building trust in the emerging net-zero infrastructure. Continuous engagement and dialogue with the science community was considered particularly important. The group also felt that science demonstrator missions will be key to building confidence in new ways of working.

What are your barriers to uptake of NZOC approaches?



Another common theme was the importance of international collaboration with the example of the ARGO collaboration again being cited as a model of best practice.

A theme not identified as part of the main workshop was the potential for citizen science to contribute to the NZOC goals.



Acknowledgements

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Contributors

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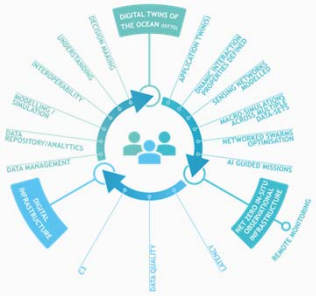

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