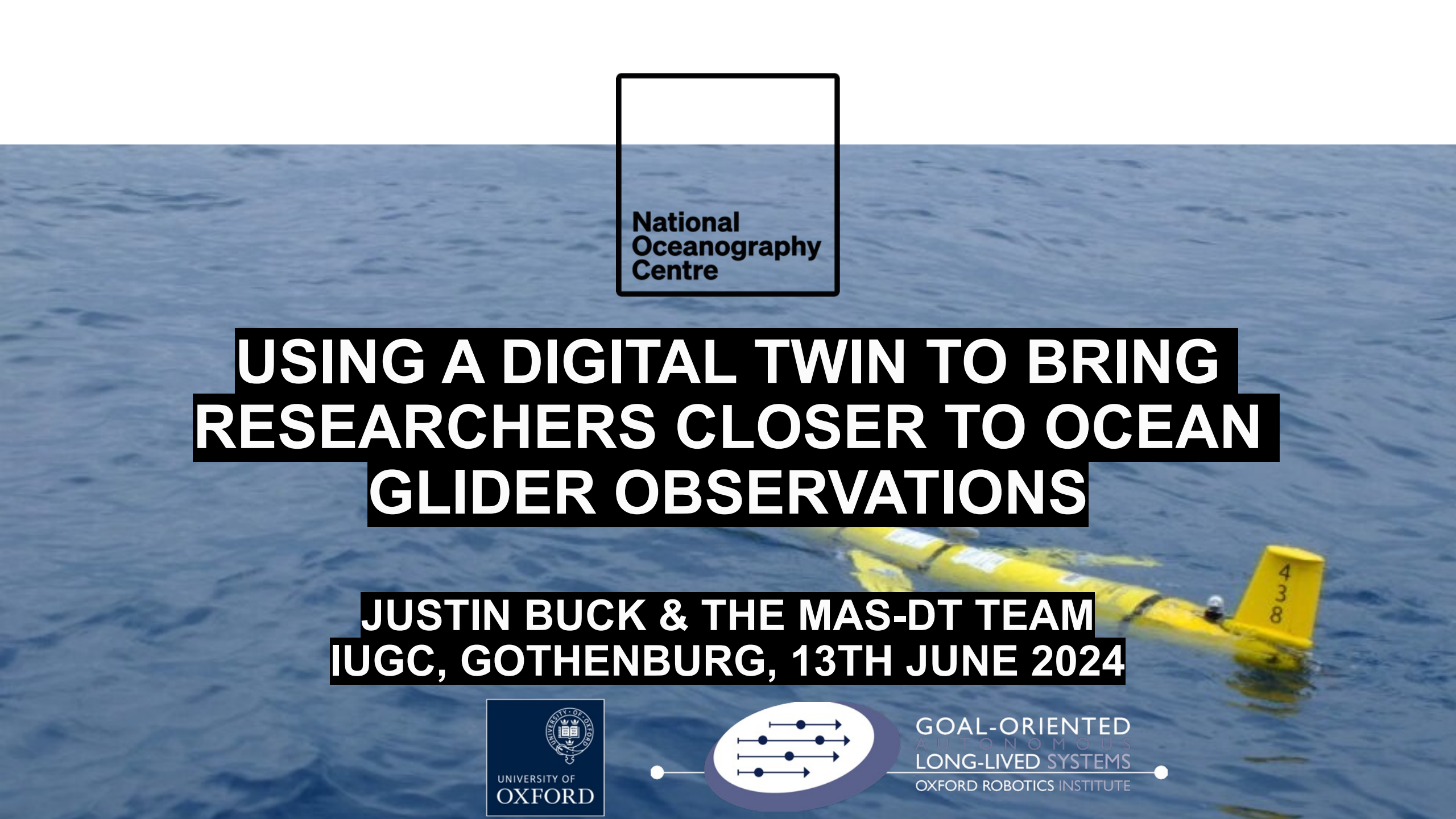
National Oceanography Centre

USING A DIGITAL TWIN TO BRING RESEARCHERS CLOSER TO OCEAN GLIDER OBSERVATIONS



JUSTIN BUCK & THE MAS-DT TEAM

IUGC, GOTHENBURG, 13TH JUNE 2024

UNIVERSITY OF OXFORD

GOAL-ORIENTED AUTONOMOUS LONG-LIVED SYSTEMS

OXFORD ROBOTICS INSTITUTE

THE MAS-DT TEAM

MARS development

Justin Buck
Alvaro Lorenzo
Ashley Morris
Dan Jones

Science and technology

Charlotte Williams
Jeff Poulton
Ryan Patmore

MARS operations & project management

Steve Woodward
Ben Allsup
Hannah Sait

Digital Ocean

Alexandra Kokkinaki
Tobias Ferreira

Oxford robotics institute

Nick Hawes
Bruno Lacerda
Thomas Dobra

National Oceanography Centre

DIGITAL TWINS OF THE ENVIRONMENT

HARNESSING DATA, CREATING VALUE

Observations underpin **public benefit**

As demand for (ocean) information grows, we need to **adapt and grow (ocean) observing**

Digital tools, providing knowledge, are the **bridge between observations and action**

Added value comes from **modelling, data sciences** and **integration with knowledge systems**

Access to actionable information is critical to realizing **value**

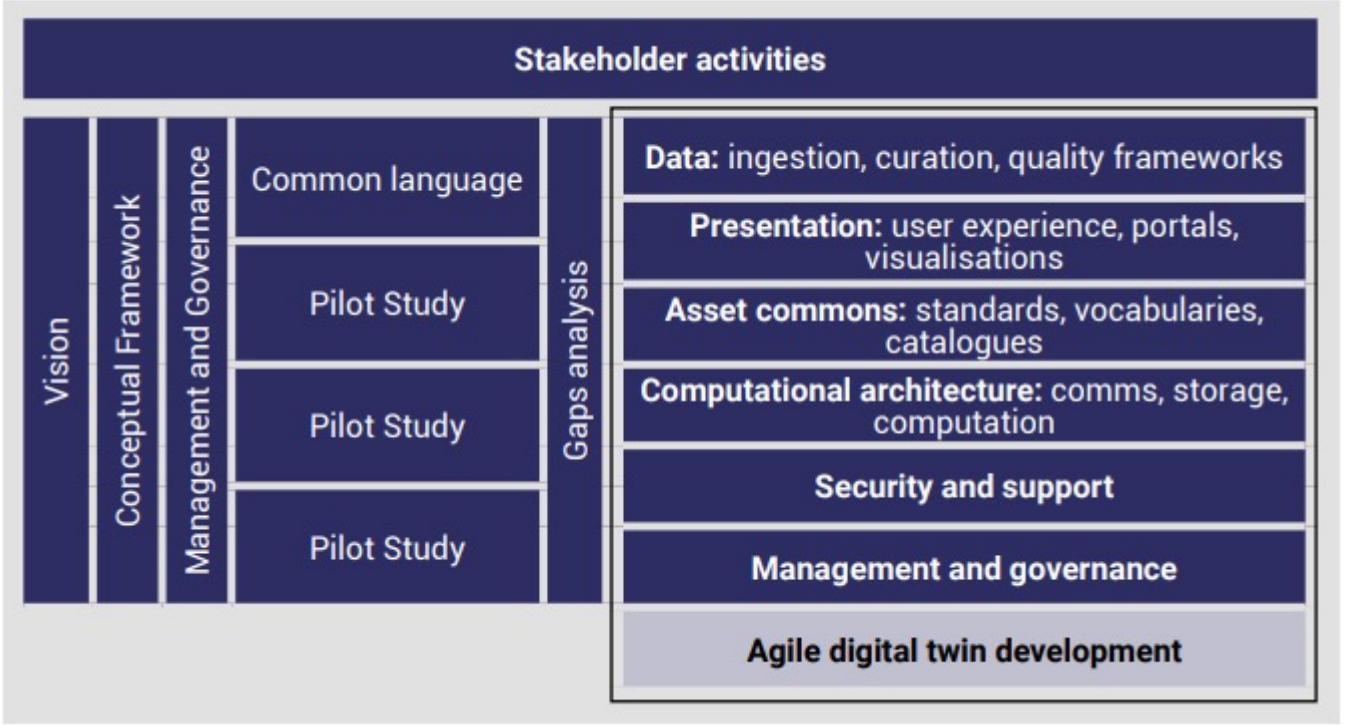
A sustainable future needs enhancements and innovation **through the value chain**

European Marine Board (2021). Sustaining *in situ* Ocean Observations in the Age of the Digital Ocean. EMB Policy Brief No. 9, June 2021. https://www.marineboard.eu/sustainable-funding-ocean-observations

WHAT IS A DIGITAL TWIN? ….. A tool to improve decisions.

A digital twin is a virtual representation of a physical asset enabled through data and simulators for real-time prediction, optimization, monitoring, controlling, and **improved decision making**.

Information Management Framework (IMF)



Siddorn, J. et al. (2022). *An Information Management Framework for Environmental Digital Twins (IMFe)*. https://doi.org/10.5281/ZENODO.7004351

SCOPING INTEROPERABLE ENVIRONMENTAL DIGITAL TWINS

National Oceanography Centre

Discovery
Data
Processes
Services
Tools
Visualisation

Land Insight

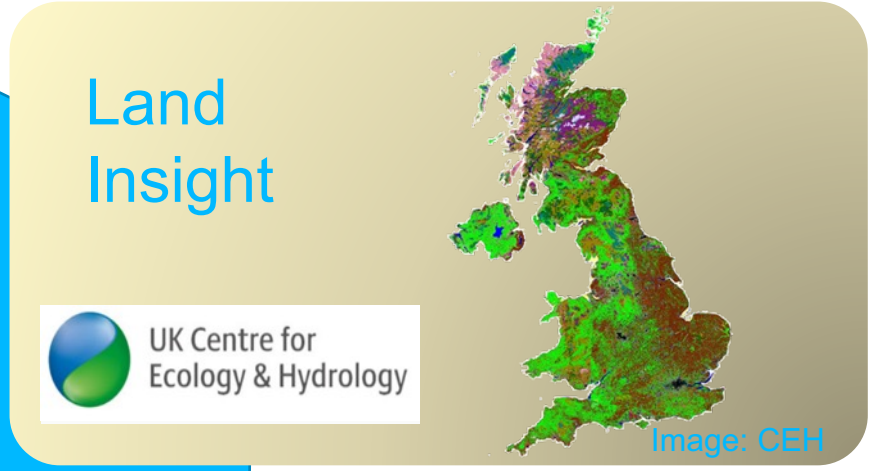
UK Centre for Ecology & Hydrology

Not all interoperability elements required for all use cases

SCOPING INTEROPERABLE ENVIRONMENTAL DIGITAL TWINS

National Oceanography Centre

Discovery
Data
Processes
Services
Tools
Visualisation



Not all interoperability elements required for all use cases

IMFe model and roadmap

Siddorn, J. et al. (2022). An Information Management Framework for Environmental Digital Twins (IMFe). Zenodo. https://doi.org/10.5281/zenodo.7004351

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THE MARINE AUTONOMY CHALLENGE

A SELECTION OF THE PLATFORMS IN THE EQUIPMENT POOL

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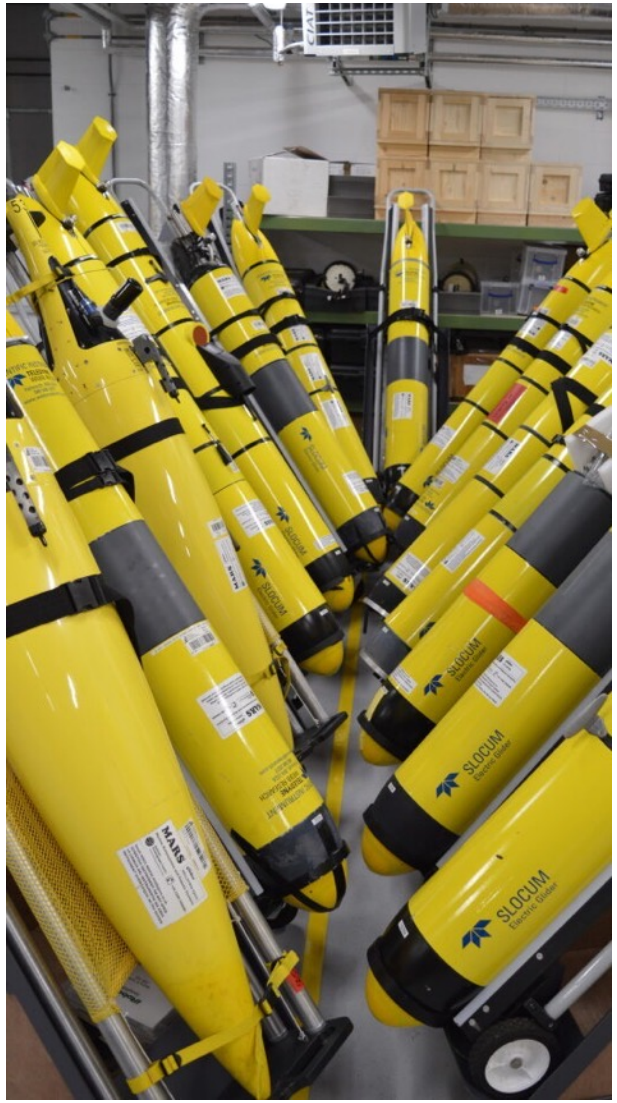

THE LAST 12 MONTHS OF NMF VEHICLE OPERATIONS

National Oceanography Centre

Hours at sea:

gliders: 25,048

autosubs: 1,725

research ships: 377

Distance Travelled (nautical miles):

gliders: 12,682

autosubs: 2,116

research ships: 1,670

Source: NOC MARS Fleet Finder, mars.noc.ac.uk/stats

THE CHALLENGES

National Oceanography Centre

ENABLE RESEARCHERS TO HAVE MORE CONTROL OF GLIDER OPERATIONS ON PROJECTS WHILE RETAINING PILOT ACCOUNTABLY

INCREASE THE VALUE OF GLIDER OBSERVATIONS TO OPERATIONAL MODELS

MAKE THE OPERATION OF INCREASINGLY COMPLEX GLIDER MISSIONS MORE EFFICIENT FOR GLIDER PILOTS

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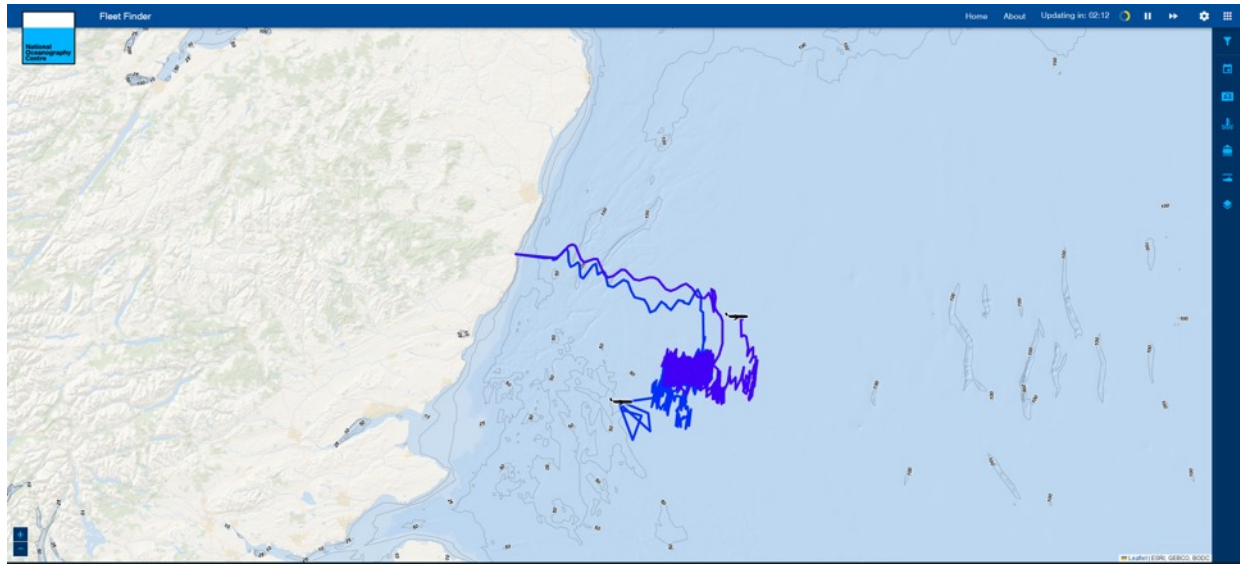
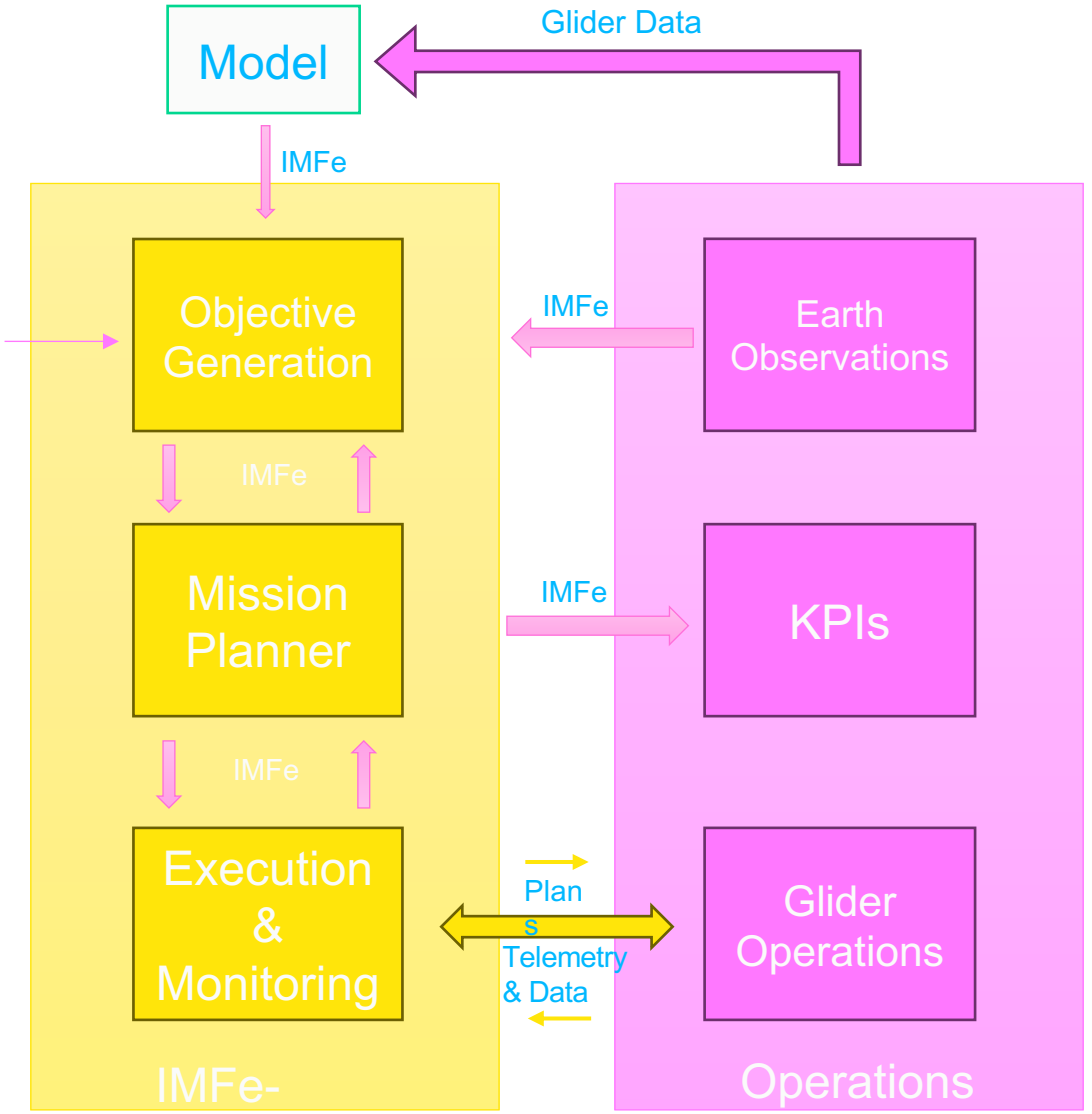
THE MARINE AUTONOMOUS SYSTEMS DIGITAL TWIN (MAS-DT) PROJECT

THE MAS-DT CONCEPT

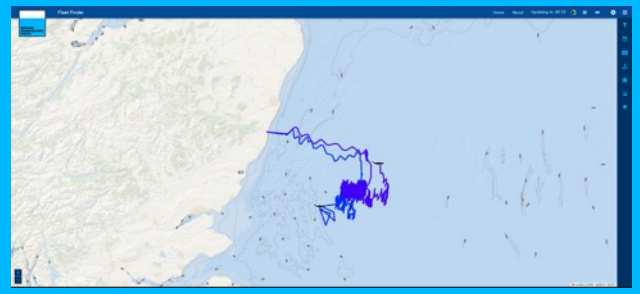
We will build a marine autonomous systems digital twin to aid in decision making by MAS users and operators.





THE MAS-DT USE CASES

Autonomous waypoint navigation



Enabling researchers to create and mission plans for approval by pilots leading to autonomous navigation

Maximising the value of ocean glider observations to operational ocean models

Adaptive glider sampling and data decimation based on the value to operational models

Mission planning and evaluation

Evaluating mission plans ensure efficient use of battery and sensors

MAS-DT AS PART OF THE DIGITAL TWINS COMMUNITY

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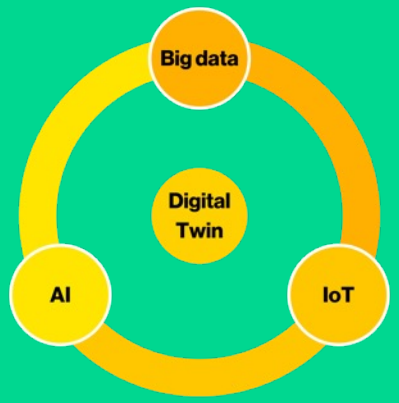
Standards and ontologies



Building on previous work implement and develop the standards needed for an interoperable plug and play digital twin

Workshops to form a UK community of practice on environmental digital twins

(Partnered with Alan Turing Institute)

Picture credit UCL

NERC IMFe senior stakeholder forum

Sustaining the forum beyond the IMFe projects accounting for the evolution of the UK community

MAS-DT TIMELINE

Jan-Mar 24

Scoping

Apr-Jun 24

Design

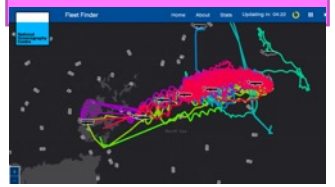
Jul-Sep 24

Development (including digital shadow)

Turing workshop

Oct-Dec 24

Trials (MOGli)



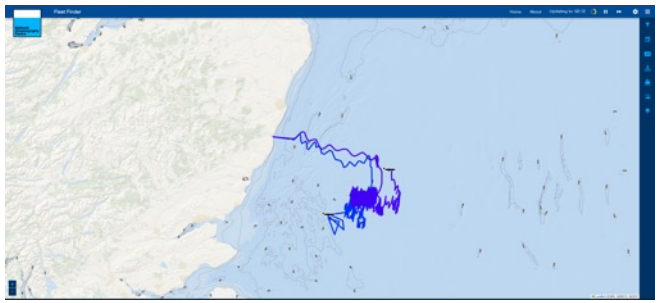
Jan-Mar25

Evaluation

GENERAL ARCHITECTURE

PI

Objective Generation



1. Generic High Level Mission Plans

2. Generic Detail Mission Plans

Adapter

Mission Planner

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Execution and Monitoring

Turn the autonomy engine on/off

Adapter

NOC C2

Synch

Pilot

Earth Observations

Comms Backbone

IMFe Registry

3. Standardised mission state Data

Adapter

NOC Glider Control Station (SFMC)

Note: All the arrows will be defined by IMFe

AUTOMATED PILOTING VIA MISSION PLANNING

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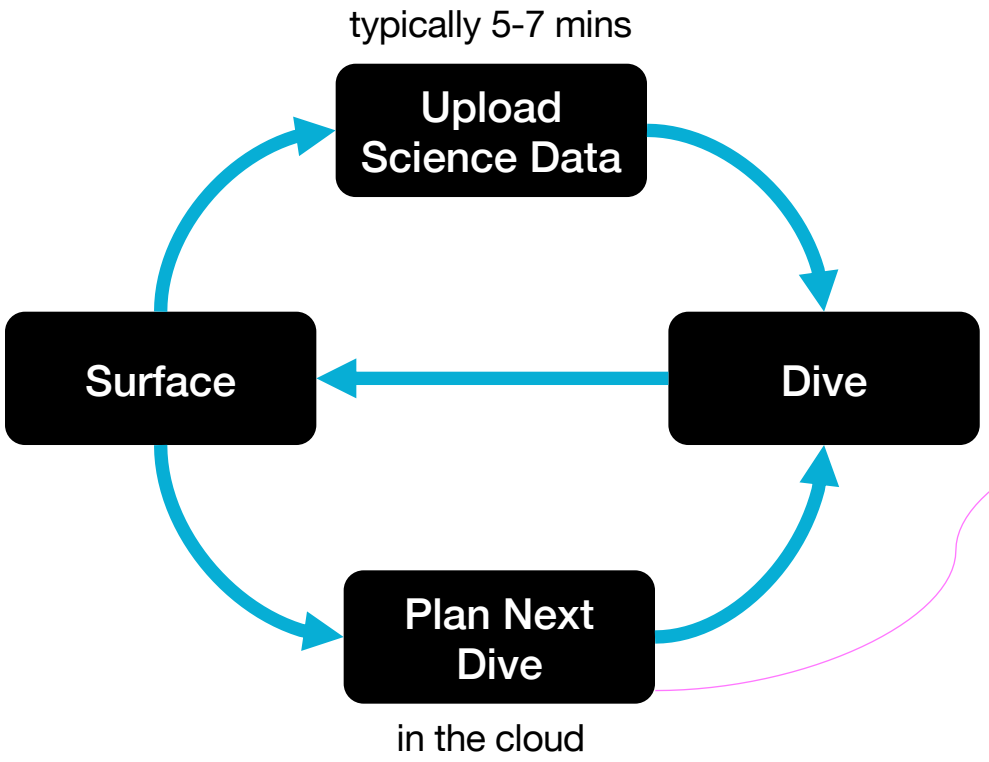
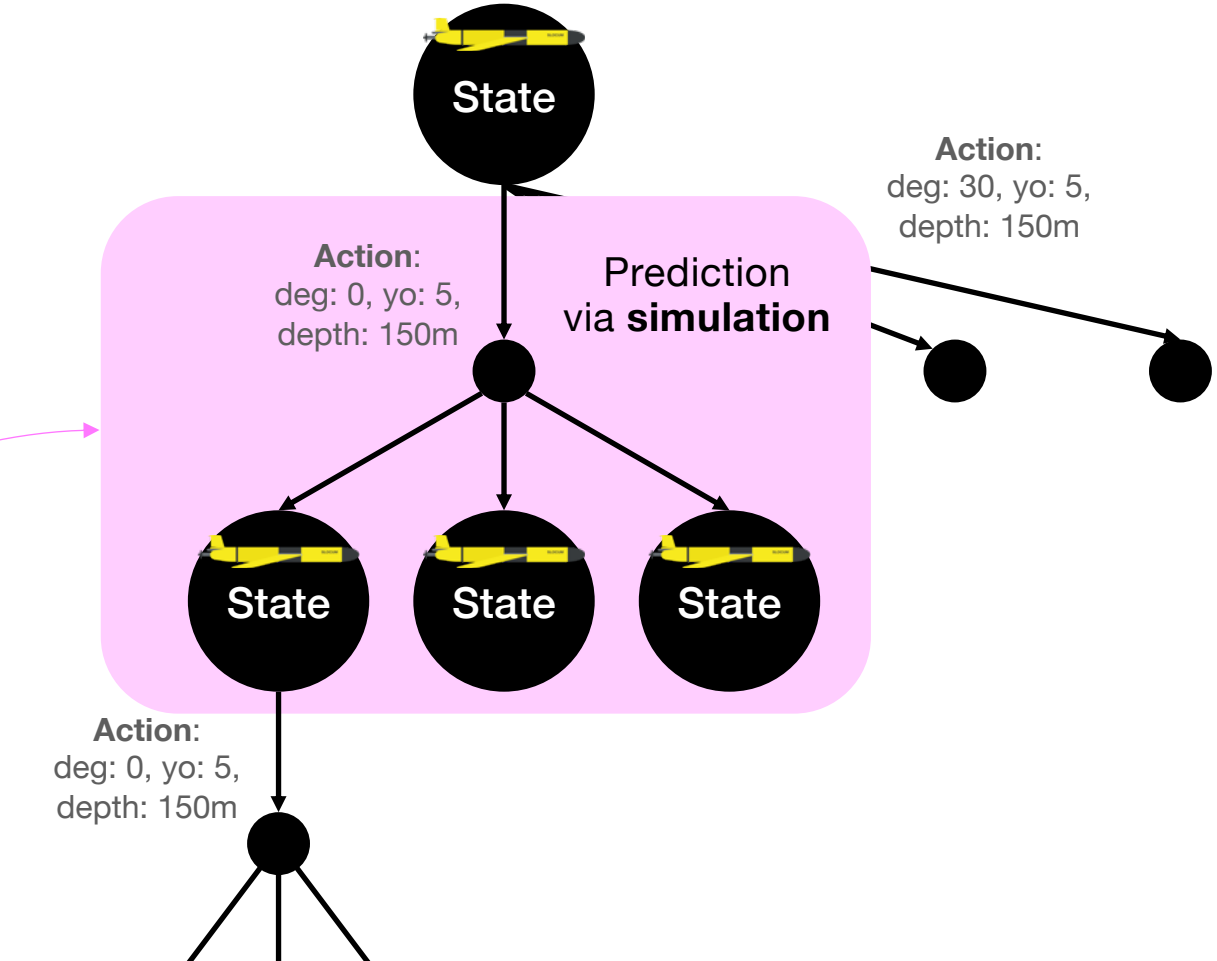
Overall Workflow



Planning

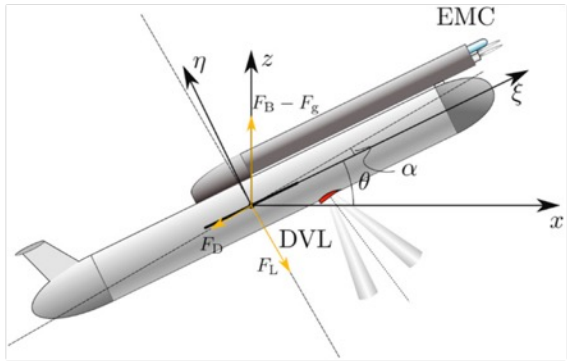


GLIDER SIMULATION

A Dynamic Flight Model for Slocum Gliders and Implications for Turbulence Microstructure Measurements

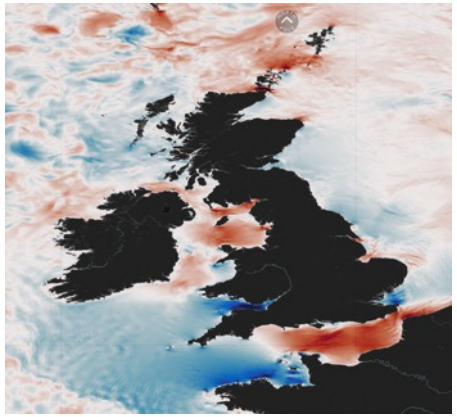
LUCAS MERCKELBACH AND ANJA BERGER

Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Geesthacht, Germany



Glider **flight model**

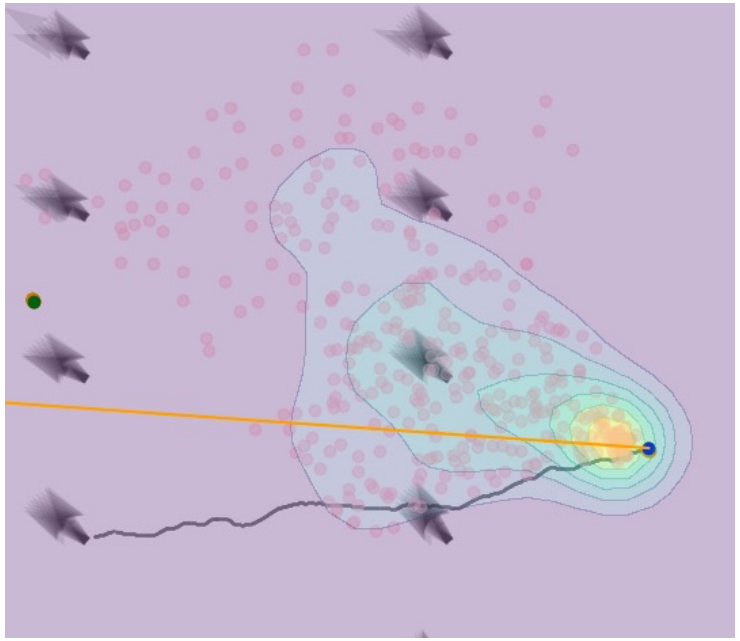
Sea water velocity **forecast**



Action / Glider **dive parameters**

```
behavior_name=yo
# yo35.ma
# Standard YO File file g2 or g3 NOC gliders
#  1 YO
#  30m depth
#  Altimeter On at maximun speed
#  Autoballast on - Full Buoyancy
#  Battery Mode Servo 26 deegrees
# See /doco/hw-it-works/autoballast.txt and masterdata for full list of b_args.
# 22 - August 2016 alvaro.lorenzo@noc.ac.uk
# 02 - Dec 2021 ben.allsup@noc clean up for g3 and thruster usage

<start:b_arg>
    b_arg: start_when(enum)          2          # pitch idle (see doco below)
    b_arg: num_half_cycles_to_do(nodim) 2       # Number of dive/climbs to perform
                                               # <0 is infinite, i.e. never finishes


# arguments for dive_to
    b_arg: d_target_depth(m)         45         #what is max depth of this glider do not set greater
    b_arg: d_target_altitude(m)      15

    b_arg: d_use_bpump(enum)         0          # 0  Autoballast/Speed control.
    b_arg: d_bpump_value(X)          300.0      # use_bpump == 0   Total amt of ballast, stored as C_AUTOBALLAST_VOLUME

    b_arg: d_use_pitch(enum)         3          # 1:battpos  2:setonce 3:servo
                                               #   in          rad rad, <0 dive
    b_arg: d_pitch_value(X)          -0.07        # -4 deg

##### Thruster params - optionally uncomment to use if thruster is installed ( 3 for depth rate or 4 for power mode) #####

        b_arg: d_use_thruster(enum)   4         # 3  Command depth rate.  See sensors for use_thruster = depthrate
                                               # 4  Command input power. See sensors for use_thruster = power

        b_arg: d_thruster_value(X)   3      # use_thruster == 3  m/s, desired depth rate. >0 for dive
                                               # use_thruster == 4  watt, desired input power, between [ 1, 9] Watts
```

Sample-based **surface predictions**



GENERAL ARCHITECTURE – FUTURE TWINS (NOT MAS-DT)

PolarRoute

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

IceNet

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Glider Path Planner

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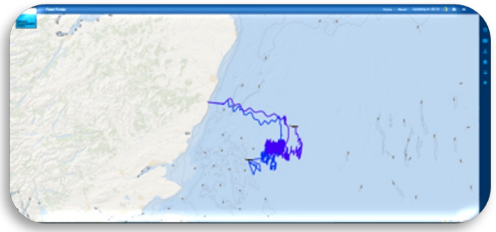
Currents Model

National Oceanography Centre

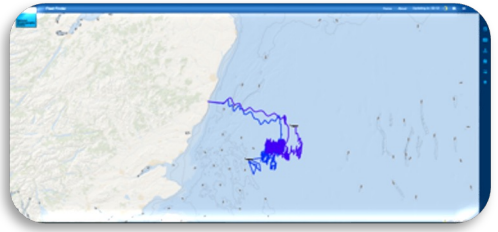
Comms Backbone

IMFe Registry



Execution and Monitoring

National Oceanography Centre



Execution and Monitoring

British Antarctic Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Shoreside

Shipside

SUMMARY

Digital tools are becoming a key element of environmental research:

- Adapt and grow (ocean) observing
- They act as the bridge between observations and action
- Development need to be aligned with interoperable frameworks

We are building a digital twin to aid in operation of gliders:

- Brings together user interface with model ocean currents, glider hydrodynamic model, and AI/ML techniques to aid decision making in glider operations
- Interoperability at the core of the design based on the IMFe
- At the design stage with integration of components about to commence and we are keen for feedback from the ocean glider community

National Oceanography Centre

THANK YOU

For more information please contact:

Justin Buck (justin.buck@noc.ac.uk)

Alvaro Lorenzo lopez (allore@noc.ac.uk)

MAS-DT is funded by the UKRI/NERC TWINE programme, grant number NE/Z503381/1

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