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HOW TO MAKE UNDERWATER EXPLORATION WITH AUTONOMOUS VEHICLES MORE RELIABLE

Achille MARTIN

08/04/2024

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STORY AT SEA

STORY AT SEA | LOCATION

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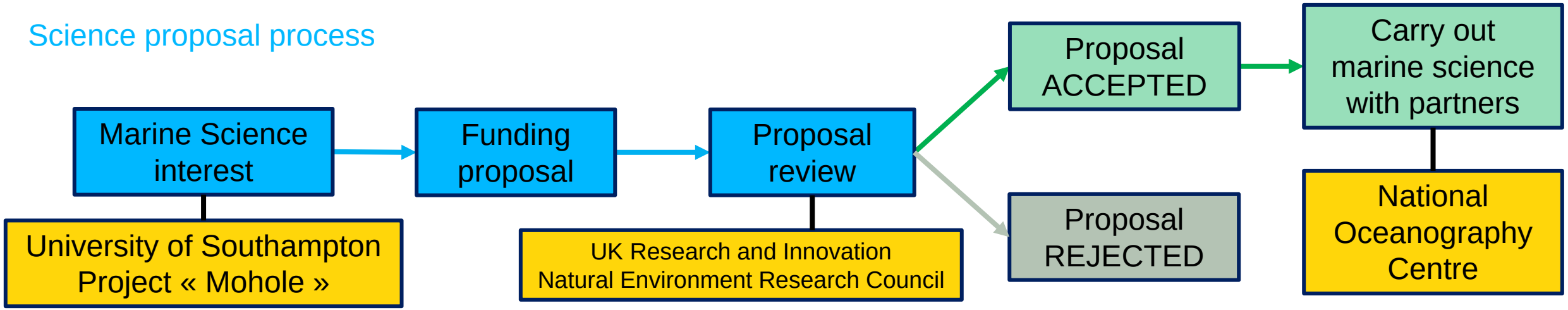
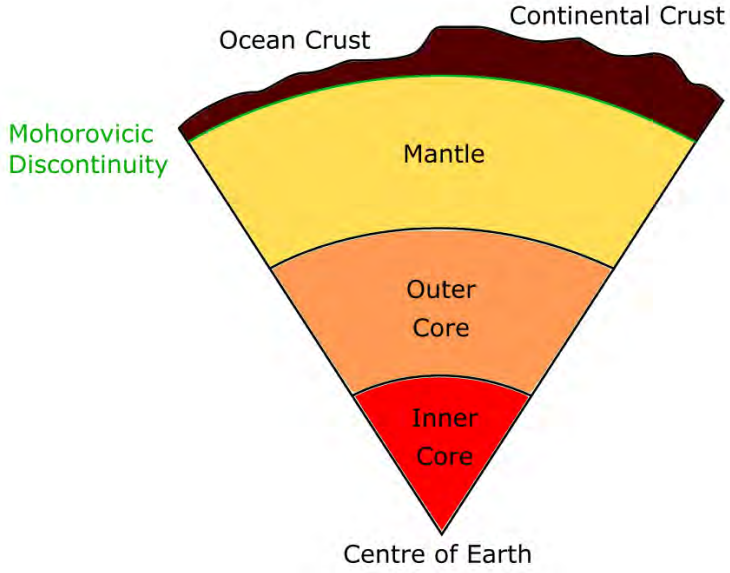
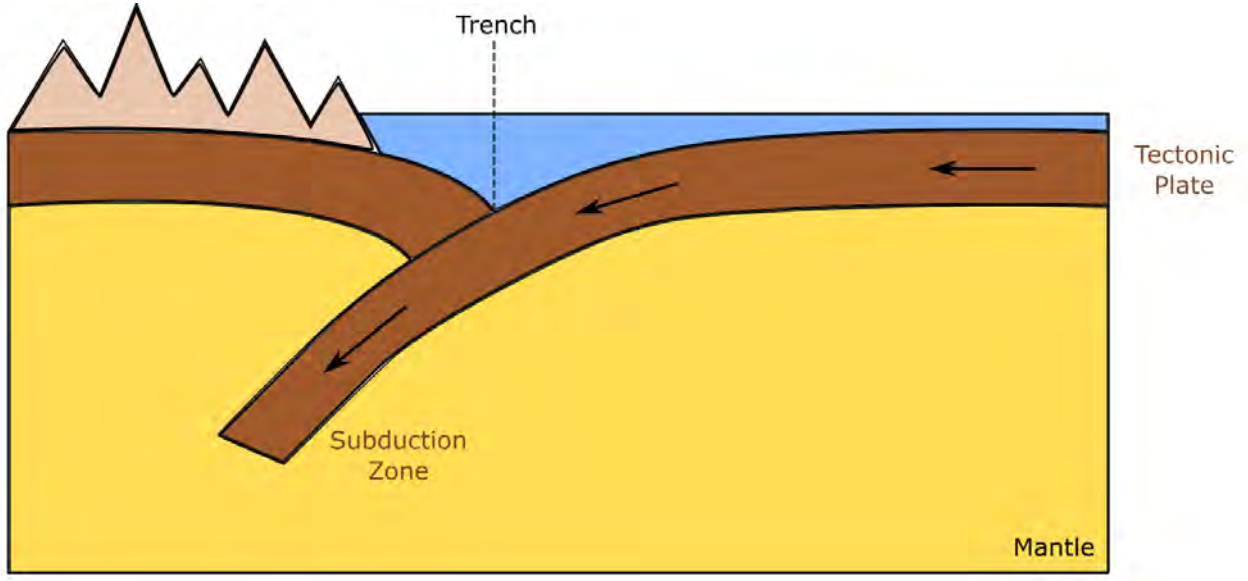
STORY AT SEA | MARINE SCIENCE

Science proposal process



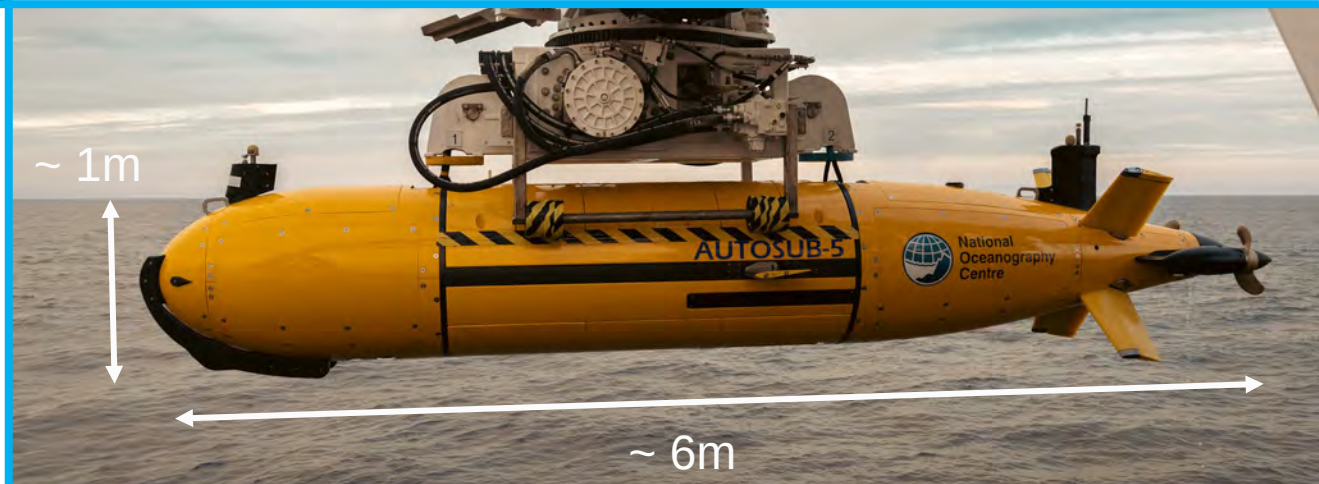




STORY AT SEA | EQUIPMENT

Royal Research Ship James Cook

Autosub 5



Autonomous = uncrewed and not remotely piloted

STORY AT SEA | UNEXPECTED EVENT

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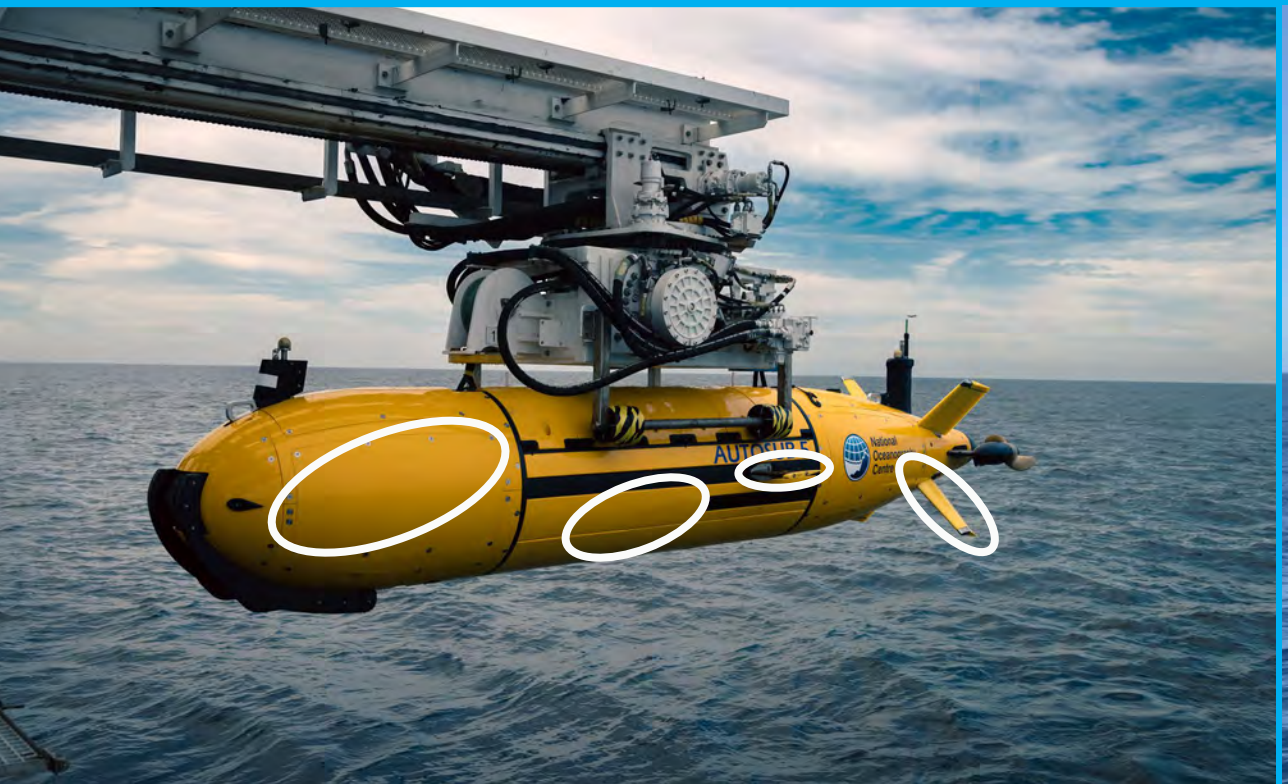
Autosub 5 BEFORE being deployed

Autosub 5 AFTER being deployed



STORY AT SEA | VEHICLE DAMAGE

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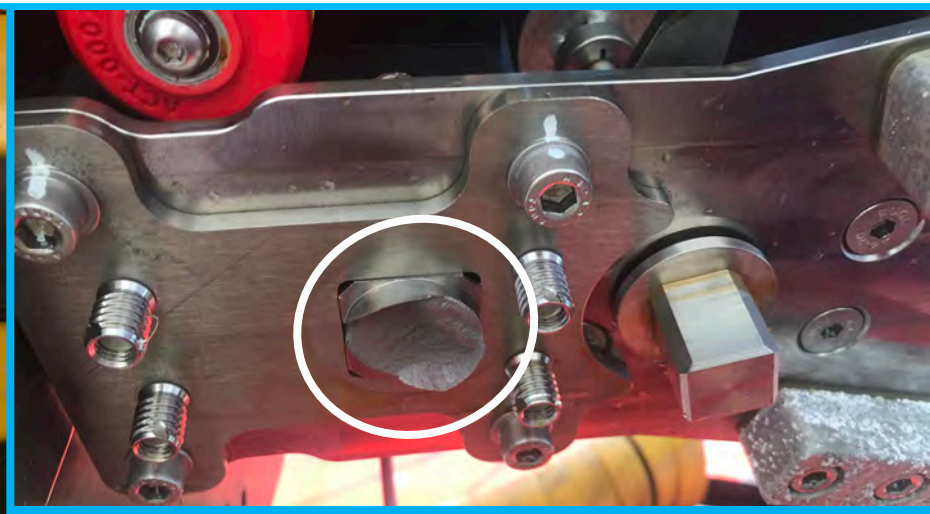
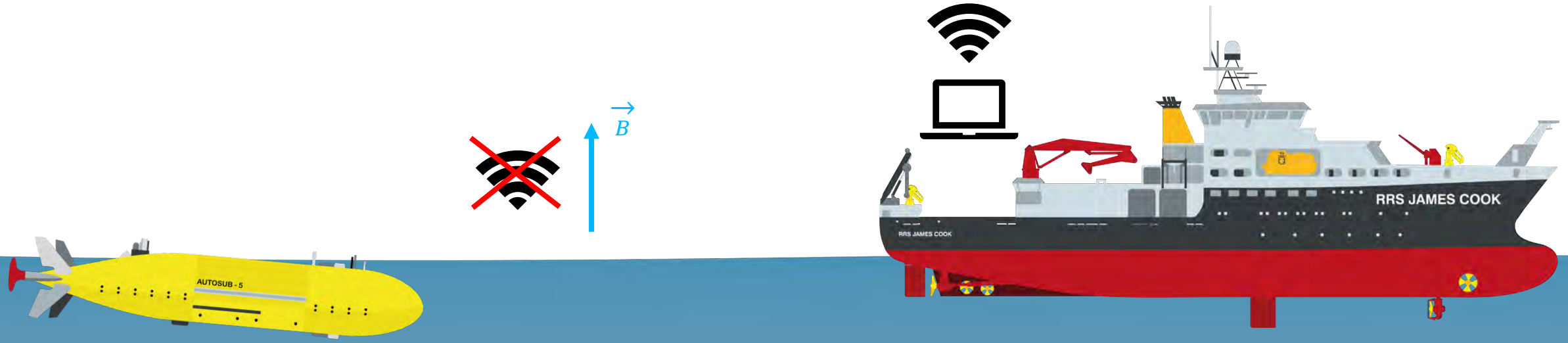


STORY AT SEA | FIRST ATTEMPT TO DEPLOY

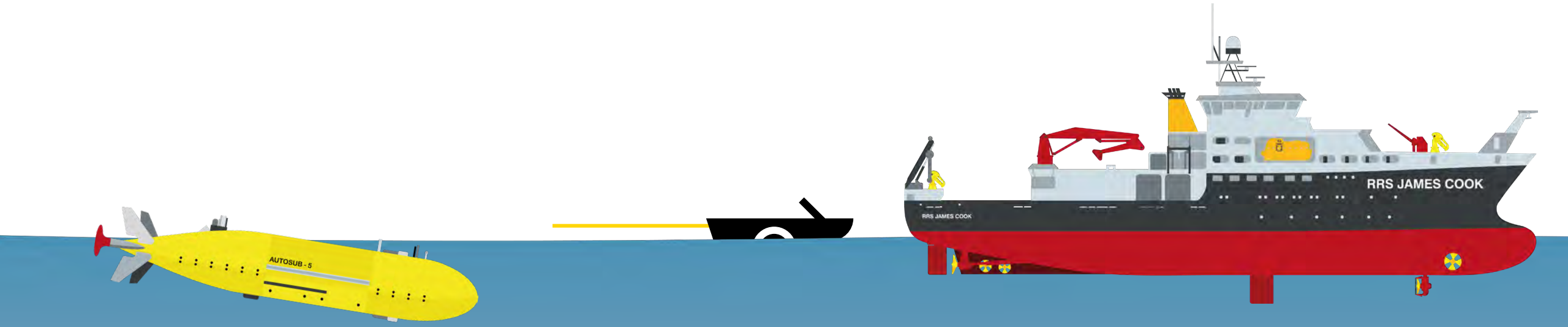


1) Autosub 5 failed to dive

2) Autosub 5 kept trying to dive

3) Autosub 5 could not receive Wi-fi communications

STORY AT SEA | SECOND ATTEMPT TO DEPLOY



4) Autosub 5 was pitching up ~ 60deg

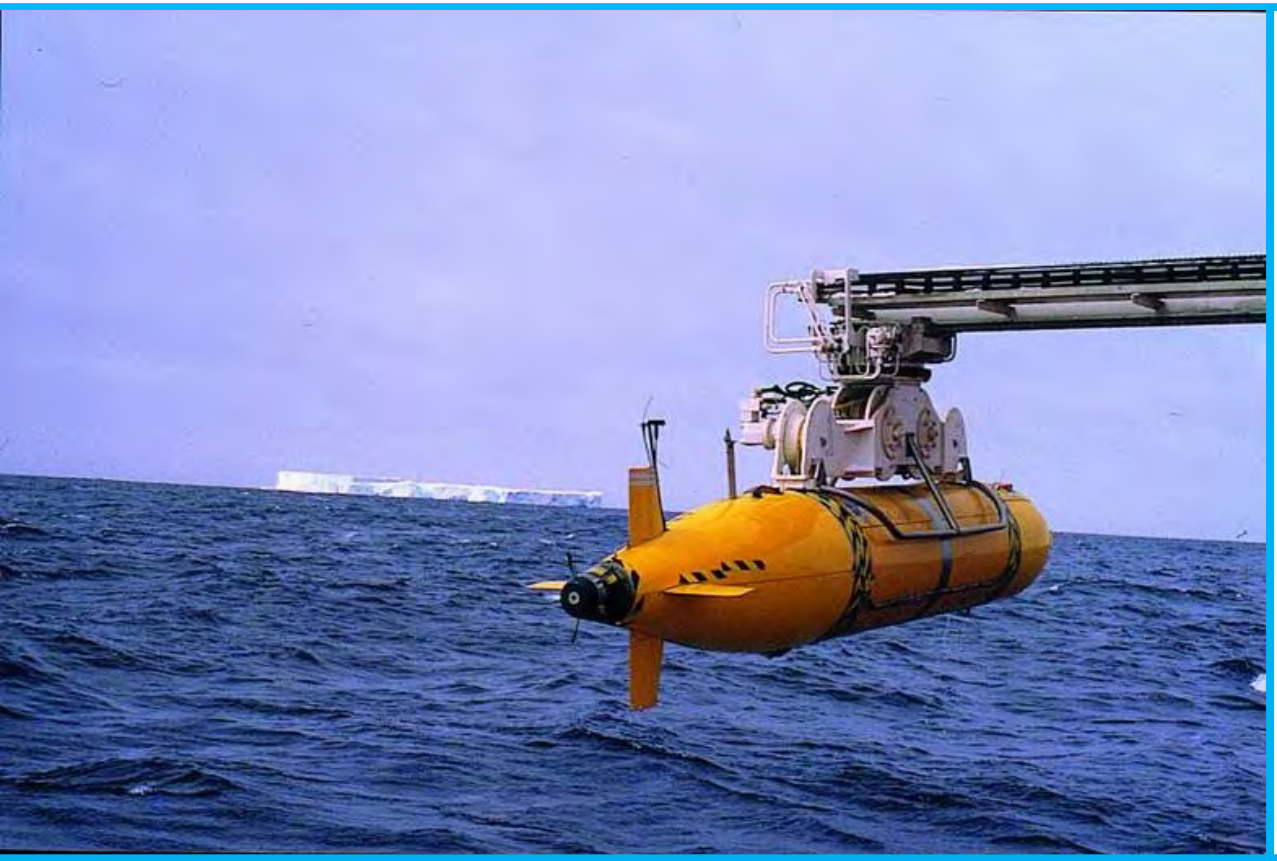
STORY AT SEA | CONSEQUENCES ON RESEARCH

CONSEQUENCE 1 = First days of expedition wasted

CONSEQUENCE 2 = Expedition cancelled without collecting any data

CONSEQUENCE 3 = Other expeditions planned in the area cancelled too

STORY AT SEA | OTHER INCIDENTS



Autosub 2

February 2005

Hugin

January 2024

HOW TO ANTICIPATE AND PREVENT DEPLOYMENT ISSUES?

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THE SIMULATOR

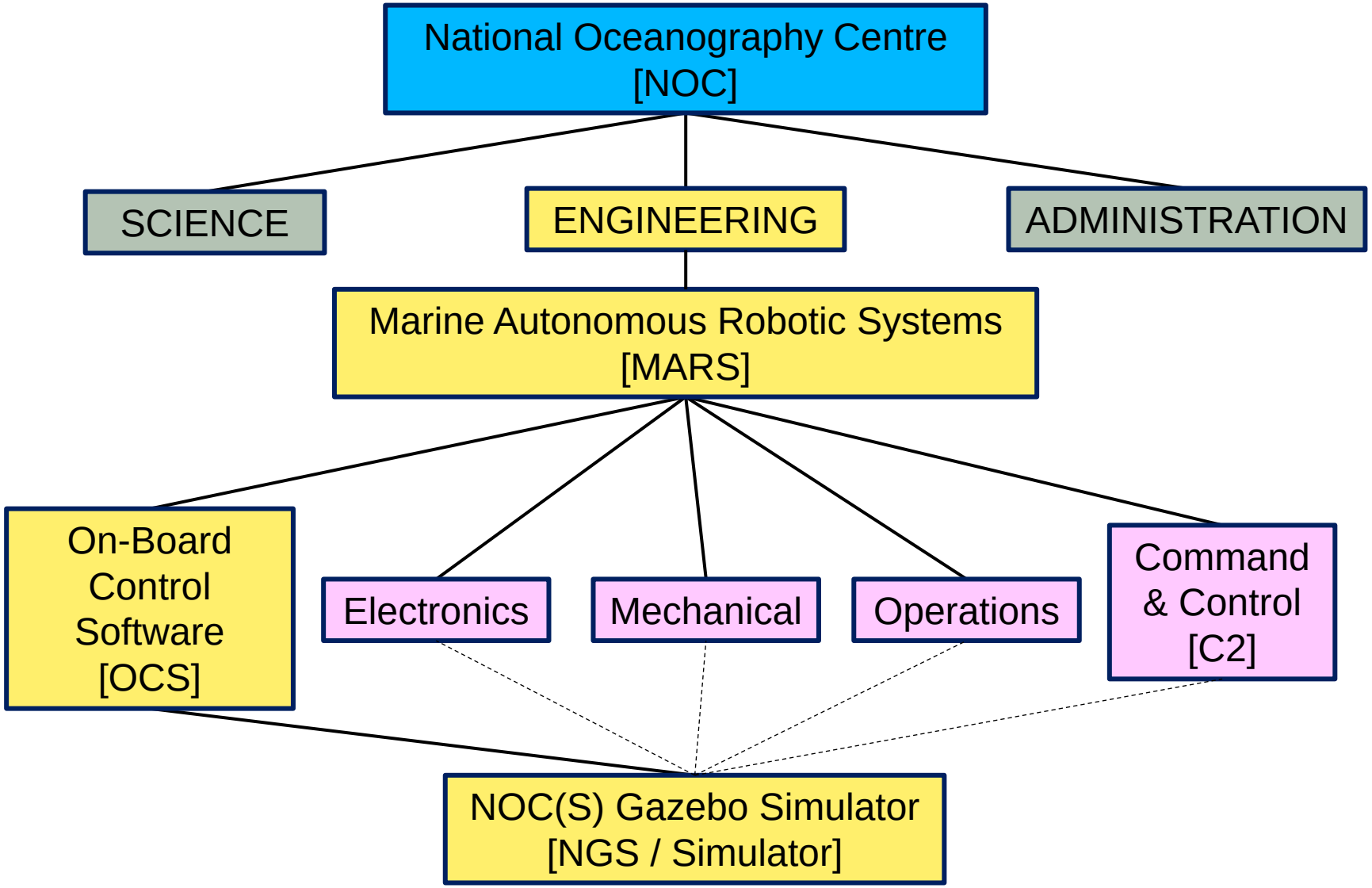
THE SIMULATOR | SELF INTRODUCTION

Achille MARTIN

Joined

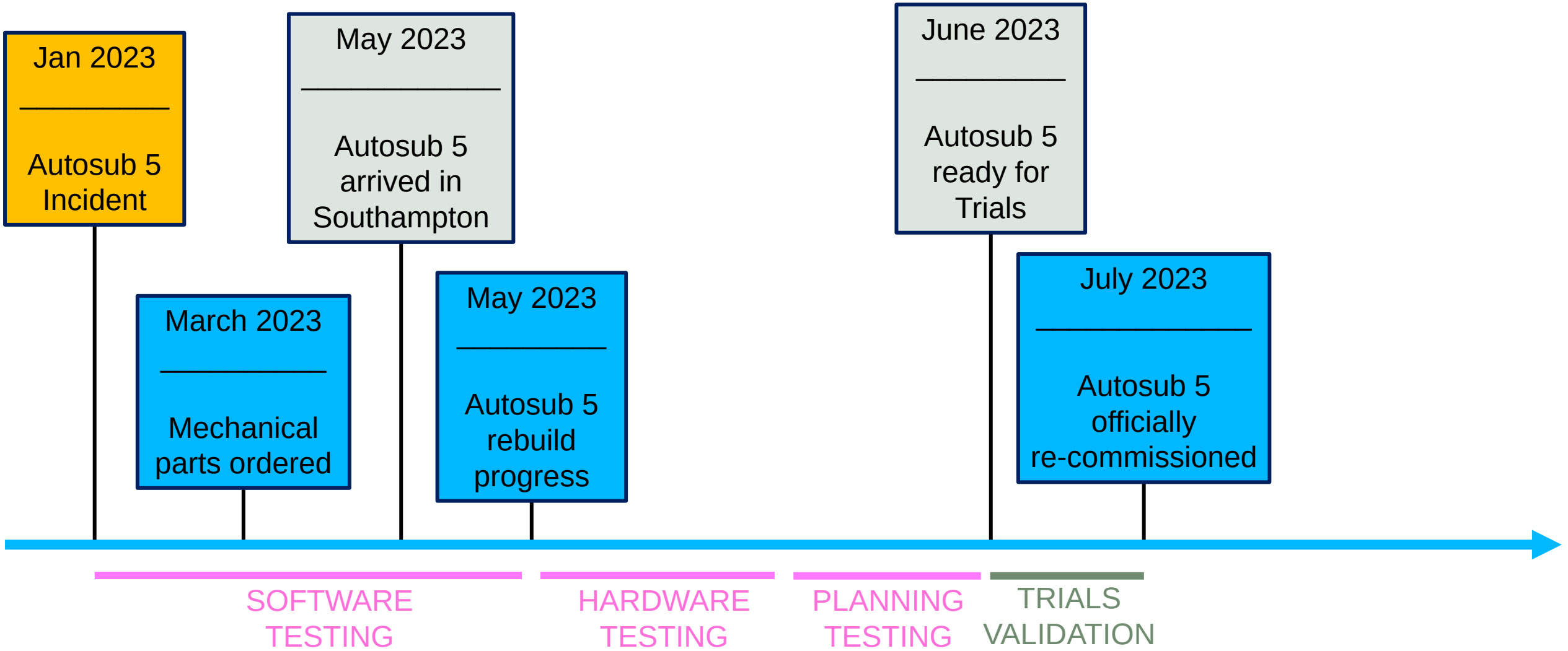
The National Oceanography Centre
Southampton, UK

in November 2019



THE SIMULATOR | RE-COMMISSIONING PROCESS

Timeline of re-commissioning Autosub 5



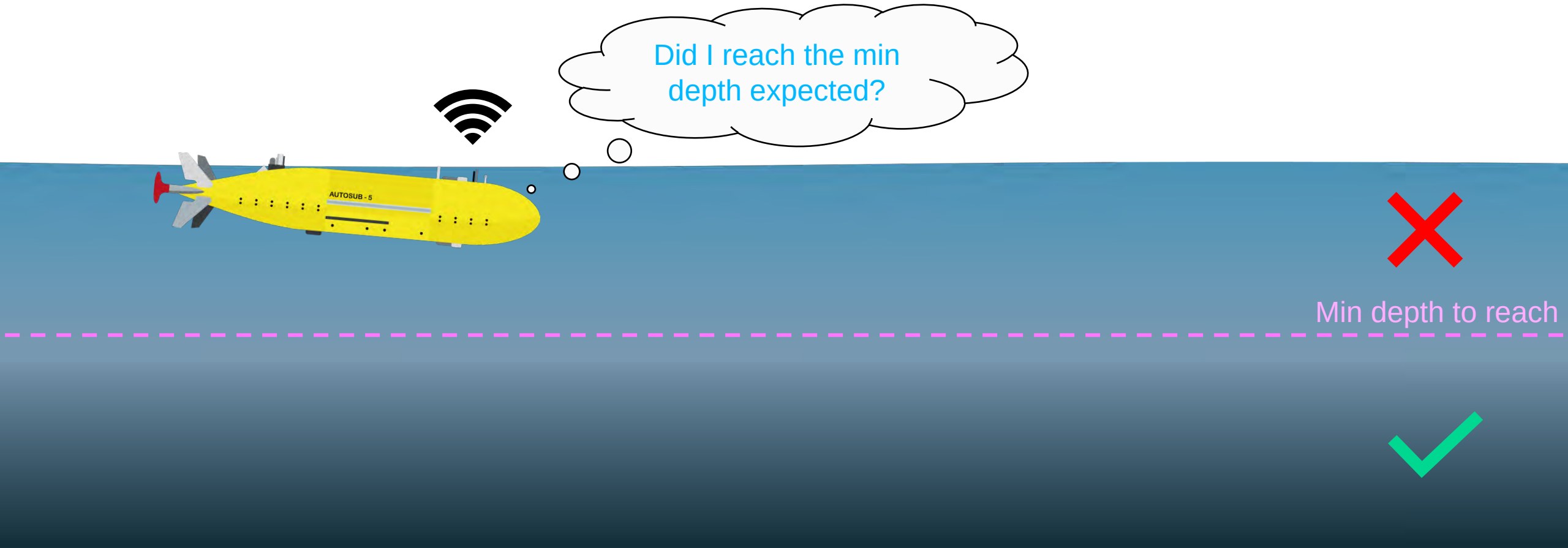
THE SIMULATOR | SOFTWARE FIXES

Fixes required

Autosub 5 failed to dive

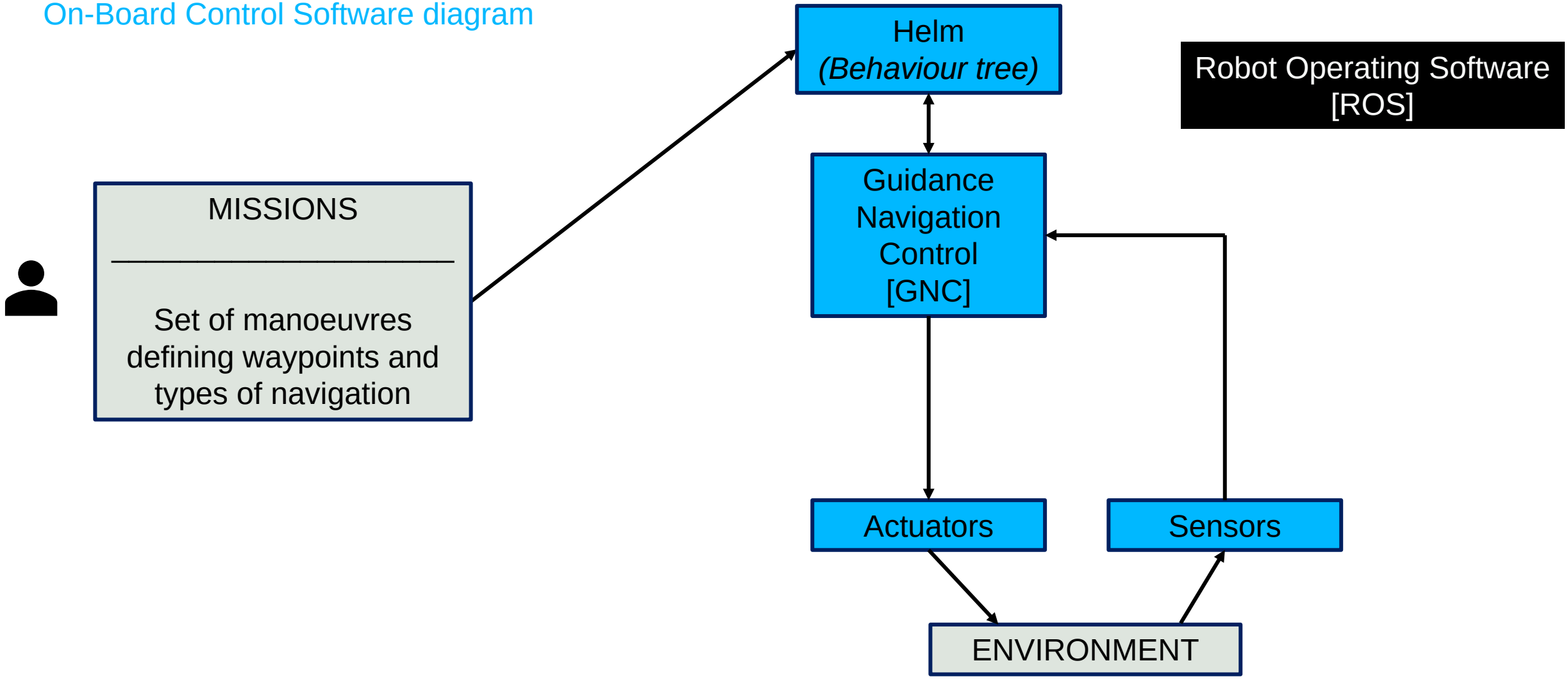
Autosub 5 kept trying to dive

Autosub 5 could not receive Wi-fi communications



THE SIMULATOR | SOFTWARE BLOCKS

On-Board Control Software diagram



THE SIMULATOR | SOFTWARE SIMULATION INTERACTION

On-Board Control Software and Simulator interaction

MISSIONS

Set of manoeuvres defining waypoints and types of navigation

Helm *(Behaviour tree)*

Guidance Navigation Control [GNC]

Conversion Functions

Virtual actuators

Virtual sensors

VIRTUAL ENVIRONMENT

NOCS Gazebo Simulator architecture

UUV Sim

Gazebo

Underwater dynamics

OCS Interface functionalities

THE SIMULATOR | SOFTWARE SIMULATION INTERFACE

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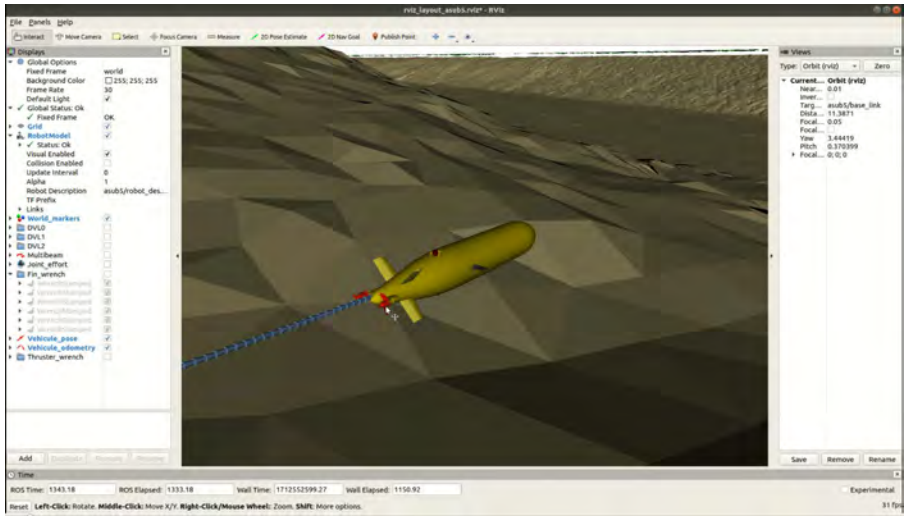
Autosub 5 Simulator introduction

Simulator environment
and virtual vehicle

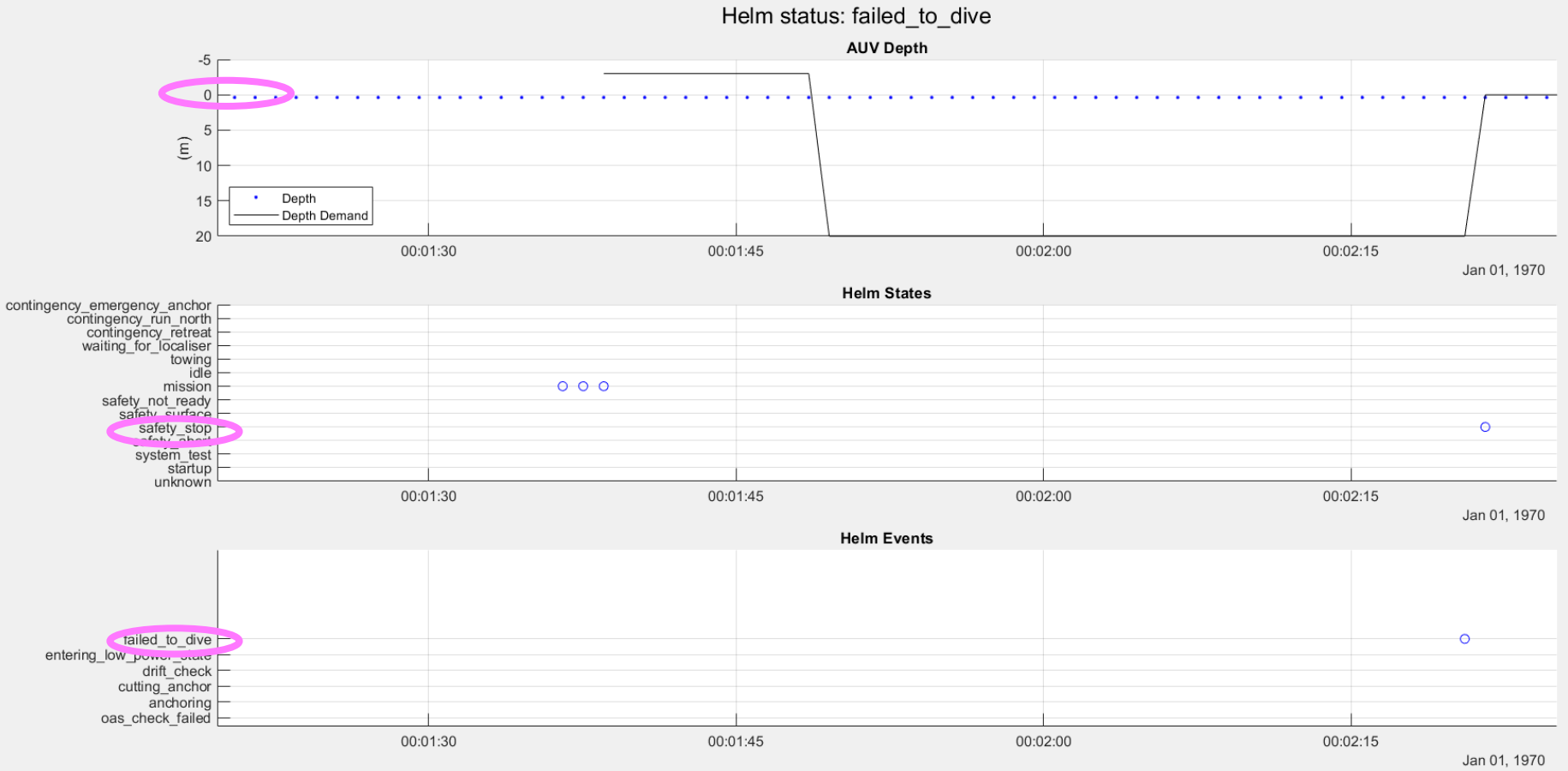
Virtual vehicle on a mission
in virtual environment



Autosub 5 simple mission example

THE SIMULATOR | SOFTWARE TESTING

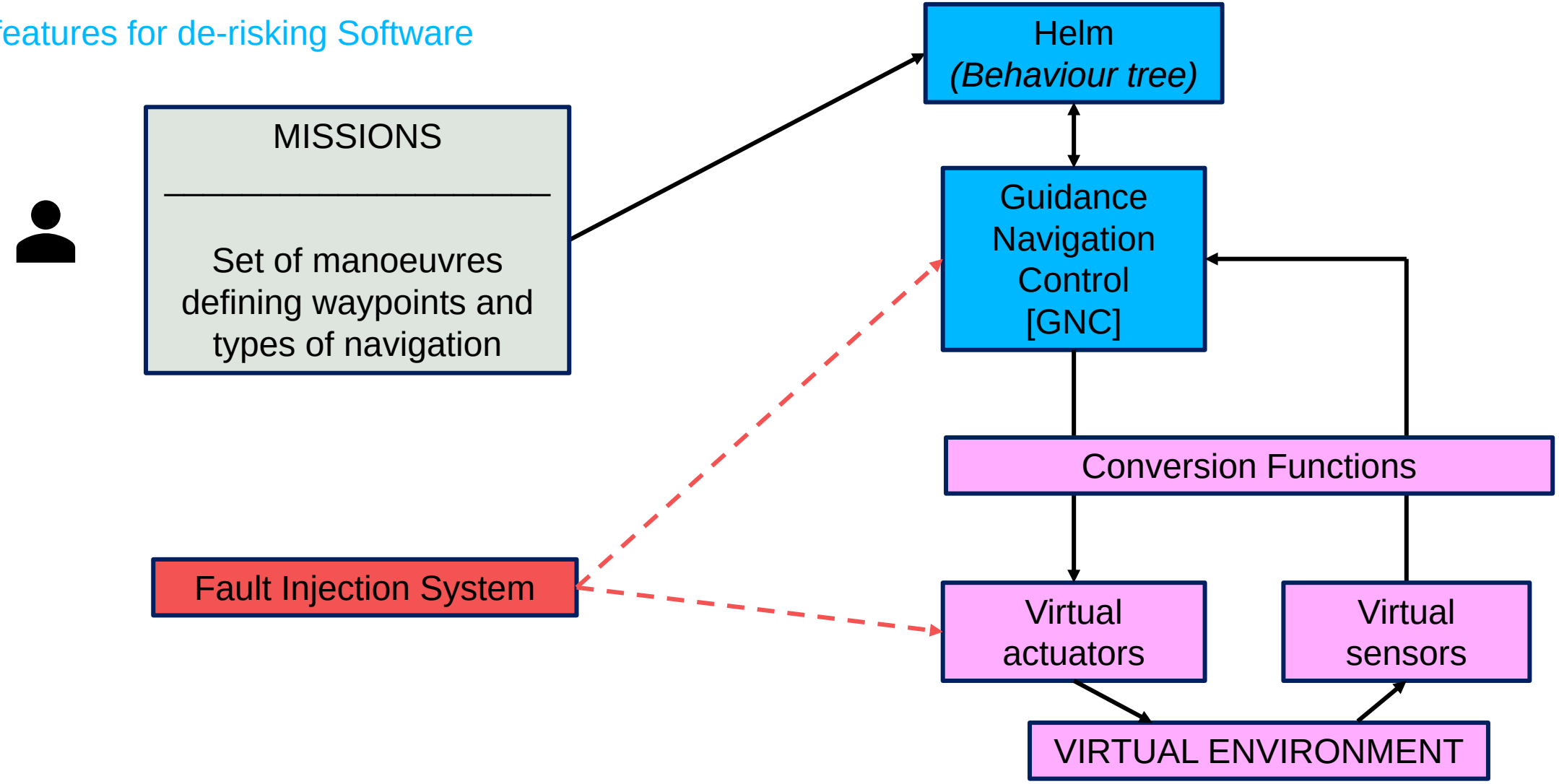
Autosub 5 failed to dive example



Autosub 5 failed to dive plot review

THE SIMULATOR | SOFTWARE DE-RISKING

More features for de-risking Software



THE SIMULATOR | HARDWARE FIXES

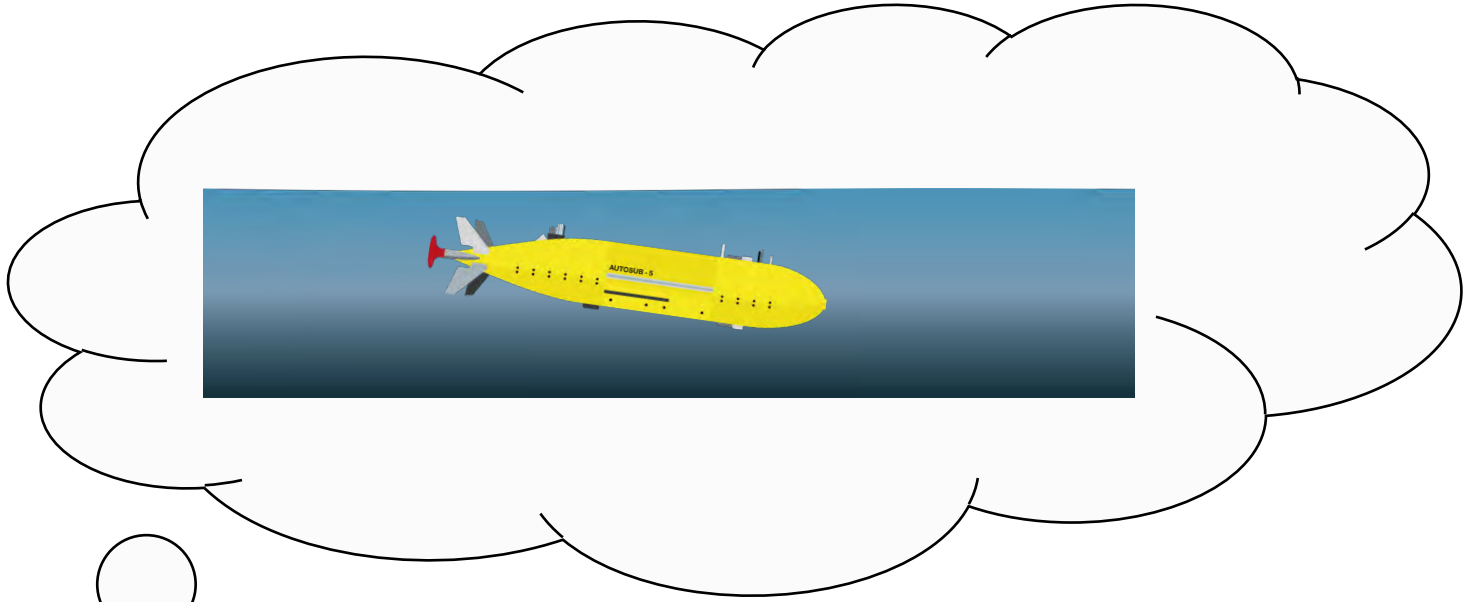
Fixes required

- Verify actuators
- Refit actuators
- Verify sensors
- Refit sensors
- Reballast vehicle

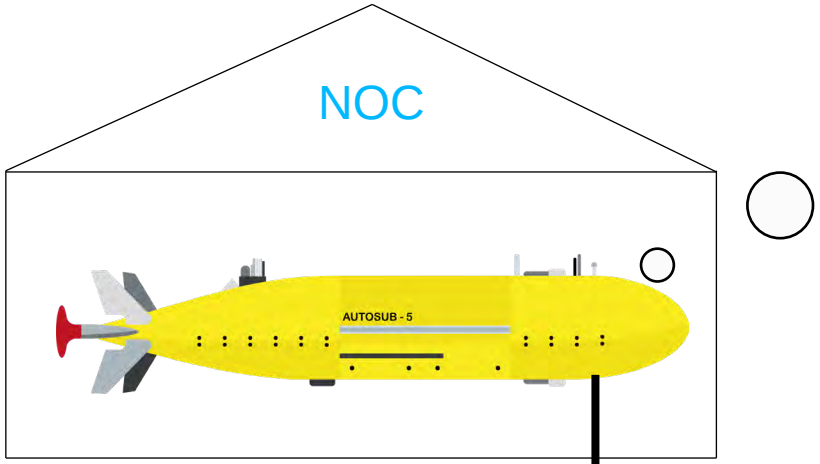
- Conductivity, Temperature, and Depth (probe) [CTD]
- Collision avoidance sonar
- Doppler Velocity Log [DVL]
- Inertial Navigation System [INS]
- Attitude and Heading Reference System [AHRS]
- Wings
- Wi-fi Beacon
- Control planes
- Thrusters

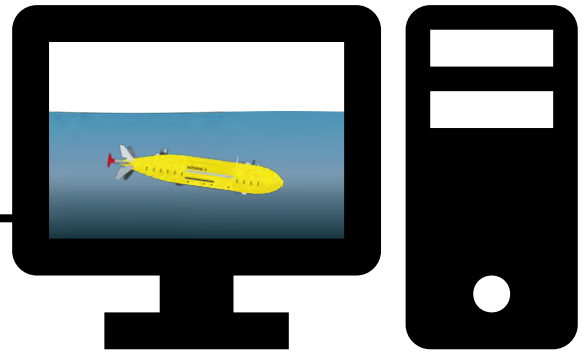
THE SIMULATOR | HARDWARE-IN-THE-LOOP CONCEPT

Hardware-in-the-loop dream



NOC

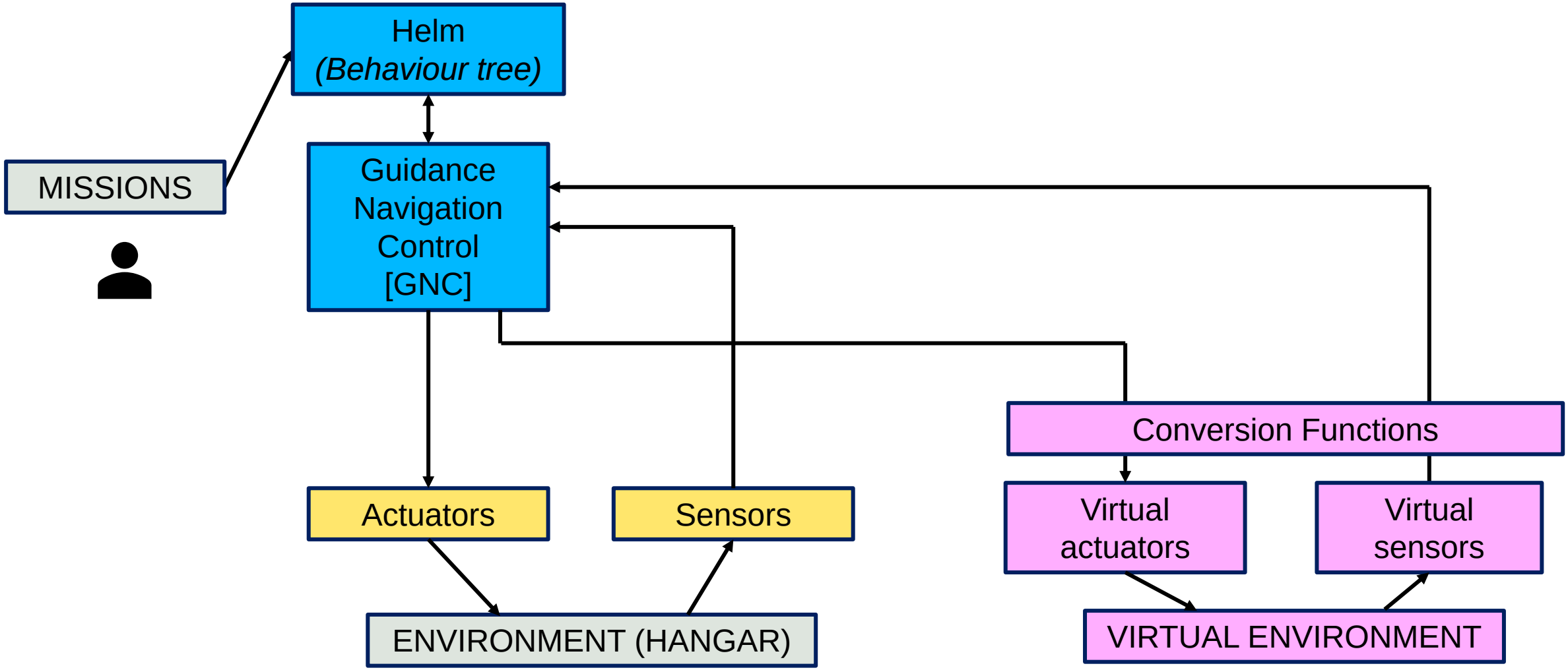




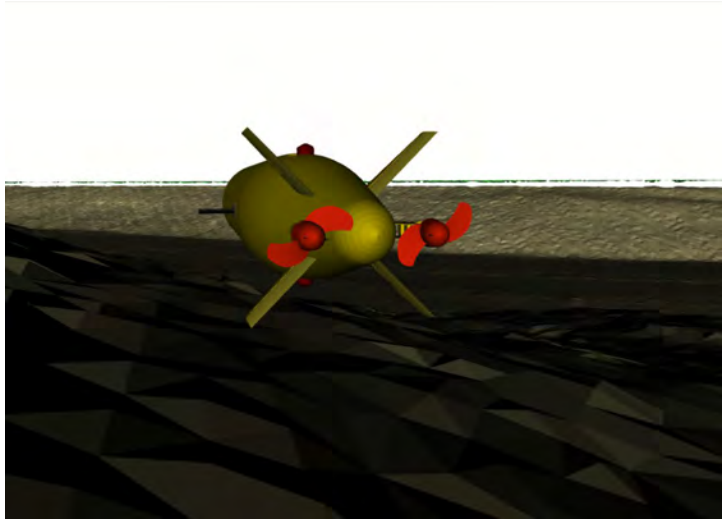
Simulator

THE SIMULATOR | HARDWARE-IN-THE-LOOP ARCHITECTURE

Hardware-in-the-loop architecture

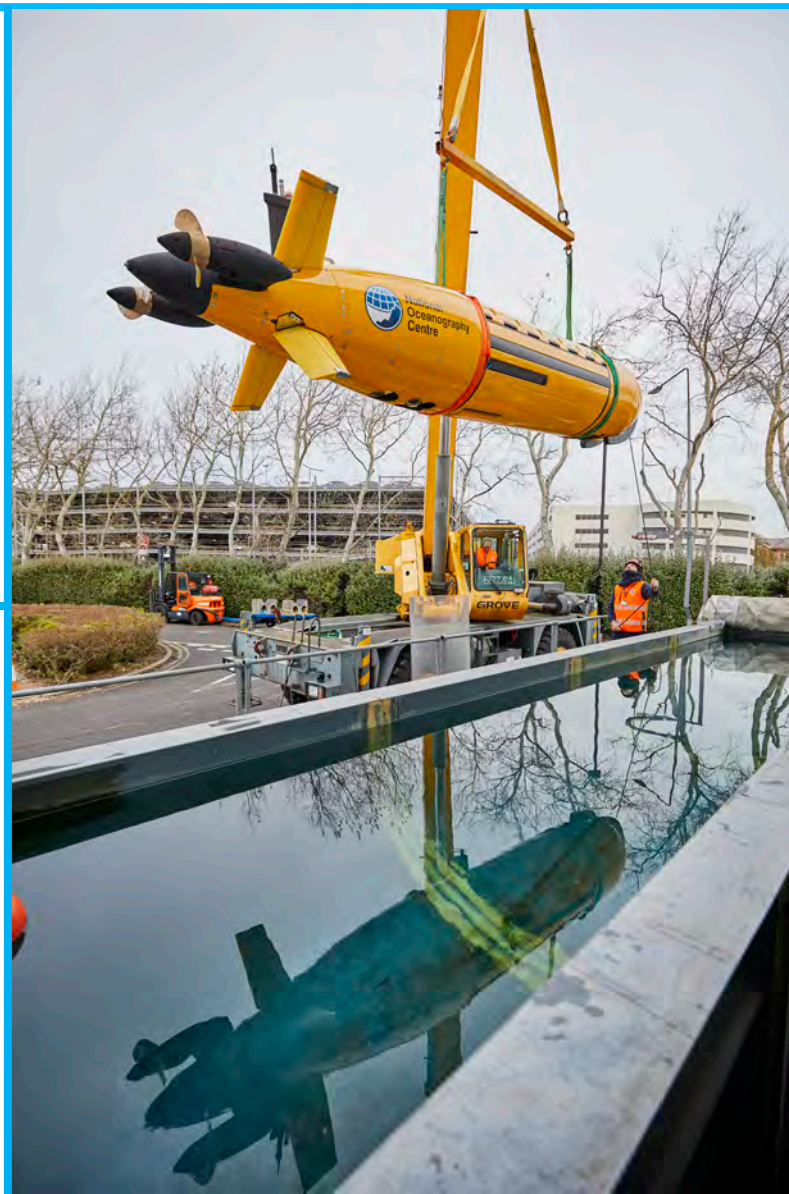


THE SIMULATOR | HARDWARE-IN-THE-LOOP TESTING



Autosub 5 system test Simulation

Autosub 5 performing system test in Simulation



Autosub 5 performing system test in hangar (HIL)

Autosub 5 system test HIL

THE SIMULATOR | HARDWARE DE-RISKING

More features for de-risking Hardware

HIL

APPLICATION 1 = Observe motion of actuators while in HIL

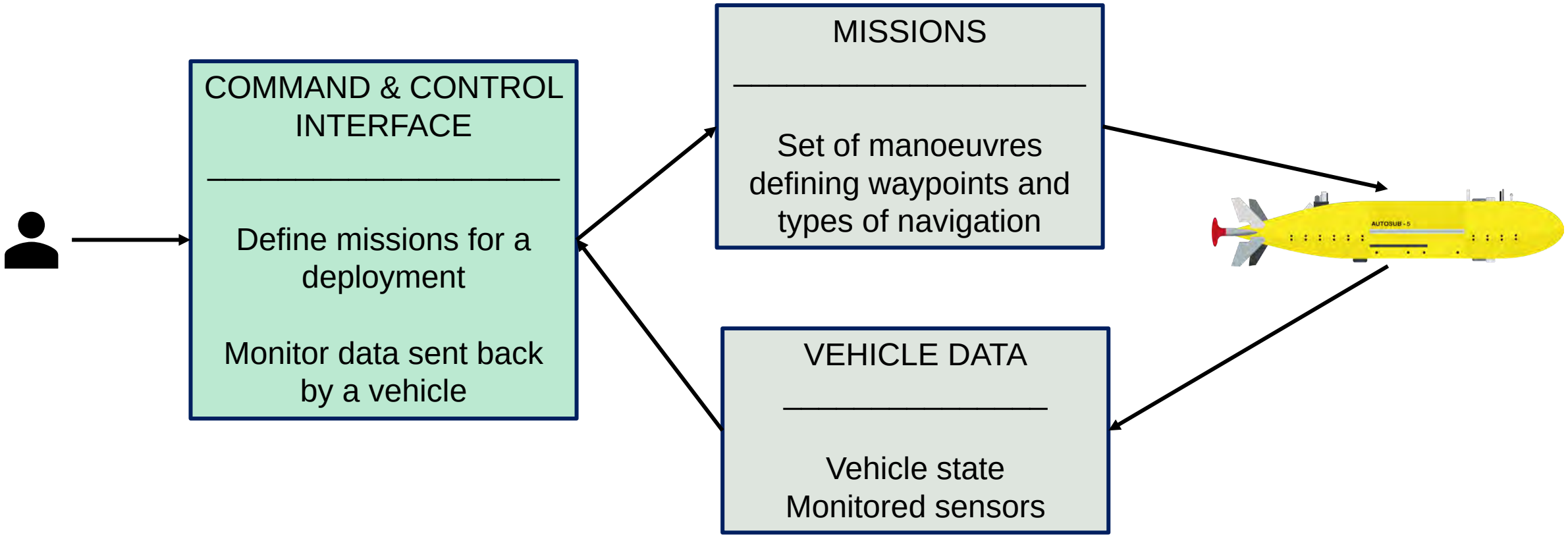
APPLICATION 2 = Physically interact with the vehicle while in HIL

APPLICATION 3 = Communicate with vehicle and sensors while in HIL

THE SIMULATOR | PLANNING FIXES

Fixes required

? ----> Planning mistakes



THE SIMULATOR | PLANNING TESTING

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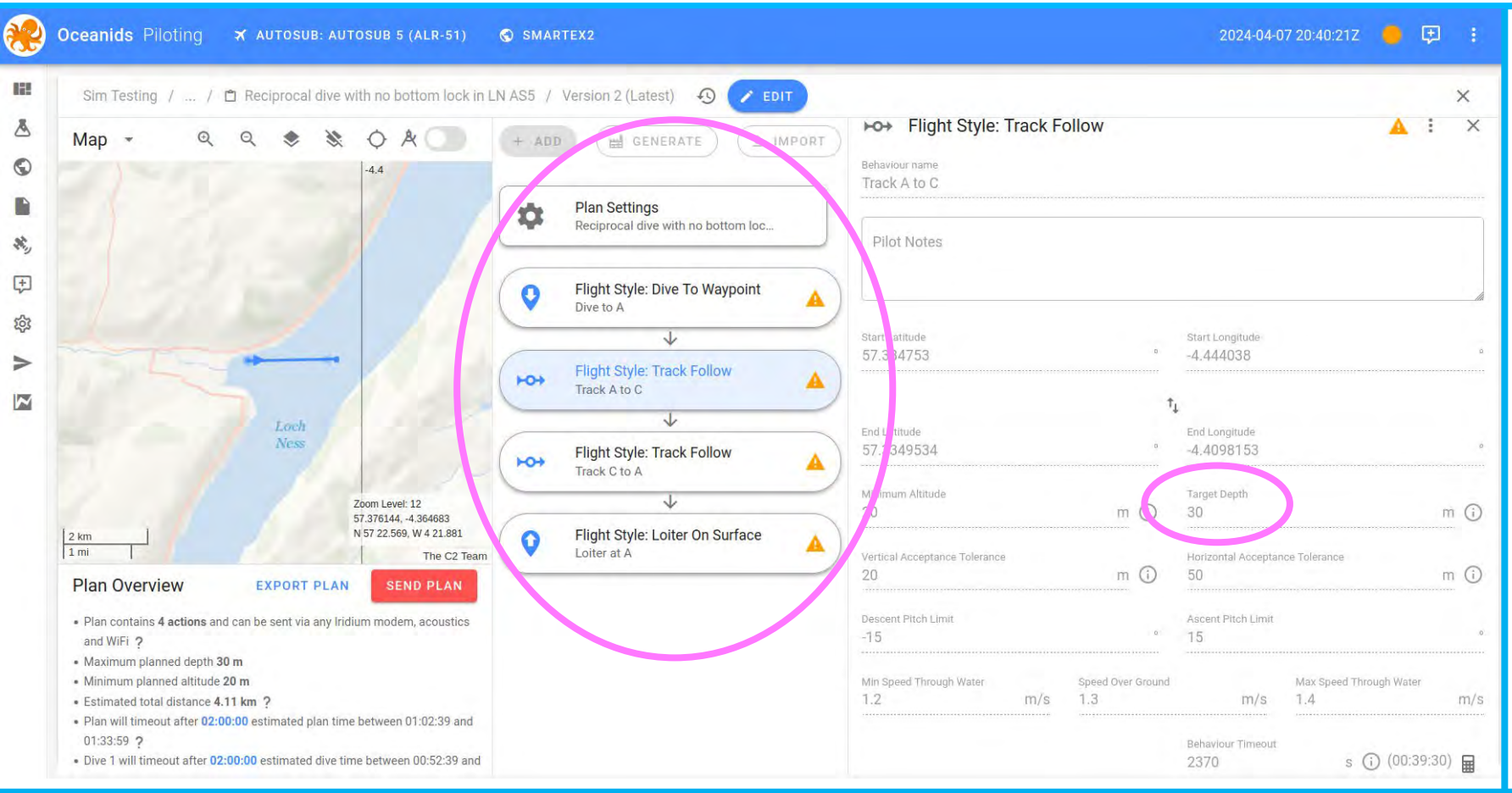
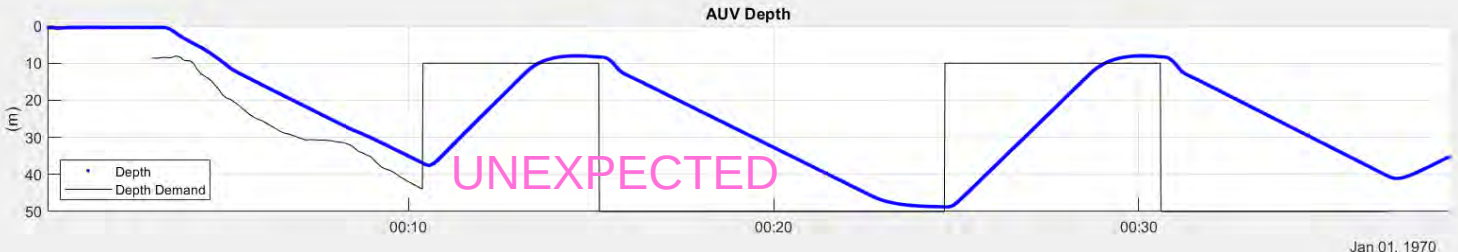


Mission planning for Autosub 5

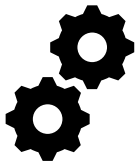
Engineering data from Autosub 5 mission in Simulation



UNEXPECTED

THE SIMULATOR | PLANNING DE-RISKING

More features for de-risking Planning



Manœuvre testing
(example: profiling)

BENEFIT 1 = Exercise C2 interface with non-released features

BENEFIT 2 = Improve communication interface between C2 and OCS

BENEFIT 3 = Serve as training platform for Operations

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VALIDATION

VALIDATION | RELIABILITY CLARIFICATION

Reliability in underwater context

Consistently achieve the objectives set for a specific platform

Metrics about reliability

METRIC 1 = Quality of data 

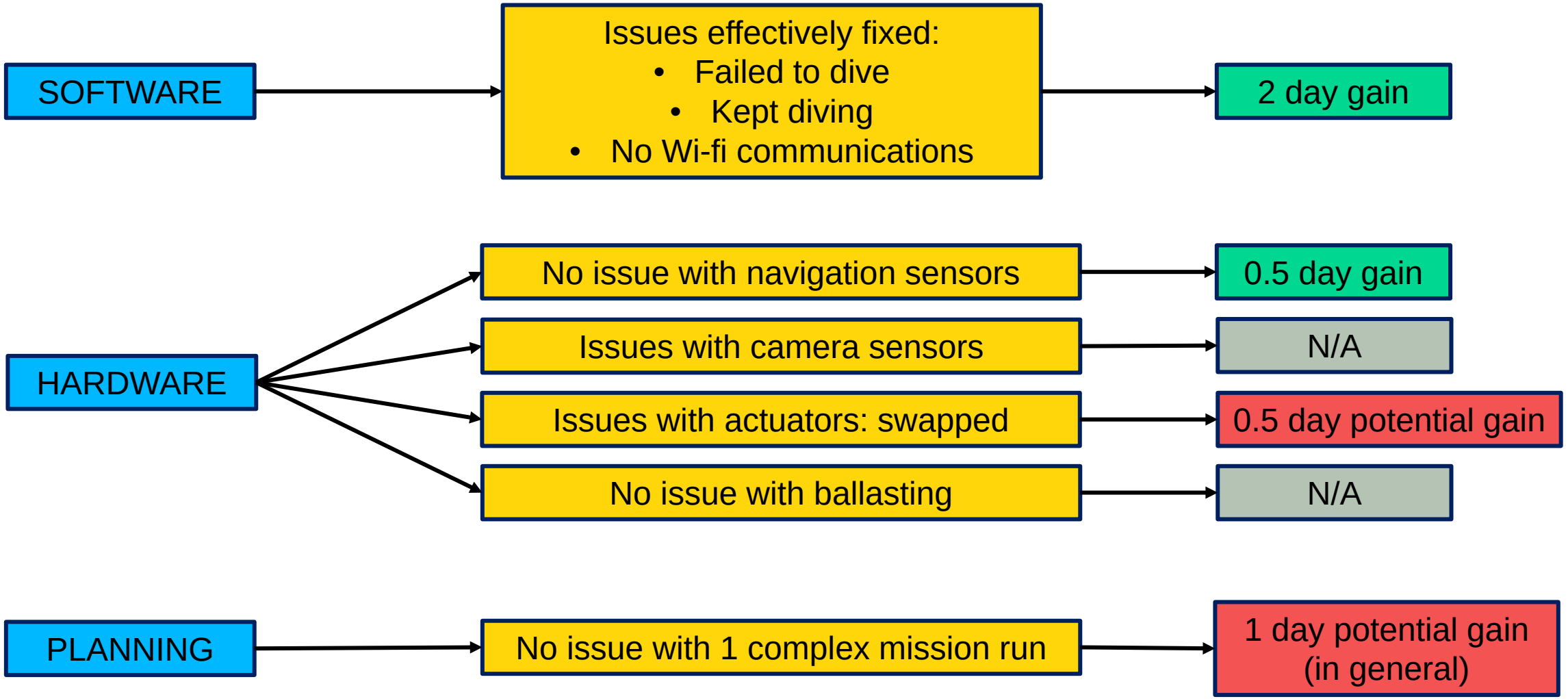
METRIC 2 = Time constraints 

METRIC 3 = Cost constraints 

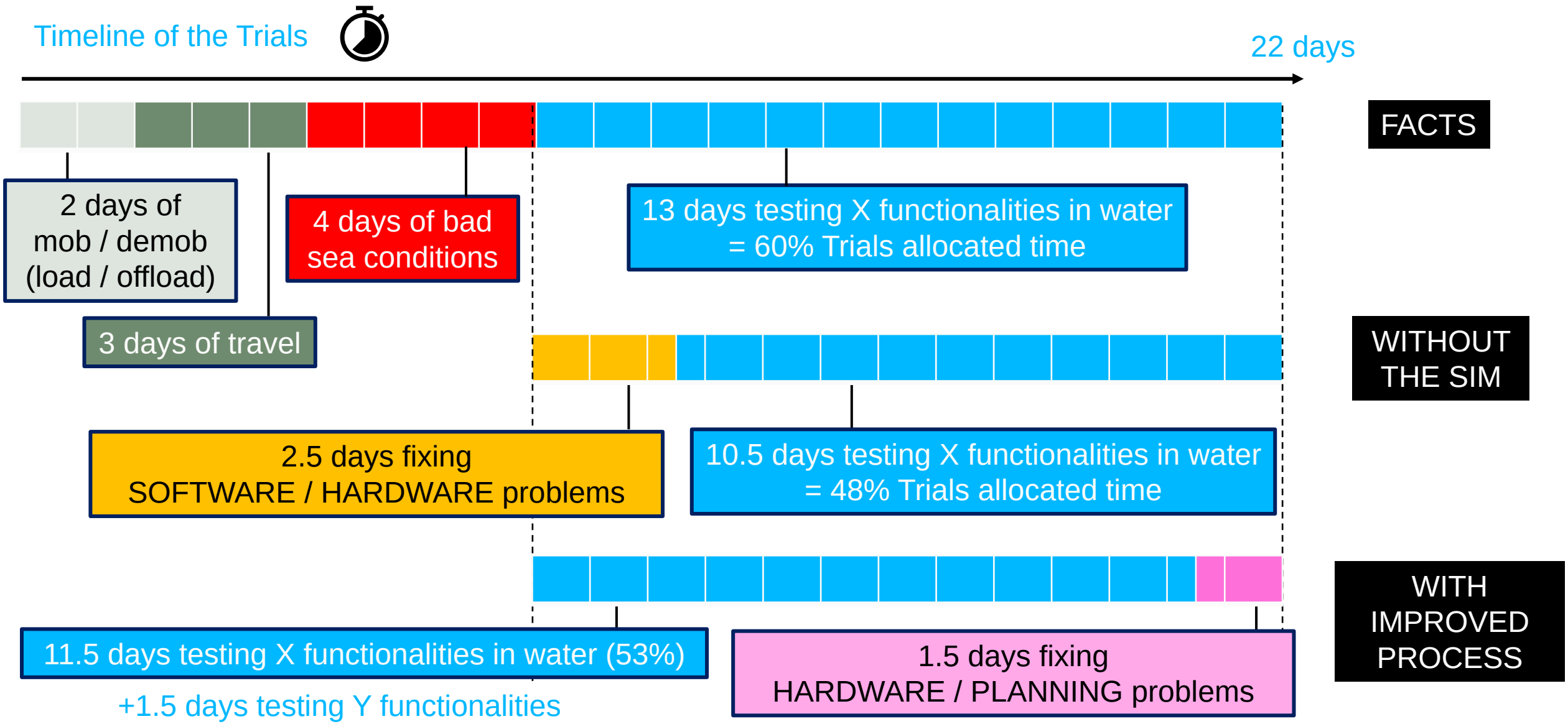
METRIC 4 = Environmental conditions 

VALIDATION | TRIALS OVERVIEW

What happened during the Trials cruise?



VALIDATION | TRIALS TIME GAINS



VALIDATION | TRIALS OTHER GAINS

Other gains

More time saved
-> more chances to get better quality datasets

More testing ahead of deployment
-> Only pay 1 engineer (Simulation) instead of all engineers on board

Area already visited multiple times
-> N/A

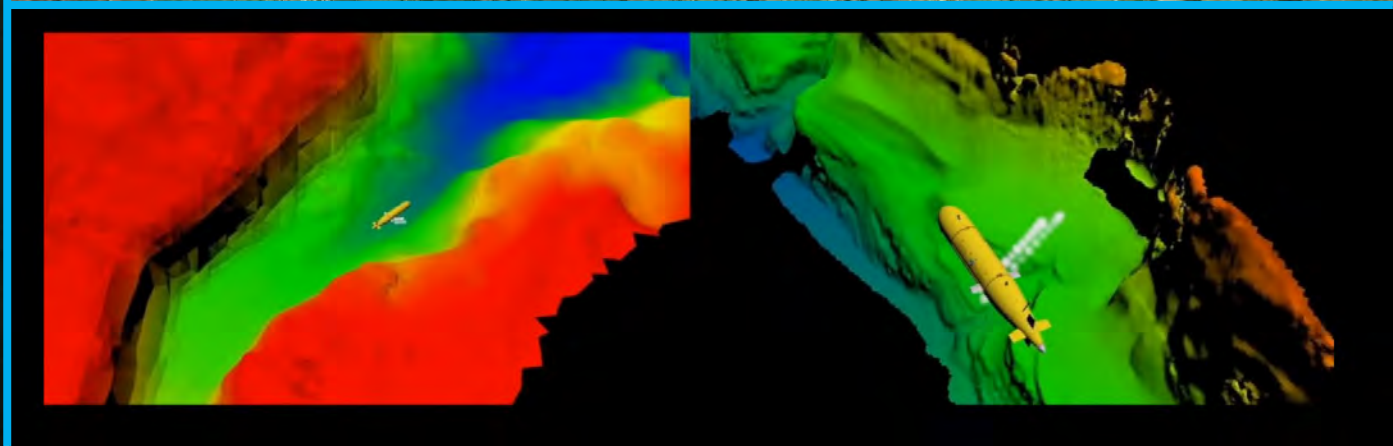
VALIDATION | NEW DEPLOYMENT

Scientific objectives achieved

Autosub 5 batteries caught fire at 4000m depth

VALIDATION | MARINE WONDERS

Why are we doing all this?
(Reminder)



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SIMULATION LESSONS
AFTER 4.5 YEARS LEADING THE SIMULATION DEVELOPMENT

Journey so far: enrinching (debugging and multi-domain / multi-team project)

Simulator has most impact on: time saving and Software aspect

Simulator has least impact on: Electronics and Mechanical aspects

Future improvements around Simulation:

- More systematic measurement of reliability (for future deployments)
- Potential improvements around virtual testbench
- Make the tool even more accessible within and outside of NOC
- Research paper in progress to share about the technical aspect of the Simulator

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ARE YOU READY

TO START USING SIMULATIONS

IN YOUR PROFESSION

TO IMPROVE

THE RELIABILITY

OF YOUR SYSTEMS AND PROCESSES?

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REFERENCES

#	Link	Description
[1]	https://noc.ac.uk/	NOC website
[2]	https://www.youtube.com/watch?v=YEFHlgzy1Dc	A day from the perspective of a NOC MARS engineer during autonomous vehicle Trials in Loch Ness (November 2021)
[3]	https://ieeexplore.ieee.org/document/9267952	IEEE reference paper on Asub5 design
[4]	https://gtr.ukri.org/projects?ref=NE%2FM021246%2F1#	Mohole research proposal by the University of Southampton
[5]	https://mars.noc.ac.uk	Follow live all our vehicles

achille.martin@noc.ac.uk

https://www.linkedin.com/in/achillemartin/

Get in touch!