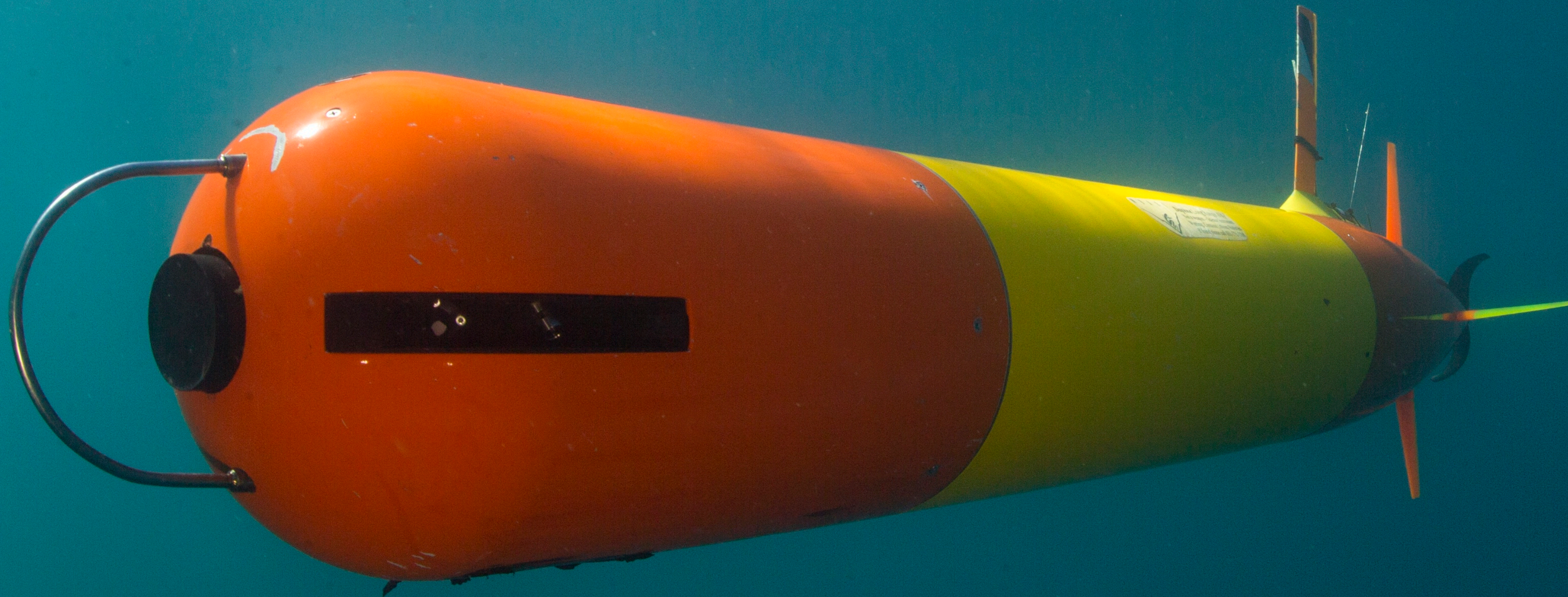


PROJECT PROPOSAL ~~2020~~ 2021

MULTI-LRAUV SIMULATION ENVIRONMENT





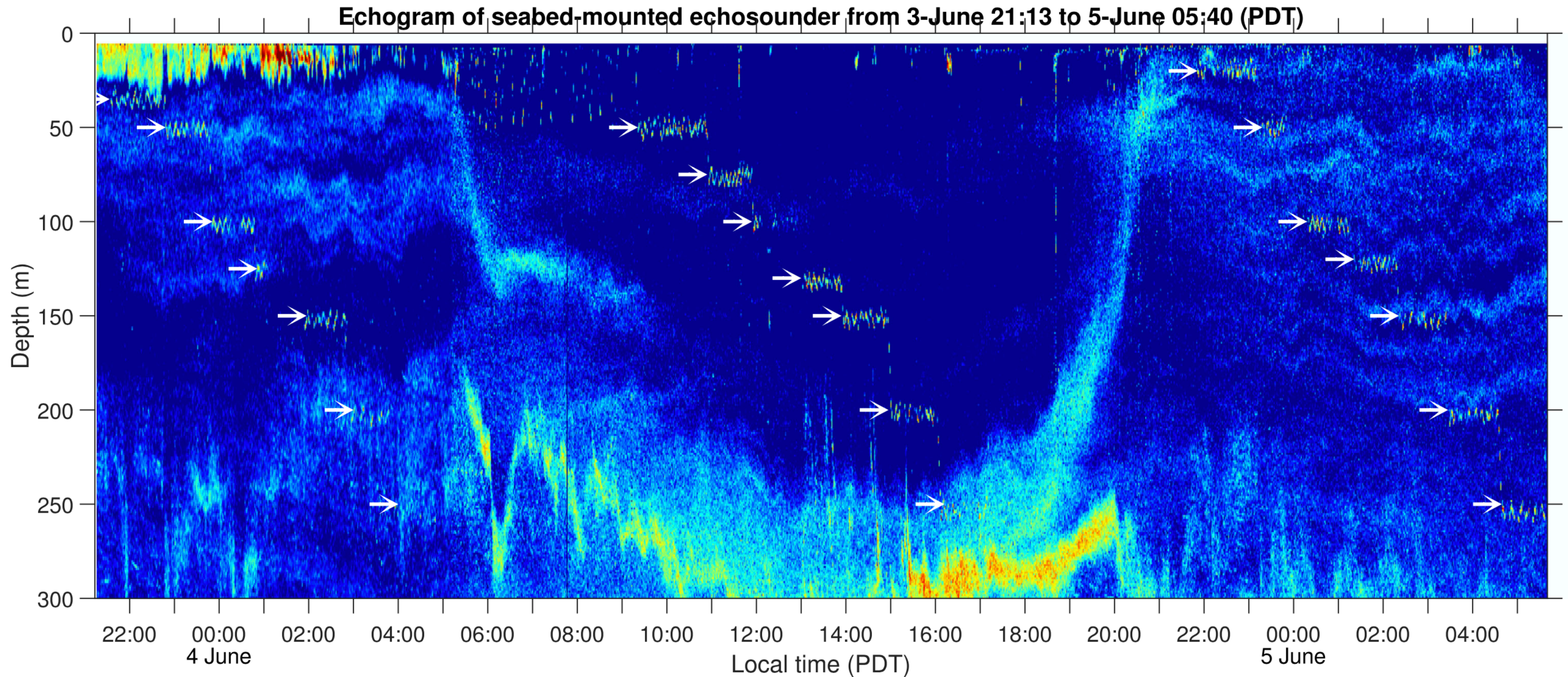
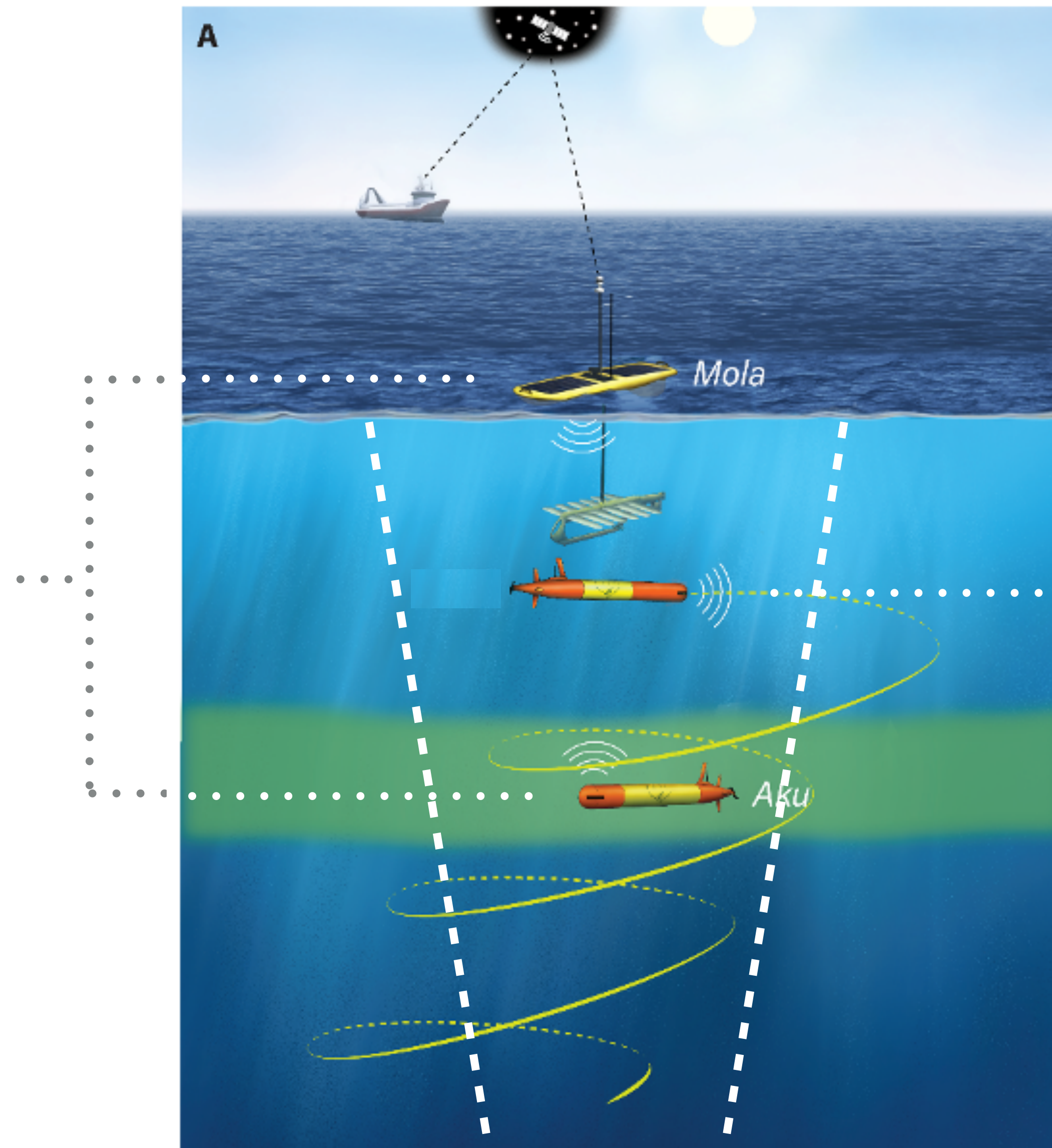


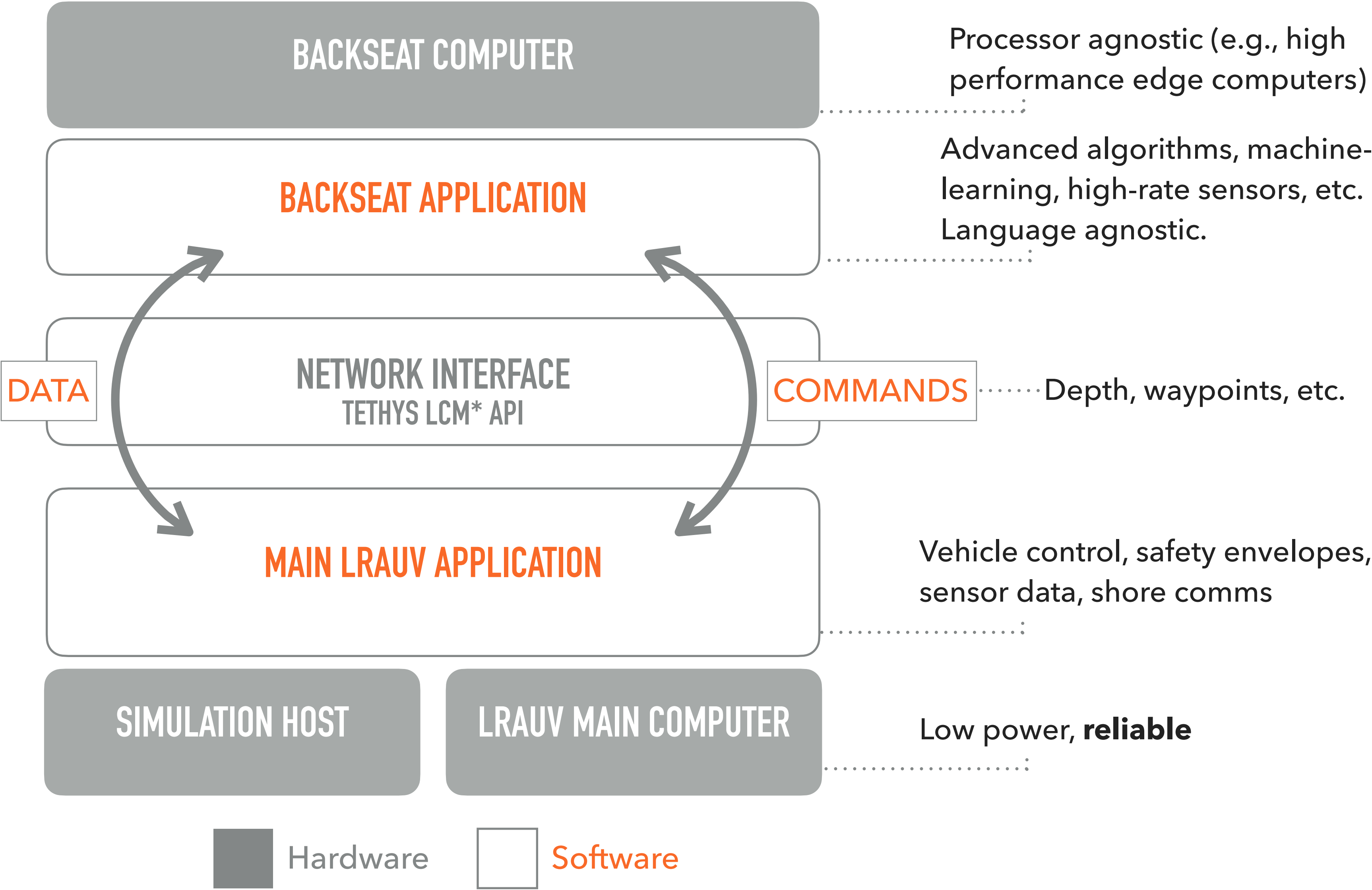
Figure: Zhang et al. 2020, Persistent Sampling of Vertically Migrating Biological Layers by an Autonomous Underwater Vehicle Within the Beam of a Seabed-Mounted Echosounder, *IEEE JOURNAL OF OCEANIC ENGINEERING*

Inter-vehicle acoustic tracking to support station-keeping/localization using range/bearing



Sentinel vehicle with a second computer (backseat) onboard running Monique's plankton proxies algorithm

Figure: Zhang et al. 2020, Lagrangian Studies of Microbial Communities in an Open-Ocean Deep Chlorophyll Maximum Using an Autonomous Robotic Fleet, *Science Robotics* (submitted)



*Lightweight Communications and Marshaling

HOW TO SCALE?

How to scale?

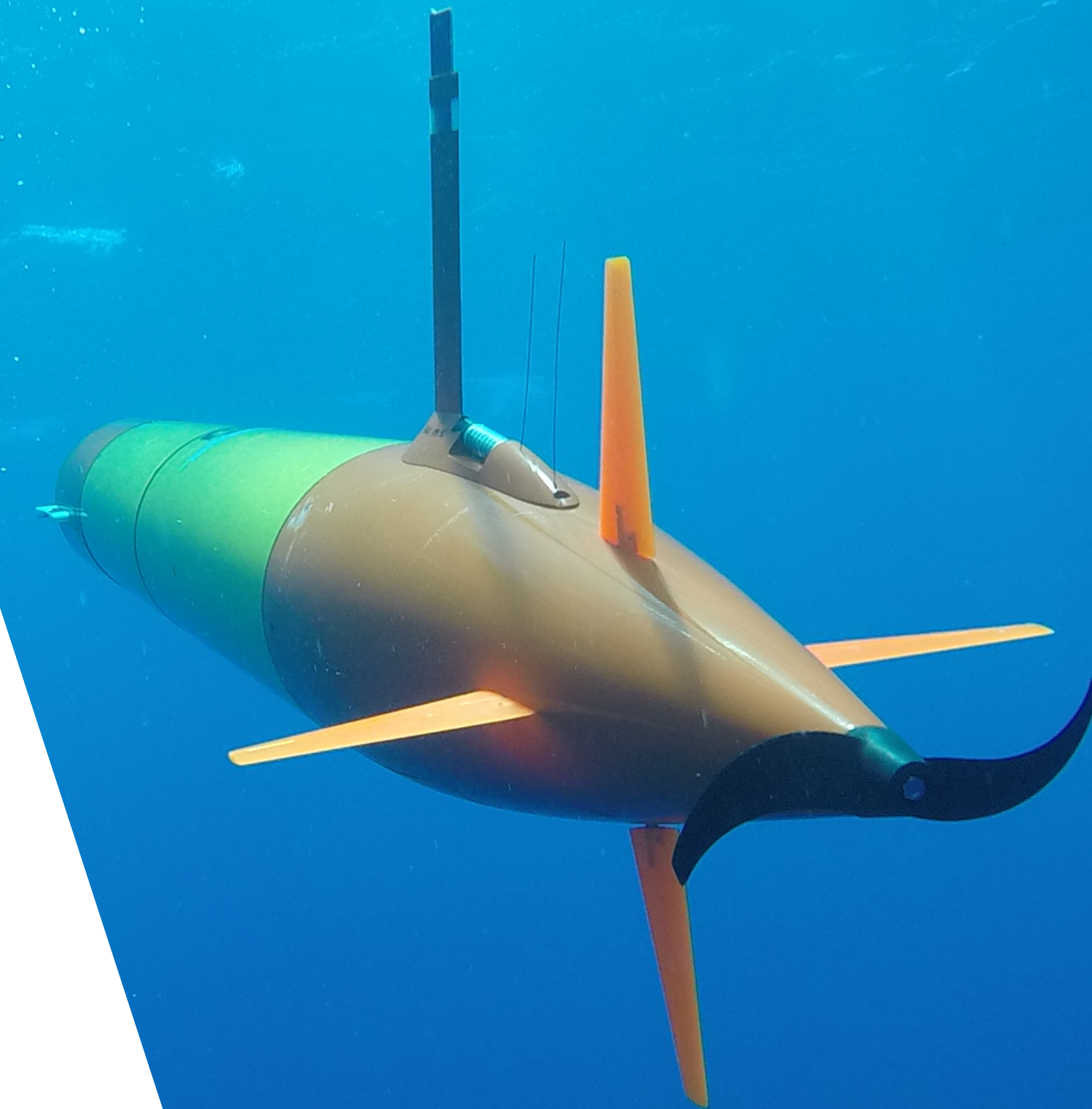
How can we scale multi-vehicle operations at MBARI? How to go from LRAUV pair to a collaborative fleet?

How to develop?

How can we scale up development for new multi-vehicle and backseat applications? How can we increase reliability and performance in the field?

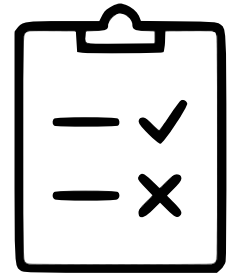
How to export?

How can we make the LRAUV software more extensible? How do we optimize our development efforts to support technology transfer?

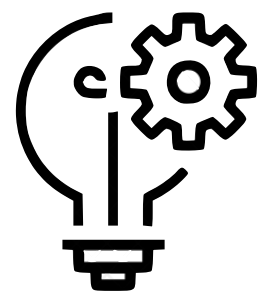


IMPROVE MULTI-LRAUV CAPABILITIES AT MBARI

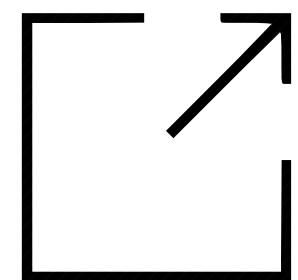
using an open-source simulation platform



Create a multi-LRAUV simulation tool that allows researchers to independently iterate and validate multi-vehicle algorithms and backseat apps in a visualized environment.

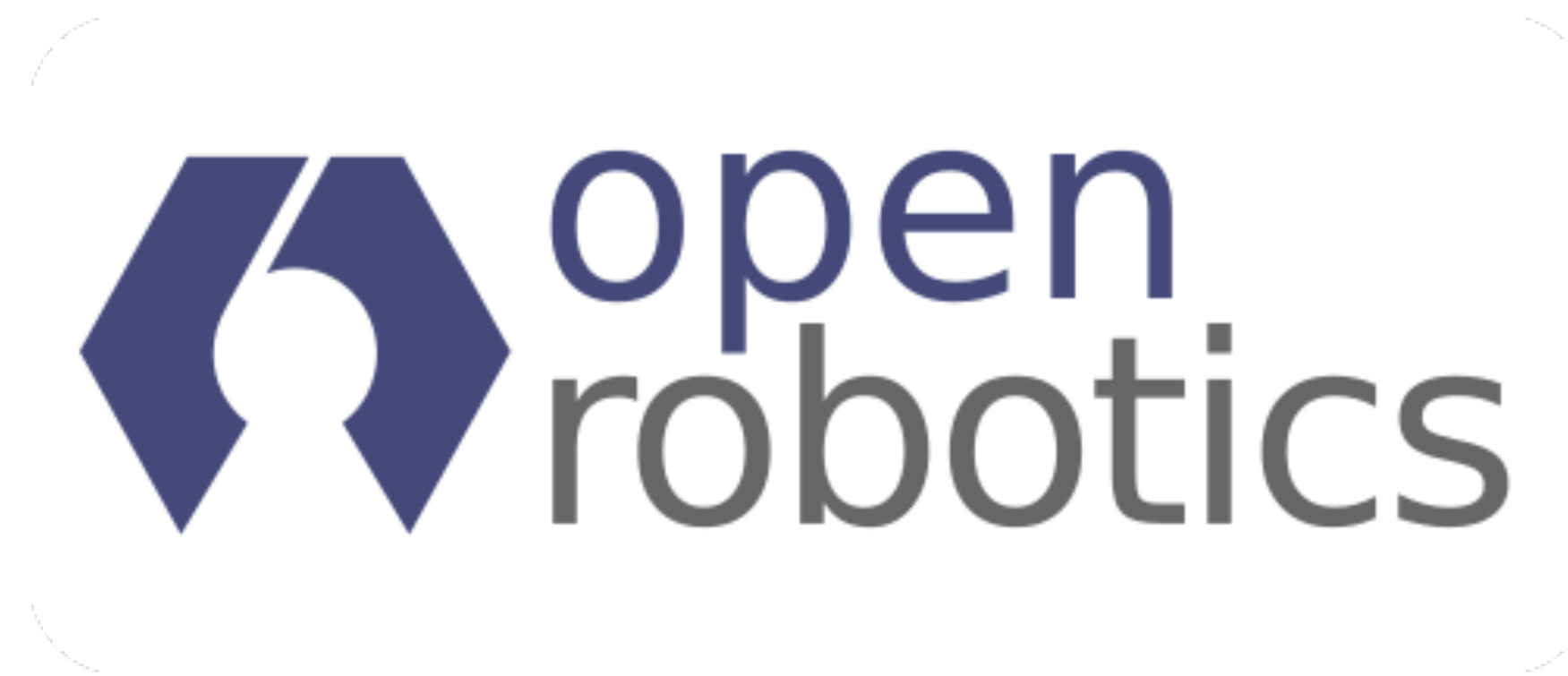


Extend LRAUV's software interfaces to allow for compatibility with an entire community of developers and the industry standard for robotics control and simulation.



Contribute to the open source robotics community to encourage cross-pollination and make development more accessible to MBARI researchers and collaborators seeking advanced methods of ocean observation.

Robot Operating System (ROS) is an open-source collection of software libraries and tools for collaborative robotics and simulation

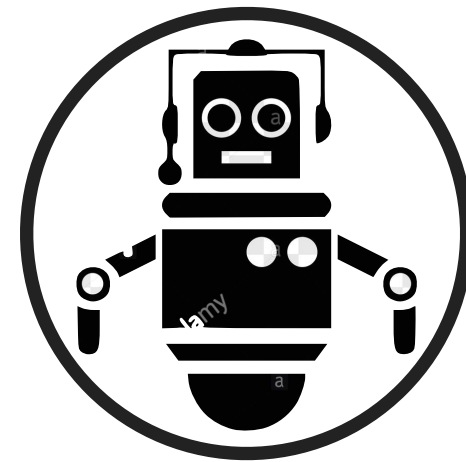


"For much of the robotics community, the open-source Gazebo robot simulator has emerged as the de facto standard environment for prototyping and testing robotic systems.", *Brian Bingham, Naval Postgraduate School*

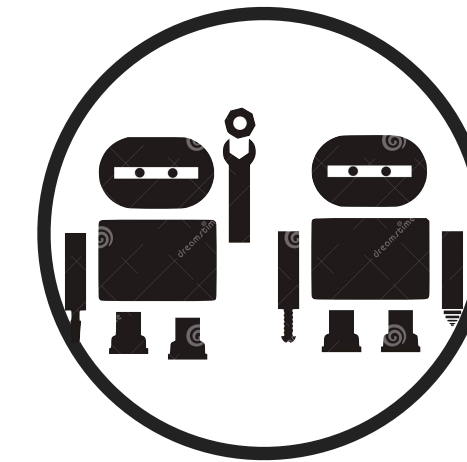


GAZEBO

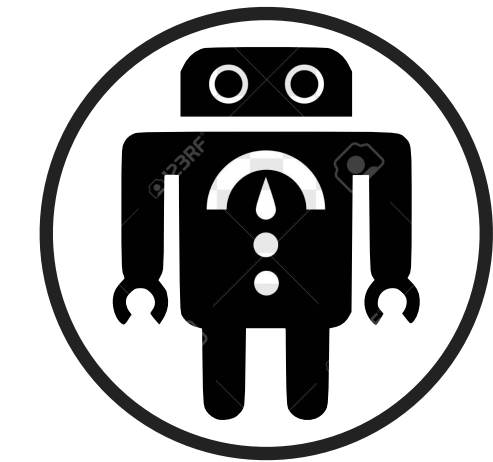
ROS

**GUI**

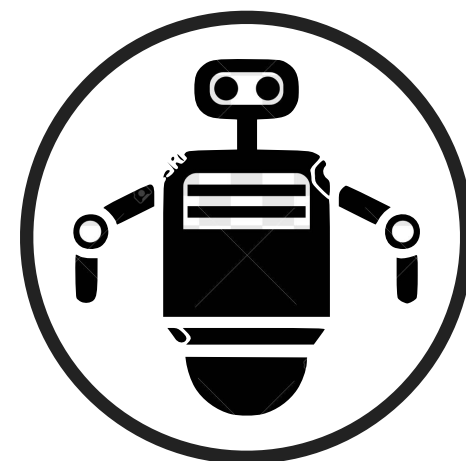
graphical user
interface to visualize
the scenario and data

**Multi-robot sim**

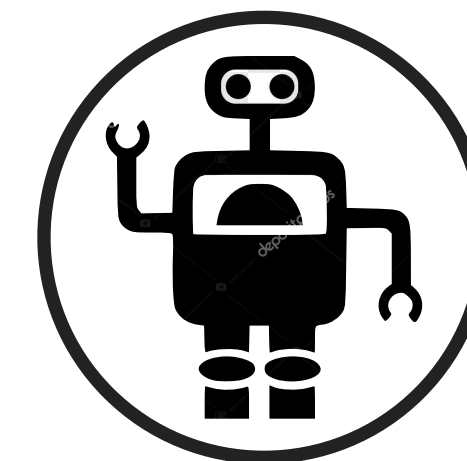
capable of multi-robot
simulation

**Environment**

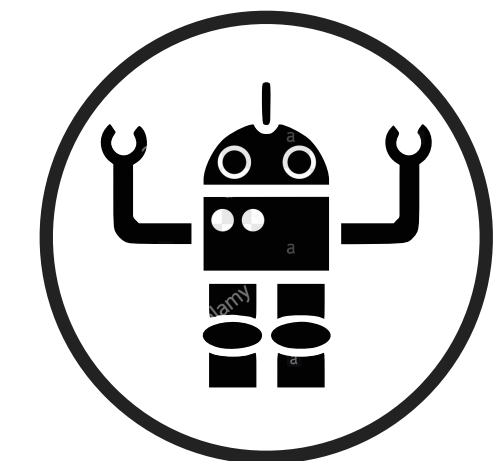
simulation of
environmental forcings
and sensors

**Extensible**

easy integration of
additional modules
and familiar interface

**SW interface**

common interface that
can be extended to
any application

**Physics engine**

simulation of rigid-
body dynamics and
collisions

WorldInsertLayers

GUI
Scene
Spherical Coordinates
Physics
Models

- ned
- ocean
 - ocean_link
- terrain_acciona
- wind_turbine
- wind_turbine_biofouling
- constant_flow_frame

Lights

Property	Value
name	ocean
is_static	☒ True
self_collide	☐ False
pose	
link	ocean::ocean_link

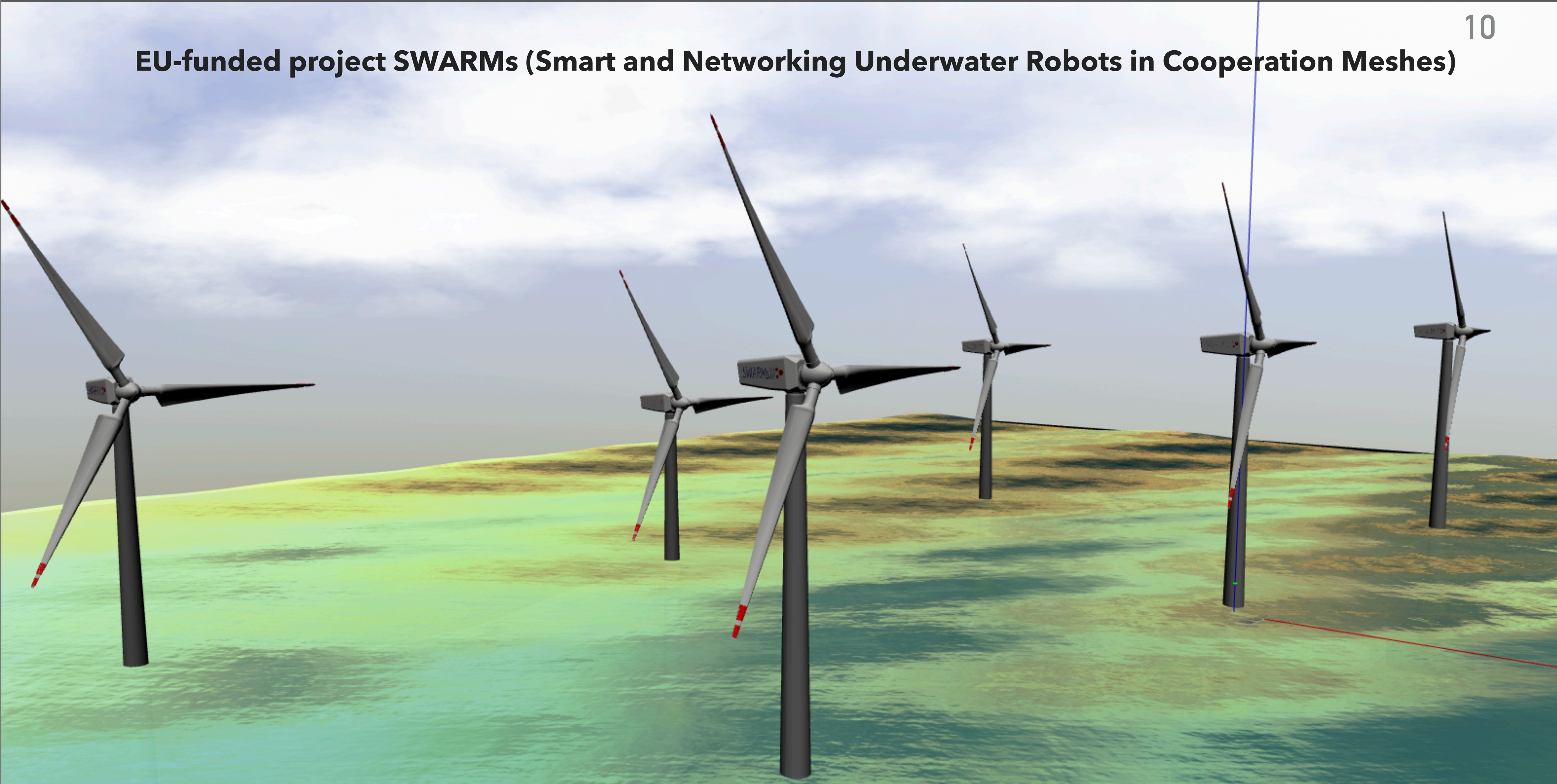


GAZEBO

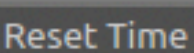


10

EU-funded project SWARMs (Smart and Networking Underwater Robots in Cooperation Meshes)



UUV Simulator: https://github.com/uuvsimulator/uuv_simulator
Manhaes, Musa Morena Marcusso, et al. "UUV simulator: A gazebo-based package for underwater intervention and multi-robot simulation." *OCEANS 2016 MTS/IEEE Monterey*. IEEE, 2016.

 Steps: 1 ▾ Real Time Factor: 1.00 Sim Time: 00 00:01:28.134 Real Time: 00 00:01:28.344 Iterations: 44067 FPS: 12.3122 



Gazebo world
model for MB

Release open-source
package and
documentation

Gazebo vehicle
model for LRAUV

Integrate Gazebo/ROS with
LRAUV application and
TethysDash web interface



Ben



Brett



Brian



Yanwu

Multi-LRAUV simulator

develop multi-vehicle and backseat applications against a simulation and port to the vehicle for execution; improve access to LRAUV and overall user experience

LRAUV ROS interface

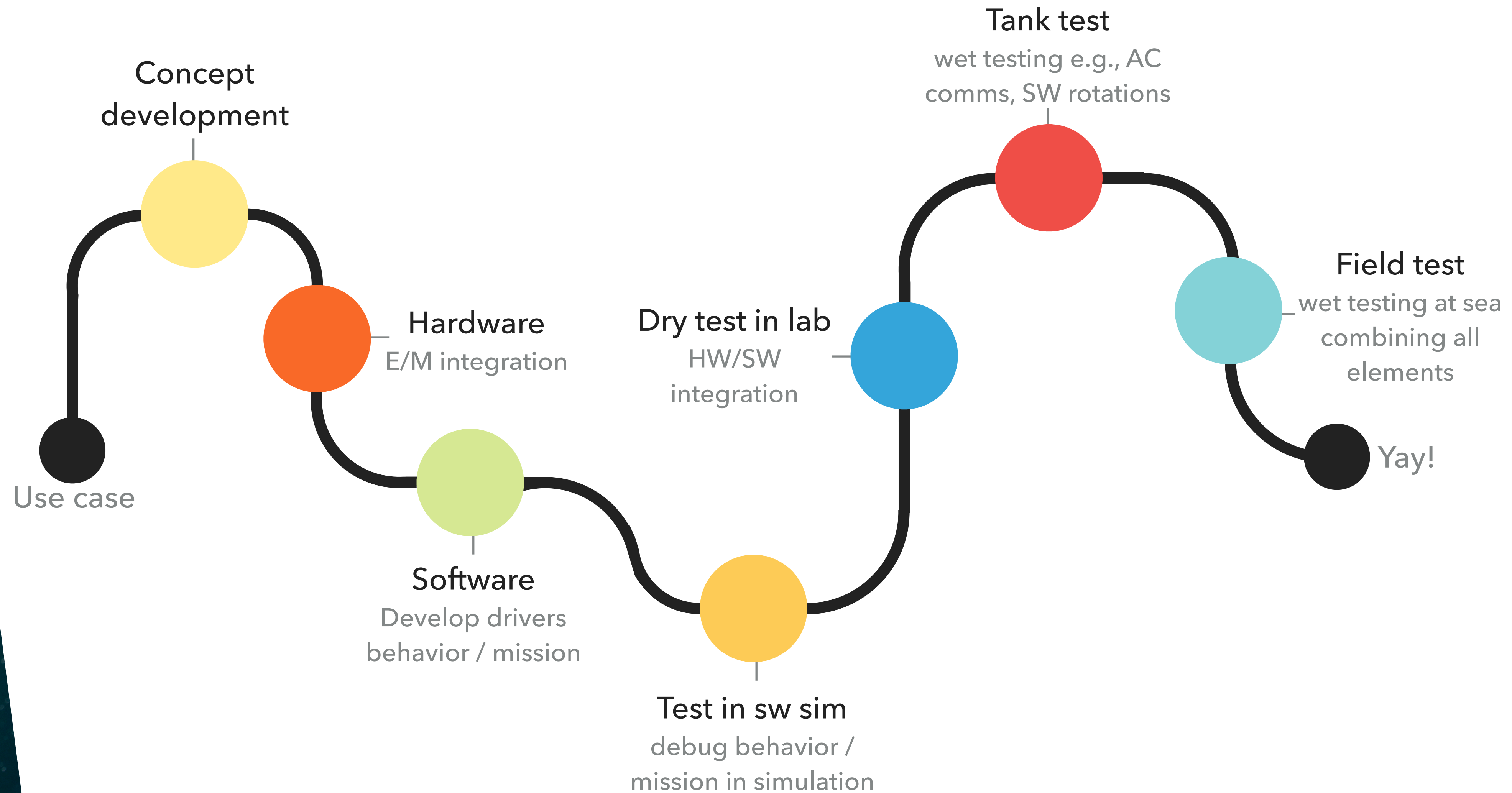
extend LRAUV's existing backseat architecture using interfaces that are widely adopted in the open-source robotics world, including in the AUV community

Open source

use tools and interfaces that promote technology transfer, and support reuse of existing resources that are available in the community







LRAUV software development pipeline



