APECS-ARICE Webinar
Polar marine robotics - Part 2

Moderation: Josefine Lenz (AWI, APECS & ARICE)






Speakers:

Massimo Caccia (CNR-INM)
Angelo Odetti (CNR-INM)
Raffaella Beroldo (CNR-INM)

Me

Angelo Odetti, PhD, Marine Engineer and Naval Architect,

Researcher, designer of marine robots and vehicles

Experience in Air Cushion Technology (Hovercraft)

Joined the CNR in 2013

Research: development of new concept vehicles for access in remote areas.

Designer of:

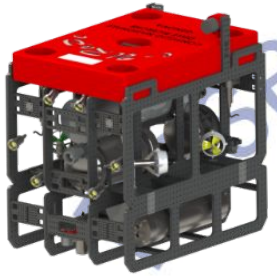
- Hybrid (ROV-AUV) vehicles: e-URoPe, PROTEUS, BLUCY
- ASV SWAMP
- Samplers, tools and actuators

Took part in two robot-based campaigns in Svalbard in 2017 and 2018

Marine Polar Robots - Design approach

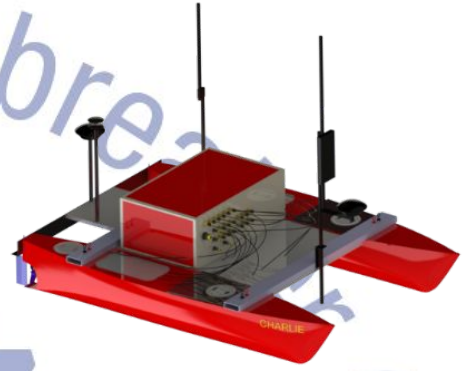
ROV
R2

ROV-AUV
e-URoPe

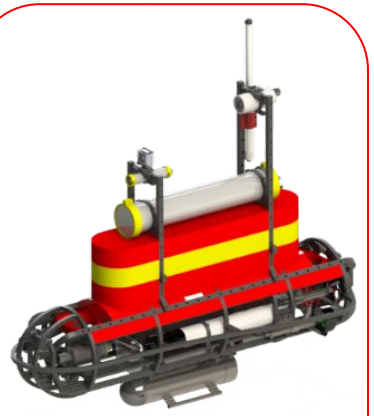


USSV
SHARK

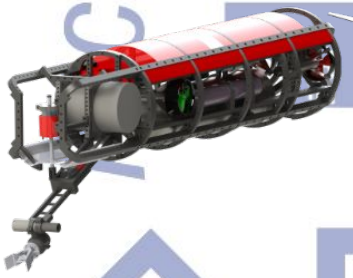
ASV
Charlie



ASV
SWAMP

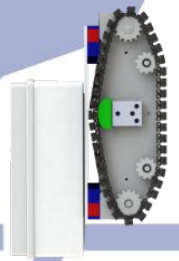


USSV
PROTEUS

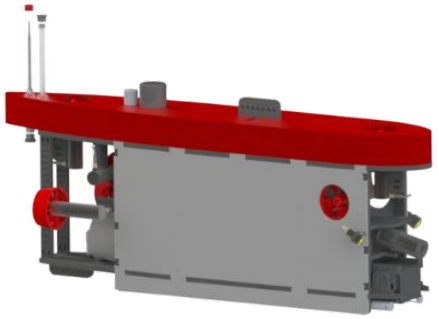


ROV-AUV
PROTEUS

UAV
OTTO

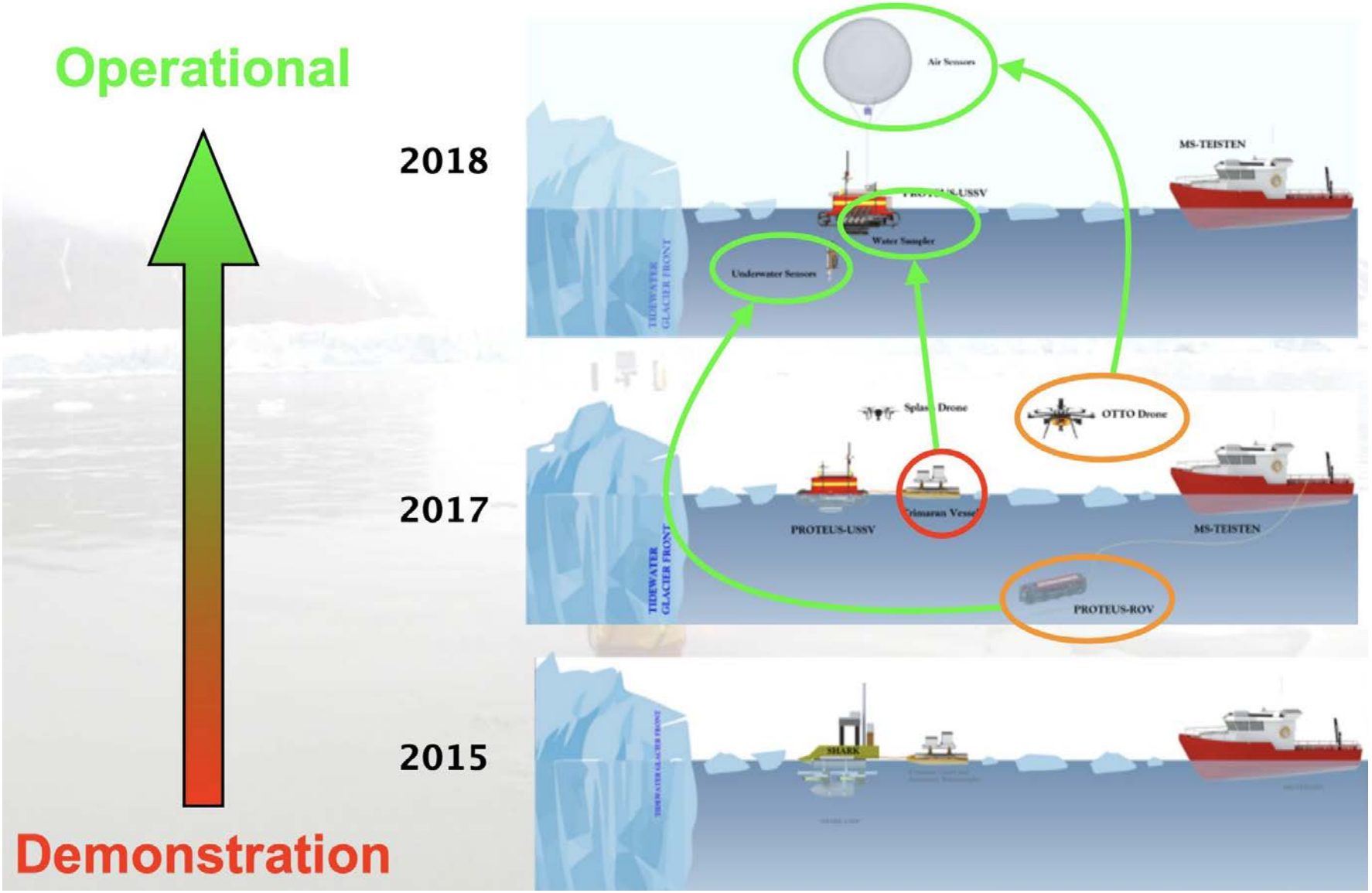


Magnetic Crawler
MARC



ROV-AUV
SUSHI

Arctic air-ice-water interface sampling



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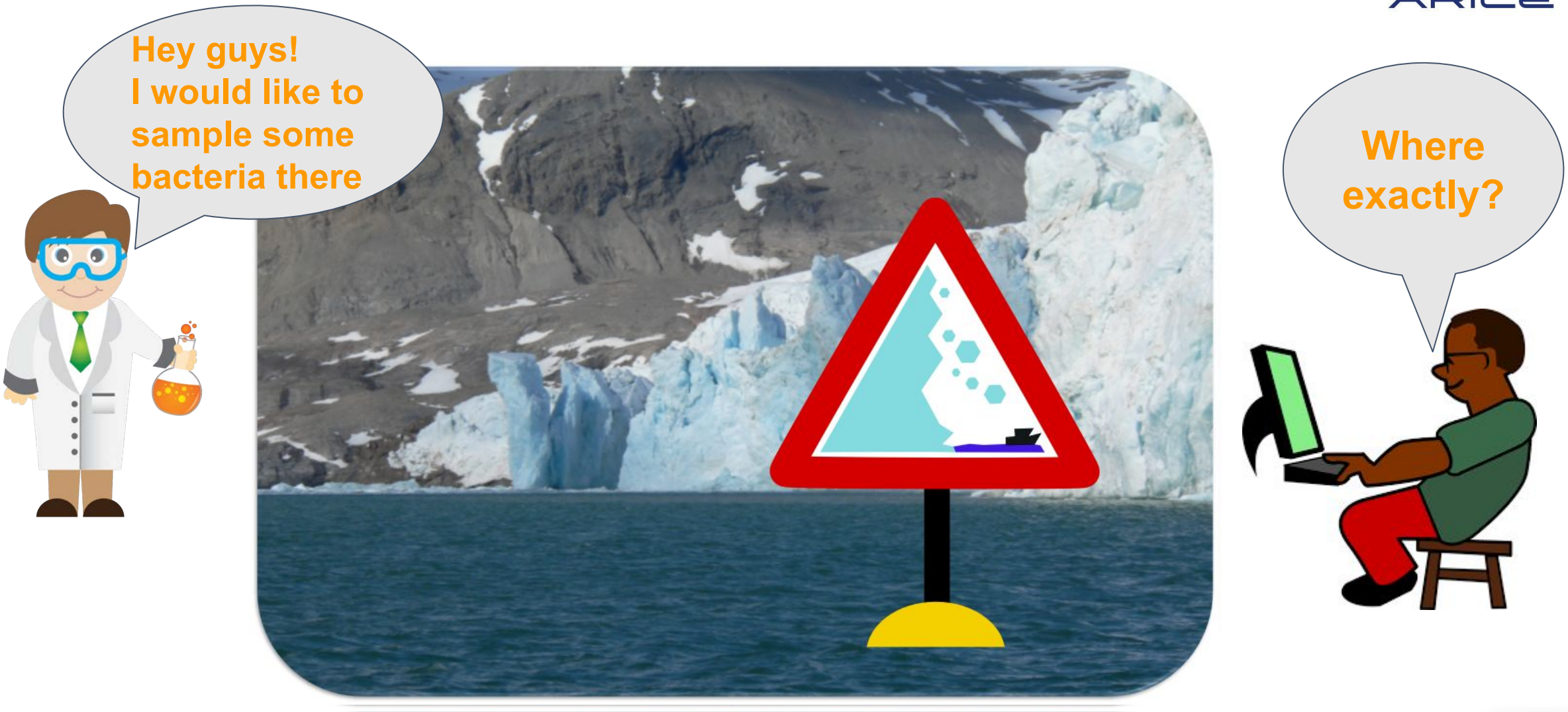
Marine Polar Robots



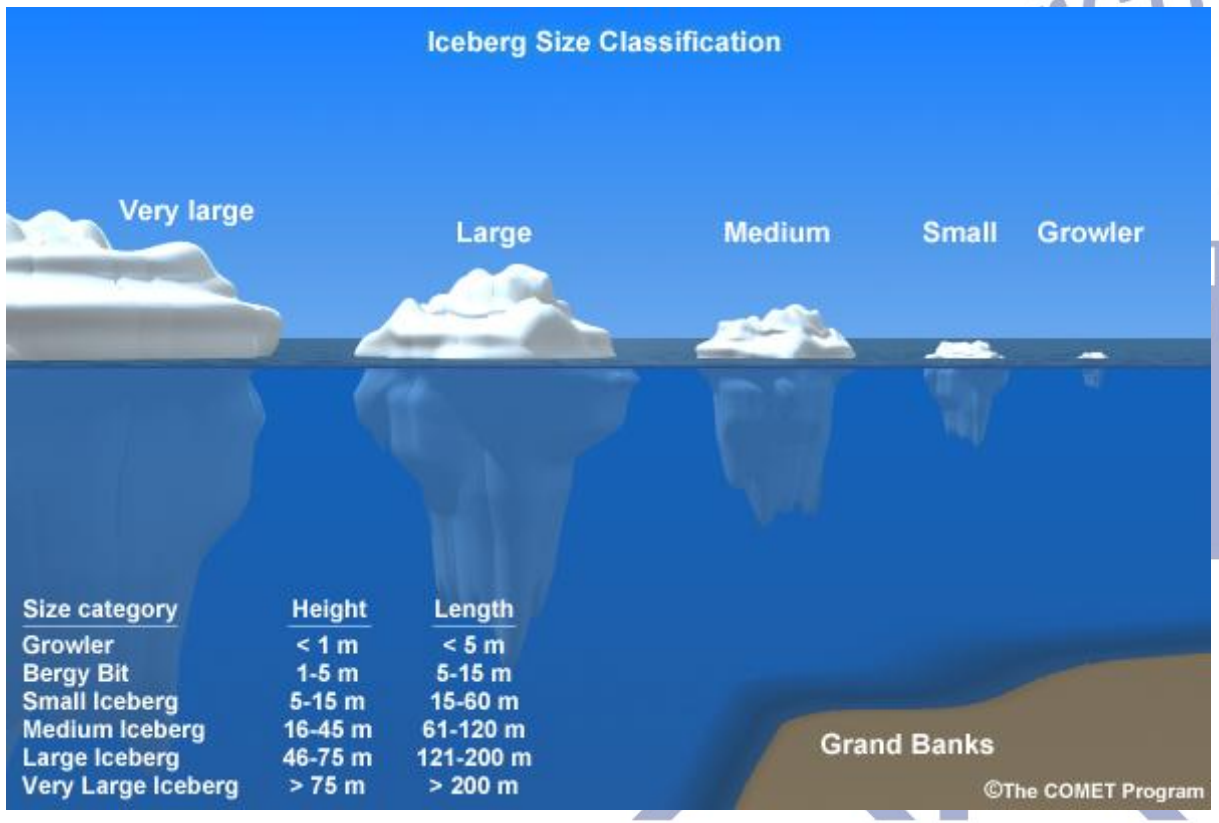
Marine Polar Robots

Operating issues:

- Moving between floating ice
- Reduced logistics
- Mission constraints
- Be able to put the Hand-on the vehicle
- Vehicle recovery?

Marine Polar Robots

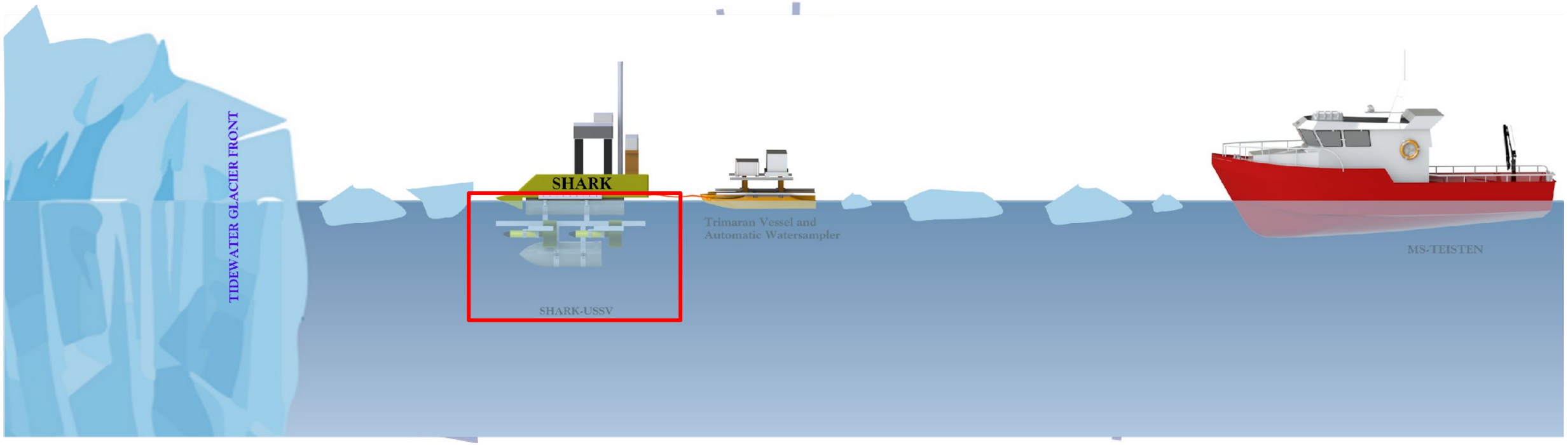
Moving between icebergs, bergy bits and growlers



Size category	Height	Length
Growler	< 1 m	< 5 m
Bergy Bit	1-5 m	5-15 m
Small Iceberg	5-15 m	15-60 m
Medium Iceberg	16-45 m	61-120 m
Large Iceberg	46-75 m	121-200 m
Very Large Iceberg	> 75 m	> 200 m

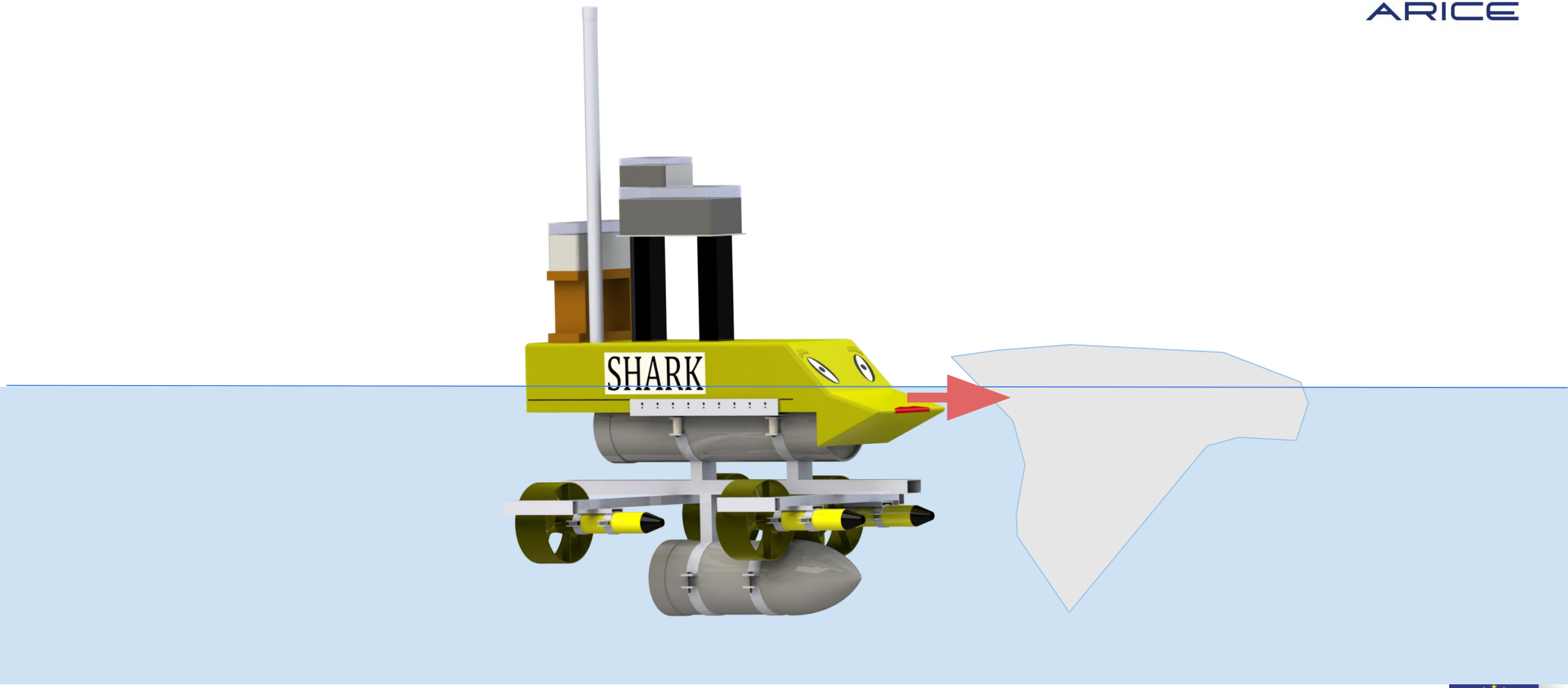
First Campaign

Moving between icebergs, bergy bits and growlers

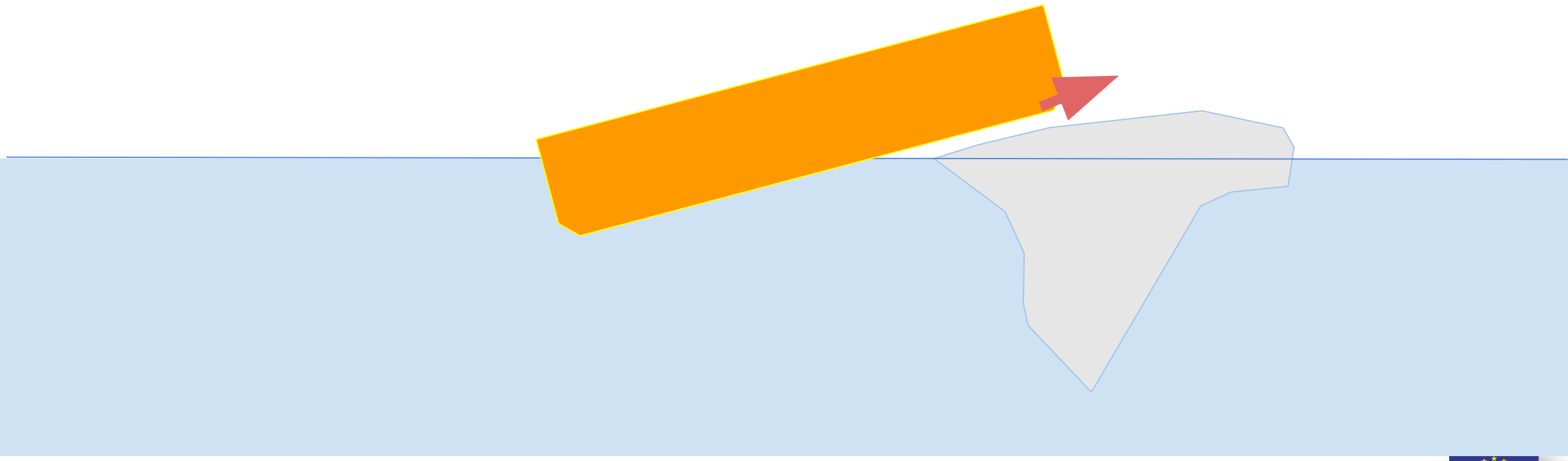


Robot shape: Unmanned Semi-Submersible Vehicle (USSV)

First Campaign

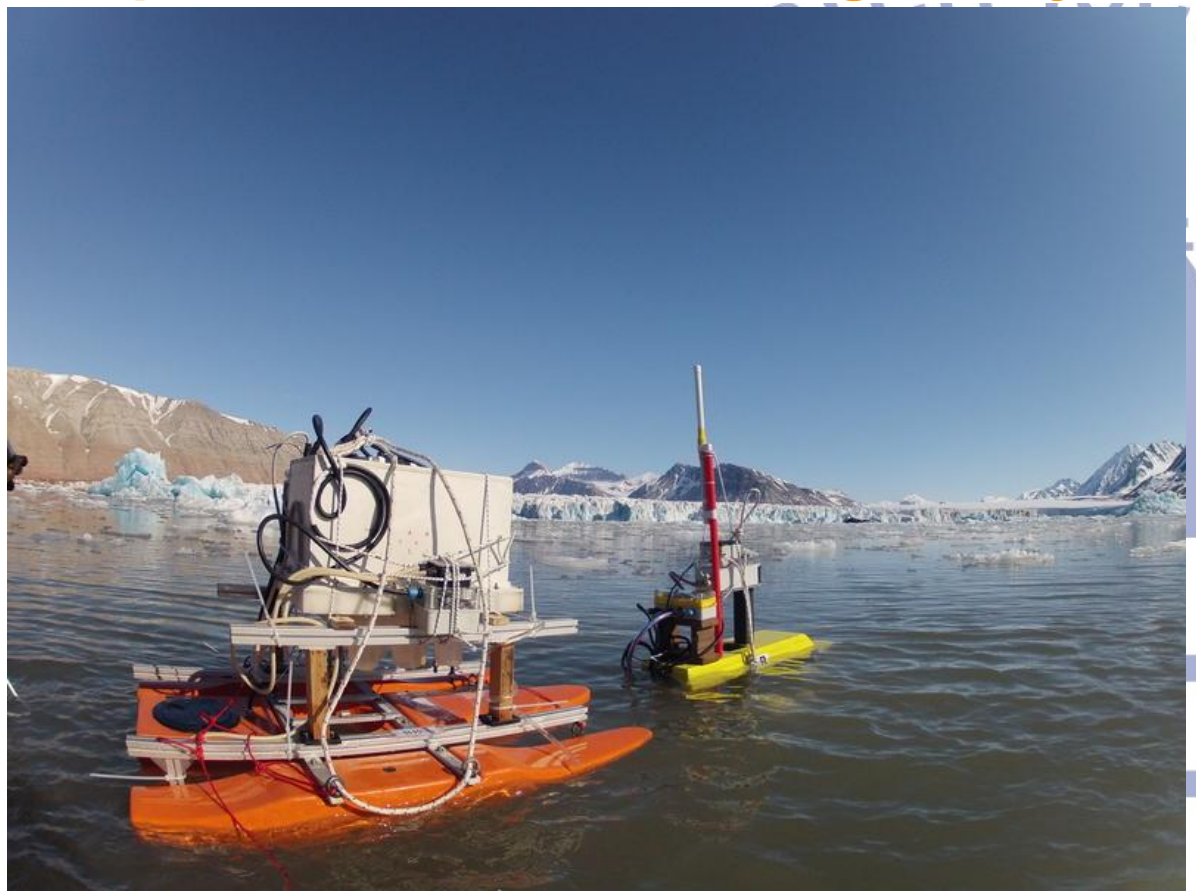


First Campaign

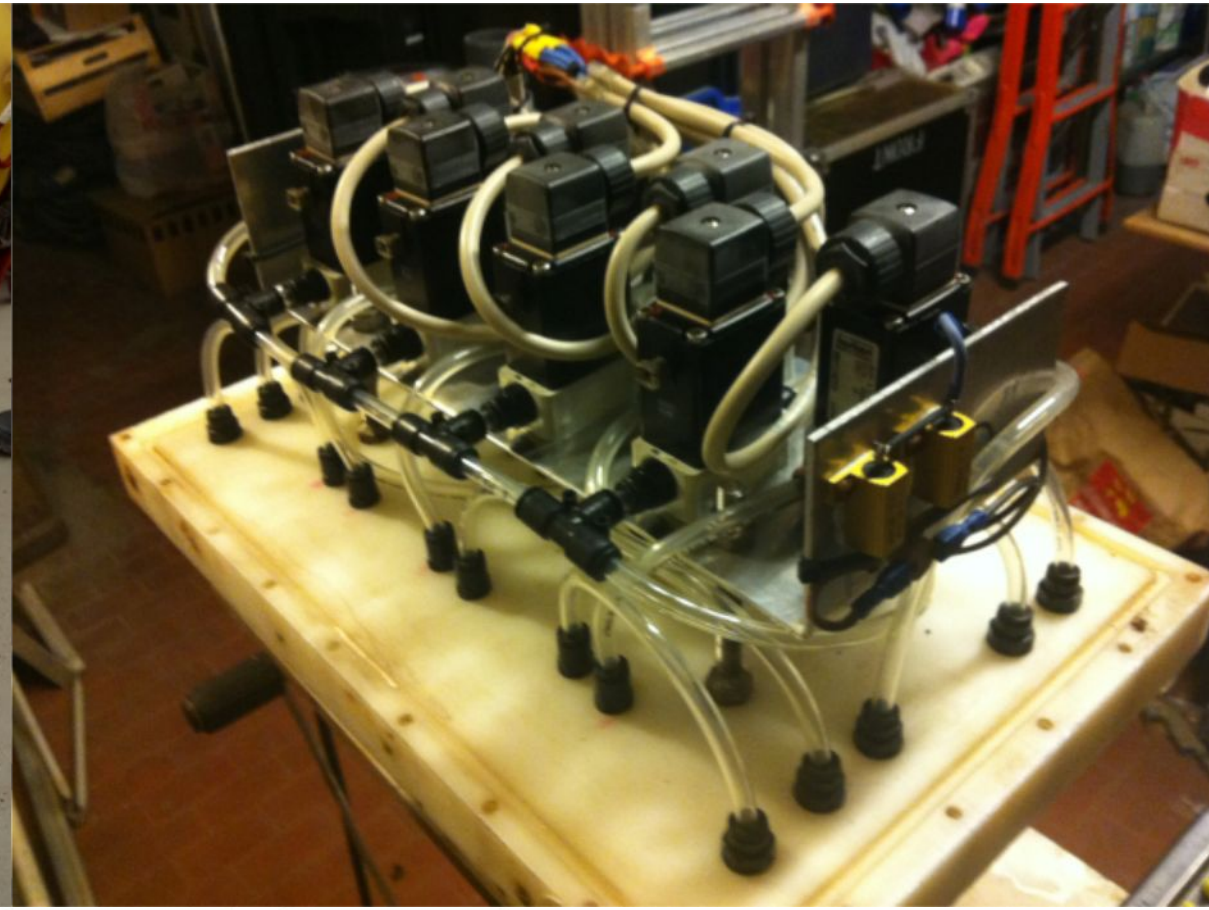


First Campaign

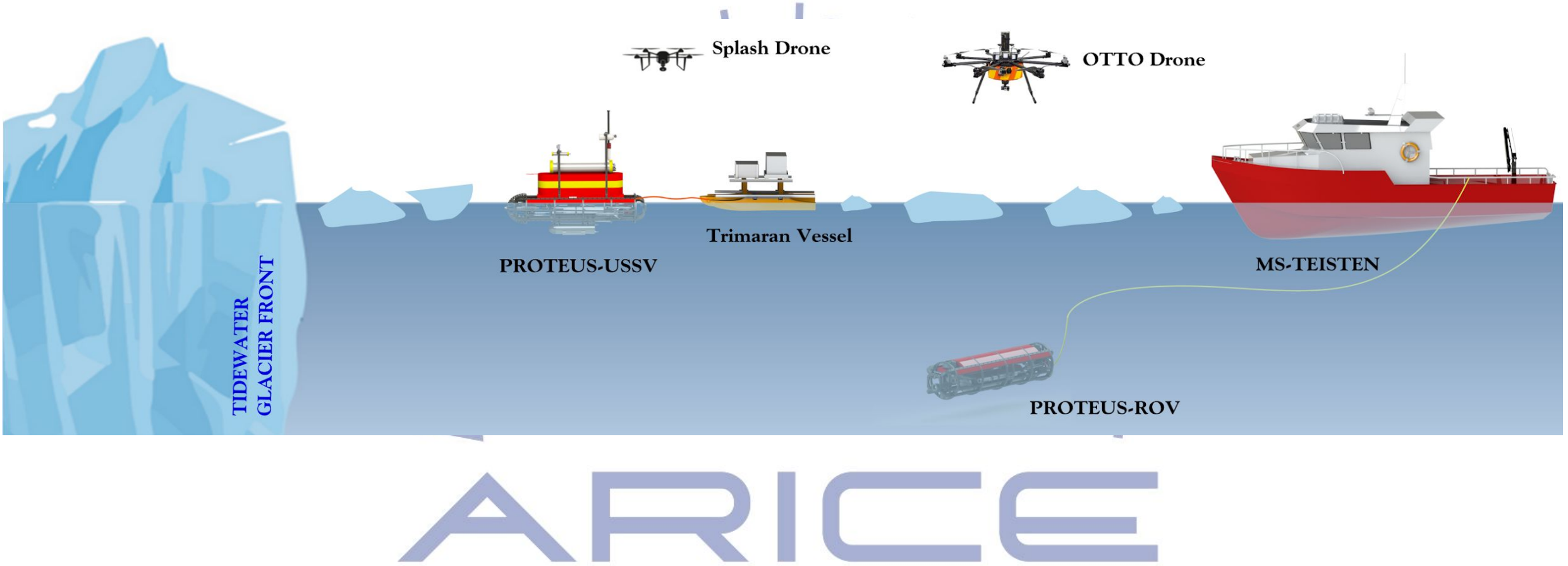
Robot shape:
Unmanned Semi-Submersible Vehicle (USSV)
with multiple thrusters for towing ability and redundancy



First Campaign



Second Campaign

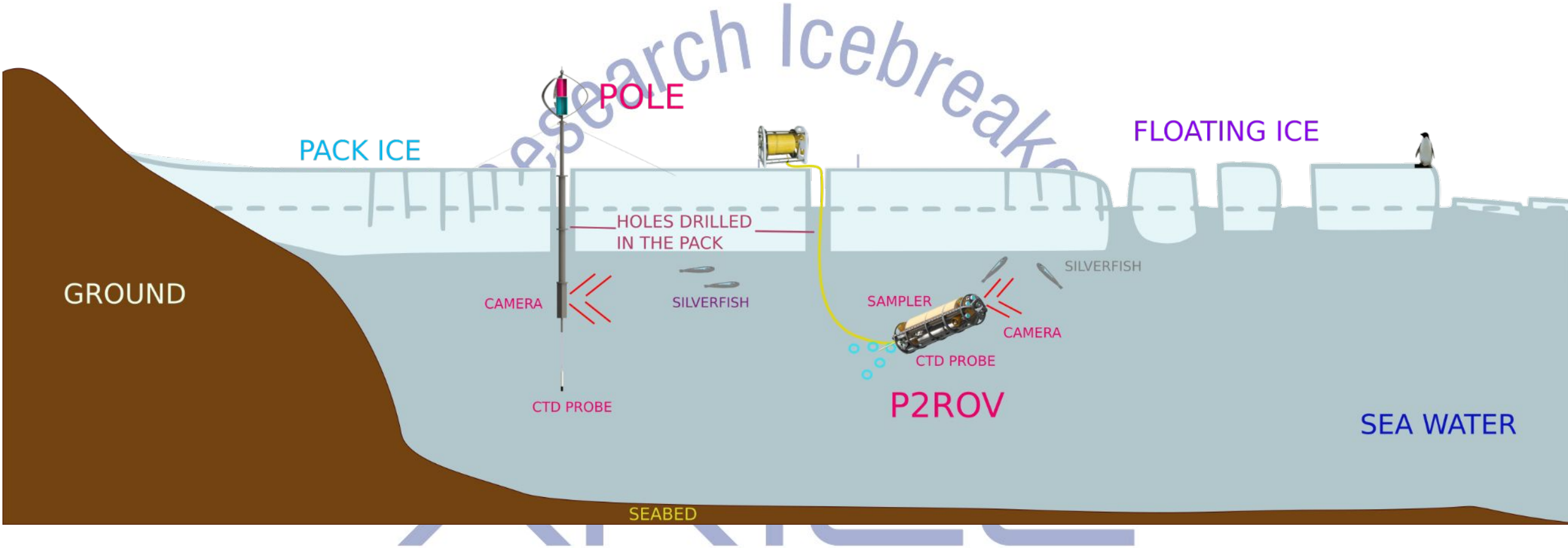


Marine Polar Robots

Reduced Logistics + Mission constraints

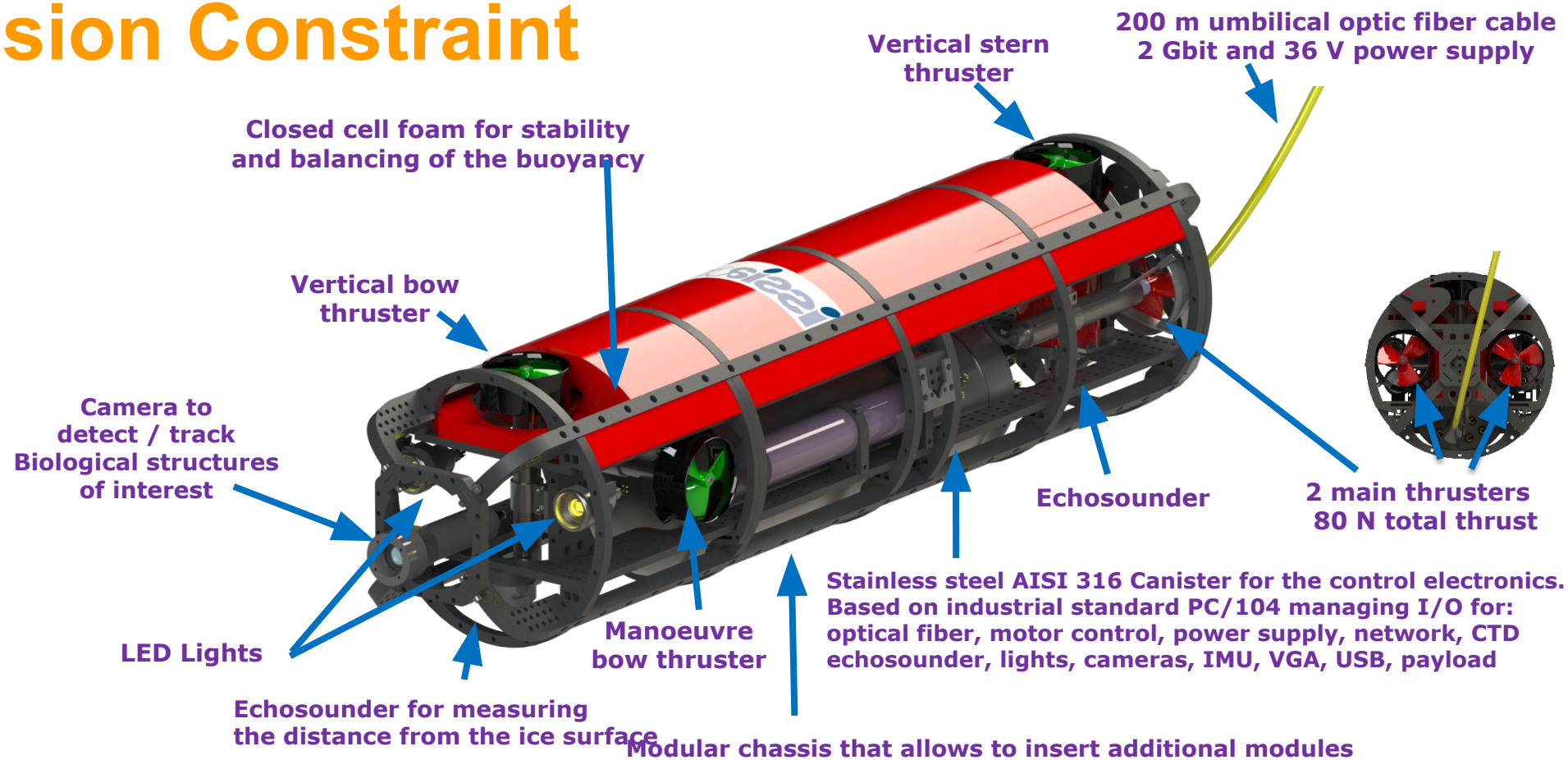
Marine Polar Robots

Reduced Logistics + Mission constraints



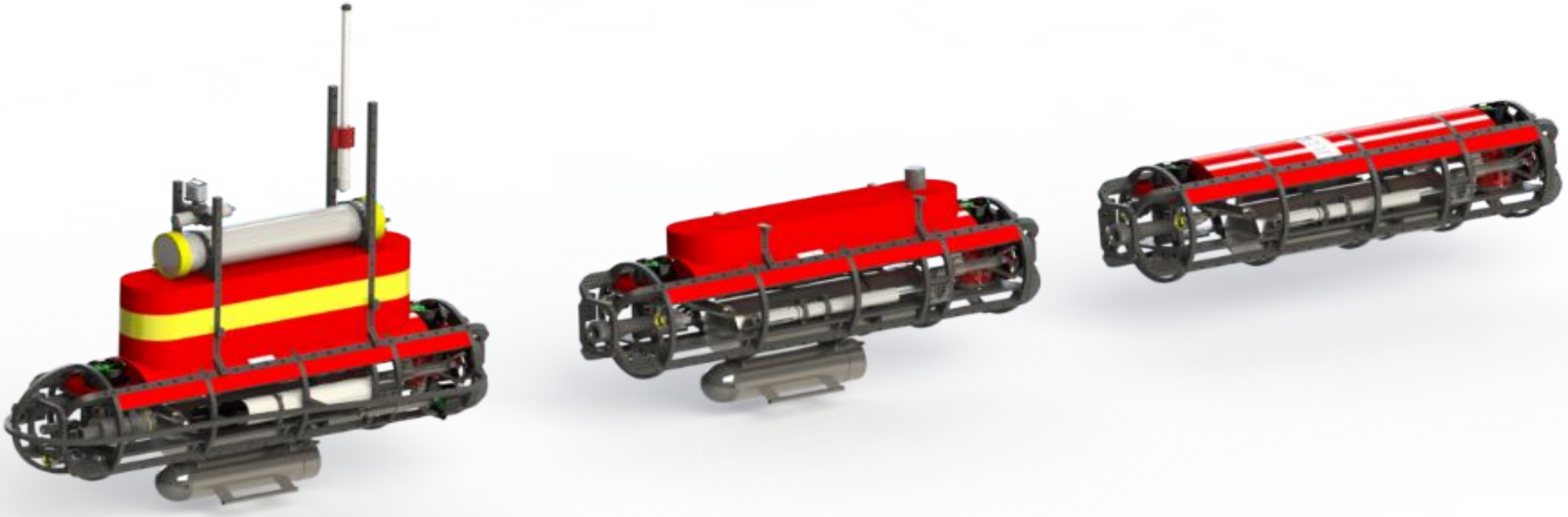
Marine Polar Robots

Mission Constraint

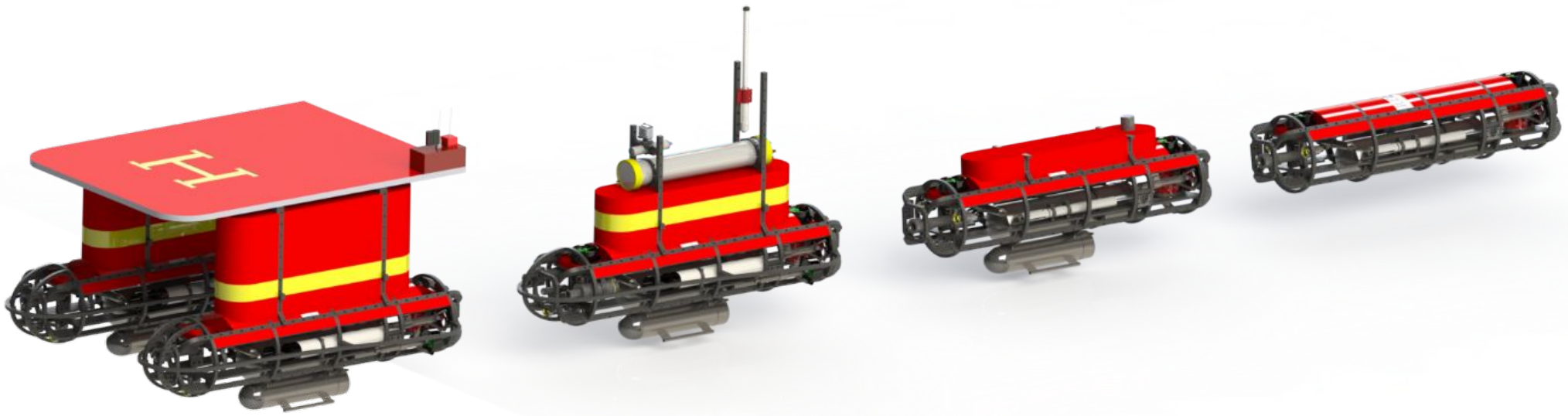


Marine Polar Robots

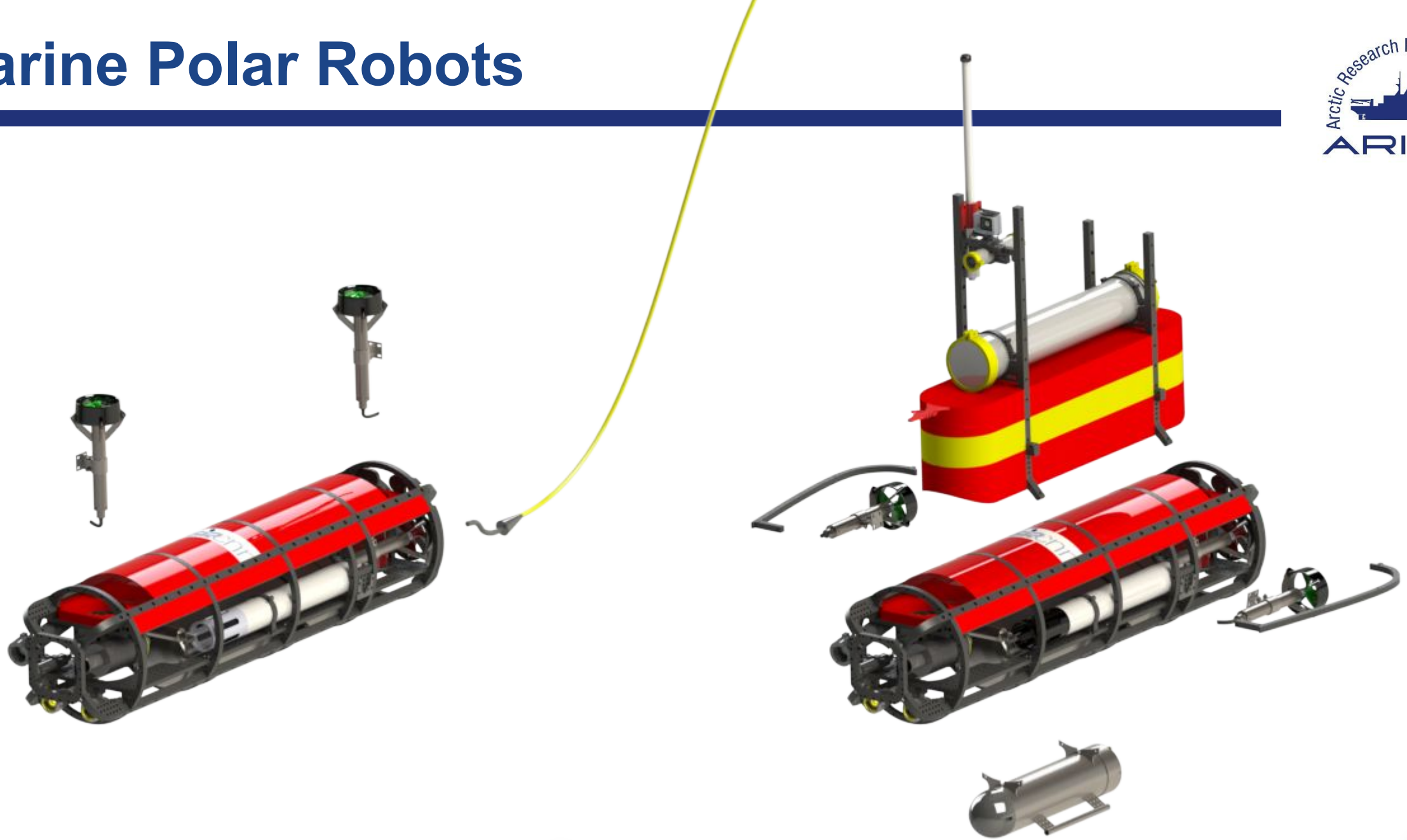
Reduced Logistics: Multi-mission vehicle



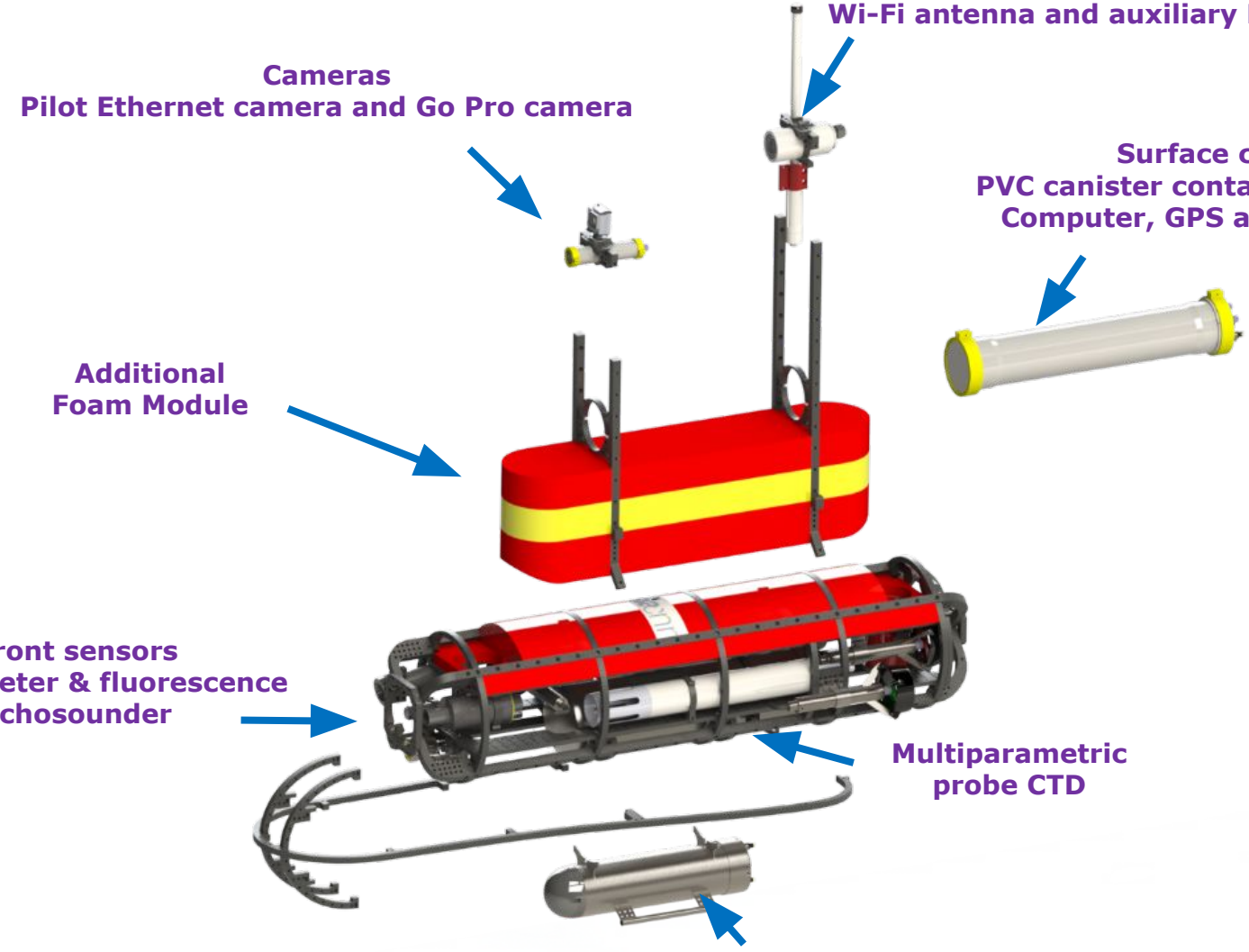
Marine Polar Robots



Marine Polar Robots



Marine Polar Robots



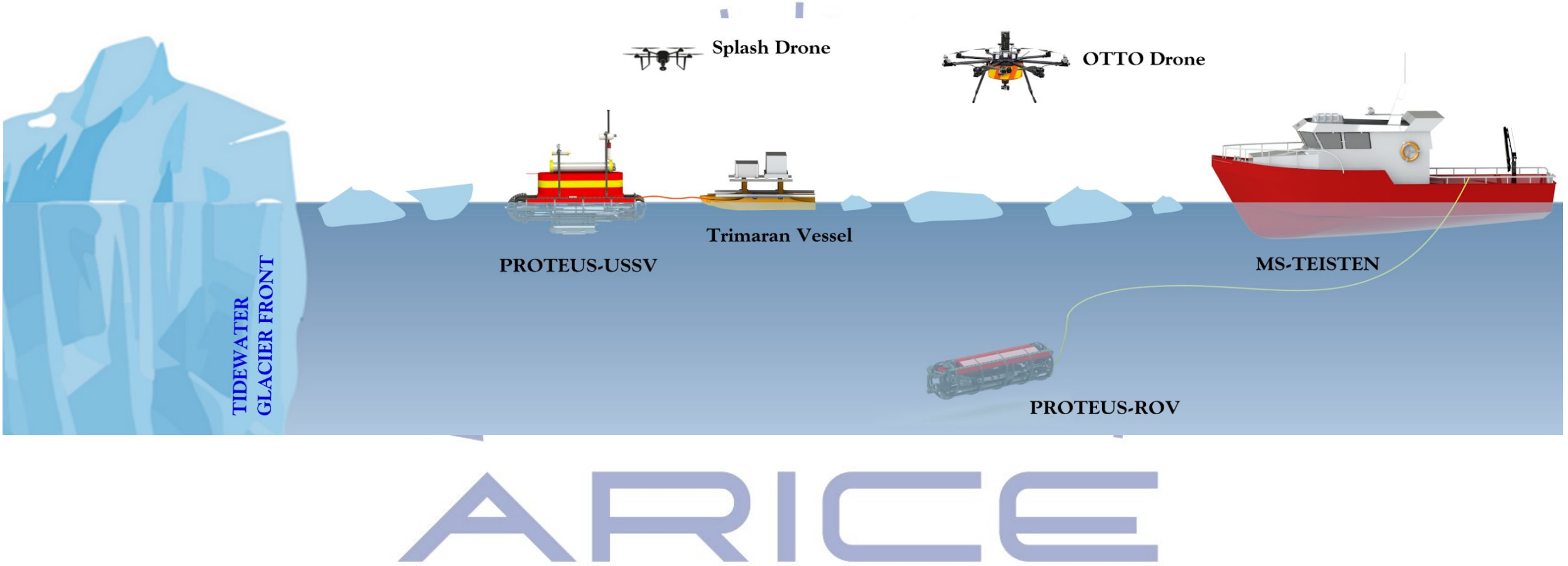
Core Vehicle:
45 kg
1400mm long
340 mm diameter
5 Thrusters

Marine Polar Robots

Robot shape:
Unmanned Semi-Submersible Vehicle (USSV)
with multiple thrusters for towing ability and redundancy

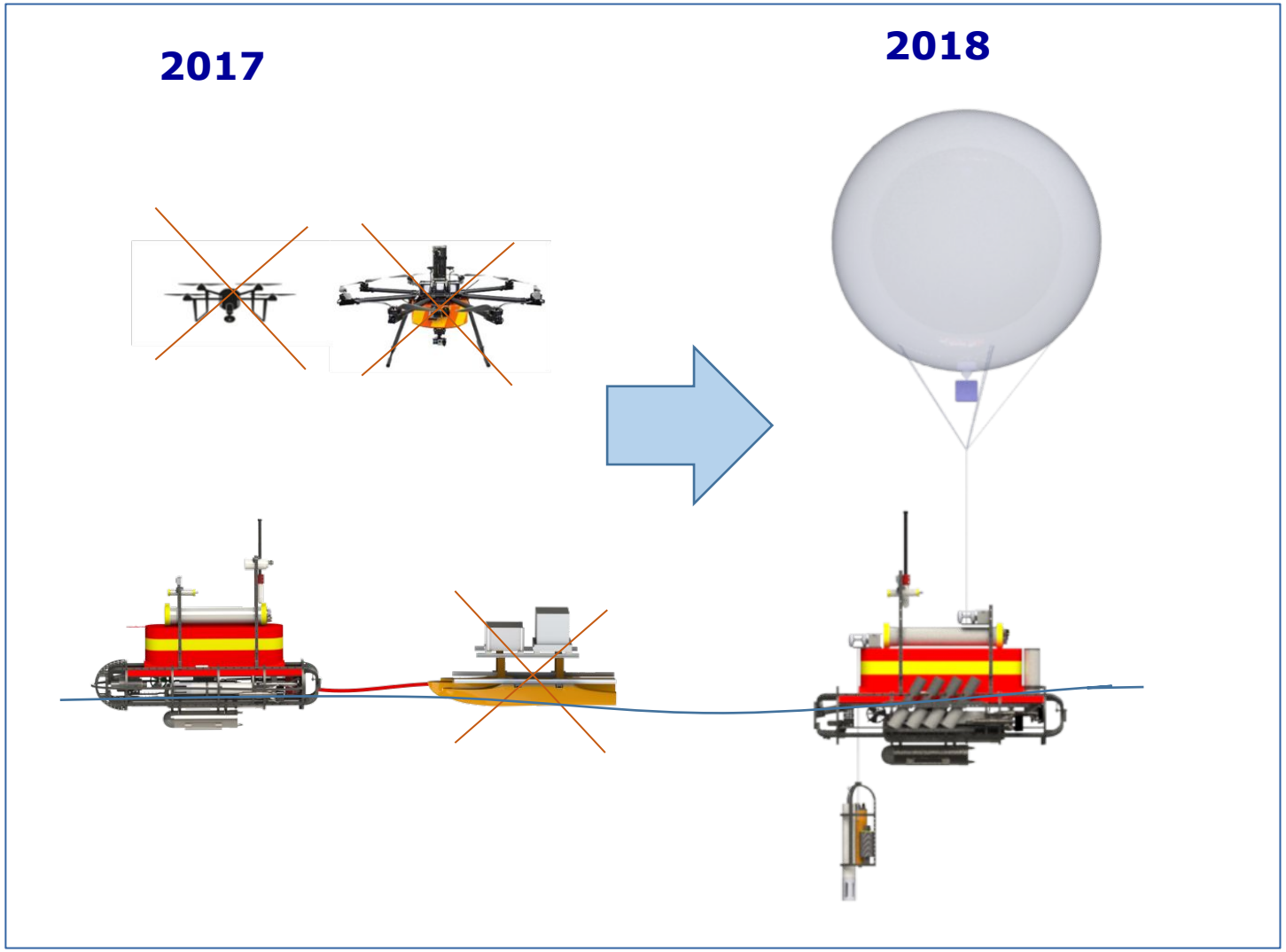
Second Campaign

Reduced Logistics ?



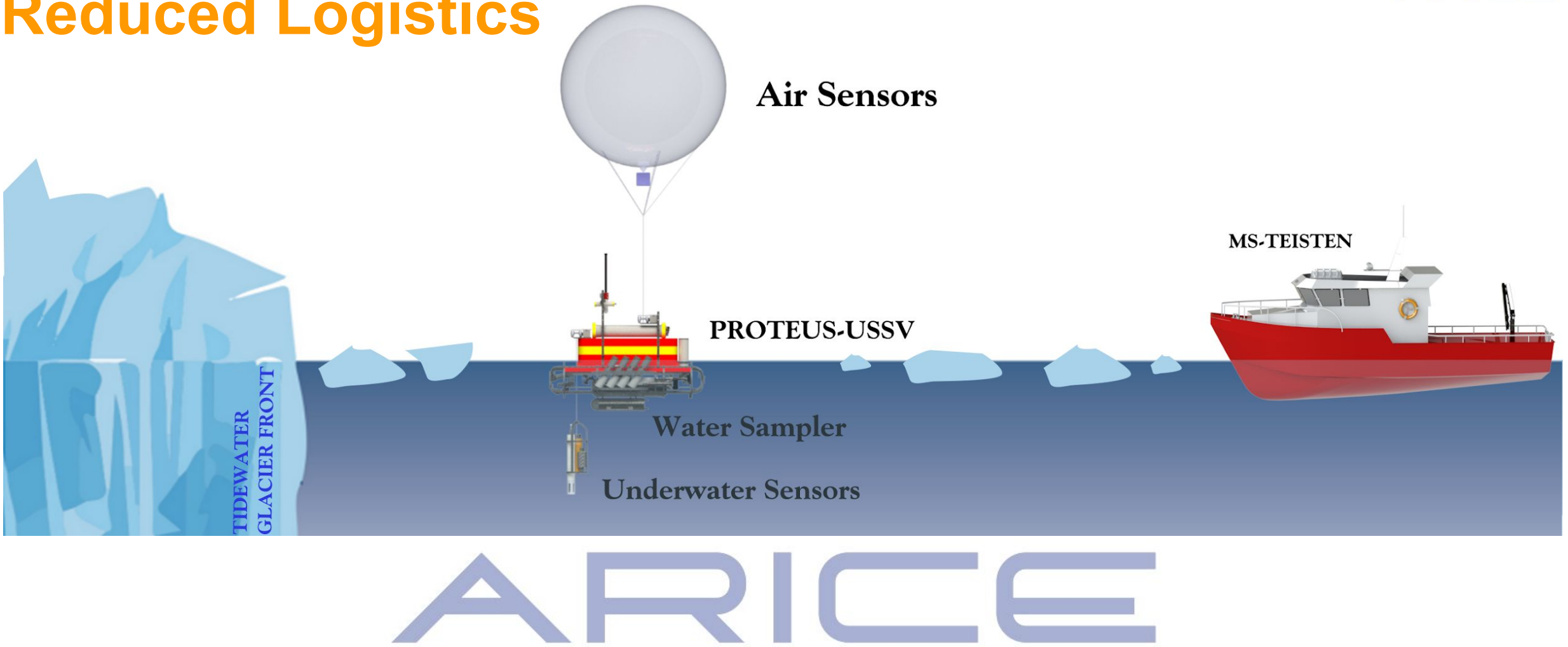
Marine Polar Robots

Reduced Logistics



Marine Polar Robots

Reduced Logistics



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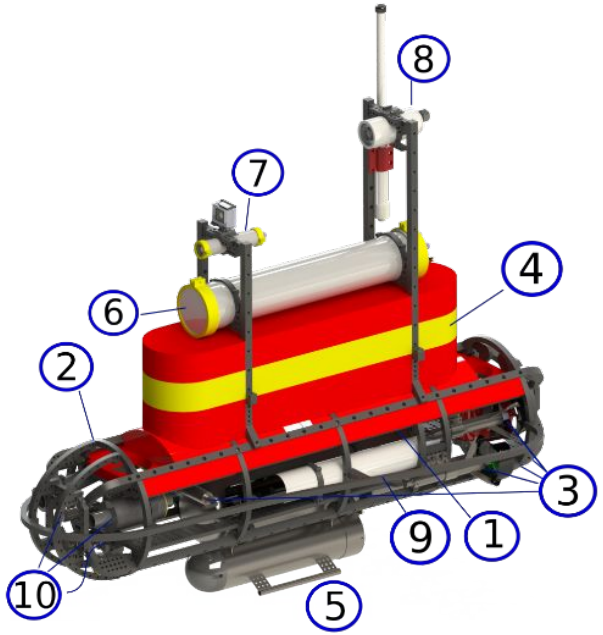
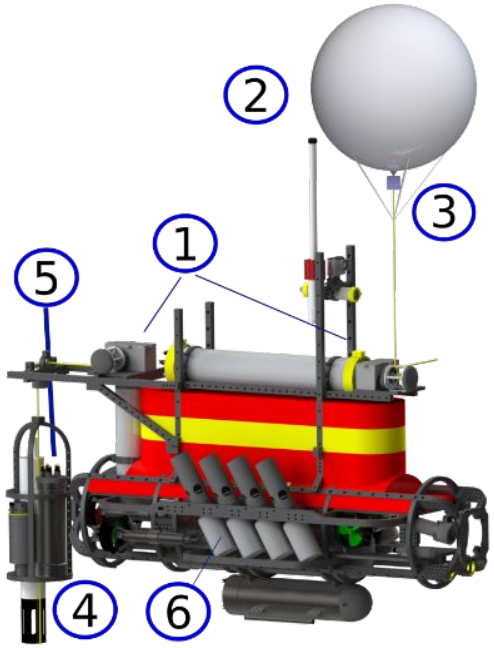
Marine Polar Robots

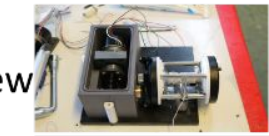


1 **Control system -** Stainless steel canister containing a Single Board Computer, two PC/104 for digital, analog and serial I/O used for interacting with sensors and actuators
2 **Frame -** Schockproof, modular, reconfigurable frame made of polyethylene
3 **Five Modular and displaceable thruster**
4 **Removable foam for USSV operations**
5 **Battery Pack for USSV operations**
6 **Surface control unit -** PVC canister containing a Single Board Computer, GPS and inertial sensors
7 **Cameras -** Pilot Ethernet camera and Go Pro camera
8 **Communications -** Wi-Fi antenna and auxiliary Ethernet camera
9 **Multi-probe CTD -** Sensor module for measuring water CTD, dissolved oxygen, pH and Redox
10 **Front sensors -** ArLoC, Turbidimeter, Fuorescence, Echosounder

Marine Polar Robots



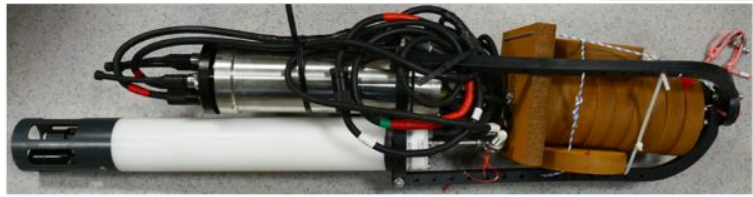
1 **Automatic Winch for marine and atmospheric sensors**
Composed by an electric motor driving a fishing reel with thread guide reduction box and worm screw



2 **Helium filled aerostat to carry the AirQino system**

3 **AirQino**
Arduino-based air quality monitoring system with low cost high-res sensors: H,T,CO,CO_2,O_3,NO_2

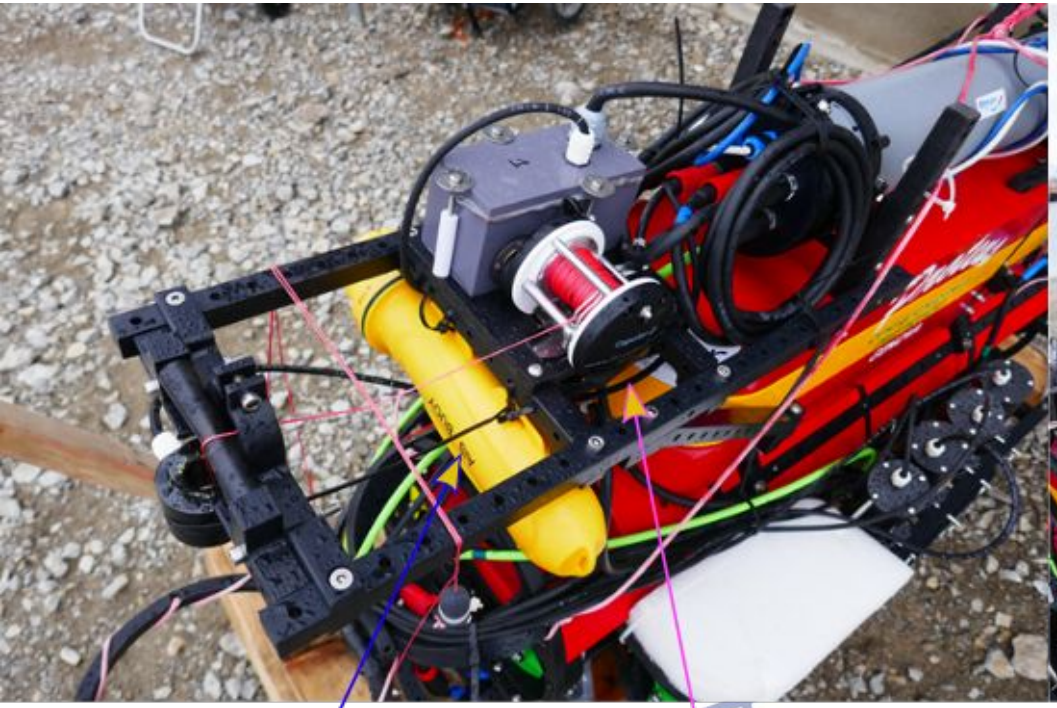
4 **Bunch of sensors**
CTD multi-parameter Idronaut 305 Plus (CTD, pH, redox, O_2)
ArLoC (Arctic Low-Cost probe) multi-sensor, fluorimeter, turbidimeter



5 **MPDACS (Multi Purpose Data Acquisition Control System)**
Used to manage, synchronize and store the data collected by the instruments

6 **MAWS (Mini Automatic Water Sampler)**
Water sampler made up of 8 replaceable bottles with an automatic cap based on magnetic forces.

Marine Polar Robots



AIS

Underwater Winch

Atmospheric Winch

Mini Automatic Water Sampler

AIS

Marine Polar Robots

Specific needs

- Sampling a good amount of samples
- Moving accurately vertical sensors
- Managing manifold sensors in one single vehicle

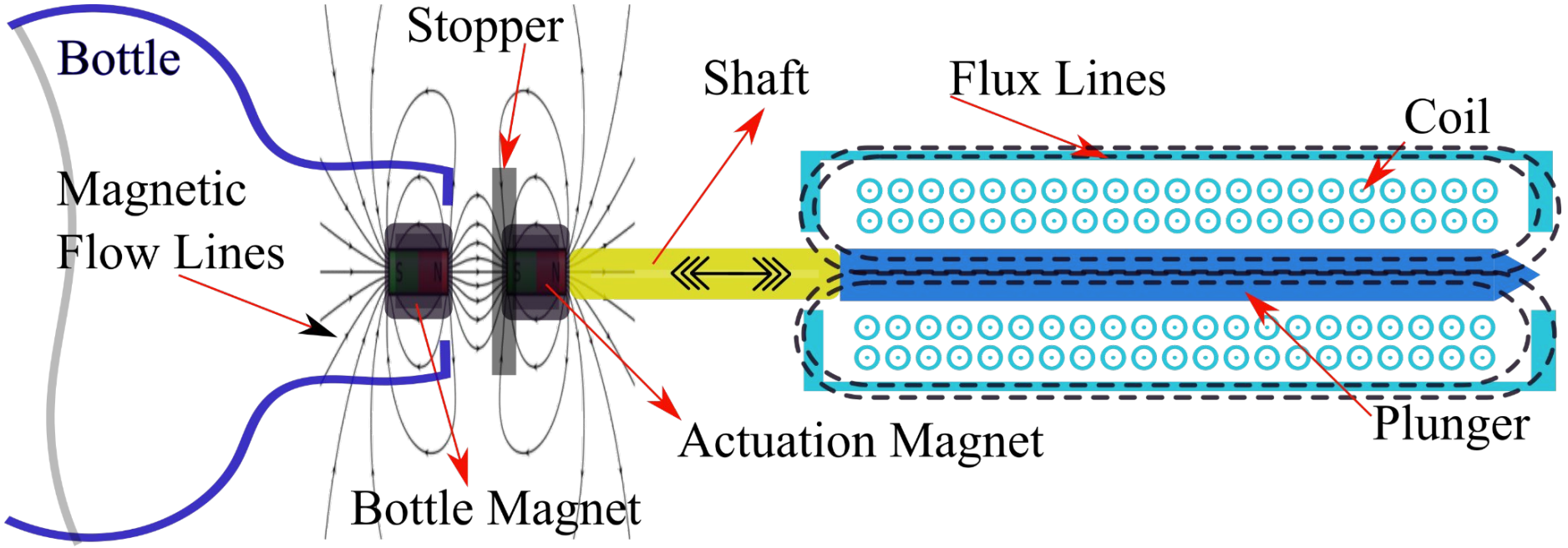
Marine Polar Robots

Mini Automatic Water Sampler (MAWS)

Marine Polar Robots

Mini Automatic Water Sampler (MAWS)

- Magnetic vs. spring stopper
- Maximum force at closure
- The force required to keep the cap open is reduced with distance

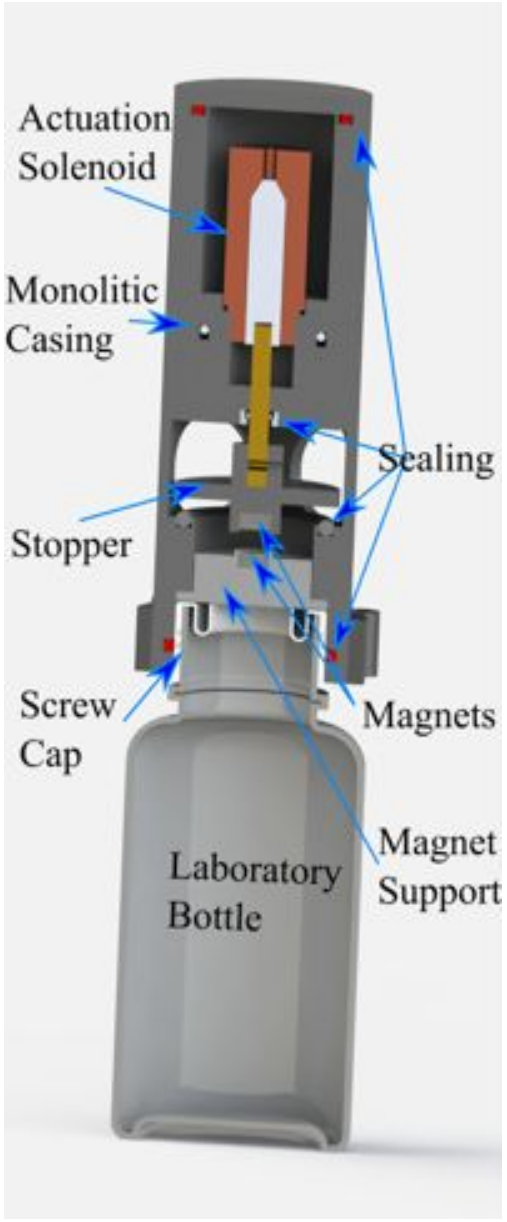


Marine Polar Robots

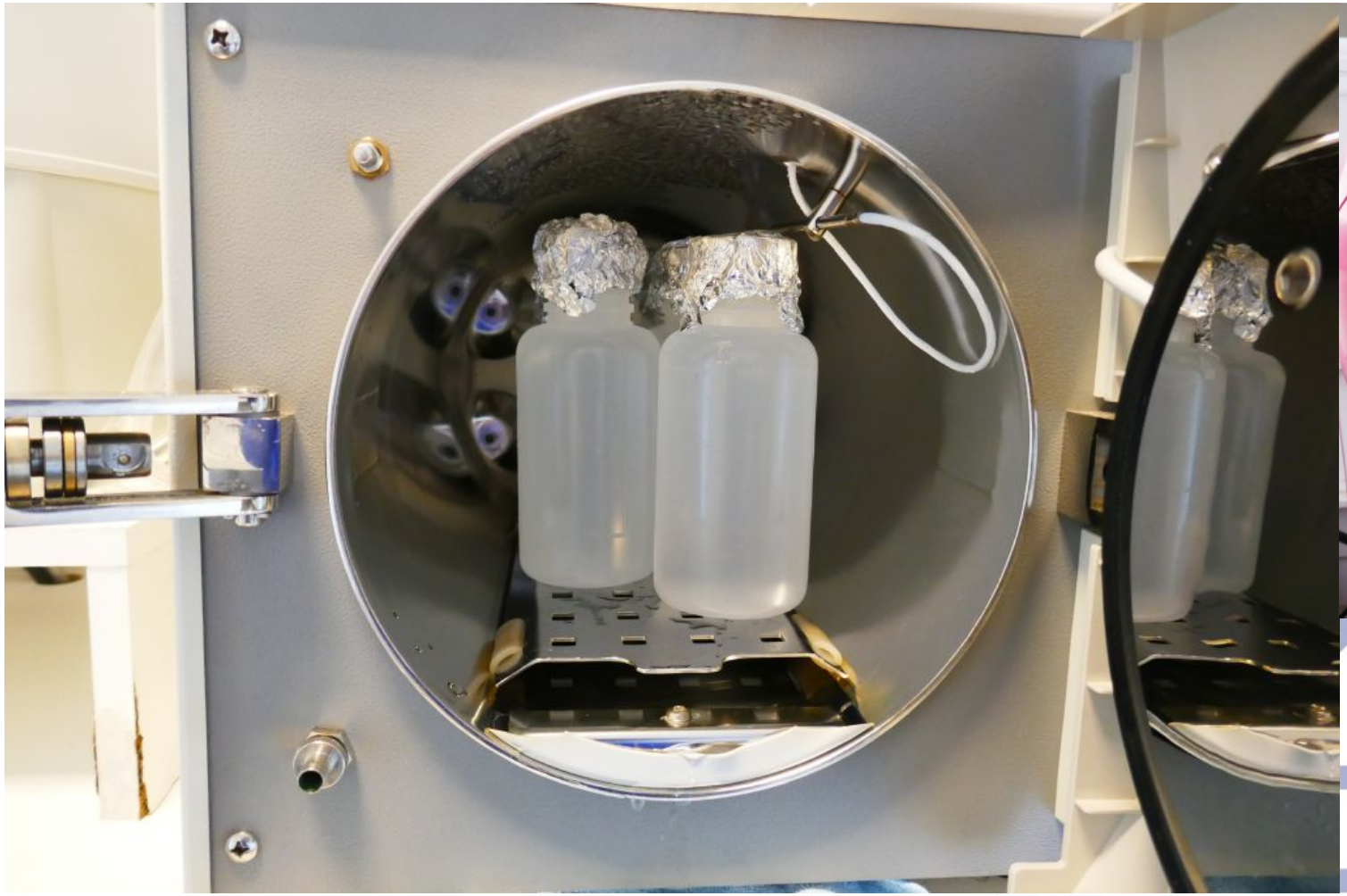
Mini Automatic Water Sampler (MAWS)

Modular automatic stopper device to be installed on the top of standard chemical laboratory bottles

- Stopper device
- Standard screw cap
- Laboratory bottle

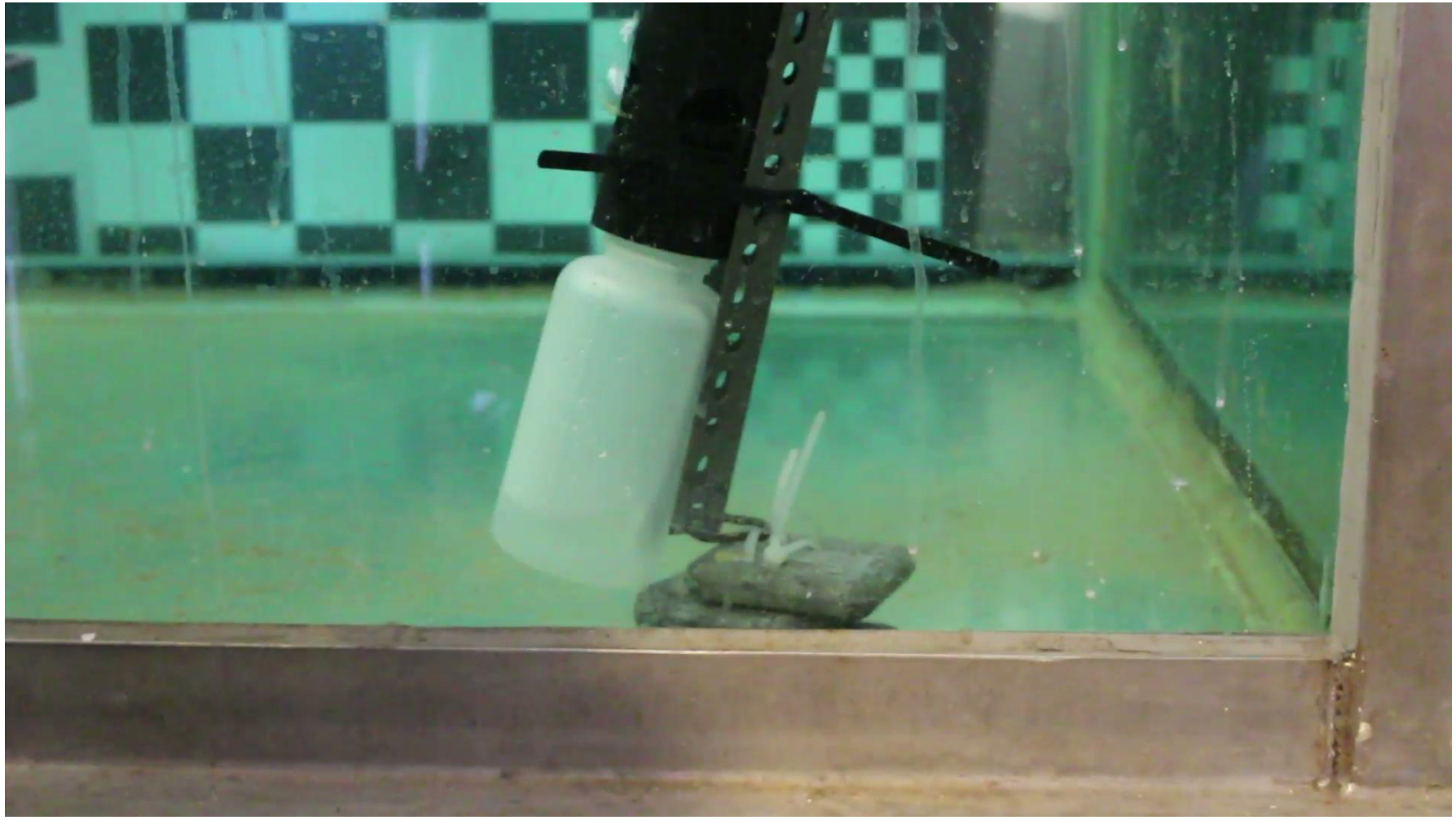


Marine Polar Robots



Marine Polar Robots

Mini Automatic Water Sampler (MAWS)



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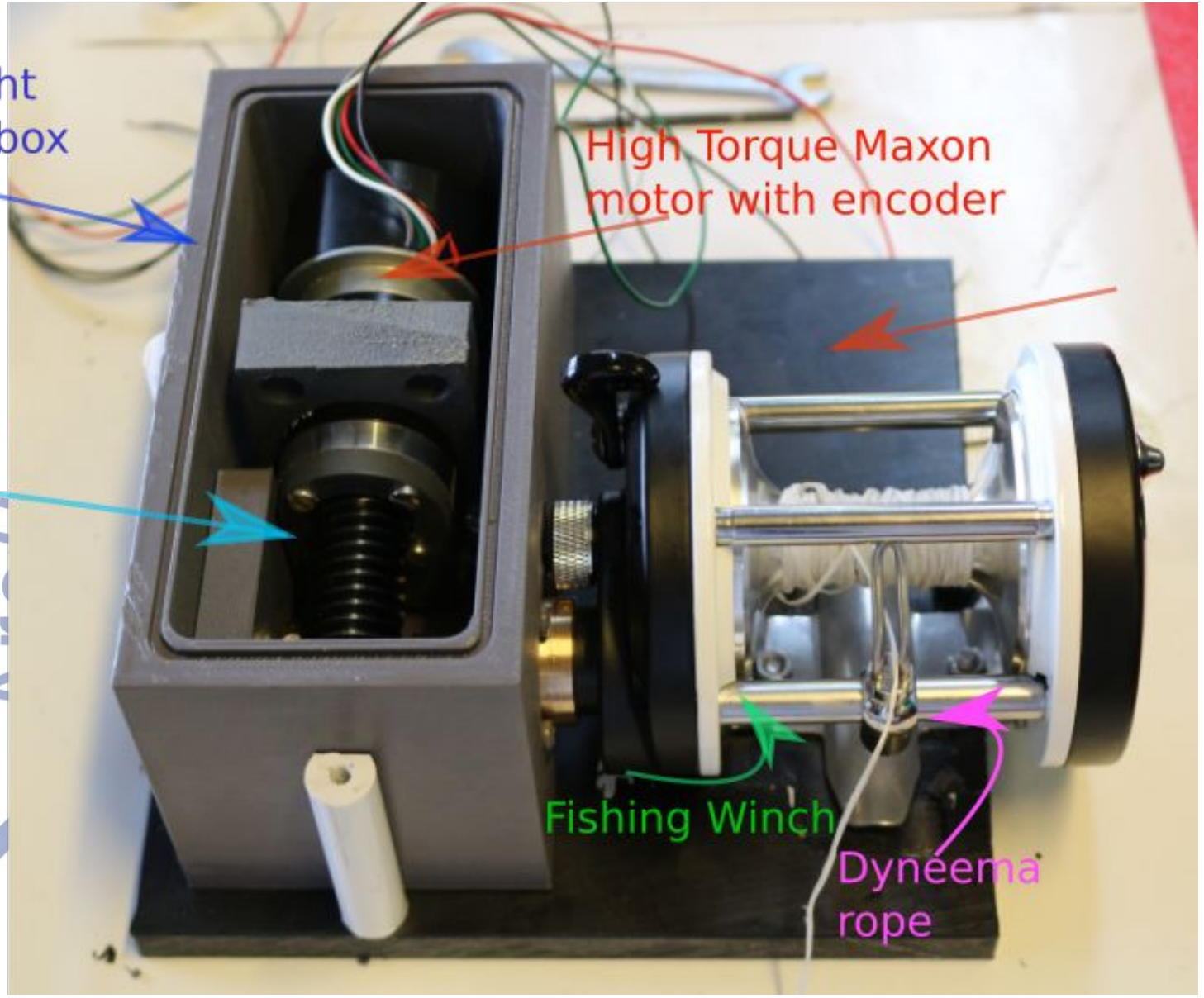
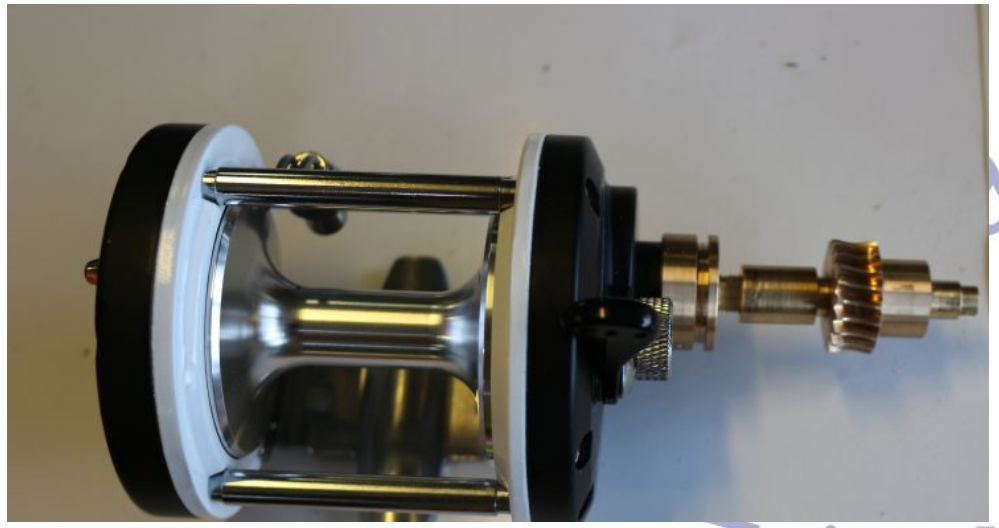
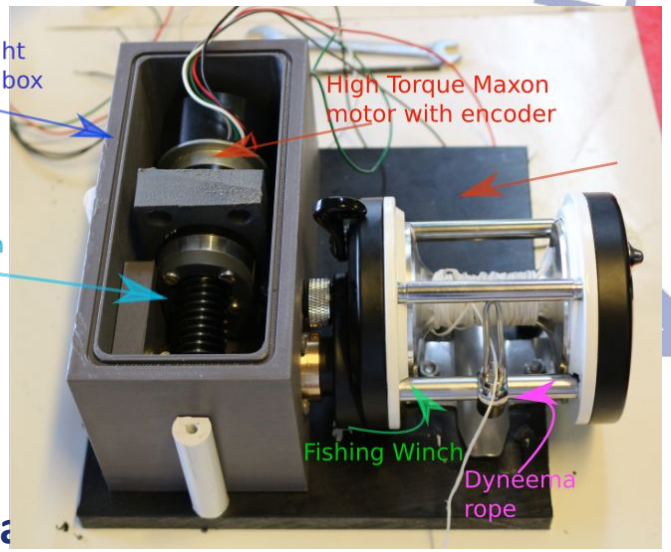
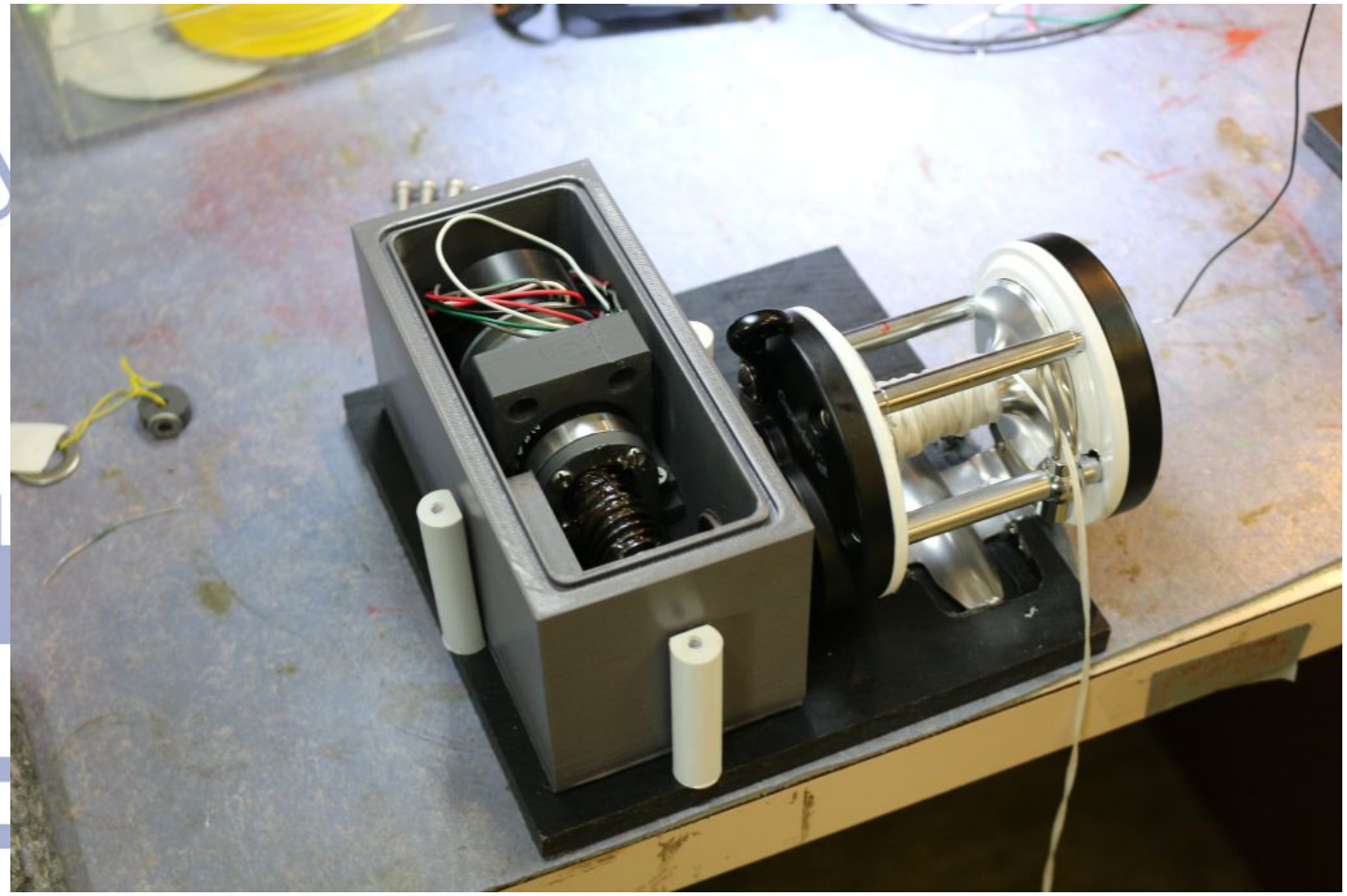


Marine Polar Robots







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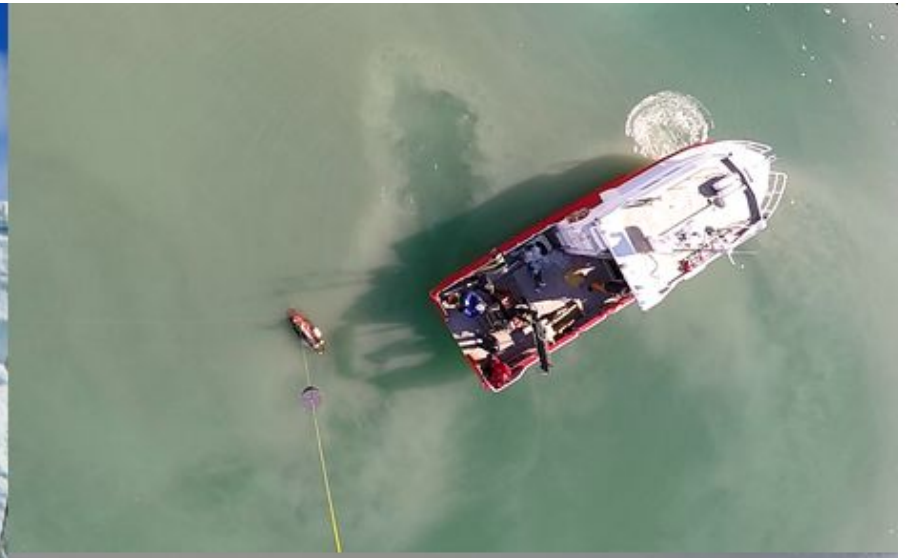
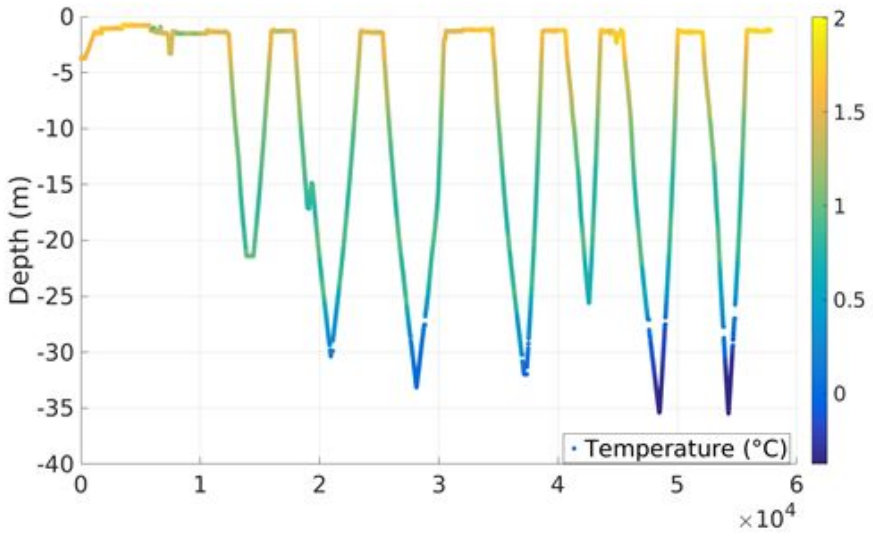


Marine Polar Robots

Data collected by the instruments are synchronized and saved by the MPDACS system (Multi Purpose Data Acquisition Control System)

- Multi-parametric probe Idronaut 305 Plus (conductivity, temperature, depth, pH, redox, oxygen)
- ArLoC multi-sensor
- fluorometer
- turbidimeter



Marine Polar Robots

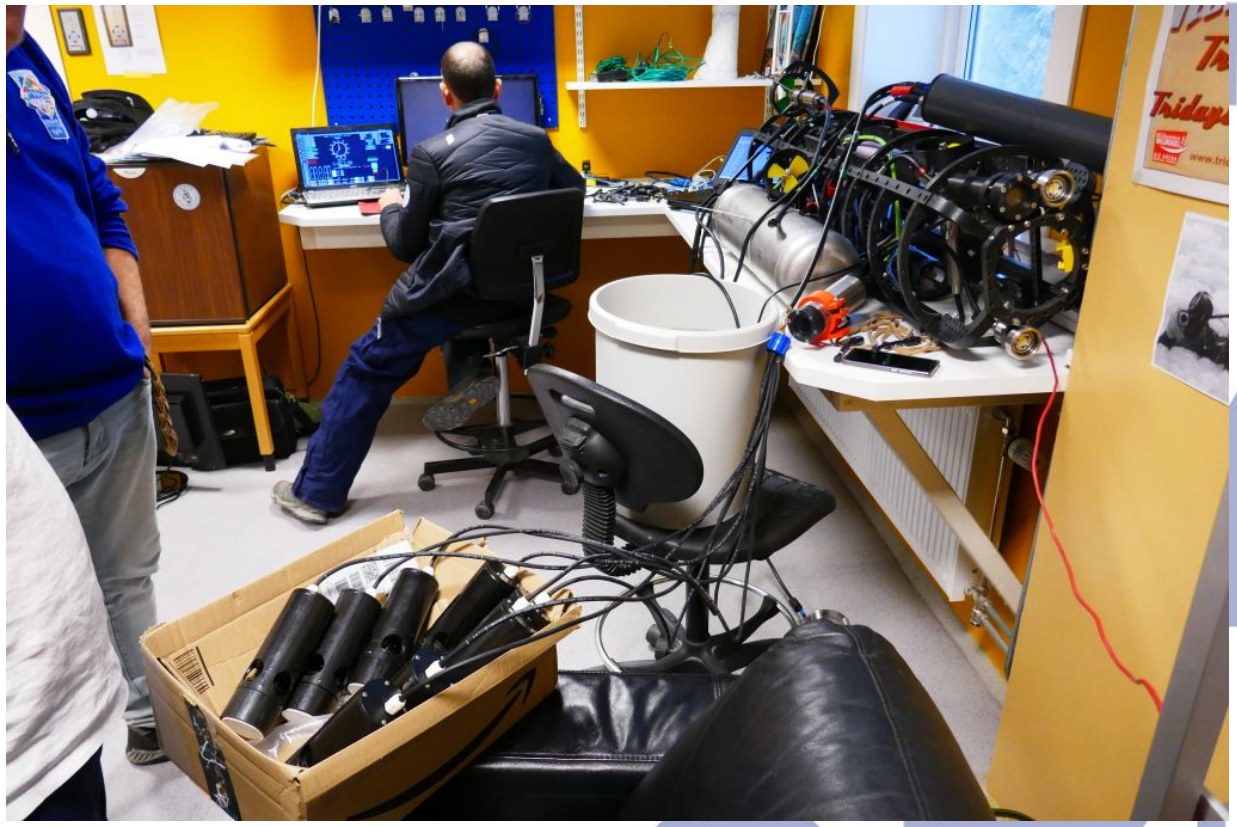
Hands-on the vehicle (and shipping issues)

- Shipping has an influence on robot (mechanical vibrations)
- Always be able to put your hands on the vehicle (commercial vehicles often are not suitable)
- Bring with you all the spare parts and tools you need (no shops, no Amazon)

→ influence on shipping cost and logistics (many boxes)

Marine Polar Robots

Hands-on the vehicle (and shipping issues)



Marine Polar Robots

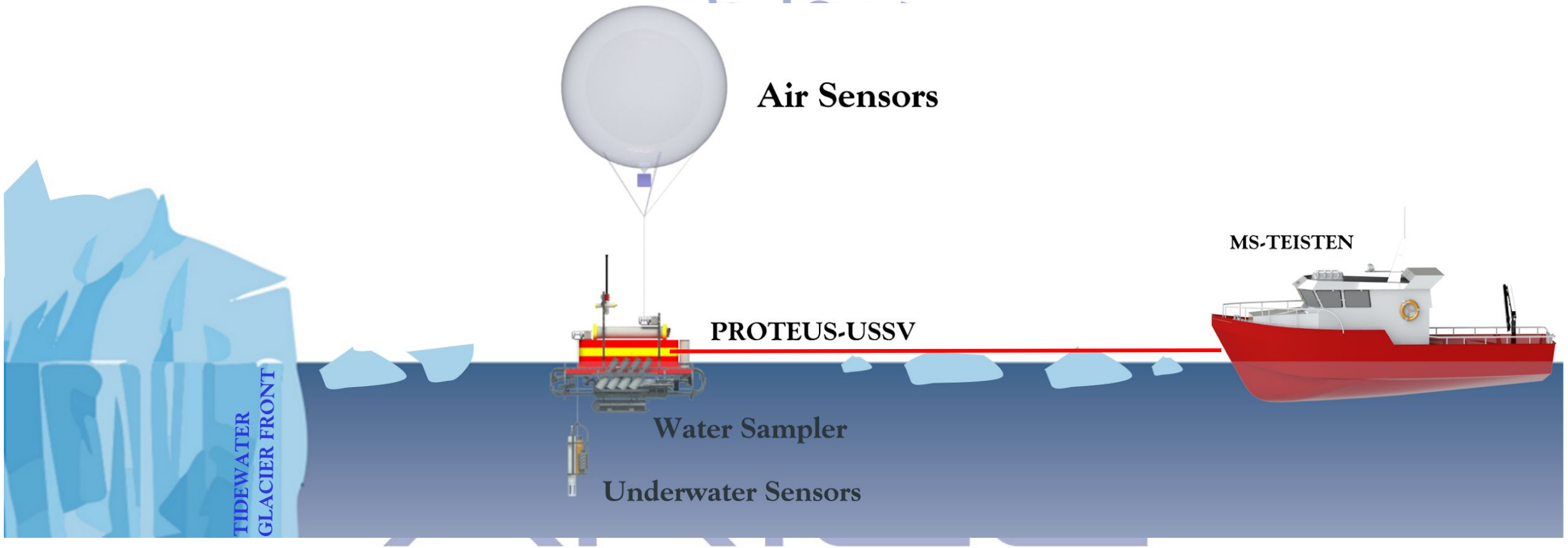
Hand-on the vehicle (and shipping issues)

Spare parts:

- **Short time**
- **Requirement to modify/adapt**

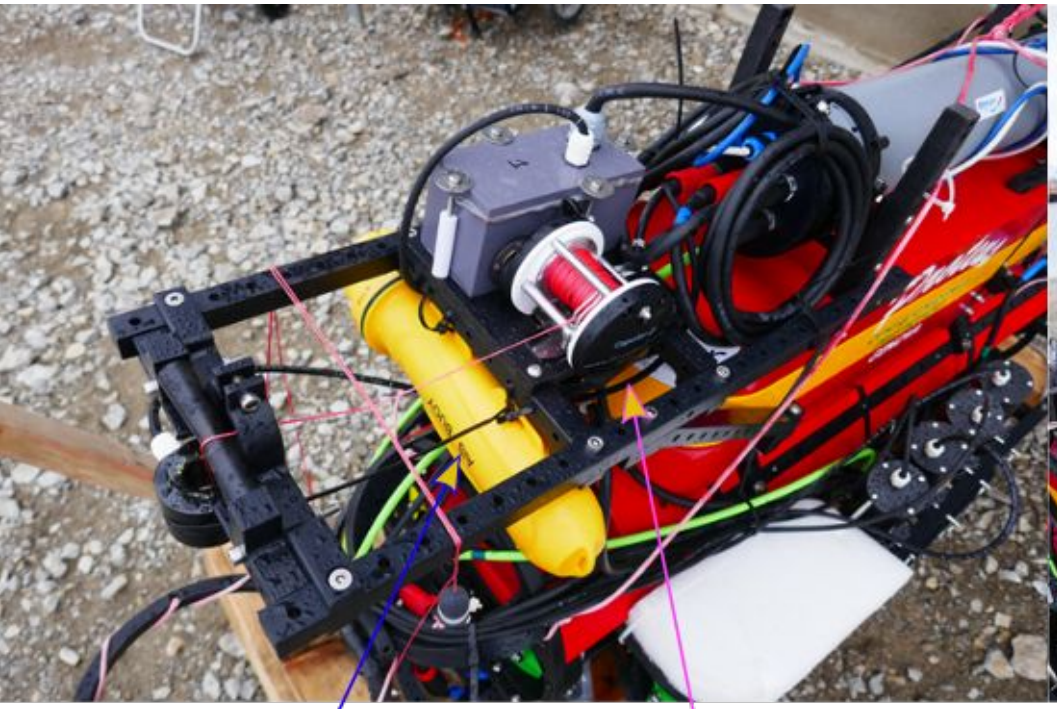
Marine Polar Robots

Vehicle recovery?



Marine Polar Robots

Vehicle recovery?



AIS

Underwater Winch

Atmospheric Winch

Mini Automatic Water Sampler

AIS

Marine Polar Robots

Design Issues:

- Low temperatures
- Reduced logistics
- Navigation problems
- Communication problems
- Multipurpose analysis

Marine Polar Robots

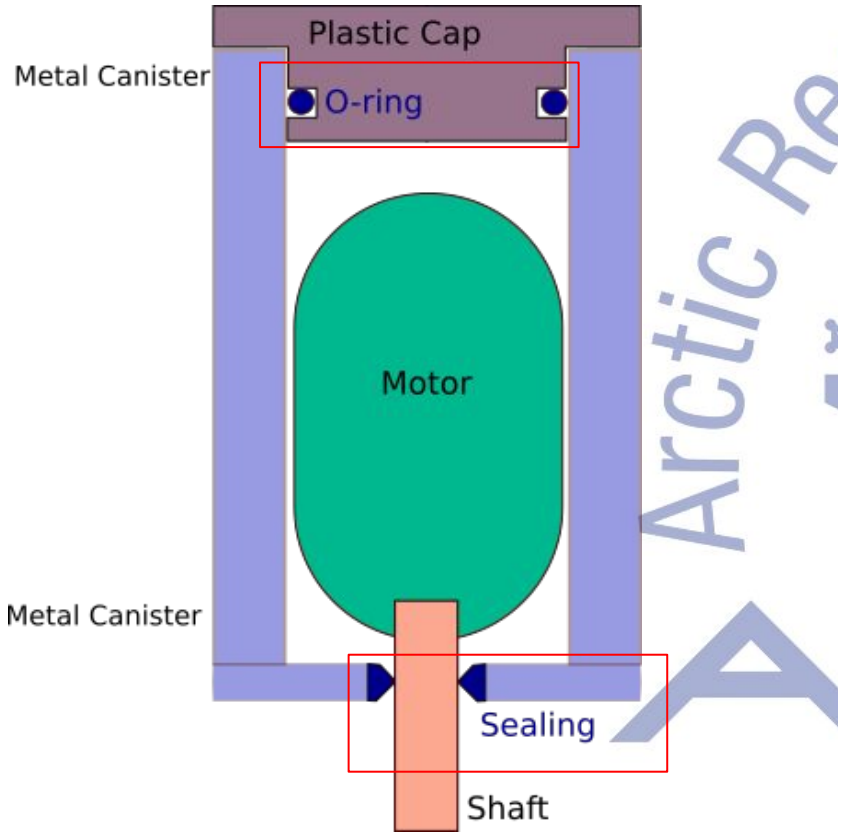
Low temperatures:

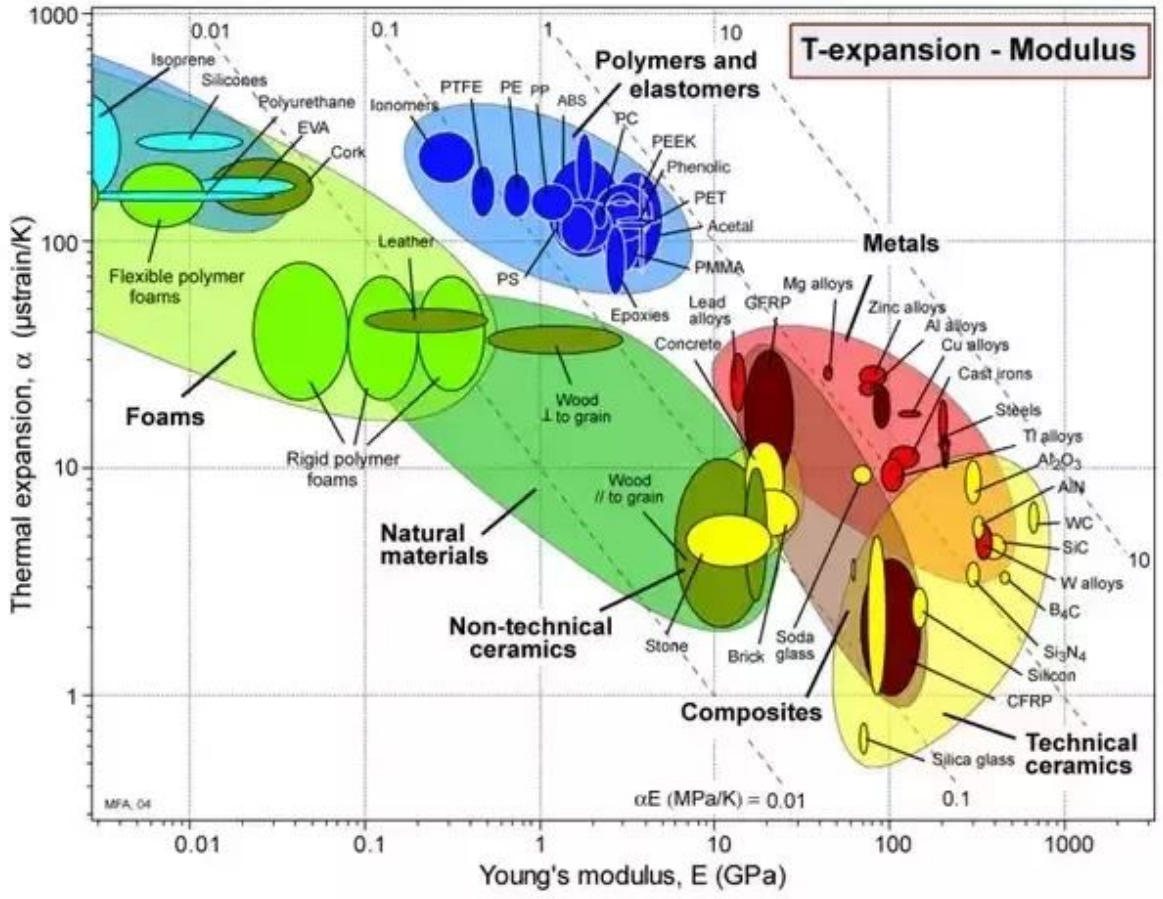
- Influence on structural design (sealings)
- Influence on endurance and batteries choice
- Influence on instrumentation
- Influence on robot mechanical design (Hand-on)

Marine Polar Robots

- **Influence on structural and mechanical design (sealings)**

Components should have compliant thermal dilatation materials





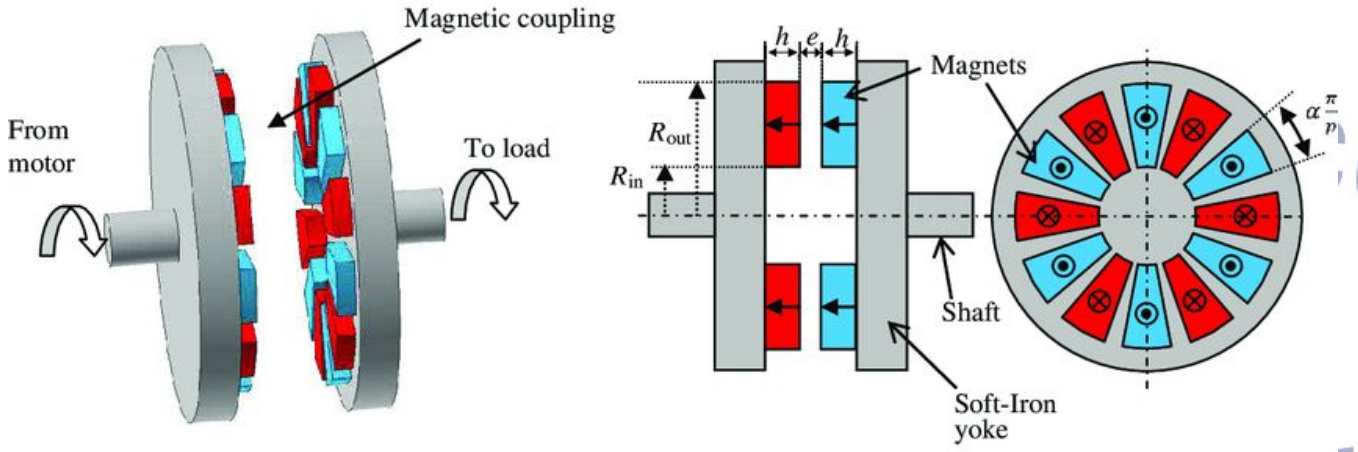
Marine Polar Robots

- **Influence on structural design (sealings)**

Components should have compliant thermal dilatation materials

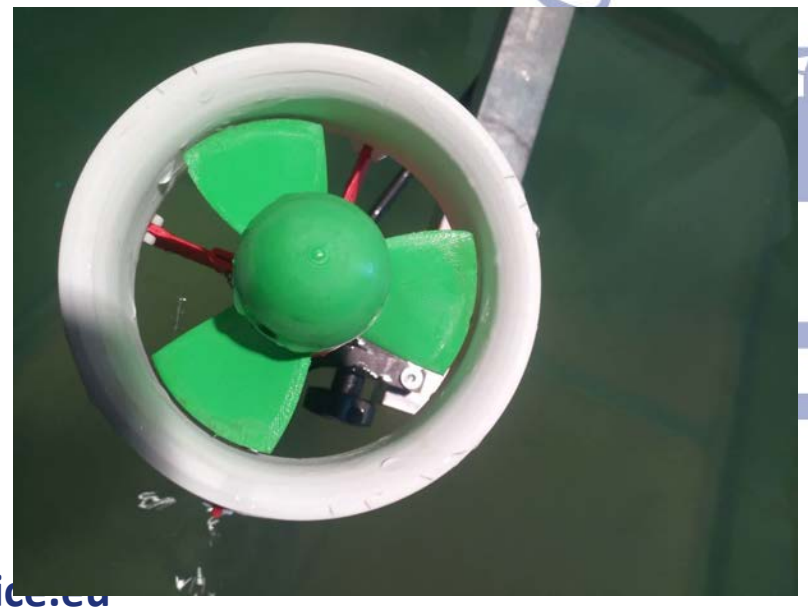
Material	Expansion Coefficients	
	10^{-6} in/in °F	10^{-6} m/m °C
Aluminum	12.8	23.1
Carbon Steel	6.5	11.7
Cast Iron	5.9	10.6
Copper	9.3	16.8
Stainless Steel	9.9	17.8
ABS Acrylonitrile butadiene styrene	35.0	63.0
HDPE High density polyethylene	67.0	120.0
PE Polyethylene	83.0	150.0
CPVC Chlorinated polyvinyl chloride	44.0	79.0
PVC Polyvinyl chloride	28.0	50.4

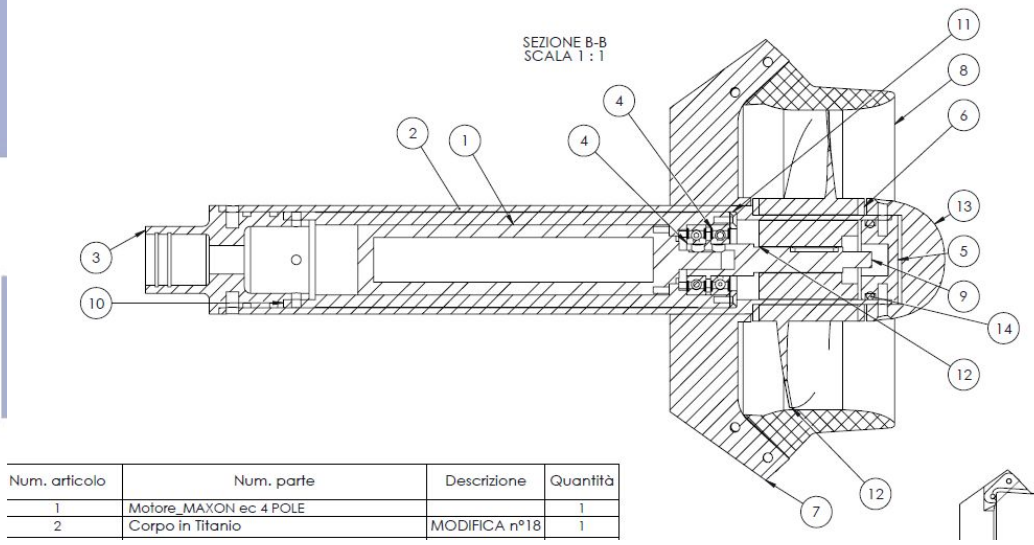
Magnetic Coupling:



Increased:

- Thrust
- Depth
- Watertightness
- Termal resistance





Num. articolo	Num. parte	Descrizione	Quantità
1	Motore_MAXON ec 4 POLE		1
2	Corpo in Titanio	MODIFICA n°18	1

Marine Polar Robots

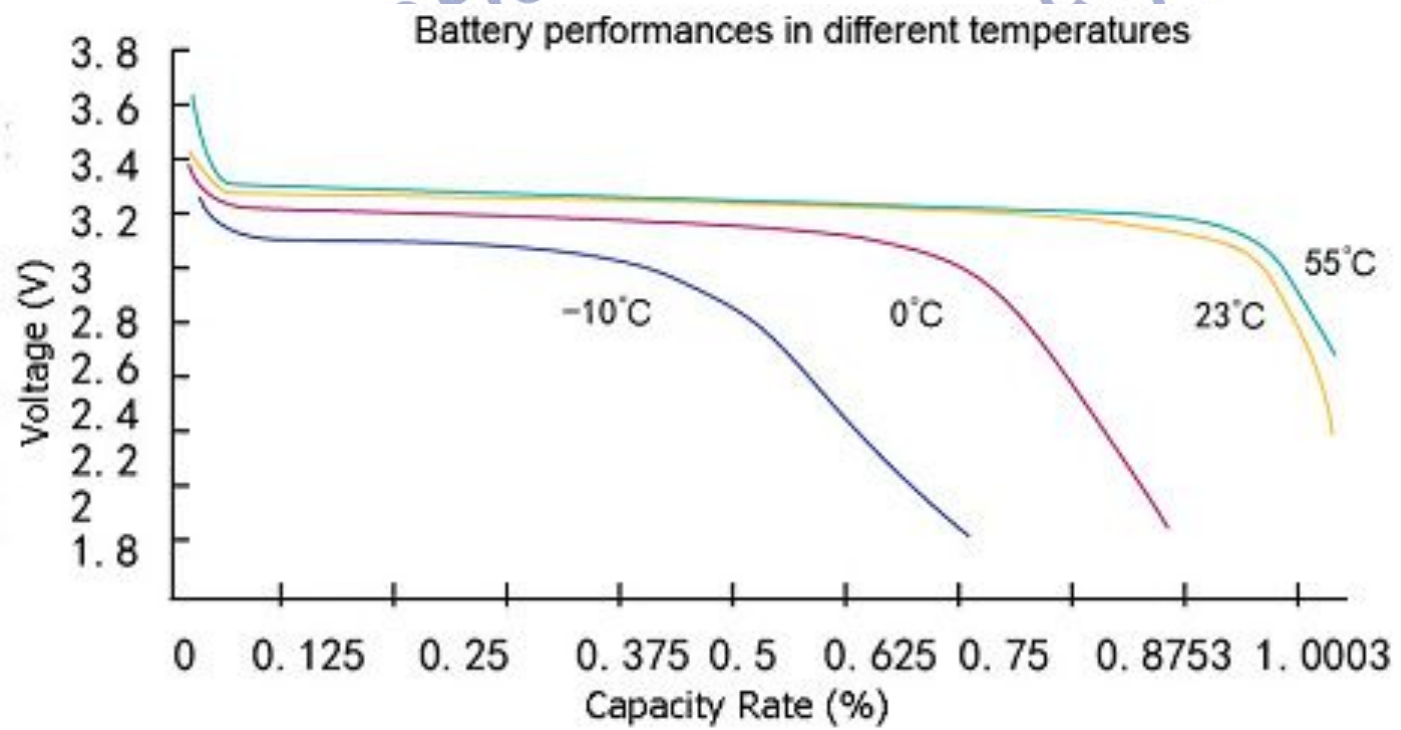
- **Influence on instrumentation**

  All the instruments should be chosen as adequate for low temperatures

  Spare parts

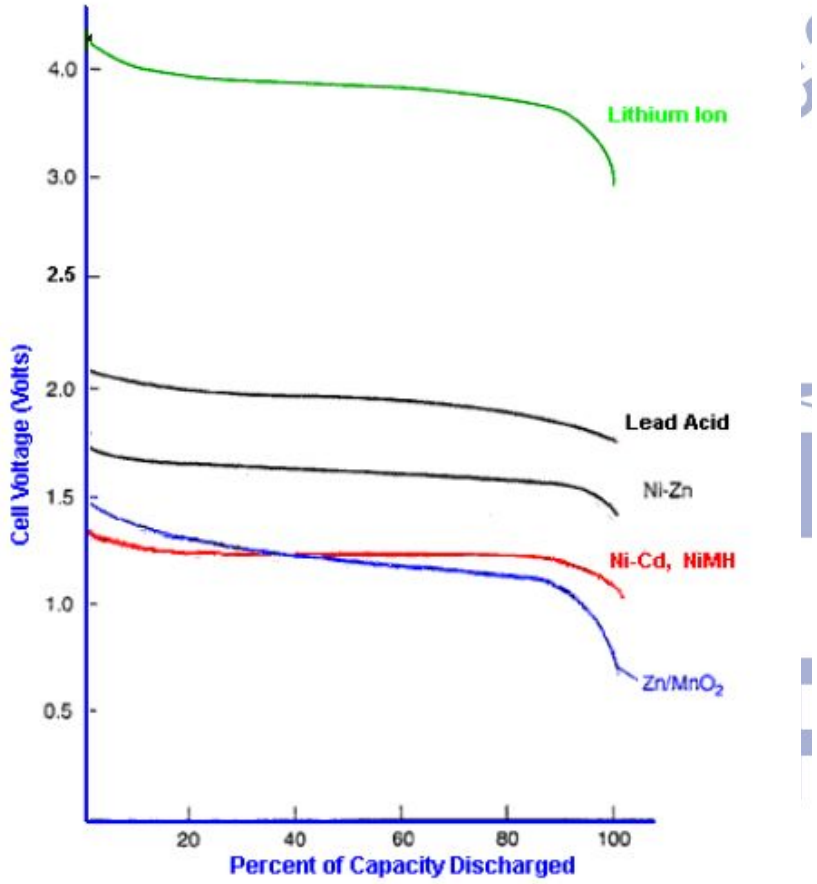
Marine Polar Robots

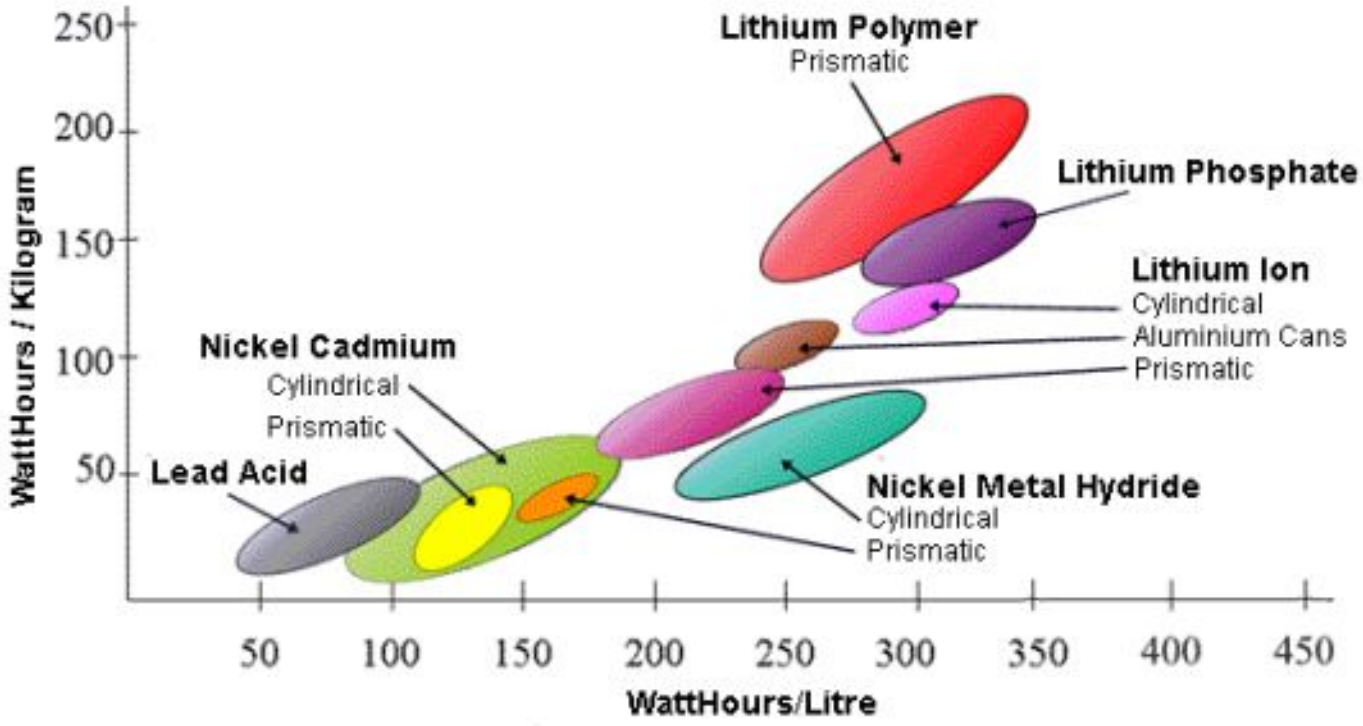
- **Influence on endurance and batteries choice**



Marine Polar Robots

- **Influence on endurance and batteries choice (chemical reasons)**





Marine Polar Robots

- **Influence on endurance and batteries choice**

Lithium batteries have better performances but

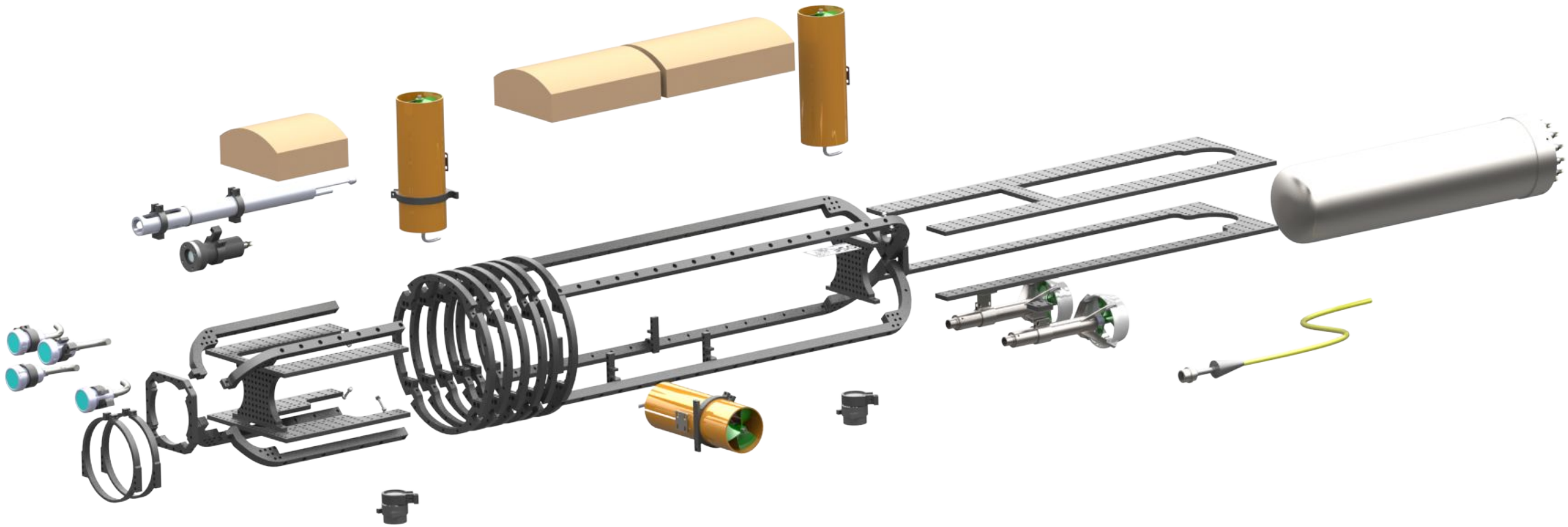
take care of the low temperatures during recharging,

Never charge lithium batteries in cold!

Marine Polar Robots

- Influence on robot mechanical design (Hand-on)
  - Always remember that you should be able to dismount something in cold environment
  - Standardised Bolts (e.g. M6 with standard Allen keys)
  - Better not using miniaturised stuff

Marine Polar Robots



Marine Polar Robots

Reduced logistics

- Transport via helicopter or small vessel/boat
- Powering requirements of used tools (is every powering source available?)
- Influence on robot mechanical design (Hand-on)
- Influence on shipment (time)
- Remember to have all the required spare-parts
- Transport limitations of some components (Batteries)

Marine Polar Robots

- **Transport limitations of some components (Batteries)**

Marine Polar Robots

Multipurpose Analysis - Requirements?

2015:

- Idronaut CTD + Oxygen, pH, Redox, TDS (total dissolved solids)
- Water sampling for microbiological study (microbial glycolytic activity)

2017:

- Idronaut CTD + Oxygen, pH, Redox, TDS (total dissolved solids)
- Arloc temperature, Chla fluorometer, CDOM fluorometer + Turbidity + Fluorescence
- SBE 16plus V2 CTD + dissolved oxygen, pH, turbidity,
- Water sampling A microbiological study microbial glycolytic activity
- Airqino: humidity, temperature, CO, CO2, O3, NO2

2018:

- Water sampling:
  - microbiological study
  - heavy metals
  - microplastics
- Airqino: humidity, temperature, CO, CO2, O3, NO2
- Idronaut CTD + Oxygen, pH, Redox, TDS (total dissolved solids)
- Arloc temperature, Chla fluorometer, CDOM fluorometer + Turbidity + Fluorescence

- **Analysis**
- **Storage**
- **Shipment**
- **Treatment**

Marine Polar Robots

Navigation and positioning problems

Robot modes:
Manual, Semi-automatic, Automatic

Operative use:
Semi-automatic working mode (auto-heading and auto-speed)

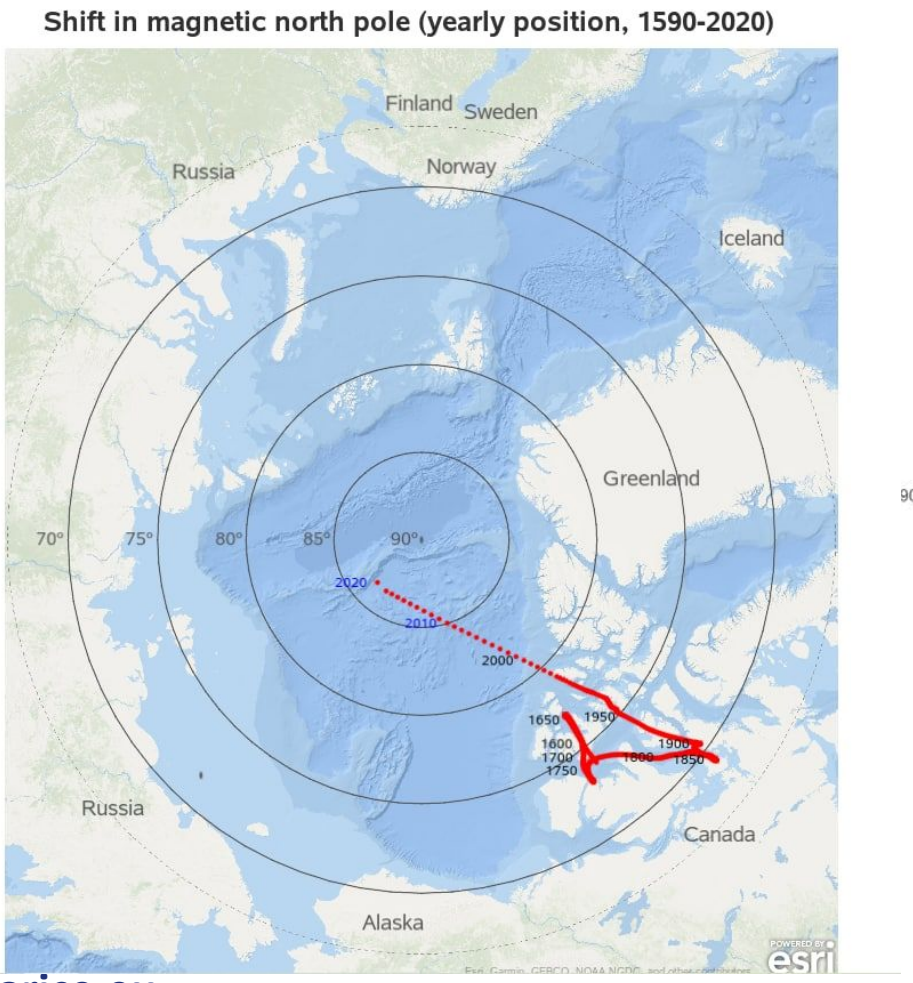
Marine Polar Robots

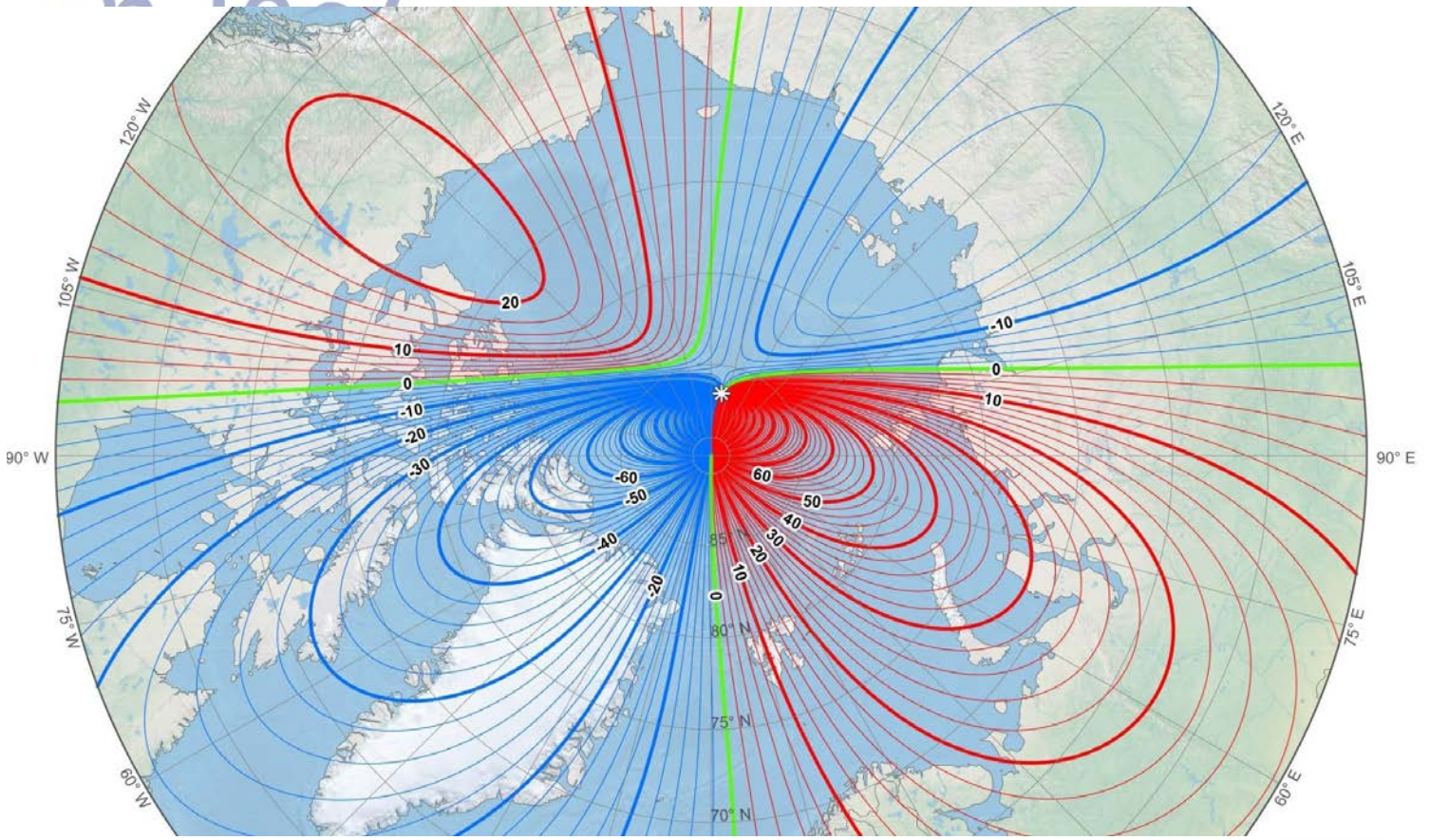
Navigation and positioning problems

Marine Polar Robots

Compass issues:

- **Close to north pole (difficult calibration)**
- **Magnetic declination**





Marine Polar Robots

GNSS:
GPS (known as NAVSTAR by the US Department of Defense)
Galileo (Europe),
GLONASS (Russia),
BeiDou (China)...

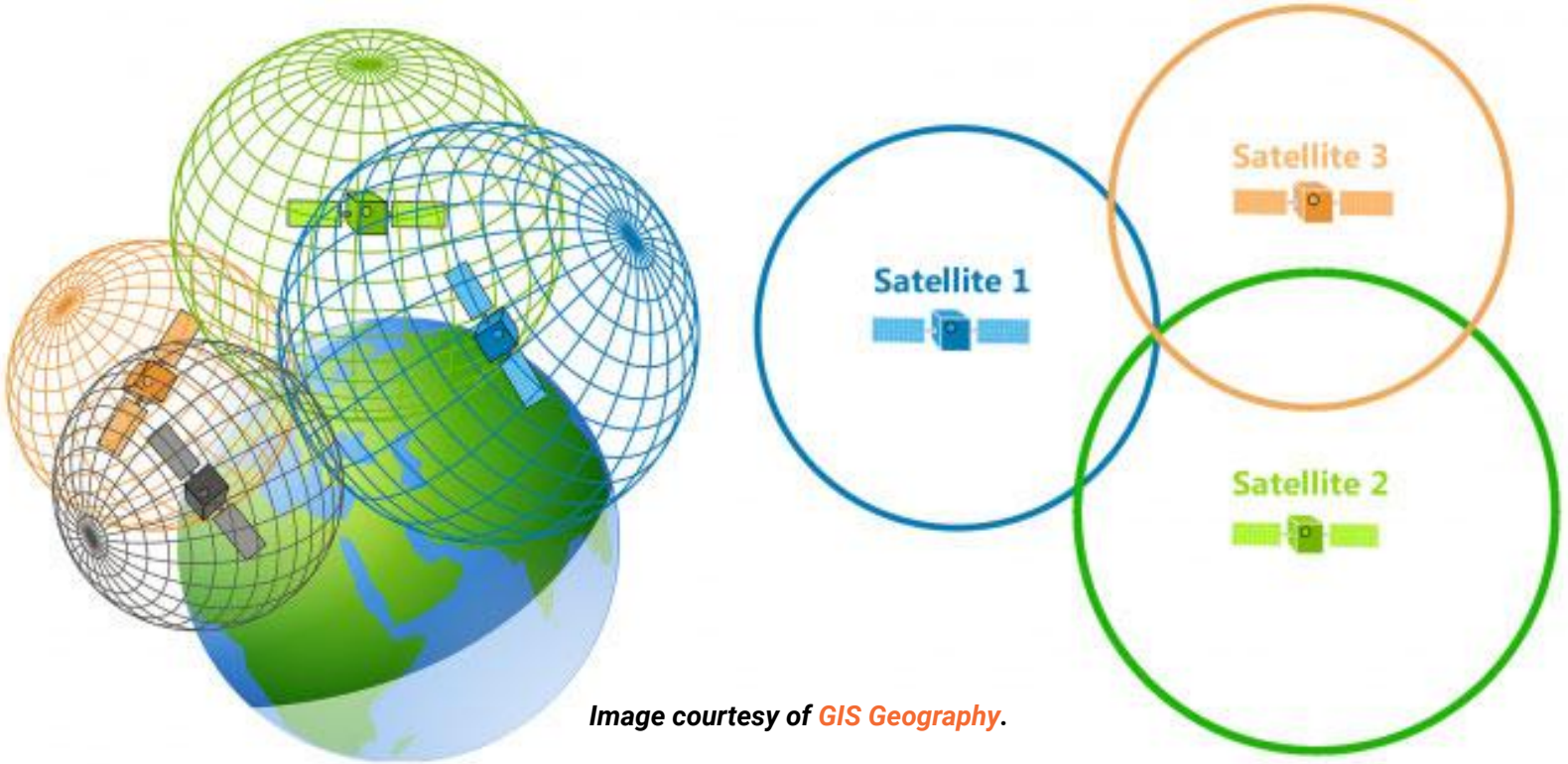
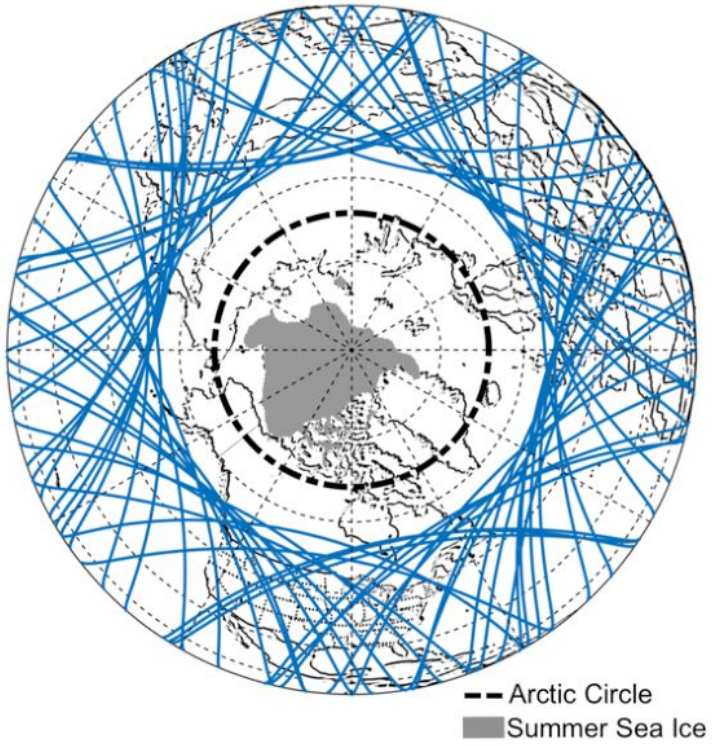


Image courtesy of GIS Geography.

Marine Polar Robots

GNSS reduced performances in the Arctic region:

- **satellite-receiver geometry**
- **ionospheric effects on the satellite signals**
- **less benefits of satellite based augmentation systems (SBAS)**



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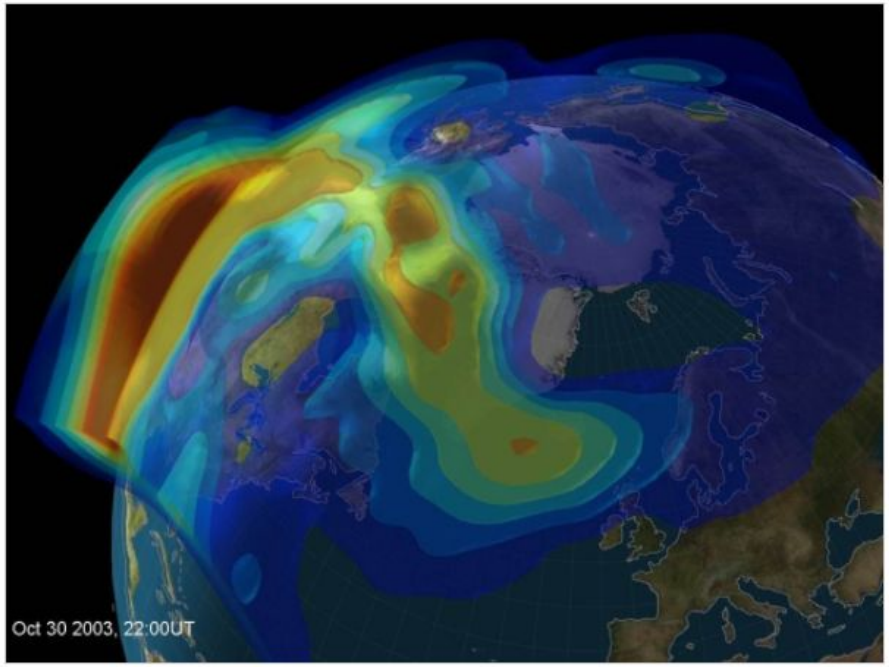
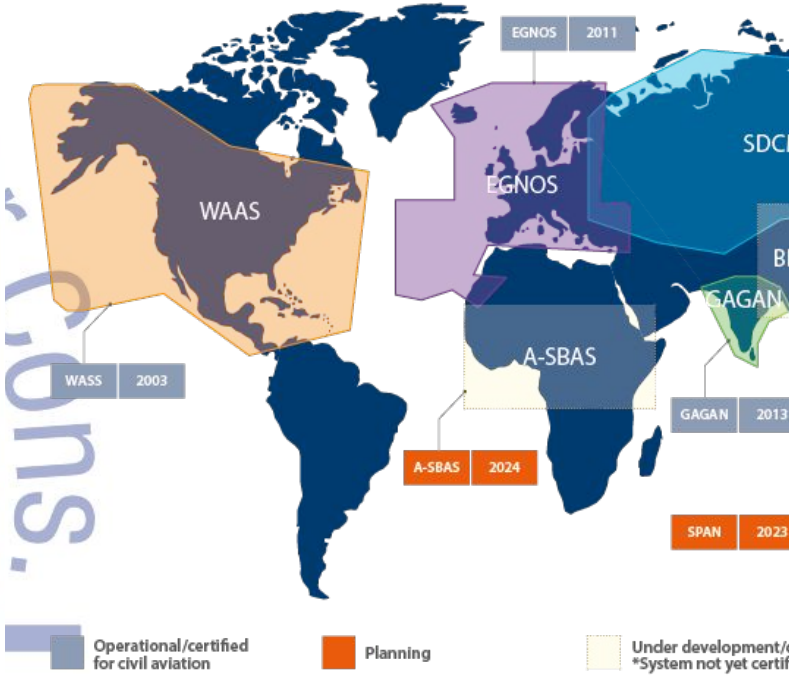


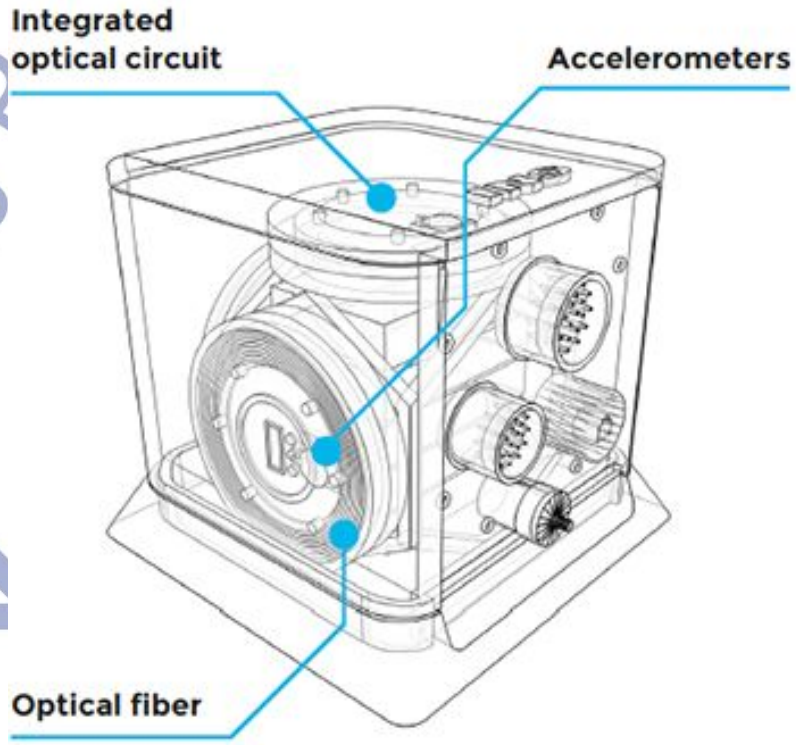
Ionosphere activity gradient. Image courtesy of the European Space Agency.



Marine Polar Robots

Solution:

- **Inertial navigation (Sensors integration) helps**
- **Use of FOG (Fiber Optic Gyro) -> HIGH COST!**



Communication problems (in Ny-Ålesund)

Communication system:

- A couple of 900 MHz Wi-Fi radios
- low speed (300 kbps maximum) Ethernet link between the robot and its control station

Respond as much as possible to:

- Modularity
- Reconfigurability
- Controllability
- Lightness -> Portability
- Constructive Easiness
- Cheapness
- Repairability

  (Modifiability)

Suitable Team

APECS-ARICE Webinar

Polar marine robotics

Questions!?






Arctic Research Icebreaker Cons.
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An international collaboration strategy for meeting the needs of marine based research in the Arctic

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APECS-ARICE Webinar

Polar marine robotics

Thank you very much!






Arctic Research Icebreaker Cons.
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Webinar recording will be available on arice.eu and on the APECS website

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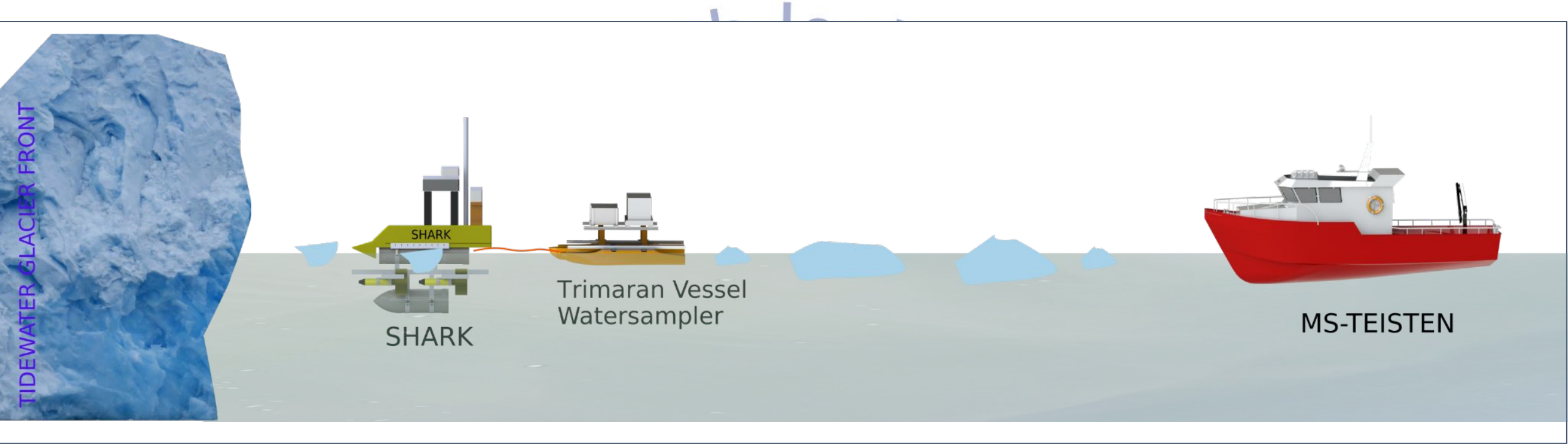

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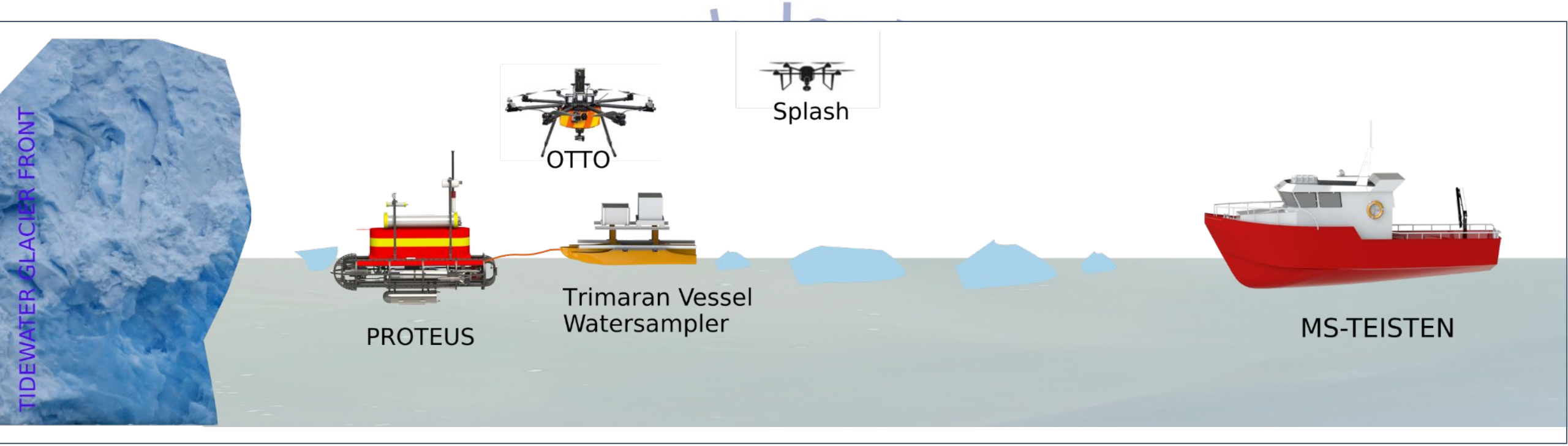
Marine Polar Robots



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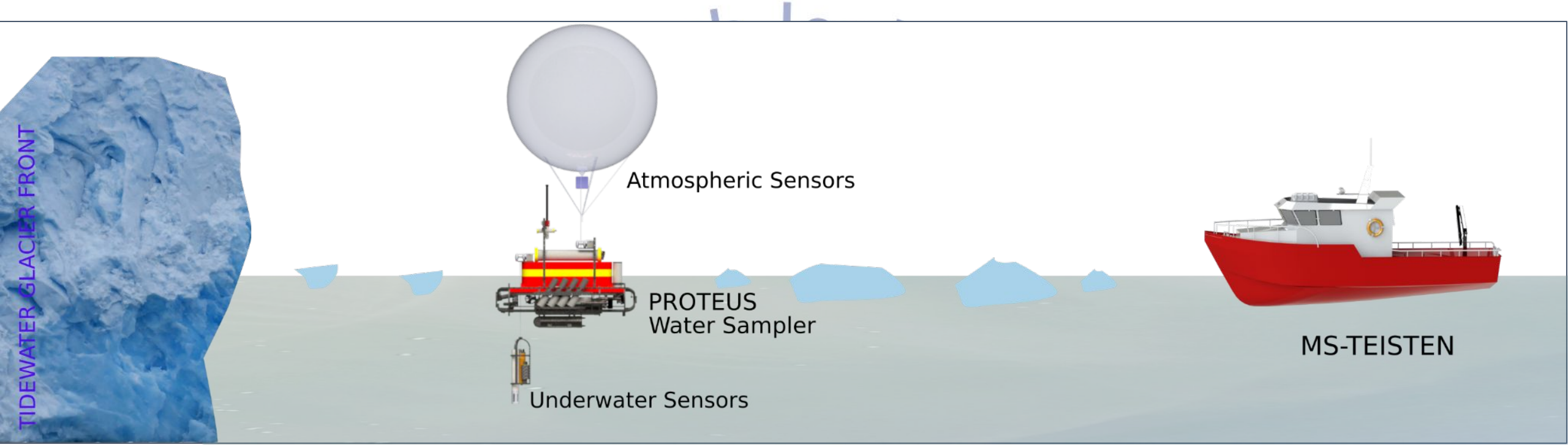

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