Motivation and Types

Today, several thousands of robots operate on and beneath the ocean surface. People may ask **Why do we need them? What do they do?** As engineers, our concern is with **how** to design competant systems, capable of operating robustly in one of the most unforgiving and extreme environment on our planet. This module teaches you the mathematical modelling, control and practical skills required to design, build and operate a functional maritime robotic systems.

Here we consider what drives the need for maritime robotic presense. These notes support **L01: System Design - Module Introduction** and **L02: System Design - Robot Types and Ocean Driving Design**. You should understand this context before moving on to the technical parts of the course.

Maritime Robotics

Robotics is the science of perceiving and manipulating the physical world with computer controlled devices. **Maritime** describes objects or activities related to the ocean. **Maritime robotics** is one of the most mature areas of mobile field robotics. Systems are widespread and routinely used due to a lack of alternative options. The subject is highly interdisciplinary, involving naval architecture, oceanography, electronics, control, sensing, communication, information processing, mechanical engineering, computer science, chemistry and material science. This module will focus on areas that are unique to maritme robotic systems (e.g. electronics, material design, stability are relevent, but not unique to robotics).

Some of the Maritime Robotic platforms at the University of Southampton and National Oceanography Centre

Why do we need maritime robotics?

The ocean covers 70% of our planet and fills 90% of liveable space. 50% of oxygen we breath comes from the ocean, and it absorbs 50% of carbon dioxide we produce. 16% of global protein intake is from fish and 13% of UK energy comes from offshore renewables. Yet < 5% of the ocean has been explored.

Robotics and autonomous systems (RAS) are identified as 1 of 8 great technologies in the UK industrial strategy. Benefits of RAS in the ocean are:

- Removal humans from remote, dangerous and uncomfortable environments
- Reduced risk of human error through the use of repeatable algorithms and processes
- Efficient and extended operational envelopes with platforms operating 24/7 that are scalable in number

The applications of of maritime robotics span **science**, **commercial** and **defence**.

Various types of maritime robot

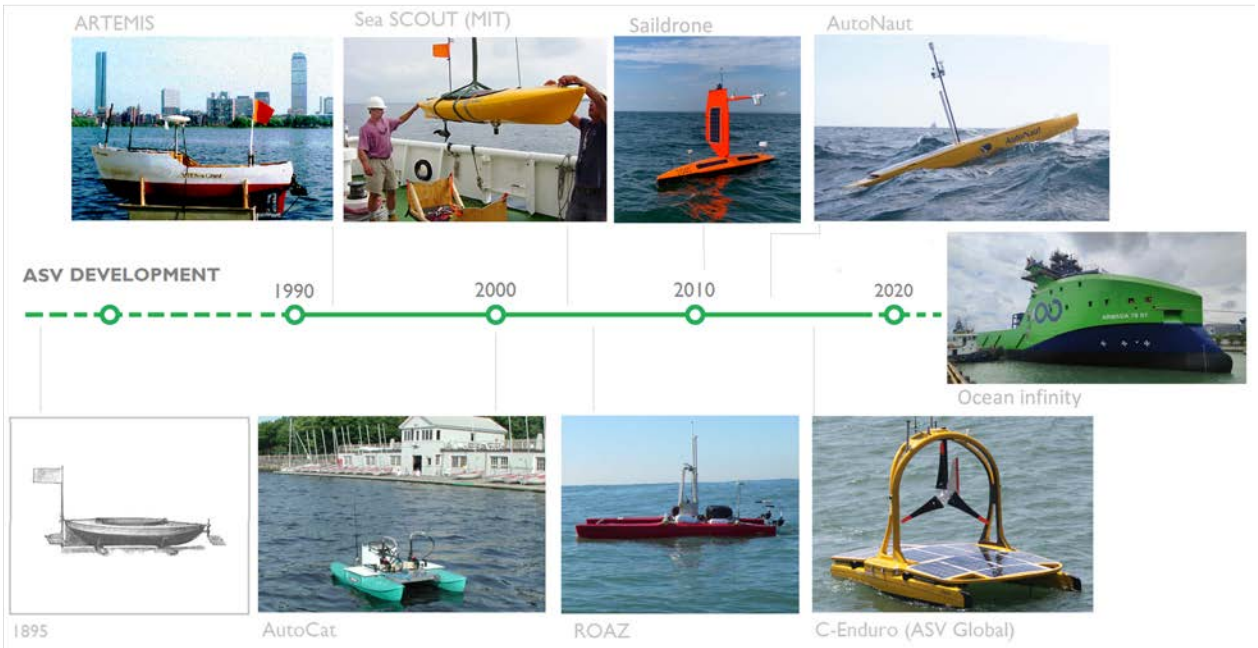
Many different types of robot are needed to address a wide range of maritime applications

Uncrewed Surface Vehicles (USV)

USVs are self propelled, untethered, crewless platforms. The majority of these are relatively small vessels (100 kg to 5 tonne) use for survey, although USVs as large as 80m long weighing 1000 tonnes have been recently launched (September 2022).

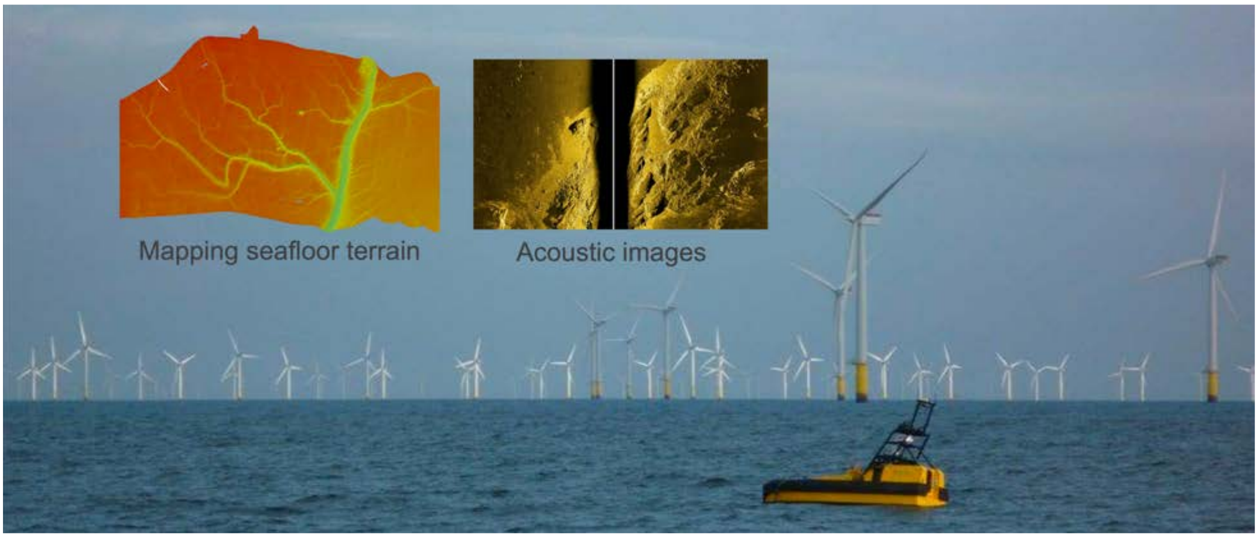
High energy USVs are used to track and localise submersibles and perform hydrographic surveys, long endurance USVs typically use wind or wave energy for propulsion and monitor oceanographic parameters, larger vessels are intended to deploy tethered submersibles and transport goods.

USV development started relatively recently, with the first examples in the 1990s



USV development timeline

The figure below shows an example of hydrographic surveys carried out by a compact high-energy USV. The advantage over crewed vessels is significantly reduced operational cost, and the small size allowing them to operate in shallow water.

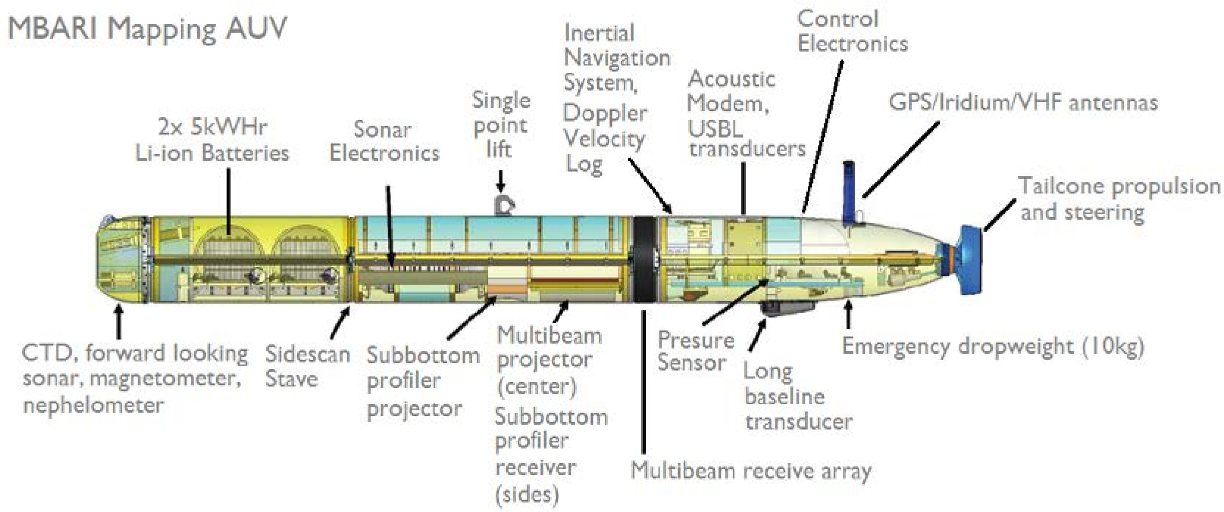


Time consuming hydrographic surveys carried out in extremely shallow water

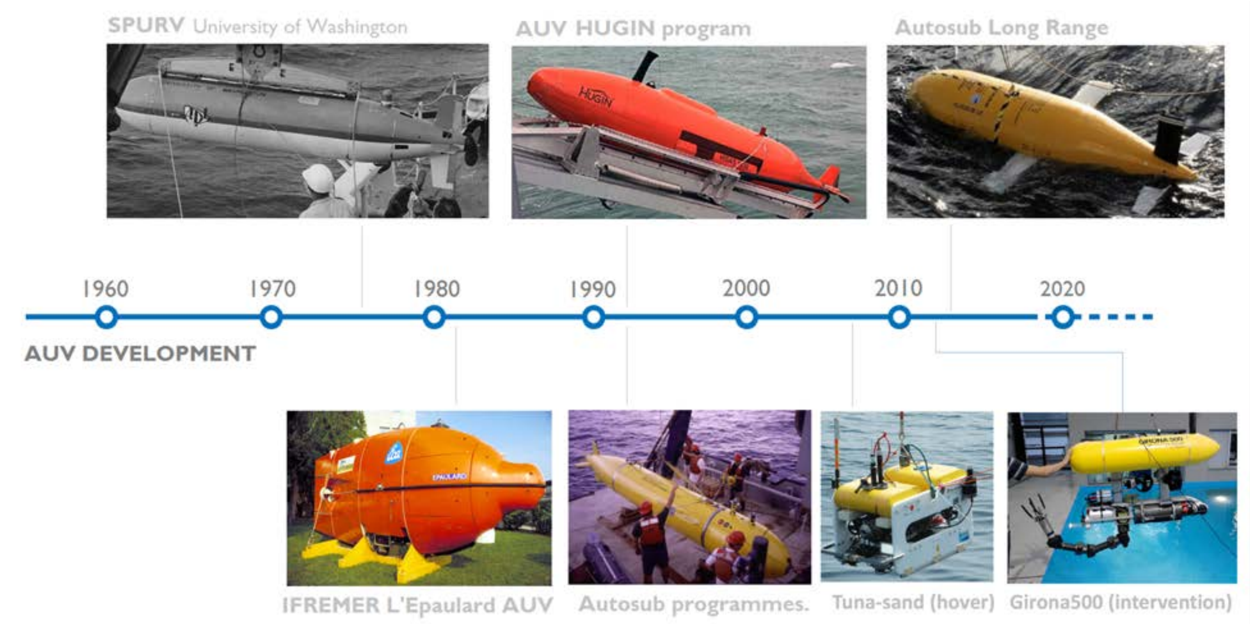
Long endurance systems use environmental forces for propulsion (wind, waves) and carry significantly less instrumentation. They are less manouvrable and have limited instrumentation. Their main advantage is that they can remain distributed in the ocean for several months to years, and so can opportunistically capture dynamic weather events.

Autonomous Underwater Vehicles (AUV)

AUVs are self-propelled, untethered crewless submersibles. They carry their own energy source and actuators, and a controlled by local computational hardware and algorithms.

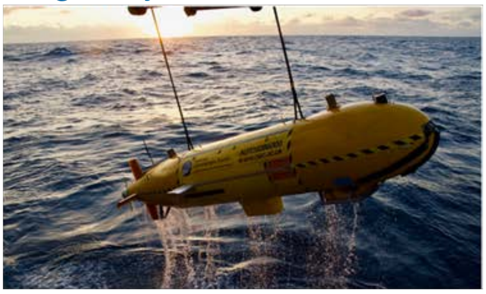


AUV construction



AUV development timeline

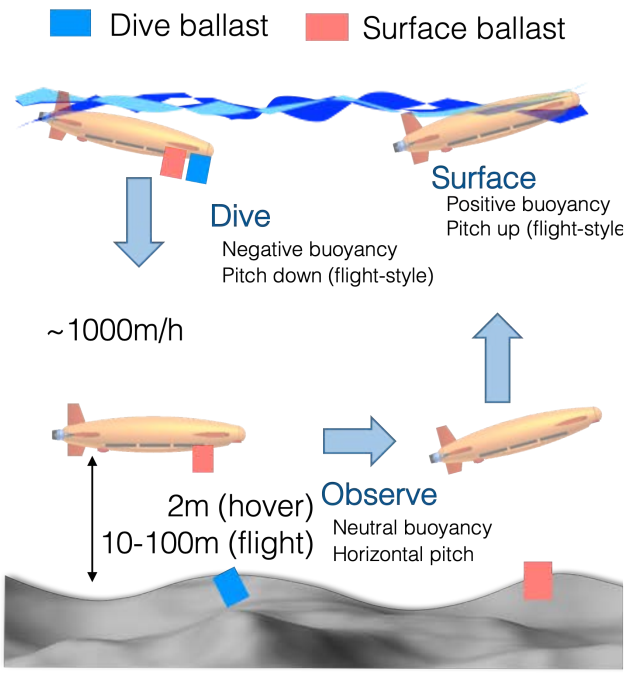
Flight-style platforms operate with continuous forward velocity (0.5 to 3m/s) and at high altitudes of 50 to 200m off the seabed. They often use acoustic mapping instruments (see sensors notes) to gather metre resolution information about seafloor terains, and can operate for a few days at a time. Although compact systems exist (50 to 100kg), they are often large enough (800kg to several tonnes) to house enough batteries to achieve a long endurance. **Hover-stlye** platforms have large numbers of thrusters (including vertical) and are capable of 3d station keeping and turning on the spot. They operate at lower speeds (0.3 to 0.5m/s), and are typically used for close inspection of seafloor or infrastructure, getting to within a few metres of their targets and taking acoustic or optical imagery and scanning the seafloor with acoustics or lasers to gather centimetre resolution data. Several systems have demonstrated docking and intervention capabilities. They typically operate for less than a day, and are relatively compact (50 to 800kg).



	Flight-style	Hover-capable
Characteristics	Untethered, battery powered single dive cycle	Untethered, battery powered single dive cycle
Size	2-12m long, 50-8000 kg	2-4m long, 50-800 kg
Dive time	Battery limited (8-72h)	Battery limited (<12h)
Speed	1 to 3m/s	0.3 to 0.5m/s
Mission type	Acoustic seafloor observation (large data volume)	Visual seafloor observation (large data volume)

Examples of flight-style and hover-style AUVs

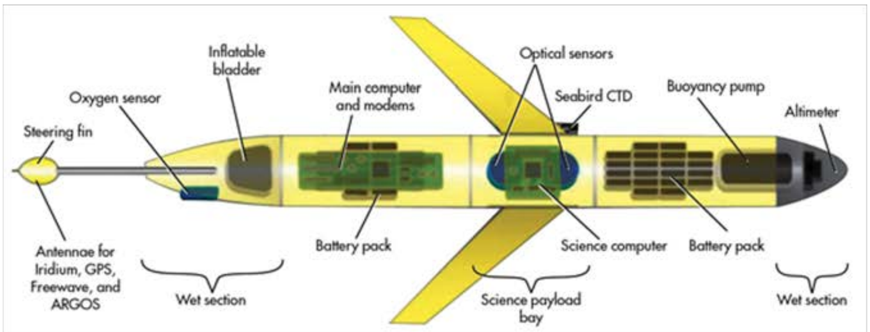
AUV seafloor surveys typically involve a single dive cycle, where the platform is recovered to replenish energy sources and download large data files. AUVs often carry one or more drop-weights to minimise energy use getting to, and back from the seafloor. These also act as safety systems, where weights can be magnetically held so that they are released if energy is lost, or are somtimes held using corroding elements so that they are passively released after a given period. This allows vehicles to return to the surface and transmit their position over satellite for eventual recovery.

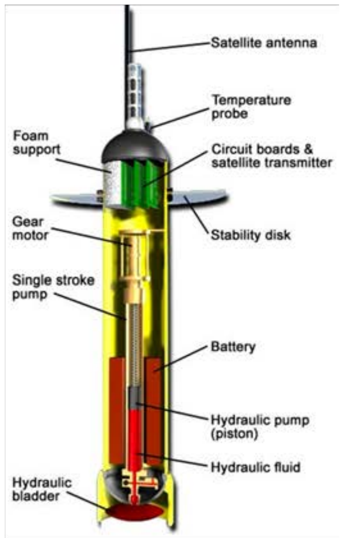


Examples of flight-style and hover-style AUVs

Gliders and Floats

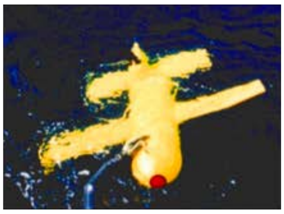
Gliders and floats are low energy platforms that gather physical oceanographic parameters (depth profiles of temperature, salinity, currents) for use in climate forcasts. Gliders operate for months, Argo floats operate for 5 years. Both platforms use variable buoyancy engines to repeatidly move up and down through the watercoloum. Argo floats 'measure' underwater currents by maintaining a fixed depth for 10 days during their dive profiles, and recording how much they have drifted between diving and surface using GPS when they are at the water surface. They do not need to be regularly recovered because the volume of data individual platforms gather is sufficiently small to transmit to shore over satellites.





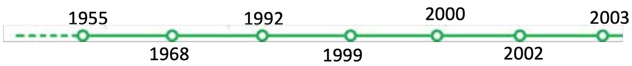
Swallow Floats – Cambridge Uni.

ALBAC Glider– University of Tokyo



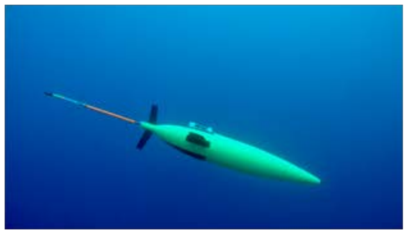
Argo - International

Spray - SIO



SOFAR Floats – Woods Hole Oceanographic Institute

Slocum – Woods Hole Oceanographic Institute



Seaglider – University of Washington

Construction of gliders and floats

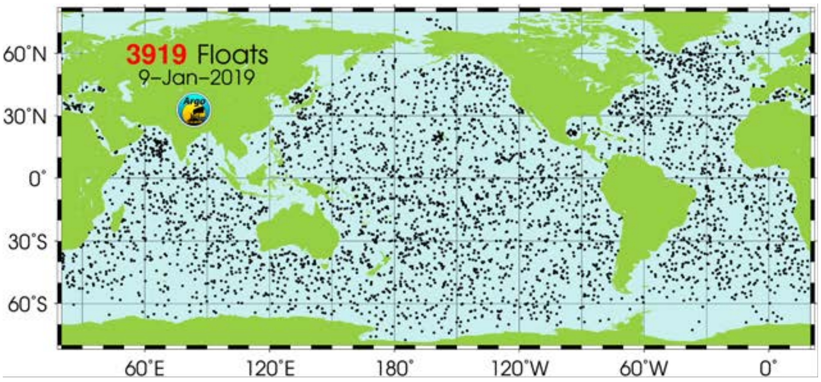
Glider

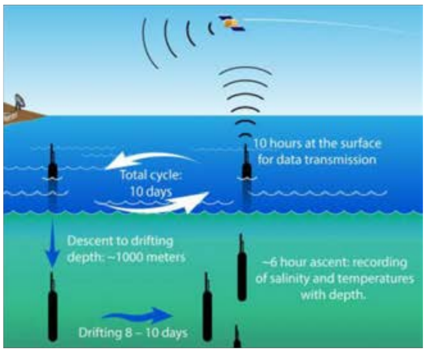
Argo floats

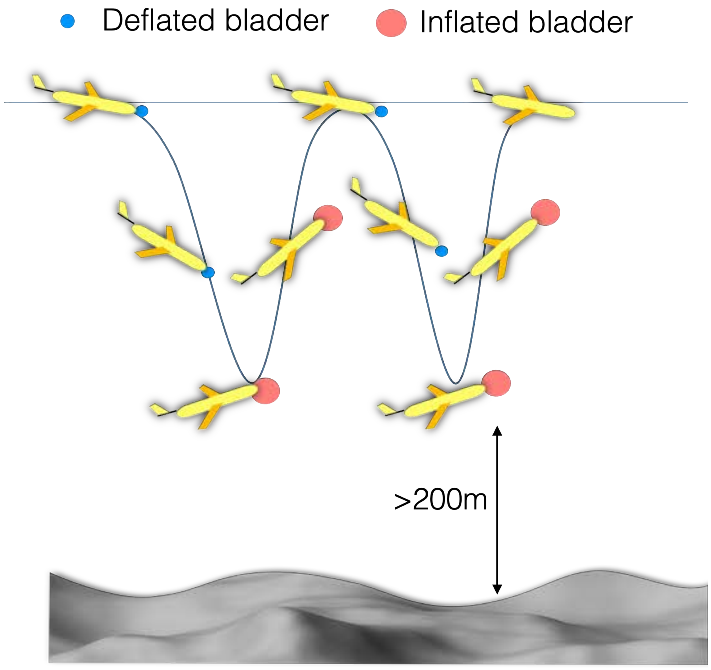
Characteristics	Untethered, battery powered multiple dive cycles	Untethered, battery powered multiple dive/drift cycle
Size	1.5-2 m long, 50~80 kg	1.3m long, 40 kg
Dive time	Battery/reliability limited (4-12months)	Battery/reliability limited (<5 years)
Speed	~0.3m/s	Drift on currents
Mission type	Physical oceanography (small data volume)	Physical oceanography (small data volume)

Specification of gliders and floats

The fact that their operation is independent of physical support means that gliders and Argo float deployments can scale to large numbers and cover global footprints.







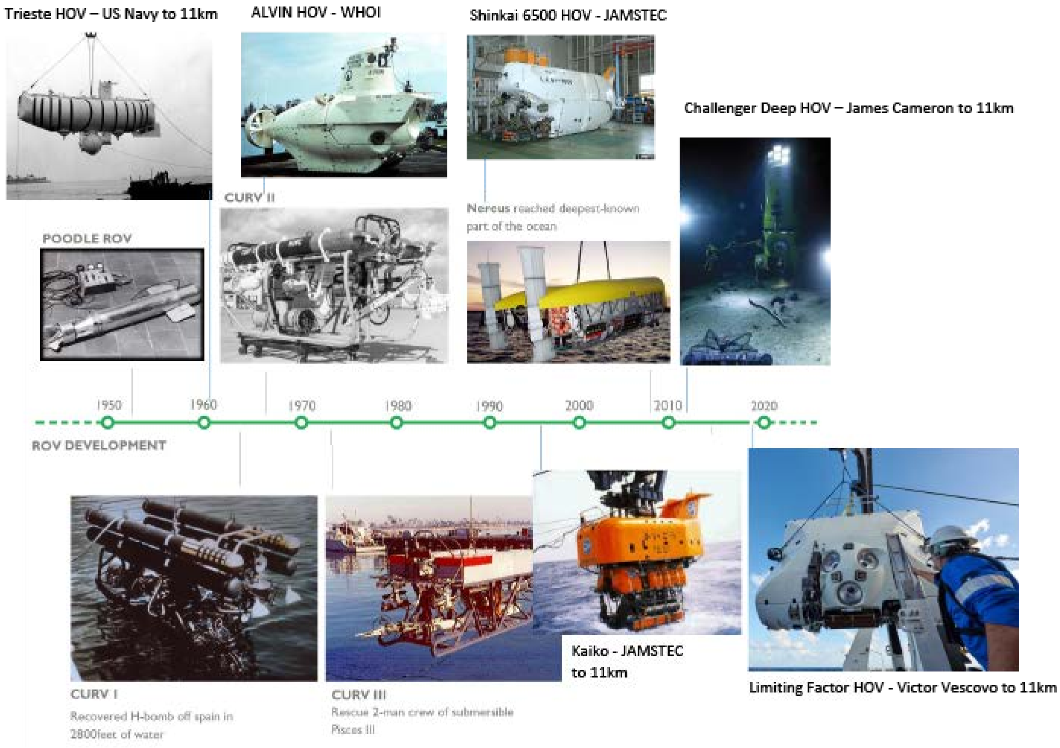
Global distribution (left) and mission profile (right) of Argo floats. The bottom figure shows the dive profile of gliders

Human Occupied Vehicles and Remotely Operated Vehicles

Crewed submersibles and ship tethered systems are typically powerful (50 to 150 HP) and rely on continuous human operation. They are used for complex missions that involve sampling, rescue, intervention and cinematography.

	Human operated vehicle	Remotely operated vehicle
		
Characteristics	Untethered, battery powered, 1-3 humans	Tethered, powered via cable
Size	7-12m long, 10-30 tonnes	2-5m long, 1-10 tonnes
Dive time	Human limited (8-12h), life support (>56h)	Maintenance/reliability limited (<72h)
Mission type	Visual seafloor observation, sampling	Visual seafloor observation, sampling, intervention

HOV and ROV specifications



HOV and ROV development timeline

HOVs need to be large (>10tonne) to accomodate humans and additional safety, mission durations are typically a few hours and operations are complex and expensive due to the involvement of humans. ROVs come in all sizes, from 10kg to 100 tonnes. Operations are complicated due to the need to manage the tether. However, the tether also allows for large amounts of power to be supplied, real-time transmission of video and sensor data, and recovery of larger amounts of samples (geological or biological) as the platforms can be physically lifted out of the water by the tether.

Examples of geological (left) and biological (right) sampling

Wrap up

You should now recognise the different types and applications of maritime robots. Next, we will discuss the common challenges posed by operating these complex systems in the ocean, and the shared robotic solutions needed to achieve robust and competant behaviour.