KULLIYYAH OF ENGINEERING

DEPARTMENT OF MECHATRONICS ENGINEERING

UNDERWATER AND AERIAL ROBOTS (MCTA 4372)

Week 1 :

Comparative Analysis of ROV, AUV, and USV in Fieldwork Applications within Underwater Robotics Technology

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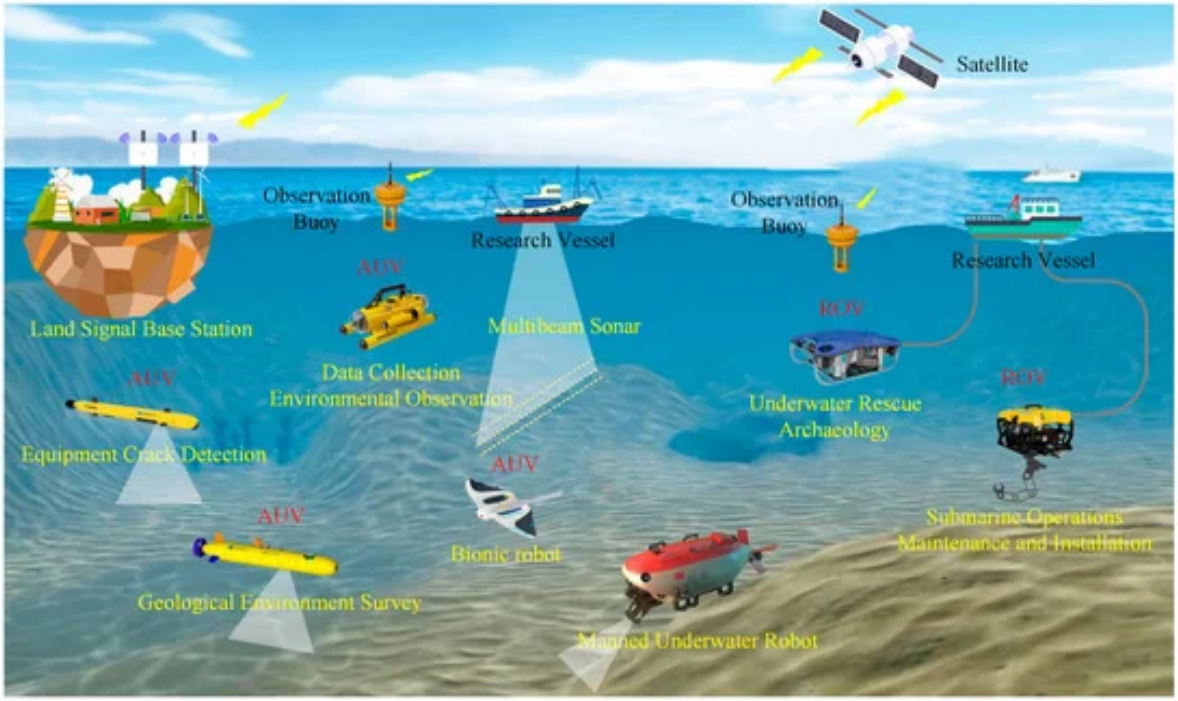
1. Introduction

- Brief overview of underwater robotics technology and its significance in marine exploration and industry.

Underwater robotics technology involves the process of designing, constructing, and operating robots that function underwater or in subaquatic conditions. These robots come in various forms, including ROVs and AUVs, some of which can operate autonomously or be remotely controlled via radio signals or other means(Miller, 2024).



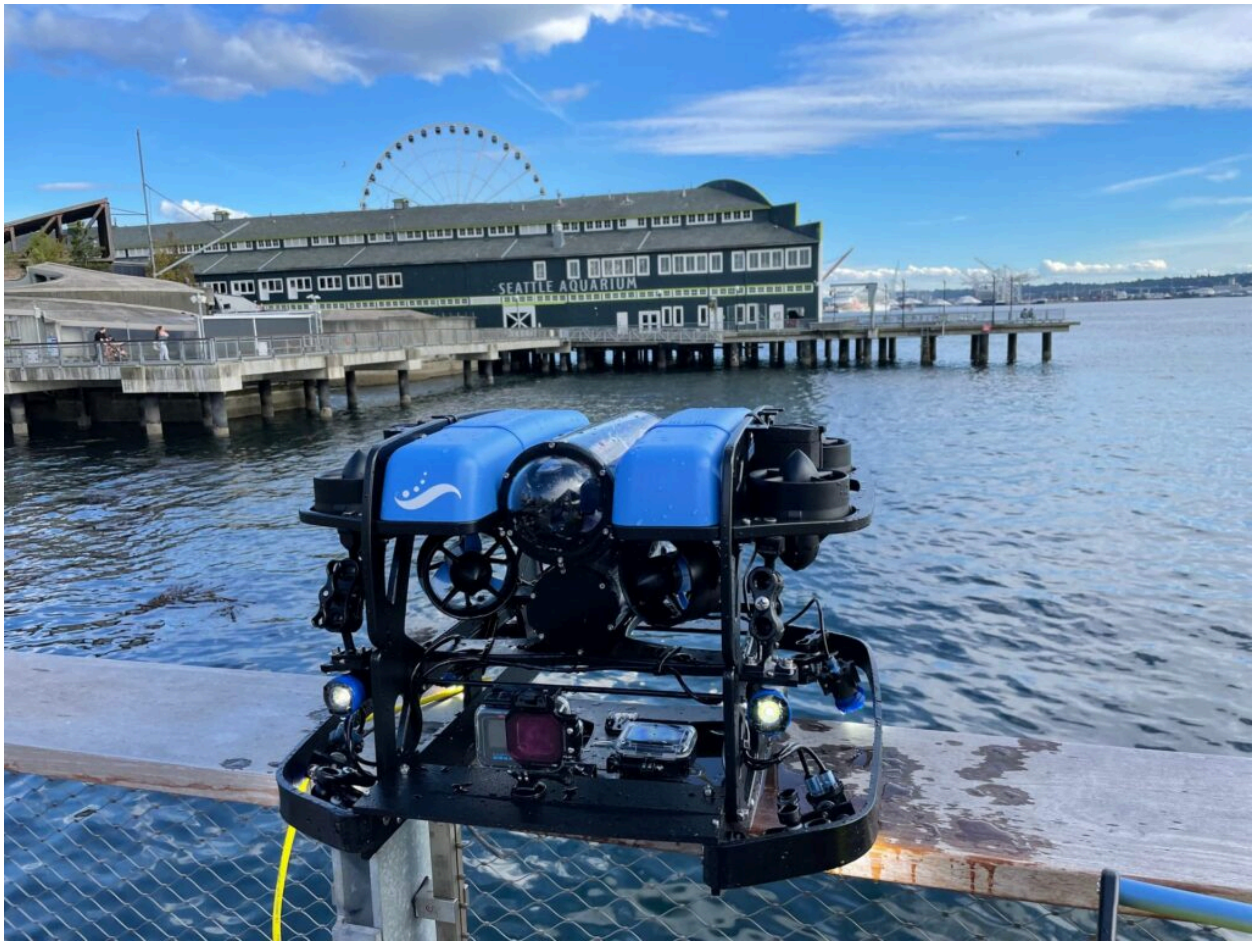
The primary purpose of these robots is to carry out tasks in submerged environments that are challenging or unsafe for humans to perform, such as underwater surveys, maintenance, and research. To accomplish these tasks, a variety of sensors can be integrated into the robots. Additionally, different designs and sizes of robots can be utilized to enhance their effectiveness in completing tasks underwater.

Definition of ROVs, AUVs, and USVs, including their primary features.

Some of the underwater robotic technologies available today include Remotely Operated Vehicles (ROVs), Autonomous Underwater Vehicles (AUVs), and Unmanned Surface Vehicles (USVs). These terms can be used interchangeably for vessels and vehicles. The primary use for

these robots is surveying and mapping in underwater conditions. A USV can function like a light rail transit on water.

Key features of an AUV include autonomy, underwater operation, navigation capabilities, and suitable sensors to perform its tasks effectively. Both underwater ROVs and USVs can be remotely controlled from a distance using radio signals. These robots are designed to operate without the need for human presence, allowing for compact designs that do not account for accommodating passengers.



2. ROVs (Remotely Operated Vehicles)

The design and operational characteristics of ROVs

The main materials used to make an underwater ROVs are plastics, stainless steel, and aluminum. Some parts need to be waterproof to keep the electronics safe while underwater.The design usually very compact with multiple sensors and other tools and come with many

propeller thrusters pointing in different directions, which helps them move easily as it have many degree of freedom[3].It make the underwater ROV seems like underwater drone .

With these thrusters, they can stay in one place underwater for some time.There are different class of ROV according to it weight and size.Underwater ROVs are typically equipped with a tether, a cable or line that serves as a vital link connecting them to the surface or the location of the control station, ensuring seamless communication and control between the operator on the surface and the ROV exploring the depths below.

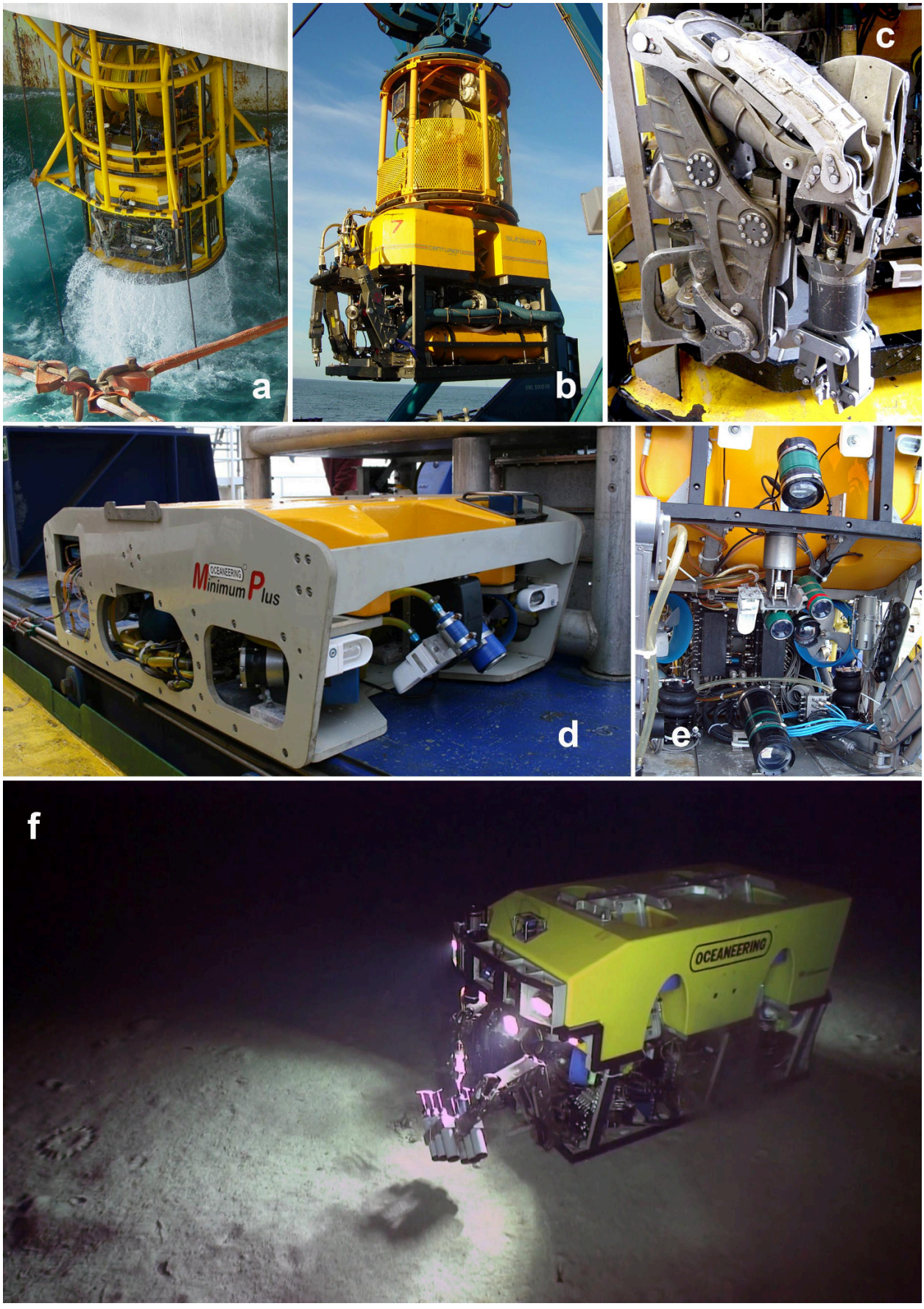
The advantages and limitations of using ROVs in underwater tasks.

Below is some advantages and limitation of underwater ROV:

Advantages	Limitation
Can work continuously without rest compare to human divers	Some of ROV equipment is heavy on the wallet for some group or party
Can covers wider area than human divers as it can swim through small spaces with its compact body	The depth range is limited by its umbilical cable length
ROV can be deploy in various cases compare to human divers that have some limitations like high pressure and cold temperature.	The inability of wireless communication systems to transmit video streams effectively in underwater environments and the coupling issue between the tether and ROV body can affect the stability of the ROV

Identify specific fieldwork applications where ROVs are preferred and justify their use.

ROVs are commonly used in the oil and gas industry to inspect underwater parts of oil rigs for issues, ensuring safety and functionality. They provide crucial inspections in areas inaccessible to divers, helping maintain the structures in good condition.The ROV also possible to do some maintaining work like underwater welding and drilling.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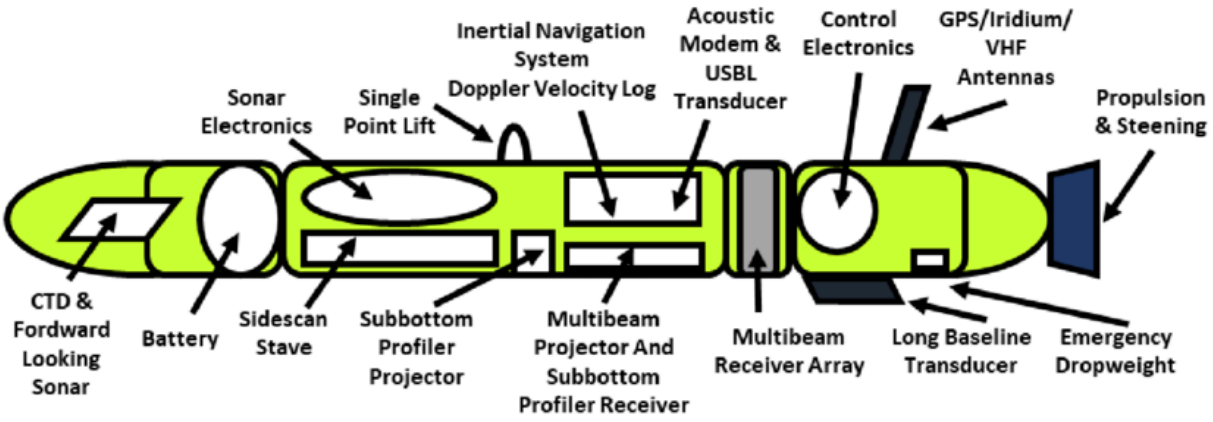
Other than oil and gas industry,ROV also can be use to conduct environmental study like hydrographic survey to map seafloor, for researcher to investigate the underwater ecosystem.The reason why ROV being used in those applications as the ROV can be remotely control even at hazardous area for human divers.It can keep the safety of human.By implement a good equipment at ROV,the high quality data can be acquired so the task can be completed effectively.

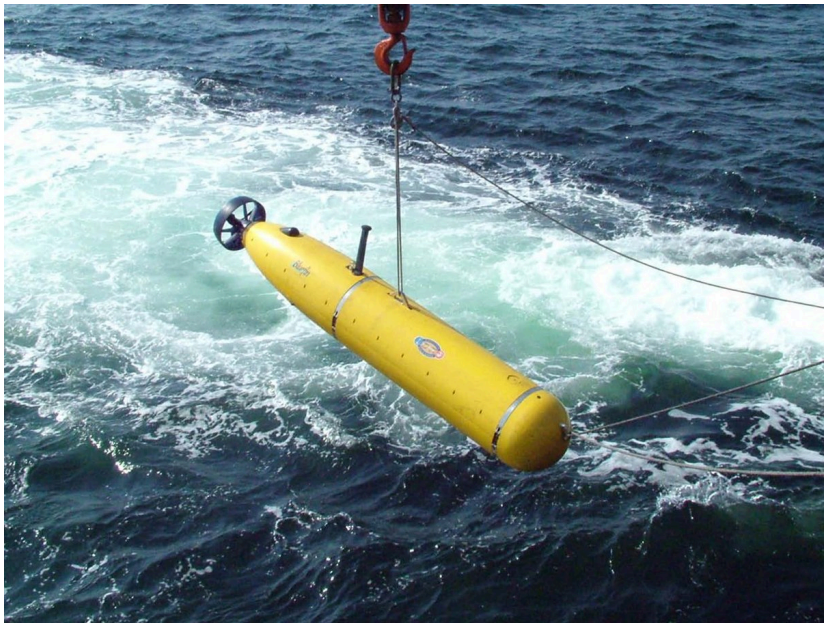
3. AUVs (Autonomous Underwater Vehicles)

The design and operational characteristics of AUVs.

Autonomous Underwater Vehicle or AUV is underwater vehicles that self propelled,untethered submersibles designed to performance numerous underwater tasks[6].



Commonly AUV come with torpedo shaped like.As we can see from picture above,its drive by single propeller.All equipment and sensors like sonar sensor,depth sensor,magnetometer and other components can be compacted inside the AUV to perform tasks like surveying and monitoring.The orientation of AUV being controlled by its steering that allowed the AUV to pitch,yow and roll.Its come with various size and weight according to what mission the AUV want to do.



Its can operate underwater without human real time control,so its can execute a tasks for a period of time without human intervention.By using proper battery capacity to run the AUV,the robot can be underwater to do tasks for longer period compare to human divers.High quality data for surveying and monitoring can be achieve by using AUV.

Advantages and limitations of AUVs in underwater exploration and data collection.

Below is the advantages and limitations of AUV in underwater exploration and data collection:

Advantages	Limitations
Able to go deep into bottom dead zone without limitations to umbilical cable.	The range and operation time of AUV is limited by battery capacity
Can cruise independently so other crew can save time by doing some other tasks	Data corruption and loss can be detected only after the end of cruise
Provide more effective and cost-efficiency in surveying as it use less tools to go underwater	Limited space of sensors compartment compare to others underwater vehicle as battery take space.
High quality data can be collected with large volume of data that can store numerous data from numerous missions.	Can experience hardware failure such as motor issues and battery life issues and hard to retrieve it if fail at seabed

Examples of fieldwork applications where AUVs offer significant benefits over ROVs and USVs.

Because of AUV capabilities that can go to seabed seamlessly,it usually used to do ocean floor mapping to study the underwater ecosystem.In oil and gas industry,AUV being used to do subsea pipeline inspection due to ability to do navigate complex underwater structure autonomously with high precisions and efficiency.

The very significant benefits of AUV to complete those task compare to ROV and USV is AUV can operate without real time human interaction and can provide high precisions and efficiency.AUVs boast a broader operational range compared to USVs and ROVs, as they don't require direct communication between humans and robots while operating underwater.

4. USVs (Unmanned Surface Vehicles)

The design and operational characteristics of USVs.

Unmanned Surface Vehicle(USV)is literally a boat without direct human control.Its come with various size and speed,according to it uses.The USV operate at surface of water,designed to fully self-righting, ensuring stability in various type of ocean conditions.USV being build and design so it can withstand ocean deployment and suitable to operating in dynamic marine environments.

Unmanned Surface Vehicles (USVs) can do a lot. They have different ways of operating, like attacking, working with humans, and collecting data. They're built with systems to launch and recover them safely. USVs are great at collecting ocean data on their own. They're also versatile and can do many tasks in different situations. USVs are made to work well in normal conditions and are vital for marine research, exploration, surveillance, and commercial activities because they can work autonomously in all kinds of marine environments.

The advantages and challenges of using USVs in marine research and industrial applications.

Below is advantages and challenges of using USVs in marine research and industrial applications.

Advantages	Challenges
USV offer autonomous operation,no need human interaction and intervention	Complexity in control systems,due to deadband and sudden change in propulsion mechanism
Can reduced operational operation compared to crewed vessel	Hard to ensure protection of cargo
Capable to offer real life data collection,for environmental monitoring	Some maritime regulations may not directly applicable to USV
Versatile uses,can use for environmental surveying and border monitoring also underwater mapping	An innovative approach can be proposed for inner hull,where it can automatically recover by itself if outer hull tilting

Scenarios where USVs are the most suitable option for marine fieldwork

Unmanned Surface Vehicles (USVs) are super useful in marine work for many reasons. They're great for keeping an eye on the environment, doing surveys, and even helping with search and rescue missions. They're also handy for commercial surveys, working alongside traditional boats to cover more ground and save money. USVs are also used in research to test new ideas and make sure navigation systems are reliable. In all these tasks, USVs show they're efficient, affordable, versatile, and good at collecting data, making them valuable tools for marine work.

5. Comparison and Selection Criteria

Comparasition between ROVs, AUVs, and USVs in terms of technology, operational depth, autonomy, data collection capabilities, and cost-effectiveness.

Aspect	ROVs	AUVs	USVs
Technology	Controlled from surface vessel	Independent	Autonomous or remotely controlled
	Cameras, sensors, manipulator arms	Sensors, scanners	Various tasks like surveys, monitoring, rescue
Operational Depth	Thousands of meters underwater	Over 6000 meters	Typically surface operations, not for deep-sea
Autonomy	Controlled from surface vessel	Fully autonomous	Autonomous or remotely controlled
	Not fully autonomous	Can adapt missions	Able to operate without constant human input
Data Collection	Cameras, sensors, sample collection	Various sensors	Mapping sensors, deploy underwater vehicles
	Real-time feedback	Autonomous data collection	Data collection capabilities
Cost-Effectiveness	Cheaper than crewed submersibles	Cost-effective, environmentally friendly	Cost-effective, versatile
	Slower for wide-area data collection	Covers large areas at lower costs	Suitable for various tasks, including surveys

The criteria for selecting an ROV, AUV, or USV for specific types of marine fieldwork and research projects.

When choosing between an ROV, AUV, or USV for marine fieldwork and research projects, several factors need consideration. Firstly, the operational depth required for the task plays a crucial role. ROVs are suitable for depths of thousands of meters, while AUVs can dive even deeper, over 6000 meters, and USVs typically operate on the water's surface. Autonomy is another key factor, with ROVs tethered to surface vessels, AUVs operating autonomously, and

USVs offering both autonomous and remote control options. The type and quality of data needed influence the decision as well; ROVs provide real-time feedback, AUVs collect data autonomously, and USVs can be equipped with mapping sensors. Cost-effectiveness also matters, with ROVs being more affordable than crewed submersibles, AUVs offering cost-effective and eco-friendly alternatives to traditional vessels, and USVs being cost-effective for various tasks. Technology requirements, environmental conditions, and specific project needs further shape the decision-making process. By carefully considering these criteria, researchers and fieldwork teams can choose the most suitable vehicle for their marine projects.

6. Case Studies

Effective Use of ROV, AUV, and USV in Fieldwork Scenarios

Case Study	Scenario	Vehicle Selection	Impact
ROV Case	Conducting a deep-sea archaeological survey to explore a sunken shipwreck at 3000 meters depth.	ROV with advanced manipulator arms and high-resolution cameras for detailed inspection.	The ROV allowed precise maneuvering and close-up examination of artifacts, providing valuable data without risking human divers. Detailed documentation of the shipwreck's condition and historical significance was achieved.
AUV Case	Mapping underwater geological features in a remote ocean region at depths exceeding 5000 meters.	AUV equipped with advanced sensor payloads for autonomous data collection.	The AUV autonomously surveyed the area, collecting high-resolution data on seafloor topography and geological structures. Detailed maps were generated for scientific research and resource exploration.
USV Case	Monitoring marine pollution levels along coastal regions for environmental research.	USV with integrated water sampling equipment and real-time monitoring sensors.	The USV autonomously navigated coastal waters, collecting water samples and monitoring pollution levels in real-time. Real-time data on pollution sources aided environmental conservation efforts.

Analysis of Vehicle Selection Impact
ROVs: Ideal for precise inspections and manipulations at great depths where human divers cannot reach, ensuring detailed data collection without endangering human lives.
AUVs: Excel in autonomous data collection tasks in remote or deep-sea environments, providing high-resolution mapping capabilities for scientific research and resource exploration.
USVs: Effective for autonomous monitoring tasks in coastal areas, offering real-time data collection capabilities for environmental research and conservation efforts, enhancing efficiency and reducing operational costs.

7. Conclusion

Summarization of distinctions among ROVs, AUVs, and USVs in underwater robotics technology

Remotely Operated Vehicles (ROVs):

- Operated from the water's surface and connected to a controller by a tether.
- Equipped with cameras, lights, sonar systems, and manipulator arms.
- Ideal for precise inspections and manipulations in challenging underwater environments. Provide real-time feedback to operators for adjustments during missions.
- Capable of capturing high-quality visual data and performing tasks like object identification and vessel hull inspections.
- Slower and less cost-effective for wide-area data collection compared to AUVs.

Autonomous Underwater Vehicles (AUVs):

- Torpedo-shaped vehicles that operate autonomously without tethers.
- Carry sensors for survey missions and adapt tasks based on encountered conditions.
- Capable of diving to depths exceeding 6000 meters for deep-sea exploration and mapping. Conduct survey missions without operator intervention.
- Collect high-resolution data on seafloor topography, geological structures, wrecks, rocks, and obstructions without human control.
- More cost-effective than crewed submersibles for wide-area exploration.

Unmanned Surface Vehicles (USVs):

- Unmanned surface vessels used for marine applications like hydrographic surveys and environmental monitoring.
- Typically operate on the water's surface and not designed for deep-sea exploration.
- Offer autonomous operation capabilities, reducing the need for human intervention.
- Equipped with mapping sensors for efficient data collection in coastal regions. Cost-effective options for marine research projects due to versatility and efficiency.
- These distinctions highlight the unique features, capabilities, autonomy levels, data collection methods, and cost-effectiveness of ROVs, AUVs, and USVs in underwater robotics technology, aiding navigation and readability.

The importance of selecting the appropriate vehicle type for specific applications in marine exploration and research

Selecting the right vehicle for marine exploration is crucial. Here's why:

- Training: Proper training is key for effective vehicle operation.
- Integration: Bringing together operators, subsystems, and sensors ensures mission success.
- Mission Needs: Each mission requires specific depth, endurance, and sensor capabilities.
- Technology: Continuous advancements enhance vehicle performance.
- Cost: Choosing the most cost-effective option is essential.

Overall, matching vehicle capabilities with mission requirements ensures successful outcomes in marine exploration.

8.References

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