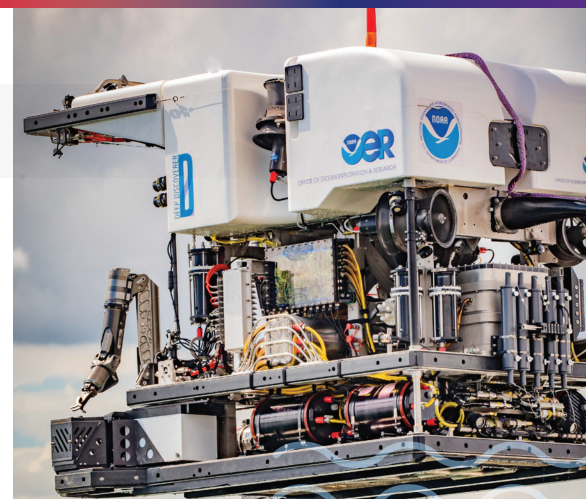
Which Robot When?



Overview

TOPIC: Underwater Robots

FOCUS: The varied technical capabilities of underwater robots (Physical Science/Engineering)

GRADE LEVEL: 6th-8th; extension and differentiation provided to adapt to other grade levels

TIME NEEDED: One or two 45-minute class periods

DRIVING QUESTIONS:

How can underwater robots help ocean explorers gather data under a variety of ocean conditions?

How do ocean explorers determine which piece of technology is best suited for their mission?

OBJECTIVES/ LEARNING OUTCOMES:

Students will:

- Become familiar with a variety of Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs) that are used by ocean explorers.
- Analyze a variety of mission scenarios that underwater robot exploration devices might encounter.
- Distinguish shape and structural features among at least three types of underwater vehicles that make each suitable for specific ocean exploration tasks.
- Discuss, analyze and decide which vehicle is best suited for which situation.
- Participate in group decision-making to reach consensus.

MATERIALS:

- Board, flip chart, or preferred online platform for tracking Which Robot When for each mission scenario
- Student handouts

NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance Expectations
MS-ETS1-1; MS-ETS1-2

Disciplinary Core Ideas
MS-ETS1.A; MS-ETS1.B

Crosscutting Concepts
Influence of Science, Engineering, and Technology on Society and the Natural World

Science & Engineering Practices
- Asking Questions and Defining Problems
- Developing and Using Models
- Engaging in Argument from Evidence

COMMON CORE CONNECTIONS
RST.6-8.1

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS
P7: FCb, FCd, FCf

Overview

SET-UP INSTRUCTIONS:

Make copies (or provide electronically to students):

- Exploration Vehicle Capability Survey (page 8) (one per team, maximum of six teams).
- *Exploration Vehicle Summary Sheets:* There are six different sheets; each team (maximum of six teams) will explore the characteristics of one of these robots. For each team, provide one copy per student so that each can read simultaneously (provide fewer copies to minimize cost/paper use).
- *Mission Scenarios* (six scenarios; each team gets one).
- *Mission Collaborative Scenario* (one for each team).

Copy the Mission Scenario Solutions chart on the board, flip chart, or online platform so that students can enter and share data with the class.

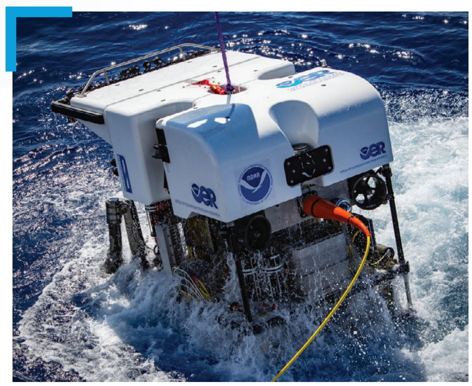
Cue up videos for student viewing:

- *Rare Sperm Whale Encounter with ROV*
- *Gulf of Mexico 2012 Monterrey: Exploring a 19th Century Shipwreck*

Educator Guide

Background

Many ocean explorers depend on robots to explore the ocean. Underwater robots allow work to be carried out at a variety of ocean depths without the expense and limitations of human-occupied submersibles. Remotely Operated Vehicles (ROVs) are linked by a tether, or bundles of cables, to a ship. An operator on board the surface vessel pilots the ROV using this tether for communication. Autonomous Underwater Vehicles (AUVs) operate independently and are not tethered- like drones that operate underwater.



ROV *Deep Discoverer* being launched off the back deck of NOAA Ship *Okeanos Explorer. Image courtesy of NOAA Ocean Exploration.*

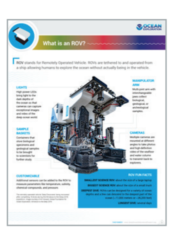
Guiding Questions

Questions to guide students toward answering the **Driving Questions**:

1. **How can underwater robots help ocean explorers gather data under a variety of underwater conditions?**
   - What conditions make underwater exploration challenging, compared to terrestrial (land) exploration? *(inability to breathe underwater; pressure even at moderate depths; cold temperatures; rough currents; lack of light)*
   - What capabilities do underwater robots have that exceed those of humans? *(they never tire; they can withstand a greater range of temperatures; they can be designed to withstand intense pressure; they do not require oxygen)*
2. **How do ocean explorers determine which piece of technology is best suited for their mission?**
   - When selecting a tool for any job, what must you consider? *(form; function; purpose/goal)*
   - What factors should be considered regarding a dive mission? *(maximum depth; size of area to be explored; potential obstacles; time needed on the seafloor)*
   - What are the various functions that an ROV or AUV can perform? *(collection of biological, geological and chemical [water] samples; photography; videography; bathymetric mapping)*

FOR MORE INFORMATION:

- *ROV Fact Sheet*



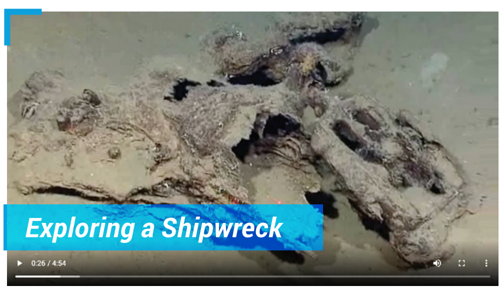
- *AUV Fact Sheet*

Educator Guide cont.

ENGAGE

- Show one or both of the following videos to get students thinking about the different ways underwater robots are used in scientific exploration of the deep ocean.
  - Ocean Exploration Trust video: *Rare Sperm Whale Encounter with ROV* (4:24)

  - NOAA Ocean Exploration video: *Gulf of Mexico 2012 Monterrey: Exploring a 19th Century Shipwreck* (4:54)



- Show one of these two Coordinated Robotics videos from Schmidt Ocean Institute to help students understand use of underwater robots in the field.
  - *Coordinated Robotics 2 - Wrap Up - FK180119* (5:02)
  - *Coordinated Robotics 2 - Week 01 - FK180119* (2:37)
- Ask students to share their observations about how robots are used for underwater exploration? Are all robots used the same?
- Introduce students to the task they are to accomplish by reading the following Student Task statement:

STUDENT TASK

Your task is to investigate underwater robots that can be used to perform various jobs that support scientific exploration of the deep ocean. You will work in teams to explore the tools and capabilities of six different Remotely Operated Vehicles, or ROVs, and Autonomous Underwater Vehicles, or AUVs, and determine which of these robots is the best one to complete specific missions.

EXPLORE

- Break the class into as many as six teams, each with four or five students, and assign a one-page summary sheet of one robot to each student on a team (*Exploration Vehicle Summary Sheets*).
- Teams should read through and discuss the description of their assigned ROV or AUV, paying attention to its specific capabilities and limitations. Each team will complete the worksheet *Underwater Vehicle Capabilities Survey* (page 8) to document capabilities for their vehicle. As a team, they are now "content experts" on their vehicle.
- Have students assign one person from each team to serve as a Mission Manager. Each Mission Manager will be given one of the Mission Scenarios.
- Each Mission Manager will present their scenario to the entire classroom and ask the teams to determine if their vehicle would work best for that Scenario. Teams should be able to reach a decision (Yes/No) in about five minutes.
- Lead students through three rounds of Mission Scenarios.

EXPLAIN

- After three rounds of Mission Scenarios, ask each team to send one or two members to another team—thereby increasing the knowledge of a second vehicle to the newly formed team.
- Run the remaining three Mission Scenario descriptions and ask the teams to refer to their vehicle knowledge to determine which robot best suits the work in each scenario.
- Ask each Mission Manager to post the results of Which Robot When into the Mission Scenario Solutions chart to document the results.
- Have a full class discussion on the process and results:
  - What information did you need in order to make these decisions?
  - Was there more than one answer/vehicle for some Mission Scenarios?

ELABORATE

- For the mission scenarios that had more than one possible answer/vehicle, ask the Mission Managers from each of those teams to share with the class their group's reasoning as to why their vehicle would be the best choice for that mission scenario.
- Lead a class discussion to see if the class can come to a consensus and select one vehicle that would be best for each mission scenario.

Educator Guide cont.

EVALUATE

- Share the final Mission Collaborative Scenario with all teams.
- This scenario is a collaborative mission, as no single ROV or AUV could efficiently accomplish all that is needed; however, the mission could be successful with a team of underwater robots. Have student teams discuss if their team's underwater robot would work and ask, "Could your underwater robots work together? How would you do that to execute a successful mission?"
- Try one of the assessment options on page 7.

Extensions

Suggestions for related activities

- Extend the discussion of why underwater research is important after having students read this article and watch these videos about the discovery of a live giant squid:
  - NOAA Ocean Exploration video: *Here Be Monsters: We Filmed a Giant Squid in America's Backyard* (:28)
  - Off the coast of Japan - *How We Found the Giant Squid | Dr. Edith Widder* (8:21)
- Have students examine the future potential uses AUVs in space exploration by reviewing *The Rise of Orpheus* on the Woods Hole Oceanographic Institution's website.

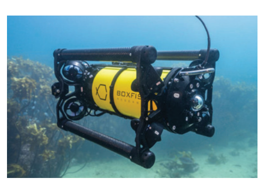
Suggestions related to other disciplines

- Write a compelling argument for the government to provide more funding to organizations that conduct underwater exploration.
- Explore how the name of the AUV *Orpheus* and the hadal zone it is designed to explore (6,000-11,000 meters—the deepest part of the ocean) relate to Orpheus and Hades in Greek mythology.
- Research famous oceanographers such as Sylvia Earle, Robert Ballard, Jacques Cousteau, and Vagn Ekman to learn what tools they use(d) for underwater exploration.
- Sketch a 2-D model of an ROV.
- See how MBARI's marine operations staff and ROV pilots performed an intricate underwater robot ballet 650 meters (2,000 feet) below the surface of Monterey Bay. *https://www.youtube.com/watch?v=m-Get7opYt0*

Check out how an ROV was used to record an underwater music video: *https://www.boxfish.nz/case_study/underwater-music-video/* (3:51)

Check out the music video for Caught in the Undertow by rock band Black Smoke Trigger: *https://www.youtube.com/watch?v=gSfvCxdvi3A* (1:07)

The Caught in the Undertow video by Black Smoke Trigger was shot using the Cinematic Boxfish ROV. *Image courtesy of Boxfish Research.*



Mission Scenarios cut and give one scenario to each team

1

We are planning an expedition to study an unexplored area off the coast of Alaska with a maximum depth of 1,800 meters. Ocean explorers are particularly interested in mapping scarps (a steep slope or cliff, formed by the movement of a geologic fault, a landslide or erosion). We want to investigate the water salinity near the feature. We will also sample organisms that may be living on these formations. One challenge of working in this area during much of the year is bad weather and sea ice.

2

Our team is studying an unexplored chain of underwater volcanoes. These may be extinct or potentially active. We want to sample geological formations as well as biological communities. We won't know exactly what types of samples will be needed until we can illuminate and see the area. The bases of these volcanoes are about 4,500 meters deep. Their summits (peaks) are around 1,500 meters deep. One of our lead researchers is not able to go to sea due to family obligations. He is very interested in participating remotely by watching a livestream video of the exploration.

3

While a team on a telecommunication ship was installing new cables on the seafloor, they came upon a Spanish galleon shipwreck lying in a deep canyon. We need a complete, detailed photographic survey of the area around the ship. The wreck lies in waters approximately 3,000 meters deep. A no-touch investigation will use video and photos of the cargo on board. This may help the team determine from which port the ship may have last sailed. These clues will help archaeologists support a recommendation that the area should be protected from disturbance.

4

As plate boundaries collide and subduct, deep trenches are formed. Along these boundaries, subduction can cause large faults as evidence to underwater earthquakes. These large seismic events also cause sediment to fall and accumulate at the trench bottom. Little is known about the processes in these areas. The Java Trench is an area with little previous study. Our team wants to better understand the landslide risk in an area at a depth of 7,400 meters in this region. Photos taken from multiple angles will help us to answer some of our questions.

5

Glass sponges are animals that form massive reef colonies. Many thought glass sponges had gone extinct 66 million years ago. However, since the late 1980s, glass sponge reefs have been discovered in cold waters around the world. We are learning that these 'living fossil' reefs are home to many animals such as fishes, crabs and sea stars. Ocean explorers plan to study the organisms living on a recently discovered glass sponge reef at a depth of 1,400 meters. We want a complete photographic record of the study area (approximately 10,000 square meters). We also need to collect samples of unknown organisms for identification.

6

The Murray Fracture Zone is 3,000 kilometers long, 90 kilometers at its widest spot, and up to 2,000 meters deep. Our expedition is tasked with creating the first high-resolution map of the entire area. The project will require continuous data collection over several days.

MISSION COLLABORATIVE SCENARIO

Your team wants to study fish communities around deep water coral reefs in the Gulf of Mexico (depth: 1,500-1,700 m). We want to understand the biodiversity of the reef. The team needs to make video recordings of fish species in a variety of habitats, particularly under coral ledges near the bottom. We need to collect samples of several fish species without disturbing the reef. This area also contains a series of caves. Each one is approximately 300 meters long. Video images of the interior of these caves will help us plan further explorations. Our scientific team wants to document how underwater micro-climates impact fish populations. The team will monitor the water temperature around the caves and the reef. We will need to take temperature samples every hour for a month.

Educator Guide cont.

MISSION SCENARIO SOLUTIONS

SCENARIO	BEST VEHICLE FOR SCENARIO	KEY CAPABILITIES/ATTRIBUTES FOR THE TASK
1		
2		
3		
4		
5		
6		

ANSWERS TO MISSION SCENARIOS

Scenario #1

- **Best option:** *Nereid Under-Ice (NUI)*
- **Possible alternatives:** *Deep Discoverer (D2), SuBastian*

Scenario #2

- **Best option:** *Deep Discoverer (D2)*
- **Possible alternatives:** *SuBastian*

Scenario #3

- **Best option:** *Little Hercules*
- **Possible alternatives:** *Deep Discoverer (D2), Orpheus, SuBastian*

Scenario #4

- **Best option:** *Orpheus*
- **Possible alternatives:** None due to depth of research site

Scenario #5

- **Best option:** *SuBastian*
- **Possible alternatives:** *Deep Discoverer (D2), Nereid Under-Ice (NUI)*

Scenario #6

- **Best option:** *Sentry*
- **Possible alternatives:** no good alternatives due to length of data collection, but students may surmise many tools could map the area

Educator Guide cont.

Assessment

ACTION	ADVANCED	DEVELOPING	BEGINNING
Discuss reasons why explorers conduct ocean exploration research	Student provides multiple valid reasons, including at least one idea that extends beyond the content presented.	Student provides two or more valid reasons based on content presented.	Student is unable to provide more than one valid reason.
Distinguish among shape and structural features of at least three types of underwater vehicles that make each suitable for specific ocean exploration tasks	Response addresses three or more types of underwater vehicles and various tasks.	Response addresses three or more types of underwater vehicles, with a focus on the same or similar tasks.	Response is limited to fewer than three types of underwater vehicles.
Use data to make decisions on which unoccupied underwater vehicle is optimal to meet the criteria of specific situations encountered in underwater exploration	Student makes decisions based on the entire set of data provided.	Student makes decisions based on a portion of the data provided.	Student makes decisions based on something other than the data provided.
Demonstrate recognition of the value of listening to different perspectives; collaborate with other teams to make decisions	Student collaborates with all team members.	Student collaborates with some, but not all, team members.	Student does not collaborate with team members.
Apply learning to further investigate ocean exploration	Student applies learning to a novel assignment.	Student applies learning to a similar assignment.	Student seems unable to apply learning.

Vocabulary

Autonomous: independent

AUV: Autonomous Underwater Vehicle; a robot that is not tethered to a ship—it can move independently to explore the ocean.

Bathymetric: Bathymetry is the study of the “beds” or “floors” of bodies of water. Bathymetric mapping refers to mapping the depths and shapes of underwater terrain.

Remotely Operated: controlled from a distance (like a remote-controlled car)

ROV: Remotely Operated Vehicle; unoccupied underwater robots that are tethered to a ship, where human “pilots” on board the ship control their movement and actions

Submersible: a craft designed to operate underwater

Subduction: the sideways and downward movement of the edge of a plate of the earth’s crust into the mantle beneath another plate

Sensor: a device that detects or measures a physical property; a sensor then records or responds to that property (e.g., a sensor to detect chemicals in water)

Tether: a rope or cable to restrict movement; a bundle of cables that connects a ROV to a ship

ALTERNATIVE ASSESSMENT IDEAS

- Students craft their own mission scenarios and trade with a partner to determine which ROVs and AUVs could perform the job.
- Students design a unique ROV or AUV to present to a Shark Tank-style panel of their peers.
- Students design and create a model of an ROV to accomplish specific tasks out of recycled materials.

Exploration Vehicle Compatibility Survey

Many ocean explorers depend on robots to explore the ocean. Underwater robots allow work to be carried out at a variety of ocean depths without the expense and limitations of human-occupied submersibles.

We will explore two kinds of robots today: Remotely Operated Vehicles, or ROVs, and Autonomous Underwater Vehicles, or AUVs. ROVs are linked by a tether, or bundle of cables, to a ship. An operator on board the surface vessel pilots the ROV using this tether for communication. AUVs operate autonomously and are not tethered--like drones that operate underwater. Most of these robots have navigation systems, and thrusters for motion forward, backward, up and down. They can be equipped with video cameras, lights and specific tools such as sensor packages, biological and geological sample collecting devices, cutters, water samplers, and measuring instruments, depending on specific exploration needs.

Your task is to investigate underwater robots that can be used to perform various jobs that support scientific exploration of the deep ocean. You will work in teams to explore the tools and capabilities of a number of different ROVs and AUVs and determine which of these robots is the best one to complete specific missions.

Name of Underwater Robot: ______________________________

Maximum Operating Depth: ______________________________

Tethered or Autonomous: ______________________________

Included Tools/Equipment: ______________________________

____

____

Special Capabilities or Advantages: ______________________________

____

____

Other Unique Details: ______________________________

____

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Educator Guide cont.

Adaptations

ONLINE LEARNING

- Share the Exploration Vehicle Summary Sheets and the Exploration Vehicle Compatibility Survey with students via preferred online platform.
- Set up a shared document on a preferred online platform for students to record their mission scenario solutions.

DIFFERENT GRADE LEVELS

- For younger grades, complete one scenario with the entire class before dividing into groups. Present fewer scenarios and limit the number of vehicle choices.
- For extension, challenge students to develop novel scenarios for particular ROVs and AUVs.

Which Robot When? Links and Resources

Page 2:
- Exploration Vehicle Summary sheets: https://oceanexplorer.noaa.gov/edu/materials/exploration-vehicle-summary-sheets.pdf
- Rare Sperm Whale Encounter with ROV (video): https://www.youtube.com/watch?v=SkBpummjR5I
- Gulf of Mexico 2012 Monterrey: Exploring a 19th Century Shipwreck (video): https://www.youtube.com/watch?v=HDjqBNMWniY&list=SP05ED679DD1E1DB17html#cbpi=/okeanos/explorations/ex1202/dailyupdates/media/video/highlights-0426/highlights-0426.html
- Deep Discoverer (photo): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1811/logs/nov13/media/img3-hires.jpg
- ROV Fact Sheet: https://oceanexplorer.noaa.gov/edu/materials/rov-fact-sheet.pdf
- AUV Fact Sheet: https://oceanexplorer.noaa.gov/edu/materials/auv-fact-sheet.pdf

Page 3:
- Rare Sperm Whale Encounter with ROV (video): https://www.youtube.com/watch?v=SkBpummjR5I
- Gulf of Mexico 2012 Monterrey: Exploring a 19th Century Shipwreck (video): https://www.youtube.com/watch?v=HDjqBNMWniY&list=SP05ED679DD1E1DB17html#cbpi=/okeanos/explorations/ex1202/dailyupdates/media/video/highlights-0426/highlights-0426.html
- Coordinated Robotics 2 - Wrap Up (video): https://www.youtube.com/watch?v=0ggXqbYTFfo&list=PLJGVqQI3okzbqF_JLN2cmLs8Fz56Tsp3O&index=1
- Coordinated Robotics 2 - Week 01 (video): https://www.youtube.com/watch?v=FXcN45rSvVI&list=PLJGVqQI3okzbqF_JLN2cmLs8Fz56Tsp3O&index=3
- Exploration Vehicle Summary sheets: https://oceanexplorer.noaa.gov/edu/materials/exploration-vehicle-summary-sheets.pdf

Page 4:
- Here Be Monsters: We Filmed a Giant Squid in America's Backyard (webpage): https://oceanexplorer.noaa.gov/explorations/19biolum/logs/jun20/jun20.html
- How We Found the Giant Squid | Dr. Edith Widder (video): https://www.ted.com/talks/edith_widder_how_we_found_the_giant_squid?language=en
- The Rise of Orpheus (webpage): https://www.whoi.edu/news-insights/content/the-rise-of-orpheus-2/
- MBARI Robot Ballet (video): https://www.youtube.com/watch?v=m-Get7opYt0
- Boxfish (webpage): https://www.boxfish.nz/case_study/underwater-music-video/
- Black Smoke Trigger (video): https://www.youtube.com/watch?v=gSfvCxdvi3A

Partners

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Information and Feedback

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