NOAA OCEAN EXPLORATION

# Designing a Scientific ROV


ROV *SuBastian* being positioned on deck after a recovery. *Image courtesy of the Schmidt Ocean Institute.*

## Overview

**TOPIC:** Underwater Robots

**FOCUS:** Scientific Remotely Operated Vehicles (ROVs) are designed to overcome many challenges associated with deep-sea environments.

**GRADE LEVEL:** 9th-12th; extension and differentiation provided to adapt to other grade levels (Engineering)

**TIME NEEDED:** One 45 or 50 minute class period

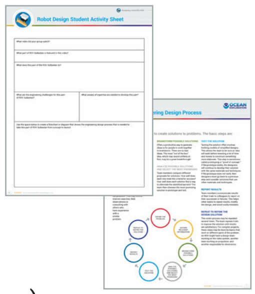
**DRIVING QUESTION:** How do engineers, designers, and scientists work together to develop scientific Remotely Operated Vehicles (ROVs) capable of exploring and studying deep-sea environments?

**OBJECTIVES/ LEARNING OUTCOMES:**

Students will:

- Explore the process of designing a scientific remotely operated vehicle (ROV).
- Identify engineering challenges and design solutions for developing components of a scientific ROV that is capable of exploring and studying deep sea environments.
- Consider the types of teamwork and engineering expertise needed to develop a scientific ROV.
- Discuss and understand the overall process engineers use to make a scientific ROV from concept to launch.

**MATERIALS/ SET-UP INSTRUCTIONS:**



Equipment:

- Video projection or online sharing capability
- Student computers or tablets for group exploration (See Adaptations [page 7] if access to student computers is not available)

Student Handouts:

- Make copies or provide electronically for students:
  - *Robot Design Student Activity Sheet* (page 8) (one per student or one per group)
  - *Engineering Design Process Student Handout* (one per student group, or display for class)

**NEXT GENERATION SCIENCE STANDARDS (NGSS)**

**Performance Expectations**
HS-ETS1-1

**Disciplinary Core Idea (DCI)**
ETS1.A: Defining and Delimiting Engineering Problems

**Crosscutting Concepts (CCC)**
Influence of science, engineering, and technology on society and the natural world

**Science & Engineering Practices (SEP)**
- Asking questions and defining problems

**COMMON CORE CONNECTIONS**
RST.11-12.7, RST.11-12.9, SL.9-10.1, SL.11-12.1

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

# Overview



Required Multimedia:

Cue up the following videos from Schmidt Ocean Institute's "Building SOI's New 4500 m ROV" playlist:

- Video 1 - Developing a Scientific ROV
- ROV *SuBastian* Animated Tour

Organize students into groups. Divide the following videos up among the groups (if more than 5 groups are needed, assign more than one group to a video).

- Video 4 - The Manipulator Arms
- Video 5 - Under Pressure
- Video 6 - Connecting the ROV to *Falkor*
- Video 7 - Foam & Pressure
- Video 8 - Building the Frame

# Educator Guide

### Background

Remotely operated vehicles (ROVs) are unoccupied robots operated by ROV pilots aboard a ship or on shore. These robots are able to work for extended periods of time and in extreme environments without posing risk to humans. Due to these advantages, ROVs are used in many fields. They come in many different sizes and can be equipped with a variety of instruments depending on the job they will be completing.

Scientific underwater ROVs, like ROV *SuBastian*, are designed to help scientists explore and study the ocean. ROVs in this class are often equipped with special tools that collect data and samples from environments that might otherwise be too deep or dangerous for scientists to explore in person. Some of the more common instruments on scientific ROVs include high definition cameras and lights, manipulator arms, and a variety of probes, sensors and sample collectors. Scientists, engineers and ROV pilots often work together to develop new instruments to attach to these substantial machines to help us investigate and better understand the ocean.

### Guiding Questions

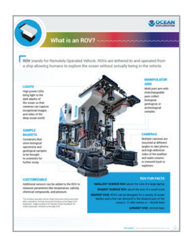
Questions to guide students toward answering the **Driving Question**:

**How do engineers, designers, pilots and scientists work together to develop scientific Remotely Operated Vehicles (ROVs) capable of exploring and studying deep-sea environments?**

- What engineering challenges must a scientific ROV overcome to be able to explore and study deep sea environments?
- Can one person alone engineer a scientific ROV from concept to launch? Why or why not?
- What areas of expertise are needed for a design team to be successful?
- What is the first step in designing an ROV?
- How do engineers use the engineering design process to go from an idea to a working ROV?

**FOR MORE INFORMATION:**

- *ROV Fact Sheet*



# Educator Guide cont.

## Introducing the Problem

### Engaging in Observation

- Introduce students to the ROV *SuBastian.* This Remotely Operated Vehicles (ROV) is an unoccupied robot that does work underwater. Scientific ROVs are engineered to explore and collect samples and data from a variety of deep ocean habitats. ROV *SuBastian* is operated from the Schmidt Ocean Institute's R/V *Falkor*.
- Show a quick preview of "Video 1 - Developing a Scientific ROV" (0:00 - 0:26).
- Discuss the following questions with students:

  *What did Lead Electrical Engineer Nic Bingham mean when he said: "We want to develop an ROV that is purpose-built for science?"*

  *What are the challenges of exploring and studying deep-sea environments? What features must ROVs have to overcome these challenges? What special features do scientific ROVs need to "do science?"*
- Encourage students to elaborate based on their prior knowledge.

  *How do scientists study environments on land? How could a scientific ROV do this in the deep ocean?*
- Record student answers to build on group discussion.

### Developing Common Questions and Ideas

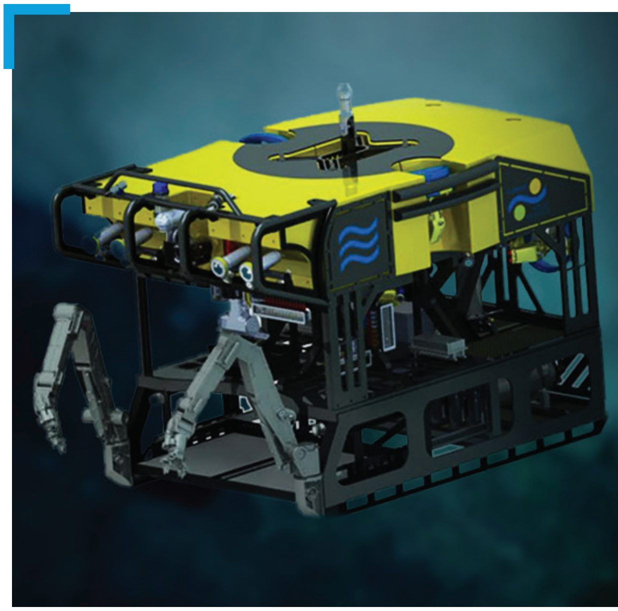
- Show the rest of "Video 1 - Developing a Scientific ROV" (0:26 - 2:40).
  - Have students work in partners or small groups to share their observations about the video.

    *What did they notice? Was there anything that surprised them? Who was talking in the video?*
  - Ask students if ROV *SuBastian* has any additional features that they want to add to the list they started.
- Lead a discussion to gather initial ideas on the design process for a scientific ROV:
  - Ask student pairs or groups to share out their initial thoughts on how scientific ROVs are engineered from concept to launch.

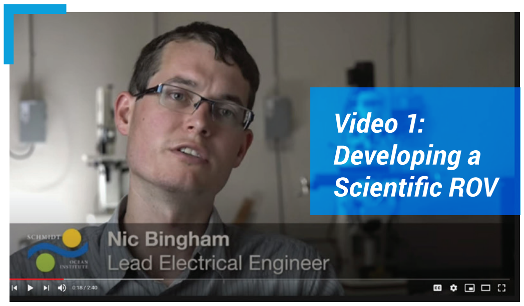
    *What is the first step in the process? What comes next?*

    *How do you get from start to finish - what are the intermediate steps?*

    *"Who" is needed to take an ROV from concept to launch?*
  - Add new student ideas and observations to the class list started after watching the video preview in the previous step.



The ROV *SuBastian* is outfitted with a suite of sensors and scientific equipment to support data and sample collection. *Image courtesy of Schmidt Ocean Institute.*




Video 1 explains and explores the beginning of the journey of developing a scientific ROV that has "the power of a rugby player, but the dexterity of a neurosurgeon." *Video courtesy of Schmidt Ocean Institute.*

## EDUCATOR GUIDANCE

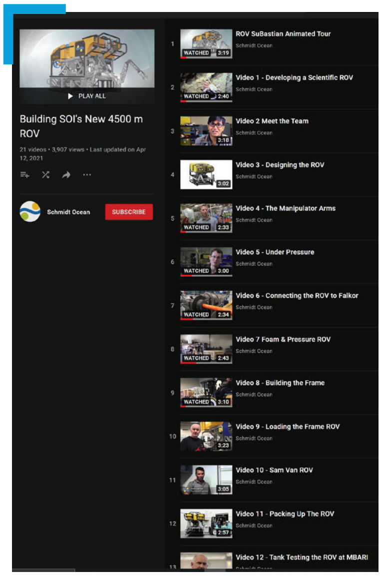
If students need prompts to get them talking about the design process for an ROV, ask them to think about and describe the design process of something that is familiar to them, such as a gingerbread house or a go-cart.

# Educator Guide cont.

## Figuring It Out

**Exploring the Engineering Design Process of a Scientific ROV Component**

- Set the Stage: Explain that due to the complexity of designing a scientific ROV, students will be working in groups to become more familiar with one part of the ROV *SuBastian*. Each group will become "experts" on that one part of the ROV - what does that part of the ROV do, what were the design challenges, who is involved in the design? Student groups will use student computers to watch videos from the Schmidt Ocean Institute's "Building SOI's New 4500 m ROV" playlist and complete the *Robot Design Student Activity Sheet* (page 8) on their part of ROV *SuBastian*. All groups will watch the "ROV *SuBastian* Animated Tour" video in addition to the video on their specific ROV part.
    - Video 4 - The Manipulator Arms
    - Video 5 - Under Pressure
    - Video 6 - Connecting the ROV to *Falkor*
    - Video 7 - Foam & Pressure
    - Video 8 - Building the Frame
- Distribute student computers and the *Robot Design Student Activity Sheet* (a minimum of one per group).
- Direct students to the "Building SOI's New 4500 m ROV" video playlist by SOI.
- Assign one part of ROV *SuBastian* from the list above to each group.
- Give students time to explore the videos on their part of ROV *SuBastian* and fill out their Activity Sheet. Have each student group prepare one speaker to share their group's findings with the class.




This activity has selected specific videos from the 'Building SOI's New 4500 m ROV.' Click here to view the full playlist. *Playlist courtesy of Schmidt Ocean Institute.*


Explore the tools and capabilities of ROV SuBastian in this animated video. *Video courtesy of Schmidt Ocean Institute.*

### Looking for Patterns

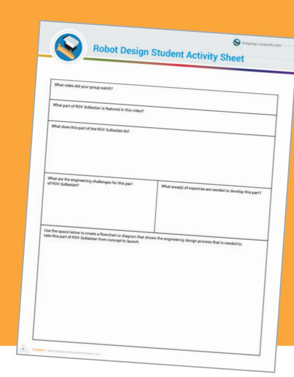
- Have one speaker from each group summarize their group's findings.

    *What part of the ROV did their team focus on? What does it do for the ROV?*
    *What challenges did the engineers have to overcome when designing that part?*
    *What expertise is needed to engineer that part of the ROV?*
    *What process did the engineers use to develop this part of ROV* SuBastian?
- Lead a discussion to build student understanding of the engineering design process used to develop a Scientific ROV from concept to launch.
- Have students reflect on all of the group's responses.

    *Were there any similarities?*
    *Were the design challenges for one part similar to another?*
    *Did some of the parts require similar areas of expertise?*
    *How did the design process for one part compare to another?*

**STUDENT TASK**

The Robot Design Student Activity Sheet is on page 8.



# Educator Guide cont.

## Synthesizing Our Thoughts

- Explain to students that they will now be working together to figure out how their piece fits into the larger engineering design process for developing a complete ROV from concept to launch.
  - Ask students to reflect on the design process that their group created for their part of ROV *SuBastian*.

    *Could this same process be used to create a complete scientific ROV? If not, what would they change? Would re-ordering the steps help?*

    *Do they need to add or remove steps to represent the entire process?*
  - Give students time to discuss within their groups. Encourage student groups to draw out a revised engineering design process for the development of a complete ROV on the back of their Activity Sheet.
  - Ask student groups to share their revised models. Did the engineering design process their group described for their part of ROV *SuBastian* work or did their group need to edit their process? What changes did they make?
- Facilitate class discussion that drives students to come to a consensus that describes the entire process for how scientific ROVs are created from concept to launch.
  - Ask students if they noticed any similarities between the groups' revised models.

    *Have they outlined a process everyone can agree on yet? Not yet?*

    *Were there steps that all groups had in common? What about the first step? What did all groups have first?*
  - As students agree on steps in the engineering design process for a scientific ROV, record them so that all students can view and discuss.
  - Once a consensus has been reached, ask for a student volunteer to summarize the class's findings.

## Putting the Pieces Together

- Display the Engineering Design Process Student Handout (or pass out one copy of the handout to each student group). Ask students to reflect on how the process they described compares to the student handout.

  *Did they have similar steps? Did they have more or less steps?*

  *Could some of their steps be combined or separated to describe the process of developing a scientific ROV from concept to launch?*

### *IN THIS SECTION*

In this section students are transitioning from using the engineering design process to describe just one part of the ROV to thinking more broadly how the engineering design process is used to solve a larger scale problem, such as developing a complete ROV.

Encourage student groups to look for similar steps in the engineering design process that each group identified for developing their individual part. Were there other steps, that were similar, but worded slightly differently? Could more broad or generalized terms be used to adapt the design process for one specific component of an ROV to a design process that describes the development of a complete ROV from concept to launch?

### EDUCATOR GUIDANCE

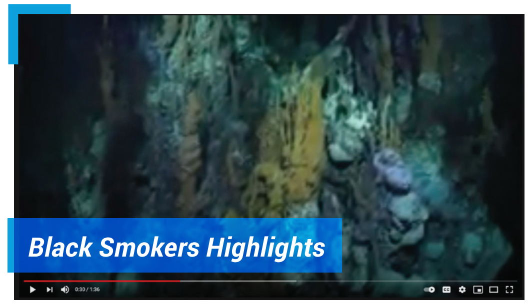
Let students drive the conversation to work toward a consensus. Encourage students to share their support or critique. Do they agree or disagree with what their peers said? What evidence supports their idea?

# Educator Guide cont.

## Extensions

### Designing new equipment for ROV *SuBastian*

- Show the Schmidt Ocean Institute video "Black Smokers Highlights with Dr. Bill Chadwick" to students. In the video Dr. Bill Chadwick describes hydrothermal vents, including what makes them challenging to explore.
- Have students work in pairs or small groups to identify one of the engineering challenges associated with exploring and studying hydrothermal vents.
- Challenge student groups to design a new instrument for ROV *SuBastian* that overcomes these engineering challenges and helps scientists study this extreme deep sea environment.
- Have students share their new "inventions" and describe the process they took in their design process.




### Deciding if the ROV is ready to launch

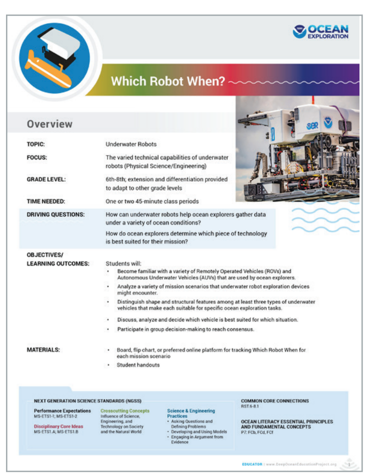
- Show "Video 14 - Preparing ROV *SuBastian* for a Dive" to students. In the video. Schmidt Ocean Institute's ROV Team gives a behind-the-scenes look at the planning process they use to set the stage for success once the ROV is in the water.
- Have students read *The Challenges of ROV Operations at Sea* Exploration Notes individually or in small groups.
  - Discuss the "Think About It" task at the end of the handout: Create a checklist or decision tree for a team to use when determining if they can launch the ROV today.


### Practice the Engineering Design Process

- Try one of the following activities so students can apply the engineering design process to tackle a new design challenge.
  - *Simple Machines: Robot Building Blocks* Student Activity (NOAA Ocean Exploration)
  - *Give Hercules a Helping Claw* STEM Learning Module (Ocean Exploration Trust)


### Explore multiple AUVs and ROVs

- Try the *Which Robot When?* Student Activity (NOAA Ocean Exploration)



# Educator Guide cont.

## Assessment

| LEARNING OUTCOME | ASSESSMENT OPTIONS |
|---|---|
| **Identify** three engineering challenges that designers face when creating a scientific ROV for exploring and studying deep sea environments | **Play** a game of "Yes, and…" where students provide examples of engineering challenges, each building on the previous response. **Describe** the challenges that would be involved in converting a terrestrial drone into an underwater ROV. |
| **Explain** how components of a scientific ROV are designed to overcome specific challenges for exploring or studying deep sea environments | Choose one part of the ROV and **create** an advertisement that describes how that part of the ROV addresses specific challenges for exploring or studying deep sea environments. |
| **Explain** why developing a scientific ROV is multidisciplinary and requires a team | **Assemble** a "dream team" to complete an ROV design project, describing each of team member's attributes. **Design** a job posting to recruit personnel for your ROV design team, describing the desired skills and experience you are looking for in your team members. |
| **Summarize** the overall engineering design process that is used to develop a scientific ROV from concept to launch | **Create** a new wrap-up video to add to Schmidt Ocean Institute's "Building SOI's New 4500 m ROV" playlist that summarizes the entire process of taking ROV *SuBastian* from concept to launch. |

## Adaptations

**LIMITED COMPUTER ACCESS**

- If student computers cannot be accessed for the group research, show the videos to the whole class. Still assign one part of the ROV to each team to become the experts.

**ONLINE LEARNING**

- Image and video links can be provided through a preferred online platform with students divided into small online breakout groups to work through elements of the activity.
- The *Robot Design Student Activity Sheet* can be adapted into a shareable online resource, using a preferred online platform (i.e.. Google Doc, Jamboard, etc.) for student groups to fill in together.

**DIFFERENT GRADE/ LEARNING LEVELS**

- For younger students, choose two or three of the videos that each show one part of the ROV *SuBastian*. Discuss as a group the purpose of that part of the ROV, the design challenges for developing that part, and the process the engineering team took to overcome the design challenge.
- For older or more advanced students, have students research instruments that have been specially designed for a scientific ROVs (ex: suction sampler or the origami inspired Rotary-Actuated Device). Ask students to choose one and consider the engineering process for developing that part, the design challenge that part overcomes, and the expertise needed to develop that part.

## Vocabulary

**Engineering Design:** a process that engineers use to create solutions to problems, consisting of brainstorming, analyzing possible solutions, testing and refining

**Hydraulic:** operated by the pressure created by forcing water, oil or another liquid to move through a confined space

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

**Remotely Operated Vehicle (ROV):** Remotely Operated Vehicle; unoccupied underwater robot that is tethered to a ship, where human "pilots" on board the ship control its movement and actions

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

**Syntactic Foam:** material in which a polymer binds together pre-formed hollow spheres (made of glass, ceramic, metal or polymer). Helps maintain neutral buoyancy of underwater robots in the water column.

**Umbilical:** a necessary link or connection

**Water Column:** a vertical expanse of water from the surface to the bottom of a body of water

# Robot Design Student Activity Sheet

Scientific underwater ROVs, like ROV *SuBastian*, are designed to help scientists explore and study the ocean. ROVs in this class are usually equipped with special tools that collect data and samples from environments that might otherwise be too deep or dangerous for scientists to explore in person.

Your task is to investigate the engineering design process used to design and develop one component of ROV *SuBastian*. Watch the video assigned to your group from the *"Building SOI's New 4500 m ROV"* playlist to answer the questions about the ROV component below. Summarize the engineering design process that the ROV engineers used to design and develop that component of ROV *Subastian*.

<table>
<tr><td>What video did your group watch?</td><td>What part of ROV SuBastian is featured in this video?</td></tr>
<tr><td colspan="2">What does this part of the ROV SuBastian do?</td></tr>
<tr><td>What are the engineering challenges for this part of ROV SuBastian?</td><td>What area(s) of expertise are needed to develop this part?</td></tr>
<tr><td colspan="2">Use the space below to create a flowchart or diagram that shows the engineering design process that is needed to take this part of ROV SuBastian from concept to launch.</td></tr>
</table>

# Designing a Scientific ROV Links and Resources

**Page 1:**
- ROV *SuBastian* (image): https://schmidtocean.org/wp-content/uploads/SuBastian-SeaTrials-20160720-5255-1.jpg
- Engineering Design Process (Student Handout): https://oceanexplorer.noaa.gov/edu/materials/engineering-design-process-handout.pdf

**Page2:**
- "Building SOI's New 4500 m ROV" playlist: https://www.youtube.com/playlist?list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU
- Video 1 - Developing a Scientific ROV: https://www.youtube.com/watch?v=zKlH6hpFgS8&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=5
- ROV *SuBastian* Animated Tour: https://www.youtube.com/watch?v=A4BzW5PGjgU&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=2
- Video 4 - The Manipulator Arms: https://www.youtube.com/watch?v=X-rXGIGly90&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=8
- Video 5 - Under Pressure: https://www.youtube.com/watch?v=3iKbKbLrsko&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=9
- Video 6 - Connecting the ROV to *Falkor*: https://www.youtube.com/watch?v=Nf26EE9nWMI&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=10
- Video 7 - Foam & Pressure: https://www.youtube.com/watch?v=ujdSJ4LYEQo&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=11
- Video 8 - Building the Frame: https://www.youtube.com/watch?v=2TyZ7gUKXKc&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=12
- ROV Fact Sheet: https://oceanexplorer.noaa.gov/edu/materials/rov-fact-sheet.pdf

**Page 3:**
- ROV *SuBastian* (image): https://schmidtocean.org/technology/robotic-platforms/4500-m-remotely-operated-vehicle-rov/
- Video 1 - Developing a Scientific ROV: https://www.youtube.com/watch?v=zKlH6hpFgS8&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=5

**Page 4:**
- Building SOI's New 4500 m ROV (playlist): https://www.youtube.com/playlist?list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU
- ROV *SuBastian* Animated Tour: https://www.youtube.com/watch?v=A4BzW5PGjgU&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=2
- Video 4 - The Manipulator Arms: https://www.youtube.com/watch?v=X-rXGIGly90&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=8
- Video 5 - Under Pressure: https://www.youtube.com/watch?v=3iKbKbLrsko&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=9
- Video 6 - Connecting the ROV to *Falkor*: https://www.youtube.com/watch?v=Nf26EE9nWMI&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=10
- Video 7 - Foam & Pressure: https://www.youtube.com/watch?v=ujdSJ4LYEQo&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=11
- Video 8 - Building the Frame: https://www.youtube.com/watch?v=2TyZ7gUKXKc&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=12

**Page 5:**
- Engineering Design Process (Student Handout): https://oceanexplorer.noaa.gov/edu/materials/engineering-design-process-handout.pdf

**Page 6:**
- Black Smokers Highlights with Dr. Bill Chadwick (video): https://www.youtube.com/watch?v=zDeDuZuR3dM
- Video 14 - Preparing ROV SuBastian for a Dive: https://www.youtube.com/watch?v=NgTXD3ZVJv4&list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU&index=18
- The Challenges of ROV Operations at Sea Exploration Notes (pdf): https://oceanexplorer.noaa.gov/edu/materials/rov-challenges-exploration-notes.pdf
- Simple Machines: Robot Building Blocks (pdf): https://oceanexplorer.noaa.gov/edu/materials/simple-machines-handout.pdf
- Give Hercules a Helping Claw (pdf): https://nautiluslive.org/sites/default/files/documents/2020-03/GiveHercHelpingClawModule.pdf
- Which Robot When? (pdf): https://oceanexplorer.noaa.gov/edu/materials/which-robot-when-activity.pdf

**Page 7:**
- Rotary-actuated device (video): https://vimeo.com/277539747

**Page 8:**
- Building SOI's New 4500 m ROV (playlist): https://www.youtube.com/playlist?list=PLJGVqQI3okzaOH4YqKxp3p3RB7PALgqCU

# Partners

NOAA OCEAN EXPLORATION SCHMIDT OCEAN INSTITUTE NAUTILUSLIVE.ORG OCEAN EXPLORATION TRUST

*Created in cooperation with the National Marine Sanctuary Foundation under federal award NA19OAR0110405 for the Deep Ocean Education Project.*

# Information and Feedback

We value your feedback on this activity, including how you use it in your formal/informal education settings. Please send your comments to: **oceanexeducation@noaa.gov**. If reproducing this activity, please cite NOAA as the source, and provide the following URL: https://oceanexplorer.noaa.gov.