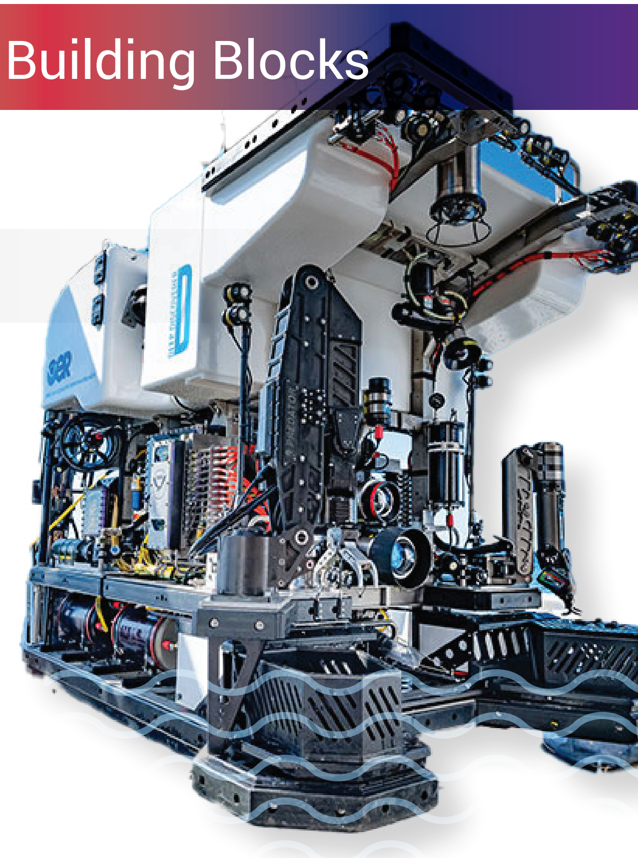
Simple Machines: Robot Building Blocks



Overview

TOPIC: Underwater Robots

FOCUS: Students practice the engineering design process as they develop a robotic arm for an ROV using simple machines.

GRADE LEVEL: 6th-8th

TIME NEEDED: Two 45-minute class sessions

DRIVING QUESTION: How are engineering designs for simple machines applied to complicated technology?

OBJECTIVES/ LEARNING OUTCOMES: Students will:

- Discover how engineers and ocean scientists design and build ROVs with robotic arms that are capable of specific movements in order to gather data and samples.
- Use the Engineering Design process to design and build a functioning hydraulic actuator and understand that a hydraulic actuator works as a mechanical device that converts energy into motion.
- Discuss the process of designing a robotic arm on an ROV, considering which features would be needed to function in the deep ocean to conduct experiments, manipulate samplers, and collect geological and biological samples.
- Recognize that engineers apply the principles of simple machines to design complex robotic arms on ROVs used for ocean exploration.
- Discuss the process of designing a robotic arm on an ROV, considering the features needed to function in the deep ocean and collect samples.

NEXT GENERATION SCIENCE STANDARDS (NGSS)

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

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

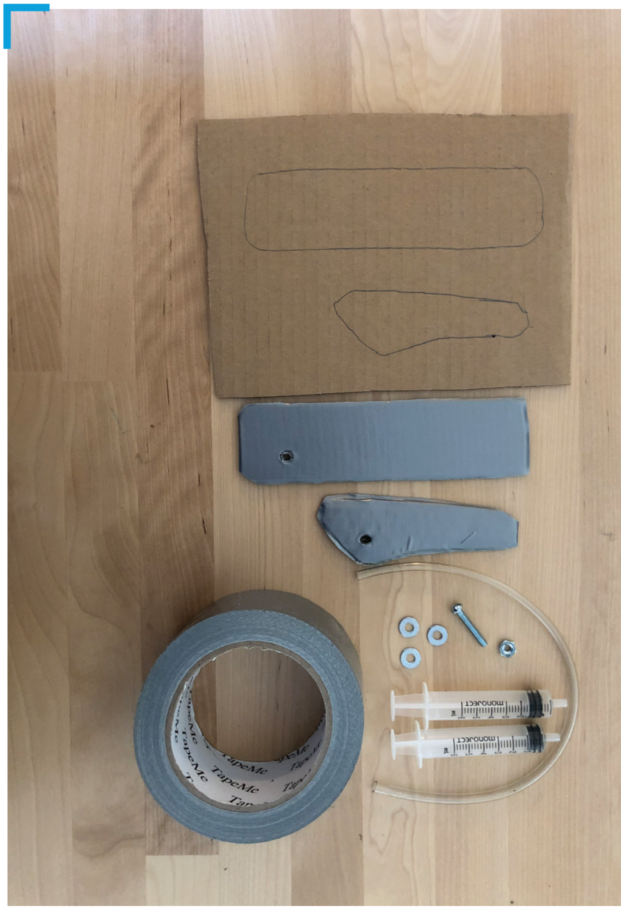
Crosscutting Concepts
Influence of Science, Engineering, and Technology on Society and the Natural World

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

COMMON CORE CONNECTIONS
RST.6-8.7

OCEAN LITERACY ESSENTIAL PRINCIPLES AND FUNDAMENTAL CONCEPTS
Principle 7, FC d

Overview cont.



MATERIALS/TOOLS: For each student group of 4-6 students:

- Student Design Challenge Activity Sheet (page 7)
- One piece of cardboard or heavy poster board, approximately 12”x12” (the stiffer the better)
- Duct tape, approximately 2” x 60”
- 1 - Machine screw with nut, #8 x1”
- 3 - flat washers, #8 hole
- 2 - oral syringes
- Two pieces of plastic tubing, approximately 3/16” inside diameter; each approximately 12” long (should fit snugly over the end of the syringes)
- Approximately 1 cup of water
- Small container, such as an 8-oz drinking cup

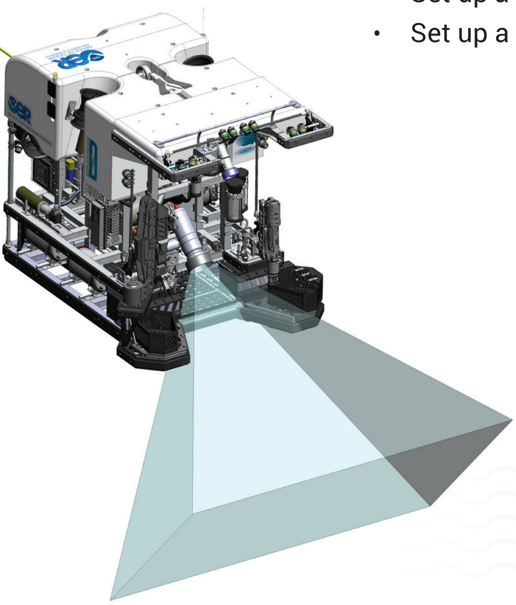
These can be shared by several student groups:

- Heavy scissors to cut cardboard (“bandage scissors” are inexpensive and work well)
- Nail or Phillips screwdriver to punch holes in cardboard

EQUIPMENT: Video projector or large-screen monitor

SET-UP INSTRUCTIONS:

- Make copies (or prepare to distribute electronically):
    - Student Design Challenge Activity Sheet (page 7)
    - *Simple Machines* Student Handout (one per student)
    - *Engineering Design Process* Student Handout (one per student)
- Cue up the video *Engineering for Discovery*
- Set up a separate set of materials for each group
- Set up a common area for all students to access shared tools, if needed

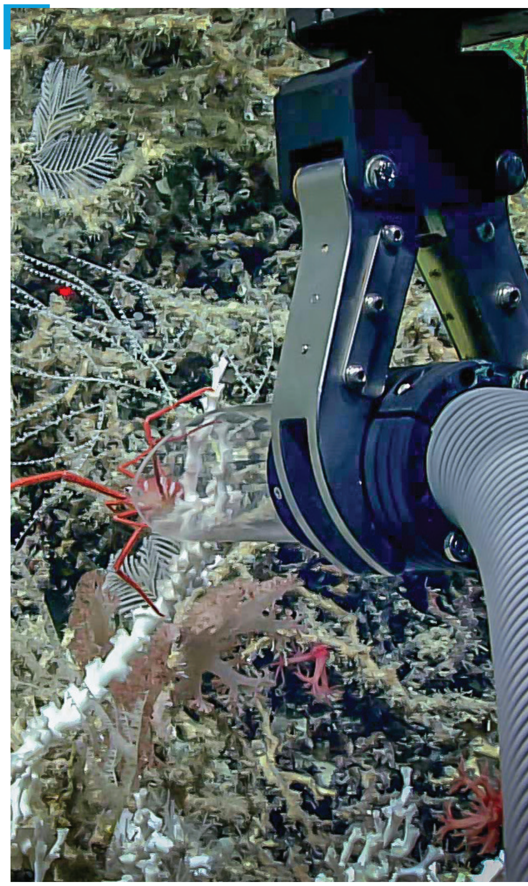


Educator Guide

Background

Ocean exploration vessels are equipped with innovative technologies to gather high definition video and images, geological and biological samples, and water quality data. Much of this exploration work is dependent on Remotely Operated Vehicles (ROVs). These are unoccupied robots usually linked to a surface ship by a group of cables. Most ROVs are equipped with one or more video cameras and lights. They may also be equipped with manipulator arms to collect samples and operate tools. These arms expand the vehicle's capabilities for gathering data about the deep-ocean environment.

NOAA's ROV *Deep Discoverer* is capable of obtaining high-quality images and collecting samples to depths as great as 6,000 meters (19,685 feet). Additionally, telepresence technologies (satellites) allow scientists with expertise in a variety of disciplines to observe and interact with exploration activities in real time, although they may be thousands of miles away from the ship.



A squat lobster sampled around 722 meters (2,369 feet) using the suction sampler. *Image courtesy of NOAA Ocean Exploration, Windows to the Deep 2019.*

Guiding Questions

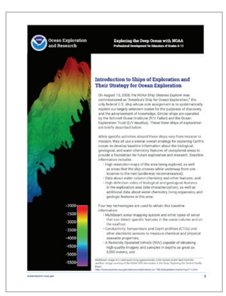
Teaching tips to support student-centered exploration toward the **Driving Question**:

How are engineering designs for simple machines applied to complicated technology?

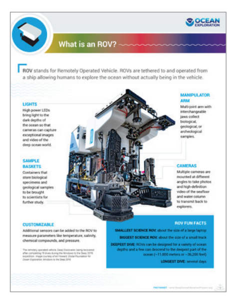
- How do simple machines reduce the amount of work required?
- How can simple machines work together in complex combinations?

FOR MORE INFORMATION:

- *Introduction to Ships of Exploration and Their Strategy for Ocean Exploration*



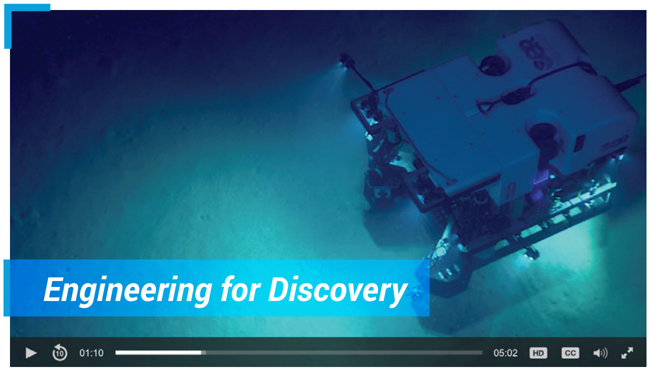
- *ROV Fact Sheet*



Educator Guide cont.

ENGAGE

Show the NOAA Ocean Exploration video *Engineering for Discovery* (5:03)



Ask students:

- In what ways has *Deep Discoverer* been engineered for ocean exploration?
- What tools are on *Deep Discoverer* that allow it to help scientists study the ocean?
- What are some of the special features of each of these tools *(ex: the grip strength of the manipulator arms)*?
- Would *Deep Discoverer* be as helpful if it only had one of these features?

EXPLORE

- **Introduce the concept of Simple Machines.**
  - Ask students what are simple machines? What are the different types of simple machines? *(Make a list together)*
  - Can you think of an example of a lever? How is a lever a simple machine? How does it make work easier?
- **Distribute** the *Simple Machines* Student Handout and discuss the different types of simple machines. *How does the class list compare to the handout? Were they able to name all of the simple machines? What were they missing, if any?*
- **Ask** students to find examples of these simple machines in the classroom (or at home). Add these examples to the class list on the board.
- **Display** an image of *Deep Discoverer* on the board.
  - Ask students if they think simple machines are used in complex systems like *Deep Discoverer*? Have students explain their reasoning.
  - **Ask** students to identify simple machines shown in the image.
  - *Alternative:* re-watch *Engineering for Discovery* from 3:29 on and have students identify simple machines shown in the video.

EXPLAIN

- **Remind** students that the ROV *Deep Discoverer* has specialized robotic arms capable of collecting samples.
- **Ask students:**
  - What type of simple machine is an arm?
  - How is the input force applied to the arm of an ROV when it is collecting samples on the seafloor?
- **Define Actuator:** a mechanical device that converts energy into some kind of motion
- **Define Hydraulic System:** a mechanism operated by the pressure created by forcing a liquid to move through a confined space.
- **Distribute oral syringes** (1 per student), pieces of plastic tubing, and a small container full of water. Provide students time to play with the oral syringes and observe how they work. Encourage students to work in pairs and investigate how multiple syringes can be used together.
- **Facilitate** student discussion based on their observations:
  - What is the effect of pushing the plunger into the tube?
  - Did anyone try to pull the plunger? Why do you think this is difficult?
  - How does the mechanism of the syringe produce force?
  - How could you adjust the force produced by a syringe?
  - Knowing that simple machines make work easier, what can you say about the syringe?
- **Ask students:** Was anyone able to connect the syringes? How did it work?
  - **Demonstrate** the hydraulic system that is created when two oral syringes are connected by plastic tubing.
- **Ask students** to consider the difference between hydraulic systems and pneumatic systems. Why do they think hydraulic systems are used by ROVs?
  - *Note: hydraulic systems use a liquid while pneumatic systems use air or other gases*

Educator Guide cont.

ELABORATE

Distribute one copy of the *Engineering Design Process* Handout to each student (or display on the screen) and review.

- **Ask students:**
  - What do they notice about the shape of the engineering design process in the handout illustration?
  - How does this relate to the building process of complex machines like ROVs?
- **Introduce** students to the Student Design Challenge (page 7).
  - *You and your team are part of a large group considering the challenges of designing ROV tools such as robotic arms. Your team has been tasked with creating a simple arm that operates using a hydraulic control system.*

Distribute one copy of the Student Design Challenge (page 7) to each student (or display on the screen) and review.

Option A:

- **Confirm** that students understand that:
  - An actuator is a mechanical device that converts energy into some kind of motion.
  - They have supplies to build a manipulator arm and a hydraulic actuator to power it.
  - The engineering process is not linear - and it is okay if their design doesn't work on the first try!
- **Give** students time to design and build their manipulator arms.

Option B:

- Have each group build the hydraulic actuator by following the directions on the Student Design Challenge (page 7) instructions.
- **Once** students have finished construction of their designs have groups demonstrate their completed hydraulic actuator and describe how it works.

EVALUATE

Ask students to reflect on their groups' design.

- What would they do to improve their design? How would this make their prototype better?
- Ask students to explain in their own words how ROVs use simple machines to sample the ocean.
- Try the assessment options on page 6.

Extensions

Extension 1

Adding tools to sample the deep sea:

- **Remind** students that ROV manipulator arms are often equipped with different tools that help them collect samples in the ocean.
- **Ask** students to brainstorm what other simple machines could be added to their ROV manipulator arms to help them sample the deep sea.
- **Give** student groups time to design and build their new tools. Provide a variety of construction items and try this extension:

Extend the function of your robotic arm

Your team is now challenged to build a model that demonstrates how hydraulic actuators could be used for a robotic arm that is able to pick up objects that are about the size of a soda can from the ocean floor. This model does NOT have to have all of the features that will be needed in the final robotic arm. You only need to show that a design using hydraulic actuators could produce the movements that would be needed to accomplish the purpose of the robotic arm. Your model needs to be able to do two things:

- Grasp an object (such as an empty plastic cup); and
- Lift the object at least one inch.

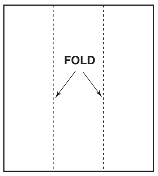
So that other teams can learn from your experience, it is very important to document how you apply the process of Engineering Design. In addition to creating a model that meets the two requirements, your team should produce a report that:

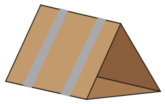
1. Defines the problem;
2. Describe your solution, including a drawing of your model;
3. Explains your construction procedure; and
4. Reports the results of your tests of the model.

If your model cannot meet the design requirements, describe the modifications that you think are necessary to make it work.

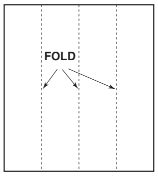
Possible Additional Materials

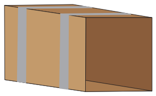
- Four pieces of cardboard or heavy poster board, each approximately 12" x 12"
- Duct tape, approximately 2" x 20'
- 9 - Machine screws with nuts, #8 x 1"
- 4 - Machine screws with nuts, #8 x 3"
- 17 - Flat washers, #8 hole
- Plastic forks or spoons
- Rubber bands
- Additional oral syringes and plastic tubing





TRIANGULAR SECTION BEAM





SQUARE SECTION BEAM

Extension 2

- **Try** the activity *Give Hercules a Helping Claw* from Ocean Exploration Trust.

Here, students use the engineering design process and common everyday materials to build their own ROV manipulator arm with a claw capable of grasping and releasing different objects.

Educator Guide cont.

Vocabulary

Actuator: mechanical device that converts energy into some kind of motion

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

Fulcrum: a support or pivot point around which a lever moves

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

Hydraulic System: a mechanism operated by the pressure created by forcing a liquid through a confined space

Input Force: the force applied to the simple machine

Lever: a rigid bar that rotates around a fixed pivot point or fulcrum (e.g., a seesaw)

Mechanical Advantage: the amount of help you can get from a simple machine

Output Force: the force produced by the simple machine

Pneumatic System: a mechanism operated by the pressure created by forcing air or another gas to move through a confined space

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

Robot: a machine (usually programmed by a computer) that can automatically perform a complex series of actions

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

Simple Machine: with no or few moving parts, a simple machine allows people to accomplish the same amount of work by applying a smaller amount of force over a longer distance.

Assessment

LEARNING OUTCOME	ASSESSMENT OPTIONS
Describe each step in the sequence of the Engineering Design Process	**Create** a poster with examples explaining the Engineering Design Process **Label** the steps of the Engineering Design Process on a worksheet.
Define an actuator as a mechanical device that converts energy into motion	**Use** the word "actuator" correctly to describe how a ROV manipulator arm works. **Draw** a diagram of an actuator with a caption describing what it does.
Recognize that engineers apply the principles of simple machines to design complex robotic arms on Remotely Operated Vehicles (ROVs) that are used for ocean exploration	**Write** an article in the style of a science mechanics trade magazine that includes an interview with an ROV engineer. **Identify** examples of simple machines on a diagram of an ROV.
Discuss the process of designing a robotic arm on an ROV, considering the features needed to function in the deep ocean and collect samples	**Create** a job posting for an engineer to design a robotic arm for an underwater ROV. **Write** a "users' manual" for next year's students to design a robotic arm.

Adaptations

ONLINE LEARNING

- If plastic syringes cannot be distributed to all students, ask those who may have them at home to demonstrate during a class video conference. Encourage other students to share an example of a simple machine they can find at home.
  - Examples: Hydraulics - office chairs that go up or down; pulley - blinds, garage doors, flag pole; Lever - seesaw, pry bar, lever (paddle) action door latches; Wedge - scissors, screw; Wheel and axle - office chairs, carts, wheeled carry-on luggage and toy cars.
- Capture ideas from small group discussions and brainstorms in a shared document on a preferred online platform.
- Use a video-sharing program such as FlipGrid for students to showcase their final products.

DIFFERENT GRADE LEVELS

- For younger students, spend additional time reviewing simple machines and do each step of construction together.
- For advanced students, distribute the *Engineering Design Process Student Handout* and offer the option of adding to the functionality of their hydraulic actuator using materials of their own choosing (See Extensions).

Student Design Challenge

You and your team are part of a large group considering the challenges of designing ROV tools such as robotic arms. Your team has been tasked with creating a simple arm that operates using a hydraulic control system.

Review of Background Information

1. What does "hydraulic" mean?
2. What is the difference between "hydraulic" and "pneumatic"?
3. What is an actuator?

Materials - per group

- One piece of cardboard or heavy poster board, approximately 12"x12" (the stiffer the better)
- Duct tape, approximately 2" x 60"
- Machine screw with nut, #8 x 1"
- 3 - Flat washers, #8 hole
- 2 - Oral syringes
- Plastic tubing, approximately 3/16" inside diameter x 12" (should fit snugly over the end of the syringes)
- Approximately one cup of water

Tools - to share

- Heavy scissors to cut cardboard ("bandage scissors" are inexpensive and work well)
- Nail or Phillips screwdriver to punch holes in cardboard

OPTION A

1. Review the Background Information above.
2. Review the Engineering Design Process.
3. Be sure you have all of the materials listed.
4. As a team, step through the Engineering Design Process to create a simple arm using a hydraulic actuator.

Use the space below to sketch out your designs.

YOUR DESIGN WORKSPACE

OPTION B

Build a Simple Hydraulic Actuator

1. **Cut** two pieces of cardboard using the pattern (Figure 1, next page).

2. **Reinforce** the cardboard pieces: Put a piece of duct tape on one side, then cut off the excess tape around the edges. Put a second piece of duct tape on the other side, and trim the edges. Repeat this process, if necessary, until the pieces are very stiff.

3. **Punch** a hole in each of the pieces as shown on the pattern. The hole should be large enough for the #8 machine screw, but not much larger.

4. **Attach** the two pieces with a #8 machine screw, three flat washers, and a #8 nut as shown in Figure 2 (next page). You may need a screwdriver to twist the machine screw through the holes. Do not tighten the machine screw assembly too much; the pieces need to be able to move freely around the machine screw. You may find that an extra washer or nut between the two cardboard pieces allows for more motion.

5. **Take** a piece of duct tape 6” long, and tear it in half lengthwise, and then tear one of these pieces in half lengthwise again. These narrower pieces of duct tape will be useful for attaching a syringe to the shorter piece of cardboard.

6. **Attach** the plunger of one syringe to the shorter piece of cardboard as indicated on the pattern. Tear one of the narrower pieces of duct tape in half, and wrap it around the plunger and cardboard as shown in Figure 3. Now wrap a second narrow piece of duct tape around the plunger at right angles to the first piece of tape. Add more tape if necessary, but you do not want the joint between the plunger and cardboard to be too tight.

7. **Tape** the syringe onto the larger piece of cardboard as shown in Figure 4. Be sure the plunger is fully inserted into the barrel of the syringe.

8. **Press** one end of the plastic tubing onto the end of the other syringe so it is firmly attached. Place the other end of the plastic tubing into a small container of water, and pull the plunger back so that water is drawn into the tubing and syringe.

   Fill the syringe as full as possible, then hold the end of the plastic tubing so that it is higher than the end of the syringe, and slowly push on the plunger until the syringe is about half-full, and there is no air in the syringe or plastic tubing. You may have to refill the syringe with more water and repeat this procedure a few times to get rid of all the air.

9. **Attach** the open end of the plastic tubing to the syringe that is taped to the cardboard assembly. Slowly press the plunger on the unattached syringe, and you should see the small arm on the cardboard assembly rotate around the machine screw. Pull out slowly on the plunger to reverse this motion. Your hydraulic actuator is complete!

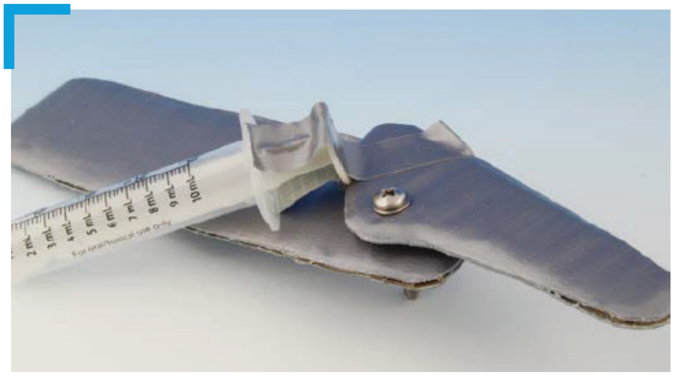


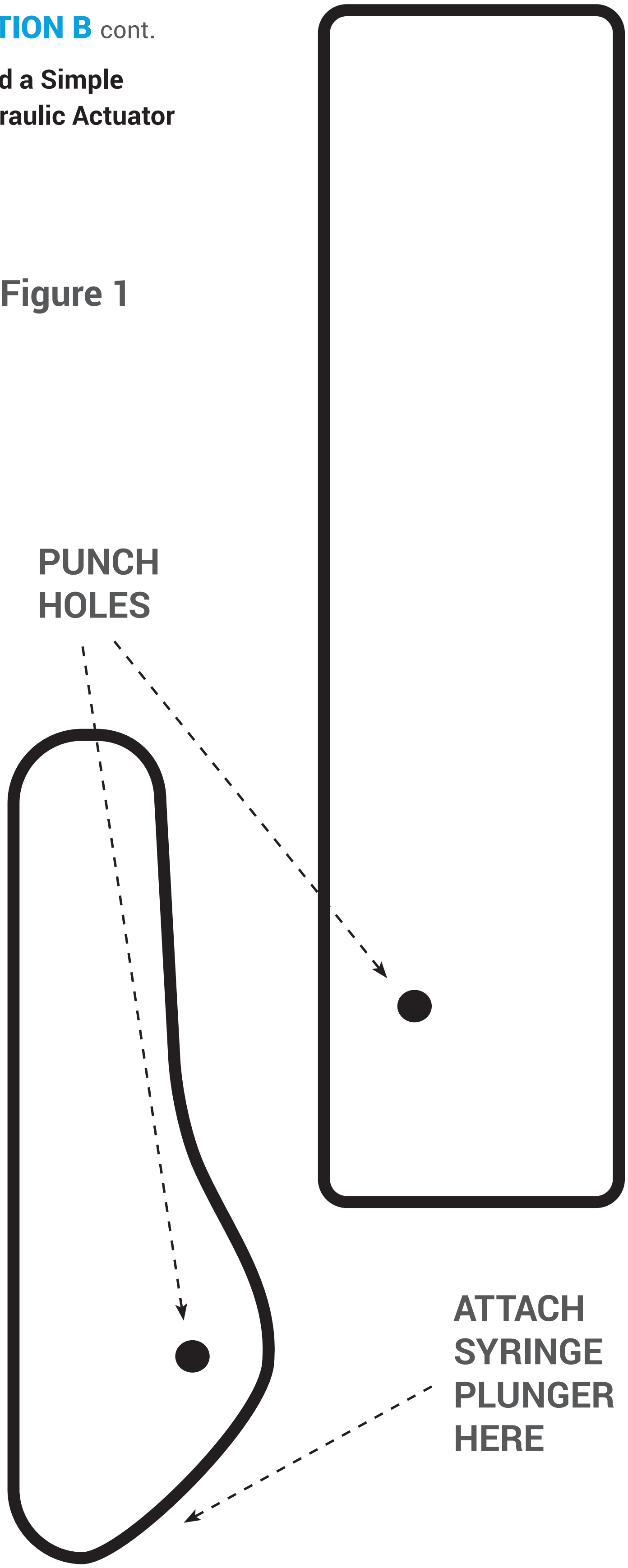
Figure 3

Figure 4

OPTION B cont.

Build a Simple Hydraulic Actuator

Figure 1



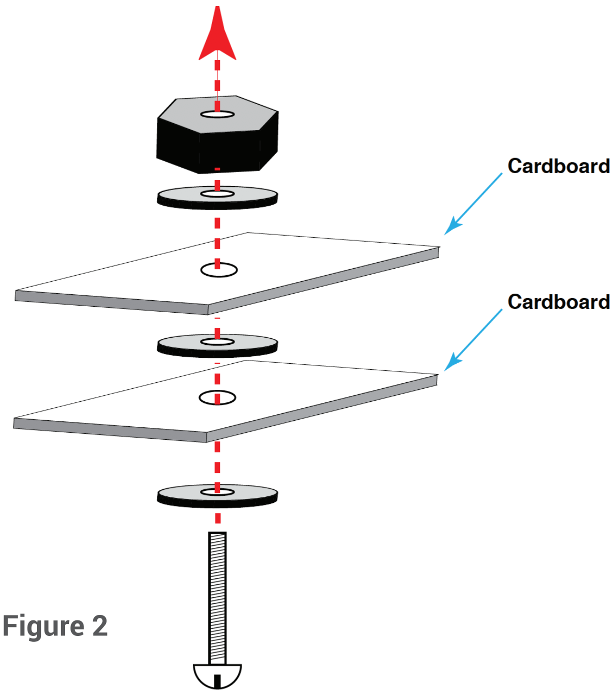


Figure 2

Simple Machines Links/Resources

Page 2:
- Simple Machines Student Handout: https://oceanexplorer.noaa.gov/edu/materials/simple-machines-handout.pdf
- Engineering Design Process Student Handout: https://oceanexplorer.noaa.gov/edu/materials/engineering-design-process-handout.pdf
- Engineering for Discovery (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1711/dailyupdates/media/video/d2/d2-1280x720.mp4

Page 3:
- Squat Lobster (image): https://oceanexplorer.noaa.gov/multimedia/daily-image/media/20210403.html
- Introduction to Ships of Exploration and Their Strategy for Ocean Exploration (pdf): https://oceanexplorer.noaa.gov/okeanos/edu/collection/media/hdwe-StrategyBkgnd.pdf
- ROV fact sheet: https://oceanexplorer.noaa.gov/edu/materials/rov-fact-sheet.pdf

Page 4:
- Engineering for Discovery (video): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1711/dailyupdates/media/video/d2/d2-1280x720.mp4
- Simple Machines Student Handout: https://oceanexplorer.noaa.gov/edu/materials/simple-machines-handout.pdf

Page 5:
- Engineering Design Process Student Handout: https://oceanexplorer.noaa.gov/edu/materials/engineering-design-process-handout.pdf
- Give Hercules a Helping Claw (activity): https://nautiluslive.org/resource/give-hercules-helping-claw

Page 6:
- Engineering Design Process Student Handout: https://oceanexplorer.noaa.gov/edu/materials/engineering-design-process-handout.pdf

Page 10:
- Deep Discoverer (image): https://oceanexplorer.noaa.gov/okeanos/explorations/ex1806/background/seeps/media/d2-hires.jpg

Partners

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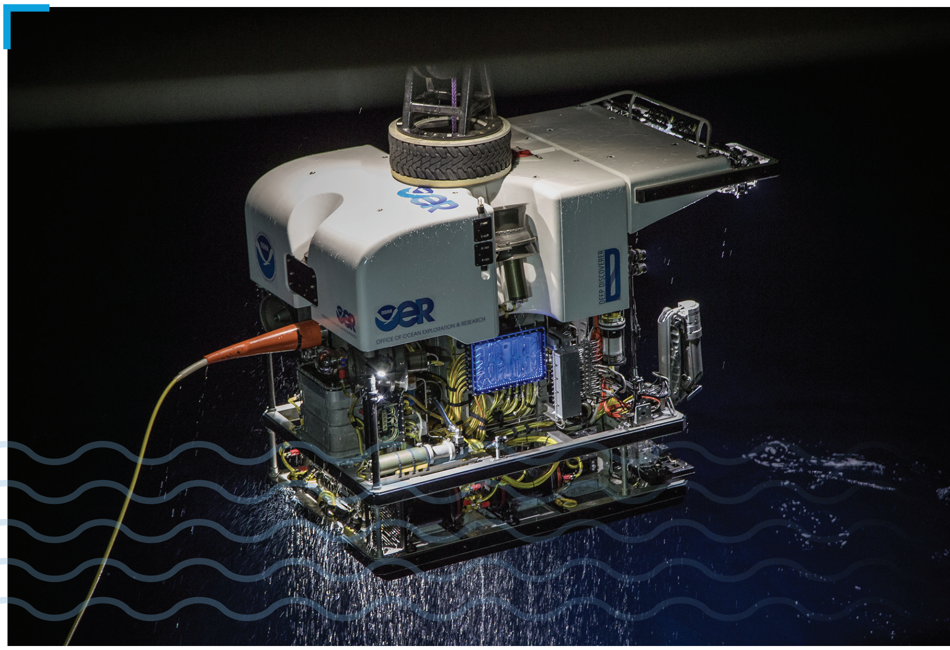

Remotely operated vehicle *Deep Discoverer* during the Northeast and Mid-Atlantic Canyons Expedition. *Image courtesy of NOAA Ocean Exploration.*

Information and Feedback

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