Build Your Own Robot Arm

Part of the IEEE Teacher In-Service Program - www.ieee.org/organizations/eab/precollege

Lesson Focus

Develop a robot arm using common materials. Students will explore design, construction, teamwork, and materials selection and use.

Lesson Synopsis

Participating teams of three or four students are provided with a bag including the materials listed below. Each team must use the materials to design and build a working robot arm. The robot arm must be at least 18 inches in length and be able to pick up an empty Styrofoam cup. Teams of students must agree on a design for the robot arm and identify what materials will be used. Students will draw a sketch of their agreed upon design prior to construction. Resulting robot arms are then tested and checked for range of motion and satisfaction of the given criteria.

Age Levels

10-18.

Objectives

- Learn design concepts.
- Learn teamwork.
- Learn problem solving techniques.
- Learn about simple machines.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- design concepts
- teamwork needed in the design process
- impact of technology in manufacturing

Lesson Activities

Students design and build a working robotic arm from a set of everyday items with a goal of having the arm be able to pick up a Styrofoam cup. Working in teams of three or four students, the students explore effective teamwork skills while learning simple robot mechanics.

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Resources / Materials

- 3" wide and approx. 22" long strips of cardboard-- 5 or so
- Binder clips (different sizes)-- 8 or more
- Brads-- @10
- Clothespins-- 6
- Craft sticks--10-15
- Fishing line-- 3-4 feet
- Hangers-- 1 or 2
- Paper clips (diff. Sizes)-- 10-15
- Pencils-- 3-4
- Rubber bands (different sizes)--15
- Tape-- clear and masking (partial rolls should be fine)
- Twine-- 3-4 feet
- Various size scraps of cardboard--10 assorted

Internet Connections

- Design Your Own Robot (www.mos.org/exhibits/robot)
- FIRST Robotics Competition (www.usfirst.org)
- IEEE Teacher In-Service Program (www.ieee.org/organizations/eab/precollege/tispt)
- IEEE Virtual Museum (www.ieee-virtual-museum.org)
- McREL Compendium of Standards and Benchmarks (www.mcrel.org/standards-benchmarks) A compilation of content standards for K-12 curriculum in both searchable and browsable formats.
- National Council of Teachers of Mathematics Principals and Standards for School Mathematics (www.nctm.org/standards)
- National Science Education Standards (www.nsta.org/standards)
- Robot Books (www.robotbooks.com)

Recommended Reading

- Artificial Intelligence: Robotics and Machine Evolution by David Jefferis (ISBN: 0778700461)
- Robotics, Mechatronics, and Artificial Intelligence: Experimental Circuit Blocks for Designers by Newton C. Braga (ISBN: 0750673893)
- Robot Builder's Sourcebook : Over 2,500 Sources for Robot Parts by Gordon McComb (ISBN: 0071406859)
- Robots (Fast Forward) by Mark Bergin (ISBN: 0531146162)

Optional Writing Activity

- Write an essay (or paragraph depending on age) about how the invention of robots and robotics has impacted manufacturing.

References

Ralph D. Painter and other volunteers - Florida West Coast USA Section of IEEE
URL: http://ewh.ieee.org/r3/floridawc

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For Teachers:
Alignment to Curriculum Frameworks

Note: All Lesson Plans in this series are aligned to the National Science Education Standards which were produced by the National Research Council and endorsed by the National Science Teachers Association, and if applicable, also to the International Technology Education Association's Standards for Technological Literacy or the National Council of Teachers of Mathematics' Principals and Standards for School Mathematics.

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces
- ✦ Transfer of energy

◆National Science Education Standards Grades 9-12 (ages 14 - 18)

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- ✦ Motions and forces
- ✦ Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- ✦ Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- ✦ Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- ✦ Standard 9: Students will develop an understanding of engineering design.
- ✦ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- ✦ Standard 11: Students will develop abilities to apply the design process.

The Designed World

- ✦ Standard 19: Students will develop an understanding of and be able to select and use manufacturing technologies.

Build Your Own Robot Arm

For Teachers:
Teacher Resources

Divide your class into teams of three or four students, and provide student handout (attached). Students are then instructed to examine the materials provided (see list below) and to work as a team to design and build a robot arm out of the materials. The robot arm must be at least 18 inches in length and be able to pick up an empty Styrofoam cup. Teams of students must agree on a design for the robot arm and identify what materials will be used. Students should draw a sketch of their agreed upon design prior to construction.

Explain that teamwork, trial, and error are part of the design process. There is no "right" answer to the problem - each team's creativity will likely generate an arm that is unique from the others designed in your class.

Resources/Materials

- 3" wide and approx. 22" long strips of cardboard-- 5 or so
- Binder clips (different sizes)-- 8 or more
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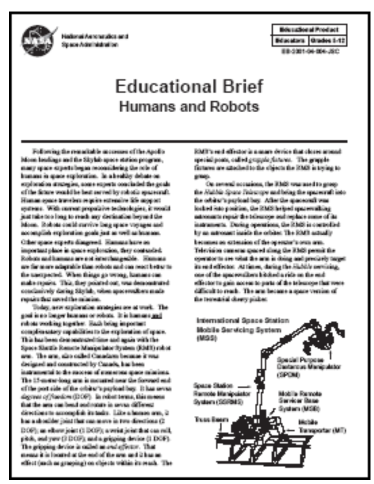
- Various size scraps of cardboard--10 assorted

Extension Ideas

"Humans and Robots," a NASA educational brief which is attached, describes the robotics features on the International Space Station. The brief's classroom activity is about making and using an ISS grapple fixture known as an end effector. The PDF file is also available at http://spacelink.nasa.gov.



Educational Brief
Humans and Robots

Build Your Own Robot Arm

Student Handout:

How To Build Your Own Robot Arm

You are a member of a team of three or four students, all working together to design and build a robot arm out of the following materials which are provided to you. The robot arm must be at least 18 inches in length and be able to pick up an empty Styrofoam cup. Your team must agree on a design for the robot arm and identify what materials will be used. Your team should draw a sketch of their agreed upon design prior to construction.

Part of the teamwork process is sharing ideas and determining which design your team will go with. Trial and error are part of the design process. There is no "right" answer to the problem - your team's creativity will likely generate an arm that is unique from the others designed in your class.

Resources/Materials

- 3" wide and approx. 22" long strips of cardboard-- 5 or so
- Binder clips (different sizes)-- 8 or more
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Student Handout:
Robot Arm Exercise Questions

- Did you use all the materials provided to you? Why, or why not?

- Which item was most critical to your robot arm design?

- How did working as a team of four help in the design process?

- Were there any drawbacks to designing as a team?

- What did you learn from the designs developed by other teams?

- Name three industries that make use of robots in manufacturing:

National Aeronautics and
Space Administration

Educational Product	
Educators	Grades 5-12

EB-2001-04-004-JSC

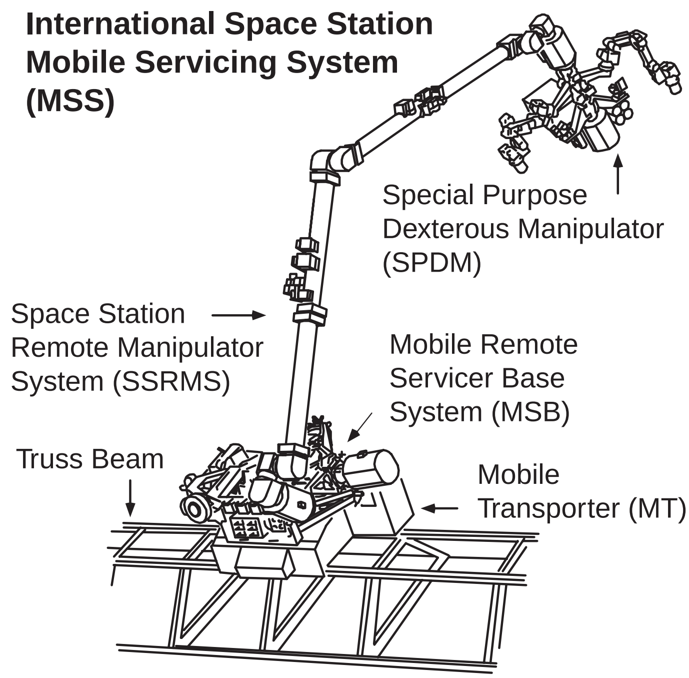
Educational Brief
Humans and Robots

Following the remarkable successes of the Apollo Moon landings and the Skylab space station program, many space experts began reconsidering the role of humans in space exploration. In a healthy debate on exploration strategies, some experts concluded the goals of the future would be best served by robotic spacecraft. Human space travelers require extensive life support systems. With current propulsive technologies, it would just take too long to reach any destination beyond the Moon. Robots could survive long space voyages and accomplish exploration goals just as well as humans. Other space experts disagreed. Humans have an important place in space exploration, they contended. Robots and humans are not interchangeable. Humans are far more adaptable than robots and can react better to the unexpected. When things go wrong, humans can make repairs. This, they pointed out, was demonstrated conclusively during Skylab, when spacewalkers made repairs that saved the mission.

Today, new exploration strategies are at work. The goal is no longer humans or robots. It is humans <u>and</u> robots working together. Each bring important complimentary capabilities to the exploration of space. This has been demonstrated time and again with the Space Shuttle Remote Manipulator System (RMS) robot arm. The arm, also called Canadarm because it was designed and constructed by Canada, has been instrumental to the success of numerous space missions. The 15-meter-long arm is mounted near the forward end of the port side of the orbiter's payload bay. It has seven *degrees of freedom* (DOF). In robot terms, this means that the arm can bend and rotate in seven different directions to accomplish its tasks. Like a human arm, it has a shoulder joint that can move in two directions (2 DOF); an elbow joint (1 DOF); a wrist joint that can roll, pitch, and yaw (3 DOF); and a gripping device (1 DOF). The gripping device is called an *end effector*. That means it is located at the end of the arm and it has an effect (such as grasping) on objects within its reach. The RMS's end effector is a snare device that closes around special posts, called *grapple fixtures*. The grapple fixtures are attached to the objects the RMS is trying to grasp.

On several occasions, the RMS was used to grasp the *Hubble Space Telescope* and bring the spacecraft into the orbiter's payload bay. After the spacecraft was locked into position, the RMS helped spacewalking astronauts repair the telescope and replace some of its instruments. During operations, the RMS is controlled by an astronaut inside the orbiter. The RMS actually becomes an extension of the operator's own arm. Television cameras spaced along the RMS permit the operator to see what the arm is doing and precisely target its end effector. At times, during the *Hubble* servicing, one of the spacewalkers hitched a ride on the end effector to gain access to parts of the telescope that were difficult to reach. The arm became a space version of the terrestrial cherry picker.

International Space Station Mobile Servicing System (MSS)



Robots on the International Space Station

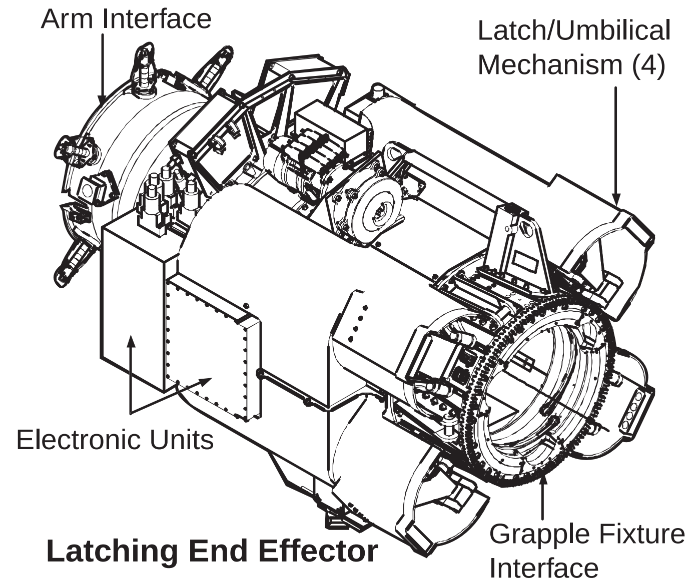
The International Space Station (ISS), currently under construction in Earth orbit, will have several robots to help astronauts complete their tasks in space. Five of the ISS international partner nations are developing robotic systems for the station. Japan is developing the JEM Remote Manipulator System. The European Space Agency and the Russian Space Agency are developing the European Robotic Arm. Canada and the United States are developing the Mobile Servicing System (MSS). Detailed information on each of these systems can be obtained at the website listed below.

Mobile Servicing System

The most complex robotic system on the ISS is the MSS. It consists of the Space Station Remote Manipulator System (SSRMS), the Mobile Remote Servicer Base System (MBS), the Special Purpose Dexterous Manipulator (SPDM), and the Mobile Transporter (MT). The MSS will be controlled by an astronaut working at one of two Robotics Work Stations inside the ISS.

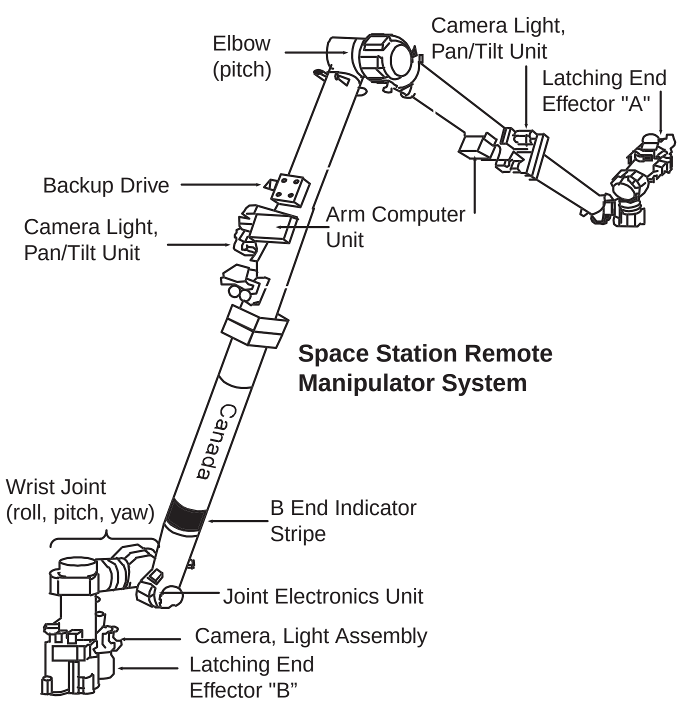
The primary functions of the MSS robotic system on the ISS are to:

- assist in the assembly of the main elements of the station (e.g. aligning newly delivered modules to the structure)
- handle large payloads
- replace orbital replacement units (plug-in equipment designed to be periodically replaced with newer units)
- support astronauts during extravehicular activities
- assist in station maintenance
- provide transportation around the station

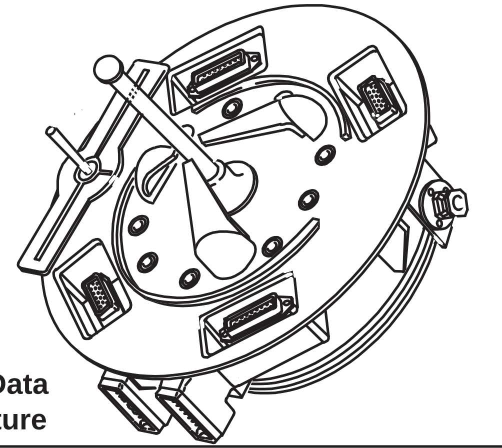


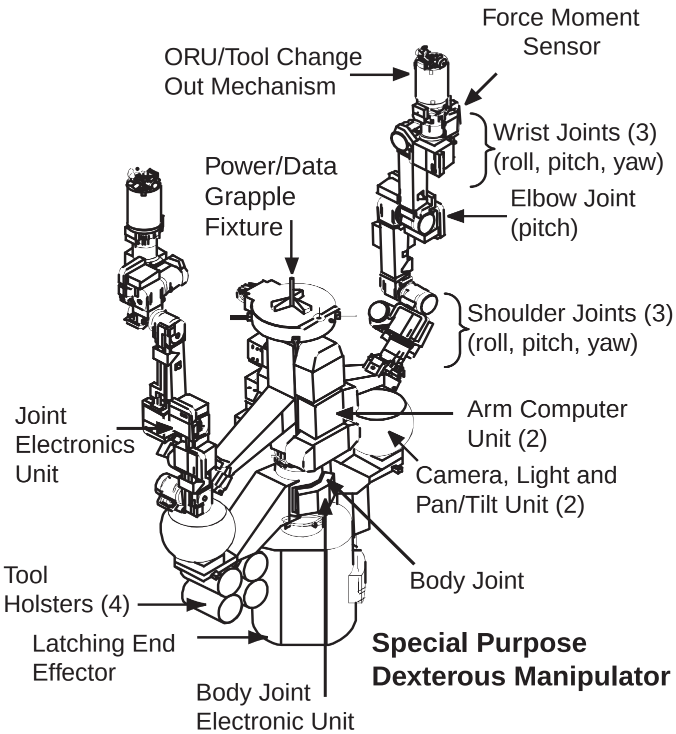
Latching End Effector

The main component of the MSS is the 17-meter-long SSRMS robot arm. It is similar to the Shuttle RMS but will ride from one end of the station to the other on the mobile transporter, which will glide along the giant truss beam. After arriving at a worksite, the arm will grasp payloads, modules, or other structures with its wire snare end effector. If a work location is too distant for the arm to reach while still attached to the transporter, the arm can connect to an intermediate grapple fixture. Electrical power will be rerouted through that fixture. The SSRMS will then release its other end and "inchworm" itself through successive fixtures until it reaches the desired site. The SSRMS is also able to pick up and connect to the SPDM. This unit consists of a pair of 3.5-meter, 7-joint arms connected to a single joint base. The SPDM can pick up small tools for repair or servicing activities or effect delicate manipulations of smaller objects than the SSRMS can handle.



Space Station Remote Manipulator System

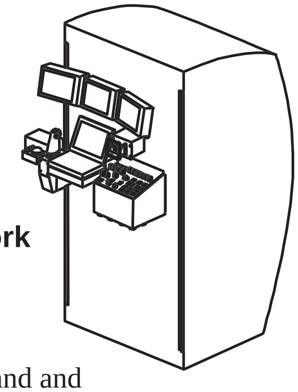

Power and Data Grapple Fixture



Special Purpose Dexterous Manipulator

The Future

Advanced robotic systems are under development for use on the ISS. The ISS provides an exceptional laboratory for testing new robots such as NASA's Robonaut.



Robotic Work Station

Robonaut will feature end effectors based on the human hand and will be capable of handling detailed and complex tasks. It will interface with the MSS and serve as a spacewalker's assistant or surrogate for tasks too dangerous for humans.

When astronauts return to Earth's Moon and set foot on Mars, they will not be alone. Robots will be there as assistants and partners in the exploration of space. Robotic research and application on the ISS will lead the way for the advanced intelligent robotic systems of the future.

Resources: For more information about robots on the International Space Station, refer to the reference section of this web site. http://spaceflight.nasa.gov/station

Classroom Activity – Making and Using an ISS End Effector

Objectives:

- Students will learn how the end effectors for the robotic arms used on the Space Shuttle and the International Space Station work.
- Students will design and construct a grapple fixture that will enable the end effector to pick up an object.

National Standards:

Science Content

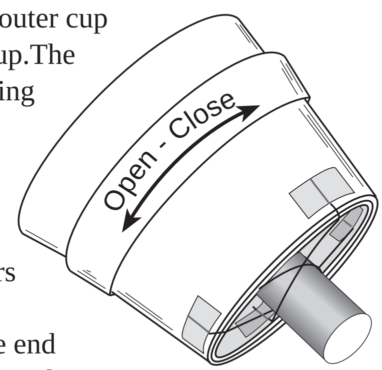
- Abilities of technological design

Technology Education Content

8. Students will develop an understanding of the attributes of design
9. Students will develop an understanding of engineering design
10. Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving
11. Students will develop abilities to apply the design process

Teaching Plan:

In this activity, students can work singly or in small groups of two or three. Have students use a sawing motion to cut through the cups. It is easier to cut through the outer cup first and then the inner cup.The important part about cutting the two cups is that their cut-off ends lie flush with each other when the cups are nested. Use the knives as scrapers to smooth the cut edges.



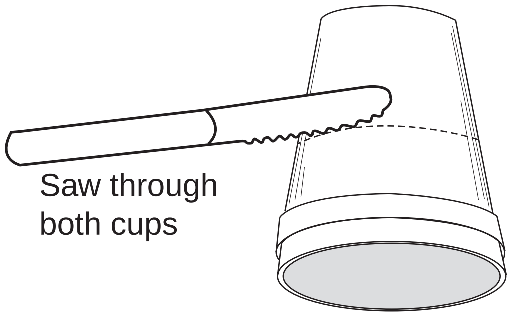
Upon completing the end effector, have your students design a grapple fixture. The idea here is to design something that the end effector can grab onto without slipping off. After grapple fixtures are completed, tell students to compare their fixture to those created by two other students or groups. Ask them to create a table or a chart comparing the strong and weak points of the fixtures they evaluated. They should summarize their results with a statement about how they can improve the fixture they designed.

Materials and Tools

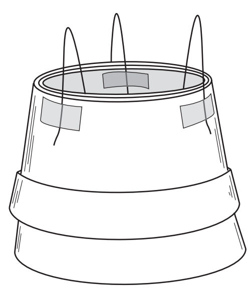
Styrofoam coffee cups (2 each)
String - 12-cm pieces (3 each)
Cellophane tape
Plastic picnic knives (serrated)

Making the End Effector:

1. Nest the two cups together and cut through both cups where indicated in the diagram by the dashed line. Smooth the cut edges by scraping them with the picnic knife edge.



2. Cut three pieces of string 12 centimeters long each.
3. Tape the end of the first string to the inside of the inner coffee cup just below the cut edge. Tape the other end of the string to the outside of the cup but do not press this piece of tape tightly yet.



4. Repeat step 3 twice more, but place the strings about 1/3 of the way (120 degrees) around the cup from the first string.
5. While holding the rim of the inner cup, rotate the outer cup until the three strings cross each other. The strings will have some slack. Pull the end of the strings on the outside until they are straight and intersect exactly in the middle of the opening. Press the tape on the outside to hold the strings.

Using the End Effector:

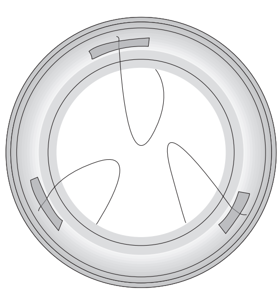
1. Use the end effector to pick up an object such as a pencil. Have someone hold a pencil upright. Open your end effector so that the strings are not crossing each other. Slip the end effector over the pencil so that the pencil extends down the center and not through any of the loops. Rotate the outer cup until the strings grasp the pencil. Pick up the pencil.
2. You may find that the pencil is too slippery to be held securely. How might you modify the pencil so that it can be held? Design a standard grapple fixture that can be mounted to other objects so that they can be picked up.
3. Compare your grapple fixture to two other grapple fixtures designed by your classmates. Which one works the best? Why? Create a chart or a table that evaluates the strong and weak points of each grapple fixture you compared. How can you improve your design?

Assessment:

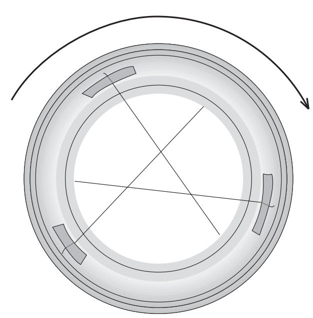
Review the tables or charts created by your students. Pay special attention to the ideas students have for improving their grapple fixtures.

Extensions:

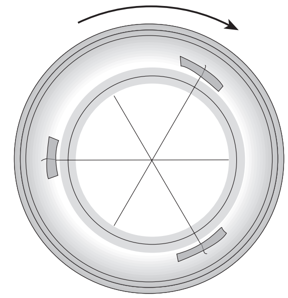
Search robot sites on the Internet and review different end effector designs. How does the design of an end effector enable it to pick up and manipulate various objects?



Open Position



Rotate Outer Cup



Continue Rotating to
Close Snares

Please take a moment to evaluate this product at **http://ehb2.gsfc.nasa.gov/edcats/educational_brief** Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.