

Ascent to Orbit

The History of Space Travel [PRESENT]

Activity: End Effectors



Background Information for the Teacher:

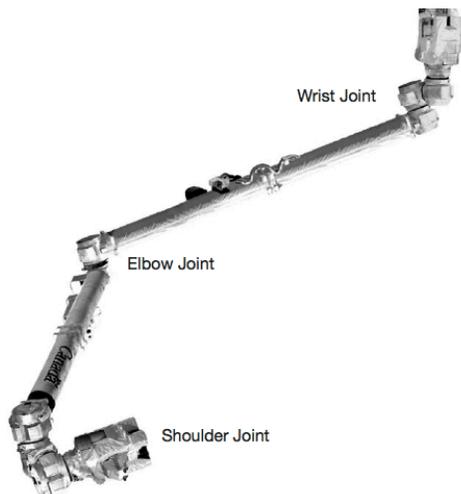
Adapted from the Canadian Encyclopedia

<http://thecanadianencyclopedia.com/articles/canadarm>

Adapted from: The International Space Station Basics packet from NASA (EW-2007-02-150-HQ).

The Era of the International Space Station

This is the beginning of a new era in space exploration in which NASA has been challenged to explore beyond low Earth orbit.



The ISS robotic arm.

The End-effector

One of the most amazing designs of the International Space Station is its robotic arm or *End-effector*, a device mechanism at the end of the arm used to grab space objects. The word “End-effector” means the last link (or endpoint) of the robot. At this endpoint, tools for the robot are attached and consist of a gripper or “hand” which is designed to interact within its surrounding environment. The End-effectors on the space shuttle’s Canadarm1 and the International Space Station’s Canadarm2 are designed to capture stationary or free-flying payloads.

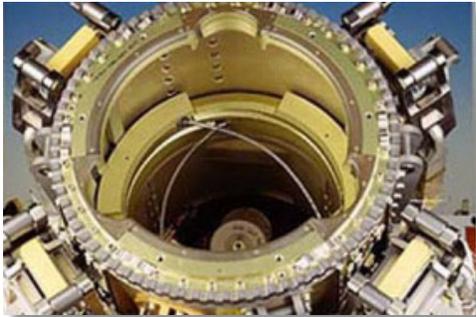
Canadarm and Canadarm2 – What’s the Difference? *Canadarm* is the name given to the Space Shuttle’s Remote Manipulator System (RMS),

Canada's contribution to the US space shuttle program. It is a remote-controlled manipulator attached to the shuttle and used in space for deploying, capturing and repairing satellites, positioning astronauts, maintaining equipment and moving cargo. The 15 m Canadarm functions like a human arm and has six joints, two at its shoulder (yaw, pitch), one at its elbow (pitch) and three at its wrist (pitch, yaw, roll). Its snare-type end effector (or hand) is cylindrical; three snare wires grasp a post or grapple fixture on a satellite or other object to be captured in space.

The next generation of the Canadarm is Canadarm2, the Space Station Remote Manipulator System (SSRMS), and a bigger and "smarter" version of the original. The Canadarm2, with its seven joints, is more maneuverable than its predecessor on the shuttle and even more agile than a human arm. This is important because the space station is a larger and more complex environment than the shuttle's payload bay. Building a brand new space station was a big job. The assembly crews of the International Space Station (ISS) had to attach modules weighing tons, extend solar panels longer than a bus, and haul equipment to and from the space shuttle.

Background Information for the Teacher, Continued...

While the mechanical arm, mounted in the shuttle's cargo bay, is the most visible part, the system also has an astronaut control station inside the shuttle, which includes hand controllers, a display and control panel and a signal processing-interface box, all to allow easy control of the Canadarm from inside the shuttle's cabin. A TV camera (or eye) located on the wrist, and an optional second TV camera at the elbow, are part of the shuttle's closed-circuit television system that provides visual cues when an astronaut is operating the manipulator. One of the five on-board shuttle computers provides the "brain" of the arm.



Grappling, the ability to grab and manipulate the Shuttle payload, or capturing an object “floating” in Space, is an imperative skill for completing many of the missions. Without it you cannot fix the Hubble, inspect the Shuttle thermal tiles for damage and assemble and service the International Space Station.

Canadarm's End-effector is a sophisticated yet simple *Snare* (a mechanism designed to grab something). Three wires, on rotating cylinders that come together as rotary motion, occurs. The wires form a triangle that shrinks to a single point as the parts turn. The wires grab a post mounted on a satellite (grapple fixture in space terminology) to secure it. This is how astronauts can capture the Hubble Space Telescope for servicing or assemble the many parts of the International Space Station.

Fun Fact: Canadarm can lift up to 266,000 kg (586,429 pounds), the mass of a school bus, using less electricity than a tea kettle. Its brain is a computer that helps astronauts operate it from a distance.



Activity Overview: In this activity, students will examine the Canadarm on both the Space Shuttle and International Space Station. Students will work in pairs to construct a simple "hand" using a design patterned after Canadarm's End-effector.

Learning Objective: Students will be able to work in teams to create a simple hand using a patterned design after the Canadarm's End-effector. Students will develop an understanding of engineering design and experimentation in problem solving.



Science Process Skills: Observing, Communicating, and Making a Model.

Estimated Time Required: Day 1 = 50 minutes, Day 2 = 30 minutes

Teacher Preparation:

- Feel free to build your own End-effector model to use as a class demo prior to the activity
- Assemble students into pairs
- Give each team the Two Styrofoam cups

Materials:

- Two Styrofoam cups
- 12 cm pieces of string
- Ruler for measuring string
- Cellophane tape
- Scissors
- Literature: Robot by DK Eyewitness Books, *Robots: From Everyday to Out of this World* by YES Magazine, *The Mighty Mars Rovers: The Incredible Adventures of Spirit and Opportunity* by Elizabeth Rusch, *The International Space Station* by Franklyn M. Branley.



Technology= NASA App, Pettison's Inventions App, NASA website (www.nasa.gov)

What You Do!

1. **[Day 1]** Engage your students by asking them the following questions:
 - Can anyone explain how objects are moved or grabbed in space?
 - Can anyone explain the function or purpose of a robotic or mechanical arm? What does it look like?
 - Is there a difference between a robotic arm as opposed to a mechanical arm? Explain.

Brainstorm student answers on the board. Keep these ideas on the board during the class period so you can refer back to them as you learn more about robotic arms and how they work. *Note:* A robotic arm is a type of mechanical arm usually involving sensors.

Science Vocabulary

- Canadarm
- End-effector
- Grapple
- Mechanical Arm
- Robotic Arm
- Snare

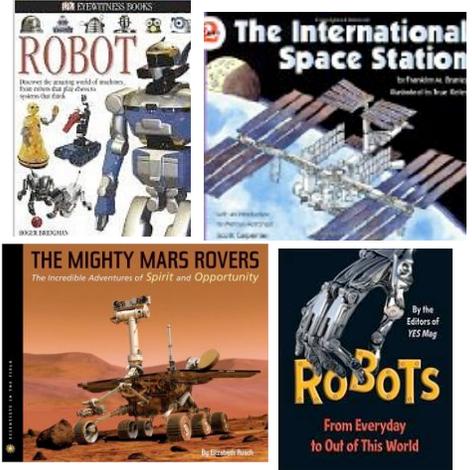


2. **TechConnect:** Via projector, have your students watch a video about the robotic arm. Go to the NASA - Home website (www.nasa.gov). In the search box type in *The International Space Station: The First Step In Exploration Posters*. Scroll down to Robotic Arm/ISS End Effector- Duration: 3 minutes. Students can also visit the NASA website using the iPad Mini. Write the title of the video on the board so that students can find it.

What You Do! Continued...

3. Have students discuss what they observed from the End-effector as soon as they are done watching the video. Then, bring the whole class back together for a discussion on the robotic arm.

4. Allow students time to look through the following literature resources: *Robot* by DK Eyewitness Books, *Robots: From Everyday to Out of this World* by YES Magazine, *The Mighty Mars Rovers: The Incredible Adventures of Spirit and Opportunity* by Elizabeth Rusch, and *The International Space Station* by Franklyn M Branley. Students should be looking for pictures of a robotic arm, specifically the end effector. After allowing them to explore the literature, ask students the following questions:



- What did the arm look like?
- Did it look and move like a real arm? Explain.
- What was the arm called?
- What is the purpose of the robotic arm?

5. Allow students to verbally share their observations in a class discussion. Then, tell students that they will work in teams to construct a simple “hand” using a design patterned after Canadarm’s End-effector. Engage students by asking them to think about why they should build an “End-effector.”

6. **[Day 2]** Assemble students in teams of four. Within each team, students will work in pairs to complete two End-effectors (one will be Canadarm, the other Candarm2).

Example of Styrofoam made End-effector

7. Distribute supplies and data sheets. Remind students that as a team, they are required to build two End-effectors, complete the data sheets and digitally document the process their own way. The directions for the End-effector activity are located on the data sheet below.



Check for Understanding

While teams are working on their End-effectors, walk around the room and ask them what makes the End-effectors work well. If students can tell you that its ability to “grapple” or open and close to grab objects makes it a useful device in space, then they understand the concept.

Modifications

For More Advanced Students: If students are able to construct their End-effector quickly and efficiently, give them a checklist of tasks that they can try to do with the End-effector. Students can try to figure out how to accomplish each task.

For Less Advanced Students: To ensure your students are following directions and saving on instructional time, you may want to have the Styrofoam cups pre-cut.



TechConnect:

To ensure that your students are receiving a sufficient challenge from this lesson, have them use the *NASA* app on the iPad Mini to view videos on the robotic arm by clicking on the rocket icon and scrolling down to videos on robotic arms and write 5 facts that they learned from watching the video.



watch
Select videos here.



TechConnect:

Another great app to explore is called *Pettson's Inventions*. This app is great because students explore with simple machines: levers, pulleys, gears, etc. that all play a role in robotics. They have tasks that they have to complete when given a list of materials. These tasks involve using the basic principles of engineering and movement. Students will be able to explore this app for hours, while they learn about the basic principles of engineering and robotics.





Canadarm End-effector

Informational Reading Handout



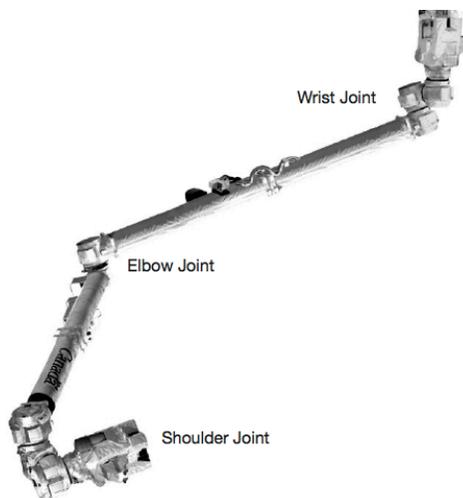
Directions: Read the handout and answer the questions afterward.

Era of The Space Shuttle and International Space Station – The Present

Adapted from <http://thecanadianencyclopedia.com/articles/canadarm> and *The International Space Station Basics* packet from NASA (EW-2007-02-150-HQ).

The Era of the International Space Station

This is the beginning of a new era in space exploration in which NASA has been challenged to explore beyond low Earth orbit.



The ISS robotic arm.

The End-effector

One of the most amazing designs of the International Space Station is its robotic arm or *End-effector*, a device mechanism at the end of the arm used to grab space objects. The word “End-effector” means the last link (or endpoint) of the robot. At this endpoint, tools for the robot are attached and consist of a gripper or “hand” which is designed to interact within its surrounding environment. The End-effectors on the space shuttle’s Canadarm1 and the International Space Station’s Canadarm2 are designed to capture stationary or free-flying payloads.

Canadarm and Canadarm2 – What’s the Difference?

Canadarm is the name given to the Space Shuttle’s Remote Manipulator System (RMS),

Canada's contribution to the US space shuttle program. It is a remote-controlled manipulator attached to the shuttle and used in space for deploying, capturing and repairing satellites, positioning astronauts, maintaining equipment and moving cargo. The 15-meter Canadarm functions like a human arm and has six joints, two at its shoulder, one at its elbow, and three at its wrist. Its snare-type end effector (or hand) is cylindrical; three snare wires grasp a post or grapple fixture on a satellite or other object to be captured in space.

The next generation of the Canadarm is Canadarm2, the Space Station Remote Manipulator System (SSRMS), which is a bigger and "smarter" version of the original. The Canadarm2, with its seven joints, is more maneuverable than its predecessor on the shuttle and even more agile than a human arm. This is important because the space station is a larger and more complex environment than the shuttle's payload bay. Building a brand new space station was a big job. The assembly crews of the International Space Station (ISS) had to attach modules weighing tons, extend solar panels longer than a bus, and haul equipment to and from the space shuttle.

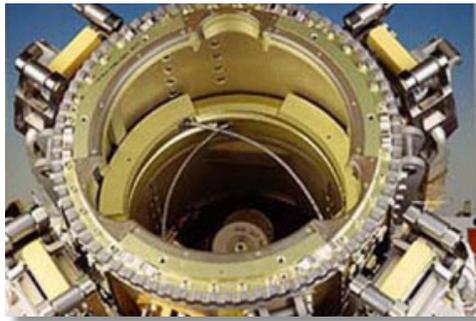


Canadarm End-effector

Informational Reading Handout



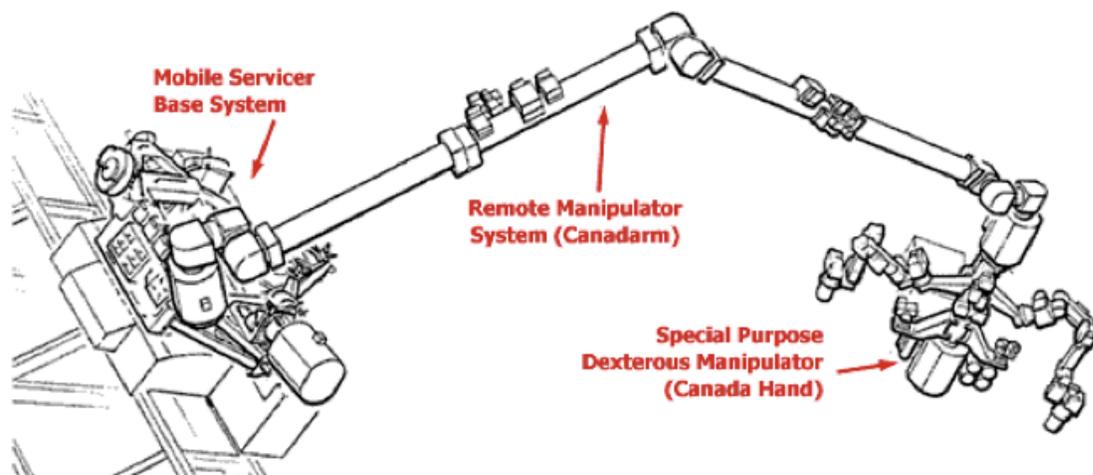
While the mechanical arm, mounted in the shuttle's cargo bay, is the most visible part, the system also has an astronaut control station inside the shuttle, which includes hand controllers, a display and control panel and a signal processing-interface box, all to allow easy control of the Canadarm from inside the shuttle's cabin. A TV camera (or eye) located on the wrist, and an optional second TV camera at the elbow, are part of the shuttle's closed-circuit television system that provides visual cues when an astronaut is operating the manipulator. One of the five on-board shuttle computers provides the "brain" of the arm.



Grappling, the ability to grab and manipulate the Shuttle payload, or capturing an object “floating” in Space, is an imperative skill for completing many of the missions. Without it we wouldn't have been able to fix the Hubble, inspect the Shuttle thermal tiles for damage and assemble and service the International Space Station.

Canadarm's End-effector is a sophisticated yet simple *Snare* (a mechanism designed to grab something). Three wires, on rotating cylinders that come together as rotary motion, occurs. The wires form a triangle that shrinks to a single point as the parts turn. The wires grab a post mounted on a satellite (grapple fixture in space terminology) to secure it. This is how astronauts can capture the Hubble Space Telescope for servicing or assemble the many parts of the International Space Station.

END-EFFECTOR



Space Station Remote Manipulator System: a new generation of space robotics



Canadarm End-effector

Informational Reading Questions



Directions: Read the handout and answer the questions afterward.

1. What is an End-effector? _____

2. What does End-effector mean? _____
3. What are the End-effectors on Canadarm and Canadarm 2 used for? _____

4. What is the Canadarm? _____
5. How many joints does the Canadarm have? Where are they located? _____

6. What is the difference between Canadarm and Canadarm 2? _____

7. How and from where is the Canadarm controlled? _____

8. Where are the video cameras located on the Canadarm? _____

9. What is grappling? _____
10. What is a snare? _____



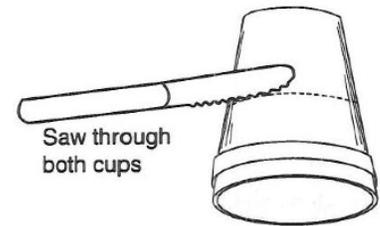
Canadarm End-effector Activity

Instructions Sheet



Directions: Follow the steps to build an “End-effector.” Have a team member video record this process including a minimum of five photos. Share your findings by completing the *Data Sheet – Questions*.

1. Place one Styrofoam cup on the other cup. Carefully cut both cups using scissors (or plastic knife like in the diagram) just below the middle of the cup as seen along the dashed line in the diagram.
2. Smooth the cut edges by scraping them with your fingers.
3. Cut three pieces of string about 12-centimeters long. Try to cut the string as close to being exactly the same as possible.
4. Place the three strings next to each other and check their closeness. Trim a piece if needed.



5. Tape one string to the inside of the cup about 2 cm below the cut edge.
6. Tape the other end of the string outside of the cup, but do not press this piece of tape tightly yet (leave it a little loose) until steps 9 and 10.
7. Repeat steps 5 and 6 for the others so they are equally apart as shown in the diagram to the right.

8. Gently hold the inner cup (bottom piece) and rotate the inner cup until the strings cross each other.
9. Check the tightness of the strings. All strings should be equally tight. Adjust the outer loose tape as needed.

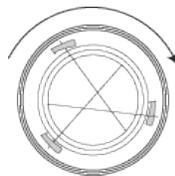


10. Check the strings intersection. All three strings should meet in the middle of the cups. Adjust the outer loose tape as needed. Carefully press the tape down so it stays.
11. Use the End-effector to grab objects like a pencil or a bottle of water.

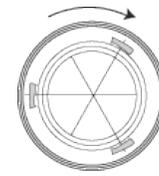
Shows the motion of checking your End-effector.



Open position



Rotate outer cup



Continue rotating to close snares



Canadarm End-effector

Instructions Sheet Continued...



Directions: How to use your End-effector:

1. Use the end effector to pick up an object such as a pencil or an empty plastic water bottle. Open the End-effector so that the strings are not crossing each other. Move the end effector over the end of the pencil. Rotate the outer cylinder to close the strings around the pencil and grasp it.
2. The End-effectors can catch objects. If you use a pencil, the strings may slide off the smooth sides. What could be added to the pencil to make certain it doesn't slide off easily?



Example of Styrofoam made End-effector

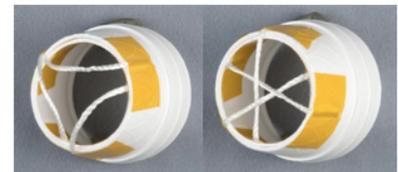


Closed snare made in activity.



Closed snare on the robotic arm.

3. Test your End-effectors and make improvements (such as shortening or lengthening the three strings or using different-sized containers). Securing the strings more tightly improves the operation and performance.
4. Share your findings as a team and write about your experience building an End-effector. Use the *Data Sheet – Questions* to record your answers.





Canadarm End-effector

Data Sheet



Directions: Attempt to complete the following tasks with your End-effector. Try each task 3 times. Calculate how many times you were successful and how many times you were unsuccessful.

Try it out!

Pick up a Pencil:

| Trial: | Successful: | Unsuccessful: |
|---------------|--------------------|----------------------|
| 1 | | |
| 2 | | |
| 3 | | |
| Total: | | |

Pick up a Water Bottle:

| Trial: | Successful: | Unsuccessful: |
|---------------|--------------------|----------------------|
| 1 | | |
| 2 | | |
| 3 | | |
| Total: | | |

Pick up a Coin:

| Trial: | Successful: | Unsuccessful: |
|---------------|--------------------|----------------------|
| 1 | | |
| 2 | | |
| 3 | | |
| Total: | | |

: (You pick what it should try to pick up)

| Trial: | Successful: | Unsuccessful: |
|---------------|--------------------|----------------------|
| 1 | | |
| 2 | | |
| 3 | | |
| Total: | | |



Canadarm End-effector Evaluation Form



Team Name (s) _____



Did building a model of the End-effector help you to develop a better understanding of its design and function?

In building your End-effector, which item was most important to its design?

How did working as a team, help in the design process?

Were there any drawbacks working as a team?

What did you learn from observing the designs developed by other teams in your class?

