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ABSTRACT

This brief discusses human movement and robotic human movement simulators. The activity for students in grades 5-12 provides a history of robotic movement and includes making an End Effector for the robotic arms used on the Space Shuttle and the International Space Station (ISS). (MVL)

National Aeronautics and
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Educational Product	
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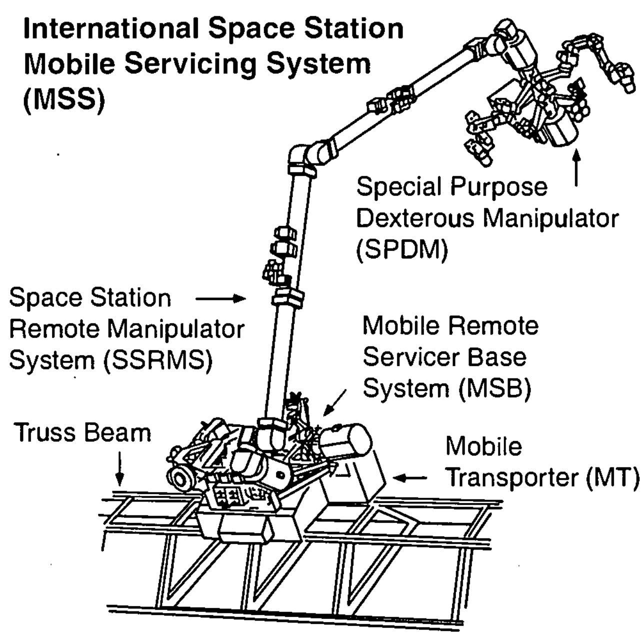
EB-2001-04-004-JSC

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 and 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.



Robots on the International Space Station

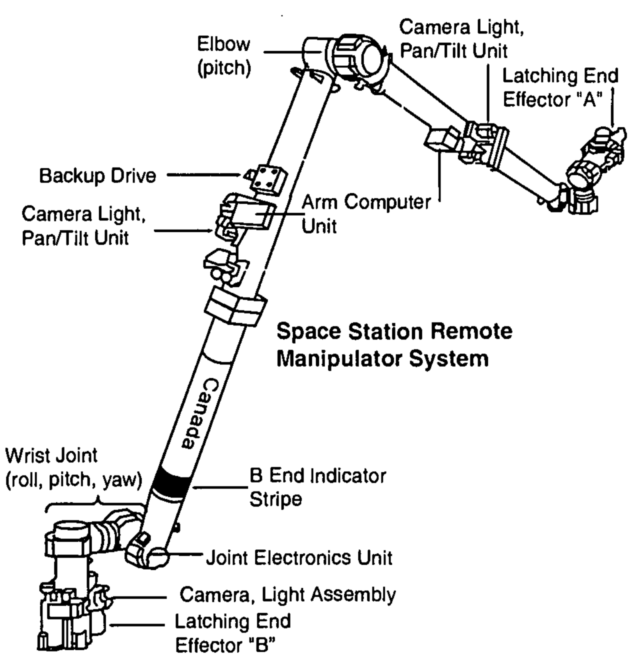
The International Space Station (ISS), currently under construction in Earth orbit, will have several robots to help astronauts complete their tasks in space. Five of the ISS international partner nations are developing robotic systems for the station. Japan is developing the JEM Remote Manipulator System. 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

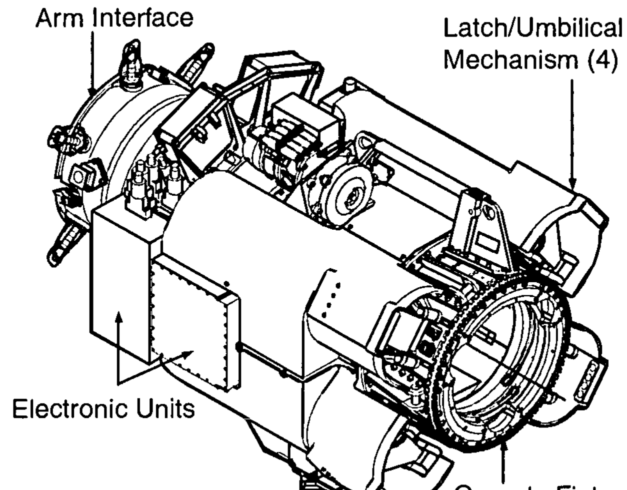
The most complex robotic system on the ISS is the MSS. It consists of the Space Station Remote Manipulator System (SSRMS), the Mobile Remote Servicer Base System (MBS), the Special Purpose Dexterous Manipulator (SPDM), and the Mobile Transporter (MT). The MSS will be controlled by an astronaut working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

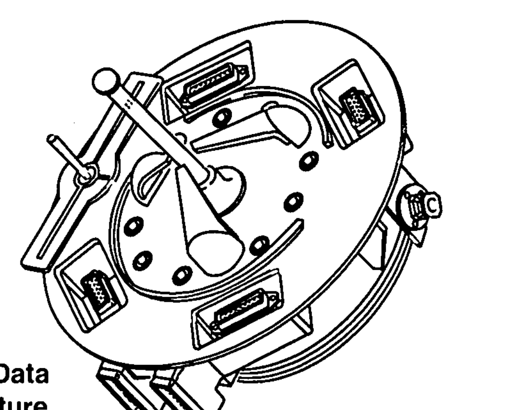


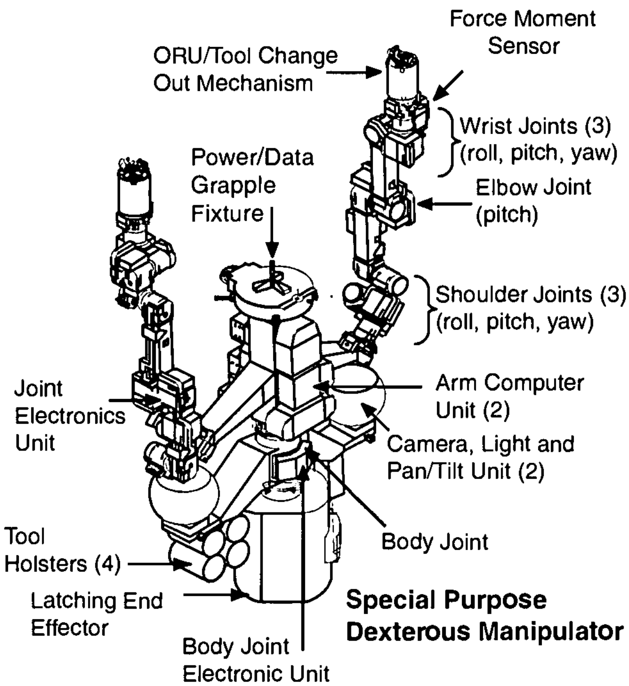
Space Station Remote Manipulator System



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.

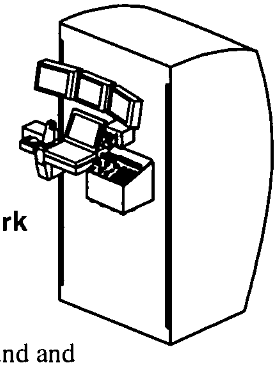

Power and Data Grapple Fixture



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. 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.


Robotic Work Station

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

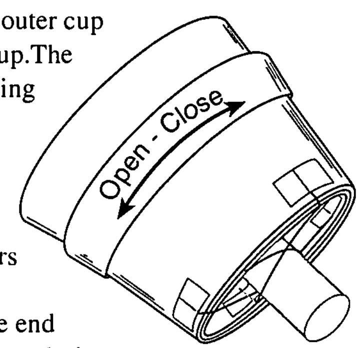
- Abilities of technological design

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.



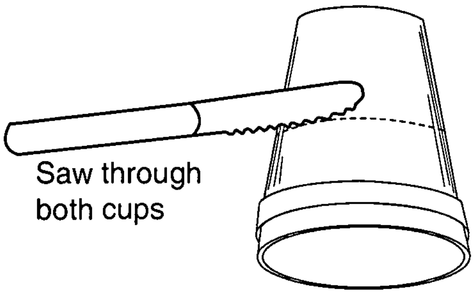
Upon completing the end effector, have your students design a grapple fixture. The idea here is to design something that the end effector can grab onto without slipping off. After grapple fixtures are completed, tell students to compare their fixture to those created by two other students or groups. 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

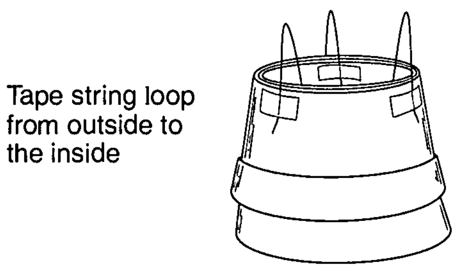
Styrofoam coffee cups (2 each)
String - 12-cm pieces (3 each)
Cellophane tape
Plastic picnic knives (serrated)

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:

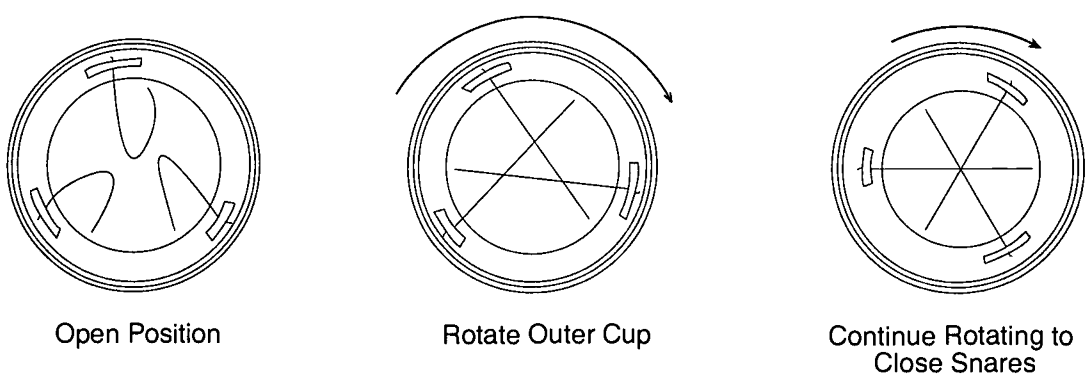
1. Use the end effector to pick up an object such as a pencil. Have someone hold a pencil upright. Open your end effector so that the strings are not crossing each other. Slip the end effector over the pencil so that the pencil extends down the center and not through any of the loops. Rotate the outer 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?



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