Mission X: Train Like an Astronaut

A ROBOTIC ARM

Ages: 8-12

Topic: Engineering design and teamwork

Standards: This activity is aligned to national standards in science, technology, health and mathematics.

Next Generation:

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

3-5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

EDUCATOR SECTION (PAGES 1-7)
STUDENT SECTION (PAGES 8-15)

Background

Why do we need robotic arms when working in space? As an example, try holding a book in your hands straight out in front of you and not moving them for one or two minutes. After a while, do your hands start to shake or move around? Imagine how hard it would be to hold your hands steady for many days in a row, or to lift something really heavy. Wouldn't it be nice to have a really long arm that never gets tired? Well, to help out in space, scientists have designed and used robotic arms for years. On Earth, scientists have designed robotic arms for everything from moving heavy equipment to performing delicate surgery. Robotic arms are important machines that help people work on Earth as well as in space.

Astronaut attached to a robotic arm on the ISS.

Look at your arms once again. Your arms are covered in skin for protection. Inside your skin are nerves, muscles and bones which allow the movements to occur. Like the skin on your arms, the robotic arms in space are also covered with fabric. The protective layers of the robotic arms on the ISS are to keep the wires, motors, and metal safe from space radiation which is similar to how your skin protects your nerves, muscles, and bones of your arms. Additionally, the robotic arms have joints much like our elbows and wrists, and even have parts that are similar to our hands which hold items.

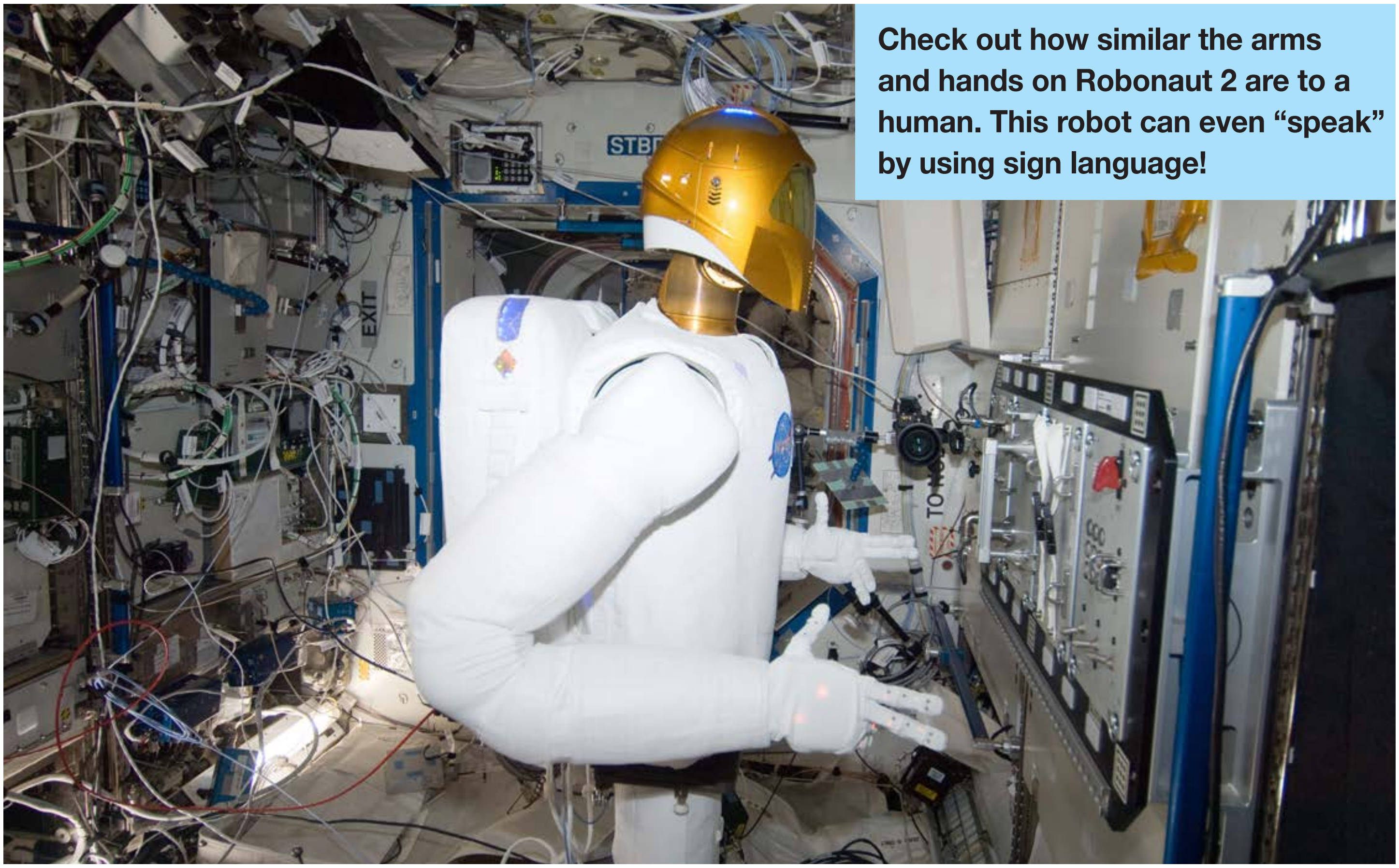
Lesson Objectives. Students will:

- discover relationships between the length of a robotic arm and the level of difficulty to grab objects
- investigate importance of hinges in arm function
- collaborate with each other in designing an arm
- test various materials for grippers end effectors
- compare and modify designs based on how well they meet performance criteria and constraints

Teacher Notes / suggestions for student engagement:

To help students engage with the material, ask some questions to help students relate the robotic arms to their own human arms and also to construction arms like cranes, forklifts, or prosthetic arms. Try to have them rotate their joints to see how their joints rotate.

This activity will ask them to design and build a robotic arm to perform some simple tasks.



Check out how similar the arms and hands on Robonaut 2 are to a human. This robot can even "speak" by using sign language!

The main space station Mobile Servicing System component is known as Canadarm2. This large robotic arm has 7 joints and can move up to 116,000 kg (256,000 pounds) worth of space station equipment. This arm moves equipment around and astronauts can even be connected to the end of the arms to move them around to different parts of the station. Can you imagine floating about 400 km (250 miles) above the Earth and being moved around by a robotic arm? What an out-of-this-world ride! Another arm on the ISS is on the Japanese Experiment Module and is known as the Remote Manipulator System. This device is actually made with two arms - a large arm and a small arm – each of which have 6 joints and are used for conducting experiments and supporting maintenance tasks.

On the ISS there is also a human-sized robot known as Robonaut 2, or R2. This robot can perform tasks that humans typically perform, but does these tasks without getting tired. R2 has arms and legs designed for specific purposes that help the astronauts perform their jobs safely while in space.

The European Robotic Arm has similar features as the other arms on the ISS in that it is designed to work with the Russian airlock and can also move equipment directly from inside the ISS to the outside of ISS. This arm uses infrared cameras to inspect the outside of the ISS and is also designed to move astronauts around the outside of the station to make it easier for them to work during spacewalks.

Teacher Notes / suggestions for use of A Robotic Arm video:

There is a short video that accompanies this activity. If time permits, have the students watch the video before they begin the activity to help them engage and build interest with the topic. Then, at the end of the activity, they can watch the video and reflect on how much they have learned about robotic arms. The video is titled, "A Robotic Arm" and can be found at http://trainlikeanastronaut.org/media.

Problem: Can we design a robotic arm to grab objects at a distance?

SAFETY SECTION!!

Sharp Hazard! Use caution when making holes in popsicle sticks.

Explore

End effectors and arms – how we grab and reach

Split the students into pairs. Give each pair a set of chopsticks. Tell the students that they have to use the chopsticks to extend their arm and that they should grab the chopsticks at the end to make their arms as long as possible. Let them try to use the chopsticks to hold a small ball (such as a ping-pong ball) or an eraser. Next, ask them if they managed to successfully complete the task, and why did it work or why didn't it?

Canadarm2 and its end effector as seen from the ISS.

How did it work? Was it more difficult to grab the eraser or the ping-pong ball? Explain to the students that astronauts sometimes have to grab things that are far away. In those cases they don't use chopsticks to make their arms longer; they use special robotic arms. Look at the pictures of a real robotic arm on page 1 and the astronaut being held by it. What is being done with the robotic arm? It is being used to help astronauts perform repairs outside of the space station. It takes time and effort to move in space, so the robotic arm helps move astronauts and equipment around outside of the space station to make repairs. Students should move their chop stick arms slowly and carefully, just like the astronauts and flight controllers who have to be very precise when using a robotic arm, and especially careful when an astronaut is attached to the arm!

Design and testing: Arm length and hinges

Can we design a robotic arm to perform specific tasks?
In this section, the students make a robotic arm with hinges that they can use to grab items from a distance.

Pre-lesson Preparation:

Prepare twelve storage bins for the activity A Robotic Arm.
In each storage bin, place:

- eight popsicle sticks
- a pair of scissors
- cotter pins (metal pin used to fasten two parts of a mechanism together)
- two erasers or pieces of a sponge

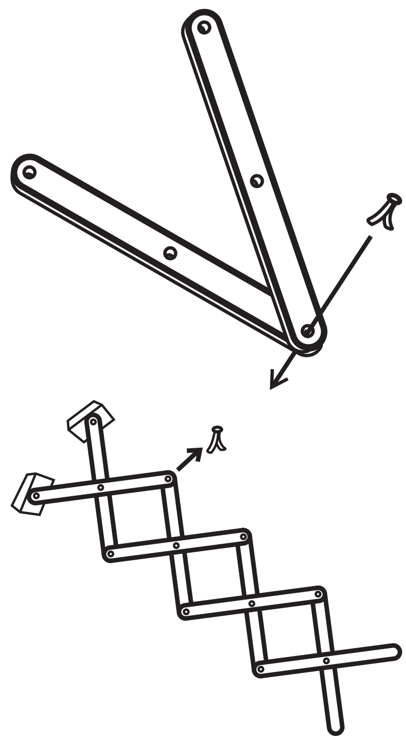
Materials:

- 96 popsicle sticks
- 24 erasers or sponge pieces
- 12 sets of chopsticks
- 12 pairs of tweezers
- 12 storage bins
- 12 ping-pong balls
- scissors
- cotter pins
- hole punch or awl (leather punch)

Procedures:

The following procedures are taken from the student section.

1. Get the materials from your teacher.
2. Check the materials. Later, you will be be able to get creative so start thinking now about which other materials can you use to make a robotic arm.
3. Punch three holes in the popsicle sticks using your teacher's hole puncher. See image for location of holes.
4. Connect two popsicle sticks using a cotter pin, forming a cross.
5. Repeat steps 4 and 5 for all other popsicle sticks.
6. Now connect all the crosses together. Carefully check the sample drawings as an example.
7. Make a cut in both erasers or sponges in the side.
8. Insert the erasers with the cuts, or sponge pieces, to the ends of the grabber.
9. Try using your robotic arm to grab an object from the table. Can you successfully do this?
10. Use your robotic arm to try to pick up an eraser and something round, like a ping-pong ball. Can you successfully do this?



Explain:

These questions are taken from the student section.

1. Was it more difficult to grab the eraser or the ping-pong ball? [Answers will vary, but most will find the eraser easier to grab due to friction and the shape of the surface.]
2. What is an object that would be difficult to hold with your end effector? [Slippery, heavy, small or very large objects may be examples.]
3. What is an object your arm would not be well designed to pick up? [Answers will vary.]
4. Did gravity play a role in how easy it was to use your robotic arm? [Answers will vary, but in general gravity will make it harder to move an object due to the object having weight. On the ISS there is a similar amount of gravity as on Earth, but because the ISS, the arm, astronauts and the objects are all falling in the same direction the effect of gravity is negligible.] For more information regarding gravity, http://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-microgravity-58.html.

Adapting the robotic arm for new conditions…

1. Try to make your robotic arm even longer. Does the arm work better when it is longer? [Answers will vary, but generally the arm is more difficult to use when longer.]
2. Remove some sections of your arm. Does your robotic arm work well when you make it shorter? [Answers will vary]
3. What material would you use to pick up an egg? [Answers will vary]
4. Remove a number of cotter pins. Does the robotic arm still work? [Answers will vary]. Depending on which cotter pin is removed, if the arm still works it will most likely work not as well.

Elaborate:

Students will adapt and test their robotic arms in different situations and get creative by designing and building a new robotic arm to perform a task. They will investigate how changes in design parameters and structure affects their arm's performance. This will allow the students to investigate arm designs and better understand the connections between design, form fit function, outcomes and specifications.

Teach another group how to use your arm, and learn how to use their arms. Use the other teams' arms to perform a task for which it was designed to perform. Astronauts in space and the Flight Control Team, on Earth, work together and communicate regarding the movements of the robotic arms. Before astronauts fly to space, they learn how to safely use the robotic arms and are taught these skills by scientists and engineers. The astronauts will practice the motions on Earth so that when they fly to space they can operate the arms to safely do their jobs. They want to make sure everybody is safe and keep the equipment, ISS, and the arm in good condition. So, as you learn from the other teams how to use their arm, be gentle with the arm and keep it in good working condition. Share with the other teams why you chose the materials you chose, and the decisions your team made that helped create your arm. Remember, learning from each other and working as a team is an important aspect of astronaut training.

Evaluate:

1. Which objects from your bin did you choose to make your arm?
2. Did your design meet the requirements and do what you wanted it to do? Circle one YES / NO
3. Place your hands in different places on the arm and do what you wanted it to do. Where should you place your hands to make the arm easiest to use? [Answers will vary.]
4. The end effector is the part of the arm that holds objects. Other than the erasers or sponges, what materials could you use for an end effector? [Answers will vary.] Surfaces with more friction are good choices. Keep in mind that the end effector and the objects to be grasped must be designed to work together.

Extend: How does the Canadarm2 end effector work?

Teacher Notes / suggestions for use of A Robotic Arm video:
Look over the suggested challenges and adjust the tasks for the age group of your students. Have the students read the student reading section, or read it to them. Also, the videos are interesting for background information and show the designs well.

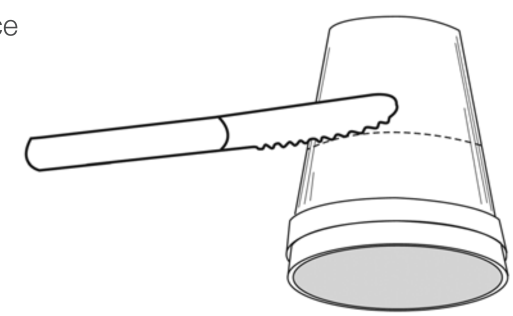
The end effector on Canadarm2 is an elegant design, and we can make a model using simple materials. This part of the activity was adapted from a NASA education activity found here https://www.nasa.gov/pdf/675573main_Technology%20Activity-SOS.pdf. Have the students look at the video before completing this section. In fact, they may want to refer back to the video again afterwards. The following is from the student section at the end of this activity.

Materials:

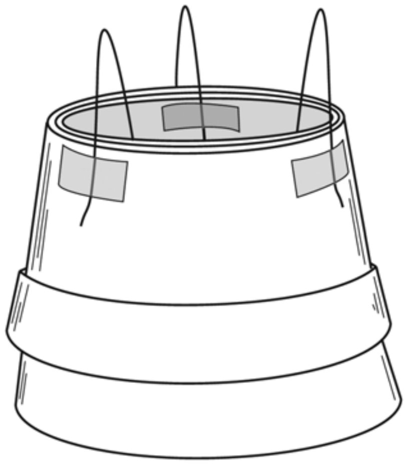
- styrofoam or paper cups (2 per end effector)
- 12-cm pieces of string (3 per end effector)
- cellophane tape
- plastic picnic knives (serrated)
- straw or lollipop (1 per end effector)

You and your colleagues are now working as Robotic Engineers for a space agency. You may work in pairs for this section, although your teacher may assign you to other sized groups.

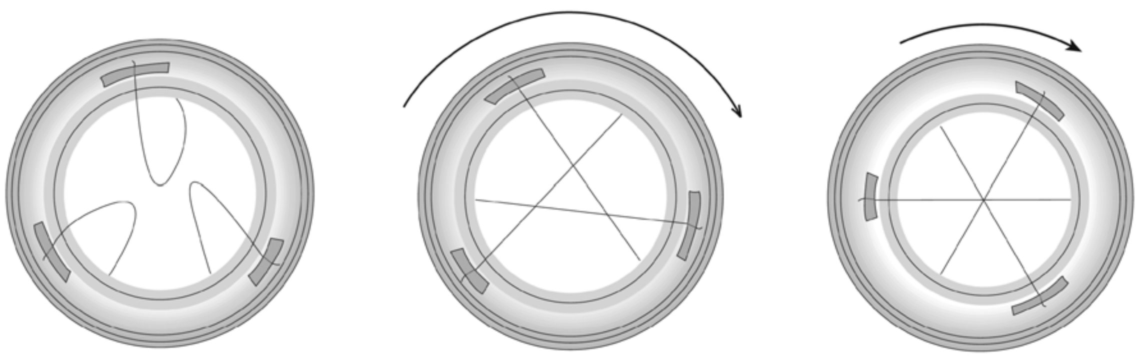
1. Nest the two cups together and cut through both cups where indicated in the diagram by the dashed line. Smooth the cut edges by scraping them with the edge of the picnic knife edge.



2. Cut three lengths of string, each about 12 centimeters (4.7 inches) long.
3. Tape the end of the first string to the inside of the inner cup just below the cut edge.
4. Tape the other end of the string to the outside of the outer cup, but do not press this piece of tape tightly yet. You will press to tighten the tape after the strings are adjusted in a later step.



5. Repeat Steps 3 and 4 twice more, but place the strings about a third of the way (120 degrees) around the cup from the first string.
6. 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 securely hold the strings.



Rotating the cups to close the snares. The snares on the Canadarm2 are designed to hold objects such as visiting vehicles in place.

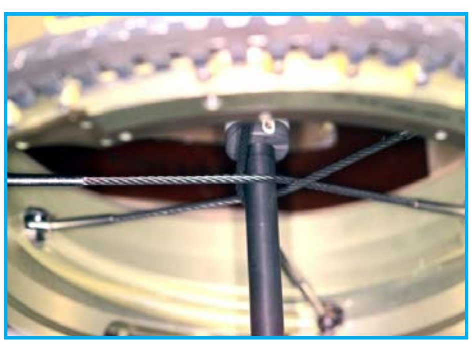
Using your End Effector

- Use the end effector to pick up the straw. Have someone hold the straw upright. Open the end effector so that the strings are not crossing each other. Slip the end effector over the straw or lollipop so that the straw extends down the center and not through any of the loops.
- Rotate the outer cup until the strings grasp the straw or lollipop. Pick up the object. The strings are like the snares on the robotic arm on the ISS, and this twisting of the snares allows the arm to hold, or grapple, objects such as visiting vehicles. Have some fun and try to grapple some other objects.

1. The object may be too slippery to be held securely. How might the straw or lollipop be modified so that it can be held? [Answers will vary.]
2. Teamwork, sharing ideas and collaborating with others is very important to engineers and other work teams. Compare your grapple fixture to two other grapple fixtures designed by your classmates. Draw them in the squares below. [Answers will vary.]

3. Which one works the best? Use complete sentences to explain why. [Answers will vary.]
5. Draw your end effector and evaluate the strongest and weakest points of each grapple fixture you compared. [Answers will vary.]
6. How can you improve your design? Use complete sentences. [Answers will vary.]
7. Can your team figure out a way for your arm and your end effector to work together? [Answers will vary.]




Snares are closed around a grapple fixture pin on the robotic arm.

Mission X: Train Like an Astronaut
A ROBOTIC ARM

Student Section

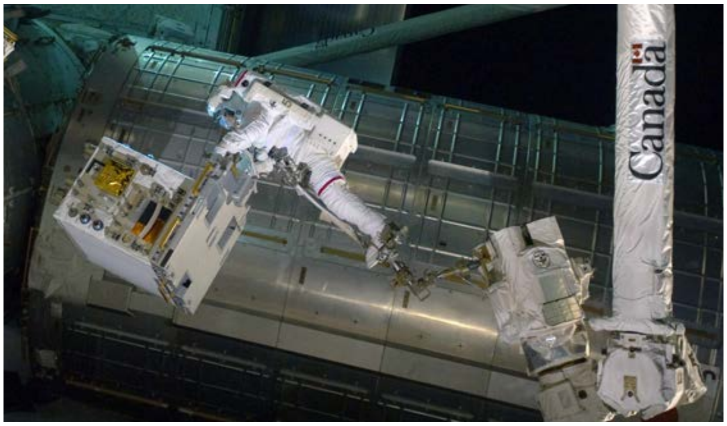
Engage:

Do you have arms like a robot? Well, the robotic arms on the International Space Station (ISS) have similarities to human arms. Look at your own arms. How many places do your arms bend between your shoulders and your fingers? Each location that bends allows your arm to move in a different direction. Now look at your hands as you pick up an object like a pencil. Notice how your fingers, hands and wrists move to allow you to pick up the pencil. Now try this: Hold your arms straight out in front of you with your palms facing downwards. Now, count to five slowly as you move your finger to touch the end of your nose. Did you notice all the movements and twisting at your elbow and wrist joint? Do it again and watch only your wrist as it moves. Does it twist? Try holding one hand under your elbow and rest it on your desk or a table and very slowly touch your nose again. Can you touch your nose while keeping the bones inside your arm and elbow joint from moving or twisting? Can you do this without letting your fingers get above eye level? Did this change the motion of your fingers? Could you feel the bones in your elbow moving around inside your skin? Your arms need all these joints to perform complicated motions throughout your day.

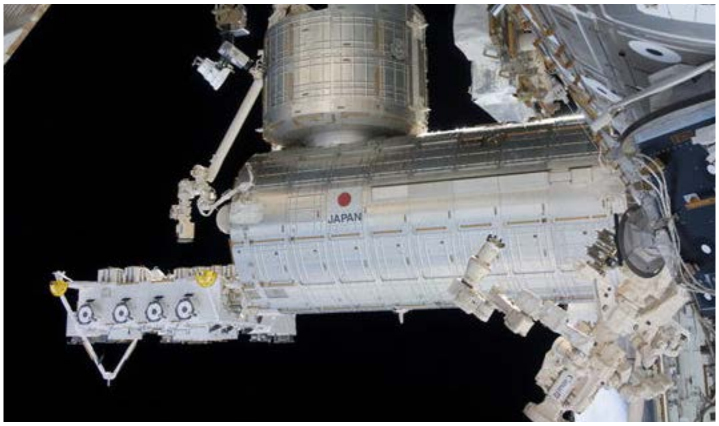
Did you know?

Japanese Experiment Module Remote Manipulator System (JEMRMS) is actually two arms – a big and a small arm – each with 6 joints to make human-like movements?

The Canadarm2 (center) and solar array panel wings on the International Space Station.



Astronaut using Canadarm2 to work on the ISS.



The ISS has many robotic arms to help the astronauts work in space.

Procedures

1. Get the materials from your teacher.
2. Check the materials. Later, you will be be able to get creative so start thinking now about which other materials you can use to make a robotic arm.
3. Punch three holes in the popsicle sticks using your teacher's hole puncher. See image for location of holes.
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7. Make a cut in both erasers or sponges in the side.
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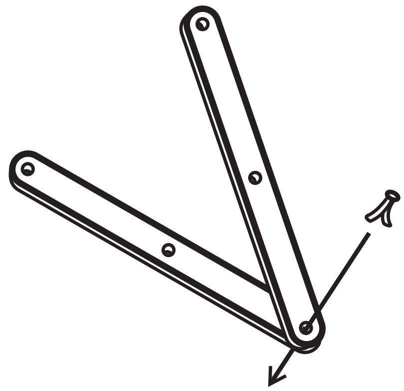
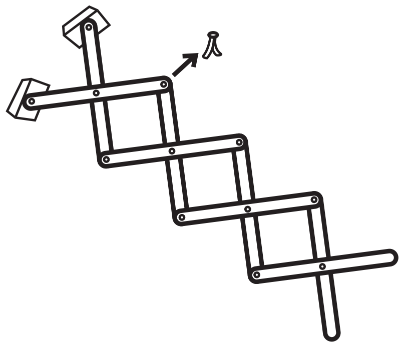
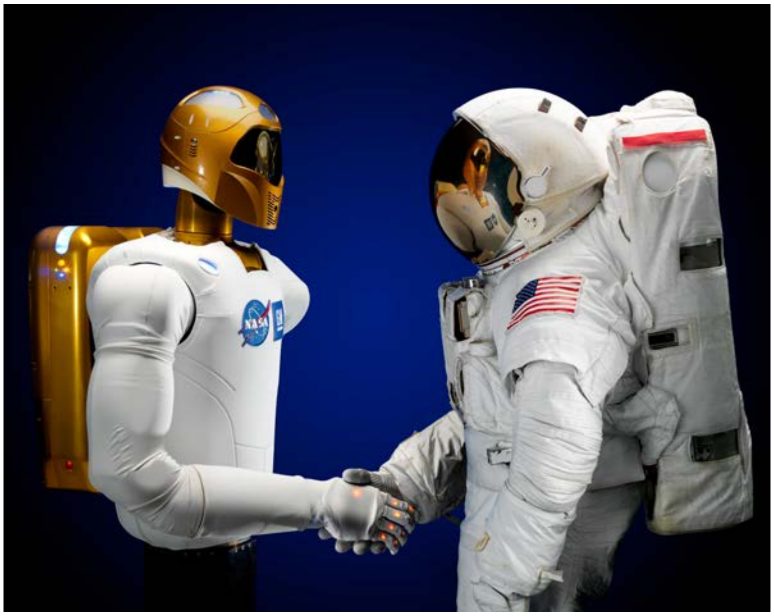




Explain

Grabbing and End Effectors

1. Was it more difficult to grab the eraser or the ping-pong ball?
2. What is an object that would be difficult to hold with your end effector?
3. What is an object your arm would not be well designed to pick up?
4. Did gravity play a role in how easy it was to use your robotic arm?



Robonauts and astronauts are both important to successful space missions.

Discuss your answers with another crew member. It is important to collaborate with others! Teamwork allows us all to do more than we could do by ourselves. This is true for astronauts, engineers, and you! Did you and your team mates get similar results? Ask them. Then, as a group, prepare to get creative and design your own Robotic Arm to answer the following questions.

> **Did you know?**
> In 1920, Czechoslovakian writer Karel Capek invented the word "robot" in his play R.U.R. (Rossum's Universal Robots). Robota, a Czech word, translates as "drudgery" or forced labor.

Adapting the robotic arm for new conditions…

1. Try to make your robotic arm even longer. Does the arm work better when it is longer?

2. Remove some sections of your arm. Does your robotic arm work well when you make it shorter?

3. What material would you use to pick up an egg?

4. Remove a number of cotter pins. Does the robotic arm still work?

Elaborate

It is time to get creative!! In this section, your team will adapt and test your robotic arms to different situations. Investigate how changes in design parameters and structure affects your arm's performance. Move things around. Change the length of your arms. Add or remove joints. Play with your design, because this will allow your team of engineers to investigate arm designs and better understand how they work. When you are ready to move on, decide on a task or skill that you would like your robotic arm to perform. Will it help humans perform a task such as opening a door or holding something hot? Once you have decided on the task you want your arm to perform, draw a design of the arm you would like to build to perform your task and get approval from your teacher before moving on to the next step. On your drawing, label the parts of the robotic arm such as the end effector or joint.

_________ teacher approval

Now, build your robotic arm and see how it works to perform your task! You are the scientists and are now working together just like a group of robotic arm engineers!

Teach another group how to use your arm, and learn how to use their arms. Use the other teams' arms to perform a task for which it was designed to perform. Astronauts in space and the Flight Control Team, on Earth, work together and communicate regarding the movements of the robotic arms. Before astronauts fly to space, they learn how to safely use the robotic arms and are taught these skills by scientists and engineers. The astronauts will practice the motions on Earth so that when they fly to space they can operate the arms to safely do their jobs. They want to make sure everybody is safe and keep the equipment, ISS, and the arm in good condition. So, as you learn from the other teams how to use their arm, be gentle with the arm and keep it in good working condition. Share with the other teams why you chose the materials you chose, and the decisions your team made that helped create your arm. Remember, learning from each other and working as a team is an important aspect of astronaut training.

Evaluate

1. Which objects from your bin did you choose to make your arm?

2. Did your design meet the requirements and do what you wanted it to do? Circle one YES / NO

3. Place your hands in different places on the arm. Where should you place your hands to make the arm easiest to use?

4. The end effector is the part of the arm that holds objects. Other than the erasers or sponges, which material can you also use for an end effector?

Extend

Student reading section

On the ISS, the main Mobile Servicing System is also known as Canadarm2. This large robotic arm has 7 joints and can move up to 116,000 kg (256,000 pounds) worth of space station equipment. This arm moves equipment around, and astronauts can be connected to the end of the arms to move them around to different parts of the station. Can you imagine floating about 400 km (250 miles) above the Earth and being moved around by a robotic arm? What an out-of-this-world ride! Another arm on the ISS is on the Japanese Experiment Module and known as the Remote Manipulator System. This arm is actually two arms - a large arm and a small arm – which both have 6 joints and are used for conducting experiments and supporting maintenance tasks. At the very end of the arm, the end effector and snare is one of the most important pieces because that is what actually holds on to objects.

On the ISS there is also a human-sized robot known as Robonaut 2, or R2. This robonaut can perform tasks that humans typically perform, but does these tasks without getting tired. R2 has arms and legs designed for specific purposes that help the astronauts perform their jobs safely while in space. The fingers and hands of R2 are very much like human hands and fingers and they close on objects to hold them in the same way your own hands work. The end effector on Canadarm2 is very different. It uses snare cables as its effector. You will get a chance to build a model of the Canadarm2 end effector in the next section!

How would you design an end effector to grab and hold on to a satellite? Remember, both the satellite and the ISS are floating in space, so if the two objects push off of each other, they will fly off in separate directions in space. Satellites and the ISS are very, very expensive, and contain precious cargo and humans on board! The method used to hold on to the satellite as the robot moves it is very important, and the design is actually fairly simple. In the extend section, you will be able to build a model of the Canadarm2 end effector and snares. One thing to keep in mind is that the grapple fixtures – the equipment used to grab and hold on to objects – must be checked and tested. This is because the snares are actually somewhat flexible cables and, because they are flexible, could possibly not be in the correct position after their prior use. Before the end effector is used to grapple objects, the snares are sometimes checked to make sure they are positioned correctly for use, and not out of position. In the video A Robotic Arm, NASA astronaut and Mission X Ambassador Mike Hopkins checks the snares to make sure they are positioned and ready to grapple a visiting resupply vehicle.

Let’s build it! How does that real end effector work?

The end effector on Canadarm2 is an elegant design, and we can make a model using simple materials. This part of the activity was adapted from a NASA education activity found here: https://www.nasa.gov/pdf/675573main_Technology%20Activity-SOS.pdf.

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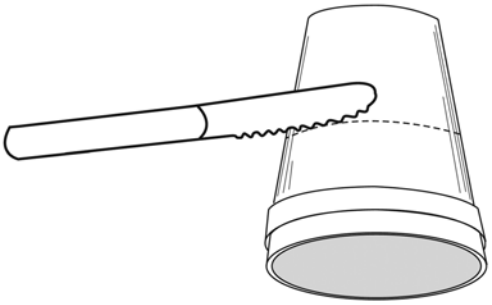
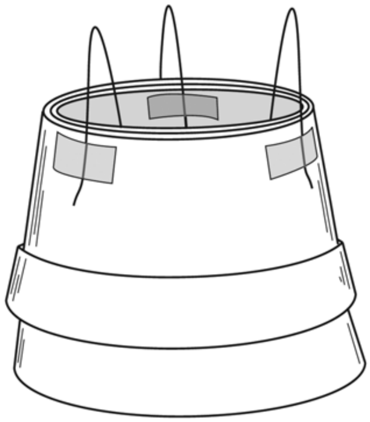
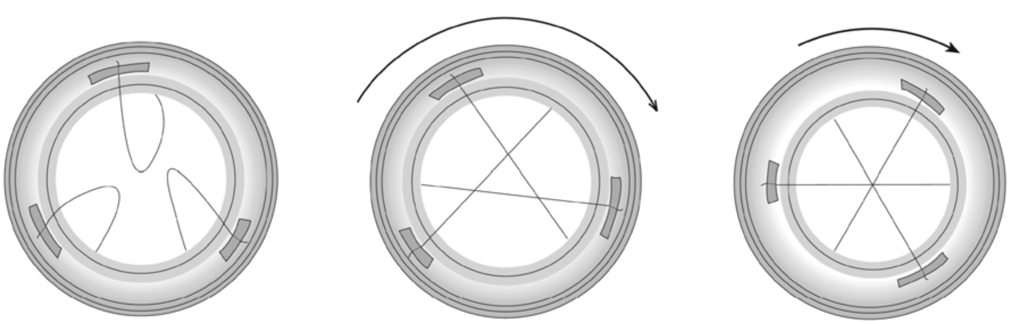


1. Nest the two cups together and cut through both cups where indicated in the diagram by the dashed line. Smooth the cut edges by scraping them with the edge of the picnic knife.
2. Cut three lengths of string, each about 12 centimeters (4.7 inches) long.
3. Tape the end of the first string to the inside of the inner cup just below the cut edge.
4. Tape the other end of the string to the outside of the outer cup, but do not press this piece of tape tightly yet. You will press to tighten the tape after the strings are adjusted in a later step.



5. Repeat Steps 3 and 4 twice more, but place the strings about a third of the way (120 degrees) around the cup from the first string.
6. 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 securely hold the strings.



Rotating the cups to close the snare

Using your End Effector

Engineers design a fixture for the snares to close around, and then these fixtures are placed on satellites or other objects that the robots will grapple. These fixtures will be simulated by straws or lollipops in this activity.

- Use the end effector to pick up the straw or lollipop. Have someone hold the straw or lollipop upright. Open the end effector so that the strings are not crossing each other. Slip the end effector over the straw or lollipop so that the straw extends down the center and not through any of the loops.
- Rotate the outer cup until the strings grasp the straw or lollipop. Pick up the object.

1. The object may be too slippery to be held securely. How might the straw or lollipop be modified so that it can be held?

2. Teamwork, sharing ideas and collaborating with others is very important to engineers and other team members.. Compare your grapple fixture to two other grapple fixtures designed by your classmates. Draw them in the squares below.

4. Which one works the best? Use complete sentences to explain why.

5. Draw your end effector and evaluate the strongest and weakest points of each grapple fixture you compared.

6. How can you improve your design? Use complete sentences.

7. Can your team figure out a way for your arm and your end effector to work together?




Snares closed around a grapple fixture pin.

Contributors and SME background

Laura Lucier, at NASA's Johnson Space Center.

At NASA and space agencies around the world, there are many groups working with robotics and spaceflight. This activity was developed with the collaboration of the Netherlands Space Office, NASA's Human Research Program Engagement and Communications team, and the Subject Matter Expert assistance of Laura Lucier. Laura holds a BSc in Mechanical Engineering with Distinction from the University of Calgary and a Masters degree in Aerospace Engineering from McGill University. While studying at McGill she performed research on the degradation of materials in the low-Earth orbit environment with the Advanced Materials and Thermal Group at the Canadian Space Agency. At the time of this publication, Laura worked at the Johnson Space Center as a NASA flight controller. Specializing in robotics, Laura plans operations involving the Canadarm2 and Dextre robots onboard the International Space Station and works on console in the Mission Control Center when the robots are being used. Her favorite parts of the job are maneuvering the robots from the ground and training astronauts on how to use them. Outside of work, Laura exercises her skills as an instrument-rated commercial pilot and SCUBA instructor. She also volunteers for CyberMentor, an Alberta-based science mentoring program for young women and enjoys playing ice hockey.

Meie Van Laar, Science Center NEMO.

A Robotic Arm is based on a lesson developed by Meie van Laar of Science Center NEMO in the Netherlands. Science Center NEMO hosts ESERO NL, the Dutch node of the European Space Education Resource Office project, an initiative by the European Space Agency (ESA). In the Netherlands ESERO is co-funded by the Netherlands Space Office.

ESERO NL uses space related themes and the genuine fascination felt by young people for space to enhance literacy and competence in STEM-related subjects and to enhance study and career choices in science and technology. To this aim it supports teachers by providing training and professional development courses and by developing class room resources. For more information visit www.ruimtevaartindeklas.nl which offers a wide range of space lessons (Dutch only).

Nicole Sentse, Life Scientist, ESA.

Nicole Sentse has been working as a Life Scientist for the European Space Agency for more than 12 years and together with Cristina Olivotto initiated the Mission X project for the European Space Agency, in cooperation with their NASA colleagues, in reply to a request from the ISS Life Science Working Group in 2010. She is currently working as independent consultant for the European Space Agency and the Netherlands Space Office.

Cristina Olivotto, ESA.

Cristina Olivotto works for Sterrenlab and collaborates with education programs in formal and informal education at primary and secondary level in international contexts. She is currently developing a series of lesson plans for primary school teachers with the European Space Agency. For more information about Sterrenlab go here http://www.sterrenlab.com/.

Ed White Elementary

American School of the Hague

We appreciate the experience and guidance of the educators and all the students who helped refine this lesson. A special thank you to Owen Davison, a grade 5 science teacher at the American School of the Hague, the Netherlands and Laura Mackay, engineering teacher at Ed White Elementary School in Texas, USA. Remember, all of these engineers, scientists and team members were once children like you are. They found their dream and followed it into the world of Robotics - you can too!

Media/graphics/images

Useful websites for further information

ISS Mobile Station Mobile Servicing System (Canadarm2)

www.asc-csa.gc.ca
http://www.nasa.gov/mission_pages/station/structure/elements/mss.html
https://www.youtube.com/watch?v=K7NvsxcoDKo&feature=youtu.be
Training on proper use of the arm
https://www.youtube.com/watch?v=6YFQf1-7T7s
https://www.youtube.com/watch?v=u4ggQdkTcLo

Japanese Experiment Module Remote Manipulator System (JEMRMS)

http://iss.jaxa.jp/en/kibo/about/kibo/rms/

Robonaut2

http://robonaut.jsc.nasa.gov/default.asp

Space Robot facts

http://er.jsc.nasa.gov/seh/robots_in_space.htm

European Robotic Arm

http://www.esa.int/spaceinvideos/Videos/1999/11/European_Robotic_Arm_ERA2
http://wsn.spaceflight.esa.int/docs/Factsheets/7%20ERA%20LR.pdf
http://www.esa.int/Our_Activities/Human_Spaceflight/International_Space_Station/European_Robotic_Arm
http://www.airbusdefenceandspacenetherlands.nl/project/era/