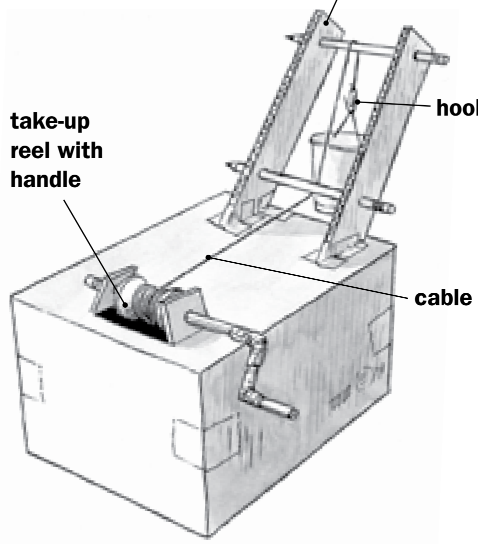
HEAVY LIFTING

LEADER NOTES

The Challenge

Design and build a crane and see how heavy a load it can lift.

In this challenge, kids follow the engineering design process to: (1) design and build a crane out of cardboard; (2) figure out ways to reinforce the arms so they don't collapse under a heavy load; (3) build a crank handle; and (4) improve their cranes based on the results of their testing.



One crane design kids could build

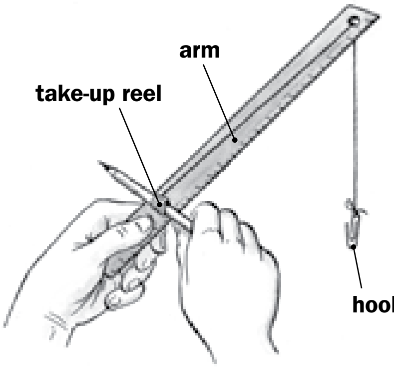
1 Prepare ahead of time

- Read the challenge sheet and leader notes to become familiar with the activity.
- Gather the materials listed on the challenge sheet.
- Build a simple crane arm out of a ruler, pencil, and string.

2 Introduce the challenge (5 minutes)

- **Tell kids some of the ways cranes will be used on the moon.** *At a lunar outpost, astronauts will need machines to build structures and move materials. One of those machines will be a crane. You've probably seen cranes lifting materials and moving them around a construction site. Cranes have a long arm, which holds a cable with a hook on the end. Whether they're on Earth or the moon, cranes have to be strong to lift heavy loads without breaking.*

- **Show kids the simple crane arm you built. Then say:** *Today you'll design and build a crane and test it by seeing how heavy a load it can lift. The arm of your crane will need a stiff beam, a cable, and something to wind up the cable. Here's a simple model showing how the different parts work together. In your crane, you might use one cardboard strip for the arm. But you could also use two or even three strips. As you test, you'll find ways to make it work better. Improving a design based on testing is part of the engineering design process.*



Simple crane arm

3 Brainstorm and design (10 minutes)

Distribute the challenge sheet. Discuss the questions in the Brainstorm and Design section.

- **How will you keep the crane's arm from breaking off the box as it lifts a heavy load?** *(Attach the arm firmly to the box. Kids can cut slits in the box top and insert the cardboard strip[s]. They can also tape the end of the arm firmly to the box.)*

- **How will you stop a heavy load from pulling the arm to the left or right?** *(Kids can add extra pieces of cardboard above, below, and next to the arm as extra support. They can also run string from the top of the arm to the back and sides of the box.)*
- **How will you wind and unwind the cable so the hook can go up and down?** *(Kids will see that a pencil is the best item to use as a spool for the string. It's challenging, however, to build something to hold the pencil. One way is to make flaps—cut them out of the top of the box, bend them up, and poke the pencil through. Another way is to build a holder out of pieces of cardboard, which kids attach to the top of the box.)*

EXTENSION IDEA—ADD A HANDLE

On the handout, adding a crank handle is listed as optional. A crane can work without one, and the focus of the activity is on getting the arm to hold a heavy load. But having a crank handle is useful because it makes it easier to turn the pencil. It provides leverage, letting kids use less force to lift the load. Depending on your group, ask kids to add a crank handle as part of the basic design or suggest they do it as an extension.

4 Build, test, evaluate, and redesign (35 minutes)

Help kids with any of the following issues. For example, if:

- **the load rips the arm off the box**—*Attach the base of the arm securely to the box. Also have kids consider cutting slits in the box and sliding the arm into them. Secure the arm to the box by taping from both above and below.*
- **the arm fails when lifting a heavy weight**—*Start over with new cardboard. Also, have kids consider using multiple pieces of cardboard for an arm, either all together or spaced apart.*
- **the arm sways under a heavy load**—*Make sure the cable is in the center of the arm. Also, support the arm using string or strips of cardboard. Finally, if kids have used multiple cardboard strips to make an arm, check that both are equal length—a crane will tilt toward the shorter arm.*
- **it's hard to secure the take-up reel**—*Build something that holds the pencil, poke holes in the box, or cut flaps out of the top of the box and poke a pencil through the flaps.*

5 Discuss what happened (10 minutes)

Have the kids present their cranes and talk about how they solved any problems that came up. Emphasize the key ideas in today's challenge by asking:

- **What kinds of tasks might astronauts use a crane for?** *(In mining, cranes could lift minerals or ice into vehicles. Cranes could also be useful for assembling structures, such as buildings, satellite dishes, or solar panels.)*
- **Engineers' early ideas rarely work out perfectly. How does testing help them improve a design?** *(Testing helps you see what works and what doesn't. Knowing this lets you improve a design by fixing the things that aren't working well or could work better.)*
- **What force was affecting your crane, and how did the design of your crane deal with it?** *(A crane has to overcome gravity, which pulls down on the cable and arm. The arm and any extra supports, such as string or additional pieces of cardboard, help spread the forces equally. If all forces are equal and balance one another, the arm won't move.)*

- **How does the way you orient a cardboard strip affect how much it can hold?** *(A cardboard strip's strength depends on how it is oriented. When the strip is oriented vertically, like a wall, most of the cardboard resists the load's downward pull. This is the strongest orientation of the strip. In contrast, when a strip is oriented horizontally, like a ceiling, only a little cardboard resists the load's downward pull. This is the weakest orientation of the strip.)*
- **How do the stories on the back of the handout help explain how NASA might use cranes on the moon?** *(Building an outpost and mining ice are both activities that require cranes.)*

EXTEND THE CHALLENGE

- **Have a "Heavyweight Champion" contest.** After kids finish building their cranes, take a basket or small bucket and add some weight. Have kids test their cranes. Eliminate all cranes that fail to lift the load. Add more weight and run another trial. How many cranes survived this round? Keep going in this manner until you have a winner.
- **Have a "Most Efficient Design" contest.** Identify the crane with the most efficient design. To determine this, put each crane on a scale and weigh it. Then, divide the weight of the heaviest load the crane lifted by the crane's weight. For example, if a crane lifted a load of six pounds and it weighs two pounds, you'd divide six by two to get three. This means that the crane lifted three times its own weight. The contest winner will be the crane with the highest number.
- **Lifting on the moon.** Ask students if it would be easier to lift an object on the moon, as compared to lifting it on Earth. *(It would be easier on the moon. This is because the force of gravity on the moon is one-sixth that of Earth's. So if a crane can easily lift a girder weighing one ton on Earth, then it can easily lift a six-ton girder on the moon.)*

CURRICULUM CONNECTIONS

Heavy Lifting ties to the following concepts commonly covered in science, math, and technology curricula. For a list of education standards supported by the activity, see pages 40 and 41.

- **Simple machines**—A crane uses three simple machines—a lever (the crank arm), a pulley (the arm's crosspieces), and a wheel and axle (the take-up reel). Because the crane is a combination of simple machines, it is called a complex machine.
- **Force and Newton's Third Law**—For a crane (or any type of structure) to be stable, all the forces—the pushes and pulls—acting on it must be balanced. Forces that are not balanced can cause movement (or even collapse). When a crane lifts a weight, its arm has many supports, guy wires, and struts to ensure that forces are spread equally. If all forces on the arm are equal and opposite, the arm won't move.
- **Measurement**—Kids measure the size of the parts of the crane and the distances between parts.

A NASA/DESIGN SQUAD CHALLENGE

HEAVY LIFTING

Living on the moon gets expensive fast. Shipping things from Earth costs about $25,000 a pound! No wonder NASA plans to use materials found on the moon, such as calcium compounds to make cement and nitrogen compounds to fertilize crops. To mine materials like these, astronauts use cranes for digging and moving heavy or bulky loads.

WE CHALLENGE YOU TO...

… design and build a crane and see how heavy a load it can lift.

BRAINSTORM AND DESIGN

Think about things that might affect how heavy a load your crane can lift.

- How will you keep the crane's arm from breaking off the box as it lifts a load?
- How will you stop a heavy load from pulling the arm to the left or right?
- How will you wind and unwind the cable so the hook can go up and down?

BUILD

1. **First, make the arm.** The arm holds the string up and away from the crane's body. Use one, two, or all three cardboard strips to design your arm. Then attach it to the box.
2. **Next, make a take-up reel.** Figure out how to make a take-up reel that lets you shorten and lengthen the cable. (Optional: add a crank to turn the take-up reel.)
3. **Finally, add the string, hook, and cup.** Run the string through the arm. Attach it to the take-up reel and hook. Poke holes in each side of the cup near the rim. Make a handle for the cup and slip it onto the hook.

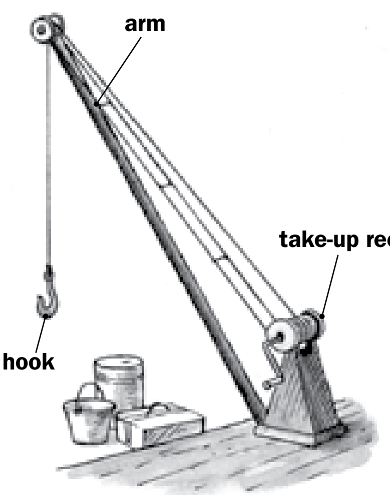
MATERIALS (per crane)

- cardboard box (shoebox size or bigger)
- 3 strips of corrugated cardboard (2 x 11 inches/5 x 28 cm)
- paper clip
- large paper cup
- 3 sharpened pencils
- scissors
- smooth string (e.g., fishing line or kite string)
- tape
- weights (e.g., batteries, pennies, marbles, or gravel)

TEST, EVALUATE, AND REDESIGN

Ready to test? Add weight to the cup. What's your crane's breaking point? Engineers improve their designs by testing them. The steps they follow are called the design process. Try some ideas and build an improved version. If:

- **the load rips the arm off the box**—*Reinforce how it attaches. Add cardboard supports. Or cut slits in the box to hold the arm. Also, add tape to the top and underside of the box.*
- **the arm crumples**—*Start over with new cardboard. Also, use several pieces of cardboard for an arm, either all together or spaced apart.*
- **the load pulls the arm to the side**—*Use extra cardboard or string to add support.*
- **the crank handle bends or slips**—*If it slips, tape it or attach it more firmly. If it bends, reinforce it.*

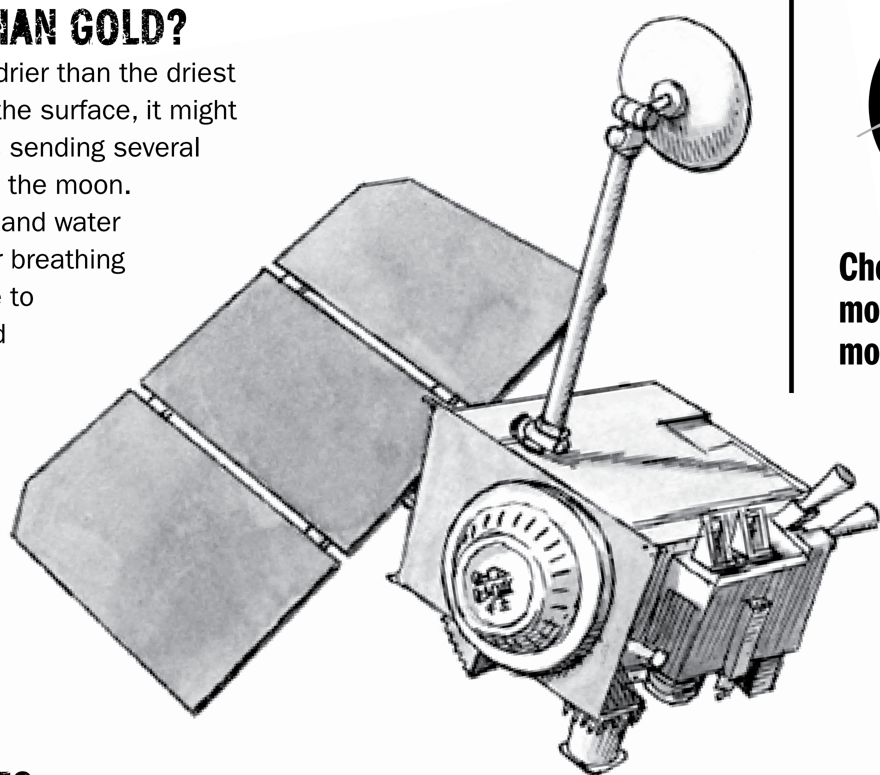


This hand-operated crane shows you the parts you'll need to include on your crane.

MORE PRECIOUS THAN GOLD?

The surface of the moon is drier than the driest desert on Earth. But under the surface, it might be a different story. NASA is sending several spacecraft to look for ice on the moon. Ice can be made into water, and water can be made into oxygen for breathing and fuel for the return home to Earth. If the spacecrafts find ice, one way to extract it is to use cranes.

NASA's Lunar Reconnaissance Orbiter (right) will study the moon's surface to find ice. If there's ice, cranes will help astronauts mine it.

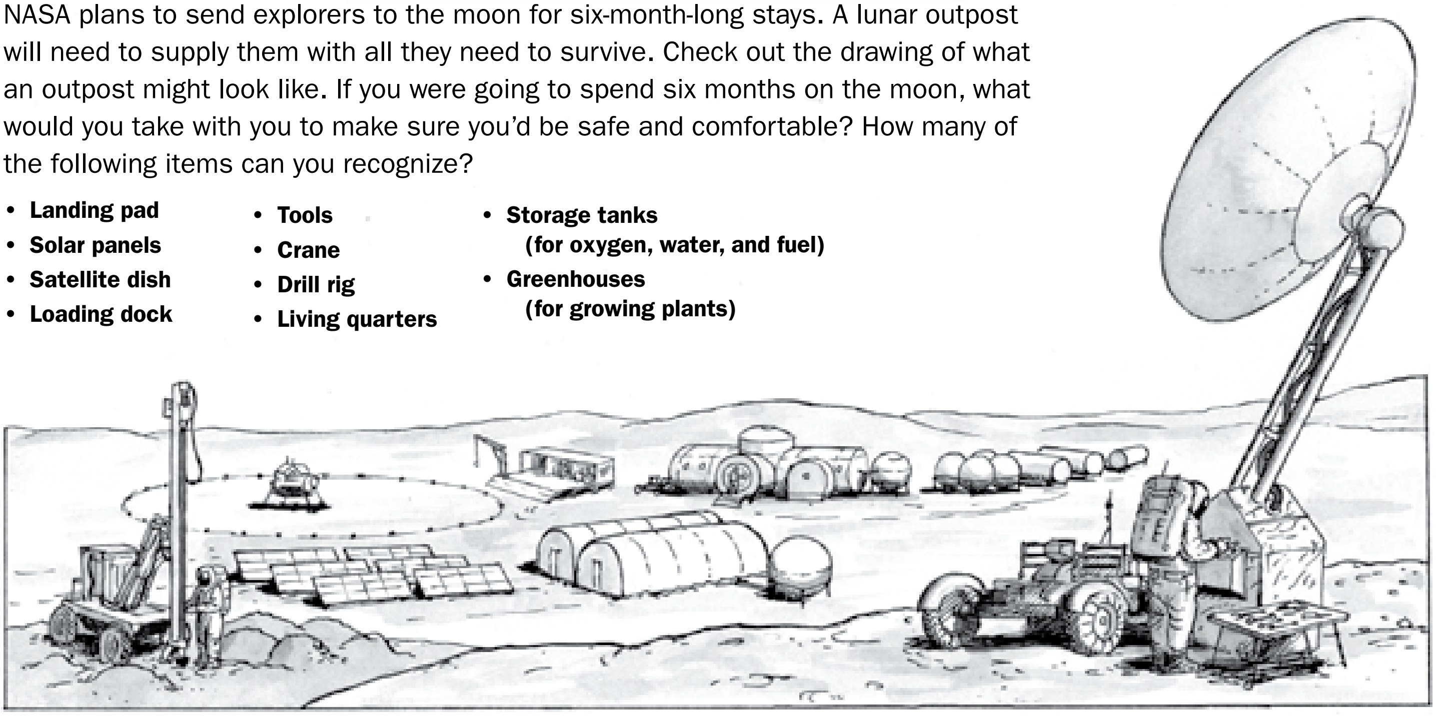


Check out NASA's moon missions at moon.msfc.nasa.gov.

HOME SWEET HOME?

NASA plans to send explorers to the moon for six-month-long stays. A lunar outpost will need to supply them with all they need to survive. Check out the drawing of what an outpost might look like. If you were going to spend six months on the moon, what would you take with you to make sure you'd be safe and comfortable? How many of the following items can you recognize?

- **Landing pad**
- **Solar panels**
- **Satellite dish**
- **Loading dock**
- **Tools**
- **Crane**
- **Drill rig**
- **Living quarters**
- **Storage tanks (for oxygen, water, and fuel)**
- **Greenhouses (for growing plants)**



Watch DESIGN SQUAD on PBS or online at pbs.org/designsquad.

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