SPACE STATION EXPLORERS KIT

Welcome to the ISS Activity Guide

SPACE STATION EXPLORERS

ISS U.S. NATIONAL LABORATORY

SPACE STATION EXPLORERS

Space Station Explorers is a consortium of organizations that use the International Space Station (ISS) to inspire and engage educators, learners, and explorers of all ages. With support from the ISS National Laboratory, consortium partners develop innovative, authentic learning experiences in science, technology, engineering, and mathematics (STEM).

THE INTERNATIONAL SPACE STATION U.S. NATIONAL LABORATORY

In 2005, Congress designated the U.S. portion of the ISS as the nation's newest national laboratory to maximize its use for improving quality of life on Earth, promoting collaboration among diverse users, and advancing STEM education. This unique laboratory environment is now available for use by non-NASA U.S. government agencies, academic institutions, and the private sector, providing these customers access to a permanent microgravity setting, a powerful vantage point in low Earth orbit, and the extreme and varied environments of space. The ISS National Lab is managed by the Center for the Advancement for Science in Space (CASIS) under agreement with NASA.

SPACE STATION EXPLORERS KIT

Welcome to the ISS Activity Guide

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Dear Educator:

Welcome onboard! This guide offers six activities appropriate for students in grades 3–8 in both classrooms and informal learning environments such as afterschool programs, camps, and museums.

Some of these are original activities developed by the Space Station Explorers team, and others are adapted from existing NASA educator resources.

For the latest version of this guide, please visit spacestationexplorers.org.

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ACTIVITY 1

GRADE LEVELS	3–8
SUBJECTS	Space Science, Mathematics
PREP TIME	< 10 minutes
DURATION	1 class period (45 minutes)

HUMANS IN SPACE:

Measuring Distances to Space Destinations

Adapted from "Earth, Moon, Mars & the International Space Station" activity from NASA Johnson Space Center's STEM on Station: International Space Station Kit

OBJECTIVES

- Students will improve their understanding of relative sizes and distances by observing and manipulating physical models.
- Students will use models and calculations to compare distances from Earth to space destinations where humans have been and where humans are headed.
- Students will record calculations and ideas in crew logbooks.

EDUCATIONAL STANDARDS

NEXT GENERATION SCIENCE STANDARDS – DISCIPLINARY CORE IDEAS & PERFORMANCE EXPECTATIONS

ESS1.B: Earth and the Solar System

- MS-ESS1-3 (Earth and Space Sciences for Middle School): Analyze and interpret data to determine scale properties of objects in the solar system.

ETS1.B: Developing Possible Solutions

- 3-5-ETS1-2, MS-ETS1-2 (Engineering Design for Grades 3–5 and for Middle School): Generate multiple possible solutions to a problem and evaluate them systematically to determine how well they meet the criteria and constraints.

COMMON CORE STANDARDS

- CCSS.ELA-LITERACY.SL.3-8.1 (Speaking and Listening for Grades 3–8): Follow agreed-upon rules for discussions and carry out assigned roles; pose and respond to questions and link to the remarks of others; explain ideas and understanding in light of the discussion.
- CCSS.ELA-LITERACY.SL.3-8.5 (Presentation of Knowledge and Ideas for Grades 3–8): Integrate multimedia and visual displays into presentations to enhance ideas and clarify information.
- CCSS.MATH.CONTENT.4.MD.A.1 (Measurement and Data for Grade 4): Solve problems involving measurement and conversion of measurements.
- CCSS.MATH.CONTENT.5.MD.A.1 (Measurement and Data for Grade 4): Convert like measurement units within a given measurement system.

VOCABULARY

- Acceleration
- Apollo missions
- International Space Station (ISS)
- Low Earth orbit (LEO)
- Lunar orbit

BACKGROUND

Destination: Moon

On May 25, 1961, President John F. Kennedy announced his goal of sending astronauts to the moon, leading to the birth of the Apollo era. It took years of hard work by hundreds of thousands of people, including scientists and engineers, to achieve this goal. Many rockets and unmanned vehicles were tested before the first American astronaut launched into space. Several missions sent astronauts to low Earth orbit—about the same height as the International Space Station (ISS) —to test technologies and practice activities such as spacewalks.

The first Apollo missions to the moon only orbited the moon without landing on it. The Apollo 11 mission finally fulfilled Kennedy's challenge. On July 20, 1969, Neil Armstrong and Buzz Aldrin took their first steps on the moon while Michael Collins orbited the moon aboard the Command/Service Module. Twelve astronauts have walked on the moon so far, and the last time humans touched the moon was during the Apollo 17 mission in 1972.

> **QUESTION:** How long did it take for Apollo astronauts to get to the moon? *[ANSWER: The Apollo 11 astronauts reached lunar orbit 76 hours (3 days and 4 hours) after launch. They did not land immediately; they made preparations for 25 hours before sending the lunar lander to the moon's surface.]*

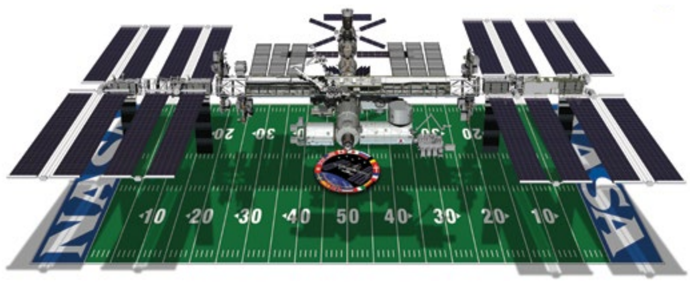
Destination: Low Earth Orbit

The ISS is one of humanity's greatest engineering feats. Assembling the ISS took 35 space shuttle missions and more than 150 spacewalks between 1998 and 2011.

> **QUESTION:** How long does it take for today's astronauts to get to the ISS? *[ANSWER: They get to the height of the ISS's orbit in nine minutes! It then takes a few more hours to align the spacecraft with the ISS to dock.]*

Destination: Mars!

So far, humans have traveled only to the ISS and the moon. We have sent robotic spacecraft to many other destinations in our solar system including planets, moons, asteroids, and even comets. The next place where humans will venture is Mars. We face many challenges in preparing for the journey to Mars and other long-duration space missions. The ISS is a crucial platform for testing new technologies and procedures that can solve these challenges.



NASA

SPACE STATION FACTS

- The ISS circles the Earth in what is known as low Earth orbit, or LEO for short.
- The ISS, including its large solar arrays, spans the area of a U.S. football field.
- The mass of the ISS is more than 419,600 kilograms (925,000 pounds), which is the same as more than 320 cars!
- The distance the ISS travels in one day is to the same as flying to the moon and back!
- The ISS completes one orbit around Earth every 92 minutes, letting astronauts see about 15 sunrises and sunsets every 24 hours.
- Fifteen countries built the ISS: Belgium, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, Russia, the United Kingdom, and the United States.
- The ISS has been continuously inhabited since 2000, usually with six people onboard.
- As of April 2019, more than 200 astronauts from 18 countries have spent time on the ISS.
- Since 2011, all crews have traveled to and from the ISS on Russian-built Soyuz capsules, which fit three people.
- It takes about 4,000 kilograms (8,800 pounds) of supplies to support three astronauts for a typical six-month stay.

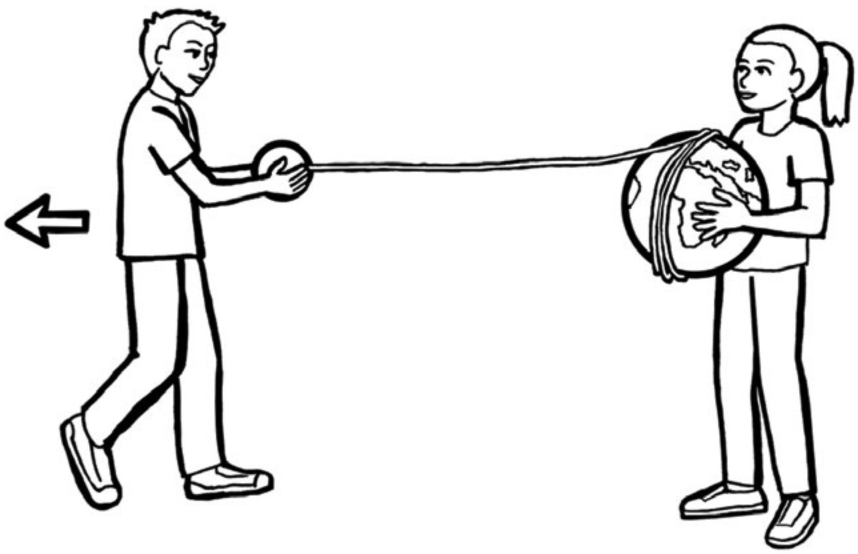
ACTIVITY 1

HUMANS IN SPACE:

Measuring Distances to Space Destinations

MATERIALS

- CREW LOGBOOK: *Any notebook can serve as a crew logbook. Just like an astronaut on the ISS, you will use your logbook to keep notes, make drawings, record data from experiments, and reflect on your experiences.*
- SPHERES REPRESENTING THE EARTH AND THE MOON: *The moon's diameter should be about 1/4 of the Earth's diameter. A good pair of spheres is a basketball for Earth with a tennis ball for the moon.*
- PIN, PAPER SCRAP, OR OTHER TINY OBJECT REPRESENTING THE ISS
- STRING
- METRIC RULERS
- MARS MODEL *(extension)*
- ISS-ABOVE DEVICE WITH WIFI CONNECTION *(extension)*
- COMPUTER MONITOR OR TV *(extension)*



PROCEDURE

1. Discuss Earth's size relative to the moon and Mars. Determine what misconceptions students may have.
2. Give the Earth model to one volunteer and the moon model to another. Ask them to move to positions that they think show the distance between the Earth and the moon.
3. Ask the Earth volunteer to wrap the string around the planet 9.5 times to approximate the distance between Earth and the moon. Tape the Earth model to that place on the string.
4. Give the end of the string to the moon volunteer, and ask the volunteers to move apart until the string is extended. The distance is probably farther than they expected!
5. Give another volunteer the object representing the ISS, and ask how close it should be to the Earth model. If the Earth model is a basketball, the ISS should be just 8 millimeters away!

CREW LOGBOOK ACTIVITY (MATH COMPONENT)

1. Have students reflect on the size relationships in their crew logbooks. Draw two spheres to represent the Earth and the moon, with the moon sphere having 1/4 the diameter of the Earth sphere. Then draw a third sphere about the size of a marker tip or pin head to represent the ISS. Color this page if time allows.
2. Using accurate relative sizes, draw the Earth on one side of the page and the moon on the other side of the page. Write 384,500 km (238,900 miles) between those two bodies to indicate the average distance between the Earth and the moon. Next, draw a tiny ISS near the Earth's surface. Emphasize metric units. Optional: Have students use dimensional analysis to convert miles into kilometers.
3. Knowing that Earth's diameter at the equator is 12,742 km (7,918 miles), calculate how many times you would need to travel around Earth's equator to match the distance to the moon.
4. Draw a picture of yourself standing on a scale on Earth, and draw another picture of yourself standing on a scale on the moon. Anywhere on the page, write down your *mass* in kilograms—remember to write the units (kg) after the number. Multiply your mass by 9.81 m/s^2 to get your *weight* in newtons (abbreviated N). Record this number near the picture of you on Earth—again including the units (N).
5. When calculating your weight on Earth, you used 9.81 m/s^2 because that's the acceleration due to Earth's gravity. What if you were on a planet or moon with a different size and/or density than Earth? Would the acceleration due to that planet's gravity be the same? Would your weight be the same? Would your mass be the same?
6. Take your weight on Earth in newtons, divide it by 6, and write your answer near your moon picture, including the units (N). This is what you'd weigh on the moon. What would you notice? Do you think you'd fly away if you jumped with enough force on the moon? Why or why not?

DIAMETER OF EARTH AT EQUATOR
12,742 km (7,918 miles)

CIRCUMFERENCE OF EARTH
40,030 km (24,874 miles)

AVERAGE EARTH-MOON DISTANCE
384,500 km (238,900 miles)

MAXIMUM EARTH-MOON DISTANCE
356,500 km (221,500 miles)

AVERAGE EARTH-MARS DISTANCE
225,000,000 km (140,000,000 miles)

MAXIMUM EARTH-MARS DISTANCE
401,000,000 km (250,000,000 miles)

WHAT ARE NEWTONS?

Weight and mass are not the same. Weight is the *force* needed to accelerate an object toward the ground. The greater the object's mass, the more force is required.

The international unit of force is the newton. Pounds are more familiar units of weight, but they are not useful in space because they are defined only in the context of Earth's gravity.

EXTENSIONS

1. Add a sphere to represent Mars! Its diameter should be half of the Earth model's diameter. Give the Mars model to another volunteer and ask where Mars should be in relation to the Earth and moon. If Earth is a basketball, the average distance to Mars would be 4.2 km (2.6 miles)!
2. How long would it take for astronauts to get to Mars? [HINT: The Mars Science Laboratory (MSL) mission with the Curiosity rover launched on November 26, 2011 and landed on Mars on August 6, 2012—a flight time of about eight and a half months.]
3. Engage students in conversations about their observations. What challenges must be addressed before we can send humans to deep space? Would you go on a mission to Mars? Have them write their ideas in their crew logbooks.
4. If your classroom has an ISS-Above (www.spacestationexplorers.org/issabove), look up the next time the ISS will pass over your location, watch the live HD video feed showing the view of Earth from the ISS, and learn about the crew currently onboard. ISS-Above also comes with free curriculum.

LEARN MORE

FIND MORE RESOURCES AT:

www.spacestationexplorers.org/resources/sse-stem-kit1/#activity1

ACTIVITY 2

MISSION PATCH DESIGN:

Crew Unity in Space

GRADE LEVELS	3–8
SUBJECTS	Space Science, History, Art
PREP TIME	30 minutes
DURATION	1 class period (45 minutes)

Adapted from NASA's Mission Patch Design activity (2011)

OBJECTIVES

- Students will learn about mission patches and the importance of teamwork in designing these patches.
- Students will design original mission patches in teams and share their designs with the class.
- In sharing their patch designs, student teams will (a) explain how they chose visual symbols to communicate themes and (b) reflect on the compromises they made to achieve their goals.

EDUCATIONAL STANDARDS

NEXT GENERATION SCIENCE STANDARDS – DISCIPLINARY CORE IDEAS & PERFORMANCE EXPECTATIONS

ETS1.C: Optimizing the Design Solution

- 3-5-ETS1-3 (Engineering Design for Grades 3–5): Test different solutions to determine which of them best solves the problem, given the criteria and constraints.

COMMON CORE STANDARDS FOR ENGLISH LANGUAGE ARTS

- CCSS.ELA-LITERACY.W.3.1 and 4.1 (Writing for Grades 3–4): Write opinion pieces on topics or texts, supporting a point of view with reasons.
- CCSS.ELA-LITERACY.W.3.8 (Writing for Grade 3): Recall information from experiences or gather information from print and digital sources; take brief notes on sources and sort evidence.
- CCSS.ELA-LITERACY.W.4.2 and 5.2 (Writing for Grades 4–5): Write informative/explanatory texts to examine a topic and convey ideas and information clearly.
- CCSS.ELA-LITERACY.SL.3-8.1 (Speaking and Listening for Grades 3–8): Follow agreed-upon rules for discussions and carry out assigned roles; pose and respond to questions and link to the remarks of others; explain ideas and understanding in light of the discussion.
- CCSS.ELA-LITERACY.SL.3-8.5 (Presentation of Knowledge and Ideas for Grades 3–8): Integrate multimedia and visual displays into presentations to enhance ideas and clarify information.
- CCSS.ELA-LITERACY.RST.6-8.4 (Science & Technical Subjects for Grades 6–8): Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context.
- CCSS.ELA-LITERACY.RH.6-8.7 (History/Social Studies for Grades 6–8): Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.

VOCABULARY

- Compromise
- Diplomacy
- Mission patch

BACKGROUND

Every space exploration mission gets a mission patch. For unmanned missions such as the Dawn mission to the asteroid belt, the New Horizons mission to Pluto, and the Juno mission to Jupiter, each mission's scientists and engineers have input on the patch design.

For crewed missions, astronauts design their own mission patch. Three people make up a typical International Space Station (ISS) crew—a unique, international group of men and women. Together, they come up with a design that represents their team and mission. This typically includes the mission number, the astronauts' names, and imagery representing meaningful aspects of the mission and crew. The design could include a vehicle such as the ISS, images related to important science or technology on that mission, patriotic symbols, and even symbols that represent fallen colleagues. Each mission patch comes with a detailed description to explain the choice of the design.

It takes creativity, collaboration, and compromise to design a patch, and it can be tricky to get everyone to agree. Space shuttle astronaut Alvin Drew said in an interview, "You've got crew members, you've got a flight control team, and you've got NASA management. [Everyone] has opinions about the design, and they don't all match…so you wind up getting a good lesson in diplomacy."

APOLLO 8

1968, crew of three astronauts

APOLLO 13

1970, crew of three astronauts

EXPEDITION 53 TO THE ISS

2017, crew of six astronauts

CASSINI-HUYGENS UNMANNED MISSION TO SATURN

launched 1997

ACTIVITY 2

MISSION PATCH DESIGN:

Crew Unity in Space

MATERIALS

- CREW LOGBOOK
- PENCIL AND ERASER
- PLAIN WHITE PAPER
- COLORED PENCILS OR CRAYONS
- OPTIONAL: COMPUTER WITH IMAGE EDITING SOFTWARE *(such as GIMP or Photoshop)*

PROCEDURE – CREW LOGBOOK ACTIVITY

1. Assign students to small teams. The first step is to select a mission for the patch. The mission could describe the class (e.g., Mr. Stenson's fourth-grade science class), or it could be an imagined space mission. If the patch represents the whole class, the design can portray characteristics unique to the class (e.g., the teacher's name, room number, period, or subject). If the patch represents an imagined space mission, each team should brainstorm their mission goal, scientific objective(s), mission name, and date or mission number. They can write their brainstorming ideas in their crew logbooks.
2. Visit some of the websites listed under "Learn More" to see patches from past space missions. Discuss the symbols and design elements you see in the patches.
3. Encourage teams to be creative and design a patch that is unique and symbolic of the team members. Students can make sketches in their crew logbooks as the design evolves. They should make their final design in color on plain white paper. Students can also design on computers if they are comfortable with image editing software such as GIMP or Photoshop.
4. Ask teams to share their designs with the class. Ask them to explain the colors and symbols used. Do the symbols have meanings beyond what the average viewer would recognize? The team can also talk about how they narrowed down ideas and made compromises to agree on their final design.
5. The educator can take digital pictures of the patches and print out copies for students to paste into their crew logbooks. The educator can also print copies for students to wear as name tags on field trips or other group excursions.

EXTENSION

The educator could reach out to a local or online patch creator to get designs made into stickers or sew-on patches.

YEAR IN SPACE

2015, focusing on two astronauts

ISS U.S. NATIONAL LAB MISSION 5

2017, representing a year of experiments

STS-134 MISSION OF SPACE SHUTTLE ENDEAVOUR TO THE ISS

2011, crew of five astronauts

STS-71 MISSION OF SPACE SHUTTLE ATLANTIS TO SPACE STATION MIR

1995, crew of seven space shuttle astronauts and three Mir cosmonauts

NEW HORIZONS UNMANNED MISSION TO PLUTO

launched 2006

LEARN MORE

FIND MORE RESOURCES AT:

www.spacestationexplorers.org/resources/sse-stem-kit1/#activity2

ACTIVITY 3

READY TO LAUNCH:

Engineering Rockets

GRADE LEVELS	3–8
SUBJECTS	Space Science, Engineering, Mathematics, Teamwork
PREP TIME	4 hours
DURATION	90 minutes

Adapted from NASA Jet Propulsion Laboratory's "DIY Space: Stomp Rockets" activity (2016)

OBJECTIVES

- Students will learn about the rockets and vehicles that carry astronauts and supplies to the International Space Station (ISS).
- Students will work in teams to design, build, and launch paper rockets. Students will experience engineering design as an iterative process as they modify and test their rocket designs to optimize performance.
- Students will calculate their rockets' maximum altitudes using scale drawings and simple geometry.

EDUCATIONAL STANDARDS

NEXT GENERATION SCIENCE STANDARDS – DISCIPLINARY CORE IDEAS & PERFORMANCE EXPECTATIONS

ETS1.A: Defining and Delimiting Engineering Problems

- 3-5-ETS1-1, MS-ETS1-1 (Engineering Design for Grades 3–5 and Middle School): Define a design problem with criteria for success; constraints on materials, time, and cost; and considerations of impacts on people or the environment.

ETS1.B: Developing Possible Solutions

- 3-5-ETS1-2, MS-ETS1-2 (Engineering Design for Grades 3–5 and Middle School): Generate multiple possible solutions to a problem, and evaluate them systematically to determine how well they meet the criteria and constraints.

ETS1.C: Optimizing the Design Solution

- 3-5-ETS1-3, MS-ETS1-3 (Engineering Design for Grades 3–5 and Middle School): Iterate and test different solutions to determine which best solves the problem, given the criteria and constraints. Identify the strengths of different solutions and combine them in a new solution.
- MS-ETS1-4 (Engineering Design for Middle School): Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

PS2.B: Types of Interactions

- 5-PS2-1 (Motion and Stability: Forces and Interactions for Grade 5): Support an argument that the gravitational force exerted by Earth on objects is directed down.

COMMON CORE STANDARDS

- CCSS.MATH.CONTENT.7.G.A.1 (Geometry for Grade 7): Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale.
- CCSS.MATH.CONTENT.7.G.A.2 (Geometry for Grade 7): Draw (freehand, with a ruler and protractor, and with technology) geometric shapes with given conditions.
- CCSS.MATH.CONTENT.HSG.CO.D.12 (Geometry – Congruence for High School): Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.).
- CCSS.MATH.CONTENT.4.MD.C.6 (Measurement and Data for Grade 4): Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure.
- CCSS.MATH.CONTENT.6.SP.B.5.C (Statistics and Probability for Grade 6): Give quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.

VOCABULARY

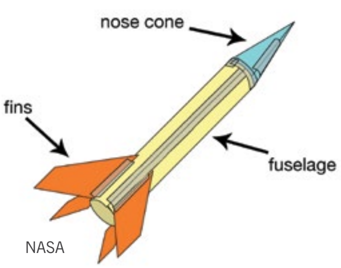
- Altitude
- Atlas V (pronounced "Atlas Five")
- Constraints
- Criteria for success
- Engineering design process
- Fins
- Fuselage
- Iterate
- Nose cone
- Saturn V ("Saturn Five")
- Soyuz
- Space Launch System (SLS)

BACKGROUND

Rockets have launched spacecraft to every planet in the solar system and have even sent humans to the moon. The first rockets to travel into space were modified missiles. For example, the Redstone missile was designed to carry explosive warheads, but it was adapted to carry the first American astronaut into space. Later rockets were designed for specific space missions. The Saturn V, for example, was designed to carry astronauts and equipment to the moon.

The space shuttles were extremely versatile, reusable rockets that carried up to seven people plus large payloads, including the Hubble Space Telescope and several modules of the ISS. Since the space shuttles were retired in 2011, all astronauts have traveled to the ISS aboard Russian-built Soyuz capsules propelled by Soyuz rockets that launch from Kazakhstan in central Asia.

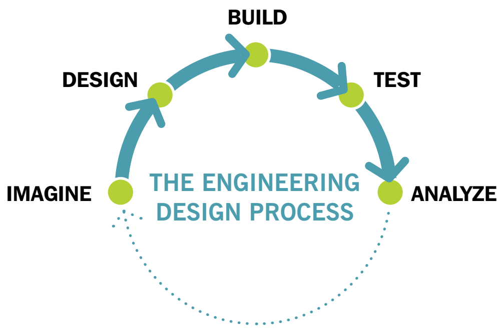
New vehicles are being developed in the United States that can take astronaut crews to the ISS. Boeing's CST-100 Starliner uses an existing NASA rocket called the Atlas V. SpaceX's Crew Dragon uses the Falcon Heavy rocket, which made its first test flight in January 2018. NASA's Orion spacecraft will use the Space Launch System (SLS), which will be the most powerful rocket NASA has ever built.



NASA

Design details depend on the mission at hand, but all rockets have a few essential parts: fuselage, fins, and nose cone. The fuselage is the main body of the rocket. The fins provide stabilization and are evenly placed around the fuselage near the tail. The nose cone is secured to the top of the rocket to help it pierce the air. The shape and size of these elements affect the amount of drag or friction between the rocket and the air. Streamlining the design to reduce drag helps the rocket go farther on the same amount of fuel.

This activity is a design challenge. Engineering design is typically an iterative process, meaning it has a series of steps that may be repeated several times as the design is tested and improved. Different textbooks use slightly different names for the steps of this process, but here is one way to describe them: **Imagine, Design, Build, Test, Analyze.**



IMAGINE: Identify the problem or challenge. What is necessary for a solution to be successful? Knowing these *criteria for success*, brainstorm and discuss possible solutions. Think about the constraints that might apply. For example, are there limits to the size, shape, or weight of the solution, or the cost of its materials? Which ideas for solutions can be adjusted to fit these constraints?

DESIGN: Choose one or more of the possible solutions you think will work well, and create drawings and/or descriptions of them. List the materials you'll need to build them.

BUILD: Gather the materials and build your design(s).

TEST: Choose a *fair* and *measurable* way to test designs. To make the tests fair, test all designs under the same conditions. To make the tests measurable, think about performance aspects you want to measure, including units of measurement (for example, the maximum height of a rocket's flight, measured in meters). Make sure you have the right equipment to make the measurements.

ANALYZE: Compare the results from the tests, and identify the strengths and weaknesses of different designs. How well does each design meet the criteria for success and fit within the constraints of the challenge?

Then start the next iteration (repeat the cycle) by going back to **Imagine:** Think about what you've learned from testing and analyzing your previous design(s). Can you combine the strengths of multiple designs into a new and improved design?

Artist's rendering of a launch of NASA's most powerful rocket, the Space Launch System. It will carry heavy loads, including crew vehicles, to the moon, Mars, and beyond.

NASA

ACTIVITY 3

READY TO LAUNCH:

Engineering Rockets

PREPARATION – *Educator does this before class*

1. Prepare for the lesson by watching NASA's video "Do It Yourself Space: Stomp Rockets" » youtu.be/5bO8dpPuG4E.
2. Reserve and mark an outdoor launch location. Choose a place clear of overhead obstructions (trees, building roofs, and power lines). If it's windy, seek a location behind a windbreak such as a gymnasium or other large building. For best altitude tracking, the launch area should be 100 meters long. At both ends of this launch area, draw straight lines like the end zone of a football field. These are the baselines where students stand to measure altitude. Label the baselines A and B, and plan to place the rocket launcher at the midpoint between them.
3. Build and test at least one rocket launcher (instructions below). An alternative to building the PVC launcher is to buy a Stomp Rocket kit available from retailers for about $20.
4. Be sure to have some spare 2-liter bottles on hand. One bottle can launch 20 or more rockets, but eventually it will fail and need to be replaced. Keep the damaged bottles to use as parts for Activity 6 – Design a Space Station!

MATERIALS

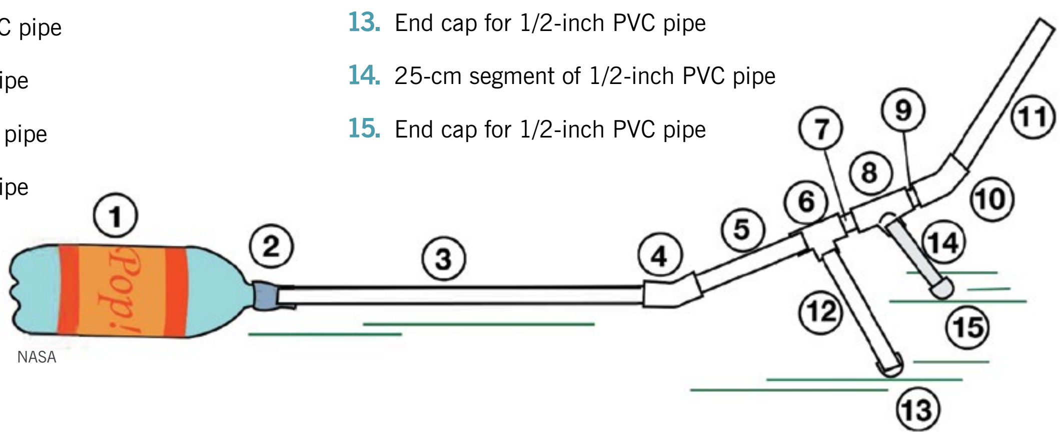
Each student team needs:

- ALL THE MATERIALS IN THE ROCKET LAUNCHER BUILDING INSTRUCTIONS *(see PREPARATION section) Multiple teams can share a single launcher.*
- EIGHT OR MORE SHEETS OF 8.5 X 11-INCH PAPER SUCH AS COPY PAPER OR CONSTRUCTION PAPER
- ROLL OF CELLOPHANE TAPE
- SCISSORS
- MARKERS
- 24-INCH LENGTH OF 1/2-INCH PVC PIPE *for the rocket form*
- EYE PROTECTION
- TWO ALTITUDE TRACKER PAGES DOWNLOADED FROM NASA AND PRINTED ON CARD STOCK » *www.jpl.nasa.gov/edu/pdfs/sr_tracker.pdf*
- TWO 18-INCH PIECES OF STRING OR THREAD *for altitude trackers*
- TWO PENNIES OR SIMILAR WEIGHTS *for altitude trackers*
- TWO PAPER CLIPS *for altitude trackers*
- CREW LOGBOOK
- GRAPH PAPER
- PROTRACTOR
- RULER *(metric units preferred)*
- 50-FOOT MEASURING TAPE OR TRUNDLE WHEEL

ROCKET LAUNCHER BUILDING INSTRUCTIONS

Materials for one launcher (numbers match labels on diagram):

1. Empty 2-liter bottle (and spare bottles)
2. Duct tape
3. 50-cm segment of 1/2-inch PVC pipe
4. 135-degree elbow connector for 1/2-inch PVC pipe
5. 18-cm segment of 1/2-inch PVC pipe
6. T connector for 1/2-inch PVC pipe
7. 4-cm segment of 1/2-inch PVC pipe
8. T connector for 1/2-inch PVC pipe
9. 4-cm segment of 1/2-inch PVC pipe
10. 135-degree elbow connector for 1/2-inch PVC pipe
11. 25-cm segment of 1/2-inch PVC pipe
12. 20-cm segment of 1/2-inch PVC pipe
13. End cap for 1/2-inch PVC pipe
14. 25-cm segment of 1/2-inch PVC pipe
15. End cap for 1/2-inch PVC pipe



NASA

PREPARATION *– Educator does this before class*

Follow the construction diagram to assemble the launcher. Insert the end of part #3 into the neck of the bottle and tape it securely with duct tape. Match the pipe lengths with the part numbers. Swing the two legs (parts #12 and #14) outward or inward until they touch the ground to form a tripod.

Test the launcher before launch day by making a quick paper rocket. Wrap a sheet of paper around a segment of 1/2" PVC pipe, making it loose enough to slide freely along the pipe.

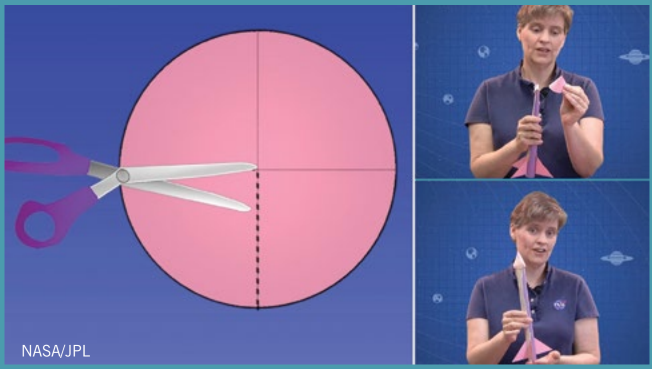
Tape the paper tube closed and tape a paper nose cone to one end. Slide the paper rocket onto the launch tube (part #11) and stomp on the 2-liter bottle to launch. If the rocket doesn't move off the launch tube, check the rocket and/or the PVC connections on the launcher to make sure they're airtight. If the launcher tends to come apart at any of the connectors, secure them with duct tape. A simplified design for a PVC pipe launcher is in this Exploratorium Science Snack: *Bottle Blast Off* » www.exploratorium.edu/snacks/bottle-blast-off.

PROCEDURE

The typical engineering design process is an iterating (repeating) cycle of a sequence of steps: Imagine, Design, Build, Test, Analyze.

Imagine, Design, and Build

1. Group students into small teams (2–4 people). Each student can build their own rocket.
2. To build the rocket's fuselage, wrap a sheet of paper around a segment of 1/2-inch PVC pipe, making it loose enough to slide freely along the pipe. Tape the paper tube along the entire seam to make it airtight. Decorate as desired.
3. To build the nose cone, pinch one end of the fuselage, fold it over, and tape it. Alternatively, cut a 3/4-circle shape from a fresh piece of paper, roll and tape it into a cone shape, and tape it to one end of the fuselage. Use enough tape to make the rocket airtight. Blow through the rocket from the bottom to check for air leaks.
4. Cut out fins (any number, any shape) and attach them symmetrically to the lower part of the fuselage. Students can experiment with the shape, size, and number of fins to maximize stability and minimize drag. Students can tape together multiple layers of paper to make their fins more rigid.
5. Each student makes an altitude tracker:
   - Cut out the shape printed on the sheet of card stock » www.jpl.nasa.gov/edu/pdfs/sr_tracker.pdf.
   - Roll the sighting tube section so that the line of A's and the line of B's are together, and then staple or tape it to form a tube. The quadrant (pie-piece-shaped) part of the tracker remains flat.
   - Use a paper clip or sharp pencil to poke a hole through the apex (point) of the quadrant.
   - Slip a piece of string through the hole and tape the end of the string to the back of the quadrant.
   - Tape a penny to the loose end of the string so it hangs vertically along the marked, labeled side of the quadrant.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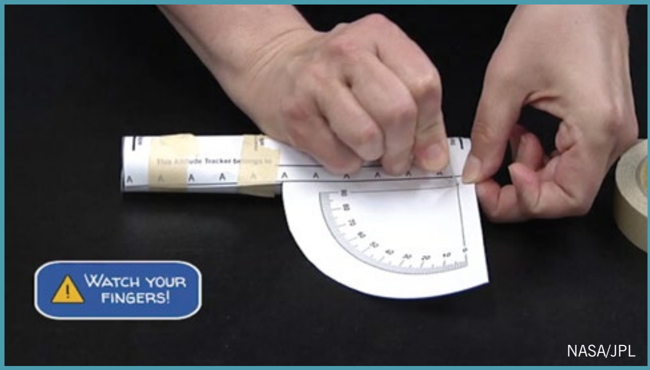

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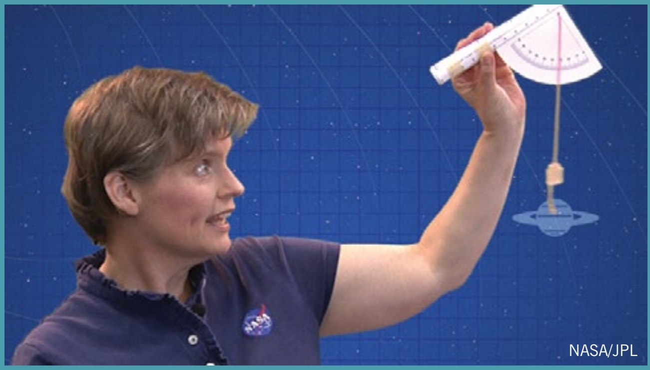

NASA/JPL

READY TO LAUNCH:
Engineering Rockets

PROCEDURE (CONTINUED)

Test Your Rocket

6. Take rockets, altitude trackers, crew logbooks, and pencils to the launch area. Before launching any rockets, measure the distance from Baseline A to the launcher and from Baseline B to the launcher, and record these measurements in the crew logbook.

7. One team member will launch a rocket while other team members stand on the baselines with altitude trackers.
   - **Safety note:** Use caution when launching the stomp rockets. Students near the launcher should wear eye protection. Keep all students clear of the launch tube and the landing area. Allow only one student, the stomper, to be near the launcher, and make sure the launch tube is pointed away from the stomper.
   - **Aiming:** Ideally, the rocket should launch straight upward. Any horizontal motion should be parallel to the baselines. If the rocket flies toward or away from a baseline, the students' altitude measurements will be less accurate. The stomper may need to point the launch tube into the wind.
   - **Stomping:** Be sure students stomp on the bottle across the bottle label, perpendicular to the bottle's body. This is the most flexible zone of the bottle, allowing it to be reused numerous times. If students stomp on the bottom end of the bottle, it may shatter.
   - **Re-inflating the bottle:** Bottles can be easily re-inflated using air from your lungs. Place your hand in a fist around the open end of the launch tube and blow into your fist to re-inflate the bottle. To prevent the spread of germs, avoid putting your mouth on the tube.


NASA/JPL


NASA/JPL


NASA/JPL

8. Altitude measurements will come out best if measurements are made from both baselines during a single rocket flight. It helps to have two students use each altitude tracker: one student is the observer and holds the tracker and the other student is the recorder and reads the measurement. The observer looks through the sighting tube, follows the rocket to its greatest height, and holds still at that maximum height. The recorder reads the number where the string crosses the scale on the quadrant and records it in the crew logbook.

Analyze

CREW LOGBOOK ACTIVITY (MATH COMPONENT)

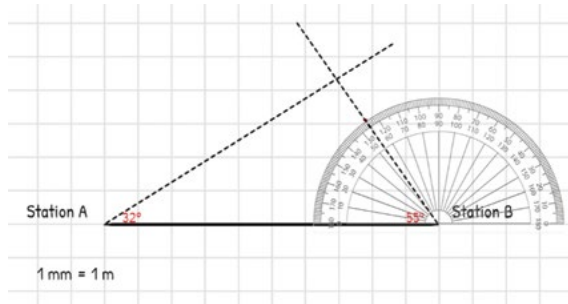
Students want to know the heights their rockets reached, but measurements from the altitude tracker are expressed as angles, not heights. Students will calculate maximum heights using graph paper, protractors, and pencils.

9. Ask students to choose a scale that fits Baselines A and B onto a single sheet of graph paper. For example, if each square on the graph paper represented 2 meters, then a row of 50 squares would represent 100 meters. Use the same scale for horizontal and vertical distance. Label the axis at major intervals (perhaps every 10 meters) and remember to write the units.

10. Using the distances recorded in your crew logbook, mark and label points for Baseline A, the launcher, and Baseline B along a horizontal line representing the ground.

11. Use a protractor to draw angle lines from points A and B based on the measurements you recorded at those baselines during a single rocket flight. (Optional: For a more accurate measurement, don't place the angle's vertex directly on point A or B; instead, position it above point A or point B by a distance equal to the observer's eye-level height.) Label the angles (include units) and which flights they represent. With a ruler, extend the angle lines from A and B so that they cross at some height above the ground line.

12. Then draw the altitude: a vertical line from the intersection of the angle lines down to the ground line. Read the graph to find the altitude in meters and label it.



NASA/JPL

13. Students can use the same sheet of graph paper to draw angle lines and altitudes for the next rocket flight. If they use different colored pencils for each flight, they should include a key on the graph showing which color represents which flight.

14. Compare the altitudes that different rockets reached, and compare the designs of those rockets. Students can compare within their group and with other groups. What factors had the largest effect on the rockets' altitude? Consider fuselage length, nose cone shape, and the number, shape, and placement of fins.

NEXT ITERATION: Imagine, Design, Build, Test, and Analyze—Again

Student analysis of the test flights should give students ideas for what they can change in their rocket designs. Repeat the whole procedure to design and test a fleet of new and improved rockets. Students should evaluate the new rockets' performance and determine if the changes they made led to improved outcomes. Continuing this process through more iterations will allow students to optimize their design to get the best performing rocket they can within the time available.

EXTENSIONS

1. Use a smartphone, tablet, or digital camera to record high-frame-rate video of the launch so the class can watch it in slow motion.

2. Try a horizontal distance competition instead of a vertical one. This can work well if a large outdoor area is not available. Clear furniture and other obstacles from a strip of floor in a long room such as a cafeteria or gymnasium. Place a basketball in the landing zone to represent Mars, and have the students launch their rockets toward Mars! Students can see how making the launch tube angle higher or lower affects the horizontal distance the rocket reaches.

3. Compare rockets to an arrow, a weather vane, or a dart. Bring one or more of these objects to class and compare them to the shape of the students' rockets.

4. Show pictures of missiles and rockets and compare them to the students' rockets.

5. Consider hosting a family rocket-launch event, during which families work together to build rockets. The knowledgeable student in each family can be the team captain and instructor.

LEARN MORE

FIND MORE RESOURCES AT:

www.spacestationexplorers.org/resources/sse-stem-kit1/#activity3

ACTIVITY 4

SPACEWALK SIMULATION:

Train Like an Astronaut

GRADE LEVELS	3–8
SUBJECTS	Engineering, Teamwork
PREP TIME	30 minutes (2–5 days before day of lesson)
DURATION	1 class period (45 minutes)

An introduction to NASA's "Train Like an Astronaut" activity series (2012)

OBJECTIVES

- The educator will access NASA's "Train Like an Astronaut," a set of educational activities that emphasize physical fitness » www.nasa.gov/tla
- In the "Crew Assembly Training" activity described here, students learn about spacewalk training. Astronauts practice for many hours to develop the strength, dexterity, and hand-eye coordination necessary to carry out delicate tasks wearing stiff spacesuits with bulky gloves.
- Students will record their impressions of the experience in their crew logbooks.

EDUCATIONAL STANDARDS

NEXT GENERATION SCIENCE STANDARDS – DISCIPLINARY CORE IDEAS & PERFORMANCE EXPECTATIONS

ETS1.A: Defining and Delimiting Engineering Problems

- 3-5-ETS1-1, MS-ETS1-1 (Engineering Design for Grades 3–5 and Middle School): Define a design problem with criteria for success; constraints on materials, time, and cost; and considerations of impacts on people or the environment.

COMMON CORE STANDARDS FOR ENGLISH LANGUAGE ARTS

- CCSS.ELA-LITERACY.SL.3.1.B, 4.1.B., 5.1.B (Speaking and Listening for Grades 3–5): Comprehension and Collaboration: Follow agreed-upon rules for discussions and carry out assigned roles.

NASA

NASA astronaut Tim Kopra

VOCABULARY

- Dexterity
- Extravehicular Activity (EVA)
- Neutral Buoyancy Laboratory
- Robonaut 2 (R2)

BACKGROUND

Astronauts go through rigorous training to prepare for missions. Many NASA team members work together to train astronauts for the challenges of space. Teamwork is essential for success.

NASA's "Train Like an Astronaut" activities cover physical fitness and nutrition in the exciting context of astronaut training. Students participate in activities modeled after the real-life physical requirements of humans traveling in space. The accompanying videos feature NASA astronauts talking about their experiences. These activities are designed get students moving, with different activities emphasizing various aspects of fitness, such as aerobic exercise, strength training, reaction time, coordination, and nutrition.

Educators should browse the 11 activities and choose what best fits their curriculum » www.nasa.gov/tla

The activity reproduced here is Crew Assembly Training. The rest of the activities are:

AGILITY ASTRO-COURSE
BASE STATION WALK-BACK
BUILDING AN ASTRONAUT "CORE"
CREW STRENGTH TRAINING
DO A SPACEWALK!
EXPLORE & DISCOVER
JUMP FOR THE MOON
MISSION: CONTROL!
SPEED OF LIGHT
TASTE IN SPACE

NASA

This 2013 photo shows NASA astronaut Chris Cassidy, Expedition 36 flight engineer, working with Robonaut 2.

BACKGROUND FOR THE "CREW ASSEMBLY TRAINING" ACTIVITY

Going outside the spacecraft is called an extravehicular activity (EVA), or spacewalk. During the Apollo missions (1969–1972), 12 astronauts carried out EVAs on the moon's surface to make observations, test equipment, and perform science experiments. Between 1998 and 2011, astronauts from several countries performed 155 EVAs to assemble the International Space Station (ISS) piece by piece. The Hubble Space Telescope was repaired and upgraded through five space-shuttle-based EVAs between 1993 and 2009.

These days, most EVAs are to repair, maintain, and upgrade parts of the ISS. Astronauts have only six to seven hours of life support during an EVA, so they need to work quickly without sacrificing safety. To make spacewalks efficient, space agencies plan them in advance and put astronauts through extensive training before the mission. Astronauts spend more than 100 hours practicing with their partners in the Neutral Buoyancy Laboratory (NBL), a giant swimming pool in Houston. The NBL is 40 feet deep, 202 feet long, and 102 feet wide, and holds 6.2 million gallons of water. It contains full-size mockups of ISS components and equipment like what the astronauts will encounter in space. Wearing training suits that mimic real spacesuits, astronauts practice seven hours in the pool for each hour they will spend on the EVA.

The bulky, pressurized gloves of a spacesuit protect astronauts from the brutal space environment. Although the gloves are engineered to let astronauts move their fingers and rotate their wrists, it's still challenging to manipulate small objects and tools wearing these gloves.

Robonaut 2 (R2) is a dexterous humanoid robot being tested on the ISS. Its hands are the same size as human hands but have greater strength and dexterity. R2 can grasp and manipulate massive objects, but it can also carry out delicate movements. R2 has been doing tasks inside the ISS modules, but a future Robonaut model could work outside to help astronauts on EVAs. This research is expanding NASA's capabilities for construction and exploration in space.

ACTIVITY 4

SPACEWALK SIMULATION

Train Like an Astronaut

MATERIALS

- CREW LOGBOOK
- CONTAINERS LARGE ENOUGH TO HOLD AT LEAST 25 LABELED PIECES OF ONE FLOOR PUZZLE
- SEVERAL PAIRS OF SNUG CHILDREN'S GLOVES AND ADULT WORK GLOVES
- TWO PIECES OF CARDBOARD LARGE ENOUGH TO COVER THE COMPLETED PUZZLES
- MARKER OR PEN
- STOPWATCH, TIMER, OR CLOCK WITH A VIEWABLE SECOND HAND IN THE ROOM

PREPARATION – Educator does this before class

PREPARE PUZZLES:

Ideally, there should be one 25-piece puzzle for every four students.

1. Assemble the puzzle on a piece of cardboard.
2. Once assembled, lay an additional piece of cardboard on top to sandwich the puzzle, then flip the sandwich so that the puzzle is upside down.
3. Remove the top piece of cardboard to reveal the back of the puzzle. Label all the pieces around the puzzle's edge A and the pieces closer to the center B. There should be roughly the same number of pieces labeled A and B.
4. If the puzzle is large, it may be necessary to label the innermost pieces C.
5. Once the pieces are labeled, disassemble the puzzle and put the pieces in a container.
6. Repeat for the rest of the puzzles.

NOTES ON SETTING UP THE CHALLENGE:

- When building a puzzle, a student will be wearing two pairs of gloves: the inner pair of gloves should be snug, and the outer pair should be thick or bulky like ski gloves or adult-sized gardening gloves. Have at least two sets of gloves available per four-student crew.
- Have hand sanitizer available if students must share gloves.
- Choose and label a "home base" and "assembly area" for each student crew. The farther apart the areas are, the more exercise the students will get as they run between them.
  - *Assembly areas should have clean, flat surfaces suitable for puzzle construction.*

PROCEDURE

1. Group students into four-person crews and ask them to choose crew names related to space.

2. Give each crew a container of puzzle pieces and tell the crews to divide the pieces among the crew members, making sure the letters on pieces in each person's hand match. For a four-student crew, two students will have small piles of B pieces and two students will have small piles of A pieces.

3. Students will assemble the puzzle picture side up, not letters up.

4. Each crew's goal is to complete their puzzle before the other crews do. The activity is structured as a race, so all crews will begin when the educator starts the timer.

5. The crews start at their home bases. Crew members holding pieces labeled "A" will go to the assembly area first, so they should put on their gloves before the timer starts.

6. Start the timer! Crew members with the "A" pieces dash to the assembly area, assemble their portion of the puzzle (picture side up), leave the puzzle at the assembly area and dash back to home base to tag their fellow crew members (and hand off the gloves if students are sharing gloves). The rest of the crew waits at home base.

7. Crew members with the "B" pieces put on their gloves, go to the assembly area, and add their pieces to the puzzle. The rest of the crew waits at home base.

8. Repeat for students with "C" pieces if applicable.

9. The crew isn't done until the final puzzle assemblers return to home base! Then the crew members note their team's time on the stopwatch or clock and record it in their crew logbooks.

10. Discussion: Ask students what it was like to work with the puzzle pieces wearing those big gloves. Ask crews if they used any strategies to speed up their work.

LEARN MORE

FIND MORE RESOURCES AT:

www.spacestationexplorers.org/resources/sse-stem-kit1/#activity4

ACTIVITY 5

STORY TIME FROM SPACE:

Max Goes to the Space Station

GRADE LEVELS	3–8
SUBJECTS	English Language Arts, Space Science
PREP TIME	< 5 minutes
DURATION	Book reading 20 minutes; discussion 40 minutes

OBJECTIVES

- Students will view a video of NASA astronaut Mike Hopkins reading *Max Goes to the Space Station* onboard the International Space Station (ISS).
- If copies of the book are available, students will practice reading comprehension by reading and discussing *Max Goes to the Space Station.*
- Students will explore space science topics covered in "Big Kid Boxes" on the book's pages.

EDUCATIONAL STANDARDS

NEXT GENERATION SCIENCE STANDARDS – DISCIPLINARY CORE IDEAS & PERFORMANCE EXPECTATIONS

PS2.A: Forces and Motion

- 3-PS2-2 (Motion and Stability: Forces and Interactions for Grade 3): Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

PS2.B: Types of Interactions

- 5-PS2-1 (Motion and Stability: Forces and Interactions for Grade 5): Support an argument that the gravitational force exerted by Earth on objects is directed down.

COMMON CORE STANDARDS FOR ENGLISH LANGUAGE ARTS

- CCSS.ELA-LITERACY.RI.4.3 (Reading Informational Text for Grade 4): Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.
- CCSS.ELA-LITERACY.RL.4.1, 5.1, 6.1 (Reading Literature for Grades 4–6): Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.
- CCSS.ELA-LITERACY.RL.4.6, 5.6, 6.6 (Reading Literature for Grades 4–6): Discuss how a narrator's or speaker's point of view influences how events are described, and explain how an author develops the point of view of the narrator or speaker.
- CCSS.ELA-LITERACY.RL.4.7, 5.7, 6.7 (Reading Literature for Grades 4–6): Make connections between the text of a story or drama and a visual or multimedia presentation of the text, including contrasting what they "see" and "hear" when reading the text to what they perceive when they listen or watch.

VOCABULARY

- Extravehicular Activity (EVA)
- Cupola
- Free fall
- Orbiting
- Modules
- Weightlessness

BACKGROUND

Through Story Time From Space, anyone can watch astronauts on the ISS read children's books and perform science demonstrations as the Earth rotates below. Both inside and outside the classroom, children and families can enjoy watching and reading along with the British, French, Japanese, and American astronauts who present these stories. The online library of free videos combines science, literacy, and entertainment.

Science Time From Space consists of educational demonstrations that complement the science concepts covered in the books. Free curricular support materials are being designed to connect the science content with the Next Generation Science Standards and Common Core Standards.

Educator Patricia Tribe and NASA astronaut Alvin Drew started Story Time From Space. Former Canadian astronaut Bjarni Tryggvason designs the science demonstrations. The ISS National Lab supports the program's research and covers flight operations to get the books and demonstration materials to the ISS.

Story Time From Space / NASA

NASA astronaut Mike Hopkins reads *Max Goes to the Space Station* for Story Time From Space.

ACTIVITY 5

STORY TIME FROM SPACE:

Max Goes to the Space Station

MATERIALS

- COMPUTER WITH INTERNET ACCESS CONNECTED TO AN AUDIOVISUAL SETUP THAT CAN PLAY VIDEO WITH SOUND
- ONE OR MORE COPIES OF THE BOOK *MAX GOES TO THE SPACE STATION*
- CREW LOGBOOK

PROCEDURE

1. If copies of the book *Max Goes to the Space Station* are available, pass them out to students so they can read along with the video.
2. Play the Story Time From Space video (17 minutes) and enjoy watching NASA astronaut Mike Hopkins read aloud to your students » storytimefromspace.com/stories/max-goes-to-the-international-space-station/
3. If time allows, explore online resources related to the book's "Big Kid Boxes." For example:

Page 12:

- Explore the ISS and its components » www.spacestationexplorers.org/explore/welcome-to-the-iss
- Tour the ISS on a computer or mobile device » esamultimedia.esa.int/multimedia/virtual-tour-iss

Page 16:

- See how astronauts sleep, brush their teeth, and even use the bathroom on the ISS (YouTube playlist by Space.com) » www.youtube.com/playlist?list=PLCE-SVF9BSTe9AhV2g-0TqsYfNHjTzZei
- An Astronaut's Guide to Life in Space (YouTube playlist by Rare Earth) » www.youtube.com/playlist?list=PLPfak9ofGSn9vOEkIz328i4xQQq7e0kjc

Page 17:

- Spot the Station – Get alerts on your computer or mobile device when the ISS will be visible overhead in your area » spotthestation.nasa.gov

Page 19:

- Science on Station – See what experiments have been and are currently onboard the ISS » www.issnationallab.org/research-on-the-iss/areas-of-research

Page 20:

- Details on the Student Spaceflight Experiments Program (grades 5–16) » ssep.ncesse.org

Page 21:

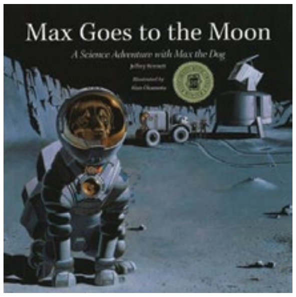
- Windows on Earth – Explore this collection of breathtaking photography by ISS astronauts, updated daily » www.windowsonearth.org

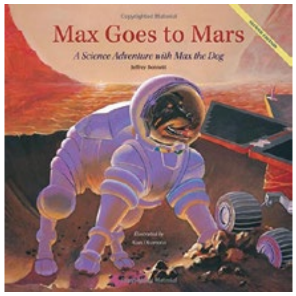
REFLECTION (CREW LOGBOOK ACTIVITY)

Write your own Max science adventure (Grades 3–5)!

Max has now been to the ISS, the moon, Mars, and Jupiter in Big Kid Science books. Where would you like to send Max next? Choose a destination, and then write and illustrate a story of Max's adventures.

Your story should be exciting and include an opportunity for Max to be a hero, but remember that he's a real dog, not a talking dog. Be sure that your story includes some real science. You could even include your own "Big Kid Boxes" on the pages or add a question and answer on each page that teaches a science fact or concept.





Big Kid Science

EXTENSIONS

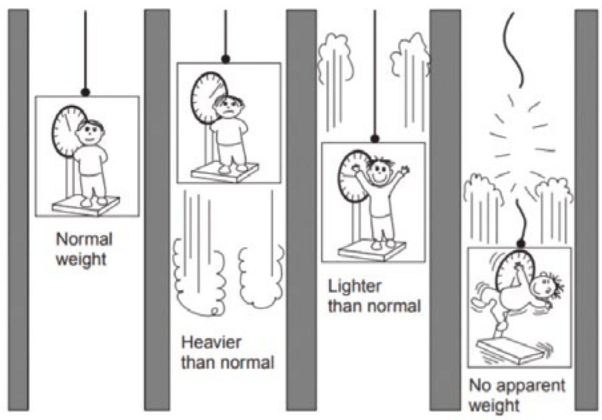
READING

Find other videos of astronauts reading children's books at the Story Time From Space website » www.storytimefromspace.com

Popular examples:

- NASA astronaut Kate Rubins reads *Rosie Revere, Engineer* by Andrea Beaty » storytimefromspace.com/rosie-revere-engineer-2/
- NASA astronaut Scott Kelly reads *Mousestronaut* by Mark Kelly » storytimefromspace.com/mousetronaut-2/

SCIENCE



Elevator Science: An Experiment with Free Fall from NASA's Microgravity in the Classroom (Grades 6–8) » www.nasa.gov/pdf/315956main_Microgravity_in_the_Classroom.pdf

If you can find a tall building with a fast elevator, you can explore the way weight changes under different conditions by taking a small bathroom scale into the elevator with you. You'll need to ride up and down for a while, so be prepared for some funny looks from others who get on the elevator with you. Note: This experiment works best if you can take the elevator many floors without stopping.

Ride the elevator up and down a couple of times.
You should notice six distinct stages in its motion:

1. As it begins to go up, the elevator accelerates, gradually increasing its upward speed.
2. Soon, the elevator settles into a steady (constant speed) upward motion.
3. As it nears the top of its trip, the elevator will slow down until it comes to a stop.
4. When you head back down, at first the elevator will accelerate downward, going faster and faster until it reaches a steady speed.
5. It will maintain the steady speed for a while.
6. As it nears the bottom of its trip, the elevator will slow down until it comes to a stop.

Once you can feel the various stages, use a bathroom scale to see what happens to your weight. During which stages does the scale show you to be heavier than your normal weight? Which stages show you to be lighter? Which stages show your normal weight? (Hint: Of the six stages, you should find that you are heavier than normal in two, lighter than normal in two, and normal in two.)

Based on what you've learned, discuss what would happen if the elevator cable were to break. What would the scale show in that case? How would this demonstrate that free fall makes you weightless like an astronaut?

LEARN MORE

FIND MORE RESOURCES AT:

www.spacestationexplorers.org/resources/sse-stem-kit1/#activity5

ACTIVITY 6

DESIGN A SPACE STATION:

Living and Working in Space

GRADE LEVELS	3–8
SUBJECTS	Engineering, Teamwork
PREP TIME	< 10 minutes
DURATION	1 class period (45 minutes)

OBJECTIVES

- Students will think about what is necessary for a space station to serve as both an orbiting laboratory and a safe home for astronauts.
- Students will use the engineering design process to create and revise space station modules with the materials provided.
- Students will practice teamwork by working in small groups on individual modules and collaborating as a larger group to assemble the complete space station.

EDUCATIONAL STANDARDS

NEXT GENERATION SCIENCE STANDARDS – DISCIPLINARY CORE IDEAS

PS2.B: Types of Interactions

- 5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down (that is, toward the planet's center).

ETS1.A: Defining and Delimiting Engineering Problems

- 3-5-ETS1-1 (Engineering, Technology, and Applications of Science for Grades 3–5): Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

ETS1.B: Developing Possible Solutions

- 3-5-ETS1-2 (Engineering, Technology, and Applications of Science for Grades 3–5): 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.

COMMON CORE STANDARDS

- CCSS.ELA-Literacy.SL.8.5 (English Language Arts for Grade 8): Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.
- CCSS.MATH.PRACTICE.MP2 (Mathematical Practice for All Grades): Reason abstractly and quantitatively.

BACKGROUND

The International Space Station (ISS) was assembled in low Earth orbit from 1998 to 2011 out of many pieces built in different countries. It has 14 pressurized modules plus a truss, huge solar panels, and two robotic arms. There are two bathrooms, six sleep stations, areas for exercising and preparing food, and workspaces for maintaining the station's systems, doing science experiments, and testing technologies for future missions to Mars and beyond.

VOCABULARY

- Habitat
- International Space Station (ISS)
- Microgravity
- Module

The Russian space agency Roscosmos contributed several modules to the ISS: Zarya, Zvezda, Pirs, Poisk, and Rassvet. A final Russian-built laboratory module called Nauka is expected to launch in 2019 and replace Pirs. The Russian modules travel on Russian rockets, but the rest of the space station's modules (with one exception) were carried in the payload bays of space shuttles.

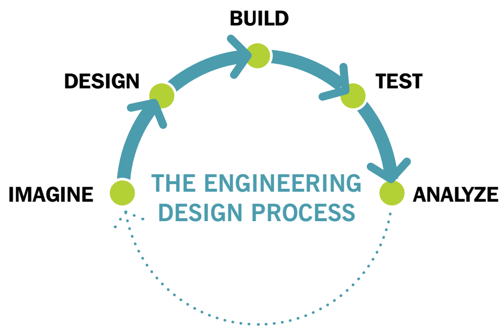
The European Space Agency contributed several modules, all built in Italy: Harmony (Node 2), Tranquility (Node 3) and its Cupola window, the Columbus laboratory, and the Leonardo storage module (a converted resupply vehicle also called the PMM). The U.S. contributed the Unity module and the Destiny laboratory. Canada contributed the gigantic Canadarm2 robotic arm. The Japan Aerospace Exploration Agency provided the Kibo laboratory, which comes with a smaller robotic arm called the Japanese Experiment Module Remote Manipulator System.

One module is an exception because it doesn't come from a space agency, didn't travel on a space shuttle, and doesn't look like a big metallic cylinder. The Bigelow Expandable Activity Module, built by Bigelow Aerospace, was launched in 2016 aboard a SpaceX Dragon cargo resupply ship. It's made of multiple segments with rigid aluminum frame pieces connected by durable fabric. This lets it fold down to fit in the Dragon vehicle and then expand once it's installed on the outside of the ISS.

The first crew of ISS astronauts lived there for four months starting in 2000. Today, the ISS is home to five or six astronauts at a time, and each astronaut stays there at least six months.

This activity is a design challenge. The engineering design process is a series of steps for solving a problem (addressing a want or need) by developing possible solutions and testing how well they work within the existing constraints (such as limited time or materials).

Different textbooks use slightly different names for the steps, but one way to describe them is: **Imagine, Design, Build, Test, Analyze.**



IMAGINE: Identify the problem or challenge. What is necessary for a solution to be successful? Knowing these *criteria for success*, brainstorm and discuss possible solutions. Think about the constraints that might apply. For example, are there limits to the size, shape, or weight of the solution, or the cost of its materials? Which ideas for solutions can be adjusted to fit these constraints?

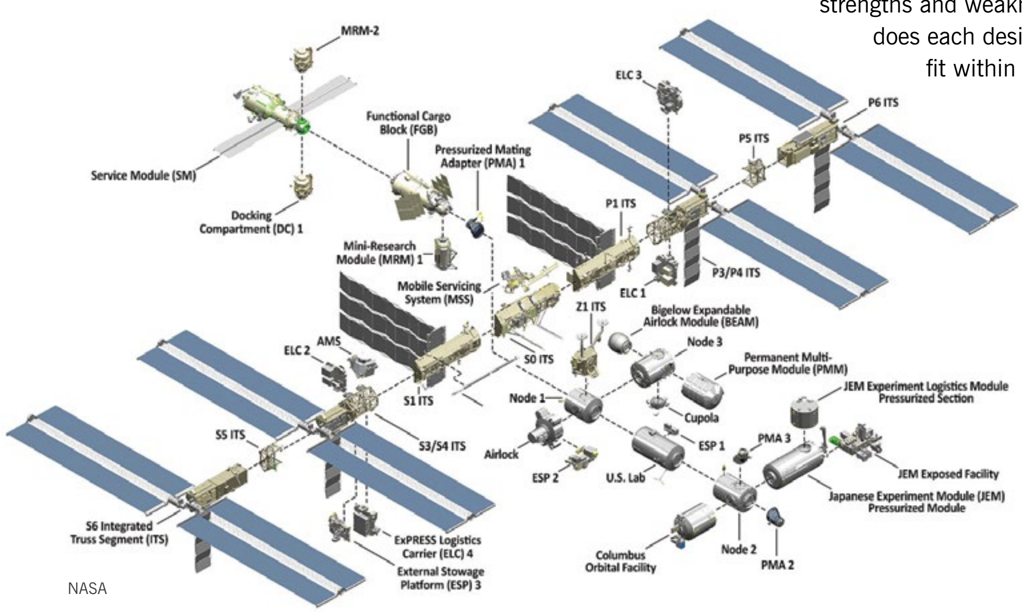
DESIGN: Choose one or more of the possible solutions you think will work well, and create drawings and/or descriptions of them. List the materials you'll need to build them.

BUILD: Gather the materials and build your design(s).

TEST: Choose a *fair* and *measurable* way to test designs. To make the tests fair, test all designs under the same conditions. To make the tests measurable, think about performance aspects you want to measure, such as whether the model has proper modules to keep humans alive.

ANALYZE: Compare the results from the tests and identify the strengths and weaknesses of different designs. How well does each design meet the criteria for success and fit within the constraints of the challenge?

Then start the next iteration (repeat the cycle) by going back to Imagine: Think about what you've learned from testing and analyzing your previous design(s). Can you combine the strengths of multiple designs into a new and improved design?



NASA

Diagram of the parts of the International Space Station

ACTIVITY 6

DESIGN A SPACE STATION:

Living & Working in Space

MATERIALS

- CLEAN, EMPTY 2-LITER BOTTLES
- UTILITY KNIFE
- PACKING TAPE OR DUCT TAPE
- ALUMINUM FOIL
- PIECES OF CARDBOARD OR FOAM CORE
- SHORT SEGMENTS OF 1/2-INCH PVC PIPE
- JOINTS FOR 1/2-INCH PVC PIPE *(such as elbow connectors and 4-way connectors)*
- MISCELLANEOUS MATERIALS *(modeling clay, craft foam, tongue depressors, pipe cleaners, etc.)*

Safety Note: Adult supervision and assistance are required when using a utility knife.

PROCEDURE

Students should work in small teams to create individual modules. The teacher can assign a different requirement for each team's module. For example, one module needs a way for astronauts to prepare food, another needs a way for astronauts to exercise, another needs a system to provide the station's electricity, another needs facilities for science experiments. The modules can have additional features as long as they meet the assigned requirement. After building their modules, teams interconnect them with PVC pipe fittings and tape.

Imagine and Design

First, identify the problem: Your team needs to make a space station module that meets some assigned requirement, such as having a way for astronauts to prepare food. Visit www.SpaceStationExplorers.org to learn about the ISS and watch videos of astronauts. Brainstorm and write your ideas in your crew logbook. What are the criteria for success in this challenge? What does a space station need to keep humans alive? What do astronauts need to do essential things like eating, sleeping, exercising, and working in space? Where would your electricity and water supply come from?

Build

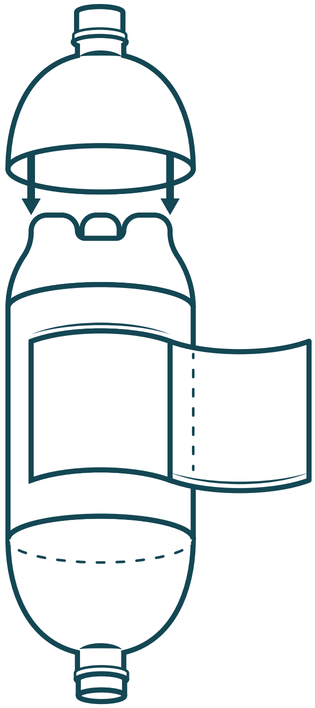
Cut a window in the side of each bottle to access the inside. As you create the interior of your module, you can use all the materials provided or chose only some of them. If there are extra bottles (including damaged ones from Stomp Rocket launchers), cut the top portion off of an extra bottle and slide it onto the bottom end of your module, so your module has connection points at both ends.

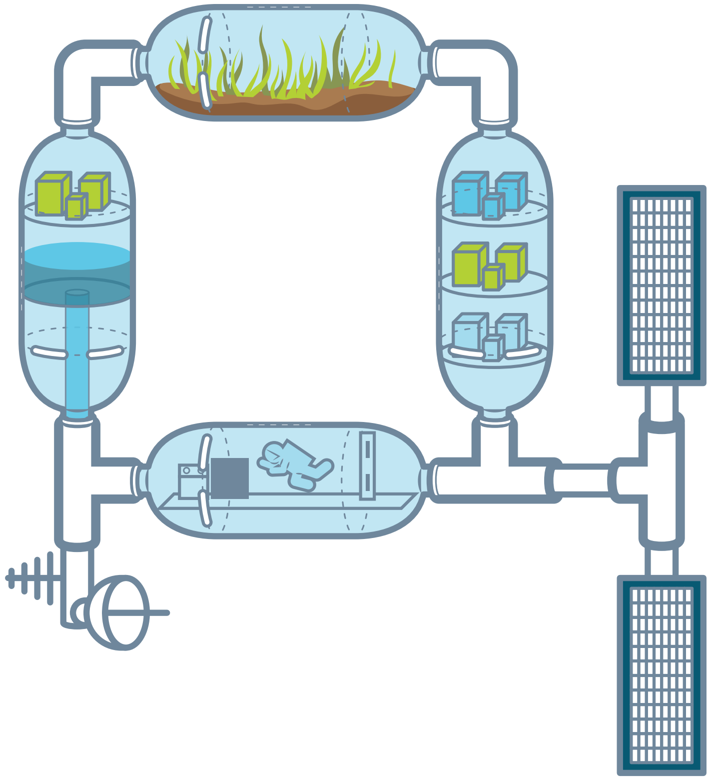
Test and Analyze

Pick up and rotate your module. Remember that in microgravity there is no sense of up or down and loose items can float freely and get lost. Do you need to modify your module for microgravity?

Next Iteration: Imagine, Design, Build, Test, and Analyze—Again

If time allows, make changes to your design so that it fulfills the criteria for success even better than your first design!





DISCUSSION (CREW LOGBOOK ACTIVITY)

In your crew logbook, sketch what the fully assembled station looks like. Assign names to the modules with a key at the bottom so that your classmates can understand your drawing.

DISCUSS THESE QUESTIONS AS A GROUP:

1. Which materials were most important in your space station design?
2. What were advantages and disadvantages to designing and building as a team?
3. What did you learn from seeing the others' creations?
4. After doing this activity, what new questions do you have about the ISS? Where will you look for the answers?

EXTENSIONS

1. How will vehicles containing astronauts or supplies attach to your space station? Compare your ideas with the ways vehicles connect to the ISS.
2. The ISS uses solar panels to power most of its electricity. But its orbit causes it to spend half of the time in Earth's shadow. How does the ISS keep its electricity going during periods when no sunlight reaches the solar panels?

LEARN MORE

FIND MORE RESOURCES AT:

www.spacestationexplorers.org/resources/sse-stem-kit1/#activity6

Dear Educator:

Now that you have explored the basics of the International Space Station's structure, orbit, crew, and research, are you ready for more? You and your learners can participate in programs that give you direct access to the ISS National Laboratory! Most of these programs are available online for free.

Space Station Explorers is a consortium of organizations that develop unique, authentic learning experiences for classrooms as well as out-of-school settings. Programs include opportunities to analyze data from ISS experiments, write code to control facilities onboard the ISS, and even build and launch experiments to space!

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Visit spacestationexplorers.org for programs and resources in these areas and more:

- **Plants in Space:** Plant seeds that have flown in space. Set up classroom experiments that parallel real investigations on the ISS. Compare your ground-based observations with data from space-based experiments and from other classrooms around the country!
- **Earth Science:** Get a new perspective on hurricanes, volcanic eruptions, glaciers, and other phenomena through beautiful photos taken by orbiting astronauts. Track the space station's location and choose targets for an automated camera to photograph from in orbit. Enjoy live video from Earth-facing cameras.
- **Robotics:** The ISS uses robotic arms to capture satellites, repair and upgrade external facilities, and install experiments. Write code to operate a real robot onboard the ISS.
- **Engineering Design:** Develop your own experiment for the ISS! In some cases, students upload code to an onboard lab facility. In other cases, students go through the whole process of designing the experiment, building it, and submitting it for NASA safety review. Then they attend the rocket launch!

NASA

SPACE STATION EXPLORERS

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