Activity Two: Design and Build a Space Habitat

Educator Notes

Challenge

Students will work as a team to design and build a model of a space habitat using the engineering design process.

Suggested Time

90 to 120 minutes
(Two full activity periods)

Learning Objectives

Students will

- Apply the steps of the engineering design process to successfully complete a team challenge.
- Design and build their own space habitat.
- Test their design, make observations, and collect data for analysis.
- Improve their model based upon the results of the experiment.

Curriculum Connection

Science and Engineering (NGSS)	
Disciplinary Core Ideas • MS-PS2-1 Motion and Stability: Forces and Interactions: Apply Newton's third law to design a solution to a problem involving the motion of two colliding objects. • MS-ETS1-1 Engineering Design: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. – ETS1.A: Defining and Delimiting Engineering Problems: The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. • MS-ETS1-3 Engineering Design: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. – ETS1.B: Developing Possible Solutions: There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. – ETS1.C: Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.	*Crosscutting Concepts* • Cause and Effect: Cause and effect relationships may be used to predict phenomena in natural or designed systems. • Systems and System Models: Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy and matter flows within systems. • Interdependence of Science, Engineering, and Technology: Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. *Science and Engineering Practices* • Asking Questions and Defining Problems: A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. • Developing and Using Models: A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. • Planning and Carrying Out Investigations: Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters.

Technology (ISTE)	
Standards for Students • Innovative Designer: Students use a variety of technologies within a design process to identify and solve problems by creating new, useful, or imaginative solutions. – 4a: Students know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts, or solving authentic problems. – 4c: Students develop, test, and refine prototypes as part of a cyclical design process. – 4d: Students exhibit a tolerance for ambiguity, perseverance, and the capacity to work with open-ended problems.	*Standards for Students (continued)* • Computational Thinker: Students develop and employ strategies for understanding and solving problems in ways that leverage the power of technological methods to develop and test solutions. – 5c: Students break problems into component parts, extract key information, and develop descriptive models to understand complex systems or facilitate problem-solving. • Global Collaborator: Students use digital tools to broaden their perspectives and enrich their learning by collaborating with others and working effectively in teams locally and globally. – 7c: Students contribute constructively to project teams, assuming various roles and responsibilities to work effectively toward a common goal.

Mathematics (CCSS)	
Content Standards by Domain • CCSS.MATH.CONTENT.6.SP.B.5: Summarize numerical data sets in relation to their context, such as by: – CCSS.MATH.CONTENT.6.SP.B.5.A: Reporting the number of observations. – CCSS.MATH.CONTENT.6.SP.B.5.B: Describing the nature of the attribute under investigation, including how it was measured and its units of measurement. • CCSS.MATH.CONTENT.7.G.B.6: Solve real-world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.	*Mathematical Practices:* • CCSS.MATH.PRACTICE.MP1: Make sense of problems and persevere in solving them. • CCSS.MATH.PRACTICE.MP3: Construct viable arguments and critique the reasoning of others. • CCSS.MATH.PRACTICE.MP5: Use appropriate tools strategically. • CCSS.MATH.PRACTICE.MP6: Attend to precision.

Preparation Time

15 to 30 minutes for setup, but several days to collect building materials

- Read the Introduction and Background, Educator Notes, and Student Handout to become familiar with the activity.
- Gather and prepare all supplies listed on the materials list.
- If using a glue gun, even cool-melt glue, set up a glue gun station for safety and supervision.
- Print copies of the Student Handout for each team.
- If presenting videos or web-based resources, test the links and the classroom technology ahead of time.

Materials

☐ Copies of Student Handout and blank paper
☐ Meterstick
☐ Paper and pencil for brainstorming
☐ Scissors
☐ Stapler and staples
☐ Tape
☐ White glue

Note: This activity also requires a large variety of building materials that can be obtained from craft scraps and recyclable materials—use your imagination! It is advised to start collecting these materials several days in advance.

The following are some suggested materials.

☐ Aluminum foil
☐ Balloons
☐ Bamboo skewers
☐ Bubble wrap
☐ Buttons or beads
☐ Cardboard scraps
☐ Cardboard tubes
☐ Foil plates
☐ Paper bags
☐ Paper clips
☐ Pipe cleaners
☐ Plastic bottles
☐ Plastic cups
☐ Popsicle sticks
☐ Straws
☐ String

Introduce the Challenge

- Provide context for this activity using the Introduction and Background information in this guide. Discuss the different types of modules in a space habitat and the types of forces they might experience during launch and assembly.
- Explain the role of engineers in designing technology to solve problems. Share the NASA for Kids video Intro to Engineering and introduce the engineering design process.
- Divide the class into teams of three to five students and pass out the Student Handout to each team. Use the handout to explain the details of the challenge, including the design constraints and your expectations for teamwork and classroom management.

Share With Students

Brain Booster

The Gateway will be much farther from Earth's surface than the International Space Station, which orbits an average of 400 km (250 miles) above our planet. The Gateway will be about 1,500 km (930 miles) above the Moon's surface at its closest approach. The space station orbits Earth in about 90 minutes, completing nearly 16 orbits per day, but the Gateway will take 8,640 minutes, or 6 days, to orbit the Moon once! This 6-day orbit will keep the Gateway out of the Moon's shadow at all times, allowing constant communication with Earth and enabling the Gateway to serve as an outpost for both lunar surface and future deep space missions.

Learn more:
https://www.nasa.gov/topics/moon-to-mars/lunar-gateway

On Location

NASA's Goddard Space Flight Center in Greenbelt, Maryland, is playing a vital role in the areas of communications and instrument development to advance spacecraft-based instruments and laser communication capabilities for use in lunar landing missions.

Learn more:
https://www.nasa.gov/feature/goddard/2019/goddard-technologists-and-scientists-prepare-for-a-new-era-of-human-exploration

Design Constraints

The space habitat must contain the following five modules:

1. Power and propulsion module with solar panels and thrusters
2. Habitation module with an exterior docking port
3. Laboratory module with an exterior docking port
4. Storage module with two exterior docking ports
5. Airlock module with an external hatch

In addition to the five modules, the following must be attached to the outside of the spacecraft:

1. Robotic arm to assist in construction and docking
2. Communications array for contacting Earth, a ground station, or other spaceships
3. Instrument package to study a nearby planet or moon

Testing Requirements

1. **Drop test**: To ensure that the five modules can withstand the stress of launching into space, each one must "survive" a drop test with no structural damage from a height of 1 m in order to be certified for assembly and installation to the space habitat. If any components break or fall off, teams must improve the design and test again.
2. **Volume constraint**: To ensure that the space habitat does not exceed the volume constraint, the entire space habitat cannot be more than 1 m high, 1 m long, or 1 m wide.
3. **Structural strength test**: To ensure that the space habitat will stay together in orbit, the completed model must undergo a structural strength test. Once it has been assembled, a team member must be able to hold it with one hand without any modules or other pieces falling off.

Facilitate the Challenge

Ask

- Answer any questions students have about the challenge or design constraints.

Imagine

- Allow students to view the available building materials before they begin planning.

Plan

- Consider requiring teams to submit their design for review before allowing them to collect building materials.

Create, Test, and Improve

- Go over classroom safety and management of the supplies before teams begin building and testing.
- Do not discourage failure, as testing and improving are part of the engineering design process.
- Ask guiding questions to help teams analyze how to apply STEM concepts to improve their design before testing again.

Safety: Students will likely be using scissors to cut irregularly shaped materials. Ensure that they are using safe cutting practices. If using glue guns, make sure the glue gun station is monitored at all times.

Share

- Allow each team an opportunity to present their model to the rest of the class.
- Engage students with the following discussion questions:
  - What challenges did your team face when completing this activity?
  - After completing the activity, what would you change about your original design?
  - What types of challenges do you think engineers are facing while designing and building components of a space habitat for NASA?

Extensions

- Challenge students to use leftover materials to create spacecraft and landing vehicles that can dock with their space habitat.
- Add a cost constraint to the challenge and create a budget for students to “purchase” materials. Assign cost to all materials based on mass, area, or type of material.

Reference

Modified from Build a Satellite to Orbit the Moon activity in NASA’s BEST Students: Beginning Engineering, Science, and Technology. https://www.nasa.gov/pdf/530250main_6to8NBSGuide.pdf

Additional Resources

- Rocket Science Ride to Station (includes simulated docking activity for students). https://rocketsciencec2e.ksc.nasa.gov/
- Digital Badging: Online NASA STEM Learning. https://www.txstate-epdc.net/digital-badging/

Activity Two: Design and Build a Space Habitat

Student Handout

Your Challenge

Work as a team to design and build a model of a space habitat using the engineering design process.

Design Constraints

The space habitat must contain the following five modules:

1. Power and propulsion module with solar panels and thrusters
2. Habitation module with an exterior docking port
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In addition to the five modules, the following must be attached to the outside of the spacecraft:

1. Robotic arm to assist in construction and docking
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3. Instrument package to study a nearby planet or moon

Testing Requirements

1. **Drop test**: To ensure that the five modules can withstand the stress of launching into space, each one must "survive" a drop test with no structural damage from a height of 1 m in order to be certified for assembly and installation to your space habitat. If any components break or fall off, improve your design and test again.
2. **Volume constraint**: To ensure that the space habitat does not exceed the volume constraint, the entire space habitat cannot be more than 1 m high, 1 m long, or 1 m wide.
3. **Structural strength test**: To ensure that your space habitat will stay together in orbit, your model must undergo a structural strength test. Once your habitat has been assembled, you must be able to hold it with one hand without any modules or other pieces falling off.

Ask

- Does your team know what they are expected to design and build?
- Does your team understand the design constraints?
- What questions does your team have about today's challenge?

Imagine

- Look over the building materials and supplies provided by your teacher. As a team, discuss and imagine how each of the materials can be used to build the parts of a space habitat. Make a list of a few of your ideas on the paper provided by your teacher.

Plan

- Draw your team's design for a space habitat model on the paper provided by your teacher.
- Make sure to label each of the five modules: power and propulsion, habitat, laboratory, storage, and airlock. Refer back to the **Design Constraints** section to review what is required for each module.
- Make sure to include the robotic arm, communications array, and instrument package.

Fun Fact

Illustrations of the Earth and the Moon often make them look really close together. Don't be fooled! They are actually really far apart. The Moon is an average of 384,400 km (238,855) away from Earth. How far away is that? That's about 30 Earth diameters away.

Learn more: https://spaceplace.nasa.gov/moon-distance/en/

Career Corner

How about a career in aerospace engineering? Modern spacecraft design requires the use of sophisticated computer equipment and software design tools, modeling, and simulations for tests, evaluation, and training. A 4-year bachelor's degree is the minimum necessary to enter this field. Colleges and universities also offer graduate programs where students can earn master's and doctoral degrees. The annual median wage for aerospace engineers is over $100,000!

Learn more: https://www.youtube.com/watch?time_continue=9&v=bnxcib-8S4s

Create, Test, and Improve

1. Build and test each module individually. Modules will not be attached to each other until after the team has successfully completed each drop test.
2. **Drop test**: Create a Drop Test Notes and Observations table on the paper provided by your teacher. Use the table below as an example. Drop each of the five modules from a height of 1 m and fill in the information on your table. Note any modules that were damaged and discuss as a team what adjustments could be made to improve the design and prevent damage during retesting.

Drop Test Notes and Observations		
Module Tested	**Describe Any Damage**	**Suggested Improvements**
Power and Propulsion		
Habitation		
Laboratory		
Storage		
Airlock		

3. Once all modules have successfully completed the Drop Test, assemble the modules according to the team's design. Additional materials may be added to strengthen the connection between each module. Remember to attach your robotic arm, communications array, and instrument package.
4. **Volume constraint:** Create a Volume Notes table on your paper like the example below. Using a meterstick, measure the length, width, and height of your completed space habitat in centimeters. Record the measurements in the table on your paper.

Volume Notes	
Dimensions	**Measurement, cm**
Length	
Width	
Height	

5. Are any of your measurements longer than 1 m (100 cm)? If so, how can the modules be rearranged so the space habitat is within the design constraints? List any design changes the team makes to comply with the design restraints on your paper.
6. **Structural strength test:** Using only one hand, pick up your space habitat model. When lifted, do any of the modules or other pieces fall off? If so, make a list, noting each item and the team's plan to reattach and make it stronger.

Share

- What challenges did your team face when completing this activity?
- After completing the activity, what would you change about your original design?
- What types of challenges do you think engineers are facing while designing and building components of a space habitat for NASA?
- Be prepared to discuss your design with the class.