



Habitation with Gateway

Assess the Structural Integrity of a Space Module

Background Information

As NASA sets its sights on returning to the Moon and preparing to travel to Mars, it is laying the foundation for human exploration deeper into the solar system by creating a Moon-orbiting outpost called Gateway.

While orbiting the Moon, this spacecraft will be a temporary home and laboratory for astronauts. The commute from Earth to Gateway will take about three days and cover approximately 250,000 miles (about 400,000 kilometers). Gateway will have living quarters for crew, workplaces for science and research, and docking ports for visiting spacecraft. These docking ports will serve as both parking spots for visiting vehicles and entrances to Gateway. Gateway will provide access to more of the lunar surface than ever before, supporting both human and robotic missions for NASA and its industry and international partners.

Like the International Space Station in Earth's orbit, Gateway is a Moon-orbiting outpost for astronaut expeditions to the Moon. The lunar space station will also serve as a practice ground for deep space missions — a place to train for life far away from Earth, including future exploration missions to Mars. Once docked, astronauts can live and work aboard Gateway for up to three months at a time, conduct science experiments, and take trips to the surface of the Moon.



Grade Range:
6-12



Time Needed:
60 Minutes



Materials List:

- Lightweight cylinders (e.g., aluminum cans or toilet paper tubes)
- 30 pieces of uncooked spaghetti per team
- Clear table or low-temperature hot gun glue
- Index cards
- Mass (e.g., lead weights, coins, washers, or similar)
- Scissors
- Metric Scale
- Rulers
- Paper/Pencil for brainstorming

In this activity, teams will take on a key engineering challenge — like those encountered when building structures for space missions like Gateway. Participants will design and construct a spaghetti space module framework and then test how much weight it can support. This hands-on challenge underscores the importance of creating strong yet lightweight structures that can withstand the rigors of space travel and support astronauts and vital equipment on future lunar outposts such as Gateway.

Career Connection

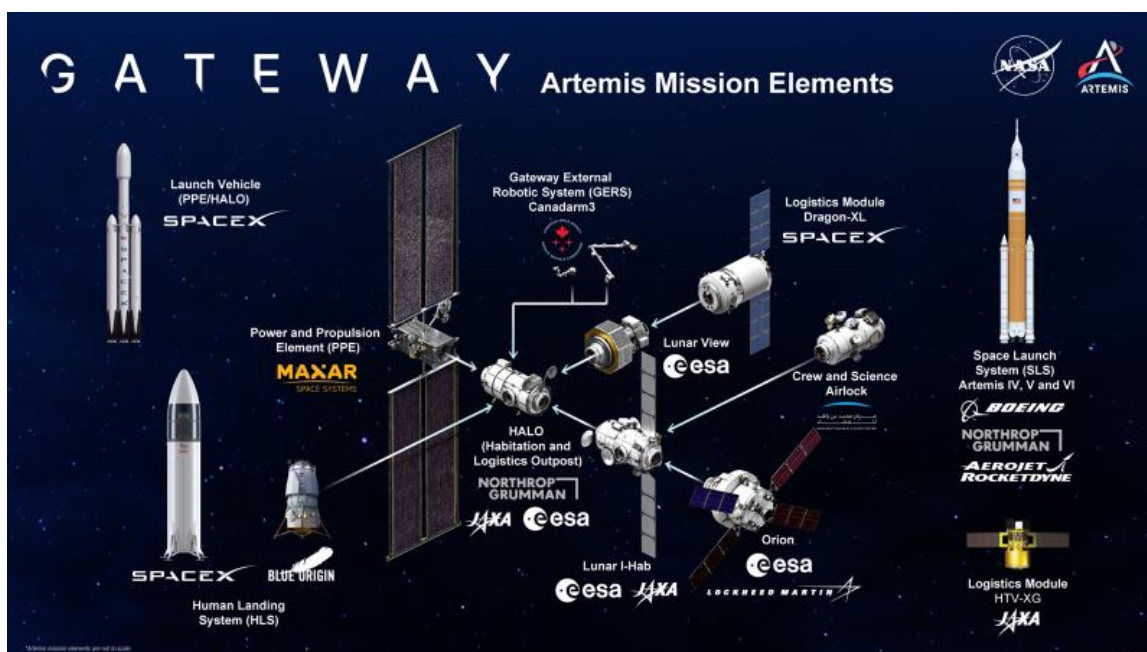
Building Gateway, our upcoming lunar-orbiting outpost, requires a team of people with diverse expertise and specialized skills working together. Below are just a few examples:

- **Aerospace Structural Engineers** are critical for ensuring spacecraft integrity. They design, analyze, and optimize structures to endure diverse loads and harsh space environments — including launch forces, microgravity, and impacts — all while prioritizing minimal weight.
- **Spacecraft Assembly Technicians** ensure engineering designs become functional spacecraft. These hands-on professionals meticulously assemble components, conduct essential tests, and troubleshoot issues, working with precision to guarantee the integrity of space vehicles.
- **Advanced Manufacturing Technicians** use cutting-edge tools and technology — like robotics, 3D printing, and computer-aided design — to build high-performance parts for aerospace systems. They help turn innovative designs into precise, reliable components for space missions.
- **Welders** play a critical role in the construction of NASA's Gateway. These skilled technicians use specialized welding techniques and tools to join critical components made of advanced aerospace materials. Their work ensures structural integrity in extreme environments such as vacuum, radiation, and temperature changes and contributes directly to the safety and performance of NASA's lunar-orbiting space station.

Activity Procedures

Safety

Practice safety-cutting techniques when using scissors. Carefully support the piece being cut. Be careful with the placement of your free hand. Avoid moving around the room with scissors or other sharp objects.

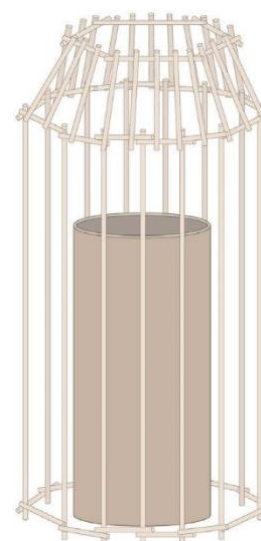


Preparation

- Gather and prepare all supplies listed on the materials list.
- If using a glue gun, even with cool-melt glue, set up a glue gun station for safety and supervision.
- If presenting videos or web-based resources, test the links and the classroom technology ahead of time.
- Determine the internal volume constraint for the space module in advance of the lesson. Any lightweight cylinder, ranging in size from a toilet paper tube to a 12-oz aluminum can, will work.
- Provide context for this activity and discuss the different types of modules in a space habitat.
- Engage students with the following discussion questions:
 - Why is a space habitat made up of individual modules?
 - Why is it important for modules to be hollow with as much open space inside as possible?
 - What are some safety concerns or consequences of a module that is not structurally strong?
 - What types of forces do modules experience on Earth, during launch, during assembly, and while in use?
- Divide the class into teams of three to five students and explain the details of the challenge, including the design constraints and your expectations for teamwork and classroom management.

Design Constraints

1. The volume constraint cylinder must fit completely and securely within the spaghetti structure each team builds. It cannot be attached to the structure with tape or any other means; it must remain loose within the structure without falling out.
2. Teams are only allowed to use the supplies provided. If they make a mistake or change their design, they **cannot** trade in used tape, glue sticks, or broken spaghetti pieces for more, nor can they trade materials with another team. Instead, they must recycle used materials into their design.
3. The module frame will be tested standing upright on its end (oriented like a soda can), and there should be a gap between the top of the volume constraint cylinder and the spaghetti structure.



Create and Improve

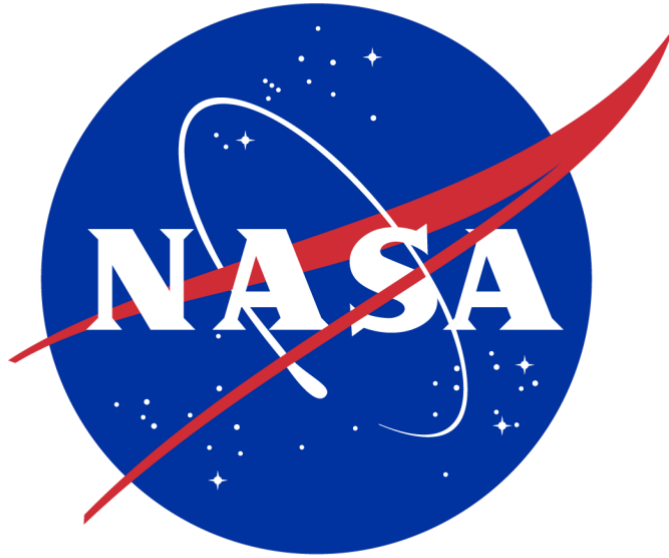
- In the first phase of the challenge, teams may only use 25 pieces of uncooked spaghetti and 50 cm of tape or one small glue stick to design and build the skeletal structure or framework of a space habitat module.
- For the interior of their module to remain open for “usable” space, the framework must be built around the cylindrical volume size constraint. The cylinder (i.e., toilet paper tube or aluminum can) must be loose within the framework and not attached in any way.
- Each team will test the strength of their design by placing it upright on its end (oriented like a soda can) and gradually adding weights until the structure “fails.” The structure has “failed” when it meets any of the following criteria:
 - Any piece of spaghetti has broken/snapped.
 - Any end of a piece of spaghetti has become detached from the tape or glue.
 - Any piece of spaghetti has bent to the point that it touches the top of the volume constraint cylinder.
- After the first weight failure test, students will measure and record the mass that was necessary to cause their module structure to fail. In the second phase of the challenge, teams will receive five additional pieces of spaghetti and an additional 10 cm of tape (no additional glue) to repair and improve their design.
- After their improved design is complete, students will again test their module structures to failure. Their goal is to increase the mass that their structure can support by 50 percent.

Challenge Questions

- What was the greatest challenge for your team today? How did you address this challenge?
- Which was most difficult: Keeping the spaghetti from bending, breaking, or becoming detached?
- What was the purpose of the design constraints? Why were you limited in how much the spaghetti could bend?

Extensions

- Add a cost constraint to the challenge and create a budget for your students to “purchase” materials. Assign cost to each piece of spaghetti and centimeter of tape. Challenge students to create the most efficient design (i.e., smallest ratio of cost to mass supported).
- Repeat the challenge using different materials for the structure.
- Would this challenge be more difficult with a larger or smaller cylinder used as a size constraint? Why?



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