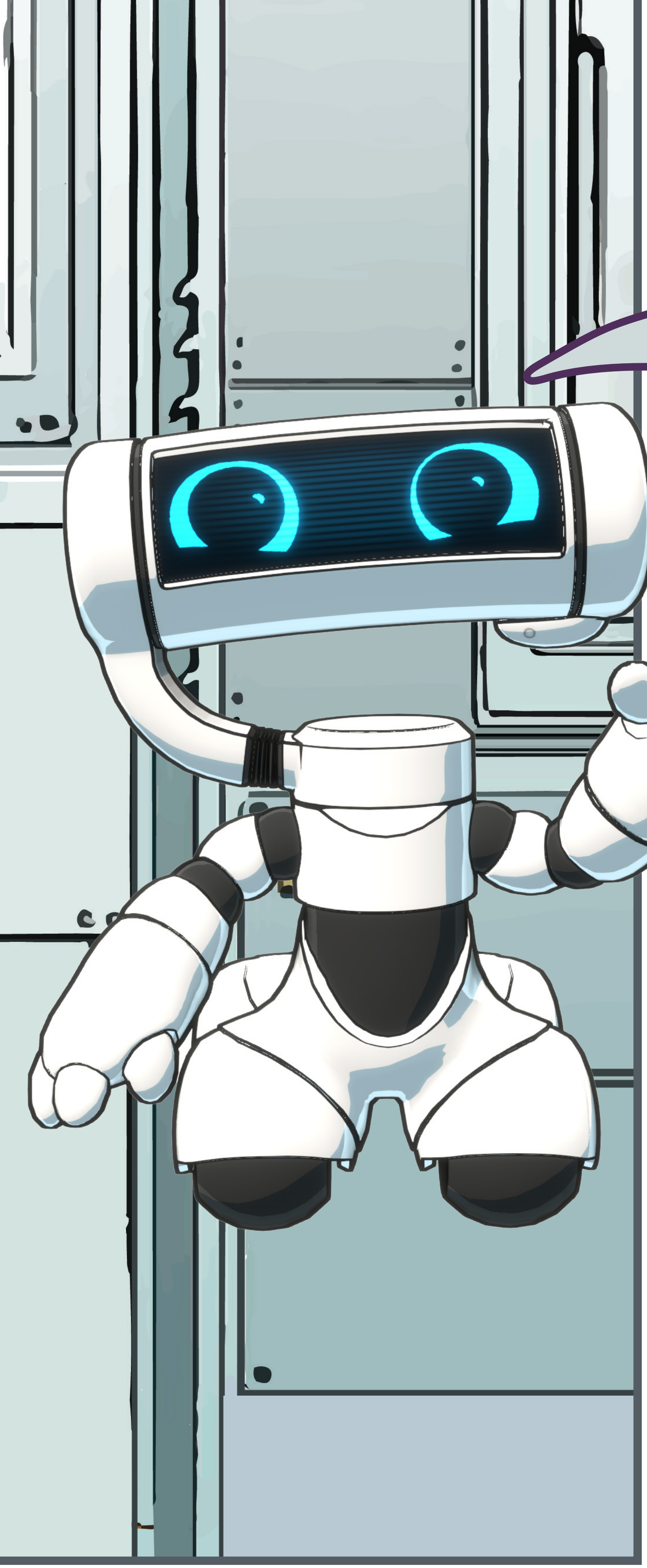
National Aeronautics and Space Administration

FIRST WOMAN

CAMP EXPERIENCE

NASA Office of STEM Engagement Next Gen STEM



Welcome Space Explorers!

This set of hands-on activities accompanies NASA's "**First Woman**" graphic novel series, which tells the story of Callie Rodriguez, the first woman to explore the Moon. While Callie is a fictional character, the first female astronaut and person of color will soon set foot on the Moon. Intended for use in K–12 informal education settings such as after-school programs, summer camps, STEM nights, and weekend workshops, this First Woman Camp Experience Guide will bring the excitement of NASA's science and technology missions to the Artemis generation of explorers.

What Is Artemis?

With Artemis missions, NASA will land the first woman and first person of color on the Moon, using innovative technologies to explore more of the lunar surface than ever before. NASA will collaborate with commercial and international partners and establish the first long-term presence on the Moon. NASA's scientists and engineers will use what they learn on and around the Moon to take the next giant leap: sending the first astronauts to Mars.

Camp Introduction

NASA is exploring the Moon, Mars, and beyond. What drives this exploration? Technology! Developing space technologies for future missions is the responsibility of NASA's Space Technology Mission Directorate (STMD). As NASA exploration takes us farther than ever, technology development in spacecraft design, deep space communications, fuel storage and transfer, and crew safety become crucial to the success of these future missions. The activities in this guide focus on four challenges in four research areas where NASA is seeking innovative solutions.

Slowing Down in Space

The first challenge is delivering heavy payloads to Mars. When a spacecraft enters an atmosphere, aerodynamic drag, or air resistance, helps to slow it down. However, the atmosphere of Mars is less dense than Earth’s. Although the atmosphere is thick enough to provide some drag, it is too thin to decelerate a heavy spacecraft for a safe landing. NASA has developed a new lightweight decelerator system. The low-Earth orbit flight test of an inflatable decelerator (LOFTID) demonstrated a crosscutting inflatable aeroshell—a type of heat shield—for atmospheric re-entry. This inflatable structure, protected by a flexible heat shield, acts as a giant brake as it traverses the Martian atmosphere.

Deep Space Communications

The second challenge is providing clear and consistent communication for long-distance missions. The farther away a spacecraft is from Earth, the more challenging it becomes to communicate in deep space. Not only is there a delay, but the signal weakens, and obstructions like solar radiation can degrade or prevent a message from reaching its intended audience. Just like a video call requires more data than a text message, advancements in spacecraft technology requires the transfer of even more data than before. Astronauts and spacecraft need to maintain contact with mission control, so NASA is testing deep space optical communications (DSOC) to overcome these challenges.

RoboTools

The third challenge is developing a robotic system for in-space servicing, assembly, and manufacturing (ISAM). In-space servicing covers fixing, fueling, improving, and reviving satellites. With in-space assembly, parts of a structure can be launched into space separately and put together once they reach their destination. In-space manufacturing involves fabrication of individual components or large structures from raw materials. Using robotic arms and tools, ISAM capabilities will extend the lives of existing spacecraft and incredible new mission concepts will be realized.

Filling Up in Space

The fourth challenge is transferring and storing rocket fuel. Most spacecraft use cryogenic propellants—gases such as hydrogen and oxygen chilled to below freezing temperatures. When cooled, these gases condense to form highly combustible liquids that provide high-energy propulsion. These fluids must be stored and transferred without temperature fluctuations that could result in fuel loss. NASA is looking for a solution to efficiently store and transfer these super-cold fluids (Cryogenic Fuel Management).

Camp Vocabulary

Drag Device - Parachute-like device that slows the spacecraft.

Velocity - Speed of an object in a specific direction.

Optical Communications - A type of long-distance communications that uses light as a means of transmitting information.

Protocol - A procedure for carrying out the exchange of data.

Degraded - Reduced in quality; in communications, analog (e.g., sound waves) or digital (e.g., computer) signals can become degraded.

Delay - A period of time by which an analog or digital signal is late or postponed.

Deep Space Network - Largest and most sensitive scientific telecommunications that contain NASA’s international array of giant radio antennas.

Cryogenics - the study of how to get to low temperatures and of how materials behave when they get there.

First Woman Camp Experience

Activities

1. Slowing Down in Space
2. Deep Space Communications
3. RoboTools
4. Filling Up in Space

Sample Camp Schedule

8:00 –8:10 a.m. .... Welcome - Artemis I Video: **We Are Focused**

8:10 –8:30 a.m. .... Icebreaker - **Cosmic Comic Game**

8:30 –10:00 a.m. .... Activity 1

10:00 –10:15 a.m. .... Break

10:15 –11:15 a.m. .... Activity 2

11:15 a.m.–12:15 p.m. . Lunch/Recess

12:15 –1:00 p.m. .... Activity 3

1:00 –1:15 p.m. .... Break

1:15 –2:45 p.m. .... Activity 4

2:45 –3:15 p.m. .... Wrap up

3:15 –3:30 p.m. .... Artemis video - **We Go as the Artemis Generation**

First Woman Novel

www.nasa.gov/calliefirst

Comprehension Questions:

Educator: go.nasa.gov/3WScoCy

Student: go.nasa.gov/3Y2Stli

Artemis: We Are Focused Video

Cosmic Comic Game

We Go as the Artemis Generation Video

First Woman Graphic Novel

Comprehension Questions

Activity 1: Slowing Down in Space

Prep time: 20 min **Activity time:** 90 min

Summary: NASA is exploring the Moon, Mars, and beyond. One of the challenges for NASA is delivering heavier payloads, especially in atmospheres that are less dense than Earth. The low-Earth orbit flight test of an inflatable decelerator (LOFTID) demonstrated a crosscutting inflatable aeroshell—a type of heat shield for atmospheric re-entry. The inflatable decelerator will act as a giant brake for slowing down spacecraft.

Learning Objective: Participants will understand how a drag device system helps safely reduce the velocity of a spacecraft during re-entry.

Outcome: Participants will design a drag device system to slow the descent of a weighted spacecraft.

Activity 2: Deep Space Communications

Prep time: 20 min **Activity time:** 45 to 60 min

Summary: As NASA explores beyond the Moon, communication is critical. Scientists and engineers use the Deep Space Network (DSN) to send messages to spacecraft. The farther the signal has to travel, the more complex it becomes to send messages and data. The signal may be blocked by obstructions, and radiation from the Sun or other celestial bodies may interfere, causing the message to degrade, become garbled, or fail to reach its destination. Deep Space Optical Communications (DSOC) is NASA's first demonstration of optical communications beyond the Earth–Moon system. When launched, DSOC will take optical communications into deep space for the first time.

Learning Objective: Participants will practice problem-solving strategies to construct a protocol, or set of instructions, for minimizing the amount of data lost or damaged during transit.

Outcome: Participants will develop and present a protocol after modeling how data is transmitted across networks.

Activity 3: RoboTools

Prep Time: 20 min **Activity Time:** 45 min

Summary: Robots will be essential to aid in repairs and updates on the mission to the Moon and beyond. On-orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1) is a robotic spacecraft equipped with tools, technologies, and techniques needed to extend satellites' lifespans even if they were not designed to be serviced in space. The servicing technologies on OSAM-1 will demonstrate that these technologies are ready for incorporation into other NASA missions.

Learning Objective: Participants will use the engineering design process to develop an interchangeable tool to aid a robot. Participants will also write instructions on how to operate the tool.

Outcome: Participants design and build a working tool that could be useful to robots working on or near the Moon.

Activity 4: Filling Up in Space

Prep time: 20 min **Activity time:** 90 min

Summary: Cryogenic propellants are gases chilled to extremely cold temperatures and condensed to form liquids at low temperatures. NASA's challenge is developing new solutions for in-space storage and transfer of cryogenic fluids—solutions that are energy, mass, and cost efficient. This is the goal of NASA's Cryogenic Fluid Management Portfolio Project.
Such solutions would benefiting a range of extended science and exploration missions throughout the solar system. This is the goal of the Cryogenic Fluid Management Portfolio Project.

Learning Objective: Participants will practice the steps of the engineering design process to create a solution to minimize the loss of cryogenic propellants in storage and transfer.

Outcome: Participants will design and model a cold-fluid transfer system.

FIRST WOMAN
CAMP EXPERIENCE

Technology drives exploration. In First Woman, Callie Rodriguez and her robot, RT, overcome obstacles to explore the Moon. Callie's trailblazing path as the first woman on the Moon demonstrates how dreams can become reality.

English

Español

MISSION BRIEFING

Activity: Slowing Down in Space

Prep Time: 20 minutes

Activity Length: 90 minutes

Task: Participants will design a drag device system to slow the descent of a weighted spacecraft from a height of 2 meters.

Scan the QR code for an instructional video of this activity.

By the end of this activity participants will

Understand how a drag system helps safely reduce the velocity of a spacecraft during re-entry.

Materials

- Scissors
- Rulers
- Clear tape
- Digital scale or balance
- Thin string (embroidery thread, fishing line)
- Small sealable bag, one per group
- Washers, marbles, or pennies to serve as mass
- Hole punch and hole reinforcements or stickers
- Cardstock or old file folders for template
- Spacecraft template, one per team (provided at the end of this activity; a paper or plastic cup glued or taped to a paper plate will also work)
- Tall ladder or overhang above a stairway or common area
- Materials to make drag device (plastic trash bags, grocery bags, wrapping paper, tissue paper, plastic tablecloths)

Preparation

1. **Gather and prepare all listed supplies. Set up areas or stations that contain all the supplies.**
2. **Group participants in teams of three to four.**
3. **Set up testing stations with safety equipment. Allow no more than three teams per testing station.**

Procedure

1. Teams will use the provided template to build a spacecraft and will place a plastic bag with 20 to 30 grams of mass to add "cargo" inside the spacecraft.
2. Allow teams to see the available materials for the drag device. The total design (spacecraft, cargo, and drag device) cannot exceed 50 grams.
3. Each team will brainstorm and sketch their design.
4. One participant from each team will then gather the

Activating Prior Knowledge

Have you ever noticed that when a bird is preparing to land, it typically has its wings spread out? Why do you think that is the case?

Have participants drop two pieces of paper, one crumpled and one flat; the only variable should be the shape and surface area of the paper. What do they notice as the pieces fall?

Connection to NASA

The Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) demonstrates an inflatable aerodynamic decelerator, a new aeroshell technology that could one day help land humans on Mars.

To learn more visit **NASA's LOFTID webpage**.

MISSION GUIDANCE

GO

- Discuss the challenge and constraints.
- Separate the testing station from the building station.

MAYBE

- Show the following videos describing LOFTID:
  - **LOFTID** being inflated (QR Below)
  - Brief summary of **LOFTID** (QR below)
  - **LOFTID** Animation (QR below)

NO GO

- Designs should not exceed 50 grams.
- Do not give suggestions or show examples of the drag device.

LOFTID Inflated | **LOFTID Summary** | **LOFTID Animation**

needed materials.

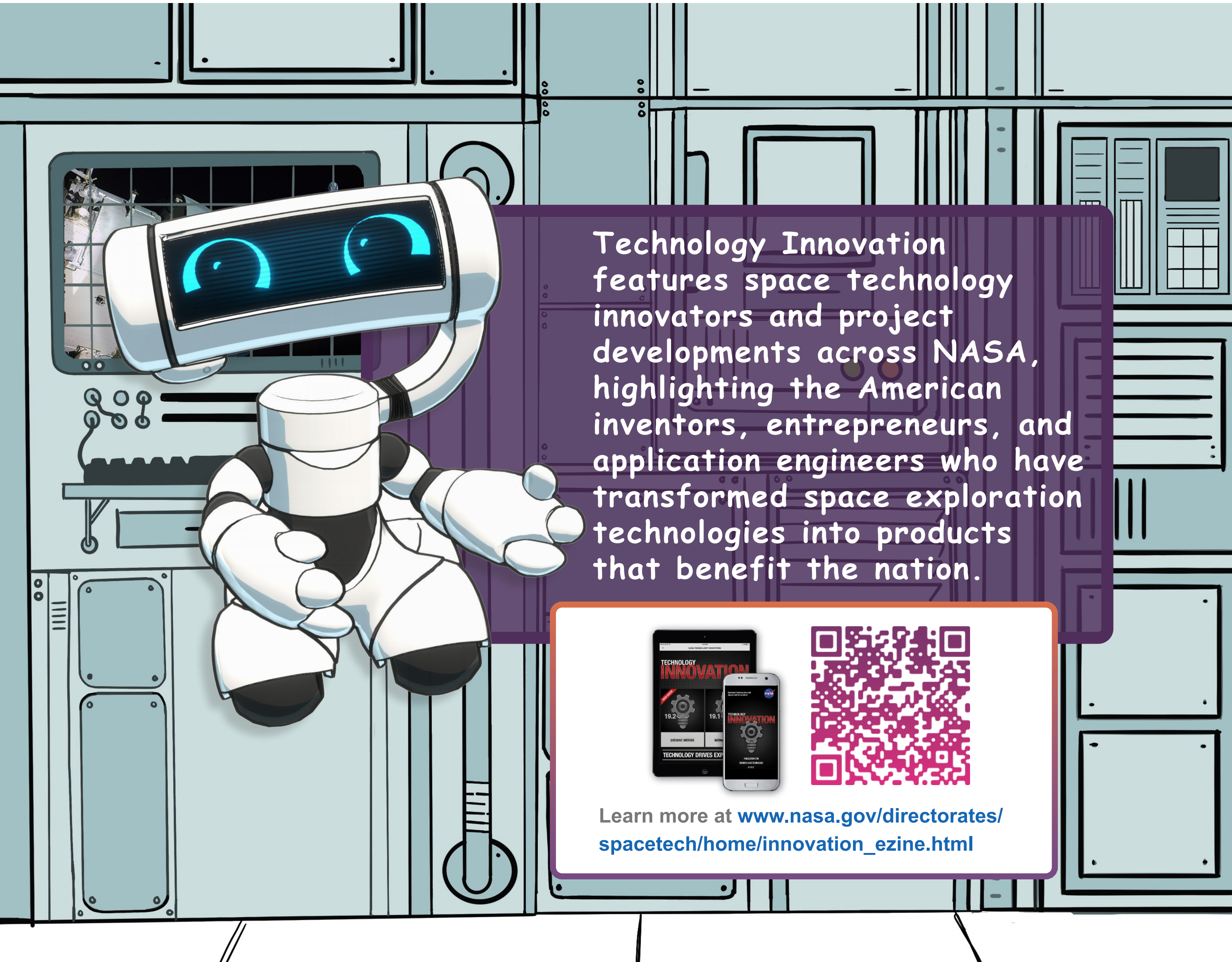
5. Teams will build and test their drag device system by dropping the spacecraft from at least 2 meters high. Compare drop times with and without the drag device.

Extension

- Have participants redesign to improve their drag device performance.
- Repeat the challenge but give a constraint for the drag device. For example, the drag device must have at least five separate angled edges.
- Calculate surface area for each drag device. Surface area can be estimated by tracing the shape of the drag device onto centimeter grid paper and counting squares. Compare drop time results for various surface areas. Plot surface area versus drop time on a graph.

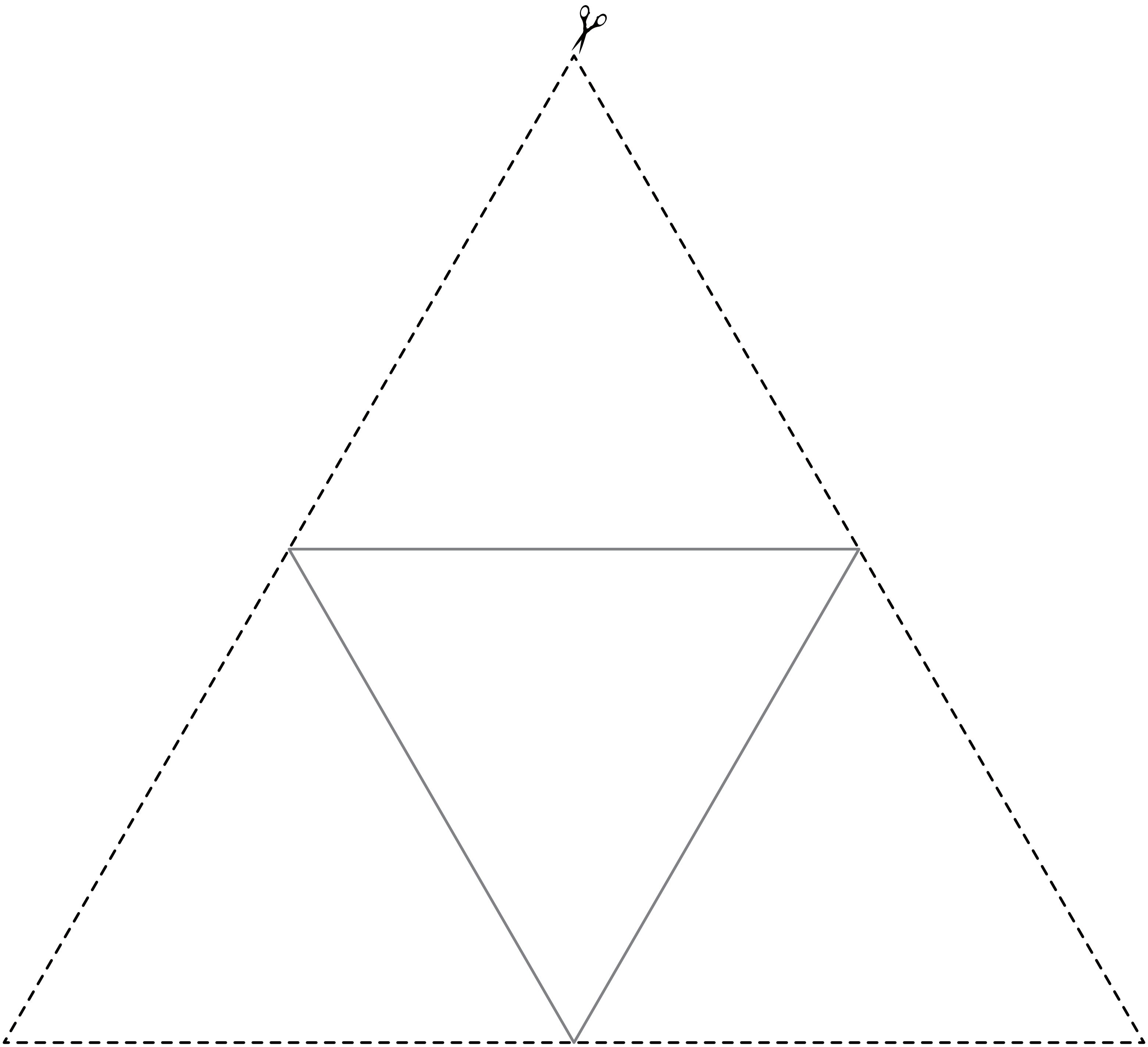
Challenge Questions

- Which drag device design characteristics provided the most reliable results?
- Which design had the slowest descent (longest drop time)?
- What information could engineers working on this project learn from your team's results?



Template

Cut out the larger triangle and fold on inner lines to create a pyramid shape. Put weights inside the pyramid shape and tape up sides.



MISSION BRIEFING

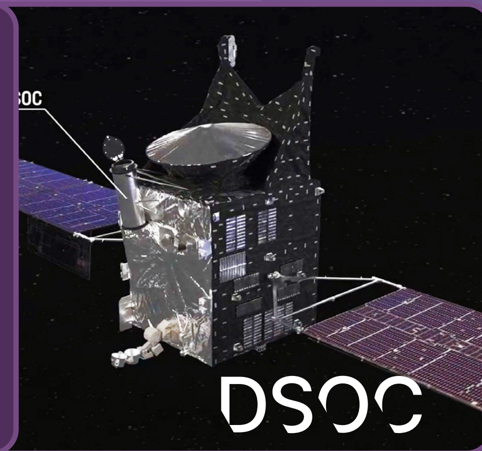
Activity: Deep Space Communications

Prep Time: 20 minutes

Activity Length: 60 minutes

Task: Participants will develop and present a protocol after modeling how data is transmitted across networks.

Scan the QR code for an instructional video of this activity.



By the end of this activity participants will

- Understand how data (referred to as "packets") can become degraded
- Test a protocol to diminish the amount of packet loss

Materials

- Dice or number cubes for each team
- Index cards
- Writing utensils
- "Delayed, Degraded, Delivered" worksheet, one per team

Preparation

1. Gather and prepare all listed supplies.
2. Make copies of the worksheet. Make sure all links are accessible.
3. Share the following videos:

   Laser Communications Relay Demonstration (LCRD) Overview (Length – 1:52)

   Laser Communications Relay Demonstration (LCRD) Ready for Launch (Length – 2:21)

Procedure for Delayed, Degraded, Delivered Game

Participants will play two rounds. Round 1 will demonstrate a signal from Earth to a spacecraft at the Moon (a distance of 382,500 kilometers, or 237,674 miles). Round 2 will demonstrate a signal from Earth to a spacecraft at Mars. The number of participants per team is doubled or tripled in Round 2 to represent the need for more relay stations to transmit a signal from Earth to Mars (a distance of 54.6 million kilometers, or 39,926,867 miles) and additional opportunities for that signal to experience degradation and delay.

1. Divide the whole group into teams.
   - Round 1: Three to five participants per team

Activating Prior Knowledge

Play a game of "Telephone," one person is given a sentence and team members must pass the message along person to person. The final team member says it out loud to the group. Did the message get confused along the way? What can be done to ensure the message is received correctly?

Connection to NASA

NASA's Deep Space Optical Communications (DSOC) experiment is the agency's first beyond low-Earth orbit (LEO) demonstration of optical communications. Much like fiber optics have replaced old telephone wires, going from radio communications to laser (sometimes referred to as "optical") communications will allow for increased data rates throughout the solar system. With increased data rates, more information can be received at once in a single downlink. Visit the **NASA DSOC webpage**.

MISSION GUIDANCE

GO

- Ensure participants have background info on:
  - Deep Space Network
  - LCRD
  - STMD Technology Demonstration Missions

MAYBE

- Demonstrate the aspects of the 3D game so participants can understand the steps.
- Complete the 3D game in a large room or even outside to give participants more space.

NO GO

- Do not allow the DSN to reveal the final location to the other participants.

DSN LCRD STMD

    - Round 2: Six to ten participants per team
2. Give each team a Delayed, Degraded, Delivered worksheet; two dice or number cubes, ; and index cards.
3. The first participant on each team will be the Deep Space Network (DSN) station on Earth sending a message to the spacecraft, which is the last participant on each team. Everyone else acts as relay stations. The relay process demonstrates how a signal is transmitted from Earth to a spacecraft.
    - Round 1: The spacecraft is at the Moon.
    - Round 2: The spacecraft is at Mars.
4. Instruct the DSN station (first participant on the team) to select a physical location within the room and write a series of brief commands on index cards (one 3- to 5-word sentence/command per card) to direct the spacecraft (last participant on the team) to the location.
    - For example: Walk 10 paces. Turn left at third desk. Continue straight for 2 paces. Stop at whiteboard.
5. The DSN station will hand each command card in sequence to the relay team. As each relay participant receives a command card, they will roll the dice; read the corresponding scenario from the Delayed, Degraded, Delivered sheet; make any instructed changes to the command card; and pass the card to the next team member. Each command card will cycle through this process until all relay participants have had a turn with each command card and the command is received by the spacecraft.
6. The last participant (the spacecraft) will collect all the command cards and try to navigate to the location based on the revised command cards.
7. Repeat steps 5 to 7 for Round 2, with larger teams representing the greater distance and number of relay stations.
8. Discuss what types of challenges the spacecraft experienced trying to execute the series of commands.

Procedure for Development of Protocol

1. Have participants develop a protocol to overcome the various scenarios they encountered in the two rounds. The protocol must ensure that both the DSN station and the spacecraft can be confident the full message will be received. Some examples of protocols that participants may implement:
    - Have data sent one packet at a time. Send one word at a time. For example, the message may be “Turn left at desk,” so the words turn, left, at, and desk would be on different index cards.
    - Double the message to ensure the message is delivered. For example, the message may be “Turn left at first desk,” and participants may choose to double each sentence: “Turn left at first desk. Turn left at first desk.”
    - Participants may decide to shorten commands as a protocol. For example, “Place tool on left side of capsule” would become “Place tool on left side.”
2. Have participants test their protocol at least once with a team of no more than five.

Protocol Constraints

- The full message must consist of a series of 3- to 5-word commands. Participants may decide that as part of their protocol they want the data to arrive in packets; if so, they have the option to write each word on a different index card.
- The location cannot be known beforehand. Only the DSN station can know the physical location within the room where the spacecraft is going.

Extension

- Allow teams to test how many relay stations work best with their protocol to deliver the full message.

Build Your Own Spacecraft!

Challenge Questions

- Did your protocol work to ensure the message was delivered and not degraded? Why or why not?
- If you could revise your protocol, what new revisions would you make?
- DSOC will be improving data rates through the solar system with 10 to 100 times the capacity. If you could improve your protocol to get results that are 10 to 100 times better, what would the outcome look like (e.g., getting data all at once, larger images, more clarity)?
- How could these technologies have helped Callie and RT in their challenges?

Delayed, Degraded, Delivered

Directions: After you receive your message from the Deep Space Network (DSN) station, roll your dice or number cubes and find the sum. Use the table below to see if your message is delayed, degraded or delivered.

Number Rolled	Scenario	Action for index card
2	Delivered - Error detection has been completed, so there is no interference with the message.	No change; deliver to next relay station
3	Degraded - Transmission encounters ionized gas, which impairs the link between the spacecraft and the DSN station.	Cross out the second word; deliver to next relay station
4	Delayed - There is no direct line of sight for the spacecraft to use the available antenna at the time of message delivery.	Delay message for 60 seconds; after 60 seconds deliver
5	Delivered - Coding techniques successfully prevent interference with message.	No change in the message; deliver to next relay station
6	Degraded - Signal-to-noise radio (signal power versus background noise) is low, so bit errors are excessive.	Cross out every word; deliver to next relay station
7	Delivered - This relay station utilizes NASA's optical terminal (like the one that will be on Artemis II), which can send in 4K (resolution of approximately 4,000 pixels).	No change; deliver to next relay station
8	Delayed - A solar flare interferes with radio communications and causes a message delay.	Delay message for 30 seconds; after 30 seconds deliver to next relay station
9	Delivered - The single antenna is unable to capture the message so an array is used to combine two or more antennas.	No change; deliver to next relay station
10	Degraded - The signal is degraded by background radio noise emitted naturally by objects in the universe.	Tear out a word in the message; deliver to next relay station
11	Degraded - There is a period of intense space weather (density of particles increased) disrupting radio frequencies.	Cross out a part of the first, third, and fifth words; deliver to next relay station
12	Degraded - The technology cooling the amplifiers is not working properly, which means additional noise is being added to the message.	Add two additional words to the end of the message; deliver to the next relay station

MISSION BRIEFING

Activity: RoboTools

Prep Time: 20 minutes

Activity Length: 45 minutes

Task: Participants will engineer and build a working tool that could be useful to robots like RT working on the Moon. Then create an instruction manual or presentation on how to operate the tool.

Scan the QR code for an instructional video of this activity.

By the end of this activity participants will

Understand the engineering design process and work in teams to make modular tool heads for a robot.

Materials

- Plastic eating utensils (forks, spoons)
- Assorted garden tools
- Small, lightweight paper cups
- Brass fasteners or clamps
- Crafting materials, such as scraps of cardboard, ice pop sticks, felt, aluminum foil, paper/foam plates, straws, polyvinyl chloride (PVC) pipe
- String or twine
- Scissors
- Safety eyewear
- Tape (variety: clear, duct, masking)
- Broom handles, dowel rods, or something similar
- Shoeboxes or other cardboard boxes
- Scratch paper and writing utensils
- Computer, tablet, smartphone, or other device
- Notebooks/Journals
- Poster board for presentations

Preparation

1. Group participants into teams of two to four.
2. Gather and prepare all listed supplies.
3. Create various task boxes where students will demonstrate their robotic tools. Task boxes can be made from shoeboxes or other cardboard boxes, and each task box will have a specific challenge (e.g., a hole to place an object inside, a screw to tighten, an object that needs to be moved from one location to another).

Procedure

1. Ask participants what challenges astronauts might face when they are wearing bulky spacesuits and thick gloves. How can robots aid with these challenges?

Activating Prior Knowledge

What types of tools do you use every day to perform tasks? (e.g., A toothbrush is used to clean your teeth.)

What is one task you do not have a tool for that you wished that you did? Draw a sketch of your tool idea and share with a partner.

Connection to NASA

From extending the lifespan of satellites, to assembling massive life-seeking telescopes in space, to refueling and repairing spacecraft on journeys to distant locations, robots are poised to make what was once thought to be impossible in space a reality. To learn more about in-space servicing, assembly, and manufacturing (ISAM),

visit **NASA's ISAM webpage**.

MISSION GUIDANCE

GO

- Tool must have at least two different interchangeable heads that can be easily changed.

MAYBE

- Create stations for each task box to prevent too many participants at one test site.

NO GO

- Only provided materials may be used.

2. Ask participants what function or purpose robots might serve on or near the Moon. What work will they be performing, or how could they assist with different tasks?
3. Show participants the task boxes and explain the challenge. Teams will be designing a new multi-tool with interchangeable parts to aid robots with various tasks.
4. Tasks might include tightening a screw, moving an object, or collecting at least two differently sized objects. The multi-tool must have at least two different interchangeable heads that can be easily changed.
5. Allow participants to explore the materials they will be able to use to build their new multi-tool. They will work in teams and collaborate, noting suggestions from all members of the team.
6. Teams will sketch their designs, which must be approved by the educator (for safety).
7. Teams will build their approved multi-tool device system using the materials provided.
8. Teams will test their device using the task boxes. Participants will record observations and answer challenge questions.
9. To share their multi-tool with others, teams should develop an instructional manual for the tool using their choice of media (poster, brochure, digital presentation, notebook, etc.).

Extension

- Explore NASA's the **Micro-g NExT** challenge to see how university students compete in this multi-tool challenge. (NExT stands for Neutral Buoyancy Experiment Design Teams.)
- Give participants a size constraint, such as a small box or tube that their tool and all its attachments can fit in to be packed away for launch. Students must design their tools to be assembled, unfolded, or extended for use.
- Have an object of a certain mass (golf ball, small weight, etc.) that their tool must be able to hold without failing.
- Have teams share the tool they invented with other classes or grade levels.

Challenge Questions

- What were some difficulties your team faced during the initial design and build process, and how did you overcome them?
- Were you surprised by the performance of your tool? Explain.
- How were you able to improve your tool during the redesign phase? What design changes did you make, and how did they improve your tool's performance?
- How could your tool help RT in any challenges from the graphic novel?

MISSION BRIEFING

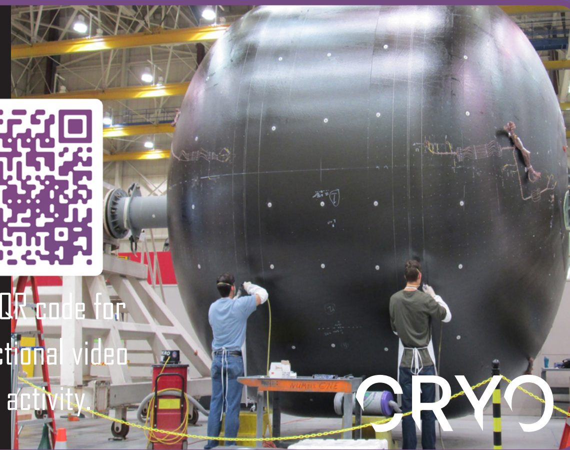
Activity: Filling Up In Space

Prep Time: 20 minutes

Activity Length: 90minutes

Task: Participants will work in teams to design, build, and test a fluid tank (cold-storage device) and a system to transfer fluid to a spacecraft. Note: This activity requires leaving the liquids overnight to record the amount of evaporation, plus a second overnight for the redesign.

Scan the QR code for an instructional video of this activity.



By the end of this activity participants will

- Understand the engineering design process and apply their knowledge of states of matter and energy transfer to build a liquid transfer system.

Materials

- Hand sanitizer or rubbing alcohol, at least 30 mL per group (Safety tip: Use the tinted variety so it cannot be mistaken for water.)
- Variety of recyclable materials for the cold-storage device, transfer system, and spacecraft (food storage tubs, egg cartons, small medicine cups, film canisters, plastic test tubes, bubble wrap, tin foil, clear wrap, insulated cups, foam cups)
- Ice cubes, small flexible cooler packs, cold water, other cooling items
- Clear tape
- Rulers
- Digital scale or balance
- Measurement cup that can hold 30 mL of liquid
- Timing device
- Thermometer
- Cardstock
- Straws and coffee stirrers of various sizes
- Pipe cleaners
- Scissors

Preparation

1. Show cryogenic videos to the students to give them background knowledge.
2. Group participants in teams of three to four.
3. This activity requires leaving the liquids overnight to record the amount of evaporation, plus a second overnight for the redesign. This schedule can be adapted as needed, but be aware that evaporation takes several hours.

Activating Prior Knowledge

Your friend brings lunch to school in a paper bag. What solutions can you come up with to keep it cold until lunchtime? What are some solutions to keep the lunch cold all day?

After participants have shared their solutions, add a weight or size constraint (e.g., must weigh less than 100 grams (0.22 lbs), must fit inside a backpack or lunch box). What solution(s) can they come up with now? Ask participants what they know about cold and room-temperature liquids and evaporation (e.g., warm liquids evaporate faster than cold liquids, liquids exposed to air evaporate faster).

Connection to NASA

NASA is working on keeping cryogenic rocket fuel chilled without adding too much weight to a spacecraft. Propellants are fluids chilled to extremely cold temperatures and condensed to form liquids. Because these fluids must be kept at low temperatures, handling and storing can be difficult. Developing cryogenic fuel management technologies is essential to NASA's future missions in science and exploration for in-space propulsion, landers, and in situ resource utilization. NASA is working on developing new solutions for in-space storage and transfer of cryogenic propellants for higher performance, longer distance, and ability to carry heavier payloads than current propellants.

MISSION GUIDANCE

GO
- All drawings should be approved before building begins.
- Only provided materials may be used.

MAYBE
- Consider cooling your liquid overnight.

NO GO
- Liquid should not leak out of the storage or transfer systems.

- If next-day testing of the transfer system is not possible, participants should at least record the evaporation the next day. They can test the transfer system on a different day.
- Do not leave the liquids in an extremely warm area of the room or there will be no liquid remaining to measure the next day or to perform the transfer demonstration.

Safety

Warn participants that the hand sanitizer and/or rubbing alcohol is poisonous and not for human consumption. Clearly label the liquids and allow access only during testing phases of the challenge.

Procedure

1. Challenge participants to design a cold-storage device and a way to transfer a cold liquid from the storage device to a spacecraft.
    - Only provided materials may be used.
    - Cold-storage devices must allow access to the liquid to measure evaporation and temperature change before and after the storage period.
    - Cold-storage devices must be designed to hold at least 30 mL of liquid.
    - The transfer system must move at least 30 mL of liquid from the storage device to the spacecraft (measuring cup) as quickly as possible.
    - Alterations can only be made during the redesign process.
2. Answer any questions teams have about the challenge and show available materials.
3. Allow participants to explore the materials. They will work in teams and collaborate, noting suggestions from all members of the team.
4. Teams will sketch their designs, which must be approved by the educator (for safety).
5. Teams will build their approved cold-storage system and transfer system using the materials provided.
6. Leave the cold-storage device and liquid overnight, measuring the liquid temperature before and after the storage time-period. Then measure the amount of evaporation that occurred overnight. Teams should record their data on the “Experiment and Record” and “Quality Assurance” sheets.
7. Transfer of the fluid from the cold-storage device to the spacecraft will take place the next day. Teams will demonstrate the transfer of fuel from the cold-storage device to the spacecraft (measuring cup).
8. After teams have tested their fluid transfer system, they should record observations and answer all challenge questions.

Extension

- Include a budget for the design. Make a cost per item used and require participants to stay within a certain budget or bid for contract with the lowest cost solution.
- Allow teams to redesign and improve their devices.
- Interview parents or grandparents about technology in their lifetime. What was the newest technology they remember as they were growing up? (e.g. color television, telephones) What did they think life would be like now?(e.g., flying cars, etc.)

Challenge Questions

- What designs were you able to keep the liquid coldest? Why?
- Which designs were able to prevent the most evaporation? Why?
- Which designs transferred the most fuel to the spacecraft? Why?
- Based on what you learned, how could Callie keep any liquid samples?

Experiment & Record

Design 1

Cold Storage

1. Before storage period record:

Mass of entire storage device without liquid (in grams)	Amount of liquid in cold fuel storage (in mL)	Mass of entire device with liquid (in grams)	Temperature of liquid at start of test (in degrees)

2. Storage time: ____

3. After storage period record:

Temperature (in degrees)	Mass of entire device (in grams)	Difference in mass due to evaporation (in grams)

Transfer System

1. Mass of transfer system____

2. Results of transfer to spacecraft.

Amount of liquid at start of transfer (in mL)	Amount of liquid at end of transfer in spacecraft (in mL)

(The spacecraft can be a measuring device to make it easier to see how much was transferred.)

Experiment & Record

Redesign

Cold Storage

1. Before storage period record:

Mass of entire storage device without liquid (in grams)	Amount of liquid in cold fuel storage (in mL)	Mass of entire device with liquid (in grams)	Temperature of liquid at start of test (in degrees)

2. Storage time: ______________________________

3. After storage period record:

Temperature (in degrees)	Mass of entire device (in grams)	Difference in mass due to evaporation (in grams)

Transfer System

1. Mass of transfer system______________________________

2. Results of transfer to spacecraft.

Amount of liquid at start of transfer (in mL)	Amount of liquid at end of transfer in spacecraft (in mL)

(The spacecraft can be a measuring device to make it easier to see how much was transferred.)

Quality Assurance

CPST

Each team is to review another team's design, then answer the following questions.

Team Name	Yes	No	Notes
Was the team able to store all 30 mL of liquid overnight?			
Was the team able to transfer all 30 mL of liquid?			
Did the team correctly record data?			

List specific strengths of the design.

List the specific weaknesses of the design.

How would you improve the design?

Inspected by: ______________________________

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