CPST

Cryogenic Propellant Storage & Transfer

For the Teacher

Challenge

To design and test a cold fuel transfer system. In this challenge, there are two aspects to design: the fuel tank (cold storage device) and a system to transfer the fuel to a spacecraft.

Materials

Items required for activity:

- Hand sanitizer or rubbing alcohol (tint so it does not look like water). Will need at least 30 mL per group.
- 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, Styrofoam cups).
- Ice cubes, small flexible cooler packs, cold water, etc.
- Clear tape
- Rulers
- Digital scale or balance
- Liquid measure to at least 30 mL
- Timing device
- Thermometer
- Cardstock
- Straws and coffee stirrers of various sizes
- Pipe cleaners
- Scissors

Pre-Activity Set-up

This activity requires leaving the liquids overnight (and a second overnight for the redesign) to record the amount of evaporation. This schedule can be adapted to fit your situation, but be aware that it takes several hours for evaporation. If students do not have time for testing transfer system the next day, at least have them come to record the evaporation and test the transfer system a different day.

Do not leave in an extremely warm area of the classroom or there will be nothing to measure the next day and transfer!

Safety Concerns

Warn students that the hand sanitizer and/or rubbing alcohol are poisonous and not for human consumption. Keep them labeled at all times and allow access only during testing phases of the challenge.

Motivate

- Discuss the Cryogenic Propellant Storage Transfer Program. (See *Background Page*)
- Videos and more information about Cryogenic Propellant Transfer Program available at *http://www.nasa.gov/mission_pages/tdm/cpst/index.html*
- A video about NASA's Cryogenic Lab is available at *http://www.youtube.com/watch?v=2IixxONAeWw*
- Discuss what they know about cold and room temperature liquids and evaporation. (Such as warmer liquids evaporate faster than cold, and liquids exposed to more air evaporate faster.)
- Challenge the students to design a cold storage device and a way to transfer the fuel from the storage device to a spacecraft. The transfer of fuel from cold storage device to spacecraft will take place in the second class session.
- The spacecraft aspect can just be a measuring cup. The main design focus is of the cold fuel storage and the transfer of liquid, not the spacecraft.

For the Teacher

Ask

- Answer any questions they have about today's challenge.

Imagine

- Be sure all students are communicating and collaborating and that suggestions and ideas are documented.

Plan

- All drawings should be approved before building begins.

Create

- Students should build their own cold storage system and transfer system.

Experiment

- Follow the directions and answer questions on the *Experiment and Record* and the *Quality Assurance* sheets.
- Leave cold storage device and liquid overnight, measuring the liquid temperature before and after the storage time period. The next day, measure the amount of evaporation that occurred overnight.
- Demonstrate the transfer of fuel from cold storage to spacecraft.

Improve

- Students improve their designs.

Challenge Closure

Engage the students in a discussion by reviewing all of the data and posing the following questions:

- Which designs were able to keep the liquid coldest? Why?
- Which designs were able to prevent the most evaporation? Why?
- Which deisgns transferred the most fuel to the spacecraft? Why?
- Discuss possible explanations for why the designs with the best results worked better.
- What information could engineers working on this project learn from your team's results?
- What other testing and calculations could you do before making your recommendations to the engineering team?
- What do you think would be the best way to present your results?

Background

Cryogenic propellants are the rocket fuels needed for future, long-term human exploration missions beyond low-Earth orbit. The challenge is to develop a means of storing and transferring these propellants in space. The Cryogenic Propellant Storage & Transfer (CPST) Technology Demonstration Mission demonstrates the capability to safely and efficiently store, transfer, and measure cryogenic propellants on-orbit. Think of this as a gas station in space.

Cryogenic propellant is sent up to space and stored until it is needed by a spacecraft to travel deeper into space. It could be stored for several weeks or even longer. It must be stored at a constant temperature to prevent fuel loss due to “boil off.”

What is “boil off?” Since the Sun and Earth are heating the storage facility, the cold liquid wants to expand. Boil off is the vaporization of a liquid when it is being heated by its natural surroundings. On Earth, at normal room temperatures this would be called evaporation. But in space, where the atmospheric pressure is different and the fuel is stored at such cold temperatures, it turns to a vapor and is vented into space to prevent the storage facility from exploding.

Why are cryogenic propellants a benefit to spaceflight? They dramatically increase the amount of the energy density of the propellant and the efficiency of the engines. As NASA seeks paths for human space exploration of multiple potential destinations such as the Moon, asteroids, the Lagrange points, Mars, and beyond, the need for high-performance and highly efficient technologies is crucial.

Videos and more information about CPST available *http://www.nasa.gov/mission_pages/tdm/cpst/cpst_overview.html*

The Challenge

In this challenge, you will be designing a cold fuel storage tank and a system to transfer the fuel to the spacecraft. After your first attempt, redesign your storage device and transfer system to improve performance. Design constraints:

- Use only the materials provided to you to create the storage devices and transfer system.
- 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.
- Device must transfer 30 mL of liquid from one device to the other as quickly as possible.
- No liquid is allowed to leak out of the storage or transfer systems.

Reminder For All Challenges

- Be sure to document all testing results.
- Make any necessary design changes to improve your results and retest.
- Complete all conclusion questions.

Our Team's Plan

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ASK

Today your mission is to design a cold fuel storage device and a way to transfer the liquid fuel to a spacecraft. What questions do you have about today's challenge?

IMAGINE

What features will you include?

PLAN

Draw and label your storage and transfer device.

Describe how the liquid will transfer from one storage device to the spacecraft.

Be sure to include measurements!

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.)

Experiment & Record

Challenge Closure

1. Which designs were able to keep the liquid coldest? Why?

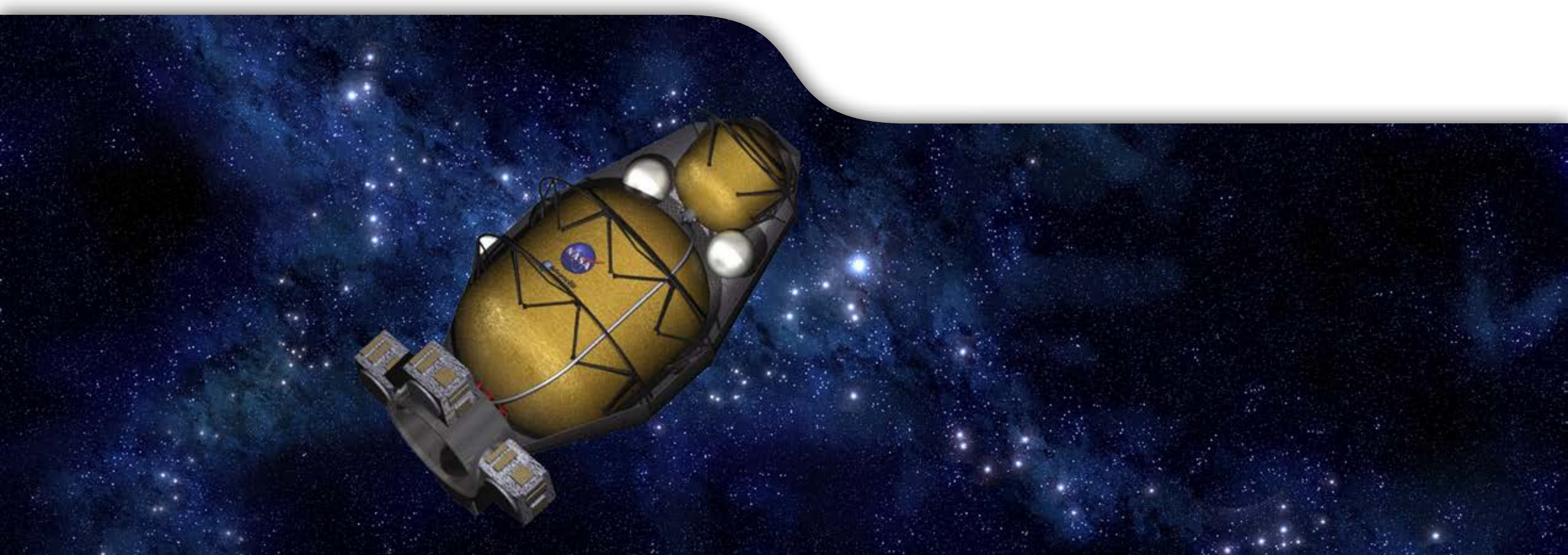
2. Which designs were able to prevent the most evaporation? Why?

3. Which designs transferred the most fuel to the spacecraft? Why?

4. What information could engineers working on this project learn from your team's results?

5. What other testing could you do before making recommendations to the engineering team?

6. What do you think would be the best way to present your results?



Quality Assurance

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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: ______________________________

Signature: ______________________________

More Fun With Engineering

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Activity One:

Cryogenic Fuel Technology has been on scientists' and engineers' minds for many years. As new technologies and more information are learned about cryogenic propellants and space travel, engineers learn more about ways to come up with solutions.

"The science of today is the technology of tomorrow."
—Edward Teller, 20th century American physicist

Interview parents or grandparents about technology in their lifetime.
What were the latest things as they were growing up? (color TV, telephones)

What did they think life would be like now? (Flying cars? Robot maids?)

Did they imagine any of the technologies we have today? (smartphones, computers)

In your imagination, what do you think life (as far as technological advancements) will be like for your children?

Draw or collect pictures of some of the answers from your interviews and your own ideas about what the technological future may hold.