GPIM

Green Propellant Infusion Mission

For the Teacher

Challenge

To design and build a simple spacecraft and environmentally friendly "green" spacecraft propellant. Students will test their propellant by measuring the thrust produced.

Materials

Spacecraft Materials:

- Clear film canisters or small sealable plastic food storage containers (one per team)
- Index cards
- Copy paper
- Poster board

Green Propellant Materials:

- Baking soda or effervescent tablets
- Vinegar
- Water
- Other ingredients can be added if budget allows, e.g., juices, flour, yeast, etc.

Other items required for activity:

- Larger piece of cardboard or wall (see note below)
- Safety goggles (one per student)
- Fishing line/thin string
- Drinking straws
- Scissors/tape/glue
- Rulers/meter sticks or tape measure
- Metric measuring spoons
- Digital scale or balance
- Drop cloth or other means of catching propellant as it leaves the spacecraft.

For the Teacher

Pre-Activity Set-up

Students will complete two challenges as part of this activity. The first will be to design a low-mass spacecraft with provided materials and the other will be to design an effective and environmentally friendly "green" propellant for the spacecraft. Students will test the effectiveness of their propellant by simulating the use of thrusters in space on a string set up across the room.

At least two test areas should be set up in the room or down a hallway. The horizontal string will need to be about 5–10 meters long and about 1 meter up from the ground. A piece of straw will need to be run through the string so it slides easily. A wall or piece of cardboard will need to be at one end of the test area so the film canister lid can bounce into it.

The students will attach their spacecraft to the straw, add propellant materials, then close spacecraft/container. When the spacecraft propellants combust, the lid will pop off and the spacecraft will travel down the string, simulating jettisoning through space. Students will measure the distance the spacecraft traveled to determine the amount of thrust produced. Students will then make observations and test to see what the environmental impact of the dispersed propellant is in the test area.

Students might have trouble quickly putting the lid on the film canister spacecraft; a suggestion is to add the liquid propellant first, then quickly add the solid.

To incorporate more math, students could calculate the amount of force in the testing of the thrusters. See *http://exploration.grc.nasa.gov/education/rocket/thrsteq.html* for more information.

NASA engineers not only look to create the best designs, but also the ones that are most cost-efficient and can be developed in a reasonable timeframe. This challenge has many aspects to it, and students will mostly likely have to work over several class periods or set a rigid timeline to fully design and test and keep up with the budget.

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Motivate

- This activity has two separate challenges: designing a spacecraft and create an effective green propellant
- Teams will divide into smaller groups representing the various partners (NASA, Commercial Partners, and Air Force) to bring a career and real world scenario to this activity.
  Some students will focus on designing the propellant and the others on the spacecraft design. Communication between members is very important in this challenge activity for both budget and design reasons.
- In this challenge, students will keep a running total of all material and testing facility rental costs. Teams should strive to be as efficient as possible with both cost and performance of spacecraft propellant.
- Discuss the Green Propellant Infusion Mission (GPIM). Here is an overview of NASA's project: *http://www.nasa.gov/mission_pages/tdm/green/*

Review with all students some of the criteria for determining environmental impact. Depending on your resources, you may add other options, such as pH or conductivity, but at a minimum collect data on appearance and clarity of the liquid. More information about testing environmental impact can be found at *http://water.epa.gov/learn/resources/measure.cfm*

- For the GPIM mission, the green fuels will be used to boost rockets in low Earth orbit (to learn more about low Earth orbit: *http://earthobservatory.nasa.gov/Features/OrbitsCatalog/*).
  For today's challenge, low Earth orbit will be simulated by setting up a piece of string/fishing line across the room.
- Students will be testing the effects of their green fuel on the environment and testing how well their propellant will be at providing thrust to the spacecraft.
- To learn more about thrust and testing in low Earth orbit, see *http://exploration.grc.nasa.gov/education/rocket/thrsteq.html* and *http://exploration.grc.nasa.gov/education/rocket/rktth1.html*
- Review with students Newton's third law of motion *http://exploration.grc.nasa.gov/education/rocket/newton3r.html*
- Introduce the challenge with students.

The GPIM spacecraft uses a low-toxic fuel that is easily handled by a technician.
Source: Aerojet Rocketdyne

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Green Propellant Infusion Mission

For the Teacher

Ask

- Students will ask any questions they may have about the challenge.

Imagine

- Students will draw out their ideas for the spacecraft and the green propellant formula.
- For safety, remind students they will submit their propellant formulas before any testing. Recommend that formulas should not exceed 5 grams of solid materials for the propellant. Formulas should involve one solid and one liquid material.

Plan

- For the spacecraft design aspect of the challenge, students will design an efficient, low-mass spacecraft system with the provided materials.
- All drawings, formula suggestions, and preliminary project budgets should be approved before construction and testing begins.

Create

- Be sure students are keeping up with material costs as they create and test their designs.
- The mass will play a big role in how far their spacecraft will travel.

Experiment

- Students will follow the directions on the *Experiment and Record* and the *Quality Assurance* sheets to complete experiment testing.
- Be sure students are wearing safety goggles at all times.

A Ball Aerospace technician prepares to fuel up a spacecraft with hydrazine. The special suit and tank of compressed air will protect him in case of a fuel leak. Source: Ball Aerospace

For the Teacher

Improve

- Students should continue to improve their formula and design so the spacecraft will travel the furthest distance and have the least amount of environmental impact. Remind students to include updates to the budget if they had to purchase more materials and re-use the testing area.

Challenge Closure

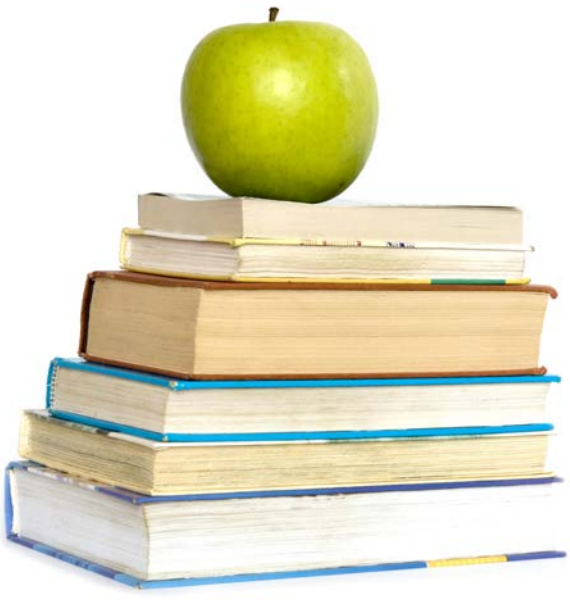
Engage the students in a discussion by reviewing all of the data and posing the following questions:

- Which spacecraft design characteristics provided the most thrust?
- Which green propellant materials provided the best overall results?
- What was the total cost of designing and testing the green propellant?
- What were your conclusions on the environmental impact of this formula?
- What changes, if any, were made to the design of the spacecraft system after testing the propellants?
- What changes were made to the green propellant to make it more environmentally friendly?
- In what ways were you able to maximize resources of time, budget, and performance?
- What other factors, not simulated in today's activity, would NASA engineers have to take into consideration?
- What other testing or calculations could you do before making your recommendations to the NASA engineering team?
- What do you think would be the best way to present your results?

Safety Concerns

In this activity, keep common sense safety in mind. Possible things to be aware of:

- Wear safety goggles at all times during testing. The lids to the containers will pop off with a lot of force!
- Students walking into strings that are spread across the room or hallways.
- Propellant formulas must be reviewed by the teacher prior to testing.



Background

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Green Propellant Infusion Mission

As you probably know, engineers and scientists are developing auto vehicle fuels and aircraft fuels that burn cleaner and more efficiently, producing less air pollution and achieving better gas mileage. Spacecraft engineers and scientists have been working toward similar goals. They want to develop a "green" propulsion system and fuel that produces more thrust with less fuel and that is safer for the environment and for humans.

We know that rockets use fuel to reach space, but how does the spacecraft move once it has ejected from the rocket and is traveling through space? A spacecraft doesn't *just* use fuel to move forward in space. Like a car, a spacecraft moves forward in space because of Newton's first law of motion: "an object stays in motion unless acted on by an outside force." To learn more about how this works see *http://www.nasa.gov/audience/forstudents/5-8/features/what-is-orbit-58.html.*

A spacecraft propulsion system includes the fuel, which is called "propellant." A spacecraft uses thrusters to push the spacecraft forward. The thrusters use propellants and can slow the spacecraft's speed, turn it in a different direction, and eventually bring it down to Earth at the end of its life.

Hydrazine is the most common spacecraft propellant, but it is highly flammable just like gasoline. It's not only dangerous, but it's poisonous for humans to touch or inhale. Technicians who fuel up the spacecraft must wear protective suits in case hydrazine escapes from the storage tank.

For NASA's Green Propellant Infusion Mission (GPIM), engineers at Ball Aerospace & Technologies Corp. are designing, building, and testing a spacecraft that burns a green fuel. This new green fuel will be cleaner for the environment, safer for people to handle, and will more efficiently fuel future spacecraft. The spacecraft demonstrating this new technology and fuel is scheduled to launched in 2015.

You can learn more about this project at *http://www.nasa.gov/mission_pages/tdm/green/gpim_overview.html*

Background

The Challenge

Your mission is to design and build a spacecraft system and a green spacecraft propellant to produce the most thrust with the least amount of environmental impact. The design constraints are:

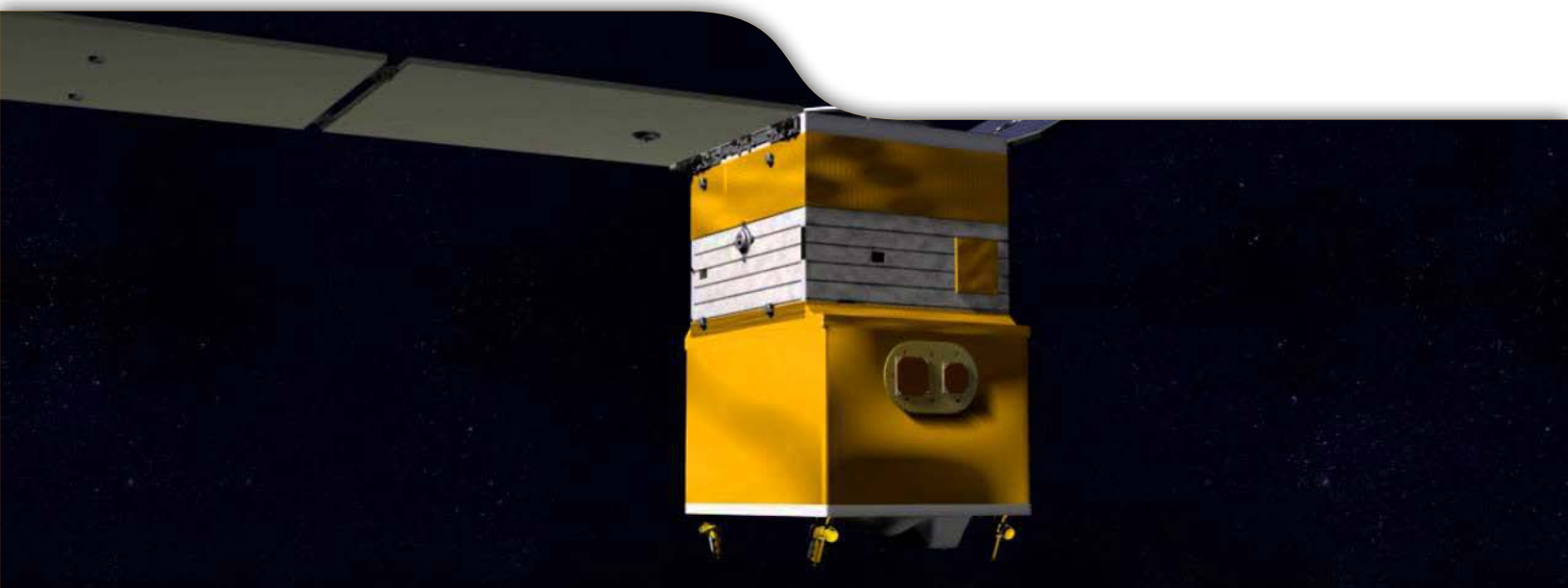
- Use only materials provided.
- Formulas for propellant must be approved before testing.
- Formulas must have only one liquid and one solid substance.
- The solid substance of fuel may not exceed 5 grams in mass.
- Record the amount of liquid substance.
- Record observations of environmental impact.

Assign Roles within your team to include:

- NASA—Responsible for the Spacecraft Design
  —Manager/Engineer
  —Budget/Communications/Engineer
- Industry—Responsible for the Fuel Design
  —Manager/Engineer
  —Budget/Communications/Engineer
- Air Force—Responsible for the environmental impact
  —Manager/Engineer
  —Budget/Communications/Engineer

Reminder For All Challenges

- Wear safety goggles at all times.
- Maintain documentation of all material costs.
- 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 team will design a green propellant and a spacecraft system.
What questions do you have about the challenge?

IMAGINE

What will be some of the formulas for the green propellant?

Liquid Substance (in milliliters)	Solid Substance (in grams)	Notes (Why did you pick this combination?)

PLAN

Draw and label your spacecraft system:

Be sure to include measurements!

What are some of your job responsibilities during this challenge?

Budget

Team Name _____

Rental of Test Area	**5-minute block of time**	**$10,000**
All Materials (including propellants, spacecraft materials, etc.)	**One gram of materials**	**$10,000**

Description of Expense	Amount	Running Total

Use another sheet if necessary

What is your preliminary total budget?

Spacecraft System:

Green Propellant:

What was the final total of expenses?

Spacecraft System:

Green Propellant:

Experiment & Record

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Record the following data while testing propellant combinations:

Formula Tested (milliliters and grams)	**Mass of Spacecraft** (in grams)	**Thrust Measurement** (distance traveled in centimeters)	**Environmental Impact Observation/ Results**

Be sure you to update your budget report with additional material costs.

Summarize the environmental impact:

Safety Concerns

Wear goggles at all times.

Experiment & Record

Challenge Closure

1. Which spacecraft design characteristics provided the most thrust? Why?

2. Which green propellant materials provided the best overall results?

3. What was the total cost of designing and testing the “green propellant”?

4. What were your conclusions on the environmental impact of this formula? How did you make this assessment?

5. What changes, if any, were made to the design of the spacecraft system after testing the propellants? Why?

6. What changes were made to the green propellant to make it more environmentally friendly?

7. In what ways were you able to maximize resources of time, budget, and performance?

8. What other factors, not simulated in today’s activity, would NASA engineers have to take into consideration?

9. What other testing or calculations could you do before making your recommendations to the engineering team?

10. 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
Did the green propellant exceed 5 grams of solid fuel?			
Did the green propellant include one solid and one liquid component?			
Did the spacecraft system produce thrust?			
Did the team correctly record data?			

List the 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

GPIM

Activity One:

We know that protecting the environment here on Earth is very important. As a society, we are always looking for ways to reuse materials on Earth and to design new products that have less of a negative impact on our planet. As we prepare for missions to Mars and deep space, can you think of ways that NASA can help to protect these new frontiers?

Activity Two:

After completing this challenge, take time to explore some other modifications to the spacecraft and/or propellant. Some suggestions might be testing the effects of crushed vs. uncrushed effervescent tablets on reaction rates, multiple thrusters, spacecraft of different shapes/sizes, etc.