National Aeronautics and Space Administration

BEST

BEGINNING ENGINEERING, SCIENCE, AND TECHNOLOGY

An Educator's Guide to the Engineering Design Process
Grades 3-5

www.nasa.gov

PREFACE

The NASA BEST Activities Guide has been developed by at team from the NASA Goddard Space Flight Center's Office of Education in support of the NASA's Exploration Systems Mission Directorate (ESMD). ESMD develops capabilities and supporting research and technology that will make human and robotic exploration possible. It also makes sure that our astronaut explorers are safe, healthy, and can perform their work during long-duration space exploration. ESMD does this by developing robotic precursor missions, human transportation elements, and life-support systems. Ultimately, this Directorate of NASA serves as a stepping stone for the future exploration of Mars and other destinations

The NASA BEST Activities Guides were designed to teach students the **Engineering Design Process**. This project created three guides to accommodate three grade groups: K-2, 3-5 and 6-8. All follow the same set of activities and teach students about humans' endeavor to return to the Moon. Specifically, how we investigate the Moon remotely (Part 1), the modes of transportation to and on the Moon (Part 2), and humans living and working on the Moon (Part 3).

The Engineering Design Process is a series of steps that engineers use to guide them through the process of solving problems. Engineers must ask a question, imagine a solution, plan a design, create that model, experiment and test that model, then take time to improve the original – all steps that are crucial to mission success at NASA. What makes this guide different from others is: (1) there are no specific instructions or a "recipe" for building the items; and (2) there are no given drawings. The emphasis is for students to understand that engineers must "imagine and plan" before they begin to build and experiment. To successfully complete the NASA BEST Activities, students must **draw their ideas first** before constructing.

Many of the activities have been adapted from others, and then aligning them with the theme of efforts to return to the Moon and to focus on the Engineering Design Process. Each activity features objectives, a list of materials, educator information, procedures, and student worksheets. When appropriate, the guide provides images, charts, and graphics for the activities. All activities are intended for **students to work in teams**. It is recommended that each team consist of 3 or 4 students. The activities can be used as in-school curriculum or after-school clubs; as a set or individually. This guide of activities was also designed to keep material costs to a reasonable limit, using materials often already found in the classroom or from home. Furthermore, all activities correlate to national science, mathematics, technology, and engineering standard(s). A list of national standards is included at the end of this guide.

We appreciate your interest in this product and remember, *let the students have fun!*

- Susan Hoban, Project Manager

ACKNOWLEDGEMENTS

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MATERIALS

Below is a suggested list of materials needed to complete all activities in this guide for a group of 24-32 students (~8 teams). However, for your convenience, a NASA BEST Kit is available for purchase from Science Kit/Boreal Laboratories (http://www.sciencekit.com/NASABEST/), which supports ~30 students.

STANDARD MEASURING TOOLS

Digital scale (1)
Graduated cylinder (1)
Meter sticks (1 per team)
Measuring tape (1)
Rulers (1 per team)
Stopwatches (1 per team)
Thermometers (2 per team)

BUILDING SUPPLIES

aluminum foil
balloons, assorted
bamboo skewers
binder clips, assorted
blindfolds (1 per team)
bubble wrap
buttons, assorted (~10 per team)
cardboard
card stock
cardboard boxes (1 per team)
c-clamps (at least two)
cheesecloth
clothespins (with springs)
cloth swatch, i.e. quilting square
coffee filters
colored pencils
cotton balls
crayons (for K-2 module)
empty paper towel tubes (1 per team)
empty toilet paper tubes (2 per team)
fishing line, ~20lb. test, 5 m
glow sticks (for K-2 module)
gluesticks
index cards
mailing tube, 4” diameter / oatmeal container
mini foil pie plates (1 per team)
modeling clay
paper bags
paper clips, assorted
pipe cleaners
plastic cups
plastic eggs (1 per team)
plastic wrap
popsicle sticks and tongue depressors
rubber bands, assorted
staplers and staples
stirrer sticks
straws
string
tape: masking, electrical, transparent and duct tapes
toy pinwheel
wheels: i.e. model car wheels (plastic or wood), empty thread spools, rotini pasta (4 per team)

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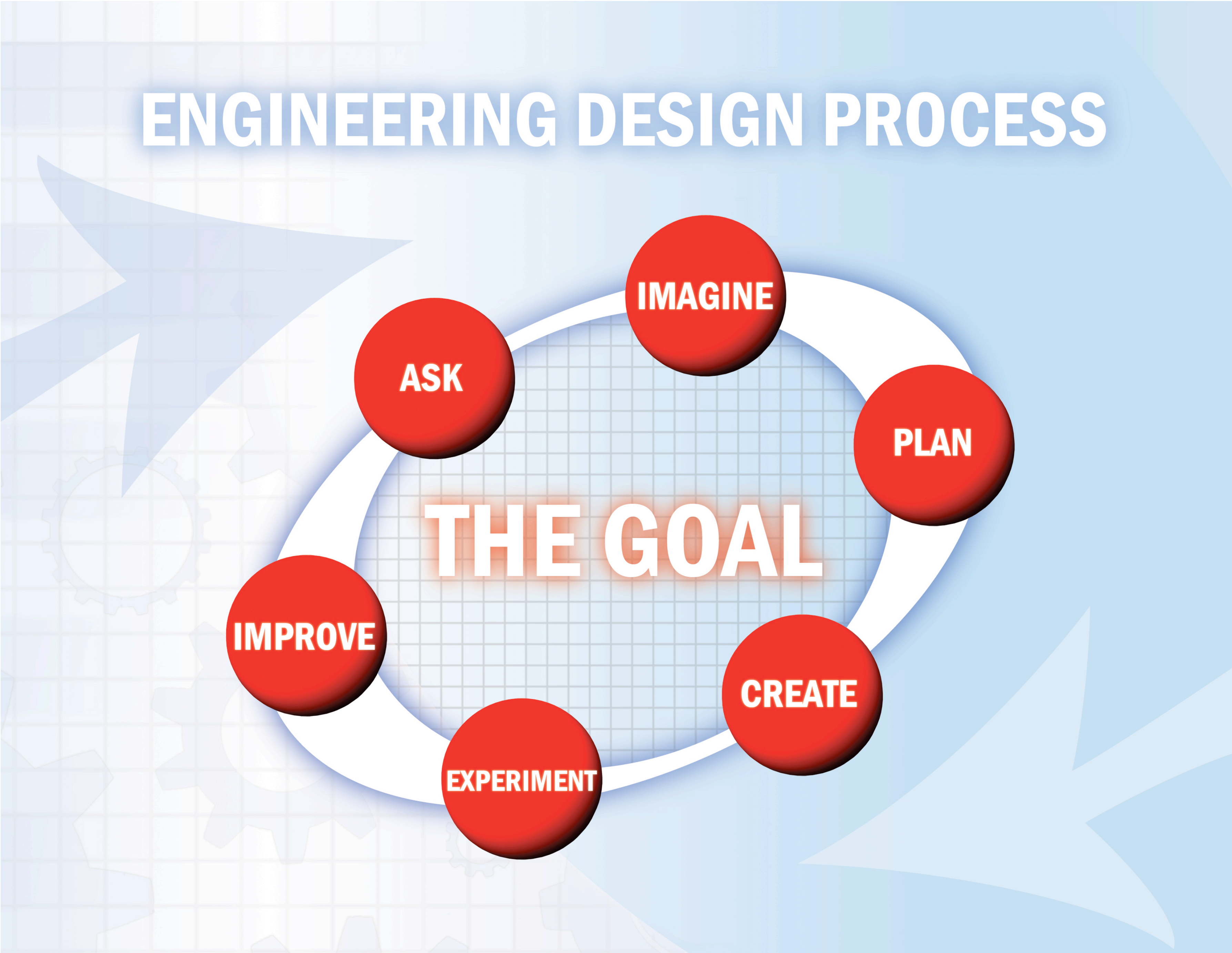

ENGINEERING DESIGN PROCESS
ASK
IMAGINE
PLAN
CREATE
EXPERIMENT
IMPROVE
THE GOAL

BUILD A SATELLITE TO ORBIT THE MOON

OBJECTIVE

To demonstrate an understanding of the Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The team challenge is to design and build a satellite that falls within certain size and weight constraints. This satellite will be designed to orbit the Moon. It will have to carry some combination of cameras, gravity probes, and heat sensors to look at or probe the Moon's surface. The satellite should withstand a 1-meter Drop Test without any parts falling off of it.

PROCESS SKILLS

Measuring, calculating, designing, evaluating

MATERIALS

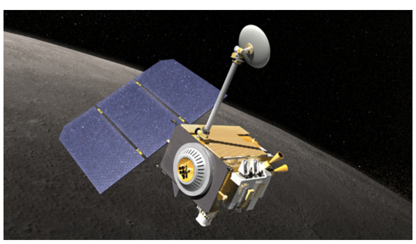
General building supplies

Bag of buttons of a variety of sizes

WORKSHEETS

Imagine and Plan (2 pages)

Experiment and Record



MOTIVATE

- Spend a few minutes asking students if they know what engineers do.
- Discuss the *Engineering Design Process*:
  - **Ask** a question first.
  - **Imagine** a possible solution.
  - **Plan out** a design and draw your ideas.
  - **Create** and construct a working model.
  - **Experiment** and test that model.
  - **Improve** and try to revise that model.

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* orally with the students (see next page).
- Have students brainstorm ideas, solve the given problems and then create a drawing of their satellite (Imagine and Plan worksheet).

CREATE AND EXPERIMENT

- Give out materials for students to build their satellites based on their designs and specifications.
- Each team should take turns dropping the satellite designs from the challenge height of one (1) meter.
- Designs should withstand the drop without any of the instruments falling off or the construction to becoming severely damaged. (Note: If damage does occur, teams will need to recreate their satellites before the next challenge.)
- Teams should make observations of the drop and record them in the data tables of their worksheet.

IMPROVE

- If there is time, have students inspect their satellite and rework their design if needed.

CHALLENGE CLOSURE

- Ask all groups to come back to their seats to have a discussion about today's activity:
  - *Name two things you learned about what engineers do through building your satellite today.*
  - *What was the hardest thing for your team to complete while building your satellite?*
  - *How did your team solve this problem?*

PREVIEWING NEXT SESSION

Ask teams to bring back their satellite model for use at the next session. You may want to store them in the classroom or have one of the club facilitators be responsible for their safe return.

DESIGN CHALLENGE

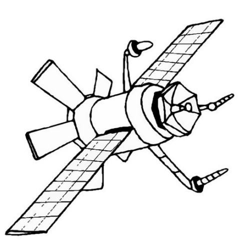
NASA's Lunar Exploration Missions

NASA's lunar exploration missions will collect scientific data to help scientists and engineers better understand the Moon's features and environment. These missions will ultimately help NASA determine the best locations for future human exploration and lunar bases.

The information gathered by lunar exploration missions will add to information collected during earlier missions. Some of these missions gathered data that caused scientists to have more questions — questions they hope to solve with new instruments. For example: scientists and engineers need to know if there is any ice on the Moon. Humans need lots of water to live, and it is way too heavy to carry with us up to the Moon! One lunar exploration mission will carry instruments (sometimes called "detectors" or "sensors") to look for ice (water in solid form). Additionally, NASA needs to make exact maps of the Moon's surface so that a safe landing site may be chosen. And, for safety, we need to make careful measurements of the radiation falling on the lunar surface.

The different instruments are designed, tested, and assembled by different teams of engineers and scientists. The separate teams must work together to make sure that the instruments are the right weight, fit correctly, and make proper measurements. Working together is an important skill for students to practice.

Overall, the weight (strictly speaking, the mass) of anything we want to send into space is the most challenging problem for the engineers. The more an object weighs, the more energy it takes to launch it.



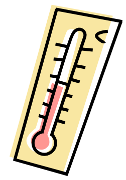
The Challenge: *Your team must build a model of a satellite that will study the Moon. The satellite should be built with the general supplies available, using the buttons as the various instruments. The total mass of the instruments, detectors, probes, sensors and solar cells (that provide electricity) can be no greater than* ***10 grams****. The satellite cannot be launched if the instruments, detectors, probes and solar cells weigh more than a total of 10 grams, so choose your instruments carefully. The final test is that the satellite must withstand a 1-meter Drop Test without any pieces falling off the team's design.*

IMAGINE AND PLAN

The objective of this activity is to design your own satellite. These are the instruments you may choose to use put on your satellite:

Camera
(Total Mass= 2.5 g)

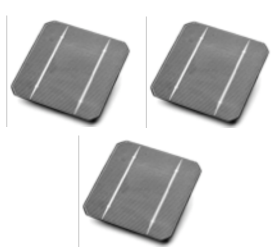
Gravity Probe
(Total Mass= 2 g)



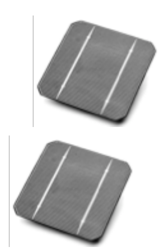
Heat Sensor
(Total Mass= 1 g)

Each of these instruments requires a certain number of solar cells to operate on your satellite. A solar cell  is a battery that collects energy from the sun to power the instruments.

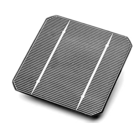
needs



needs



needs



IMAGINE AND PLAN (continued)

Using the diagram on the previous page, if you were to build a satellite with two (2) cameras and one (1) heat sensor, how many solar cells would you need? Write the number sentence below for this problem:

____

Using the diagram on the previous page, if you were to build a satellite with two (2) cameras and one (1) heat sensor, would the total mass be greater or less than the mass limit for the challenge? Write a number sentence that illustrates this number statement:

____

Now draw your own satellite. Include the correct number of solar cells it will need. Also, label your chosen instruments with their name and mass.

EXPERIMENT AND RECORD

Part One

Experiment Hypothesis – Complete the following statement:

When our team's satellite is dropped from a height of one (1) meter,

____

____

____

Part Two

Experiment Observations – Describe what happened during your satellite's drop from a height one (1) meter.

____

____

____

Did any instruments fall off the satellite?	Yes	No
Was the satellite damaged during the fall?	Yes	No

If you answered yes to either question above, explain how your team could improve the design to make sure these errors would not happen again.

____

____

____

____

LAUNCH YOUR SATELLITE

OBJECTIVE

To demonstrate understandings of the Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The team challenge is to launch the satellite that was built in the last activity by using a balloon rocket. The goal is to get the satellite to travel as far as possible.

PROCESS SKILLS

Observing, communicating, measuring, collecting data, inferring, predicting, and making models.

MATERIALS

Satellite model from last activity

General building supplies

Binder clips or clothes pins

Round balloons (several per group)

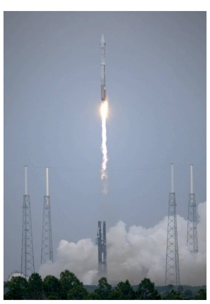
5-meter fishing line set-up strung between two tables

WORKSHEETS

Imagine and Plan

Experiment and Record

PRE-ACTIVITY SET-UP



The fishing line apparatus should be at least 5 meters in length. Clamp or tie one end at table or chair height and stretch the line across the space to another table/chair at the same level. Holding the free end of the line taut for each trial enables easy restringing of the successive balloon rockets. The line must be very taut for best results. Shoot the rockets toward the tied end. Two fishing line set-ups should be sufficient for most clubs. *Note: If the opening in the balloons tends to stick, try putting a little hand lotion inside the opening.*

MOTIVATE

- Ask the groups to retrieve their satellite that was created during the last session.
- Show the video of a recent rocket launch titled, "Liftoff…To the Moon!"
  http://lunar.gsfc.nasa.gov/launch.html

SET THE STAGE: ASK, IMAGINE, PLAN

- Ask the students, *How can we best launch our satellite to go to the Moon?* We need it to go far to get into orbit around the Moon. The objective is to *design* a balloon rocket that will take their satellite as far as possible on the fishing line.
- Demonstrate how a balloon rocket works by sending a balloon connected to a straw up the fishing line. Do not model how best to attach the satellite or how best to power the rocket, other than releasing the air by using your fingers.
- Ask students to imagine a solution for a balloon rocket design and then draw their ideas.

CREATE

- Challenge the teams to build their rockets based on their plans and remind them to keep within specifications.

EXPERIMENT

- Send each team to their assigned launch sites to test their rockets, filling in the data tables as they conduct each trial launch.

IMPROVE

- After their first trials, allow teams to make adjustments to their rockets.
- Teams re-launch satellites and record launch distance.
- Teams should then discuss how far their rocket traveled and which combination of variables gave the best results.

CHALLENGE CLOSURE

- Engage the students in the following questions:
  - *Which straw length did you choose and why did you choose it?*
  - *What was the hardest part of the activity today?*
  - *If you had more time, what other rocket element would you change (ex: balloon shape or size)?*

PREVIEWING NEXT SESSION

Ask teams to think about how humans navigate robotic rovers on a distant planet or moon. How are they programmed? How do the rovers receive messages from a team on Earth?

IMAGINE AND PLAN

Last session, you designed and built your NASA satellite to go to the Moon. This session, you will **plan** and **create** a balloon rocket, and attach your satellite to the balloon. You will then launch your satellite using the balloon rocket.

Sketch your balloon rocket design that includes the satellite design:

EXPERIMENT AND RECORD

Your challenge is to launch your balloon rocket the farthest distance. First, you will test different straw lengths when using only ONE balloon, which will slide along a fishing line.

The rocket elements that you can control are:

1. **Length of the balloon**

   Always blow up the balloon to the same size (how long or how many breaths will you use to inflate?)

2. **Length of the straw**

   This is the "dependent variable." You will find out which length of straw allows your balloon rocket to go the farthest.

	Trial 1	Trial 2	Trial 3
Straw Length	Short ______ cm	Medium ______ cm	Long ______ cm
Length of Balloon	______ cm	______ cm	______ cm
Distance Traveled	______ cm	______ cm	______ cm

Now let's try to improve our rocket even more! What other variables could you test?

____

____

EXPERIMENT AND RECORD (continued)

Now that you have experimented with all of the different lengths of straw, change the dependent variable from the **straw length** to the **number of balloons** that you will use.

	Trial 1	Trial 2	Trial 3
Number of Balloons			
Straw Length	______ cm	______ cm	______ cm
Distance Traveled	______ cm	______ cm	______ cm

Draw a picture of the final balloon rocket that your team will use based on the data collected from the trials. Label the straw length and the number of balloons used.

PREPARE FOR A MISSION

OBJECTIVE

Students will demonstrate an understanding of the Engineering Design Process by completing an assigned mission.

CHALLENGE

Teams will execute a mini-simulation of a robotic mission. The ultimate goal is to get the human-robot from one end of the course to the other, and the robot should pick something up, i.e "lunar rock", at the end of the course.

PROCESS SKILLS

Mapping, communication, measuring, graphing, logical thinking

MATERIALS

Meter stick

Colored pencils or crayons

WORKSHEETS

Imagine and Plan (2 pages)

Create

Experiment and Record

PRE ACTIVITY SET-UP

Set up a small obstacle course with a few chairs, waste paper baskets, and/or a table as designed on the Student Imagine and Plan Worksheet.

Please note: This activity may require two 60-90 minute sessions to complete.

MOTIVATE

- Explain to the students that many of NASA's missions are conducted by robots. While some robots can make decisions based on data received from sensors, humans must program the robots - we tell robots what to do and how to execute their missions.

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- First, have students draw their chosen course on the map. Students must include at least one right turn and one left turn.
- Let students practice commands to use with their robot. These commands should be directional words, plus a number for steps to be taken.

CREATE

- Programming – Students will define the robot's route through the lunar landing site and calculate the number of steps needed for each command. They will then create a command sequence to use for their robot that matches the route they have planned on their maps.
- Teams will calculate based on measurements of the course and calculations made through calibration techniques.
- Students will need to measure the distances included in their chosen routes and compare these measurements with the distance each step equals for their robot. They will then calculate the number of steps for the robot to take as it navigates the course.

EXPERIMENT

- Student teams now must navigate the lunar landing site, using the command sequence each team designed. Have students designate one student per team to deliver each command. Designate another team member to run a stopwatch. Position the robots at the start and have the teams sitting or standing aside from the obstacle course. The student designated to deliver commands are to deliver one command at a time and instruct the robot to perform the command. Have each team record how much time it takes to successfully complete the experiment when the robot picks up the "lunar ice".

CHALLENGE CLOSURE

Engage students in the following questions:

- *Did each team pick the same route or were there several routes to get to the lunar ice? Which route worked the best?*

PREVIEWING NEXT SESSION

Ask teams to think about how a spacecraft might land on the Moon safely. Ask them to think about why it does not make sense to use a parachute on the Moon because there is no air on the Moon to fill up the parachute.

DESIGN CHALLENGE

The Discovery Mission

Every NASA mission has several parts leading to its success. When leading a remote mission on another planet or moon, NASA scientists and engineers must plan every step of the mission carefully. When using robots or rovers, each mission team calibrates and programs these machines to accomplish the mission objective, such as to travel to certain locations on that planet or moon. In addition, NASA must use radio signals to send their commands. So a mission on a distant planet could take minutes to hours to days to communicate to that robot.

The Challenge: Your team has been chosen to operate a robotic Discovery Mission on the surface of the Moon. You will be given a specific starting location, and your robot must move through a lunar landscape to the location of the "lunar ice" without bumping into any "lunar boulders" or other obstacles. To successfully complete the Discovery Mission, your robot must pick up a piece of "lunar ice."

Before your robot begins to move on the lunar surface, you will have to complete the following activities:

1. ***Designate your robot*** - *One student in each team must volunteer to be the robot. The robot will be the person who actually walks through the course, following the instructions of her/his team. The team should give their robot a name.*
2. ***Map the robot's route*** – *Using the map in your worksheets, mark out a route for the robot.*
3. ***Learn to communicate with your robot*** – *Each team must develop commands for your robot. You will practice these commands until you and the robot are comfortable with them. These will be the commands that you will give the robot to travel through the path you have drawn on the map.*
4. ***Program the robot*** – *you will use the commands that you practiced to tell the robot how to navigate the path you have drawn on the map. First you will make measurements of the distances in the course and the distance in one robot step. You will use these calculations to determine how many steps the robot needs to take in each direction.*

Your mission will be complete when your robot picks up a piece of "lunar ice.

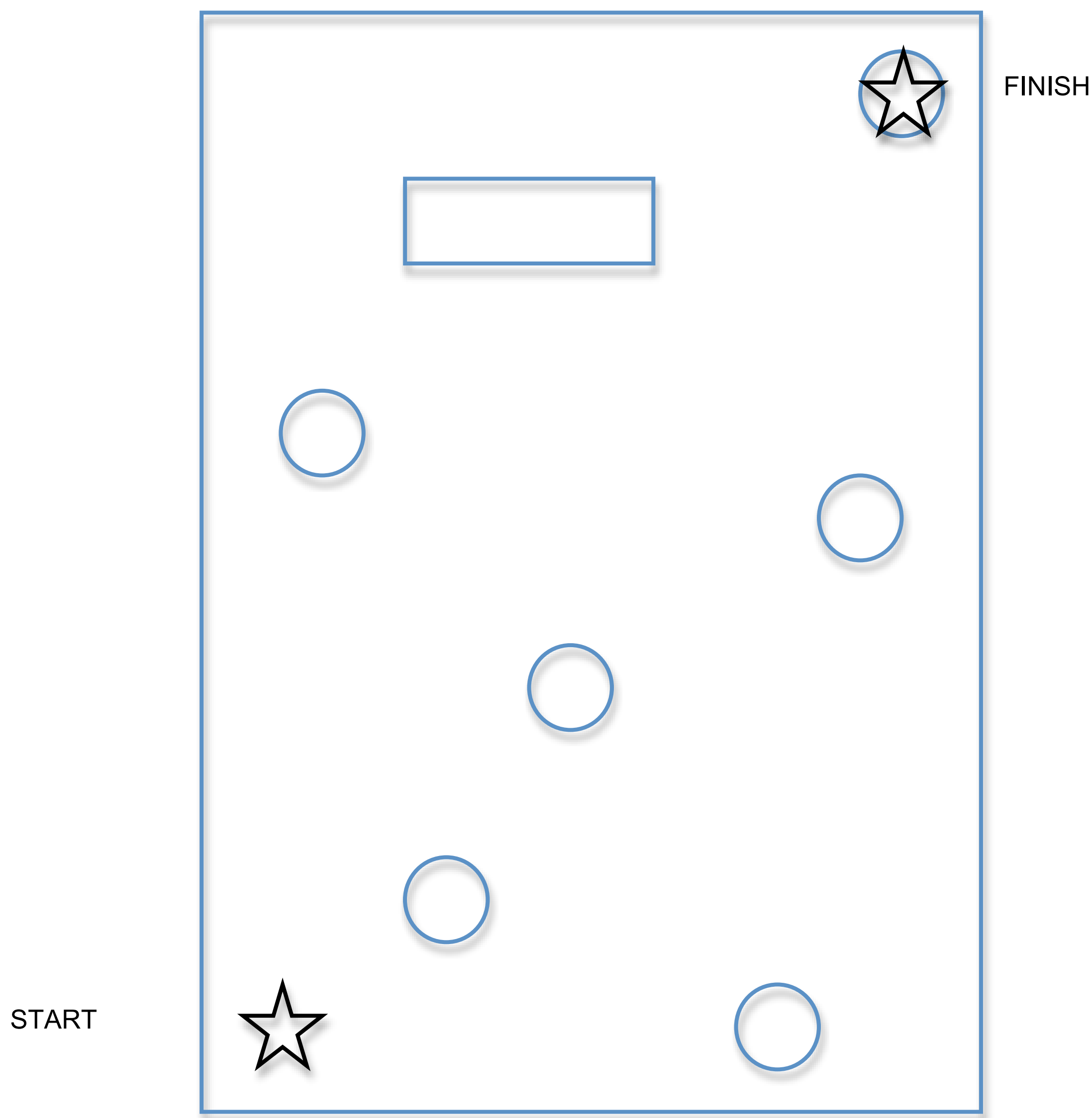
IMAGINE AND PLAN

STEP 1 – Designate your robot.

One person from your team must volunteer to be the robot.

STEP 2 - Mapping

Below is a map for the Discovery Mission. Using a pencil, draw small arrows on your map and create a route your robot will take to get to the landing site. You must include at least one right turn and one left turn.



STEP 3 – Communicate with your robot

When you program a robot, you must use simple words and be specific in your directions. If you want your robot to go forward, how many steps should the robot go?

1. Measure your robot's step length in centimeters with a meter stick.

   Our robot's step length is ________________ centimeters.

2. For example, if your first robotic movement is 420 centimeters and your robot's step length is 30 centimeters you can solve for the number of steps using this formula:

   Distance of movement divided by Step length = Number of Robot Steps

   420 cm / 30 cm = 14 steps

Robot Calibration			
Path Taken by Robot	Distance (cm)	Do the Math (Distance / Robot step length)	Number of Robot Steps
Movement #1			
Movement #2			
Movement #3			
Movement #4			
Movement #5			
Movement #6			
Movement #7			
Movement #8			

CREATE

STEP 4 – Program your robot

Review the map with your robot's route and the chart with the number of steps for each movement. Now your team needs to create commands for your robot to match your route. Write down one command that matches each arrow on your map.

Command Sequence

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

EXPERIMENT AND RECORD

Execute the Discovery Mission!

It is time to let your Robot explore the Moon! You planned your route and practiced your commands, now let's complete the mission. One team member will be responsible for delivering the commands. Another team member must use a stopwatch to time how long it takes for the Robot to make each movement to reach the Lunar ice sample. Record each time in the table below to compare how long the mission took for each team!

Discovery Mission Data Table

Command and Movement	Time (seconds)
Movement #1	
Movement #2	
Movement #3	
Movement #4	
Movement #5	
Movement #6	
Movement #7	
Movement #8	

DESIGN A LUNAR ROVER

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The teams' challenge is to design and build a model of a Lunar Rover that will carry equipment and people on the surface of the Moon. It must be able to roll down a ramp. Later, they will design and build a landing pod for this rover and simulate a lunar landing. The goal is that the rover survives the landing so that it can roll down a ramp.

PROCESS SKILLS

Measuring, calculating, designing, evaluating

MATERIALS

General building supplies and tools

small plastic people (2 per rover)

plastic eggs

pennies to represent cargo weight

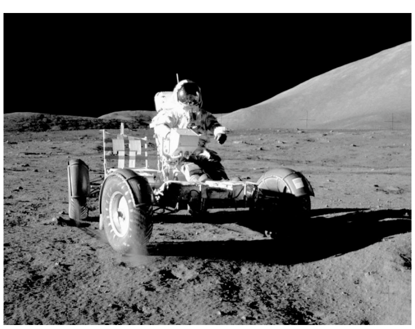
"wheels" (spools, model wheels, etc)

Something to use as a ramp (a flat surface that would enable the rover to roll for 25 cm or more)

STUDENT WORKSHEETS

Imagine and Plan

Experiment and Record



MOTIVATE

- Show the video about the Apollo 15 Lunar Rover on the Moon:

  starchild.gsfc.nasa.gov/Videos/StarChild/space/rover2.avi

- Ask students to pay attention to the comments made about the difficulties in driving in the lunar soil.

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students
- Remind students to imagine a solution and draw their ideas first.

CREATE

- Challenge the teams to build their Lunar Rovers based on their designs. Remind them to keep within specifications.
- While each group is working, the teacher should create a ramp in which all groups will use to roll their rovers and record observations.

EXPERIMENT

- Students will let their rover roll down the ramp and record their observations.
- Students will test how much cargo weight their rovers can support by adding pennies to the plastic egg. Each penny represents 1 gram of cargo weight.

IMPROVE

- Students should *improve* their Lunar Rovers models based on results of the *experiment* phase.

CHALLENGE CLOSURE

The summary of this activity will come at the very end (two sessions from now), after the simulated lunar landing.

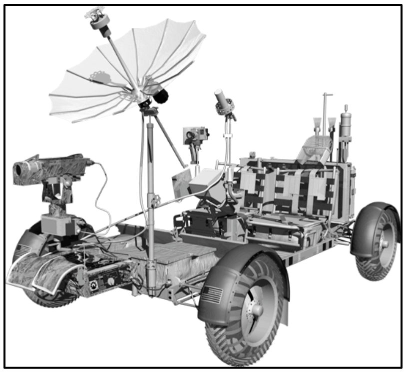
PREVIEWING NEXT SESSION

Ask teams to bring back their Lunar Rover model for use in next session's challenge. You may want to store them in the classroom or have the facilitator be responsible for their safe return next week.

Ask teams to think about potential landing pods during the next session. Tell students they will be building the landing pod out of the materials that have been available to them. The pod will be dropped from as high as possible (out a second story window, off a tall ladder, or the top of a staircase).

DESIGN CHALLENGE

Let's Go For A Ride!



During the first set of activities, we have spent some time thinking about how to get to the Moon. Now we need to think about landing on the Moon, and what we are going to do once we get there. Astronauts will need a mode of transportation to get around to investigate different areas of the Moon. During the Apollo missions, astronauts drove a Lunar Rover several kilometers away from their spacecraft. Today you get to be the engineers designing a new Lunar Rover that can perform functions the Apollo Lunar Rover could not. Thus, your challenge is to build a model of a Lunar Rover that will eventually carry *people and cargo* on the Moon.

The Challenge: Each team must design and build a Lunar Rover with the following constraints:

1. *It needs to carry one plastic egg snugly. The egg may NOT be taped or glued into place. The egg will represent the materials carried in and around the Moon.*
2. *It needs to carry 5 grams of cargo weight (the pennies) inside the plastic egg (1 penny = 1 gram of cargo weight).*
3. *It must have room for two plastic people. The people do not land with the rover. They will get in the rover on the Moon and drive it around.*
4. *It must roll down a ramp unassisted for 50 cm or more.*
5. *It must survive the "landing". This means it should be able to roll down the ramp after the landing, and the plastic egg should not have popped open.*

IMAGINE AND PLAN

What parts do you need to make your rover roll?

____

____

____

What will hold the egg in place?

____

____

____

Draw your Lunar Rover:

EXPERIMENT AND RECORD

Test your rover on three different styles of a landing ramp, adjusting the length and height of the ramp (from the floor) each time. Measure the distance it travels down the ramp with the 5 grams of cargo weight.

Trial	Ramp Length (cm)	Ramp Height (cm)	Distance Travelled (cm)
1			
2			
3			

Sketch the ramp design that worked best for your rover, making sure to label the height and length of the ramp in cm:

DESIGN A LANDING POD

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The team challenge is to design and build a Landing Pod for the model Lunar Rover that was built in the previous session.

PROCESS SKILLS

Measuring, calculating, designing, evaluating.

MATERIALS

General building supplies and tools

Bubble wrap

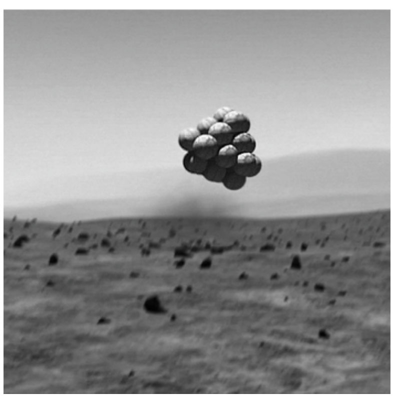
Balloons

Scale

STUDENT WORKSHEETS

Imagine and Plan

Experiment and Record



MOTIVATE

- Show the video titled "Six Minutes of Terror."

  marsrovers.nasa.gov/gallery/video/challenges.html

- Ask students to pay attention to the ways NASA slowed the rovers down as they entered the atmosphere. Notice how some techniques will or will not work on the Moon. Explain that with no atmosphere on the Moon, a parachute will not work!

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- Remind students to imagine a solution and draw their ideas.

CREATE

- Challenge the teams to build their Landing Pod based on their designs. Remind them to keep within specifications.
- Make sure to remove cargo from previous lesson and then test the mass of each design.

EXPERIMENT

- The students should test to make sure that the rover, carrying the empty plastic egg, fits inside the Landing Pod. They should also be sure that they are able to open the Landing Pod after it comes to rest. Each group will complete two trial drops and within this phase they will have the opportunity to make one improvement to their Landing Pod before experimenting with a second trial drop.

CHALLENGE CLOSURE

Engage the students in the following questions:

- *What is the hardest part of this activity and how did your team overcome the challenge?*
- *How many pieces of bubble wrap in total did your team use?*
- *Do you need to improve your design again? How will it change?*

PREVIEWING NEXT SESSION

Ask teams to bring back their Lunar Rover model and the Landing Pod for use in the next session's challenge. You may want to store them in the classroom or have one of the facilitators be responsible for their safe return next week.

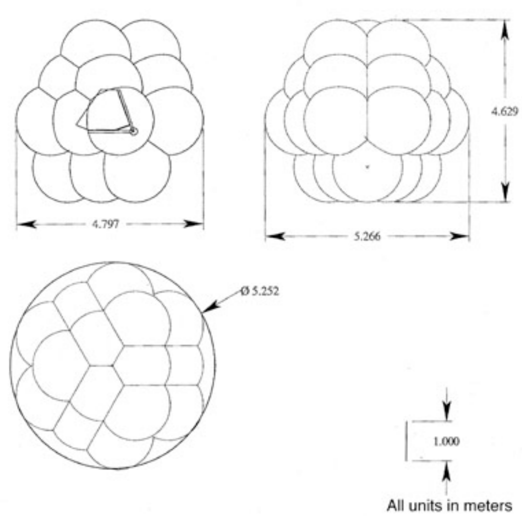
Remind the teams that their Landing Pods, loaded with their Lunar Rovers, will be "landing" from a long drop. Decide whether to drop each Lander from a second story window, ladder, etc, then let the students know the height from which the models will be dropped.

Fragile Cargo! Handle with Care!

Now that we have designed our Lunar Rover that will carry our astronauts on the lunar surface, we need to think about safely delivering the Lunar Rover to the Moon's surface. When NASA sent its two robotic rovers, **Spirit** and **Opportunity,** to Mars, they landed on Mars in a very interesting fashion: they fell out of the Martian sky and bounced on the surface until they came to a stop! How did they do that? They were inside a landing pod made of...AIR BAGS! Wasn't that a clever idea? Now it's your turn. Your challenge is to build a Landing Pod so that your Lunar Rover will land safely on the surface of the Moon. Once the landing is complete, you will open the Landing Pod and roll your Lunar Rover down a ramp.

The Challenge: To design and build a Landing Pod with the following constraints:

1. *It must safely deliver your Lunar Rover to the surface from a height given by the teacher.*
2. *It must land RIGHT-SIDE up. The rover must be able to roll out, so it must land in the correct orientation.*
3. *It must be reusable. The pod must be able to open so students can retrieve their Lunar Rover, and then use the Landing Pod again.*
4. *The combined mass of the Lunar Rover and the Landing Pod cannot exceed 300 grams.*



The "landing" is simulated by the facilitator. Suggestions: toss it safely out of a second story window, or toss it across the classroom. Just be sure the students know ahead of time what to expect.

IMAGINE AND PLAN

From what height will you drop your rover for testing?

____

____

____

How do you plan to protect the rover inside the Landing Pod?

____

____

____

What will you use to protect the outside of the Landing Pod?

____

____

____

How will you make sure the Landing Pod lands right-side up?

____

____

____

IMAGINE AND PLAN (continued)

Sketch your Landing Pod:

Sketch a view of your Landing Pod that shows the "door" or "hatch":

EXPERIMENT AND RECORD

Make two test drops with your Landing Pod, but the first drop should be half the height of the final drop height given by your teacher. For example, if the final test drop is 3 meters, you should first test a drop at 1.5 meters (150 cm). Record what happens to your Landing Pod and the Lander inside.

Trial	Drop Height (m)	Observations
1		
2		

What is the biggest difficulty that your rover faces?

____

____

____

What changes should your team make to your Landing Pod to improve its landing?

____

____

____

LANDING THE ROVER

OBJECTIVE

Students will demonstrate an understanding of the testing phase of the Engineering Design Process by testing their landing pod designs.

CHALLENGE

The Landing Pod, with the Lunar Rover inside, is to land and deliver the payload safely when dropped from a significant height.

PROCESS SKILLS

Predicting, observing, measuring, evaluating.

MATERIALS

General building supplies and tools

WORKSHEETS

Experiment and Record

Improve

MOTIVATE

- Show the video titled, "Seven Minutes of Terror" and ask students to explain why this type of landing would not work for the Moon.

  http://anon.nasa-global.edgesuite.net/qt.nasa-global/ccvideos/jpl/phx20080327-480cc.mov

- Inform the students how high the Landing Pods will be dropped and then show them this height for a visual connection.

SET THE STAGE, ASK, IMAGINE, PLAN

- Host a discussion amongst all the students about their design process. Ask the students to compare their experiences with other group experiences. Also have them share their designs and discuss similarities and differences. Ask students what would they do to the designs if there were no rules or constraints?

EXPERIMENT

- Gather the teams together – everyone should observe all of the landing events.
- One at a time, drop the Landing Pods.
- Open each Landing Pod after it comes to rest. Place ramp up against the Landing Pod and let the Lunar Rover roll out. (It might require a little push.)
- The students should measure the distance the rover rolls and check to see if the egg stayed closed.

IMPROVE

After all of the Landing Pods have "landed," engage the students in a discussion guided by the following questions:

- *What do you worry most about when your Landing Pod hits the surface?*
- *What is similar about all the designs built? What is different?*

CHALLENGE CLOSURE

Ask the students to listen as you read the following:

- *Think about any observations you made during the experiment to land the Lunar Rover. Now think about any changes that you could make to your Lunar Rover and Landing Pod to improve them for future uses. Sketch or draw a picture on a separate piece of paper to show any changes you would make to the Lunar Rover and Landing Pod.*

PREVIEWING NEXT SESSION

Soon we will send the next generation of explorers to the Moon and onward to Mars and other destinations in the solar system aboard a new crew exploration vehicle. The next session will have teams design and build a *Crew Exploration Vehicle* (CEV) that will carry two cm-sized passengers safely and will fit within a certain size limitation.

EXPERIMENT AND RECORD

Drop Height (m)	Number of Pieces of Bubble Wrap Used	Distance Rolled (cm)

Post Landing Questions

Did your Landing Pod remain closed during impact? **Y** **N**

Did the egg remain closed during impact? **Y** **N**

Did your rover roll down the ramp? **Y** **N**

How far did it roll? ___________ cm

Draw a picture showing your Lunar Rover and Landing Pod after the drop. Label any damage that may have occurred.

IMPROVE

Review each team's design. Pick one design characteristic from each team's landing pod that you liked.

____

____

____

____

____

Draw a new and improved design for a landing pod that combines your design ideas with the characteristics you liked from the other teams.

DESIGN A CREW EXPLORATION VEHICLE

OBJECTIVE

To demonstrate an understanding of the Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The teams' challenge is to design and build a Crew Exploration Vehicle (CEV) that will carry two cm-sized passengers safely and will fit within a certain volume (size limitation). The CEV will be launched in the next session.

PROCESS SKILLS

Measuring, calculating, designing, evaluating.

MATERIALS

General building supplies and tools

2 small plastic people

STUDENT WORKSHEETS

Imagine and Plan

Experiment and Record

MOTIVATE

- Show the NASA BEST video titled "Repeatability":

  http://svs.gsfc.nasa.gov/goto?10515

- Ask the students why it is important to test their own designs.

SET THE STAGE, ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- Remind students to *imagine* and *plan* before building. . Ask them to list the challenges they face in meeting the design constraints. Why should they not tape or glue the people in place?

CREATE

- Challenge the teams to build their CEVs based on their designs. Remind them to keep within specifications.

EXPERIMENT

- Each team should conduct two drop tests from about 1 meter. The students can simply hold the CEV model over their heads and drop it. They should record their results after each test, and note what changes they plan to make as a result of the drop test.

IMPROVE

- After each drop test, the students should *improve* the CEV models based on the results of the experiment.

CHALLENGE CLOSURE

- Ask the students, *What was the greatest challenge for your team today?*

PREVIEWING NEXT SESSION

Ask teams to bring back their CEV model for use in next session's challenge. You may want to store them in the classroom or have one of the facilitators be responsible for their safe return next week.

Ask teams to think about potential launch mechanisms during the next week. Tell them they will be building a launcher out of the standard materials that have been available to them, including large rubber bands.

DESIGN CHALLENGE

Taking humans back to the Moon…40 years later!

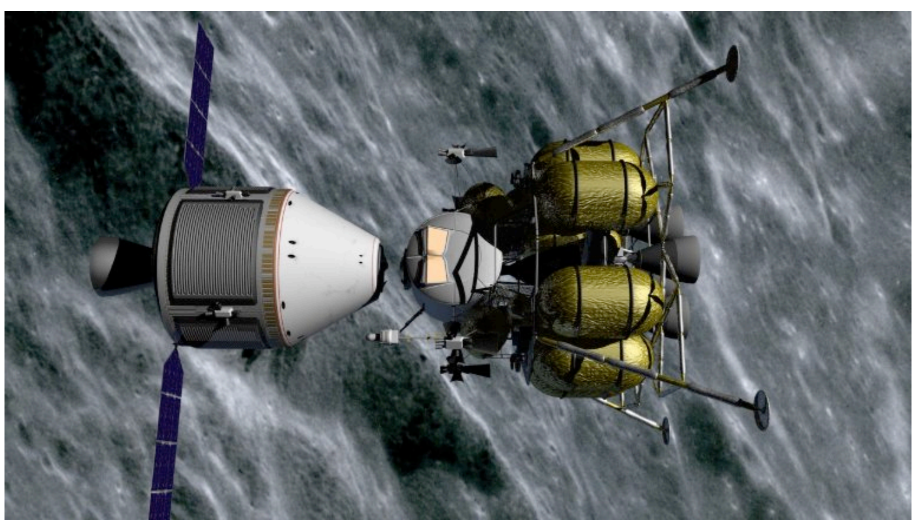
NASA needs a vehicle to take people to the Moon. The Space Shuttle cannot do that, because it was never designed to leave the Earth's orbit. NASA scientists and engineers are working on a space vehicle that can take astronauts to the Moon, Mars, and beyond. This spacecraft is called the Crew Exploration Vehicle (CEV). The CEV is a vehicle to transport human crews beyond low-Earth orbit and back again. The CEV must be designed to serve multiple functions and operate in a variety of environments.

The Challenge: Design and build a *Crew Exploration Vehicle* to meet the following constraints:

1. *Safely carry two little plastic people. You must design and build a secure seat for these people, without gluing or taping them in place. The people should stay in their seats during a Drop Test from over your head.*

2. *Create a hatch that can open and close on your vehicle.*

3. *Fit within the 4" mailing tube provided (or the size constraints as indicated).*



IMAGINE AND PLAN

Draw a picture of the top of your Crew Exploration Vehicle (CEV):

Draw a picture of the inside of your CEV to show where the people sit:

IMAGINE AND PLAN (continued)

Review your team's design. Answer the questions in the table.

Vehicle components	Use	Measurement or Calculation
Little plastic people	Crew	How many?
CEV	Carries crew to Moon	Does it meet the size restrictions?
Hatch	Allows entry and exit	How many people wide? How many people tall?

EXPERIMENT AND RECORD

Drop your CEV from over your head. Answer the questions in the table.

Trial Number	Results
1	Did the people stay in their seats? Did the door fly open?
2	Did the people stay in their seats Did the door fly open?

Suggest some ways you could improve your design of your CEV:

____

____

____

____

LAUNCH YOUR CEV

OBJECTIVE

To demonstrate an understanding of the Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The challenge is to design and build a Reusable Launcher for the Crew Exploration Vehicle (CEV) that they built last week. The CEV should travel 3 meters when launched. The Reusable Launcher should produce repeatable results.

PROCESS SKILLS

Measuring, calculating, designing, evaluating.

MATERIALS

General building supplies and tools

C-clamps and lots of rubber bands

Model CEV that was built last week

STUDENT WORKSHEETS

Imagine and Plan

Experiment and Record

Quality Assurance

Fun with Engineering at Home

Pre Activity Set Up - See next page.

MOTIVATE

- Show the first two minutes of the video titled "Constellation: Flight Tests". (if time permits, show all)

www.nasa.gov/mission_pages/constellation/multimedia/index.html

- Ask the students what was the most important lesson learned from those images? (test, test and test again!)

SET THE STAGE, ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- Emphasize to teams that the objective is to build a launcher that gives repeatable results. It is more important for the CEV to launch the same distance each time than for the CEV to be launched the farthest.

CREATE

- Challenge the students to build a Reusable Launcher based on their designs.

EXPERIMENT

- Conduct two sets of tests: 3 launches, each using three different set-ups and record the data. For example, if they are launching by pulling back a rubber band, they should measure how far back they pull the rubber band each time they do it. They would do it three times each at three different "pulls" and record those results.

IMPROVE

- Students *improve* the Reusable Launcher based on results of the tests.

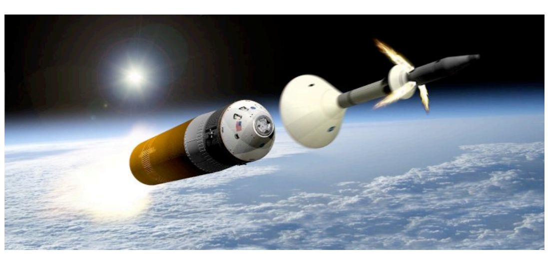
CHALLENGE CLOSURE

Engage the students with the following questions:

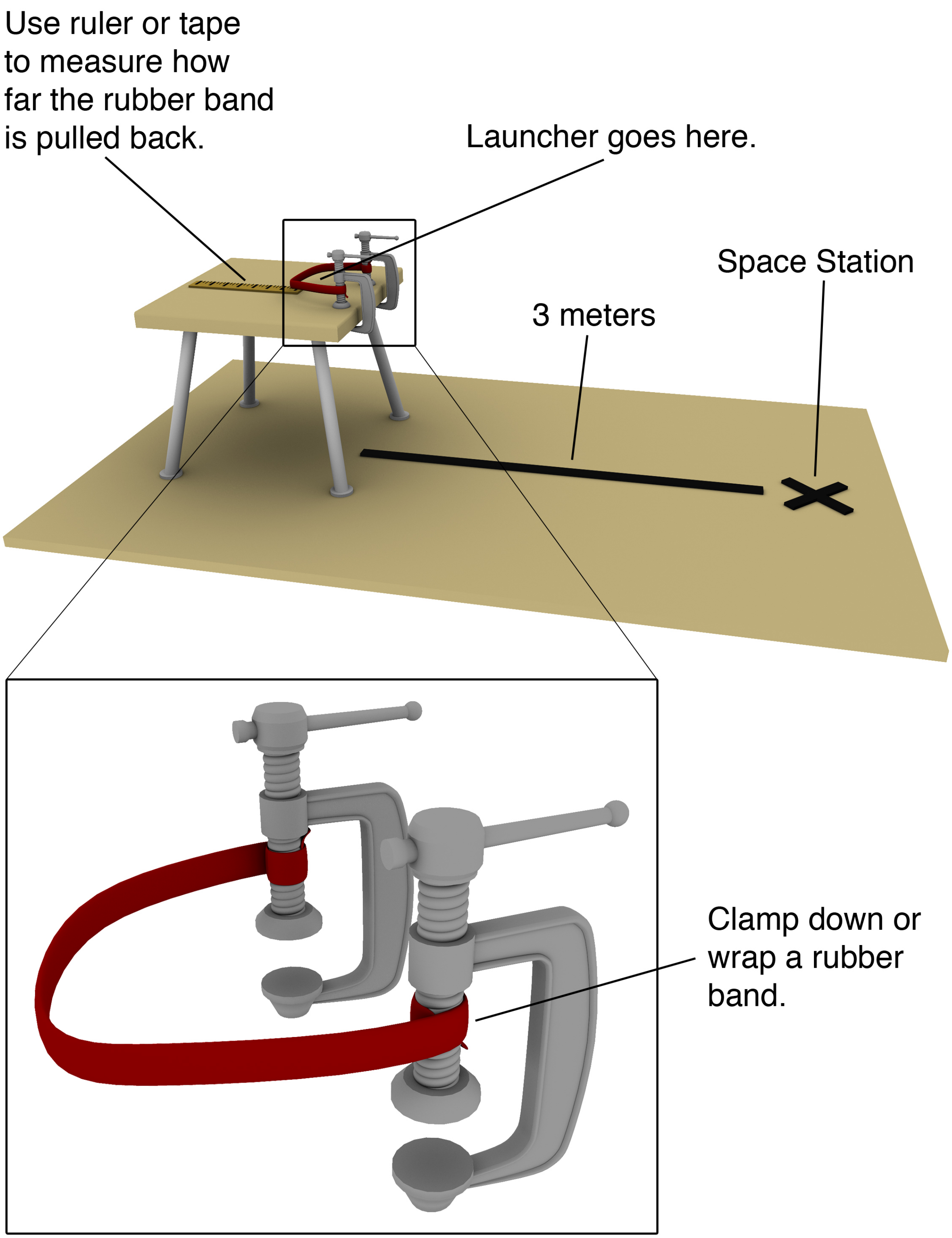
- *Why was it important that the launcher be reusable?*
- *Why was it important that your results were repeatable?*

PREVIEWING NEXT SET OF ACTIVITIES (SERIES 3)

The Moon is a very harsh environment. There is no atmosphere to protect astronauts and their equipment from solar radiation and the extreme temperature swings between night and day. Next session, we will begin to find ways to protect astronauts from those extreme temperature changes.



LAUNCH YOUR CEV



DESIGN CHALLENGE

It's Time to Launch into Space!

Last session, you built a model of a Crew Exploration Vehicle. During this session, you must design and build a Reusable Launcher. You will then launch your CEV! On the way to the Moon, your CEV is going to rendezvous with the International Space Station to pick up some supplies. When you launch your CEV, the goal is to get into orbit close to the International Space Station.

The Challenge: Design a Launcher that meets the following constraints:

1. *Launch the CEV into orbit so that it may rendezvous with the International Space Station. The goal is to launch the CEV 3 meters.*
2. *Be reusable.*
3. *Demonstrate a repeatable outcome. If you set up the Launcher the same way twice, the CEV should travel the same distance both times. It is more important that the CEV is launched the same distance using the same setup than it is to get the CEV to launch the farthest distance.*

IMAGINE AND PLAN

What job does a Reusable Launcher do?

____

____

What components must a Reusable Launcher have to do the job?

____

____

What do you need to build your Launcher?

____

____

____

Draw a picture of your team's Reusable Launcher:

EXPERIMENT AND RECORD

If you change how far back you pull the rubber band, how will it affect the launch?

____

Measure how far back you pull the rubber band. Enter that in the first three boxes of column one. Pull the rubber band back farther and measure the new distance. Record it in the second three boxes. Change it again for the third set.

Distance rubber band is pulled back	Trial	Dependent Variables	
		Distance traveled (m)	Distance from target (m)
Setup A: _____ cm	1		
Setup A: _____ cm	2		
Setup A: _____ cm	3		
Setup B: _____ cm	1		
Setup B: _____ cm	2		
Setup B: _____ cm	3		
Setup C: _____ cm	1		
Setup C: _____ cm	2		
Setup C: _____ cm	3		

FILTER THE DUST

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The team mission is to design a reusable air-filter system that will identify optimal materials that could be used to filter the air on the Moon.

PROCESS SKILLS

Measuring, counting, designing, evaluating

MATERIALS

General building supplies and tools

Pinwheel

Paper towel tube

Hairdryer (cool setting)

Masking tape

Air filter materials (cheesecloth, coffee filter, fabric)

Lunar dust (2 cups of dirt or sand)

Plastic spoon

WORKSHEETS

Imagine and Plan

Experiment and Record

MOTIVATE

- Ask students to provide examples of air filters and how they are used on Earth.
- Lead students to discuss why it would be important to filter air on the Moon, for example, in a lunar habitat or a vehicle.

SET THE STAGE: *ASK, IMAGINE, PLAN*

- Share the *Design Challenge* with the students.
- Have students practice their measuring skills to identify the length given pictures on the *Imagine and Plan* worksheet.

CREATE

- Challenge the students to build an air filter device based on their plans. Remind them to keep within specifications.
- While each group is working, the teacher should set up the pinwheel at the end of a desk.

EXPERIMENT

- Using the cool setting on a hairdryer, teams will test their design by placing the paper towel tube to the hairdryer and holding their design in the middle of the tube
- Students will test the lunar dust flow and record their data.

IMPROVE

- If there is time, have students inspect their designs and the experiment results. Allow teams to rework their design if needed.

CHALLENGE CLOSURE

- Engage the students in the following questions:
  - *Which material would not filter enough lunar dust?*
  - *Which material would filter the lunar dust but not let much air pass through?*
  - *Which filter material would work best on the Moon? Why?*

PREVIEWING NEXT WEEK

Next session students will learn about the principles of energy transfer. When humans go to the Moon, we will need to protect our bodies from the extreme differences in temperature. Have students think of examples their families use for thermal protection, such as if they go camping!

Lunar Dust Buster

Have you ever opened a fragile item packed in a box filled with Styrofoam peanuts? If you plunge your hands into the foam peanuts to search for the item, when you pull it out foam peanuts are clinging to your arms. Try to brush them off, and they won't fall off—instead, they seem to hop away, only to cling to your legs or elsewhere. The smaller peanuts seem to cling even tighter. In fact, if you break a foam peanut into bits, the tiny lightweight bits are almost impossible to brush off. This behavior is classic static cling. It's also the behavior of lunar dust and possibly also Martian dust.

The dozen Apollo astronauts who landed on the Moon between 1969 and 1972 found moon dust to be an unexpected challenge. Not only was it so rough that it wore partially through the outer gloves of their space suits, but also it stuck to everything. The more they tried to brush it away, the more it worked its way into the space suits' fabric. Lunar dust can be unsafe for humans to breathe and it is now a challenge to find a way to filter the air. NASA astronauts will need proper air filters to allow them to live and work on the Moon.

The Challenge: *Your mission is to design a reusable air-filter that will identify materials that could be used to filter the air on the Moon. The challenge is to identify which material allows the right amount of airflow. Your team must design an air filter that tests three different materials. The design must meet the following constraints:*

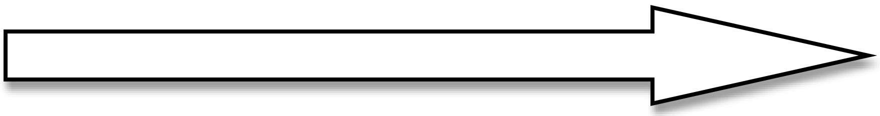
1. *The filter must be reusable. You may not use glue or tape to attach it to the paper towel tube.*
2. *Air must pass through your filter. You will test this by using a hairdryer and a pinwheel as you count the number of rotations it makes with each material.*
3. *Filter materials must block out a large amount of lunar dust. You will test this by gently shaking dirt through each material and measuring the before and after amounts.*

IMAGINE AND PLAN

Practice your measuring skills

Using a metric ruler, determine the length of each object below.

1. The arrow is ______ cm long.



2. The row of rocks is ______ cm long.

3. The row of leaves is ______ cm long.

Draw a picture to show how you will attach each filter material to the tube.

What type of fabric will you use as your third material choice?

____

EXPERIMENT AND RECORD

Your teacher should already have the pinwheel attached to the end of the desk. Use a piece of masking tape to mark one blade on your pinwheel. This will help you count how many times the pinwheel spins for each filter test.

Turn on the hairdryer and try different positions of the filter from the pinwheel. Measure the distance between your filter and the pinwheel. Identify the farthest distance that the filter can be held from the pinwheel and still make it spin. Record that distance in the table below.

Using a stopwatch, count the number of times the pinwheel rotates in 15 seconds. Record the data below.

Filter Material	Distance of Filter from Pinwheel (cm)	Number of Pinwheel Rotations in 15 seconds
Cheesecloth		
Coffee Filter		
Fabric		

EXPERIMENT AND RECORD (continued)

Now you will test each filter material to find out how much lunar dust will pass through.

1. Test only one material at a time. Place the cheesecloth filter on a balance and add two scoops of dirt into the middle of the filter. Record this measurement in the "Before" box in the table below.
2. Pick up both sides of each filter and hold it over a plate or piece of paper. Gently shake it for 5 to 10 seconds to allow the dirt to pass through the filter material. Replace the filter back on the balance and record the "after" mass measurement.
3. Complete the "Change in Mass of Sample" box by subtracting the "after" measurement from the "before" measurement to show the amount of lunar dust that passes through each filter.
4. Repeat steps 1-3 for the coffee filter and fabric samples and record the data in the table below.

	Cheesecloth	**Coffee Filter**	**Fabric**
Mass Measurement (Before)	_____ g	_____ g	_____ g
Mass Measurement (After)	_____ g	_____ g	_____ g
Change in Mass of Sample (Before – After =)	_____ g	_____ g	_____ g

IS IT HOT OR COLD UP THERE?

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The team mission is to gather and analyze data in order to understand the factors that affect how things get warmer and cooler (thermal transfer).

PROCESS SKILLS

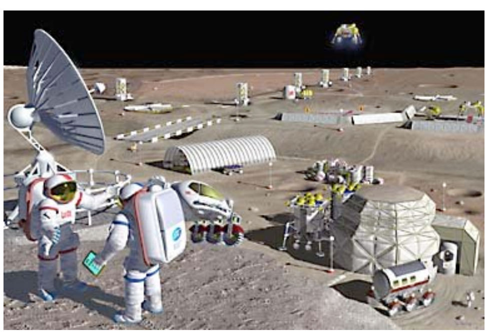
Experimental design, measuring, graphing and data analysis

MATERIALS

Thermometers
Stopwatches
Graduate cylinders
Plastic/styrafoam cups

WORKSHEETS

Imagine and Plan
Experiment and Record



MOTIVATE

- Let students pretend to be molecules. First have them stand still and close together. Then have the students wiggle and then walk and move around to demonstrate more thermal energy entering the system. Have them move faster and jump up and down as even more thermal energy enters the system. Then have the students stop to notice where they are standing. (Note: They should be much farther apart and should feel much warmer than they were originally.)

SET THE STAGE: *ASK, IMAGINE, PLAN*

- Share the *Design Challenge* with the students
- Students will need to graph their results after the experiment. Share the graphing video with them to demonstrate how to build a graph. http://svs.gsfc.nasa.gov/goto?10515
- *Building a graph is not a math standard often taught in 3rd grade, depending on your state. It is your discretion of whether or not to have students graph their data.*

CREATE

- Students should gather their materials and set up for the experiment.

EXPERIMENT

- Have students follow the directions on the *Experiment and Record* worksheet to complete their experiment.
- Students should graph the temperature results as a line graph and analyze.

IMPROVE

- If there is time, have students explore ideas of other ways they could investigate the principle of thermal transfer.

CHALLENGE CLOSURE

- Engage the students in the following questions:
  - *How did the temperature of the hot water change? Cold water?*
  - *Do you think the temperatures in the cup will reach the same temperature as the air in room? If so, predict how long this would take.*

PREVIEWING NEXT WEEK

The Moon is a very harsh environment. There is no atmosphere to protect astronauts and their equipment from solar radiation and the extreme temperature swings between night and day. Next session, we will begin to find ways to protect astronauts from those extreme temperature changes by experimenting with insulation.

DESIGN CHALLENGE

Oh, to not have an atmosphere!

There is no atmosphere on the Moon, so temperatures fluctuate through a very wide range. In the shadowed areas of the Moon, the temperature ranges from as low as –180 ^{o}C (or – 300 ^{o}F), and in the sunlit areas it is about 100 ^{o}C (or 212 ^{o}F), which is the boiling point for water! These are serious extremes for human beings! Furthermore, there are spots on the Moon that are permanently exposed to the Sun, and others permanently in shadow. It is in the permanently shadowed areas of some craters that scientists believe may have water ice.

Anyone living on the Moon, even for a short while, will have to deal with this temperature variation and be protected properly from damaging effects. Thus we must understand how heat moves. So how can we prevent heat from being transferred to or from our bodies? In other words, how can we insulate ourselves from the wide variations of temperature in the lunar environment?

The Challenge: Your mission is to complete an experiment that will help you understand how thermal energy flows, and what factors affect the rate of temperature change.

Follow these steps to complete the experiment:

1. *Assign each group member a job for this experiment: Timer, Data Recorder, and Thermometer Reader.*
2. *Collect necessary materials for experiment and label the outsides of each plastic cup so you know which cup is the hot water and which is the cold water.*
3. *Record the temperature of the room.*
4. *Using a graduated cylinder, collect 50 mL of cold tap water and pour it into one plastic cup. Repeat for hot water.*
5. *Every 30 seconds for the next 5 minutes, record the temperature for each cup of water.*
6. *Graph your results (optional).*

IMAGINE AND PLAN

What exactly is thermal energy transfer? Simply put, it is the method of things warming up or cooling down. Today you will be conducting an experiment to demonstrate that movement of atoms and molecules, by measuring the change in temperature. Take a few minutes and find the definitions of these two words:

HEAT

____

____

TEMPERATURE

____

____

Before you gather the equipment for the experiment, first draw out the experimental set-up below. Make sure to label everything.

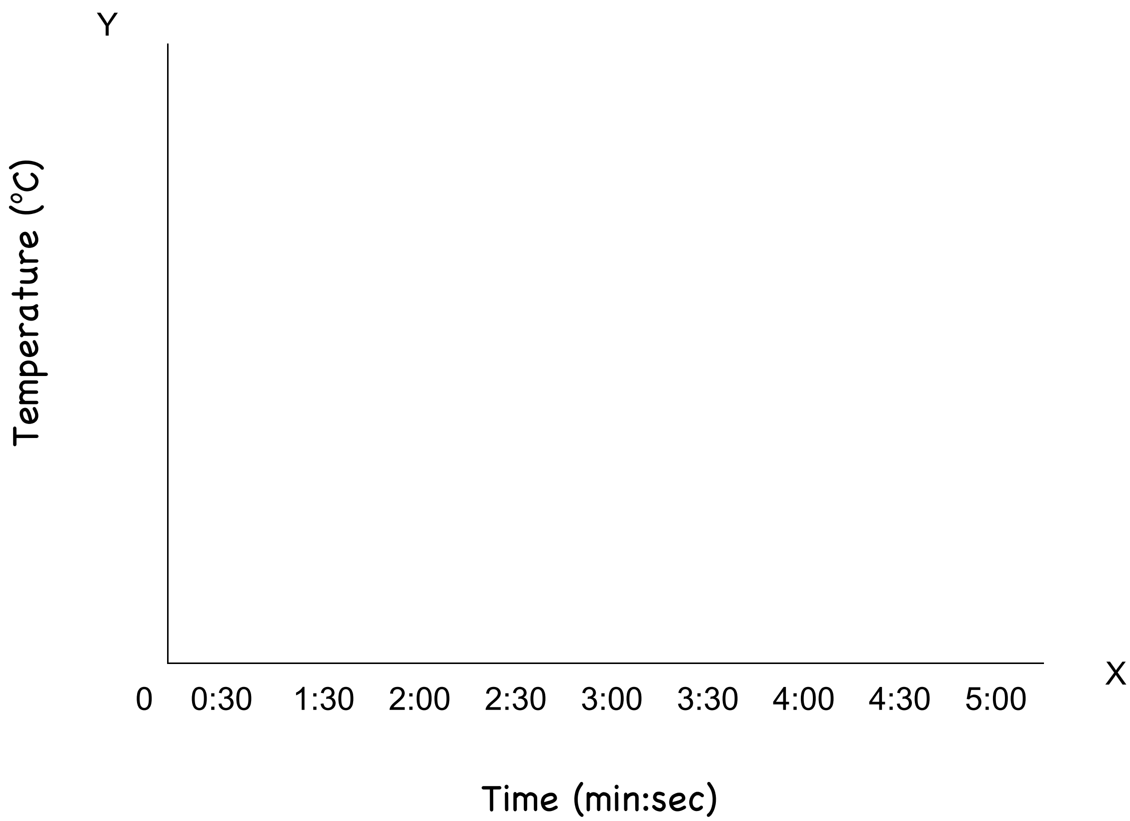
EXPERIMENT AND RECORD

1. Collect necessary materials for experiment and label the outsides of each plastic cup so you know which cup is the hot water and which is the cold water.
2. Record the temperature of the room: _______________ °C
3. Using a graduated cylinder, collect 50 mL of cold tap water and pour it into one plastic cup. Repeat for hot water (from the tap).
4. Record the temperature for each cup of water every 30 seconds for 5 minutes total. Record your results below.

Time Min:sec	Cold Water Cup °C	Hot Water Cup °C
0:00		
0:30		
1:00		
1:30		
2:00		
2:30		
3:00		
3:30		
4:00		
4:30		
5:00		

EXPERIMENT AND RECORD (continued)

Graph the results from your experiment. Remember, the y-axis is your dependent variable, which means the change in temperature is *dependent* upon the time (x-axis). Label the y-axis below and plot your data using dots. Connect your dots to make a line. Draw two lines in two different colors to distinguish the data from each cup.



By looking at the results in the graph, can you predict the time it would take for the temperature of both cups to reach room temperature?

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BUILD A LUNAR THERMOS

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The team mission is to apply the understanding of thermal transfer to design a Lunar Thermos that will hold 100ml of water constant to within 5° over 5 minutes.

PROCESS SKILLS

Experimental design, measuring, graphing and data analysis

MATERIALS

General building supplies

Thermometers

Stopwatches

Graduate cylinders

Small and large plastic/styrafoam cups

Insulating materials (e.g. bubble wrap, paper, towels, sand, water, foil, etc)

WORKSHEETS

Imagine and Plan

Experiment and Record

MOTIVATE

- Ever wonder how much is involved in today's spacesuits? Check out this interactive site to learn about NASA's spacesuits:
  http://www.nasa.gov/audience/foreducators/spacesuits/home/clickable_suit.html

SET THE STAGE: *ASK, IMAGINE, PLAN*

- Share the *Design Challenge* with the students
- Have students first recall what thermal energy transfer is and draw a picture that depicts a warm human standing on the Moon during a cold, lunar night. Then have the students draw the opposite, a "cool" human standing in the extreme heat of a hot lunar day.
- Students will need to graph their results after the experiment. Share the graphing video with them again, if needed: http://svs.gsfc.nasa.gov/goto?10515
- *Building a graph is not a math standard often taught in 3rd grade, depending on your state. It is your discretion of whether or not to have students graph their data.*

CREATE

- Challenge the students to devise a system to keep water at a constant temperature.

EXPERIMENT

- Have students follow the directions on the *Experiment and Record* worksheet to complete their experiment.
- Students should graph the temperature results as a line graph and analyze.

IMPROVE

- If there is time, have students inspect their designs and the experiment results. Allow teams to rework their design if needed.

CHALLENGE CLOSURE

- Engage the students in the following questions:
  - *Did your thermos keep the cold water at a constant temperature for 5 minutes?*
  - *What would have been different if you were trying to keep hot water from cooling off instead of keeping cold water from warming up?*
  - *How would you make your thermos more effective?*

PREVIEWING NEXT WEEK

This session we were trying to stop the transfer of heat energy using insulation. What if we needed to capture heat energy? Why would we need to capture heat energy if we wanted to live on the Moon?

DESIGN CHALLENGE

Protecting humans while exploring the Moon

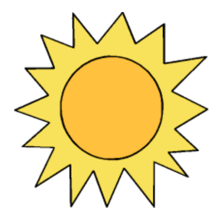
When we go to the Moon, we will need to protect our bodies from the extreme differences in temperature (remember, the Moon's surface temperature can go from -180^{o}C to 100^{o}C in just one day!). Just think about the number of layers you would wear when going outside on a very cold winter's day. We want to keep our bodies at a fairly constant temperature. Since humans are mostly composed of water, how can we keep from losing or gaining too much heat energy?

The Challenge: Your mission is to find an insulating material that can help keep humans at a steady temperature while working on the Moon. Your team will need to keep 100 ml of water at a relatively constant temperature by designing and building a "Lunar Thermos". Your "Thermos" should change by no more than 5^{o} over 5 minutes. You can use any combination of materials to use as your insulation.

IMAGINE AND PLAN

Draw a picture of a warm human standing on the Moon in the cold, lunar night. Label what is warm and cold. Use arrows to show which way the heat moves.

Now imagine that the sun comes up, and the human is standing on the hot lunar surface. Re-draw the picture and label what is warm, cold, and which way the heat moves.



Describe a method for keeping the human at the right temperature for the cold nights *and* hot days.

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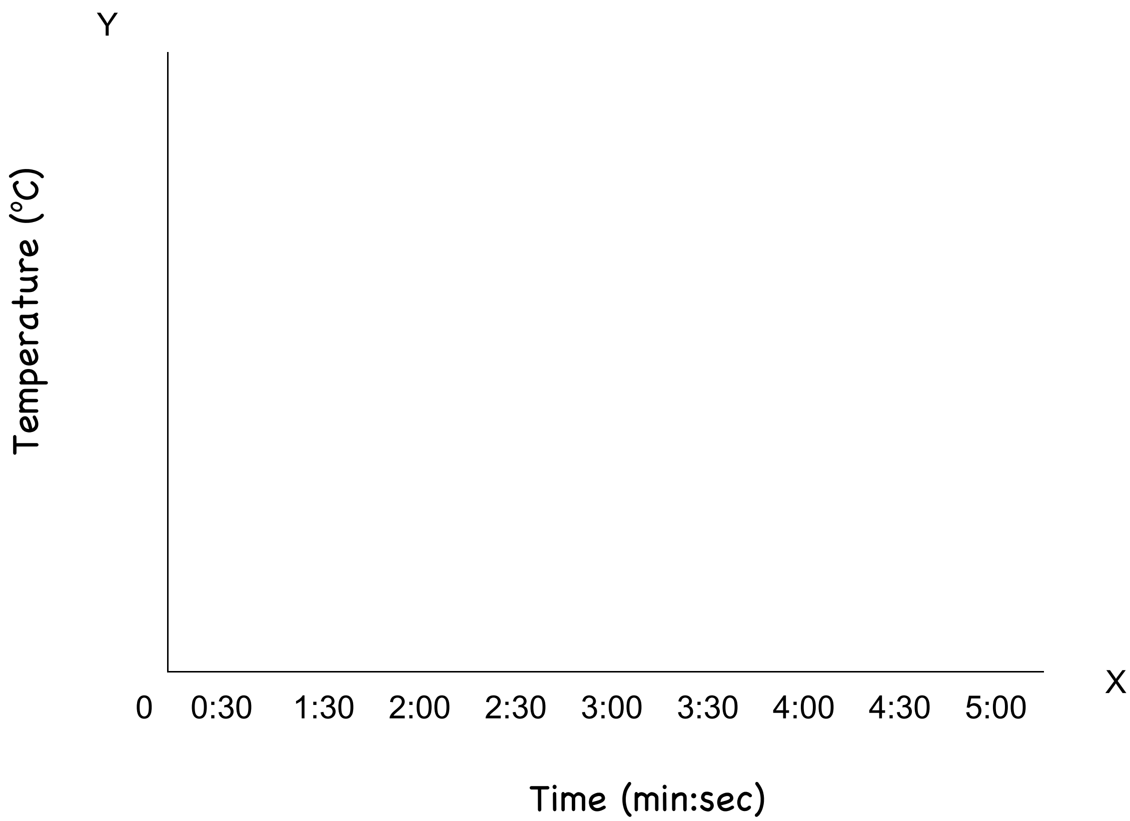
EXPERIMENT AND RECORD

1. Collect necessary materials and insulate your cup.
2. Record the temperature of the room: _______________ °C
3. Using a graduated cylinder, collect 100 mL of cold tap water and pour it into the insulated plastic cup.
4. Record the temperature of the water every 30 seconds for 5 minutes total. Record your results below.

Time Min:sec	Cold Water Temperature °C
0:00	
0:30	
1:00	
1:30	
2:00	
2:30	
3:00	
3:30	
4:00	
4:30	
5:00	

EXPERIMENT AND RECORD (continued)

Graph the results from your experiment. Remember, the y-axis is your dependent variable, which means the change in temperature is *dependent* upon the time (x-axis). Label the y-axis below and plot your data using dots. Connect your dots to make a line.



By looking at the results in the graph, can you predict the time it would take for the cold water cup to reach room temperature?

____

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BUILD A SOLAR OVEN

OBJECTIVE

To demonstrate an understanding of Engineering Design Process while utilizing each stage to successfully complete a team challenge.

CHALLENGE

The team mission is to design and build a solar box cooker, and test it out to see if it works well enough to make S'mores!

PROCESS SKILLS

Experimental design, measuring, graphing and data analysis

MATERIALS

Thermometers

Stopwatches

Cardboard box

Aluminum pans

Aluminum foil

Black construction paper

One piece of plexiglass big enough to cover the box or plastic wrap

Sunshine, OR gooseneck lamp with 100 W bulb

S'mores fixin's (graham crackers, marshmallows and chocolate)

Oven mitts

WORKSHEETS

Imagine and Plan

Experiment and Record

MOTIVATE

- Have students watch the video "Living on the Moon":

  http://svs.gsfc.nasa.gov/goto?10515

SET THE STAGE: *ASK, IMAGINE, PLAN*

- Share the *Design Challenge* with the students
- Tell students that if they succeed in their design, a tasty treat will be had!

CREATE

- Hand out the materials to the students and challenge them to build their own solar ovens.

EXPERIMENT

- Have students follow the directions on the *Experiment and Record* worksheet to complete their experiment.
- Once the oven is built, students should place a S'more and the thermometer in the box and cover the top with plastic wrap.
- Place the box in direct sunlight (they may have to tilt the box so that there are no shadows inside). If it is a cloudy day, use a goose neck lamp with the 100W bulb.
- Ensure students use oven mitts when moving the plexiglass lid or removing items from the solar oven once exposed to the sun.

IMPROVE

- If there is time, have students inspect their designs and the experiment results. Allow teams to rework their design if needed.

CHALLENGE CLOSURE

- Engage the students in the following questions:
  - *Whose oven got to the highest temperature?*
  - *Whose oven melted the marshmallows and the chocolate?*
  - *Does it make a difference to use actual sunlight compared to light from a lamp? Why or why not?*
  - *What else could you cook using a solar oven?*

END OF PROGRAM

This session concludes the NASA Beginning, Engineering, Science and Technology activities. Students now should have a firm grasp of the Engineering Design Process and how it is applied in real applications of our quest to travel to the Moon, Mars and beyond. Fill out a certificate for each student for completing all the steps to becoming a NASA BEST student (see end of guide).

DESIGN CHALLENGE

Can we cook while on the Moon?

While we might have to bring just about everything with us when we establish a habitat on the Moon, one thing we won't need is solar energy. There may be no atmosphere, no climate nor weather on the Moon, but that all means it DOES make it an ideal place to collect solar energy. The majority of the Moon is exposed to sunlight constantly, except briefly during a rare lunar eclipse. If that energy could be harnessed, we could use it to power most everything in our habitat…including that most important device that helps us cook our food – an oven!

The Challenge: Your mission is to design and build a solar oven to cook your own S'mores simply using a cardboard box, aluminum foil, black paper and some plastic wrap. Your solar oven must meet the following specifications:

1. *It must have a "footprint" of no more than 40 cm x 40 cm.*
2. *In 10 minutes, the temperature inside the box must increase by 10^{o}C.*
3. *You may use any available materials to line the bottom and inside of box.*

IMAGINE AND PLAN

Joceyln built three different solar ovens with a cardboard box and a clear plastic lid. The clear lid allows sunlight to pass into the box, but will not let the heat out, just like a greenhouse! Jocelyn's three different designs were:

Box 1: a plain empty box

Box 2: a box with black construction paper placed on the floor of the box.

Box 3: a box with black construction paper on the floor and aluminum foil on the sides of the box.

Which of these three solar ovens do you think collected the most heat?

____

Do you think black construction paper affects how well a solar oven works?

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What purpose do you think the aluminum foil might serve?

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____

Now sketch your solar oven:

EXPERIMENT AND RECORD

1. Using the materials provided, build you solar oven based on your design. Remember the goal is to capture heat in your oven to cook S'mores.
2. Record the starting temperature of the oven: __________________ °C
3. Place one S'more in the middle of the oven (1 graham cracker, 1 piece of chocolate, 1 marshmallow). Close the lid and begin cooking.
4. Record the temperature change in the table below. Make sure to use oven mitts when lifting the lid or manipulating anything inside the oven!

Time Min:sec	Oven Temperature °C	Time Min:sec	Oven Temperature °C
0:00		5:30	
0:30		6:00	
1:00		6:30	
1:30		7:00	
2:00		7:30	
2:30		8:00	
3:00		8:30	
3:30		9:00	
4:00		9:30	
4:30		10:00	
5:00		10:30	

ALIGNMENT TO NATIONAL STANDARDS

Science

	3	4	5
Science as Inquiry			
Develop abilities necessary to do scientific inquiry.	✓	✓	✓
Develop understanding about scientific inquiry.	✓	✓	✓
Science and Technology			
Develop abilities to technological design.	✓	✓	✓
Develop understanding about science and technology.	✓	✓	✓
History of Nature and Science			
Develop understanding of science as a human endeavor.	✓	✓	✓

Technology & Engineering

	3	4	5
Creativity and Innovation			
Apply existing knowledge to generate new ideas, products or processes.	✓	✓	✓
Create original works as a means of personal or group expression.	✓	✓	✓
Use models and simulations to explore complex systems and issues.	✓	✓	✓
Research and Information Fluency			
Locate, organize, analyze, evaluate, synthesize and ethically use information from a variety of sources and media.	✓	✓	
Evaluate and select information sources and digital tools based on the appropriateness to specific tasks.	✓	✓	
Critical Thinking, Problem Solving, and Decision Making			
Identify and define authentic problems and significant questions for investigation.	✓	✓	✓
Digital Citizenship			
Exhibit a positive attitude toward using technology that supports collaboration, learning and productivity.	✓	✓	

Mathematics

	3	4	5
Numbers and Operations			
Compute fluently and make reasonable estimates.	✓	✓	✓
Analyze change in various contexts.	✓	✓	✓
Geometry			
Use visualization, spatial reasoning, and geometric modeling to solve problems.		✓	✓
Measurement			
Understand measureable attributes of objects and the units, systems, and processes of measurement.	✓	✓	✓
Apply appropriate techniques, tools, and formulas to determine measurements.	✓	✓	✓
Problem Solving			
Build new mathematical knowledge through problem solving.	✓	✓	✓
Solve problems that arise in mathematical and in other contexts.	✓	✓	✓
Apply and adapt a variety of appropriate strategies to solve problems.	✓	✓	✓
Communication			
Communicate mathematical thinking coherently and clearly to peers, teachers and others.	✓	✓	✓
Analyze and evaluate the mathematical thinking and strategies of others.	✓	✓	✓
Use the language of mathematics to express mathematical ideas precisely.	✓	✓	✓
Connections			
Recognize and apply mathematics in contexts outside of mathematics.	✓	✓	✓
Representation			
Use representations to model and interpret physical, social and mathematical phenomena.	✓	✓	✓

ORIGINATING MATERAL

Build a Satellite to Orbit the Moon adapted from

www.lpi.usra.edu/education/explore/moon/lro.shtml

Launch Your Satellite adapted from **Rockets Educator Guide**

www.nasa.gov/pdf/58269main_Rockets.Guide.pdf

Prepare for a Mission adapted from **Principles of Remote Exploration** at

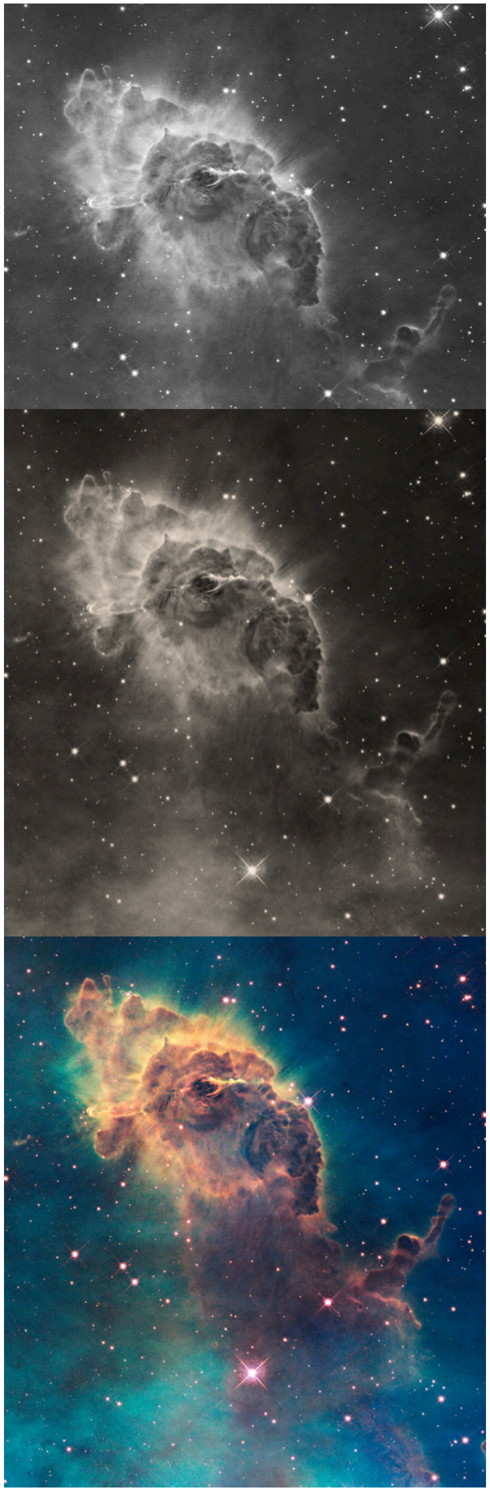
learners.gsfc.nasa.gov/PREP/

Design the new Crew Exploration Vehicle! adapted from **NASA's KSNN™ 21st Century Explorer newsbreak "What will replace the space shuttle?"** at

education.jsc.nasa.gov/explorers/pdf/p5_educator.pdf

Build a Solar Oven was adapted from **Lunar Nautics**, *but is also a very popular activity found in many science textbooks.*

www.nasa.gov/audience/foreducators/topnav/materials/listbytype/
Lunar_Nautics_Designing_a_Mission.html



National Aeronautics and Space Administration

This certifies that

is officially a NASA BEST STUDENT!

For the achievment in understanding and applying the Engineering Design Process.