National Aeronautics and Space Administration

BEST

BEGINNING ENGINEERING, SCIENCE, AND TECHNOLOGY

An Educator's Guide to the Engineering Design Process
Grades 6-8

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). In addition, for your convenience, a NASA BEST Kit is available for purchase from Science Kit/Boreal Laboratories (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)

MATERIALS FOR ACTIVITIES AND GENERAL BUILDING SUPPLIES

aluminum foil
balloons, assorted
bamboo skewers
binder clips, assorted
blindfolds (1 per team)
bubble wrap
buttons or beads, 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 and crayons
cotton balls
empty paper towel tubes
empty toilet paper tubes
fishing line, ~20lb. test, 5 m
film canisters
glue sticks
hairdryer
index cards
mailing tube, 4” diameter / oatmeal canister
mini foil pie plates (1 per team)
modeling clay
paper bags
paper clips, assorted
pennies (at least 10 per team)
pipe cleaners
plastic cups
plastic eggs (1 per team)
plastic people (i.e. Lego or Playmobil)[1]
plastic wrap
popsicle sticks and tongue depressors
rubber bands, assorted
shoe boxes
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, or rotelle pasta (4-6 per team)

1 If toy plastic people are unavailable, encourage students to make their own “astronauts”.

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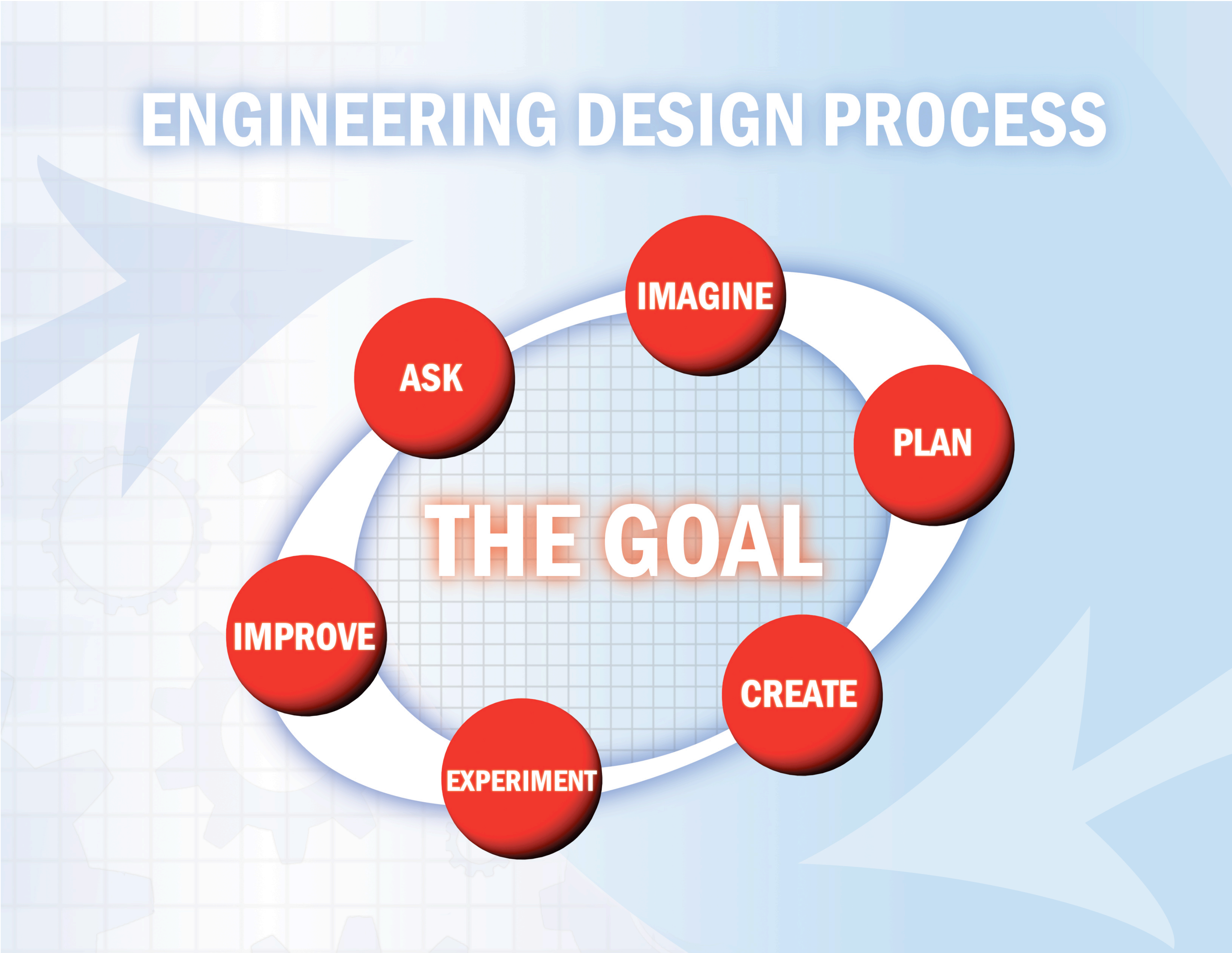
APPENDIX


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

To design and build a satellite that falls within certain size and weight constraints. It will have to carry a combination of cameras, gravity probes, and heat sensors to investigate the Moon's surface. The satellite will need to pass 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

1 Mailing tube or shoebox or other container (used as a size constraint)

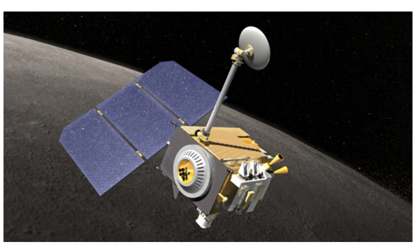
STUDENT WORKSHEETS

Imagine and Plan (2 pages)

Experiment and Record

Quality Assurance

Fun with Engineering at Home



MOTIVATE

- Spend a few minutes asking students if they know what engineers do.
- Discuss the *Engineering Design Process*:
  - **Ask** a question about the goal.
  - **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

- Distribute materials for students to build their satellites based on their designs and specifications.
- Ask teams to double check mathematical calculations, designs and models to make sure they are within specified design constraints.
- Visit each team and test their designs to ensure they fit within the size specification of the cylinder or box you are using.

EXPERIMENT

- Have student test their satellites by dropping them from a 1-meter height.
- Emphasize the importance of experimenting with a new design and receiving feedback for optimizing success in engineering.

IMPROVE

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

CHALLENGE CLOSURE

Engage the students in a discussion with the following questions:

- *List two things you learned about what engineers do through building your satellite today*
- *What was the greatest difficulty your team had today while trying to complete the satellite challenge?*
- *How did your team solve this problem?*

PREVIEWING NEXT SESSION

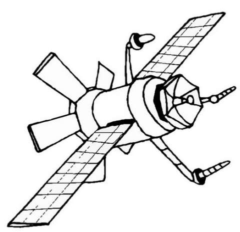
Ask teams to bring back their satellite model for use at the next session. You may want to store them in the classroom or have one of the club facilitators be responsible for their safe return.

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 to determine a safe landing site. In addition, NASA will need to make careful measurements of the radiation falling on the lunar surface for the safety of future lunar explorers.



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

The Challenge: *Your mission is to build a model of a lunar exploration satellite with the general building supplies provided. Use different shape/sizes of buttons or beads to represent the various instruments. The design constraints are:*

1. *The total mass of the instruments, detectors, probes, sensors and solar cells can be no greater than **60 kilograms**.*
    a. *The satellite cannot be launched if the mass of instruments, detectors, probes and solar cells exceeds a total of 60 kilograms, so choose your instruments carefully.*

DESIGN CHALLENGE (continued)

   b. *Your satellite infrastructure is separate, thus you need not be concerned with its mass for this activity.*

2. *The entire satellite must* ***fit within the __________ (i.e. mailing tube, oatmeal canister)****. This item serves simply as a size constraint. The satellite is not to be stored in this or launched from this item.*

3. *At least two instruments must "deploy" (unfold or pop out) when the satellite is launched. These instruments must be mounted on a part that moves.*

4. *The satellite must withstand a 1-meter Drop Test without any pieces falling off.*

ASK

What questions do you have about today's challenge?

Detectors or Instruments	Use	Mass (kg)	Number of solar cells needed to power
Camera	takes pictures	30	1
Gravity Probe	measures gravity	20	2
Heat Sensor	measures temperature	10	3
Solar Cell	collects energy from the Sun to power an instrument, detector, sensor, or probe	1	n/a

Our satellite will have the following instruments:

Instrument	Mass
	kg
	kg
	kg
Total Number of Solar Cells:	kg
Total weight of instrument package	kg
Approximate Volume of Satellite	cm^3
Describe how you approximated the volume of the satellite:	

IMAGINE AND PLAN (continued)

Sketch out each view of the satellite with its instruments you intend to build.

Top View	Bottom View
Left-side View	Right-side View

How will the instruments deploy when the satellite is launched?

____

EXPERIMENT AND RECORD

Pair up with another team to do a Drop Test. Each team should evaluate another team's drop by completing the Quality Assurance worksheet (next page). Drop your satellite from a height of 1 meter. If needed, use a meter stick to measure the height.

What happened when you completed the 1-meter Drop Test?

____

____

Did any pieces fall off? If yes, which ones?

____

____

What kind of changes will you need to make to your satellite?

____

____

Sketch your satellite with these new modifications.

What is the total mass of your instruments and solar cells with these new changes?

____

QUALITY ASSURANCE FORM

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

Name of satellite reviewed: ______________________________

	YES	NO
Does the satellite fit within specified mailing tube?		
Did the satellite withstand the Drop Test?		
Will the instruments deploy upon launch?		

How did the team address the size constraint on the satellite?

Total mass of the instruments is: ______________ grams

List the specific strengths of the design.

List the specific weakness of the design:

How would you improve the design?

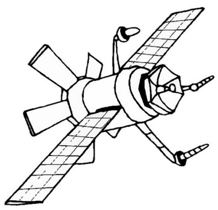
Inspected by: ___________________________________

____

____

____

FUN WITH ENGINEERING AT HOME



Today we designed and built a satellite model to orbit the Moon. We used the same process that engineers use when they build something. We had to **ASK**: what is the challenge? Then we thought, talked and **IMAGINED** a solution to the challenge. We **PLANNED** with our group and **CREATED** our model satellite. Finally, we **EXPERIMENTED** or tested our model by having other groups look at it and give us feedback. Last, we went back to our work stations and tried to **IMPROVE** our satellite. These are the same 6 steps engineers use when they try to solve a problem or a challenge.

While at home, see what you can learn about satellites — how they work, what they are used for, and how we get them up into orbit. You may even want to see if you can find out what kind of sensors, instruments and probes the satellites orbiting the Earth carry.

You can find this information in books, magazines or on the Internet. Here are some Internet links you may want to use:

World Book at NASA: Artificial Satellites

www.nasa.gov/worldbook

The World Almanac for Kids Science: Artificial Satellites

www.worldalmanacforkids.com

NASA Space Place

spaceplace.nasa.gov/en/kids/quiz_show/ep001/

LAUNCH YOUR SATELLITE

OBJECTIVE

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

CHALLENGE

To design a balloon rocket to launch the satellite that was built in the last activity. The goal is to get the satellite to go as far as possible.

PROCESS SKILLS

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

MATERIALS

Satellite model from previous activity

General building supplies

Rulers or meter sticks

Binder clips or clothes pins

Balloons (several per group)

Straws

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

STUDENT WORKSHEETS

Design Challenge

Ask, Imagine and Plan

Experiment and Record

Quality Assurance

Fun with Engineering at Home

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: Use clips or clothes pins to hold filled balloon shut before launch. 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 they created during the last session.
- Show the video of a recent rocket launch, titled, "Liftoff…To the Moon!"
  lunar.gsfc.nasa.gov/launch.html

SET THE STAGE: ASK, IMAGINE, PLAN

- Share the *Design Challenge* with the students.
- 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 the students, "How can we use this set up to launch your satellite?" Remind students that one end of the set us is the launch pad and the other end is the Moon.
- Have students take the time 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. In addition, teams will need to design a system to attach their satellites to the launch set up. Remind students to keep within specifications.

EXPERIMENT

- Send each team to their assigned launch sites to test their rockets, completing the data table 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 their data.
- Teams discuss how far their rocket traveled and which combination of variables gave the best results.

CHALLENGE CLOSURE

Engage the students in the following questions:

- *What was the greatest challenge today for your team?*
- *Why is the balloon forced along the string?*
- *How did changing the straw length/number of balloons affect how far the rocket travelled on the fishing line?*

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?

DESIGN CHALLENGE

3, 2, 1…We have lift-off!

NASA launches several rockets each year, and this is in addition to the Space Shuttle launches. There are actually several launch facilities around the United States. You probably know of the launch pad at Kennedy Space Center in Florida, but did you know there is a launch facility at Vandenberg Air Force Base in California, Wallops Flight Facility in Virginia, and White Sands Missile Range in New Mexico? A rocket is just the launch vehicle that carries a **payload** into space. A payload is the load, or package or set of instruments, needing to be delivered to a destination. When you watched the video for this session, you saw an Atlas V rocket carry a payload, the LRO and LCROSS satellites, to a destination: an orbit around the Moon.

The Challenge: Your mission is to design and build a launch vehicle to send a payload to the Moon. Your payload is the satellite you built at the last session. The launch vehicle is a balloon rocket assembly. Your team must also determine how to attach your satellite to the balloon assembly and then launch it down a fishing wire. The design constraints are:

1) *For the first set of trials, you must change the length of the straw on your rocket.*

2) *Once you have selected an appropriate straw length, select one other rocket element for your design and modify only that element during your trials. The rocket elements are:*

    a. *number of balloons*

    b. *type of balloon(s): long or round (if time and materials permit)*

ASK

What questions do you have about today's challenge?

IMAGINE AND PLAN

How will you choose what lengths to make the straw?

____

Predict how the effect of the length of the straw on the launch assembly might change the launch distance of your satellite.

____

____

Explain what you think is happening with the straw that changes how far the rocket travels?

____

____

What is the next rocket element (or variable) do you plan to test? How are you going to test it?

____

____

Predict what will happen when you make these changes.

____

____

IMAGINE AND PLAN (continued)

Sketch your balloon rocket assembly and include your satellite:

EXPERIMENT AND RECORD

Experiment 1. Select the number and shape of balloons you want to use. This is your control. Only modify the length of straw for each trial.

	Trial 1	Trial 2	Trial 3
Straw Length (cm)			
Distance traveled (cm)			

Number of balloons?	Balloon shape?

Experiment 2. Change the number of balloons for each trial, but keep the straw length and shape of balloons constant.

	Trial 1	Trial 2	Trial 3
Number of Balloons			
Distance traveled (cm)			

Length of straw?	Balloon shape?

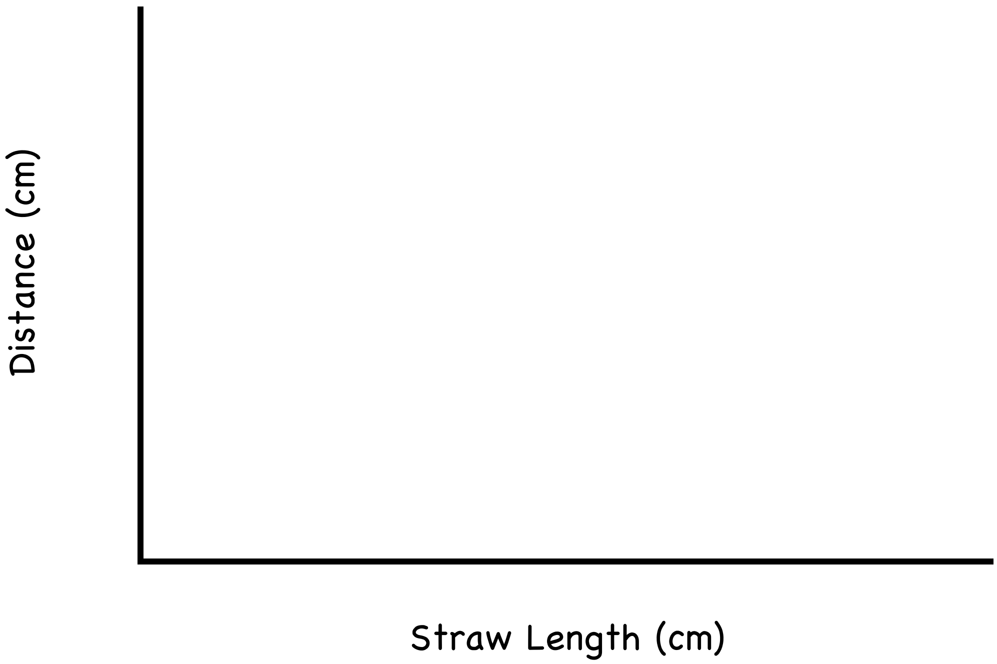
Experiment 3 (if time and materials permit). Select different shapes of balloons for each trial but keep the straw length and number of balloons constant.

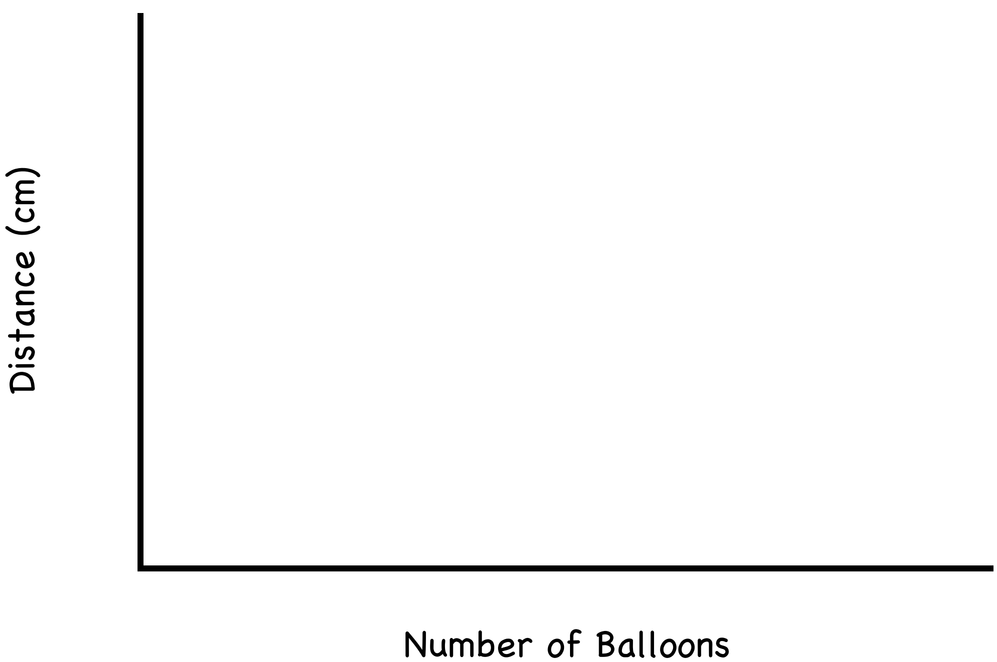
	Trial 1	Trial 2	Trial 3
Shape of balloon(s)			
Distance traveled (cm)			

Length of straw?	Number of balloons?

EXPERIMENT AND RECORD (continued)

Plot the data from your tables into the graphs below.





QUALITY ASSURANCE FORM

Each team is to observe another team's launch, then answer the following questions.

Name of satellite/rocket reviewed: ______________________________

What was the farthest distance the rocket travelled?

______________________cm

What design components were on the rocket that made it travel this far?

Straw Length?	
Number of Balloons?	
Balloon Shape?	

List specific strengths of the design.

List specific weakness of the design:

How would you improve the design?

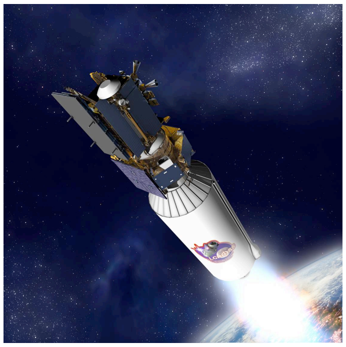
Inspected by: ____

____

____

____

FUN WITH ENGINEERING AT HOME



Today we designed and built a balloon rocket to send our lunar satellite to the Moon. Though simply a model using classroom supplies, you still used the same process that engineers use when they build a rocket assembly to put satellites in space. While at home, see what you can learn about rockets — how they work, what they are used for, and what types of fuel is used to get them into space.

American rocketry was pioneered by Dr. Robert Goddard. NASA's Goddard Space Flight Center is named after him. For further reading about Dr. Goddard:

www.nasa.gov/centers/goddard/about/dr_goddard.html

To read about the Ares V rocket, check out this link:

www.nasa.gov/mission_pages/constellation/ares/rocket_science.html

NASA's Marshall Space Flight Center studies propulsion and manages the Michoud Facility in New Orleans.

www.nasa.gov/centers/marshall/about/index.html

CHALLENGE: What kind of rockets carry satellites into space? Are these the same kind of rockets that carry astronauts into space? Ask your family members to help you investigate!

PREPARE FOR A MISSION

OBJECTIVE

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

CHALLENGE

To execute a mini-simulation of a robotic mission with a goal to command a human-robot through a set course to retrieve a piece of lunar ice.

PROCESS SKILLS

Mapping, communication, measuring, graphing, logical thinking

MATERIALS

Rulers or meter sticks

Blindfolds

"prize" as lunar ice sample

STUDENT WORKSHEETS

Design Challenge

Ask, Imagine and Plan (4 pages)

Experiment and Record

Quality Assurance

Fun with Engineering at Home

PRE ACTIVITY SET-UP

Set up a small obstacle course with a few chairs, waste paper baskets, and/or a table. The course does not have to be too complicated, but set it up so students will have to take at least one right turn and one left turn. Also, give the students enough obstacles so there is more than one path to take to the "finish". An area of about 25 square meters is recommended.

Please note: This activity will require two 60-90 minute sessions to complete. Make sure to set up the obstacle course exactly the same for both sessions.

MOTIVATE

- 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. They must include at least one right turn and one left turn.
- Let students practice commands to use with their robot. These commands are simple words, plus a number for steps taken.

CREATE

- Students will identify the robot's route through the lunar landing site and count the number of steps needed for each command to calibrate the distance the robot travels on a given command. From this, a command sequence for their robot can be created, then tested on the planned route of their maps.

EXPERIMENT

- Student teams must navigate the lunar landing site, using the command sequence each team designed. Have students cut out the commands into strips of paper and 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 students designated to deliver commands are to deliver one command at a time – one student walks to the robot, delivers one command, then returns to the team. Robot performs the command. The next student then walks to the robot and delivers the command, returns, etc. Only one command is delivered at a time to represent one line of code sent over a radio signal. The rest of the team cannot deliver another command until they have determined if the robot has successfully executed that 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?*
- *Why did you have to deliver each command separately? How does it related to communicating with robots in space?*

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 must calibrate and program these machines to accomplish the mission objective, such as to travel to certain locations on that planet or moon.

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 retrieve a piece of "lunar ice" for analysis.

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

1. ***Designate your robot*** - *One student per 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. Select a name for your robot.*

2. ***Map the landing site*** – *Using the chart in your worksheets, create a map of the landing site, making sure to accurately measure the distances between objects.*

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.*

DESIGN CHALLENGE (continued)

4. ***Calibrate your robot*** *– After practicing a set of commands with your robot, you must measure the distance the robot travels with each step or command sequence.*

5. ***Program the robot*** *– Use the commands you developed to successfully direct the robot through the predetermined route based on the calibrations you made of how far your robot travels with each step.*

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

ASK

What questions do you have about today's challenge?

IMAGINE AND PLAN

STEP 1 – Designate a team member to be your robot and create a name for your robot.

STEP 2 – Map the landing site. Produce a map of the lunar "landing site" to plan your robot's route. Observe the site, measure the distance between objects and accurately replicate their positions in the grid below. Think about the units you need to use for your measurement and what strategy you will use to make your measurement. For example, can you use floor tiles?

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? Practice the words below with your robot and see if your robot follows the commands correctly.

Sample Command for Robot	Action by robot
MOVE FORWARD TWO STEPS	Walk forward two steps.
MOVE BACKWARD ONE STEP	Walk backward one step.
TURN RIGHT 90°	Turn to the right
TURN LEFT 180°	Turn to the left to face the opposite direction.
BEND AND GRAB	Bend at the waist and pick up the lunar ice sample

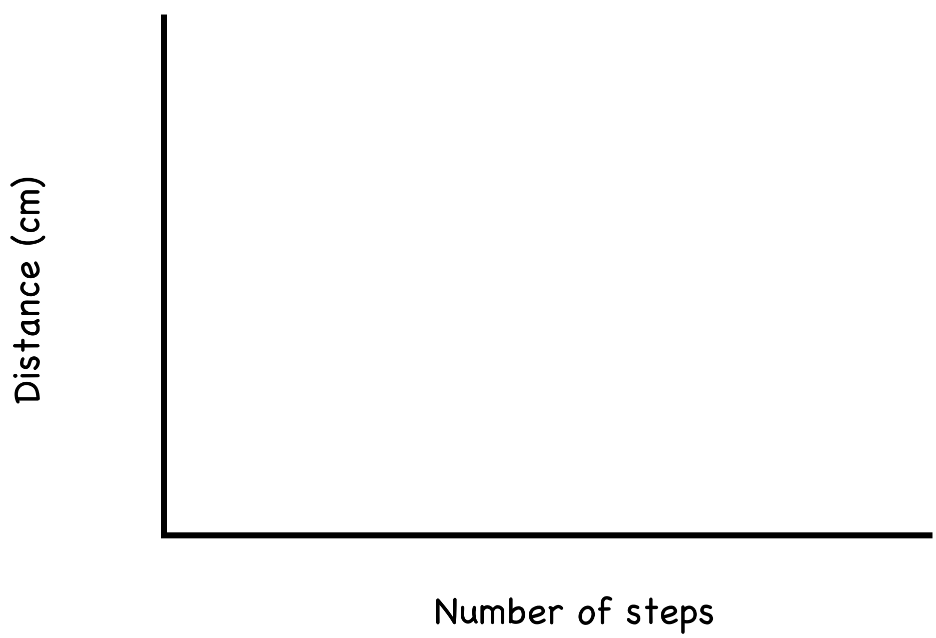
As a team, decide on the type of commands you want to use to program your robot. You may use the ones suggested above and create your own, but once those vocabulary terms are designated in this list, you may not use any other new commands once your robot has landed in the starting position.

Additional commands to use:

STEP 4 – Calibrate your robot

Practice delivering forward commands to your blindfolded robot. Measure the distance traveled by the robot for each command. Repeat three times and calculate a mean. Graph your results.

	Trial 1	Trial 2	Trial 3	Mean
Forward 1 step	cm	cm	cm	cm
Forward 2 steps	cm	cm	cm	cm
Forward 4 steps	cm	cm	cm	cm
Forward 6 steps	cm	cm	cm	cm
Forward 8 steps	cm	cm	cm	cm



Can you predict how far your robot will travel in 10 steps? ____________ cm

STEP 5 – Program your robot

Review the map with your team and plan a route for your robot. Based upon the calibration results, create commands for your robot to match your route. Write down one command for each slot below.

Command Sequence

1.	11.
2.	12.
3.	13.
4.	14.
5.	15.
6.	16.
7.	17.
8.	18.
9.	19.
10.	20.

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. Take the complete command sequence your team designed and cut each command out of the page as separate strips of paper. Designate two team members to deliver the commands to the Robot and divide those strips of paper among them. Another team member, using a stopwatch, times how long it takes for the Robot to reach the Lunar ice sample and successfully complete the mission. Don't forget that the Robot must be blindfolded! If the Robot makes a mistake or runs into an obstacle, the team must stop the mission, return to mission control to reconvene and discuss the issue, then modify the command sequence and resend the radio signal (strip of paper with command) to the Robot.

Record each team's time in the table below to compare how long the mission took for each team! Afterwards, pair up with another team to complete your Quality Assurance assessment.

Discovery Mission Data Table

Team Name	Time (seconds)
1.	
2.	
3.	
4.	
5.	

QUALITY ASSURANCE FORM

Each team is to observe another team's Discovery Mission, then answer the following questions.

Name of Robot and team reviewed: ___________________________

Did the team deliver commands to the Robot one sequence at a time? (only one radio signal per command sequence)

Did the Robot execute commands correctly?

Did the Robot reach its destination with the original set of commands?

If not, how many times did the team have to reprogram the Robot to reach the lunar sample?

____

List 2 or 3 recommendations you have for this team:

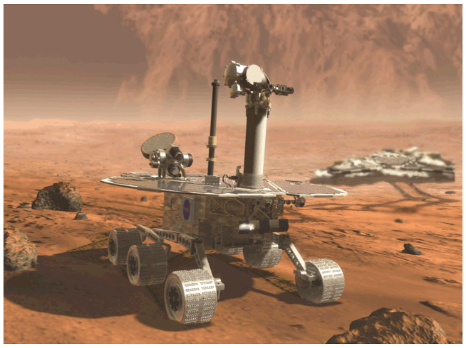
Inspected by: ____________________________________

____

____

____

FUN WITH ENGINEERING AT HOME



Today we conducted a simulated, robotic Discovery Mission. We practiced many of the very same activities that NASA scientists and engineers do when planning and executing a remote exploration mission, such as mapping, calibration, communication and programming. Learn more about the efforts to develop a lunar robotic rover prototype to further study the Moon:

www.frc.ri.cmu.edu/projects/lri/scarab/index.html

CHALLENGE: While at home, recruit your family members to try a Discovery Mission at home! Rearrange some furniture or household items to set up the Lunar Landing Site. Demonstrate to everyone the steps needed to accomplish the mission – ask your teacher for new worksheets from the activity to give to your family to use. If you have a big family or are doing this with lots of friends, you could break into teams and race to the end. Be creative with an item to collect as a lunar ice sample, and have fun!

YOU BE THE TEACHER! Explain to your family why it is important to map the site prior to sending a rover to retrieve a sample. Emphasize why engineers must repeat an exercise before getting sustainable results.

DESIGN A LUNAR BUGGY

OBJECTIVE

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

CHALLENGE

To design and build a model of a Lunar Buggy that will carry equipment and astronauts on the surface of the Moon as well as determine the best slope of ramp for the rover to travel the farthest distance.

PROCESS SKILLS

Measuring, calculating, designing, evaluating

MATERIALS

General building supplies

Meter stick

Digital scale

Small plastic people (i.e. Lego)

Plastic eggs

Pennies to represent cargo weight

Wheels

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

STUDENT WORKSHEETS

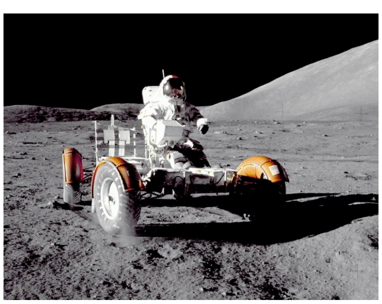
Design Challenge

Ask, Imagine and Plan (2 pages)

Experiment and Record (2 pages)

Quality Assurance

Fun with Engineering at Home



MOTIVATE

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

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

- Ask students to pay particular attention to the comments made about the difficulties in driving on the lunar surface.

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 Buggies based on their designs. Remind them to keep within specifications.
- While each group is working, designate one or two students to create a ramp with a slope of 1 over 3 in which all groups will use to roll their buggies and record observations.

EXPERIMENT

- Students must test their designs down the ramp and record the distance travelled for each trial.
- Student should try a "Goldilocks" experiment and test various slopes to give the best distance travelled with their Lunar Buggy. What slope is too little? What slope is too much? What slope is just right? Have the students record their results.

IMPROVE

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

CHALLENGE CLOSURE

Engage the students in the following questions:

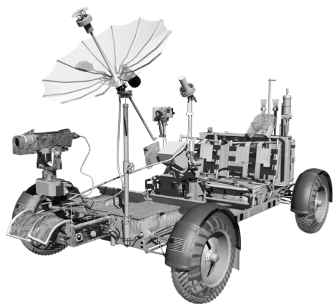
- *Did the cargo mass make a difference on your Buggy's performance?*
- *How did the slope of the ramp affect your Buggy's performance?*

PREVIEWING NEXT SESSION

Ask teams to bring back their Lunar Buggy 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 session.

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).

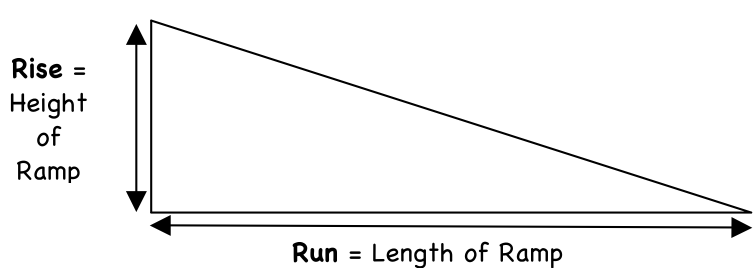
Let's Go For A Ride!



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 how to deliver cargo to the Moon. 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 Buggy several kilometers away from their spacecraft. Today you get to be the engineers designing a new Lunar Buggy that can perform functions the Apollo Lunar Buggy could not. Thus, your challenge is to build a model of a Lunar Buggy that astronauts will eventually use to carry *astronauts and cargo* on the Moon.

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

1. *Carry one plastic egg snugly. The egg may not be taped or glued into place. (The egg represents the cargo hold.)*
2. *Be able to roll with the cargo hold carrying 10 pennies.*
3. *Have room for two "astronauts". (You may use plastic people provided to you or make your own.)*
4. *Roll on its own down a ramp with a rise-over-run of 1-over-3 for a distance of approximately 100 cm in a straight line beyond the ramp.*
5. *Cargo hold and astronauts must stay in place and in tact as the Buggy rolls down the ramp.*



ASK

What questions do you have about today's challenge?

IMAGINE AND PLAN

What parts do you need in order to make your buggy roll?

____

____

____

What will hold the egg in place?

____

____

____

What will hold the astronauts in place?

____

____

____

What is the height of the ramp (rise) and its length (run) for this Challenge?

Rise	cm
Run	cm

IMAGINE AND PLAN (continued)

Draw your Lunar Buggy and provide a close-up view of your wheel and axle design:

Buggy design:
Wheel and axle design:

EXPERIMENT AND RECORD

After you have created your model Lunar Buggy based on your drawings during, test your vehicle on the ramp set up in the room and record how far it travels beyond the ramp. Indicate the changes your team makes to the design to get the best performance for your Lunar Buggy. Remember, the challenge is to have your Lunar Buggy travel at least 100cm beyond the ramp in a straight line!

Trial	Distance Traveled (cm)	Modification to make to design
1		
2		
3		
4		

Use the space below to draw the updated plans for your newly designed Buggy.

EXPERIMENT AND RECORD (continued)

Now that you tested your Buggy at a constant slope of 1 over 3, what slope do you think would make your Lunar Buggy travel the farthest? Write your hypothesis below in a complete sentence.

____

____

____

Set up your ramp with different slopes and record how far your Lunar Buggy travels beyond the ramp each time.

Trial	Rise-over Run	Distance Traveled (cm)
1	1 over 3	
2		
3		
4		
5		
6		

At what slope did the buggy no longer roll, but slid or fell off the ramp?

____

Science Pop Question! What force is acting on the Lunar Buggy to get it to roll down the ramp?

____

QUALITY ASSURANCE FORM

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

Name of Lunar Buggy reviewed: ______________________

How far does the buggy roll on a ramp with slope of 1-over-3?

______________ cm

Did the egg or astronauts fall out on the ramp with slope of 1-over-3?

Using a digital scale, measure the mass of the Lunar Buggy (without the penny cargo).

______________ grams

Do you think the mass has an impact on the Buggy's performance? Explain your answer.

List specific strengths of the design.

List specific weakness of the design:

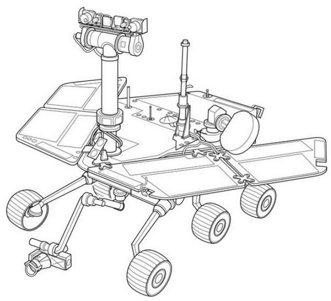
Inspected by: ______________________________

____

____

____

FUN WITH ENGINEERING AT HOME



Today we designed and built a Lunar Buggy model to transport astronauts and cargo on the Moon. Before humans can travel to other planets, we first must send robotic rovers to these remote locations to investigate the surface of that planet. While at home, see what you can learn about the robotic rovers that NASA has already built and used to investigate other planets. For example, you can learn about the challenges in building the Mars Exploration Rovers from this website:

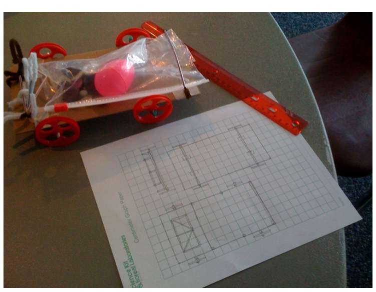
marsrover.nasa.gov/gallery/video/challenges.html

Here are some questions to discuss with your family members:

1. *What Apollo mission used Lunar Buggy and how was it delivered to the Moon's surface for that mission?*
2. *Using the imagery from the Lunar Reconnaissance Orbiter, can you locate any remnants of the Apollo missions?*

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

3. *What is the most important consideration when designing a vehicle that will carry astronauts and cargo?*
4. *What kind of cargo might a vehicle need to carry on the Moon for future missions?*



YOU BE THE TEACHER!

Explain to your family why the PLAN step in the Engineering Design Process is so important. Use your latest experiment with the Lunar Buggy as an example.

DESIGN A LANDING POD

OBJECTIVE

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

CHALLENGE

To design and build a Landing Pod for the model Lunar Buggy that was built in the previous session.

PROCESS SKILLS

Measuring, calculating, designing, evaluating.

MATERIALS

General building supplies

Balloons

Bubble wrap and/or packaging material

Cardboard and/or shoeboxes

STUDENT WORKSHEETS

Design Challenge

Ask, Imagine and Plan (2 pages)

Experiment and Record

Quality Assurance

Fun with Engineering at Home

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

MOTIVATE

- Show the video titled "Entry, Decent, and Landing (EDL)."

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

- Ask students to pay particular attention to the ways NASA slowed the rovers down as they entered the atmosphere. Note the difference between the Martian atmosphere to that of 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 the Lunar Buggy must be secured inside the Pod but cannot be taped or glued in place.

EXPERIMENT

- Each team must complete three trial drops and record observations.
- The actual "landing" is simulated by the facilitator. Suggestions: Drop Landing Pods safely out of a second story window, from a landing of a stairwell or from the top of a ladder. Just be sure the students know ahead of time what to expect.
- Open each Landing Pod after it comes to rest and check Buggy is upright.
- Using the same ramp as last session with a slope of 1-over-3, place the Landing Pod at the top of the ramp and let the Lunar Buggy roll out. (It might require a little push.).
- The students should measure the distance the Buggy rolls and check to see if the egg stayed closed.

IMPROVE

- Students *improve* their Landing Pods based on results of the three trial drops.

CHALLENGE CLOSURE

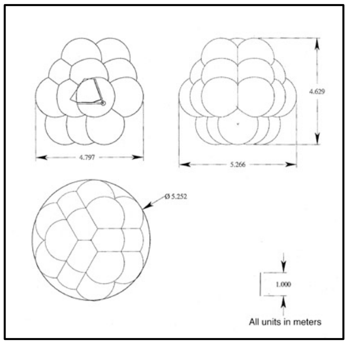
Engage the students with the following questions:

- *Which materials worked best to protect the Lunar Buggy?*
- *If you knew you ahead of time that your Buggy had to survive a landing, would you have made any changes to your Buggy design?*

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.

Fragile Cargo! Handle with Care!



Now that you have designed a Lunar Buggy that will transport astronauts around the lunar surface, you need to think about safely delivering this vehicle to the Moon. 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, slowed down by a parachute and then bounced on the surface until they came to a stop! How did they do that? The rovers were inside a landing pod made of AIR BAGS! But the Martian atmosphere and surface is very different from the Moon, so to repeat this on the Moon would require several design modifications.

The Challenge: Each team must design and build a Landing Pod that will safely deliver your Lunar Buggy to the Moon's surface. The Landing Pod must meet the following constraints:

1. *It must safely deliver your Lunar Buggy to the surface from a height given by the teacher.*
2. *It must land RIGHT-SIDE up. The buggy must be able to roll out, so it must land in the correct orientation.*
3. *Materials of the landing pod must be reusable for other missions on the lunar surface. If a balloon pops or tape folds over on itself, those items are then not reusable.*
4. *The pod must have a hatch or door for release of the Lunar Buggy, and then roll out with no more than a nudge onto the ramp. Therefore, the Lunar Buggy cannot be taped or glued inside the Landing Pod.*
5. *.The Lunar Buggy should not suffer any damage from the lunar landing and still be able to roll down a ramp with a slope of 1-over-3 and 100cm beyond the ramp.*

ASK

What questions do you have about today's challenge?

IMAGINE AND PLAN

From what height will you drop Landing Pod for testing?

____

____

How do you plan to protect the buggy 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 on the surface in the Buggy's correct orientation?

____

____

____

IMAGINE AND PLAN (continued)

Draw your Landing Pod:

Outside view with door or "hatch"
Inside view with Buggy placement

EXPERIMENT AND RECORD

Perform several drop tests with your Landing Pod. Start with a height less than the height being used for the actual lunar landing (height mentioned by teacher). Note carefully how it lands and think about what changes need to be made to improve the landing.

Trial	Drop Height (m)	Observations
1		
2		
3		

What is the most difficult constraint to satisfy in your Landing Pod?

____

____

List the design changes made to your Landing Pod between trials:

____

____

____

Now for the actual lunar landing! Follow your teacher's instructions and answer the following questions.

Post Lunar Landing

Did the Landing Pod remain closed during impact? (YES or NO)	Did the Lunar Rover land in an upright position? (YES or NO)	How far did the rover roll down the ramp? (cm)

QUALITY ASSURANCE FORM

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

Name of Lunar Buggy/Landing Pod reviewed: ______________________

Total mass of the Lunar Rover and Landing Pod is: _______grams

Did the Landing Pod land upright when dropped from a height of 2 meters?

List specific strengths of the design.

List specific weakness of the design:

How would you improve the design?

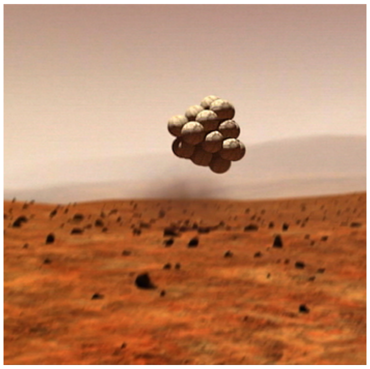
Inspected by: ____

____

____

____

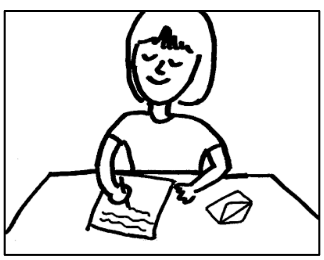
FUN WITH ENGINEERING AT HOME



Today we simulated the landing of your Lunar Buggy on the Moon. This activity models the way the Mars Exploration Rovers were landed onto the surface of Mars. Tell your family about how your Landing Pod survived the stress of impact. What were its strong points? If you could design it again, would you do anything different? Ask family members if they have any ideas on how to improve the Landing Pod your team designed.

Mars is not the only planet NASA has visited through robotics. Do a little research with your family members to answer these questions:

1. NASA has also dropped satellites into the atmospheres of Venus and Jupiter. What happened to those spacecraft?
2. When humans landed on the Moon, what kind of a vehicle did they use? How was this vehicle slowed down to prevent an impact on the surface?



CHALLENGE: Write a one-page letter to the NASA engineers working on lunar exploration telling them of your suggestions for building a Landing Pod that will deliver its payload safely to the surface.

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

To design and build a Crew Exploration Vehicle (CEV) that will carry 2 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

Digital scale

Mailing tube, oatmeal canister, or small coffee can (used as size constraint)

2 plastic people (i.e. Lego)

STUDENT WORKSHEETS

Design Challenge

Ask, Imagine and Plan (3 pages)

Experiment and Record

Quality Assurance

Fun with Engineering at Home

MOTIVATE

- Show the NASA BEST video titled "Repeatability":

  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.

CREATE

- Challenge students to build their CEV's based on their designs. Remind them to keep within specifications.
- Visit each team and test their designs to ensure they fit within the size specification of the cylinder you are using.

EXPERIMENT

- Each team must conduct three drop tests and record the results.

IMPROVE

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

CHALLENGE CLOSURE

Engage the students with the following questions:

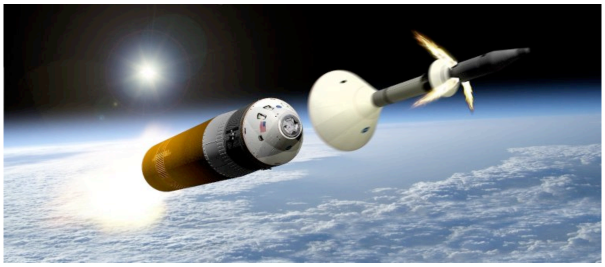
- *What was the greatest challenge for your team today?*
- *Why was it important that the hatch stay closed during the Drop Tests?*
- *What process will your CEV undergo that makes it important for the astronauts to be secured safely in their seats?*

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 session.

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

Taking humans back to the Moon…40 years later!



NASA needs a new vehicle to take astronauts to the Moon because the Space Shuttle was never designed to leave the Earth's orbit. NASA and its industry partners are working on a space vehicle that will 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: *Each team must design and build a Crew Exploration Vehicle with the following constraints:*

1. *It must safely carry two "astronauts". You must design and build a secure seat for these astronauts, without gluing or taping them in place. The astronauts should stay in their seats during each drop test.*
2. *The CEV must **fit within the __________ (i.e. mailing tube, oatmeal canister)**. This item serves simply as a size constraint. The CEV is not to be stored in this or launched from this item.*
3. *It must include an internal holding tank for fuel with a volume of 30 cm^3. (Note: your tanks will not actually be filled with a liquid.)*
4. *It must have a mass of no more than 100 grams.*
5. *It must have one hatch that opens and closes and is a size that your "astronauts" can easily enter/exit from. The hatch should remain shut during all drop tests.*

ASK

What questions do you have about today's challenge?

IMAGINE AND PLAN

Draw your Crew Exploration Vehicle (CEV) and show a view with the hatch. Also include an inside look at where your astronauts sit and where the internal tank is positioned:

CEV Data Table

Vehicle components	Use	Measurement or Calculation
Astronauts	Crew	Mass: _______________ grams each _______________ grams total
CEV	Carries crew to Moon	Mass: _______________ grams
Hatch	Allows entry and exit	Dimensions: _______________ cm (long) by _______________ cm (wide)
Internal Tank	Stores liquid fuel	Mass: _______________ grams Volume: _______________ cm^3
Mailing Tube	To test size constraint	Volume: _______________ cm^3

Make a drawing of a cylinder and show how to calculate volume

EXPERIMENT AND RECORD

Drop your CEV model from three different heights: 1 meter, 2 meters and 3 meters. The drop height is the *control* or *independent variable* of this experiment. Record a *dependent variable* from each drop, noting the results of the drop. For example, the number of astronauts that stayed in their seats during the drop is a dependent variable because its results are dependent upon the height of the drop.

Independent Variable **Drop Height**	**Dependent variable(s)**
1 meter	
2 meters	
3 meters	

What is the most difficult constraint to satisfy in your CEV?

____

____

List the design changes made to your CEV between trials:

____

____

____

QUALITY ASSURANCE FORM

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

Name of CEV reviewed: ________________________

Total mass of the Crew Exploration Vehicle is: _________grams

Does the CEV fit within specified dimensions?

Does the hatch open and close?

Did the astronauts stay in their seats during the drop tests?

List specific strengths of the design:

List specific weaknesses of the design:

How would you improve the design?

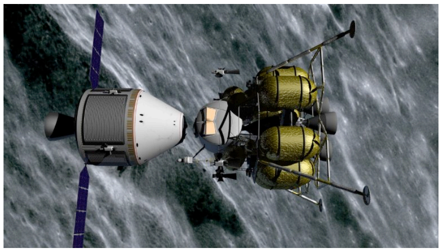
Inspected by: ______________________________________

____

____

____

FUN WITH ENGINEERING AT HOME



Today we designed and built a Crew Exploration Vehicle (CEV) model to carry astronauts to the Moon. While at home, see what you can learn about satellites and rockets that are launched into orbit. Next session, you will be designing a launcher for the Crew Exploration Vehicle. It will be important to test launch the CEV several times so that we may send humans SAFELY into space.

Sending humans back to the Moon is a highly debated subject amongst leading scientists, engineers, politicians and the public. Try hosting a family discussion about this topic. Use these questions as a guide:

1. *Do you believe we should send humans back to the Moon? Why or why not?*
2. *Would you want to go to the Moon?*
3. *What might be some of the dangers for humans in a new CEV?*
4. *What is the most dangerous part of the journey to the Moon?*

To learn more about what NASA is doing to build a CEV, go to
education.jsc.nasa.gov/explorers/p5.html
This NASA site talks about new NASA spacecraft:
www.nasa.gov/mission_pages/constellation/main/index.html

LAUNCH YOUR CEV

OBJECTIVE

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

CHALLENGE

To design and test a Reusable Launcher for the Crew Exploration Vehicle (CEV). The CEV should travel 5 meters when launched.

PROCESS SKILLS

Measuring, calculating, designing, evaluating.

MATERIALS

General building supplies

Ruler or measuring tape

C-clamps

Rubber bands of various sizes and thickness

Model CEV that was built last session

STUDENT WORKSHEETS

Design Challenge

Ask, 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 the objective is to create a launcher that gives repeatable results. It is more important for the CEV to reach 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 and ideas.

EXPERIMENT

- Students will test different rubber bands and different distances the rubber band is pulled back. One rubber band is used per experiment, but tested at three different “pull lengths”. All data is recorded in the data table.

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.

DESIGN CHALLENGE

It's Time to Launch into Space!

For years, NASA has been reusing launch components to send rockets and the Space Shuttle into space. For example, the solid rocket boosters (SRB's) on the Space Shuttle are often retrieved from the ocean, brought back to Kennedy Space Center, then cleaned and prepped for another Shuttle Launch. Why? The same reason we recycle our aluminum cans. It helps the environment and helps us save money for future launches. During this session, you must design and test a Reusable Launcher for your Crew Exploration Vehicle. On your CEV's journey to the Moon, it must first rendezvous with the International Space Station to pick up supplies. Therefore, your goal will be to launch your CEV into orbit close to the International Space Station.

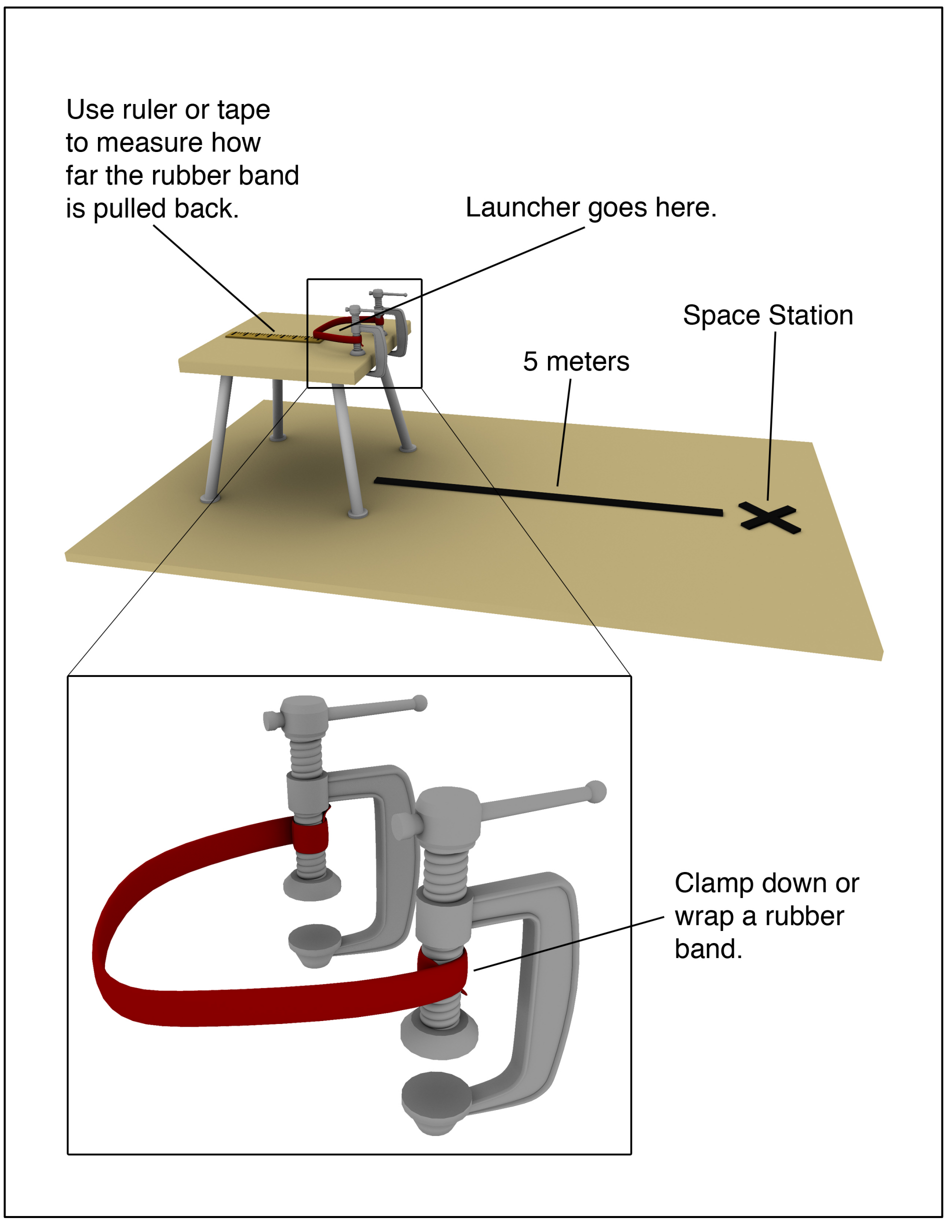
The Challenge: To design and test a Reusable Launcher with the following constraints:

1. *Launch the CEV into orbit so that it may rendezvous with the International Space Station. The goal is to launch the CEV* ***5 meters****. See the drawing on the next page.*
2. *Be reusable for each trial. If your rubber band breaks because it was pulled too far, it is not reusable for another launch.*
3. *Must determine the right combination of type of rubber band and how far it should be pulled back. You will experiment with three types of rubber bands and try three different lengths to pull those rubber bands back (think of a sling shot, but attached to a table).*
4. *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.*

ASK

What questions do you have about today's challenge?

IMAGINE AND PLAN



To the left is a drawing of how to set up your Reusable Launcher. Remember, the goal is to find the right combination of (1) type of rubber band and (2) the length it is pulled for your CEV to meet the target of the Space Station 5 meters away.

IMAGINE AND PLAN (continued)

What type of rubber bands will your team choose to use? Draw or describe them in the box below.

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

____

____

How will you test yoru rubber bands to see if they will work well as a "Reusable Launcher"?

____

____

Draw a picture of your team's Reusable Launcher:

EXPERIMENT AND RECORD

Choose your three rubber bands and set up the Reusable Launcher for your experiment. Enter the independent variables and the results of each test for each of the three rubber bands.

Trial	Independent Variables		Dependent Variables	
	Type of rubber band (description)	Rubber band pulled length (cm)	Distance traveled (m)	Distance from target (m)
1				
2				
3				
1				
2				
3				
1				
2				
3				

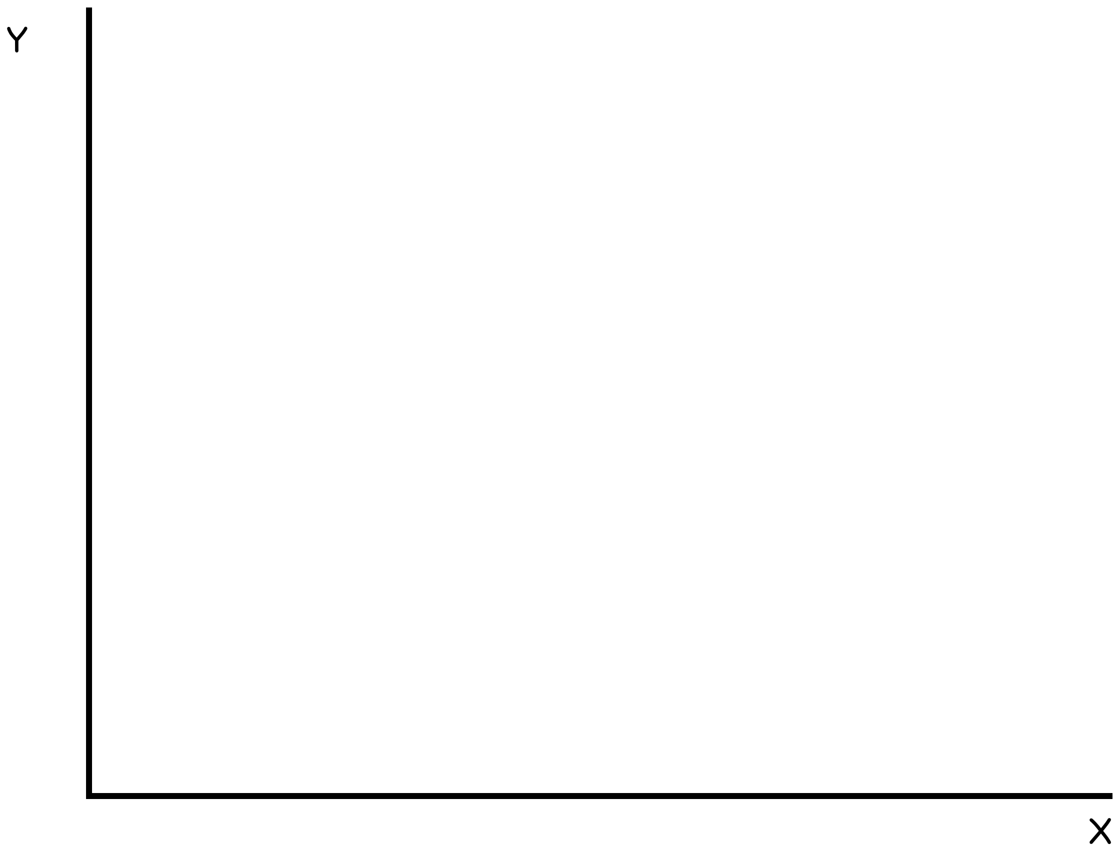
Did you get a repeatable outcome? If not, how will you improve your design to get consistent results?

____

____

EXPERIMENT AND RECORD (continued)

Use the data from the data table to make a graph of your results. The x-axis is the independent variable and the y-axis is the dependent variable. Label each axis with its measured units, and make tick marks on the graph with numbers so that you will be able to plot your data. Plot three sets of data, using a different color for each type of rubber band.



Are you able to determine if there is a relationship between the distance the rubber band is pulled and the distance that your CEV traveled? If so, describe that relationship.

____

____

____

QUALITY ASSURANCE FORM

NAMES OF ENGINEERS:

What was the dependent variable tested by the team? __________

Did the launcher successfully send the CEV 5 meters out?

If no, what was the distance accomplished by the launcher?

Did the CEV sustain any damages from the launch?

List specific strengths of the design:

List specific weaknesses of the design:

How would you improve the design?

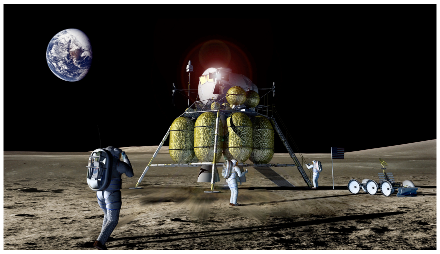
Inspected by: ______________________________________

____

____

____

FUN WITH ENGINEERING AT HOME

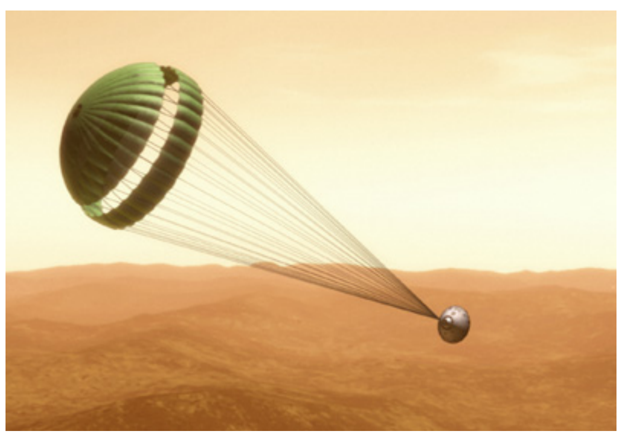


Today you designed and built a Reusable Launcher to launch the CEV model that you built last session. You were designing the Reusable Launcher to get to a certain distance (5-meters), so that the CEV could meet up with the International Space Station on its way to the Moon. We used the same process that engineers use when they build something. Share with your family this movie and have a discussion about humans returning to the Moon:

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

YOU BE THE TEACHER!

Explain to your family why we cannot use a parachute for landing on the Moon.



FILTER THE DUST

OBJECTIVE

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

CHALLENGE

To design a reusable air-filter system that will identify optimal materials that could be used to filter the air used in a lunar habitat.

PROCESS SKILLS

Measuring, counting, designing, evaluating

MATERIALS

General building supplies and tools

Digital scale

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

Quality Assurance

Fun with Engineering at Home

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 calculating percent change on their worksheets.

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 a discussion with 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 SESSION

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

Measuring percent change

The amount of increase or decrease in a value can be shown as the percent change. For example, a lunar rover might originally carry 490 kg of payload but over time that amount reduces to only 420 kg of payload.

To identify this increase or decrease in value you can use the following steps:

1. Subtract the new value from the starting value. (490 – 420 = 70 kg)
2. This number (70 kg) tells you the change in value.
3. Divide the change in value by the starting value. (70 / 490 = .1429)
4. Change the decimal number to a percent by moving the decimal point two places to the right. (.1429 = 14.29%)

Now it's your turn to practice. Identify the percent change in the following problems:

A. The lunar crater Copernicus was studied during a recent robotic mission. The first mission covered 64 km but the second mission only covered 32 km. What is the percent change in the amount of kilometers studied?

____

B. Astronauts working on the Moon would vary in the amount of calories that are needed at each meal. Nutritionists could prepare meals with roughly 3,200 calories. Smaller body types may only require the intake of 1,900 calories. What is the percent change in the amount of calories consumed by smaller body types?

____

IMAGINE AND PLAN (continued)

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

Set your pinwheel so it is standing straight up and tape it to the edge of a desk. Use a piece of masking tape to mark one blade on your pinwheel to help you count how many times the pinwheel spins.

Turn on the hairdryer and identify the farthest distance that the filter can be held from the pinwheel to still make it spin. Record that distance in the table below.

Using a stopwatch, count the number of times the pinwheel rotates in 20 seconds. Record the data below.

Filter Material	Distance of Filter from Pinwheel (cm)	Number of Pinwheel Rotations in 20 seconds
Cheesecloth		
Coffee Filter		
Fabric		

Calculate the pinwheel rotation per minute for each filter.

Filter Material	Number of Pinwheel Rotations per minute
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 the mass.
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 mass again.
3. Calculate the percent change of the sample.
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
Percent Change Of Sample	_____	_____	_____

QUALITY ASSURANCE FORM

TEAM NAME:

NAMES OF ENGINEERS:

	YES	NO
Are the filters reusable on each of the experiment designs?		
Was the percent change calculated correctly for each filter?		

How are the filters attached to the paper towel tube?

Which filter material allowed the greatest amount of airflow?

Which filter material blocked the greatest amount of lunar dust?

List the specific strengths of the design.

List the specific weakness of the design:

How would you improve the design?

Inspected by: ______________________________

Signatures: ______________________________

____

____

FUN WITH ENGINEERING AT HOME

Today we learned about how difficult it is to remove static particles from clothing and the air and how dangerous lunar dust can be to an astronaut's spacesuit. We also experiment with different ways we could filter the lunar dust particles to prevent those particles from entering a lunar habitat. Gather your family and investigate the number of household items your family uses to help these same problems. What happens when your pants stick to your legs out of the dryer? Try inspecting the air filter on their home furnace. Discuss with your family members why that filter is important to your home. Does it need to be replaced? How often should it be replaced?

YOU BE THE TEACHER!

Explain to your family why lunar dust is so different from Earth dust. How can something so small have jagged edges that can tear through material?

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

To design an experiment, gather and analyze data in order to understand the factors that affect how things get warmer and cooler (heat transfer).

PROCESS SKILLS

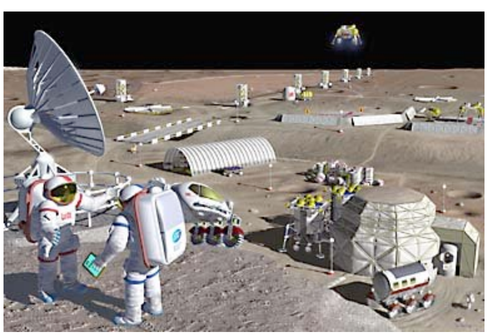
Experimental design, measuring, graphing and data analysis

MATERIALS

Thermometer
Timers
Graduate cylinders
Small plastic cups
Graph paper

WORKSHEETS

Imagine and Plan
Experiment and Record
Quality Assurance Form
Fun with Engineering at Home



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.

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.
- If there are four team members, save time by having two students do the test with the hot water while the other two students do the test with the cold water.
- Stirring the water *gently* is helpful because the temperature of the water in a small sample is usually not uniform when left sitting.
- 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 a discussion with the following questions:
  - *What insulating materials seem to aid in a decreasing thermal transfer?*
  - *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 SESSION

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. *As a team, decide upon the (a) volume of water to use in each cup and (b) how hot or how cold the water should be. Measure and fill cups.*
5. *Decide on best practice for measuring the temperature. How often should you check the temperature of the water and for how long?*
6. *For trial 2, decide on a type of insulating material to use and repeat the experiment.*
7. *Graph your results. What is the temperature in the room?*

IMAGINE AND PLAN

Today you will create and conduct an experiment to demonstrate the movement of atoms and molecules, by measuring the change in temperature. Take a few minutes and find the definitions of these words and phrases:

HEAT

____

____

TEMPERATURE

____

____

EQUILIBRIUM

____

____

THERMAL ENERGY TRANSFER

____

____

Before you begin setting up an experiment, can you predict how the temperature will change in each cup? Using the vocabulary from above, write a hypothesis to the experiment:

____

____

____

____

IMAGINE AND PLAN (continued)

Design your experiment:

How much water do you plan to use for each cup?___________________________

Where will you get your hot water? ____

Where will you get your cold water? ____

How often will you check the change in temperature of the water?_____________

What will you use as insulation for Trial 2? __________________________________

Draw your experimental set-up:

EXPERIMENT AND RECORD

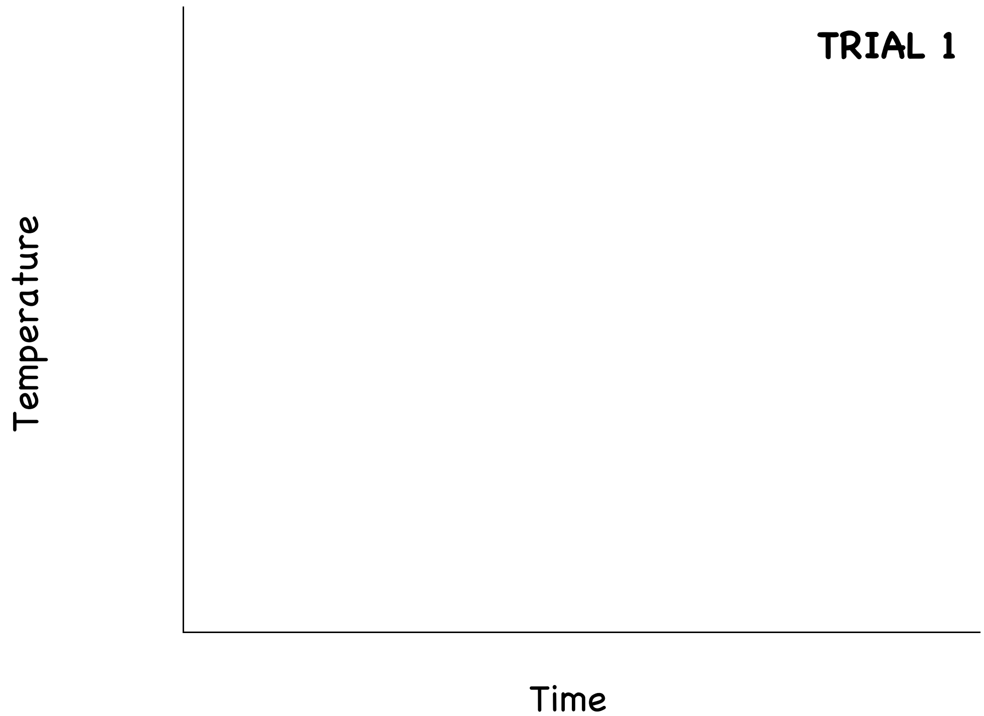
1. Record the temperature of the room: _______________ °C
2. Using a graduated cylinder, collect the cold water and pour it into one plastic cup. Repeat for hot water.
3. Record the temperature for each cup of water as planned earlier and record the results below.
4. Add an insulating material around each cup and repeat the experiment.

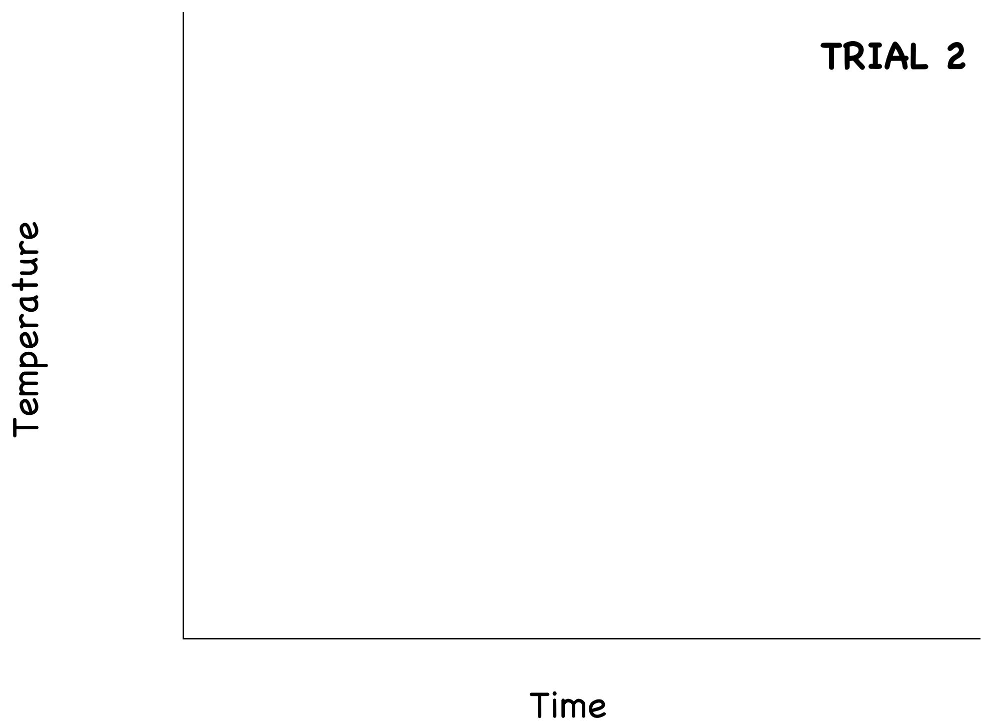
Time Min:sec	Cold Water Cup °C		Hot Water Cup °C	
	Trial 1	Trial 2	Trial 1	Trial 2
0:00				

If you need more space, continue your data table on the back of the paper.

EXPERIMENT AND RECORD (continued)

Determine the type of graph needed to show your results for each cup. Graph your results from your experiment.





QUALITY ASSURANCE FORM

TEAM NAME:

NAMES OF ENGINEERS:

	YES	NO
Were the cups properly labeled for the hot and cold water?		
Did the team use enough water to perform the experiment properly?		
Did the team graph the data correctly?		
Did the hot or cold water cup ever reach equilibrium?		

How many times was the temperature measured? ________________

List the specific strengths of the experiment.

List the specific weakness of the experiment:

How would you improve the experiment?

Inspected by: ____________________________________

Signatures: ____________________________________

____

____

FUN WITH ENGINEERING AT HOME

Today we designed an experiment to understand the principle of thermal transfer. We chose water because it is such a large part of the human body, and if we try to inhabit the Moon we will have to pay close attention to keeping the human body safe from the extremes of temperature on the surface of the Moon. While at home, why not try this same experiment with your family? All you need are the cups, a thermometer, a clock with a second hand and some insulating material. Once you complete the experiment, ask your family members these questions:

- ☆ *In science the term "**equilibrium**" refers to a system being in balance. What were the two factors (related to heat) that were trying to balance each other in this experiment?*
- ☆ *If you set out a cup of hot water on a table, what change, if any, will happen to its temperature, and when will that change stop?*
- ☆ *If you set out a cup of cold water on a table, what change, if any, will happen to its temperature, and when will that change stop?*

YOU BE THE TEACHER!

Do you think you can explain the principle of thermal transfer as it applies to boiling water for tea? What happens to the water in the tea kettle when you place it on the stove and turn the heat on?

Try and think of ways we need to insulate ourselves here on Earth to keep our bodies at "equilibrium". For example, does your family like to go camping?

BUILD A LUNAR THERMOS

OBJECTIVE

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

CHALLENGE

To design an insulator for a cup with 100ml of hot or cold water that will keep the original temperature within 5°over 5 minutes. This activity is to apply the understanding of heat transfer.

PROCESS SKILLS

Experimental design, measuring, graphing and data analysis

MATERIALS

General building supplies

Thermometer

Timers

Graduate cylinders

Small and large plastic cups

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

WORKSHEETS

Imagine and Plan

Experiment and Record

Quality Assurance

Fun with Engineering at Home

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 pictures 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.

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.

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 a discussion with the following questions:
  - *Did your thermos meet the design specification?*
  - *How long should a thermos keep something warm (or cool) to make it a "good" thermos?*
  - *Does it matter, then, whether the application of keeping my soup warm until lunch is as effective as keeping my body at roughly "body temperature" when on the Moon?*
  - *Can you create your own design specifications for building a thermos to keep soup warm and building a suit to keep a body warm on the Moon? How would they differ?*

PREVIEWING NEXT SESSION

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}C over 8 minutes. You can use any combination of materials as your insulation.

IMAGINE AND PLAN

1. Draw a picture of a warm human standing on the Moon in the cold, lunar night. Label what is warm and what is cold and use arrows to show the direction of heat transfer.

2. Now imagine that the sun comes up, and the human is standing on the hot lunar surface. Re-draw the picture, and add the same labels: warm, cool, and which way the heat transfers.

3. Now, imagine a method for keeping the human not too warm, not too cool, but just right! Draw a picture or write a paragraph to explain your method for keeping the human at the right temperature for the cold nights and hot days.

IMAGINE AND PLAN (continued)

Design your experiment:

Do you need to design the experiment differently for the two different temperatures of water? Why or why not?

____

____

____

____

What will you use as insulation? ______________________________________

Draw your experimental set-up:

EXPERIMENT AND RECORD

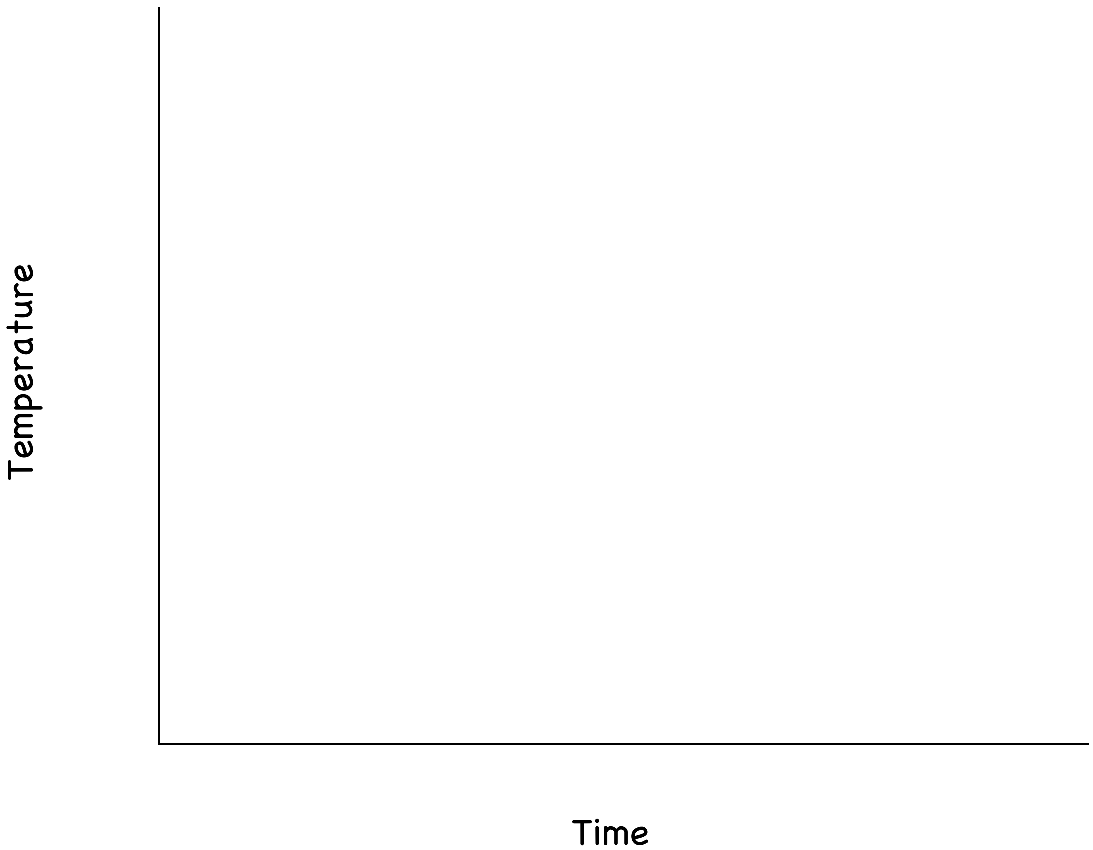
1. Collect necessary materials and insulate your cups.
2. Record the temperature of the room: _______________ °C
3. Using a graduated cylinder, collect 100 mL of each type of water and pour it into their designated cups.
4. Record the temperature of the water and enter your data below.

Time Min:sec	Cold Water Temperature °C	Hot Water Temperature °C
:00		
1:00		
2:00		
3:00		
4:00		
5:00		
6:00		
7:00		
8:00		

	Cold Water (warm up rate)	Hot Water (cool down rate)
Start temperature		
End temperature		
Temperature Difference		

EXPERIMENT AND RECORD (continued)

Graph the results from your experiment.



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

____

____

How do these results differ from the results of the experiment of the previous session? (e.g. how do the slopes of the lines differ?)

____

____

QUALITY ASSURANCE FORM

NAMES OF ENGINEERS:

	YES	NO
Were the cups properly insulated?		
Did the insulation around the cups slow down thermal transfer?		
Did the team graph the data correctly?		
Did the hot or cold water cups ever reach equilibrium?		

Calculate the rate of change in the hot water cup.

Change in temperature / 8 minutes =

____________________ ^{o}C per min

List the specific strengths of the experiment.

List the specific weakness of the experiment:

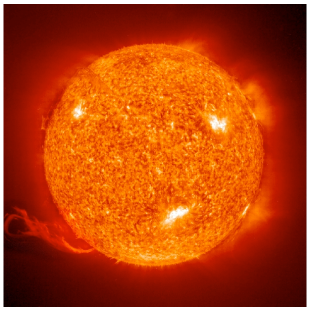
How would you improve the experiment?

Inspected by: ____

Signatures: ____

____

____



During the last two sessions we have learned about the flow of heat and how objects try to reach equilibrium. We also experimented with a way to slow down that thermal transfer. What would happen if we actually wanted to harness that energy?

Talk with your family members about all the ways we could use energy from the Sun to do work for us. Can you think of four (man made or nature)?

1.
2.
3.
4.

Challenge: Identify at least four NASA spacecraft that use solar panels.

(The picture below is your first clue!)

1.
2.
3.
4.

BUILD A SOLAR OVEN

OBJECTIVE

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

CHALLENGE

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

General building supplies

Thermometer

Timers

Cardboard box

Aluminum pans

Aluminum foil

Black construction paper

One piece of plexiglass big enough to cover the box

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

Quality Assurance

Fun with Engineering at Home

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 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 with the following questions:
  - *Whose oven had the highest temperature? What was that temperature?*
  - *Whose oven melted the marshmallows and the chocolate?*
  - *What could you have done to make your solar oven work better?*
  - *Does it make a difference using actual sunlight compared to light from a lamp? Why or why not?*
  - *What else could you cook using a solar oven?*
  - *How did the distances from the bottom reflective surface affect the cooking of the food in your oven?*

END OF PROGRAM

This session concludes the NASA Beginning, Engineering, Science and Technology series. 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. Print 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?

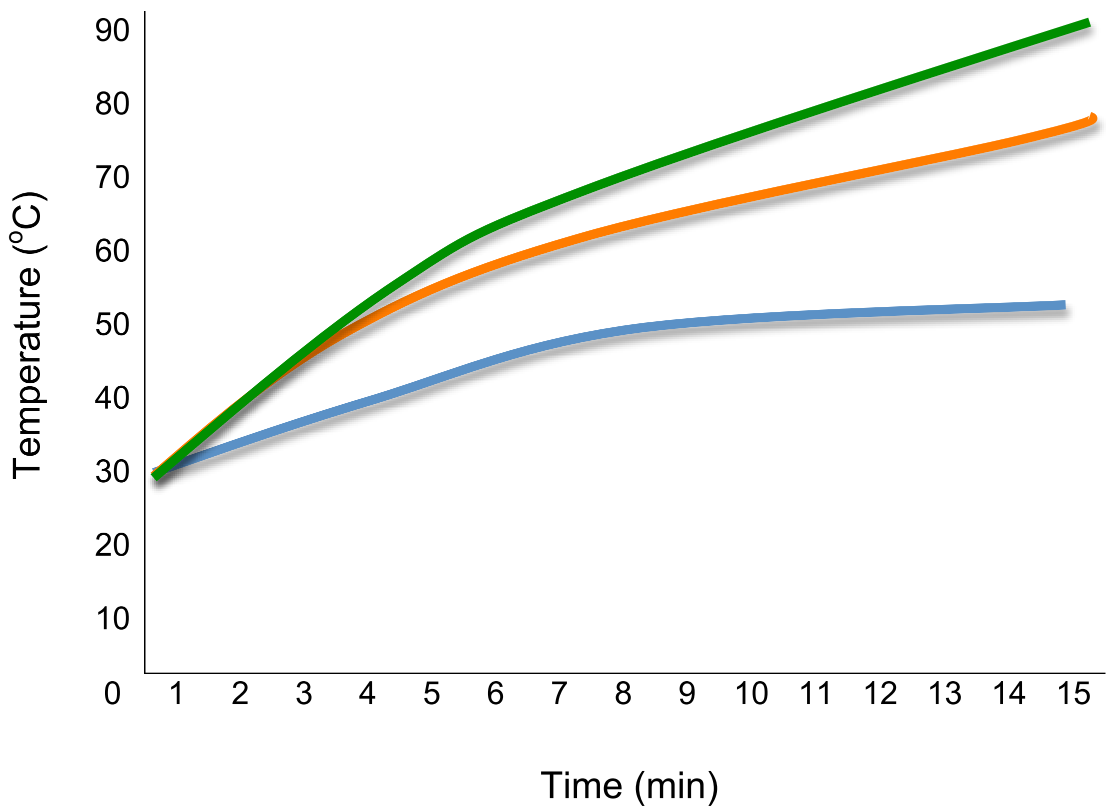
While we might have to bring just about everything with us when we establish a habitat on the Moon, one thing we won't need is solar energy. There may be no atmosphere, no climate nor weather on the Moon, but that all means it DOES make it an ideal place to collect solar energy. The majority of the Moon 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 and a few extra materials. 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 15°C.*
3. *You may use any available materials to line the bottom and inside of box.*
4. *Your food may not touch the bottom of the oven directly. You must design a way to best cook the two S'mores without touching the bottom.*
5. *You must cook the two S'mores at two different heights. You will also test which height allows food to cook at a faster rate.*

IMAGINE AND PLAN

Below is a graph showing data that demonstrates the efficiency of three different solar oven designs: (1) plain box, (2) box with a black bottom and (3) a box with aluminum foil and a black bottom.



Which line (blue, orange or green) do you think represents the solar oven that is just an empty box? Explain why.

____

Which of line do you think represents the solar oven with aluminum foil and a black bottom? Explain why.

____

What purpose do you think aluminum foil might serve?

____

____

IMAGINE AND PLAN

How will you meet the design constraint of the food not being allowed to touch the bottom surface of the solar oven?

____

____

____

Predict how the height of your food from the bottom surface will affect how quickly it is cooked.

____

____

Draw and label 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. Record the heights of the food from the oven floor: ______ cm ______ cm
4. Place the S'mores in the oven. Close the lid and begin cooking.
5. 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	

EXPERIMENT AND RECORD (continued)

Record any observations of your food while it is cooking. These observations will help to determine which food placement height allows for quicker cooking.

Time Min:sec	S'more 1 ______ cm	S'more 2 ______ cm
1:00		
2:00		
3:00		
4:00		
5:00		
6:00		
7:00		
8:00		
9:00		
10:00		

QUALITY ASSURANCE FORM

TEAM NAME:

NAMES OF ENGINEERS:

	YES	NO
Did the solar oven increase in temperature by more than 10ºC?		
Did this team's design differ from your team's design?		
Did both S'mores melt?		

Which height position worked best in this solar oven? ________

List the specific strengths of the design:

List the specific weakness of the design:

How would you improve the design?

Inspected by: ____________________________________

Signatures: ____________________________________

____

____

FUN WITH ENGINEERING AT HOME

Today we learned a fun way to harness the Sun's energy, trapping the radiant heat from the Sun to cook food. With your family members, look up the meaning of "the greenhouse effect". Can you explain what "the greenhouse effect" has to do with the solar oven your team designed and built?

Discuss with your family members the following question:

Why do we use the term "the greenhouse effect" when talking about global warming?

YOU BE THE TEACHER!

Show your family how to build a solar oven. Test it out by cooking something new. How about baking a pizza in your solar oven? Grab a frozen pizza from the store or make one from scratch. Use the results of your experiment to determine at what height to place your pizza in the oven.

This marks the end to the NASA Beginning, Engineering, Science and Technology series. We encourage you to continue to look for more activities, articles and podcasts about NASA any day and every day!

www.nasa.gov

ALIGNMENT TO NATIONAL STANDARDS

SCIENCE

	6	7	8
Science as Inquiry			
Develop abilities necessary to do scientific inquiry.	✓	✓	✓
Develop understanding about scientific inquiry.	✓	✓	✓
Develop understanding of objects in the sky.	✓	✓	✓
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.	✓	✓	✓
Physical Science			
Motions and forces	✓		✓
Transfer of Energy			✓

TECHNOLOGY & ENGINEERING

	6	7	8
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

	6	7	8
Numbers and Operations			
Compute fluently and make reasonable estimates.	✓	✓	✓
Measurement			
Understand measureable attributes of objects and the units, systems, and processes of measurement.	✓	✓	✓
Understand, select and use units of appropriate size and type of measure angles, perimeter, area, surface area, mass, temperature and volume.	✓	✓	✓
Solve problems involving scale factors, using ratio and proportion.	✓	✓	✓
Data Analysis and Probability			
Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.	✓	✓	✓
Select and use appropriate statistical methods to analyze data.	✓	✓	✓
Develop and evaluate inferences and predictions that are based on data.	✓	✓	✓
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.	✓	✓	✓
Algebra			
Use mathematical models to represent and understand quantitative relationship.	✓	✓	✓
Analyze change in various contexts.	✓	✓	✓
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.	✓	✓	✓

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

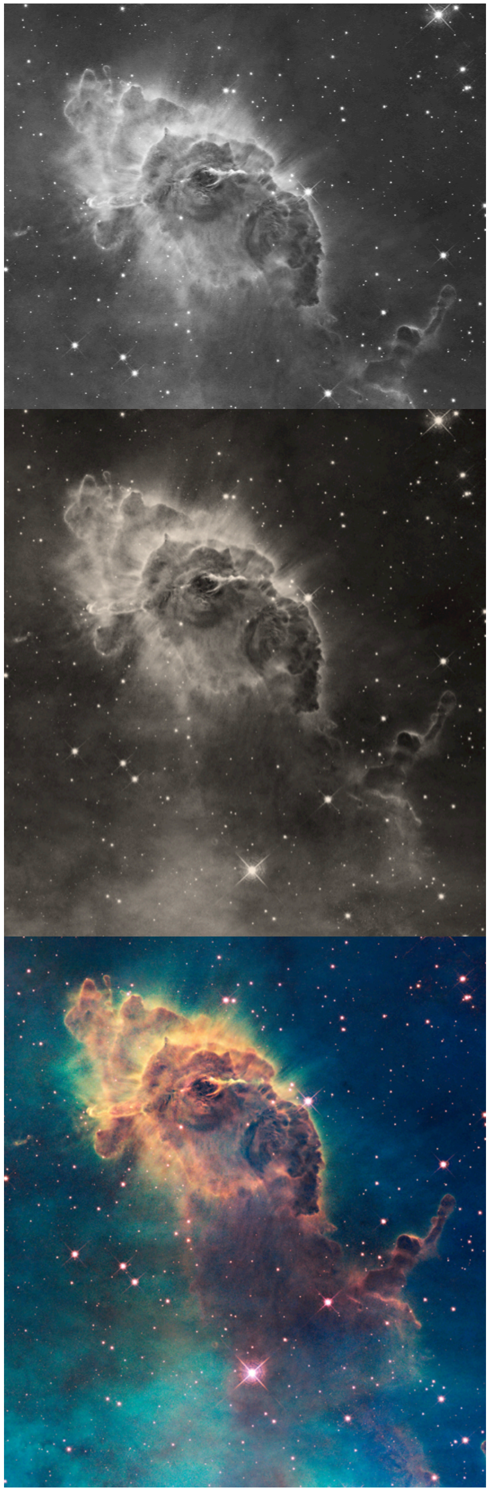
learners.gsfc.nasa.gov/PREP/

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.