NASA's BEST Activities

***B**eginning **E**ngineering **S**cience and **T**echnology*

An Educators Guide to Engineering Clubs

Grades 6-8

Table of Contents

General Supplies List for Activities 1-12

The General Supplies list is only a suggested list of supplies. The intent is to provide a wide variety of simple, readily available, relatively inexpensive, building supplies. Any particular item may be substituted for, and additional materials will only positively contribute toward supporting the imagination of the students.

General Club Supplies	Quantity
9-V Battery (for digital balance)	2
Aluminum foil sheets	100
Balance (digital; 1 g limit)	1
Balloons (assorted shapes and size)	100
Binder (1" plastic – 3 ring)	24
Bubble wrap	100 square feet
Bulldog clips	1 box-small
C - clamps	1 pk-2 (2")
Cardboard	10 square feet
Cards (3" x 5")	100
Clear tape (adhesive)	10
Clothes pins	30
Construction paper	50 sheets
Copy paper (multi-use)	2 reams
Cotton Balls	50
Craft Sticks	100
Cups - styrofoam (approx 8 oz)	20
Cups - paper (3 oz cone)	30
Cups – plastic (approx 8 oz)	20
Duct tape	1 roll
Eggs – plastic	10
Fishing line - 20 lb test	1 roll
Glue sticks	20
Graph paper	100
Manila folders	20
Masking tape	5 rolls
Meter stick	3
Paper bags (small - approx 1-2 qt)	20
Paper Clips (jumbo)	1 box
Paper clips (small)	1 box
Pencils	10
Pipe cleaners	100
People or action figures (small – plastic)	20

Popsicle sticks	100
Rubber bands (large - No 33)	1 bag - 1/4 lb
Rubber bands (regular - No 16)	1 bag - 1/4 lb
Ruler	10
School glue	10
Stapler	10
Staples	500
Stirrers – plastic	50
Stopwatch	5
Storage Box (large - approx 12 gal)	1
Straws (Drinking)	100
String	1 roll
Tape Measure	1
Tongue depressors (plain or foam-covered)	50
Wrap – plastic	1 roll
Storage bags (1 gal)	50
Storage bags (1 qt)	50

Activity-Specific Supplies List

Activity	Activity Name	Specific supplies (6 - 8)
1	**Build a Satellite**	Mailing tube (4" inside diam) or shoe box
	To Orbit the Moon	Small candies or weights (e.g. Shocktarts)
		Different small candies or weights (e.g. Sweetart chews)
2	**Launch Your Satellite**	Toilet paper rolls
		Balloons (assorted size, shape)
		Fishing line (approx 20 lb test)
		Clamps (C-type or other)
		Binder clips
		Clothes Pins
		Rulers or meter sticks

3	**Design a Lunar Rover**	"Astronauts" (2-cm plastic)
		Plastic egg
		Plastic wheels for rover
		Ramp for LR to Roll Down
		Pennies
		Rulers or meter sticks
4	**Design a Landing Pod**	Bubble wrap (not required)
5	**Landing the Rover**	Bubble wrap (not required)
6	**Mission Preparation**	Rulers
		Graph paper
7	**Mission Execution**	Rulers
		Graph paper
		Blindfolds
8	**Design the New CEV**	Mailing tube (4" inside diam)
		"Astronauts" (2-cm plastic)
9	**Launch the CEV**	CEV (built the previous week)
		Clamps
		Rubber bands
10	**It's Either Very Hot or Very Cold Up There**	Graduated cylinders
		Hot and cold water
		Thermometers
		Stopwatch
		Cups (plastic - approx 12 oz)
		Insulation materials
		Graph paper
		Chart paper

11	**Build a Lunar Thermos**	Graduated cylinders
		Hot and cold water
		Thermometers
		Stopwatch
		Cups (plastic - approx 5 oz)
		Cups (plastic - approx 12 oz)
		Insulation materials
		Graph paper
12	**Build a Solar Oven**	Thermometers
		Timers
		Cardboard box
		Plexiglass cover
		Aluminum foil
		Materials to heat (ex "S'mores")
		Gooseneck Lamp - 250 W bulb

National Mathematics Education Standards

Content Standard	Strand(s)	1	2	3	4	5	6	7	8	9	10	11	12
Number and Operations	Compute fluently and make reasonable estimates	*	*	*	*	*	*	*	*	*	*	*	*
Measurement	Understand measurable attributes of objects and the units, systems, and processes of measurement.	*	*	*	*	*	*	*	*	*	*	*	*
	Understand, select, and use units of appropriate size and type to measure angles, perimeter, area, surface area, mass, temperature, and volume.		*	*	*	*	*	*	*	*	*	*	*
	Solve problems involving scale factors, using ratio and proportion;			*		*							
Data Analysis and Probability	Develop and evaluate inferences and predictions that are based on data.	*	*	*	*	*	*	*	*	*	*	*	*
	Select and use appropriate statistical methods to analyze data.		*	*	*	*			*	*	*	*	*
Algebra	Use mathematical models to represent and understand quantitative relationships		*										
	Analyze change in various contexts.		*	*		*					*	*	*

National Science Education Standards

Content Standard	Strand(s)	1	2	3	4	5	6	7	8	9	10	11	12
Science as Inquiry	Develop abilities necessary to do scientific inquiry	*	*	*	*	*	*	*	*	*	*	*	*
	Develop understanding about scientific inquiry	*	*	*	*	*	*	*	*	*	*	*	*
Earth and Space Science	Structure of the earth system												
	Earth's History												
	Earth in the solar system												
Science and Technology	Develop abilities of technological design	*	*	*	*	*	*	*	*	*	*	*	*
	Develop understanding about science and technology	*	*	*	*	*	*	*	*	*	*	*	*
History of Nature and Science	Develop understanding of science as a human endeavor	*	*	*	*	*	*	*	*	*	*	*	*
	Nature of Science												
	History of Science												
Physical Science	Properties of and changes in states of matter										*	*	*
	Motions and forces		*	*	*	*	*	*		*			
	Transfer of Energy		*			*				*	*	*	*
Personal and Social Perspectives	Science and technology in society	*	*	*	*	*	*	*	*	*	*	*	*
	Populations, resources, and environments						*	*				*	*

National Technology and Engineering Education Standards

Content Standard	Strand(s)	1	2	3	4	5	6	7	8	9	10	11	12
Basic Operations and Concepts	Understanding of the nature and operation of technology systems.	*	*	*	*	*	*	*	*	*	*	*	*
	Proficiency in the use of technology.												
Technology Research Tools	Use of technology to locate, evaluate and collect information from a variety of sources.	*	*	*	*	*	*	*	*	*	*	*	*
	Use technology tools to process data and report results.												
	Evaluate and select new information resources and technological innovations based on the appropriateness for specific tasks.												
Technology Problem-solving and Decision-making Tools	Employ technology in the development of strategies for solving problems in the real world.	*	*	*	*	*	*	*	*	*	*	*	*
	Use technology resources for solving problems and making informed decisions.	*	*	*	*	*	*	*	*	*	*	*	*
Engineering Design	Brainstorming	*	*	*	*	*	*	*	*	*	*	*	*
	Modeling, Testing, Evaluating, and Modifying	*	*	*	*	*	*	*	*	*	*	*	*

NASA's BEST Activities
Beginning Engineering Science and Technology

Lesson Plan Cover Pages for Activity #______

Unit Title:

Objective(s):

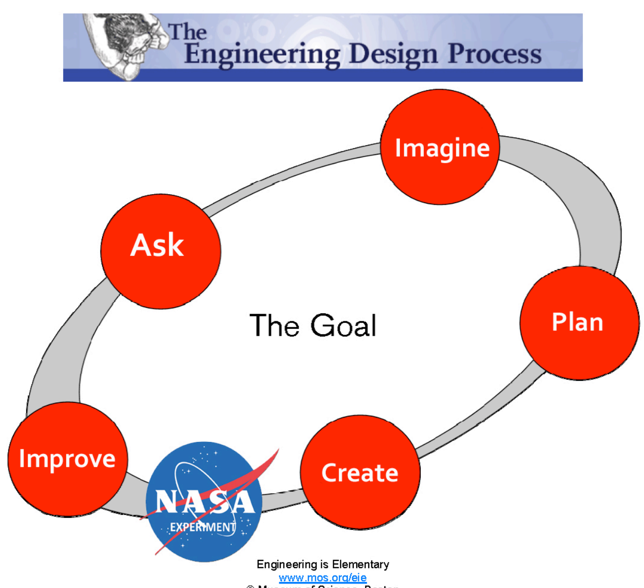
Evaluation procedures:

Materials:

Instructional procedures:

Stage 1: Motivation

- Motivate students by telling them how excited you are about the club – let them know that they are very special; they will be learning how to become ENGINEERS.
- Spend a few minutes asking them if they know what engineers do. Let them know that we will be experiencing what engineers do during our time together today. Take a few minutes to review the Engineering Design Process steps.



Stage 2: Set the Stage: Ask, Imagine, Plan

- The **Design Story and Challenge** will paint the picture or set the context for the students for this first challenge. It is important that you set the context with this story before jumping into the challenge. It is this story that makes the science, mathematics and engineering come to life; it is the story that makes the hands on activities have relevance and meaning.
- Share the **Design Story and Challenge** orally with the students (provided in teacher pages). Have them ask questions about the challenge. This is the **ASK** phase of the Engineering Design Process.
- Put the students in teams of 3 around the room – try to separate the teams so they are not working "on top" of one another.
- Encourage students to **IMAGINE and PLAN** before building. Ask them to use their worksheets to capture their design ideas. Ask them to list the challenges they face in meeting the design constraints.

Stage 3: Create and Experiment

- Discuss how important **EXPERIMENTING** and feedback is for engineers. The *imagine, plan, create, experiment, improve* loop is key for engineers to be successful.
- Ask members of each team to check calculations and check designs and models to make sure they are within specified design constraints.
- For activities that require the use of thermometers - Remember, the thermometers are glass. They have a small rubber "keeper" on them so that they will not roll on a table when laid down. Tell the students that someone should always be holding the thermometer, they should never just stand it up in a cup and remove their hand (because it will tip over, spilling the water and possibly breaking the thermometer).

Stage 4: Re-Design and Re-Build - Improve

- Time permitting, allow students to re-design and re-build **(IMPROVE)** their projects based on experiment notes and observations.

Stage 5: Challenge Closure

- When discussing Challenge Closure questions with student teams, you may not always receive suggested answers. Try to facilitate an interaction where you put these thoughts in play and ask for feedback. Encourage all teams to offer thoughts.

Stage 6: Previewing Next Week

- Previewing stage is specific to each week's topic. Please see individual lesson plans for extensive descriptions.

Activity #1: Build a Satellite to Orbit the Moon!

This activity was adapted from
www.lpi.usra.edu/education/explore/moon/lro.shtml

Activity Objective(s):	The teams' challenge is to design and build a satellite that falls within certain **size** and **mass** limits. This satellite will be designed to orbit the Moon. It will have to carry some combination of cameras, gravity probes, and heat sensors to look at or probe the Moon's surface. The satellite should withstand a 1-meter Drop Test without any parts falling off of it.
Lesson Duration:	One 60 - 90 minute session
Process Skills:	Measuring, calculating, designing, evaluating.
Materials and Tools: (Per group of 3 students)	General building supplies 1 Bag "Shockers" candy 1 Bag "Chewy Sweet Tarts" candy 1 Mailing tube or shoebox or other container (used as a size constraint)
Club Worksheets: (Make copies for each student to put in binder.)	Engineering Design Process Detector or Instrument Table of Uses and Masses Satellite IMAGINE and PLAN EXPERIMENT Notes Satellite Re-design Summary - Questions/Discussions for Understanding Fun with Engineering at Home Quality Assurance - Checking Each Other's Satellite Models

Club Facilitator or Teacher Notes for Activity #1:

Stage 1: Meet and Motivate

- Give students nametags and have them go around and share their names – it is important that everyone get to learn the names of the club participants.
- Spend a few minutes asking them if they know what engineers do….. then let them know that we will be experiencing what engineers do during our time together today….. Take a few minutes to go over the Engineering Design Process steps – hand out the ***Engineering Design Process*** Worksheet.

Stage 2: Set the Stage, Ask, Imagine, Plan

- Share the **Design Story and Challenge** orally with the students (see page).
- Hand out the ***Detector or Instrument Table of Uses and Masses*** worksheet and the ***Satellite IMAGINE and PLAN Worksheet*** (1 of each of these worksheets per team)
- Let the challenge begin and encourage them to **IMAGINE and PLAN** before building.

Stage 3: Create and Experiment

- Give out the scissors, glue and tape. Challenge the teams to **CREATE** or build their satellites based on their designs. Remind them to keep within specifications.
- Ask members of each team to check mathematical calculations and check designs and models to make sure they are within specified design constraints.
- Hand out the **EXPERIMENT Notes** worksheet. Discuss how important **EXPERIMENTING** and feedback is for engineers.

Stage 4: Improve

- Use experiment results to **IMPROVE** (Re-Design and Re-Build) satellite models.

Stage 5: Challenge Closure

- Give out the Summary: Questions/Discussion for Understanding worksheet (1 per team). Ask each team to fill out the worksheet.
- In summary have a short discussion with all teams. Ask them, “What was the greatest challenge for your team today?” Expect answers such as:

- Planning and creating a satellite with detectors that fits within a certain space and weight set of specifications
- Calculate weights of instruments/detectors, making sure that our instruments do not add up to more than the allowed weight limit
- Getting the instruments to deploy properly
- Consider what it means to build something that will be launched into space
- Work as a team, communicate
- Imagine, plan, create, experiment, improve steps

Stage 6: Previewing Next Week

- Ask teams to bring back their satellite model for use in next week's club challenge. They will be launching the satellite using a balloon rocket. You may want to store them in the classroom or have one of the facilitators be responsible for their safe return next week.
- Ask teams to think about satellites during the next week, ask their parents about satellites, look up satellites in books or on the Internet.
- Please give each student the *Fun With Engineering at Home* worksheet. Tell them to share this sheet with their family. Tell them to ask their family to help them with the Home Challenge found on this sheet.

Special Notes: For Those with 90 minute Clubs

Quality Assurance

- Hand out the Quality Assurance Test worksheets (1 per team) and ask them to fill out the top section with team name and participants' names.
- Ask each team to put their satellite model together with their Quality Assurance Test worksheet around the edges of the room. Ask each team to move one notch clockwise to offer feedback to the neighboring team, using the Quality Assurance Test worksheet.
- The Quality Assurance Team conducts the Drop Test and records their findings.

Design Story and Challenge: (For Teacher Use)

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, and will ultimately help them determine the best locations for future human missions 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 <u>way</u> 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 we need to make exact maps of the Moon's surface. And, for safety, we need to make careful measurements of the radiation falling on the lunar surface so that we may design ways to protect humans from the radiation.

The different instruments are designed, tested, and assembled by different teams of engineers and scientists. The separate teams have to work together to make sure that the instruments are the right weight, fit correctly, and make proper measurements.

Overall, the <u>mass</u> of anything we want to send into space is the most challenging problem for the engineers. The more mass an object has, the more energy it takes to launch it.

Design Challenge

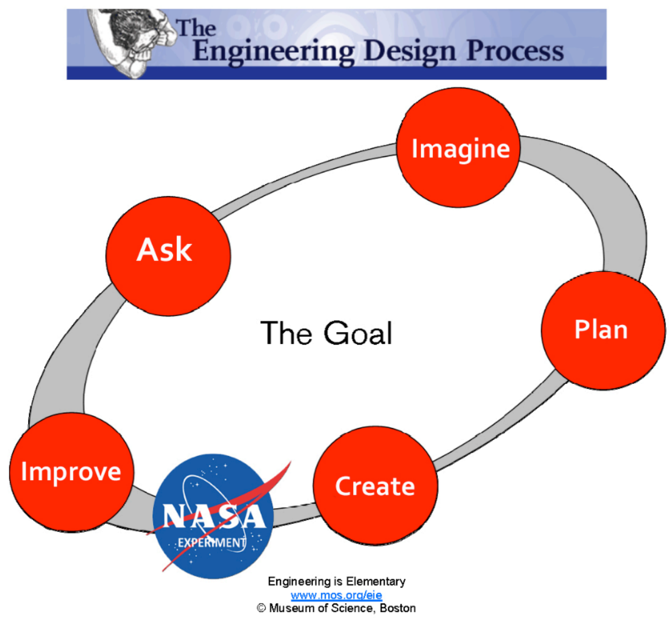
The students must build a model of a lunar exploration satellite with the general building supplies, using the candies as the various instruments. The total mass of the instruments, detectors, probes, sensors and solar cells (that provide electricity) can be no greater than **45 kilograms**. The satellite cannot be launched if the mass of instruments, detectors, probes and solar cells exceeds a total of 45 kilograms, so choose your instruments carefully (the satellite infrastructure is separate and the engineers need not be concerned with its mass for this activity). Also, the satellite must **fit within the provided cardboard mailing tube or shoebox**. 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. Additionally the orbiter must withstand a 1-meter Drop Test without any pieces falling off.

Student Worksheets for Activity # 1

Build a Satellite to Orbit the Moon!

Artist's conception of the Lunar Reconnaissance Orbiter - Image courtesy of NASA.

<u>Engineering Process</u>



The Engineering Design Process is a series of steps that engineers use to guide them as they solve problems.

1. **Ask** a question or set a challenge
2. **Imagine** a solution to the question or challenge
3. **Plan** a solution - Include drawings and diagrams
4. **Create** – Follow your Plan, build your design
5. **Experiment** – Test what you've built
6. **Improve** – Talk about what works and what doesn't; modify your creation.

Detector and Instrument Table of Uses and Masses

Detectors or Instruments (Candy Pieces)	Use	Mass
Camera (3 Blue Shockers)	Takes Pictures (needs 1 solar cell to operate)	30 kilograms
Gravity Probe (2 Orange Shockers)	Measures Gravity (needs 2 solar cells to operate)	20 kilograms
Heat Sensor (1 Purple Shocker)	Measures Temperature (needs 3 solar cells to operate)	10 kilograms
Solar Cell (1 chewy sweet tart)	Collects Energy from the Sun to Power an Instrument, Detector, Sensor, or Probe	1 kilogram

Design Challenge: NASA is sending a satellite to the Moon to take pictures to decide where to build a lunar base for people to live and work. The satellite is also looking for evidence of ice on the Moon. The satellite must fit within the launch tube and the mass of the instrument package must not exceed 45 kilograms (the satellite infrastructure is separate, and the engineers need not be concerned with its mass for this activity). 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. The finished product must withstand a 1-meter Drop Test.

Satellite IMAGINE and PLAN Sheet

Team Name: ____

List of Materials That Our Group Will Use:

Data Table for Instrument Package

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:	

Draw the top view of the satellite with Instruments and Solar Cells

Bottom View of Our Satellite with Instruments and Solar Cells

Left Side View of Our Satellite with Instruments and Solar Cells

Right Side View of Our Satellite with Instruments and Solar Cells

EXPERIMENT Notes

What happens when we drop the satellite from 1 meter?

Do any pieces fall off?

How will the instruments deploy when the satellite is launched?

Does the way the satellite gets launched affect how the instruments are deployed?

Satellite Re-Design

We made the following changes to our satellite:

The total mass of our instruments and solar cells is:

Our new drawing of our satellite is:

Summary: Questions/Discussions for Understanding

List two things you learned about what **engineers** do through building your satellite today:

1.

2.

What was the greatest difficulty you and your team had today while trying to complete the satellite challenge?

Tell how you solved your greatest team difficulty in 2-3 sentences.

Team Name: ____

Fun with Engineering at Home

Lesson 1: Building a Satellite to Orbit the Moon!

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. Then 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 team station and tried to **IMPROVE** our satellite. These are the same 6 steps engineers use when they try to solve a problem or a challenge.

Home Challenge: During this week, 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 satellites carry that are currently orbiting the earth.

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

1. World Book at NASA: Artificial Satellites
www.nasa.gov/worldbook
2. The World Almanac for Kids Science: Artificial Satellites
www.worldalmanacforkids.com
3. NASA Space Place
spaceplace.nasa.gov/en/kids/quiz_show/ep001/

Ask your parents, grandparents, brothers or sisters to help you find out more about satellites. Have fun!

Quality Assurance – Checking Each Others' Satellite Models

Team Name: ______________________________

Participants' Names: ______________________________

____

____

To be filled in by the Quality Assurance team:

Fits within specified tube: YES or NO

Did the satellite withstand the Drop Test? YES or NO

Will the instruments deploy upon launch? YES or NO

Total volume of the satellite is: ______________ cm^3

How did you estimate the volume of 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 Team: ______________________________

Participant Signatures: ______________________________

____

____

Activity #2:   Launch Your Satellite!

Image of a Delta rocket at lift-off. Courtesy of NASA.

Activity Objective(s):	The teams' challenge is to launch the lunar satellite that they built last week using a balloon rocket. The objective is to get your satellite to go as far as possible.
Lesson Duration:	One 60-90 minute session
Process Skills:	Observing, communicating, measuring, collecting data, inferring, predicting, making models.
Materials and Tools: (Per group of 3 students)	Satellite model from last week's activity General building supplies Binder clips or clothes pins Round balloons (several per group) 5 meter fishing line set-up strung between two tables
Club Worksheets: (Make copies for each student to put in binder.)	Rocket Elements Balloon Rocket Assembly Design Data Tables and Graphs Experiment Notes Improvement Phase of Rocket Design Summary Fun With Engineering at Home Quality Assurance

NOTE: This activity was adapted from NASA educational products:
Rockets Educator Guide EG-2003-01-108-HQ www.nasa.gov/pdf/58269main_Rockets.Guide.pdf

Club Facilitator or Teacher Notes for Activity #2:

Pre-Activity Set-up: The fishing line apparatus should be at least 5 meters in length. Clamp or tie one end at table height and stretch the line across the space to another table at the same level. Holding the free end of the line taught for each trial enables easily restringing the successive balloon rockets. The line <u>must</u> be very taut for best results. Shoot the rockets toward the c-clamped end. Two fishing line set-ups should be sufficient for most clubs.

<u>Stage 1: Meet and Motivate</u>

- Keep the same grouping of children from week #1 and ask everyone to retrieve their satellite.
- Re-share the **Design Story** orally with the students (provided in teacher pages in Activity 1). This week the **ASK** phase of the Engineering Design Process is, *How can we best launch our satellite to go to the Moon?* We need for it to go <u>far</u> to get into orbit around the Moon. *The objective is to plan and create a rocket that will take our satellite as far as possible.*

<u>Stage 2: Set the Stage, Ask, Imagine, Plan</u>

- Talk about the need for a rocket to launch their satellite from last session. The engineer-students must now imagine, plan and create a way to attach their satellite to a balloon rocket. The balloon rocket is attached to a straw that slides along the fishing line.
- Demonstrate how a balloon rocket works by sending a balloon connected to a straw along the fishing line using a push from your hands. 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.
- Hand out the ***Rocket Elements Data Table*** and the ***Rocket Design Sheet*** (1 of each of these worksheets per team). Ask them to think about the different rocket elements on the *Rocket Elements* data table – which ones will they concentrate on as a team? <u>Make sure they understand that they may only change ONE variable during any set of trials.</u>
- Let the challenge begin and encourage them to **IMAGINE and PLAN** before building.

<u>Stage 3: Create and Experiment</u>

- Challenge the teams to **CREATE** or build their rockets based on their plans. Remind them to keep within specifications.
- Hand out **Experiment Notes** worksheet.
- Send each team to their assigned launch sites to test their rockets, filling in the data table as they conduct each trial launch.

Stage 4: Improve

- Teams return to their rockets and satellites to make adjustments to their rockets. Hand out the Improvement Phase of Rocket Design worksheet.
- Teams re-launch satellites for one last measurement to try to improve their rocket's launch distance using the data from all of their trials to optimize the design. Write down the new data.
- At the end of the session, teams report out how far their rocket traveled, and explain which combination of variables gave the best results.

Stage 5: Challenge Closure

- Give out the Summary: Questions/Discussion for Understanding worksheet (1 per team).
- In summary have a short discussion with all teams. Ask them, "What was the greatest challenge for your team today?" Expect answers such as:
  - Deciding which rocket elements to change and why
  - Considering how to change the rocket elements
  - Working as a team, communicate
  - Imagine, plan, create, experiment, improve steps

Stage 6: Previewing Next Week

- Ask students to think about how their satellite design would have to change to carry human beings. In a few weeks they will build a Crew Exploration Vehicle model to take people to the Moon.
- Next week, students will begin to think about how exploration will be done before we send humans back to the Moon. Initially, we will need to develop lunar rovers and students will have the chance to design a Lunar Rover.

Special Notes: For Those with 90 minute Clubs

Quality Assurance

- Hand out the ***Quality Assurance*** worksheets (1 per team) and ask them to fill out the top section with team name and participants' names.
- Ask each team to take their satellite, rocket and their quality assurance test worksheet to their assigned launch site. Ask each team to move one notch clockwise to offer feedback to the neighboring team, using the Quality Assurance Test worksheet.
- Ask each team to test their neighbor's rocket and offer them feedback on the quality assurance test worksheet.

Student Worksheets for Activity #2 - Launch Your Satellite!

Image of a Delta rocket at lift-off – Courtesy of NASA.

Rocket Elements – Imagine, Plan, Create

Design Notes

Last session, you designed and built your NASA satellite to orbit the Moon. This session, you will **plan** and **create** a balloon rocket assembly, attach your satellite to the balloon and launch it. **The objective is to shoot the rocket the farthest distance.**

The rocket elements that you can control are:

1) type of balloon(s) (long or round)
2) number of balloons, and
3) length of straw for sliding along the fishing line.

- You can choose to test any one of the rocket elements by changing it for each set of three trials. But, you need to keep the other rocket elements the same during those trials if you are to learn about the element you are changing.

- Think about your design. Make some sketches, and then build your rocket. For the first set of trials, try changing the length of the straw. Fill in the Data Table (Worksheet 3) as you go along. After you have filled in the Data Table, if there is time, plot your data in a graph: distance traveled (cm) vs. straw length (cm) or distance traveled (cm) vs number of balloons.

- Once you have found the length of the straw that allows your balloon rocket to go farthest, then you could try changing something else, like the shape or number of balloons. Fill in the second Data Table for these next three trials. Remember, only change one element for each set of trials.

Balloon Rocket Assembly Design

Top View of Our Balloon Rocket Assembly

Side View of Our Balloon Rocket Assembly

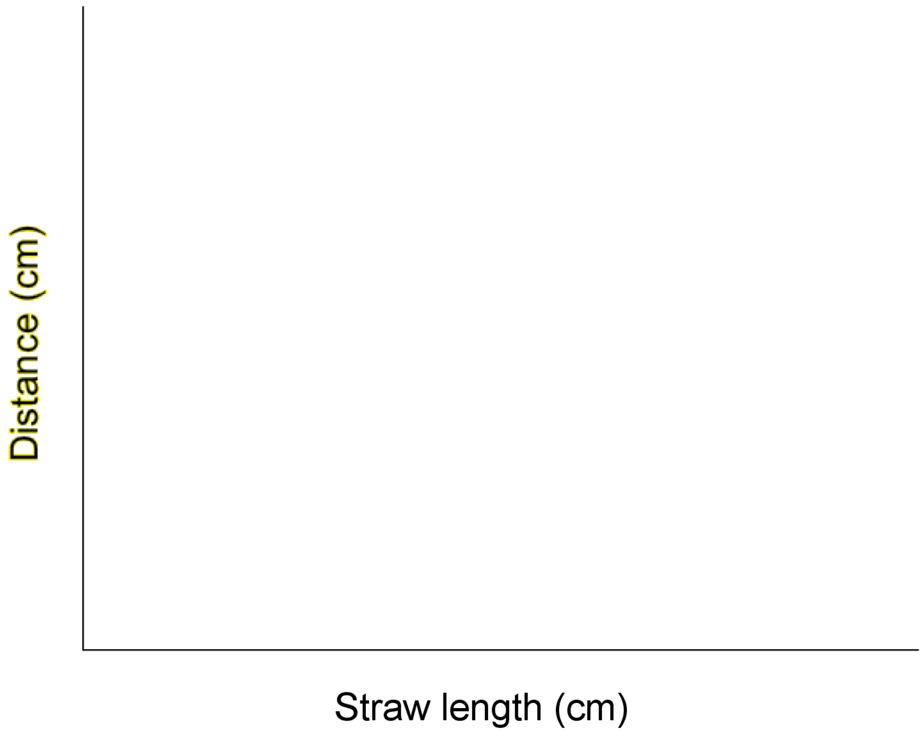
DATA TABLES and GRAPHS

Rocket Elements	Trial 1	Trial 2	Trial 3
Straw Length (cm)			
Number of Balloons (hold constant)			
Shape of Balloon(s) (hold constant)			
Distance traveled (cm)			

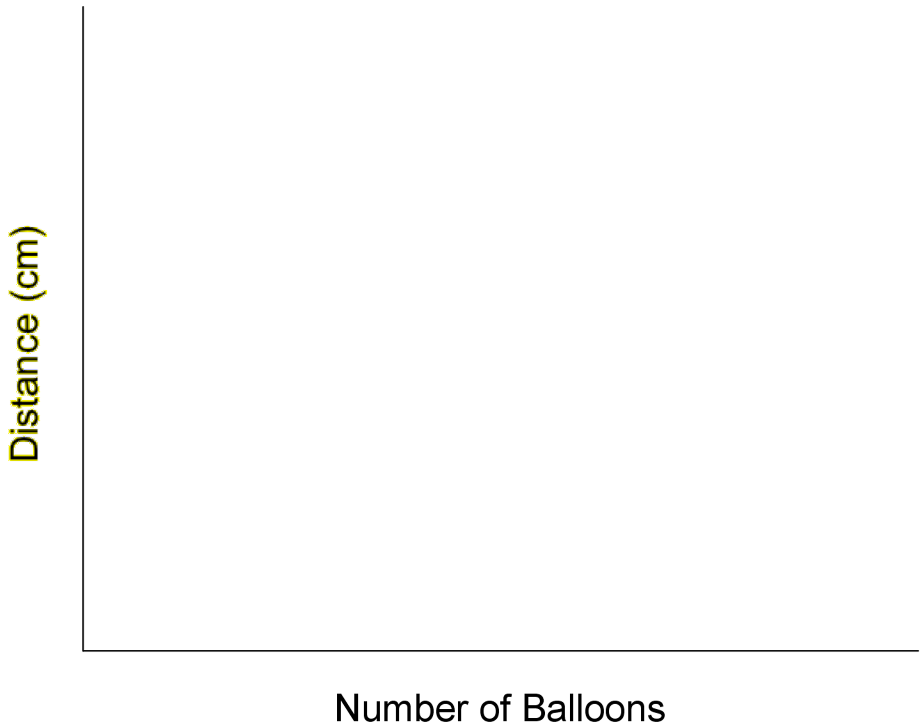
Rocket Elements	Trial 4	Trial 5	Trial 6
Straw Length (cm) (hold constant)			
Number of Balloons			
Shape of Balloon(s) (hold constant)			
Distance traveled (cm)			

Rocket Elements	Trial 7	Trial 8	Trial 9
Straw Length (cm) (hold constant)			
Number of Balloons (hold constant)			
Shape of Balloon(s)			
Distance traveled (cm)			

As you do your trials, fill in the *Distance Traveled* box for each rocket trial then fill in the graphs on the next pages. You'll need to add the number scale for each axis.



Conclusions from data and graph: How does changing this rocket element affect how far the rocket flies?



Conclusions from data and graph: How does changing this rocket element affect how far the rocket flies?

Experiment Notes

How did you choose what lengths to make the straw?

What do you predict will happen to your rocket as you change the length of the straw for each trial?

What do you think is happening with the straw that changes how far the rocket flies?

What is the next rocket element that you would like to test?

What do you predict will happen as you make your changes?

Improvement Phase of Rocket Design

Make final adjustments to your rocket to maximize the distance it will fly, based on all of your previous data.

Our team chose to adjust the following rocket elements:

We made this choice because:

DATA TABLE

Rocket Elements	**New Trial after re-design**
Straw Length (cm)	
Number of Balloons	
Balloon Shape	
Distance traveled (cm)	

Summary: Questions/Discussion for Understanding

What was the greatest challenge today for your team?

Why is the balloon forced along the string?

Which rocket element or variable seemed to have the greatest effect on the rocket distance traveled?

What would you predict would happen if the fishing line were set at an angle (such that there is now some vertical elevation)? If there is time, test it!

Team Name: ____

Fun with Engineering at Home

Activity 2: Launch Your Satellite!

Home Challenge: Today we designed and built a rocket model to send our lunar satellite to the Moon. We used the same process that engineers use when they build something.

During this week, see what you can learn about rockets – how they work, what they are used for, and how we get them up into space. You may even want to see if you can find out what kind of satellites rockets carry into orbit. What kinds of rockets carry people?

You can find this information in books, magazines or even on the Internet.
Ask your parents, grandparents, brothers or sisters to help you find out more about satellites. Have fun!

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

Quality Assurance - Checking the Balloon Rocket Assembly

Team Name: ______________________________________

Participants' Names: __________________________________

____

____

To be filled in by the Quality Assurance team:

Fill out the table below and launch the rocket. Then fill out the distance traveled.

Balloon Shape	
Number of Balloons	
Straw Length (cm)	
Distance traveled (cm)	

What are some of the strengths of this team's design?

What are some weaknesses of this team's design?

List 2-3 recommendations you have for this team to consider:

1.

2.

3.

Inspected by Team: __________________________________

Participant Signatures: _________________________________

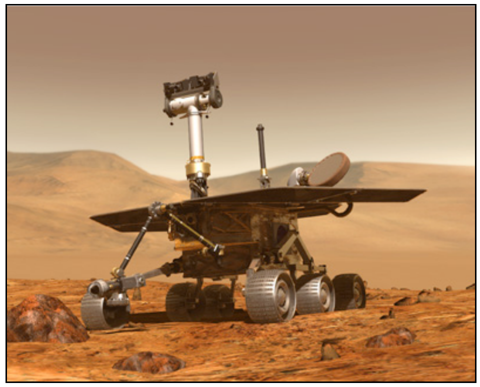
____

____

<u>Teacher Notes for Activities 3-5:</u>

In preparation of returning humans to the Moon and eventually to explore Mars, NASA will continue to use remote exploration tools to gather important data for upcoming space exploration missions. Students will become involved in the engineering design process to master objectives that further illustrate remote exploration tools that NASA uses. Over the next three sessions, teams will work to design and create a model of a Lunar Rover that will carry equipment and people on the surface of the Moon and a Landing Pod. The Landing Pod, with the Lunar Rover inside, is to land and deliver a payload safely when dropped from a significant height. Design specifications are given for each activity that must be followed when creating the Lunar Rover and Landing Pod. The Lunar Rover is designed and built in Activity 3. The Landing Pod is designed and built in Activity 4, and the actual "landing" of the Lunar Rover in the Landing Pod is Activity 5.

Activity #3: Design a Lunar Transport Rover!



Artist conception of a Rover: Courtesy NASA
Two rovers that look like this are on Mars NOW!
*See **http://marsrovers.nasa.gov** for more information on the Mars Exploration Rovers*

Activity Objective(s):	The teams' challenge is to design and build a model of a Lunar Transport Rover that will carry equipment and people on the surface of the Moon. It must be able to roll down a ramp. Next week they will design and build a landing pod for this rover, and the week after that, they will simulate a lunar landing. The goal is that the rover survives the landing so that it can roll down a ramp.
Lesson Duration:	One 60-90 minute session
Process Skills:	Measuring, calculating, designing, evaluating
Materials and Tools: (Per group of 3 students)	▪ General building supplies and tools ▪ (2) small plastic people (approx 2 cm each) ▪ plastic egg ▪ (4) plastic wheels ▪ Something to use as a ramp (a book would work, but preferably a flat surface that would enable the rover to roll for 50 cm or more)
Club Worksheets: (Make copies for each student to put in binder.)	Lunar Rover Design Challenge Lunar Rover Imagine and Plan Experiment Sheet and Data Table Fun With Engineering at Home Quality Assurance

Club Facilitator or Teacher Notes for Activity #3:

Stage 1: Set the Stage, Ask, Imagine, Plan

- Share the **Challenge** (see page) orally with the students.
- Show the Mars Rover Entry, Landing and Descent video called "Six Minutes of Terror." Ask them to pay attention to the ways NASA slowed the rovers down as they entered the atmosphere. Tell them to keep in mind that some of the techniques will work on the Moon, and some will not. They should think about what the difference would be (no atmosphere on the Moon which means a parachute device won't work).
- The NASA website with more video on the Mars rovers is:
    - marsrover.nasa.gov/gallery/video/challenges.html
- Hand out the ***Lunar Rover Design Sheet*** (1 of each of these worksheets per team).
- Let the challenge begin and encourage them to **IMAGINE and PLAN** before building.

Stage 2: Create

- Challenge the teams to **CREATE** or build their Lunar Rovers based on their designs. Remind them that they have a mass limit that includes the rover they are making today plus the Landing Pod that they will make (300 grams max).

Stage 3: Experiment

- They should set up a ramp to let their rover roll. They should describe the slope of the ramp in terms of "rise-over-run." In other words, "rise" is how high off the table the "up" end of the ramp is, and "run" is how long the ramp is.
- They need to discover what slope to set up the ramp to get the rover to roll. They also need to discover what slope is too steep for their rover. NASA would be very concerned about both the safety of the rover and the safety of the people. If the ramp is too steep, the rover might tumble or slide dangerously, or the impact at the bottom might jar the egg or the astronauts loose.
- This is a "Goldilocks" experiment. What slope is too little? What slope is too much? What slope is JUST RIGHT? They should record their results.

Stage 4: Re-Design and Re-Build - Improve

- Students **IMPROVE** (Re-Design and Re-Build) their rover models based on results of the EXPERIMENT phase.

Stage 5: Challenge Closure

The Summary of this activity will come after the simulated lunar landing.

Stage 6: Previewing Next Week

- Ask teams to bring back their Lunar Rover model for use in next week's club challenge. You may want to store them in the classroom or have one of the facilitators be responsible for their safe return next week.
- Ask teams to think about potential Landing Pods during the next week. Tell them they will be building the Landing Pod out of the standard materials that have been available to them. The pod, with the rover carrying the egg inside the pod, will be dropped from as high as possible (out a second story window? Or at least off a tall ladder, or the top of a staircase.)

Special Notes: For Those with 90 minute Clubs

Quality Assurance

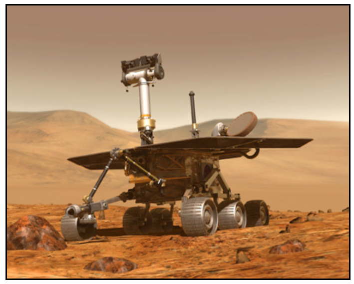
- Discuss how important FEEDBACK is for engineers. Hand out the Quality Assurance worksheets (1 per team).
- Ask each team to put their Lunar Rover model together with their ***Quality Assurance*** worksheet around the edges of the room. Ask each team to move one notch clockwise to offer feedback to the neighboring team, using the Quality Assurance Test worksheet. The Quality Assurance Teams will test a ramp with a ratio of rise-over-run of 1-over-3. Note, Quality Assurance Teams should also check the mass of the rover using a balance.
- Teams then return to their stations and discuss the comments from the Quality Assurance Team. What changes were suggested? Do they make sense?

Design Challenge:

The Lunar Rover must meet the following Engineering Design Constraints:

- Carry one plastic egg snugly. The egg may NOT be taped or glued into place. (The egg will be what materials are carried in around the Moon.)
- Have room for two plastic people. (The people do not land with the rover. They will get in the rover on the Moon and drive it around.)
- Roll on its own down a ramp with a rise-over-run of 1-over-3 for a distance of approximately 50 cm.
- Survive the “landing.” This means it should be able to roll down the ramp after the landing, and the plastic egg should not have popped open.
- Determine the “best” slope for a ramp for your rover. Which “rise-over-run” allows your rover to safely roll the farthest on its own?
- Looking forward to next week: the combined mass of the Lunar Transpor Rover and the Landing Pod must be less than 300 grams.

Student Worksheets for Activity #3 –
Design a Lunar Transport Rover!

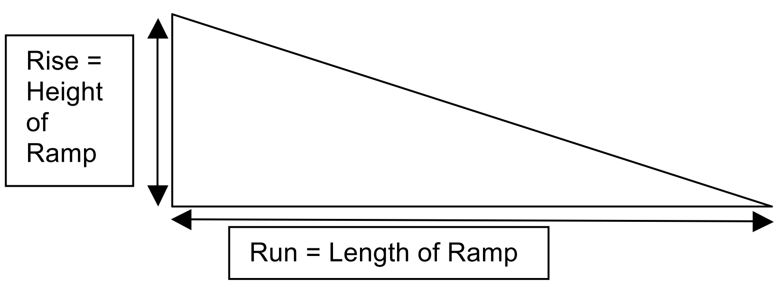


Artist conception of a Rover - Courtesy of NASA.

Lunar Rover Design Challenge

The Lunar Rover must meet the following Engineering Design Constraints:

- Carry one plastic egg snugly. The egg may NOT be taped or glued into place. (The egg will be what materials are carried in around the Moon.)
- Have room for two plastic people. (The people do not land with the rover. They will get in the rover on the Moon and drive it around.)
- Roll on its own down a ramp with a rise-over-run of 1-over-3 for a distance of approximately 50 cm.
- Survive the "landing." This means it should be able to roll down the ramp after the landing, and the plastic egg should not have popped open.
- Determine the "best" slope for a ramp for your rover. Which "rise-over-run" allows your rover to safely roll the farthest on its own?
- Looking forward to next week: the combined mass of the Lunar Transportation Rover and the Landing Pod must be less than 300 grams.



Imagine and Plan Worksheet

What parts do you need to make your rover roll?

What will hold the egg in place?

How does the steepness (slope or “rise-over-run”) of the ramp affect your design of the rover?

What is the total mass of the components you are using?

Top View of Lunar Rover:

Sketch of how you are building the wheel assembly:

Data Table

You need to determine how steep the ramp needs to be to get the rover to roll. You also need to determine how steep the ramp is when the rover no longer rolls, but falls or slides. Make several tests to determine how steep it is for it to be "just right." Make sure to do one test at rise-over-run of 1-over-3, since that is in your Design Constraints.

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

Would it have made more sense to measure the distance in meters? Why or why not?

Experiment Notes

Use this page to makes notes about the design of your rover as you test its performance as a function of the slope of the ramp.

For example, at what slope does the egg fall out?

Do you need to make changes to the rover design?

Team Name: ____

Fun with Engineering at Home

Activity 3: *Design a Lunar Rover!*

Home Challenge: Today we designed and built a Lunar Rover model to transport people and cargo on the Moon. During this week, see what you can learn about rovers that NASA has already built and used. 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 talk about with your parents, grandparents, brothers or sisters:

NASA used a parachute to slow the descent of the Mars rovers onto Mars. Why can we not use a parachute to land a spacecraft on the Moon?

They also used a heat shield on the Mars entry spacecraft. Why do we not need one of those on the Moon?

What is the most important consideration when designing a rover that will carry people and cargo?

What kind of cargo might the rover need to carry on the Moon?

Describe how the “rise-over-run” (we call this “slope”) of the ramp affects how fast and far the rover rolls. In order to get the rover to roll, a force must be acting on it. If you do not push the rover, and it rolls anyway, what force is acting on it?

Quality Assurance – Checking the Lunar Rovers

Team Name: ____

Participants' Names: ______________________________________

____

____

To be answered by the Quality Assurance team:

Total mass of the Lunar Transportation Rover is: ______________grams

How much mass is left for the Landing Pod? ____________ grams

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

Did the egg fall out on the ramp with slope of 1-over-3? YES or NO

Specific Design Strengths

Specific Design Weaknesses

How would you improve this design?

Inspected by Team: ______________________________

Participant Signatures: ______________________________

____

____

Activity #4: Design a Landing Pod!

Apollo 11 Lunar Module
Descent Nozzle
history.nasa.gov/ap11ann/kippsphotos/apollo.html - Image courtesy of NASA.

Activity Objective(s):	The teams' challenge is to design and build a Landing Pod for the model Lunar Rover that they built last week.
Lesson Duration:	One 60-90 minute session
Process Skills:	Measuring, calculating, designing, evaluating.
Materials and Tools: (Per group of 3 students)	General building supplies and tools Bubble wrap
Club Worksheets: (Make copies for each student to put in binder.)	Landing Pod Design Challenge Landing Pod Imagine and Plan Experiment Notes and Data Table Fun With Engineering at Home Quality Assurance

Club Facilitator or Teacher Notes for Activity #4:

Stage 1: Set the Stage, Ask, Imagine, Plan

- Share the **Design Challenge** (in teacher pages) orally with the students. This is the **ASK** phase of the Engineering Design Process.
- Discuss the Mars Rover Entry, Landing and Descent video called "Six Minutes of Terror." Remind them why a parachute won't work on the Moon (no atmosphere on the Moon).
- The NASA website with more video on the Mars rovers is: marsrover.nasa.gov/gallery/video/challenges.html The "Six Minutes of Terror" video is near the bottom of the page in the **Entry, Descent and Landing (EDL)** section.
- Hand out the ***Landing Pod Design Sheet*** (1 of each of these worksheets per team).
- Let the challenge begin!

Stage 2: Create

- Challenge the teams to **CREATE** or build their Landing Pod based on their designs. Remind them to keep within specifications. Remind them that they have a mass limit that includes the rover they made last session today plus the Landing Pod that they will make today (300 grams max).

Stage 3: Experiment

- The students should test to make sure that the rover, carrying the plastic egg, fits inside the Landing Pod. They should test that when dropped, the Landing Pod lands right side up (meaning that the wheels of the rover are on the bottom). They should also be sure that they are able to open the Landing Pod after it comes to rest without damaging the rover.

Stage 4: Re-Design and Re-Build - Improve

- Students **IMPROVE** (Re-Design and Re-Build) their rover models based on results of the EXPERIMENT phase.

Stage 5: Challenge Closure – After Lunar Landing

- The Summary of this activity will come after the simulated lunar landing.

Stage 6: Previewing Next Week

- Ask teams to bring back their Lunar Rover model and the Landing Pod for use in next week's club challenge. You may want to store them in the classroom or have one of the facilitators be responsible for their safe return next week.
- Remind the teams that their Landing Pods, loaded with their Lunar Rovers will be "landing" (after being dropped out of a second story window? Or at least thrown vigorously off a tall ladder or the top of a staircase. Just make sure they know from how high their models will be released.)

Special Notes: For Those with 90 minute Clubs

Quality Assurance

- Discuss how important FEEDBACK is for engineers. Hand out the Quality Assurance worksheets (1 per team).
- Ask each team to put their Landing Pod with the Lunar inside, together with their ***Quality Assurance*** worksheet around the edges of the room. Ask each team to move one notch clockwise to offer feedback to the neighboring team, using the Quality Assurance Test worksheet. The Quality Assurance Teams will toss the Landing Pod up in the air to see if it lands right side up. Note, Quality Assurance Teams should also check the mass of the loaded Landing Pod using a balance.
- Teams then return to their stations and discuss the comments from the Quality Assurance Team. What changes were suggested? Do they make sense?

Design Challenge

The **Landing Pod** must meet the following Engineering Design Constraints:

- It must safely deliver your Lunar Rover to the surface from a height given to you by your teacher.
- The Rover, inside the pod, must land RIGHT-SIDE up. (The rover must be able to "roll out", so it must land in the correct orientation with wheels on the surface.)
- The landing pod must be reusable. You must be able to open it, retrieve the Lunar Rover, and then use the Landing Pod again.

The combined mass of the Lunar Rover and the Landing Pod must be 300 grams or less.

Student Worksheets for Activity #4 - Design a Landing Pod!

Apollo 11 Lunar Module
Descent Nozzle
history.nasa.gov/ap11ann/kippsphotos/apollo.html - Image courtesy of NASA.

Landing Pod Design Challenge

The **Landing Pod** must meet the following Engineering Design Constraints:

- It must safely deliver your Lunar Rover to the surface from a height given to you by your teacher.
- The Rover, inside the pod, must land RIGHT-SIDE up. (The rover must be able to "roll out"; so it must land in the correct orientation with wheels on the surface.)
- The landing pod must be reusable. You must be able to open it, retrieve the Lunar Rover, and then use the Landing Pod again.

The combined mass of the Lunar Rover and the Landing Pod must be 300 grams or less.

Imagine and Plan

From how high will your Landing Pod (with the rover inside) be dropped?

What are your ideas for how to protect the rover inside the Landing Pod?

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

Imagine and Plan

Illustrate the following views of your Landing Pod:

Top View of Landing Pod:

Side view of Landing Pod

Sketch the “door” or “hatch” component of the Landing Pod:

Experiment Notes and Data Table

Make several test drops with your Landing Pod. Start at a height less than the height from which it eventually be dropped. Note carefully how it lands and think about what changes you should make to improve the landing.

Trial	Drop Height (m)	Observations
1		
2		
3		
4		
5		

What is the most difficult constraint to satisfy?

What changes will you make to strengthen you design?

Team Name: ____

Fun with Engineering at Home

Activity 4: *Design a Landing Pod for the Lunar Rover!*

Today we designed and built a Landing Pod for the Lunar Rover model we built last week. The Landing Pod must safely deliver the rover by protecting it from the impact and landing upright. Next week, the "landing" will take place.

Home Challenge: During this week, see what you can learn about landings that have taken place in the past. For example, NASA has landed spacecraft on the Moon and Mars.

Here are some questions to talk about with your parents, grandparents, brothers or sisters:

NASA has also dropped satellites into the atmospheres of Venus and Jupiter. What happened to those spacecraft?

Where in the Solar System, besides Earth, have humans visited? When was that? What kind of a lander did they use? How did it slow down before impact on the surface?

Why did Apollo 13 not land on the Moon? Who said, "Houston, we've had a problem," and what was the problem to which they were referring?

www.nasm.si.edu/collections/imagery/apollo/AS13/a13.htm

Quality Assurance – Checking Each Other's Landing Pods

Team Name: ____

Participants' Names: ____________________________________

____

____

To be answered by the Quality Assurance team:

Total mass of the Lunar Transportation Rover + Landing Pod is: ________grams

Did the Landing Pod land upright when dropped from a height of 1 meter?

YES or NO

Specific Design Strengths:

Specific Design Weaknesses:

How would you improve this design?

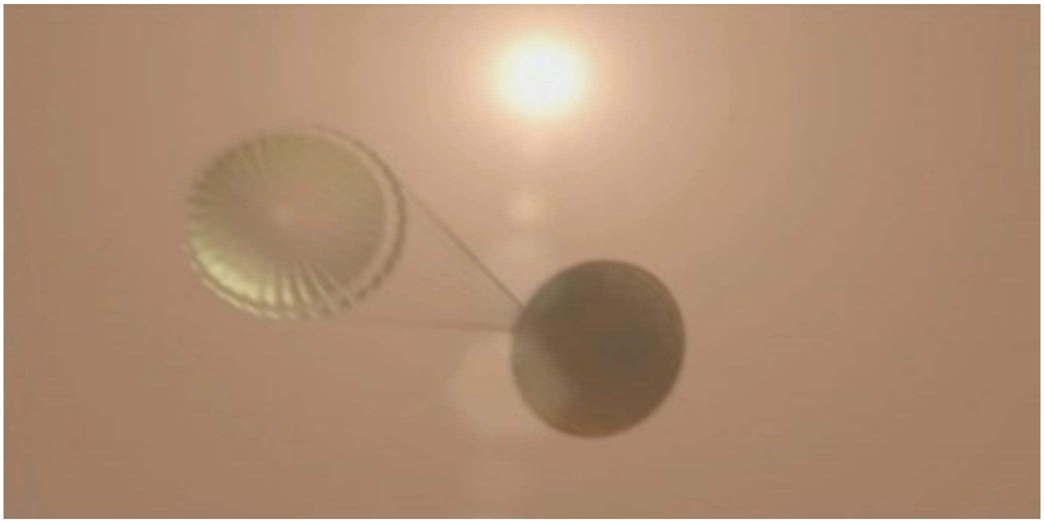
Inspected by Team: ____________________________________

Participant Signatures: ______________________________

____

____

Activity #5: Landing the Rover



The Phoenix Lander glides towards Mars just after its parachute is deployed.
Image courtesy of NASA Jet Propulsion Laboratory, Phoenix Mars Mission

Activity Objective(s):	The Landing Pod, with the Lunar Rover inside, is to land and deliver the payload safely when dropped from a significant height.
Lesson Duration:	One 60-90 minute session
Process Skills:	Predicting, observing, measuring, evaluating.
Materials and Tools: (Per group of 3 students)	General building supplies and tools Bubble wrap
Club Worksheets: (Make copies for each student to put in binder.)	The Rover Has Landed! Data Table and Discussion Questions Summary Fun With Engineering at Home

Club Facilitator or Teacher Notes for Activity #5:

Stage 1: Set the Stage, Ask, Imagine, Plan

- Remind the students of the **Challenge: Today the Landing Pods, with the Lunar Rovers inside, will be dropped from _________ m.** (Tell them from how high the Landing Pods will be dropped.)
- Ask the following questions in preparation for the launch. Encourage all students to participate in the discussion.
    - What were your design constraints on the combination of Landing Pod and Lunar Rover?
    - When you were designing the Landing Pod, what were the decisions you had to make to meet the design constraints?
    - What are you most concerned about when your Landing Pod hits the surface?

Stage 2: The Landing

- Hand out the ***Landing Data Table*** (1 worksheet per team) and gather the teams together – everyone should observe all of the landing events.
- Bring one of the balances near the drop site. Remind the teams that they have a maximum mass limit that includes the Lunar Rover plus the Landing Pod of 300 grams. Check the mass of each "loaded spacecraft." The students should write the mass on the top of the Landing Data Table.
- One at a time, "drop" the Landing Pods (from a second story window is best. If you are dropping from a ladder, add some force to the drop and/or give it a vigorous throw outward and/or upward).
- Open each Landing Pod after it comes to rest. First check to see if the Rover is upright. Place ramp up against the Landing Pod and let the Lunar Rover roll out. (It might require a little push.)
- The students should:
    - Check to see if the Rover landed upright.
    - Measure height of ramp.
    - Measure the length of ramp.
    - Measure the distance the rover rolls.
    - Check to see if the egg stayed closed.

Stage 3: Improve

- Students **IMPROVE** (Re-Design and Re-Build) their Landing Pods based on their observations from the first drop.

- If there is time, after the teams make changes to their Landing Pods, the teacher will drop it again. (Everybody doesn't need to watch this time.) The students should collect the measurements for the second trial on the **Landing Data Table**.

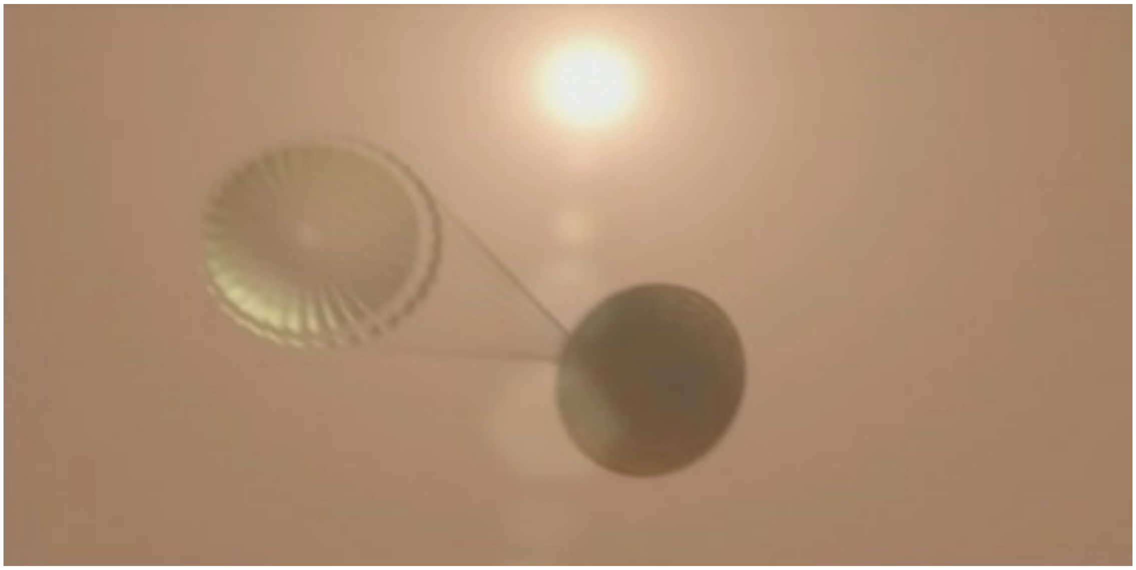
Stage 4: Landing Challenge Closure

- Hand out the Summary Sheets (1 per team).

Stage 5: Previewing Next Week

- Starting next week, we will be thinking about what it takes for humans to live on the Moon.
- If time permits, show the media clip *Return to the Moon: The Journey Begins*. (www.nasa.gov/mission_pages/exploration/multimedia/index.html) *Return to the Moon: The Journey Begins* is found at the bottom of the page.
- Discuss some of the things they see in the video such as equipment, tanks, housing structures, and solar panels. Encourage students to think of ways these items could play a part in living on the Moon.

Student Worksheets for Activity #5 - Landing the Rover



The Phoenix Lander glides towards Mars just after its parachute is deployed.
Image courtesy of NASA Jet Propulsion Laboratory, Phoenix Mars Mission.

Activity #5: Landing the Rover

Mass Constraint: Lunar Rover + Landing Pod = _________ grams.

Landing Data Table

Trial	Drop Height (m)	Ramp Rise-over-Run	Distance Rolled (cm)
1			
2			
3			

Post Landing Questions

Did your Landing Pod remain closed during impact?

Did the Pod land such that the Rover is upright when unwrapped?

Did the egg remain closed during impact?

Did your rover roll down the ramp?

How far did it roll?

Did you need to make design changes?

If so, what changes did you make?

Summary

Consider the entire project: designing and building the Lunar Rover, designing and building the Landing Pod, and actually launching the Landing Pod with the Lunar Rover inside. What was the most challenging aspect of this process?

Did you think about the whole process when you were designing the Lunar Rover? Did you worry about how it would survive the landing as you were building it, or did you not think about that until you were building the Landing Pod?

If you were to start this project again, would you change the design of the Lunar Rover? If so, how?

Would you change the design of the Landing Pod? If so, how?

Team Name: ____

Fun with Engineering at Home

Activity 5: *Landing the Rover*

Today we simulated the landing of the Landing Pod containing the Lunar Rover. 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?

Home Challenge: During this week, talk to your family members to see if they have any ideas on how to improve the Landing Pod. 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.

Teacher Notes for Activities 6-7:

Many of NASA's missions are conducted by robots. Although some robots have the ability to make decisions based on data they receive from sensors, the original programs given to the robots are written by humans. Humans tell robots what to do and how to execute their missions. The following activities are based on **Principles of Remote Exploration**, an extensive, technology-based sample-analysis mission simulation for middle school students. Teams will execute a mini-simulation of a robotic mission, to get the flavor of Mission Planning, including mapping, communication, calibration and simple programming. The ultimate goal at the end of Activity 7 is to get the human-robot from one end of the course to the other, and the robot should pick something up (A "lunar rock") at the end of the course. To make it more interesting, you may wish to place a "warm" object (room temperature) and a "cold" object (a box of ice cream sandwiches?) on the chair, and include a constraint in the mission to use a temperature sensor to decide which "rock" to retrieve. (Hands will work just fine as temperature sensors.)

You will be required to set up a small obstacle course ("landing site") with a few chairs and/or a table. The course does not have to be too complicated, but you should set it up so that the students must execute at least one right turn and at least one left turn.

Activity #6: Mission Preparation
Session 1

*This activity is based on **Principles of Remote Exploration**, an extensive, technology-based sample-analysis mission simulation for middle school students.* ***learners.gsfc.nasa.gov/PREP***

Image of a Mars rover - Courtesy of NASA

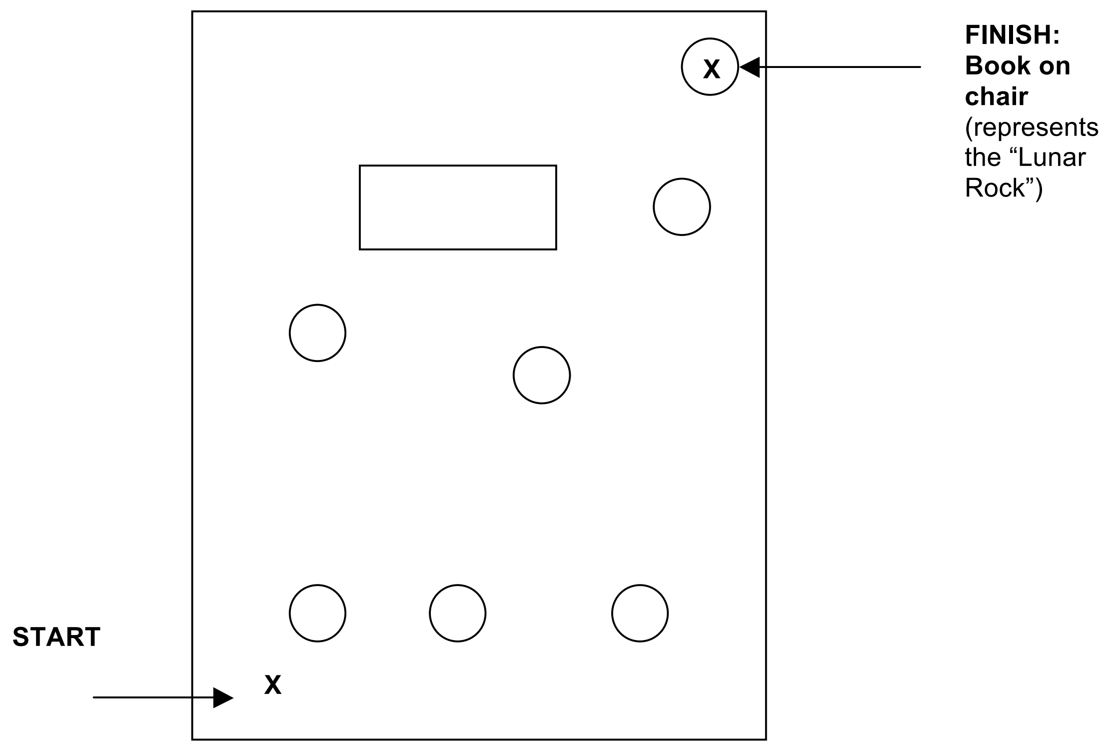
Activity Objective(s):	Teams will execute a mini-simulation of a robotic mission, to get the flavor of Mission Planning, including mapping, communication, calibration and simple programming. The ultimate goal is to get the human-robot from one end of the course to the other, and the robot should pick something up (A "lunar rock") at the end of the course.
Lesson Duration:	Two 60 minute sessions
Process Skills:	Mapping, communication, measuring, graphing, logical thinking.
Materials and Tools: (Per group of 3 students)	Rulers Graph paper, if available
Club Worksheets: (Make copies for each student to put in binder.)	Mapping Communications Calibration Mission Plan Summary Fun With Engineering at Home, Part A

Club Facilitator or Teacher Notes for Activity #6:

Session 1: SET-UP

Set up a small obstacle course ("landing site") with a few chairs, small table, and/or boxes (any "obstacle" with a fairly well defined "foot print" will do). The course does not have to be too complicated, but you should set it up so that the students must execute at least one right turn and at least one left turn. Also, give the students enough obstacles so that they have a choice of how to get from one end to the other (that is, so there is more than one path). The overall size of the landing site is also arbitrary, needing to fit within a convenient area that is available to the club, but probably an area at least 25 square meters would be best.

An example might look like this (table is rectangle, chairs are circles):



Remember: you will be using this exact same landing site set-up for two consecutive weeks, so you must be able to duplicate the arrangement of tables and chairs next week. This means you have to have your own "map" of the set up to place obstacles in the same place.

<u>Stage 1.1: Set the Stage</u>

- Explain to the students that many of NASA's missions are conducted by robots. Although some robots have the ability to make decisions based on data they receive from sensors, the original program given to the robots is written by humans. Humans tell robots what to do and how to execute their missions. Today students will divide into teams and select primary responsibilities that will enable them to prepare for a simulated robotic Discovery Mission. Next week they will carry out the mission and evaluate its success.

<u>The Discovery Mission Challenge</u>

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 from there to the location of the "lunar ice" without bumping into any "lunar boulders" or other obstacles. To successfully complete the Discovery Mission Challenge, your robot must pick up a piece of "lunar ice."

A NASA mission has several parts, and you will be responsible for carrying out each component of the mission. Before your robot begins to traverse the lunar surface, you will have to complete the following activities:

- <u>Map the "landing site"</u> – your team will make a scale map that you will use to determine the path that your robot should take. You will mark out a route for the robot on this map, and then you will translate this path into a program for the robot.
- <u>Learn to communicate with your rover</u> – you will develop a simple language to pass commands to 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 traverse the path you have drawn on the map.
- <u>Calibrate your robot</u> – you must determine how your robots motions translate into standard units. For example, ONE robot step will equal how many centimeters? You will use this information to tell the robot how to traverse the route you have planned on the map.
- <u>Program the robot</u> – you will use the commands that you developed and the calibration to make a command set that will tell the robot how to traverse the path you have drawn on the map.

- Next session, your robot will get the opportunity to execute the program you have written at the "landing site." Your mission will be complete when your robot picks up a piece of "lunar ice."

- Break the students into three-person teams (four members are ok if necessary). Each member of the team should choose a primary role for today's preparation phase, though the team members will work together to accomplish all phases of the mission:
  - **Robot (BOT)**: One of the students in the team should volunteer to be the robot. The BOT will be the person who actually walks through the course, following the instructions of her/his team. The team should give their robot a name.
  - **Communicator (COM)**: One of the team members will be the person who directly communicates with the robot throughout the BOT's progress in the landing site. COM will read commands to the BOT.
  - **Mapper (MAP)**: Initially the team will construct a scale map of the landing site. One team member will chart the robot's progress on the map that the team made of the landing site. This is an important job for the *Improve* phase: If the robot has problems on the first attempt, the team will use these notes on the map to determine how to change the robot's course on the second attempt.

Stage 1.2: Pre-Mission Activities

Logistics Note: Mapping, Communication and Calibration can be done at the same time, so that while one group is mapping the "landing site," the other groups can be developing their command language and calibrating their robot.

Mapping

The students should take a ruler and a blank piece of paper (graph paper is really preferable for this) to the "landing site" and make a map of it. It is more important that the scale of the map be accurate than that it is drawn beautifully. For example, they may use symbols for the chairs, they do not need to try to draw pictures that look like chairs. Remember that the purpose of the map is for the BOT to navigate through the area using only the explicit instructions given to him by the Communicator.

Communication

The teams develop a "language" (a set of commands) that they will use with their BOT. These commands should be one or two words, plus perhaps a number (that indicates the number of steps the BOT moves). The Communicator may not talk in any other way to the BOT except giving him the explicit commands. And the BOT will not be able to talk except to repeat the commands. A few example commands might be:

FORWARD 3 (meaning walk forward 3 steps)
RIGHT (meaning execute a 90 degree right turn)
LEFT (meaning execute a 90 degree left turn)

They may come up with other simple commands, but they must remember that the BOT must follow the commands exactly. The team should make a list of their commands. If a command is not in their list, they may not use it once the robot is in the landing site. Remind them that they will need a set of commands for picking up the "lunar rock" at the very end.

COM should practice giving commands to BOT. COM must determine how many commands BOT can reliably execute in each command sequence. COM should keep a log indicating which commands they give to BOT each time, to keep track of what BOT can remember.

A command sequence is delivered as follows:

A. COM touches BOT's shoulder
B. COM: HELLO <BOT's name>
C. BOT: HELLO
D. COM reads the command sequence
E. BOT repeats the sequence exactly
F. Steps D and E are repeated until BOT repeats the sequence correctly
G. COM: CORRECT. GOODBYE.
H. BOT: GOODBYE

The command-response pattern is important to be sure the BOT understands the command. The greetings at the beginning and the end of the sequence serve to tell the BOT when to start listening and when to stop. COM repeats this many times to familiarize the BOT and to determine how many commands the BOT can actually remember. Three or four commands seem to be a reasonable number.

Calibration

- This part of the preparation puts together the map and the behavior of the BOT. If the team wants the BOT to go forward 2.5 meters before turning left, they must be able to tell the BOT exactly how many steps to take. Thus the team has to measure how far the BOT actually moves each step. A simple suggestion here is have the BOT walk a set number of steps, measuring the distance covered. Dividing the total distance by the number of steps provides the distance the BOT walks each step.

- Once the command set is developed, the BOT practices executing the commands, and MAP keeps track of the actual performance of the robot. MAP should keep a log of the measurements. For example, how much distance does the BOT cover when s/he executes each FORWARD 3 command? Is FORWARD 6 really the same as two FORWARD 3 commands?

Programming

Once Mapping, Communication and Calibration are complete, the teams chart the course for their BOT. First, they draw their chosen course on the map. Then they use their calibration data to determine what command sequence they must use to get the BOT through the course. Once they have their full command sequence, they break it into chunks, according to what they determined their BOT could remember. These chunks are then listed, in order, on the Mission Program.

Stage 1.3: Closure for Session 1

The Summary Sheets will be handed out next week, at the end of the Discovery Mission. Bring the students into a brief discussion to assess their progress at this point. Ideally, they will have a completed program for their BOT and will be ready to drop the BOT at the starting point to begin their mission next session. If they are not this far along, they can use the first part of the next session to finish programming their BOT. Send them home with "Fun with Engineering at Home, Part A."

Student Worksheets for Activity #6 – Mission Preparation

Image of a Mars rover - Courtesy of NASA

Mapping

Goal: Produce to-scale map of "landing site" to plan the robots traverse.

Use graph paper or blank white paper and rulers to map out the "landing site."

What is your measurement strategy? (Hint: are there floor tiles or other ways to scale up one measurement to a larger distance?)

What units are you using for measurement?

How accurate are your measurements?

How accurate do you think they need to be? (Come back to this question after you have calibrated your BOT and see if you give the same answer!)

What is the scale of your map?

Can you identify regions that might be difficult for your BOT to navigate?

What are the most important features in your map for the BOT?

Communications

Goal: Develop a communications strategy with the BOT.

The teams develop a "language" (a set of commands) that they will use with their BOT. These commands should be one or two words, plus perhaps a number (that indicates the number of steps the BOT moves). The Communicator may not talk in any other way to the BOT except giving him the explicit commands. And the BOT will not be able to talk except to repeat the commands. A few example commands might be:

FORWARD 3	(meaning walk forward 3 steps)
RIGHT	(meaning execute a 90 degree right turn)
LEFT	(meaning execute a 90 degree left turn)
BEND and GRAB	(meaning grab for the "lunar ice")

Make a list of your commands. If a command is not in the list, you may not use it once the robot has started the discovery process.

COMMANDS

COM should practice giving commands to BOT. COM must determine how many commands BOT can reliably execute in each command sequence. COM should keep a log indicating which commands they give to BOT each time, to keep track of what BOT can remember.

A command sequence is delivered as follows:

A. COM touches BOT’s shoulder
B. COM: HELLO <BOT’s name>
C. BOT: HELLO
D. COM reads the command sequence
E. BOT repeats the sequence exactly
F. Steps D and E are repeated until BOT repeats the sequence correctly
G. COM: CORRECT. GOODBYE.
H. BOT: GOODBYE

Determine the appropriate length for a command sequence. Three or four commands seems to be a reasonable number.

Practice delivering a command sequence so that it becomes easy for your BOT to repeat the commands and execute them. Remember, your BOT may feel under pressure in the “landing site,” so you want to help the BOT feel prepared.

How many commands can your BOT remember?

Does it make a difference if you try to do it fast? Why?

Does telling your BOT to move FORWARD 8 get the same results as FORWARD 4 twice? Or FORWARD 2 four times? How close are the results, in both time and distance?

How long does it take you to move the BOT across the room?

Now put a chair in the path of the BOT so you have to move around it. Now how long does it take you to move across the room?

Calibration

Goal: Calibrate the BOT's movements.
Listen as COM give commands, then measure the distance traveled by the BOT.
Repeat several times and get an average value. Plot the results. Scale up.

Calibration Data Table: What units are you using?

	Trial 1	Trial 2	Trial 3	Average
Forward 1				
Forward 2				
Forward 3				
Forward 4				
Forward 6				
Forward 8				

Graph Your Results: What should the y-axis label be?

# of Steps

What is your measurement strategy? (from the toe, left foot, right foot, etc)

How accurate are your measurements?

How accurate do you think they need to be?

Look at your graph. What is the relationship between number of steps and distance traveled?

Estimate how far the rover will go in 10 steps.

Now try it out. How close were you?

Mission Plan

Goal: Chart your BOT's traverse through the "landing site." Develop a plan that results in a Command Sequence using your command language,

- Use the map you made of the "landing site" to determine the best path for the BOT to take to get from the Starting point to the Finish, where the "lunar rock" awaits.
- Now develop a Command Sequence, using your command language, that will result in your BOT getting from the Starting point, to the Finish, and then picking up the "lunar rock."
- Break the Command Sequence into bite-sized chunks. Recall, you determined how many commands your BOT could remember. Write out the command sequence, with the chunks numbered. You will be required to tell your teacher which chunk you are delivering each time. You may NOT change the chunks in real time.

GOOD LUCK!

Command Sequence	
1.	15.
2.	16.
3.	17.
4.	18.
5.	19.
6.	20.
7.	21.
8.	22.
9.	23.
10.	24.
11.	25.
12.	26.
13.	27.
14.	28.

Summary

What was the most challenging aspect of completing this Discovery Mission?

Why was it important to make a good map in the first part of the Mission?

What does NASA do that is like measuring the length of your BOT's footsteps?

What would you do differently the next time?

Team Name:____

Fun with Engineering at Home – Part A

Activity 6: Mission Preparation

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 mission, such as Mapping, Calibration, Communication and Programming.

Home Challenge: During this week, why not try to do a Discovery Mission at home? You could rearrange some chairs and maybe a table to set up the Landing Site. You could help you family members understand why making a good map is important, and why you must calibrate your BOT. You could even blindfold the BOT to make it more challenging! If you have a big family or are doing this with lots of friends, you could break into teams and race to the end. Maybe the “lunar rock” could be something fun, like a treat! These are the steps:

- Mapping: make the map of the Landing Site (you’ll need a ruler)
- Communication: develop a command language and practice with the BOT
- Calibration: calibrate your BOT’s steps (you’ll need a ruler)
- Programming: plan a route through the Landing Site and program it using your command language.
- Mission Execution: BOT traverses the Landing Site, following the commands.

HAVE FUN!!

Activity #7: Mission Execution

This activity is based on ***Principles of Remote Exploration****, an extensive, technology-based sample-analysis mission simulation for middle school students.* ***learners.gsfc.nasa.gov/PREP***

Image of Mars rover - Courtesy of NASA

Activity Objective(s):	Teams will execute a mini-simulation of a robotic mission, to get the flavor of Mission Planning, including mapping, communication, calibration and simple programming. The ultimate goal is to get the human-robot from one end of the course to the other, and the robot should pick something up (A "lunar rock") at the end of the course.
Lesson Duration:	Two 60 minute sessions
Process Skills:	Mapping, communication, measuring, graphing, logical thinking.
Materials and Tools: (Per group of 3 students)	Rulers Graph paper, if available
Club Worksheets: (Make copies for each student to put in binder.)	Mapping Communications Calibration Mission Plan Summary Fun With Engineering at Home, Part B

Session 2: SET-UP

The landing site (obstacle course) must be reconstructed exactly as it was in Session 1.

Stage 2.1: Mission Readiness Review

Assemble the students in their teams. Ask each team to share their calibration results. They should show the graph they have made of the BOT's movements.

> **Discussion Questions**
>
> Does each BOT have the same calibration factor? (That is, One BOT step equals how many centimeters?) Why or Why not?
>
> Why must we convert the BOT's steps into standard units?
>
> If suddenly you were asked to work with a new BOT, would you have to change any of your calculations? If so, what would change? Why?

Stage 2.2: Mission Execution

- Missions should begin as soon as a team is ready to go.
- The BOT is placed at the starting point. COM delivers the first set of commands, using the command protocol. Map keeps track of the BOT's progress. If the BOT successfully executes the commands, the next set is delivered. If BOT makes a mistake or runs into an obstacle they go back to the beginning and get a second chance. If they still cannot execute properly, they get sent back to Mission Control for a tune-up, and the next team gets to go.
- Students **IMPROVE** by examining their maps and making corrections to their command sequence.

Stage 2.3: Challenge Closure

Hopefully everyone will have gotten to the "lunar ice." Ask them to share with you whether they found this activity easy or hard. Ask them to imagine if they were programming a robot that was a quarter million miles away. Would that be easy? Hand out the Summary Sheets (please collect one per team and save in a folder for NASA).

Stage 2.4: Previewing Next Week

- The Moon is a very harsh environment. Students will now begin to think about returning humans to the Moon by designing and constructing the new Crew Exploration Vehicle.
- Ask students to think about how their satellite design from Activity #1 would have to change to carry human beings. Next week they will build a Crew Exploration Vehicle model to take people to the Moon.

Student Worksheets for Activity #7 - Mission Execution

Image of Mars rover - Courtesy of NASA

Fun with Engineering at Home – Part B

Activity 7: Mission Execution

Today we conducted a simulated, robotic Discovery Mission. Now consider what challenges would face living humans instead of mechanical robots: aside from air and water there are extreme temperature variations on the Moon because the Moon lacks an atmosphere.

Home Challenge: During this week consider the ways in which we deal with this problem on Earth. Research on the web and/or talk with family and friends. List three ways we protect ourselves from extreme cold on Earth. List three ways we protect ourselves from extreme heat.

Protect against Cold:

- ____
  ____
- ____
  ____
- ____
  ____

Protect against Heat:

- ____
  ____
- ____
  ____
- ____
  ____

On the Moon: Which of the ways that you described above as working on Earth will work on the on the Moon, and why?

- ____
  ____
  ____

HAVE FUN!!

Teacher Notes for Activities 8 and 9:

America will send the next generation of explorers to the Moon aboard a new crew exploration vehicle. NASA's Constellation Program will send human explorers back to the Moon, and then onward to Mars and other destinations in the solar system. By completing activities 8 and 9, student teams will be challenged to design and build a *Crew Exploration Vehicle* (CEV) that will carry two cm-sized passengers safely and will fit within a certain size limitation. The CEV will be launched in activity 9.

Activity #8: Crew Exploration Vehicle

This activity was adapted from NASA educational products:
NASA's KSNN™ 21st Century Explorer newsbreak "What will replace the space shuttle?"
education.jsc.nasa.gov/explorers/pdf/p5_educator.pdf

Artist's conception of a new exploration vehicle. - Image courtesy of NASA

Activity Objective(s):	The teams' challenge is to design build a *Crew Exploration Vehicle* (CEV) that will carry people and an internal tank for holding liquids. This CEV must fit within a certain volume (size limitation), carry two cm-sized passengers safely and have a hatch that opens and closes. The CEV will be launched in next week's activity.
Lesson Duration:	One 60-90 minute session
Process Skills:	Measuring, calculating, designing, evaluating.
Materials and Tools: (Per group of 3 students)	General building supplies and tools (2) small plastic people (approx 2 cm each)
Club Worksheets: (Make copies for each student to put in binder.)	CEV Design Challenge and Data Table CEV Imagine and Plan Experiment Notes Summary - Questions/Discussions for Understanding Fun With Engineering at Home Quality Assurance Sheets - Checking Each Other's CEV Models

Club Facilitator or Teacher Notes for Activity #8:

Stage 1: Set the Stage, Ask, Imagine, Plan

- Share the **Design Story and Challenge** orally with the students (provided in teacher pages).
- Hand out the ***CEV Design Sheet*** (1 of each of these worksheets per team).
- Let the challenge begin - Encourage them to **IMAGINE and PLAN** before building. Why should they not tape or glue the people in place?

Stage 2: Create

- Challenge the teams to **CREATE** or build their CEVs based on their designs. Remind them to keep within specifications.
- Ask members of each team to check mathematical calculations and check designs and models to make sure they are within specified design constraints.

Stage 3: Experiment

- Discuss how important **EXPERIMENTING** is for engineers.
- Each team should conduct three drop tests: 1 each at 1, 2 and 3 meters. They should record their results.

Stage 4: Re-Design and Re-Build - Improve

- Students **IMPROVE** (Re-Design and Re-Build) CEV models based on results of the EXPERIMENT phase.

Stage 5: Challenge Closure

- Give out the Summary: Questions/Discussion for Understanding worksheet (1 per team).
- In summary have a short discussion with all teams. Ask them, “What was the greatest challenge for your team today?” Expect answers such as:
    - Planning and creating a CEV so that the people and the tank fit inside safely. (They should mention the constraints.) For example, designing a tank to fit within a certain volume, when no shape was given.
    - Keeping the people in the seats without tape or glue. Keeping the hatch shut during the drop test.
    - Work as a team, communicate
    - Imagine, plan, create, experiment, improve steps

Stage 6: Previewing Next Week

- Ask teams to bring back their CEV model for use in next week's club challenge. You may want to store them in the classroom or have one of the facilitators be responsible for their safe return next week.
- Ask teams to think about potential launch mechanisms during the next week. Tell them they will be building a launcher out of the standard materials that have been available to them, including large rubber bands. They will conceive of a design (IMAGINE) on their own – there is not a pre-designed launcher.

Special Notes: For Those with 90 minute Clubs

Quality Assurance

- Discuss how important FEEDBACK is for engineers. Hand out the Quality Assurance worksheets (1 per team) and ask them to fill out the top section with team name and participants' names.
- Ask each team to put their CEV model together with their ***Quality Assurance*** worksheet around the edges of the room. Ask each team to move one notch clockwise to offer feedback to the neighboring team, using the Quality Assurance Test worksheet. The Quality Assurance Teams will conduct a 2-m Drop test. Note, Quality Assurance Teams should also check the mass of the CEV using a balance.
- Teams then return to their stations and discuss the comments from the Quality Assurance Team. What changes were suggested? Do they make sense?

Design Story and Challenge: (For Teacher Use)

Crew Exploration Vehicle

NASA needs a vehicle to take people to the Moon. The Space Shuttle cannot do that, because it is not designed to leave the Earth's orbit. NASA scientists and engineers are working on a space vehicle that can take astronauts to the Moon, Mars, and beyond. This spacecraft is called the Crew Exploration Vehicle (CEV). The CEV is a vehicle to transport human crews beyond low-Earth orbit and back again. The CEV must be designed to serve multiple functions and operate in a variety of environments.

Design Challenge

Using your supply of building materials, you will design and build a CEV model.
Your Crew Exploration vehicle must meet the following Engineering Design Constraints:

- Safely carry two little plastic people. You must design and build a secure seat for these people, **without gluing or taping them in place**. The people should stay in their seats during a 2-m Drop Test.
- Include an internal holding tank for liquids, able to hold at least 20 cm^3 of liquid.
- Have a mass of no more than 100 grams.
- Fit within the mailing tube provided. (Each club received two or three mailing tubes. The teams can share to see if their CEV fits.)
- Have one hatch that opens and closes. The hatch should remain shut during a 2-m Drop Test.

Student Worksheets for Activity #8 – Crew Exploration Vehicle!

Artist's conception of new exploration vehicle - Image courtesy of NASA

CEV Design Challenge, Data Table and Questions

Design Challenge

Your Crew Exploration vehicle must meet the following Engineering Design Constraints:

- Safely carry two little plastic people. You must design and build a secure seat for these people, **without gluing or taping them in place**. The people should stay in their seats during a 2-m Drop Test.
- Include an internal holding tank for liquids, able to hold at least 20 cm^3 of liquid.
- Have a mass of no more than 100 grams.
- Fit within the mailing tube provided.
- Have one hatch that opens and closes. The hatch should remain shut during a 2-m Drop Test.

CEV Data Table

Please complete entries in table.

CEV components	Use	Measurement or Calculation
Little plastic people	Crew	Mass: __________ g each; __________ g total
Internal tank	Stores liquids	Mass:__________ g Volume__________ cm^3
Hatch	Allows entry and exit	Dimensions: _________ cm (long) x _________ cm (wide)
Mailing Tube	To test size constraint	Volume __________ cm^3
CEV	Transport people	Mass:__________ g Volume __________ cm^3

CEV Imagine and Plan Worksheet

How will you calculate the volume of the internal tank?

How did you decide where to put the internal tank?

How will you make sure that the people can fit through the hatch?

How will you make sure the hatch doesn't pop open during the Drop Test?

Illustrate the following views of your Crew Exploration Vehicle:

Top View of CEV:

Outer View of CEV with Hatch:

Cut-away view of CEV to show inside with people:

Cut-away view of CEV to show inside with internal tank:

EXPERIMENT – Drop tests

Your dependent variables are the conditions that you are testing.
EXAMPLE of dependent variable: Number of people that stayed in their seats during drop test.

Control Variable – Height of Drop	**Dependent variable(s)**
1 meter	
2 meters	
3 meters	

How will you improve your design using these results?

Summary: Questions/Discussions for Understanding

What was the greatest difficulty you and your team had today while trying to complete the CEV challenge?

Tell how you solved your greatest team difficulty in 2-3 sentences.

Why was it important that the hatch stay closed during the Drop Test?

What process will your CEV undergo that makes it important for the people to be secured safely in their seats?

Team Name: ____

Fun with Engineering at Home

Activity 8: Design the new Crew Exploration Vehicle

Home Challenge: Today we designed and built a Crew Exploration Vehicle (CEV) model to carry people to the Moon. During this week, see what you can learn about satellites and rockets get launched into orbit. Next week, you will be designing a launcher for the Crew Exploration Vehicle. It will be important to launch the CEV without hurting the people inside it. Sending humans SAFELY into space is very important for NASA.

Here are some questions to talk about with your parents, grandparents, brothers or sisters:

- Are you interested in sending humans to the Moon?
- Do you want to go to the Moon?
- What are some reasons that people might want to go to the Moon?
- What might be some of the dangers for humans in the CEV?
- What is the most dangerous part of the journey to the Moon?

The NASA website has lots of information on space travel. Go to www.nasa.gov and type CEV into the search box. What do you learn?

To learn more about what NASA is doing to build a CEV, go to the following website: education.jsc.nasa.gov/explorers/p5.html

This NASA site talks about new NASA spacecraft:
www.nasa.gov/mission_pages/constellation/main/index.html

Quality Assurance – Checking Each Other's CEV Models

Team Name: ____

Participants' Names: ____

____

____

To be answered by the Quality Assurance team:

Total mass of the CEV is: ______________grams

What volume of liquid will the internal tank hold? ____________ cm3

How did you determine the volume of the internal tank?

____

____

____

Does the CEV fits within specified dimensions: YES or NO

Does the hatch open and close? YES or NO

Do the people stay in their seats during the Drop Test? YES or NO

Does the hatch stay closed during the Drop Test? YES or NO

Specific Design Strengths:

Specific Design Weaknesses:

How would you improve this design?

Inspected by Team: ____________________________________

Participant Signatures: ________________________________

____

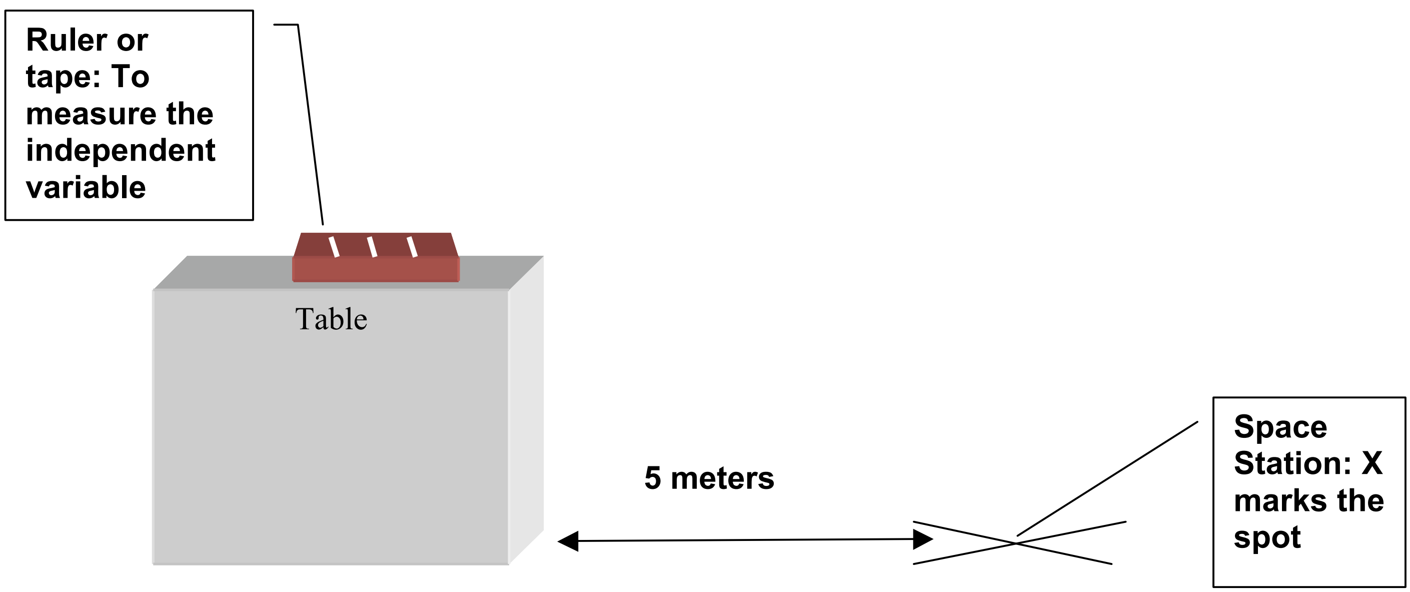
____

Activity #9: Launch Your Crew Exploration Vehicle!

Ares Rocket and Altair Lunar Lander, Courtesy NASA

Activity Objective(s):	The teams' challenge is to design and build a Reusable Launcher for the *Crew Exploration Vehicle* (CEV) that they built last week. The CEV should travel 5 meters when launched. The Reusable Launcher should produce repeatable results.
Lesson Duration:	One 60-90 minute session
Process Skills:	Measuring, calculating, designing, evaluating.
Materials and Tools: (Per group of 3 students)	General building supplies and tools C-clamps and lots of rubber bands Model CEV that was built last week
Club Worksheets: (Make copies for each student to put in binder.)	Reusable Launcher Design Challenge: Imagine and Plan Reusable Launcher Data Table Experiment Notes Graph Your Experiment Data Summary - Questions/Discussions for Understanding Fun With Engineering at Home Quality Assurance - Checking Each Other's Reusable Launchers

This is rough sketch of the set-up. The students should figure out how to make a launcher, and how to determine the independent variable. For example, if a team is using a sling-shot, the independent variable would be the distance the rubber band is pulled back.



Club Facilitator or Teacher Notes for Activity #9:

Stage 1: Set the Stage, Ask, Imagine, Plan

- Share the **Design Story and Challenge** orally with the students.
- Hand out the ***Reusable Launcher Design Challenge: Imagine and Plan Sheets*** (1 of each of these worksheets per team).
- Let the challenge begin and encourage them to **IMAGINE and PLAN** before building. It is important to emphasize that <u>the objective is to build a launcher that gives repeatable results</u>. It is more important that the CEV is launched the same distance using the same set-up than it is to get the CEV to launch the farthest distance.

Stage 2: Create

- Challenge the teams to **CREATE** or build their Reusable Launchers based on their designs. Remind them to keep within specifications.

Stage 3: Experiment

- Discuss how important **EXPERIMENTING** is for engineers.
- Each team should conduct three sets of tests: 3 launches, each using three different set-ups. (For example, if they are launching by pulling back a rubber band, they should measure how far back they pull the rubber band each time they do it. They would do it three times each at three different “pulls” and record those results.)

Stage 4: Re-Design and Re-Build - Improve

- Students **IMPROVE** (Re-Design and Re-Build) Reusable Launchers based on results of the EXPERIMENT phase.

Stage 5: Challenge Closure

- Give out the Summary: Questions/Discussion for Understanding worksheet (1 per team).
- In summary, have a short discussion with all teams. Ask them, “What was the greatest challenge for your team today?” Expect answers such as:
  - Figuring out how to design a Launcher that could be used again and again.
  - Getting repeatable results.
  - Landing near the 5-meter mark.
  - Working as a team, communicating
  - Imagine, plan, create, experiment, improve steps

Stage 6: Previewing Next Week

- The Moon is a very harsh environment. There is no atmosphere to protect astronauts and their equipment from solar radiation and the extreme temperature swings between night and day. Next week, we will begin to find ways to protect astronauts from those extreme temperature changes. Send them home with "Fun with Engineering at Home."

Here is a link to a great NASA animation of a lunar landing!

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

Special Notes: For Those with 90 minute Clubs

Quality Assurance

- Discuss how important FEEDBACK is for engineers. Hand out the Quality Assurance worksheets (1 per team) and ask them to fill out the top section with team name and participants' names.
- Ask each team to put their Reusable Launcher together with their ***Quality Assurance*** worksheet around the edges of the room. Ask each team to move one notch clockwise to offer feedback to the neighboring team, using the Quality Assurance worksheet. The Quality Assurance Teams will conduct a launch test with the CEV. How close does it come to the 5-meter mark?
- Teams then return to their stations and discuss the comments from the Quality Assurance Team. What changes were suggested? Do they make sense?

Design Story and Challenge:

It's Time to Launch into Space!

Last session, you built a model of a Crew Exploration Vehicle. During this session, you must design and build a Reusable Launcher. You will then launch your CEV!

On the way to the Moon, your CEV is going to rendezvous with the International Space Station to pick up some supplies. When you launch your CEV, the goal is to get into orbit close to the International Space Station.

This is a picture of the International Space Station (courtesy NASA). If you want to see real footage of people on the International Space Station, you can see videos from space on the ReelNASA YouTube channel:

www.youtube.com/reelnasa

There's a great shot of a shuttle launch there, too! Turn the sound up **LOUD**!

Design Challenge

Your Reusable Launcher must meet the following Engineering Design Constraints:

- Launch the CEV into orbit so that it may rendezvous with the International Space Station. The goal is to launch the CEV 5 meters.
- Be reusable.
- 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 set-up than it is to get the CEV to launch the farthest distance.

Student Worksheets for Activity # 9 - Launch Your Crew Exploration Vehicle!

Artist's conception of a new CEV - Image courtesy of NASA

Reusable Launcher: Imagine and Plan

<u>It's Time to Launch into Space!</u>

Last session, you built a model of a Crew Exploration Vehicle. During this session, you must design and build a Reusable Launcher. You will then launch your CEV!

On the way to the Moon, your CEV is going to rendezvous with the International Space Station to pick up some supplies. When you launch your CEV, the goal is to get into orbit close to the International Space Station.

<u>Design Challenge</u>

Your Reusable Launcher must meet the following Engineering Design Constraints:

- Launch the CEV into orbit so that it may rendezvous with the International Space Station. The goal is to launch the CEV <u>5 meters</u>.
- Be reusable. It must not fall apart when you use it!
- 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 set-up than it is to get the CEV to launch the farthest distance.**

What job does a Reusable Launcher do?

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

What building materials do you have that might be useful in building the components you mentioned above?

Top View of Reusable Launcher:

Side View of Reusable Launcher:

Reusable Launcher Data Table

Describe what component of the Reusable Launcher set-up you are changing in order to change how far the CEV is launched. This is the Independent Variable.

In the first column, describe the set-up for each of three configurations. For example, if you pull and release a rubber band as part of your Launcher, measure how far back you pull the rubber band. Enter that in the first three boxes of Launcher Set-Up. You would then change that distance, and enter the new distance in the second three boxes. Change it again for the third set.

Independent Variable: Launcher Set-up (Units?)	**Trial Number**	**Dependent Variables**	
		Distance traveled (meters)	**Distance from target (meters)**
Set-up 1:	1.1		
Set-up 1:	1.2		
Set-up 1:	1.3		
Set-up 2:	2.1		
Set-up 2:	2.2		
Set-up 2:	2.3		
Set-up 3:	3.1		
Set-up 3:	3.2		
Set-up 3:	3.3		

EXPERIMENT Notes

What do you need to keep track of to make sure you get consistent results?

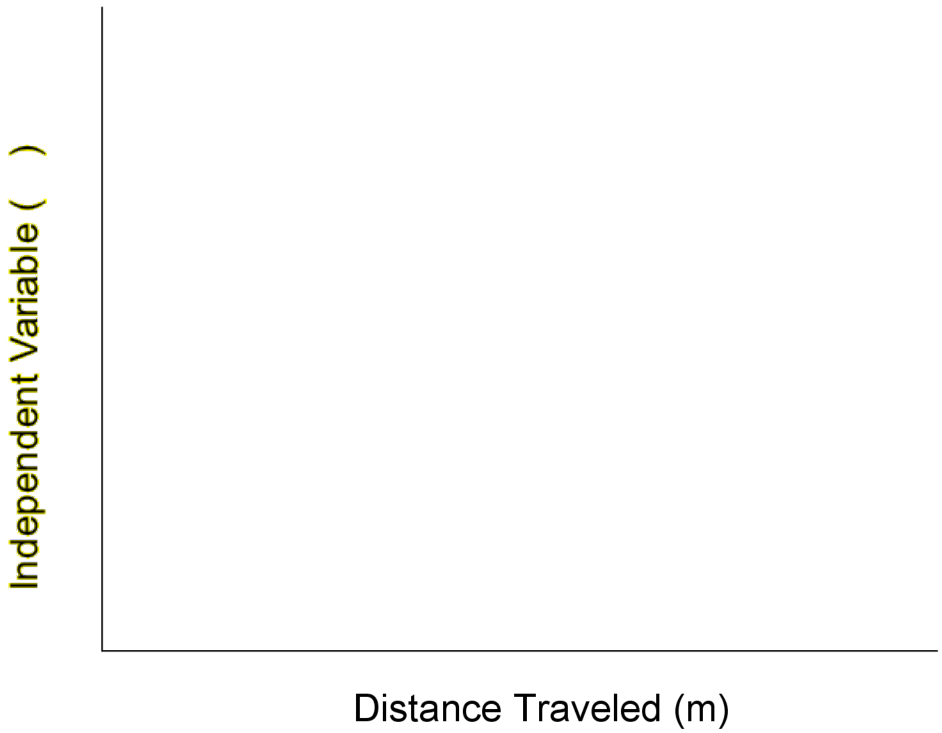
Are you able to repeat the experiment using the same set-up and get consistent results?

If not, why?

How will you improve your design to improve your repeatability?

Graph Your Experiment Data

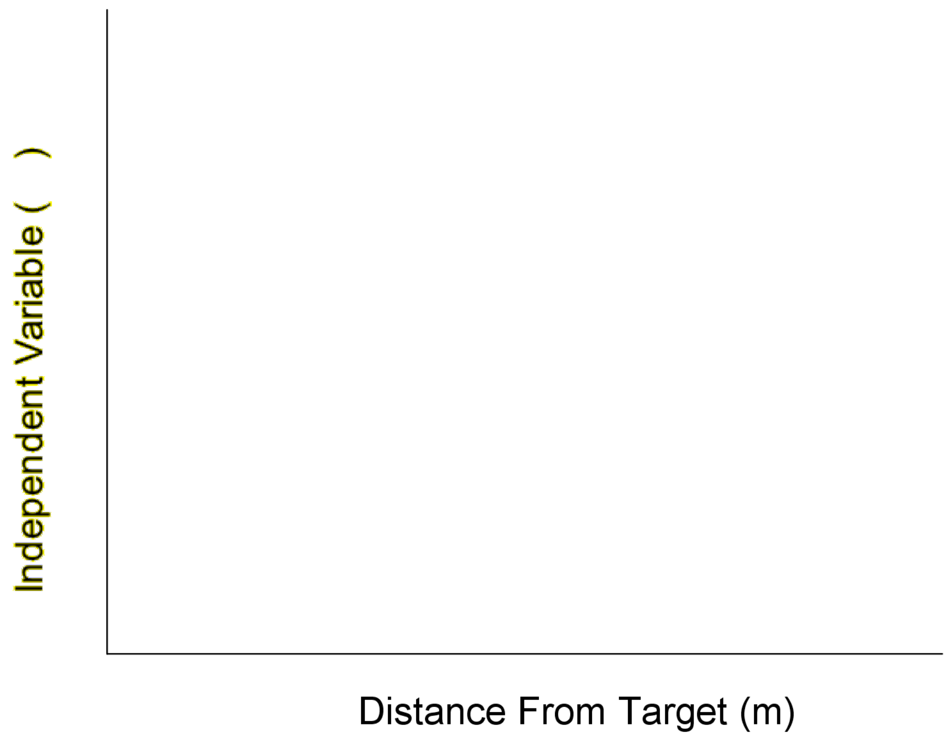
Use the data from the data table to make a graph of your results. You should fill in the units for the independent variable, and make tick marks on the graph with numbers so that you will be able to plot your data.



Are you able to determine if there is a relationship between the independent variable and the distance that your CEV traveled?

If so, describe that relationship.

Label this graph like you did the previous graph.



How is this graph similar or different from the previous graph?

Do they look the same?

What would it look like if you plotted Distance Traveled on one axis and Distance from the Target on the other axis? If there is time, try this and see if your prediction was correct.

Summary: Questions/Discussions for Understanding

What was the greatest difficulty you and your team had today while trying to complete the Reusable Launcher challenge?

Tell how you solved your greatest team difficulty in 2-3 sentences.

Why was it important that the launcher be reusable?

Why was it important that your results were repeatable?

Team Name: ____

Fun with Engineering at Home

Activity 9: Launch Your Crew Exploration Vehicle

Today you designed and built a Reusable Launcher to launch the CEV model that you built last week. 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.

Home Challenge: Next week we will switch gears from getting off the Earth to landing on the Moon. Here are some questions to talk about with your parents, grandparents, brothers or sisters:

How a spacecraft might land on the Moon safely?
Why it doesn't make sense to use a parachute on the Moon?

Here is a link to a great NASA animation of a lunar landing!

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

For Fun:

This is a picture of the International Space Station (courtesy NASA). If you want to see real footage of people on the International Space Station, you can see videos from space on the ReelNASA YouTube channel:

www.youtube.com/reelnasa

There's a great shot of a shuttle launch there, too! Turn the sound up **LOUD**!

Quality Assurance– Checking the Reusable Launchers

Team Name: ______________________________

Participants' Names: ______________________________

____

____

To be answered by the Quality Assurance team:

Describe what component of the Reusable Launcher set-up is changing in order to change how far the CEV is launched. This is the Independent Variable.

Use the set-up that the team says will get the CEV closest to 5 meters.

Independent Variable: Launcher Set-up (Units?)	**Trial Number**	**Dependent Variables**	
		Distance traveled (meters)	**Distance from target (meters)**
Set-up 1:	QA.1		
Set-up 1:	QA.2		
Set-up 1:	QA.3		

Specific Design Strengths:

Specific Design Weaknesses:

How would you improve this design?

Inspected by Team: ______________________________

Participant Signatures: ______________________________

____

____

Activity#10: It's Either Very Hot or Very Cold Up There!

Artist's conception of working on the Moon - Courtesy NASA.

Activity Objective(s):	In this activity, and the follow-up activity next week, teams will design and conduct experiments that will help them understand the basic principles of thermal transfer – how things warm up and cool down. They will carefully gather data and then analyze that data in order to make generalizations about the factors that affect how things get warmer and cooler. These conclusions will be used in the design of a Lunar Thermos next week.
Lesson Duration:	One 60 minute session
Process Skills:	Experimental design, graphing, measuring, and data analysis.
Materials and Tools: (Per group of 3 students)	Thermometers Timers Graduated cylinders Small plastic cups Graph paper, if available
Club Worksheets: (Make copies for each student to put in binder.)	Imagine Plan – Experimental Design Data Table Challenge Closure / Summary Fun With Engineering at Home

Club Facilitator or Teacher Notes for Activity #10:

Stage 1: Set the Stage

Explain to the students that there is no atmosphere on the Moon, so temperatures fluctuate through a wide range. In the shadowed areas the temperature is –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!

On the Moon, there are surfaces permanently exposed to the Sun, and surfaces permanently in shadow. It is in the permanently shadowed areas of some craters that the possible existence of ice has been speculated by some scientists. Anyone living on the Moon will have to deal with this temperature variation, and be properly protected from damaging effects. Thus we must understand how thermal energy is transferred, and, for our concerns, how we can prevent thermal energy 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?

Finally, a quick review of several vocabulary terms might be useful:

> **Heat** = the transfer of energy from a warm place to a cooler place.
>
> **Temperature** = measurement of the energy associated with the motion of molecules in a substance.
>
> **Equilibrium** = two variables, parts, or conditions of a system in balance.

- Break the students into two or four-person teams. Give them the **challenge** (this is the "ASK" part of the engineering design process):
- Given a specific volume of a substance, let's choose water (since about 72% of the human body is water), design an experiment that enables us to understand how thermal energy flows.

Stage 2: Plan – Part 1

- The goal of this exercise of for the students to discover that, without intervention, heat always moves from a warmer place to a cooler place. Some directed guidance/questioning may be necessary to help the students design an experiment that makes sense.
- Some questions that might help with this process are:
    - What is the temperature in the room?
    - How much water should we put in the cup?
    - How can we keep track of our measurements so that we can see a change? (In other words, what should our data table look like?)
    - Is there a difference between the rate that water cools and warms?
    - What specific jobs will each member of the group going to perform?

Stage 3: Plan – Part 2

Briefly write out the step-by-step description of the experiment. Encourage the students to make diagrams of the experimental set-up.

Stage 4: Experiment

- Have each group experiment with at least one type of insulation around the outside of their cups.
- Groups should share information about the insulation materials.
- Measure the temperature at the start (time = 0).
- Gently (very gently) stir the water continuously and measure the temperature every 30 seconds or minute for 5-10 minutes, recording the results in the data table. The team members should take turns reading the measurements and recording the results in the data table.
- 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.
- In either case, for most clear results, the hot and cold samples must be nearly the same amount.
- Then repeat both tests using different insulation materials and compare the results. The best way to track the data is with graphs, but it's possible simply to examine the pattern of change in the data in order to arrive at a conclusion.
- Note-1: The clearest results will occur if both samples of water (hot and cold) are the same difference from room temperature, but this isn't a big deal.
- Note-2: Clearer results will be observed if the samples begin with a temperature at the greatest difference from room temperature.
- Note-3: Stirring the water very gently is helpful because the temperature of the water in a small sample is usually not uniform when left sitting.
- Note-4: The teacher must judge how much time to guide the students in running their individual tests.
- Note-5: Do the students predict that the temperature in either sample will eventually reach room temperature? (This is called "thermal equilibrium" – the temperature at which any objects in the same environment will reach when mutually sharing their thermal energy).
- What insulating materials seem to aid in a decreasing thermal transfer?

Stage 5: Improve

The students must answer the questions posed in the challenge. Did the data show a clear process of thermal transfer? Was there a clear difference between warming up and cooling off? Was there a difference in cooling and warming based on the use of insulation materials? If the results are not clear, what modifications could teams make to make a more successful test(s)?

Stage 6: Graphical Analysis

If there is time the students can graph the warming and cooling curves and see if they look alike. Put Temperature on the Y-axis and Time on the X-axis. Both cooling and warming curves could be plotted on the same graph for best comparison.

Stage 7: Challenge Closure

- Hand out the Challenge Closure / Summary Sheets.

Challenge Closure (Answer Key):

- 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 today's investigation?

  1) The heat of the room and 2) the heat of the water inside the cup

- As in today's 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?

  The hot water will cool down until its temperature is the same as the air in the room

- Describe this in terms of the flow of energy:

  The energy in the hot water will flow out of the water into the surrounding air in the room until they are the same

- 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?

  The cold water will warm up until its temperature is the same as the air in the room

- Describe this in terms of the flow of energy:

  The energy in the air in the room will flow into the water in the cup until they are the same

- Imagine an astronaut stepping out of her warm space vehicle onto the surface of the Moon; what two factors would be operating that are similar to the factors that you investigated in your experiment?
    - *The warmth of the astronaut*
    - *The extreme heat or cold of the Moon*
- Imagine that same astronaut, dressed as you are today, stepping out onto the surface of the Moon:
    - What thermal problems would she encounter?

      She would be either frozen or toasted
    - Would she want her body temperature to achieve equilibrium with the Moon's temperature?

      No way!
    - How could equilibrium be <u>prevented</u>?

      Put her in a protective suit that will insulate her from extremes of temperature

Stage 9: Previewing Next Week

- The Moon is a very harsh environment. There is no atmosphere to protect astronauts and their equipment from solar radiation and the extreme temperature swings between night and day. Next week, we will begin to find ways to protect astronauts from those extreme temperature changes by experimenting further with <u>insulation</u>. We will be testing the lasting-affect of an insulated container (simulating the astronaut in her suit).

Student Worksheets for Activity # 10 –
It's Either Very Hot or Very Cold Up There!

Artist's conception of working on the Moon - Image courtesy of NASA

ASK:

Goal: Given a specific volume of a substance, let's choose water (since about 72% of the human body is water), **design an experiment** that enables us to understand how thermal energy flows (this is called "heating" or "cooling"), and what factors affect temperature change.

Materials:
- Thermometer (must use the Celsius scale)
- Graduated cylinder
- Small plastic cups
- Various insulating materials
- Hot and cold water from a tap

IMAGINE:

Brainstorm some possible solutions to the questions:

What is an "experiment"?

What things do we have to "control"?

What things will we measure?

How will I know my conclusion is correct?

PLAN:
What is the temperature in the room?

How much water should we put in the cup?

What temperature should we make the water in the cup at the start?

What insulating materials should we use?

How can we keep track of our measurements so that we can see a change?

Is there a difference between the rate that water cools and warms with various insulating materials?

TEST

Cool Down Experiment
Room Temperature = _______
Volume (mL) = _____

Time (min)	Temp (^oC)	Time (min)	Temp (^oC)

Analysis:
Does the data indicate a pattern or a trend?

What insulation materials were used and what were the effects?

Warm Up Experiment:

Room Temperature = _______

Volume (mL) = _____

Trial 1 **Trial 2**

Time (min)	Temp (°C)	Time (min)	Temp (°C)

Does the data indicate a pattern or a trend?

What difference did alternative insulation materials make throughout this experiment?

Summary

In science the term "**equilibrium**" refers to a system being in balance. What were the two thermal factors (things related to heat) that were trying to achieve balance in today's investigation?

- As in today's 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?
  - Describe this in terms of the flow of energy:

- 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?
  - Describe this in terms of the flow of energy:

- Imagine an astronaut stepping out of her warm space vehicle onto the surface of the Moon; what two factors would be operating that are similar to the factors that you investigated in your experiment?
  -
  -

- Imagine that same astronaut, dressed as you are today, stepping out onto the surface of the Moon:
  - What problem (other than the fact that there is no air) would she encounter?
  - Would she want her body temperature to achieve equilibrium with the Moon's temperature?
  - How could equilibrium be <u>prevented</u>?

Team Name: ____

Fun with Engineering at Home

Activity 10: It's Either Very Hot or Very Cold Up There!

Today we designed and conducted experiments with energy flowing into or out of containers of water. We chose water to experiment with 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.

Home Challenge: During this week talk with your parents and friends about all the ways we keep the human body safe from extremes of temperature on the Earth (even though the range of variation is not nearly as great as that found on the Moon).

- List four ways we do something with our bodies to prevent temperature extremes from affecting them (two related heat; two related to cold):
  - ____
  - ____
  - ____
  - ____
- Now list four things we do to change the environment we live in so that the environment does not harmfully affect us because of temperature extremes (two related to heat; two related to cold):
  - ____
  - ____
  - ____
  - ____

HAVE FUN!!

Activity #11 - Build a Lunar Thermos

Technicians work on the thermal protection system tiles on space shuttle Discovery – Courtesy of NASA

Activity Objective(s):	In this activity, the teams will use what they learned last week to design a Lunar Thermos that should hold the temperature of the 100 ml of water constant to within 5 degrees over 8 minutes.
Lesson Duration:	One 60-90 minute session
Process Skills:	Experimental design, measuring, graphing, and data analysis.
Materials and Tools: (Per group of 3 students)	▪ General building supplies ▪ Thermometers ▪ Timers ▪ Graduated cylinders ▪ Small plastic cups ▪ Larger plastic cups ▪ Insulating materials (e.g., bubble wrap, paper, paper towels, sand, water, aluminum foil, etc.) ▪ Hot and cold water from the tap ▪ Graph paper, if available
Club Worksheets: (Make copies for each student to put in binder.)	Imagine Plan Experiment Summary Fun With Engineering at Home

Club Facilitator or Teacher Notes for Activity #11:

Stage 1: Set the Stage: ASK

- Review the concepts of energy transfer from last week.
    - The equilibrium temperature is room temperature.
    - Left alone, water in a cup will come to equilibrium; that is, cold water will warm up to room temperature, and hot water will cool down to room temperature.
    - The heat energy is transferred between the water and the surrounding air.
    - Heat energy always flows from hot to cold:
        - To cool down and come to equilibrium with the air, warm water gives up some of its heat to the air.
        - To warm up and come to equilibrium with the air, cool water takes some heat from the air.
- *ASK*: Today's engineering challenge centers on the question: *how can we minimize the transfer of heat energy?* When we go to the Moon, we will need to protect our bodies from the extreme differences in temperature. Recall from last week, in the shadowed areas the temperature is –180 ^oC (or – 300 ^oF), and in the sunlit areas it is about 100 ^oC (or 212 ^oF), which is the boiling point for water! These are serious extremes for human beings! We want to keep our bodies at a fairly constant temperature.

Stage 2: Imagine

- Let's start by building a container to keep water at a constant temperature (since we are mostly water anyway!).
- Hand the Imagine worksheets out to the students. Before giving them access to building materials, ask them to draw a picture that depicts the transfer of energy, from, for example, a warm human standing on the Moon to the cold, lunar night. They should label what is warm, what is cold, and which way the heat transfers. Then ask them to draw the opposite picture: a "cool" human standing in the extreme heat of a hot lunar day. Again, they should label the components and which way the heat flows.
- Now, on the second page of the Imagine worksheet, ask them to devise a method for keeping the human not too warm, not too cool, but just right!

Stage 3: Plan

- Hand out the Plan Worksheet. They should now be able to see what building materials they will be able to use. Ask them to devise a system to keep water at a constant temperature.

Design Specifications: Today's challenge is to keep 100 ml of water at a relatively constant temperature. It should change by no more than 5 degrees over 8 minutes.

- Do we have to design differently for hot water than for cold water? [No.]
- Why? [Because the insulation blocks the transfer of heat *from* a warm region *to* a cool region – which is what heat wants to do. The system has no way of knowing which is "inside" and which is "outside" the thermos, only that heat flows from regions of higher temperatures to regions of lower temperatures.]

Stage 4: Create

- Students use the materials to build a thermos to insulate the water in the Dixie cup. They should have access to all kinds of insulating materials. Most materials will help insulate, though aluminum foil will conduct heat fairly well. Don't tell them this; they should discover it for themselves.

Stage 5: Experiment

The students should run two experiments. One should measure the rate that cold water warms up, and the other should measure the rate at which hot water cools off. They should record a measurement in the data table every 30 seconds. The team members should take turns reading the measurements and recording the results in the data table.

- Remind the students about the design constraint: the temperature should change by no more than 5 degrees over 8 minutes.
- Did the thermos meet the design constraint? If not, give the students an opportunity to improve the insulation and run one more test.

Stage 7: Challenge Closure

- Hand out the Summary Sheets (one per team).

Stage 8: Previewing Next Week

- This week we were trying to stop the transfer of heat energy using insulation. Next week we will capture heat energy to make a solar oven.

Special Notes For those with 90-minute clubs:

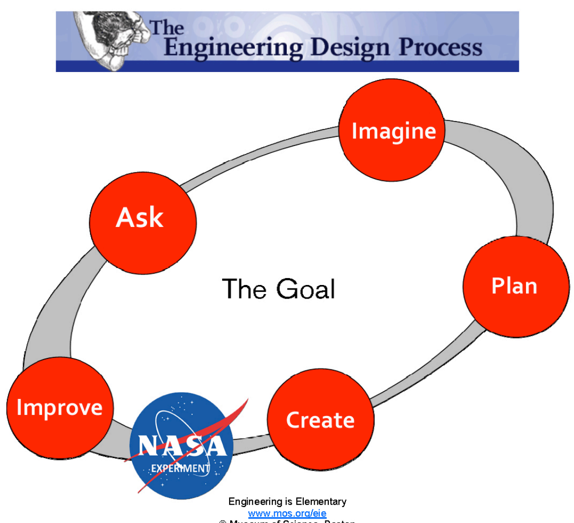
Graphical Analysis: If there is time, the students can graph the warming and cooling curves from their experiments. Put Temperature on the Y-axis and Time on the X-axis. Both cooling and warming curves could be plotted on the same graph for best comparison.

Guiding Questions: Ask them to predict, using the graph, how long until the warm and cool samples reach room temperature. In other words, "How effective is your thermos?"

Ask them to think about how long a thermos should keep something warm (or cool) to make it a "good" thermos.

How does the application affect the answer? In other words, does it matter whether the application is keeping my soup warm until lunch time, compared to keeping my body at roughly "body temperature" when on the Moon? What is the implication for *design specifications*? Ask them to make design specifications for both examples (soup and a human body on the Moon).

Note to Educator/Facilitator:



Have you been reinforcing the Engineering Design Process? Remember, the process is the important learning objective. The students should be having fun!

Student Worksheets for Activity # 11 – Build a Lunar Thermos

Technicians work on the thermal protection system tiles on space shuttle Discovery – Courtesy of NASA

IMAGINE

Draw a picture that depicts the transfer of energy, from a warm human standing on the Moon to the cold, lunar night. Label what is warm, what is cold, and which way the heat transfers.

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.

Devise a method for keeping the human not too warm, not too cool, but just right.

PLAN

<u>Design Specifications:</u> Today's challenge is to keep 100 ml of water at a relatively constant temperature. It should change by no more than 5 degrees over 8 minutes.

Do we have to design differently for hot water than for cold water?

Why or why not?

Sketch your design. What will you use as insulation?

EXPERIMENT: Data Table and Results

Room Temperature = _______

COLD WATER: warm up rate		**WARM WATER: cool down rate**	
Time (sec)	Temp (deg)	Time (sec)	Temp (deg)
0 (at the start)		0 (at the start)	

RESULTS

COLD WATER: warm up rate	**WARM WATER: cool down rate**
Starting Temperature =	Starting Temperature =
Final Temperature =	Final Temperature =
Temperature Difference =	Temperature Difference =

4. Summary

How effective is your thermos?

- Did your thermos meet the design specification?

- Predict how long until the warm and cool samples reach room temperature.

- How long should a thermos keep something warm (or cool) to make it a "good" thermos?

- How does the application affect the answer? In other words, does it matter whether the application is keeping my soup warm until lunch time, compared to keeping my body at roughly "body temperature" when on the Moon?

- What is the implication for *design specifications*? Create your own design specifications for both examples (soup and a human body on the Moon).

- How could you have made your thermos more effective?

Team Name: ____

Fun with Engineering at Home

Activity 11: Build a Lunar Thermos!

Today we designed a Lunar Thermos to control the amount of energy flowing into or out of containers of water. We chose water to experiment with 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. Next week, we will begin to think about how to harness solar energy to do work for us on the Moon.

Home Challenge: During this week talk with your parents and friends about all the ways we could use energy from the Sun to do work for us.

- List four uses of energy from the Sun that you can see around you every day. These can be uses by humans, but you may also include ways in which the energy from the Sun affects nature.
    - ____
    - ____
    - ____
    - ____

Check out this website to learn more about solar energy:

www1.eere.energy.gov/solar/solar_time_2000.html

Check out this website to see how NASA uses solar energy on the International Space Station

www1.eere.energy.gov/solar/solar_time_2000.html

HAVE FUN!!

Activity #12: Powered by the Sun!

A solar cooker heats up in the sun! Photo courtesy of S. Hoban.

Activity Objective(s):	In this activity, teams will use data and graphs to determine the best components to use for a solar box cooker. They will design and build a box cooker, and test it out to see if it works well enough to make S'mores!
Lesson Duration:	One 60 minute session
Process Skills:	Experimental design, measuring, graphing, and data analysis.
Materials and Tools: (Per group of 3 students)	Thermometer Ruler Timers Tape String Cardboard box Manila folders Straws (5 per group) 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, marsh mellows and chocolate)
Club Worksheets: (Make copies for each student to put in binder.)	Design Challenge Imagine and Plan Experiment: Observations Summary Fun With Engineering at Home

Club Facilitator or Teacher Notes for Activity #12:

Stage 1: Set the Stage - Ask

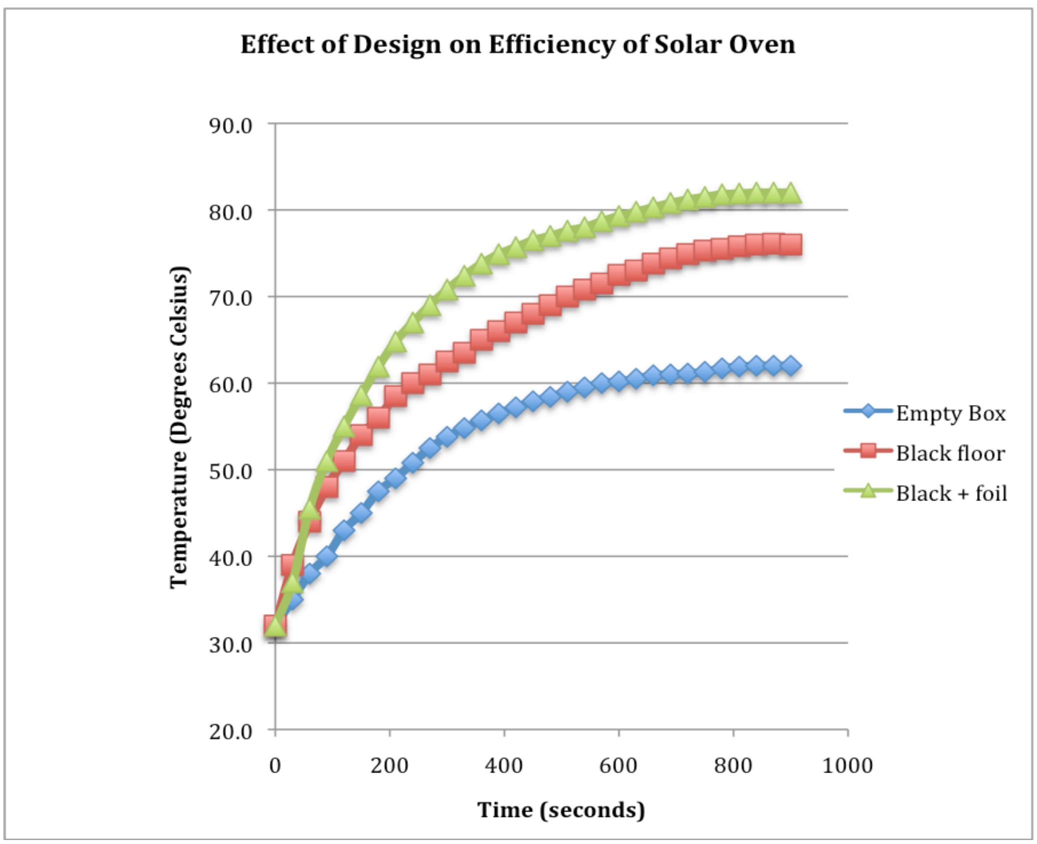
Explain to the students that there is no atmosphere on the Moon, so temperatures fluctuate through a wide range. In the shadowed areas the temperature is –180 ^{o}C (or – 300 ^{o}F), and in the sunlit areas it is about 100 ^{o}C (or 212 ^{o}F), which is the boiling point for water! These are serious extremes for human beings!

Since there is no atmosphere and thus no clouds on the Moon, there are no cloudy days! During the daytime, it is always sunny! So why not take advantage of all that sunshine, and put the Sun to work? Ask the students to come up with some ideas of how they could use solar energy to do some work for them.

Today we'll build an oven that uses energy from the Sun to cook food. This reflective solar cooker uses the Sun's energy to cook marshmallows. The target cooking area is the space where the light concentration is greatest. Never look directly at the Sun! It could damage your eyes. Don't allow the cooker to reflect sunlight into your eyes. Let's make S'mores! It's easy!

Stage 2: Imagine and Plan

- Distribute the **Design Challenge** worksheet.



- Ask the students to look at the graph on the worksheet (see previous page). Three different scenarios are depicted on the graph:
    1. A plain cardboard box, covered with plexiglass
    2. A cardboard box with black construction paper on the bottom
    3. A cardboard box with black construction paper on the bottom and aluminum foil on the sides
- Ask the students to discuss among themselves which materials seem to make a better solar cooker. They should also
- Hand out the **Imagine and Plan** worksheet, and ask them to list the materials they want to use for their solar cooker, answer questions, and sketch a design.

Stage 3: Create

- Build the solar cooker!

Stage 4: Experiment

- Now that the students have their solar oven, hand out the **Experiment: Data Table** worksheet.
- Students should record the temperature on the thermometer before placing it in the box.
- Students should place food and thermometer inside box with lid closed.
- 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 the goose neck lamp with the 100W bulb.
- Students should record the temperature on the thermometer every 30 seconds for 10 minutes. At the end of 10 minutes, ask them to report out around the room. Whose cooker got to the highest temperature? Whose cooker melted the marshmallows?
- If there is time, the students should graph their data. From the graph in the handout, which design does their data most closely resemble?

Stage 5: Challenge Closure

- Hand out the Challenge Closure / Summary Sheets.

Student Worksheets for Activity # 12 – Powered by the Sun!

A solar cooker heats up in the sun! Photo courtesy of S. Hoban

Design Challenge

During the lunar day, the sun shines very brightly and it gets very hot. Why not put the Sun to work? Today, we will design and build a solar oven. To test the oven, we will try to make S'mores!

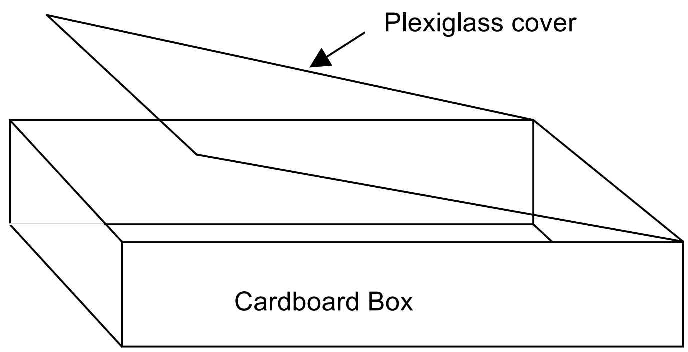
Materials:

- Thermometer
- Timers
- Ruler
- String
- Tape
- Straws (5 per group)
- Manila Folder
- 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)

Design Specifications

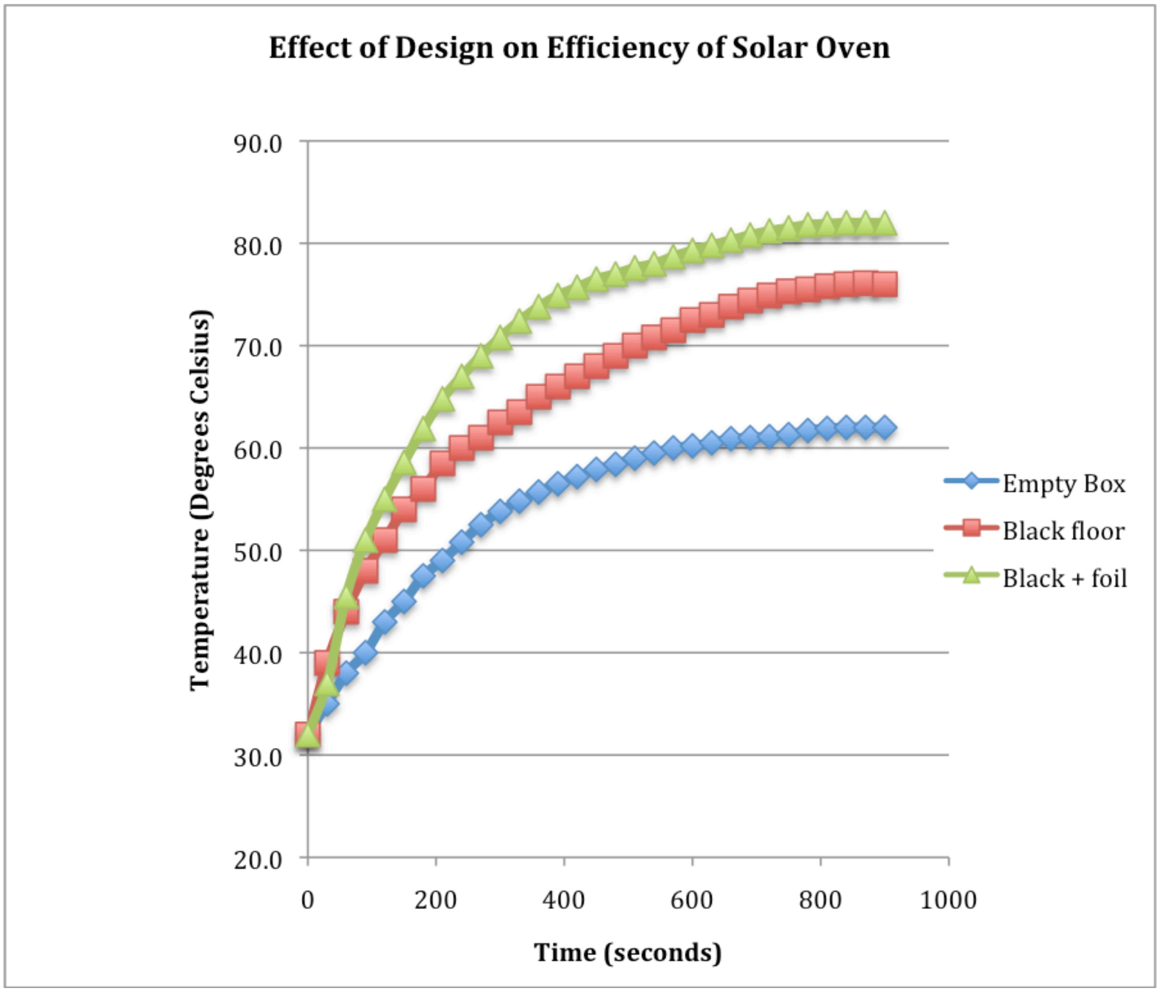
Your solar oven must meet the following specifications:

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 degrees Celsius.
3. You may use any available materials to line the bottom and inside of box. Your food may not touch the bottom of the solar oven directly. You must design a way to best cook two S’mores off of the bottom surface, keeping in mind how height may play a role in how quickly the food is cooked.
4. You must cook two S’mores at two different heights. You will also test which height allows food to cook at a quicker rate.



IMAGINE and PLAN

Here is some information on solar ovens that other people have made. Use this information to help you design your solar oven.



All of these solar ovens were made of a cardboard box covered with a clear, plexiglass lid. For the most part, plexiglass allows sunlight to pass through, but it will not let the heat back out.

The curve labeled "Empty Box" represents the data from an empty cardboard box with no changes made to it.

The curve labeled "Black floor" was for the same box, but with black construction paper placed on the floor of the box.

The curve labeled "Black + foil" was still the same box with the black construction paper on the floor, but also with aluminum foil lining the sides of the box.

What difference do the different materials make in the design of the solar over?

How do you think the black construction paper affects how well the solar oven works?

What purpose do you think the aluminum foil might serve?

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.

Sketch and label the design for your solar oven:

Experiment: Data Table

Now that you have built your solar oven, let's see if we can make S'mores! Follow these steps:

1. Record the temperature and heights of the food in the room in the chart.
2. Place the thermometer and the uncooked S'mores in the solar oven.
3. Record the temperature in the chart below every 30 seconds.

Room Temperature: _____________ ^{o}C

Food Heights: #1_____ cm / #2 _____ cm

Time	**Temperature**
0 seconds	
30 seconds	
60 seconds	
90 seconds	
120 seconds	
150 seconds	
180 seconds	
210 seconds	
240 seconds	
270 seconds	
300 seconds	
330 seconds	
360 seconds	
390 seconds	
420 seconds	
450 seconds	
480 seconds	
510 seconds	
540 seconds	
570 seconds	
600 seconds	

Experiment: Cooking Observations

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	S’more at Height #1	S’more at Height #2
60 sec.		
120 sec.		
180 sec.		
240 sec.		
300 sec.		
360 sec.		
420 sec.		
480 sec.		
540 sec.		
600 sec.		

5. Summary

1. Did your S'mores melt? What was the maximum temperature reached by your solar oven?

2. What could you have done to make your solar oven work better?

3. Do you think it would make a difference to use actual sunlight compared to light from a lamp? Why or why not?

4. What other things could you use a solar oven for other than making S'mores?

5. How did the distances from the bottom reflective surface affect the cooking of the food in your solar oven?

Team Name: ____

Fun with Engineering at Home

Activity 12: Powered by the Sun!

Today we designed and built an oven that uses solar energy (or the light from a lamp) to heat things up.

Home Challenge: During this week talk with your parents and friends about all the ways we could use solar energy here on Earth.

List four uses for solar energy that you have heard about:

- ____
- ____
- ____
- ____

Look up “the greenhouse effect.” Can you explain what “the greenhouse effect” has to do with your solar oven?

What else does the greenhouse effect have to do with?

HAVE FUN!!

BEST Activity Resources:

Developers and Contributors:

Dr. Susan Hoban	NASA Goddard Space Flight Center, UMBC
Don Hidgon	NASA Goddard Space Flight Center, UMBC
Brittany Hamolia	NASA Goddard Space Flight Center, UMBC
Tracy Clark-Keegan	UMBC
Jamie Gurganus	UMBC