NASA's BEST Activities

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

An Educator's Guide to Engineering Clubs
Grades K–2

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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 cheap, building supplies. Any particular item may be substituted, and additional materials will 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 pkg. of 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

1	**Build a Satellite to Orbit the Moon**	Mailing tube (4" inside diam) or Shoe Box Shockers (formerly ShockTarts) SweeTart Chews
2	**Launch Your Satellite**	Toilet paper rolls Balloons (assorted sizes, shapes) Fishing line (approx. 20 lb test) Clamps (C-type or other) Binder clips Clothes Pins Rulers or meter sticks
3	**Design a Lunar Transport (LT) System**	”Astronauts“ (two 2-cm plastic) Plastic egg Plastic wheels for rover Ramp for LT to Roll Down Pennies Rulers or meter sticks
4	**Design a Landing Pod**	Bubble wrap (not required)

5	**The Rover Has Landed**	Bubble wrap (not required)
6	**Mission: Preparation**	Rulers Graph paper
7	**Mission: Ready, Set, Explore!**	Rulers Graph paper Blindfolds
8	**Design the New CEV**	Mailing tube (4" inside diam.) "Astronauts" (two 2-cm plastic)
9	**Launch the CEV**	CEV (built the previous week) Clamps Rubber bands
10	**Is it Hot or Cold Up There?**	Graduated cylinders Hot and cold water Thermometers Stopwatch Cups (plastic—approx. 12 oz) Insulation materials Graph paper Chart paper Two Glowsticks / team
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 (e.g., "S'mores")

Alignment to National Standards

Each activity in this guide features objectives, a list of materials, educator information, procedures, and student worksheets. When appropriate, the guide provides images, charts, and graphics for the activities. Each activity correlates to national science, mathematics, technology, and engineering standards. Matrix charts relating activities to national standards are included because many lessons are interdisciplinary. National Standards were obtained from the following Web resources:

http://www.educationworld.com/standards/national/science/index.shtml
http://www.iste.org
http://www.nsta.org

National Science Education Standards

Content Standard	Strand	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	Develop understanding of properties of Earth materials			*					*				
	Develop understanding of objects in the sky			*	*	*	*	*			*	*	*
	Develop understanding of changes in Earth and sky			*	*								

Science and Technology	Develop abilities of technological design	*	*	*	*	*	*	*	*	*	*	*	*
	Develop understanding about science and technology	*	*	*	*	*	*	*	*	*	*	*	*
	Develop abilities to distinguish between natural objects and objects made by humans												
History of Nature and Science	Develop understanding of science as a human endeavor	*	*	*	*	*	*	*	*	*	*	*	*

National Technology & Engineering Education Standards

Content Standard	Strand	1	2	3	4	5	6	7	8	9	10	11	12
Creativity and Innovation	Apply existing knowledge to generate new ideas, products, or processes	*	*	*	*	*	*	*	*	*		*	*
	Create original works as a means of personal or group expression	*	*	*	*	*	*	*	*	*		*	*
	Use models and simulations to explore complex systems and issues	*	*	*	*	*	*	*	*	*		*	*
Research and Information Fluency	Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media	*	*	*	*				*	*			

	Evaluate and select information sources and digital tools based on the appropriateness to specific tasks	*	*	*	*				*	*			
Critical Thinking, Problem Solving, and Decision Making	Identify and Define authentic problems and significant questions for investigation	*	*	*	*				*				
Digital Citizenship	Advocate and practice safe, legal, and responsible use of information and technology	*	*	*	*				*		*		
	Exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity	*	*	*					*	*			
	Demonstrate personal responsibility for lifelong learning		*	*	*	*	*	*	*	*	*	*	*

National Mathematics Education Standards

Content Standard	Strand	1	2	3	4	5	6	7	8	9	10	11	12
Numbers and Operations	Understand numbers, ways of representing numbers, relationships among numbers, and number systems		*	*	*	*	*	*	*	*	*	*	*
	Understand meanings of operations and how they relate to each other	*	*										

	Compute fluently and make reasonable estimates	*	*										
Measurement	Understand measurable attributes or objects and the units, systems, and processes of measurement	*	*	*	*	*	*	*	*	*	*	*	*
	Apply appropriate techniques, tools, and formulas to determine measurements		*	*	*	*	*	*	*	*	*	*	*
Data Analysis and Probability	Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them		*										*
	Select and use appropriate statistical methods to analyze data		*										*
	Develop and evaluate inferences and predictions that are based on data		*										*
Problem Solving	Build new mathematical knowledge through problem-solving	*											
	Solve problems that arise in mathematical and in other contexts	*											
	Apply and adapt a variety of appropriate strategies to solve problems	*											
	Monitor and reflect on the process of mathematical problem solving	*											

Communication	Organize and consolidate mathematical thinking through communication	*	*	*	*	*	*		*		*	*	*
	Communicate mathematical thinking coherently and clearly to peers, teachers, and others	*	*	*	*	*	*		*		*	*	*
	Analyze and evaluate the mathematical thinking and strategies of others	*	*	*	*	*	*		*		*	*	*
	Use the language of mathematics to express mathematical ideas precisely	*	*	*	*	*	*		*		*	*	*
Connections	Recognize and apply mathematics in contexts outside of mathematics	*	*	*	*	*	*		*		*	*	*

Lesson Plan Cover Page

Unit Title:

Objective(s):

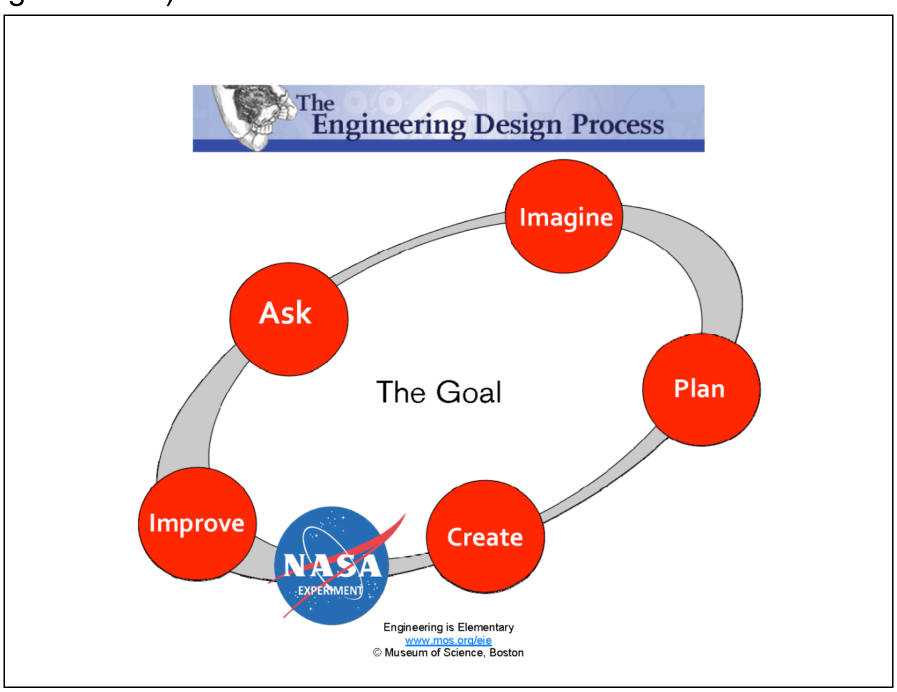
Evaluation procedures:

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 like those that work for NASA who build rockets and satellites.
- 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 (see figure below).



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

- Share the **Design Story and Challenge** orally with the students (provided in teacher pages). This story provides the context and motivation for trying to accomplish the challenge. This is the **ASK** phase of the Engineering Design Process.
- The **Design Story and Challenge** will paint the picture for the students for each challenge. It is important that you set the context with this story before jumping into the challenge to make the science, mathematics, and engineering come to life; it is the story that makes the hands-on activities have relevance and meaning.
- Put the students in teams of three 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 mathematical calculations and check designs and models to make sure they are within specified design constraints.
- For activities that require the use of thermometers—Note: 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 students to be careful when handling the thermometer.

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

- Time permitting, allow students to re-design and re-build 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.

- Once the Challenge Closure/Summary Sheets are completed, please collect one per team and save in a folder for NASA if you are participating in a NASA evaluation. If not, you may wish to collect these for your own evaluation purposes.

Stage 6: Previewing Next Week

- The 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 http://www.lpi.usra.edu/education/explore/moon/lro.shtml

Artist's conception of the Lunar Reconnaissance Orbiter. The LRO mission will conduct investigations that will prepare for future human exploration of the Moon. Credit: NASA

Objective(s):	The teams' challenge is to build a satellite that falls within certain size and weight limits. This satellite will be designed to orbit the Moon. It will have to carry come combination of cameras, gravity probes, and heat sensors to look at or probe the Moon's surface.
Lesson Duration:	One 60–90 min session
Process Skills:	Measuring, calculating, designing, evaluating
Materials and Tools: (per group of three students)	General building supplies 1 bag "Shockers" candy or other small candies 1 bag "Chewy SweetTarts" candy or other candies
Club Worksheets: (Copy for each student's binder)	Engineering Design Process Detector or Instrument Table of Uses and Weights Satellite Design Summary: Questions/Discussions for Understanding Fun with Engineering at Home

Club Facilitator, or Teacher, Notes for Activity #1

Stage 1: Meet and Motivate

- Welcome the students and set the stage by telling them they will be learning how to become ENGINEERS.
- Spend a few minutes asking them if they know what engineers do. 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 next page).
- Hand out the ***Detector or Instrument Table of Uses and Weights*** worksheet and the ***Satellite IMAGINE and PLAN Worksheet.***

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 and remind them to keep within specifications.

Stage 4: Challenge Closure

- Give out the *Summary: Questions/Discussion for Understanding* worksheet and instruct groups to complete each question.
- 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
    - Consider what it means to build something that will be launched into space
    - Imagine, plan, create, experiment, improve steps
    - Calculate weights of instruments/detectors, making sure that our instruments do not add up to more than the allowed weight limit

Stage 5: Previewing Next Week

- Ask teams to bring back their satellite 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.
- Distribute the *Fun with Engineering at Home* worksheet. Tell them to share this sheet with their family and ask their family to help them with the Home Challenge found on this sheet.

Design Story and Challenge:

NASA's Lunar Exploration Missions

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

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

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

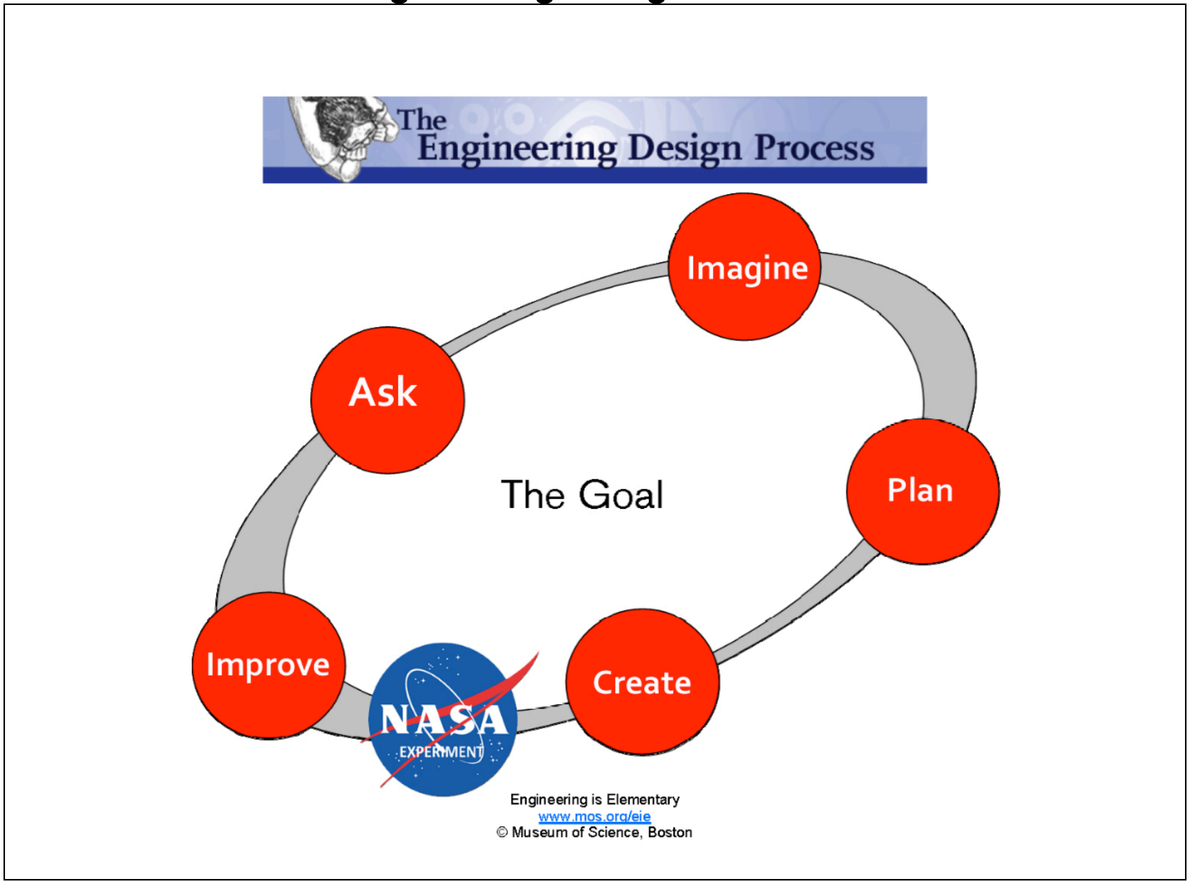
Overall, the weight (strictly speaking, the mass) of anything we want to send into space is the most challenging problem for the engineers. The more an object weighs, the more energy it takes to launch it.

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 big candies are the instruments and represent **large weights**. The small candies are the solar cells and represent **small weights** (see the Data Table). The total weight of the instruments, detectors, probes, sensors and the solar cells that power them can be no greater than **four large weights** and **five small weights** in total.

Student Worksheets for Activity #1
Build a Satellite to Orbit the Moon!

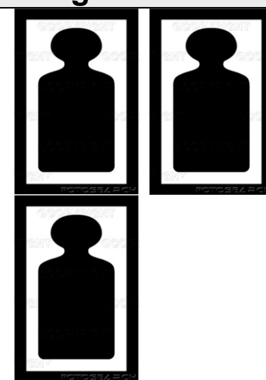
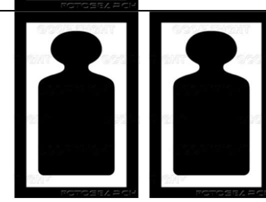
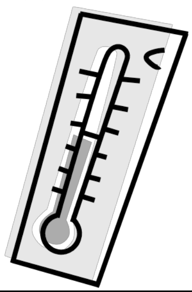
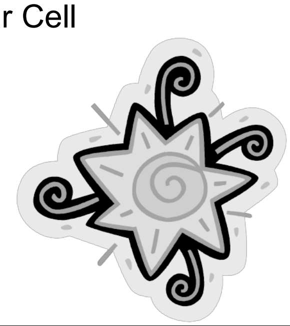
Engineering Design Process



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 Weights

Detectors or Instruments	Use	Weight
Camera 	Takes Pictures (needs one solar cell to operate)	
Gravity Probe 	Measures (needs two solar cells to operate)	
Heat Sensor 	Measures Temperature (needs three solar cells to operate)	
Solar Cell 	Collects Energy from the Sun to Power an Instrument, Detector, Sensor, or Probe	

Satellite Imagine and Plan Sheet

Team Name:____

Draw your sensors and probes—and draw their weights beside them:

How many total big weights?

How many total small weights?

Draw your satellite. Label the sensors, probes, and solar cells:

Summary: Questions/Discussions for Understanding

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

1.

2.

What was the hardest thing you and your team had to do today while building the satellite?

How did your team solve this problem?

Team Name: ____

Fun with Engineering at Home

Activity #1: Build 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 six 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 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
   http://www.nasa.gov/worldbook
2. The World Almanac for Kids Science: Artificial Satellites
   http://www.worldalmanacforkids.com
3. NASA Space Place
   http://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!

Activity #2: Launch Your Satellite!

A Delta II rocket lights its main engine and nine solid-fueled boosters to begin the Dawn mission to the asteroid belt. Photo Credit: 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 three 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: (Copy for each student to put in binder.)	Rocket Elements Data Table Balloon Rocket Assembly Design Improvement Phase of Rocket Design Summary Fun With Engineering at Home

NOTE: This activity was adapted from NASA educational products:
***Rockets Educator Guide** EG-2003-01-108-HQ –*
http://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 easy restringing of the successive balloon rockets. The line must 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.

Stage 1: Meet and Motivate

- Keep the same grouping of children from week #1 and ask groups to retrieve their satellite that was created during the last session.
- 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 it to go far 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.

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

- 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 up 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. If the opening in the balloons tends to stick, try putting a little bit of hand lotion inside the opening.
- Hand out the ***Rocket Elements Data Table*** and the ***Rocket Design Sheet*** (one 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?
- Let the challenge begin—Encourage them to **IMAGINE and PLAN** before building. Do not hand out the scissors, tape or glue for 7–10 minutes. Ask them to use their worksheets to sketch their design ideas.

Stage 3: Create and Experiment

- Give out the scissors, glue, and tape. Challenge the teams to **CREATE** or build their rockets based on their plans and remind them to keep within specifications.

- 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: Re-Design and Re-Build—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. Write down the new data.

- At the end of the session, teams report how far their rocket traveled and explain which combination of variables gave the best results.

Stage 5: Final Launch and Challenge Closure

- The teams launch their balloon rockets, one at a time. The FINAL DISTANCE is recorded for each team.
- At the end of the session, teams report how far their rocket traveled and explain which combination of rocket elements gave the best results.
- Give out the Summary: Questions/Discussion for Understanding worksheet (one 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:
  - Deciding which rocket elements to change and why
  - Considering how to change the rocket elements
  - Working as a team, clearly communicating ideas
  - Imagine, plan, create, experiment, improve steps
  - Launching the rocket with the satellite

Stage 6: Previewing Next Week

- Next week, we will switch gears from getting off Earth to landing on the Moon.
- Ask teams to think about how a spacecraft might land on the Moon safely. Ask them to think about why it doesn't make sense to use a parachute on the Moon (there is no air on the Moon to fill up the parachute!).

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

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

Student Worksheets for Activity #2*: Launch Your Satellite!*

A Delta II rocket lights its main engine and nine solid-fueled boosters to begin the Dawn mission to the asteroid belt. Photo Credit: NASA

Rocket Elements Data Table—Imagine, Plan, Create

Design Notes

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

<u>You want to shoot the rocket the farthest distance.</u>

Build your rocket with ONE balloon attached to a piece of drinking straw, which will slide along a fishing line stretched between two tables. You control the length of the drinking straw. You will find out which length of straw allows your balloon rocket to go the farthest.

DATA TABLE

Rocket Elements	Trial 1	Trial 2	Trial 3
Straw Length	**Short** **______ cm**	**Medium** **_____ cm**	**Long** **______ cm**
Distance traveled (cm)			

Balloon Rocket Design

Top View of Our Balloon Rocket

Side View of Our Balloon Rocket

Improvement Phase of Rocket Design

Now that you have experimented with all of the different lengths of straw, build your final rocket—the one you expect to go the farthest.

Which straw length did you choose?

Why did you choose it?

DATA TABLE

Rocket Elements	**New Trial After Re-design**
Balloon Shape (long or round)	
Balloon Length (cm)	
Straw Length (cm)	
Distance traveled (cm)	

If you had more time, now you could test another rocket element, like Balloon Length!

Summary: Questions/Discussion for Understanding

What was the hardest part of the activity for your team today?

If you had more time to create and test the rocket, what rocket elements would you change? Why would your team change this rocket element?

Team Name:____

Fun with Engineering at Home

Activity 2: Launch Your Lunar Satellite

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. 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 rocket. Finally, we **EXPERIMENTED** or tested our rocket by having other groups look at it, launch it, and give us feedback. Last, we went back to our team station and tried to **IMPROVE** our rocket. These are the same six steps engineers use when they try to solve a problem or a challenge.

Home Challenge: 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!

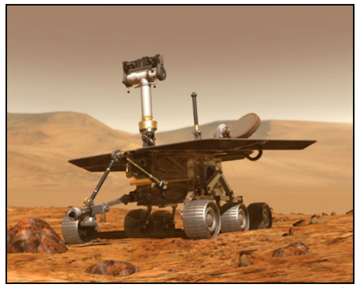
American rocketry was pioneered by Dr. Robert Goddard. NASA's Goddard Space Flight Center is named after him. For further reading about Dr. Goddard: http://www.nasa.gov/centers/goddard/about/dr_goddard.html

To read about the Ares V rocket, check out this link:
http://www.nasa.gov/mission_pages/constellation/ares/rocket_science.html

Teacher Notes for Activities 3–5:

In preparation of returning humans to the Moon and eventually on 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 Landing Pod 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 Rover!



Artist conception of a rover: Image courtesy of NASA
Two rovers that look like this are on Mars NOW!

Activity Objective(s):	The teams' challenge is to design and build a model of a Lunar Rover that will carry equipment and people on the surface of the Moon. It must be able to roll down a ramp. 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 three students)	▪ General building supplies and tools ▪ (2) small plastic people (approx. 2 cm each) ▪ (1) plastic egg ▪ (10) pennies to represent cargo weight ▪ (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 25 cm or more) ▪ Metric rulers
Club Worksheets: (Make copies for each student to put in binder.)	Lunar Rover Design Challenge Lunar Rover Imagine and Plan Sheets Experiment/Observation Notes Sheet Fun With Engineering at Home

Club Facilitator, or Teacher, Notes for Activity #3:

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

- Share the **Design Story and Challenge** orally with the students (see next page).
- Show the Mars Rover Entry, Landing, and Descent video called "Six Minutes of Terror."

  (http://marsrovers.jpl.nasa.gov/gallery/video/challenges.html).
- 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. Explain to them that with no atmosphere on the Moon, a parachute device would not work).
- The NASA Web site with more video on the Mars rovers is:

  http://marsrover.nasa.gov/gallery/video/challenges.html
- Hand out the ***Lunar Rover Design Sheet*** (one of each of these worksheets per team) and let the challenge begin!

Stage 2: Create

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

Stage 3: Experiment

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

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

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

Stage 5: Challenge Closure

The Summary of this activity will come at the very end (two weeks from now), 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 students they will be building the landing pod out of the standard materials that have been available to them. The pod will be dropped from as high as possible (out a second story window? at least off a tall ladder, or the top of a staircase).

Story and Design Challenge: *(For Teacher Use)*

Let's Go For A Ride!

Over the past weeks, we have spent some time thinking about how to get to the Moon. Now we need to think about landing on the Moon, and what we are going to do once we get there. NASA has two very famous rovers on Mars already. Their names are **Spirit** and **Opportunity**. They landed on Mars in a very interesting fashion: they fell out of the Martian sky and bounced on the surface until they came to a stop! How did they do that? They were inside a landing pod made of...AIR BAGS! Wasn't that a clever idea? Now it's your turn! Your job over the next three weeks is to build a model of a Lunar Rover. The rover's job will be to carry people and cargo on the Moon. You also have to figure out a way to land your Lunar Rover safely on the surface by designing and building a Landing Pod. Once the landing is complete, you will open the Landing Pod and roll your Lunar Rover down a ramp.

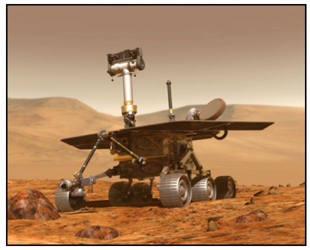
(The "landing" is simulated by the facilitator. Suggestions: toss it out of a second story window, or toss it across the classroom. Just be sure the students know ahead of time what to expect.)

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.)
- Carry cargo weight inside the plastic egg, represented by pennies. Groups should test how much cargo weight they can carry in the egg and record this observation (1 penny = 1 gram of cargo weight).
- 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 about 25 cm or more.
- 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.

Student Worksheets for Activity #3: *Design a Lunar Rover!*



Artist conception of a rover. Image 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.)
- Carry cargo weight inside the plastic egg, represented by pennies. Groups should test how much cargo weight they can carry in the egg and record this observation (1 penny = 1 gram of cargo weight).
- 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 about 25 cm or more.
- Survive the “landing.” This means it should be able to roll down the ramp after the landing, and the plastic egg should not have popped open.

Imagine and Plan Worksheet

What parts do you need to make your rover roll?

What will hold the egg in place?

Sketch of our Lunar Rover

Experiment

Observation Notes

Rover Experiment Data Table	
Number of Pennies Carried:	___________ pennies
Gram(s) of Cargo Weight Carried:	___________ gram(s) (Remember: 1 penny = 1 gram of cargo weight)
Length of the Roll Down the Ramp:	___________ cm

Team Name:____

Fun with Engineering at Home

Activity 3: Design a Lunar Rover!

Today we designed and built a Lunar Rover model to transport people and cargo on 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 Lunar Rover. 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 rover. These are the same six steps engineers use when they try to solve a problem or a challenge.

Home Challenge: 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 Web site:

http://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 <u>not</u> use a parachute to land a spacecraft on the Moon?

They also used a heat shield on the Mars entry spacecraft. Why do we <u>not</u> 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?

Activity #4: *Design a Landing Pod!*

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

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 three 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

Club Facilitator, or Teacher Notes, for Activity #4:
Design a Landing Pod!

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

- Share the **Design Story** and **Challenge** (in teacher pages) orally with the students.
- Discuss the Mars Rover Entry, Landing, and Descent video called "Six Minutes of Terror." Explain to them why a parachute won't work on the Moon (no atmosphere on the Moon).
- Discuss ways to land the rover safely and make a list of ideas on chart paper or a blackboard.
- The NASA Web site with more video on the Mars rovers is: http://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*** (one set of worksheets per team).
- Let the challenge begin—Encourage them to **IMAGINE and PLAN** before building. Ask them to use their worksheets to capture their design ideas.

Stage 2: Create

- Challenge the teams to **CREATE** or build their Landing Pod based on their designs. Remind them to keep within specifications.
- Members should also be sure that the egg inside the rover is empty and is not carrying remaining cargo from the previous lesson.

Stage 3: Experiment

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

Stage 4: Challenge Closure

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

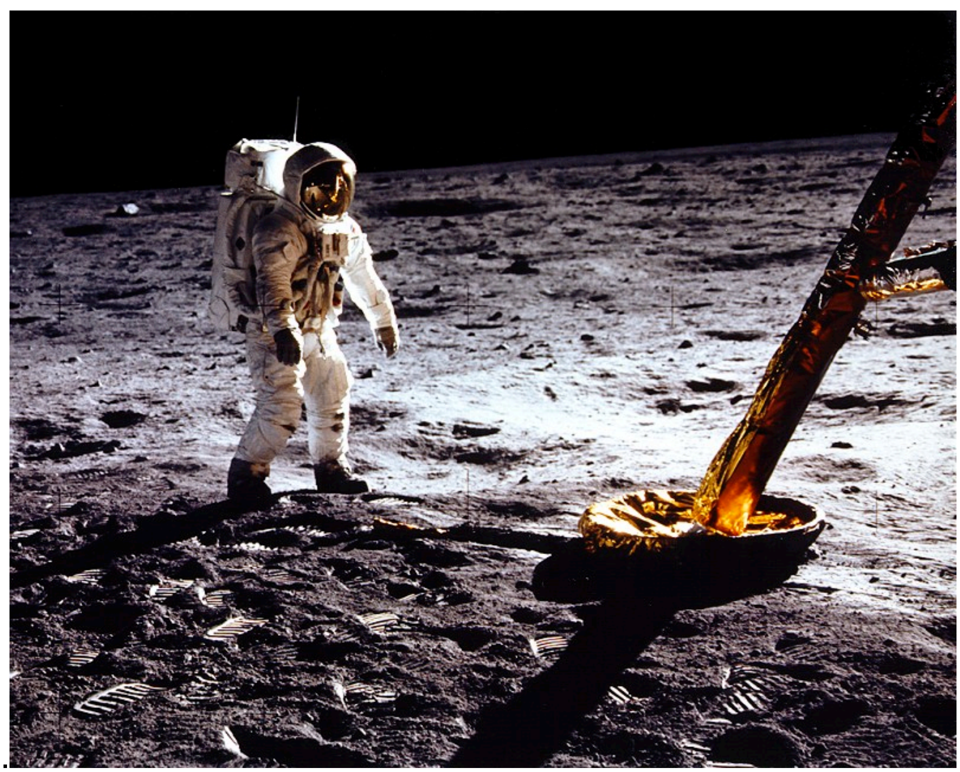
Stage 5: Previewing Next Week

- 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 a second story window? Or at least off a tall ladder, or the top of a staircase. Just make sure they know from how high their models will be dropped.)

Design Challenge (For Teacher Use)

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.
- It must land RIGHT-SIDE up. (The rover must be able to roll out, so it must land in the correct orientation.)
- It must be reusable. You must be able to open it, retrieve the Lunar Rover, and then use the Landing Pod again.



Buzz Aldrin and the Apollo 11 *Lunar Module on the Mono. Image courtesy of NASA.* *http://history.nasa.gov/ap11ann/kippsphotos/apollo.html*.

Student Worksheets for Activity #4: *Design a Landing Pod!*

Image courtesy of NASA—Apollo 11 *Lunar Module Descent Nozzle*
http://history.nasa.gov/ap11ann/kippsphotos/apollo.html

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.
- It must land RIGHT-SIDE up. (The rover must be able to roll out, so it must land in the correct orientation.)
- It must be reusable. You must be able to open it, retrieve the Lunar Rover, and then use the Landing Pod again.

Imagine and Plan Worksheet

What height will be used to drop your rover? ________________________

List or draw pictures of the materials you will use to protect the rover *inside* the Landing Pod.

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

Estimate, or predict, the total amount of pieces of bubble wrap you will use to create your Landing Pod.

We predict that our group will use _____________ pieces of bubble wrap to create our Landing Pod.

Draw a picture of the side of your Landing Pod:

Draw a picture of the “door” or “hatch” of the Landing Pod:

Experiment Notes and Data Table

Make two test drops with your Landing Pod. Use a height that is less than the final drop height given by your teacher. Note carefully how it lands and think about what changes you should make to improve the landing.

Trial	Drop Height (m)	Observations—What happened during trial 1?
1		

What is one change you should make to your Landing Pod to improve the landing?

Trial	Drop Height (m)	Observations—What happened during trial 2?
2		

What is the hardest part of this experiment?

What is the total number of bubble wrap pieces used for your 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?

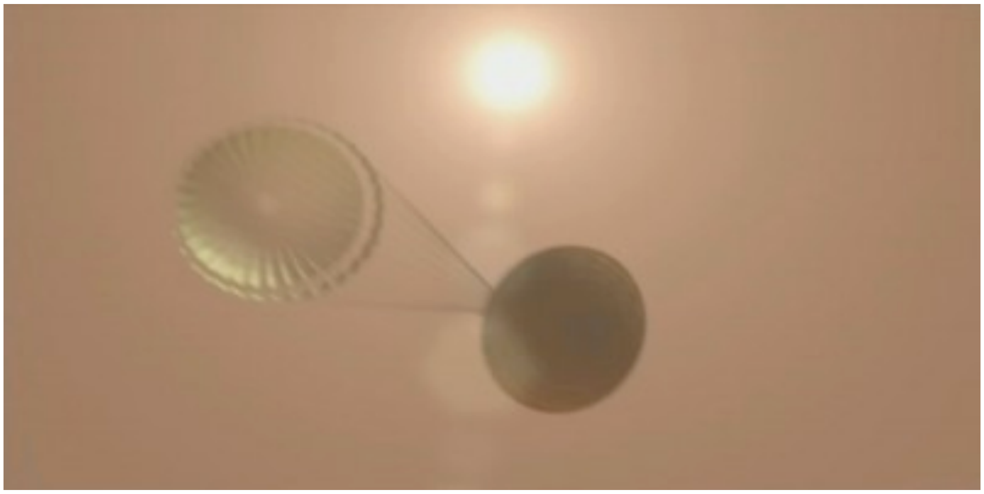
Where in the Solar System, besides Earth, have humans visited? When was that? What kind of a lander did they use? How did it slow down before impact on the surface?

Who was "Buzz" Aldrin, and what cartoon character do you think might have been named for him? Why?

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?

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

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 three 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 **Design Story** and today's **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 and then show them this height for a visual connection.)
- Assemble students in a whole-group format and have a discussion using the questions below as a guide. Take answers from members of each group, and ask the students to compare their experiences to other group experiences. Allow students to view all group designs and discuss similarities and differences.
    - What were some of the most important parts of the Lunar Rover to keep safe and how did you keep them safe?
    - What would you add to your designs if there were no building rules or limits?

Stage 2: The Landing

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

Stage 3: Improve

- After all of the Landing Pods have "landed," engage the students in a discussion guided by the following questions:
    - What do you worry most about when your Landing Pod hits the surface?
    - What is similar about all the designs built? What is different?
- Students return to their tables and answer the discussion ***Post-Landing Questions*** on the worksheet as a team.

Stage 4: Landing Challenge Closure

- Hand out the Summary/Challenge Closure Sheets.

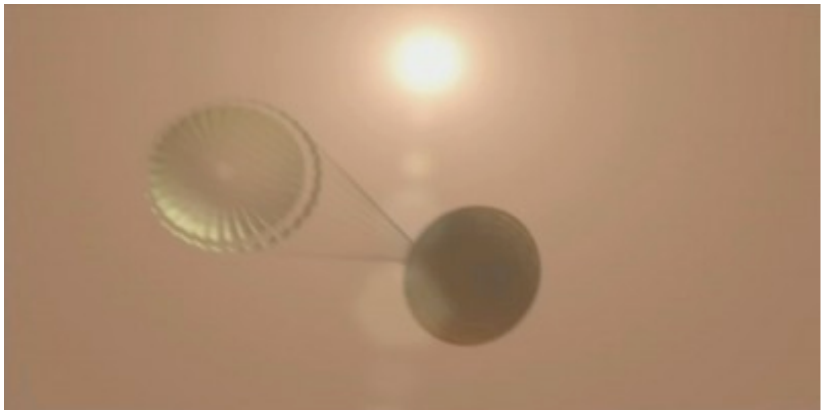
Stage 5: Previewing Next Week

- Up until now, we have been thinking about how to get to the Moon. Starting next week, we will be thinking about what it takes to live on the Moon. If time permits, show the media clip *Return to the Moon: The Journey Begins* (found at the bottom of the Web page given below).

  http://www.nasa.gov/mission_pages/exploration/multimedia/index.html

- 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.

Landing Data Table

Trial	Drop Height (m)	Number of Pieces of Bubble Wrap Used	Distance Rolled (cm)
1			

Post Landing Questions

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

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

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

How far did it roll? __________ cm

If you were to drop your design again, would you need to make design changes?

Y **N**

Draw a picture showing your Lunar Rover and Landing Pod after the drop:

Summary

Think about any observations you made about what happened during the experiment to land the Lunar Rovers. Think about changes you would now make to improve both the Lunar Rover and Landing Pod for future attempts.

Draw a picture of a new Lunar Rover (label changes on your picture):

Draw a picture of a new Landing Pod (label changes on your picture):

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.

Bring these letters to the NASA STEM Club next week, and your teacher will turn them in to NASA.

Please put your name ONLY ON THE BACK of the letter, not on the front of the letter, because NASA is not allowed to post the names of children on the World Wide Web. Be sure to include the name of your school and the name of your teacher.

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 up something (a "lunar rock") at the end of the course. 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. Set up the course to look as close to the drawing in the teacher's pages as possible. If you cannot do that, then you should redraw the map for them and replace the one included in the student pages.

Activity #6: Mission: Preparation

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

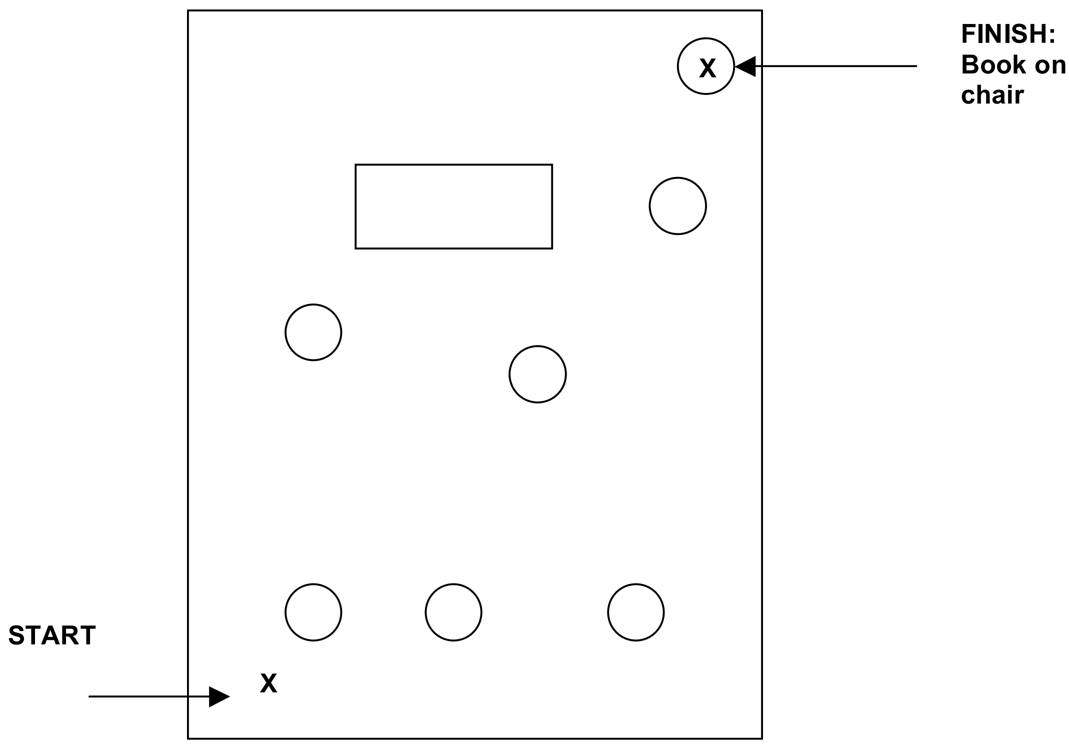
Artist's conception of a Mars Rover on the planet's surface. Image courtesy of NASA.

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 up something (a "lunar rock") at the end of the course.
Lesson Duration:	Two 60–90 minute sessions
Process Skills:	Mapping, communication, measuring, graphing, logical thinking
Materials and Tools: (Per group of three 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:

SET UP

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. Set up the course to look as close to the drawing below as possible. If you cannot do that, then you should redraw the map for them (replace the one included in the student pages).



Stage 1.1: Set the Stage

- Display and read the Robots storybook found at
  http://www.nasa.gov/audience/forstudents/k-4/stories/ames-robots-storybook.html

- 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 are written by humans. Humans tell robots what to do and how to execute their missions. Today, the teams will prepare for a mini, robotic Discovery Mission.

The Discovery Mission Challenge

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

A NASA mission has several parts, and you will be responsible for carrying out each component of the mission. Before your robot begins to move on 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. Each member of the team should choose a role for today’s robotic 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 communicates with the robot once it has “landed.” This person will read commands to the robot.
- **Mapper (MAP)**: One team member will chart the robot’s progress on the “landing site” map. 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 robots 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

Review and become familiar with the “landing site” map provided by the teacher.

Communication

Review the commands that they will use with their robot. These commands are one word, plus perhaps a number. The commands are:

- FORWARD 1, 2, 3, or 4 (number of steps)
- TURN RIGHT
- LEFT
- REACH OUT
- PICK UP LUNAR ROCK

Calibration

The BOT will practice executing the commands. Examine how much distance the BOT covers. For example, when s/he executes a FORWARD 3 command how far do they move? Measure.

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. One command will be given at a time.

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*

Artist's conception of a Mars Rover on the planet's surface. Image courtesy of NASA.

Mapping

Goal: To produce a map of the "landing site"
The map, on the next page, will represent the landing site in the room. Follow the steps below to create your landing site map.

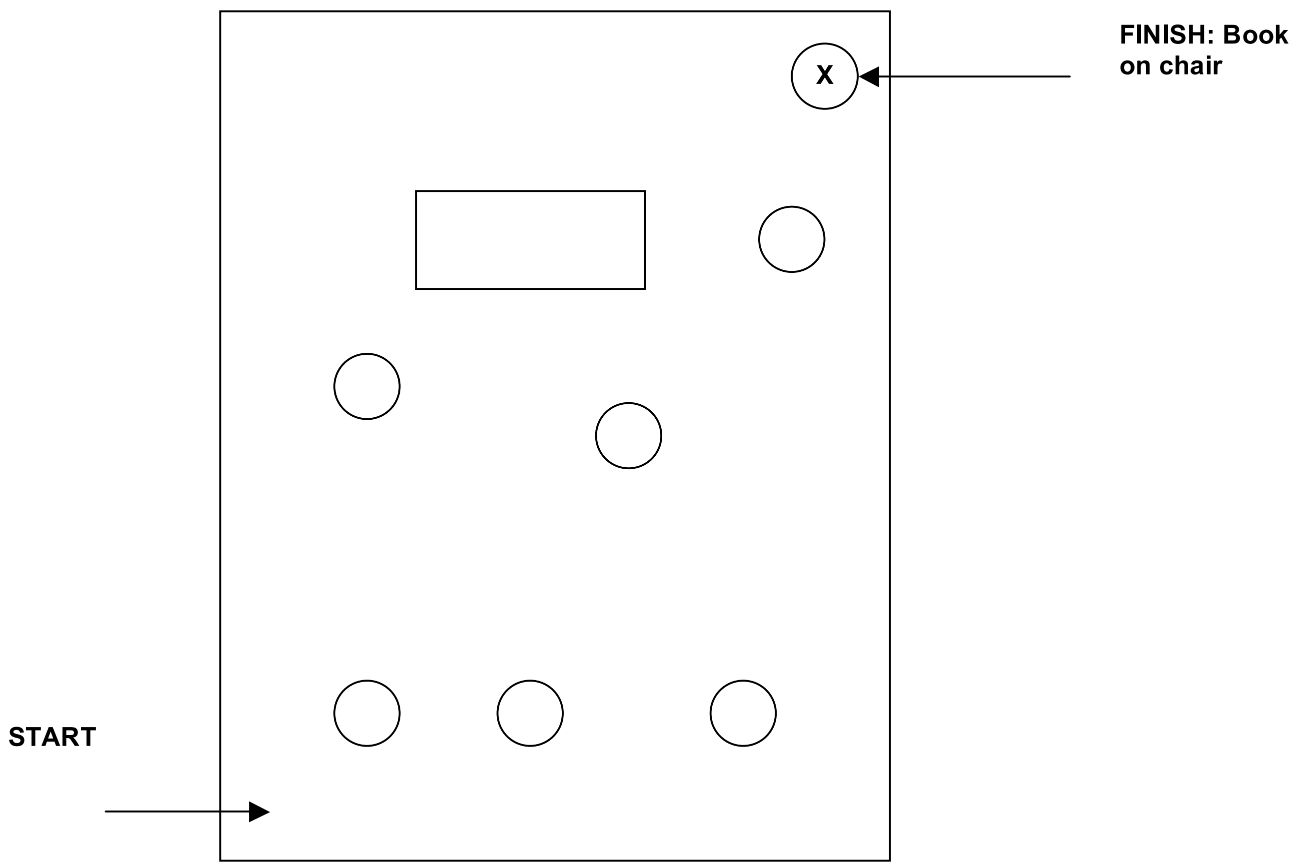
Step 1: Where is the table on your map? Color the table on your map green.

Step 2: Where are the chairs on your map? Color the chairs red on your map.

Step 3: Is there a wastebasket on your map? Color the wastebasket yellow.

Step 4: Using a pencil, draw small arrows on your map that shows the route you will take to navigate the landing site. You must include one right turn and one left turn.

<u>Your Team's Map</u>



Communications

Goal: Develop a communications strategy with the BOT.

Below is the language to use with your BOT. These commands are simple words, and sometimes followed by a number.

The commands are:

- **FORWARD 1, 2, 3, or 4 (number of steps)**
- **TURN RIGHT**
- **LEFT**
- **REACH OUT**
- **PICK UP LUNAR ROCK**

If a command is not in the list, you may not use it once the robot has "landed."

Calibration

The BOT will practice the commands. How far does it go?

FORWARD 1	CM
FORWARD 2	CM
FORWARD 3	CM
FORWARD 4	CM

Try again.

FORWARD 1	CM
FORWARD 2	CM
FORWARD 3	CM
FORWARD 4	CM

Was it the same?

Mission Plan

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

- Use the map 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."

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 hardest part of completing this Discovery Mission?

What would you do differently the next time?

Team Name:____

Fun with Engineering at Home

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: Ready, Set, Explore!

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

Artist's concept of a Mars rover. Image 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 up something (a "lunar rock") at the end of the course.
Lesson Duration:	Two 60–90 minute sessions
Process Skills:	mapping, communication, measuring, graphing, logical thinking
Materials and Tools: (Per group of three students)	Rulers Graph paper
Club Worksheets: (Make copies for each student to put in binder.)	Mapping Communications Calibration Mission Plan Summary Fun with Engineering at Home, Part B

Club Facilitator, or Teacher, Notes for Activity #7:

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, but no later than 30 minutes into the period.
- The BOT is placed at the starting point. COM delivers the commands one at a time. MAP keeps track of the BOT's progress. If the BOT successfully executes the command and stops where the team wanted it, the next command is delivered. If BOT is not where the team wanted it, they go back to the command and make adjustments, thus getting a second chance.
- Students **IMPROVE** by examining their maps and making corrections to their command sequence.

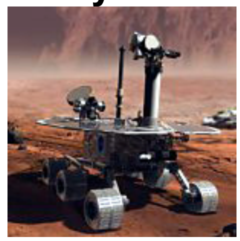
Stage 2.3: Challenge Closure

- Hand out the Summary Sheets (please collect one per team and save in a folder for NASA if you are participating in a NASA evaluation).

Stage 2.4: Previewing Next Week

Ask students to think about how their satellite design 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*: Ready, Set, Explore!*



Artist's concept of a Mars rover. Image courtesy of NASA.

Fun with Engineering at Home—Part B

Activity 7: *Ready, Set, Explore!*

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 Moon, and why?

____
____
____

Teacher Notes for Activities 8 and 9:

America will send the next generation of explorers to the Moon aboard a new *Crew Exploration Vehicle* (CEV). 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 CEV that will carry two 2-cm sized passengers safely and will fit within a certain size limitation. The CEV will be launched in Activity 9.

Activity #8: Design the New *Crew Exploration Vehicle*!

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

Artist's conception of the Orion Crew Exploration Vehicle. Image courtesy of NASA.

Activity Objective(s):	The teams' challenge is to design and build a *Crew Exploration Vehicle* (CEV) that will carry two 2-cm sized passengers safely and will fit within a certain volume (size limitation). The CEV will be launched in the next session.
Lesson Duration:	One 60-90 minute session
Process Skills:	Measuring, calculating, designing, evaluating.
Materials and Tools: (Per group of three students)	▪ General building supplies and tools ▪ Two small plastic people (approx. 2 cm each)
Club Worksheets: (Make copies for each student to put in binder.)	CV Imagine and Plan CEV Data Table Experiment Notes Summary—Questions/Discussions for Understanding Fun with Engineering at Home

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.
- Hand out the ***CEV Design Challenge, Imagine and Plan Sheets*** (one of each of these worksheets per team) and let the challenge begin.
- Encourage them to **IMAGINE and PLAN** before building. Ask them to list the challenges they face in meeting the design constraints. Why should they not tape or glue the people in place?

Stage 2: Create

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

Stage 3: Experiment

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

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

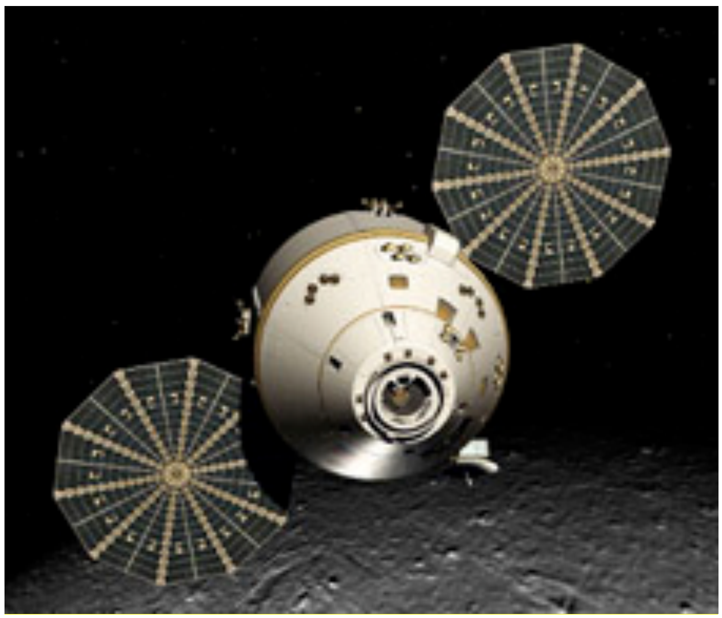
- After each drop test, the students **IMPROVE** (Re-Design and Re-Build) CEV models based on the results of the experiment.

Stage 5: Challenge Closure

- Give out the Summary: Questions/Discussion for Understanding worksheet (one 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 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.



Mock Up of Orion CEV orbiting the Moon. Image courtesy of NASA.

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 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.

To learn more about what NASA is doing to build a CEV, go to the following Web site:

http://education.jsc.nasa.gov/explorers/p5.html

Using your supply of building materials, you will design and build a CEV model.

Design Challenge

Your CEV 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 Drop Test from over your head.
- Fit within the mailing tube provided. (Each club received two or three mailing tubes. The teams can share to see if their CEV fits.)

Student Worksheets for Activity #8

Design the New Crew Exploration Vehicle!

CEV Design Challenge, Imagine, and Plan Worksheet

Design Challenge

Your CEV 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.
- Fit within the mailing tube provided.

Draw a picture of the top of your team's CEV:

Draw a picture of the inside of your team's CEV to show the people:

CEV Data Table

Please complete entries in the table. The blank boxes are for you to add additional components.

CEV components	Use	Measurement or Calculation
Little plastic people	Crew	How many?
CEV	Carries crew to Moon	Does it fit in the mailing tube?
Hatch	Allows entry and exit	How many people wide? How many people high?

EXPERIMENT—Drop tests

Drop your CEV from over your head.
Answer the questions in the table.
Go back and IMPROVE your design before the next test.

Trial Number	**Results**
1	Did the people stay in their seats? Did the door fly open? How will you improve your design?
2	Did the people stay in their seats Did the door fly open? How will you improve your design?
3	Did the people stay in their seats? Did the door fly open? How will you improve your design?

Summary: Questions/Discussions for Understanding

What was the hardest part of the CEV challenge for your team today?

Tell one step your team took to solve this problem?

Team Name: ____

Fun with Engineering at Home

Activity #8: Designing a New Crew Exploration Vehicle

Today we designed and built a Crew Exploration Vehicle (CEV) model to carry people to 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 CEV. 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 CEV. These are the same six 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 and rockets get launched into orbit. Next week, you will be designing a launcher for the CEV. 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:

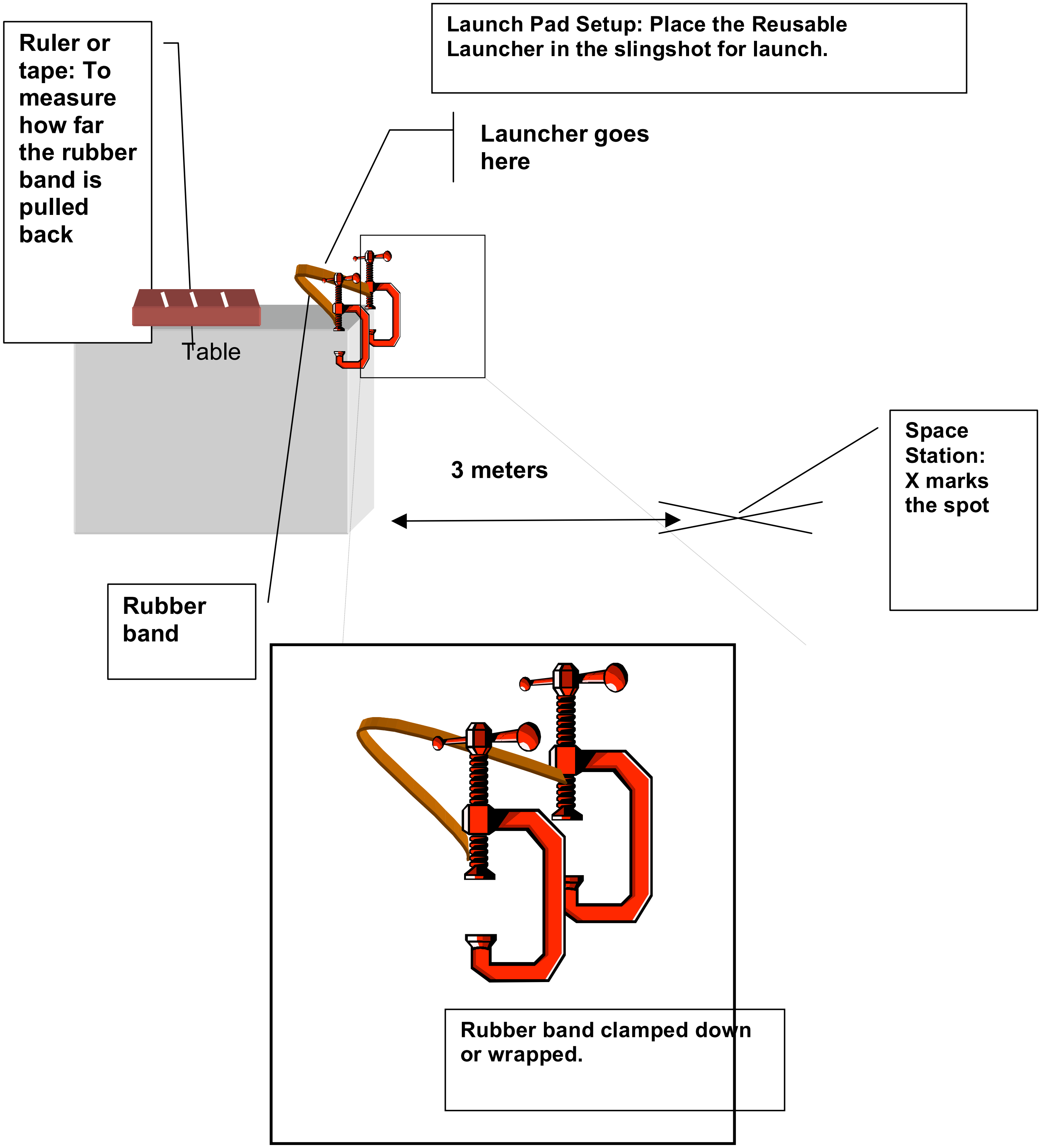
- Are you interested in sending humans to the Moon?
- Do you want to go to the Moon?
- What are some reasons that people might want to go to the Moon?
- What might be some of the dangers for humans in the CEV?
- What is the most dangerous part of the journey to the Moon?

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

Activity #9: Launch Your Crew Exploration Vehicle!

Ares *Rocket and Altair Lunar Lander. Image courtesy of NASA*

Activity Objective(s):	The challenge is to design and build a Reusable Launcher for the *Crew Exploration Vehicle* (CEV) that they built last week. The CEV should travel 3 meters when launched. The Reusable Launcher should produce repeatable results.
Lesson Duration:	One 60–90 minute session
Process Skills:	Measuring, calculating, designing, evaluating.
Materials and Tools: (Per group of three 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 Sheets Reusable Launcher Data Table Summary Sheet—Questions/Discussions for Understanding Fun with Engineering at Home


Launch Pad Setup: Place the Reusable Launcher in the slingshot for launch.
Ruler or tape: To measure how far the rubber band is pulled back
Launcher goes here
Table
3 meters
Space Station: X marks the spot
Rubber band
Rubber band clamped down or wrapped.

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 from Activity #8.
- Hand out the ***Reusable Launcher Design Challenge: Imagine and Plan Sheets*** (one worksheet for each student).
- Keep the students together as a group to discuss how to approach this activity. They need to build the container that will hold their CEV. That container (plus the CEV) will be put into the slingshot mechanism. 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 setup than it is to get the CEV to launch the farthest distance.
- Students share their ideas. Record on chart paper.

Stage 2: Create

- Break the students into groups of two. **CREATE** or build a Reusable Launcher based on their designs and ideas.

Stage 3: Experiment

- Display the Reusable Launcher Data Table on the overhead projector or document camera.
- Conduct two sets of tests: three launches, each using three different setups. Record data.

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

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

Stage 5: Challenge Closure

- Display the Summary: Questions/Discussion for Understanding worksheet on the overhead projector or document camera.
- In summary, discuss the questions. 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.
    - Getting repeatable results.
    - Landing near the 3-meter mark
    - Working as a team, communicating
    - Imagine, plan, create, experiment, improve steps

Stage 6: Previewing Next Week

- Next week we will switch gears from getting off Earth to landing on the Moon.
- 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.
- Here is a link to a great NASA animation of a lunar landing!

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

Design Story and Challenge: (For Teacher Use)

It’s Time to Launch into Space!

Last week, you built a model of a Crew Exploration Vehicle. This week, you must design and build a Reusable Launcher. You will then launch a CEV!
On the way to the Moon, the CEV is going to meet 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:

http://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 meet with the International Space Station. The goal is to launch the CEV 3 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 setup than it is to get the CEV to launch the farthest distance.

Student Worksheets for Activity #9

Launch Your Crew Exploration Vehicle!

Image courtesy of NASA.

Reusable Launcher: Imagine and Plan Worksheet

It's Time to Launch into Space!

Last week, you built a model of a Crew Exploration Vehicle. This week, you must design and build a Reusable Launcher. You will then launch a CEV!

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

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 3 meters.
- 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 setup than it is to get the CEV to launch the farthest distance.**

Reusable Launcher Imagine and Plan Worksheet

What job does a Reusable Launcher do?

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

What do you need to build your Launcher?

Reusable Launcher Imagine and Plan Worksheet Page 2

Draw a picture of your team's Reusable Launcher:

Reusable Launcher Data Table

What might you be trying to learn if you change the distance that you pull the rubber band backwards before launching?

In the first column, write the distance the rubber band will be pulled in the first set of launches. Be sure to measure from the edge of the launching surface to the point of release. You would then change that distance, and enter the new distance in the second three boxes.

Distance the rubber band is pulled backwards prior to test launch.	**Trial Number**	**Dependent Variables**	
		Distance traveled (meters)	**Distance from target (meters)**
Setup A: _______ cm	1		
Setup A: _______ cm Should be the same as above	2		
Setup A: _______ cm Should be the same as above	3		
Setup B: _______ cm	1		
Setup B: _______ cm Should be the same as above	2		
Setup B: _______ cm Should be the same as above	3		

Summary: Questions/Discussions for Understanding

What was the hardest part of the Reusable Launcher challenge for your team today?

Tell one way your team solved this problem.

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 we designed and built a Reusable Launcher to launch the CEV model that we built last week. We were designing the Reusable Launcher to get to a certain distance (3-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. We had to **ASK**: what is the challenge? Then we thought, talked, and **IMAGINED** a solution to the challenge. Then we **PLANNED** and **CREATED** our Reusable Launcher. Finally, we **EXPERIMENTED** or tested our launcher by trying two different setups to see how that affected the distance that the CEV traveled. Last, we went back to our team station and tried to **IMPROVE** our Reusable Launcher. These are the same six steps engineers use when they try to solve a problem or a challenge.

Home Challenge: Next week, we will switch gears from getting off 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!

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

This is a picture of the International Space Station (courtesy of 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:

http://www.youtube.com/reelnasa

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

Teacher Notes for Activities 10–12:

One of NASA's goals is to return humans to the Moon by 2020. There are missions planned for lunar surface exploration beyond what the Apollo missions were able to accomplish. These future lunar missions will be lengthened to allow for more research and study of the lunar environment and its effects on human living systems and lifestyles. Activities 10–12 concentrate on topics that relate to living on the Moon and will help students to understand how living on the Moon will differ from life as they know it on Earth.

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

Artist's conception of a future lunar base. Image courtesy of 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.
Lesson Duration:	One 60 minute session
Process Skills:	Scientific inquiry, measuring, and data analysis.
Materials and Tools: (Per group of three students)	▪ Thermometers ▪ 2 plastic cups ▪ 2 glow sticks ▪ Hot and cold tap water
Club Worksheets: (Make copies for each student to put in binder.)	Imagine 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 °C (or –300 °F), and in the sunlit areas it is about 100 °C (or 212 °F), which is the boiling point for water! These are serious extremes for human beings!

Additionally, because of the unusual rotation of 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, even for a short while, 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 <u>prevent</u> thermal energy from being transferred (to or from our bodies): in other words, how can we <u>insulate</u> ourselves from the wide variations of temperature in the lunar environment?

Because of the complexity of the concepts included in this lesson, the teacher may have to include a mini-lesson on molecules. Lead a discussion of the following vocabulary words and then complete the activity below:

- **Heat** = The energy that an object has due to movement of molecules.
- **Molecule =** Small particles that make up living and non-living things.
- **Temperature** = A measure of the amount of heat or thermal energy.

Stage 2: IMAGINE

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

- In this lesson, participants will become familiar with using and recording information taken with a thermometer. They will also learn about the relationship between heat and energy.
- Molecules with a lot of energy move faster than molecules with a smaller amount of energy. In this activity, participants will use heat as an energy source to illustrate this phenomenon. When a glowstick is placed in hot water, the molecules inside the glowstick move faster, causing it to shine brightly. When the glowstick is placed in ice water, the molecules inside the glowstick move slower. This results in less illumination.

Stage 3: ACT—The Experiment

- Break the students into teams of three and distribute the **Challenge** worksheet.
- Explain that the students will be completing an experiment that will help us to understand how thermal energy (heat) flows through substances, such as water.
- Allow students to gather materials and begin experiment as they work through the Challenge worksheet.

Stage 4: Analysis/Challenge Closure

- Hand out the Challenge Closure / Summary Sheets.
- Students will work in teams to answer questions based on their experience with this experiment. Questions should be used to evaluate present levels of understanding for the concepts presented.

Stage 5: 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 with <u>insulation</u>.

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

Artist's conception of a future lunar mission. Image courtesy of NASA

ASK:

Goal: **Conduct an experiment** to learn about the relationship between temperature and energy.

Materials:

- Thermometer (must use the Celsius scale)
- 2 small plastic cups
- Hot and cold water from a tap
- 2 glowsticks

IMAGINE:
Draw a picture of what you think the glowstick will look like when it is placed in cold water.

Draw a picture of what you think the glowstick will look like when it is placed in hot water.

TEST:

Challenge Worksheet

Your group will be completing an experiment to understand the relationship between energy (heating and cooling) and temperature.

Follow the steps to complete the experiment:

- Assign each group member a job for this experiment: Materials, Recorder, and Thermometer.
- Have the Materials Manager collect the necessary materials for the experiment.
- Label the outsides of each plastic cup so you know which cup is the hot water and which is the cold water.
- Remove a glowstick from its wrapper. Bend the glowstick until you hear a snap to activate the glowstick.
- Place hot water in one cup and cold water in the second cup.
- Start with the cup containing the hot water. Test the temperature of the water by placing the thermometer in the water. Record the temperature. Next, place the glowstick in the hot water and record at least one observation about the glowstick in the chart below.
- Test the cup containing the ice water. Place the thermometer in the water and record the temperature. Now place the glowstick in the water. Record the temperature and at least one observation about the glowstick in the chart below.

Cup	**Temperature (°C)**	**Glowstick Observation(s)**
Hot Water		
Cold Water		

CHALLENGE CLOSURE

Draw a picture of how the glowstick appeared in the cold water from the experiment.

Draw a picture of how the glowstick appeared in the hot water from the experiment.

Fill in the blank with a word that correctly completes the following sentences.

Warm water caused the molecules in the glowsticks to move _______________.

Cool water caused the molecules in the glowsticks to move ________________.

Team Name: ____

Fun with Engineering at Home

Activity10: *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 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 to 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. *Photo credit: 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 °C over 5 minutes.
Lesson Duration:	One 60 minute session
Process Skills:	Experimental design, measuring, graphing, and data analysis.
Materials and Tools: (Per group of three 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 water from the tap
Club Worksheets: (Make copies for each student to put in binder.)	Imagine Plan Experiment (includes Data Table) 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.
    - Left alone, water in a cup will come to room temperature; 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 room temperature with the air, warm water gives up some of its heat to the air.
    - To warm up and come to room temperature with the air, cool water takes some heat from the air.
- *ASK*: Today's engineering challenge centers on the question: *How can we keep from losing 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 °C (or –300 °F), and in the sunlit areas it is about 100 °C (or 212 °F), 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

- Hand the Imagine worksheets out to the students. Before giving them access to building materials, ask them to look at a picture of a warm human standing on the Moon on a cold, lunar night and label what is warm, what is cold, and which way the heat transfers. Then ask them to look at a picture of a human standing in the extreme heat of a hot lunar day and label what is warm, what is cold, and which way the heat transfers.
- Now, ask them to devise a method for keeping the human not too warm, not too cool, but just right!

Stage 3: PLAN

- Let's start by building a container to keep water at a constant temperature (because we are mostly water anyway!).
- 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 °C over 5 minutes.

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

- Review how to read a thermometer. Practice with students.
- The teacher should measure the room temperature and share that temperature with the teams.
- The students should take the starting temperature of the hot water and record. They should record a measurement in the data table every 30 seconds. Teacher should circulate and assist in reading of the thermometers. 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 °C over 5 minutes.
- **Note**: The thermometers have a small rubber "keeper" on them so that they will not roll on a table when laid down, however, it is a good idea to 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 6: IMPROVE

- 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.

Stage 8: Previewing Next Week

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

Student Worksheets for Activity #11: *Build a Lunar Thermos!*

Technicians work on the thermal protection system tiles on Space Shuttle Discovery*. Photo credit: NASA.*

IMAGINE

Imagine a warm human standing on the Moon on a cold, lunar night. Label what is warm, what is cold, and which way the heat transfers or flows.

Now imagine that the Sun comes up, and the human is standing on the hot lunar surface. Label what is warm, what is cold, and which way the heat transfers or flows.

IMAGINE

Think of 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 °C over 5 minutes.

Sketch and label your design that will keep water the same temperature, or a constant temperature.

What will you use as insulation?

EXPERIMENT

Room Temperature = _______

Starting Temperature of the Water = ___________

WARM WATER: cool down rate	
Time (every 30 seconds)	**Temp (deg)**
:30	
1:00.	
1:30	
2:00	
2:30	
3:00	
3:30	
4:00	
4:30	
5:00	

Summary

How well did your thermos work?

- Did your thermos keep the water warm?
- Predict how long until the water reaches room temperature.
- How could you have made your thermos work better?

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 Web site to see how NASA uses solar energy:

http://spaceplace.nasa.gov/en/kids/helios_fact.shtml

Activity #12: Powered by the Sun!

A solar cooker heats up in the Sun! Photo courtesy of Don Higdon.

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 three students)	▪ Thermometer ▪ Timers ▪ Cardboard box ▪ Aluminum pans ▪ Aluminum foil ▪ Black construction paper ▪ One piece of Plexiglass big enough to cover the box ▪ Sunshine, OR gooseneck lamp with 100 W bulb ▪ S'mores fixin's (graham crackers, marshmallows and chocolate)
Club Worksheets: (Make copies for each student to put in binder.)	Design Challenge Imagine and Plan Experiment: Data Table Summary Fun with Engineering at Home

Club Facilitator, or Teacher, Notes for Activity #12:

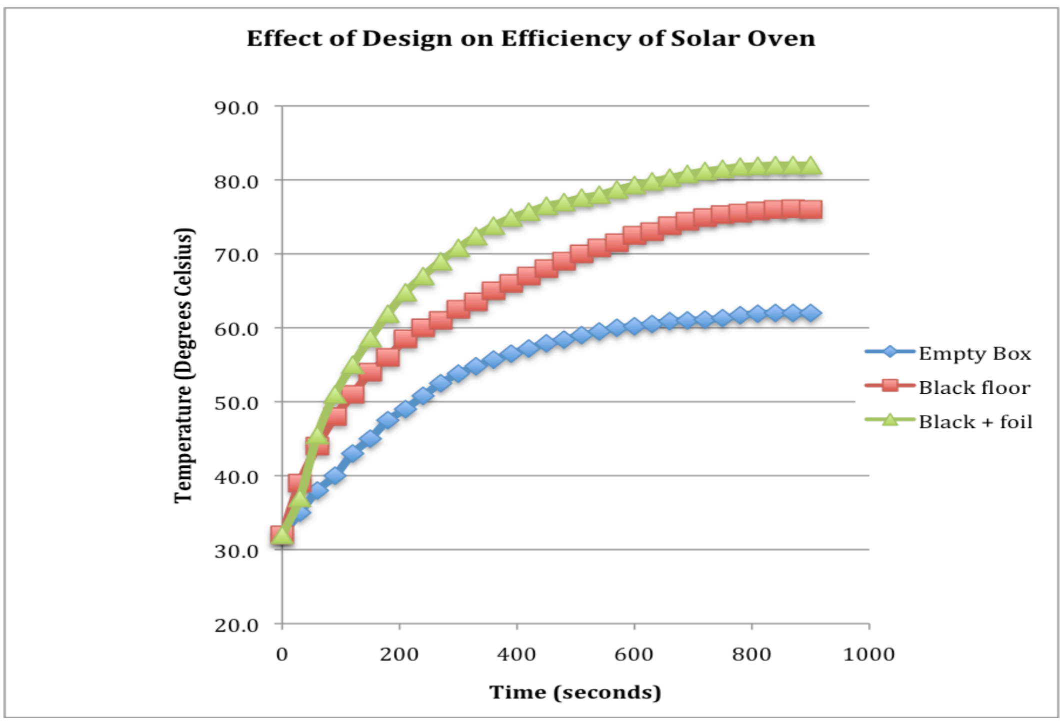
Stage 1: Set the Stage—Ask!

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 °C (or –300 °F), and in the sunlit areas it is about 100 °C (or 212 °F), which is the boiling point for water! These are serious extremes for human beings!

Because 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. 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 above). Three different scenarios are depicted on the graph:
  - A plain cardboard box, covered with Plexiglass
  - A cardboard box with black construction paper on the bottom
  - A cardboard box with black construction paper on the bottom and aluminum foil on the sides
- Hold a class discussion to identify which materials seem to make a better solar cooker based on the graph.
- Hand out the **Imagine and Plan** worksheet, and ask them to list the materials they want to use for their solar cooker, and to draw a picture of their 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 a s'more and the thermometer in the box and close the Plexiglass lid.
- 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 100 W bulb.
- Students should record the temperature on the thermometer every minute 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 and the chocolate?
- 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 oven is built to experiment with s'mores. Photo courtesy of Don Higdon.

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!

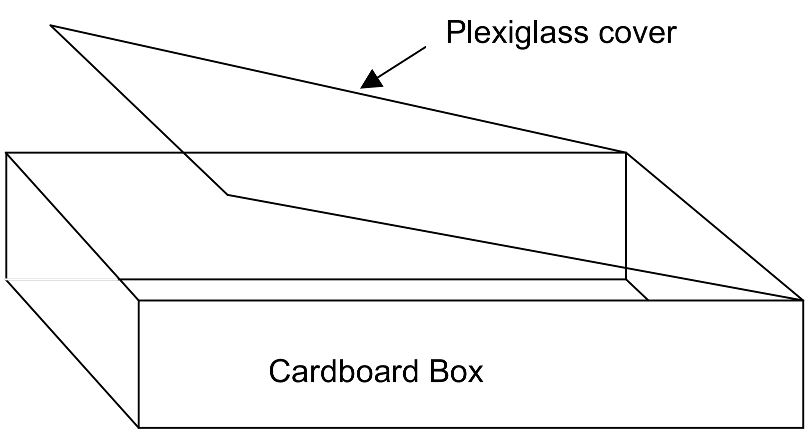
Materials:

- Thermometer
- Timers
- 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

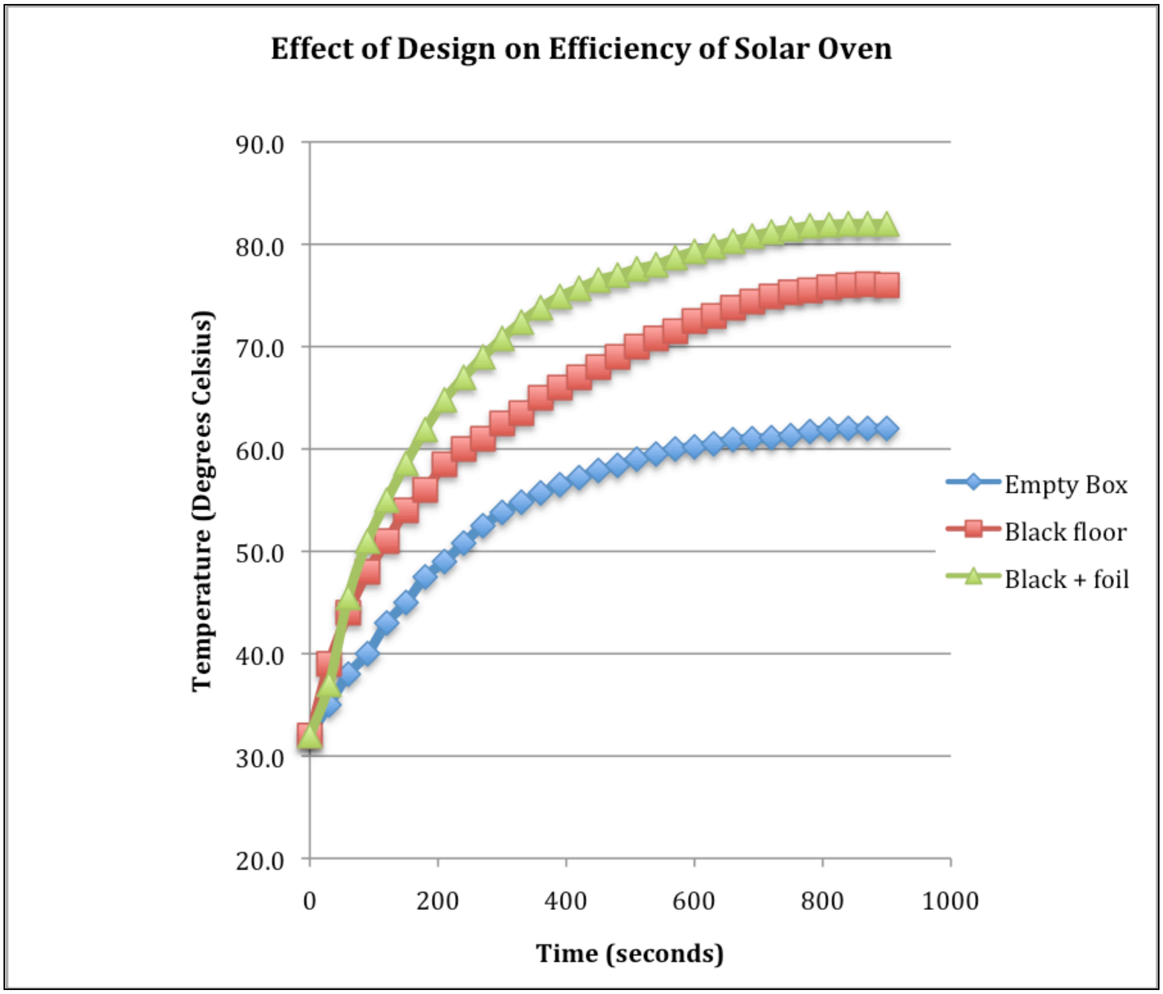
Your solar oven must meet the following specifications:

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 10 ^{o}C
3. You may use any available materials to line the bottom and inside of box.



IMAGINE and PLAN

Here is some information on solar ovens that other people have made. Use this information to participate in a class discussion before building your solar oven.



1. Which shape on the lines reaches the highest temperatures?
   Triangle Square Diamond

2. Which shape on the lines above reaches the lowest temperatures?
   Triangle Square Diamond

3. Why do you think you should use black construction paper instead of other colors like white, yellow, or blue?

4. How do you think the aluminum foil helps to cook the food inside the solar oven?

5. Sketch 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 in the room in the chart below.
2. Place the thermometer and the uncooked s'more in the solar oven.
3. Record the temperature in the chart below each minute.

Room Temperature: __________ ^{o}C

Time	**Temperature**
1 minute	
2 minutes	
3 minutes	
4 minutes	
5 minutes	
6 minutes	
7 minutes	
8 minutes	
9 minutes	
10 minutes	

Summary

1. Did your s’mores melt? What was the highest temperature reached by your solar oven?

2. What changes would you make to your solar oven? Draw a picture of your new design and label the parts.

3. What other things could you use a solar oven for other than making s’mores?

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 up things.

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:
  - ____
  - ____
  - ____
  - ____

How does the Sun help plants on Earth?

How does the Sun help people on Earth?

What do you think would happen if the Sun "turned off?"

HAVE FUN!!