NASA's BEST Activities

Beginning Engineering Science and Technology

An Educators Guide to Engineering Clubs
Grades 3–5

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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 for, and additional materials will only positively contribute toward supporting the imagination of the students.

General Club Supplies	Quantity
9-V Battery (for digital balance)	2
Aluminum foil sheets	100
Balance (digital; 1 g limit)	1
Balloons (assorted shapes and size)	100
Binder (1” plastic, 3 ring)	24
Bubble wrap	100 square feet
Bulldog clips	1 box, small
C-clamps	1 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—□tyrofoam (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, ¼ lb
Rubber bands (regular, No. 16)	1 bag, ¼ 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 Materials List:

Activity	Activity Name	Specific Supplies
1	**Build a Satellite to Orbit the Moon**	Mailing tube (4" inside diameter)
		or Shoe Box
		ShockTarts
		SweetTartChews
2	**Launch Your Satellite**	Toilet paper rolls
		Balloons (assorted size, shape)
		Fishing line (approx. 20 lb test)
		Clamps (C-type or other)
		Binder clips
		Clothes Pins
		Rulers or meter sticks
3	**Design a Lunar Transporter 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 diameter)
		"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
11	**Build a Lunar Thermos**	Graduated cylinders
		Hot and cold water
		Thermometers
		Stopwatch
		Cups (plastic, approx. 5 oz)
		Cups (plastic, approx. 12 oz)
		Insulation materials

		Graph paper
12	**Build a Solar Oven**	Thermometers
		Timers
		Cardboard box
		Plexiglass cover
		Aluminum foil
		Materials to heat (ex. "s'mores")
		Gooseneck Lamp—100 W bulb

Alignment to National Standards

Each activity in this guide features objectives, a material list, 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:

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

National Science Education Standards

Standards	Strands	1	2	3	4	5	6	7	8	9	10	11	12
Science and Technology	Develop abilities of technological design	*	*	*	*	*	*	*	*	*	*	*	*
	Develop understanding about science and technology	*	*	*	*	*	*	*	*	*	*	*	*
Science as Inquiry	Develop abilities necessary to do scientific inquiry.	*	*	*	*	*	*	*	*	*	*	*	*
	Develop understanding about scientific inquiry.	*	*	*	*	*	*	*	*	*	*	*	*
	Develop understanding of objects in the sky.			*	*	*	*	*	*	*	*	*	*
Physical Science	Develop understanding of properties of objects and materials.										*	*	*
	Develop understanding of light, heat, electricity, and magnetism.										*	*	*

National Mathematics Education Standards

Standard	Strand	1	2	3	4	5	6	7	8	9	10	11	12
Number Operations	Compute fluently and make reasonable estimates	*		*	*	*	*		*				
	Analyze change in various contexts		*	*	*	*				*	*	*	*
Geometry	Use visualization, spatial reasoning, and geometric modeling to solve problems	*			*	*	*	*	*				
Measurement	Understand measurable attributes or objects and the units, systems, and processes of measurement		*	*	*	*	*	*	*	*	*	*	*
	Apply appropriate techniques, tools, and formulas to determine measurements		*	*	*	*	*	*	*	*	*	*	*
Connections	Recognize and apply mathematics in contexts outside of mathematics	*	*	*	*	*	*	*	*	*	*	*	*

Data Analysis and Probability	Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them		*							*	*	*	*
	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	*	*	*	*	*	*	*	*	*	*	*	*
	Communicate mathematical thinking coherently and clearly to peers, teachers, and others	*	*	*	*	*	*	*	*	*	*	*	*
	Analyze and evaluate the mathematical thinking and strategies of others	*	*	*	*	*	*	*	*	*	*	*	*
Representation	Create and use representations to organize, record, and communicate math ideas		*				*	*	*	*	*	*	*
	Use representations to model and interpret physical, social, and mathematical phenomena		*	*	*	*	*	*	*	*	*	*	*

National Technology and Engineering Standards

Standards	Strands	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.	*	*	*	*	*	*	*	*	*	*	*	*
	Identify trends and forecast possibilities.		*										
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.	*	*	*	*			*	*	*		*	*
	Exhibit leadership for digital citizenship.	*	*	*	*			*	*	*		*	*
Technology Operations and Concepts	Understand and use technology systems.	*	*	*	*			*	*	*		*	*

NASA's BEST Activities

Beginning Engineering Science and Technology

Lesson Plan Cover Page

Unit Title:

Objective(s):

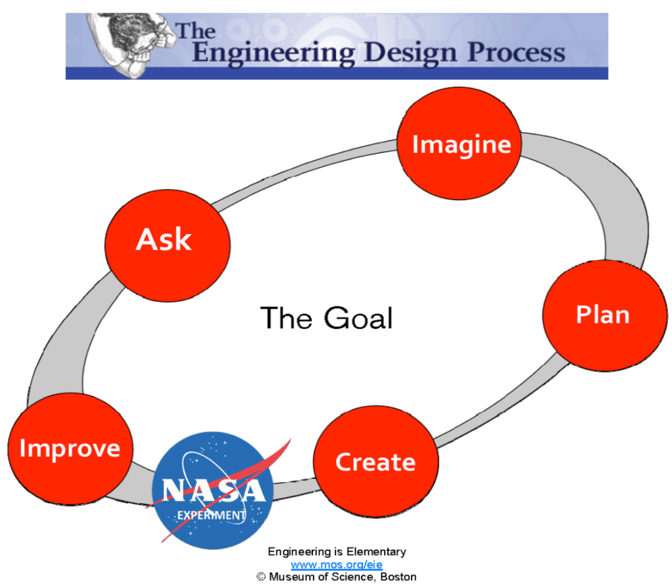
Evaluation procedures:

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 at NASA who build rockets and satellites.
- Spend a few minutes asking them if they know what engineers do. Let them know that they will be experiencing what engineers do during your time together today. Take a few minutes to review the Engineering Design Process steps.



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 this first 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

- CREATE is the stage they have been waiting for. Let them have fun!
- 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. 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 4: Re-Design and Re-Build—Improve

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

Stage 5: Challenge Closure

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

- If you are working with a NASA team, once Challenge Closure/Summary Sheets are completed, please collect one per team and save in folder for NASA.

Stage 6: Previewing Next Week

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

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

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

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

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

Club Facilitator, or Teacher, Notes for Activity #1:

Stage 1: Meet and Motivate

- Welcome the students and give them name tags and have them go around and share their names—it is important that everyone get to learn the names of the club participants.
- Spend a few minutes to let the students know that they will be experiencing what engineers do and take a few minutes to go over the Engineering Design Process steps.
- Hand out the ***Engineering Design Process*** Worksheet and let students get started!

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

- Share the **Design Story and Challenge** orally with the students. This is the **ASK** phase of the Engineering Design Process.
- Hand out the ***Detector or Instrument Table of Uses and Weights*** worksheet and the ***Satellite IMAGINE and PLAN Worksheet*** (one of each of these worksheets per team)
- Let the challenge begin and encourage teams to **IMAGINE and PLAN** before building.

Stage 3: Create and Experiment

- Give out the scissors, glue, and tape. Challenge the teams to **CREATE** or build their satellites based on their designs. Remind them to keep within specifications. The "instruments" can be made of small candies, buttons, or pennies.

Stage 4: Challenge Closure

- Give out the Summary: Questions/Discussion for Understanding worksheet (one per team).
- In summary, have a short discussion with all teams. Ask them, "What was the greatest challenge for your team today?" Expect answers such as:
    - Planning and creating a 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
    - Work as a team, communicate
    - Imagine, plan, create, experiment, improve steps
    - Calculate weights of instruments/detectors, making sure that the 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.
- Ask teams to think about satellites during the next week; ask their parents about satellites; and look up satellites in books or on the Internet.
- There is really no homework, but you do want to encourage students to stay engaged mentally during the next week so they are ready for the club when club time comes once again in seven days. Please give each student the Fun With Engineering at Home worksheet. Tell them to share this sheet with their family. Tell them to ask their family to help them with the Home Challenge found on this sheet.

Special Notes: *For Those with 90 Minute Clubs*

Quality Assurance

- Hand out the Quality Assurance worksheets (one per team) and ask them to fill out the top section with team name and participants' names.
- Ask each team to put their satellite model together with their Quality Assurance worksheet around the edges of the room. Ask each team to move one notch clockwise to offer feedback to the neighboring team, using the Quality Assurance Test worksheet.
- The teams then return to their desks and find out what suggestions the Quality Assurance Team made for improvements to their design.

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. Such data will ultimately help NASA determine the best locations for future human missions and lunar bases.

The information gathered by lunar exploration missions will add to information collected during earlier missions. Some of these missions gathered data that prompted 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). NASA will also need to make exact maps of the Moon's surface. And, for safety, we need to make careful measurements of the radiation falling on the lunar surface.

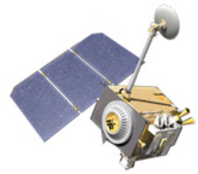
The different instruments are designed, tested, and assembled by different teams of engineers and scientists. The separate teams must work together to make sure that the instruments are the right weight (mass), fit correctly, and make proper measurements.

Overall, the weight (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 satellite to study the Moon with the general building supplies, using the candies as the various instruments. The total mass of the instruments, detectors, probes, sensors, and solar cells (that provide electricity) can be no greater than **10 grams**. The satellite cannot be launched if the instruments, detectors, probes, and solar cells weigh more than a total of 10 grams, so choose your instruments carefully. The combined mass of satellite and instruments can be no more than 100 grams. Also, the satellite must **fit within the provided cardboard mailing tube**. The final test is that the orbiter must withstand a 1-meter Drop Test without any pieces falling off.

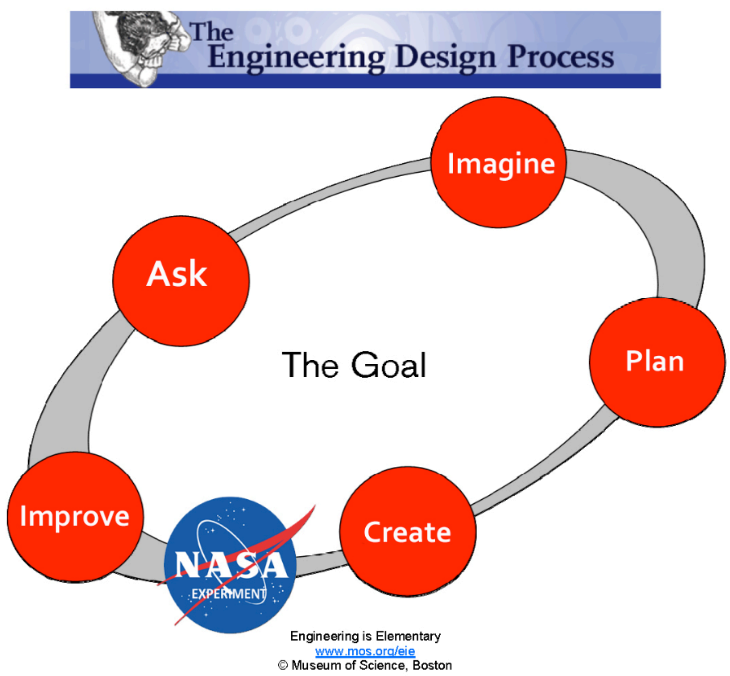
Student Worksheets for Activity #1: Build a Satellite to Orbit the Moon!



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

Engineering 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

Use a balance to determine the mass of the satellite's payload.

Detectors or Instruments (Candy Pieces)	**Use**	**Weight (Mass)**
Camera (three pennies, buttons, or small candies)	Takes pictures (needs one solar cell to operate)	
Gravity Probe (two pennies, buttons, or small candies)	Measures gravity (needs two solar cells to operate)	
Heat Sensor (one penny, button, or small candy)	Measures temperature (needs three solar cells to operate)	
Solar Cell (one penny, button, or small candy)	Collects energy from the Sun to power an instrument, detector, sensor, or probe	

Design Challenge:

The total weight (mass) of the instruments, detectors, probes, sensors, and the solar cells that provide electricity can be no greater than **10 grams**. The satellite cannot be launched if the instruments, detectors, probes, and solar cells weigh more than a total of 100 grams. The total weight of satellite plus instruments may be no more than 100 grams. Also, the satellite must **fit within the cardboard mailing tube provided**. The orbiter must be able to withstand a **1-meter Drop Test** without any pieces falling off.

Satellite IMAGINE and PLAN Sheet

Team Name: ____

List of materials that our group will use:

The instruments our group will attach to the satellite are:

We selected them because:

The total weight (mass) of our instruments and solar cells is:

Top view of our satellite with instruments and solar cells:

Bottom view of our satellite with instruments and solar cells:

Left side view of our satellite with instruments and solar cells:

Right side view of our satellite with instruments and solar cells:

Satellite Re-Design Sheet

Team Name: ____

We made the following changes to our satellite:

The total weight of our instruments and solar cells is:

Our new drawing of our satellite is:

Summary: ***Questions/Discussions for Understanding***

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

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

Tell how you solved your greatest team difficulty in two-to-three sentences.

Team Name: ____

Fun with Engineering at Home

Activity # 1: Building a Satellite to Orbit the Moon

Today we designed and built a satellite model to orbit the Moon. We used the same process that engineers use when they build something. We had to **ASK**: what is the challenge? Then we thought, talked, and **IMAGINED** a solution to the challenge. Then we **PLANNED** with our group and **CREATED** our model satellite. Finally, we **EXPERIMENTED** or tested our model by having other groups look at it and give us feedback. Last, we went back to our team station and tried to **IMPROVE** our satellite. These are the same 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
   www.nasa.gov/worldbook
2. The World Almanac for Kids Science: Artificial Satellites
   www.worldalmanacforkids.com
3. NASA Space Place
   spaceplace.nasa.gov/en/kids/quiz_show/ep001/

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

Quality Assurance: *Checking Each Other's Satellite Models*

Team Name:____

Participants' Names: ____

____

____

To be filled in by the Quality Assurance team:

Fits within cardboard mailing tube: YES or NO

Did the satellite withstand the Drop Test? YES or NO

Total weight (mass) of the instruments is: _______________ grams

What did you like about the design?

How would you improve the design?

Inspected by Team: ____

Participant Signatures: ____

____

____

Activity #2: Launch Your Satellite!

Image of a Delta *rocket preparing for launch. 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 the 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 setup strung between two tables
Club Worksheets: (Make copies 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 Quality Assurance Worksheet

Club Facilitator, or Teacher, Notes for Activity #2:

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

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

Stage 1: Meet and Motivate

- Keep the same grouping of children from week #1. Ask everyone to retrieve their satellite that they created last week during club session #1.
- Re-share the **Design Story** orally with the students (provided in teacher pages in Activity 1). This week, the **ASK** phase of the Engineering Design Process is, *How can we best launch our satellite to go to the Moon?* We need for it to go 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 of the balloons is sticking, try putting a little hand lotion inside.
- 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. 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 variables gave the best results.
- Give out the Summary: Questions/Discussion for Understanding worksheet (one per team).
- In **Summary** have a short discussion with all teams. Ask them, "What was the greatest challenge for your team today?" Expect answers such as:
    - Deciding which rocket elements to change and why
    - Considering how to change the rocket elements
    - Working as a team, clearly communicating ideas
    - Imagine, plan, create, experiment, improve steps
    - Launching the rocket with the satellite

Stage 6: Previewing Next Week

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

Special Notes: *For Those with 90 Minute Clubs*

<u>Quality Assurance</u>

- Hand out the ***Quality Assurance*** worksheets (one per team).
- Ask each team to take their satellite, rocket, and their quality assurance test worksheet to their assigned launch site. Ask each team to move over one position clockwise to offer feedback to the neighboring team, using the Quality Assurance worksheet.
- Ask each team to test their neighbor's rocket and offer them feedback on the Quality Assurance test worksheet.
- The teams then return to their seats to discuss the comments from the Quality Assurance Team on how to improve their satellite.

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

Image of Delta *rocket preparing to launch. Photo credit: NASA*

Rocket Elements Data Table—Imagine, Plan, Create

Design Notes

Last session, you designed and built your NASA satellite to orbit the Moon. This session, you will **plan** and **create** a balloon rocket assembly, and attach your satellite to the balloon. You will then launch your satellite using the balloon rocket. **The objective is to shoot the rocket the farthest distance.** Your rocket may consist of ONE balloon attached to a piece of drinking straw, which will slide along a fishing line stretched between two tables.

The rocket elements that you can control are:

1) **Type of balloon** (for these trials all the balloons will be round)
   PICK ONE FOR ALL TRIALS:

2) **Length of balloon**
   ALWAYS BLOW UP THE BALLOON TO THE SAME SIZE:
   (how long, or how many breaths?)

3) **Length of straw**
   THIS IS THE DEPENDENT VARIABLE. You will find out which length of straw allows your balloon rocket to go the farthest.

DATA TABLE

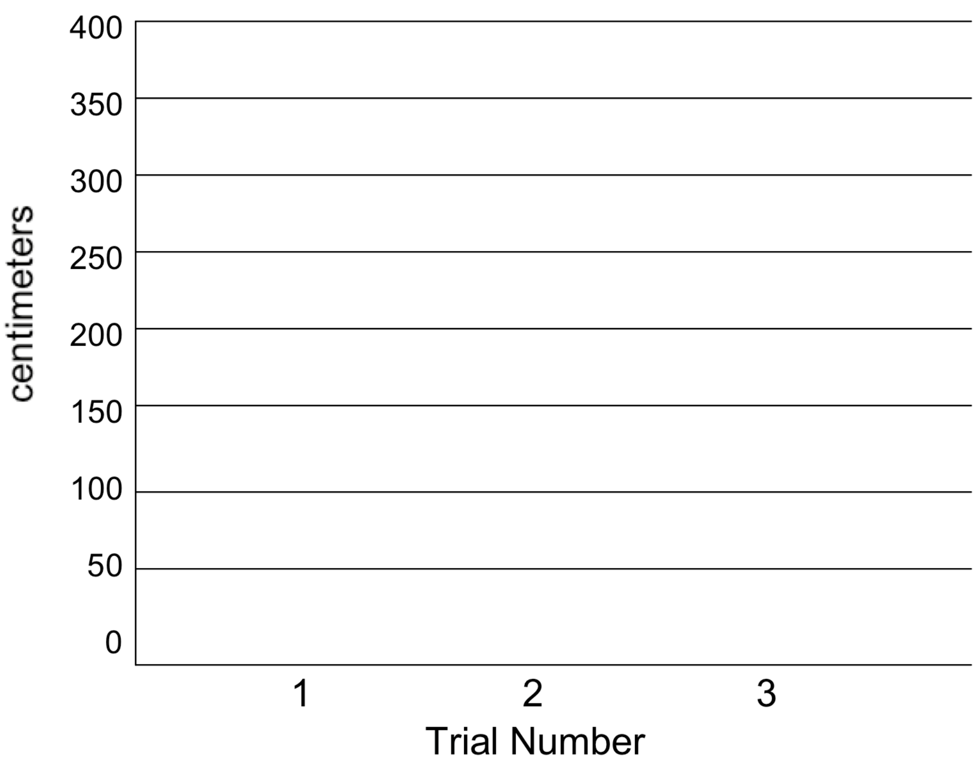
Rocket Elements	Trial 1	Trial 2	Trial 3
Straw length (cm)			
Distance traveled (cm)			

***NOTES*:**

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

For this first test, we shall try changing the length of the straw. If you have time in your club, once you have found the length of the straw that allows your balloon rocket to go the farthest, then you could try changing something else, like the shape of the balloon. This way. you will learn how changing the balloon shape effects how far the rocket flies. Fill in all the white boxes in the table above with your plans for your rocket trials. Remember, only change one element as you move from trial 1 to trial 3.

As you do your trials, fill in the *Distance Traveled* box for each rocket trial, then fill in the graph below.



Balloon Rocket Assembly Design

Top View of Our Balloon Rocket Assembly

Side View of Our Balloon Rocket Assembly

Improvement Phase of Rocket Design

Make adjustments to your rocket by changing a rocket element. Fill out the new table and re-launch your rocket.

Our team chose to adjust the following rocket element:

We made this choice because:

DATA TABLE

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

Summary: *Questions/Discussion for Understanding*

What was the greatest challenge today for your team?

Why is the balloon forced along the string?

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

How did you make this decision?

If you had more time to create and test the rocket, what rocket elements would you experiment with and why?

Team Name: ____

Fun with Engineering at Home

Activity 2: Launch your Lunar Satellite

Home Challenge: Today we designed and built a rocket model to send our lunar satellite to the Moon. 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, go to:

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

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

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

Quality Assurance: *Checking Each Other's Balloon Rocket Assembly*

Team Name: ________________________________

Participants' Names: ________________________________

____

____

To be filled in by the Quality Assurance team:

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

Balloon Shape	
Balloon Length (cm)	
Straw Length (cm)	
Distance traveled (cm)	

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

What are some weaknesses of this team's design?

List 2–3 recommendations you have to improve the design:

1.

2.

3.

Inspected by Team: ________________________________

Participant Signatures: ________________________________

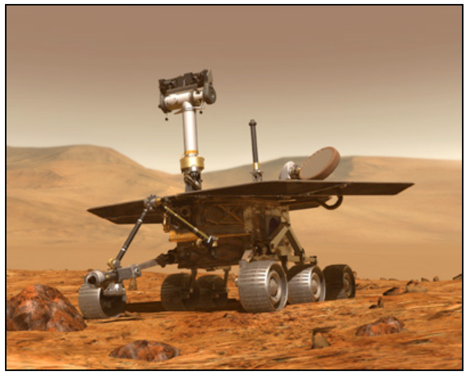
____

____

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, which 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: Courtesy of NASA.
Two rovers that look like this are on Mars NOW!
See marsprogram.jpl.nasa.gov/ for more information on the Mars Exploration Rovers

Activity Objective(s):	The teams' challenge is to design and build a model of a Lunar 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 ▪ (2) Tootsie Roll Candies (or regular size candies that will be used to simulate a cargo weight of 5 grams) ▪ (4) plastic wheels ▪ Something to use as a ramp (a book would work, but preferably a flat surface that would enable the rover to roll for 50 cm or more) ▪ Metric Ruler for making distance measurements
Club Worksheets: (Make copies for each student to put in binder.)	Lunar Rover Design Challenge Lunar Rover Imagine and Plan Sheets Experiment Sheet and Data Table Fun with Engineering at Home Quality Assurance

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

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

- Share the **Design Challenge** orally with the students.
- Show the Mars Rover entry, landing, and descent video called "Six Minutes of Terror." Ask them to pay attention to the ways NASA slowed the rovers down as they entered the atmosphere. Tell them to keep in mind that some of the techniques will work on the Moon, and some will not. They should think about what the difference would be (no atmosphere on the Moon, which means a parachute device won't work).
- The NASA Web site with more video on the Mars rovers is:

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

  (The "Six Minutes of Terror" video is near the bottom of the page in the **Entry, Descent, and Landing (EDL)** section.)
- Hand out the ***Lunar Rover Design Sheet*** (one per team).
- Let the challenge begin and encourage them to **IMAGINE and PLAN** before building.

Stage 2: Create

- Challenge the teams to **CREATE** or build their Lunar Rovers based on their designs. Remind them to keep within specifications.
- Create a ramp for the lunar rover to roll down. Each team will be responsible for determining the correct height of the ramp to allow their rovers to roll down successfully.

Stage 3: Experiment

- Students will let their rover roll down the ramp and they will record measurements of the distance the rover travels, the height they used for their ramp, and any observations for three trials. An average of these distances should be calculated by each group. They will need their rover to travel an average distance of at least 50 cm.

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

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

Stage 5: Challenge Closure

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

Stage 6: Previewing Next Week

- Ask teams to bring back their Lunar Rover model for use in next week's club challenge. You may want to store them in the classroom or have one of the facilitators be responsible for their safe return next week.
- Ask teams to think about potential landing pods during the next week. Tell them they will be building the landing pod out of the standard materials that have been available to them. The pod 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).

Special Notes: For Those with 90 Minute Clubs

Quality Assurance

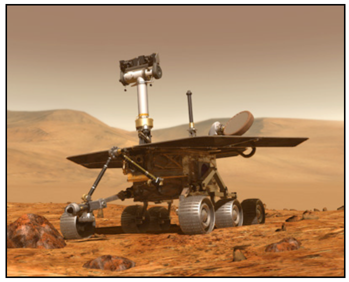
- Discuss how important FEEDBACK is for engineers. Hand out the Quality Assurance worksheets (one per team) and ask them to fill out the section with the team name and participants' names.
- Ask each team to put their Lunar Rover model, together with their *Quality Assurance* worksheet, around the edges of the room. Ask each team to move over one position clockwise to offer feedback to the neighboring team, using the Quality Assurance Test worksheet. The Quality Assurance Teams will test the average distance traveled down the ramp to meet the 50-cm guideline.
- Teams then return to their stations and discuss the comments from the Quality Assurance Team. What changes were suggested? Do they make sense?

Design Challenge:

The Lunar Rover must meet the following Engineering Design Constraints:

- Carry one plastic egg snugly. The egg may NOT be taped or glued into place. (The egg will be what materials are carried in around the Moon.)
- Have room for two plastic people. (The people do not land with the rover. They will get in the rover on the Moon and drive it around.)
- Roll on its own down a ramp for an average distance of 50 cm or more.
- Be strong enough to hold approximately 5 grams of cargo weight, represented by two "Tootsie Roll," or other candies, inside the egg.
- 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
Two rovers that look like this are on Mars NOW!
See marsprogram.jpl.nasa.gov/ for more information on the Mars Exploration Rovers

Lunar Rover Design Challenge

- The Lunar Rover must meet the following Engineering Design Constraints:
- Carry one plastic egg snugly. The egg may NOT be taped or glued into place. (The egg will be what materials are carried in around the Moon.)
- Have room for two plastic people. (The people do not land with the rover. They will get in the rover on the Moon and drive it around.)
- Roll on its own down a ramp for an average distance of 50 cm or more.
- Be strong enough to hold approximately 5 grams of cargo weight, represented by two Tootsie Roll candies inside the egg.
- 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?

How will the height or rise of the ramp affect the roll of the Lunar Rover?

Sketch of our Lunar Rover:

Experiment Notes and Data Table

Observation Notes

Ramp Attempts	Distance	Ramp Height	Ramp Length
Trial 1	_____ cm	_____ cm	_____ cm
Trial 2	_____ cm	_____ cm	_____ cm
Trial 3	_____ cm	_____ cm	_____ cm
Total Distance:	_____ cm	_____ cm	_____ cm
Average of Trials:	_____ cm	_____cm	_____cm

Sketch of Ramp Design:
(Label height and length of ramp in centimeters)

Team Name: ____

Fun with Engineering at Home

Activity 3: Design a Lunar Rover!

Home Challenge: Today, we designed and built a Lunar Rover model to transport people and cargo on the Moon. During this week, see what you can learn about rovers that NASA has already built and used. For example, you can learn about the challenges in building the Mars Exploration Rovers from this Web site:

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

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

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

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

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

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

Quality Assurance: *Checking Each Other's Lunar Rovers*

Team Name: ____

Participants' Names: ____

____

____

To be answered by the Quality Assurance team:

Does the rover roll an average distance of 50 cm? _________

At what height was the ramp placed to allow the rover to roll 50 cm? ________

Did the egg fall out of the rover while on the ramp? YES or NO

Specific Design Strengths

Specific Design Weaknesses

How would you improve this design?

Inspected by Team: ________________________________

Participant Signatures ________________________________

____

____

Activity #4: Design a Landing Pod!

Apollo 11 *Lunar Module*
Descent Nozzle—Photo courtesy of NASA
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 Quality Assurance

Club Facilitator, or Teacher, Notes for Activity #4:

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

- Share the **Design Story** and **Challenge** orally with the students.
- Discuss the Mars Rover entry, landing, and descent video called "Six Minutes of Terror." Remind them why a parachute won't work on the Moon (no atmosphere on the Moon). Discuss this idea briefly to check for understanding of concepts.
- The NASA website with more video on the Mars rovers is: marsrover.nasa.gov/gallery/video/challenges.html
- Hand out the ***Landing Pod Design Sheet*** (1 of each of these worksheets per team).
- Let the challenge begin and encourage them to **IMAGINE and PLAN** before building.
- Assign a final drop height to be used in the lunar landing simulation and write this on the board.

Stage 2: Create

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

Stage 3: Experiment

- The students should test to make sure that the rover, carrying the plastic egg, fits inside the Landing Pod. (All cargo placed inside the plastic egg from the previous lesson should be removed.)
- When dropped, the Landing Pod should land right side up and they should also be sure that they are able to open it, without damaging the Rover, and making sure the Landing Pod is reusable, after it comes to rest.

Stage 5: Challenge Closure

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

Stage 6: Previewing Next Week

- Ask teams to bring back their Lunar Rover model 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.

Special Notes: *For Those with 90 Minute Clubs*

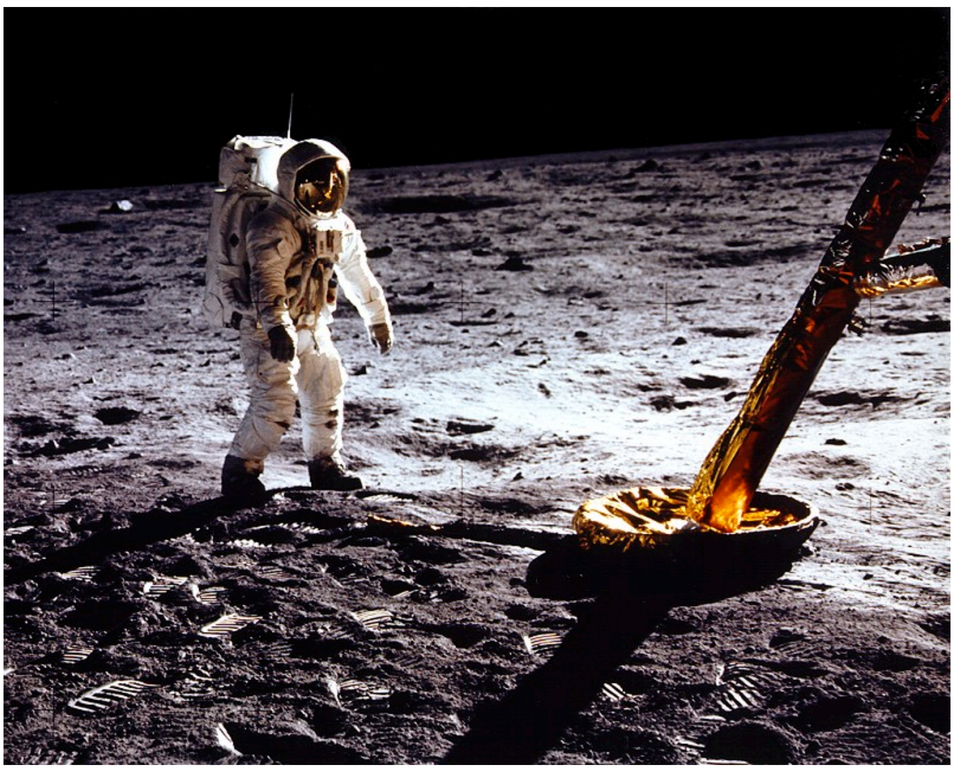
Quality Assurance

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

Design Challenge

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

- It must safely deliver your Lunar Rover to the surface from a height given to you by your teacher.
- The Rover, inside the pod, must land RIGHT-SIDE up. (The rover must be able to roll out, so it must land in the correct orientation with wheels on the surface.)
- The Landing Pod must be reusable. You must be able to open it, retrieve the Lunar Rover, and then use the Landing Pod again.
- The combined mass of the Lunar Rover and the Landing Pod must be 300 grams or less.



Buzz Aldrin and the Apollo 11 *Lunar Module on the Moon. Photo courtesy of NASA*
history.nasa.gov/ap11ann/kippsphotos/apollo.html

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

Landing Pod Design Challenge

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

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

- It must safely deliver your Lunar Rover to the surface from a height given to you by your teacher.
- The Rover, inside the pod, must land RIGHT-SIDE up. (The rover must be able to "roll out," so it must land in the correct orientation with wheels on the surface.)
- TheLanding Pod must be reusable. You must be able to open it, retrieve the Lunar Rover, and then use the Landing Pod again.
- The combined mass of the Lunar Rover and the Landing Pod must be 300 grams or less.

Imagine and Plan Worksheet

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

How will you protect the rover inside the Landing Pod?

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

What will protect the outside of the Landing Pod?

How will you get the rover to roll out of the Landing Pod?

Sketch a side view of the Landing Pod:

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

Experiment Notes and Data Table

Make two test drops with your Landing Pod. The first drop should be half the height of the final drop. Note carefully how it lands and think about what changes you should make to improve the landing for the final time.

Final Drop Height: ________ m (Assigned by your teacher.)

Trial	Drop Height (m)	Observations
1	½ of the final drop height: ____________	
2	Final drop height: ____________	

What is the biggest difficulty your rover faces?

What changes will you make to strengthen 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?

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

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

Quality Assurance: *Checking Each Other's Landing Pods*

Team Name: ____

Participants' Names: ____

____

____

To be answered by the Quality Assurance team:

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

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

YES or NO

Specific Design Strengths:

Specific Design Weaknesses:

How would you improve this design?

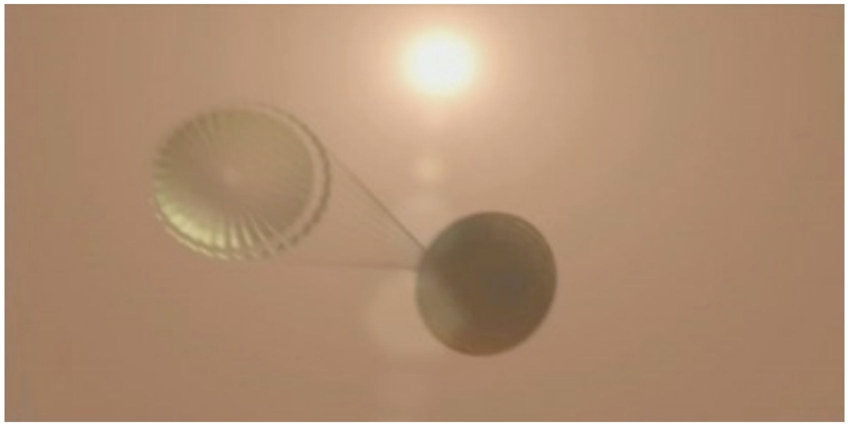
Inspected by Team: ________________________________

Participant Signatures: ________________________________

____

____

Activity #5: Landing the Rover!



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

Activity Objective(s):	The Landing Pod, with the Lunar Rover inside, is to land and deliver the payload safely when dropped from a significant height.
Lesson Duration:	One 60–90 minute session
Process Skills:	Predicting, observing, measuring, evaluating.
Materials and Tools: (Per group of 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.)
- Allow groups to work in different parts of the room to reflect upon their tasks. Within each group, assign one recorder to write group responses on a piece of chart paper. The remaining two students will become reporters and will report out the group's remarks. Write the following questions on the chalkboard or a piece of chart paper and display them clearly for each group to see:
    - What were some of the most important ideas that you had to keep in mind when designing and building the Lunar Rover and Landing Pod?
    - What would you add to your designs if there were no building rules or limits?
    - What do you worry most about when your Landing Pod hits the surface?

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.
- Bring one of the balances near the drop site. Remind the teams that they have a mass limit of 350 grams max, which includes the Lunar Rover plus the Landing Pod. Check the mass of each "loaded spacecraft." The students should write the mass on the top of the Landing Data Table.
- One at a time, drop the Landing Pods. (Dropping them from a second story window is best. If you are dropping from a ladder, add some force to the drop.)
- Open each Landing Pod after it comes to rest. Place the ramp up against the Landing Pod and let the Lunar Rover roll out. (It might require a little push.)
- The students should:
    - Measure the height of ramp.
    - Measure the distance the rover rolls.
    - Check to see if the egg stayed closed.

Stage 3: Improve

- Students should answer the discussion questions on the worksheet as a team.
- Students **IMPROVE** (Re-Design and Re-Build) their Landing Pods based on their observations from the first drop.
- If there is time, after the teams make changes to their Landing Pods, the teacher will drop it again. (Everybody doesn't need to watch this time.) The students should collect the measurements for the second trial on the **Landing Data Table**.

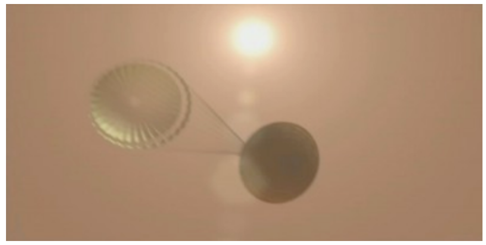
Stage 4: Landing Challenge Closure

- Hand out the Summary Sheets. (If you are working with a NASA team, please collect one per team and save in a folder for NASA.)

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 Now* at <www.nasa.gov/mission_pages/exploration/multimedia/index.html)>. The *Return to the Moon: The Journey Begins Now* link is found at the bottom of the page.
- Discuss some of the things they see in the video such as equipment, tanks, housing structures, and solar panels. Encourage students to think of ways these items could play a part in living on the Moon.

Student Worksheets for Activity #5: *Landing the Rover!*



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

The Rover Has Landed!

Mass Constraint:

Lunar Rover + Landing Pod = ___________________ grams.

Landing Data Table

Trial	Drop Height (m)	Ramp Height (cm)	Distance Rolled (cm)
1			
2			

Post Landing Questions (Answer for Both Trials):

Did your Landing Pod remain closed during impact? **Trial 1 Y N**
Trial 2 Y N

Did the egg remain closed during impact? **Trial 1 Y N**
Trial 2 Y N

Did your rover roll down the ramp? **Trial 1 Y N**
Trial 2 Y N

How far did it roll? Trial 1: __________________ cm
Trial 2: __________________ cm

Did you need to make design changes? **Y N**

If so, what changes did you make?

Summary

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

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

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

Team Name: ____

Fun with Engineering at Home

Activity 5: *The Rover Has Landed!*

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 next week, and your teacher can turn them in to NASA. Neatness and spelling count!!

Please put your name 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 also include ON THE BACK of the letter, 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 and Execution, 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.* ***learners.gsfc.nasa.gov/PREP***

Image of a Mars rover, courtesy of NASA.

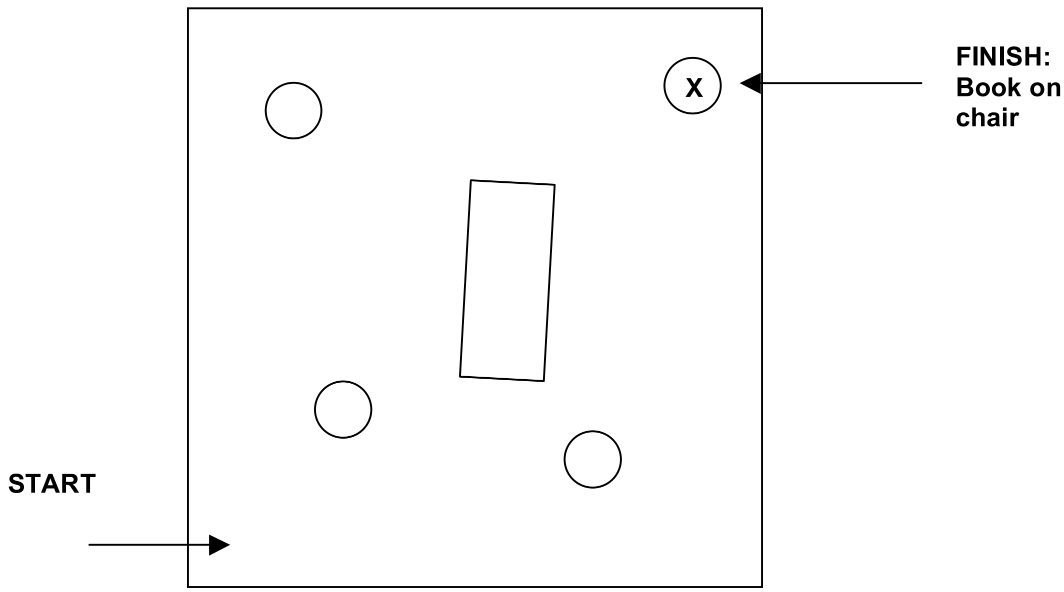
Activity Objective(s):	Teams will execute a mini-simulation of a robotic mission, to get the flavor of Mission Planning and Execution, including mapping, communication, calibration and simple programming. The ultimate goal is to get the human-robot from one end of the course to the other, and the robot 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:

Part A: SET UP

Block off a small obstacle course or Landing Site. Use 3 chairs, 1 table, and 1 wastebasket as obstacles within the Landing Site. Use the following diagram to arrange your space as close to this image as possible (See the map on Student Page 2 that they will be using). Each chair will need to be labeled #1, #2, and #3 so they are easy to identify by your students on their maps.

(The table is a rectangle, and the chairs/wastebasket are circles):



Stage 1.1: Set the Stage

- 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 programs given to the robots are written by humans. Humans tell robots what to do and how to execute their missions. Today, the teams will conduct a miniature 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 Challenge, your robot must pick up a piece of "lunar rock."

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

- Map the "landing site"—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.
- Learn to communicate with your rover—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.
- Calibrate your robot—you must determine how your robot's 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.
- Program the robot—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 rock."

- 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.
    - **Calibrator (CAL)**: One team member will count the number of steps in relation to given obstacles and the dimensions of the landing site.

Stage 1.2: Pre-Mission Activities

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

Mapping

The students should take the map of the "landing site" and a pencil to the designed course and answer the related questions found on the worksheet. This will allow them to establish measurements using the steps they take for the site layout.

Communication

The teams develop a "language" (a set of commands) that they will use with their rover. These commands should be one word, plus a number (the amount of steps to take). A few suggested commands are:

FORWARD N	(where N is the number of steps)
RIGHT N	(where N is the number of steps AFTER the right turn)
LEFT N	(where N is the number of steps AFTER the left turn)

They may come up with other one-word commands. They should make a list of their commands. If a command is not in their list, they may not use it once the robot has "landed."

COM should practice giving commands to BOT once the list is established. BOT should practice listening carefully to each command as it is given. An example of a command sequence is delivered as follows:

a. COM touches BOT's shoulder
b. COM: HELLO Robot Smith
c. BOT: HELLO
d. COM: Forward 5
e. COM: Right 3
f. steps d & e are repeated until BOT reaches ending location
g. COM: CORRECT. GOODBYE.
h. BOT: GOODBYE

The command-response pattern is important to be sure the BOT understands the command. The greetings at the beginning and the end of the sequence serve to tell the BOT when to start listening and when to stop.

Calibration

Once the command set is developed, the BOT practices executing the commands. Teams will work to identify the number of steps needed to navigate around obstacles within the course.

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.

Stage 1.3: Closure for Part A

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

Student Worksheets for Activity #6*: Mission: Preparation!*

Image of a Mars rover, courtesy of NASA.

Mapping

Goal: To produce a map of the "landing site"

The map, which you will create, will represent the landing site in the room. Follow the steps below to create your landing site map.

Step 1: Identify the table on your map. Color the table on your map green.

Step 2: Identify the chairs on your map. Color the chairs on your map red.

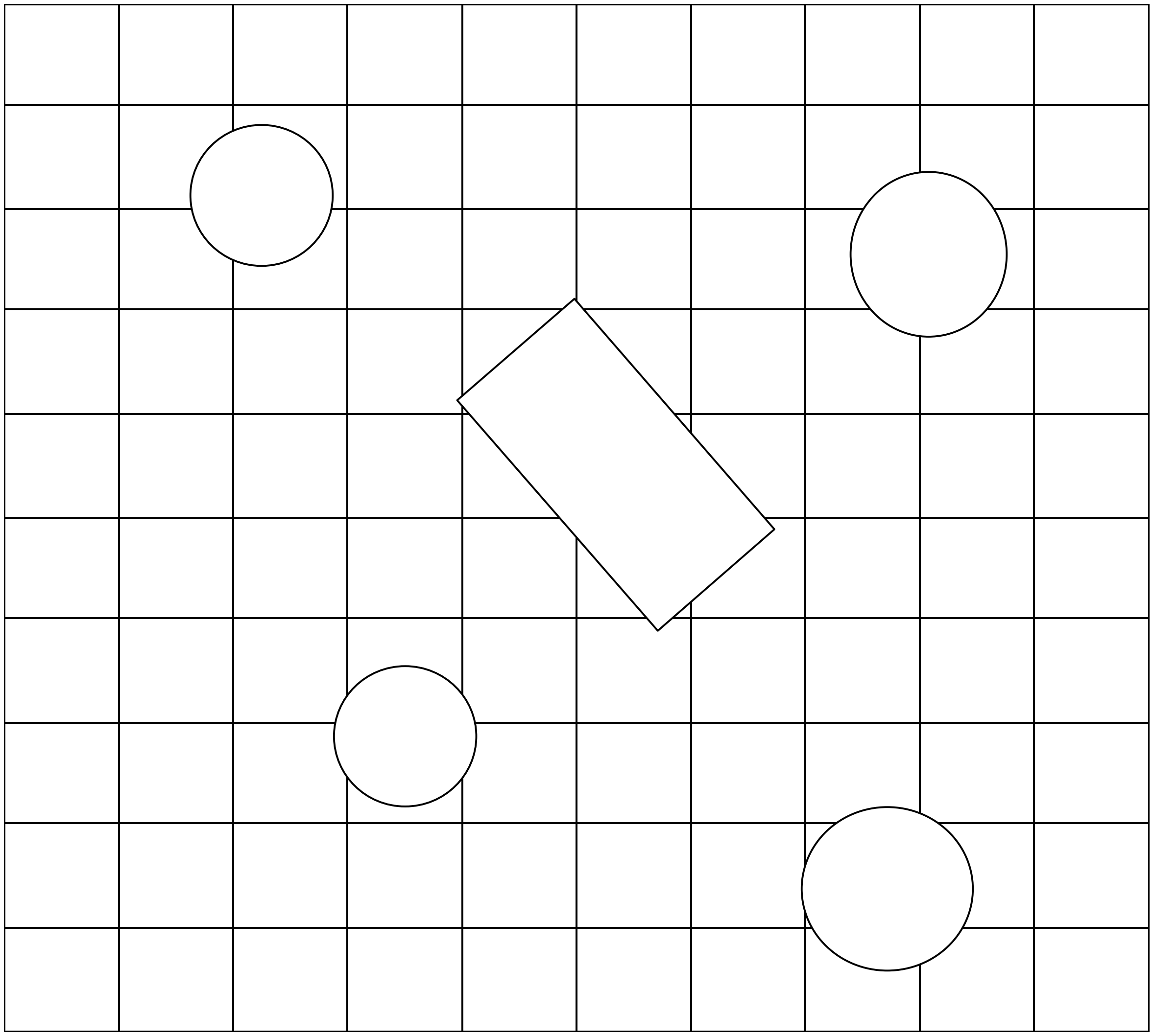
Step 3: Identify the wastebasket on your map. Color the wastebasket yellow.

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.

What areas within the landing site may be more difficult for your robot to navigate?

What steps will you take to ensure that your robot navigates the course accurately based on this map?

Team Name: ____________________________________



Communications

Goal: Develop a communications strategy with the BOT.

Determine a language to use with your BOT. These commands should be one word, plus perhaps a number. A few suggested commands are:

FORWARD N	(where N is the number of steps)
RIGHT N	(where N is the number of steps AFTER the right turn)
LEFT N	(where N is the number of steps AFTER the left turn.

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

Commands

Goal: To develop commands to navigate within the landing site.

COM should practice giving commands to BOT. Teams should now think about all the movements the robot is going to have to make to navigate through the landing site that was just mapped.

An example command sequence could be delivered as follows:

a. COM touches BOT's shoulder
b. COM: HELLO Roboman
c. BOT: HELLO
d. COM: Forward, 5
e. BOT repeats the command and performs action
f. COM: Right, 3
g. BOT: repeats the command and performs action
h. COM: CORRECT. GOODBYE.
i. BOT: GOODBYE

Create a list of commands that you will use in the chart below. Keep in mind all of the directions that your robot may need to navigate in order to reach the ending location successfully. You will only be able to use the commands that you add to this list.

COMMAND	ACTION

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

Calibration

Goal: Calibrate the rover's movements.

Your team will need to be at the landing site to complete the robot calibration. You will be identifying the number of steps your robot needs to take in order to navigate around each of the obstacles below.

Object	**# of Steps (Front of Object)**	**# of Steps (Side of Object)**
Chair #1		
Chair #2		
Chair #3		
Wastebasket		
Table		

How many steps across is the entire landing site? ____________________

How many steps in length is the entire landing site? __________________

Using this information and your map, your team will now work together to develop a command list to navigate your robot through the landing site. You will need to develop a plan that includes both a left and right turn and one that uses commands only from the list that was created. Identify how many steps will need to be taken in each direction.

Mission Plan

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

- Use the map you made of the "landing site" to determine the best path for the BOT to take to get from the Starting point to the Finish, where the "lunar rock" awaits.
- Now develop a Command Sequence, using your command language that will result in your BOT getting from the Starting point, to the Finish.

GOOD LUCK!

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

Summary

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

What step in today's process was the most important to this activity?

Explain why your team felt that this was the most important step.

What would you do differently the next time?

Team Name:____

Fun with Engineering at Home—Part A

Activity 6: Mission: Preparation!

Today, we conducted a simulated, robotic Discovery Mission. We practiced many of the very same activities that NASA scientists and engineers do when planning and executing a mission, such as Mapping, Calibration, Communication, and Programming.

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

These are the steps:

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

HAVE FUN!!

Activity #7: Ready, Set, Explore!

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

Artist's conception 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:

Part B: SET UP

The landing site (obstacle course) must be reconstructed exactly as it was in Session 1. Students will be using worksheets from Session 1 during Session 2.

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 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?
- If suddenly you were asked to work with a new BOT, would you have to change any of your calculations? If so, what would change? Why?

Stage 2.2: Mission Execution

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

Stage 2.3: Challenge Closure

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

Stage 2.4: Previewing Next Week

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

Student Worksheets for Activity #7*: Ready, Set, Explore!*

Image of a Mars rover, 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 this 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: Crew Exploration Vehicle

This activity was adapted from NASA educational products:

NASA's KSNN™ 21st Century Explorer newsbreak "What will replace the Space Shuttle?" education.jsc.nasa.gov/explorers/pdf/p5_educator.pdf

Artist's conception of a new space 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 ▪ (2) small plastic people (approx. 2 cm each)
Club Worksheets: (Make copies for each student to put in binder.)	CEV Design Challenge and Data Table CEV Imagine and Plan Sheets Experiment Notes Summary Sheet—Questions/Discussions for Understanding Fun with Engineering at Home Quality Assurance Sheets—Checking Each Other's CEV Models

Club Facilitator, or Teacher, Notes for Activity #8:

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

- Share the **Design Story and Challenge** orally with the students (provided in teacher pages). Explain to the students that up to this point, all activities that have been completed have prepared them for returning to the Moon with robots. With the design of a new CEV, humans will return to the Moon. Show the video "Return to the Moon: The Journey Begins Now." This is the **ASK** phase of the Engineering Design Process.
- Hand out the ***CEV Design Sheet*** (one of each of these worksheets per team).
- Let the challenge begin and 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.
- Teachers should also create a CEV during this time to be used in the Experiment phase. Students will observe only this CEV during the next step and use notes to help re-design their CEV.

Stage 3: Experiment

- Display the teacher-created CEV that has been completed prior to, or during, this lesson and allow students to observe construction methods and materials.
- Each team should observe three drop tests: one each at 1, 2, and 3 meters. They should take notes on observations from each drop.

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

- Return to home base to **IMPROVE** (Re-Design and Re-Build) CEV models based on observations of the EXPERIMENT phase.

Stage 5: Challenge Closure

- Give out the *Summary: Questions/Discussion for Understanding* worksheet (one per team).
- 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 size, when no shape was given.

- Keeping the people in the seats without tape or glue. Keeping the hatch shut during the drop test.
- Working as a team, communicating.
- Imagine, plan, create, experiment, improve steps

Stage 6: Previewing Next Week

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

Special Notes: For Those with 90 Minute Clubs

Quality Assurance

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

Design Story and Challenge:

Design Story

NASA scientists and engineers are working on a space vehicle that can take astronauts to the Moon, Mars, and beyond. The Space Shuttle cannot do that because it is not designed to leave Earth's orbit. The new 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.

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 2-m Drop Test.
- Include an internal holding tank for liquids. The tank may be no larger than 10 cm x 2 cm.
- Fit within the mailing tube, shoebox, or whatever container is provided.
- Have one hatch that opens and closes. The hatch should remain shut during a 2-m Drop Test.

Student Worksheets for Activity #8*: Crew Exploration Vehicle (CEV)!*

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

<u>CEV Design Challenge, Data Table, and Questions</u>

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, **<u>without gluing or taping them in place</u>**. The people should stay in their seats during a 2-m Drop Test.
- Include an internal holding tank for liquids. The tank may be no larger than 10 cm x 2 cm.
- Fit within the mailing tube, shoebox, or whatever container is provided.
- Have one hatch that opens and closes. The hatch should remain shut during a 2-m Drop Test.

CEV Data Table

CEV components	Use	Measurement or Calculation
Little plastic people	Crew	Dimensions: _________ cm (long) x _________ cm (wide)
Internal Tank	Stores liquids	Dimensions: _________ cm (long) x _________ cm (wide)
Hatch	Allows entry and exit	Dimensions: _________ cm (long) x _________ cm (wide)

Extra: what is the surface area of the Internal Tank? ___________ cm^2
How did you figure that out?

CEV Imagine and Plan Worksheet

How did you decide the shape of the internal tank and its location in the CEV?

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

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

Sketch the following:

<u>Top View of CEV</u> <u>Outer View of CEV with Hatch:</u>

<u>Inside of CEV (with people):</u> <u>Inside of CEV (with internal tank):</u>

EXPERIMENT—Observing Drop Tests

Drop your CEV from three different heights. Record any observations to make future improvements to the construction of your CEV.

Control Variable—Height of Drop	Observations
1 meter	
2 meters	
3 meters	

How will you improve your design using these results?

Summary: ***Questions/Discussions for Understanding***

Describe the greatest difficulty your team faced while completing the CEV challenge today in two-to-three sentences.

Explain how your team overcame this difficulty while constructing your CEV.

What other materials might have worked well in the construction of your CEV?

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

Team Name: ____

Fun with Engineering at Home

Activity 8: Crew Exploration Vehicle

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

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

Are you interested in sending humans to the Moon?

Do you want to go to the Moon?

What are some reasons that people might want to go to the Moon?

What might be some of the dangers for humans in the CEV?

What is the most dangerous part of the journey to the Moon?

- The NASA Web site has lots of information on space travel. Go to www.nasa.gov and type CEV into the search box. What do you learn?
- To learn more about what NASA is doing to build a CEV, go to the following Web site:
  education.jsc.nasa.gov/explorers/p5.html
- This NASA site talks about new NASA spacecraft:
  www.nasa.gov/mission_pages/constellation/main/index.html

Quality Assurance: *Checking Each Other's CEV Models*

Team Name: ____

Participants' Names: ____

____

____

<u>To be answered by the Quality Assurance Team:</u>

Total mass of the CEV is: _______________grams

What is the area measurement of the internal tank? _____________ cm^2

How did you determine the area of the internal tank?

Does the CEV fits within specified dimensions: YES or NO

Does the hatch open and close? YES or NO

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

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

<u>Specific Design Strengths:</u>

<u>Specific Design Weaknesses:</u>

<u>How would you improve this design?</u>

Inspected by Team: ____

Participant Signatures: ___________________________________

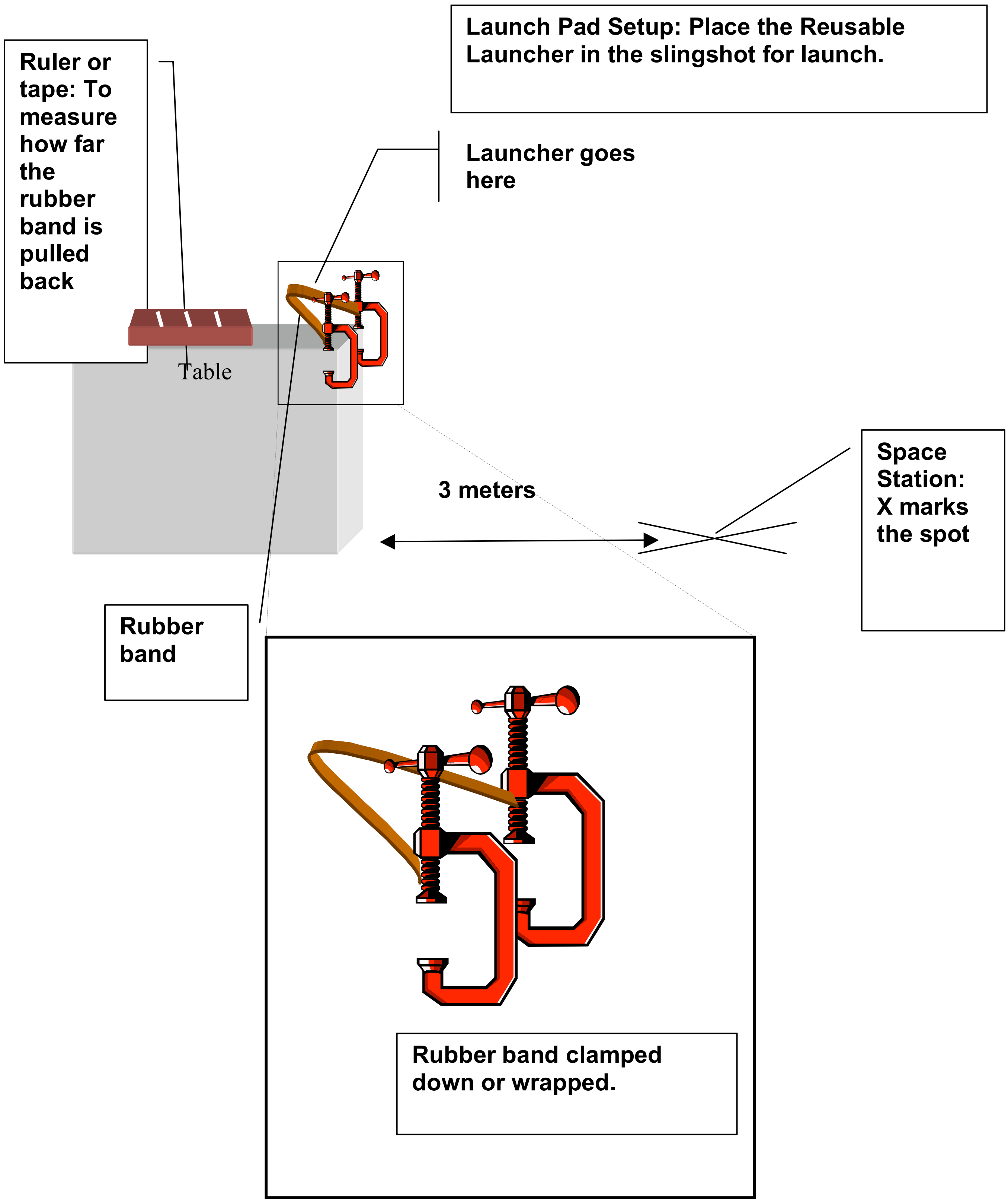
____

____

Activity #9: Launch Your Crew Exploration Vehicle!

Ares Rocket and Altair Lunar Lander, Image courtesy of NAS.

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

Stage 2: Create

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

Stage 3: Experiment

- Each team should conduct three tests: three launches each with a different pull-length for the designed Launcher. They will launch the CEV three times at three different "pull-lengths" (ex. 10 cm, 15 cm, and 20 cm) and record those results. The goal is to achieve repeatable results at each of these lengths and determine which length is the best for the designed vehicle.

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

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

Stage 5: Challenge Closure

- Give out the Summary: Questions/Discussion for Understanding worksheet (one per team).
- In summary, have a short discussion with all teams. Ask them, "What was the greatest challenge for your team today?" Expect answers such as:
    - Figuring out how to design a Launcher that could be used again and again.
    - Getting repeatable results.
    - Landing near the 3-meter mark.
    - Working as a team, communicating.

Stage 6: Previewing Next Week

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

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

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

Special Notes: For Those with 90 Minute Clubs

Quality Assurance

- Discuss how important FEEDBACK is for engineers. Hand out the Quality Assurance worksheets (one per team) and ask them to fill out the top section with team name and participants' names.
- Ask each team to put their Reusable Launcher, together with their ***Quality Assurance*** worksheet, around the edges of the room. Ask each team to move over one position clockwise to offer feedback to the neighboring team, using the Quality Assurance worksheet. The Quality Assurance Teams will conduct a launch test with the CEV. How close does it come to the 3-meter mark?
- Teams then return to their stations and discuss the comments from the Quality Assurance Team. What changes were suggested? Do they make sense?

Design Story and Challenge: (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 your CEV!

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

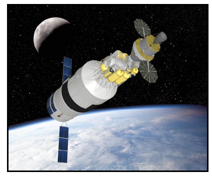
This is a picture of the *International Space Station* (courtesy of NASA). If you want to see real footage of people on the *International Space Station*, you can see videos from space on the ReelNASA YouTube channel. There's a great shot of a Shuttle launch there, too! Turn the sound up **LOUD**!

Design Challenge

Your Reusable Launcher must meet the following Engineering Design Constraints:

- Launch the CEV into orbit so that it may rendezvous with the *International Space Station*. The goal is to launch the CEV <u>3 meters</u>.
- Be able to be used over and over again.
- 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: Launching the Crew Exploration Vehicle!



Ares Rocket and Altair Lunar Lander. Graphic 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 (CEV). This week, you must design and build a Reusable Launcher. You will then launch your CEV! On the way to the Moon, your CEV is going to rendezvous with the *International Space Station* to pick up some supplies. When you launch your CEV, the goal is to get into orbit close to the International Space Station.

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.**

What job does a Reusable Launcher do?

What are important parts of a Reusable Launcher and what must it be able to do well?

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

Sketch the following views of your Reusable Launcher:

Top View: Side View:

Reusable Launcher Data Table

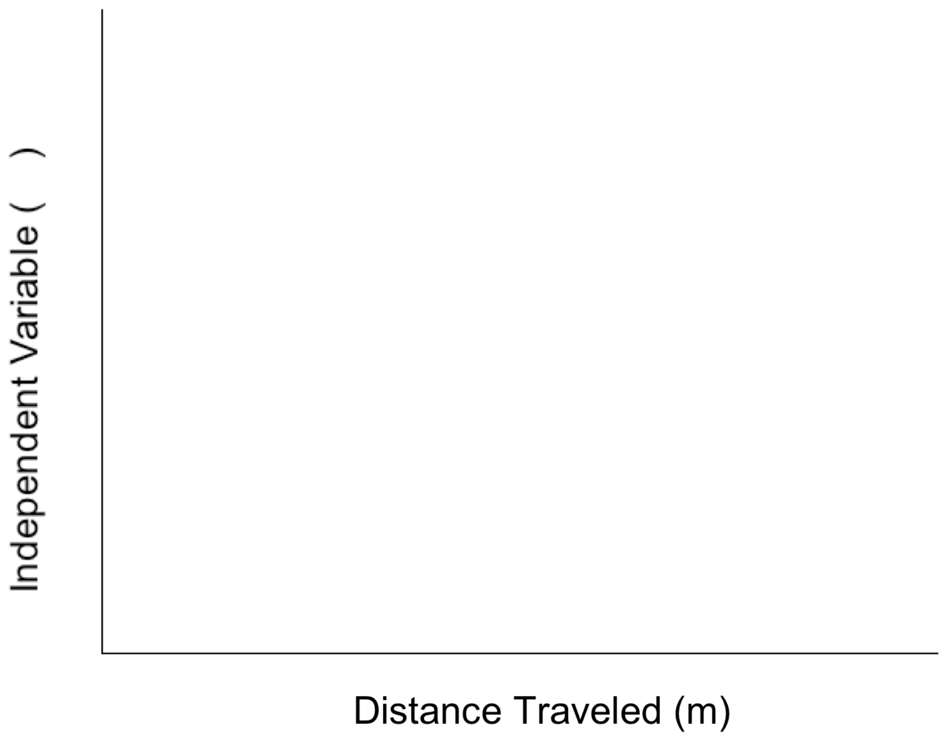
The component of the Reusable Launcher setup that you will be changing is the distance that you pull the rubber band backward prior to launch. This is the **Independent Variable**. What might you be trying to learn or observe by changing the distance that you pull the rubber band backward before launching?

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. Change it again for the third set.

Independent Variable: Distance the rubber band is pulled backwards prior to test launch.	**Trial Number**	**Dependent Variables**	
		Distance traveled (meters)	**Distance from target (meters)**
Setup 1: ______ cm	1.1		
Setup 1: ______ cm	1.2		
Setup 1: ______ cm	1.3		
Setup 2: ______ cm	2.1		
Setup 2: ______ cm	2.2		
Setup 2: ______ cm	2.3		
Setup 3: ______ cm	3.1		
Setup 3: ______ cm	3.2		
Setup 3: ______ cm	3.3		

Graph Your Experiment Data

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



Describe the results that are seen on the graph. What is the relationship between the Independent Variable and the Distance Traveled?

Summary: *Questions/Discussions for Understanding*

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

Tell how you solved your greatest team difficulty in two-to-three sentences.

Why was it important that the launcher be reusable?

Why was it important that your results were repeatable?

Team Name: ____

Fun with Engineering at Home

Activity 9: Launch Your Crew Exploration Vehicle

Today you designed and built a Reusable Launcher to launch the CEV model that you built last week. You were designing the Reusable Launcher to launch the CEV a certain distance (3 meters), so that the CEV could meet up with the *International Space Station* on its way to the Moon.

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 might a spacecraft land on the Moon safely?

Why it doesn't make sense to use a parachute on the Moon?

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

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

For Fun:
This is a picture of the *International Space Station* (courtesy 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. There's a great shot of a Shuttle launch there, too! Turn the sound up **LOUD**!

Quality Assurance: *Checking Each Other's Reusable Launchers*

Team Name: ______________________________________

Participants' Names: ______________________________________

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____

To be answered by the Quality Assurance team:

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

Use the setup that the team says will get the CEV closest to 3 meters.

Independent Variable: Distance the rubber band is pulled backwards prior to launch.	**Trial Number**	**Dependent Variables**	
		Distance traveled (meters)	**Distance from target (meters)**
Setup 1:	QA.1		
Setup 1:	QA.2		
Setup 1:	QA.3		

Specific Design Strengths:

Specific Design Weaknesses:

How would you improve this design?

Inspected by Team: ______________________________________

Participant Signatures ______________________________________

____

____

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

Artist's conception of living and working on the Moon. 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:	Experimental design, graphing, measuring, and data analysis.
Materials and Tools: (Per group of three students)	▪ Thermometers ▪ Timers ▪ Graduated cylinders ▪ Small plastic cups ▪ Graph paper, if available ▪ Chart Paper (one piece)
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

- Share the Design Story orally with students.
- Lead a discussion of the following vocabulary words and then complete the activity below:
- **Heat** = The energy an object has because of the movement of its atoms and molecules which are continuously jiggling and moving around, hitting each other and other objects. When we add energy to an object, its atoms and molecules move faster increasing its energy of motion or heat. Even objects that are very cold have some heat energy because their atoms are still moving.
- **Temperature** = A measure of the average heat or thermal energy of the particles in a substance. Temperature does not depend on the size or type of object.
- The objective of this activity is for students to discover that heat energy always flows from the warmer region to the cooler region.

Activity:

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

Stage 2: Act—The Experiment

- Distribute the **Challenge** worksheet.
- Have students post their chart paper in the room and assign a Reporter from each group to record the results from the experiment. Groups can then begin to analyze and compare their results with other groups in the room.
- Explain that the students will be completing an experiment that will help us to understand how thermal energy flows, and what factors affect the rate of temperature change.
- Allow students to gather materials and begin the experiment as directed on the worksheet.
- The available materials for this activity are:
    - Thermometer (must use the Celsius scale)
    - Clock or timer for each group
    - Graduated cylinder
    - Small plastic cups
    - Hot and cold water from a tap

- Measure the room's temperature and the temperature of the water in the two cups at the start (time = 0).
- Note 1: The clearest results will occur if both samples of water (hot and cold) are the same difference from room temperature, but this isn't a big deal.
- Note 2: Clearer results will be observed if the samples begin with the temperature at the greatest difference from room temperature (in other words the hotter and colder the better).
- Note 3: 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, however it is a good idea to tell the students that someone should always be holding the thermometer, and they should never just place it in a cup and remove their hand (because it will absolutely tip over, spilling the water, and possibly breaking the thermometer).

Stage 3: Data Analysis

- Each student should graph the temperature results on a line graph. They can then analyze the lines for similarities and differences in the rates of change.
- Put Temperature on the *y*-axis and Time on the *x*-axis. Both sets of results could be plotted on the same graph for best comparison.

Stage 4: Challenge Closure

- Hand out the Challenge Closure / Summary Sheets.

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 insulation. Please hand out "Fun with Engineering at Home."

Design Story—***(For Teacher Use)***

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 protected properly from damaging effects. Thus, we must understand how thermal energy is transferred, and, for our concerns, how we can prevent thermal energy from being transferred (to, or from, our bodies). In other words, how can we insulate ourselves from the wide variations of temperature in the lunar environment?

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

Artist's conception of living and working on the Moon. Image courtesy of NASA.

ASK:

Goal: **Conduct an experiment** that enables us to understand how thermal energy flows (this is called "heating" or "cooling"), and what factors affect the <u>rate</u> of temperature change.

<u>Materials:</u>

- Thermometer (must use the Celsius scale)
- Graduated cylinder
- Timer or clock
- Small plastic cups
- Hot and cold water from a tap

IMAGINE:

Brainstorm some possible solutions to the questions:

Where does heat go when a hot substance cools off?

Where does heat come from when a cool substance warms up?

EXPERIMENT

Challenge Worksheet

Your group will be completing an experiment that will help you to understand how thermal energy flows, and what factors affect the rate of temperature change. Follow the steps to complete the experiment:

- Assign each group member a job for this experiment: Timer, Recorder, and Thermometer Reader.
- Collect necessary materials for experiment and label the outsides of each plastic cup so you know which cup is the hot water and which is the cold water.
- Record the temperature of the room.
- Using a graduated cylinder, collect 50 mL of cold tap water and pour it into one plastic cup. Repeat for hot water.
- Every 30 seconds for the next 5 minutes, record the temperature for each cup of water. Record results in the chart below.

Room Temperature:	________________ ^{o}C	
	Cold Water Cup	**Hot Water Cup**
0 minutes		
30 seconds		
1 minute		
1 minute, 30 seconds		
2 minutes		
2 minutes, 30 seconds		
3 minutes		
3 minutes, 30 seconds		
4 minutes		
4 minutes, 30 seconds		
5 minutes		

CHALLENGE CLOSURE

A. How did the temperature of the hot water change?

B. How did the temperature of the cold water change?

C. Do you think the temperatures in the cup will reach the same temperature as the air in room? If so, predict how long this would take.

D. Make a graph of how the temperature changes with time for both of your samples. Now revisit your answer to Question C above.

Team Name: ____

Fun with Engineering at Home

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

Today, we designed and conducted experiments with heat 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. *On each orbiter, are about 24,000 unique tiles, each manufactured with a serial number that identifies that tile's size, shape, and location on the vehicle.*

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

Photo credit: NASA/Kim Shiflett

Club Facilitator, or Teacher, Notes for Activity #11:

Stage 1: Set the Stage: ASK

- Explain the concepts of energy transfer below:
  - The equilibrium temperature is room temperature.
  - Left alone, water in a cup will come to equilibrium; that is, cold water will warm up to room temperature, and hot water will cool down to room temperature.
  - The heat energy is transferred between the water and the surrounding air.
  - Heat energy always flows from hot to cold:
    - To cool down and come to equilibrium with the air, warm water gives up some of its heat to the air.
    - To warm up and come to equilibrium with the air, cool water takes some heat from the air.
- **ASK**: Today's engineering challenge centers on the question: *How do we keep from losing or gaining too much 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.
- **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 2: IMAGINE

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

Stage 3: PLAN

- Hand out the Plan Worksheet. They should now be able to see what building materials they will be able to use. Ask them to devise a system to keep water at a constant temperature.
- Explain the term "insulation" and ask the students to provide examples.
- Why is insulation important in today's challenge? What does it prevent? (Be careful here to note that insulation keeps hot things hot, AND cool things cool.)

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, although aluminum foil will conduct heat fairly well. Don't tell them this; they should discover it for themselves.

Stage 5: EXPERIMENT

- The students should run an experiment, which should measure the rate that cold water warms up. They should record a measurement in the data table each minute for five minutes. 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.

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.

Special Notes: For Those with 90 Minute Clubs

Graphical Analysis:

If there is time, the students can graph the data from their experiments. Put Temperature on the *y*-axis and Time on the *x*-axis.

Guiding Questions:

Ask them to predict, using the graph, how long until the cool samples reach room temperature. In other words, “How effective is your thermos?”

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

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

Technicians work on the thermal protection system tiles on Space Shuttle Discovery*. On each orbiter are about 24,000 unique tiles, each manufactured with a serial number that identifies that tile's size, shape, and location on the vehicle. Photo credit: NASA/Kim Shiflett*

IMAGINE

Draw a picture that depicts a warm human standing on the Moon in the cold, lunar night. Label what is warm and what is cold. Now draw arrows to show which way the heat transfers. (Will your arrow point from the cold, lunar night to the human? Or, will your arrow point from the warm human to the cold, lunar night?)

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

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

PLAN

Design Specifications:

Today's challenge is to keep 100 mL of cold water at a relatively constant temperature. It should change by no more than 5 °C over 5 minutes.

What is insulation and why is it important in today's challenge?

Sketch your design. What will you use as insulation?

EXPERIMENT

Room Temperature = ______°C

COLD WATER: warm-up rate	
Time (sec)	Temp (deg)

Summary

How effective is your thermos?

- Did your thermos keep the cold water at a constant temperature for 5 minutes?

- Predict how long it would take for the cool water sample to reach room temperature.

- What would have been different if you were trying to keep hot water from cooling off instead of keeping cold water from warming up?

- How could you have made your thermos more effective?

Team Name: ____

Fun with Engineering at Home

Activity 11: Build a Lunar Thermos!

Today we designed a Lunar Thermos to control the amount of energy flowing into or out of containers of water. We chose water to experiment with because it is such a large part of the human body, and if we try to inhabit the Moon we will have to pay close attention to keeping the human body safe from the extremes of temperature on the surface of the Moon. Next week, we will begin to think about how to harness solar energy to do work for us on the Moon.

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

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

Activity #12: Powered by the Sun!

A solar cooker heats up in the Sun!
Photo credit, S. Hoban.

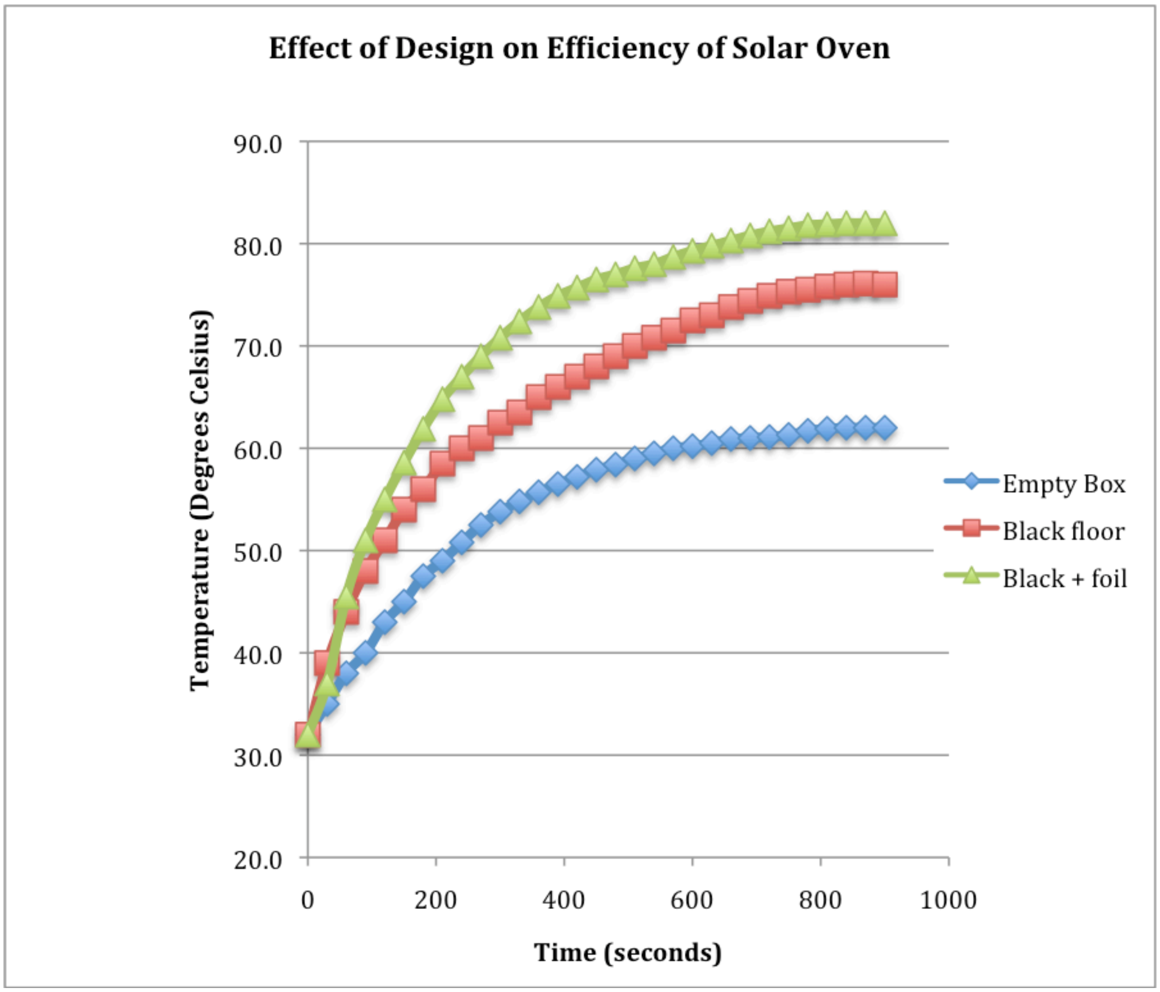
Activity Objective(s):	In this activity, teams will use data and graphs to determine the best components to use for a solar box cooker. They will design and build a box cooker, and test it out to see if it works well enough to make s'mores!
Lesson Duration:	One 60 minute session
Process Skills:	Experimental design, measuring, graphing, and data analysis.
Materials and Tools: (Per group of 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:
    1. A plain cardboard box, covered with Plexiglass
    2. A cardboard box with black construction paper on the bottom
    3. A cardboard box with black construction paper on the bottom and aluminum foil on the sides
- Ask the students to discuss among themselves which materials seem to make a better solar cooker.
- 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 gooseneck lamp with the 100 W bulb.
- Students should record the temperature on the thermometer every 30 seconds for 10 minutes. At the end of 10 minutes, ask them to report out around the room. Whose cooker got to the highest temperature? Whose cooker melted the marshmallows 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 cooker heats up in the Sun!
Photo credit, S. Hoban.

Design Challenge

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

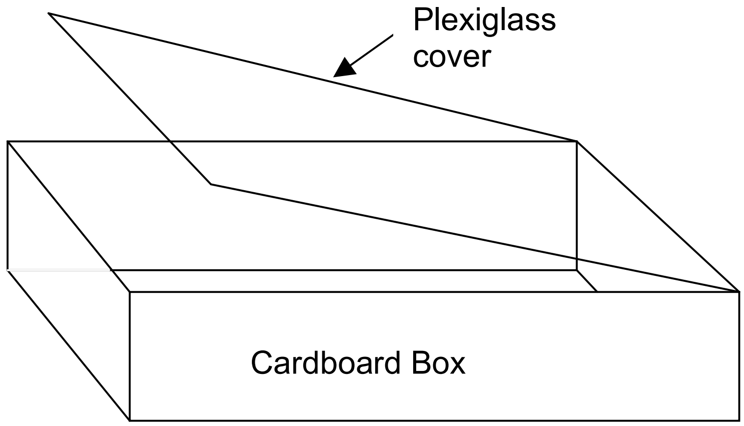
Materials:

- Thermometer
- Timers
- 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:

- It must have a "footprint" of no more than 40 cm x 40 cm.
- In 10 minutes, the temperature inside the box must increase by 10 °C
- 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 help you design your solar oven.

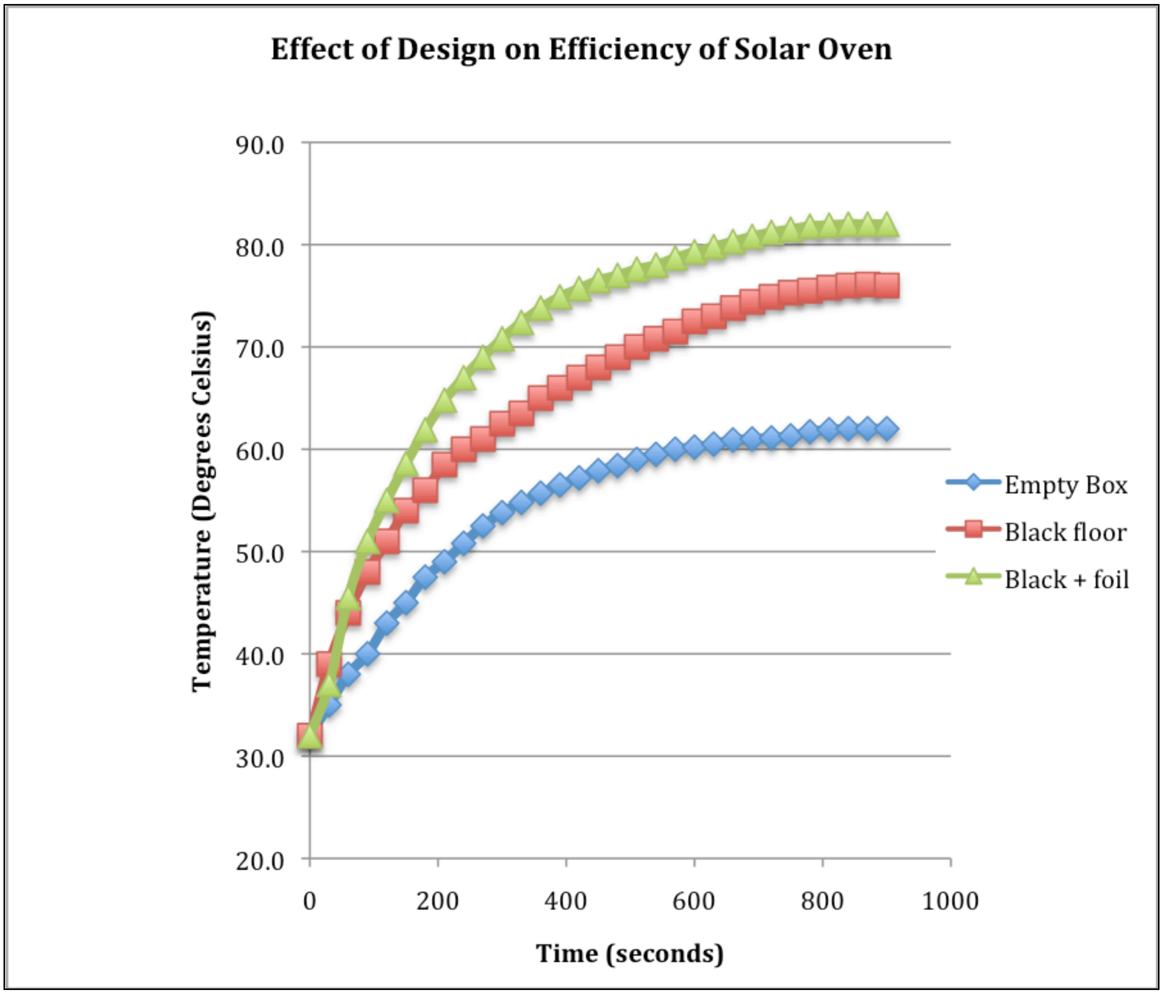


Image Notes:

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

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

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

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

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

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

What purpose do you think the aluminum foil might serve?

Sketch your plans 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:

- Record the temperature in the room in the chart below.
- Place the thermometer and the uncooked s'more in the solar oven.
- Record the temperature in the chart below every 30 seconds.

Room Temperature: ______________ °C

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

Summary

Did your s'mores melt? What was the maximum temperature reached by your solar oven?

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

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

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 things up.

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

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

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

What else does the greenhouse effect have to do with?

HAVE FUN!!