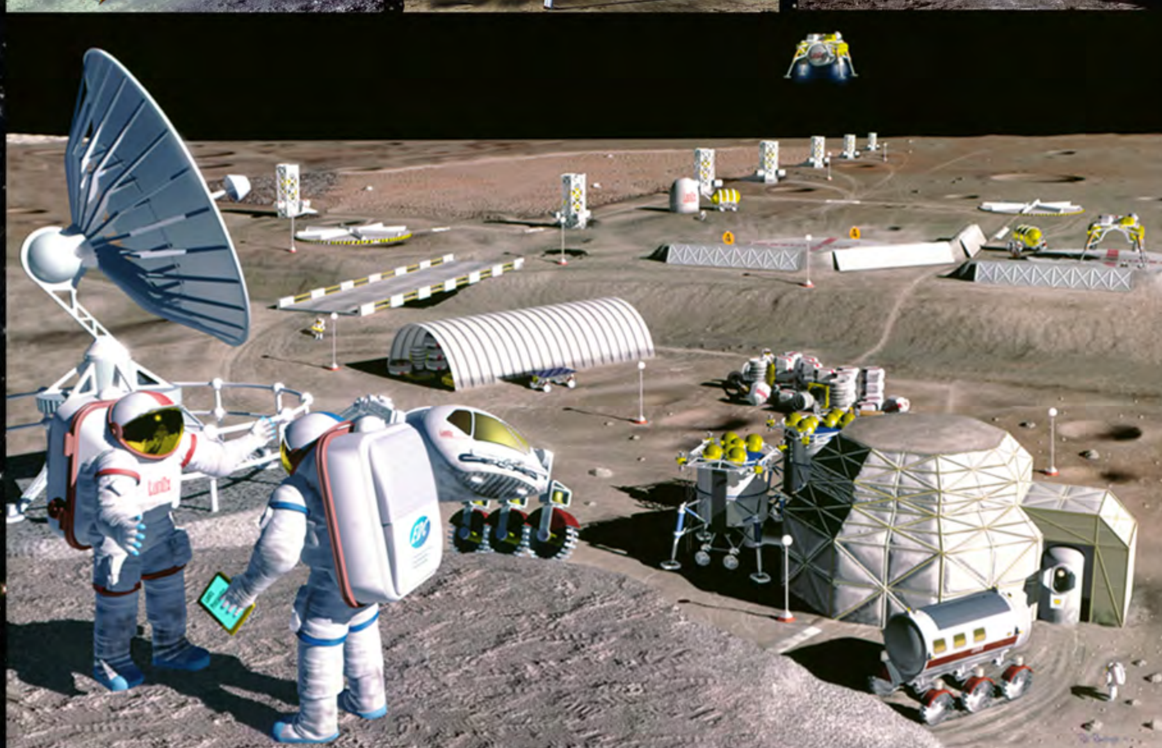
National Aeronautics and Space Administration

Student Employee Handbook



Educational Product	
Educator's & Students	Grades 6–8

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LUNAR NAUTICS
SPACE SYSTEMS, INC.

In conjunction with:

National Aeronautics and Space Administration
Exploration Systems Mission Directorate
Washington, DC

George C. Marshall Space Flight Center
Academic Affairs Office
Huntsville, AL 35812

Discovery Place, Inc.
Charlotte, NC

Employee Handbook

Table of Contents

Lunar Base Proposal, Design and Budget Checklist

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

Below is a checklist to help you organize your proposal.

- ❏ Name of Team
- ❏ Names of Team members
- ❏ Mission Title
- ❏ Mission Destination
- ❏ Mission Objectives
- ❏ List of Chosen Science Experiments and Why Selected
    - ❏ Camera/Telescopes
    - ❏ Retroreflectors
    - ❏ Collector Detectors
    - ❏ Seismology and Ejecta Detectors
    - ❏ Magnetic Detectors
    - ❏ Electrictrical Detectors
- ❏ Miner Design
- ❏ Model of Miner
- ❏ Lunar Base Design
- ❏ Model of Lunar Base
- ❏ Types of Evaluation Tests and Anticipated Results
- ❏ Mission Timeline
- ❏ List of Backup Systems
- ❏ Expected Mission Results
- ❏ Mission Costs (maximum limit $14 billion total mission cost)
- ❏ Executive Summary
    - ❏ Team Name
    - ❏ Mission Title
    - ❏ Destination
    - ❏ Science Conducted
    - ❏ Miner Functions
    - ❏ Lunar Base Layout
    - ❏ Length of Mission
    - ❏ Anticipated Mission Results
    - ❏ Total Mission Costs

Can We Take It With Us?

Shuttle Payload Inventory Sheet

Team Members: ____

Mission
Your mission is to select successfully the payload items for your upcoming space mission.

Task
Your task is to use the following guide to create the maximum payload without going over the maximum weight allowance. You will be given 80 pennies.

Challenge
You will not be given the maximum weight allowance. You must, through no more than three trials, carefully use the balances to select the maximum required payload items without going over the predetermined (NASA) maximum payload weight.

Your goal is to obey correctly the ratios and pack the maximum items without going over the maximum weight.

Human weight in space suits: three pennies per person
Food weight: one penny per meal
Tool weight: two pennies per tool
Medical kit: five pennies per kit

Requirements
Minimum trip three days
Minimum two humans per flight
Each human must have three meals per day
Each human must have two tools
Each human must have one medical kit

Items to be Included in Payload	Trial #1	Trial #2	Trial #3	Final Recommendation
Humans in Space Suits	______ pennies (# of humans × 3)	______ pennies (# of humans × 3)	______ pennies (# of humans × 3)	______ pennies (# of humans × 3)
Food	______ pennies (# of humans × 3 meals × # days)	______ pennies (# of humans × 3 meals × # days)	______ pennies (# of humans × 3 meals × # days)	______ pennies (# of humans × 3 meals × # days)
Tools	______ pennies (# of tools × 2)	______ pennies (# of tools × 2)	______ pennies (# of tools × 2)	______ pennies (# of tools × 2)
Medical Kits	______ pennies) (# of humans × 5)	______ pennies (# of humans × 5)	______ pennies (# of humans × 5)	______ pennies (# of humans × 5)
Total # of Pennies	______ **pennies**	______ **pennies**	______ **pennies**	______ **pennies**

Destination Determination

Student Data Sheet

Team Name: ____

Team Members: ____

Using information from the materials about the Moon by the National Aeronautics and Space Administration (NASA), the Lunar Nautics computer programs or other sources, discover and choose a destination that your Lunar Nautics mission will explore.

1. Our destination is
____
____
____

2. We chose it because
____
____
____

3. Major surface features are
____
____
____

4. Resources found at this site are
____
____
____

5. ❏ It has been explored before.
❏ It has not been explored before.

6. __________ (number) spacecraft have already visited our destination.

7. Spacecraft that have been to our destination studied
____
____
____

8. We want to study
____
____
____

Design a Lunar Lander

Student Data Sheet

Team Name: ____

Team Members: ____

The next step in planning your Lunar Nautics mission is to prepare a design for your Lunar Lander. Use the Lunar Nautics Proposal, Design and Budget Checklist worksheet to assist your team in moving through the design process.

Step 1: Identify the Problem

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____

Step 2: Design a Solution

Review the lander elements located in this manual beginning on page 6. You may also want to review designs of other NASA lander or vehicle concepts. Use this space to record your design decisions.

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Step 3: Implement the Design

Print out the lunar lander background and components from the Lunar Nautics CD (Educator Resources/Extras/Lunar Lander Template) to create a design for your lander.

Step 4: Evaluate the Design

Rate your design	Poor		Average		Great
Lander design is functional	1	2	3	4	5
Design shows innovation	1	2	3	4	5

What things could you change about your design to make it better?

Step 5: Communicate Your Design

List the important points that you will share about your design during your final Lunar Nautics presentation.

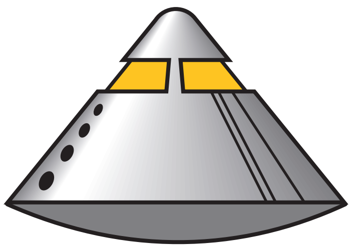
Your objective is to build the most practical and balanced lunar lander that will land on the Moon with enough fuel left. Here is some general information to help your design decisions.

The Ascent Stage contains the crew cabin, instrument panels and controls, oxygen, ascent body chassis with navigational thrusters and rocket engine(s), and enough fuel and battery power to return to lunar orbit and rendezvous with the unmanned Crew Exploration Vehicle (CEV). The Ascent Stage also carries communications equipment.

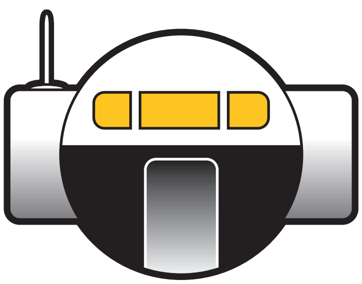
The Descent Stage contains the landing platform chassis with legs, descent fuel and primary rocket engine(s), and cargo compartments. The Descent Stage also carries drinking water for several days stay and primary battery power and oxygen. A ladder for access from the Ascent Stage to the lunar surface is attached to the Descent Stage's landing legs.

Crew Compartment

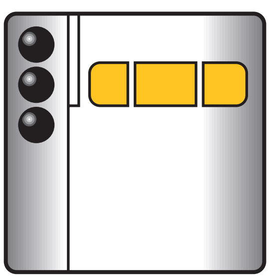
The Crew Compartment's shape is determined by practical use such as length of mission, size of the astronauts, and crew, and some aerodynamics.



Crew Compartment with room for three astronauts for a 5-day excursion



Crew Compartment with room for five astronauts on a 5-day excursion or three astronauts on a 14-day excursion

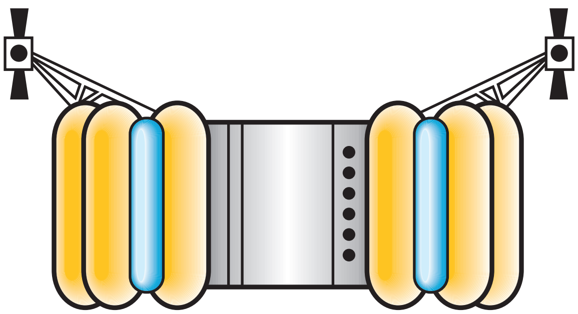


Crew Compartment with room for six astronauts on a 7-day excursion or four astronauts on a 14-day excursion

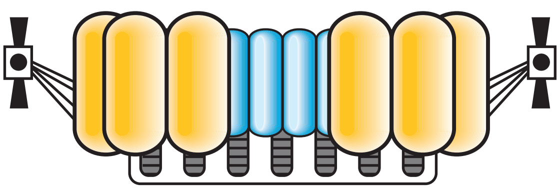
Crew Compartment with room for two astronauts on a 3-day excursion

Rocket Fuel

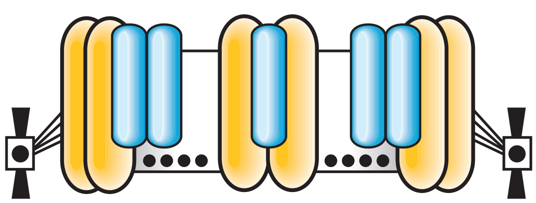
A typical liquid engine uses hydrogen as fuel and oxygen as oxidant. In the liquid engine, the fuel and oxidant are stored separately at extremely low temperatures. These are then fed to either the descent engine(s), ascent engine(s) or thrusters as needed to land, maneuver or dock with the CEV. The most vital component of any rocket is the propellant, which accounts for 90 to 95 percent of the rocket's total weight.



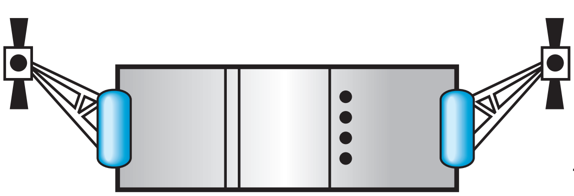
Large amount of fuel and oxidizer tanks for descent



Large amount of fuel and oxidizer tanks for descent



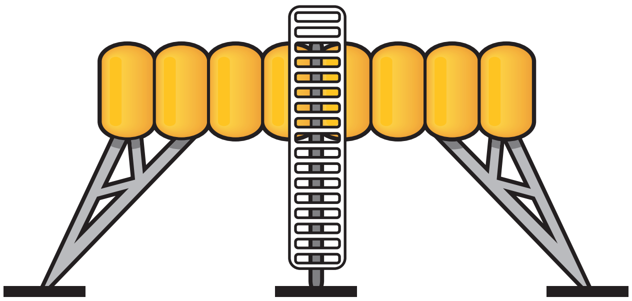
Medium amount of fuel and extra oxidizer tanks for descent



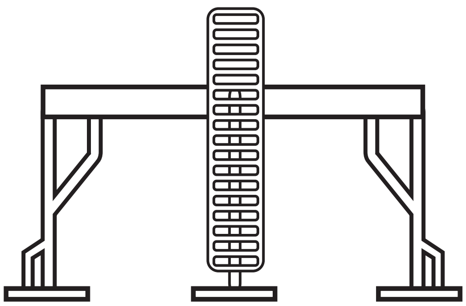
No fuel and a small amount of oxidizer tanks for descent

Landing Legs

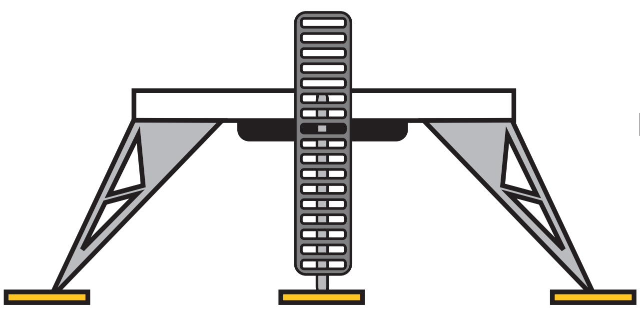
Landing legs are the points of contact between the spacecraft and the surface it lands on. Most landing legs have shock-absorbing properties built in to them. Some legs must be deployed into a usable position, while some are rigid on the spacecraft. Also, some legs are crushable to provide a cushioned landing.



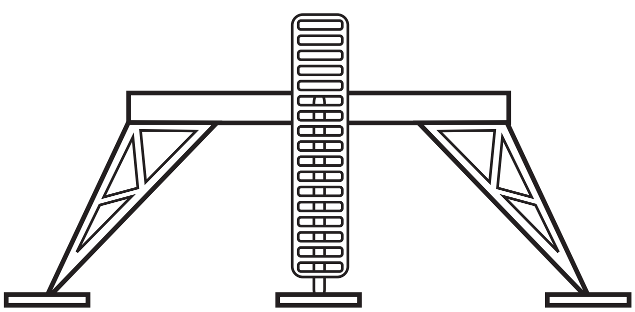
Rigid legs with a medium amount of fuel tanks



Crushable legs with no storage space



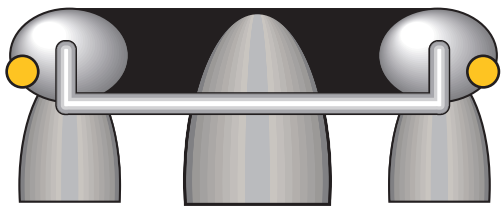
Rigid legs with extra storage space



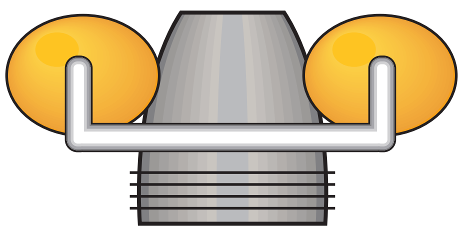
Deployed legs with no storage space

Rocket Engines

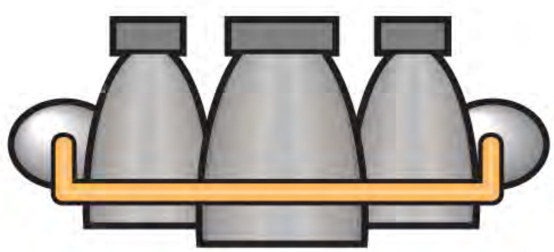
A typical liquid engine uses hydrogen as fuel and oxygen as oxidant. The chemical energy of the propellants is released in the form of heat in the combustion chamber. A liquid engine requires an igniter in case the propellants fail to spontaeneously ignite on contact.



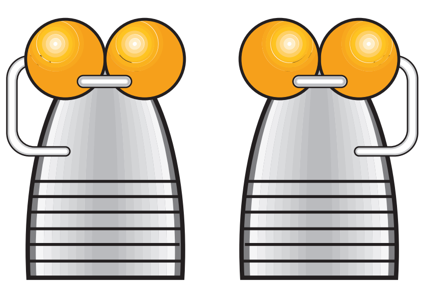
Small triple-rocket engines with no fuel tanks attached



Large single-rocket engine with fuel tanks attached



Large triple-rocket engines with no fuel tanks attached



Dual rocket-engines with fuel tanks attached

Science Instruments

Student Data Sheet

Team Name: ____________________

Team Members: ____________________

Discover and choose science instruments that your Lunar Nautics mission will use to explore the Moon. Use information from the materials about science instruments, the computer programs or other sources.

1. We want to study

2. Our instruments are

3. We chose them because

4. Our instruments cost

5. Our budget total is

Design a Lunar Miner

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

The next step in planning your Lunar Nautics mission is to prepare a design for your lunar miner. Use the Lunar Nautics Proposal, Design and Budget Checklist worksheet to assist your team in moving through the design process.

Step 1: Identify the Problem

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____
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Step 2: Design a Solution

Review the miner design templates to locate possible components for your miner. You may also want to review designs of other NASA miner or vehicle concepts. These can be found on your Lunar Nautics CD. Use this space to record your design decisions.

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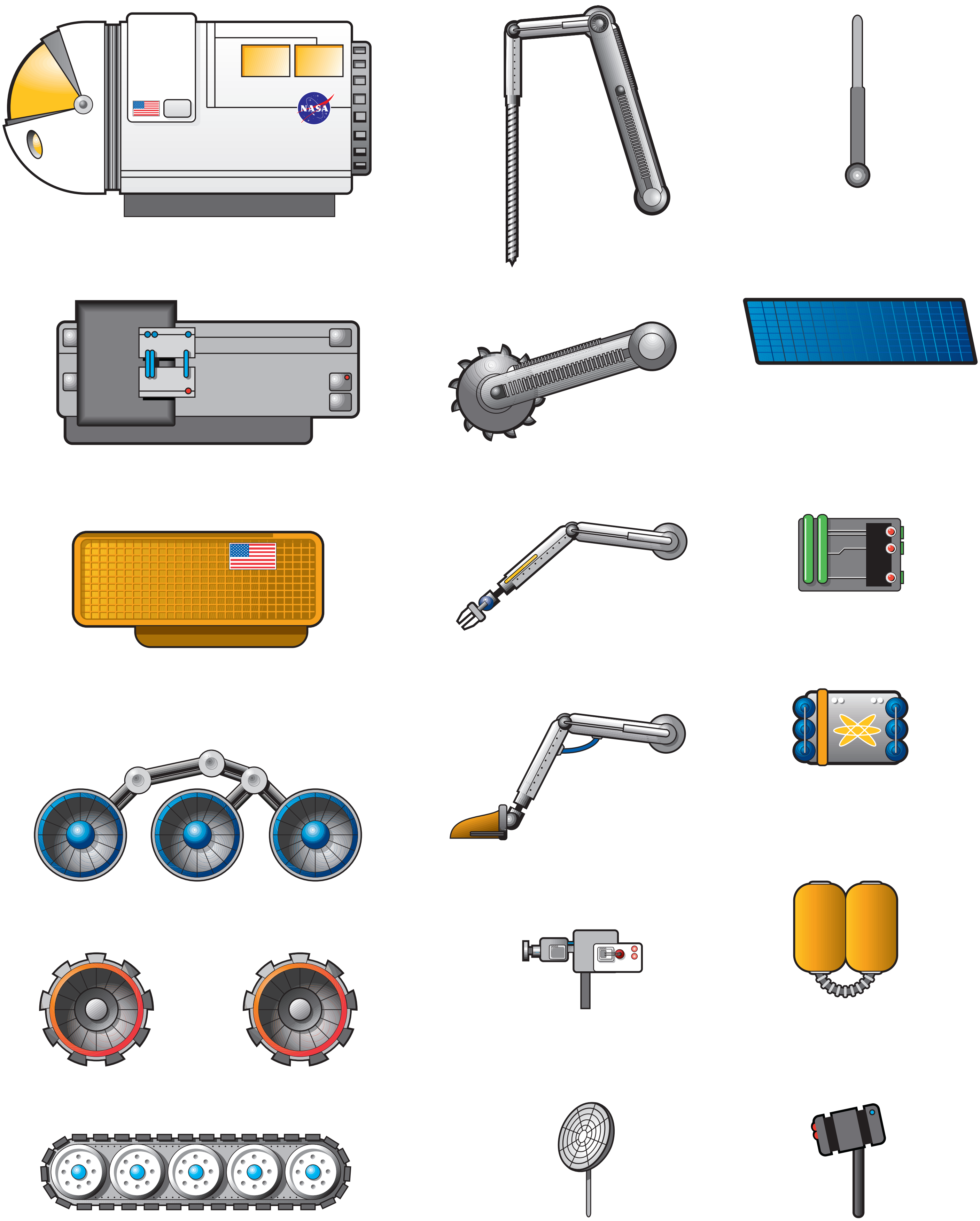
Step 3: Implement the Design

Use the miner design template on the Lunar Nautics CD to complete your design or print out the components on page 12 (refer to the Lunar Nautics CD for their specific names and functions) to create a blueprint student sheet.

The design printout can be used as a blueprint for building the 3-dimensional (3-D) model.


NASA

Step 4: Evaluate the Design

Rate your design	Poor		Average		Great
Miner design is functional	1	2	3	4	5
Design shows innovation	1	2	3	4	5

What things could you change about your design to make it better?

Step 5: Communicate Your Design

List the important points that you will share about your design during your final Lunar Nautics presentation.

Build a 3-Dimensional Lunar Miner

Student Data Sheet

Team Name: ____

Team Members: ____

Context
Lunar rocks and minerals are very important to the construction and long-term viability of a lunar base. Vehicles will be specifically designed to mine, collect and transport useful materials.

Challenge
Using computer templates, design and then construct a 3-D model of a lunar miner that can traverse a lunar terrain.

Technological Design Steps
The design process can be broken down into the following steps:

1. Identify appropriate problems for technological design.
2. Design a solution or product.
3. Implement the proposed design.
4. Evaluate completed technological designs or products.
5. Communicate the process of technological design.

Design
As a team, discuss the following questions about your proposed lunar miner:

1. What will be needed to move on the lunar terrain?
2. Will sample collection be needed?
3. Will the miner be manned or unmanned?
4. What scientific instruments will be needed?
5. What attachments will be needed?
6. Are backup systems needed?

Activities

1. Describe the job responsibilities of the project engineer, test engineer, facilities engineer and the developmental engineer.
2. Open the computer to Design a Lunar Miner (or use the Design a Miner template provided by your teacher).
3. Use the answer to the questions above and samples of other space vehicles to create the most effective design for your team's miner.
4. Print out your miner design to serve as a blueprint for building a model of your miner.
5. Save your design as a picture to be used in your Lunar Nautics presentation.

Evaluate Your Team's Design

- What process was used in determining your design?
- How did your group make decisions about what should be included in your miner design?
- How effective were your team members in working together?

1	2	3	4	5
Poor				Exceptional

- What could you do to improve on your decision making process?
- How could you work better as a team?

Building a 3-Dimensional Model

What process was used in determining your design?

1. Implement the design that your team prepared. It is acceptable to make improvements to your design as you construct your miner.
2. Determine the scale that will be used for your miner.
3. Remember all safety rules when using materials.
4. Under the test engineer's leadership, develop a summary of the construction process and a list of information to be presented in the final presentation.
5. Evaluate your team's final product.
   a. What changes, if any, did you make to your design during the construction process?
   b. Why were these changes necessary?
   c. What characteristics of your miner have the potential to make it an award-winning project?
   d. How effective were your team members in working together?

1	2	3	4	5
Poor				Exceptional

6. How could you work better as a team?

How Successful was your product?

Criteria

1. The rover/miner must travel over the surface of the Moon.
2. The rover/miner must sort three samples of a designated material.
3. The rover/miner must transfer the samples to a specified collection area.
4. The robot is timed
   a. Robot meets all criteria and has fastest time = 5 points
   b. Robot meets all criteria with 2nd fastest time = 4 points
   c. Robot meets all criteria with 3rd fastest time = 3 points
   d. Robot meets at least 2 criteria = 2 points
   e. Robot meets at least 1 criterion = 1 point

Design a Lunar Base

Student Data Sheet

Team Name: ____

Team Members: ____

The next step in planning your Lunar Nautics mission is to prepare a design for your lunar base. Use the Lunar Nautics Proposal, Design and Budget Checklist worksheet to assist your team in moving through the design process.

Step 1: Identify the Problem

Step 2: Design a Solution

Review the lunar base design templates on the Lunar Nautics CD to locate possible components for your lunar base. You may also want to review designs of other NASA lunar base concepts.These can be found on your Lunar Nautics CD. Use this space to record your design decisions.

Step 3: Implement the Design

Use the lunar base design template on the Lunar Nautics CD to complete your design or print out the components (pages 19 and 20). Refer to the CD for specific names and functions of components to create a blueprint student sheet.

The design printout can be used as a blueprint for building the 3-D model.

Step 4: Evaluate the Design

• Rate your design	Poor		Average		Great
• Lunar base design is functional	1	2	3	4	5
• Design shows innovation	1	2	3	4	5

• What things could you change about your design to make it better?

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Step 5: Communicate Your Design

List the important points that you will share about your design during your final Lunar Nautics presentation.

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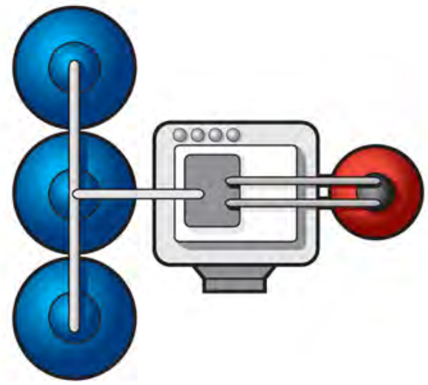

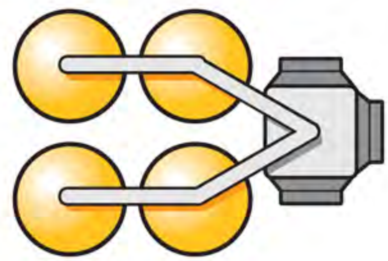

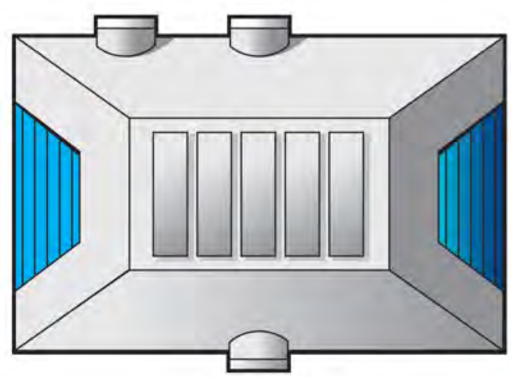

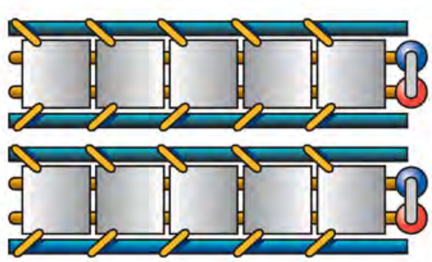

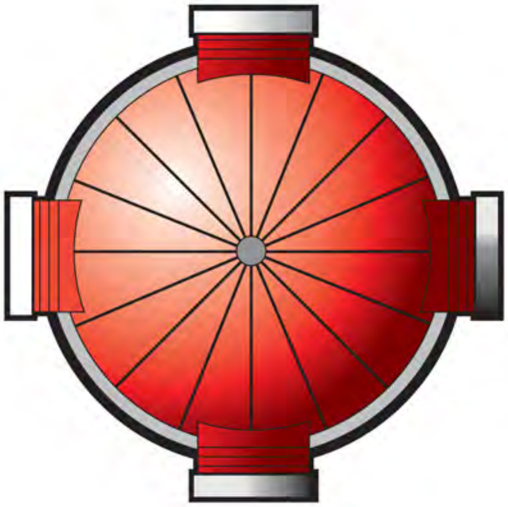
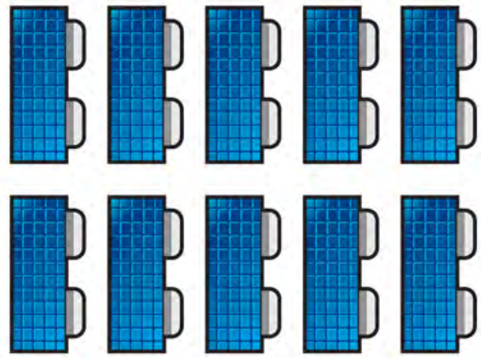
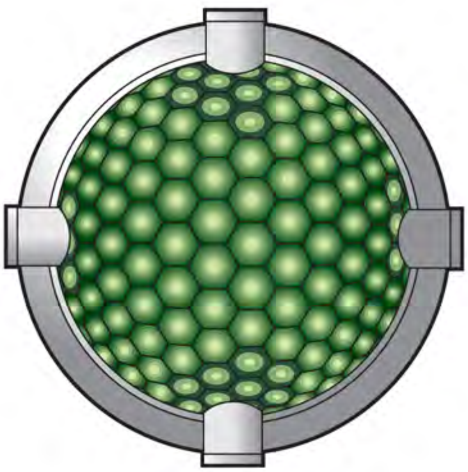


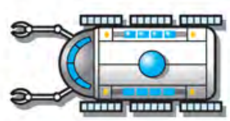
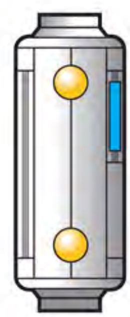
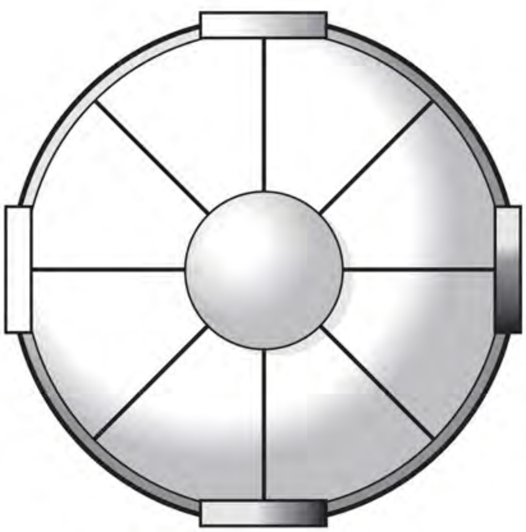


Build a 3-Dimensional Lunar Base

Student Data Sheet

Team Name: ____

Team Members: ____

Design Brief

Context
What will the first lunar base actually look like? No one knows yet, but many have been designed. In the 1950s and 1960s, scientists and engineers who hoped that by the next century a lunar base would be fully operational put forth many designs. In 1992, NASA developed and rejected the First Lunar Outpost reference mission. Igloos, railroads, buses, ecospheres and domes, have all been proposed. Inflatable structures, underground structures, structures at the South Pole and space ports at lunar libration points have all been designed. Hotels, laboratories, observatories, sports arenas, and mining and manufacturing plants are all very real possibilities. What would a lunar base that you designed look like?

Challenge
Using computer templates, design and then construct a 3-D model of a lunar base.

Technological Design Steps
The design process can be broken down into the following steps:

1. Identify appropriate problems for technological design.
2. Design a solution or product.
3. Implement the proposed design.
4. Evaluate completed technological designs or products.
5. Communicate the process of technological design.

Design
As a team, discuss the following questions about your proposed lunar base:

1. How many astronauts will need habitation?
2. What science or experiments will astronauts conduct?
3. What communications will they need?
4. Are airlocks needed?
5. How will power be provided?
6. Are vehicles needed for transportation?
7. What will be mined or manufactured?
8. How will the heat from systems be eliminated?
9. Are backup systems needed?

Activities

1. Describe the job responsibilities of the project engineer, test engineer, facilities engineer and the developmental engineer.
2. Open the computer to Design a Base (or use the Design a Base template provided by your teacher).
3. Use the answer to the questions above and samples of other lunar base design concepts to create the most effective design for your team's lunar base.
4. Print out your lunar base design to serve as a blue print for building a model of your base.
5. Save your design as a picture to be used in your Lunar Nautics final presentation.

Evaluate Your Team's Design

- What process was used in determining your design?
- How did your group make decisions about what should be included in your lunar base design?
- How effective were your team members in working together?

1	2	3	4	5
Poor				Exceptional

- What could you do to improve on your decision making process?
- How could you work better as a team?

Building a 3-Dimensional Model

1. Implement the design that your team prepared. It is acceptable to make improvements to your design as you construct your base.
2. Determine the scale that will be used for your base.
3. Remember all safety rules when using materials.
4. Under the test engineer's leadership, develop a summary of the construction process and a list of information to be presented in the final presentation.
5. Evaluate your team's final product.
   a. What changes, if any, did you make to your design during the construction process?
   b. Why were these changes necessary?
   c. What characteristics of your base have the potential to make it an award-winning project?
   d. How effective were your team members in working together?

1	2	3	4	5
Poor				Exceptional

6. How could you work better as a team?

Mission Patch Design

Student Data Sheet

Team Name: ____

Team Members: ____

For every journey into space, a patch or emblem is designed that identifies its unique mission. Mission teams use color, shapes, images and text to represent different aspects of the mission. The following are two examples.

Apollo Program
The Project Apollo insignia was a disk circumscribed by a band displaying the words “Apollo” and “NASA.” The center disk bore a large letter “A” with the constellation Orion positioned so that its three central stars formed the bar of the letter. To the right was the Earth, with the Moon in the upper left of the center disc. The Moon’s face represented the mythical god Apollo. A double trajectory passed behind both spheres and through the central stars.

Apollo 11 Mission
The American eagle, symbolic of the United States, was about to land on the Moon. In its talons, an olive branch indicated the crew “came in peace for all mankind.” The Earth, the place from which the crew came and would return safely to fulfill President John F. Kennedy’s challenge to the nation, rested on a field of black, representing the vast unknown of space.

Design Elements
Write down the important elements of your mission that you want to include in the design.

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Design your team’s mission patch on the Lunar Nautics CD or draw your patch on a separate piece of paper. You can also print out the blank templates found in the “Journey to the Moon” section of the Lunar Nautics CD.

Lunar Nautics Presentation Funding Worksheet

Team Name: ____

Team Members: ____

Should This Mission Be Funded?

Category	Number of Points (circle)				
	Strongly Agree				Strongly Disagree
Mission Objectives Amount of useful science accomplished	5	4	3	2	1
Model of Miner and Objectives Miner is well designed, feasible, shows innovation	5	4	3	2	1
Objectives Clear	5	4	3	2	1
Model of Lunar Base(s) Base is well designed, feasible, shows innovation	5	4	3	2	1
Lunar Base Components and Objectives List of facilities Explanation of why facilities selected	5	4	3	2	1
Astronaut Living and Working Space Explanation Safety and security considered	5	4	3	2	1
Science Instruments and Objectives List of instruments Explanation of why instruments selected	5	4	3	2	1
Mission Costs Within or under budget	5	4	3	2	1
Mission Timeline Realistic	5	4	3	2	1
Mission Results Science and technology achieved on this mission worth taxpayer dollars	5	4	3	2	1

Total Points ____________________

Let's Investigate the Geography and Geology of the Moon

Team Name: ____

Team Members: ____

Using the Moon lithograph and computer resources, answer the following questions about the Moon.

1. What are the dark and light features of the Moon?

2. When was the Moon formed?

3. What is the powdery lunar soil called?

4. How was this powdery soil formed?

5. What country's spacecraft first orbited the Moon?

6. What country's spacecraft first landed on the Moon?

7. Who was the first man to walk on the Moon? What was the date?

8. How much lunar rock and soil did Apollo astronauts return to Earth?

9. What is President George W. Bush's 2004 plan for lunar exploration?

10. Is there water on the moon? How do we know?

11. What do False color images tell us?

Strange New Moon

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

A. Moon Design Description

1. Describe your team's Moon. Your description will be compared with findings of the observation team.

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B. Prelaunch Reconnaissance: Earth-Bound Observations of Another Team's Moon

1. Estimate your distance from the Moon: __________ meters.

2. Using your viewer (with blue cellophane attached to simulate Earth's atmosphere) observe the Moon. What types of things do you observe? Record any observations (e.g., shape of Moon, color, size, etc.).

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3. Discuss all of the observations with your team members while at Mission Control. Record any team observations that differ from yours.

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4. As a team, write questions to be explored in future missions to the Moon. What else do you wish to know and how will you find that information out (e.g., special features of the moon, life of any kind, etc.)?

   a.

   b.

   c.

   d.

C. Mission 1: The Flyby (e.g., Luna, Pioneer, Ranger, Zond (1959 to 1966) and Hiten (1990):

Using their viewers (with the cellophane removed), each team will have a turn at walking quickly past one side of the Moon. A distance of 1.524 meters needs be maintained from the Moon. Teams will then meet back at Mission Control with their backs to the Moon until all teams have completed their flyby of the Moon.

1. Record your observations of the Moon. What did you see that was the same as your Earth observations? What did you see that was different? Can you hypothesize (make a scientific guess) as to why there were any differences?

____
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____
____

2. Record any similarities or differences that your team observed.

____
____
____
____
____

3. List your team's ideas as to what you want to observe on your next orbiting mission

   a.

   b.

   c.

   d.

D. Mission 2: The Orbiter (e.g., Luna Spacecraft, Lunar Orbiter Spacecraft, 1966 to 1974; *Apollo 8*, 1968; *Hiten*, 1990; *Clementine*, 1994; Lunar Prospector, 1998; and SMART 1, 2003):

Using a viewer, each team takes a total of 2 minutes to orbit (circle) the Moon at a distance of 0.61 meters. Divide up the amount of time each member of the team gets to orbit within the 2 minutes.

After your observation, return to Mission Control.

1. Record your observations of the Moon. What did you see that was the same as your Earth or flyby observations? What did you see that was different? Can you hypothesize (make a scientific guess) as to why there were any differences?

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2. Record any similarities or differences that your team observed.

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3. As a team, develop a plan for your landing expedition onto the Moon's surface.

a. Where will you go and why? How did your team decide where to land?

b. What are the risks or benefits of landing there?

c. What specifically do you want to explore at this site?

d. What type of special equipment or instruments would you need to accomplish your exploration goals? (Remember, anything you bring has to be small and light enough to bring on a spacecraft.)

E. Mission 3: The Lander (e.g., Surveyor Spacecraft, 1966 to 1968; Apollo 11, 12, 14, 15, 16 and 17, 1969 to 1972):

Each team will approach their landing site and mark it with a push pin or masking tape. Each team member will take a turn observing the landing site through their viewer. Field of view (the area that you can see through your viewer) is kept constant by aligning the viewer with the push pin located inside and at the top of the viewers. Each team has a total of 5 minutes to view the landing site. After each member views the landing site, return to Mission Control.

1. Now that you have landed, what do you think you can accomplish at this landing site?
____
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2. How long (in days) will it take you to get the job accomplished?____________________

3. Was your mission able to accomplish your exploration goals? Why or why not?
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4. What were the greatest challenges of this mission (personally and as a team)? What would you change for the next mission?
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____

F. Moon Design Versus Observation

1. For the Moon you observed, compare the designer's description of their Moon to your observation descriptions. How was it different? How was it similar?

G. List the members of your team

1.
2.
3.
4.
5.
6.

Digital Imagery

Student Data Sheet

Team Name: ____

Team Members: ____

1. Each student takes a sheet of graph paper and draws a square, 10 boxes by 10 boxes
2. The "sender" should shade-in boxes in the square to create a simple picture. Do not allow the "receiver" to see the picture.
3. The sender then "Reads" the picture to the receiver, using the digital code below. If a square is blank, say, "Zero"; if the square is filled in, say, "One."
4. The sender uses the code, starting with the top row and reading from left to right.
5. Upon hearing the code, the receiver transfers the information to his or her square on the graph paper.
6. At the end of the first row, the sender says: "End row one." Repeat this at the end of each row (e.g., "End row two," etc.).
7. At the end of the last row, look at the picture on the receiver's paper. Check the results to see how accurate the transfer was.
8. Switch roles and repeat steps 1 through 7.
9. Answer the following questions on a separate sheet of paper.

   a. What was the most difficult part of the activity to do?

   ____

   ____

   b. Can you think of a better way to transmit and receive information?

   ____

   ____

   c. Describe how a digital image is formed based on your experiment.

   ____

   ____

   d. How is the information electronically coded?

   ____

   ____

Impact Craters Activities A and B

Student Data Sheet

Team Name: ____

Team Members: ____

Impact craters are formed when pieces of asteroids or comets strike the surface of a planetary body. Craters are found on all the terrestrial planets, on the Earth's Moon and on most satellites of planets.

Activity A

1. Mix the plaster of paris. A mixture of two parts plaster of paris to one part water works best. The plaster hardens in 10 to 20 minutes, so you must work quickly. Have your data chart and materials ready before the plaster is mixed.

2. Pour a 5-cm or more layer of plaster in a small, deep, disposable container.

3. Choose at least three types of projectiles.

4. Write a description of each projectile on your data chart.

5. Measure the mass and dimensions of each projectile and record on the data chart.

6. Drop projectiles into the plaster of paris.

   a. Drop all projectiles from the same height or several experiments may be conducted from different heights. Record data and crater observations.
   b. Drop the projectiles from different heights. Record all height data and crater observations.

Activity B

1. Choose at least three projectiles from set A or set B.

2. Write a description of each projectile on your data chart.

3. Measure the mass and dimensions of each projectile and record on the data chart.

4. Drop projectiles into the dry material.

   Set A: Drop all projectiles from the same height or several experiments may be conducted from different heights. Record data and crater observations.
   Set B: Drop the projectiles from different heights. Record all height data and crater observations.

DATA CHART
Activity A and B

DATE ______________________

NAMES ______________________

____

Projectile Description Mass (g) Dimensions (cm)	Time Activity A Only	Height	Longest Ray if Available	Sketch of Crater and Comments (note diameter and depth) (cm)

Lunar Core Sample

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

Directions

A core sample is a cylendrical section of something that has been cut out using a hollow tube. In this activity, you will be making lunar surface core samples. It is your job to observe and determine all the scientific information you can from these samples. After the instructor demonstrates how, take one core sample from the lunar surface sample and respond to items 1 through 7 on a separate sheet of paper. Then take a second core sample to compare to the first core sample and respond to items 8 through 12.

1. Describe the color of your lunar sample:
2. Describe the surface features of your lunar sample:
3. Draw a picture of any surface features you see on your lunar sample:
4. What is your hypothesis (scientific guess) about the cause of any texture you see on your lunar sample?
5. How many layers does your lunar core sample contain?
6. Draw a picture showing the layers of your lunar core sample.
7. Which layers were made first? Why?
8. Draw a picture of the second core sample showing any layers and surface features.
9. Compare the two core samples and list any similarities or differences from your first lunar core sample.
10. Would a lunar core sample be important to the study of the Moon? Why?
11. Where would be the best place to study a lunar core sample, on Earth or on the Moon? Why?
12. What would account for your two samples being different, if both come from the Moon?

Edible Rock Abrasion Tool

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

In this activity, you will be using the following items to model how scientists can use a robotic tool to make observations about a rock on the surface of the Moon.

1. A bar-type cookie will represent a simulated rock from the lunar surface.
2. Powdered sugar will represent dust on the surface of the Moon that tends to cover many rocks.
3. A jumbo pretzel stick will represent the Rock Abrasion Tool (RAT).

Introduction

How do planetary geologists study rocks on a planet or the Moon? NASA uses robotic rovers to do this type or study on the Moon and on the surface of Mars. Most people think that if you want to study the rocks on the Moon or Mars surface, all you have to do is have the rover look at the rock. Right? Well, not exactly. There are two major problems. First, the rocks found on the Moon are usually covered with dust. If a robotic rover were to study just the surface of the rock, scientists would actually be studying the dust, not the rock itself. Second, even under the dust, the surface of the rock might have been changed by its exposure to impacts by meteorites and radiation.

To observe a pristine (or fresh) sample of a rock, geologists on Earth would break the rock open with a rock hammer. However, the current robots being sent to Mars and eventually back to the Moon are fairly small and will not necessarily have a geologist's rock hammer as one of their instruments. Instead of breaking the rock open with a hammer, the rover will have a special tool called the RAT. The RAT is a special high-speed drill capable of removing the outer layers of the rock and exposing underlying material for examination by instruments onboard the rover. This is as close as we can get to sending a real field geologist to the Moon.

1. To start, you should have a bar-type cookie (Moon rock) in a muffin cup. Powdered sugar should cover the top surface and both sides of your bar-type cookie. Look at the original rock sample and record your observations on the following:

   a. Color ______________________________
   b. Texture ______________________________
   c. Surface features ______________________________

2. Using your craft stick, ruler and pencil, look at the original rock sample and record your observations on the following:

a. Length (cm): ______________________________
b. Width (cm): ______________________________
c. Height (cm): ______________________________

(Hint: Use the craft stick to measure the rock sample by placing it along side the cookie and marking its length on the craft stick with the pencil. Measure the marked area of the craft stick using the ruler and record your measurement. You can erase each mark before making the next measurement if you wish.)

3. Gently rotate your RAT on the surface of the rock so that it slightly erodes away the surface of the cookie. Observe this newly exposed region and record your observations below.

a. Look back at your observations on question number 1. How is this new surface different from the original surface?

____
____
____
____

b. Notice how the “dust” (sugar) builds up along the edge of the drilled area. How would you keep the dust from getting into the “RAT hole” and contaminating the freshly drilled rock sample?

____
____
____
____
____

c. Rotate your RAT again and apply slightly more pressure to dig deeper into the rock sample. Record your observations of the freshly drilled sample.

____
____
____
____
____

d. Measure the depth of drilled “RAT hole (cm).” ______________________________

e. Measure the diameter of drilled “RAT hole (cm).” ______________________________

8. Brainstorm as to which of the following types of rocks this could be and explain why you think it is this type of rock.

   a. IGNEOUS rocks are rocks that are made from molten materials that well up from inside a planetary body and cool to solidify into rock.

   b. METAMORPHIC rocks are rocks that have been changed by temperature and/or pressure.

   c. SEDIMENTARY rocks are rocks that have been eroded away from their original rock type and have been deposited and accumulated to solidify into new rock.

   d. Record your determination.

9. Draw a diagram of your rock sample and label the parts of the rock including the part of the rock revealed by the RAT.

Investigating Lunar Missions

Space Exploration

The Exploration Systems Mission Directorate (ESMD) is an organization within NASA dedicated to creating new capabilities, supporting technologies and foundational research that enables sustained and affordable human and robotic exploration.

ESMD's strategy for creating these new capabilities, supporting technologies and foundational research flows from four overarching principles. These principles are:

Based on these principles, the directorate develops tasks targeted to creating new capabilities and engaging in research and development.

The ESMD ultimately decides whether a project or mission proceeds or not.

Let's Investigate Lunar Missions

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

On the Internet, visit the Lunar Nautics Lunar Exploration Timeline or <www.spds.nasa.gov/planetary/lunar/lunartimeline.html>. On this site, you will find past, operating, in-development and under-study missions, or use information sheets and books to research different space missions.

Select one mission to explore further, and answer the following questions about your selected mission.

1. What is the name of your mission?

2. What is the goal of the mission?

3. Summarize launch details of your mission. Include the type of vehicle used for launch.

4. What science instruments does the spacecraft carry?

5. What is the size and weight of the spacecraft?

6. How is the spacecraft powered?

7. Are there many parts to the spacecraft?

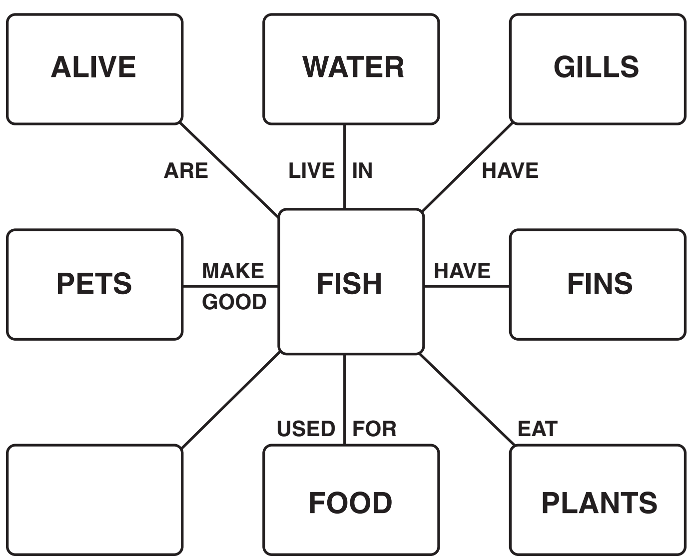
8. Does the spacecraft carry humans, and, if so, how many?

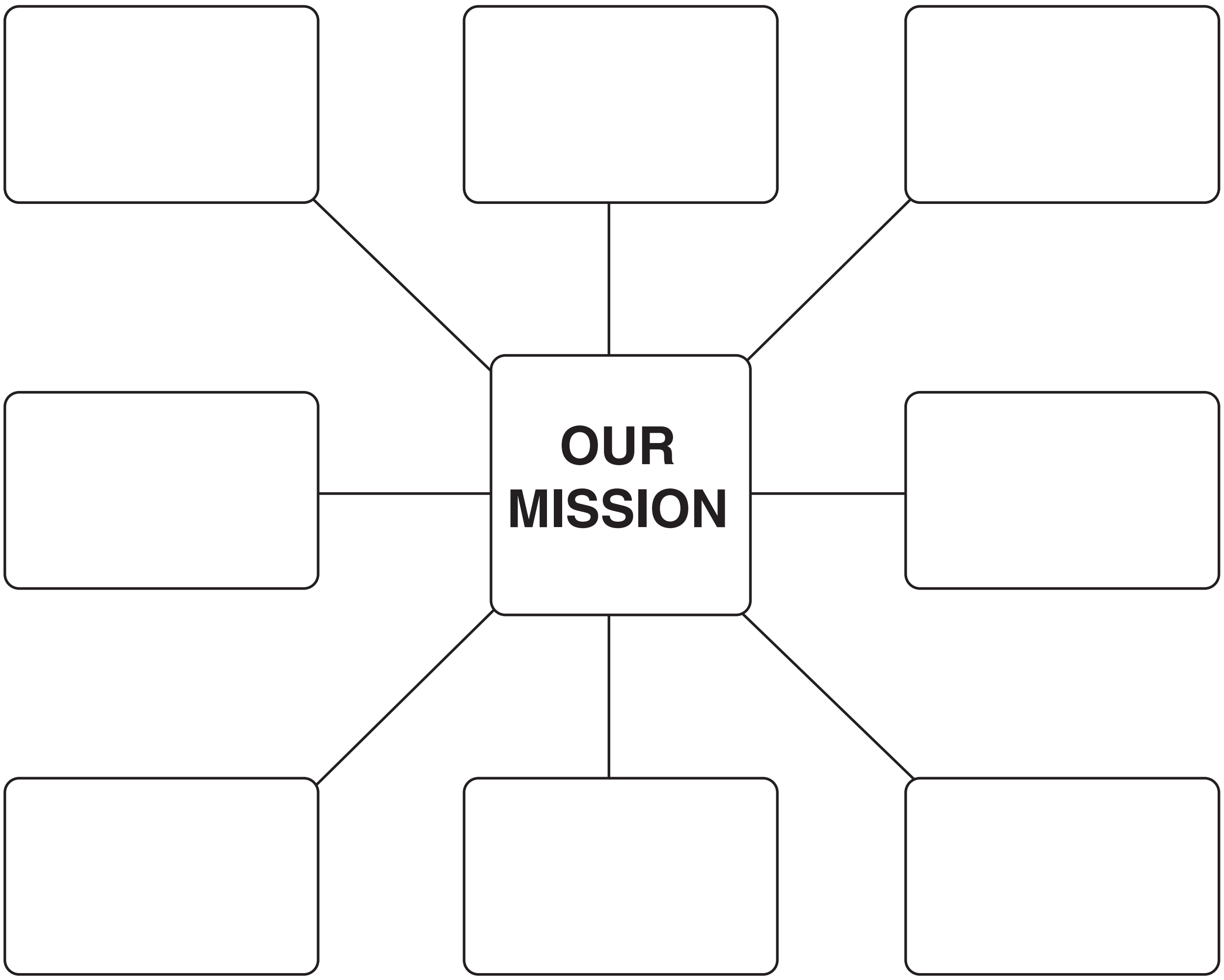
9. What is the timeline of the mission (i.e., start, finish and expected duration)?

10. If the mission has already occurred, was it successful?

11. When brainstorming for your team proposal, write what comes to mind as it relates to your team mission in the empty boxes on page 43 such as: 1) what your mission is, 2) what you want to discover and 3) what your mission needs. You can write more than one thought in each box. You can draw other boxes off of the existing boxes or draw your own on a separate piece of paper. After you have finished, compare your notes to your teammates' notes.

For example:



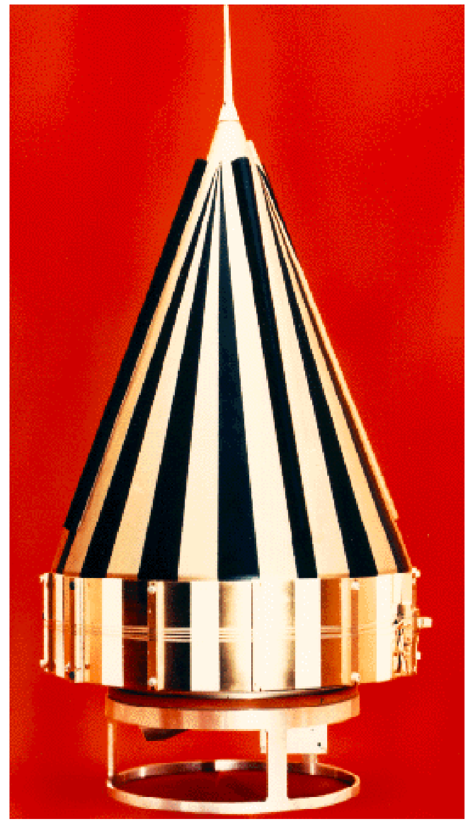

OUR
MISSION

Edible Pioneer 3 Spacecraft

Student Data Sheet

Team Name: ____

Team Members: ____



Look at the Pioneer 3 Spacecraft components picture and build your spacecraft.

Follow these instructions:

1. Place one sugar cone on a small plate.
2. Next, open the airhead extreme sour belts.
3. Take one airhead and place the beginning of that airhead even with the base of the sugar cone.
4. Using marshmallow crème or icing as your glue, stick the airhead to the sugar cone, draping the other end of the airhead over the point of the cone.
5. Continue to attach airhead tapes to the cone as if it were a carousel. Save one airhead for the circumference (base) of the cone.
6. Once the cone is covered, trim the excess tape from the tip of the cone. Use the marshmallow crème or icing to paste down any loose ends.
7. Paste the final tape around the base of the cone (circumference) with marshmallow crème or icing.
8. Finally, attach a HERSHEY'S KISS to the tip of the cone.
9. Attach an identification label to each spacecraft part.

Pioneer 3 Checklist

❑ Spacecraft is made with care and creativity.
❑ Spacecraft contains all parts.
❑ Spacecraft parts are labeled. For a list detailing parts, go to <http://en.wikipedia.org/?title=Pioneer_3>.
❑ You can clearly explain the function of each part of the spacecraft.

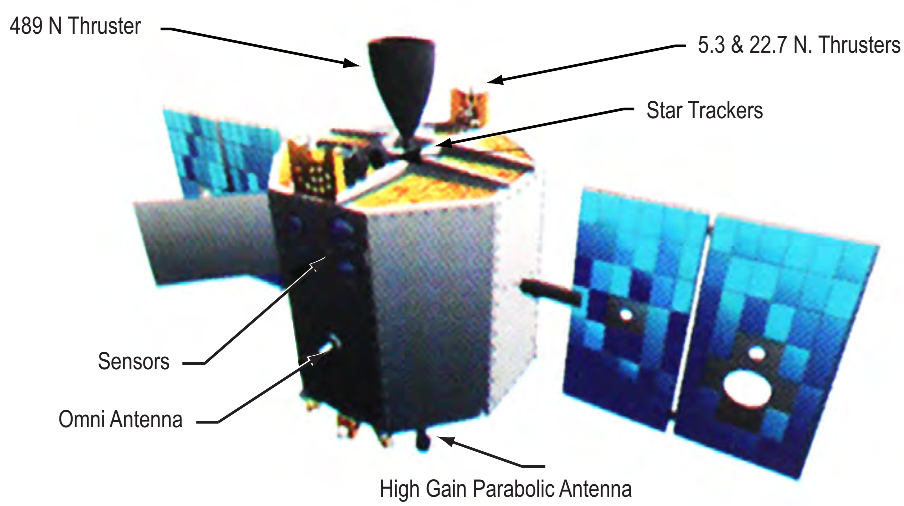
Edible Clementine Spacecraft

Student Data Sheet

Team Name: ____

Team Members: ____

DSPSE Spacecraft



Look at the Clementine Spacecraft components (fact sheet) picture and build your spacecraft.

Follow these instructions:

1. First, connect the three marshmallows using a toothpick through their center (it should resemble a skewer). This represents the central unit.
2. Attach a Fig Newton, positioned vertically, to the side of the marshmallow stack using a toothpick. This represents the side panels.
3. Repeat step number 2 on the opposite side of the marshmallow stack.
4. Using toothpicks, separately attach two gumdrops to the bottom of the marshmallow stack. These represent the high-gain parabolic antennas.
5. Attach one gumdrop, using toothpicks, to the side of the marshmallow stack. This represents the omniantenna.
6. On the top of our marshmallow stack, attach one gumdrop to each side with a toothpick. These represent the 5.3- and 22.7-N thrusters.
7. Insert the Blow Pop into the center of our marshmallow stack. This represents the 489-N thruster.

Student Checklist:

❏ Spacecraft is made with care and creativity.
❏ Spacecraft contains three thrusters.
❏ Spacecraft contains two high-gain sntennas.
❏ Spacecraft contains an omniantenna.
❏ Spacecraft parts are labeled and function defined.
❏ Student can clearly explain the function of each part of the spacecraft.

Clementine Spacecraft Team Rubric

Assign points from 1 to 4, where:

4 = Complete, fully developed, everything accounted for, very accurate.
3 = Mostly complete, most things accounted for and accurate.
2 = Partly complete, much is missing, some inaccuracy.
1 = Missing or omitted information or mostly inaccurate.

_____ Spacecraft is made with care and creativity.

_____ Spacecraft contains four side panels.

_____ Spacecraft contains a high-gain parabolic antenna.

_____ Spacecraft contains an omniantenna.

_____ Spacecraft parts are labeled and the function of each part defined.

_____ Student can clearly explain the function of each part of the spacecraft.

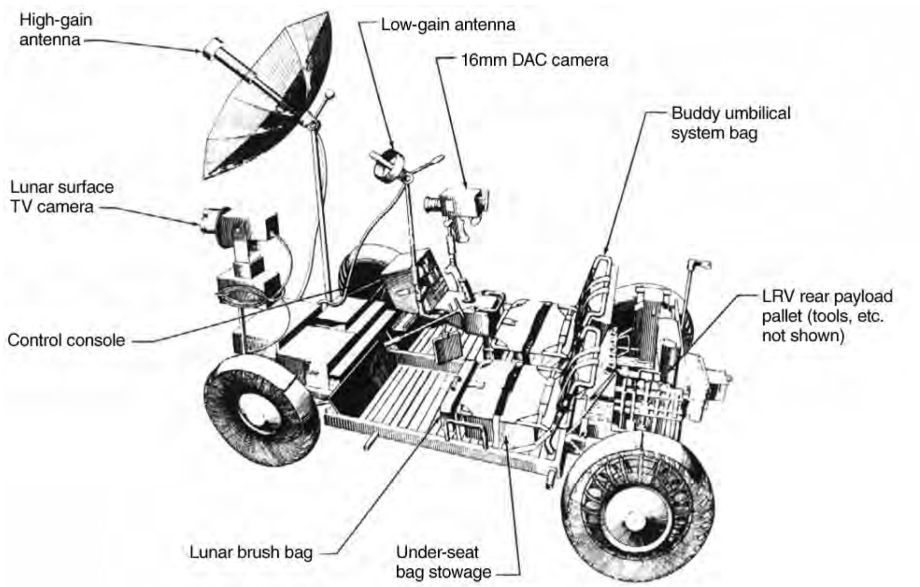
_____ (Total/24) × 100 = _____ percentage

Edible Lunar Rover

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________



Look at the Lunar Rover Spacecraft components (fact sheet) picture and build your spacecraft.

Follow these instructions:

1. Lay one sheet of graham crackers flat. If crackers have been separated, use marshmallow crème or icing to glue two individual graham crackers together (side-by-side). This is the center of your vehicle.
2. Place one individual graham cracker at each end of the graham cracker sheet from step number 1 (these graham crackers should be perpendicular). These mark the front and back of your vehicle.
3. Using the marshmallow crème or icing, glue all four graham crackers together.
4. Attach one Oreo wheel to all four spots where the end graham crackers meet the center graham crackers (four wheels in all).
5. Glue one regular-size marshmallow to the center of each Oreo wheel.
6. Create two seats with the four crème wafers. To create the seats, glue two wafers flat, side-by-side, along the back of the center graham cracker pair.
7. Now, glue the second two wafers upright and attached to the first two wafers (one pair of wafers equals one complete seat, with bottom seat and backrest).
8. Make seatbelts for each seat by gluing two pretzels side-by-side, vertically along the backrest of each seat.

9. Attach one crème wafer flat, in front of the seats and one wafer behind the seats. These will stabilize the seats and act as a base for additional equipment (e,g., front antenna and front camera).
10. Create the lunar surface camera. Near the center front crème wafer, stack two Starburst fruit chews flat, near the edge (in front of the seats).
11. Glue a Tootsie Roll to the top of the Starburst stack. This represents the lunar surface camera.
12. To the right of the lunar surface camera, glue one gumdrop flat, on top of the wafer. This is the base of the antenna.
13. Insert one toothpick into the gumdrop (toothpick should stand straight up).
14. Attach two jumbo marshmallows to the top of the toothpick (kabob style). Insert a toothpick into the center of the antenna. Attach a gumdrop to the end of the toothpick. This represents the high-gain antenna.
15. In front of the right seat, glue three gumdrops flat.
16. Insert one toothpick into two of the gumdrops. Place a Tootsie Roll to the top of one toothpick. This represents the side camera.
17. Now, place a marshmallow on the last toothpick. This represents the low-gain antenna.
18. Stack two Tootsie Rolls on top of the last gumdrop. This represents the control panel.
19. Use your imagination to create and add in additional parts shown on the fact sheet.

Student Checklist

❏ Rover is made with care and creativity.
❏ Rover contains three seats.
❏ Rover contains a high-gain antenna.
❏ Rover contains a low-gain antenna.
❏ Rover contains four wheels.
❏ Rover has additional parts.
❏ Rover parts are labeled and the function of each part defined.
❏ Student can clearly explain the function of each part of the spacecraft.

Rover Team Rubric

Assign points from 1 to 4, where:

4 = Complete, fully developed, everything accounted for, very accurate.
3 = Mostly complete, most things accounted for and accurate.
2 = Partly complete, much is missing, some inaccuracy.
1 = Missing or omitted information or mostly inaccurate.

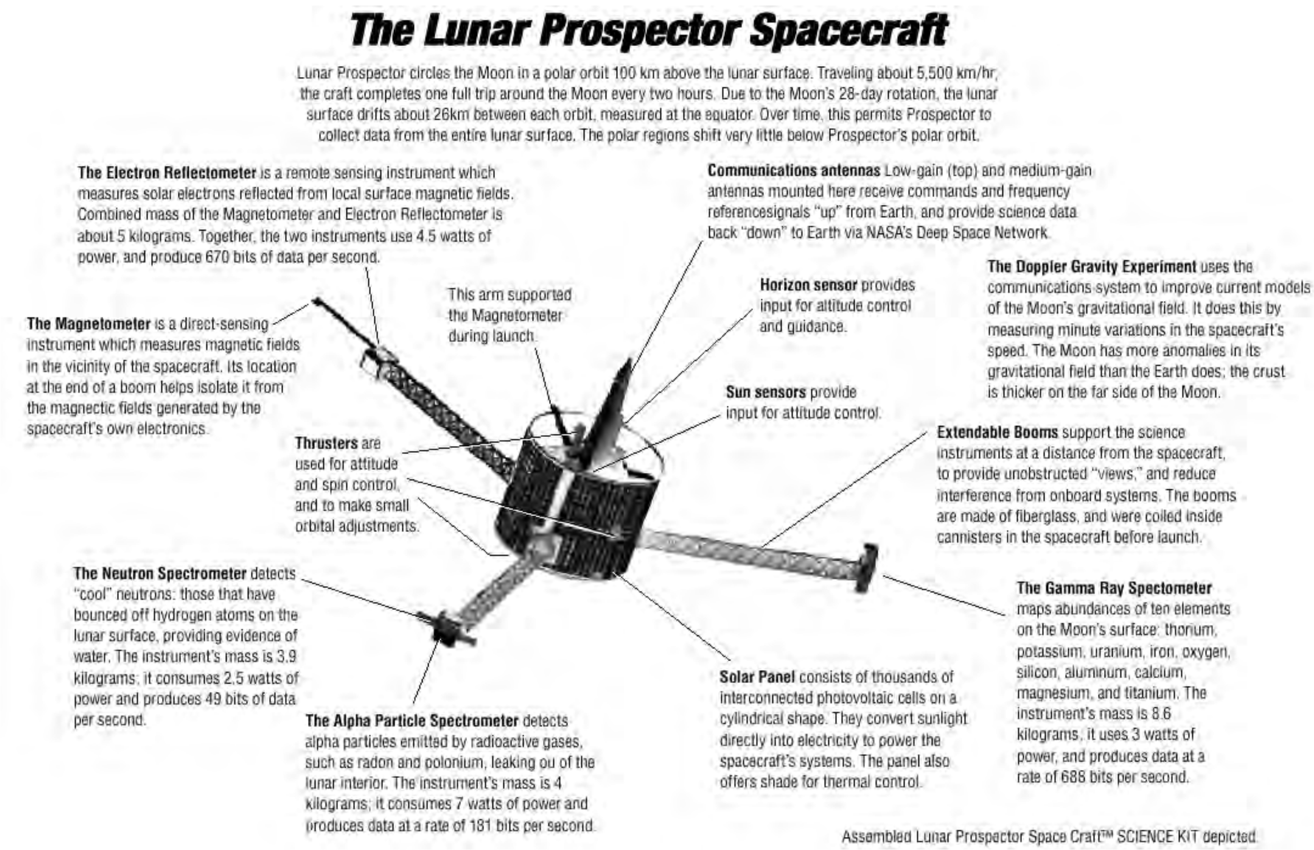
_____ Rover is made with care and creativity.
_____ Rover contains three seats.
_____ Rover contains a high-gain antenna.
_____ Rover contains a low-gain antenna.
_____ Rover contains four wheels.
_____ Rover has additional parts.
_____ Rover parts are labeled and the function of each part defined.
_____ Student can clearly explain the function of each part of the Rover.
_____ (Total/32) × 100 = _____ percentage

Edible Lunar Prospector

Student Data Sheet

Team Name: ____

Team Members: ____



Look at the Lunar Prospector Spacecraft components (fact sheet) picture and build your spacecraft.

Follow these instructions:

1. Connect three jumbo marshmallows together in a right triangle, using toothpicks to link them. For added stability, use two toothpicks between each marshmallow.
2. Repeat step number 1 to form a second triangle, using three additional marshmallows.
3. Place the first triangle on top of the second triangle. Use a toothpick to join each marshmallow to the marshmallow under it. This represents the center cylinder.
4. Insert a pretzel rod into the center of each marshmallow in the bottom triangle. These represent the extendable booms.
5. Attach a gumdrop to the end of two of the pretzel rods. These represent the spectrometers.
6. Attach the Starburst Fruit Chew to the third pretzel rod. This represents the reflectometer.

7. Insert a toothpick into the far side of the Starburst fruit chew.
8. Add a gumdrop to the end of the toothpick in step number 7. This represents the mangetometer.
9. Using one toothpick for each, attach two Jujy Fruits pieces to two of the marshmallows in the top marshmallow triangle. This represents a thruster and a sun sensor.
10. Push one peppermint stick into the top of the other marshmallow in the top marshmallow triangle.This represents the communication antenna.
11. Using a diagram of the spacecraft and some imagination, add additional instruments and engineering components onto your spacecraft.

Lunar Prospector Checklist

❏ Lunar Prospector is made with care and creativity.
❏ Lunar Prospector contains three extendable booms.
❏ Lunar Prospector contains a communication antenna.
❏ Lunar Prospector contains two spectrometers.
❏ Lunar Prospector contains one reflectometer.
❏ Lunar Prospector has additional parts.
❏ Lunar Prospector parts are labeled and the function of each part defined.
❏ Student can clearly explain the function of each part of the spacecraft.

Lunar Prospector Team Rubric

Assign points from 1 to 4, where:

4 = Complete, fully developed, everything accounted for, very accurate.
3 = Mostly complete, most things accounted for and accurate.
2 = Partly complete, much is missing, some inaccuracy.
1 = Missing or omitted information or mostly inaccurate.

_____ Lunar Prospector is made with care and creativity.
_____ Lunar Prospector contains three extendable booms.
_____ Lunar Prospector contains a communication antenna.
_____ Lunar Prospector contains two spectrometers.
_____ Lunar Prospector contains one electron reflectometer.
_____ Lunar Prospector has additional parts.
_____ Lunar Prospector parts are labeled and the function of each part defined.
_____ Student can clearly explain the function of each part of the Rover.
_____ (Total/32) × 100 = _____ percentage

Lunar Reconnaissance Orbiter

Component Functions Table

Student Data Sheet

Team Name: ____

Team Members: ____

Read the descriptions below and try to think of how robots are like humans by listing parts of the body that are like the robot parts.

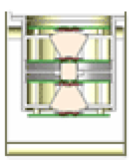
Computers

Computers manage a variety of intelligent functions such as navigation and propulsion, storing information from scientific instruments and sending information to Earth.

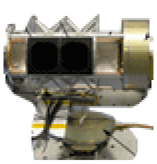
High-Gain/Low-Gain Antennas

Receivers and transmitters are used for communication between the spacecraft and Earth-based controllers. The antennae "hear" and "speak" for the spacecraft.

Instruments

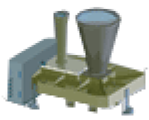


Cosmic Ray Telescope for the Effects of Radiation
Cosmic Ray Telescope for the Effects of Radiation (CRaTER) measures radiation. It will test special shielding that could be used to protect bases and spacecraft radiation. Radiation can be very harmful to people; we have to know the amount of radiation in different places on the Moon so that we can live and work there safely and for a long time.



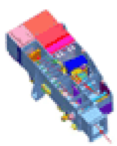
DIVINER
DIVINER (DLRE) will measure and map the temperatures during the day and night at different places on the Moon's surface. This will help engineers design habitats for people and will help scientists figure out where ice might be.

Lunar Exploration Neutron Detector
Lunar Exploration Neutron Detector (LEND) will help scientists map where they find the element hydrogen. Water is two parts hydrogen and one part oxygen—good ol "H-two-O" (H_2O). If scientists find hydrogen, they probably will have found water ice. The presence of ice could be useful for drinking water or broken down into hydrogen and oxygen and used for fuel.



Lunar Orbiter Laser Altimeter
Lunar Orbiter Laser Altimeter (LOLA) will send harmless laser beams to the Moon's surface. The beams will bounce back to LOLA and can be used to make a map of the entire surface; a map that shows scientists features as small as a foot and a half across. LOLA will help scientists figure out how smooth or rough the surface is and if ice is there, because different surfaces cause laser beams to scatter in different ways.

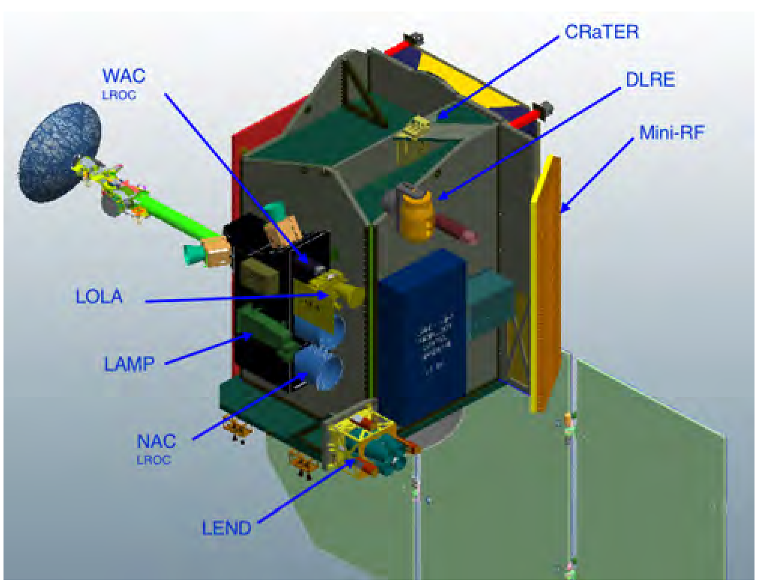
Lunar Reconnaissance Orbiter Camera
Lunar Reconnaissance Orbiter Camera (LROC) will collect very detailed pictures of possible future landing sites and places for habitats. The camera's pictures will help scientists learn about different lunar soils. LROC consists of a wide angle camera (WAC) and a narrow angle camera (NAC).



Lyman Alpha Mapping Project
Lyman Alpha Mapping Project (LAMP) will use ultraviolet light that is reflected off the Moon's surface from starlight. Using this tiny bit of light, scientists can look into places that regular cameras cannot see into, places like very deep craters that are always in the shadows. These places are protected from the sun's heat and radiation. This means that they are very cold, and they may have hidden ice.

Magnetometer Boom (Extended Arm)
This is an 11-meter-long "arm" extending from the spacecraft. There are instruments in the middle and on the end of it that are used to detect and measure magnetic fields.

Mini-Radio-Frequency Technology Demonstration System
The Mini-Radio-Frequency (Mini-RF) Technology Demonstration system is a unique miniaturized multimode radar observatory.



Orientation Thrusters
These are small rocket thrusters used for delicate maneuvers that rotate the spacecraft. Thrusters are useful for aiming instruments and pointing the antennae toward Earth.

Solar Arrays
These are the source of energy for instruments and transmitters. The solar power is then stored in the onboard battery.

Spacecraft
The bus is the core structure (or framework) to which bus spacecraft components are attached. This is made out of aluminum, the same metal used in soft drink cans.

Thermal Control
Mechanism that dissipates heat generated from the spacecraft out into space.

Robots Versus Humans

Student Data Sheet

Team Name: ____

Team Members: ____

Overview
When spacecraft such as the Lunar Reconnaissance Orbiter (LRO) are sent into space to study far off places, the spacecraft, its systems and instruments are an extension of the engineers and scientists back on Earth. Many functions and senses of the human body are emulated in spacecraft.

Materials
- LRO Spacecraft Components
- LRO: A Robot in Our Own Image
- LRO: LRO Facts Sheets
- Chart paper
- Magic markers

Procedure
Part 1: What is a Robotic Spacecraft
1. Obtain a copy of the following handouts for your team: LRO Fact Sheets, Spacecraft Components and Robot Versus Humans Student Sheets.
2. Record a group definition of a robot on a piece of paper. One person in the group should record the definition and another should report the definition to the whole class.
3. Record the capabilities or features your team would recommend for a robot that would be sent into space to explore another planet.

____

____

____

____

4. Review the LRO Spacecraft Component sheet. Discuss and predict the humanlike function of each of the parts.
5. Cut out the different spacecraft components and then arrange and attach them to a sheet of paper in a logical configuration.
6. Label each of the spacecraft components with its name as well as the predicted humanlike function. Give your robot a name.
7. Display your robot to the whole class.
8. Share the rationale for your team's design.

____

____

____

____

9. Record the capabilities or features your team would recommend for a robot that would be sent into space to explore another planet.

Part 2: Making the Connections to the Lunar Reconnaissance Orbiter

1. Use your team's copy of the LRO Component Functions Table to predict the function of each component.
2. What did your team discover about the LRO spacecraft? How will the key components of the LRO's technological design enable it to carry out its mission? Discuss whether or why each component is essential to the success of the mission.

Questions

1. What are the five human senses?

2. What are some of the main systems of the body?

3. How is a spacecraft a robot?

4. Does the robot that you designed have humanlike capabilities?

5. What would you hope to discover with your robot?

6. What questions would your robot help scientists answer?

Edible Lunar Reconnaissance Orbiter Spacecraft

Student Data Sheet

Team Name: ____

Team Members: ____

Look at the LRO Spacecraft picture and build your spacecraft. Consult the LRO Component functions table (previous Student Data Sheet) for the meaning of abbreviations in these instructions.

Follow these instructions:

1. Create a rectangular box by gluing four crème wafers together using the marshmallow crème or icing.

2. Close the bottom of the box with one crème wafer using the marshmallow crème or icing to glue it together. This represents the body of your spacecraft.

3. On the back side of your spacecraft, glue one Starburst to the bottom right corner. Glue a Skittle to the front of the Starburst. This represents LEND.

4. On the same back side, glue a Starburst and Skittle, side-by-side, in a horizontal line. These represent LAMP and NAC.

5. Directly above the LAMP and NAC, glue one Tootsie Roll and a candy corn (side-by-side). These represent LOLA and WAC.

6. Glue the pretzel stick to the left side of the Tootsie Roll. The pretzel should extend off the the back edge of your spacecraft.

7. Attach a marshmallow to the far end of the pretzel. This represents your satellite dish.

8. On the top right side of your spacecraft, glue a Skittle to the edge. This represents CRaTER.

9. Just below CRaTER on the right side of your spacecraft, glue a candy corn. This represents DIVINER.

10. Prop the individual graham cracker on the front, right corner of our spacecraft. Attach the graham cracker in this spot using two pretzels to connect the graham cracker to the spacecraft. This represents Mini-RF.

Student Checklist

❏ LRO is made with care and creativity.
❏ LRO contains two LROC instruments.
❏ LRO contains LEND.
❏ LRO contains LOLA.
❏ LRO contains four LAMP instruments.
❏ LRO contains CRaTER.
❏ LRO contains DIVINER.
❏ LRO contains Mini-RF.
❏ LRO has additional parts.
❏ LRO parts are labeled and function defined.
❏ Student can clearly explain the function of each part of the LRO.

Lunar Prospector Team Rubric

Assign points from 1 to 4, where:

4 = Complete, fully developed, everything accounted for, very accurate.
3 = Mostly complete, most things accounted for and accurate.
2 = Partly complete, much is missing, some inaccuracy.
1 = Missing or omitted information or mostly inaccurate.

_____ LRO is made with care and creativity.
_____ LRO contains two LROC instruments.
_____ LRO contains LEND.
_____ LRO contains LOLA.
_____ LRO contains four LAMP instruments.
_____ LRO Contains CRaTER.
_____ LRO contains DIVINER.
_____ LRO contains MINI-RF.
_____ LRO has additional parts.
_____ LRO parts are labeled and the function of each part defined.
_____ Student can clearly explain the function of each part of the LRO.
_____ (Total/44) × 100 = _____ percentage

Rocket Staging: Balloon Staging

Student Data Sheet

Team Name: ____

Team Members: ____

Traveling into outer space takes enormous amounts of energy. In this activity you will demonstrate rocket staging that was first proposed by Johann Schmidlap in the 16th century.

Procedure

1. Thread the fishing line through the two straws.

2. Stretch the fishing line snugly across a room and secure its ends.

3. Cut the coffee cup in half so that the lip of the cup forms a continuous ring.

4. Inflate the first balloon about three-fourths full of air and squeeze its nozzle tight. Pull the nozzle through the ring. Twist the nozzle and hold it shut with a spring clothespin.

5. Inflate the second balloon. Make sure the front end of the second balloon extends through the ring a short distance. As the second balloon inflates, it will press against the nozzle on the first balloon and take over the clip's job of holding it shut. Clip the nozzle of the second balloon shut.

6. Take the balloons to one end of the fishing line and tape each balloon to a straw with masking tape. The balloons should point parallel to the fishing line.

7. Remove the clip from the first balloon and untwist the nozzle.

8. Remove the nozzle from the second balloon as well, but continue holding it shut with your fingers.

9. Conduct a rocket countdown.

10. Release the balloon that you are holding.

11. Using your design sheet, design and describe your own multistage rocket.

TOP VIEW

SIDE VIEW

DESIGN SHEET

Design a rocket that has at least two stages. In the space below, describe what each stage will do. Do not forget to include a place for payload and crew.

DESCRIPTION

Your Name: ______________________

Rocket Name: ____________________

Soda Bottle Rocket

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

Objective
To construct and launch a simple soda bottle rocket.

Purpose
Working in teams, students will:
- Construct a simple bottle rocket from 2-liter soft drink bottles and other materials.
- Understand how air pressure works with action/reaction.
- Develop skills in teamwork, communication and problem solving.

Materials
Per Class:
- Student sheets
- 2-liter plastic soft drink bottles
- Low-temperature glue guns
- Poster board
- Tape
- Modeling clay
- Scissors
- Safety Glasses
- Decals
- Stickers

Procedure
1. Wrap and glue or tape a tube of poster board around the bottle.
2. Cut out several fins of any shape and glue them to the tube.
3. Form a nose cone and hold it together with tape or glue.
4. Press a wad of modeling clay into the top of the nose cone.
5. Glue or tape nose cone to upper end of bottle.
6. Decorate your rocket.
7. When all rockets are complete, it is time to launch.
8. Have students fill their rockets with their chosen amount of water. Note: Some water may be lost when the rocket is placed on the launch pad. Bring extra water in case of spillage or for multiple launches per team.
9. Head to the launch site!

10. Evaluate the performance of each rocket. Scoring will be as follows (Longest Flight = Highest Flight):
    a. First place = 5 points
    b. Second place = 4 points
    c. Third place = 3 points
    d. Fourth place = 2 points
    e. Fifth place = 1 point

11. Also evaluate each bottle rocket on its quality of construction. Observe how well fins align and attach to the bottle. Also observe how straight the nose cone is at the top of the rocket. Compare the altitude the rockets reach with their design and quality of the construction. Score the quality of construction on a scale from 1 (poor quality) to 5 (top quality):

Quality Elements	**Score**
a. Alignment of fins	______
b. Attachment of fins to bottle	______
c. Straightness of nose cone	______
d. Neatness of construction	______
e. Overall construction	______
f. Total	______

Questions

1. What is the purpose of the nose cone?

____
____
____

2. What is the purpose of fins?

____
____
____

3. Describe the effect that more/less water has on the upward movement and distance of the rocket?

____
____
____

Swinging Tray

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

Overview

Knowing that gravity is responsible for keeping satellites in orbit leads us to this question. Why do astronauts appear to float in space? The answer is simple. The Space Shuttle orbiter falls in a circular path about Earth and so does everything in it.

Procedure

1. Observe the demonstration presented by your teacher.

Questions

1. What do we call the path that the tray moves in?

____
____
____
____

2. If the strings are held at a shorter distance to the tray, shortening the tray's orbit, what happens to the speed of the tray?

____
____
____
____

3. Pulling on the string is acting as a force called what?

____
____
____
____

4. What would happen if the centripetal force in this experiment were removed by cutting the string?

____
____
____
____

Lunar Base Supply Egg Drop

Student Data Sheet

Team Name: ____

Team Members: ____

Context

Any future lunar base will be made as self-sufficient as possible, it will likely need periodic resupply from Earth. This can be achieved more cheaply and efficiently with a passive style landing of a supply payload. The lack of atmosphere on the Moon will prevent the use of devices such as parachutes or aerobrakes to slow the descent of the payload. Even in the reduced gravity of the Moon (about one-sixth that of Earth), the design of the payload package is critical to the successful resupply of the base. The design of the package must ensure that much needed supplies arrive intact.

Challenge

Package a raw egg payload in a package no larger than 20.32 × 20.32 × 20.32 × cms, so that it may be recovered unharmed (the shell and yolk should be intact) when dropped from a building's second story (height of at least 9.144 m). No "drag devices" (e.g., parachutes, aerobrakes or other devices that the instructors feel have been included in the design purely to slow the descent of the payload) may be used.

Technological Design Steps

The design process can be broken down into the following steps:

1. Identify appropriate problems for technological design.
2. Design a solution or product.
3. Implement the proposed design.
4. Evaluate completed technological designs or products.
5. Communicate the process of technological design.

Design Evaluation

1. What was the problem for your team to solve? What was your product designed to do?

2. Describe the job responsibilities of the project engineer, test engineer, facilities engineer and the developmental engineer.

3. Draw a sketch of your design and label all key elements.

4. How did your team decide what your package would look like?

5. Did you change your package after designing? After building? If so, what revisions did your team make?

6. How did your team work together to solve problems?

7. How did you approach someone on your team who had a different idea about the product?

8. Describe how you coped with constraints such as using only the supplied materials, time and other trade offs when designing your package?

____
____
____
____
____

9. Rate how well your team did in planning, organizing materials, working together and using appropriate techniques in building your prduct.

1 2 3 4 5

Poor Exceptional

10. Describe how you used constraints such as using only the supplied materials, time and other trade offs when designing your package?

____
____
____
____
____

11. How successful was your product?

a. Shell intact: complete success	=	5 points
b. Shell intact, yolk broken: partial success	=	3 points
c. Shell broken, yolk intact: partial success	=	3 points
d. Shell broken, yolk broken: mission failure	=	1 point

Notes:

____
____
____
____
____

Rover Race

Student Data Sheet

Team Name: ____

Team Members: ____

Context
Lunar rocks and minerals are very important to the construction and long term viability of a lunar base. Vehicles will be specifically designed to mine, collect and transport useful materials. These vehicles must be tested for their feasibility, versatility and reliability.

Challenge
Design, build and test a lunar rover/miner that can traverse a lunar terrain obstacle course and sort three samples of a designated mineral into a collection area.

Technological Design Steps
The design process can be broken down into the following steps:

1. Identify appropriate problems for technological design.
2. Design a solution or product.
3. Implement the proposed design.
4. Evaluate completed technological designs or products.
5. Communicate the process of technological design.

Design Evaluation
1. What was the problem for your team to solve? What was your product designed to do?

2. Describe the job responsibilities of the project engineer, test engineer, facilities engineer and the developmental engineer.

3. Draw a sketch of your design and label all key elements.

4. How did your team decide what your vehicle would look like?

5. Did you change your vehicle after designing? After building? If so, what revisions did your team make?

6. How did your team work together to solve problems?

7. How did you approach someone on your team who had a different idea about the product?

8. Describe how you used constraints such as using only the supplied materials, time and other trade-offs when designing your package?

____
____
____
____
____
____

9. Rate how well your team did in planning, organizing materials, working together and using appropriate techniques in building your product.

1 2 3 4 5

Poor Exceptional

10. What happened when you tested your team's design?

____
____
____
____
____

11. How successful was your product?

____
____

12. Criteria:
   a. Rover/miner must travel over the surface of the Moon.
   b. Rover/miner must sort three samples of a designated material.
   c. Rover/miner must transfer samples to a specified collection area.
   d. Robot is timed.
   e. Evaluation parameters.
      1. Robot meets all criteria and has fastest time = 5 points
      2. Robot meets all criteria with second fastest time = 4 points
      3. Robot meets all criteria with third fastest time = 3 points
      4. Robot meets at least two criteria = 2 points
      5. Robot meets at least one criterion = 1 point

Notes:

____
____
____
____
____
____

Potato Astronaut

Student Data Sheet

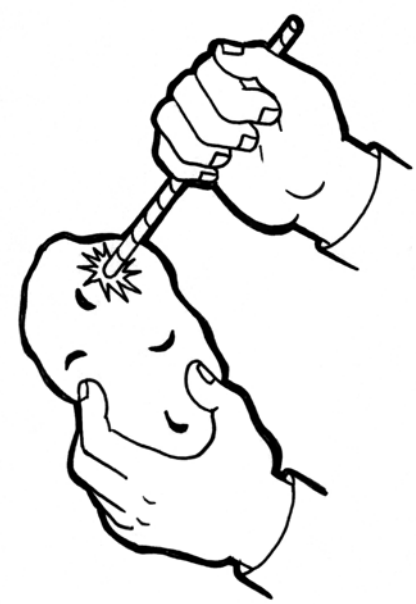
Team Name: ____

Team Members: ____

Overview
Astronauts on spacewalks are likely to encounter fast-moving particles called meteoroids. A meteoroid is usually a fragment of an asteroid consisting of rock and/or metal. It can be very large with a mass of several hundred metric tons, or it can be very small–a micrometeoroid which is a particle smaller than a grain of sand.

Materials
Per Team
• Plastic (milkshake-size) straw
• Potato
• Various materials to layer (e.g., tissue paper, notebook paper, handkerchiefs, rubber bands napkins, aluminum foil, wax paper, plastic wrap, etc

Procedure



1. Hold a raw potato in one hand (see illustration.) While grasping the straw with the other hand, stab the potato with a slow motion. Observe how deeply the straw penetrates the potato.
2. Repeat the experiment, but this time stab the potato with a fast motion. Observe how deeply the straw penetrates the potato. Compare observations with the results of step 1.
3. Think of ways to protect the potato from damage caused by impacts using just the materials available in the classroom. Adding one layer at a time.
4. Test the new method for protecting a potato.
5. Refine your method for protecting the potato. Your layers of materials can be no thicker than 5 mm.
6. Conduct additional impact tests with the straw.

Safety Precautions: Be careful to hold the potato as illustrated so that the straw does not hit your hand. Work gloves will provide additional protection.

Questions
1. Can you name other protective garments or devices

____
____
____
____
____

2. How does the function determine the form?

____

____

____

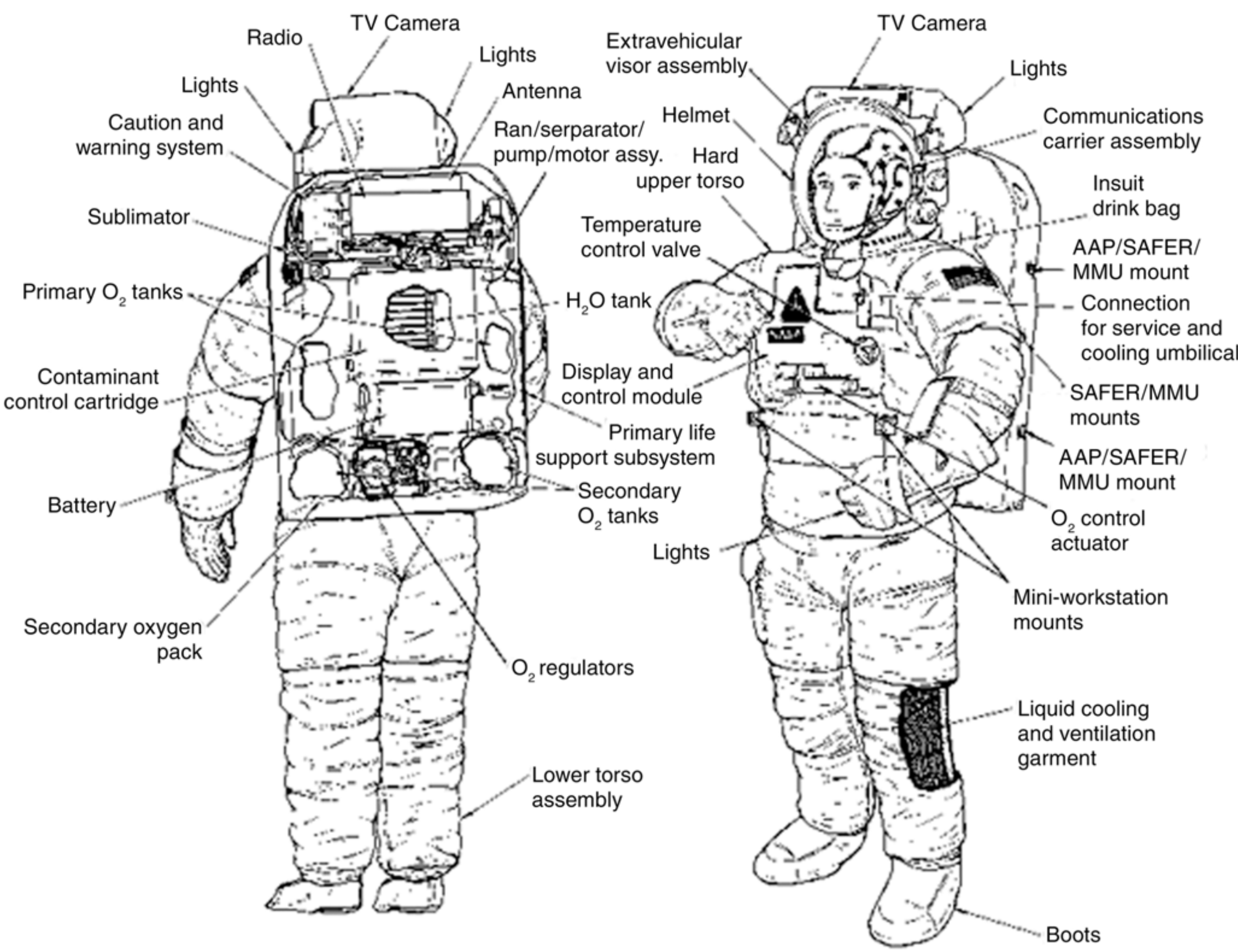
____

____

____

What is happening?

The Shuttle extra-vehicular mobility unit (EMU) has 14 layers to protect astronauts on extra-vehicular activities (EVAs). The inner layers comprise the liquid-cooling-and-ventilation garment. First comes a liner of nylon tricot over which is placed a layer of spandex fabric laced with plastic tubing. Next comes the pressure bladder layer of urethane-coated nylon and a fabric layer of pressure restraining Dacron®. Above the bladder and restraint layer is a liner of neoprene coated nylon ripstop. This is followed by a seven-layer thermal micrometeoroid garment of aluminized Mylar®, laminated with Dacron® scrim. The outer layer of the suit is made of Orth-Fabric, which consists of a blend of Gortex®, Kevlar® and Nomex® materials (see figure on page 75).



Bending Under Pressure

Student Data Sheet

Team Name: ____

Team Members: ____

Overview

Maintaining proper pressure inside a spacesuit is essential to astronaut survival during a spacewalk. A lack of pressure will cause body fluids to turn to gas, resulting in death in a few seconds.

While making spacewalks possible, pressure produces its own problems. An inflated spacesuit can be very difficult to bend. In essence, a spacesuit is a balloon with an astronaut inside. The rubber of the balloon keeps in oxygen that is delivered to the suit from pressurized oxygen tanks in the backpack. However, as pressure inside the balloon builds up, the balloon's walls become stiff, making normal bending motions impossible. Lack of flexibility defeats the purpose of the spacewalk-mobility and the ability to do work in space.

Materials

Per Team

- 2 long balloons
- 3 heavy-duty rubber bands
- 1 Slinky®

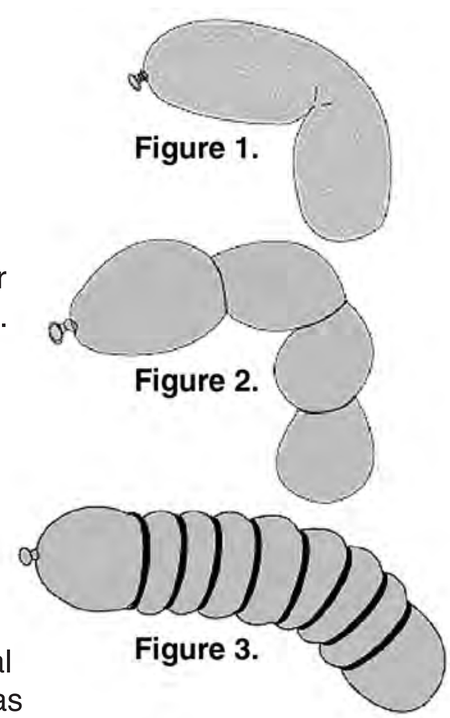
Procedure

Inflate a long balloon and tie it off. The balloon represents the pressure bladder of a spacesuit arm. Try to bend the balloon in the middle (see fig. 1).

Inflate a second long balloon. As you are inflating the balloon, slip heavy-duty rubber bands over the balloon at intervals so that, as inflation continues, the balloon is pinched by the rubber bands. It is easier to accomplish this by preinflating the balloon. It may be necessary to double the rubber band to pinch the balloon enough for the demonstration. (see fig. 2).

Compare the force required for bending this balloon with the force needed for the first balloon.

Use a Slinky as an alternative to the rubber bands. Place the Slinky on a desktop and pick up one end. Slip in the balloon and inflate it. As the balloon inflates, it will be pinched in a spiral pattern by the Slinky. The pattern will achieve the same result as the rubber bands (see fig. 3).



Questions

1. What other items are inflated?

___

___

___

2. How do you think that these other inflatables might compare to the balloon as you would try to bend them?

___

___

___

What is happening?

Spacesuit designers have learned that strategically placed breaking points at appropriate locations outside the pressure bladder (i.e., the balloon-like layer inside a spacesuit) makes the suit become more bendable. The breaking points help form joints that bend more easily than materials without joints. Other techniques for promoting bending include stitching folds that spread apart and contract with bending into the restraint layer and building joints into the restraint layer like ribs on vacuum cleaner hoses.

Spacesuit Designer

Student Data Sheet

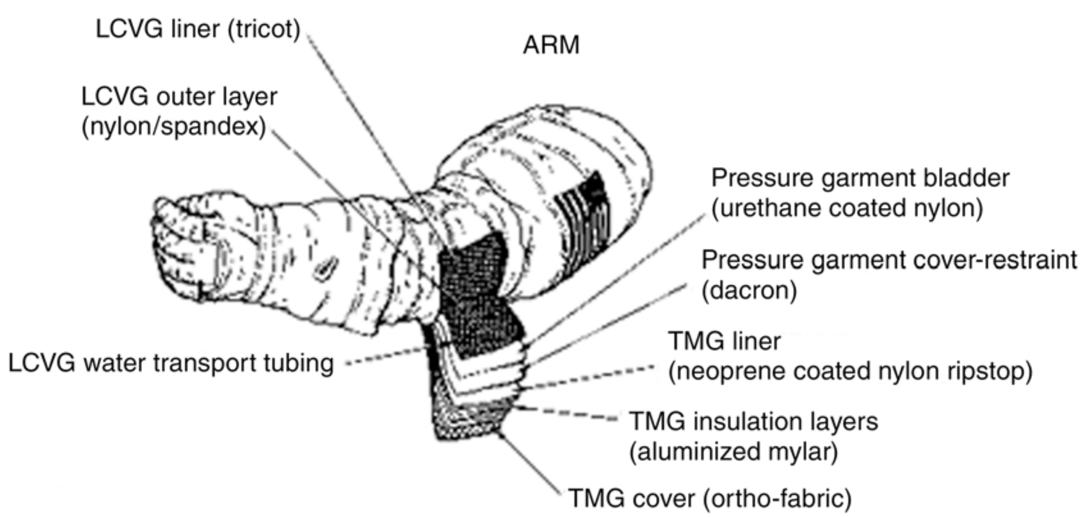
Team Name: ____

Team Members: ____

Context
In spite of many decades of experience in developing and evaluating space suits, they are still fatiguing to wear. The internal pressure of the suit creates resistance to movements of the arms, hands and legs. The exhaustion factor of spacesuits can be reduced somewhat by ensuring that the suit fits properly. The position of the suit's joints must precisely match the position of the astronaut's joints. During the extended exploration of the Moon that will take place from a lunar base, space suit fit will be more important than ever.

To avoid the expensive and time consuming process of creating custom-made suits for astronauts, as NASA did during the Apollo missions, suits with interchangeable parts are used. Differently sized upper and lower torsos are available, but arm and leg lengths are still difficult to match. NASA has solved this problem by creating sizing inserts that are added or removed from the restraint layer in the arms and legs to achieve the right fit. Selecting the right combination of rings provides the best fit possible.

Challenge
Design and build a space suit arm that provides maximum range of motion, excellent fit and maximum comfort, allowing astronauts to explore the surface of the Moon. Excursions on the surface may last up to 8 hours. The garment must be flexible enough to allow the wearer to collect geologic samples and operate a variety of tools and experimental equipment. The design must be rugged enough to permit repeated use and be able to be serviced simply and quickly.



Materials

Per Team

- 10.16-cm diameter PVC cut into segments of the following lengths:
  - 25 mm: four
  - 50 mm: four
  - 75 mm: three
  - 100 mm: two
- Vinyl clothes-dryer hose (25 cm)
- Duct tape
- Measuring tape
- Scissors
- Thick rubber gloves
- Wire cutters
- Spacesuit Designer Student Sheets
- Role cards

Procedure

1. Distribute role cards and Students Sheets.
2. Explain importance of well-fitting spacesuits (see overview).
3. Tell the students to select one member of their team to serve as the astronaut. It should be someone with good range of motion.
4. Their objective is to fit a suit arm that provides maximum range of motion, excellent fit and maximum comfort to that astronaut.
5. Distribute the PVC rings, dryer hose, gloves, measuring tape, duct tape and scissors to each group. Wire cutters may be necessary if teams decide to use less than the 25 cm of dryer hose that is provided.
6. The students should begin by measuring the arm and mapping the range of motion of the arm without the suit.
7. How many instructions you give for the actual construction of the spacesuit arm is up to you. Useful tips are:
   a. Use two of the 50-mm segments with the clothes dryer hose to create the elbow; fitting the hose ends over one end of each of the segments.
   b. Slip the cuff of one of the gloves over a 50-mm pipe segment. The fit may be tight, but try to slide the ring in so that it just reaches the position of the wrist. Trim off the excess of the cuff so that the glove can be affixed to the ring with duct tape.
   c. PVC rings are joined with duct tape.
8. After completing the arm, the group should test it by placing the astronaut's arm into the suit arm. They will then evaluate the arm by repeating the range of motion tests.
9. Final adjustments and changes can be made to improve comfort and range of motion before evaluation by the instructor.
10. Evaluate each group on range of motion, fit, workmanship and overall quality of design.

Questions

1. What other measurements were useful for creating a good fit?

____

____

____

2. How many measurements do you think would be required to design an entire spacesuit?

3. How would the lower gravity condition of the Moon affect the fit of the spacesuit?

Technological Design Steps

The design process can be broken down into the following steps:

1. Identify appropriate problems for technological design.
2. Design a solution or product.
3. Implement the proposed design.
4. Evaluate completed technological designs or products.
5. Communicate the process of technological design.

Design Evaluation

1. What was the problem for your team to solve? What was your product designed to do?

2. Describe the job responsibilities of the project engineer, test engineer, facilities engineer and the developmental engineer.

3. Draw a sketch of your design and label all key elements.

4. How did your team decide what your spacesuit would look like?

5. Did you change your spacesuit after designing? After building? If so, what revisions did your team make?

6. How did your team work together to solve problems?

7. How did you approach someone on your team who had a different idea about the product?

____
____
____
____
____
____

8. Describe how you used constraints such as using only the supplied materials, time and other trade offs when designing your package?

____
____
____
____
____
____

9. Rate how well your team did in planning, organizing materials, working together and using appropriate techniques in building your product.

1	2	3	4	5
Poor				Exceptional

10. What happened when you tested your team's design?

____
____
____
____
____
____

11. How successful was your product, as judged by instructors on range of motion, fit, workmanship and overall quality of design?

    a. Scoring values:
        1. First Place = 5 points
        2. Second Place = 4 points
        3. Third Place = 3 points
        4. Fourth Place = 2 points
        5. Fifth Place = 1 point

    Notes:

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Solar Power: Solar Energy

Student Data Sheet

Team Name: ____

Team Members: ____

Overview

Photovoltaics is the direct conversion of light into electricity at the atomic level. Some materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity. Photovoltaic or solar cells are made of silicon (sand). Solar cells are used to power calculators and watches as well as lights, refrigerators and even cars. Solar electricity is quiet, clean and nonpolluting. Solar cells can be used individually, as a module or in an array (see figure 1.)

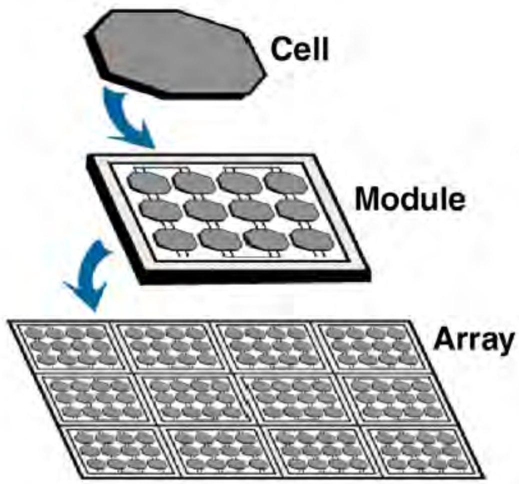

Figure 1. A solar cell, solar module and a solar array.

Materials

Per Team
- 4 0.55-volt solar cells with leads
- Short lengths of 22-gauge wire
- 8 to 10 small alligator clips
- 1 small LED flashlight bulb (red)
- 1 multimeter capable of measuring voltages below 5 volts and current below 1 amp
- 1 reflector light socket (lamp)
- 5 light bulbs (15 watts, 40 watts, 60 watts, 75 watts and 100 watts)
- 1 20-ohm, 0.5-W resistor
- Several pieces of cellophane of various colors
- Screens of different mesh sizes and materials
- Transparent material such as wax paper
- Clear material such as a plate of glass or plastic

Procedure

1. To connect the solar cells in series, connect them as follows (see figure 2):
   a. Connect the negative (black) lead from cell #2 to the positive (red) lead of cell #1.
   b. Connect the negative (black) lead from cell #3 to the positive (red) lead of cell #2.
   c. Connect the negative (black) lead from cell #4 to the positive (red) lead of cell #3.
   d. Connect the positive (red) lead from cell #4 to one end of the 20-ohm resistor.

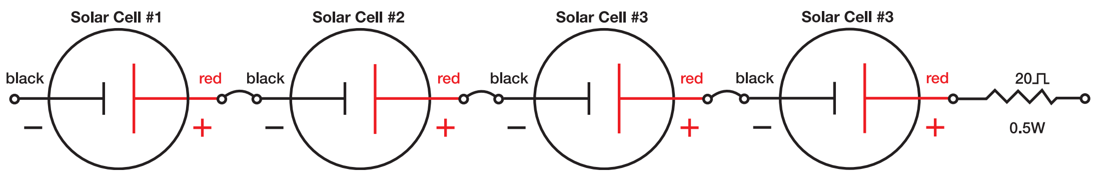

Figure 2. Series assembly of four solar cells and a resistor.

2. To measure voltage across the LED, connect the multimeter, LED and solar cells together using alligator clips as follows (see figure 3):
   a. Connect the negative (black) lead from the LED to the negative (black) lead of the multimeter.
   b. Connect the positive (red) lead from the LED to the positive (red) lead of the multimeter.
   c. Use the 22-gauge wire to extend the leads, if necessary.
   d. Connect the negative (black) lead of cell #1 to the negative (black) leads of the LED/ multimeter combination.
   e. Set the control switch of the multimeter to VDC and a range of at least 5 volts.
   f. Connect the unconnected lead of the 20-ohm resistor to the positive (red) leads of the LED/ multimeter combination.
   g. Place a light bulb in the reflector lamp and shine it on the solar cells. Be sure to keep the reflector at a constant distance from the solar cells.
   h. Observe and record the voltage indicated on the voltmeter.
   i. Repeat the above experiment using different wattage light bulbs. Different wattage light bulbs produce a different number of lumens of light.

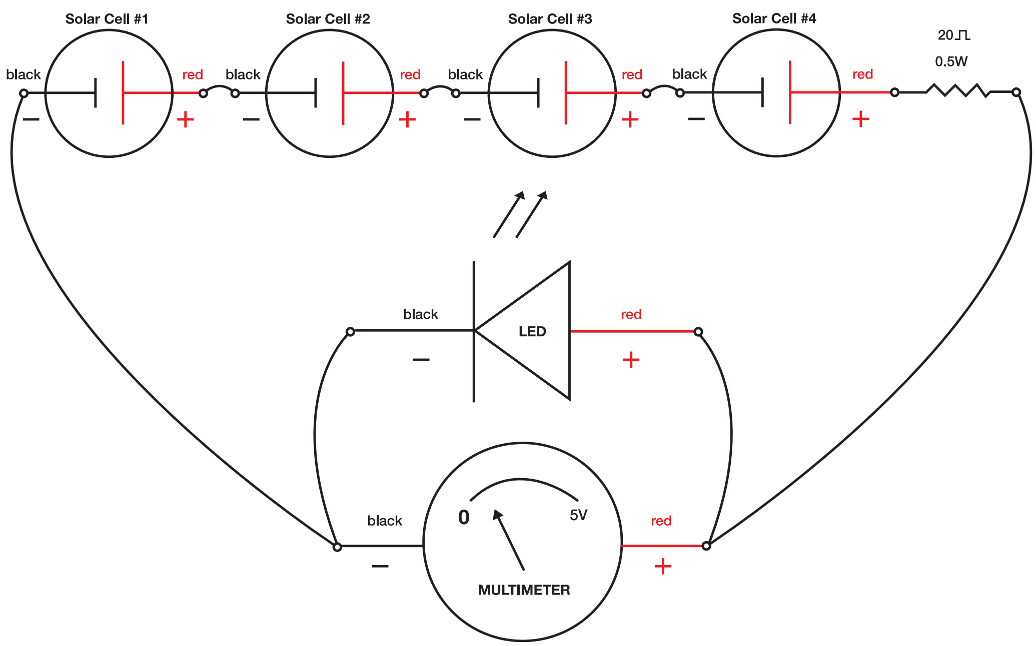

Figure 3. Electrical hookup to measure voltage.

3. To measure current through the LED, connect the multimeter, LED and solar cells together using alligator clips as follows (see figure 4):
   a. Connect the negative (black) lead from the LED to the negative (black) lead of the multimeter.
   b. Connect the positive (red) lead from the LED to the unconnected lead of the 20-ohm resistor.
   c. Use the 22-gauge wire to extend the leads, if necessary.
   d. Set the control switch of the voltmeter to AMPS and a range of at least 1 amp.
   e. Connect the negative (black) lead of cell #1 to the positive (red) lead of the multimeter.
   f. Place a light bulb in the reflector lamp and shine it on the solar cells. Be sure to keep the reflector at a constant distance from the solar cells.
   g. Observe and record the current indicated on the multimeter.
   h. Repeat the above experiments using different wattage bulbs. Different wattage light bulbs produce a different number of lumens of light.

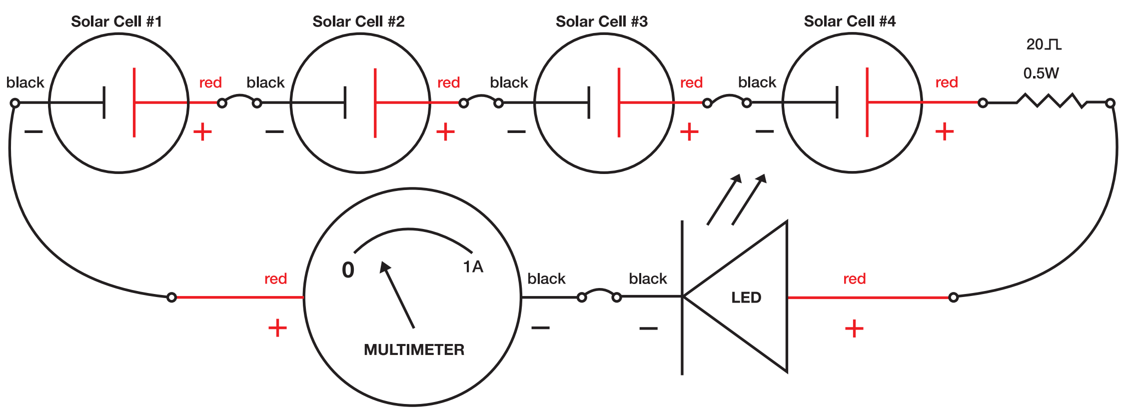

Figure 4. Electrical hookup to measure current.

4. Perform the following variations to the above experiments.
   a. Observe the relationship of lumens to the voltage/current output of the solar cells.
   b. Experiment with angles of the light to the solar cells.
   c. Experiment with the distance of the light to the solar cells.
   d. Place each cover material (i.e., colored cellophane, screening, wax paper, glass or clear plastic) over the solar cells as shown (fig. 5). Observe and record the results.

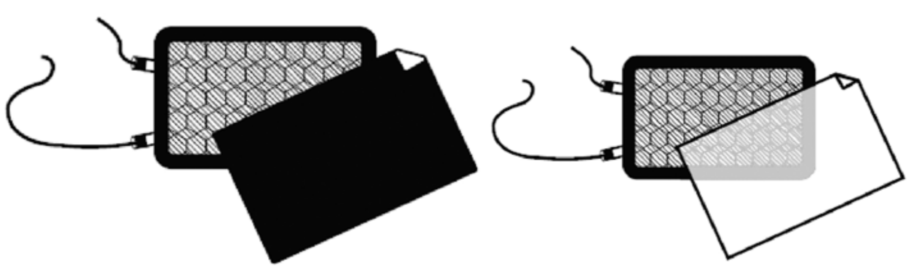

Figure 5. Solar cells being covered by different materials.

Questions

1. What happened when the light source is turned away from the photovoltaic cells?

2. What do you think will happen with the light source at different angles from the photovoltaic cells?

3. What happens when the light source is at different distances from the photovoltaic cells?

4. What happens when different watt bulbs are used to shine on the photovoltaic cells?

5. What do you think will happen when different materials cover the photovoltaic cells?

6. List the materials used and what happened to the voltmeter/LED when each was used.

What is happening?

Series connected sources (i.e., batteries, solar cells, etc.): A method of connection in which the positive terminal of one device is connected to the negative terminal of another. The voltages add and the current is limited to the least of any device in the string.

Parallel connected sources (i.e., batteries, solar cells, etc.): A method of connection in which positive terminals are connected together and negative terminals are connected together. Current output adds and voltage remains the same.

Solar Oven

Student Data Sheet

Team Name: ______________________________

Team Members: ______________________________

Context
One of the biggest challenges in establishing a lunar base is to supply it with adequate power. Although various power sources have been proposed and are under consideration, solar power will definitely play a significant role

Challenge
Construct a solar oven that will cook a hot dog in the shortest time. All teams will be provided with instructions and materials to build a basic solar oven. All teams are encouraged to modify and expand upon the basic design to construct the most efficient oven possible.

Technical Design Steps
The design process can be broken down into the following steps:

1. Identify appropriate problems for technological design.
2. Design a solution or product.
3. Implement the proposed design.
4. Evaluate completed technological designs or products.
5. Communicate the process of technological design.

Materials
Per team:
- 1 3.79-liter plastic milk container
- Scissors and/or razor knives
- Aluminum foil
- Wire coat hanger (untwisted)
- Plastic wrap
- Hot dog
- Cotton balls
- Cotton batting
- Construction paper (assorted colors with plenty of black available)
- Cardboard
- Wire cutters
- Masking tape
- Books or other objects that can be used to prop up the oven at the proper angle
- Student sheets
- Role cards
- Watch or clock with second hand

Note: With the exception of the milk container, aluminum foil, wire coat hanger, plastic wrap and hot dog, specific construction materials can vary as long as all teams have equal access to materials.

Procedure

1. Introduce the challenge. The object is to use the available materials to build the most efficient solar oven that is able to cook a hot dog in the least amount of time.
2. Divide the class into teams.
3. Distribute role cards and explain the responsibilities of each team.
4. Distribute Student Sheets and discuss the steps of the design process.
5. Students should use the Student Sheets to guide the design process.
6. Provide students with directions to build a basic solar oven and encourage them to modify and expand upon the basic plan as they see fit (these directions are included in the Student Sheets).

Basic Solar Oven Instructions

1. Using scissors and leaving the mouth of the container intact, cut away the side of the milk container with the handle.
2. Line the inside of the milk container with aluminum foil. Try to keep the foil as smooth as possible and avoid wrinkles.
3. Untwist the coat hanger and cut a section approximately 30.48 cm in length.
4. Push one end of the wire through the bottom of the milk container using the scissors to cut a hole if necessary.
5. Skewer the hot dog with the wire and pass the wire through the mouth of the container.
6. Cover the open part of the oven with plastic wrap.
7. Remind students that these are only the directions to build a basic solar oven and they are free to alter and expand upon these plans to make the most efficient solar oven possible.
8. Allow teams a predetermined amount of time to construct their ovens (approximately 30 minutes should be sufficient).
9. After construction is complete, have all teams bring their oven to a designated area in the sun. Teams should use books and other objects to prop the ovens at an angle that allows them to receive direct sunlight.
10. Teams may adjust their ovens during cooking.
11. The instructor will determine when the hot dogs are completely cooked. The team whose oven completely cooks the hot dog in the shortest time wins. Depending on the weather, where you live and the time of year, cooking times may range from 10 minutes to 30 minutes. Obviously, this activity works better on hot, sunny days.
12. Points will be awarded as follows:
    a. Hot dog cooked in shortest time = 5 points.
    b. Hot dog cooked in next shortest time = 4 points.
    c. Hot dog cooked in next shortest time = 3 points.
    d. Hot dog cooked in next shortest time = 2 points.
    e. Hot dog cooked in next shortest time = 1 point.
13. Discuss the results as a class.

Questions

1. What role did the aluminum foil play in the solar oven?

2. What modifications from the basic design increased the efficiency of the oven?

3. What modifications did not prove effective?

4. How would you redesign your oven based on the lessons you have learned?

Design Evaluation

1. What was the problem for your team to solve? What was your product designed to do?

2. Describe the job responsibilities of the project engineer, test engineer, facilities engineer and the developmental engineer.

3. Draw a sketch of your design and label all key elements.

4. How did your team decide what your solar oven would look like?

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5. Did you change your solar oven after designing? After building? If so, what revisions did your team make?

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6. How did your team work together to solve problems?

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7. How did you approach someone on your team who had a different idea about the product?

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8. Describe how you coped with constraints such as using only the supplied materials, time and other trade-offs when designing your package?

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9. Rate how well your team did in planning, organizing materials, working together and using appropriate techniques in building your product.

1	2	3	4	5
Poor				Exceptional

10. What happened when you tested your team's design?

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11. How successful was your product?

a. Scoring values:
   1. Hot dog cooked in shortest time = 5 points
   2. Hot dog cooked in next shortest time = 4 point
   3. Hot dog cooked in next shortest time = 3 points
   4. Hot dog cooked in next shortest time = 2 points
   5. Hot dog cooked in next shortest time = 1 point

Notes:

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Microgravity—Come-Back Bottle

Student Data Sheet

Team Name: ____

Team Members: ____

Overview

The ability to store and reuse energy has been very important to the development of technology for civilization. This experiment will really get you rolling as you observe the interplay of kinetic and potential energy.

Materials

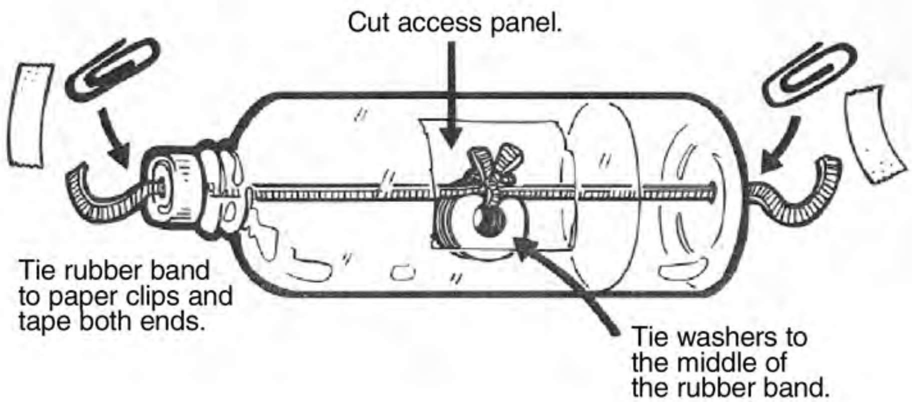
PerTeam:

- Plastic soda bottle, any size
- 5 large washers
- 1 large paper clip
- 2 small paper clips
- Nail or drill
- Scissors or hobby knife
- Duct tape
- Assorted thick rubber bands
- Meter stick

Procedure

1. Punch or drill a hole in the cap of the soda bottle.
2. Punch or drill a hole in the bottom of the soda bottle. Be sure both these holes are large enough to pass your rubber band through them.
3. Cut an access panel into the side of the soda bottle. This panel should be large enough to allow your fingers to work inside the bottle.
4. Cut a heavy rubber band in half, and feed one end of the rubber band through the hole that you made in the cap. It should be fed from the inside of the cap. Tie the free end of the rubber band to a small paper clip, and tape the small paper clip to the top of the cap. You may decide to try different types of rubber bands or try using more than one rubber band to see if this changes the way your come-back bottle works.

5. Drop the free end of the rubber band through the neck of the soda pop bottle, and screw the cap back onto the bottle.
6. Pull the free end of the rubber band through the access panel that you cut. Unbend the large paper clip and form a tiny hook at one end that will fit through the hole in the bottom of the soda bottle. Pass the hook through the hole you made in the bottom of the bottle. Hold the rubber band by the free end, and catch a piece of the rubber band with the tiny hook. Pull the hook out through the hole and attach (tie) the rubber band to the other small paper clip. Tape the paper clip to the bottom of the bottle.



7. Through the access panel cut into the bottle, use a second rubber band to tie the washers to the middle of the rubber band that stretches between the ends of the bottle. You can vary the number of washers that you use to see if that makes a difference on how your come-back bottle works.
8. Test your come-back bottle (experiment/modify):
   a. Roll your bottle gently across the floor, and observe its motion.
   b. Try out different rolling techniques.
   c. Make modifications to your come-back bottle to get it to roll farther.
9. Come-Back Bottle Race:
   a. Roll your bottle along the floor to wind it up. Give it a push.
   b. Ask your partner to place a foot on the floor to mark the place where your bottle stops moving forward.
   c. Measure the distance that your bottle rolls backward.
   d. The bottle that rolls back the farthest is the winner.

Questions

1. What causes the come-back bottle to roll back and forth?

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2. Can the astronauts make a come-back bottle work in space?

3. Will the rubber band wind up in space? Will the bottle roll along the floor?

4. Can you think of some creative ways to make the come-back bottle work in space?

Microgravity Sled

Student Data Sheet

Team Name: ____

Team Members: ____

Context
Prior to an astronaut's mission, one of the most difficult things to prepare for is the lower gravity conditions he or she will face. The best way to study and prepare for the effects of lower gravity conditions is through the use of NASA's Weightless Environment Training Facility (WETF) at the Neutral Buoyancy Lab (NBL) in Houston, TX.

This challenge activity will provide students with a chance to experience what this training is like through the building of the frame for a lunar geologic sample collection sled in a simulated microgravity environment.

Challenge
Work as a team to build your lunar geologic sample collection sled in the shortest amount of time in a simulated microgravity environment.

You will get to practice on dry land before we head to the pool. Use these practice runs to develop a plan that will allow you to finish in the shortest amount of time at the pool.

Materials
Per team:
- PVC parts:
  - 8 58.42-m sections
  - 4 46.99-cm sections
  - 2 22.86-cm sections
  - 2 15.24-cm sections
  - 6 5.08-cm sections (spacers)
  - 1 60.96-cm section with all lengths marked off (used as a measuring stick)
  - 6 90-degree elbow couplings
  - 4 45-degree elbow couplings
  - 8 T-couplings
- 1 mesh dive bag per team to hold PVC and couplings
- Access to a swimming pool (approximately 1.2-m deep)
- Stopwatches
- Laminated copies of the structure diagram (two per team)
- Mask and snorkel or swim goggles (one per student, optional)
- "Reaching for the Stars" Microgravity Training Video, or Internet access to view video/pictures of astronauts training in pool
- Swimsuit (one per person)

Procedure

1. Watch videotape or use Internet to view astronauts using the pool to train for microgravity.
2. Teams will practice building the structure on dry land. Teams can use the diagrams while building. Have teams practice with verbal communication and without. Each practice session can be timed to check for improvement.
3. Depending on the size of the teams, you may want to limit the teams to two team members per team in the water at a time with the other on the side assisting with parts. Make sure the teams switch at least once to allow all team members a chance at assembly in the pool.
4. Discuss the question, "How will building the structure in the simulated microgravity environment—the pool—be different than on dry land?"
5. Allow time for teams to make their final plans and for discussion.

At the Pool:

1. Locate teams a minimum of 1.83 m away from each other along the side of the pool.
2. Teams may organize their parts at poolside as long as they do not lay them out in the shape of the structure.
3. Start the stopwatch.
4. Each team builds their structure on the bottom of the pool. Students must swim down to the bottom carrying the parts and put them together there, returning to the surface when they need more parts or air, whichever comes first.
5. Record times of completion.
6. Remove structures from pool. Build the structure on dry land to ensure that all parts have been removed from the pool. Replace parts in dive bags.

Questions

1. What plan did your team have for construction? Did you need to change your plan in any way?

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2. How was the activity in the water different than on dry land?

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3. What would it be like to build this structure in the microgravity of space? On the Moon?

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Design Evaluation

1. What happened when you tested your building plan on land? Explain.

2. What happened when you tested your building plan in the water?

3. Describe the job responsibilities of each team member in the building plan.

4. How did your team work together to solve problems?

5. How did you approach someone on your team who had a different idea about the product?

6. Describe how you coped with constraints such as using only the supplied materials, time and other trade offs when designing your package?

7. Rate how well your team did in planning, organizing materials, working together and using appropriate techniques in building your product.

1	2	3	4	5
Poor				Exceptional

8. How successful was your plan (shortest time equals most successful)?

   a. Scoring values:
      1. First place = 5 points
      2. Second place = 4 points
      3. Third place = 3 points
      4. Fourth place = 2 points
      5. Fifth place = 1 point

Notes:

In conjunction with:

National Aeronautics and Space Administration
Exploration Systems Mission Directorate
Washington, DC

George C. Marshall Space Flight Center
Academic Affairs Office
Huntsville, AL 35812

Discovery Place, Inc.
Charlotte, NC

National Aeronautics and Space Administration

George C. Marshall Space Flight Center
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