COOL SUITS
Activity topic selected from NASA’s KSNN™ 21st Century Explorer newsbreak “How will your imagination help you become an explorer?”

Educator Section

Introduction
Astronauts depend upon their space suits to hold in air needed for breathing as well as pressure to keep them alive in the near vacuum of space. Space suits also help keep astronauts at a comfortable temperature; neither too hot nor too cold. For this reason, space suits are made from materials and colors that reflect large amounts of energy. By avoiding the absorption of energy, the astronauts are kept at a comfortable temperature for longer periods of time.

Lesson Objective
In this lesson, students understand the relationship between energy reflection/absorption and color.

Problem
Which color, black or white, reflects energy better? Which color absorbs energy better?

Learning Objectives
The students will

- gather data by measuring temperature in 2 different colored envelopes (black and white).
- use data to infer which color reflects energy better and which color absorbs energy better.

Materials
- NASA’s KSNN™ 21st Century Explorer 30-second newsbreak, “How will your imagination help you become an explorer?” (Download the newsbreak at http://ksnn.larc.nasa.gov.)
- 1 thermometer to serve as the control for the entire class (calibrated in units of 1-2 degrees Celsius)
- 2 construction paper envelopes – can be prepared in advance. (See Pre-lesson Instructions.)
  - 1 sheet (8.5” x 11”) of black construction paper
  - 1 sheet (8.5” x 11”) of white construction paper
  - tape, staples or glue to fasten the construction paper envelopes
- 2 thermometers (calibrated in units of 1-2 degrees Celsius)
- cotton balls or tissue paper (approx. 2 handfuls)
- 1 small box (shoe box, lid not needed)
- stopwatch, or timepiece with a second hand (watch or clock)
Per student

- Cool Suits Student Section

Safety
Remind students about the importance of classroom and lab safety. Caution them about the proper use of thermometers.

Pre-lesson Instructions

- Students should work in groups of 2 or 3.
- Locate a sunny area such as a windowsill, or an outside location for the “test site”.
- Each group will need 2 small envelopes: one made out of black construction paper, and the other made out of white construction paper. To save time, make the envelopes prior to class. (See diagram.)

Lesson Development
To prepare for this activity, the following background information is recommended:

- Read the following text taken from the Observation Section of the Cool Suits Student Section.

Observation
Living and working in space is challenging. Outside the spacecraft, astronauts depend upon their space suits to hold in air needed for breathing as well as pressure to keep them alive in the near vacuum of space.

Space suits also help keep astronauts at a comfortable temperature; neither too hot nor too cold. In the harsh environment of space, temperature can vary greatly from the extreme heat of the Sun (solar energy) to the extreme coldness of the darkness of space. For this reason, space suits are made from different colors and materials that reflect large amounts of energy. By avoiding the absorption of energy, the astronauts are kept comfortable for longer periods of time.
In this activity you will test 2 different colors (black and white) to see if color affects energy reflection and absorption.

- If needed, additional research can be done on the following science topics:
  - solar energy
  - heat
  - light
  - reflection
  - absorption

**Instructional Procedure**

Throughout this lesson, emphasize the steps involved in the scientific method. These steps are identified in **bold italic** print throughout the Instructional Procedure Section.

1. Show NASA’s KSNN™ 21st Century Explorer newsbreak “How will your imagination help you become an explorer?” to engage students and increase student knowledge about this topic.
2. Remind students about solar energy, energy in the form of heat and light, and reflection and absorption.
3. Review the problem with the students.
   **Problem:** Which color reflects energy better? Which color absorbs energy better?
4. Have the students read the **Observation** Section in the Cool Suits Student Section and discuss in their groups.
5. As a class, have students identify the colors and materials of the clothes they are wearing. List common characteristics, such as similar colors, similar materials, etc. Discuss whether the colors and materials they chose to wear are affected by the season. How will their choices change when the seasons change?
6. Encourage your students to discuss and make observations about this topic by completing the first two columns in the KWL (KNOW/WANT TO KNOW/LEARNED) chart on the Cool Suits Student Section. Use the KWL chart to help students organize prior knowledge, identify interests, and make real-world connections. As students suggest information for the “KNOW” column, ask them to share “How they have come to know this information.”
7. Ask your students if they have predictions relating to this activity and the “problem question”. Help them refine their predictions into a **hypothesis**. In their Student Section, they should restate the “problem question” as a statement based upon their observations and predictions. Encourage students to share their hypothesis with their group.
8. Students will **test** their hypothesis following this procedure.
   (The following steps are taken from the Student Section. Educator specific comments are in italics.)

   *Place one thermometer without an envelope at the “test site” to act as a control. For this experiment, the “test site” will be a sunny area such as a windowsill, or an outside location.*

   1. Put both envelopes inside a small box to hold them upright while you are working with them.
   2. Stuff cotton balls or tissue paper inside the envelopes and then carefully place a thermometer inside each envelope. The thermometers should be upright in the envelope and the bulb of the thermometer should touch the cotton or tissue, not the envelope. See the diagram below.
3. Let the thermometers rest in the envelope for about 1 minute to record the temperature of the new environment. Then check the temperature in degrees Celsius. Record this data at 0 minutes in the Cool Suits Data Sheet. Also, record the temperature from the control thermometer, which your teacher will have. 

   Let the students know where the “control” thermometer is placed, and announce the temperature for them to record in the 0 minutes column of the Cool Suits Data Sheet.

4. Take each envelope from the box and place them in the “test site” (windowsill or outside) where they will receive direct sunlight. Make sure that both envelopes receive the same amount of sunlight.

5. Predict how many degrees the temperature will change in each envelope over the 5-minute period. Record the predicted temperatures on the Cool Suits Data Sheet. Discuss your predictions with your group.

6. After 5 minutes, collect and record data by reading and recording the temperature of the thermometers on the Cool Suits Data Sheet. Discuss the data with your group.

7. Every 5 minutes for the next 30 minutes, repeat steps 5 and 6.

   Make sure the students predict the next temperature change before collecting the data from the thermometers.

8. After taking all measurements, study the data and draw conclusions by answering the questions following the Cool Suits Data Sheet.

   Using this information, ask students to determine if the data supports or refutes their hypotheses.

Conclusion

- Discuss the answers to the Cool Suits Student Section questions.
- Have the students update the LEARNED column in their KWL chart.
- Ask students to compare their individual data to the class data. What patterns can be found?
- Ask students how their findings relate to the development of new space suits for space exploration?
- Ask students “what they wonder now?” Encourage students to design their own experiments.
Assessment

- Assess student knowledge through questioning.
- Observe and assess student performance throughout the activity using the attached Scientific Investigation Rubric.

Activity Alignment to National Education Standards

**National Science Education Standards (NSES):**

- **Content Standard A: Science as Inquiry**
  - Abilities necessary to do scientific inquiry (K-8)
  - Understandings about scientific inquiry (K-8)
- **Content Standard B: Physical Science Standards**
  - Properties and changes of properties in matter (5-8)
  - Transfer of energy (5-8)
- **Content Standard E: Science and Technology**
  - Abilities of technological design (K-8)
- **Content Standard F: Science in Personal and Social Perspectives**
  - Changes in environments (K-4)

**National Mathematics Education Standards (NCTM):**

- **Data Analysis and Probability Standard:**
  - Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
    - collect data using observations, surveys, and experiments
  - Develop and evaluate inferences and predictions that are based on data
    - propose and justify conclusions and predictions that are based on data and design studies to further investigate the conclusions and predictions

**Health Education Standards (AAHPERD):**

- **Standard 4:** Students will analyze the influence of culture, media technology and other factors on health.
  - Describe ways technology can influence personal health (K-4)

Curriculum Explorations

To extend the concepts in this activity, the following explorations can be conducted:

**Mathematics**

Create a line graph to show the change in temperature of each envelope. Predict what the line graph would look like if you kept the thermometers in the sunlight for another 20 minutes. Predict what the line graph would look like as the Sun sets.

**National Mathematics Education Standards (NCTM) (3-5):**

- **Algebra Standard:**
  - Understand patterns, relations, and functions
    - represent and analyze patterns and functions, using words, tables, and graphs
- **Data Analysis and Probability Standard:**
  - Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
    - collect data using observations, surveys, and experiments
• represent data using tables and graphs such as line plots, bar graphs, and line graphs
• Develop and evaluate inferences and predictions that are based on data
  • propose and justify conclusions and predictions that are based on data and design studies to further investigate the conclusions or predictions

Language Arts
Ask students to explain the experiment. How might students improve this experiment? Where might there have been mistakes made? How might these mistakes have affected the results?

National Council of Teachers of English Standards (NCTE):
• Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Engineering and Design
Try the experiment again with “insulators” other than cotton balls or tissue paper. For example: sand, Styrofoam, or plastic.

Try the experiment again with material other than construction paper. For example: aluminum foil, glass or plastic.

Challenge the students to design and create a “space suit” that will maintain a steady temperature in extreme hot and cold temperatures. Students will be given an empty paper towel tube and asked to design the tube so that the temperature will not vary more than 5 degrees Celsius when it is put in sunlight and then in the freezer.

National Science Education Standards (NSES):
  Content Standard E: Science and Technology
  • Abilities of technological design (K-8)

Sources and Career Links
Thanks to subject matter experts Sharon Garrison and Heather Paul for their contributions to KSNN™ and Noticiencias NASA™ on the development of this education material.

Find out more about Sharon Garrison and her work at the NASA Institute for Advanced Concepts (NIAC) at the Goddard Space Flight Center: http://www.niac.usra.edu.

Heather Paul is a project engineer for the Advanced Extravehicular Activity (AEVA) team at the NASA Johnson Space Center, working on the designs for the next generation space suits that astronauts will wear on the moon and Mars. To find out more about her visit: http://quest.arc.nasa.gov/people/bios/space/paulh.html and http://profiles.jsc.nasa.gov.

This activity was adapted from NASA educational products.
Lesson development by the NASA Johnson Space Center Human Health and Performance Education Outreach team.
### Scientific Investigation Rubric

**Experiment:** COOL SUITS

<table>
<thead>
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<td>The student described at least one recommendation for NASA in the area of space suit design.</td>
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Point Total

**Grading Scale:**
- A = 22 - 24 points
- B = 19 - 21 points
- C = 16 - 18 points
- D = 13 - 15 points
- F = 0 - 12 points

**Point total from above:** ________ / (24 possible)

**Grade for this investigation:** ________________
Educator Section

Introduction
NASA is designing and testing models of a possible future spacecraft that will take us back to the moon and to Mars. This spacecraft is called the Crew Exploration Vehicle (CEV). An expendable rocket will launch the CEV, though many components of the CEV will be reusable.

Lesson Objective
To design and build a model of a Crew Exploration Vehicle (CEV).

Problem
Can I design and build a Crew Exploration Vehicle (CEV) that will be a model for future space exploration?

Learning Objectives
The students will
- design a model CEV for future space exploration.
- develop a conclusion based upon the results of this design.
- compare individual results to class results by looking for patterns.

Materials

For educator (not recommended for student use)
- ice-pick or other sharp instrument to poke holes in the containers for the students
- hot-glue gun to help attach/build the CEV parts

Per group (3 - 4 students per group)
- an assortment of household recyclables such as paper plates, plastic containers, milk jugs or cartons, craft sticks, etc.
- assorted fasteners such as tapes, brads, staples, rubber bands
- graph paper
- scissors
- markers

Grade Level: 3-5
Connections to Curriculum: Science and Technology
Science Process Skills: observing, predicting, inferring, comparing, communicating (Association for the Advancement of Science)

Teacher Preparation Time: 30 minutes
Lesson Duration: Two 45-minute periods
Prerequisite: none

National Education Standards addressed in this activity include Science (NSES) and Technology (ITEA). For an alignment to standards in this activity, see page 4.

Materials Required
- household recyclables
- fasteners
- graph paper
- scissors
- markers

Educator use only:
- ice-pick or sharp instrument
- hot-glue gun

NASA’s KSNN™ 21st Century Explorer 30-second newsbreak – “What will replace the space shuttle?”
Per student

- Designing a Crew Exploration Vehicle Student Section

Safety
Remind students about the importance of classroom and lab safety. Be sure recyclables are clean and dry with no sharp edges. Only the teacher should use the hot glue gun or sharp instruments.

Pre-lesson Instructions

- Students should work in groups of 3 – 4 students.

Lesson Development
To prepare for this activity, the following background information is recommended:

- Read the following text taken from the Observation Section of the Designing a Crew Exploration Vehicle Student Section.

Observation
The space shuttle is the world’s first reusable spacecraft and the first spacecraft in history that can carry large satellites both to and from orbit. The space shuttle is designed for low-Earth orbit. It cannot go to the moon or to Mars. Since we hope to send people to these places soon, we need to design a new space vehicle.

NASA scientists and engineers are working on a space vehicle that can take astronauts to the moon, Mars, and beyond. This spacecraft is called the Crew Exploration Vehicle (CEV). The CEV is a vehicle to transport human crews beyond low-Earth orbit and back again. The CEV must be designed to serve multiple functions and operate in a variety of environments.

Development of the CEV will take place in stages and will require many support systems. Support systems will include launch vehicles, in-space transportation, navigation and communication, life support, extravehicular activity (the ability to leave the spacecraft), and mission operations support.

Using recyclable materials, you will design and build a CEV model.

- If needed, additional research can be done on the following science topics:
  - rocket design such as fuel tanks, rocket boosters, landing systems, etc.

Instructional Procedure
Throughout this lesson, emphasize the steps involved in the scientific method. These steps are identified in bold italic print throughout the Instructional Procedure Section.

1. Show NASA’s KSNN™ 21st Century Explorer newsbreak “What will replace the space shuttle?” to engage students and increase student knowledge about this topic.
2. Review the process of design with students. They will sketch, build, test, rebuild, and test again.
3. Review the problem with the students.
   Problem: Can I design and build a Crew Exploration Vehicle (CEV) that will be a model for future space exploration?
4. Have the students read the Observation Section in the Designing a Crew Exploration Vehicle Student Section and discuss in their groups.
5. Encourage your students to discuss and make **observations** about this topic by completing the first two columns in the KWL (KNOW/WANT TO KNOW/LEARNED) chart on the Designing a Crew Exploration Vehicle Student Section. Use the KWL chart to help students organize prior knowledge, identify interests, and make real-world connections. As students suggest information for the “KNOW” column, ask them to share “How they have come to know this information.”

6. Ask your students if they have predictions relating to this activity and the “problem question”. Help them refine their predictions into a **hypothesis**. In their Student Section, they should restate the “problem question” as a statement based upon their observations and predictions. Encourage students to share their hypothesis with their group.

7. Students will **test** their hypothesis following this procedure.
   (The following steps are taken from the Student Section. Educator specific comments are in italics.)

   1. Design your CEV on graph paper. Be sure you include these items:
      - a place for the crew
      - fuel tank
      - rocket boosters
      - storage space for life support (air, water, food and waste)
      - storage place for cargo
      - power source (fuel cells)
      - landing system
      - other items if you can explain why
   
      Make sure your drawing is complete:
      - label all parts
      - create a materials list
      - name the spacecraft
      - list all group members names
   
   2. Explain your drawing to your teacher and classmates. You may make changes based upon their suggestions.
      
      Allow time for students to improve designs based upon suggestions.

   -- **SUGGESTED PLACE TO STOP ACTIVITY. RESUME AT NEXT CLASS PERIOD.** --

   3. Gather building materials. You may want to use paper towel rolls, yogurt cups, empty 2-liter bottles, jar lids, wire, empty cereal boxes, etc.

      **Students may bring in recyclable materials they choose from home.**

      **NOTE: Educator may want to have a sharp instrument (ice-pick) to poke holes in the containers for the students. A hot-glue gun may also be helpful to attach/build the CEV parts.**

   4. **Collect data** by making notes on your design paper as you build. Indicate changes in your plans.

      **Encourage students to add notes during the design process. Ask them to compare the final product to their first drawing. How has the design changed?**

   5. When your CEV is complete, write a short statement to convince NASA that your CEV is worthy of future space exploration.
6. Make improvements to your model and **draw conclusions** by answering the Study Data questions. Does your design support or refute your hypothesis?

*Have the students answer the Study Data questions on the Designing a Crew Exploration Vehicle Student Section.*

**Conclusion**
- Discuss the answers to the Designing a Crew Exploration Vehicle Student Section questions.
- Have the students update the LEARNED column in their KWL chart.
- Ask students to compare their designs. What patterns can be found?
- Ask students “what they wonder now?” Encourage students to design their own experiments.

**Assessment**
- Assess student knowledge through questioning.
- Observe and assess student performance throughout the activity using the attached Scientific Investigation Rubric.

**Activity Alignment to National Education Standards**

**National Science Education Standards (NSES):**
Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry (K-8)
- Understandings about scientific inquiry (K-8)

Content Standard E: Science and Technology
- Abilities of technological design (K-8)

**International Technology Education Association (ITEA):**
Design
- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World
- Standard 11: Students will develop the abilities to apply the design process.

**Curriculum Explorations**
To extend the concepts in this activity, the following explorations can be conducted:

**Language Arts**
Ask students to explain their design process. How would students change their designs if they could begin again?
National Council of Teachers of English Standards (NCTE):
• Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Engineering and Design
If you could have used other materials, how would you have designed your CEV?
Launch and entry stages are harsh on astronauts due to forces more than 3 times the Earth’s gravity. How could you design a vehicle to help astronauts withstand these forces?

National Science Education Standards (NSES):
Content Standard E: Science and Technology
• Abilities of technological design (K-8)

International Technology Education Association (ITEA):
Design
• Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Sources and Career Links
Thanks to subject matter experts Dr. Chirold Epp, Roger Crouch and Marc Timm for their contributions to KSNN™ and Noticiencias NASA™ on the development of this education material.

Dr. Chirold Epp is a physicist at the NASA Johnson Space Center and is working with the program to return humans to the moon. He is currently leading the development of technologies required to land humans safely and accurately on the lunar surface. To find out more about NASA's return to the moon see: http://www.nasa.gov/exploration.

Roger Crouch is a NASA astronaut, and you can find out more about him at http://www.jsc.nasa.gov/Bios/PS/crouch.html.

Marc Timm works in the Constellation Systems Division at NASA HQ Exploration Systems Mission Directorate (ESMD). This division is responsible for developing the Crew Exploration Vehicle (CEV) and related exploration architecture elements. Find out more at http://microgravity.grc.nasa.gov/constellations.

Lesson development by the NASA Johnson Space Center Human Health and Performance Education Outreach team.
Scientific Investigation Rubric

Experiment: DESIGNING A CREW EXPLORATION VEHICLE

Student Name ___________________________  Date ____________________

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<td><strong>Point Total</strong></td>
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- C = 16 - 18 points
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Point total from above: _________ / (24 possible)

Grade for this investigation ______________________
Lesson Objective
To design and build a model of a Crew Exploration Vehicle (CEV).
During this lesson, you will
• design a model CEV for future space exploration.
• develop a conclusion based upon the results of this design.
• compare your results to class results looking for patterns.

Problem
Can I design and build a Crew Exploration Vehicle (CEV) that will be a model for future space exploration?

Observation
The space shuttle is the world’s first reusable spacecraft and the first spacecraft in history that can carry large satellites both to and from orbit. The space shuttle is designed for low-Earth orbit. It cannot go to the moon or to Mars. Since we hope to send people to these places soon, we need to design a new space vehicle.

NASA scientists and engineers are working on a space vehicle that can take astronauts to the moon, Mars, and beyond. This spacecraft is called the Crew Exploration Vehicle (CEV). The CEV is a vehicle to transport human crews beyond low-Earth orbit and back again. The CEV must be designed to serve multiple functions and operate in a variety of environments.

Development of the CEV will take place in stages and will require many support systems. Support systems will include launch vehicles, in-space transportation, navigation and communication, life support, extravehicular activity (the ability to leave the spacecraft), and mission operations support.

Using recyclable materials, you will design and build a CEV model.

Use the first column of this KWL chart to organize your observations about spacecraft design. Brainstorm with your group what you want to know about spacecraft design, then list in the second column of this KWL chart.

<table>
<thead>
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<th>KNOW</th>
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Hypothesis
Based on your observations, answer the “problem question” with your best guess. (Can I design and build a Crew Exploration Vehicle (CEV) that will be a model for future space exploration?) Your hypothesis should be written as a statement.

My hypothesis: _____________________________________________________________________

Materials
Per group
- an assortment of household recyclables such as paper plates, plastic containers, milk jugs or cartons, craft sticks, etc.
- assorted fasteners such as tapes, brads, staples, rubber bands
- graph paper
- scissors
- markers

Safety
Review your classroom and lab safety rules.

Test Procedure
1. Design your CEV on graph paper. Be sure you include these items:
   - a place for the crew
   - fuel tank
   - rocket boosters
   - storage space for life support (air, water, food and waste)
   - storage place for cargo
   - power source (fuel cells)
   - landing system
   - other items if you can explain why

   Make sure your drawing is complete:
   - label all parts
   - create a materials list
   - name the spacecraft
   - list all group members names

2. Explain your drawing to your teacher and classmates. You may make changes based upon their suggestions.

3. Gather building materials. You may want to use paper towel rolls, yogurt cups, empty 2-liter bottles, jar lids, wire, empty cereal boxes, etc.

4. Collect data by making notes on your design paper as you build. Indicate changes in your plans.

5. When your CEV is complete, write a short statement to convince NASA that your CEV is worthy of future space exploration.

6. Make improvements to your model and draw conclusions by answering the Study Data questions. Does your design support or refute your hypothesis?
Study Data

1. Did your CEV design change as you built your model? How?

2. Why was your drawing helpful? How would your drawings and notes help other CEV builders?

3. Does this data support your hypothesis? Why or why not?

4. Compare all of the CEV models in your class to look for similarities and differences.

5. Based on what you did in this CEV design activity, what would your recommendations be to NASA on designing a new CEV?

Conclusion

- Update the LEARNED column in your KWL chart.
- Restate your hypothesis and explain what happened during testing.
FOOD FOR SPACEFLIGHT

Activity topic selected from NASA’s KSNN™ 21st Century Explorer newsbreak “Why do astronauts eat tortillas instead of bread?”

Educator Section

Introduction
Food is a basic need. What kinds of foods make good space food? Of course taste is important, but foods are also chosen for their nutritional value. In addition to having enough to eat, explorers also need ways to package and store food. Growing food might also be an option during space travel. Food is not only a basic need but also a comforting reminder of home. Scientists continue to increase space food choices and to look for the best foods for a long-duration flight. Many of the foods currently eaten by astronauts while in space are very similar to what you eat on Earth.

Lesson Objective
This lesson will help you select and compare foods for spaceflight suitability, and package them for spaceflight.

Problem
What foods are best suited for spaceflight and what makes foods suitable for spaceflight?

Learning Objectives
The students will
• select foods to test for spaceflight suitability.
• subject foods to spaceflight suitability testing based upon criteria.
• gather data by sorting foods based upon the results of the suitability for spaceflight testing.
• develop packaging for the suitable foods for spaceflight.
• develop a conclusion based upon the results of this activity.

Materials

Per group
• assorted packaging materials such as
  o zipper seal bags of all sizes

Grade Level: 3-5
Connections to Curriculum: Science and Health
Science Process Skills: observing, predicting, communicating, inferring, classifying, measuring (Association for the Advancement of Science)
Teacher Preparation Time: 30 minutes
Lesson Duration: 60 minutes, requires pre-lesson homework
Prerequisite: basic nutritional requirements from the food guide pyramid (www.mypyramid.gov)

National Education Standards addressed in this activity include Science (NSES), Health (NHES) and Technology (ITEA). For an alignment to standards in this activity, see page 5.

Materials Required
safety glasses
a variety of foods for testing
assorted packaging materials such as:
- zipper seal bags
- paper bags
- aluminum foil
- plastic wrap
- recyclable storage containers
- plastic shopping bags
- tape
mailing labels or masking tape
markers

- paper bags
- aluminum foil
- plastic wrap
- recyclable storage containers
- plastic shopping bags
- tape
- mailing labels or masking tape
- markers

Per student
- a portion size of a variety of foods for testing (See Pre-lesson Instructions.)
- 1 pair of safety glasses
- Food for Spaceflight Student Section

Safety
Remind students about the importance of classroom and lab safety. Students should wear eye protection during this activity. Review the rules for smelling (wafting) in the science lab. Tasting is not allowed in the science lab. This activity requires proper clean up.

Pre-lesson Instructions
- Students should work in groups of 3 or 4.

The day before the lesson...
- Preface the lesson for tomorrow by talking with your students about foods suitable for spaceflight.
  - What are some foods that you would like to take on a field trip? Take into account nutritional value, crumbs produced, preparation, storage, and spoilage (would you take milk?).
  - What do you think would make a good space food package? This may require some research on your part, including reading the web text.
These and other questions should get your class on the path to critical thinking about food choices to be taken and eaten in space.

- Set the stage for developing and conducting tests on the foods the students decide to bring to class. Discuss what foods would be suitable for spaceflight based on the following questions.
  - How do astronauts eat in space?
  - Is eating in space the same as eating on Earth?
  - Do astronauts eat the same foods we do?
  - How do the astronauts make sandwiches?
  - How do the astronauts drink?
  - What if astronauts want ketchup on their meat?
  - Can you eat chips in space?
  - How do you dip chips in picante` sauce in space?
  - What do food packages on Earth look like? If I were to take them into space, how would I store them?

- Post some criteria in the classroom about food suitability for spaceflight. These might include:
  - easy to package
Lesson Development
To prepare for this activity, the following background information is recommended:

- Read the following text taken from the Observation Section of the Food for Spaceflight Student Section.

**Observation**
As astronauts travel into space, they need energy and proper nutrition to keep them going. Astronauts have to take their food with them when they go into space. Preparation varies with the food type. Some foods can be eaten in their natural form, such as fruit. Other foods require adding water to rehydrate them, such as macaroni and cheese or spaghetti. There are no refrigerators in space, so space food must be specially prepared and preserved to avoid spoilage, especially on longer missions.

One of the favorite foods of the astronauts is the tortilla. Tortillas are popular in space for several reasons. First, they are nutritious. Tortillas contain large amounts of carbohydrates that the body needs to function. Second, tortillas are easily stored since they lay flat and they don’t take up too much room. Third, tortillas are one of the perfect space foods because they do not produce crumbs.

Crumbly or loose foods can float and contaminate the inside of the International Space Station or space shuttle and become an annoyance or even a hazard to crews and equipment. Tortillas are easier to handle in reduced gravity and they also stay fresh longer than sliced bread. Making a wrap type sandwich with a tortilla requires less handling than when using two slices of bread.

Unlike tortillas found in restaurants, NASA’s are mold resistant. The specially formulated tortillas are produced with less water than normal and are packaged in plastic bags filled with nitrogen. The tortillas taken on the ISS have a shelf life of about eighteen months.

In this activity you will select, compare, test and package foods for spaceflight suitability.

- If needed, additional research can be done on the following science topics:
  - food packaging
  - bacteria found on food
  - rehydration
  - thermostabilization
  - food guide pyramid
  - dehydration
  - history of space food
  - freeze drying
Instructional Procedure

Throughout this lesson, emphasize the steps involved in the scientific method. These steps are identified in **bold italic** print throughout the Instructional Procedure Section.

1. Show NASA’s KSNN™ 21st Century Explorer newsbreak “Why do astronauts eat tortillas instead of bread?” to engage students and increase student knowledge about this topic.
2. Remind students about nutritional guidelines and food packaging for spaceflight.
3. Review the problem with the students. **Problem:** What foods are best suited for spaceflight and what makes foods suitable for spaceflight?
4. Have the students read the **Observation** Section in the Food for Spaceflight Student Section and discuss in their groups.
5. Encourage your students to discuss and make **observations** about this topic by completing the first two columns in the KWL (KNOW/WANT TO KNOW/LEARNED) chart on the Food for Spaceflight Student Section. Use the KWL chart to help students organize prior knowledge, identify interests, and make real-world connections. As students suggest information for the “KNOW” column, ask them to share “How they have come to know this information.”
6. Ask your students if they have predictions relating to this activity and the “problem question”. Help them refine their predictions into a **hypothesis**. In their Student Section, they should restate the “problem question” as a statement based upon their observations and predictions. Encourage students to share their hypothesis with their group.
7. Students will **test** their hypothesis following this procedure. (The following steps are taken from the Student Section. Educator specific comments are in italics.)

   **Go over the rules of the science lab regarding smelling (wafting) and tasting.** Tell your students that just as in the food lab at Johnson Space Center, you may not taste in the science lab. Taste testing at JSC is done in a separate area from the lab and you should do the same.

   1. Brainstorm with your teacher and class about the kinds of foods the astronauts take into space. Discuss why foods must be freeze-dried, thermostabilized, or dehydrated.
   2. Place the portioned foods that your group brought from home in one location for discussion. Observe these foods with your group. Discuss with your group why you brought the foods you did.
   3. As a group, set up a list of properties that would make your food suitable for spaceflight. You will look for these properties during testing. Record these properties on the Food for Spaceflight Data Sheet.
   
   **After formulation of properties, call on groups to share them, and modify them if needed with suggestions from class discussion. Refer to the posted criteria about food suitability for spaceflight.**

   4. What types of tests would qualify the foods for spaceflight? As a group, create tests for the foods you brought from home. These tests will discover if the food shows properties that would make them suitable for spaceflight.

   **Give the groups time to discuss these ideas. Tests might include:**
   - handling the food to test for crumbs
   - wafting the food to test for desirable smells
   - simulated bite test to produce crumbs
   - reviewing the food label to test for proper nutrition and portion size

   5. Record your tests on the Food for Spaceflight data sheet in the student section.
6. Put on your safety glasses. Remember smelling rules in the science lab and do not taste.

   *Stress the importance of keeping eye protection on during this portion of the lesson. Go over the rules of the science lab regarding smelling (wafting) and tasting.*

7. **Test** each food using the suitability tests you formulated.

   *Have students test food items and decide which would be acceptable for spaceflight. For testing, stay within the capabilities of your classroom. Narrow the choices as time allows.*

8. **Collect and record data** on the Food for Spaceflight Data Sheet.

9. Based on your test and the posted criteria, decide if each food is suitable for spaceflight and check “yes” or “no” on the Food for Spaceflight Data Sheet.

   *After testing, compare the results of your test to the posted criteria on what makes food suitable for spaceflight.*

10. Gather all food items that are suitable for spaceflight together. Set all other food items aside.

11. Discuss the packaging materials you have to use and determine which packaging material would be best for each food.

12. Package the foods with the food packaging material. Label each food item with mailing labels or tape and a marker.

13. Record the materials used for packaging each food on the Food for Spaceflight Data Sheet.

14. After conducting all tests, packaging and labeling, **study the data and draw conclusions** by answering the questions following the Food for Spaceflight Data Sheet.

   *Using this information, ask students to determine if the data supports or refutes their hypotheses.*

### Conclusion
- Discuss the answers to the Food for Spaceflight Student Section questions.
- Have the students update the LEARNED column in their KWL chart.
- Ask students to compare their individual data to the class data. What patterns can be found?
- Ask students “what they wonder now?”

### Assessment
- Assess student knowledge through questioning.
- Observe and assess student performance throughout the activity using the attached Scientific Investigation Rubric.

### Activity Alignment to National Education Standards

**National Science Education Standards (NSES):**

- **Content Standard A: Science as Inquiry**
  - Abilities necessary to do scientific inquiry (K-8)
  - Understandings about scientific inquiry (K-8)

- **Content Standard B: Physical Science Standards**
  - Properties and changes of properties in matter (5-8)
Content Standard E: Science and Technology
- Abilities of technological design (K-8)
- Understanding about science and technology (K-8)

National Health Education Standards (NHES):
Health Education Standard 3: Students will demonstrate the ability to practice health-enhancing behaviors and reduce health risks.
- identify responsible health behaviors
- Identify personal health needs

International Technology Education Association (ITEA):
Standard 3: Relationships among technologies and the connections between technology and other fields.
- Various relationships exist between technology and other fields of study (3-5)

Curriculum Explorations
To extend the concepts in this activity, the following explorations can be conducted:

Mathematics
Introduce students to sorting by using a Venn diagram to sort foods that are acceptable and not acceptable for spaceflight.

National Mathematics Education Standards (NCTM) (3-5):
Data Analysis and Probability Standard:
- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
  - collect data using observations, surveys, and experiments
  - represent data using tables and graphs such as line plots, bar graphs, and line graphs

Language Arts
Ask students to explain the experiments they designed. How might students improve this experiment? Where might there have been mistakes made? How might these mistakes have affected the results?

National Council of Teachers of English Standards (NCTE):
- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

Sources and Career Links
Thanks to subject matter experts Dr. Scott Smith, Vickie Kloeris, Dr. Michele Perchonok, and Dr. Mark Ott for their contributions to KSNN™ and Noticiencias NASA™ on the development of this education material.

Dr. Scott Smith is the lead for Johnson Space Center’s Nutritional Biochemistry Laboratory. Find out more about Dr. Smith: http://spaceflight.nasa.gov/shuttle/support/people/ssmith.html.

Vickie Kloeris oversees nutrition requirements for astronauts and ensures that plenty of consumables are available for International Space Station missions as the ISS Food System Manager at Johnson Space Center. To find out more about her visit: http://www.nasa.gov/pdf/64770main_ffs_bio_kloeris.pdf.
Dr. Michele Perchonok is the Shuttle Food System Manager and the Advanced Food System Lead at Johnson Space Center. Read her biography, and other space food lab biographies, at: http://www.nasa.gov/audience/formedia/presskits/spacefood/biographies.html.

Dr. Mark Ott works with the microbiology lab at Johnson Space Center. You can find out about Dr. Ott’s work at http://sf.jsc.nasa.gov/EFO/microbiology.htm.

Original lesson development by the NASA Johnson Space Center Human Health and Performance Education Outreach team.
Scientific Investigation Rubric
Experiment: FOOD FOR SPACEFLIGHT

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student developed a clear and complete hypothesis.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student followed all lab safety rules and directions.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student followed the scientific method.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student recorded all data on the data sheet and drew a conclusion based on the data.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student asked engaging questions related to the study.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student conducted all food tests they designed according to the spaceflight criteria.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Point Total

Point total from above: _________ / (24 possible)

Grade for this investigation ______________________

Grading Scale:
A = 22 - 24 points
B = 19 - 21 points
C = 16 - 18 points
D = 13 - 15 points
F = 0 - 12 points
Lesson Objective
This lesson will help you select and compare foods for spaceflight suitability, and package them for spaceflight.

During this lesson, you will
- select foods to test for spaceflight suitability.
- subject foods to spaceflight suitability testing based upon criteria.
- gather data by sorting foods based upon the results of the suitability for spaceflight testing.
- develop packaging for the suitable foods for spaceflight.
- develop a conclusion based upon the results of this activity.

Problem
What foods are best suited for spaceflight and what makes foods suitable for spaceflight?

Observation
As astronauts travel into space, they need energy and proper nutrition to keep them going. Astronauts have to take their food with them when they go into space. Preparation varies with the food type. Some foods can be eaten in their natural form, such as fruit. Other foods require adding water to rehydrate them, such as macaroni and cheese or spaghetti. There are no refrigerators in space, so space food must be specially prepared and preserved to avoid spoilage, especially on longer missions.

One of the favorite foods of the astronauts is the tortilla. Tortillas are popular in space for several reasons. First, they are nutritious. Tortillas contain large amounts of carbohydrates that the body needs to function. Second, tortillas are easily stored since they lay flat and they don’t take up too much room. Third, tortillas are one of the perfect space foods because they do not produce crumbs.

Crumbly or loose foods can float and contaminate the inside of the International Space Station or space shuttle and become an annoyance or even a hazard to crews and equipment. Tortillas are easier to handle in reduced gravity and they also stay fresh longer than sliced bread. Making a wrap type sandwich with a tortilla requires less handling than when using two slices of bread.

Unlike tortillas found in restaurants, NASA’s are mold resistant. The specially formulated tortillas are produced with less water than normal and are packaged in plastic bags filled with nitrogen. The tortillas taken on the ISS have a shelf life of about eighteen months.

In this activity you will select, compare, test and package foods for spaceflight suitability.

Use the first column of this KWL chart to organize your observations about foods for spaceflight. Brainstorm with your group what you want to know about foods for spaceflight, then list in the second column of this KWL chart.
<table>
<thead>
<tr>
<th>KNOW</th>
<th>WANT TO KNOW</th>
<th>LEARNED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Hypothesis**

Based on your observations, answer the “problem question” with your best guess. (What foods are best suited for spaceflight and what makes foods suitable for spaceflight?) Your hypothesis should be written as a statement.

My hypothesis: ________________________________________________________

**Materials**

Per student
- a portion size of a variety of foods for testing (brought from home)
- 1 pair of safety glasses

Per group
- assorted packaging materials such as
  - zipper seal bags of all sizes
  - paper bags
  - aluminum foil
  - plastic wrap
  - recyclable storage bags
  - tape
- mailing labels or masking tape
- markers

**Safety**

Review your classroom and lab safety rules. Put on safety glasses when instructed. Use wafting when observing odor. Tasting is not appropriate in the science lab.

**Test Procedure**

1. Brainstorm with your teacher and class about the kinds of foods the astronauts take into space. Discuss why foods must be freeze-dried, thermostabilized, or dehydrated.
2. Place the portioned foods that your group brought from home in one location for discussion. Observe these foods with your group. Discuss with your group why you brought the foods you did.
3. As a group, set up a list of properties that would make your food suitable for spaceflight. You will look for these properties during testing. Record these properties on the Food for Spaceflight Data Sheet.

4. What types of tests would qualify the foods for spaceflight? As a group, create tests for the foods you brought from home. These tests will discover if the food shows properties that would make them suitable for spaceflight.

5. Record your tests on the Food for Spaceflight data sheet in the student section.

6. Put on your safety glasses. Remember smelling rules in the science lab and do not taste.

7. Test each food using the suitability tests you formulated.

8. Collect and record data on the Food for Spaceflight Data Sheet.

9. Based on your test and the posted criteria, decide if each food is suitable for spaceflight and check “yes” or “no” on the Food for Spaceflight Data Sheet.

10. Gather all food items that are suitable for spaceflight together. Set all other food items aside.

11. Discuss the packaging materials you have to use and determine which packaging material would be best for each food.

12. Package the foods with the food packaging material. Label each food item with mailing labels or tape and a marker.

13. Record the materials used for packaging each food on the Food for Spaceflight Data Sheet.

14. After conducting all tests, packaging and labeling, study the data and draw conclusions by answering the questions following the Food for Spaceflight Data Sheet.

Record Data

<table>
<thead>
<tr>
<th>Type of food</th>
<th>Property to test</th>
<th>Test applied to food</th>
<th>Results of test</th>
<th>Suited for spaceflight?</th>
<th>Food packaging material used</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes ☐ No ☐</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>Yes ☐ No ☐</td>
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<td>Yes ☐ No ☐</td>
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<td>Yes ☐ No ☐</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Yes ☐ No ☐</td>
<td></td>
</tr>
</tbody>
</table>
Study Data
1. What did your testing prove?

2. What are common properties for the foods that you decided could be eaten in space?

3. What packaging material was used the most often? Why?

4. Does this data support your hypothesis? Why or why not?

5. How do your results compare to class results?

Conclusion
- Update the LEARNED column in your KWL chart.
- Restate your hypothesis and explain what happened during testing.
LET’S INVESTIGATE MARS

Activity topic selected from NASA’s KSNN™ 21st Century Explorer newsbreak “Why do we want to study and travel to Mars?”

Educator Section

Introduction
In 2004, NASA landed two robot rovers called Spirit and Opportunity on Mars. These rovers investigated rocks and soil and took pictures of features that seem to prove Mars was very wet in the past.

Finding evidence that helps prove Mars had liquid water in the past supports the ideas and beliefs that life could have existed on Mars. Many questions about the history of water on Mars are likely to remain unanswered until samples are returned from the red planet for examination on Earth.

The real search is just beginning. With robots helping humans explore, we will learn enough about Mars to help make it possible to live there safely.

Lesson Objective
To formulate an original, collaborative, inquiry investigation based on recent Mars robotic investigations.

Problem
What do I need to know about Mars in order to live there in the future?

Learning Objectives
The students will:

• formulate an original question based on recent Mars robotic investigations.
• formulate an original, collaborative inquiry investigation.
• present their inquiry question and investigation to the class.
• revise the investigation based on feedback from the class.

Materials

• NASA’s KSNN™ 21st Century Explorer 30-second newsbreak, “Why do we want to study and travel to Mars?” (Download the newsbreak at http://ksnn.larc.nasa.gov.)
• computer with Internet access
  o A suggested list of web sites to use for research is located in the Lesson Development Section.
  o It is recommended that you bookmark research web sites on student computers for quicker access during this activity.
• printed materials for research (books, periodicals, printed research from the Internet)
• Designing a Mars Inquiry Investigation (Appendix A)

Per group (3 or 4 students per group)
• research from Mars resources (provided by the instructor)
  o These resources can be accessed via the Internet on a computer in the classroom or printed out and available for student use.
  o URLs for research web sites are located in the Lesson Development Section.
• Let’s Investigate Mars Student Section
• Scientific Inquiry Investigation Chart (Appendix B)

Safety
Remind students about the importance of classroom, Internet and lab safety. Please use Internet Acceptable Use Agreement guidelines as directed by your school.

Pre-lesson Instructions
• Students should work in groups of 3 or 4. Each group will be called a “crew”.
• Create bookmarks for URLs on student computers or print web pages for student use. (URLs are listed in the Lesson Development Section.)
• Print the Designing a Mars Inquiry Investigation (Appendix A) and post in several places around the room for crew use.
• Print copies of the Feedback Form for Crew Presentation (Appendix E) so that each student has one form per crew presentation. (Only one form is included in the Let’s Investigate Mars Student Section.)

Lesson Development
To prepare for this activity, the following background information is recommended:
• Read the following text taken from the Observation Section of the Let’s Investigate Mars Student Section.

  The tests for life used by the Viking Mars missions in 1976 were based on the idea that life would cause changes in the air or soil in the same way that life on Earth does. However, the Viking tests did not detect the presence of life on Mars.

  In 2004, NASA landed two robot rovers called Spirit and Opportunity on Mars. These rovers investigated rocks and soil, and took pictures of features that seem to prove Mars was very wet in the past.

  Finding evidence that helps prove Mars had liquid water in the past supports the ideas and beliefs that life could have existed on Mars. Many questions about the history of water on Mars are likely to remain unanswered until samples are returned from the red planet for examination on Earth.

  Mars is almost certain to have been warmer and wetter in its distant past, so the existence of simple life has been a tantalizing possibility for some time. The real search is just beginning. With robots helping humans explore, we will learn enough about Mars to help make it possible to live there safely.

  To understand how to instruct your class using inquiry education, read the following text. During this activity, your students will formulate questions and an inquiry based, collaborative
investigation using the following guideline on inquiry education from the National Science Education Standards:

What is inquiry in education? The National Science Standards note:

Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations.

- The following URL’s provide additional information on Mars. These web sites will be used later in the inquiry investigation for student research.
  - To see pictures from Mars: http://marsrovers.nasa.gov/home/index.html
  - To find out about a futuristic Mars base: http://www.exploremarsnow.org/
  - To play games about Mars, learn more facts about Mars, do fun activities, and find out about special events: http://marsprogram.jpl.nasa.gov/funzone_flash.html
  - To find out what other students are doing with Mars: http://marsrovers.nasa.gov/classroom/students.html
  - To participate in a Mars rock program: http://marsprogram.jpl.nasa.gov/rockworld/
  - To find out more about the Mars rovers: http://marsrovers.nasa.gov/classroom/

- You may want to do research on testing environments. If so, find out more about ground analogs at: http://www.nasa.gov/centers/ames/research/factsheets/FS-100103.1ARC.html

- If needed, additional research can be done on the following science topics:
  - Viking Mars Missions
  - Mars rovers: Spirit and Opportunity
  - Mars future habitat
  - ground analogs

**Instructional Procedure**

Throughout this lesson, emphasize the steps involved in an inquiry based, collaborative investigation. This lesson should be led and monitored by the instructor in order to keep the lesson on time.

This educator section is numbered and correlated to the Student Section and to the Scientific Inquiry Investigation Chart (Appendix B) for instructional purposes. *Educator specific notes appear in italics.*

Use the Scientific Inquiry Investigation Chart (Appendix B) to guide the instructional procedure throughout the lesson. Each student will complete their own chart as the crew designs their inquiry investigation.

Keep the investigations simple.

In order for the students to know how they will be graded, review with the class the performance indicators on the Scientific Investigation Rubric (Appendix F).
Students will form their inquiry based, collaborative investigation using the following procedure. 
(The following steps are taken from the Student Section. Educator specific comments are in italics.)

1. **Problem**
   What do I need to know about Mars in order to live there in the future?
   The problem is pre-recorded on your Scientific Inquiry Investigation Chart (Appendix B).

   *Review the problem with the students. Refer students to the Scientific Inquiry Investigation chart where they will see that this has been pre-recorded. Tell the students that they will be using this chart to record their inquiry investigation as they proceed through the steps.*

2. **Observation**
   *Have the crews make general observations about Mars by doing the following:*
   - Show NASA’s KSNN™ 21st Century Explorer newsbreak “Why travel to Mars?” to engage students and increase student knowledge about this topic.
   - Have the students read the Observation Section in the Let’s Investigate Mars Student Section and discuss in their crews.

   The tests for life used by the Viking Mars missions in 1976 were based on the idea that life would cause changes in the air or soil in the same way that life on Earth does. However, the Viking tests did not detect the presence of life on Mars.

   In 2004, NASA landed two robot rovers called Spirit and Opportunity on Mars. These rovers investigated rocks and soil, and took pictures of features that seem to prove Mars was very wet in the past.

   Finding evidence that helps prove Mars had liquid water in the past supports the ideas and beliefs that life could have existed on Mars. Many questions about the history of water on Mars are likely to remain unanswered until samples are returned from the red planet for examination on Earth.

   Mars is almost certain to have been warmer and wetter in its distant past, so the existence of simple life has been a tantalizing possibility for some time. The real search is just beginning. With robots helping humans explore, we will learn enough about Mars to help make it possible to live there safely.

   *Record any notes that you have from your observations on the Scientific Inquiry Investigation Chart (Appendix B).*
   - Encourage your students to make notes in the Observation Section on the Scientific Inquiry Investigation Chart (Appendix B).

3. **Brainstorming, Question**
   With your crew, you will formulate a question to solve.

   You are a mission specialist planning a mission to Mars with your crew. You will live off the land when you get to Mars, using the resources there for survival. To find out about Mars before you travel; you and your crew will plan and implement an investigation using the scientific method.

   Keep this thought in mind when you are formulating the question for your investigation: What do I want to know about living and working on Mars?

   With your crew, brainstorm and formulate a question for your investigation. Record the question formed from your brainstorming on the Scientific Inquiry Investigation Chart (Appendix B).

   *You may want to discuss these sample questions to get them started on a brainstorming session:*
   - What is there on Mars for my crew to use to sustain life?
• What must my crew take with us to survive?
• Is there a fuel source, and an alternative fuel source?
• Were will your crew live?
• Will your crew grow some of your food in crops?
• Will your crew recycle water, air, waste?
• Who will you bring with you to Mars?
• What is the layout of your community?
• Will you and your crew ever leave Mars? If so, when will you leave?

Make sure the students keep their questions simple.

After brainstorming, the crews will write their question on the Scientific Inquiry Investigation Chart (Appendix B).

4. Hypothesis

On the Scientific Inquiry Investigation Chart (Appendix B), restate your question as a statement based upon your observations and predictions. Share your hypothesis with the class.

An example might be:

Question: “Were will we live on Mars?”
Hypothesis: “My team of mission specialists will live in the lava tubes that are found underneath the surface on Mars.”

Encourage crews to refine their hypothesis as needed. After developing their hypothesis, the crews will write their hypothesis on the Scientific Inquiry Investigation Chart (Appendix B).

5. Further Investigation

Your crew should make further investigations about your question, by doing the following:

• Read the web text provided at NASA’s KSNN™ 21st Century Explorer newsbreak “Why do we want to study and travel to Mars?” at http://ksnn.larc.nasa.gov.

You may print the web text for students to read, read the text aloud to the class, or have students visit the web site.

• Conduct research on Mars by using the teacher provided information.

These web sites were provided in the Lesson Development Section. You should have each crew investigate the URL’s that are pertinent to their investigation only, in order to keep the lesson on time. You may want to set a time limit for the crews during this Internet research. If computer access is not available to students, material from these web sites can be printed and copied.

• Use the Further Mars Investigation Chart (Appendix C) as an additional resource for Mars facts.

Record the sources and your notes on the Scientific Inquiry Investigation Chart (Appendix B). Use a separate piece of paper if needed.

6. Title

Your crew should formulate a name for your inquiry investigation. Record your title on the Scientific Inquiry Investigation Chart (Appendix B).

7. Purpose

The purpose of an inquiry investigation is to find out more about something specific.
With your crew, decide on the purpose of your investigation of Mars. Ask yourselves “What is it that your crew wants to know more about?” Record the purpose of your inquiry on the Scientific Inquiry Investigation Chart (Appendix B).

Remind the crews that the purpose of their investigation is directly tied to the question and their hypothesis.

8. Testing Environment
Decide whether or not your crew will be conducting the investigation on Earth or on Mars. If you are conducting the test on Earth, where will you perform your inquiry investigation? Who will do the testing? If you are conducting the test on Mars, how will you get the inquiry investigation there? Who will do the testing on Mars? Record the answers on the Scientific Inquiry Investigation Chart (Appendix B).

Ask the crews to think about the following:
- Where will the crew do the testing? On Earth, as a ground analog? Or, will they conduct their test on Mars?
- How will crews get the inquiry investigation to that location?
- Who or what will do the testing on Mars?

9. Materials
What materials will your crew need during the investigation? List your materials on the Scientific Inquiry Investigation Chart (Appendix B).

10. Test Procedure
Formulate the test procedure to answer the question your crew developed earlier. This should be a step by step procedure to test your crew's hypothesis. Keep your tests and the steps simple. On the Scientific Inquiry Investigation Chart (Appendix B), list the steps your crew will use to conduct the investigation. If you need more room for your steps, use the back of the sheet, and continue numbering the steps.

The crews will not actually conduct this test; they only need to think of “how” they would test it if they could conduct the test.

This may take longer for some groups. Make sure assistance and ideas are given to each crew to jump start their thinking process. You may want to ask the students to think about the following:
- What, how, and why are the crews testing?
- What is your crew trying to find out?
- What are the desired results of your crew’s inquiry investigation?

Record Data: Think about the important information you will collect during the test procedure of your inquiry investigation. Your crew will need to develop a data sheet for recording this information. A sample, blank data sheet is shown on Appendix D. What are you trying to find out? Will this data help you solve the problem question? If your data do not fit on this sample sheet, use the back of your paper to make your own. Remember, you will not actually record data, but need to think about how you will collect it. Some things you might want to include on your data sheet are units of measure, title, labels, and key or legend.

Make sure the crews think about their data before designing their data sheet. With the sample, blank data sheet, they can fill in the column and row headers, and use as many or as few rows and columns as needed. Additional rows and columns may be drawn if necessary. A redesigned sheet may have to be made on the back of the paper.
Study Data: If you had actually conducted your test, you would have data to study. Your crew will study the data by predicting if the data can be organized graphically. Your crew will then predict which graphic organizer you will use to display your data. It could be a bar graph, a pie chart, a Venn diagram, a pictograph, or something else. Decide on which graphical organizer your group will use and record this on the Scientific Inquiry Investigation Chart (Appendix B).

On the Scientific Inquiry Investigation Chart (Appendix B), the crews will circle which graphical organizer they will use, or they can write in their own.

Conclusion: With your crew, predict what the conclusion might be, based upon your test procedure. Record your predicted conclusion on the Scientific Inquiry Investigation Chart (Appendix B).

-- SUGGESTED PLACE TO STOP ACTIVITY. RESUME AT NEXT CLASS PERIOD. --

Homework: Assign the class homework to invent a crew name.

Tell your students that they will be presenting their investigations in class. Have them bring from home items that would enhance their presentation. Remind them to keep it simple.

11. Present Your Inquiry Investigation
With your crew, plan to present your investigation to the class. Prepare any items for the presentation that you have brought from home. Decide which section of the Scientific Inquiry Investigation Chart (Appendix B), each crew member will read.

Give the crews time to organize their demonstrations. Then, have each crew present their inquiry investigation to the class.

Make sure to conduct evaluations during each presentation – see Step 12. Evaluation.

12. Evaluation
Your classmates will evaluate you and your crew on your investigation so that you may improve your crew inquiry. You will also do a self-evaluation using the Feedback Form for Crew Presentation (Appendix E). Do not place your names on any of the feedback forms that you use during these presentations. Use the Feedback Form for Crew Presentation (Appendix E) for the evaluations. Use one form per crew presentation.

Make enough copies of the Feedback Form for Crew Presentation (Appendix E) so that each student has one form per crew presentation.

Each student who is evaluating an inquiry investigation should provide alternative explanations for testing the crew’s hypothesis on the evaluation form.

After evaluations are complete, collect and redistribute the feedback forms to the correct crews.

NOTE: If time does not allow for this presentation, the teacher may provide individual crew feedback using the same form.

13. Reflect
After the presentations, answer the following questions with your crew about your investigation.

• How will the inquiry investigation you designed help make Mars more habitable for humans?
• How does your inquiry compare to other groups?
• Could we live on Mars in the future?

Lead the class in a discussion to the answers of these questions.
14. Revise

How can your crew change or improve your inquiry investigation using the comments from the feedback form? Use the class feedback forms to revise, edit and rewrite your inquiry investigation. How was this class feedback helpful? What changes did you make to your inquiry investigation that improved it, based on your critiques?

_Crews should reflect on their inquiry investigation and revise it according to the written evaluation of their presentation to the class._

Assessment

- Assess student knowledge through questioning.
- Observe and assess student performance throughout the activity using the Scientific Investigation Rubric (Appendix F).
- Assess student knowledge based on written comments from the class on the Feedback Form for Crew Presentation (Appendix E).
- Objective assessment may be given to the Scientific Inquiry Investigation Chart (Appendix B).

Activity Alignment to National Education Standards

**National Science Education Standards (NSES):**

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry (K-8)
- Understandings about scientific inquiry (K-8)

Content Standard B: Physical Science
- Properties of objects and materials (K-8)

Content Standard C: Life Science
- Organisms and their environment (K-4)
- Populations and ecosystems (5-8)
- Diversity and adaptations of organisms (5-8)

Content Standard D: Earth and Space Science
- Properties of Earth materials (K-4)
- Earth in the solar system (5-8)

Content Standard E: Science and Technology
- Abilities of technological design (K-8)

Content Standard F: Science in Personal and Social Perspectives
- Types of resources (K-4)
- Changes in the environment (K-4)

**National Health Education Standards (NHES):**

Health Education Standard 3: Students will demonstrate the ability to practice health-enhancing behaviors and reduce health risks.
- 4: demonstrate strategies to improve or maintain personal health

**National Mathematics Education Standards (NCTM):**

Representation Standard:
- Create and use representations to organize, record, and communicate mathematical ideas
• Select, apply, and translate among mathematical representations to solve problems

Communication Standard:
• Organize and consolidate their mathematical thinking through communication
• Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
• Analyze and evaluate the mathematical thinking and strategies of others

U.S. National Geography Standards (NCGE):
• Standard 14: How human actions modify the physical environment
• Standard 15: How physical systems affect human systems
• Standard 18: How to apply geography to interpret the present and plan for the future

National Language Arts Standards (NCTE):
• Standard 1: Students read a wide range of print and non-print texts to build an understanding of texts, of themselves, and of the cultures of the United States and the world; to acquire new information; to respond to the needs and demands of society and the workplace; and for personal fulfillment. Among these texts are fiction and nonfiction, classic and contemporary works.
• Standard 4: Students adjust their use of spoken, written, and visual language (e.g., conventions, style, vocabulary) to communicate effectively with a variety of audiences and for different purposes.
• Standard 8: Students use a variety of technological and information resources (e.g., libraries, databases, computer networks, video) to gather and synthesize information and to create and communicate knowledge.
• Standard 12: Students use spoken, written, and visual language to accomplish their own purposes (e.g., for learning, enjoyment, persuasion, and the exchange of information).

Curriculum Explorations
To extend the concepts in this activity, the following explorations can be conducted:

Mathematics
Discuss the different types of graphic organizers the crews used, and the type of data represented. Discuss the reasoning for selecting the graphic organizers and the pros and cons of each type.

National Mathematics Education Standards (NCTM):
Representations Standard:
• Create and use representations to organize, record, and communicate mathematical ideas
• Select, apply, and translate among mathematical representations to solve problems

Communication Standard:
• Organize and consolidate their mathematical thinking through communication
• Communicate their mathematical thinking coherently and clearly to peers, teachers, and others
• Analyze and evaluate the mathematical thinking and strategies of others

Language Arts
Crews can look at similar questions and inquiry investigations from the class presentations and write descriptions of how these inquiry investigations would benefit NASA in developing a Mars habitat in the future.
National Council of Teachers of English Standards (NCTE):
- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

History
Are there laws in space? If so, how do they govern space travel, other planets, and heavenly bodies? Who makes the space laws? What is in store for the future of space law? Do research to answer the questions, and prepare a timeline of the development of laws in space.

National Council for Geographic Education (NCGE):
- Standard 18: To apply geography to interpret the present and plan for the future.

Liberal Arts
Design a new crew patch to represent your crew on their investigation to Mars. This URL may be helpful in creating your crew patch: http://schools.spsd.sk.ca/victo/projects/Grassroots/Planet%20WebQuest/crewpatch.html. Visit this web site to view mission patches from previous NASA spaceflights: http://www.hq.nasa.gov/office/pao/History/mission_patches.html.

National Visual Arts Standards:
- Content Standard 3: Choosing and evaluating a range of subject matter, symbols and ideas
- Achievement Standard: Students
  - explore and understand prospective content for works of art
  - select and use subject matter, symbols, and ideas to communicate meaning

Sources and Career Links
Thanks to subject matter experts John Connolly and Kurt Klaus for their contributions to KSNN™ and Noticiencias NASA™ on the development of this education material.

John F. Connolly is currently assigned to NASA Headquarters’ Exploration Systems Mission Directorate as a Special Assistant to the Associate Administrator. He leads the Agency’s effort to design the lunar architecture that will return humans to the moon. You can find out more about Mr. Connolly at http://exploration.jsc.nasa.gov/marsref/toc.pdf.

Kurt Klaus is a planetary geologist, formerly an exploration geophysicist. He currently works with The Boeing Company. He has been involved in special projects such as the Mars Society’s Mars Desert Research Station, and the Crew Exploration Vehicle Program. He has a B.S in Geology, a Master’s Degree in Planetary Geology, and is an alumnus of the International Space University.

Original lesson development by the NASA Johnson Space Center Human Health and Performance Education Outreach team.
## Designing a Mars Inquiry Investigation

<table>
<thead>
<tr>
<th>Step</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. State Problem</td>
</tr>
<tr>
<td>2. Make Observations</td>
</tr>
<tr>
<td>3. Design Question</td>
</tr>
<tr>
<td>4. Formulate Hypothesis</td>
</tr>
<tr>
<td>5. Conduct Further Research</td>
</tr>
<tr>
<td>6. Title Inquiry Investigation</td>
</tr>
<tr>
<td>7. State Purpose of Inquiry Investigation</td>
</tr>
<tr>
<td>8. Identify Testing Environment</td>
</tr>
<tr>
<td>9. Identify and Locate Materials</td>
</tr>
<tr>
<td>10. Formulate Test Procedure</td>
</tr>
<tr>
<td>- Data Collection</td>
</tr>
<tr>
<td>- Study Data</td>
</tr>
<tr>
<td>- Conclusion</td>
</tr>
<tr>
<td>11. Present Inquiry Investigation</td>
</tr>
<tr>
<td>12. Evaluate Inquiry Investigation</td>
</tr>
<tr>
<td>13. Reflect on Presentation</td>
</tr>
<tr>
<td>14. Revise Presentation</td>
</tr>
</tbody>
</table>
# Appendix B

## Scientific Inquiry Investigation Chart

<table>
<thead>
<tr>
<th>#</th>
<th>Step</th>
<th>Need to do</th>
<th>Crew Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Problem</td>
<td>State the problem.</td>
<td>What do I need to know about Mars in order to live there in the future?</td>
</tr>
<tr>
<td>2</td>
<td>Observation</td>
<td>Take notes from observations about Mars.</td>
<td>Watched KSNN? □ Yes □ No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Read Observation Section? □ Yes □ No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Notes on my observations: (important facts)</td>
</tr>
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<td>1.</td>
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<td>2.</td>
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<td>3.</td>
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<td>4.</td>
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<td>5.</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>6.</td>
</tr>
<tr>
<td>3</td>
<td>Brainstorm, Question</td>
<td>Write the question my crew wants to answer.</td>
<td>QUESTION:</td>
</tr>
<tr>
<td>4</td>
<td>Hypothesis</td>
<td>Decide on a crew hypothesis.</td>
<td>HYPOTHESIS:</td>
</tr>
<tr>
<td></td>
<td>Further Investigation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>----------------------</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Do further research on your question.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>My question:________</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>___________________</td>
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<td></td>
<td>___________________</td>
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</tbody>
</table>

|   | Printed sources: |   |
|   | Web sources: |   |
|   | My notes: |   |

<table>
<thead>
<tr>
<th></th>
<th>Title</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>Decide on a title for your investigation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Purpose</th>
<th></th>
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</thead>
<tbody>
<tr>
<td>7</td>
<td>Decide on the purpose of your investigation.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Testing Environment</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>Decide where you will do your testing.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(circle one) Mars</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Earth</td>
<td></td>
</tr>
</tbody>
</table>

|   | How will the crew get the test to the test site? |   |
|   | Who will do the testing? |   |

<table>
<thead>
<tr>
<th></th>
<th>Materials</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Make a materials list.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Materials list:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.</td>
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<td>2.</td>
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<td>3.</td>
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<td>4.</td>
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<td>5.</td>
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<td>6.</td>
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<td>7.</td>
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<td>8.</td>
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<td>9.</td>
<td></td>
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<td></td>
<td>10.</td>
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</tr>
<tr>
<td></td>
<td>Test Procedure</td>
<td>What, how, and why are the crews testing?</td>
</tr>
<tr>
<td>---</td>
<td>----------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>10</td>
<td>Write the test procedure (steps for conducting the test).</td>
<td>1. What is your crew trying to find out?</td>
</tr>
<tr>
<td></td>
<td>What are the crews desired results of the inquiry investigation?</td>
<td></td>
</tr>
</tbody>
</table>

Test Procedure, Step 1  <br>(What do I do first?)

Test Procedure, Step 2  <br>(What do I do next?)

Test Procedure, Step 3  <br>(Continue to explain how to test.)

Test Procedure, Step 4  <br>(Continue to explain how to test.)

Test Procedure, Step 5  <br>(Continue to explain how to test.)

Test Procedure, Step 6  <br>(What is the last step in my testing?)

Collect Data  <br>Make sure you design a data sheet for information you want to record and keep. Design your data sheet using Appendix D or the back of this page.
|   | Study Data | Will you be able to make your data into a graphic organizer?  ☐ Yes  ☐ No |
|   | Conclusion | Predict: What will your conclusion be based on your testing? |
|11 | Present your Investigation Inquiry | Presentation | When? Where? |
|   |   | | Do we have items to enhance the presentation? List the items and why you chose them. |
|   |   | | Which section of the chart will each crew member read? |
|12 | Evaluation | Complete the Feedback Form for Crew Presentation (Appendix E). | Fill out one evaluation for each crew as well as for your own inquiry investigation. |
|13 | Reflect | Reflection | What was the feedback from the class, and my crew, on our inquiry investigation? |
|14 | Revise | Revision | How can I change/improve my investigation based on the class feedback? |
## Appendix C

### Further Mars Investigation Chart

<table>
<thead>
<tr>
<th></th>
<th>Mars</th>
<th>Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from Sun</td>
<td>228,526,848 kilometers (142 million miles)</td>
<td>149,668,992 kilometers (93 million miles)</td>
</tr>
<tr>
<td>Radius Distance from the core of the planet to the crust</td>
<td>3,397 kilometers (2,111 miles)</td>
<td>6,378 kilometers (3,963 miles)</td>
</tr>
<tr>
<td>Mass</td>
<td>0.11 of Earth’s</td>
<td>1</td>
</tr>
<tr>
<td>Density</td>
<td>3.94 g/cm³ (2.075 oz/in³)</td>
<td>5.52 g/cm³ (2.91 oz/in³)</td>
</tr>
<tr>
<td>Surface Gravity</td>
<td>0.38 of Earth’s</td>
<td>1</td>
</tr>
<tr>
<td>Rotation on axis (time it takes for the planet to spin around once on its axis)</td>
<td>24.6 hours</td>
<td>23.9 hours</td>
</tr>
<tr>
<td>Revolution around the Sun</td>
<td>687 days</td>
<td>365 days</td>
</tr>
<tr>
<td>Temperature at surface</td>
<td>-87°C (-125°F) Low 30°C (-22°F) High</td>
<td>-88°C (-126°F) Low 58°C (136°F) High</td>
</tr>
<tr>
<td>Natural Satellites</td>
<td>Phobos and Deimos</td>
<td>The Moon</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Carbon Dioxide</td>
<td>Nitrogen, Oxygen</td>
</tr>
</tbody>
</table>
Appendix D

Title of Data Sheet

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
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</tr>
</tbody>
</table>

Key:
### Feedback Form for Crew Presentation

Name of Group: ______________________________________________

Title of Investigation: __________________________________________

<table>
<thead>
<tr>
<th>Rank the presentations from 1 to 5</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disagree</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Agree</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Circle the number 1 – 5

<table>
<thead>
<tr>
<th>The question was clear.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>The hypothesis was clear.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The title was consistent with the hypothesis.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The purpose fit the question.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>I understood the test procedure.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The data collection chart is clear.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The group worked together well.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>The presentation was clear.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Suggestions for improvement:
1. 
2. 
3. 

Explain how you could have conducted the test in a different way.
# Scientific Investigation Rubric

**Experiment:** LET’S INVESTIGATE MARS

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student developed a clear and complete question and hypothesis.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student followed all directions and safety rules.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student followed the steps in the formulation of a scientific inquiry.</td>
<td></td>
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</tr>
<tr>
<td>The student completed the Scientific Inquiry Investigation Chart.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student participated in preparing the presentation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student revised their investigation according to the written class feedback on the Feedback Form for Group Presentation.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Point Total

Point total from above: __________ / (24 possible)

Grade for this investigation ________________

**Grading Scale:**

- **A** = 22 - 24 points
- **B** = 19 - 21 points
- **C** = 16 - 18 points
- **D** = 13 - 15 points
- **F** = 0 - 12 points
Lesson Objective
To formulate an original, collaborative, inquiry investigation based on recent Mars robotic investigations.

During this lesson, you will
- formulate an original question based on recent Mars robotic investigations.
- formulate an original, collaborative inquiry investigation.
- present their inquiry question and investigation to the class.
- revise the investigation based on feedback from the class.

Problem
What do I need to know about Mars in order to live there in the future?

Safety
Review your classroom, Internet and lab safety rules.

Test Procedure

1. Problem
   What do I need to know about Mars in order to live there in the future?
   The problem is pre-recorded on your Scientific Inquiry Investigation Chart (Appendix B).

2. Observation
   The tests for life used by the Viking Mars missions in 1976 were based on the idea that life would cause changes in the air or soil in the same way that life on Earth does. However, the Viking tests did not detect the presence of life on Mars.
   In 2004, NASA landed two robot rovers called Spirit and Opportunity on Mars. These rovers investigated rocks and soil, and took pictures of features that seem to prove Mars was very wet in the past.
   Finding evidence that helps prove Mars had liquid water in the past supports the ideas and beliefs that life could have existed on Mars. Many questions about the history of water on Mars are likely to remain unanswered until samples are returned from the red planet for examination on Earth.
   Mars is almost certain to have been warmer and wetter in its distant past, so the existence of simple life has been a tantalizing possibility for some time. The real search is just beginning. With robots helping humans explore, we will learn enough about Mars to help make it possible to live there safely.
   Record any notes that you have from your observations on the Scientific Inquiry Investigation Chart (Appendix B).
3. **Brainstorming, Question**  
With your crew, you will formulate a question to solve.  
You are a mission specialist planning a mission to Mars with your crew. You will live off the land when you get to Mars, using the resources there for survival. To find out about Mars before you travel; you and your crew will plan and implement an investigation using the scientific method. Keep this thought in mind when you are formulating the question for your investigation: What do I want to know about living and working on Mars?  

With your crew, brainstorm and formulate a question for your investigation. Record the question formed from your brainstorming on the Scientific Inquiry Investigation Chart (Appendix B).

4. **Hypothesis**  
On the Scientific Inquiry Investigation Chart (Appendix B), restate your question as a statement based upon your observations and predictions. Share your hypothesis with the class.  
An example might be:  
Question: “Where will we live on Mars?”  
Hypothesis: “My team of mission specialists will live in the lava tubes that are found underneath the surface on Mars.”

5. **Further Investigation**  
Your crew should make further investigations about your question, by doing the following:  
- Read the web text provided at NASA’s KSNN™ 21st Century Explorer newsbreak “Why do we want to study and travel to Mars?” at http://ksnn.larc.nasa.gov.  
- Conduct research on Mars by using the teacher provided information.  
- Use the Further Mars Investigation Chart (Appendix C) as an additional resource for Mars facts.  

Record the sources and your notes on the Scientific Inquiry Investigation Chart (Appendix B). Use a separate piece of paper if needed.

6. **Title**  
Your crew should formulate a name for your inquiry investigation. Record your title on the Scientific Inquiry Investigation Chart (Appendix B).

7. **Purpose**  
The purpose of an inquiry investigation is to find out more about something specific.  
With your crew, decide on the purpose of your investigation of Mars. Ask yourselves “What is it that your crew wants to know more about?” Record the purpose of your inquiry on the Scientific Inquiry Investigation Chart (Appendix B).

8. **Testing Environment**  
Decide whether or not your crew will be conducting the investigation on Earth or on Mars. If you are conducting the test on Earth, where will you perform your inquiry investigation? Who will do the testing? If you are conducting the test on Mars, how will you get the inquiry investigation there? Who will do the testing on Mars? Record the answers on the Scientific Inquiry Investigation Chart (Appendix B).

9. **Materials**  
What materials will your crew need during the investigation? List your materials on the Scientific Inquiry Investigation Chart (Appendix B).
10. Test Procedure
Formulate the test procedure to answer the question your crew developed earlier. This should be a step by step procedure to test your crew's hypothesis. Keep your tests and the steps simple. On the Scientific Inquiry Investigation Chart (Appendix B), list the steps your crew will use to conduct the investigation. If you need more room for your steps, use the back of the sheet, and continue numbering the steps.

Record Data: Think about the important information you will collect during the test procedure of your inquiry investigation. Your crew will need to develop a data sheet for recording this information. A sample, blank data sheet is shown on Appendix D. What are you trying to find out? Will this data help you solve the problem question? If your data do not fit on this sample sheet, use the back of your paper to make your own. Remember, you will not actually record data, but need to think about how you will collect it. Some things you might want to include on your data sheet are units of measure, title, labels, and key or legend.

Study Data: If you had actually conducted your test, you would have data to study. Your crew will study the data by predicting if the data can be organized graphically. Your crew will then predict which graphic organizer you will use to display your data. It could be a bar graph, a pie chart, a Venn diagram, a pictograph, or something else. Decide on which graphical organizer your group will use and record this on the Scientific Inquiry Investigation Chart (Appendix B).

Conclusion: With your crew, predict what the conclusion might be, based upon your test procedure. Record your predicted conclusion on the Scientific Inquiry Investigation Chart (Appendix B).

11. Present Your Inquiry Investigation
With your crew, plan to present your investigation to the class. Prepare any items for the presentation that you have brought from home. Decide which section of the Scientific Inquiry Investigation Chart (Appendix B), each crew member will read.

12. Evaluation
Your classmates will evaluate you and your crew on your investigation so that you may improve your crew inquiry. You will also do a self-evaluation using the Feedback Form for Crew Presentation (Appendix E). Do not place your names on any of the feedback forms that you use during these presentations. Use the Feedback Form for Crew Presentation (Appendix E) for the evaluations. Use one form per crew presentation.

13. Reflect
After the presentations, answer the following questions with your crew about your investigation.
- How will the inquiry investigation you designed help make Mars more habitable for humans?
- How does your inquiry compare to other groups?
- Could we live on Mars in the future?

14. Revise
How can your crew change or improve your inquiry investigation using the comments from the feedback form? Use the class feedback forms to revise, edit and rewrite your inquiry investigation. How was this class feedback helpful? What changes did you make to your inquiry investigation that improved it, based on your critiques?
## Designing a Mars Inquiry Investigation

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>State Problem</td>
</tr>
<tr>
<td>2.</td>
<td>Make Observations</td>
</tr>
<tr>
<td>3.</td>
<td>Design Question</td>
</tr>
<tr>
<td>4.</td>
<td>Formulate Hypothesis</td>
</tr>
<tr>
<td>5.</td>
<td>Conduct Further Research</td>
</tr>
<tr>
<td>6.</td>
<td>Title Inquiry Investigation</td>
</tr>
<tr>
<td>7.</td>
<td>State Purpose of Inquiry Investigation</td>
</tr>
<tr>
<td>8.</td>
<td>Identify Testing Environment</td>
</tr>
<tr>
<td>9.</td>
<td>Identify and Locate Materials</td>
</tr>
</tbody>
</table>
| 10. | Formulate Test Procedure  
  |   • Data Collection  
  |   • Study Data  
  |   • Conclusion |
| 11. | Present Inquiry Investigation |
| 12. | Evaluate Inquiry Investigation |
| 13. | Reflect on Presentation |
| 14. | Revise Presentation |
### Scientific Inquiry Investigation Chart

<table>
<thead>
<tr>
<th>#</th>
<th>Step</th>
<th>Need to do</th>
<th>Crew Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Problem</td>
<td>State the problem.</td>
<td>What do I need to know about Mars in order to live there in the future?</td>
</tr>
<tr>
<td>2</td>
<td>Observation</td>
<td>Take notes from observations about Mars.</td>
<td>Watched KSNN? □ Yes □ No&lt;br&gt;Read Observation Section? □ Yes □ No&lt;br&gt;Notes on my observations: (important facts)&lt;br&gt;1.&lt;br&gt;2.&lt;br&gt;3.&lt;br&gt;4.&lt;br&gt;5.&lt;br&gt;6.</td>
</tr>
<tr>
<td>3</td>
<td>Brainstorm, Question</td>
<td>Write the question my crew wants to answer.</td>
<td>QUESTION:</td>
</tr>
<tr>
<td>4</td>
<td>Hypothesis</td>
<td>Decide on a crew hypothesis.</td>
<td>HYPOTHESIS:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
</tbody>
</table>
| 5 | Further Investigation | Do further research on your question.  
My question:  
________________  
________________ |
|   |   | Printed sources:  
Web sources:  
My notes: |
| 6 | Title | Decide on a title for your investigation |
| 7 | Purpose | Decide on the purpose of your investigation. |
| 8 | Testing Environment | Decide where you will do your testing.  
(circle one)  
Mars  Earth  
How will the crew get the test to the test site?  
Who will do the testing? |
| 9 | Materials | Make a materials list.  
Materials list:  
1.  
2.  
3.  
4.  
5.  
6.  
7.  
8.  
9.  
10. |
<table>
<thead>
<tr>
<th></th>
<th>Test Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Write the test procedure (steps for conducting the test).</td>
</tr>
<tr>
<td>2.</td>
<td>What, how, and why are the crews testing?</td>
</tr>
<tr>
<td>3.</td>
<td>What is your crew trying to find out?</td>
</tr>
<tr>
<td>4.</td>
<td>What are the crews desired results of the inquiry investigation?</td>
</tr>
<tr>
<td>5.</td>
<td>Test Procedure, Step 1 (What do I do first?)</td>
</tr>
<tr>
<td>6.</td>
<td>Test Procedure, Step 2 (What do I do next?)</td>
</tr>
<tr>
<td></td>
<td>Test Procedure, Step 3 (Continue to explain how to test.)</td>
</tr>
<tr>
<td></td>
<td>Test Procedure, Step 4 (Continue to explain how to test.)</td>
</tr>
<tr>
<td></td>
<td>Test Procedure, Step 5 (Continue to explain how to test.)</td>
</tr>
<tr>
<td></td>
<td>Test Procedure, Step 6 (What is the last step in my testing?)</td>
</tr>
<tr>
<td></td>
<td>Collect Data</td>
</tr>
<tr>
<td></td>
<td>Make sure you design a data sheet for information you want to record and keep. Design your data sheet using Appendix D or the back of this page.</td>
</tr>
<tr>
<td></td>
<td>Study Data</td>
</tr>
<tr>
<td>---</td>
<td>------------</td>
</tr>
<tr>
<td><strong>Will you be able to make your data into a graphic organizer?</strong></td>
<td>Yes ☐ No ☐</td>
</tr>
<tr>
<td><strong>Circle the graphic organizer you will use:</strong></td>
<td>Bar Graph</td>
</tr>
<tr>
<td></td>
<td>Pie Chart</td>
</tr>
<tr>
<td></td>
<td>Venn Diagram</td>
</tr>
<tr>
<td></td>
<td>Pictograph</td>
</tr>
<tr>
<td></td>
<td>Other ___________</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>11 Present your Investigation Inquiry</th>
<th>12 Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Presentation</strong></td>
<td><strong>Complete the Feedback Form for Crew Presentation (Appendix E).</strong></td>
</tr>
<tr>
<td></td>
<td>When? Where?</td>
<td>Fill out one evaluation for each crew as well as for your own inquiry investigation.</td>
</tr>
<tr>
<td></td>
<td>Do we have items to enhance the presentation? List the items and why you chose them.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Which section of the chart will each crew member read?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>13 Reflect</th>
<th>14 Revise</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Reflection</strong></td>
<td><strong>Revision</strong></td>
</tr>
<tr>
<td></td>
<td>What was the feedback from the class, and my crew, on our inquiry investigation?</td>
<td>How can I change/improve my investigation based on the class feedback?</td>
</tr>
</tbody>
</table>
### Further Mars Investigation Chart

<table>
<thead>
<tr>
<th></th>
<th>Mars</th>
<th>Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from Sun</td>
<td>228,526,848 kilometers (142 million miles)</td>
<td>149,668,992 kilometers (93 million miles)</td>
</tr>
<tr>
<td>Radius Distance from the core of the planet to the crust</td>
<td>3,397 kilometers (2,111 miles)</td>
<td>6,378 kilometers (3,963 miles)</td>
</tr>
<tr>
<td>Mass</td>
<td>0.11 of Earth’s</td>
<td>1</td>
</tr>
<tr>
<td>Density</td>
<td>3.94 g/cm³ (2.075 oz/in³)</td>
<td>5.52 g/cm³ (2.91 oz/in³)</td>
</tr>
<tr>
<td>Surface Gravity</td>
<td>0.38 of Earth’s</td>
<td>1</td>
</tr>
<tr>
<td>Rotation on axis (time it takes for the planet to spin around once on its axis)</td>
<td>24.6 hours</td>
<td>23.9 hours</td>
</tr>
<tr>
<td>Revolution around the Sun</td>
<td>687 days</td>
<td>365 days</td>
</tr>
<tr>
<td>Temperature at surface</td>
<td>-87°C (-125°F) Low 30°C (-22°F) High</td>
<td>-88°C (-126°F) Low 58°C (136°F) High</td>
</tr>
<tr>
<td>Natural Satellites</td>
<td>Phobos and Deimos</td>
<td>The Moon</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>Carbon Dioxide</td>
<td>Nitrogen, Oxygen</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

**Key:**

---
Appendix E

Feedback Form for Crew Presentation

Name of Group: ______________________________________________

Title of Investigation: __________________________________________

<table>
<thead>
<tr>
<th>Rank the presentations from 1 to 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>Disagree</td>
</tr>
</tbody>
</table>

Circle the number 1 – 5

- The question was clear.
- The hypothesis was clear.
- The title was consistent with the hypothesis.
- The purpose fit the question.
- I understood the test procedure.
- The data collection chart is clear.
- The group worked together well.
- The presentation was clear.

Suggestions for improvement:
1.
2.
3.

Explain how you could have conducted the test in a different way.
MOON MINING

Activity topic selected from NASA’s KSNN™ 21st Century Explorer newsbreak “Why return to the moon before going to Mars?”

Educator Section

Introduction
Many things were learned from the rock samples that the astronauts brought back with them from the moon during NASA’s Apollo flights to the moon. What we learn on the moon will help us plan for crewed space missions to Mars, making it as safe and efficient as possible.

Lesson Objective
This lesson simulates the locating and the mining of ilmenite for oxygen on the moon.

Problem
How can I find and mine valuable resources from a simulated moon surface?

Learning Objectives
The students will
• gather data by spectroscopically locating the simulated ilmenite.
• collect simulated ilmenite by mining the simulated lunar surface.
• gather data by using observations while extracting oxygen from the simulated ilmenite over time.
• develop a conclusion based upon the results of this simulation.
• compare individual results to class results to look for patterns.

Materials
• NASA’s KSNN™ 21st Century Explorer 30-second newsbreak, “Why return to the moon before going to Mars?” (Download the newsbreak at http://ksnn.larc.nasa.gov.)

Per group (2 students working together)
• 1 disposable plate moon
  o 3 effervescent tablets
  o ice
  o white divided disposable plate (paper, plastic, or foam) with 3 or more sections

See how to make the disposable plate moon in the Pre-Lesson Instructions Section.

Grade Level: 3-5
Connections to Curriculum: Science
Science Process Skills: observing, classifying, measuring, inferring, predicting, communicating (Association for the Advancement of Science)
Teacher Preparation Time: 30 minutes
(20 minutes the day before and 10 minutes the day of the lesson.)
Lesson Duration: 45 minutes
Prerequisite: none
National Education Standards addressed in this activity include Science (NSES), Mathematics (NCTM) and Geography (NCGE). For an alignment to standards in this activity, see page 5.

Materials Required
effervescent tablets
ice
white divided disposable plates
spoons
quart size, freezer, zipper seal bags
8.5” x 11” red transparencies
8.5” x 11” blue transparencies
centimeter rulers
safety glasses
graph paper (sample included)
stopwatches

NASA’s KSNN™ 21st Century Explorer 30-second newsbreak – “Why return to the moon before going to Mars?”
- 1 - 8.5” x 11” red transparency
- 1 - 8.5” x 11” blue transparency
- 1 quart size, freezer, zipper seal bag
- 1 spoon
- centimeter ruler
- stopwatch, or timepiece with a second hand (watch or clock)

Per student
- safety glasses
- graph paper
- Moon Mining Student Section

Safety
Remind students about the importance of classroom and lab safety. Students should wear eye protection during this activity. Refer to MSDS sheets concerning effervescent tablets: http://www.msdssearch.com/msdssearch.htm. Use disposable latex-free gloves as necessary. This experiment will require proper clean up.

Pre-lesson Instructions
- Students should work in groups of 2.
- Identify a sunny location for the test site.
- Prepare the disposable plate moon: (at least one day before)
  - Crush three effervescent tablets and mix with enough crushed ice to fill in one section of a white, divided disposable plate. Work quickly so that the ice does not melt and activate the effervescent tablet.
  - Place only crushed ice into the other sections of the white, divided disposable plate.
  - Prepare and freeze one disposable plate per group.
  - Keep cold until students are ready to conduct the test procedure (this will ensure that the ice does not melt and activate the effervescent tablet).

Lesson Development
To prepare for this activity, the following background information is recommended:
- The mineral ilmenite is Iron Titanium Oxide. You can read more about ilmenite here: http://mineral.galleries.com/minerals/oxides/ilmenite/ilmenite.htm. If the Internet is available to students in the classroom, visit this web site as part of the activity preparation. If the Internet is not available in the classroom, you may want to print this page and share it with your students.
- Read the following text taken from the Observation Section of the Moon Mining Student Section.

Observation
Many things were learned about the moon during the Apollo flights to the moon. Much of this knowledge comes from the rock samples that the astronauts brought back with them from the moon. These samples were one of the greatest benefits of sending humans to the lunar surface. Before their missions, the astronauts went through training, to recognize different types of rocks and their significance.

NASA’s Vision for Space Exploration calls for a return to the moon before going to Mars, and beyond. We’ll learn how to “live off the land” by making oxygen and rocket propellants from
the local materials, and we'll be testing new technologies and operations. Living and working on the moon will be a test run for living and working on Mars and beyond.

In this lesson, you will locate and simulate the mining of ilmenite for it’s oxygen from the surface of the moon. You will then collect the oxygen that is extracted from the ilmenite.

- If needed, additional research can be done on the following science topics:
  - Apollo mission with lunar sample returns (11, 12, 14, 15, 16, 17)
  - ilmenite
  - geology / geologist
  - metamorphic rock
  - igneous rock and the formation of glass
  - spectroscopy
  - solar energy

**Instructional Procedure**

Throughout this lesson, emphasize the steps involved in the scientific method. These steps are identified in **bold italic** print throughout the Instructional Procedure Section.

1. Show NASA’s KSNN™ 21st Century Explorer newsbreak “Why return to the moon before going to Mars?” to engage students and increase student knowledge about this topic.

2. Review the problem with the students.
   **Problem:** How can I find and mine valuable resources from a simulated moon surface?

3. Have the students read the **Observation** Section in the Moon Mining Student Section and discuss in their groups.

4. Encourage your students to discuss and make **observations** about this topic by completing the first two columns in the KWL (KNOW/WANT TO KNOW/LEARNED) chart on the Moon Mining Student Section. Use the KWL chart to help students organize prior knowledge, identify interests, and make real-world connections. As students suggest information for the “KNOW” column, ask them to share “How they have come to know this information.”

5. Ask your students if they have predictions relating to this activity and the “problem question”. Help them refine their predictions into a **hypothesis**. In their Student Section, they should restate the “problem question” as a statement based upon their observations and predictions. Encourage students to share their hypothesis with their group.

6. Students will **test** their hypothesis following this procedure.
   (The following steps are taken from the Student Section. Educator specific comments are in italics.)
   
   1. Put on your safety glasses.
   2. **Observe** your disposable plate moon with your partner.
   3. Draw a line to divide the graph paper in half. Sketch your disposable plate moon on one half of the graph paper. Label your drawing. Title the drawing “Before Mining”.
   4. Place red transparency on half of the plate, and blue transparency on the other half.
   5. Look for ilmenite (effervescent tablets) by moving the transparencies around the plate. What color can you see the ilmenite through? What color hid the ilmenite? NASA researchers use colors to locate certain items on the surface of other bodies. This is called “spectroscopically” locating the ilmenite.
6. When the ilmenite is located, extract the section it is in from the disposable plate (take it off of the plate with the spoon) and place it into the zipper seal bag. Zip the bag, making sure all air is locked outside the bag.

7. Place the bag in a sunny location. This represents the solar energy that may be used to power the machinery that extracts the oxygen from the ilmenite.

8. Evenly flatten out the contents of the bag by pushing it down with your palms. This will allow you to see the profile, or side, of the bag.

9. **Observe** the bag. Sketch an outline of what the profile of the bag looks like on your Moon Mining Data Sheet.

10. Measure from the tabletop to the top of the bag, using the profile, or side, of the bag. **Record data** on your Moon Mining Data Sheet at zero minutes. (See diagram.)

11. Predict how the bag will change over time, and record your prediction on your Moon Mining Data Sheet.

   *You may want to guide the class into what they think might happen to the bag to make their predictions.*

12. Guess what is inside the bag. **Record** on your Moon Mining Data Sheet.

13. Every 3 minutes for the next 12 minutes, repeat steps 9-12. Do not disturb the ilmenite sample.

   *Not disturbing the bag is important to the experiment. Have students measure and observe without touching or moving the bag.*

14. Discuss what you see happening to your zipper sealed bag with your group. Why is the ice melting?

15. Sketch your disposable plate moon on the other half of the graph paper. Make sure you label where the ilmenite was found. Label your drawing. Title your drawing "After Mining". What are these deep places on the moon called?

   *Have your students compare the “mined” ilmenite drawing with the original moon drawing. Ask students to discuss the differences they see.*

16. After taking all measurements, **study the data** and **draw conclusions** by answering the questions following the Moon Mining Data Sheet.

   **Sample answers to the Study Data questions on the Moon Mining Student Section:**
   1. giving off gas (simulated oxygen)
2. energy, can be solar energy

3. all over the moon, the darker areas of the moon’s surface, mostly craters

4. using colors, or possibly using other methods such as magnets

Using this information, ask students to determine if the data supports or refutes their hypothesis.

Conclusion

- Discuss the answers to the Moon Mining Student Section questions.
- Have the students update the LEARNED column in their KWL chart.
- Ask students to compare their individual data to the class data. What patterns can be found?
- Is there another way that you could find this ilmenite? Brainstorm how.
- Ask students “what they wonder now?” Encourage students to design their own experiments. What other objects could have been used for the land surface?
- What other items necessary for human life can be taken from the surface of the moon?

Assessment

- Assess student knowledge through questioning.
- Observe and assess student performance throughout the activity using the attached Scientific Investigation Rubric.

Activity Alignment to National Education Standards

**National Science Education Standards (NSES):**

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry (K-8)
- Understandings about scientific inquiry (K-8)

Content Standard D: Earth and Space Science
- Properties of Earth materials (K-4)
- Structure of the Earth system (5-8)

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in local challenges (K-8)

**National Mathematics Education Standards (NCTM):**

Data Analysis and Probability Standard:
- Develop predictions that are based on data

**U.S. National Geography Standards (NCGE):**
- Standard 14: How human actions modify the physical environment
- Standard 16: The changes that occur in the meaning, use, distribution, and importance of resources
Curriculum Explorations
To extend the concepts in this activity, the following explorations can be conducted:

Mathematics
Ask students to display their data in any way that they choose. Ask them to explain why they have chosen to display their data in this format.

Analyze the data, looking for patterns and trends.

National Mathematics Education Standards (NCTM):
Algebra Standard:
- Understand patterns, relations, and functions
  - represent and analyze patterns and functions, using words, tables, and graphs

Data Analysis and Probability Standard:
- Develop and evaluate inferences and predictions that are based on data
  - propose and justify conclusions and predictions that are based on data and design studies to further investigate the conclusions or predictions

Language Arts
Ask students to explain the experiment. How might students improve this experiment? Where might there have been mistakes made? How might these mistakes have affected the results?

National Council of Teachers of English Standards (NCTE):
- Students conduct research on issues and interests by generating ideas and questions, and by posing problems. They gather, evaluate, and synthesize data from a variety of sources (e.g., print and non-print texts, artifacts, people) to communicate their discoveries in ways that suit their purpose and audience.

History
Research the ownership of the moon. Are there laws that protect space travelers and property in space?

National Council for Geographic Education (NCGE):
Standard 18: To apply geography to interpret the present and plan for the future.

Sources and Career Links
Thanks to subject matter experts Michael Wargo, Kay Tobola, Christine Shupla, Dr. Donald Bogard, Dr. Gary Lofgren, and Harrison Schmitt for their contributions to KSNN™ and Noticiencias NASA™ on the development of this education material.

Michael Wargo is an Exploration Systems lunar scientist. You can find out more about what Mike does at: [http://www.nasa.gov/vision/earth/everydaylife/real_glass.html](http://www.nasa.gov/vision/earth/everydaylife/real_glass.html).

Kay Tobola is an educator with ARES (Astromaterials, Research and Exploration Science) at NASA Johnson Space Center. Learn more about ARES at [http://ares.jsc.nasa.gov/](http://ares.jsc.nasa.gov/).

Christine Shupla is an educator with The Lunar and Planetary Institute (http://www.lpi.usra.edu/).

Dr. Donald Bogard, chief scientist, astromaterials, NASA Johnson Space Center was instrumental in the formation of the background information for this activity. You can find out more about what he does here [http://ares.jsc.nasa.gov/People/bogarddon.html](http://ares.jsc.nasa.gov/People/bogarddon.html).
Dr. Gary Lofgren is a planetary geoscientist/lunar curator, director of the experimental petrology laboratory at NASA JSC. Dr. Lofgren was instrumental in the educational formation of these activities. You can find out more about Dr. Lofgren at this site http://ares.jsc.nasa.gov/People/lofgrengary.html.

For a related career profile, learn about Apollo 17 Lunar Module pilot Harrison Schmitt, who was a professional geologist before becoming an astronaut. Find out more by visiting http://www.hq.nasa.gov/office/pao/History/alsj/a17/a17.crew.html.

Lesson development by the NASA Johnson Space Center Human Health and Performance Education Outreach team.
### Scientific Investigation Rubric

**Experiment:** MOON MINING

<table>
<thead>
<tr>
<th>Student Name __________________________</th>
<th>Date ________________</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Performance Indicator</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>The student developed a clear and complete hypothesis.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student followed all lab safety rules and directions.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student followed the scientific method.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student recorded all data on the data sheet and drew a conclusion based on the data.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student asked engaging questions related to the study.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The student mined simulated ilmenite and collected oxygen from the ilmenite.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Point Total**

- **Point total from above:** _________ / (24 possible)
- **Grade for this investigation** ________________

**Grading Scale:**
- A = 22 - 24 points
- B = 19 - 21 points
- C = 16 - 18 points
- D = 13 - 15 points
- F = 0 - 12 points
Lesson Objective
This lesson simulates the locating and the mining of ilmenite for oxygen on the moon.

During this lesson, you will
- gather data by spectroscopically locating the simulated ilmenite.
- collect simulated ilmenite by mining the simulated lunar surface.
- gather data by using observations while extracting oxygen from the simulated ilmenite over time.
- develop a conclusion based upon the results of this simulation.
- compare individual results to class results to look for patterns.

Problem
How can I find and mine valuable resources from a simulated moon surface?

Observation
Many things were learned about the moon during the Apollo flights to the moon. Much of this knowledge comes from the rock samples that the astronauts brought back with them from the moon. These samples were one of the greatest benefits of sending humans to the lunar surface. Before their missions, the astronauts went through training, to recognize different types of rocks and their significance.

NASA’s Vision for Space Exploration calls for a return to the moon before going to Mars, and beyond. We’ll learn how to “live off the land” by making oxygen and rocket propellants from the local materials, and we’ll be testing new technologies and operations. Living and working on the moon will be a test run for living and working on Mars and beyond.

In this lesson, you will locate and simulate the mining of ilmenite for its oxygen from the surface of the moon. The mineral ilmenite is Iron Titanium Oxide. After mining, you will then collect the oxygen that is extracted from the ilmenite.

Use the first column of this KWL chart to organize your observations about mining.
Brainstorm with your group what you want to know about mining, then list in the second column of this KWL chart.
Hypothesis
Based on your observations, answer the “problem question” with your best guess. (How can I find and mine valuable resources from a simulated moon surface?) Your hypothesis should be written as a statement.

My hypothesis: ________________________________________________________________

Materials
Per group
- 1 disposable plate moon prepared by your instructor before class
- 1 - 8.5” x 11” red transparency
- 1 - 8.5” x 11” blue transparency
- 1 quart size, freezer, zipper seal bag
- 1 spoon
- centimeter ruler
- stopwatch, watch or clock

Per student
- 1 pair of safety glasses
- graph paper

Safety
Review your classroom and lab safety rules. Put on safety glasses when instructed.

Test Procedure
1. Put on your safety glasses.
2. Observe your disposable plate moon with your partner.
3. Draw a line to divide the graph paper in half. Sketch your disposable plate moon on one half of the graph paper. Label your drawing. Title the drawing “Before Mining”.
4. Place red transparency on half of the plate, and blue transparency on the other half.
5. Look for ilmenite (effervescent tablets) by moving the transparencies around the plate. What color can you see the ilmenite through? What color hid the ilmenite? NASA researchers use colors to locate certain items on the surface of other bodies. This is called “spectroscopically” locating the ilmenite.
6. When the ilmenite is located, extract the section it is in from the disposable plate (take it off of the plate with the spoon) and place it into the zipper seal bag. Zip the bag, making sure all air is locked outside the bag.

7. Place the bag in a sunny location. This represents the solar energy that may be used to power the machinery that extracts the oxygen from the ilmenite.

8. Evenly flatten out the contents of the bag by pushing it down with your palms. This will allow you to see the profile, or side, of the bag.

9. Observe the bag. Sketch what it looks like on your Moon Mining Data Sheet.

10. Measure from the tabletop to the top of the bag, using the profile, or side, of the bag. Record data on your Moon Mining Data Sheet at zero minutes. (See diagram.)

11. Predict how the bag will change over time, and record your prediction on your Moon Mining Data Sheet.

12. Guess what is inside the bag. Record on your Moon Mining Data Sheet.

13. Every 3 minutes for the next 12 minutes, repeat steps 9-12. Do not disturb the ilmenite sample.

14. Discuss what you see happening to your zipper sealed bag with your group. Why is the ice melting?

15. Sketch your disposable plate moon on the other half of the graph paper. Make sure you label where the ilmenite was found. Label your drawing. Title your drawing “After Mining”. What are these deep places on the moon called?

16. After taking all measurements, study the data and draw conclusions by answering the questions following the Moon Mining Data Sheet.
Record Data

### Moon Mining Data Sheet

<table>
<thead>
<tr>
<th></th>
<th>0 minutes</th>
<th>3 minutes</th>
<th>6 minutes</th>
<th>9 minutes</th>
<th>12 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sketch the outline of the bag profile</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure in cm from the table to the top of the zipper bag (laying flat)</td>
<td>Predict</td>
<td>Actual</td>
<td>Predict</td>
<td>Actual</td>
<td>Predict</td>
</tr>
<tr>
<td>What do you think is inside the bag?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other observations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Study Data

1. What do you think the ilmenite is doing in the bag as it is warmed to room temperature by solar energy?

2. What do we need to mine ilmenite from the surface of the moon?

3. Where is ilmenite found on the moon?
4. How do we locate ilmenite on the moon?

5. Does this data support your hypothesis? Why or why not?

6. How do your results compare to class results?

Conclusion
• Update the LEARNED column in your KWL chart.
• Restate your hypothesis and explain what happened during testing.
Rocket Activity

Newton Car

Objective
To investigate the relationship between mass, acceleration, and force as described in Newton’s second law of motion.

Description
Small student teams use a wooden car and rubber bands to toss a small mass off the car. The car, resting on rollers, will be propelled in the opposite direction. During a set of experiments, students will vary the mass being tossed from the car and change the number of rubber bands used to toss the mass. Students will measure how far the car rolls in response to the action force generated.

Materials
Newton Cars (see separate instructions)
Cotton string
Two rubber bands (size 19)
Medicine bottles (see Tip)
25 straight drinking straws (not flexi)
Meter stick or ruler
Metric beam balance or scale
Scissors or lighters (see Management below)
Popcorn seeds, washers, pennies, marbles, paper clips, etc. (for filling the bottles)
Eye protection

National Science Content Standards:
Unifying Concepts and Processes
• Evidence, models, and explanation
• Change, constancy, and measurement
Science as Inquiry
• Abilities necessary to do scientific inquiry
Physical Science
• Position and motion of objects
• Motions and forces
• Properties of objects and materials
Science and Technology
• Understanding about science and technology

National Mathematics Content Standards:
• Number and Operations
• Measurement
• Data Analysis and Probability

National Mathematics Process Standards:
• Problem Solving
• Reasoning and Proof
• Communication
• Connections
• Representations

Management
This activity requires a smooth floor or long tables for a rolling surface. Be sure teams understand how to set up the car and are consistent in their placement of straws. Demonstrate the “loading” of the car. After attaching the rubber band and string to the car, press the bottle into the “V” of the rubber bands. This process must be done the same way each time. Also demonstrate the string cutting process. The string must be cut and the
Slide rubber band ends over twin posts

Slip rubber band through string loop

Stretch string over third post

Loading the Newton Car

scissors moved out of the way in one smooth and quick movement. Lighters can also be used for burning through the string. Have students light the ends of the string dangling down from the knot. The flame will climb up the strings and burn through the knot. Students must wear eye protection with either string cutting technique.

Background

Although the purpose of the Newton Car is to investigate Newton’s second law of motion, it provides an excellent demonstration of all three laws. The car is a slingshot-like device. Rubber bands are stretched between two posts and held with a string loop ringing a third post. A bottle, holding various materials that can be changed to vary its mass, is placed between the stretched rubber bands. When the string is cut, the bottle is tossed off the car and the car travels the other way on straw rollers.

Newton’s first law is demonstrated by the act of exerting a force. The car remains at rest until the mass is expelled, producing a force. The car then moves. The action force exerted on the car produces an equal and opposite reaction force. The car moves the other way from the tossed bottle. This demonstrates Newton’s third law.

How far the car moves demonstrates the second law. The magnitude of the force is determined by how much mass is tossed and how fast it is accelerated off the car.

By varying the mass and the number of rubber bands, students are able to see a visual demonstration of the relationship of mass and acceleration on force. The greater the mass of the bottle and its contents and the greater the acceleration (more rubber bands), the greater the force. The effect is that the car will travel further in the opposite direction. (Refer to pages 19-23 for a more detailed explanation of Newton’s laws of motion.)

Materials

1 1 X 3 X 8 inch board*
3 1/4” diameter by 2 1/2” long dowels (or wood screws)
Wood glue

Procedure Making Newton Cars

1. Cut the board into 12 8” lengths. (Optional: Bevel one edge as shown on the previous page.)
2. Drill three 1/4” holes 3/8” deep for the dowels. If using screws for posts instead of dowels, skip Step 3.
3. Glue the dowels into the holes. If desired, bevel the upper end of the dowels with sand paper.

* Note: Dimensions of lumber are based on rough cuts. When planed, thickness and width are smaller. A 1X3” board is actually 0.75 by 2.5 inches.
Procedure

The Experiment

1. Provide student teams with the instruction sheet on how to set up the Newton Car and the data sheet.
2. Clear areas for each team to set up their experiment.
3. Provide a station where teams can fill their bottles with different materials to change their total mass. Place the popcorn seeds, washers, etc., in different bowls for easy access. The bottles do not have to be filled to the top. However, the rubber bands should be positioned around the approximate center of mass of the bottle to get a uniform toss.
4. Check each team to ensure they are being consistent in their procedures. For instance, placing straws differently for each test would introduce a new variable into the experiment that could affect the results.

Tip: Provide masking tape so that students can use small tape pieces to mark the positions of the straws for consistency.

Discussion

• How does adding additional rubber bands change the acceleration?

Like all matter, the bottle has inertia, which is the property of resistance to change in motion. Newton's first law of motion is often referred to as the law of inertia. A force is needed to change the motion of the bottle. In this experiment the inertia of the bottle retards the contraction of the rubber band. Two rubber bands, working together, are able to contract more rapidly and consequently are able to impart a greater acceleration to the bottle.

Tip: Ask a pharmacist for a donation of new, 8-dram-size medicine bottles.

Assessment

• Review the experiment report for completeness and check team statements, explaining the relationship between mass, acceleration, and the distances the Newton Cars traveled.
• Ask students for other examples of Newton’s laws of motion at work.

Extensions

• Newton’s second law of motion can also be demonstrated using a water rocket. Vary the pressure in the water rocket by using different numbers of pumps. Vary the amount of water inside the bottle. Changes in mass and acceleration will affect the performance of the rocket in flight.

Tip: Ask a pharmacist for a donation of new, 8-dram-size medicine bottles.
Newton Car Experiment Procedures

1. Tie six string loops approximately this size.
2. Fill the plastic bottle with small weights provided by your teacher. Measure the mass of the filled bottle and record the amount on your data sheet for test 1.
3. Set up your Newton Car as shown in the picture. Slide the rubber band through the first string loop. Slip the ends of the rubber band over the two posts. Pull the string back to stretch the rubber bands, and slip the loop over the third post to hold the loop.

4. Lay the straws on a smooth floor or tabletop. Place them like railroad ties 5 centimeters apart. Put the Newton Car on top of the straws at one end of the line.
5. Using the scissors, cut the string. Quickly move the scissors out of the way! The rubber band will toss the bottle off the Newton Car while the car rolls the other way on the straws.
6. Measure how far the Newton Car moved and record the distance on the data sheet.
7. Repeat the experiment using two rubber bands. Be sure to set up the straws and place the Newton Car on them exactly as before. Record your data.
8. Put different weights in the bottle and measure its mass. Record the mass and repeat the experiment with one and two rubber bands. Record your data.
9. Once more, put different weights in the bottle and measure its mass. Record the mass and repeat the experiment with one and two rubber bands. Record your data.
10. Answer the questions on the data sheet and write a general statement about the relationship between the mass and number of rubber bands used and the distance the Newton Car travels.
Newton Car Experiment Report

<table>
<thead>
<tr>
<th>Test</th>
<th>Mass of Bottle</th>
<th>Number of Rubber Bands</th>
<th>Distance Car Traveled</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
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<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Team Members: ____________________

____________________

____________________

Did the number of rubber bands affect how far the Newton Car moved? Describe what happened.

____________________

____________________

Did the mass of the bottle affect how far the Newton Car moved? Describe what happened.

____________________

____________________

Construct a bar graph showing how far the Newton Car moved for each test.

![Bar Graph](image)

On the back of this page write a short statement explaining the relationship between the amount of mass in the bottle, the number of rubber bands used, and the distance the Newton Car traveled.
**Rocket Activity**

3...2...1...*PUFF!*

**Objective**
Students will learn about rocket stability as they construct and fly small paper rockets.

**Description**
Students will construct small “indoor” paper rockets, determine their flight stability, and launch them by blowing air through a drinking straw.

**Materials**
- Sheet of 8.5 x 11 paper (white or colored)
- Cellophane tape
- Scissors
- Ruler
- Meter stick or tape measure
- Fat, round pencil or dowel (see tips, p. 43)
- Eye protection
- Drinking straws
- Copy of the SLS paper rocket plans

**Management**
Hold on to the straws until students have completed their rockets and tested them for stability. Select a clear space for the launches. Depending upon student lung power, rockets may fly 7-10 meters. Be sure students wear eye protection. Although the rockets have little mass, pointed nose cones could injure eyes. Make sure students understand that the rockets are not to be launched toward anyone.

**Background**
Rocket stability is an important issue for rocket scientists. The success of a space launch depends upon “pinpoint” accuracy. If a future NASA Space Launch System rocket arrives in space in the wrong orbit, it may not have enough fuel or supplies to make rendezvousing with the International Space Station or an asteroid possible. The crew would have to return to Earth and “chalk off” a failed mission.
Stability means making sure the rocket follows a smooth path in flight. If it wobbles, the ride will be rough and extra fuel will be burned to get back on course. If it tumbles, it's time to push the destruct button! An unstable rocket is dangerous.

Fortunately, it is relatively easy to ensure stability when traveling through the atmosphere if two things are kept in mind. These two things are center of mass and center of pressure.

Center of mass (COM) is easy to demonstrate. It is the balance point of a rocket. Think of it like balancing a meter stick on an outstretched finger. If the stick rests horizontally, the COM is directly over your finger. If the COM is to the right of your finger, the stick will tip to the right. If to the left of your finger, the stick will tip to the left.

An object, tossed into the air, rotates around its COM. Rockets also try to rotate around their COM while in flight. If this rotation is allowed to happen, the rocket becomes unstable. This is where center of pressure (COP) comes to the rescue.

COP is also a balance point. It is the balance point of the pressure exerted on the rocket surface by air molecules striking it as it flies through the air. Like COM, there is a midpoint for the air pressure on the rocket body. This is the COP. For a stable rocket, the COP is located to the rear of the rocket and the COM is to the front. To understand why the rocket is stable, let's take a look at a couple of devices that also depend upon the placement of COM and COP.

A weather vane pivots on a vertical axle (COM) when the wind blows. One end of the vane is pointed and the other end has a broad surface. When the wind blows, the broad end of the vane catches more air (more air pressure) and is blown downwind. The narrow end of the vane has less pressure exerted on it and points into the wind.

One end of an arrow is long, narrow, and pointed while the other end has large feathers (or plastic fins). In flight, greater air pressure is exerted on the feathers than on the narrow end. This keeps the arrow from tumbling around its COM and on course to its target.

In both examples, there was more surface area on one side of the COM than on the other. Both devices were stable. Stability of a rocket is the same thing.

In this activity, students will build paper rockets and test them for stability using a drop test. Later activities will further explore the COM/COP concept and employ an advanced string test for rocket stability.

The positions of center of mass (red dot) and center of pressure (blue +) are shown for a weather vane, arrow, and rocket. The center of pressure is to the rear of the center of mass in each device. This enables them to point into the wind.

**Procedure First Activity**

1. Demonstrate the construction technique for making paper rockets. (Refer to the diagrams on the next page.)
   a. Cut a strip of paper for the rocket body (about 4 cm wide by 28 cm long).
   b. Use a round pencil as a form and roll the strip around the pencil.
   c. Tape the long seam.
   d. Close off one end to make a nose cone.
   e. Cut out three or four fins.
   f. Tape the fins to the open (lower) end of the rocket. Bend them outward to space them equally.

2. After students have constructed their rockets, show them how to perform drop tests to check for stability. Hold the rocket horizontally at eye level and drop it to the floor. If the nose of the rocket hits the floor first, the rocket is stable and ready for flight. If the rocket falls horizontally or the fin end hits first, the rocket is unstable. Larger fins may be needed to stabilize the rocket. Have
students perform their own stability tests and make adjustments to their rockets if needed.

3. Finally, demonstrate the launch procedure for the rocket. Stand at one end of your launch range. Insert a straw into the rocket body. Aim the rocket down range and puff strongly into the straw. Liftoff!

4. Talk over ideas for safety. Discuss wearing safety glasses. Ask students what should be done when they retrieve their rockets for another launch. (Other students should wait until the range is clear before launching.)

5. Have students improve their rocket design by holding distance trials. Students will launch their rocket three times and find the average distance the rocket travels. They will then try to improve their rocket design to get greater distance. The student data sheets outline the procedures and provide space to jot down and analyze data.

Making and Attaching Fins

Cut tabs and spread. Tape tabs to rocket tube.

Procedure  Second Activity
1. Give students SLS rocket patterns to assemble. Two different patterns are provided, one for thin pencils or dowels and one for fat pencils and dowels. (These rockets do not have any fins. The actual SLS rocket uses steerable rocket engines to keep the rocket stable in flight.) After forming the rocket body, the upper end of the tube is folded four times and taped.
2. Before flying these rockets, have students repeat the stability drop test.

Discussion
- **Why is the SLS rocket stable even though it doesn’t have any fins?**
  Folding the paper makes the nose cone end of the rocket heavier than the tail end. Run a balance test with a finger. The balance point (center of mass) is far forward. The center of pressure is to the rear. This combination stabilizes the rocket for flight. The stability control for the paper version of the SLS rocket is similar to the control used by the Chinese for their fire arrows (See pictorial history section.) The actual SLS rocket will employ steerable engines to maintain stability.
- **How do paper rockets work?**
  Unlike traditional rockets, paper rockets do not carry their own propellants. Instead, a sharp puff through the straw momentarily fills the rocket tube with “high pressure” air. The tube directs the air back through the opening, producing an action force. The rocket launches because of the equal and opposite reaction force (Newton’s third law).

Assessment
- Have students write and illustrate a paragraph that describes their improvements to their rockets and how these improvements affected their experimental results.

Extensions
- Have students investigate fin size and placement for its effect on flight stability.

Tip  Segments of a 1/4” or 3/8” dowel can be substituted for fat pencils. Cut the dowels slightly longer than the paper strips. The extra length makes rolling the tubes easier.

Completed SLS rocket
1. Launch your rocket three times at the same launch angle. Each time, measure how far it flew. Record your measurements in the data sheet below under the space labeled “Rocket 1.” Calculate the average distance for the three flights.

2. What can you do to improve the distance your rocket travels? Can you think of any improvement for your rocket? Design and build a new rocket. Predict how far it will fly. Record your answer below in the space labeled “Rocket 2.” Launch your second rocket three times and measure its distance. Record your data below. What is the difference between your predicted and actual distance? Did Rocket 2 fly farther than Rocket 1? Write your answers below.

3. Did your changes in the rocket improve its flight? Design and build a third rocket. Fly it the same way you did for Rockets 1 and 2. Did Rocket 3 fly farther than Rocket 2?

4. On the back of this paper, write a short paragraph describing the improvements you made to your rockets, how well they flew, and what you can conclude from your experiments. Draw pictures to illustrate how each rocket looked.

<table>
<thead>
<tr>
<th>ROCKET 1</th>
<th>Flight Distance (in cm)</th>
<th>Make notes about the flights here.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flight 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flight 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flight 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average Distance</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ROCKET 2</th>
<th>Flight Distance (in cm)</th>
<th>Make notes about the flights here.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance Prediction</td>
<td>Flight 1</td>
<td></td>
</tr>
<tr>
<td>Difference between your prediction and the average flight distance</td>
<td>Flight 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flight 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average Distance</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ROCKET 3</th>
<th>Flight Distance (in cm)</th>
<th>Make notes about the flights here.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance Prediction</td>
<td>Flight 1</td>
<td></td>
</tr>
<tr>
<td>Difference between your prediction and the average flight distance</td>
<td>Flight 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flight 3</td>
<td></td>
</tr>
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<td>Average Distance</td>
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</table>
Impact Craters

Purpose
To determine the factors affecting the appearance of impact craters and ejecta.

Background [also see “Teacher's Guide” Pages 1, 2, photo on 8, 12, and photo on 13]

The circular features so obvious on the Moon’s surface are impact craters formed when impactors smashed into the surface. The explosion and excavation of materials at the impacted site created piles of rock (called ejecta) around the circular hole as well as bright streaks of target material (called rays) thrown for great distances.

Two basic methods forming craters in nature are:
1) impact of a projectile on the surface and 2) collapse of the top of a volcano creating a crater termed caldera. By studying all types of craters on Earth and by creating impact craters in experimental laboratories geologists concluded that the Moon's craters are impact in origin.

The factors affecting the appearance of impact craters and ejecta are the size and velocity of the impactor, and the geology of the target surface.

By recording the number, size, and extent of erosion of craters, lunar geologists can determine the ages of different surface units on the Moon and can piece together the geologic history. This technique works because older surfaces are exposed to impacting meteorites for a longer period of time than are younger surfaces.

Impact craters are not unique to the Moon. They are found on all the terrestrial planets and on many moons of the outer planets.

On Earth, impact craters are not as easily recognized because of weathering and erosion. Famous impact craters on Earth are Meteor Crater in Arizona, U.S.A.; Manicouagan in Quebec, Canada; Sudbury in Ontario, Canada; Ries Crater in Germany, and Chicxulub on the Yucatan coast in Mexico. Chicxulub is considered by most scientists as the source crater of the catastrophe that led to the extinction of the dinosaurs at the end of the Cretaceous period. An interesting fact about the Chicxulub crater is that you cannot see it. Its circular structure is nearly a kilometer below the surface and was originally identified from magnetic and gravity data.
Aristarchus

Typical characteristics of a lunar impact crater are labeled on this photograph of Aristarchus, 42 km in diameter, located West of Mare Imbrium.

- **Raised rim** - rock thrown out of the crater and deposited as a ring-shaped pile of debris at the crater’s edge during the explosion and excavation of an impact event.

- **Floor** - bowl shaped or flat, characteristically below surrounding ground level unless filled in with lava.

- **Central uplifts** - mountains formed because of the huge increase and rapid decrease in pressure during the impact event. They occur only in the center of craters that are larger than 40 km diameter. See Tycho crater for another example.

- **Walls** - characteristically steep and may have giant stairs called terraces.

- **Ejecta** - blanket of material surrounding the crater that was excavated during the impact event. Ejecta becomes thinner away from the crater.

- **Rays** - bright streaks starting from a crater and extending away for great distances. See Copernicus crater for another example.
Impact Craters

Preparation

Review and prepare materials listed on the student sheet.
In this activity, marbles or other spheres such as steel shot, ball bearings, golf, or wooden
balls are used as impactors dropped from a series of heights onto a prepared “lunar sur-
face.” Using impactors of different mass dropped from the same height will allow stu-
dents to study the relationship of mass of the impactor to crater size. Dropping impactors
from different heights will allow students to study the relationship of velocity of the
impactor to crater size.

The following materials work well as a base for the “lunar surface” topped with a dust-
ing of dry tempera paint or other material in a contrasting color:

- all purpose flour - Reusable in this activity and keeps well in a covered container.
- baking soda - It can be recycled for use in the lava layer activity or for many
  other science activities. Reusable in this activity, even if col-
  ored, by adding a clean layer of new white baking soda on
  top. Keeps indefinitely in a covered container. Baking soda
  mixed (1:1) with table salt also works.
- corn meal - Reusable in this activity but probably not recyclable. Keep
  only in freezer in airtight container.
- sand and corn starch - Mixed (1:1), sand must be very dry. Keeps only in freezer in
  airtight container.
- dry tempera paint or powdered drink mixes or glitter - Sift on top; use a sieve, screen, or flour sifter. A contrasting
  color to the base materials gives striking results.

Pans should be plastic, aluminum, or cardboard. Do not use glass. They should be at
least 7.5 cm deep. Basic 10"x12" aluminum pans or plastic tubs work fine, but the
larger the better to avoid misses. Also, a larger pan may allow students to drop more
marbles before having to resurface the target materials.

A reproducible student “Data Chart” is included; students will need a separate chart for
each impactor used in the activity.
**In Class**

1. Begin by looking at craters in photographs of the Moon and asking students their ideas of how craters formed.

2. During this activity, the flour, baking soda, or dry paint may fall onto the floor and the baking soda may even be disbursed into the air. Spread newspapers under the pan(s) to catch spills or consider doing the activity outside. Under supervision, students have successfully dropped marbles from second-story balconies. Resurface the pan before a high drop.

3. Have the students agree beforehand on the method they will use to “smooth” and resurface the material in the pan between impacts. The material need not be packed down. Shaking or tilting the pan back and forth produces a smooth surface. Then be sure to reapply a fresh dusting of dry tempera paint or other material. Remind students that better experimental control is achieved with consistent handling of the materials. For instance, cratering results may vary if the material is packed down for some trials and not for others.

4. Allow some practice time for dropping marbles and resurfacing the materials in the pan before actually recording data.

5. Because of the low velocity of the marbles compared with the velocity of real impactors, the experimental impact craters may not have raised rims. Central uplifts and terraced walls will be absent.

6. The higher the drop height, the greater the velocity of the marble, so a larger crater will be made and the ejecta will spread out farther.

7. If the impactor were dropped from 6 meters, then the crater would be larger. The students need to extrapolate the graph out far enough to read the predicted crater diameter.

**Wrap-Up**

Have the class compare and contrast their hypotheses on what things affect the appearance of craters and ejecta.
Extensions

1. As a grand finale for your students, demonstrate a more forceful impact using a slingshot.

2. What would happen if you change the angle of impact? How could this be tested? Try it! Do the results support your hypothesis?

   If the angle of impact is changed, then the rays will be concentrated and longer in the direction of impact. A more horizontal impact angle produces a more skewed crater shape.

3. To focus attention on the rays produced during an impact, place a paper bulls-eye target with a central hole on top of a large, flour-filled pan. Students drop a marble through the hole to measure ray lengths and orientations.

4. Use plaster of Paris or wet sand instead of dry materials.

5. Videotape the activity.

6. Some people think the extinction of the dinosaurs was caused by massive global climate changes because of a meteorite impact on Earth. Summarize the exciting work that has been done at Chicxulub on the Yucatan coast of Mexico.

7. Some people think Earth was hit by an object the size of Mars that caused a large part of Earth to “splash” into space, forming the Moon. Do you agree or disagree? Explain your answer.

8. Physics students could calculate the velocities of the impactors from various heights. (Answers from heights of 30 cm, 60 cm, 90 cm, and 2 m should, of course, agree with the velocity values shown on the “Impact Craters - Data Chart”.)
## Impact Craters - Data Chart

<table>
<thead>
<tr>
<th>Impactor #</th>
<th>gm</th>
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<tr>
<td>drop height = 30 cm</td>
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<tr>
<td>velocity = 242 cm/s</td>
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<tr>
<td>crater diameter</td>
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</tr>
<tr>
<td>crater depth</td>
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<tr>
<td>average length of all rays</td>
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<tr>
<td>drop height = 60 cm</td>
<td></td>
</tr>
<tr>
<td>velocity = 343 cm/s</td>
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</tr>
<tr>
<td>crater diameter</td>
<td></td>
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<tr>
<td>crater depth</td>
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<td>average length of all rays</td>
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<tr>
<td>drop height = 90 cm</td>
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</tr>
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<td>average length of all rays</td>
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</table>

<table>
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<th>total</th>
<th>average</th>
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<td>crater diameter</td>
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<td>average length of all rays</td>
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<td>average length of all rays</td>
<td>average length of all rays</td>
</tr>
</tbody>
</table>
### Impact Craters

**Key Words**
- impact
- impactor
- ejecta

**Procedure**

**Making an hypothesis**

1. After looking at photographs of the Moon, how do you think the craters were formed?

   ___________________________

   ___________________________

   ___________________________

2. What do you think are factors that affect the appearance and size of craters and ejecta?

   ___________________________

   ___________________________

   ___________________________

**Preparing a “lunar” test surface**

1. Fill a **pan** with **surface material** to a depth of about 2.5 cm. Smooth the surface, then tap the pan to make the materials settle evenly.

2. Sprinkle a fine layer of **dry tempera paint** evenly and completely over the surface. Use a **sieve** or **sifter** for more uniform layering.

**Materials**

- 1 pan
- “lunar” surface material
- tempera paint, dry
- sieve or sifter
- balance
- 3 impactors (marbles or other spheres)
- meter stick
- ruler, plastic with middle depression
- protractor
- “Data Chart” for each impactor
- graph paper
Impact Craters

3. What does this “lunar” surface look like before testing?

Cratering Process

1. Use the balance to measure the mass of each impactor. Record the mass on the “Data Chart” for this impactor.

2. Drop impactor #1 from a height of 30 cm onto the prepared surface.

3. Measure the diameter and depth of the resulting crater.

4. Note the presence of ejecta (rays). Count the rays, measure, and determine the average length of all the rays.

5. Record measurements and any other observations you have about the appearance of the crater on the Data Chart. Make three trials and compute the average values.

6. Repeat steps 2 through 5 for impactor #1, increasing the drop heights to 60 cm, 90 cm, and 2 meters. Complete the Data Chart for this impactor. Note that the higher the drop height, the faster the impactor hits the surface.

7. Now repeat steps 1 through 6 for two more impactors. Use a separate Data Chart for each impactor.

8. Graph your results.
   Graph #1: Average crater diameter vs. impactor height or velocity.
   Graph #2: Average ejecta (ray) length vs. impactor height or velocity.
   Note: on the graphs, use different symbols (e.g., dot, triangle, plus, etc.) for different impactors.
Results

1. Is your hypothesis about what affects the appearance and size of craters supported by test data? Explain why or why not.

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

2. What do the data reveal about the relationship between crater size and velocity of impactor?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

3. What do the data reveal about the relationship between ejecta (ray) length and velocity of impactor?

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

4. If the impactor were dropped from 6 meters, would the crater be larger or smaller? How much larger or smaller? (Note: the velocity of the impactor would be 1,084 cm/s.) Explain your answer.

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________

5. Based on the experimental data, describe the appearance of an impact crater.

____________________________________________________________________

____________________________________________________________________

____________________________________________________________________
6. The size of a crater made during an impact depends not only on the mass and velocity of the impactor, but also on the amount of kinetic energy possessed by the impacting object. Kinetic energy, energy in motion, is described as:

\[ KE = \frac{1}{2}(mv^2) \]

where, \( m \) = mass and \( v \) = velocity.
During impact, the kinetic energy of an asteroid is transferred to the target surface, breaking up rock and moving the particles around.

7. How does the kinetic energy of an impacting object relate to crater diameter?

8. Looking at the results in your Data Tables, which is the most important factor controlling the kinetic energy of a projectile, its diameter, its mass, or its velocity?

9. Does this make sense? How do your results compare to the kinetic energy equation?

10. Try plotting crater diameter vs. kinetic energy as Graph #3. The product of mass (in gm) and velocity (in cm/s) squared is a new unit called “erg.”
Activities—Designing Spacesuits for Mars

Technology Education, Science, and Mathematics
Introduction:

The steps spacesuit engineers and technicians followed in achieving a goal of creating reliable spacesuit systems for exploration of the surface of the Moon and for construction and maintenance work in Earth orbit were the same as those used in nearly every technological endeavor:

Challenge
Design and construct a protective garment that will permit humans to venture safely into outer space and perform work.

Research
Investigate the environment in which the garment will be worn and determine what protective measures must be employed.

Management
Organize the effort into teams that design suit subsystems and investigate and select appropriate materials and technologies.

Fabricate Prototypes
Construct and assemble suit subsystems into the completed garment.

Evaluate
Test the garment in a simulated space environment and make modifications where needed.

Manufacture
Construct operational spacesuits.

Ongoing Evaluation
Continue refining spacesuit subsystems to improve efficiency, reliability, versatility, and safety while lowering costs.

The pages that follow outline a multifaceted technology education activity on spacesuits. This activity, designed for an entire class to work on as a team, combines skills and content from science, mathematics, and technology. The challenge is to design and build a full-scale wearable model spacesuit to be used to explore the surface of Mars. Since no human expeditions to Mars are planned for many years, actual Martian spacesuits have not yet been built and there are no “right” answers. Consequently, this activity permits students to participate in “leading edge” research.

The overview of the activity is contained in a Design Brief format. It begins with a title and a context statement (introduction) and is followed by a challenge to create a Martian spacesuit. This is followed by information on materials, equipment, procedures, and evaluation. The success of the activity depends upon how well the students organize their work and communicate with each other. A computer with project software can be used to monitor the progress of the project or a flow chart can be constructed on a chalk or bulletin board. As an added aid to communication, Interface Control Documents (ICD) are created as systems are designed. (Reproducible master on page 49. Sample
If desired, the project can be divided among several classes (or even several schools) which will each have to work together. This is the way major NASA projects are divided between contractors and subcontractors located across the country.

To support the activity, a collection of Teacher Tech Briefs (TTB) are included. These briefs provide suggestions for your use when guiding students in accomplishing their tasks. For example, if student teams conclude that high-speed particles (micrometeoroids) are a problem in the Martian environment, plans are provided for a device that measures impact damage to materials. TTBs are not intended as “blueprints” for students to use. Rather, they provide information on one of many ways in which the task can be accomplished. Students will build an impact test stand of their own design. TTBs aid you in facilitating the students’ ideas. Following the TTBs is a section on spacesuit testing apparatus used at the NASA Johnson Space Center. The apparatus are “one of a kind” devices created by following the same design process students will use.

Exploration Briefs (EBs) are suggestions for activities that can be used to help students understand the nature of the environment for which they are designing a spacesuit. They provide background information and instructions for simple demonstrations and experiments that may be tried. A “bank” of additional ideas follow the EBs.

The guide concludes with appendices that list resources, such as NASA publications and Internet web sites, where students can obtain more information to help them in their research and development work.
Design Brief

Context:
Spacesuits are one of the important enabling technologies that have permitted humans to explore outer space. To survive the hostile environment, humans had to be covered with a protective shell as they exited their spacecraft. This shell contained a part of Earth's surface environment while remaining flexible and impervious to the unique hazards, such as high-speed particle impacts, encountered there. These requirements meant that engineers and technicians had to spend long hours investigating and selecting appropriate materials, finding ways of fabricating and joining suit parts together, and providing operating pressure, power, and communications while assembling a garment that was tough but flexible. The task was achieved with such great success that astronauts and cosmonauts have safely conducted thousands of hours of extravehicular activity.

Challenge:
Design and build a protective garment that will permit future space travelers to explore the surface of Mars. The garment must protect the person inside from the hazards of the Martian environment while remaining comfortable to wear. Excursions on the surface will nominally last 8 hours, but the garment will have to function as long as 10 hours in emergency situations. The garment must be flexible enough to enable the wearer to walk up to 10 kilometers, collect geologic samples, and operate a variety of tools and experimental apparatus. Furthermore, the garment's design must be rugged enough to permit repeated use and be able to be serviced simply and quickly. Along with the garment, design a collection of geologic sampling tools, such as rock hammers, and a general set of tools for assembly and repair activities. These tools should be easy to use while wearing the protective garment, be safe and rugged, and interface with a general purpose tool carrier that must also be designed.

Procedures:
Select subcontractor teams to design and construct each of the garment's components, such as the helmet or gloves. Teams will coordinate their work with each other as materials for and sizes of the components are selected.

Materials:
Use whatever materials you find to construct the garment's components. Test these materials to ensure they will survive the Martian environment. Existing tools can be modified for use on Mars.

Evaluation:
Conduct periodic team evaluations of the progress of the garment and tool design process. When all components are completed, integrate them for a full test in a simulated Martian environment. Evaluate the garment and tools on the basis of the criteria presented in the context section.
Briefly explain how this system functions.
Interface Control Document

System Name: Space Helmet

Project No. 8

Date: Nov. 22, 1997

Rev. No. 4

Team Members

Page 1 Of 1

The helmet seals off the top of the suit. It has a window for looking out and a sun visor. The neck ring connects to the shoulders of the suit.

Interface Control Documents are a communication tool that helps the various Martian Surface Exploration Suit design teams to coordinate with each other. This sample shows a design for a space helmet. The team working on the upper torso will learn from this document how large the connection with the helmet has to be.
Rocket Activity

Foam Rocket

Objective
Students will learn about rocket stability and trajectory with rubber band-powered foam rockets.

Description
Students will construct rockets made from pipe insulating foam and use them to investigate the trajectory relationship between launch angle and range in a controlled investigation.

Materials
- 30 cm-long piece of polyethylene foam pipe insulation (for 1/2” size pipe)
- Rubber band (size 64)
- Styrofoam food tray, cardboard, or stiff posterboard
- Duct tape
- Scissors
- Meter stick
- Press tack
- Washer or nut
- Quadrant plans printed on card stock
- Rocket construction instructions
- Experiment data sheet
- Masking tape
- Launch record sheet
- Eye protection
- For class - tape measure

Management
Select a large room with a high ceiling for the launch range, such as a cafeteria or gymnasium. Place markers on the floor at 1 meter intervals starting at 5 meters and going to 20 meters. If it is a calm day, the investigation can be conducted outside. Although the rockets can be launched outside on windy days, the wind becomes an uncontrolled variable that may invalidate the results. Prepare some sample rocket fins to show how they are constructed. Refer to the construction instructions.
page for details. Before conducting the investigation, review the concept of control. In this investigation, control will be how much the rubber band is stretched when launching the rockets. The experimental variable will be the angle of launch. Students will compare the launch angle with the distance the rocket travels. Organize students into teams of three. One student is the launcher. The second student confirms the launch angle and gives the launch command. The third student measures the launch distance, records it, and returns the rocket to the launch site for the next flight. The experiment is repeated twice more with students switching roles. The distances flown will be averaged. Teams will try different angles and determine what the best launch angle should be to obtain the greatest distance from the launch site.

**Background**
The foam rocket flies ballistically. It receives its entire thrust from the force produced by the elastic rubber band. The rubber band is stretched. When the rocket is released, the rubber band quickly returns to its original length, launching the foam rocket in the process. Technically, the foam rocket is a rocket in appearance only. The thrust of real rockets typically continues for several seconds or minutes, causing continuous acceleration, until propellants are exhausted. The foam rocket gets a quick pull and then coasts. Furthermore, the mass of the foam rocket doesn't change in flight. Real rockets consume propellants and their total mass diminishes. Nevertheless, the flight of a foam rocket is similar to that of real rockets. Its motion and course is affected by gravity and by drag or friction with the atmosphere. The ability to fly foam rockets repeatedly (without refueling) makes them ideal for classroom investigations on rocket motion.

The launch of a foam rocket is a good demonstration of Newton's third law of motion. The contraction of the rubber band produces an action force that propels the rocket forward while exerting an opposite and equal force on the launcher. In this activity, the launcher is a meter stick held by the student.

| Tip | Be sure the range-measuring student measures where the rocket touches down and not where the rocket ends up after sliding or bouncing along the floor. |

In flight, foam rockets are stabilized by their fins. The fins, like feathers on an arrow, keep the rocket pointed in the desired direction. If launched straight up, the foam rocket will climb until its momentum is overcome by gravity and air drag. At the very top of the flight the rocket momentarily becomes unstable. It flops over as the fins catch air. The rocket becomes stable again when it falls back to the ground.

When the foam rocket is launched at an angle of less than 90 degrees, its path is an arc whose shape is determined by the launch angle. For high launch angles, the arc is steep, and for low angles, it is broad.

When launching a ballistic rocket straight up (neglecting air currents) the rocket will fall straight back to its launch site when its upward motion stops. If the rocket is launched at an angle of less than 90 degrees, it will land at some distance from the launch site. How far away from the launch site is dependent on four things. These are:

- gravity
- launch angle
- initial velocity
- atmospheric drag

Gravity causes the foam rocket to decelerate as it climbs upward and then causes it to accelerate as it falls back to the ground. The launch angle works with gravity to shape the flight path. Initial velocity and drag affects the flight time.

In the investigation, students will compare the launch angle to the range or distance the foam rocket lands from the launch site. Launch angle is the independent variable. Gravity can be ignored because the acceleration of gravity will remain the same for all flight tests. Atmospheric drag can also be ignored because the same rocket will be
flown repeatedly. Although students will not know the initial velocity, they will control for it by stretching the rubber band the same amount for each flight. The dependent variable in the experiment is the distance the rocket travels.

Assuming student teams are careful in their control of launch angles and in the stretching of the launch band, they will observe that their farthest flights will come from launches with an angle of 45 degrees. They will also observe that launches of 30 degrees, for example, will produce the same range as launches of 60 degrees. Twenty degrees will produce the same result as 70 degrees, etc. (Note: Range distances will not be exact because of slight differences in launching even when teams are very careful to be consistent. However, repeated launches can be averaged so that the ranges more closely agree with the illustration.

**Procedures** Constructing a Foam Rocket
1. Using scissors, cut one 30-cm length of pipe foam for each team.
2. Cut four equally spaced slits at one end of the tube. The slits should be about 12 cm long. The fins will be mounted through these slits.
3. Cut a 12 cm length of duct tape down the middle to make two pieces. Place one piece over the other, sticky to shiny side, to make the tape double-strong.
4. Slip a rubber band over the tape and press the tape around the nose end of the rocket (opposite the end with the slits). Press the tape tightly and reinforce it with another length of tape wrapped around the tube.
5. Cut fin pairs from the foam food tray or stiff cardboard. Refer to the fin diagram. Both fin pairs should be notched so that they can be slid together as shown in the diagram. Different fin shapes can be used, but they should still “nest” together.
6. Slide the nested fins into the slits cut in the rear end of the rocket. Close off the slits with a piece of duct tape wrapped around the foam tube. The rocket is finished.

**Procedure** Making the Launcher
1. Print the quadrant pattern (page 78) on card stock paper.
2. Cut out the pattern and fold it on the dashed line.
3. Tape the quadrant to the meter stick so that the black dot lies directly over the 60 cm mark on the stick.
4. Press a push tack into the black dot.
5. Tie a string to the push tack and hang a small weight, such as a nut or a washer, on the string. The weight should swing freely.
6. Refer to the diagram to see how the launcher is used.

**Discussion**
- Why didn’t the experiment protocol call for launching at 0 and 90 degrees?
  Assuming a perfect launch, a rocket launched straight upwards should return to the launch pad. Any variation in the impact site will be due to air currents and not to the launch angle. A rocket launched horizontally will travel only as long as the time it takes to drop to the floor.

- Shouldn’t the rocket be launched from the floor for the experiment?
  Yes. However, it is awkward to do so. Furthermore, student teams will be measuring the total distance the rocket travels, and
consistently launching from above the floor will not significantly affect the outcome.

**Assessment**
- Have student teams submit their completed data sheets with conclusions.
- Have students write about potential practical uses for the foam rocket (e.g., delivering messages).

**Using the Launcher**

Loop the rubber band over the launcher end. Pull on the fin end of the rocket until the nose cone is aligned with the 30 cm mark. Tilt the launcher up at the chosen angle as indicated with the string and weight on the quadrant. Launch the rocket!

Launch ready for a 45-degree angle launch.

Cut slots the same width as the thickness of the fin stock.

Nest fins together.

Different fin shapes can be used.
Extensions

• For advanced students, the following equation can be used for estimating range assuming level ground and no air resistance.

\[
\text{Range} = \frac{V_0^2 \sin 2\alpha}{g}
\]

\[V_0 = \text{Initial Velocity}\]
\[g = 9.8 \text{ meters/second}^2\]
\[\alpha = \text{Launch Angle}\]

\((g \text{ is the acceleration of gravity on Earth})\)

Students will have to determine initial velocity. If available, an electronic photogate (science lab probeware) with timer can be used for determining the initial velocity. Otherwise, challenge students to devise a method for estimating initial velocity. One approach might be to launch the rocket horizontally from a tabletop and measure the horizontal distance the rocket travels as it falls to the floor. Using a stopwatch, measure the time the rocket takes to reach the floor. If the rocket takes 0.25 seconds to reach the floor and traveled 3 meters horizontally while doing so, multiply 3 meters by 4. The initial velocity will be 12 meters per second. Students should repeat the measurement several times and average the data to improve their accuracy. (This method assumes no slowing of the rocket in flight due to air drag.)

• Different kinds of fins can be constructed for the foam rocket. Try creating a space shuttle orbiter or a future rocket plane for exploring the atmosphere of other planets.
Build a Foam Rocket

1. Cut four slits 12 cm long 90 degrees apart.

2. Cut 12 cm strip of duct tape in half lengthwise. Place one strip on top of other.

3. Tape launcher rubber band to nose end of rocket.

4. Add tape strip around the nose to strengthen the attachment.

5. Cut out fins with notches.

6. Slide fins together.

7. Slide fins into slits.

8. Close fin slits with narrow strip of duct tape.

Ready for flight!
Launcher Quadrant Pattern
(Actual Size)

Fold on dashed line. Lay fold on upper edge of meter stick and wrap paper around to the other side. The black dot of the protractor should be placed on the 60 cm mark of the stick. Tape ends to hold protractor in place.
Rocket Range Experiment

Team Member __________________________

Names: __________________________

1. Assign duties for your team. You will need the following positions:
   Launch Director, Launcher, and Range Officer. (Team members will switch jobs later.)

2. First Launch:
   **Launcher** - Attach the rocket to the launcher and pull back on string until its tail reaches the
   60-cm mark. Tilt the launcher until it is pointing upwards at a angle of between 10 and 80
   degrees. Release the rocket when the launch command is given.
   **Launch Director** - Record the angle on the data table. Give the launch command. Record the
   distance the rocket travels.
   **Range Officer** - Measure the distance from the launcher to where the rocket hits the floor (not
   where it slides or bounces to). Report the distance to the launch director and return the rocket
   to the launcher for the next launch.

3. Repeat the launch procedures four more times but with a different angle (between 10 and 80
   degrees) each time.

4. Run the entire experiment twice more but switch jobs each time. Use the same launch angles
   used for the first set of launches.

5. Compare your data for the three experiments.

   **Data Table 1**
   
<table>
<thead>
<tr>
<th>Launch Angle</th>
<th>Distance</th>
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   **Data Table 2**

<table>
<thead>
<tr>
<th>Launch Angle</th>
<th>Distance</th>
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   **Data Table 3**

<table>
<thead>
<tr>
<th>Launch Angle</th>
<th>Distance</th>
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</table>

   From your data, what launch angle should you use to achieve the greatest distance from the
   launch site? Test your conclusion.

Why didn’t the instructions ask you to test for 0 and 90 degrees?
LAUNCHING TO THE MOON AND BEYOND

www.nasa.gov
Ares V Rocket

Color the Ares V rocket and Altair lunar lander.
Ares I Rocket

Color the Ares I rocket and Orion crew vehicle.
Moon Maze!

Help the Altair lunar lander find the Orion crew vehicle.
Connect the Dots

Draw the Ares V rocket by using the numbered dots.
Outta This World Word Search

Locate the words from the list in the jumble below.

ALTAIR  ENGINE  MOON
ARES    ENGINEER  NASA
ASTRONAUT  EXPLORATION  ORION
CARGO    FLIGHT  ROCKET
CONSTELLATION  LAUNCH  SCIENCE
CREW     MARS  SPACE
EARTH    MISSION  TECHNOLOGY
Ares I Cut-Out

Cut-out the pieces to create an Ares I rocket.

Here is a hint!
It should look like this when you are done!
The Challenge

Design and build a shock-absorbing system that will protect two “astronauts” when they land.

In this challenge, kids follow the engineering design process to: (1) design and build a shock-absorbing system out of paper, straws, and mini-marshmallows; (2) attach their shock absorber to a cardboard platform; and (3) improve their design based on testing results.

1 Prepare ahead of time
   - Read the challenge sheet and leader notes to become familiar with the activity.
   - Gather the materials listed on the challenge sheet.
   - Fold an index card into a spring (see illustration).

2 Introduce the challenge (5 minutes)
   - Tell kids why a spacecraft that can land gently is important for getting astronauts to and from the moon safely.

   NASA is looking for safe landing sites on the moon. Once they find one, they need to design and build a spacecraft that can land there without injuring astronauts or damaging the spacecraft. Today you’ll make a lander—a spacecraft that can land safely when you drop it on the floor. As you test, you’ll find ways to make it work better. Improving a design based on testing is called the engineering design process.

   - Show kids the spring made out of an index card.

   When you jump off a high step, you bend your back and knees to absorb some of the energy and break your fall. That’s what a shock absorber does—absorbs the energy of an impact. Soft things, like marshmallows, cotton balls, foam, and bubble wrap absorb shock well. You can also use paper, like this index card made into a spring by folding it like an accordion.

3 Brainstorm and design (10 minutes)

Distribute the challenge sheet. Discuss the questions in the Brainstorm and Design section.

   - What kind of shock absorber can you make from these materials to help soften a landing? (Mini-marshmallows can serve as soft footpads. Cards can be folded into springs. Straws can provide a flexible structure. Rubber bands can flex and hold things together.)

   - How will you make sure the lander doesn’t tip over as it falls through the air? (Making the parts below the platform weigh more than the parts on the top helps the lander fall straight down. Also, it helps to evenly distribute the weight on top of the platform.)

4 Build, test, evaluate, and redesign (35 minutes)

Help kids with any of the following issues. For example, if the lander:

   - tips over when it drops—Move the cup slightly away from the side that’s tipping. Or, reposition the parts of the shock-absorbing system to better balance the weight.
bounces instead of landing softly—Change the size, position, or the number of shock-absorbing parts. Kids can also add mini-marshmallows for landing-pad feet. Or, they can use marshmallows at key junctions in the lander’s frame to help absorb energy.

Discuss what happened (10 minutes)

Have the kids show each other their landers and talk about how they solved any problems that came up. Emphasize the key ideas in today’s challenge by asking:

- What forces affected your lander as it fell? (It accelerated [sped up] as it fell due to the pull of gravity. Air also pushed on it, and this air resistance slowed it down.)
- After testing, what changes did you make to your lander? (Answers will vary.)
- Engineers’ early ideas rarely work out perfectly. How does testing help them improve a design? (Testing helps you see what works and what doesn’t. Knowing this lets you improve a design by fixing the things that aren’t working well or could work even better.)
- What did you learn from watching others test their landers? (Answers will vary. But in general, kids will see that there are many ways to successfully tackle a challenge.)
- The moon is covered in a thick layer of fine dust. How might this be an advantage? A disadvantage? (If the dust layer is soft, it would help cushion a landing. However, if it is too soft, a lander could sink into it and get stuck. Also, the lander’s rocket engine could send up clouds of dust, which could get into the machinery and cause it to jam or malfunction.)

EXTEND THE CHALLENGE

- Hold a “How High Can You Go?” contest. Have kids drop their landers from two feet. Eliminate all landers that bounce out their “astronauts.” Next, raise the height to three feet. Continue in this fashion until a winner emerges. You can also increase the challenge by having kids add a third marshmallow “astronaut” to their cups.
- Test springs of different sizes. Have kids see if the number of folds in an index card makes a difference in the amount of force the spring can absorb. Have them fold index cards with two, four, and six folds. Have them test to see how much of a difference these different springs make in how softly a lander touches down.

CURRICULUM CONNECTIONS

Touchdown ties to the following concepts commonly covered in science, math, and technology curricula. For a list of education standards supported by the activity, see pages 38 and 39.

- Potential and kinetic energy—When the lander hits the surface, its motion (kinetic) energy is changed into stored (potential) energy, which gets stored in the shock absorbers.
- Acceleration due to gravity—The lander accelerates (speeds up) as it falls due to Earth’s gravitational pull.
- Air resistance—Air exerts a force on the lander as it falls, slowing it down.
- Measurement—Kids measure the various heights from which they drop the lander.
Landing on the moon is tricky. First, since a spacecraft can go as fast as 18,000 miles per hour (29,000 km/hour) on its way to the moon, it needs to slow way down. Then it needs to land gently. That lander has astronauts inside, not crash-test dummies. Easy does it!

**Materials (per lander)**
- 1 piece of stiff paper or cardboard (approximately 4 x 5 in/10 x 13 cm)
- 1 small paper or plastic cup
- 3 index cards (3 x 5 in/8 x 13 cm)
- 2 regular marshmallows
- 10 miniature marshmallows
- 3 rubber bands
- 8 plastic straws
- scissors
- tape

**Brainstorm and Design**

Think about how to build a spacecraft that can absorb the shock of a landing.

- What kind of shock absorber can you make from these materials that can help soften a landing?
- How will you make sure the lander doesn’t tip over as it falls through the air?

**Build**

1. **First, design a shock-absorbing system.**
   Think springs and cushions.

2. **Then, put your spacecraft together.**
   Attach the shock absorbers to the cardboard platform.

3. **Finally, add a cabin for the astronauts.**
   Tape the cup to the platform. Put two astronauts (the large marshmallows) in it. *(NOTE: The cup has to stay open—no lids!)*
TEST, EVALUATE, AND REDESIGN

Ready to test? Drop your lander from a height of one foot (30 cm). If the “astronauts” bounce out, figure out ways to improve your design. Study any problems and redesign. For example, if your spacecraft:

- **tips over as it falls through the air**—Make sure it’s level when you release it. Also check that the cup is centered on the cardboard. Finally, check that the weight is evenly distributed.

- **bounces the astronauts out of the cup**—Add soft pads or change the number or position of the shock absorbers. Also, make the springs less springy so they don’t bounce the astronauts out.

THE COOLEST JOB AT NASA

When people asked Cathy Peddie what she wanted to do when she grew up, she would point at the sky and say, “I want to work up there!” Now an engineer at NASA, she manages the Lunar Reconnaissance Orbiter (LRO) project. She calls it “the coolest job at NASA.” LRO will orbit the moon for at least a year and collect information to help NASA prepare for having people live and work there. Hear her describe the mission at: learners.gsfc.nasa.gov/mediaviewer/LRO.

BURIED ALIVE?

The first people who landed on the moon took a big risk. That’s because the moon is covered with a thick layer of fine dust. No one knew how deep or soft this layer was. Would a spacecraft sink out of sight when it landed? Now we know—the layer is firm. In the picture, you can see that Apollo 11’s lander pads sank only about 2 inches (5 cm) into the dust. What a relief! This helped NASA figure out the kinds of shock absorbers and landing systems its spacecraft need.

Only 12 people have ever visited the moon. But someday soon NASA plans to have teams of astronauts living there for six months at a time.
Field Trip to the Moon

DESCRIPTION
Students explore the Moon’s habitability and sustainable resources with activities that culminate with plans for the design and creation of a lunar station.

OBJECTIVES
Students will
- Utilize an inquiry-based learning approach that fosters team building and introduces students to careers in science and engineering
- Develop their cooperative learning skills to design a self-sufficient lunar station

NASA SUMMER OF INNOVATION
UNIT
Life Science—Survival
GRADE LEVELS
4 – 6
CONNECTION TO CURRICULUM
Science, Technology, Engineering, and Mathematics
TEACHER PREPARATION TIME
2 hours
LESSON TIME NEEDED
4 hours Complexity: Moderate

NATIONAL STANDARDS

National Science Education Standards
Science as Inquiry
- Understanding of scientific concepts
- Abilities necessary to do scientific inquiry
- Skills necessary to become independent inquirers about the natural world
- The dispositions to use the skills, abilities, and attitudes associated with science

Life Science
- Characteristics of organisms
- Organisms and environments
- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Earth and Space Science
- Structure of the Earth system

Science and Technology
- Abilities to distinguish between natural objects and objects made by humans
- Abilities of technological design

Science in Personal and Social Perspectives
- Personal health
- Types of resources
- Changes in environments
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Technology Education Performance Indicators for Students
Creativity and Innovation
- Apply existing knowledge to generate new ideas, products, or processes
- Use models and simulations to explore complex systems and issues

Research and Information Fluency
- Process data and report results
- Locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media
Critical Thinking, Problem Solving, and Decision Making
- Identify and define authentic problems and significant questions for investigation
- Plan and manage activities to develop a solution or complete a project
- Collect and analyze data to identify solutions and/or make informed decisions
- Use multiple processes and diverse perspectives to explore alternative solutions

Technology Operations and Concepts
- Understand and use technology systems
- Select and use applications effectively and productively
- Transfer current knowledge to learning of new technologies

MANAGEMENT
Gather all materials listed in the guide or purchase the NASA Kit (http://corecatalog.nasa.gov/mediatype.cfm?media=1) as needed. Using medium-sized cardboard boxes, create a toolbox for each team. In addition to placing and sorting materials into each toolbox, you will also need time to cut out the task, data, and other items from the reproducible.

CONTENT RESEARCH
Field Trip to the Moon is a special program developed by NASA. It will take them on a virtual mission to the Moon. On their journey they will discover some of the differences between Earth and the Moon and what makes our planet unique and habitable. They will continue their mission by working in teams to design a permanent, self-sustaining lunar station where humans can live and work. During the investigation, students will also learn about some of the many careers needed to establish a successful lunar habitat.

A common misconception students may have about the Moon is that it has an atmosphere and no gravity. Be sure to clarify that it has no atmosphere and only 1/6th the gravity found here on Earth.

The lesson is divided into six sections or investigations. Each section contains content information to guide the students in their investigations.

Key Concepts:
- The Moon and Earth have very different environments.
- Earth contains all the elements in its environment necessary for life: water, food, air, energy, radiation protection, and shelter.
- Establishing a permanent human habitat on the Moon requires complex engineering design and construction procedures.
- Many different people with many different backgrounds and careers will be needed to establish a permanent habitat on the Moon.

Key Terms:
- Ecosystem: a biological community of interacting organisms and their physical environment
- Engineering: the branch of science and technology concerned with the design, building, and use of engines, machines, and structures
- Geology: the science that deals with the Earth’s physical structure and substance, its history, and the processes that act on it
- Habitat: the natural home or environment of an animal, plant, or other organism
- Medical: the science or practice of medicine
- Navigation: the process or activity of accurately ascertaining one’s position and planning and following a route

LESSON ACTIVITIES
The Field Trip to the Moon curriculum guide is divided into six investigations that are described below.

Ecosystem Investigation
This team will investigate ecosystems and food webs. Using the information they gather, they will design a
sustainable ecosystem for the lunar station.

**Geology Investigation**
This investigation locates and analyzes resources at the chosen landing site. The student teams will then determine the natural resources available and select a mining area.

**Habitat Investigation**
This investigation identifies the living, working, and recreational space needed for humans on the Moon. The student teams will then design a model of a sustainable habitat for humans.

**Engineering Investigation**
This investigation determines the energy resources available on the Moon and design a power station for the lunar station.

**Navigation Investigation**
This investigation chooses one of two possible landing sites on the Moon. The students will then pack the rocket so that all the needed materials from each team will fit in the cargo bay.

**Medical Investigation**
This investigation explores various types of emergencies that may occur on the Moon and select the medical equipment that would be best suited for responding to those emergencies.

The complete *Field Trip to the Moon* curriculum guide can be found at [Field Trip to the Moon - Educator Guide](http://www.nasa.gov/audience/forstudents/9-12/career/index.html)

**ADDITIONAL RESOURCES**
- *Field Trip to the Moon* companion guide
  [Companion Guide](http://www.nasa.gov/audience/forstudents/9-12/career/index.html)
  [LRO/LCROSS Edition](http://www.nasa.gov/audience/forstudents/9-12/career/index.html)
- Apollo 40th anniversary
- LRO/LCROSS mission page
  [http://lcross.arc.nasa.gov/](http://lcross.arc.nasa.gov/)

**DISCUSSION QUESTIONS**
Begin the lesson with a few questions to stimulate discussion about lunar exploration. Answers will vary based on students' prelesson knowledge and should not be considered correct or incorrect but only to motivate discussion. Possible answers are provided for guidance.

- What have you heard or what do you know about human missions to the Moon? *There have been only 12 humans to walk on the moon from 1969–1972 during the Project Apollo missions.*
- What do you think it would be like to live the Moon? *Less gravity, no life (biosphere), atmosphere, water, or solar radiation protection.*
- What makes Earth habitable? *Atmosphere, water, solar energy, and biosphere*
- How is being on the Moon different than being on Earth? *Atmosphere, water, gravity, and biosphere*

**ASSESSMENT ACTIVITIES**
After each task in the investigations is completed, have the Communications Officers share their team's progress with the rest of the class. Inform the students that in order to complete the next task, they may need to draw from other teams' reports. Encourage them to ask questions of other teams.

**ENRICHMENT**
Have students determine which careers would be necessary to design, construct, and maintain a lunar habitat. They can research NASA careers at: [http://www.nasa.gov/audience/forstudents/9-12/career/index.html](http://www.nasa.gov/audience/forstudents/9-12/career/index.html)

[www.nasa.gov](http://www.nasa.gov)
Egg Drop Lander

Objective
Students will create a package to contain and successfully land a raw egg, unbroken from a fall to the ground. They will learn how velocity and acceleration from falling objects relate to a force on landing.

- Target concept: Acceleration
- Preparation time: 1 hour
- Activity time: 1 hour
- Student group size: Teams of three (3 to 12 per adult)

Materials
- Raw egg
- Parachute material (plastic trash or shopping bags)
- Packing material (gelatin, popcorn, foam, bubble wrap, etc.)
- Masking tape
- Yardstick or meter stick
- Stopwatch

Procedure
1. Each team of three students will build its own lander capsule. You may wish to build more than one for experimentation. Select someone to be a timekeeper, distance measurer and data recorder.
2. Choose the parachute and packaging material you will use around the egg. Design and build your lander. Attach the parachute.
3. The landing site will be a $1 \times 1$ ft target.
4. From the top of a ladder over the target, drop your lander. A balcony is a good place to use too.
5. Record the distance and time it takes for the egg lander to reach the ground.
6. Examine and record the lander. A drop is successful if the egg does not crack.

Data and Results
1. List the packaging material used. Which material and packing technique worked the best?
2. Draw your design.
3. Time of the fall $\text{______ s}$
4. Distance of the fall $\text{______ ft (m)}$
5. At what speed did the box hit the ground: $\text{ft/s (m/s)? ________}$
   $(\text{speed} = \text{distance/time or ft/s (m/s)}$
Additional Approach
From what you learned in packaging and protecting the egg in this lander drop test, design a capsule from a model rocket nose cone that can contain the egg. Test drop that capsule to prove the egg in it can land safely. There are also commercial rocket kits that can carry eggs. Get one of those as a design comparison and fly it, then have students build their own version of an egg-carrying rocket with their capsule. Launch the egg in the rocket and see how well the parachute brings it down.
The Catalina Sky Survey near Tucson, Ariz., discovered two small asteroids on the morning of Sunday, September 5, 2010 during a routine monitoring of the skies.

Asteroid 2010RX30 is about 15 meters in diameter and will pass within 248,000 kilometers of Earth. Asteroid 2010RF12, about 10 meters in diameter, will pass within 79,000 kilometers of Earth.

Both asteroids should be observable near closest approach to Earth with moderate-sized amateur telescopes.

Neither of these asteroids has a chance of hitting Earth. A 10-meter- sized near-Earth asteroid from the undiscovered population of about 50 million would be expected to pass almost daily within a lunar distance, and one might strike Earth's atmosphere about every 10 years on average. The last asteroid that was observed to enter Earth's atmosphere in this size range was the Great Daylight Fireball of 1972 which streaked above the Grand Tetons. It was about 5 meters in diameter but skipped out of the atmosphere and never struck ground.

Small asteroids appear very faint in the sky, not only because they are small in size, but because their surfaces are very dark and reflect very little sunlight. The formula for the brightness of a typical asteroid that is spotted within a few million kilometers of Earth is given by:

$$R = 0.011 d \ 10^{-\frac{m}{5}} (m)$$

where:  
R is the asteroid radius in meters,  
d is the distance to the asteroid from Earth in kilometers, and  
m is the apparent brightness of the asteroid viewed from Earth. Note, the faintest star you can see with the naked eye is about \(m = +6.5\). The planet Venus when it is brightest in the evening sky has a magnitude of \(m = -2.5\). The asteroid is assumed to have a reflectivity similar to lunar rock.

Problem 1 - What does the formula estimate as the brightness of these two asteroids when they are closest to Earth on September 8, 2010?

Problem 2 - Astronomers are anxious to catalog all asteroids that can potentially impact Earth and cause damage to cities. Suppose that at the typical speed of an asteroid (10 km/sec) it will take about 24 hours for it to travel 1 million kilometers (3 times lunar orbit distance). What is the astronomical brightness range for asteroids with diameters between 1 meter and 500 meters?

Space Math  http://spacemath.gsfc.nasa.gov
Problem 1 - What does the formula estimate as the brightness of these two asteroids when they are closest to Earth on September 8, 2010?
Answer:

**2010RX30**, R=15 meters, d = 248,000 kilometers

\[ 15 = 0.011 \times (248,000) \times 10^{-2m} \]

then \[ 0.0055 = 10^{0.2(m)} \]

\[ \log(0.0055) = -0.2m \]

so \( m = +11.3 \) magnitudes

**2010RF12**, R=10 meters, d= 79,000 kilometers

\[ 10 = 0.011 \times (79,000) \times 10^{-2m} \]

then \[ 0.011 = 10^{0.2(m)} \]

\[ \log(0.011) = -0.2m \]

so \( m = +9.7 \) magnitudes

Problem 2 - Astronomers are anxious to catalog all asteroids that can potentially impact Earth and cause damage to cities. Suppose that at the typical speed of an asteroid (10 km/sec) it will take about 24 hours for it to travel 1 million kilometers (3 times lunar orbit distance). What is the astronomical brightness range for asteroids with diameters between 1 meter and 500 meters?

Answer: First evaluate the equation for d = 1 million km and solve for m®

\[ R = 0.011 \times (1.0\times10^6) \times 10^{-2m} \]

\[ R = 1.1 \times 10^4 \times 10^{-2m} \]

so \( m(R) = -5 \log(0.000091R) \)

For R = 1 to 500 meters, \( m = +20.2 \) to +6.7

The most common asteroids have sizes between 1 meter and 50 meters, so the detection of such small, faint, and rapidly moving asteroids with ground based telescopes is a major challenge and may be a matter of luck in most cases.

For more information, read the NASA press release at

"Two Asteroids to Pass By Earth Wednesday"

http://www.nasa.gov/topics/solarsystem/features/asteroid20100907.html