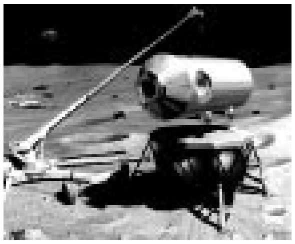
Unit 3



The Future

Lunar Land Use
Life Support Systems
Lunar Biosphere

The activities in this unit spark interest in responsible land use and sustainable human settlements on the Moon. Each activity uses and reinforces all the knowledge the students have been gaining about the Moon and Earth from Units 1 and 2. These activities require teamwork, research, and development of model systems.

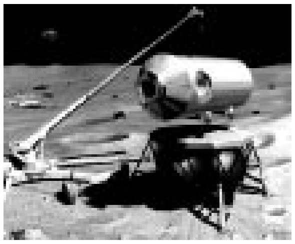
A Resource Section for Unit 3 is on Page 100.

Unit 3

Resource Section

This list presents possible independent and commercial sources of items to complement the activities in Unit 3. The sources are offered without recommendation or endorsement by NASA. Inquiries should be made directly to the appropriate source to determine availability, cost, and ordering information before sending money. Contact your NASA Teacher Resource Center (see pages 147-148) for more lists of resources available directly from the National Aeronautics and Space Administration.

Bottle Biology, by the Bottle Biology Project, 1993, Kendall/Hunt Pub. Co.,127 p. An idea book for exploring the world through plastic bottles and other recyclable materials.
Dept. of Plant Pathology, College of Agricultural and Life Sciences, University of Wisconsin-Madison
1630 Linden Dr.
Madison, WI 53706
608-263-5645



Lunar Land Use

Purpose

To design a development on the Moon that is suitable, feasible, and beneficial.

Background [also see "Teacher's Guide" Pages 14, 15]

In this activity teams of students will present proposals for developments on the Moon in a competition for approval from a student-staffed Lunar Council. This activity commonly runs 8 class days.

Preparation

Review and prepare materials listed on the student sheet.

In Class

Present the scenario and divide the class into cooperative teams of 4-5 students. Each team will represent a development corporation that will make a proposal before the Lunar Council.

You will also need 3 other students to comprise this Lunar Council.

Each student will have assigned duties, as described on the reproducible "Information Sheets."

Scenario: Travel to and from the Moon has become economical. As a result, the Moon's development has become inevitable and several corporations have already approached the United Nations about the prospects of developing lunar projects. In response, the U.N. has set up a Lunar Council to consider the feasibility and suitability of each proposal.

You may want to brainstorm ideas with the class for projects on the Moon; they may include mining communities, scientific bases, telescopic outposts, government headquarters, recreational bases, tourist sites, etc. You could assign a different idea to each team.

Distribute an "Information Sheet" to each development team. Give them 3-5 days to decide what their developments will be and to design their maps, models, diagrams, etc. Not only must they present their plan before the Lunar Council, but they must convince the council of the plan's worthiness. Lobbying efforts and advertising are all part of the game as long as they are fair.

Lunar Land Use

Distribute “Information Sheets” to the Lunar Council. Their task is to organize and run a hearing regarding development on the Moon. The ultimate approval for development is in their hands.

When most of the teams have finished, let the Lunar Council set the hearing date and let the proceedings begin.

Wrap-up

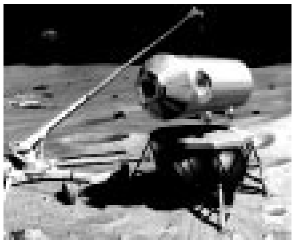
Once a decision is rendered, distribute the “Wrap-up Questions” or discuss them as a class.

Extensions

1. Have the students bid for project sites or use the landing sites chosen in the “Lunar Landing Sites” activity on Page 83.

2. Hold a classroom debate on “Who owns the Moon?”

3. Have the students compare Antarctica to the Moon.



Lunar Land Use

Purpose

To design a development on the Moon that is suitable, feasible, and beneficial.

Key Words

development

feasible

beneficial

Materials

maps of the Moon

"Moon ABCs Fact Sheet"

backgound information on the Moon

"Information Sheets"

art and construction supplies

Scenario

Travel to and from the Moon has become economical; as a result, the Moon's development has become inevitable. Several corporations have already approached the United Nations with lunar proposals.

In response, the U.N. has set up a Lunar Council to look at the suitability and feasibility of each proposal.

If your team is one of the development corporations, then your job is to decide what you want to build on the Moon and where to put it, to make the maps, diagrams, and/or 3-dimensional models of your project, and to convince the Lunar Council that your project is worthy of approval.

If you are a Lunar Council member, then the development of the Moon rests on your decisions.

Procedure

1. Read the "Information Sheet" given to your group, either a development team or the Lunar Council, and divide the duties.

2. Each development team must execute a development plan and design all necessary maps, diagrams, and/or 3-dimensional models.

3. Each development team must follow the guidelines set forth by the Lunar Council.

4. Each development team must present a plan for approval.

5. The Lunar Council reviews all the plans and decides which, if any, will be accepted.

Names: ____

Date: ________________

Lunar Land Use

Team Member Information Sheet

Tasks

Your team must decide what you want to build and where you want to build it. Everyone on your team should be assigned one or more of the following tasks:

Chief Engineer: oversees the entire project, makes critical decisions, assists in the design of the project.

Lunar Geologist : studies the Lunar Sample Disk and researches the minerals that may exist on the Moon for mining and/or for use as building materials. Chooses a suitable site for the project.

Media Consultant: oversees development of all the visual aid materials your team uses to present your proposal, such as maps, posters, and models. Also coordinates the use of slides, photographs, laser disc, etc. used to enhance your presentation.

Administrator: keeps notes, assists media consultant, works closely with the reporter to develop the speech to be given to the Lunar Council and types this final written proposal.

Reporter: works closely with all members to write the speech that will be given before the Lunar Council. The actual presentation may be made by any one or all team members.

Remember, you will have to “sell” your ideas before the Lunar Council. You need a well-planned project. Focus on how your project will be used, how it will benefit people, how it is environmentally friendly, etc.

Anything goes as long as it is actually possible. For example, if you are asked where the money is coming from to back your project you could say you have investors who will recover their money plus interest when the project makes money. You cannot have stories like “a limousine drove by and out popped a suitcase full of money.” Have fun!

Names: ____

Date: ______________

Lunar Land Use

Lunar Council Information Sheet

Tasks

You are representatives of the United Nations and have been chosen to decide how the Moon will be developed. Your job is to organize and run a hearing where various teams will make proposals to you concerning the development of the Moon. Your ultimate task will be to choose one or more of the proposals brought before you. If you wish, you can choose none of the proposals or allow certain ones with restrictions or improvements.

Everyone on the Council should hold one of the following positions:

Chairperson: runs the hearing by calling on the teams for their presentations, calls on Council members and the public to ask questions, makes critical decisions for the Council, announces the final decisions.

Timekeeper : decides how long the presentations and the question/answer period will last, keeps track of time during the hearing, and stops teams that go overtime.

Administrator: develops rating sheet with other members, keeps notes, writes, and sends out any bulletins to the development teams.

Names: ______________________________

Date: ______________

Lunar Land Use

Lunar Council Information Sheet

Bulletins and Ratings

Your Council should issue bulletins periodically to give guidelines and announcements to all the development teams. An example is given below:

Lunar Council Bulletin 1-1

To: All development teams
From: Lunar Council
Regarding: Hearing timeline and financial background

We have decided to allow each team 5 minutes to make their presentations following which the Council will have 10 minutes for questions and answers. Finally, the public will have another 10 minutes for questions and answers. Any variation to this policy will require permission from the Council before the hearing.

Council members also will be asking you for your sources of money. We want to be sure that if your proposal is chosen, you will be able to build it.

You also will need to develop a rating sheet to judge each team fairly. An example is given below:

Group #	Feasibility 1-10	Pollution 1-10	Income 1-10	Planning 1-10	TOTAL
1					
2					

After all the teams have made their presentations, the Council retires and renders a decision on which team, if any, will be allowed to develop.

Names: ______________________________

Date: ______________

Lunar Land Use

Wrap-up Questions

1. Did your team work together well? Why or why not?

2. Do you think it is important to have hearings like this one before the Moon is developed? Why or why not?

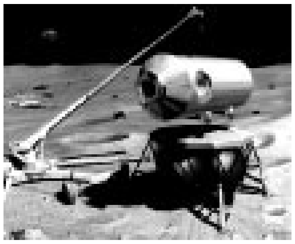
3. Do you think the Lunar Council's decision was fair? Why or why not?

4. Should we allow developments on the Moon? Why or why not?

5. Do you think the Moon should belong to everyone or to whomever can get there and use it first? Why?

6. How is the Moon and its development similar to the development of Antarctica?

7. What kind of environmental problems do you think we need to be aware of on the Moon?



Life Support Systems

Purpose

To design and build models of life support systems for a settlement on the Moon.

Background [also see "Teacher's Guide" Pages 14, 15]

A future lunar base will have to be a self-contained habitat with all the life support systems necessary for the survival of people, animals, and plants. In this series of activities, the students will be designing and building models of nine life support systems which are crucial to our successful settlement of the Moon.

The nine life support systems are:

"Air Supply,"
"Communications,"
"Electricity,"
"Food production and delivery,"
"Recreation,"
"Temperature control,"
"Transportation,"
"Waste management," and
"Water supply."

This activity is based on the Marsville activity on life support systems developed by the Challenger Center and is used with permission.

Preparation

Review and prepare materials listed on the student sheets. Separate student activity sheets are included for each of the nine life support systems. Spaces for answers are not provided on all sheets, so students will need extra paper.

In Class

After dividing students into teams, you may want to have each person assume a role on the team, e.g., organizer, recorder, researcher, builder, artist, writer, etc. Distribute a student activity sheet to each team.

Each team must define the requirements of their system, exploring how these requirements are currently being met on Earth. Team members will research the limitations and/or opportunities posed by the Moon's environment. The "Moon ABCs Fact Sheet" and maps of the Moon should be used as resource materials.

Each team will decide how the system will operate and what it will contain. A key part of the problem-solving process is the students' ability to evaluate the system solution in terms of whether it provides the greatest good and least harm to the persons and things affected.

Each model of a life support system must incorporate at least four facts from the "Moon ABCs Fact Sheet."

Models do not have to function physically, but each team member must be able to explain how the models should function.

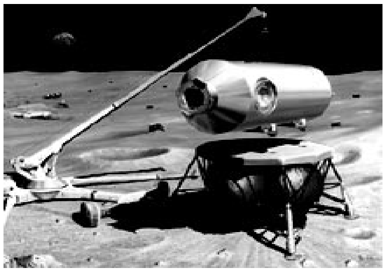
Wrap-up

Have each team share what they have learned with the entire class.

1. Did the students find that the Moon's environment placed limits on their designs of life support systems?

2. Did the students find opportunities for development on the Moon that could not happen on Earth?

3. Summarize the aspects and conditions of the Moon which make life support such a challenge.



Air Supply

Purpose

To design and build a model air supply system for a human settlement on the Moon.

Key Words

atmosphere

photosynthesis

Materials

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1. The atmosphere of Earth is a combination of several gases; review them from the "**Moon ABCs Fact Sheet**." What gas do humans and animals need to breathe in?

___

2. What primary gas do humans and animals breathe out?

___

3. What is photosynthesis?

___

___

___

4. During the process of photosynthesis, what gas must green plants take in ?

___

5. What gas do the green plants produce?

___

6. A process called electrolysis can separate water into hydrogen gas and oxygen gas. Another process is being developed which can extract oxygen from rocks and soil that contain it. Do you think these processes could be useful on the Moon? How?

___

___

___

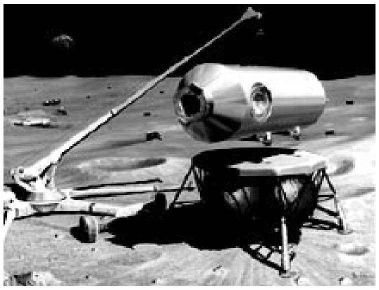
___

7. Review the "Moon ABCs Fact Sheet." Will the Moonbase settlers automatically be able to breathe the atmosphere or will special provisions need to be made?

8. Design an air supply system to be used by the Moonbase inhabitants which will rely on oxygen and carbon dioxide available only from the Moon's resources. You may assume that ample electricity will be available.

9. Construct a model of this system based on your design. It must include the application of at least four facts from the "Moon ABCs Fact Sheet." For example, how will the Moon's gravity affect the design of your system? Maybe your system will be very heavy but still portable by only a few Moonbase workers because the Moon's gravity is only 1/6th of Earth's gravity.

Sketch of my model



Communications

Purpose

To design and construct a model of a communications system to be used by people living and working on the Moon.

Key Words

communications

Materials

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1. What different ways do we have of communicating with each other here on Earth? Do some methods work better short distance than long distance? What are the strong points of each of these methods? What limitations does each have?

2. Why do you think communication would be important in each of the following situations:

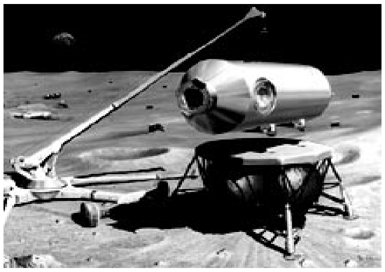
   - Between Moonbase settlers within their constructed settlement,
   - Between settlers in the settlement and those conducting missions elsewhere on the surface of the Moon,
   - Between Moonbase and Earth (How long does it take for a radio signal to travel the distance between Earth and the Moon?)

3. Review the facts you have learned about the Moon. Do you think any of the communications methods on Earth (from Question 1) would be impractical on the Moon? Why or why not? Which communications methods on Earth do you think would be particularly useful on the Moon? What features of these methods might you have to modify?

4. Design a communications system to be used by the Moonbase inhabitants which will have components to satisfy the different situations listed in Question 2. You may assume that ample electricity will be available.

5. Construct a model of this system based on your design. It must include the application of at least four facts from the "**Moon ABCs Fact Sheet.**" For example, how will the Moon's gravity affect the design of your system? Maybe your system will be very heavy but still portable by only a few Moonbase workers because the Moon's gravity is only 1/6th of Earth's gravity.

Sketch of my model



Electricity

Purpose

To design and build a model electrical power supply system for a human settlement on the Moon.

Key Words

electricity

solar power

nuclear energy

Materials

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1. Think of all the things you do during a regular school day, from the minute you wake up until the time you go to sleep. List each activity which requires electricity.

2. What other activities in your town, city, or state use electricity?

3. What is the source of the electric power for your town or city? Is it a steam generating plant that burns natural gas, oil, or coal? Is it a nuclear-fission plant?

4. List other ways to produce electricity.

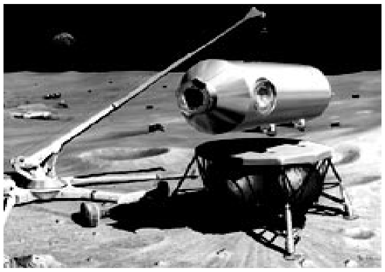
5. How is electricity transmitted from the generating plant to other places?

6. Review the facts you have learned about the Moon. Do you think the lack of atmosphere, natural gas, oil, and coal on the Moon would affect the production of electricity? How? Would materials have to be shipped from Earth? Should the lunar settlement rely on materials shipped from Earth? Your team's job is to supply the electricity needed by the life support systems at the Moonbase.

7. Review the "**Moon ABCs Fact Sheet.**" Design an electrical power generating plant and transmission system for the Moonbase inhabitants. Important issues to consider include pollution, radioactive waste storage, length of daylight on the Moon, and power storage.

8. Construct a model of this system based on your design. It must include the application of at least four facts from the "Moon ABCs Fact Sheet."

Sketch of my model



Food Production

Purpose

To design and build a model of a food production and delivery system for a human settlement on the Moon.

Key Words

food groups

nutrition

consumption

self-sustaining

Materials

food groups chart

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1. Review the basic food groups. What are examples of food in each group. What basic jobs for the body does each group perform? Make a chart on a separate paper with your answers.

2. With your class, make a list of the foods and liquids everyone consumed in the past 24 hours. Organize your list in the following way: Put each food group in a different column; then cross out all the items you consider "junk food" and cross out each item made from an animal which must eat another animal to live.

3. We know that, with the exception of carnivores, animals eat plants. But what do green plants "eat" in addition to carbon dioxide, sunlight, and water? Include in your answer a discussion of the nitrogen cycle.

4. It is likely that space in the Moonbase will be limited. Protein sources like cattle and vegetable sources like corn require substantial space for production. Reviewing your list from Question 2, what are other sources of protein which take less space? What fruits and vegetables could be produced in limited space?

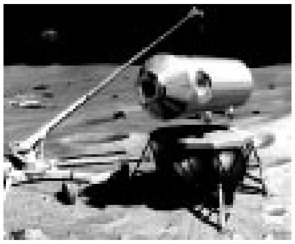
5. Review the "**Moon ABCs Fact Sheet**" to determine what conditions of sunlight exist. Remember that other teams are responsible for providing you with a water supply (which will probably have to be used cautiously or rationed,) with electricity, with a temperature control system in the constructed Moonbase, and with an air supply of carbon dioxide and oxygen for plants and animals you wish to grow. Remember also that all original stocks of plants and animals must be transported from Earth. With these reminders, your task is to design a food production and delivery system in the Moonbase which will:

   a) supply the inhabitants with all of their nutritional needs,

   b) be self-sustaining without additional stock from Earth, and

   c) provide products appealing enough that the inhabitants will enjoy eating their meals.

6. Construct a model of this system based on your design. It must include the application of at least four facts from the "Moon ABCs Fact Sheet." For example, how will the Moon's gravity affect the design of your system? Maybe your system will be very heavy but still portable by only a few Moonbase workers because the Moon's gravity is only 1/6th of Earth's gravity.



Recreation

Purpose

To design and build a model of recreational facilities for a human settlement on the Moon.

Key Words

entertainment

sedentary lifestyle

active lifestyle

Materials

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1. What value does entertainment have?

2. What do you do for entertainment? Brainstorm other forms of entertainment which people enjoy doing.

3. Reviewing your list from Question 2, what activities require you to consider the physical environment? What features of the environment does each activity depend upon?

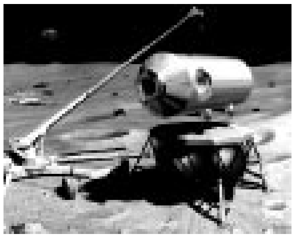
4. What value do you think entertainment would have on the Moon? (Would the Moonbase settlers need entertainment?)

5. Review the "**Moon ABCs Fact Sheet.**" Which of the recreational activities on your list do you think would be possible on the Moon? Include in your answer which activities would be the most practical and popular.

6. Remembering that the Moon has features different from those of Earth, what might be applied to developing new forms of recreation?

7. Design recreational facilities for the Moonbase inhabitants which satisfy any special recreational needs you think they will have and include some new forms of recreation based on the "Moon ABCs Fact Sheet." You may assume that ample electricity will be available.

8. Construct a model or models of the facilities based on your design. It must include the application of at least four facts from the "Moon ABCs Fact Sheet." For example, how will the Moon's gravity affect your designs?



Temperature Control

Purpose

To design and build a model temperature control system for a human settlement on the Moon.

Key Words

Farenheit

Celcius

Materials

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1. Review the clothes you and your classmates wear during each season of the year, both indoors and outdoors. You may want to write this information on a chalk board or paper.

2. How many degrees does the temperature have to change for you to switch from shorts to jeans, from bare hands to gloves, or to add a shirt over a swimming suit?

3. What effect do Sun, clouds, wind, and your own activity level have on the temperature choices you just made?

4. What are the coldest and hottest temperatures you ever experienced?

5. What is the number of degrees between these two extremes you felt?

6. Besides your selection of clothing, what other precautions did you take to protect your body?

7. Think back to a severe hot spell or cold snap your town experienced or that you heard about. List the effects of these temperature extremes on soil, plants, animals, buildings, water use, and electrical use.

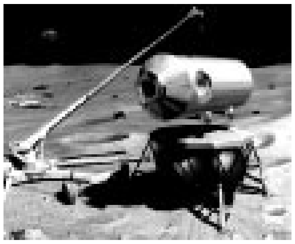
8. What different environments on Earth (both indoor and outdoor) could be uncomfortable or actually dangerous to us if we did not control the temperature to which our bodies were exposed?

9. What different ways do we have of controlling the temperature on Earth?

10. Review the "**Moon ABCs Fact Sheet.**" How do tempera tures on the Moon compare with temperatures on Earth? Will the Moonbase inhabitants be able to exist without special temperature controls on the surface of the Moon? How about in their constructed Moonbase settlement?

11. Design a temperature control system to protect the Moonbase inhabitants and their possessions/equipment both on the surface of the Moon and in their settlement. You may assume that ample electricity will be available.

12. Construct a model of this system based on your design. It must include the application of at least four facts from the "Moon ABCs Fact Sheet." For example, how will the Moon's gravity affect the design of your system? Maybe your system will be very heavy but still portable by only a few Moonbase workers because the Moon's gravity is only 1/6th of Earth's gravity.



Transportation

Purpose

To design and build a model transportation system for a human settlement on the Moon.

Key Words

transportation

Materials

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1. What are some different ways we transport people and goods on Earth?

2. What physical features of Earth do these methods require in order to function?

3. Write down the strong points and limitations of each transportation system you listed in Question 1.

4. What do you think would need to be transported on the Moon in each of the following situations:

    a) within the Moonbase settlement,

    b) between the settlement and other points on the Moon.

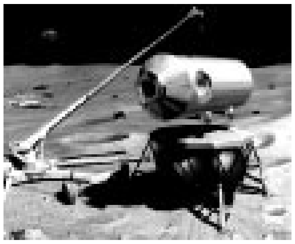
5. Review the "**Moon ABCs Fact Sheet.**" Do you think any of the transportation methods on Earth (from Question 1) would be impractical on the Moon? Why or why not?

6. Which transportation methods on Earth do you think would be particularly useful on the Moon? What features might you have to modify?

7. Design a transportation system to be used by the Moonbase inhabitants which will have components to satisfy the different situations they could encounter (Question 4). For this activity you may assume that some of the basic construction materials you need will be transported from Earth to the settlement. You may also assume that ample electricity will be available.

8. Construct a model of this system based on your design. It must include the application of at least four facts from the "Moon ABCs Fact Sheet." For example, how will the Moon's gravity affect the design of your system? Maybe your system will be very heavy but still portable by only a few Moonbase workers because the Moon's gravity is only 1/6th of Earth's gravity.

Sketch of my model



Waste Management

Purpose

To design and build a model waste management system for a human settlement on the Moon.

Key Words

recycling

biodegradable materials

nondegradable

self-sustaining

Materials

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1. Your school, in many ways, is like a miniature town. It has a system for governance, health care, traffic control, a work schedule for its inhabitants, recreation, AND waste disposal. To get a better idea of how much waste your school generates every week, find out how many students plus teachers, administrators, other staff (and animals, if any) are regularly in the buildings.

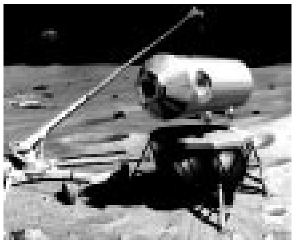
2. Next, interview the cafeteria staff and the custodial staff for the answers to these questions:
   (a) What gets thrown away?
   (b) How many pounds get thrown away every week? Calculate how many pounds of trash this is for every person in the school.
   (c) Are there any items which can be recycled before disposal? If yes, what are the recycled items?
   (d) What items are biodegradable?
   (e) What is the garbage/trash packed in for removal?
   (f) Where is it taken?
   (g) According to building codes, how many toilets must there be to accommodate all the people?

3. Waste is a "hot" topic in our society. Why? Discuss what you know about the following phrases: Excessive packaging, landfills, toxic waste, disposable plastic goods, nondegradable material, water pollution, and air pollution.

4. In movies like those starring “Indiana Jones,” well preserved, ancient artifacts are often found in the desert. Scientists also find preserved artifacts in polar ice; for example, mastodons or ancient people. Why aren’t they decayed?

5. Review the “**Moon ABCs Fact Sheet.**” The Moonbase must be an enclosed, self-sustaining settlement. Just like your school, it must perform the basic functions of a town. Other teams are responsible for designing and constructing several other types of systems (air supply, communications, electricity, food production and delivery, recreation, temperature control, transportation, and water supply). Your team’s job is to dispose of the waste which could be generated by these systems. Design a waste disposal system for the Moonbase. Be sure to decide what importance, if any, will be given to biodegradable materials, recycling, and the Moon outside of the constructed settlement.

6. Construct a model of this system based on your design. It must include the application of at least four facts from the “Moon ABCs Fact Sheet.” For example, how will the Moon’s gravity affect the design of your system? Maybe your system will be very heavy but still portable by only a few Moonbase workers because the Moon’s gravity is only 1/6th Earth’s gravity.



Water Supply

Purpose

To design and build a model water supply system for a human settlement on the Moon.

Key Words

water conservation

drought

Materials

"Moon ABCs Fact Sheet"

construction materials such as cardboard boxes and tubes, blocks, hoses, straws, string, pins, rubber bands, tape, etc.

Procedure

1 Think of all the things you do during a regular school day, from the minute you wake up until the time you go to sleep. List each activity which involves water.

2. Are there any water activities you could eliminate for a day? a week? longer?

3. What other activities in your town use water? Could any of those activities be eliminated?

4. During a dry summer, have you ever heard a public announcement that "water conservation measures are in effect"? What activities are affected by this announcement?

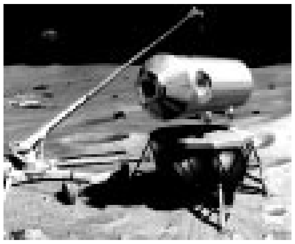
5. Imagine if summer drought continued for years, then how could water be conserved for people? for animals? for crops? for businesses?

6. Review the "**Moon ABCs Fact Sheet.**" Where is the water on the Moon and in what form or forms does it exist?

7. Design a water supply system to be used by the Moonbase inhabitants which will rely only on water available from the Moon's resources. You may assume that ample electricity will be available.

8. Construct a model of this sytem based on your design. It must include the application of at least four facts from the “Moon ABCs Fact Sheet.” For example, how will the Moon's gravity affect the design of your system? Maybe your system will be very heavy but still portable by only a few Moonbase workers because the Moon's gravity is only 1/6th of Earth's gravity.

Sketch of my model



Lunar Biosphere

Purpose

To build a biosphere that is a balanced, self-enclosed living system able to run efficiently over a long period of time.

Background [also see "Teacher's Guide" Pages 14, 15]

Earth is the ultimate **biosphere**, literally a "life ball." It holds and sustains all life known to humanity. As men and women look to traveling and living beyond our blue planet, we see conditions that are too harsh to sustain life as we know it.

Conditions on the Moon are not favorable for sustaining life because of the absence of water, organic topsoil, and **atmosphere**. Also **lunar** days (equal to 14 Earth days) and nights are very long. Water must be brought from Earth or made using oxygen from lunar **regolith** and hydrogen from Earth. Nutrients need to be added to lunar regolith and plants have to be grown in a self-enclosed system. What's more, artificial light must be used during the long, dark periods.

This activity challenges students to create a working model of a lunar biosphere that is a balanced, self-enclosed living system able to run efficiently over a long period of time.

Preparation

Review and prepare materials listed on the student sheet. Here are some suggestions.

Seedlings: About two weeks prior to this activity, sprout the seedlings for use in the biospheres. Successful biospheres have been made using mung, radish, and peanut. Tomato seedlings can also be used, as well as ferns, vines, and simple garden weeds.

Soil materials: Collect bins or bags to hold the variety of soil materials: vermiculite, permiculite, cinder, gravel, sand, silt, clay, and fertilizer.

Animals: Students should collect live critters to live in the biospheres. These can include -- insects (ants, cockroaches, beetles, etc.), mollusks (snails, slugs, etc.), arachnids (spiders, etc.), and crustaceans (sow bugs).

Plastic bottles for biospheres: Use 2-liter soda bottles with the black base. Remove the black base by submerging it in a large pot of hot (but not boiling) water. This softens the glue holding the base onto the bottle without melting the plastic. Take off the label. With an exacto knife or razor, cut off the top spout of the bottle. For safety, it is best not to allow students to do the cutting. You may place the spout with your other plastic recyclables as it will not be used in this activity. Prepare one container per student.

Lunar Biosphere

The students will plug the holes in the black base with wax, tape, or clay. The base must be watertight. They will then fill the base with a predetermined soil mixture. They will add water, seedlings, and animals as decided by the team. Finally, they will invert the plastic container into the base, seal it with clear, plastic tape, and label it. The label should include the student's name, names of team members, date, and time the biosphere was sealed.

In Class

After discussing the background information and purpose of this activity, divide the class into cooperative teams of 4 students each.

Biosphere mobiles

Have each team create a hanging mobile with the theme “Biosphere.” Each hanging component represents one part of the living Earth system, e.g., water, plants, animals, people, air, Sun, soil, etc.

After mobiles have been balanced and hung from the ceiling, have the students predict what would happen if one part were removed or just shifted. Ask the students to shift or remove one part. Does the biosphere remain balanced? Ask the students to try to rebalance and hang their mobiles. Have them relate what they see to what might happen if a part of any biosphere is changed or removed.

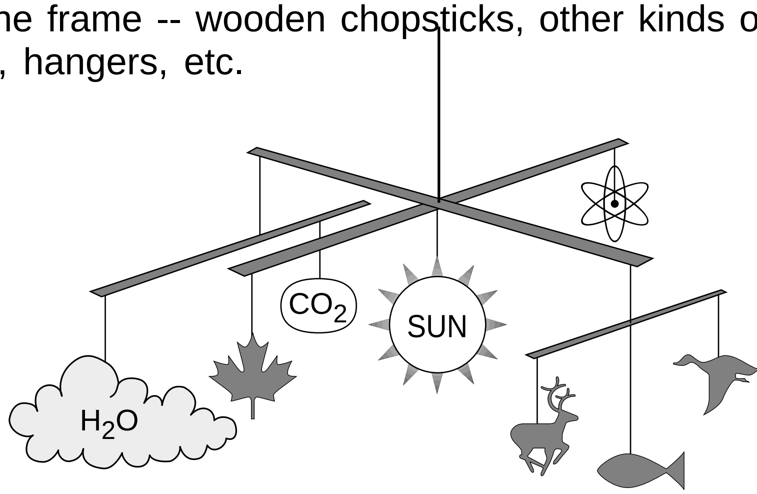
Materials

cardboard or heavy-weight paper

markers or crayons

string

something to use as the frame -- wooden chopsticks, other kinds of sticks, plastic drinking straws, hangers, etc.



Making Biospheres

After discussing the importance of a balanced biosphere, you may choose to have the students number themselves from 1 to 4 for a role assignment within each team:

1 = Botanist - person who studies plants,
2 = Agronomist - person who studies soils and crops,
3 = Science Specialist - person who relates conditions of soil and water to optimal plant growth,
4 = Zoologist - person who studies animals.

Distribute the "Team Member Information Sheets." Students are responsible for reading and sharing the data contained on their own sheets. Have them log their shared information on their worksheet -- as outlined in Question 3 on page 133.

Before the actual construction, each team must decide the following for their lunar biospheres:

1. best lunar soil mixture
for example, vermiculite, permiculite, cinder, sand, gravel, fertilizer, etc.

2. amounts of each type of soil material
for example: 10 Tablespoons of sand
10 Tablespoons of silt
10 teaspoons of vermiculite
1/2 teaspoon of fertilizer

3. optimal lighting
for example: direct sunlight, shade, artificial lamp, etc.

4. optimal amount of water to add to the biosphere before sealing it
for example: 5 Tablespoons of water

5. kinds and amounts of seedlings and animals to include inside
for example: mung, radish, peanut seedlings -- use just one type or a combination. If these are not available, then other seedlings can easily be used. Other examples include ferns, vines, and garden weeds. Have students explain why they made their choices. Students can also do preliminary research on their organisms.

Note: Each lunar biosphere must include plants and animals.

After teams have discussed and decided these five points, then each student will make his/her own biosphere.

The biospheres must be completely sealed with clear, plastic tape.
No air or other materials can go in or out.
Once the biosphere is sealed, it cannot be opened again.

Each lunar biosphere should be labeled with the student's name, names of team members, date, and time it was sealed. Put this label on the black base.

After the biospheres are built, they should be set under the lighting conditions chosen by the teams.

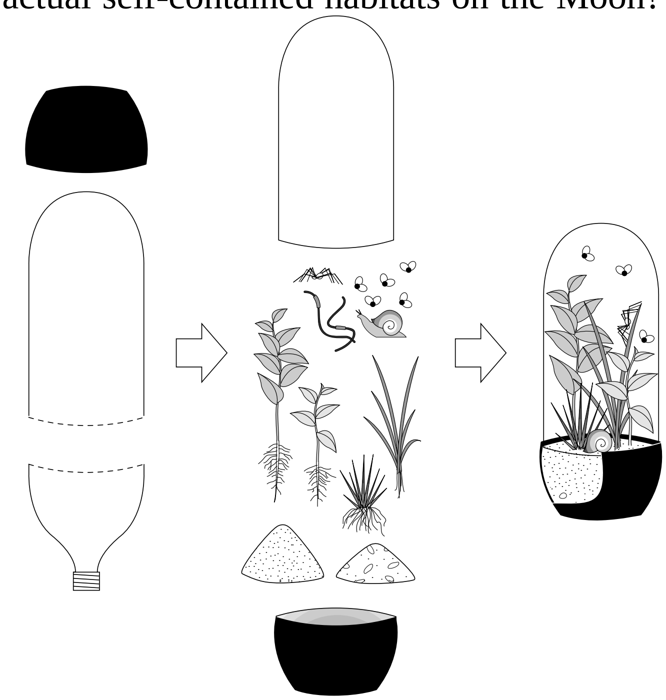
A “Data Sheet” and an “Observation Sheet” are provided for student use.

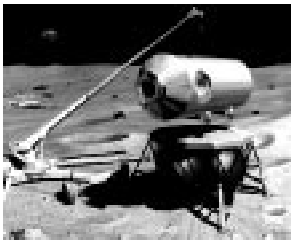
Wrap-up

Are some lunar biospheres doing better than others?

What are some of the factors leading to the success or failure of the biospheres?

Based on this experience of making a model lunar biosphere, what is your opinion on the potential success of actual self-contained habitats on the Moon?





Lunar Biosphere

Purpose

To build a biosphere that is a balanced, self-enclosed living system able to run efficiently over a long period of time.

Key Words

biosphere

soil

atmosphere

organism

photosynthesis

agronomist

botanist

zoologist

Materials

"Data and Observation Sheets"

"Team Member Information Sheets"

measuring cups & spoons

plastic 2-liter bottle, cut

vermiculite

permiculite

cinder

gravel, sand

silt, clay

fertilizer

seedlings and animals

water

clear, plastic tape

lamp

Procedure for Teams

1. Discuss and list the questions you may want to ask before you start to build a lunar **biosphere.**

____

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2. How and where could you find possible solutions to these questions?

____

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____

____

3. List all important information you obtained from the **botanist, agronomist, science specialist, and zoologist** that will assist you in planning the most efficient and effective lunar biosphere possible.

Procedure for Each Person

4. Fill out the "**Biosphere Data Sheet**" with your team's choices of best **soil mixture, types and numbers of seedlings and other organisms, optimal lighting conditions, and the optimal amount of water** to add to the biosphere before sealing it. Remember that you are striving to create a living system that will remain balanced over a long period of time.

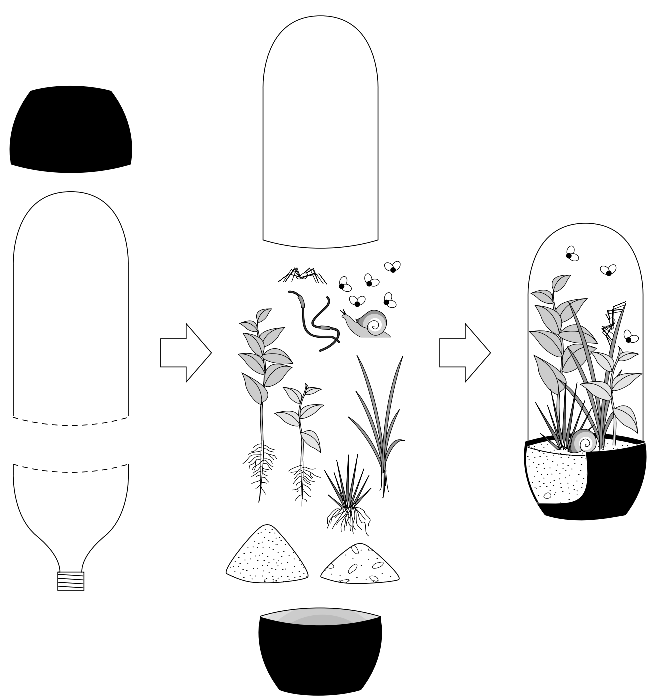
5. Obtain a pre-cut **plastic bottle** from your teacher and build your <u>personal</u> biosphere following the team's recommendations.

6. Seal your biosphere with clear, **plastic tape**. We are simulating a lunar biosphere, therefore no air or other materials can go in or out. After your biosphere is sealed, it cannot be reopened.

7. Label the biosphere with your name, names of your team members, date, and time it was sealed. Put the label on the black base.

8. Set your biosphere under the **lighting** conditions chosen by the team.

9. Fill in the "**Biosphere Observation Sheet**" as directed by your teacher.



Team Members: Name: ____________________

Date: ____________

Lunar Biosphere - Data Sheet on Materials Used

Soil Material	Amount Used

Seedlings / Animal organisms	Amount Used

Lighting Conditions:

Amount of water added to Biosphere before it was sealed:

Date and Time it was sealed:

Team Members:

Name: ______________________________

Date: ________________

Lunar Biosphere - Observation Sheet

Date	Lighting Conditions	Height of Seedlings (cm)			Observations	Color Sketches
		Mung	Radish	Peanut		

Name: ______________________________

Date: ________________

Lunar Biosphere

Team Member Information Sheet

for Botanist

Mung bean, *Phaseolus aureus*
origin: India, central Asia

The mung bean, a bushy annual which grows 76 - 90 meters tall, has many branches with hairy bean-like leaves. Flowers are yellowish-green with purple streaks and produce long, thin, hairy pods containing 9 - 15 small yellow seeds. Seeds are used to produce bean sprouts.

Radish, *Raphanus sativus*
origin: temperate Asia

The radish produces white, red, or black roots and stems under a rosette of lobed leaves. It is an annual or biennial plant, which grows several inches high. Radishes should be planted 1 cm deep, and will sprout in 3 - 7 days. When planted together with other root crops, radishes can be used to decoy pests, and the spaces left in the soil when they are pulled out provide growing room for the other root crops, which grow more slowly.

Peanut, *Arachis hypogaea*
origin: South America

The peanut, an annual vegetable which belongs to the pea family, grows from 15 - 76 cm tall. Flowers are small yellow clusters that grow on stems called pegs. Pegs grow downward and push into the soil. Nuts develop from these pegs 2.54 - 7.6 cm underground.

Name: ______________________________

Date: _______________

Lunar Biosphere

Team Member Information Sheet

for Agronomist

Soil has four functions:

1) supply water to plants,
2) supply nutrients (lunar regolith, however, needs to have nutrients added to it),
3) supply gases (oxygen and carbon dioxide), and
4) support plants.

The ideal soil holds moisture and nutrients while letting excess water drain to make room for air.

Types of soil:

clay - small particles, less than 1/256 mm, which pack closely. Poor drainage.
sand - irregular particles between 1/16 mm and 2 mm. Holds very little water.
silt - between clay and sand-size particles. Not very fertile, packs hard.
loam - a mixture of clay, silt, and sand. The best kind of soil.

Name: ______________________________

Date: ________________

Lunar Biosphere

Team Member Information Sheet

for Science Specialist

Growing Conditions

Mung bean - grows best in full sun, in a rich, well-drained soil. It shouldn't be allowed to dry out completely.

Radish - is a cool season crop, and can take temperatures below freezing. It can tolerate partial shade. Soil should be well-drained. If water supply gets low, then radishes become woody.

Peanut - needs lots of Sun and warmth. It is relatively tolerant of dry soil. These seeds are very sensitive to fertilizer.

Soil - can be improved by the addition of fertilizers, which provide nutrients to the plant. This makes the plant healthier, and better able to resist disease and pest attacks.
Vermiculite and perlite are "puffed up" minerals that are used to lighten heavy clay soils with air spaces, or to help sandy soils hold more water. They do not directly provide nutrition to the plants.

Name: ______________________________

Date: ________________

Lunar Biosphere

Team Member Information Sheet

for Zoologist

Mung bean - has no serious pest or disease problems.

Radish - has no serious disease problems. Maggots and aphids may be a pest problem, but radishes are usually harvested quickly enough so these do not have much effect.

Peanut - may be attacked by nematodes, aphids, and in some areas, by rodents.

Glossary

Words that appear in *italic* type within a definition also are defined in the Glossary.

A'a: Blocky, angular, and rough type of *lava* flow.

Agglutinates: Common particle type in *lunar sediment*; agglutinates consist of small *rock*, *mineral*, and glass fragments bonded together with glass.

Agronomist: Scientist who studies soil management and the production of field crops.

Anomaly: A deviation from the common rule, type, or form; something abnormal or inconsistent.

Anorthosite: An *igneous rock* made up almost entirely of *plagioclase feldspar*.

Antenna: A conductor by which electromagnetic waves are transmitted or received.

Apollo: U.S. Space Program which included 6 piloted *lunar* landings between 1969 and 1972. Apollo *astronauts* collected and returned 382 kilograms of *rock* and *sediment* samples from the Moon.

Astronaut: Person engaged in or trained for spaceflight.

Atmosphere: Mixture of gases that surround a planet.

Basalt: Fine-grained, dark-colored *igneous* rock compsed primarily of *plagioclase feldspar* and *pyroxene*; other minerals such as *olivine* and *ilmenite* are usually present.

Beneficial: Advantageous, helpful.

Biodegradable (see *Nondegradable*)**:** Capable of decaying and being absorbed by the environment.

Biosphere: The part of Earth's *crust*, water, and *atmosphere* where living organisms can survive.

Botanist: Scientist who studies plant life.

Breccia: Rock consisting of angular, coarse fragments embedded in a fine-grained matrix.

Celsius: A temperature scale that assigns the value 0^{o} C to the freezing point of water and the value of 100^{o} C to the boiling point of water at standard pressure.

Channel: A furrow or narrow passageway in the ground.

Communicatons: A means of transmitting and receiving information.

Console: A desklike structure that is the control unit of an electrical or electronic system.

Consumption: The act of eating or drinking; using energy and materials.

Core: The central region of a planet or moon frequently made of different materials than the surrounding regions (*mantle* and *crust*). Earth and the Moon are thought to have cores of iron and nickel.

Crater (see *Impact*)**:** A hole or depression. Most are roughly circular or oval in outline. On Earth most natural craters are of volcanic origin. On the Moon most are of impact origin.

Crater chain: Several craters along a general line.

Crust: The outermost layer of a planet or moon, above the *mantle*.

Dark mantle deposits: Deposits of dark glass on the Moon, possibly products of volcanic fire fountaining.

Density: Mass per volume; how much material in a given space.

Descartes: *Lunar highlands* site of *Apollo* 16 landing on April 21, 1972.

Development: The act of bringing into being or advancing to a more effective state.

Differentiation: Chemical zonation caused by differences in the densities of minerals; heavy materials sink, less dense materials float.

Drought: Extended period of dry weather, especially one causing damage to crops.

Earthquake: Sudden motion or trembling of Earth caused by the abrupt release of slowly accumulated elastic energy in *rocks*.

Ejecta: Material thrown out from and deposited around an *impact crater*.

Electricity: Energy caused by the motion of electrons, protons, and other charged particles.

Entertainment: Amusement, or diversion; something to hold attention for pleasure.

Erosion: Removal of weathered *rocks* by moving water, wind, ice, or gravity.

Eruption (see *Source*)**:** A break out or brust of volcanic matter.

Farenheit: A temperature scale with the freezing point of water assigned the value 32° F and the boiling point of water 212°F.

Farside: The side of the Moon that never faces Earth.

Feasible: Capable of being done or accomplished; probable, likely.

Fissure: Crack extending far into a planet or moon through which *magma* travels to and *erupts* onto the surface.

Food groups: Categories into which all foods are divided; meats and protein, fruits, vegetables, dairy, carbohydrates, and sugars.

Fra Mauro: Landing site of *Apollo* 14 on the Moon on February 5, 1971.

Geologist: Scientist who studies Earth, its materials, the physical and chemical changes that occur on the surface and in the interior, and the history of the planet and its life forms. Planetary geologists extend their studies to the Moon, planets, and other solid bodies in the Solar System.

Giant impact theory: An explanation for the origin of the Moon from Earth debris which collected in space after a *projectile* the size of planet Mars smashed into a growing Earth.

Hadley-Appenine: Landing site of *Apollo* 15 on the Moon on July 31, 1971.

Highland "soil": *Sediment* on the surface of the *lunar highlands*; composed of broken *rock* and *mineral* fragments, and glass produced by *impact*.

Highlands: Oldest exposed areas on the surface of the Moon; extensively cratered, and chemically distinct from the *maria*.

Igneous: *Rocks* or processes involving the formation and solidification of hot, molten *magma*.

Ilmenite: Opaque mineral found in *basalt*; nearly pure iron-titanium oxide ($FeTiO_3$.)

Impact (see *Crater*)**:** The forceful striking of one body, such as a *meteorite*, against another body such as a moon or planet.

Impactor (see *Projectile, Meteorite*)**:** Object that impacts a surface.

KREEP: On the Moon, type of *highlands rock* rich in potassium (K), rare-earth elements (REE), and phosphorus (P).

Latitude: The angular distance North or South from the Earth's equator measured in degrees on the meridian of a point; Equator being 0° and the poles 90°N and 90°S.

Lava: fluid *magma* that flows onto the surface of a planet or moon; erupted from a *volcano* or *fissure*. Also, the *rock* formed by solidification of this material.

Levee: Zones in a *lava* flow where the lava between the zones is moving faster than the lava outside the zones.

Lifestyle (see *Sedentary*)**:** A person's general pattern of living.

Longitude: The angular distance East or West, between the meridian of a particular place on Earth and that of Greenwich, England, expressed in degrees or time.

Lunar: Of or pertaining to the Moon.

Magma: Term applied to molten rock in the interior of a planet or moon. When it reaches the surface, magma is called *lava*.

Magma Ocean: Term used to describe the layer of *magma*, hundreds of kilometers thick; thought to have covered the Moon 4.5 billion years ago.

Magnetic field: The region of "altered space" that will interact with the magnetic properties of a magnet. It is located mainly between the opposite poles of a magnet or in the energetic space about an electric charge in motion.

Mantle: A mostly solid layer of Earth lying beneath the *crust* and above the *core*; consisting mostly of iron, magnesium, silicon, and oxygen.

Mare basalt: Rocks making up the dark, smooth, *mare* areas of the Moon

Mare "soil": *Sediment* on the surface of the *lunar maria*; fragments of *basalt rocks*, broken *mineral* grains, and glass produced by *impact*.

Maria (mare): Dark areas on the Moon covered by *basalt lava* flows.

Metamorphic: *Rocks* that have recrystallized in a solid state as a result of changes in temperature, pressure, and chemical environment.

Meteorite (see *Impactor, Projectile*)**:** A metallic or stony (silicate) body that has fallen on Earth or the Moon from outer space.

Meteoritic bombardment: Intensive and prolonged *impacts* of a surface by *meteorites* or other *impactors*.

Mineral: Naturally occurring inorganic solid with a definite chemical composition and crystal structure.

Moonquake (see *Earthquake*)**:** Sudden motion or trembling of the Moon caused by the abrupt release of slowly accumulated elastic energy in *rocks*.

Mountain: A natural elevation of a planetary surface.

NASA: United States federal agency; National Aeronautics and Space Administration.

Nearside: The side of the Moon that always faces Earth.

Nondegradable (see *Biodegradable*)**:** Something that can not be chemically decomposed.

Norite: *Igneous* rock found in the *lunar highlands* composed of *plagioclase* and *pyroxene*.

Nuclear energy: Process by which the fission of ^{235}U releases heat to make steam, which then drives turbines to create electricity.

Nutrition: Process by which animals and plants take in and utilize food material.

Ocean of Storms: Landing site of *Apollo* 12 on the Moon on Nov. 19, 1969; Oceanus Procellarum.

Olivine: *Mineral* found in *basalt*; ranges from Mg_2SiO_4 to Fe_2SiO_4.

Orange "soil": On the Moon, a mixture of very small dark orange and black glass balls which formed from quickly cooled *lava* droplets during a *pyroclastic eruption*.

Organism: Any form of animal or plant life.

Pahoehoe: *Basaltic lava* with a smooth, billowy, or ropy surface.

Photosynthesis: The process by which plants convert water and carbon dioxide into carbohydrates, using sunlight as the source of energy and the aid of chlorophyll.

Plagioclase feldspar: Common *mineral*; ranges from $NaAlSi_3O_8$ to $CaAl_2Si_2O_8$.

Plate tectonics: Theory formulated in the late 1960s that states the Earth's *crust* and upper *mantle* (a layer called the lithosphere) is broken into moving pieces called plates. The formation of *mountains* and *volcanoes*, and the occurrence of *earthquakes* have been explained using this theory.

Pressure ridges: Long, narrow wavelike folds in the surface of *lava* flows; formed where lava may have buckled up against slower moving or stationary lava downstream.

Projectile (see *Impactor, Meteorite*)**:** Object that *impacts* a surface.

Pyroclastic eruption: Explosive eruption of *lava* producing and ejecting hot fragments of rock and lava.

Ray: Streak of material blasted out and away from an *impact crater*.

Recycling: To treat or process waste materials making them suitable for reuse.

Regolith (see *Sediment, Soil*)**:** Loose, unconsolidated *rock, mineral*, and glass fragments. On the Moon, this debris is produced by *impacts* and blankets the surface.

Rille: Long *channel* on the Moon crossing the surface of *maria*; probably formed either as an open channel in a *lava* flow, or as an underground tube carrying hot lava which collapsed as the lava flowed out.

Robot: A machine that does mechanical tasks on command and operates automatically.

Rock: A naturally formed solid that is an aggregate of one or more *minerals*.

Scale: The relationship of a distance on a map or model to the true distance in space; written as a ratio, such as 1:24,000.

Sea of Serenity: One of the *maria* on the Moon's *nearside*; Mare Serenitatis.

Sea of Tranquillity: Landing site of *Apollo* 11 on the Moon on July 20, 1969; Mare Tranquillitatis.

Sedentary (see *Lifestyle*)**:** characterized by much sitting and little physical activity.

Sediment (see *Regolith*)**:** Soild *rock* or *mineral* fragments transported and deposited by wind, water, gravity, or ice; preciptitated by chemical reactions; or secreted by organisms; accummulated as layers in loose, unconsolidated form.

Sedimentary: *Rock* formed when *sediment* is compacted and lithified.

Self-sustaining: Able to exist and function without outside help.

SNC meteorites (see *Meteorite*)**:** Group of meteorites with relatively young ages (slightly over 1 billion years old) that probably came from Mars.

Soil (see *Regolith, Sediment*)**:** The upper layers of sediment on Earth that support plant growth.

Solar power: Energy derived from the Sun or sunlight for use as a source of *electricity*.

Solar system: TheSun and all the objects (planets, moons, asteroids, and comets) that orbit the Sun.

Solar wind: The stream of charged particles (mainly ionized hydrogen) moving outward from the Sun with velocities in the range 300-500 kilometers per second.

Source (see *Eruption*)**:** Location where *igneous* matter (*lava* and gases) erupts onto the surface; vent, *fissure, volcano,* etc.

Spacecraft: Vehicle capable of traveling in outer space.

Stratigraphy: Study of layered rock to understand the sequence of geological events.

Taurus-Littrow: Landing site of *Apollo* 17 on the Moon on Dec. 11, 1972.

Terrain: Area of the surface with a distinctive geological character.

Tool carrier: Storage container for tools on the *Apollo Lunar* Roving Vehicle.

Transportation: The means of carrying something from one place to another.

Troctolite: *Igneous* rock found in the *lunar highlands* composed of *plagioclase* and *olivine*.

Vesicle: Bubble-shaped cavity in a volcanic rock formed by expanding gases.

Volatiles: Chemical elements that enter a vapor phase at relatively low temperatures.

Volcano: *Mountain* formed from the eruption of *igneous* matter through a *source* vent.

Water conservation: The wise use of water as a natural resource; the prevention of loss or waste of water.

Weathering: The mechanical breakdown and chemical alteration of *rocks* and *minerals* at Earth's surface during exposure to air, moisture, and organic matter.

Zoologist: Scientist who studies animals.

(This Glossary was compiled by Meredith Lee, Hawai'i Space Grant College.)

NASA Spacelink: An Electronic Information System

NASA Spacelink is a computer information service that individuals may access to receive news about current NASA programs, activities, and other space-related information, historical data, current news, lesson plans, classroom activities, and even entire publications. Although it is primarily intended as a resource for teachers, the network is available to anyone with a personal computer and a modem.

Users need a computer, modem, communications software, and a long-distance telephone line to access Spacelink. The data word format is 8 bits, no parity, and 1 stop bit. The Spacelink computer access number is (205) 895-0028.

NASA Spacelink is also available through the Internet, a worldwide computer network connecting a large number of educational institutions and research facilities.
Internet address is 192.149.89.61

For more information, contact:

NASA Spacelink Administrator
Marshall Space Flight Center
Mail Code CA-21
Marshall Space Flight Center, AL 35812
Phone: (205) 544-6527

NASA Educational Satellite Videoconferences

During the school year, NASA delivers a series of educational programs by satellite to teachers across the country. The content of each videoconference varies, but all cover aeronautics or space science topics of interest to the educational community. The broadcasts are interactive: a number is flashed across the bottom of the screen, and viewers may call collect to ask questions or to take part in the discussion. For further information, contact:

Videoconference Coordinator
NASA Aerospace Education Services Program
300 North Cordell
Oklahoma State University
Stillwater, OK 74078-0422
Phone: (405) 744-7015

Technology and Evaluation Branch
Education Division
Code FET
NASA Headquarters
Washington, DC 20546-0001
Phone: (202) 358-1540

Teacher Resource Center Network

To make additional information available to the education community, NASA's Education Division has created the NASA Teacher Resource Center Network. Teacher Resource Centers (TRCs) contain a wealth of information for educators: publications, reference books, slides, audio cassettes, videocassettes, telelecture programs, computer programs, lesson plans and activities, and lists of publications available from government and nongovernment sources. Because each NASA Field Center has its own areas of expertise, no two TRCs are exactly alike. Phone calls are welcome if you are unable to visit the TRC that serves your geographic area. A list of centers and the geographic regions they serve appears on Pages 147 and 148.

To offer more educators access to NASA educational materials, NASA has formed partnerships with universities, museums, and other educational institutions to serve as Regional Teacher Resource Centers (RTRCs). For the location of the RTRC nearest you, please contact the TRC serving your geographic region.

NASA's Central Operation of Resources for Educators (CORE) was established as part of the Teacher Resource Center Network to facilitate the national and international distribution of NASA-produced educational materials in audiovisual format. Orders are processed for a small fee that includes the cost of the media. Send a written request on your school letterhead for a catalog and order forms. For more information, contact:

NASA CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074
Phone: (216) 774-1051, Ext. 293 or 294

General Information for Teachers and Students

If you live in:		Center Education Program Officer	Teacher Resource Center
Alaska Arizona California Hawai'i Idaho Montana	Nevada Oregon Utah Washington Wyoming	Chief, Educational Programs Branch Mail Stop 204-12 **NASA Ames Research Center** Moffett Field, CA 94035-1000 PHONE: (415) 604-5543	NASA Teacher Resource Center Mail Stop T12-A **NASA Ames Research Center** Moffett Field, CA 94035-1000 PHONE: (415) 604-3574
Connecticut Delaware Dist. of Columbia Maine Maryland Massachusetts	New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont	Chief, Educational Programs Mail Code (130) **NASA Goddard Space Flight Center** Greenbelt, MD 20771-0001 PHONE: (301) 286-7206	NASA Teacher Resource Laboratory Mail Code 130.3 **NASA Goddard Space Flight Center** Greenbelt, MD 20771-0001 PHONE: (301) 286-8570
Colorado Kansas Nebraska New Mexico	North Dakota Oklahoma South Dakota Texas	Center Education Program Officer Education and Public Services Branch (AP-4) **NASA Johnson Space Center** Houston, TX 77058-3696 PHONE: (713) 483-1257	NASA Teacher Resource Center Mail Code AP-4 **NASA Johnson Space Center** Houston, TX 77058-3696 PHONE: (713) 483-8696
Florida Georgia Puerto Rico Virgin Islands		Chief, Education Services Branch Mail Code PA-ESB **NASA Kennedy Space Center** Kennedy Space Center, FL 32899-0001 PHONE: (407) 867-4444	NASA Educators Resource Laboratory Mail Code ERL **NASA Kennedy Space Center** Kennedy Space Center, FL 32899-0001 PHONE: (407) 867-4090
Kentucky North Carolina South Carolina Virginia West Virginia		Center Education Program Officer Office of Education Programs, Mail Stop 400 **NASA Langley Research Center** Hampton, VA 23681-0001 PHONE: (804) 864-8102	NASA Teacher Resource Center **Virginia Air and Space Center** 600 Settler's Landing Road Hampton, VA 23669-4033 PHONE: (804) 727-0900 x757

If you live in:	Center Education Program Officer	Teacher Resource Center
Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin	Acting Chief, Office of Educational Progams Mail Stop 7-4 **NASA Lewis Research Center** 21000 Brookpark Road Cleveland, OH 44135-3191 PHONE: (216) 433-2957	NASA Teacher Resource Center Mail Stop 8-1 **NASA Lewis Research Center** 21000 Brookpark Road Cleveland, OH 44135-3191 PHONE: (216) 433-2017
Alabama, Arkansas, Iowa, Louisiana, Missouri, Tennessee	Director, Executive Staff Code DX01 **NASA Marshall Space Flight Center** Marshall Space Flight Center, AL 35812-0001 PHONE: (205) 544-8843	NASA Teacher Resource Center **U.S. Space and Rocket Center** Huntsville, AL 35807-7015 PHONE: (205) 544-5812
Mississippi	Manager, Educational Programs Mail Stop MA00 **NASA John C. Stennis Space Center** Stennis Space Center, MS 39529-6000 PHONE: (601) 688-1107	NASA Teacher Resource Center Building 1200 **NASA John C. Stennis Space Center** Stennis Space Center, MS 39529-6000 PHONE: (601) 688-3338
The Jet Propulsion Laboratory (JPL) serves inquires from all over the nation related to space and planetary exploration and other JPL activities.	Manager, Educational Affairs Office Mail Code 183-900 **Jet Propulsion Laboratory** 4800 Oak Grove Drive Pasadena, CA 91109-8099 PHONE: (818) 354-8251	NASA Teacher Resource Center JPL Educational Outreach Mail Code CS-530 **Jet Propulsion Laboratory** 4800 Oak Grove Drive Pasadena, CA 91109-8099 PHONE: (818) 354-6916
California (mainly cities near Dryden Flight Research Facility)		Public Affairs Office (Tri. 42) NASA Teacher Resource Center **Dryden Flight Research Facility** Edwards, CA 93523-0273 PHONE: (805) 258-3456
Virginia and Maryland's Eastern Shores		Education Complex-Visitor Center Building J-17 **Wallops Flight Facility** Wallops Island, VA 23337-5099 PHONE: (804) 824-2297 / 2298