

# 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.

The maps produced by Clementine and Lunar Prospector will be useful for planning other types of missions, such as automated sample returns, robotic rovers, or human exploration. The chemical data allow sensible choices of landing sites to be made to optimize the scientific or industrial return from future missions.

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 Educator Resource Center (see Page 146) for more 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”

background 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.

# Lunar Land Use

## 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.

# Life Support Systems

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 ?

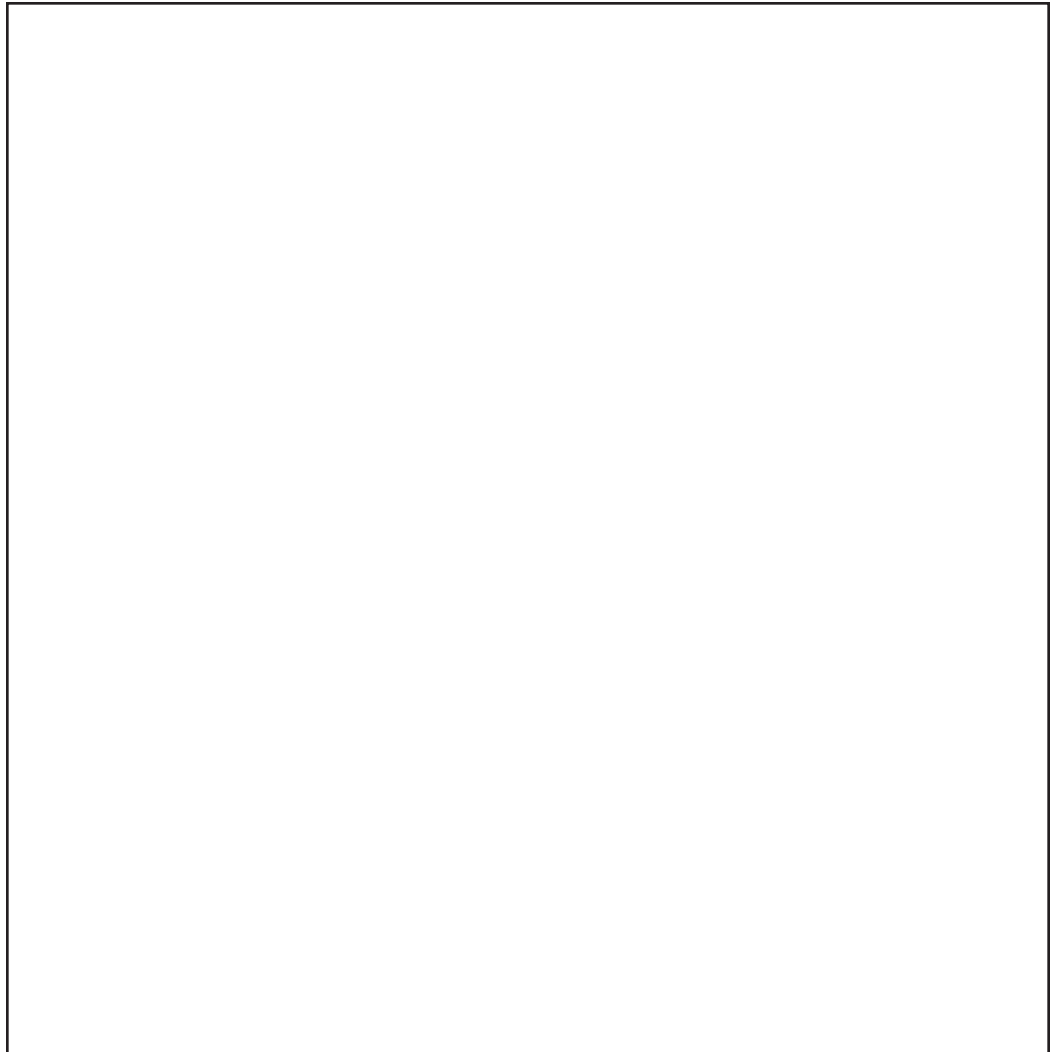
5. What gas do the green plants produce?

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?

# Air Supply

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.

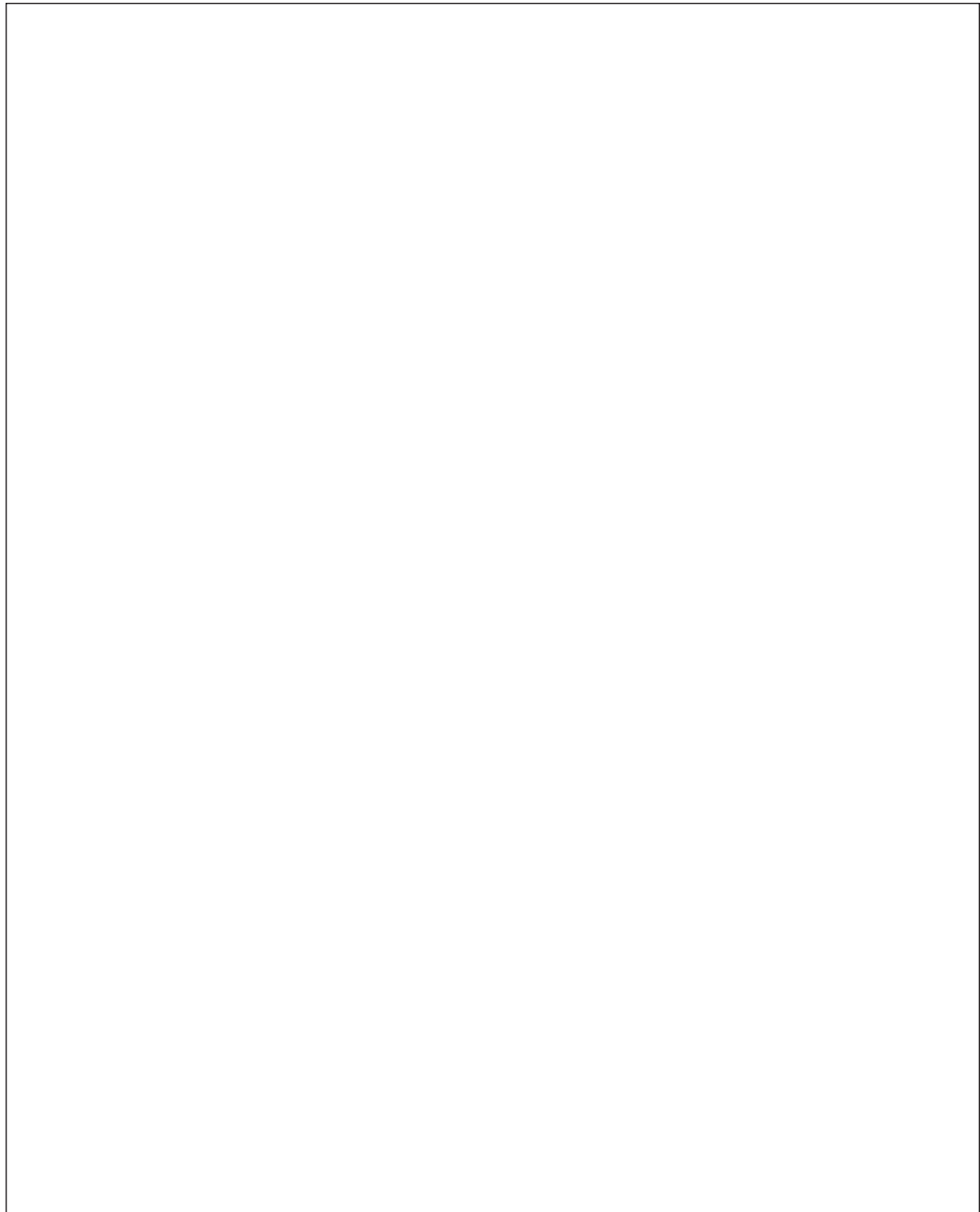
## Procedure

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.

# Communications

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.

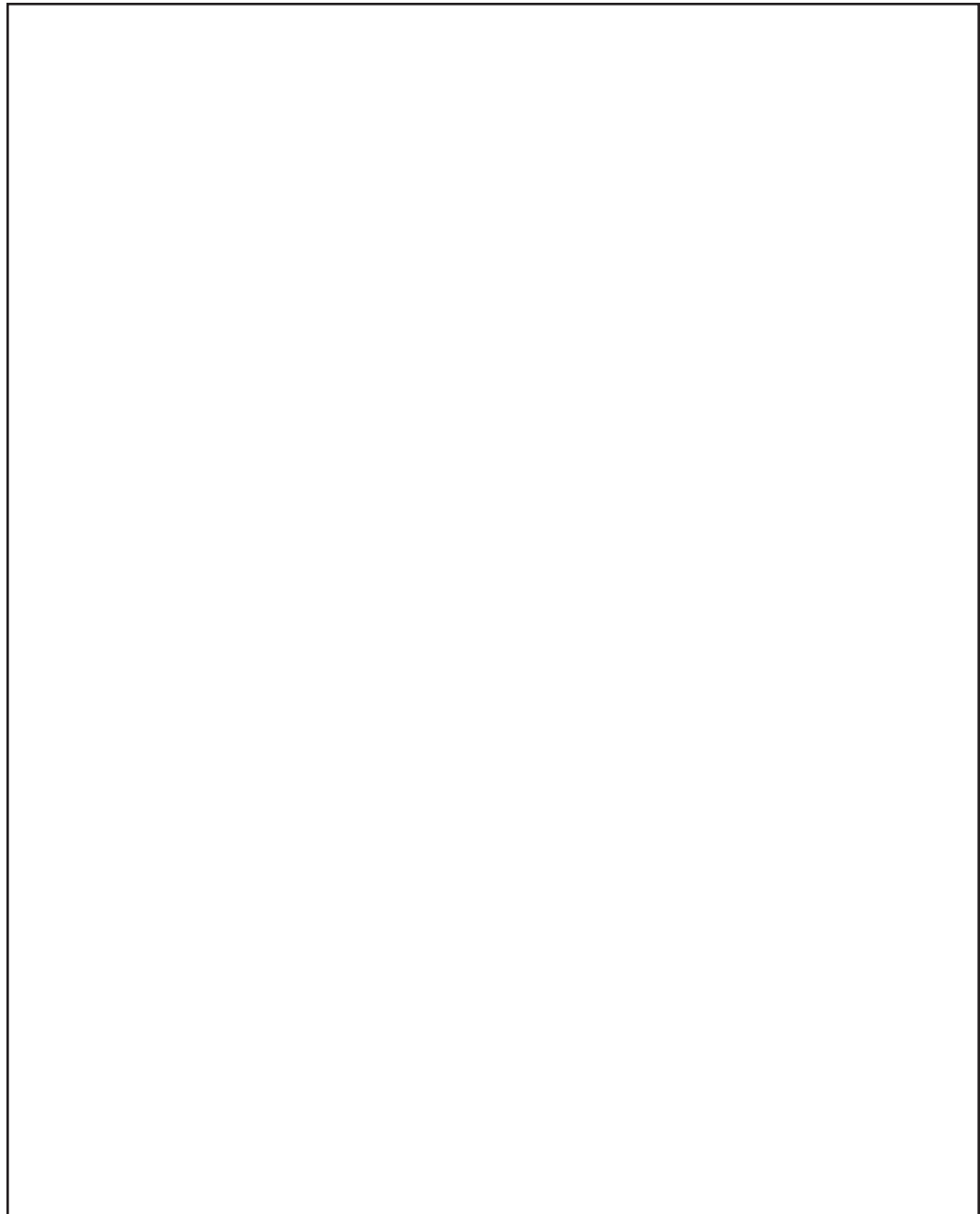
## Procedure

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.

# Electricity

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?

# Food Production

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?

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

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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?

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# Recreation

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

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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.

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

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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

Fahrenheit

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?

# Temperature Control

9. What different ways do we have of controlling the temperature on Earth?
10. Review the “**Moon ABCs Fact Sheet.**” How do temperatures 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.

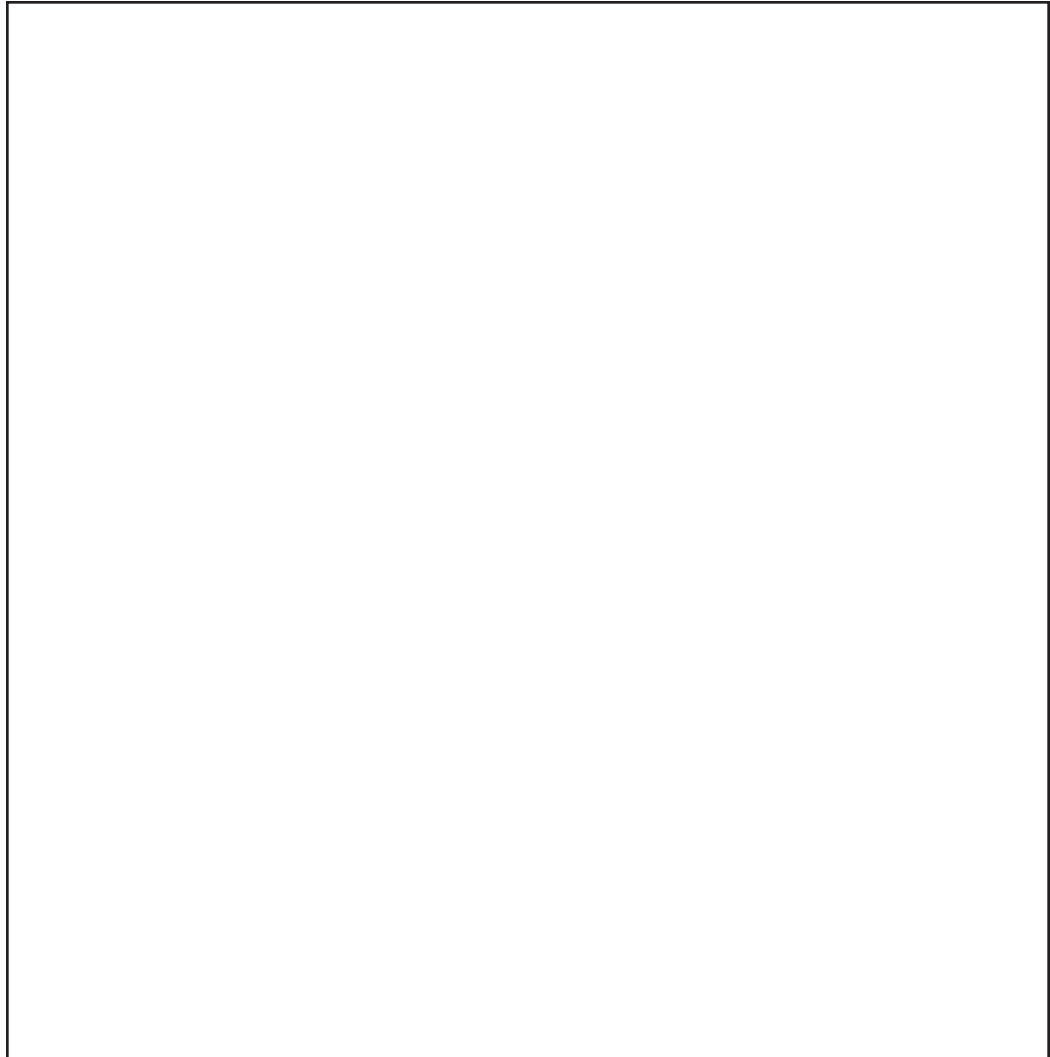
## Procedure

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.

# Transportation

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.

# Waste Management

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.

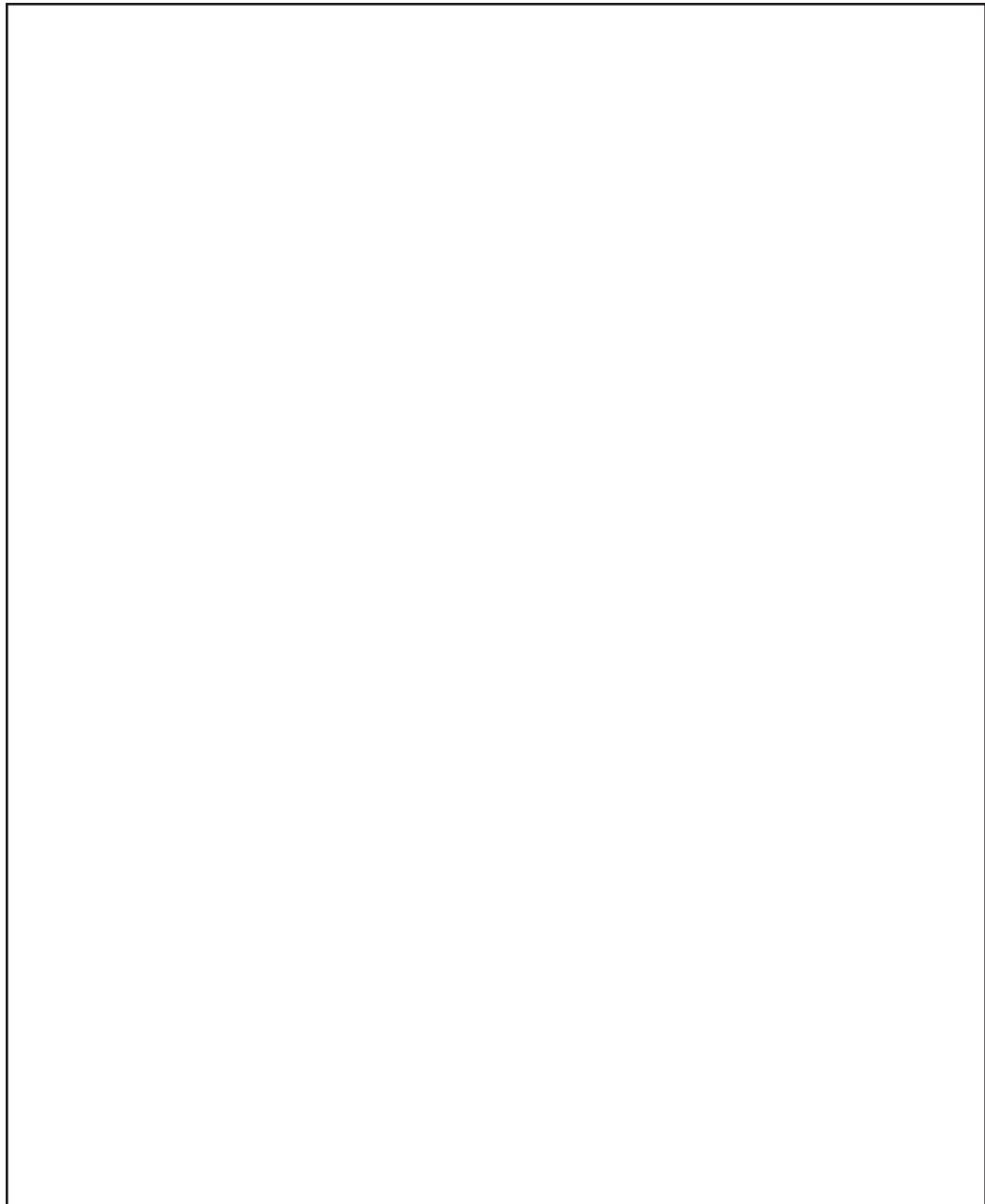
## Procedure

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.

# Water Supply

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





# 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.

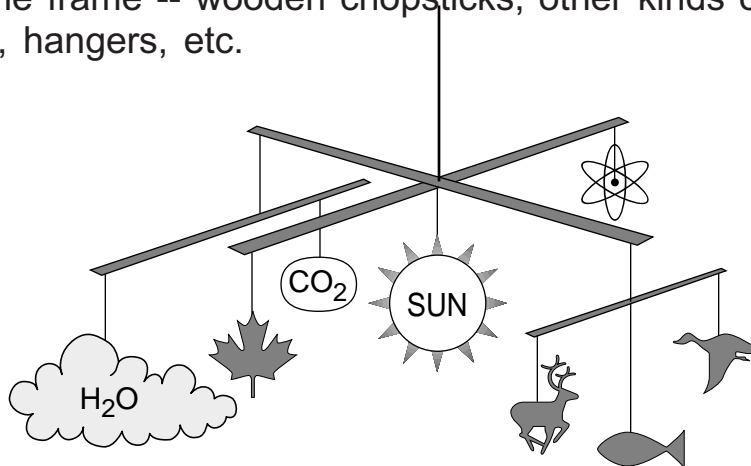
## Materials

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.





# Lunar Biosphere

## 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.

# Lunar Biosphere

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.

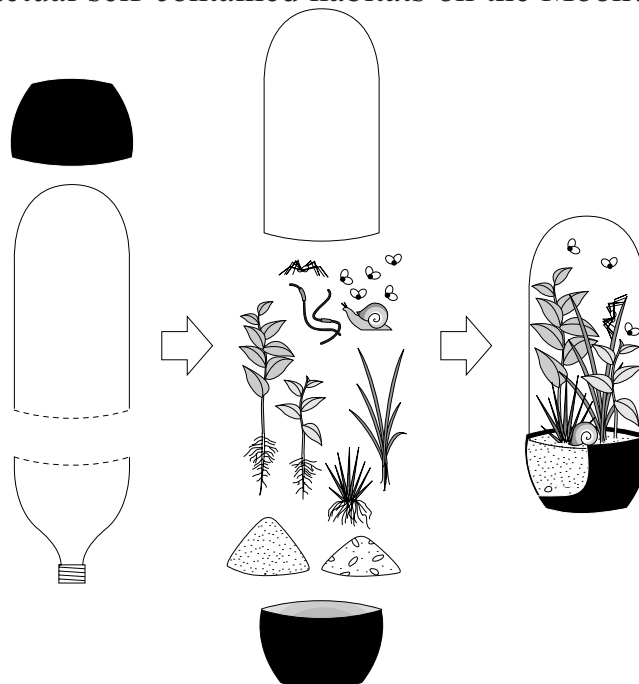
A “Data Sheet” and an “Observation Sheet” are provided for student use.

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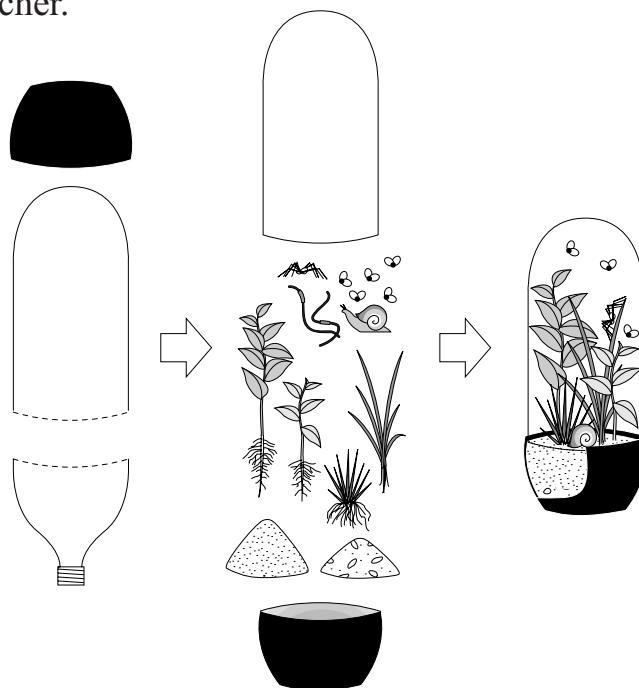
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3. List all important information you obtained from the **botanist, agronomist, science specialist, and zoologist** that will assist you in planning the most efficient and effective lunar biosphere possible.

# Lunar Biosphere

## 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 personal 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<br>Conditions | Height of Seedlings (cm) |        |        | Observations | Color<br>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.

# World Wide Web Resources for Educators for the Moon

## Lunar Exploration

[Lunar & Planetary Institute \(Exploring the Moon\)](http://cass.jsc.nasa.gov/moon.html)

<http://cass.jsc.nasa.gov/moon.html>

[Johnson Space Center \(future human exploration\)](http://www-sn.jsc.nasa.gov/explore/explore.htm)

<http://www-sn.jsc.nasa.gov/explore/explore.htm>

[International Lunar Exploration Working Group](http://ilewg.jsc.nasa.gov/)

<http://ilewg.jsc.nasa.gov/>

[National Space Science Data Center \(Moon homepage\)](http://nssdc.gsfc.nasa.gov/planetary/planets/moonpage.html)

<http://nssdc.gsfc.nasa.gov/planetary/planets/moonpage.html>

[Exploring the Moon](http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Materials/Sciences/Astronomy/Our.Solar.System/Earth's.Moon/Exploring.The.Moon.Teacher.Guide.4-12/.index.html) on-line version of this publication at NASA Spacelink

<http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Materials/Sciences/Astronomy/Our.Solar.System/Earth's.Moon/Exploring.The.Moon.Teacher.Guide.4-12/.index.html>

## Apollo Mission

[Apollo Experiment Operations](http://www-sn.jsc.nasa.gov/explore/Data/Apollo/Apollo.htm)

<http://www-sn.jsc.nasa.gov/explore/Data/Apollo/Apollo.htm>

[Apollo Lunar Surface Journal](http://www.hq.nasa.gov/office/pao/History/alsj/)

<http://www.hq.nasa.gov/office/pao/History/alsj/>

## Clementine Mission

[Lunar data from the Clementine Mission](http://nssdc.gsfc.nasa.gov/planetary/clementine.html)

<http://nssdc.gsfc.nasa.gov/planetary/clementine.html>

[Clementine Explores the Moon, annotated slide set](http://cass.jsc.nasa.gov/publications/slidesets/clementine.html)

<http://cass.jsc.nasa.gov/publications/slidesets/clementine.html>

[Clementine Mission - Images of the Moon](http://cass.jsc.nasa.gov/research/clemen/clemen.html)

<http://cass.jsc.nasa.gov/research/clemen/clemen.html>

## Lunar Prospector Mission

[Homepage from NASA Ames Research Center](http://lunar.arc.nasa.gov/)

<http://lunar.arc.nasa.gov/>

[Lunar Prospector homepage from Lockheed-Martin](http://juggler.lmsc.lockheed.com/lunar/)

<http://juggler.lmsc.lockheed.com/lunar/>

[National Space Science Data Center](http://nssdc.gsfc.nasa.gov/planetary/lunarprosp.html)

<http://nssdc.gsfc.nasa.gov/planetary/lunarprosp.html>

## Planetary Exploration

[Planetary Science Research Discoveries web magazine](http://www.soest.hawaii.edu/PSRdiscoveries/)

<http://www.soest.hawaii.edu/PSRdiscoveries/>

[Hands-on classroom activities for planetary science](http://www.soest.hawaii.edu/spacegrant/class_acts/)

[http://www.soest.hawaii.edu/spacegrant/class\\_acts/](http://www.soest.hawaii.edu/spacegrant/class_acts/)

[NASA Spacelink](http://spacelink.nasa.gov/)

<http://spacelink.nasa.gov/>

[Views Of The Solar System \(Calvin Hamilton/LANL\)](http://bang.lanl.gov/solarsys/)

<http://bang.lanl.gov/solarsys/>

[The Nine Planets - Moon pages \(Bill Arnett/SEDS\)](http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets/luna.html)

<http://seds.lpl.arizona.edu/nineplanets/nineplanets/nineplanets/luna.html>

[Welcome to the Planets \(PDS/JPL\)](http://pds.jpl.nasa.gov/planets/)

<http://pds.jpl.nasa.gov/planets/>

[Guide to the Solar System \(McDonald Observatory\)](http://stardate.utexas.edu/resources/ssguide/SSG_Content.html)

[http://stardate.utexas.edu/resources/ssguide/SSG\\_Content.html](http://stardate.utexas.edu/resources/ssguide/SSG_Content.html)

[NSSDC Planetary Image Catalog](http://nssdc.gsfc.nasa.gov/imgcat/)

<http://nssdc.gsfc.nasa.gov/imgcat/>

[NASA Planetary Photojournal](http://photojournal.jpl.nasa.gov/)

<http://photojournal.jpl.nasa.gov/>

[NASA Image eXchange \(NIX\)](http://nix.nasa.gov/)

<http://nix.nasa.gov/>



# NASA Resources for Educators

**NASA's Central Operation of Resources for Educators (CORE)** was established for the national and international distribution of NASA-produced educational materials in audiovisual format. Educators can obtain a catalogue and an order form by one of the following methods:

- NASA CORE  
Lorain County Joint Vocational School  
15181 Route 58 South  
Oberlin, OH 44074
- Phone (440) 774-1051, Ext. 249 or 293
- Fax (440) 774-2144
- E-mail [nasaco@leeca.esu.k12.oh.us](mailto:nasaco@leeca.esu.k12.oh.us)
- Home Page: <http://spacelink.nasa.gov/CORE>

## Educator Resource Center Network

To make additional information available to the education community, the NASA Education Division has created the NASA Educator Resource Center (ERC) network. ERCs contain a wealth of information for educators: publications, reference books, slide sets, audio cassettes, videotapes, telelecture programs, computer programs, lesson plans, and teacher guides with activities. Educators may preview, copy, or receive NASA materials at these sites. Because each NASA Field Center has its own areas of expertise, no two ERCs are exactly alike. Phone calls are welcome if you are unable to visit the ERC that serves your geographic area. A list of the centers and the regions they serve includes:

*AK, AZ, CA, HI, ID, MT, NV, OR,  
UT, WA, WY*  
NASA Educator Resource Center  
Mail Stop 253-2  
**NASA Ames Research Center**  
Moffett Field, CA 94035-1000  
Phone: (650) 604-3574

*CT, DE, DC, ME, MD, MA, NH,  
NJ, NY, PA, RI, VT*  
NASA Educator Resource Laboratory  
Mail Code 130.3  
**NASA Goddard Space Flight Center**  
Greenbelt, MD 20771-0001  
Phone: (301) 286-8570

*CO, KS, NE, NM, ND, OK, SD, TX*  
JSC Educator Resource Center  
Space Center Houston  
**NASA Johnson Space Center**  
1601 NASA Road One  
Houston, TX 77058-3696  
Phone: (281) 483-8696

*FL, GA, PR, VI*  
NASA Educator Resource Laboratory  
Mail Code ERL  
**NASA Kennedy Space Center**  
Kennedy Space Center, FL 32899-0001  
Phone: (407) 867-4090

*KY, NC, SC, VA, WV*  
Virginia Air and Space Museum  
NASA Educator Resource Center for  
**NASA Langley Research Center**  
600 Settler's Landing Road  
Hampton, VA 23669-4033  
Phone: (757) 727-0900 x 757

*IL, IN, MI, MN, OH, WI*  
NASA Educator Resource Center  
Mail Stop 8-1  
**NASA Lewis Research Center**  
21000 Brookpark Road  
Cleveland, OH 44135-3191  
Phone: (216) 433-2017

*AL, AR, IA, LA, MO, TN*  
U.S. Space and Rocket Center  
NASA Educator Resource Center for  
**NASA Marshall Space Flight Center**  
P.O. Box 070015  
Huntsville, AL 35807-7015  
Phone: (205) 544-5812

*MS*  
NASA Educator Resource Center  
Building 1200  
**NASA John C. Stennis Space Center**  
Stennis Space Center, MS 39529-6000  
Phone: (228) 688-3338

NASA Educator Resource Center  
JPL Educational Outreach  
Mail Stop CS-530  
**NASA Jet Propulsion Laboratory**  
4800 Oak Grove Drive  
Pasadena, CA 91109-8099  
Phone: (818) 354-6916

*CA cities near the center*  
NASA Educator Resource Center for  
**NASA Dryden Flight Research Center**  
45108 N. 3rd Street East  
Lancaster, CA 93535  
Phone: (805) 948-7347

*VA and MD's Eastern Shores*  
NASA Educator Resource Lab  
Education Complex - Visitor Center  
Building J-1  
**NASA Wallops Flight Facility**  
Wallops Island, VA 23337-5099  
Phone: (757) 824-2297/2298

**Regional Educator Resource Centers (RERCs)** offer more educators access to NASA educational materials. NASA has formed partnerships with universities, museums, and other educational institutions to serve as RERCs in many states. A complete list of RERCs is available through CORE, or electronically via NASA Spacelink at <http://spacelink.nasa.gov>

**NASA On-line Resources for Educators** provide current educational information and instructional resource materials to teachers, faculty, and students. A wide range of information is available, including science, mathematics, engineering, and technology education lesson plans, historical information related to the aeronautics and space program, current status reports on NASA projects, news releases, information on NASA educational programs, useful software and graphics files. Educators and students can also use NASA resources as learning tools to explore the Internet, accessing information about educational grants, interacting with other schools which are already on-line, and participating in on-line interactive projects, communicating with NASA scientists, engineers, and other team members to experience the excitement of real NASA projects.

Access these resources through the NASA Education Home Page: <http://www.hq.nasa.gov/education>

**NASA Television (NTV)** is the Agency's distribution system for live and taped programs. It offers the public a front-row seat for launches and missions, as well as informational and educational programming, historical documentaries, and updates on the latest developments in aeronautics and space science. NTV is transmitted on the GE-2 satellite, Transponder 9C at 85 degrees West longitude, vertical polarization, with a frequency of 3880 megahertz, and audio of 6.8 megahertz.

Apart from live mission coverage, regular NASA Television programming includes a Video File from noon to 1:00 pm, a NASA Gallery File from 1:00 to 2:00 pm, and an Education File from 2:00 to 3:00 pm (all times Eastern). This sequence is repeated at 3:00 pm, 6:00 pm, and 9:00 pm, Monday through Friday. The NTV Education File features programming for teachers and students on science, mathematics, and technology. NASA Television programming may be videotaped for later use.

For more information on NASA Television, contact:  
NASA Headquarters, Code P-2, NASA TV, Washington, DC 20546-0001 Phone: (202) 358-3572  
NTV Home Page: <http://www.hq.nasa.gov/ntv.html>

**How to Access NASA's Education Materials and Services, EP-1996-11-345-HQ** This brochure serves as a guide to accessing a variety of NASA materials and services for educators. Copies are available through the ERC network, or electronically via NASA Spacelink. NASA Spacelink can be accessed at the following address: <http://spacelink.nasa.gov>

