Live From Mars Program 3

Touchdown

Live Friday, July 4, 1997 and during *Pathfinder's* first week on Mars

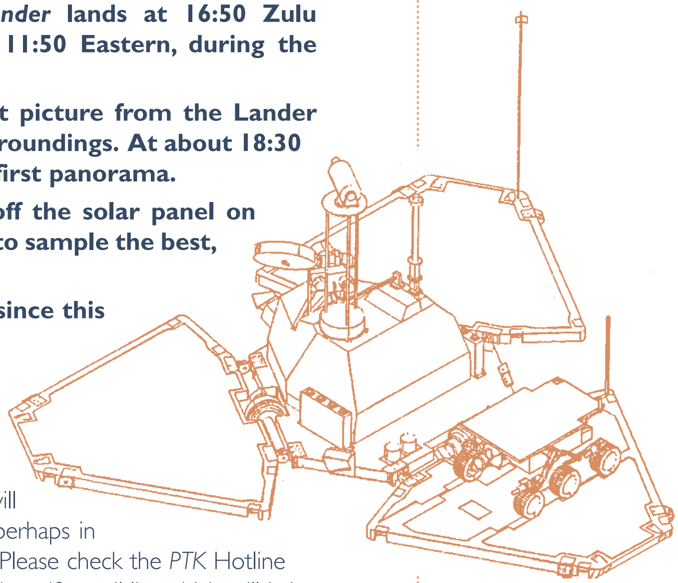
Live Sites: Mars, NASA JPL *Pathfinder* Mission Control, Science Centers and Planetariums

This is NASA's current plan for July 4, 1997: *Pathfinder* lands at 16:50 Zulu (Greenwich Mean Time), approximately 08:50 Pacific, 11:50 Eastern, during the Martian night—No light, no live images.

At approximately 17:00 Pacific, 20:00 Eastern—the first picture from the Lander camera, looking at the rover (still on its petal) and its surroundings. At about 18:30 Pacific, 21:30 Eastern, mission planners hope to see the first panorama.

"Sometime that day" the *Sojourner* rover should roll off the solar panel on which it's been sitting, and move about a meter to begin to sample the best, nearest rock sample with its APXS instrument.

Please note: ALL of these events are subject to change, since this will be an unfolding event.



We've said earlier that implementing *Live From Mars* is already an unusual opportunity, since the NASA missions extend over two school years. In addition, *Pathfinder's* landing on July 4, 1997, and the week following as the *Sojourner* rover explores the surface, comes at a time when most schools are out of session. *Passport to Knowledge* will cooperate with NASA to provide programming during this week, perhaps in conjunction with other broadcasters, but plans are not yet finalized. Please check the *PTK* Hotline in late Spring 1997 for detailed times and dates, and/or join the *updates-lfm* mail-list which will bring you the latest. But you should understand this is indeed "Real Science, Real Time." Mission emergencies could alter plans at any time, and both *Pathfinder* and *MGS* are inherently risky missions.

However, we are equally certain that, if all goes well, *Pathfinder* and Mars will be on the nightly national and local TV newscasts, on the front pages of newspapers, and all over the Internet (on the *Live From Mars* site at JPL and NASA's other sites, but mirrored on many other host computers in anticipation of the heavy load of interested visitors.)

The Activities which follow provide you with hands-on projects you can do before the end of the 1996-97 school year, to prepare your students for what they and their families can expect to see during those exciting first weeks of July. Some teachers have already suggested that "Mars" could be the "Summer Reading"/independent study project for 1997. On-line you'll find more discussion about this, and suggested books which might be added to "reading" the electronic and print media. Other veteran *PTK* teachers plan special July 4 sessions with their students, at school if they can arrange to have it open, at local parks or other public spaces (before the July 4 fireworks, for example) or at local science centers. Again, you'll be able to read about their plans on-line, under "Teacher Resources".

Many science centers and planetariums will take advantage of live NASA-TV news feeds carried on Spacenet 2 and widely used by museums and community colleges for Shuttle and other mission coverage, and mount special public programs. In Spring 1997, *PTK* will post on-line information about plans as they are finalized with science centers and museums. *Pathfinder's* landing provides a perfect example of how education can continue outside the classroom, involving parents and local resources beyond the school, and even extending beyond the school year, turning the Universe and the media into living textbooks.

We hope we're successful in this new kind of educational endeavor and that we'll receive your feedback about successes, and suggestions about how to best to realize such activities in the future.

The Incredible Light Bulb-Egg Drop Challenge

Teacher Background: The Incredible Bouncing Spacecraft

Pathfinder will enter the upper atmosphere of Mars at 7.6 kilometers per second at a 14.2 degree angle (90 degrees would be straight down). It will meet its peak atmospheric shock, encountering forces 25 times Earth's gravity, at 32 kilometers above the surface. At 10 kilometers above the ground, a parachute will deploy at nearly twice the speed of sound (400 meters per second). Rockets inside the backshell will fire to further slow the lander's descent. Shortly before landing, a set of airbags will inflate to cushion the impact. After a few seconds, the tether attaching the lander to the backshell and parachute will be severed, and, with 90 percent of the fuel expended, the rockets will carry the shell and other debris away from the landing area. Then, protected (hopefully) by its airbags, *Pathfinder* will bounce on the Martian surface, perhaps as high as a ten-story building, before finally coming to rest after its 8-month journey.

VOCABULARY

- atmosphere
- deploy
- descent
- gravity
- kilometer
- payload
- retro-rocket
- simulation

Objective

- Students will demonstrate an understanding of the challenges of soft landing a spacecraft on Mars by designing, building and testing their own "interplanetary lander."

Materials: For each team of students

- a square yard of tightly woven nylon material
- a paper lunch bag
- a plastic shopping bag
- 2–3 balloons
- two paper clips
- five feet of string
- three 8 1/2 x 11 inch sheets of paper
- masking tape
- a raw egg (now you know it's going to be fun!) or a light bulb

Materials: For the whole class

- a sensitive scale (e.g. postal scale)

NOTE: In advance of class decide whether your school's policies (and your own prudence) permit you to use light-bulbs, or whether you will choose to use an egg, or other "fragile payload". Exercise caution. Discourage students from leaning off ladders or out of windows! We suggest enlisting help in the final "Drop Test."

ENGAGE

From top of a ladder or table, drop a box of paper clips to the floor. It's noisy and messy, but nothing's broken. Ask students to think of ways they might safely land a fragile spacecraft on another planet. Tell them that in this Activity, they are going to play the role of NASA engineers, and are going to design, build and test their own interplanetary landers.

EXPLORE/EXPLAIN

In the above discussions, students may suggest the use of retro-rockets as in the Apollo moon landings or as seen in many science fiction films. Explain to students that while retro-rockets do work, they add significant size and weight to a spacecraft and, if their thrust is applied too close to a planet's surface, they can seriously disturb or contaminate the things scientists wish to study. Thus, in this Activity, they will be challenged to come up with small, light-weight alternatives that don't use retro-rockets for safely landing a very fragile payload on the surface of Mars.

Procedure

Divide the class into Engineering Teams and distribute a set of the above materials to each of the teams. Tell them they have exactly one class period to design and build a lander out of some or all of the materials they have received. The fragile payload they will be challenged to land safely is the egg or light bulb which, when placed in their "descent module", must survive a fall of three stories without breaking. At the end of the class period, their landers will be put away and retrieved on the first fair weather day available for testing. Tell students that each team is in competition with the others for an all important NASA contract and that the team which builds the lightest lander that successfully lands an unbroken egg or light bulb will be the winner.

When the big day arrives, record the weight of each lander and then, amid appropriate pomp and ceremony, have a colleague or parent volunteer drop each entry, one by one, out of a third story window, or off the school's roof.

An exciting alternative is to invite your local fire department to take part using one of their big hook and ladder trucks. Invite the local news media to cover the event. Video tape the contest and send us a copy here at *PTK* !

Additional Alternatives

Give the student teams the additional challenge of keeping the overall size of their lander to a certain volume, e.g., no more than 12 inches cubed. You may also wish to use this Activity as a take home assignment and possibly allow students to get advice from parents. This may prove an unfair advantage, however, to students with engineers in the family.

Expand/Adapt/Connect

In this Activity, students tested their creations on home ground. As a follow up, challenge them to research relevant similarities and differences between Earth, the Moon and Mars and draw conclusions as to how these might affect the design of their lander. The Moon has no atmosphere. Parachutes would be useless in slowing down landers on the Moon. Mars does have an atmosphere, but it's very thin. Therefore, a descent device that relied solely on a parachute to slow it down would not work nearly as well on Mars as on Earth, unless it were much bigger. This, in turn, adds weight and volume to the spacecraft. Mars has only about one third of Earth's gravity. Therefore, objects fall more slowly on Mars. Dropping something from a relatively low height on Earth would cause the object to have the same speed on impact.

Students studying physics will have ample opportunities to take this Activity further. They can, for example, study a lander's changing potential and kinetic energies as it falls. They can also study the rate of fall of the lander and compare final velocities, with and without parachutes, while learning about drag. Also noting that the force of gravity on Mars is only 38% of that on Earth, they can calculate how high a drop on Mars would result in the same velocity upon impact as a drop from a three story building on earth.

Write a news report for July 4, 1997, the day *Pathfinder* is scheduled to land on Mars.

Research the descent and landing sequence (link to JPL's *Pathfinder* page from the *LFM* site) and what scientific data it will be collecting as it descends through the Martian atmosphere. Do the same for the *Sojourner* rover as it leaves the lander and begins to traverse the Martian landscape. How is it powered, how long will it function, what data will it be sending back to Earth?

Research *MARS '96*, the Russian mission slated to take off in mid-November 1996, but to arrive at Mars after *Pathfinder.* Report to the class on similarities and differences between the Russian and American missions in terms of the rocket being used and the design of the lander. See if any Russian or German schools are on-line (the German space agency and German researchers are involved in both missions and German scientists contributed the "A" and "P" in *Sojourner's* APXS). Begin sharing updates on what your class is doing via the Internet.

SUGGESTED URLS

http://nssdc.gsfc.nasa.gov/planetary/mesur.html

http://www.nap.edu/readingroom/books/nses/egg6d.html

(Special thanks to PTK Advocate Fran O'Rourke-Hartman, of Cedar Wood Elementary School, Everett, Washington, whose students prototyped this Activity last year.)

Creating Craters

Teacher Background: Craters as Clocks and Clues

Almost all objects in the solar system that have solid surfaces (including planets, satellites and asteroids) have craters. While a few are of volcanic origin, most are the result of impacts from space. Much of the cratering we see dates back to a “period of bombardment” in the early days of the solar system (about 4 billion years ago) when the gravitational pull of larger bodies attracted smaller objects which crashed into them. This process has been important in the evolution of the planets. Cratering caused early melting of the planets’ crusts and excavated fresh sub-surface material. Impacts from space continue, but at a slower rate. Recent examples include the occasional meteorite fall on Earth and the collision of Comet Shoemaker-Levy 9 with Jupiter in July, 1994.

The Earth, our Moon and the planet Mars all bear the scars of impacts from space, but the Moon and Mars have many more craters than Earth. This is partly because water covers almost three-fourths of our planet, and partly because geologic processes like crustal movements and wind and weather have eroded most of the craters over time. There is no atmosphere or plate tectonics on the Moon, where many craters are visible. Many lunar craters still have steep walls and are very rugged in appearance—evidence of the lack of weathering.

Mars occupies a middle ground between Earth and the Moon in terms of craters. Widespread cratering is visible, but more craters are seen in Mars’ Southern hemisphere than in the North. Since the initial bombardment was presumably quite uniform across the planet, the relative lack of craters in the north correlates well with evidence of geological activity we can see in the region (faulting, uplifting, volcanism and flooding). All these would have served to obliterate earlier cratering. (See Activities 1.3 and 2.2 for more on this.) Thus the presence or absence of cratering in different parts of the planet helps date these regions relative to each other.

Mars also has a thin atmosphere and while no rain currently falls, there almost certainly has been running surface water in the past. Strong regional and even global dust storms periodically scour the surface. Martian craters show the effects of weathering. They are shallower, have lower rims and, generally, look much less rugged than most lunar craters.

On these and other worlds, the presence of craters within other craters, or superimposed over the rims of other craters, or craters on top of flow channels, or vice versa, helps create a planetary timeline.

VOCABULARY
- crater
- ejecta
- impact
- mass
- velocity

Objectives

- Students will work in teams to model crater formation and to investigate how mass, velocity and size of projectile affect an impact crater.
- Students will be able to identify and name the parts of an impact crater, and compare and contrast craters found on the Earth, the Moon and Mars.

Materials: For each team of 3 or 4 students

- images of craters on Mars, Earth, and Moon
- box, lined with trash bag; the sides should be at least 4 inches high (lid to photocopier paper box works well)
- flour to fill box approximately 3” deep
- three balls of the same size, about 1” across, of differing weight (e.g. ball bearing, wooden ball, and Styrofoam ball)
- three marbles of different sizes
- metric ruler
- safety goggles (one for each student)
- 2 dark colors of dry tempera paint, e.g. purple and green—you will need 2 colors besides the white flour. You might also try chocolate powder to see if you think this gives better results.
- scale to weigh projectiles (or teachers can supply weight information)
- meter stick
- plant sprayer (optional)
- plastic shovels or cups (for scooping flour)

ENGAGE

Pass out images of craters on Earth, the Moon and Mars. Ask students to identify these images, and to compare and contrast the physical features of these environments, as can be deduced from the images. Which environment(s) can support life? What observations support this hypothesis? Can the lunar environment support life? Can the Martian environment support life? How do we know? What theories are there regarding the issue of life on Mars? What clues do scientists look for to support the theory that water may once have existed on Mars?

Part 1: Formation of Impact Craters: How Mass, Velocity and Size Affect Impact Craters

EXPLORE

Procedure

1. Tell students that in this Activity, they will simulate the work of Planetary Geologists, and study craters.

2. Review directions on Activity 3.2 Student Worksheet.

3. Before beginning the hands-on activities, ask students to predict what factors they think will most affect the size of the craters they are going to make: the *mass*, *velocity* or *size* of an impacting projectile? Have students record these predictions in their Mission Logbooks.

4. After completing the Activity, compile and average student data. Have students share their conclusions and compare these with their pre-Activity prediction.

EXPAND/ADAPT/CONNECT

Students can create graphs illustrating the data gained from these investigations.

Older students can extend data to calculate potential and kinetic energy. Potential energy represents the force of the earth's gravitational pull. The formula for calculating potential energy is (mass) x (gravity) x (height) where the acceleration due to gravity = 980 cm/s/s, height is in centimeters and mass is in grams. Using the large marble, have students calculate the potential energy when the marble is released from the three different drop heights and finally when it is thrown from a height of 200 cm. As the marble falls, its potential energy becomes kinetic energy (the energy of bodies in motion). The formula for calculating kinetic energy is (1/2) x (mass) x (velocity) x (velocity) or 1/2 m vv or 1/2 mv^2.

Students may also calculate the kinetic energy for each of the above 4 drop conditions. Note: If only kinetic and potential energies were involved in this Activity, then the energy calculated should be equal. However, the marble in drop 4 "picked up" extra acceleration when it was thrown into the flour, so the kinetic energy came partly from potential energy and partly from your contribution of additional kinetic energy! The other marbles had only kinetic energy from their potential energy.

Part 2: Crater Structure: Parts of an Impact Crater

ENGAGE

Review the three factors affecting the initial size of a crater: mass, velocity and size of impacting object. Ask students to sketch a newly made crater, from both a birds-eye and cross-section perspective.

EXPLORE

Procedure

1. Have students continue procedure as outlined on Activity 3.2 Student Worksheet.

2. Have students complete a new set of sketches illustrating the structure of craters with appropriate labels. Add to Mars Mission Logbooks.

EXPAND/ADAPT/CONNECT

Have students go on-line and download images of craters from different planets. Suggest they record what they find in their Mission Logbooks. Ask them to explain how these craters may have been formed, pointing out examples of new and older craters and looking for signs of weathering and clues that water may have existed at these sites.

Have them revisit and annotate their predictions. Remember, we would like to see the results, so please send them to *PTK*.

Research the theory about the impact that is believed to have killed the dinosaurs

Write a "You Are There" news article about it, using the Five "Ws"—Who, What, When, Where, and Why.

SUGGESTED URL

http://cass.jsc.nasa.gov/pub/education/k12/exmars96/classact.html

Detecting Magnetic Materials in "Martian" Soil

Teacher Background

Pathfinder's experiments will begin even as the lander is descending through the thin Martian atmosphere. The spacecraft will look at the atmospheric structure and perform weather experiments—sampling pressure, temperature, and density of the atmosphere. After landing it will periodically look at the weather with its instruments, while the lander's camera records dust particle sizes and shapes, as well as panoramas. The camera has multiple color filters that will be used to figure out what minerals occur on Mars.

The Alpha Proton X-ray Spectrometer (APXS), an instrument on the Rover, will help determine the composition of the surface rocks. Those investigations will represent a reference point, or "ground truth" to help scientists calibrate remote-sensing information collected from orbit by *MGS* and successor spacecraft. A series of small magnets and a reference test chart will help test the magnetic component of Martian dust and any movement of the dust over time.

Objectives

- Students will simulate some *Pathfinder* experiments by devising methods of collecting and measuring magnetic substances in pseudo-Martian soil.
- Students will run controlled experiments to test the efficiency of each method and evaluate the efficiency of various collection methods.

Materials:

- bar magnets (1 for each team of 3 to 4 students)
- 1 box plastic sandwich baggies
- white construction paper
- petri dishes (4 per team)
- metric scale (1 per team)
- 1 bucket clean white sand
- 1 qt. iron filings
- measuring cups
- hand lens (1 per team)
- Data Collection Table (student made)

Before class, make synthetic Martian soil in following mixtures, labeled "A", "B", "C", and "D":

Mixture A 3 3/4 cups white sand 1/4 cup iron filings Mixture A = 6.25% magnetic	Mixture B 3 1/2 cups white sand 1/2 cup iron filings Mixture B = 12.5% magnetic
Mixture C 3 cups white sand 1 cup iron filings Mixture C =25% magnetic	Mixture D 3 1/2 cups white sand 1/2 cup soil Mixture D = ?% magnetic

ENGAGE

Explain to students that they are to design a method to separate and measure percentages of magnetic material found in 4 different samples of "Martian" soil.

Activity 3.3 Teacher Demonstration

Carefully place 1/4 cup "Martian" soil in clean petri dish. Examine with a hand lens. Record total weight. Cover the end of a bar magnet with a plastic baggie and demonstrate one possible method (scraping the magnet through the soil) to separate the magnetic substance from the non-magnetic substances in the "Martian" soil. Place magnetic substances collected in clean petri dish. Repeat procedure until you feel all magnetic substances have been removed from sample. (Ask students whether there should be a limit on the number of times you can repeat this procedure.) Brainstorm other methods (e.g. pouring the soil over the magnet, or spreading out the soil in a thin layer and passing the magnet over it). List ideas on chalkboard and allow time for students to discuss the pros and cons of each method. List the materials that will be on hand for their experiment and the need for careful measurements, observations and recording of data. Each team will need to construct a data table and formulate a procedure for conducting a well-controlled scientific investigation.

VOCABULARY

atmosphere
conclusions
hypothesis
petri dish
procedure
observations
Scientific Method
spectrometer

Explore

Procedure

1. Complete Teacher Demo as described above.

2. Allow time for each Mars Mission Team to design an experiment that tests 3 different methods of separating magnetic substances from the four samples of Martian soil. Each experimental design should include the following:

> ***statement of purpose, hypothesis, materials list, procedure, record of observations, and conclusion.***

3. All teams complete their experiments, recording data and preparing a lab report. Individual teams report findings and results to class.

Younger students might follow the sample procedure outlined below:

a. Prepare a soil sample that contains a known amount of magnetic material.

b. Try various collection methods and weigh the amount of magnetic material collected with each method.

c. Calculate the efficiency of each method; i.e., the weight collected divided by the weight originally present. Does each collection method approach 100% efficiency? Examine the separated magnetic substance with a hand lens. Was any white non-magnetic sand collected with the dark magnetic material? Why?

d. Repeat the experiment a few times. How reproducible are your results? How accurate are they?

e. Are your results consistent for each soil sample?

f. Did your experiment support your original hypothesis? What are your conclusions?

Expand/Adapt/Connect

Find out more about how *Pathfinder* actually assesses the magnetic properties of true Martian soils. (Hint: no baggies are involved!) Look on-line. Send questions to *Researcher Q&A* and post replies on your Bulletin Board.

Research the Alpha Proton X-ray Spectrometer. How does it work? What data will it send back to scientists on Earth? Why is this data important and how will it be used? What will the Alpha Proton X-ray Spectrometer not be able to do?

If you became a member of the "Planet X Mission" Planning Team, what requirements would you put on a soil sampling device? Record your ideas in your Mars Mission Logbook.

You are the Chief Scientist in the lab that will be investigating samples returned from Mars in 2003 (or thereabouts.) Write a detailed Laboratory Procedure that provides guidelines for the non-contamination of the returning samples by terrestrial material—and vice versa, keeping Earth safe from Mars!

How Pathfinder's rover got its name: SOJOURNER

The name *Sojourner* was chosen for the Mars *Pathfinder* rover after a year-long, worldwide competition in which students up to 18 years old were invited to select a heroine and submit an essay about her historical accomplishments. The students were asked to address in their essays how a planetary rover named for their heroine would translate these accomplishments to the Martian environment.

...Valerie Ambroise, 12, of Bridgeport, CT, submitted the winning essay about Sojourner Truth, an African-American reformist who lived during the Civil War era. An abolitionist and champion of women's rights, Sojourner Truth, whose legal name was Isabella Van Wagener, made it her mission to "travel up and down the land," advocating the rights of all people to be free and the rights of women to participate fully in society. The name *Sojourner* was selected because it means "traveler."

JPL scientists and engineers working on the Mars *Pathfinder* project and Planetary Society staff members reviewed the 3,500 total entries received from all over the world, including essays from students living in Canada, India, Israel, Japan, Mexico, Poland and Russia. Nearly 1,700 of the essays were submitted by students aged 5 to 18 years old.

for further information, see:

http://www-rover.jpl.nasa.gov/projects/rover/name.htm

SUGGESTED URLS

http://mpfwww.jpl.nasa.gov/sci_desc.htm/#APXS
http://ceps.nasm.edu:2020/MARS/Viking_lab.html

Live From Mars Program 4

Destination Mars

Tape: Feed date TBD

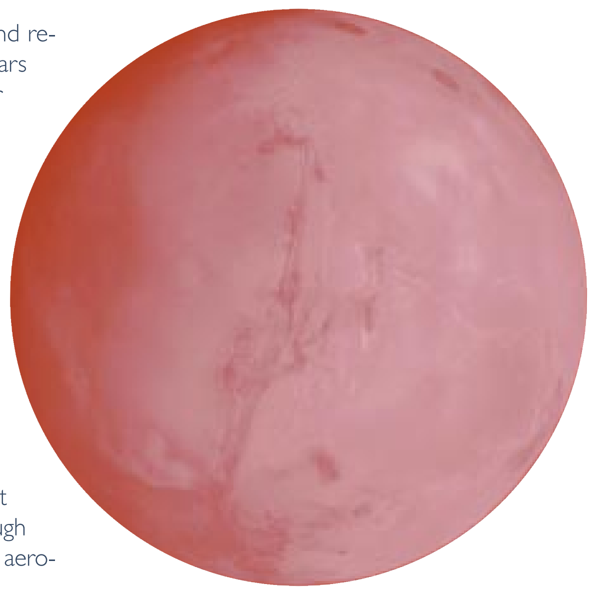
The PBS Teacher Resource Service does not schedule satellite time as far in advance as the publication date of this Guide: broadcast schedule information will be found on-line and via the *PTK* Hotline (1-800-626-LIVE). We anticipate carriage by participating PBS stations and NASA-TV: "Check Local Listings!"

Destination Mars is a one hour taped program, and will be available to teachers in October of 1997. This edited compilation of previous programming is intended to allow you either to:

- introduce an entirely new class of students to the unit by providing a digest of the "story to date." Teachers may then implement the entire *Live From Mars* electronic field trip in the Fall of '97 as one complete teaching unit, culminating with the live broadcast of Program 5, "Today on Mars", in November, 1997.

Or to:

- review the *LFM* Module begun in the 1996-1997 school year, and re-engage students to resume their roles as members of the Mars Mission Team before beginning the activities suggested for Program 5, "Today on Mars", airing in November. This would work, for example, for 5th graders who will enter 6th grade in '97-98, especially with a pre-planned "hand-off" between 5th and 6th grade teachers.



"Destination Mars" will carry students from the launches of *MGS* and *MPF* through *Pathfinder's* landing and *Sojourner's* deployment. It will incorporate the best student interactions from the earlier live programs, and the most engaging and informative responses from NASA's Mars mission team. It will include some of the hands-on demonstrations featured earlier, and thus—along with this Guide and the project's on-line resources—provide new adopters of *Live From Mars* with a complete orientation to the project. It will also feature updates on both *Pathfinder* and *Surveyor,* including a first look at the imagery and science data that's already been received (though *MGS* will only just have arrived in September to begin 4 months of aero-braking to lower itself into its final mapping orbit.)

To assist you in using this program, a transcript will be published on-line as an HTML document, linking images and other resources to the words and sequences of the videotape.

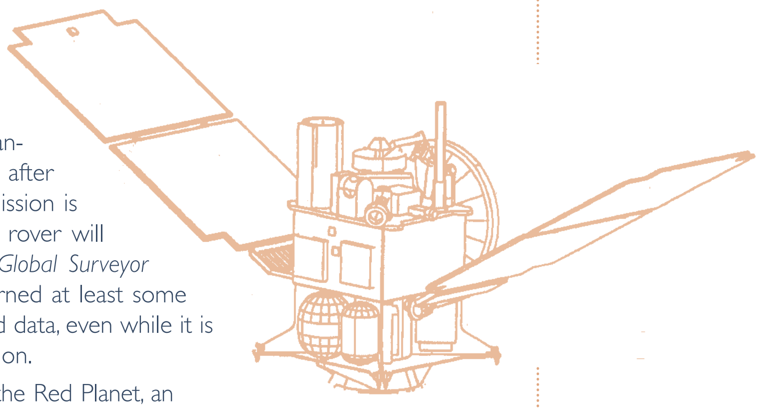
Since the content of the program is a compilation of the "best" of what's gone before, we suggest you choose from the Activities already proposed for Programs 1 through 3. On-line you will find teacher input selected from ***discuss-lfm,*** with comments about how best to implement these Activities in the classroom. In some ways, therefore, what you'll be able to do in Fall 1997 should be even more powerful than what we've initially suggested, since you'll be standing on the shoulders of your colleagues who already implemented *Live From Mars*, and contributed new creativity to the project.

Live From Mars Program 5

Today on Mars

Live Sites: Mars, NASA JPL, school sites TBA

The PBS Teacher Resource Service does not schedule satellite time as far in advance as the publication date of this Guide: broadcast schedule information will be found on-line and via the *PTK* Hotline (1-800-626-LIVE). We anticipate carriage by participating PBS stations and NASA-TV: "Check Local Listings!"



Today on Mars will truly be "live from Mars", featuring real-time imagery returning from the Red Planet. The *Pathfinder* lander completes its primary mission in 30 Earth days, but planners hope it will continue to operate for some time after that, perhaps on through 1998. *Sojourner's* baseline mission is for 7 days—but again, there's hope the plucky, little rover will keep going, and going, and going. Meanwhile, Mars *Global Surveyor* should be in orbit and in all likelihood will have returned at least some "contingency science", new high-resolution images and data, even while it is adjusting its orbit down to its final, planned configuration.

"Today on Mars" will be a kind of Weathercast for the Red Planet, an update on the temperature, winds and other information gathered from the missions. Has Mars in fact dropped 20 degrees since Viking landed, as *Hubble Space Telescope* data seem to indicate? What have the travels of *Sojourner* shown us, both about Mars itself, and about the capabilities of small exploratory rovers? What has APXS told us about the actual composition of the rocks? What can *MGS* see from orbit with its powerful cameras?

Mission scientists, some of whom students will have met almost one year earlier, will comment on the highs and lows of the journey to Mars, what they've learned about Mars, about high-risk, high-reward life on the scientific frontier, and what they hope will happen next. We'll see how the simulated Martian landscape at JPL has evolved since we saw it last in April 1997: the scientists will now have created a model of the actual landing site where *Pathfinder* sits on Mars. The technicians and engineers will be assessing *Pathfinder's* and *Sojourner's* strengths and weaknesses as they continue to build and test the next generation of landers and rovers.

The program will also feature on-camera student demonstrations about how to use the Internet to access and analyze the wealth of new data that's coming back, so that participating schools can literally get their hands on the same raw numbers with which the scientists are also working. *MGS* scientists will show how the spacecraft is able to characterize the Martian surface from orbit.

This is the final video currently planned as part of *Live From Mars*. But just as with *Pathfinder*, circumstance may permit an "extended mission." Additional programming may follow, most likely via NASA-TV. Indeed, in Fall '97, *Surveyor's* primary mission is just beginning, with its main data collection slated for early 1998 and on throughout that year. And our other component, the Internet, will provide ways to follow *MGS's* mission on through 1998—at which time NASA's next two Mars missions should be ready to launch!

The process of scientific inquiry is open-ended; what we learn from the *MPF* and *MGS* missions will only lead to greater challenges in the continuing exploration of our solar system and beyond. Similarly, this *Live From Mars* electronic field trip module is open-ended. It is intended to be used again, in whole or in part, with multiple school groups in the coming years. Re-use of the print and video components along with on-line access will allow students and teachers to continue their learning "mission" right alongside the Mars scientists. Real Science at Real Locations with Real Scientists in Real Time!

Today's Weather on Mars

Teacher Background: Seasons, weather and climate on Earth and Mars

The primary influence on Earth's seasonal temperature changes arises from the fact that its axis of rotation (its daily spin on an imaginary North Pole/South Pole line) is tilted relative to the plane of its orbit (its yearly path around the Sun). This tilt amounts to about 23 and a half degrees.

Mars' axis of rotation is also tilted to the plane of its orbit: about 25 degrees (almost the same as Earth). Thus, Mars also has seasons. As on Earth, scientists call these seasons summer, fall, winter and spring with opposite seasons occurring simultaneously in the northern and southern hemispheres. However, since Mars takes almost twice as long to go around the sun as does Earth, its seasons are almost twice as long as ours.

The Earth is actually *closest* to the Sun in early January and *farthest* from the Sun in early July. However, Earth's orbit is so close to circular that the tilt of our planet's axis has far more to do with temperature differences from summer to winter than our planet's distance from the Sun. Mars' orbit is considerably more elliptical than Earth's. Mars' distance from the Sun varies from as little as approximately 128 million miles (207 million kilometers) to as much as about 154 million miles (249 million kilometers). Thus, at times, Mars is about 20% closer to the Sun than at other times and this changing distance from the Sun also significantly influences its seasons.

Because a planet travels fastest around the Sun when it is closest to it and slowest when it is farthest away, this also has an effect on the length of the seasons in the different hemispheres. During the current epoch, Mars is closest to the Sun when it's summer in the southern hemisphere. Thus, southern hemisphere summers on Mars are currently shorter but warmer than those in the northern hemisphere, while northern hemisphere winters are shorter but colder than those in the southern hemisphere. Southern hemisphere summer temperatures can be as much as 60° F degrees (33° C) warmer than those in the northern hemisphere.

Because Mars is farther from the Sun than Earth, its average seasonal temperatures are, as you would imagine, colder than on earth. Mars has an atmosphere that's mostly carbon dioxide. This creates a greenhouse effect, but because the atmosphere is so thin, the resulting increase in global temperature is only about 5 to 10 degrees. Overall, Mars is much colder than Earth.

On a warm summer afternoon, near the Martian equator, the surface temperature can occasionally climb to 65° F (18°C). Even a few centimeters above the surface, however, temperatures are lower. And at this same spot, the temperature at sunset will have dropped to below freezing and during the night the thermometer will plunge to more than 100 degrees below zero F. Around Mars' Northern polar cap, during the long winter nights, temperatures can fall to as much as 200 degrees below zero F!

Normally, the thin Martian atmosphere is clear and the planet's surface can be easily seen. Occasionally, there are clouds. The white or blue-white clouds are composed of H_2O ice crystals or, more commonly, carbon dioxide ice crystals. These can be seen around the summits of Mars' huge, extinct volcanoes, along the sunrise limb of the planet or in the canyons. Yellowish clouds are the result of fine grains of Martian desert dust being blown into the air. Occasionally, especially when warm summers come to the Southern hemisphere, giant dust storms spread to cover most of the planet for weeks in billowing clouds that are several miles high.

Martian surface winds are normally quite light (between about 4 and 15 miles per hour [6.5–24 km/hour]). On occasion, however, surface winds gust to about 50 miles (80 km) per hour and, during dust storms can blow at over 300 miles (480 km) per hour. Because the Martian atmosphere is so thin, however, you would feel much less pressure from the wind than if you stood in a similar speed wind on earth.

Light frosts do occur on Mars and light snows may occasionally fall, but most of the build up in the Martian polar caps during the winter months is due to direct condensation of H_2O and carbon dioxide out of the atmosphere.

The Martian Sun Times

An interesting multidisciplinary extension using Viking data invites students to become weather reporters for *The Martian Sun-Times* can be found on-line. For the full activity, see:

http://www.ucls.uchicago.edu/MartianSunTimes/For_Teachers.html

Skills involved include Inferring, Interpreting Data, Identifying Variables, and Graphing

Activity I: Seasons on Mars and Earth: Endless Summer Vacation?

Activity II: Today on Mars and Earth: Hot is a Relative Term

Activity III: Atmospheric Conditions on Mars and Earth: Is It All Sun All the Time?

Activity IV: Probing Earth: What Should We Pack?

The project, developed at the University of Chicago, also suggests the teacher may want to have encyclopedia and other book resources available for students to read about the Dust Bowl which took place in the Great Plains region of the United States in the 1930s. Students will find interesting the songs written by Woody Guthrie about the effects of the Dust Bowl...

Objective

• Students will research temperature and wind data locally, nationally and internationally and compare these to conditions on Mars, and draw conclusions about differences and causes.

Materials

Engage

▼ maximum/minimum thermometer ▼ an anemometer ▼ barometer ▼ state map ▼ map of the world	▼ map of Mars ▼ weather data maps of Mars (contained in the Teacher Materials) ▼ newspaper (showing weather data)

Ask students about temperature and wind. What is the hottest they can ever remember it being in their town? The coldest? What's the average wind speed? How high are wind speeds in a hurricane? A tornado?

Explore/Explain

Explain to the students that they will research temperature and wind conditions on Earth and then compare these to our neighbor world, Mars.

Procedure

If your school has a weather station, ask students to make daily records of maximum and minimum temperatures and the relative humidity over the course of a couple of weeks. If your school has the necessary equipment, have students record the average and peak wind speeds as well. If your school (or another school in your area) has kept such records over the past year, have students access these records and examine them. From this data or other sources such as the weather office at a local TV or radio station, The Weather Channel, the National Weather Service or the World Almanac, ask them to research the average daytime high and nightime low temperature records in their area for each month of the year, as well as the all-time high and low temperature records for their state, the country and the world.

Ask students to examine the average high and low temperatures in their area at different times of the year (especially summer and winter). Ask them to consider the length of day and night and the height of the sun in the sky, but also such factors as relative humidity, elevation, wind direction, ocean influences, etc. Tell students to research the average high and low temperatures in January and July in San Francisco, Miami, Rio de Janeiro, Quito, Riyadh, Jakarta and Sydney. Have them post these temperatures on their world map. How do these temperatures and day-night temperature differences vary with latitude? Consider other factors such as distance from equator, elevation, tropical or desert environment, or ocean influences.

Next turn students' attention to Mars. Have students access *Viking*-based Mars temperature data from the Web, or give teams copies of the temperature data sheets in your Teacher Materials. After helping students become familiar with these temperature maps, have them compare these maps to the surface features of Mars. Ask them to make tables (on paper, or as computer spreadsheets) of the average daytime high and nightime low temperatures during summer and winter on Mars, for latitudes at 45 and 80 degrees north and south latitude by averaging temperatures at longitudes of 0, 90, 180 and 270 degrees. Next, have students compute the difference between daytime highs and nightime lows for each of these locations. Challenge them to explain the temperatures and day-night temperature differences that they observe. Have them compare the maximum and minimum temperatures they observe on Mars with the temperature records for their city, state, country and Earth as a whole.

Give students information about the average and peak winds on Mars and have them compare these to average winds in their area. Compare the wind speeds in Martian dust storms with the winds in such terrestrial storms as hurricanes and tornadoes.

VOCABULARY

anemometer
barometer
climate
thermometer
weather

Note:

The primary landing site on Mars for the *Pathfinder* spacecraft is in the area of Ares Vallis, somewhere around latitude 20 degrees north and longitude 31 degrees at a time that will be late summer in Mars' northern hemisphere. Challenge your students to come up with a weather forecast for the date of the landing (July 4, 1997) for this landing site and a general temperature forecast for the next six months on Mars (that is, through December 1997) for this location.

SUGGESTED URLS

http://humbabe.arc.nasa.gov
http://www.atmos.washington.edu

Expand/Adapt/Connect

Teachers can introduce the formulas for converting Celsius to Fahrenheit and vice versa, as well as kilometers per hour to miles per hour, and give their students practice manipulating the algebraic equations.

Teachers of students in higher grades can use this Activity to give students experience in graphing such variables as maximum temperature, minimum temperature and temperature difference against time or longitude, and superimposing graphs of Earth data with corresponding graphs from Mars.

Have teams of students research and prepare weather reports for different locations on Mars. Then with appropriate graphics and maps which they prepare themselves, have them deliver 3 to 5 minute "Team Coverage" weather reports from around the Red Planet for the latest edition of the "Interplanetary News Network" (which premiered with weathercasts for Pluto and Neptune during our previous *Live from the Hubble Space Telescope* Module). Suggest that a student report from both the North and South polar caps. Others can be stationed on top of Olympus Mons, and on the equatorial plains near Valles Marineris and in front of a monstrous dust storm heading their way. Videotape the broadcasts, and send us copies at *PTK.*

Tell students that they are meteorologists on board the first human mission to Mars and ask them to write excerpts from their Weather Log compiled over a year's stay on the surface of the Red Planet. Students could either stay where they landed, or ask them to imagine that their team has been equipped with a special roving vehicle that will allow them to travel to the exotic locations to be found all over Mars.

Real Science, Real Scientists ...Real Time

Tracking Martian Weather with actual NASA data

Some of the most revolutionary aspects of contemporary science and science education arise from the new tools used to collect and share data, and new approaches to involving secondary school students directly in the analysis of raw data.

Martian weather data will return to Earth at the speed of light, be shared in near real time with the Principal Investigators (P.I.'s) for each of the science instruments, and then—again in near real time—be made available to other researchers and the general public over the Internet. This special Expand section is intended to give the reader of the Print Guide sufficient information *and motivation* to go on-line, where you will find full details about how to access and use the incoming stream of new Martian data and images.

Both *MPF* and *MGS* have instruments recording weather information: here are excerpts from NASA briefings:

Mars *Pathfinder*

"...The Imager for Mars *Pathfinder* is a stereo imaging system with color capability provided by a set of selectable filters for each of the two camera channels... A number of atmospheric investigations are carried out using IMP images. Dust particles in the atmosphere are characterized by observing Phobos at night. Water vapor abundance is measured by imaging the Sun through filters in the water vapor absorption band ...Images of wind socks located at several heights above the surrounding terrain are used to assess wind speed and direction ...The IMP investigation also includes the observation of wind direction using a small wind sock mounted above a reference grid, and a calibration and reference target mounted to the lander.

Atmospheric Structure Instrument/Meteorology Package

The ASI/MET is an engineering subsystem which acquires atmospheric information during the descent of the lander through the atmosphere and during the entire landed mission... Data acquired during the entry and descent of the lander permits the reconstruction of profiles of atmospheric density, temperature and pressure from altitudes in excess of 100 km to the surface.

...The ASI/MET instrument hardware consists of a set of temperature, pressure and wind sensors... Temperature is measured by thin wire thermocouples mounted on a meteorological mast that is deployed after landing. The location of one thermocouple is chosen to measure atmospheric temperature during descent, and three more monitor atmospheric temperatures 25, 50, and 100 cm above the surface during the landed mission. Pressure is measured by a Tavis magnetic reluctance diaphragm sensor similar to that used by *Viking,* both during descent and after landing. The wind sensor employs six hot wire elements distributed uniformly around the top of the mast. Wind speed and direction 100 cm above the surface are derived from the temperatures of these elements.

Mars *Global Surveyor*

In late 1997 and more especially on through 1998, Mars *Global Observer* will also provide weather information, along with global imagery, topographic mapping and soil and rock profiles. Here's what the *MGS* Radio Science team at Stanford University intend:

The *MGS* Radio Science Team will employ a technique called radio occultation to probe the Martian atmosphere. Twice per orbit, *MGS* will be occulted by Mars and an ultrastable radio transmission from the spacecraft to Earth will pass through and be perturbed by the thin atmosphere of Mars. (ed. As the spacecraft goes behind Mars and then emerges from behind the planet— "occultation"— the radio signal returning to Earth will be affected by the varying amount and character of the Martian atmosphere through which it's being transmitted.) ...Analysis of the perturbations ...will yield profiles of the temperature and pressure of that atmosphere as a function of height above the planet's surface. Team members are hopeful that sophisticated inversion techniques which they are developing will permit the derivation of temperature and pressure profiles with a resolution of 10 meters!

The atmospheric profiles will provide the basis for the *Daily Martian Weather Report* which will be posted to this page (ed. note: see URL listing below) as raw data is collected and analyzed. Please come back and find out about the Martian climate, the atmospheric temperatures and pressures, the effects of Martian dust storms (massive temperature inversions), and the very interesting seasonal variations which occur as polar ice caps form and thaw.

How to access Real Science, Real Time

The *Live From Mars* Web site will provide updated links to all the weather data and imagery returning from both missions. It will also point to curriculum materials developed by the research teams who built and use the various instruments. Encouraging P.I.'s and their co-workers to engage directly in Education and Outreach is another innovative aspect of these missions. Just as with the *Live from Mars* project, it's a chance for your students to engage in Real Science, with Real Scientists.

MGS Radio

To fully appreciate the significance of the *MGS* radio occultation measurements, think about this. If you were to launch a weather balloon from the surface of Mars, you would be able to measure the temperature and pressure at many heights as the balloon rose through the Martian atmosphere. You would essentially be able to collect one profile each of atmospheric temperature and pressure. Using the radio occultation technique, the *MGS* scientists have the potential to collect two of these sets of profiles for each orbit of the *MGS* spacecraft. With 12 orbits per day and 687 days in a Martian year, the Radio Science Team members may gather as much data on the Martian atmosphere as if they were able to release many thousands of weather balloons at various locations on the red planet and measure the temperature and pressure at 10 meter intervals above the Martian surface!

URLS

http://mpfwwww.jpl.nasa.gov

http://nova.stanford.edu/projects/mgs/dmwr.html

Sun, Shadows, Surface Structure... and the Face on Mars

Teacher Background

As we've seen, one of the most enduring beliefs about Mars is that it once was inhabited. Remember the 19th century mania about canals and the alluring fiction of H.G. Wells and Orson Welles? Since the Viking mission, some people think they can see new physical evidence of a past civilization on Mars: they interpret images of one particular area as showing a face—a kind of monumental structure rather like the Sphinx and Pyramids of ancient Egypt. Most scientists are very skeptical about this, and argue that the face is just a trick of the light playing on natural surface formations. Still public interest remains. This Activity uses the face as a way to dramatize the kind of image interpretation planetary geologists must do to account for illumination angles before they can determine surface structure. It also serves as an antidote to contemporary wishful-thinking which echoes Percival Lowell's now discredited beliefs. Armed with experience in image analysis, students (and their parents) can better make up their own minds about the face, the pyramids, the library and other fabulous monuments on Mars.

VOCABULARY
image
angle
ratio
shadow
elevation
depression

Objective

- Students will use light and shadow information to make inferences regarding the three dimensional shapes of specific objects photographed on the surface of Mars.
- Students will explain the limitation of some data in reaching definitive conclusions about the shape of the specified objects.
- Students will explain what further data would be needed to more precisely describe the three dimensional shape of the objects.

Materials: For each student or team of students

- a 1 x 3 x 6 inch piece of modeling clay
- a bright light source that can cast sharp shadows in a darkened room
- two rulers
- a protractor
- a transparent grid overlay
- copy of Image A
- copy of Image B
- a video camera, if available
- copies of Shadow Patterns 1-5

ENGAGE

Procedure

Tell students that they are on an Imaging Team whose task is to interpret the first images sent back to Earth from a planetary probe to an unknown world. Distribute copies of Shadow Pattern 1A to students. Explain that this is a simulated image from an orbiting spacecraft of a planetary surface feature and that the dark area is a shadow cast by the surface feature. Ask them to write down what they think is the actual shape of the feature. Tally answers on the board. Distribute copies of Shadow Pattern 1B. Again, pose the same question. Tally answers on the board. (If they seem to need a clue, tell them that the surface features are either a dome shaped mountain or a bowl shaped crater.) Allow time for discussion and re-evaluation of their original guesses. Then reveal to students that without an additional piece of information, there is no way they can conclusively state the answer.

SUGGESTED URLS

http://barsoom.msss.com/education/facepage/face.html

http://barsoom.msss.com/education/happy_face/happy_face.html

Explore/Explain

Procedure

1. Explain to students that without knowing the direction of the incoming light they don't really know whether the surface feature in question is a mountain or a bowl shaped crater with no rim.

2. To illustrate, complete the following demonstration: Using two 3-D models (one of a mountain and one of a rimless bowl shaped crater) in a darkened room, hold the light source at nearly right angles to the surface of the clay (as would happen if the sun was low in the sky). First hold the light *right* and then *left* of each feature and refer to Shadow Patterns 1A and 1B as you do this. Show students that relative to the same incoming light, a shadow cast by the mountain differs from that cast by the crater. Explain that when scientists examine new images of planetary features from orbiting spacecraft, they must take the viewing angle of the spacecraft and the angle of the sun into account. If they don't, the images may be misinterpreted. Also note that the images from spacecraft are 2-D renderings of 3-dimensional objects and the way something looks often depends on the angle from which we are viewing it *and* the angle of incoming light.

3. Distribute Shadow Patterns 2 and 3, pieces of modeling clay and light sources to teams of students. Tell them that in each Shadow Pattern image the arrow indicates the direction of the incoming sunlight and the letter "N" indicates the direction North. For each pattern, challenge them to discover the direction the sun would appear in the sky if they were standing on the surface of the planet where the feature is located and the approximate shape of the surface feature. Have students model the surface features with their clay and reproduce the shadow patterns using their light sources. Have teams verify each others' models.

4. Once students have mastered the above, distribute Shadow Pattern 4A. Ask them to determine the direction of the sun in the sky if they were on the surface of the planet, and the nature and shape of the surface features casting these shadows. Write their hypotheses on the board and discuss.

5. Distribute copies of Shadow Pattern 4B. Explain that this is an image of the same region on the planet but taken about 12 hours later. Ask students to determine the direction of the sun if they were on the surface when the image was taken. Tell them to examine this image and compare it to the one taken 12 hours earlier. Each team should discuss what physical feature(s) might be represented by the shadows in 4A and 4B, then construct a model using light sources and clay. Teams can verify each others' models.

6. Distribute copies of Shadow Pattern 5A and again ask teams to determine the direction of the sun in the sky and guess the shape and nature of the surface features casting the shadow. (Note: A variety of correct answers are possible based on only this one image.) After various possibilities are formulated and discussed, tell students that you have inside information that at the time this image was taken the sun was rather high in the eastern sky and the surface features in question are actually a series of straight and narrow trenches in the surface of the planet. Three of these trenches run East and West and are the same length. The fourth trench runs North and South and is about half the length of the others. Using this information, ask teams to model these trenches and shadow patterns using clay and light sources. Next, ask students what the shadow pattern created by these trenches would look like if the sun were *lower* in the planet's eastern sky when the image was taken. Have teams recreate this with light sources and clay. After teams have shared their models, reveal the correct answer (Shadow Pattern 5B). Explain that while this example was clearly contrived for the purpose of humor, the point made is a very important one: surface features can take on very different appearances depending on the direction and height of the incoming sunlight and that more than one image is often needed to accurately deduce the nature of a planetary surface feature. Without such help, the eye and brain can easily be deceived!

The Face on Mars: Tools to Explore the *Viking* images

MGS's camera was designed by Michael Malin, who is not only an ingenious researcher, but also a scientist of wide interests, ranging from Mars to Antarctica. (see biographical excerpt on p. 6) His company, Malin Space Science Systems, will be handling all the image processing for *MGS* and supporting public education and access. One of Malin's goals is to help people understand complex phenomena with the best of today's tools. His fascinating home pages provide ways to explore the Face on Mars for yourself: here a sampler of what you can find at:

http://barsoom.msss.com/education/facepage/face.html

In July, 1976, Viking *Orbiter I was acquiring images of the Cydonia region of Mars as part of the search for potential landing sites for* Viking *Lander 2. On 25 July, 1976, it photographed a region of buttes and mesas along the escarpment that separates heavily cratered highlands to the south from low lying, relatively crater-free, lowland plains to the north. Among the hills was one that, to the* Viking *investigators scrutinizing the images for likely landing sites, resembled a face ...Subsequent to this release, some people have argued, mostly in the lay literature, that the face-like hill is artificially shaped. Although their argument has been expanded to a host of nearby features, none commands public interest like the "Face." This page will provide interested persons with both the raw* Viking *images, transformed to GIF format, and a brief tutorial (with examples) of image processing techniques applied to create "better looking" images...*

7. Distribute copies of Image A and B. Explain to students that these are two actual images of Mars taken by the *Viking* orbiters. Explain that Image B is an enlargement of a section of Image A, but taken at a different time of day on Mars. Challenge students to draw a square inside Image A to show the area covered by Image B. Then ask students to draw an arrow next to Image A to indicate the direction of the incoming rays of the sun at the time this picture was taken. Have them do the same for Image B. Verify their results. Finally, have them create a model of the terrain shown in Figure A.

8. Discuss how they would figure out the height or depth of the elevations or depressions. Students should realize that they do not have enough information for a definitive answer. They must also know the height of the sun above the horizon at the location of each surface feature and the length of the shadow to know how high or deep the surface features really are. Lead students to a realization of this important point by having them experiment with the length of shadows cast by a ruler. Have them stand a ruler on edge by sticking it in a piece of modeling clay and record the length of the shadow cast by the light when it is held directly over the ruler (at 90°–to the top of the desk or table top—at 60°, 45°, 30° and 10°).

9. Distribute the transparent grid overlays and have students return to Shadow Patterns 2, 3 and 4. Tell them the grids they have just received are a measuring scale for their spacecraft images. From the height of the spacecraft above the planetary surface, it has been determined that each square on the grid is exactly three square miles. For each Shadow Pattern, tell them the elevation angle of the sun above the horizon and ask them to calculate the approximate height or depth of the surface feature creating each shadow.

10. Finally, challenge students to use their modeling clay, their light sources and the class video camera to create shapes that cast different shadows and make the overall shape look different when the incoming light comes from varying angles and varying directions. Have teams of students secretly record their modeled shapes with the video camera and then challenge the other students to figure out the actual shape of the modeled clay by trying to duplicate the shape with a piece of clay themselves. Each team, as they challenge the rest of the students can offer clues (e.g. the direction and elevation angle of the incoming light).

Expand/Adapt/Connect

Younger students love shadow play. This entire exercise can be done qualitatively with them. They can be led to see that lower angles make longer shadows. They may also want to note the length of their own shadows vs. their own height as well as the direction of their own shadows in the playground at different times during the school day.

With older students, teachers can make the exercise more quantitative by plotting angle vs. shadow length or introducing simple trigonometry and then challenging students to calculate the height or depth of a surface feature based on the elevation angle of the incoming sunlight. Older students can even use a flag pole to create a sun dial. Have them mark the length and direction of the shadow that the flagpole casts at various times during the school day. By measuring the angular height of the sun, they can calculate the height of the flag pole and come to a good understanding of how the sun travels across the sky of Earth (or Mars). Doing the experiment in December vs. March vs. June will also dramatically demonstrate how height, rising and setting points of the sun change during different seasons on Earth (and Mars). Students can create tables to indicate whether the length of the ruler's shadow in inches is a function of the elevation angle of the light. Thus, for example, they will see that length of the ruler's shadow equals the height of the ruler when the elevation angle of the light is 45 degrees and that the shadow is about twice as long as the ruler is high when the elevation angle of the light is about 27 degrees, etc.)

Students may download the Face on Mars image (see URL, p. 53), taken by the Viking spacecraft in 1976, along with images of this same feature created by a computer simulating the sun coming from other directions. Students may prepare an oral presentation to the class on what they think the object *really* looks like. Research and report on the public debate surrounding this image. Students may be challenged to recreate the Face on Mars in 3-dimensions from the information contained in the on-line images. They should use their modeling clay, light source and the video camera in the process.

Download the image of the "Happy Face" on Mars. Is it also the work of an intelligent, optimistic, ancient Martian civilization?

Have students debate whether, because of the wide interest in the Face on Mars, NASA should target this area for any special coverage. Does popular interest (public = taxpayers) overrule scientists' confidence that the Face is merely a natural formation? (ed. NASA Administrator Dan Goldin recently told a very persistent questioner that he, Goldin, was sure the questioner was wrong, but that the public did have the right to see the best images of the site, if NASA could obtain them without compromising its science mission, which seemed a responsive and responsible answer.)

Closing Activities

We expect that *Live From Mars* will be something of a wild ride for you and your students, just as for the spacecraft traveling to the Red Planet. Just as in traditional field trips down here on Earth, there may be some bumps along the way! This section of the Guide, however, is designed to encourage your students to look back over the experiences they've shared and the new information they've explored. Contemporary educational research convincingly demonstrates that understanding is reinforced by the process of articulating new information for others. We hope these multi-dimensional, inter-disciplinary Activities suggest ways to do that in an engaging and exciting manner rather than as a dry "course review". These Activities should encourage students to go back to their Mars Mission Logbooks and see their own work as a valuable resource, as they synthesize the new facts they've mastered, digest the comments they've heard or read from the expert scientists and engineers, and use the research skills they've developed. Direct your students to review the pre-assessment activity they completed as they began this journey (see p. 10)—they will be amazed at what they've accomplished!

These three Activities also appeal to different grades, and utilize different types and levels of resources.

- Activity B.1, "A Flag for Mars", is appropriate for younger students, tapping artistry and language skills as well as new knowledge of the Red Planet.
- Activity B.2, "Where Next?", invites more extensive technical and scientific research: *PTK* proposes two variants, one with, and one without, on-line access.
- Lastly, Activity B.3, "To Terraform, or Not to Terraform?" relies less on the science and logistics of exploring Mars and more on discussing and debating moral and philosophical issues.

LFM does not expect any class to do all of these, but we are sure you and your students will benefit from an opportunity to look back over what you've learned. We also know that student work on any of these Activities will be some of the most compelling and specific evidence of what they've absorbed/retained from this unusual learning experience.

"Red Rover, Red Rover"

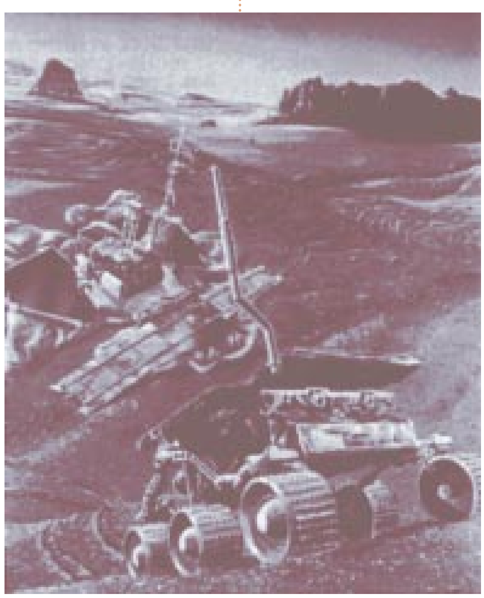
Featured in *LFM* Program 2 will be "student drivers"... operating mini-planetary rovers. From around the world, middle school students are learning how to explore Mars remotely with robotic rovers when they participate in the "Red Rover, Red Rover" Project, a hands-on, educational project launched by The Planetary Society.

Students design and build robotic vehicles from LEGO Dacta kits (the educational division of LEGO) and operate the rovers via sophisticated computer software that mimics the control programs used by planetary scientists to explore other worlds. Each "Red Rover, Red Rover" team also creates a Mars-scape at their site so that the rovers may operate in an "alien" terrain of miniature volcanoes, impact craters, canyons and starry skies.

for more information see:

http://www.planetary.org/tps/explorers-red-rover.html

or call the Planetary Society (see Multimedia Resources)



Activity B.1: A Flag for Mars

Objective

• Students will demonstrate understanding of the geographical and political significance of flags by researching and discussing the historical use of flags on Earth, debating ownership issues for interplanetary exploration, and designing a flag for Mars.

Materials

- paper/pencils
- drawing/construction paper
- scissors/glue
- on-line and/or print encyclopedias, and other research sources
- Mars Mission Logbooks

Engage

Display a variety of flags (U.S., state, school, Girl Scout, etc.). Ask students to identify the group of people which each flag represents. Ask them what is implied when a flag is placed at a location, i.e., the New World, the Moon, the South Pole. How do explorers "stake out" or lay claim to this new territory? Whom do the explorers represent?

Explore

Procedure

If possible, implement this activity as an interdisciplinary unit, allowing students to integrate cross discipline skills within the context of their "science" unit.

1. Begin this project by having students research the history of their own flags, either for their city, state, region, province and/or country. Why do people have flags? What do the graphic elements of your flag symbolize? How were they selected? Was there any discussion? Were alternate designs proposed and debated? Who approved the flag? Has the flag changed over time (like the U.S. flag) or has it remained the same?

2. Ask students to use what they have learned from the *Live From Mars* Activities. Encourage them to consider shape, colors, symbols, and overall design.

3. Have students design original Mars flags. Create a bulletin board for displaying student work.

4. Once students have completed their flags, ask them to write an essay about their design. Younger students may want to write a descriptive essay explaining their decisions about what to include in a flag. Older students might want to write a persuasive essay to convince a global "Earth Explores the Solar System" (EESS!) committee that their particular design should be adopted.

Remind students that the life of a productive scientist or engineer involves a lot more than number-crunching on a computer: a researcher must be able to write well to convince funding agencies to support his or her future activities. Modern science is increasingly a multi-disciplinary activity, almost inevitably involving language arts and communications skills along with content knowledge and logical thinking skills.

Expand/Adapt/Connect

Have students debate the ownership of planets in the Solar System. Who should govern them? What laws might be needed? How would enforcement be handled? Students might find the Antarctic Treaty, referenced in *Live from Antarctica* and *LFA* 2 of interest:

http://quest.arc.nasa.gov/Antarctica/background/NSF/treaty.html

Review the Student Handout for Activity B.3, Gary Allen's article appearing in *Space News*. If appropriate for your students' reading and comprehension skills, pass out copies and invite even younger students to discuss the colonization of Mars. (See MultiMedia Resources for relevant literary materials.)

Have students create their Mars flags using paint program software. Submit for inclusion on the *Live From Mars* web site.

SUGGESTED URLS

http://www.law.uoknor.edu/flags.html
http://www.adfa.oz.zu/CS/flg/col/Alpha.html
http://www/qflags.com
http://www.magick.net/mars
http://www.magick.net/mars
http://spot.colorado.edu/~marscase/home.html

Mary Urquhart

An example of the variety of people involved in studying Mars

I'm a fifth-year graduate student in the Astrophysical, Planetary, and Atmospheric Sciences department at the University of Colorado in Boulder.

I went into science because I wanted to understand everything I could about how the natural world works. ...I learned at a very young age that curiosity is a good thing, and that science is a life-long process of learning.

Between her fourth and fifth years as an undergraduate, Mary had an internship at the U.S. Geological Survey in Menlo Park, CA and was given the opportunity to be one of the first people to see and work with the images from the Magellan spacecraft.

...The idea that a planet could be so similar in mass and size to Earth and yet be so different geologically from Earth was intriguing to me. I found my interest in planetary science reborn and with it a dilemma that would follow me to graduate school...

I was attending, and eventually leading, field trips to all sorts of wonderful places that have features related to other planets. First was Meteor Crater in Arizona, next was Hawaii to study volcanoes, then Yellowstone National Park to study hydrothermal systems (what I'm now doing research on was an idea born from that trip). In addition, I have led trips to Death Valley, the Mojave Desert and Rocky Mountain National Park. To me, these trips bring into clearer focus the similarities between our planet and its neighbors in a way that just looking at pictures or reading papers never will. If you can't actually go to Venus, Mars, or the Moon, why not do the next best thing?

Science isn't all in books, it's about discovering new things and looking at the world in new ways. For me, it's also sharing that experience with others.

Activity B.2 "Where Next?"

Engage:

Share with your students this July 1996 press clip:

> **NASA Seeks Proposals for Mars Landing Sites**
>
> NASA's Office of Space Science plans to award this autumn as many as 15 grants of up to $20,000 per year for two years to university, industry and government groups that propose the most scientifically promising landing sites for the agency's Mars *Surveyor* Program ...which is intended to search for life and water sources on the red planet and increase understanding of the planet's volatile climate and history ...the grants are available for those missions to be launched after 2000. The studies NASA officials select will provide detailed geological maps of proposed landing sites, exploration strategy, the types of scientific data they expect to find at the site, and will include a description of rover or land transport required...
>
> *Space News*, July 1–7, 1996

Explain/Explore

Passport to Knowledge is *not* suggesting that student teams compete with career scientists to propose fully detailed and budgeted plans for NASA's actual missions to Mars in the 21st. Century— but we do suggest that an exciting Closing Activity, drawing on all dimensions of the *Live From Mars* Module, would be to invite students, working in teams, to research and write-up *their* suggested landing sites, scientific rationales and type of spacecraft for the "Next" Mars missions.

Note to teachers: this Activity also provides an extremely powerful way to assess the new learning which students will have gained from participation in the Module. Best done in Fall 1997, after what we hope will be *Pathfinder's* safe landing and successful primary mission, it's also possible to undertake the Activity at the end of the 1996-1997 school year: as indicated by the news clip quoted above, NASA's actual invitation went out in Fall '96, before *MPF* or *MGS* were even launched!

Procedure

PTK invites students to participate in two different ways, in two different mediums.

Print Only

If your class and school still lacks on-line access, have students research references in books, encyclopedias, newspapers, magazines, and CD-ROM's. Use the materials in this Guide and in the *LFM* videos as resources. Encourage students to make formal reports, with carefully thought-out rationales, compelling language, and, if possible, a budget generally comparable to those for *MGS* and *MPF*, scaled upward to reflect increasing size of rover, etc. After sharing your students' work with parents and others, please be sure to send some of the more interesting proposals to *PTK* (keep copies for yourself) In an era of "Net Days" and other special incentives from phone companies and others, consider ways to get on-line, then your students can take advantage of "peer review" (kids commenting from across America and around the world) and direct interaction with expert mentors.

With Internet Access

Just as *Live from Mars* began with an on-line collaborative activity, *PTK* will host an on-line discussion forum *debate-lfm* where students can interact with Mars experts to brainstorm, research and refine their missions plans. *PTK* will invite experienced Mars researchers to serve as on-line mentors: they'll make suggestions, and provide references. They'll respond to student input and point out the pro's and con's of sites and strategies. *PTK* will also provide links which include some of the actual sites proposed by career scientists to NASA, but we will encourage students to evaluate and debate the real proposals and make their own. Since this activity can only be done on-line, we will provide more information about it in late Spring 1997, after the second *LFM* program, which airs April 24th.

SUGGESTED URLS

http://nssdc.gsfc.nasa.gov/planetary/marsland.html

http://cmex-www.arc.nasa.gov/ MarsTools/Mars_Cat/Mars_Cat.html

Activity B.3: "To Terraform or Not to Terraform?"

Teacher Background

"Mars is interesting because it can be colonized." That's the provocative lead sentence of an article appearing in *Space News*, July 8-14, 1996, by Gary A. Allen Jr., an engineer at NASA Ames Research Center. Allen argues against focusing Mars exploration on the scientific search for evidence of past life, which he (rather dismissively) calls "exopaleontology." Instead he proposes colonizing Mars with human explorers on the fastest track possible as the best strategy, and references his own paper in the *Journal of the British Interplanetary Society*, JBIpS, arguing for a one-way mission to Mars delivering 940 colonists at a cost "comparable to simply exploring the planet." ("One-way"—you can see why we call this provocative! However, JBIpS was where Arthur C. Clarke first proposed Earth-orbiting satellites: it serves as a sounding board for ideas that at first seem improbable, some of which end up as mundane [sic] fact within 50 years.)

On a related topic, other scientists, respected NASA Ames exobiologist Chris McKay among them, discuss ways to terraform Mars, unlocking the oxygen and water now trapped in its frozen crust by seeding the poles with hardy microscopic plants, darkening the surface, heating up the entire planet as a consequence, and so recapturing the thicker atmosphere and warmer, wetter conditions which most scientists accept were once present on Mars. (This is the theme of Kim Stanley Robinson's three award-winning science fiction novels, *Red Mars*, *Blue Mars*, *Green Mars*.) Some researchers even argue that if there are still Martian life-forms, microscopic and trapped in the permafrost, they can be "captured" and put in cold storage, just as smallpox germs once were here on Earth. In short, build a protected zoo for microbes, and make Mars fit for humans. To others, this does not seem environmentally correct treatment of any legitimate, current inhabitants of Mars.

Materials

- Copies of article: Allen Jr., Gary A. "Options for Exploring Mars" in *Space News*, July 8-14, 1996, p 13.

Engage

Have students read (or read aloud with them) Allen's article. Allow time for students to share their initial reactions to the ideas in this article.

Explore/Explain

Ask students to consider our current reactions to how European invaders treated the Native American peoples. Encourage students to review their Mars Mission Logbooks and the work they and their peers have done over the course of the entire project. Have them research the issues (encourage use of on-line as well as print resources), then group them in teams with similar perspectives, and marshal arguments to prepare them to debate, or discuss, or otherwise report on the issues involved in one or other of the two distinct but related propositions: "Humans should Colonize Mars rather than sending Robot Missions to Explore it for Ancient Life," and/or: "Humans should Terraform Mars, whether there are extant Martian Life-forms, or Not."

Expand/Adapt/Connect

If you lack on-line access, stage a debate in class, as a formal debate, or in the format of TV talk show. Or, prepare a class newsletter summarizing the various printed reports. Or contact local scientists, share your students' work with them, and ask them to come in to class to respond. Prepare students to receive and interact with "experts".

On-line *LFM* will provide (moderated) opportunities for students to share their arguments and interact, both by asynchronous postings (e-mail, via the debate mail-list) and live WebChats to be joined by Mars experts. Depending on the level of interest, technologies and connectivity possessed by participating classes, *LFM* may facilitate CU-SeeMe or other forums to exchange comments between classes. Check the *LFM* Site in late Spring 1997 and onwards for the latest!

As in all other Closing Activities, please record and share the most interesting student work with *PTK* by mail or on-line.

As should be apparent, *PTK* and *LFM* do not consider Activity B.3 to be about "right answers" to the propositions, but more about appropriate questions and interesting arguments deploying information acquired during the project in thoughtful, convincing ways.

SUGGESTED URLS

http://cmex-www.arc.nasa.gov/MarsNews/Zubrin.html
http://www.newscientist.com/pstourist/limit/mars/index.html
http://www-space.arc.nasa.gov/division/ssx/ssx.html
http://www.magick.net/mars
http://spot.colorado.edu/~marscase/home.html

Getting the Most from On-line

The on-line components of *Live From Mars (LFM)* not only provide extensive information but also—perhaps more importantly—help the project come alive by connecting people together...

- **linking students and teachers directly with NASA experts**
- **allowing students to collaborate with other students**
- **encouraging teachers to interact with one another and with the *LFM* Team**

The *Passport to Knowledge* philosophy is ease of use and equity of access. We want teachers with a wide range of network skills and technologies—from simple e-mail up to full T-1 connectivity—to find success. *LFM* will work for those just getting started in cyberspace, even if their access is not from the classroom but at home or at the workplace of an involved parent. For schools with a little more technology and training, inexpensive cameras and free software can bring moving images and audio into classrooms, via CU-SeeMe, RealAudio and other similar technologies

How to start

All participants in *Live From Mars* should sign up for the ***updates-lfm*** mail-list. This service won't overwhelm your mailbox (we plan no more than two e-mail messages per week). ***updates-lfm*** will keep you informed about the latest opportunities and also bring you lively behind-the-scenes accounts (*Field Journals*) from the men and women on the front lines of exploring Mars. *Field Journals* can be used as reading exercises, discussion starters, or for information about careers.

To join the ***updates-lfm*** mail-list, send an e-mail message to:
listmanager@quest.arc.nasa.gov

In the body of the message, write only these words:
subscribe updates-lfm

You'll soon receive a reply showing you're subscribed, and full information about *Live From Mars.*

Other mail-lists available via e-mail include:

mail-list name	who posts	function	frequency	dates
updates-lfm	*PTK* Team	*LFM* info & *Field Journals*	1 or 2 per week	throughout project
discuss-lfm	educators	teachers share ideas	varies, perhaps 15-30/week	throughout
discuss-digest-lfm	educators	teachers share ideas	once daily only	throughout
debate-lfm	student teams	students plan Planet Explorer Toolkit	varies	10-11/96
answers-lfm	*PTK* Team	stream of Question/Answer pairs	varies	10/96-12/97/TBA

To join any of these groups, send an e-mail message to:
listmanager@quest.arc.nasa.gov

In the message body, write only these words: subscribe **<listname>**
For example: **subscribe discuss-lfm**

To participate via the World Wide Web ("the Web", or WWW)
http://quest.arc.nasa.gov/mars

Getting On-line for the First Time

If you want to get on-line, but aren't, follow these suggestions:

1) Watch out for Net Day in your state or city... and make sure you're included!
2) Ask your colleagues. It's easy to forget those closest at hand! It's likely there are teachers, administrators, or resource personnel who know what's available locally.
3) Don't forget your students. Today's youth is often leading the charge in this exciting arena.
4) Don't forget your students' parents: there's probably a relative with an Internet connection.
5) Check with a local University, most have some type of connectivity available, and some provide it to fellow educators.
6) Call your School Administrators, School District, County Office, and/or State Board of Education. Inquire about special deals on hardware, phone rates or Internet subscriptions—some are there for the asking.

Temporary Acess

If you can get on-line only temporarily, visit "Getting U.S. Teachers On-line", a Web document found at:

http://quest.arc.nasa.gov/on-line/table.html

As noted above, teachers using all three components of PTK projects report they and their students get more from the experience. We really encourage you to go on-line, participate, and—as one of our most eloquent PTK Advocates puts it—"Don't just surf the 'Net, make waves!"

Live From Mars Web Site

LFM's Web Site provides three complementary kinds of on-line materials and experiences, some designed for teachers, and some for students:

- **Informational**
- **Interactive**
- **Collaborative and Sharing**

Informational opportunities include:

- An archive of *Biographies* and *Field Journals* Get to know the men and women of the NASA missions through their personal stories—what they were like as kids, their diverse career paths, day-to-day activities, their dreams and frustrations, and why they thrive on all the hard work of exploring Mars!
- Backgrounders—packed with information about Mars and current and future missions. Also, lots of pictures and pointers to other great Mars Web sites.
- Image Processing in the Classroom: designed to engage visual learners, and providing software to simulate what the career astronomers are doing.

Interactive Resources

- *Researcher Q&A* (Question and Answer) Mars experts will be available to answer student questions via e-mail. The resource will be supported from October 1996 through the end of the project's interactive phase (exact date TBD.). All questions will be answered, and all Q&A pairs will be archived and searchable using simple key-words.
- Live interactions with Mars experts. Using technologies such as WebChat and CU-SeeMe, Mars experts will connect with your students in real-time. Live events will be scheduled about once per month from October 1996 through the end of the project
- A discussion group connecting teachers to one another and to the *LFM* Team is available via e-mail and on the Web. Weekly WebChats are also arranged for the same purpose.
- *Challenge Questions* Once per week, for the six weeks prior to each live television broadcast, a new brainteaser will provide your students with a challenge to solve. Submit your answers for a chance at fun prizes.

Collaborative and Sharing

- The Planet Explorer Toolkit

As an Opening Activity, students brainstorm what instruments might be needed to document a landscape in their neighborhood, then go on-line to arrive at a consensus decision about how to design an Instrument Package. Then they record their sites, share the data on-line, analyze their results —and use them to figure out where five Mystery Sites are located, based on patterns of temperature, geology, flora and fauna, and other indicators determined by the students themselves. Winners will be announced on-line and on-camera. (***updates-lfm*** and the Web Site will have full details.)

- As Closing Activities, this Guide suggests "Where Next?" and "To Terraform or Not to Terraform?": while an individual classroom can undertake these, ***debate-lfm*** will provide an on-line forum in which your students arguments can be heard.
- *Student Stumpers* Students create riddles for other students to answer via direct e-mail; dialogue between youngsters is the goal.
- *Student Gallery* Examples of stellar student work are collected on-line and displayed for the World (Wide Web) to see.

If you want the World Wide Web, but only have e-mail...

Many of the *LFM* WWW materials are also available to "e-mail only" users through a special service; for more details, send a message to:

email-lfm@quest.arc.nasa.gov

And if you want to sample the on-line materials but as yet have no on-line access, there's even a way to do that: call 1-800-626-LIVE and follow the option menu to find out about "Please Copy This Disk."

Glossary

acceleration The rate at which velocity changes with time, caused by the application of a force.

action-reaction The law that when one body exerts a force on another, the second body exerts an force equal in magnitude, but in the opposite direction.

aerobraking The method of using the force of friction between a spacecraft and the atmosphere to slow and lower its orbit.

altimeter An instrument for measuring altitude (height) with respect to a fixed level, such as sea level.

anemometer A device for measuring the speed of wind.

angle The space between two straight lines meeting in a point or two surfaces meeting along a line, measured in degrees.

atmosphere A layer of gas surrounding a planet or celestial body.

autonomous Independent; ruling or managing itself.

avalanche A large mass of snow, ice, rocks, mud, etc. sliding swiftly down a mountain.

axis An imaginary line that passes through the poles of a body, such as the Earth, about which it rotates.

balanced The state of equality; to make two things or parts equal in weight or value.

barometer An instrument that measures the pressure of the atmosphere used for forecasting changes in the weather and finding the height above sea level.

canyon A long, narrow valley with high cliffs on each side, often with a stream running through it.

center of mass That point of a material body or system of bodies which moves as though the system's total mass existed at the point and all external forces were applied at the point. Also known as the center of inertia. Also, center of balance.

climate The average weather conditions of a place over a period of years.

climatology The branch of meteorology concerned with the atmosphere together with the variations in both space and time reflected in weather behavior over a period of many years.

cone Anything shaped like a solid object having a flat, round base that narrows to a point at the top. "The cone of a volcano."

constellation A grouping of stars in the sky, which has usually been given a mythological name (like Leo or Orion). Stars in a constellation are not usually at the same distance from Earth but spread throughout space.

crater A hollow bowl-shape such as that created by a volcano or impact from a meteorite hitting a planet's surface.

data Facts or experimental evidence or measurements which can be studied in order to make conclusions or judgments.

datum surface A permanently established horizontal plane or level to which soundings, ground elevations, water surface elevations, and tidal data are referred; reference level or reference plane.

delta A triangle-shaped piece of land formed when sand and soil are deposited at the mouth of a river.

density The mass of a given substance per unit of volume.

deploy To spread out or extend.

depression A hollow of any size on a plain surface having no natural outlet for surface drainage.

descent The act of descending or moving down to a lower place.

diameter A straight line passing through the center of a circle or sphere, from one side to the other.

ejecta Material which is discharged by a volcano or collision.

electromagnetic spectrum The total range of wavelengths or frequencies of electromagnetic radiation, extending from the longest radio waves to the shortest known cosmic rays.

elevation Vertical distance to a point or object from sea level or some other datum.

ellipse A closed, elongated shape which describes the orbits of planets.

emission Any radiation of energy by means of electromagnetic waves, as from a radio transmitter.

erosion The loosening and transportation of rock debris. The wearing away of the land, chiefly by rain and running water.

extinct No longer active or living; having died out.

flow patterns Erosion on the surface of an object due to the flow of water or other liquids.

force The influence on a body which causes it to accelerate.

friction The rubbing of a surface against something which slows it down, creating heat

geologist A person who specializes in the study of the earth.

geology The study of the science of the earth, its history, and its life as recorded in the rocks.

gravity The force of attraction that is felt between two or more bodies, such as the pull between the Earth and the Moon.

hydrosphere The water portion of the earth as distinguished from the solid part (lithosphere) and from the gaseous outer envelope (atmosphere).

hypothesis An unproved idea that may explain certain facts or can be used as the basis for reasoning, study, and the design of experiments.

image Any reproduction of an object produced by means of focusing light, sound, electron radiation or other emanations coming from the object or reflected by another object.

imaging The formation of images of objects.

impact The action of one object hitting another with force.

infrared (IR) Heat radiation. Its wavelength is between light and radio waves, in the range from about 0.75 micrometers to 1000 micrometers.

kilometer A unit of measure equal to 1,000 meters or about 5/8 mile.

lander Spacecraft deployed to the surface of a planet equipped with scientific instrumentation for data collection.

landform All the physical, recognizable, naturally formed features of land, having a characteristic shape.

laser A device that sends out light waves in a very narrow and strong beam of a specific, coordinated wavelength. (Light Amplification through Stimulated Emission of Radiation.)

latitude The angular distance north or south of the Equator of a spherical body (such as the Earth). Latitude is measured in degrees, minutes and seconds of arc.

longitude The angular distance east or west of an imaginary line (the meridian) on a spherical body, such as the Earth. Longitude is measured in degrees, minutes and seconds of arc.

meandering Winding back and forth; the snakelike appearance of streams or rivers.

microns A unit of wavelength equal to one millionth of a meter.

observation The act or power of seeing or noticing and writing down some fact.

opposition The situation of two celestial bodies having celestial longitudes or sidereal hour angles differing by 180 degrees.

orbit The path followed by a planet, a satellite, or a star around a more massive body in its gravity induced motion.

outflow channels Large channels on Mars created by releases of vast amounts of water. Surface feature on Mars, evidence that liquid water once existed there in great quantity.

pahoehoe A Hawaiian name for a volcanic lava flow whose surface is glassy, smooth, and undulating; the lava is basaltic and also known as ropy lava.

payload That which an aircraft, rocket, or the like carries over and above what is necessary for the operation of the vehicle.

petri dish A shallow glass or plastic dish with a loosely fitting overlapping cover used for bacterial plate cultures and plant and animal tissue cultures.

plate tectonics Geologic theory based on a model of the earth characterized by a small number of semi-rigid plates which float on some viscous underlayer in the mantle. Movement and collision of plates results in volcanism and seismic activity.

precipitation Any or all forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground.

pressure A force which is exerted uniformly in all directions; its measure is the force exerted per unit area.

probe A spacecraft with instruments in it for exploring the upper atmosphere of a planet.

pulse A brief burst of energy.

radar A system using beamed and reflected radio-frequency energy for detecting and locating objects, measuring distance or altitude, navigating, homing and other purposes.

radiation The energy or rays sent out from atoms and molecules because of changes inside them. Light, heat, radio waves and X-rays are kinds of radiation.

ratio The relation of one thing to another in size, amount, proportion.

retro-rocket Small rocket on a spacecraft that produces thrust in a direction opposite to the direction in which the spacecraft is moving, in order to reduce speed, especially for landing.

retrograde motion The apparent backward motion of a planet in the sky, which occurs because the Earth overtakes the planet.

robotics The science or technology of producing and using robots (a completely self-controlled electronic, electric, or mechanical device).

rover A mobile robotic device remotely controlled equipped with instrumentation for data collection.

Scientific Method The systematic collection and classification of data and usually the formulation and testing of hypotheses based on the data. A way to gather facts and explain them.

simulate To mimic some or all of the behavior of a system.

simulation Something that is designed to look or act like or seem to be something else.

slope The inclined surface of any part of the earth or a planet's surface.

sonar Device that sends sound waves through water and picks them up after they strike some object and bounce back. Used to determine the depths of oceans, location of submarines, etc.

spectrometer A spectroscope that is provided with a calibrated scale for measuring wavelength. (A spectroscope is an optical instrument which produces a spectrum for visual observation.)

spectrum (plural *spectra*) The spreading out of radiation given off by an object according to color or wavelength. For example, the rainbow of colors that make up so-called white light, where each color corresponds to a different wavelength of radiation in the spectrum.

stream table A device used to simulate (replicate) the flow of water in a stream or river.

thermal Having to do with heat.

thermometer A device for measuring temperature. Usually measured in degrees Celsius or Fahrenheit.

topographic map A map showing relief and elevation.

trajectory The curve described by an object moving through space, as of a planet around the sun, a projectile fired from a gun, or a rocket in flight.

velocity The speed and direction of a moving object.

volcano A fissure or vent in the crust through which molten rock rises to the surface to form a mountain.

weather The conditions outside at any particular time and place with regard to temperature, sunshine, rainfall, etc.

Elementary School

Print

Adler, David A. *A Picture Book of Sojourner Truth.* New York: Holiday House, 1994. ISBN: 0-8234-1072-2.

Brewster, Patricia. *Ellsworth and the Cats from Mars.* New York: Houghton Mifflin, 1981. ISBN: 0-395-30364-8.

Eco, Umberto and Carmi, Eugenio. *The Three Astronauts.* New York: Harcourt Brace Jovanovich, 1989. ISBN: 0-152-86383-4.

Mars. Odyssey, May, 1996 issue. Peterborough, NH: Cobblestone Publishing. (WWW site at **http://www.cobblestone.pub.com** or call: 603-924-7209)

Red Planet Connection (K-2 or 3-5 Edition): The Science Magazine for Future Martians. Tempe, Arizona: Arizona State University. (Contact Tricia Dieck at 602-965-1788 or email Tricia at: saelens@imap2.asu.edu. $30.00 for 30 copies, four times per year.)

Slote, Alfred. *My Robot Buddy.* New York: J. B. Lippincott, 1975. ISBN: 0397-31641-0.

Vogt, Gregory. *Mars and the Inner Planets* (A First Book). New York: Franklin Watts: 1982. ISBN: 0-531-04384-3.

Young, Ruth. *A Trip to Mars.* New York: Orchard Books, 1990. ISBN: 0-531-05892-1.

Multimedia

Hugg-A-Planet Mars. 8" diameter soft pillow that includes Martian features. Order from the Planetary Society (see list of organizations) Item #528, $15.00 non-members,/$14.00 member.

Mars (full disk); Mars Atmosphere. Color Prints 20" X 16" from The Planetary Society. ($9.00 each)

Mars Alpha City and Marsville Simulations. (See Middle School Resource List)

Mars Globe by Repolgel. 12" diameter globe portrays Mars at a scale of 1:250,000. Color of globe is similar to the Martian surface. Detail of Martian features based on 6,000 Viking images. ($89.00 Carolina Science & Math Catalog. Call 1-800-334-5551)

Mars Map. 39" X 40" Mercator projection combining albedo markings with thousands of craters, mountains and other surface features. ($7.95; Order from *Sky and Telescope*)

Mars *Pathfinder* Landing Animation. Produced by Engineered Multimedia, Inc under direction from NASA JPL. Roswell, GA: Engineered Multimedia, 1996. (8 minute, color videotape) Send $9.95 plus $3.00 shipping and handling to: Engineered Multimedia, Inc., 800 Old Roswell Lakes Parkway, Suite 100, Roswell, GA. 30076.

Middle School

Print

Brewster, Duncan. *Mars.* (Planet Guides) New York. Miles Cavendish, 1992. ISBN:1-85435-372-1.

Hamilton, Virginia. *Willie Bea and the Time the Martians Landed.* New York: Greenwillow, 1983. ISBN 0-688-02390-8.

Hoover, H.M. *The Winds of Mars.* New York: Dutton Children's Books, 1995. ISBN: 0-525-45359-8. Winner of the Parent's Choice Award.

Mars Underground News. Newsletter. Pasadena, California: The Planetary Society. Published four times a year. ($15.00 non-members, $10.00/members; contact The Planetary Society at 1-800-969-MARS or E-mail tps.cj@genie.com)

Red Planet Connection. Grades 6-8: see elementary level resources

Simon, Seymour. *Mars.* New York: William Morrow and Company, 1987. ISBN: 0-688-06584-8.

Sky Publishing Corporation, 1996. Monthly sky maps, astronomy clubs, planetariums, and Internet resources, Hubble images, how to buy a telescope, and more. (Cost $4.95. E-mail: orders@skypub.com or call: 800-253-0245)

Stine, G. Harry. *Handbook of Model Rocketry.* Revised Fifth Edition. New York: Prentice Hall Press, 1987. ISBN: 0-668-05360-7.

The Universe at Your Fingertips: An Astronomy Activity and Resource Notebook. Edited by Andrew Franknoi. San Francisco, CA: Astronomical Society of the Pacific, 1995. ISBN: 1-8886733-00-7. ($29.95; Call ASP at: 1-800-335-2624 to order.)

Vogt, Gregory. *Viking and the Mars Landing.* Brookfield, CT: The Millbrook Press, c 1991. ISBN: l-878841-32-7.

Wells, H.G. *The War of the Worlds.* Complete and unabridged. New York: A Tom Doherty Associates Book, 1987. ISBN: 0-812-50515-8.

Wilford, John Noble. *Mars Beckons:* The mysteries, the challenges, the expectations of our next great adventure in space. New York: Vintage Books, 1990. ISBN: 0-679-73531-3.

Multimedia

Destination: Mars. Software. Redmond, WA: Compu-Teach, 1995. IBM/Mac diskette and CD-ROM. ($39.95; Contact Compu-Teach at 1-800-44-TEACH. E-mail: cmpteach@wolfenet.com) ($39.95; Contact Compu-Teach at 1-800-44-TEACH. E-mail: cmpteach@wolfenet.com)

Mars City Alpha Kit. Simulation. Produced by The Challenger Center.

Alexandria, VA: The Challenger Center. ($85.00 plus shipping; contact The Challenger Center.)

Quest for Planet Mars. (Space Age) Videotape. WQED/Pittsburgh and NHK/Japan in association with the National Academy of Sciences, 1992. (58 minutes, color) (Call 1-800-262-8600, Public Media Video)

PC Sky: The Sky Simulator. Software for the IBM PC. Produced by CapellaSoft. La Mesa, CA: CapellaSoft. Complete virtual night sky. (Call 1-800-827-8265 or E-mail: crinklaw@n2.net)

Planet Mars Plus Mercury—Exploration of a Planet. Videotape. Video Presentation. Whittier, CA: Finley-Holiday Film Corp. (60 minutes). Two award winning NASA programs. ($24.95; available from the Planetary Society)

Star Gazer: Guide to the Heavens. CD-ROM. Produced by Carina Software. San Ramon, CA: Carina Software. (Mac only; Windows version available late fall, 1996) (Contact Carina Software, 510-355-1266)

Resources High School

Print

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UNIFYING CONCEPTS AND PROCESSES STANDARDS

Correlation of *Live From Mars* activities with the "Unifying Concepts and Processes Standards" of the National Science Education Standards of the National Research Council (National Academy Press ©1996, pg.104 ff.)

NRC/NAS#	Systems...	Evidence...	Change...	Evolution...	Form...	Other*
Activity A.1 Mission Logbooks	•	•	•			P
Activity A.2 Mission Team	•				•	P
Activity A.3 Earth/Mars Comparisons	•	•	•	•	•	I, T
Activity A.4 Geology/Areology	•	•	•	•	•	I
Activity 1.1 Rocket Science 101		•	•	•	•	T, H
Activity 1.2 Topography		•	•		•	T, I
Activity 1.3 Follow the Water		•	•	•		P, H
Activity 2.1 Observing Mars	•	•	•			H, I
Activity 2.2 Reading Volcanoes		•	•	•	•	I
Activity 2.3 Rovers from Junk	•	•	•	•	•	T, I
Activity 3.1 Light Bulb Drop	•	•	•	•	•	T, I
Activity 3.2 Creating Craters	•	•	•		•	I
Activity 3.3 Magnetic Materials		•	•			I, T
Activity 4 No original Activities						
Activity 5.1 Martian Weather	•	•	•	•		I
Activity 5.2 Surface Structure	•	•	•			I, T, H
Activity B.1 Mars Flag					•	P, H
Activity B.2 Where Next?		•			•	T, P
Activity B.3 Colonize/Terraform Debate		•			•	P, H

*NAS/NRC suggests 8 categories of content standards: "Unifying Concepts and processes in science" is clarified on the left. Most of the Activities in *LFM* relate so directly to 3 of the other categories, that no individual correlation is indicated (i.e., Physical Science, Life Science, and Earth and Space Science.) However, the initials below indicate correlations of Activities with the 4 remaining categories:

Science as Inquiry = I

Science & Technology = T

Science in personal & social perspectives = P

History & Nature of Science = H

Systems	=	Systems, Order and Organization
Evidence	=	Evidence, models and explanation
Change	=	Change, Constancy and measurement
Evolution	=	Evolution and equilibrium
Form	=	Form & Function

http://quest.arc.nasa.gov/mars

Passport to Knowledge Hotline:

1-800-626-LIVE