Project Notes

Programs and Initial Air Dates and Times

Program 1 — Countdown
November 19, 1996, 13:00-14:00 Eastern

Program 2 — Cruising Between the Planets
April 24, 1997, 13:00-14:00 Eastern

Program 3 — Touchdown
July 1997, Exact date, time, and channel to be announced

Program 4 — Destination Mars
Fall 1997, Exact date and time to be announced

Program 5 — Today on Mars
November 1997, Exact date and time to be announced

Primary Satellite Coordinates

Ku-band: PBS K-12 Teacher Resource Service: Telstar 401, 97 degrees West, transponder 8, horizontal, 11915 Mhz, audio on 6.2 and 6.8

Please note: this refers to carriage on the primary satellite used by PBS. Carriage on the satellite itself does *not* guarantee broadcast by any individual PBS station. Please check local listings well in advance of air time to verify local arrangements! An on-line listing of confirmed carriage by local stations and educational networks will be accessible starting October 1, 1996.

C-band: NASA TV: Spacenet 2, 69 degrees West, transponder 5, channel 9, horizontal, frequency 3880 Mhz, audio on 6.8

NASA TV has indicated it will carry programs at the time and date scheduled. However Shuttle schedules and other factors may modify this. Again, please check current schedules close to air time. NASA TV publishes its daily schedule over NASA Spacelink. The *Live From Mars* Home Page (see below) will also provide a pointer to this information.

Videotapes

Tapes of the programs as broadcast will be available through NASA CORE, phone (216) 774-1051. For other availability, check the *Passport to Knowledge: Live From Mars* Information Hotline:

1-800-626-LIVE (1-800-626-5483)

Off-Air Taping Rights

The producers have made the standard public television Extended Rights period of "one year after initial broadcast" available for free classroom use.

Live From Mars is a *Passport to Knowledge* project. *Passport to Knowledge* is supported, in part, by the National Science Foundation, under award ESI-9452769. Opinions expressed are those of the authors and not necessarily those of the Foundation.

NATIONAL SCIENCE FOUNDATION

This project was supported, in part, by the

National Science Foundation

Live From Mars is also supported by **NASA's Mars Exploration Directorate**, (managed by the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA), **the Office of Space Science, NASA K-12 Internet Initiative** and **PBS K-12 Teacher Resource Service.**

Contingency Announcement

Field research on a scientific frontier is inherently unpredictable. Even traditional school trips are subject to weather and disruptions. An electronic field trip is no different: the *Live From Mars* programs are dependent on many factors ranging from a successful launch and landing, to all domestic links holding. The production team has put in place contingency plans for most eventualities. In the event of temporary loss of signal, live programming will continue from ground sites, interspersed with pre-taped segments.

On-line Resources

On-line resources are a unique element of this project and are described in more detail in this Guide. Background information is already available, and will remain accessible indefinitely, so long as it remains current. The project's interactive and collaborative components, such as *Researcher Q & A* will commence October, 1996, and will be supported at least through December, 1997.

To subscribe via e-mail, contact:

listmanager@quest.arc.nasa.gov

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

Need more Information?

Educators may contact the *Passport to Knowledge* Education Outreach Coordinator, Jan Wee
phone: **(608) 786-2767**
fax: **(608) 786-1819**
e-mail: **janw@quest.arc.nasa.gov**
with questions about on-line access, broadcast and tape availability, with feedback and suggestions, or with comments or queries on any other matter concerning *Passport to Knowledge* or this *Live From Mars* module.

VISIT *LFM* ON-LINE AT
http://quest.arc.nasa.gov/mars

Live From Mars

Passport to Knowledge

electronic field trips to scientific frontiers
via interactive television and on-line networks

made possible, in part, by
NASA, the National Science Foundation, and public television

Dear Educator,

Get ready for the trip of a lifetime. The adventure begins at Cape Canaveral in the final months of 1996. Then eight months later, on July 4, 1997, an alien object will streak through Mars' dark sky, glowing bright as its heat shield encounters the planet's thin atmosphere. Decelerating with a parachute and small retro-rockets, the spacecraft will slow, and then a new type of airbag will deploy. It'll touch down, bounce as high as a ten story building, and tumble over rocks and boulders. After this bumpy landing, the airbags deflate, 3 petals unfold, and Mars *Pathfinder* will awaken on the Red Planet.

Within hours, the first new images from the Martian surface in over 20 years will be radioed back to Earth. A few more hours, and a micro-rover, *Sojourner*, will roll away from the lander to begin its mission—to sample rocks and analyze the Martian soil in ways never before done. All this for $150 million, the price of a few modestly-budgeted science fiction movies! Two months later, Mars *Global Surveyor* arrives. It then begins a complex series of maneuvers, using Mars' atmosphere to lower itself gradually into a mapping orbit. Like many aspects of *Pathfinder*, this aero-braking maneuver has also never before been done. *Pathfinder* and *Surveyor* are part of a new NASA design philosophy and exploration strategy: build more, smaller, cheaper spacecraft and launch them more frequently—Mars missions every two years!

Live from Mars, the electronic field trip that will follow these spacecraft, is also unique, innovative—and somewhat risky. But just as for NASA's new Mars missions, the upside should be unusually rewarding.

- Your students will be exposed to science and data more current than that found in any textbook.
- They'll go behind the scenes at Cape Canaveral and NASA's Jet Propulsion Laboratory, sites which are humanity's literal and metaphorical launch-pads to the Universe.
- They'll be exposed to high-tech careers that may open up new academic and personal pathways.
- They'll have a chance to use the Internet to communicate with some of the world's foremost researchers, and also to collect and share data with fellow-students.

This Guide provides the key to unlock this rare opportunity. It's designed to provide an easy-to-use route through the rich multimedia materials which every *Passport to Knowledge* project offers. This is an interactive experience; you'll also find many ways suggested here through which to communicate back to *Live from Mars*. We hope you and your students learn a lot... and also have great fun. Remember, something you say in class, or that a student may read on-line, or see during the videos, just may be the vehicle which will, in the future, launch that youngster to the Red Planet—not on an electronic field trip, but in reality.

So, Onwards and Upwards, to Mars!

Sincerely,

Erna Akuginow
Executive Producer

Geoffrey Haines-Stiles
Project Director

Project Staff and Acknowledgements

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SPECIAL THANKS

To all the men and women of the Mars *Pathfinder* Mission ✦ the Mars *Global Surveyor* Mission ✦ Jet Propulsion Laboratory, California Institute of Technology ✦ NASA-TV ✦ Kennedy Space Center ✦ Cape Canaveral Air Station ✦ Johnson Space Center ✦ Lockheed-Martin Astronautics ✦ McDonnell Douglas Corporation ✦ Astrogeology Team, USGS, Flagstaff, AZ ✦ Worcester Public Schools, MA ✦ Broward County Schools, FL ✦ Muncie Schools, Muncie, IN ✦ The Mars Exploration Directorate

Table of Contents

What's unique about *Passport to Knowledge* electronic field trips?

- the most current content, including real time images and data
- a direct connection to places inaccessible to students through any other means
- participation by some of the world's foremost scientists and researchers
- hands-on discovery Activities designed to simulate "real world" science
- interactive opportunities for students to question experts, and receive individual answers
- collaborative opportunities for teachers to work with other teachers, and students with other students
- support for educators via the *Passport to Knowledge* Information Hotline, 1-800-626-LIVE (626-5483) and on-line

This Teacher's Guide was compiled, edited and/or written by
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Pat Haddon and
Erna Akuginow

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Sasha Haines-Stiles and
Brian Sullivan

Poster Design
Brian Sullivan

Live From Mars Project Overview

Live From Mars is an integrated multimedia project, which uses

- on-line resources
- print materials
- live interactive video and tape

Each medium contributes what it does best. Participants in past projects report that students benefit most when all three components are utilized to the fullest.

On-line . . . .

The Internet breaks down the walls of the classroom and brings the world and world-class researchers to any school, any place, any time.

- On-line opportunities facilitate direct, individual interactions with leading scientists, experts and their support teams, through "Researcher Q&A"
- "Field Journals" and "Biographies" provide behind-the-scenes anecdotes which personalize the scientific process
- Images and weather data direct from Mars will be available via the Internet in close to real time
- On-line collaborative activities encourage students to collect data locally, and share it nationally and internationally, validating their efforts by seeing their research and writing published on the Internet
- Teachers share curriculum ideas and implementation challenges with other teachers via on-line mail-lists
- All materials, including the discussions, remain accessible indefinitely via an on-line Archive
- The project provides on-line components both for those limited to e-mail only, and those with full access to the World Wide Web

A Guided Tour of the project's on-line environment is accessible via:

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

Mike Malin

I am the "principal investigator" on three camera systems that will be sent to Mars over the next four years: the high- and low-resolution cameras (one system) on the Mars Global Surveyor 1996 mission...

...See p. 6 for more bio

Barbara Weinman on pg. 6

Print . . . .

The print materials provide all a teacher needs to create classroom lessons and Activities: the Guide (also accessible on-line) provides a teacher-friendly, easy-to-use introduction to the entire project, and is co-packaged with camera-ready masters of Student Worksheets and key visuals to support the Activities, an original full-color poster, and background NASA publications.

- Hands-on Activities simulate key aspects of the research seen during the project and illuminate key scientific concepts.
- Many of the Activities suggest adaptations up and down in grade level beyond middle school.
- Many of the Activities suggest ways to connect across the disciplines to math, social studies, language arts, art and computer classes. Icons signal these opportunities.

math | social studies | lang. arts | art | computers

Objective

- Students will identify the human components of a Mars Mission Team.
- Students will organize these jobs into categories and write a formal application for a position on the Mars Mission Team...

- Each Activity retains the pedagogically sound ENGAGE, EXPLORE, EXPLAIN, EXPAND format of previous Guides.
- Opening and Closing Activities help teachers create a productive anticipatory set and/or reinforce learning after the live video or on-line interactions
- A Teacher's Kit provides more extensive materials, including the Guide and its co-packaged publications, a bonus color poster, a Mars slide set, a VHS teacher orientation tape including NASA animations and Activity demos, a Mars CD-ROM, and curriculum materials underwritten by the *Mars Exploration Directorate* of NASA's JPL—and more. (To order the Kit, fill in and return the form co-packaged with this Guide.)

ENGAGE

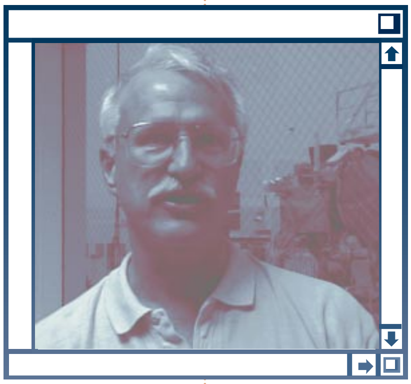
Approximately 3.8 billion years ago, Mars and Earth are believed to have been very similar. Understanding what happened to Mars may help us understand our own planet and its future…

Video . . . .

Television provides the sights and sounds, the people, places and processes, which put a living *context* around the *text*.

- Personal portraits of the researchers and their lives humanize the hard work of doing science and demystify high-tech careers
- Cutting-edge telecommunications connects students to remote and otherwise inaccessible locations
- Graphics and dynamic visuals simplify complex concepts
- Live, two-way exchanges between students and researchers symbolize the interactive possibilities universally available via the Internet

Teachers rate the *live* component of the *Live From...* videos highly, although most teachers use them on *tape*: there's no contradiction. The excitement of the original live interactions is maintained while teachers gain flexibility by using the videos on tape.

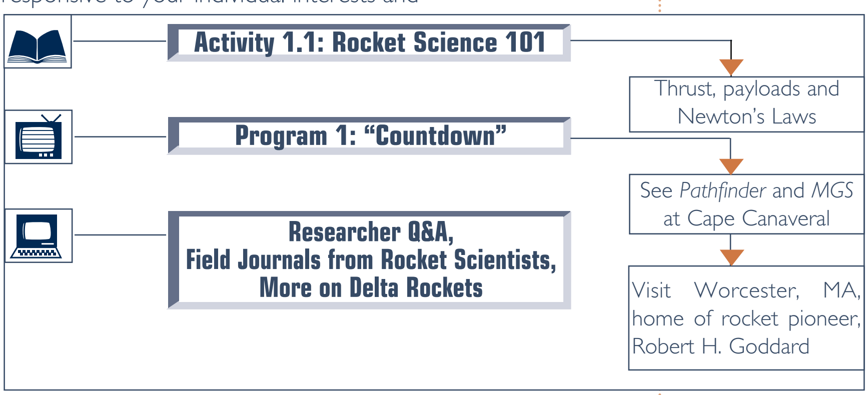


How the Components work together—an example

Activity 1.1, "Rocket Science 101" uses simple balloons to give students hands-on experience with issues of thrust, fuel and payloads, as an application of Newton's Laws. On November 19, 1996, *Live From Mars,* Program 1, "Countdown", will feature a real-world application of these principles with a report on the launch of Mars *Global Surveyor.* Students in Worcester, MA, childhood home of American rocket pioneer Robert H. Goddard, will interact live with today's rocket scientists at Cape Canaveral, where Mars *Pathfinder* is being readied for launch. And on-line students can find background information on the Delta II rockets that will be used for both missions.

If *you* have questions, you'll find ***discuss-lfm*** responsive to your individual interests and needs: this on-line Teachers' Lounge allows you to make suggestions, ask for advice and share ideas, creating a "Virtual Community" which turns the Guide, videos and other on-line materials into living documents which will evolve during the course of the project.

There's no "royal road to math" said Euclid, and there's no one way to implement *Live From Mars*. We hope you'll work with us to find *many* right ways to bring the exploration of the Red Planet to life for your students.



A Unique Opportunity

Live From Mars is an electronic field trip that can take you and your students along on one of the most exciting scientific adventures of this decade. But *LFM* also has the potential to make significant contributions to your students' learning of, and attitude towards science; advance your own professional growth through exposure to cutting-edge knowledge and state-of-the-art technology, and boost your school systems' effectiveness as a valuable launch pad for 21st Century learning.

Ambitious thoughts? High-flying rhetoric? Another educational gimmick? I think not. In fact, I have rearranged my Grade 6 science curriculum over the past three years in order to implement previous Modules from the *Passport to Knowledge* series. *Live From Antarctica, Live From the Stratosphere,* and *Live From the Hubble Space Telescope* were all unique, and did not always precisely parallel my course of study. So how was I able to rationalize to students, parents and administrators the "fine tuning" of my curriculum and schedule which was necessary each year to implement an electronic field trip?

Quite simply, the *Live From...* specials were too good to miss! Let me share my reasoning by listing the following special opportunities which I think *Live From Mars* will also provide:

- *Live From Mars* will make your classroom a place for active student learning
- *Live From Mars* will connect your students to working scientists applying in the real world many of the principles you'll first present to them in the classroom
- *Passport to Knowledge* activities help teachers meet many of the objectives outlined in the National Science Standards (National Academy of Sciences/National Research Council) and the Benchmarks For Scientific Literacy (AAAS/Project 2061) (See Matrix, inside back cover of this Guide)
- *Live From Mars* encourages the use of current and appropriate assessment practices which will help you meet district and state-wide mandates for which you probably have no extra books, or budgets, or materials!
- *Live From Mars* suggests relevant, flexible, immediate and practical ways to use new and emerging information technologies. Many schools are in the process of getting wired up to the 'Net and acquiring the hardware to incorporate the new technology. This major capital outlay will result in close scrutiny on the part of your administration, Board of Education and your community about its effectiveness. Too often the software, the content, gets left until last. *Live From Mars* provides structured, pedagogically sound and SAFE use of the Internet for students
- In line with current pedagogical theory and NSF's new initiative to engage parents more directly in their youngster's education, *Live From Mars* provides an opportunity for extensive and positive public outreach. Many teachers have made parents and community resources part of their previous electronic field trip experience—extending, enhancing and reinforcing student learning and excitement. And this dynamic multimedia experience affords wonderful opportunities for positive publicity for your class, school and district.

Mike Malin

Mike Malin, designer and builder of Mars camera systems, Malin Space Science Systems, San Diego, CA

...The most interesting part of my job today is thinking up new instruments for future missions. There is tremendous competition to provide instruments for up-coming spaceflights, and the things that limit what we can do (size, weight, power, and cost), added to the intensity of the competition, make for an exciting challenge.

I decided to work in a space-related field when I was very young. Exactly when I cannot remember, but I clipped articles from newspapers that described rocket flights several years before the first satellites were orbited (when I was 5 or 6 years old). Throughout my education, I studied as much science as I could, in class, by going to the public library and reading, and by visiting the Griffith Park Planetarium (in Los Angeles, where I grew up). I continued to keep a scrapbook of newpaper and magazine articles until I went to college...

Barbara Weinman

I am not a science teacher, and so I don't have the opportunity to do all the interesting experiments and to adequately follow the lesson plans in the guide... I teach English as a second language on the high school level. I have students from all over the world... but many of them are on the elementary level in terms of their language, science, and social studies background. The Live From Antarctica project was a mind-blowing experience for them. That is why we are back again this year for more excitement.... I am using all the materials, messages, updates, journals, questions and answers as our reading materials—as my vehicle for teaching vocabulary enrichment and reading comprehension skills. They will be getting science concepts at the same time. and it is real! It is not dry workbooks.... I have spent the last few days replaying the videos, pausing often, to translate and explain everything which is said. All the unfamiliar words go on the blackboard, are explained, and then the tape is replayed so they can again hear the words used in context. This is listening comprehension, but it is not artificial, it is real.

Barbara Weinman, ESL Teacher, NJ

A Special Challenge

Previous *Passport to Knowledge Live From...* modules could be implemented in four to six weeks. These interactive, multimedia Modules make excellent interdisciplinary units—with all disciplines enhancing and enriching the science content.

Live From Mars, however, differs from the previous *Live From...* modules in an important and quite challenging aspect. This electronic field trip will be following two missions to Mars in *Real Time*—from the launches of Mars *Global Surveyor* and Mars *Pathfinder* in November/December 1996 through the touchdown of Mars *Pathfinder* on the Red Planet on or around July 4, 1997, and continuing as scientists (and students) receive and analyze the data from *MPF* and *MGS* on through 1997 and into 1998. In short, this electronic field trip—from launch through landing—spans two academic school years! The implementation of this unique learning experience requires flexibility in planning; you may find one of the following models suitable for your own situation.

Model A — Teacher will have class for one academic year only

Follow the suggested timeline for Programs 1 and 2, and complete Activities coordinated with Programs 3 and 5 as a "set" or preview for the next phases of the missions to Mars. Students should be encouraged to continue following the mission by watching newscasts and other special programs in the summer of 1997, catching up —if possible—with broadcasts 4 and 5 on PBS, or NASA-TV in the 1997-98 school year (broadcast information to be announced), and monitoring the missions' further progress via on-line and print media reports.

Model B — Teachers in consecutive grade levels team up to implement *LFM* over two years

For example, if *LFM* were implemented in grades 5 and 6, the fifth grade (Class A) would complete activities suggested in the Teacher's Guide for Programs 1-3 during the 1996–97 school year. When matriculated into grade 6 (1997-98), these students (Class A) would review their previous experiences (using Program 4) and continue their Mission to Mars with the activities coordinated with Program 5.

The 1996–97 sixth grade (Class B), however, would follow Model A.

Model C — Home schoolers or "looping" teachers

Implement *Live From Mars* as detailed in project timeline (co-packaged with guide).

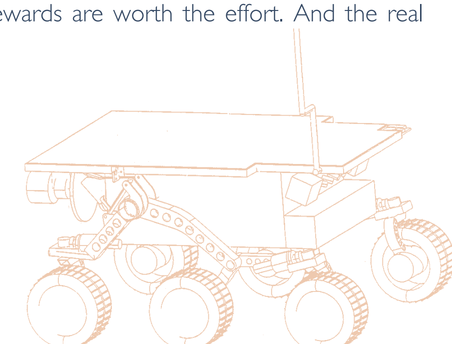
Model D — New class of students in the 1997-98 school year (or beyond)

Implement *Live From Mars* as a complete project, utilizing taped broadcast from 1996-97, the printed Guide and on-line resources. Check out the ***discuss-lfm*** archive on-line to learn what worked best for teachers the year before, and build on their successes!

▼ **Note: All materials, Teacher's Guide, videotapes, on-line access, will continue to be available beyond 1997.**

A special challenge? You bet—but the rewards are worth the effort. And the real winners will be our students.

Patricia Haddon
Summit Middle School
Summit, New Jersey



Teachers' comments on student responses to *PTK's Live from the Hubble Space Telescope*

"Hands-On became minds-on. Great stuff for an inner-city school."
— 6th grade teacher, FL

"My students are realizing that they can communicate with people around the world, and realizing the vast possibilities for jobs in today's world."
— 2nd grade teacher, UT

"... they got a feel for the importance of the work being done, and some of the dark science was brought to light. They started to understand the electromagnetic spectrum."
— amateur astronomer assisting a classroom teacher

"...through the Internet they can travel anywhere and ask questions of experts in any field."
— 7th and 8th grade teacher, IL

"With a modem-equipped computer, a universe of information is (literally) at one's fingertips."
— 5th grade teacher, TX

A Note on Assessment

Live From Mars—like every *Passport to Knowledge* module—is very different from traditional instruction. But the *PTK* project team, like you, the dedicated educator, needs to know what students "get" from participating in *LFM.*

When we say "get" we're not just thinking about factual information on Mars or general knowledge about the exploration of space. In line with the National Science Education Standards (NAS/NRC), and initiatives such as AAAS's Project 2061 *(Science for All Americans, Benchmarks for Scientific Literacy)* and new state and district assessment criteria, *PTK* strives to develop

- positive student attitudes towards science and high technology
- a better understanding of the scientific method and research process
- more powerful and sophisticated research skills
- practice in applying the new tools of the Information Age to education whether in school, at home or in informal learning settings such as planetariums and science centers

But how do we know we—and you—are achieving these goals? In the past *PTK* has provided Teacher and Student Evaluations in our Guides. We've learned much from these questionnaires but we've found the student surveys too open-ended. We also learned that more targeted teacher surveys would provide better feedback. This time we're customizing our evaluations. If you're a teacher, please register by returning the pre-paid, pre-addressed postcard included in this Guide (additional copies can be enlarged from the master below). Those of you accessing the guide on-line will find instructions on how to respond via e-mail. All those registering will be sent a survey targeted to their grade and subject area. We believe this will help us, and you, better understand the contributions and challenges of *PTK* and *Live From Mars.*

PTK found that specific evidence of student work (Mission Logbooks from *LFS*, Antarctic flags and poetry from *LFA*, videotapes of overnight star parties or presentation of class projects, on-line student contributions to the "Great Planet Debate during *LHST*) were extremely useful and revealing assessment tools. Throughout the Guide we've provided suggestions for Activities which will generate this type of student work. We hope they will also help you, the teacher, identify specific, measurable, student learning outcomes and aid you in your individual student assessments.

Space missions use acronyms, and throughout this Guide you'll find the following shorthand.

MPF: Mars Pathfinder

MGS: Mars Global Surveyor

JPL: Jet Propulsion Laboratory

APXS: Alpha Proton X-ray Spectrometer

PTK: Passport to Knowledge

LFM: Live From Mars

LFA: Live From Antarctica

LFS: Live From the Stratosphere

LHST: Live From the Hubble Space Telescope

We encourage you to share your student's achievements with us on-line. Some of it may be published, thereby validating your students' efforts and perhaps motivating others.

To submit materials on-line, see: Student Gallery on the *LFM* web site

To submit hard copies, send original materials (make a copy for your records) to:

Passport to Knowledge, **P.O.Box 1502, Summit, NJ 07902-1502**

To contact EDC directly with questions or suggestions specifically about Assessment, call:

1-212-807-4200 (ask for "*Passport to Knowledge)*"

Registration Form

Reply to: EDC, 96 Morton Street
7th Floor, New York, NY 10014

- Name ____________________________
- School Address ______________________
- work telephone number _______________
- e-mail address _____________________
- Grade level (Please check only one.)
  ___ lower elementary ___ upper elementary ___ middle school ___ high school ___ other
- Subject taught (Please check only one.) ___ generalist ___ science specialist ___ other specialist
- Number of classes in which you will use *Live From Mars?* ___
- Describe the size of the area in which your school is located? (Please check only one.)
  ___ rural ___ suburban ___ small city ___ medium/large city (over 1,000,000)
- Which previous *Passport to Knowledge* modules have you participated in? ___ *Live From Antarctica* ___ *Live From the Stratosphere* ___ *Live From the Hubble Space Telescope* ___ None
- How often have you used on-line curriculum projects other than *Passport to Knowledge modules?*
  ___ Many times ___ A few times ___ Once ___ Never
- Are you planning to team-teach this curriculum? __ Yes __ No

Copy and paste from this card

NASA Mission Objectives

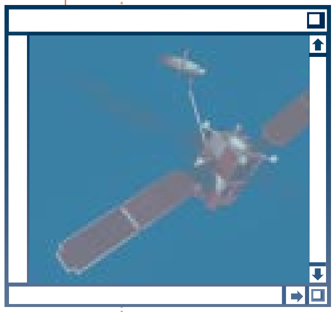
NASA defines its science and engineering objectives for the two 1996 Mars missions as follows:

Mars *Global Surveyor*

1 to enhance the global understanding of the geology and climate of Mars by characterizing the planet's surface and geological processes… monitoring global weather and the thermal structure of the atmosphere… monitoring surface features, polar caps, polar energy balance, atmospheric dust, and clouds over a seasonal cycle

2 provide multiple years of in-orbit communications relay capability for Mars lander and atmospheric vehicles from any nation interested in participating in international Mars exploration, and

3 Support planning for future missions with measurements that could impact landing site selection

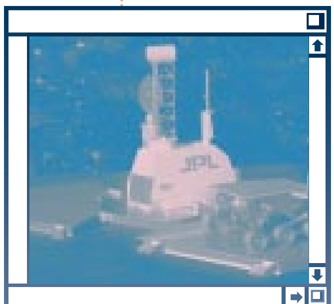


Surveyor's instruments include the Mars Orbiter Camera (MOC), the Mars Orbiter Laser Altimeter (MOLA), Thermal Emission Spectrometer (TES), as well as a magnetometer, electron reflectometer, a radio relay for the Russian and other Mars missions, and a radio science experiment. Adapted from the Mars *Global Surveyor* Fact Sheet co-packaged with this Guide, and available on-line at:

http://mgs-www.jpl.nasa.gov/mgs-home.html

Mars *Pathfinder*

Mars *Pathfinder's* mission is described as: "...primarily an engineering demonstration of key technologies and concepts for eventual use in future missions to Mars employing scientific landers. *Pathfinder* also delivers science instruments to the surface of Mars to investigate the structure of the Martian atmosphere, surface meteorology, surface geology, form, structure and elemental composition of Martian rocks and soil. In addition a free-ranging surface rover is deployed to conduct technology experiments and to serve as an instrument deploying mechanism."



Pathfinder's key science instruments are the Atmospheric Structure Instrument/Meteorology Experiment (ASI/MET), the Imager for Mars *Pathfinder,* or IMP, (both aboard the lander) and an Alpha-Proton X- Ray Spectrometer (APXS) on the *Sojourner* rover. Adapted from the Mars *Pathfinder* "A New Trail to the Red Planet" co-packaged with this Guide, and available on-line at:

http://mpfwww.jpl.nasa.gov

Passport to Knowledge goals for *Live From Mars*

1 to provide students with an engaging, informative learning experience as they "travel" to Mars—via interactive TV and the Internet—alongside NASA's spacecraft

2 to provide teachers with an easy-to-use suite of integrated multimedia "tools" with which to bring the science and engineering of the Mars missions to life for students

3 to provide teachers with materials and learning experiences which embody the National Science Education Standards, and show science as inquiry, from a personal and social perspective, and in the context of the history of earth and space science

4 to present the wide range of interdisciplinary skills and diverse careers required to support cutting-edge science

5 to connect students at nation-wide sites directly with NASA and other researchers, who will provide first-person perspectives on up-to-date science content

6 to provide interactive and collaborative opportunities which motivate students to function as active scientific thinkers, and which validate their participation

7 to document significant student outcomes facilitated by *Live From Mars*

***Passport to Knowledge* and *Live From Mars* are...**
Real Science,
Real Scientists,
Real Locations,
Real Time..

Opening Activities

Countdown to *Live From Mars*

On the Project Launch Pad

Assuming that most of your students have not taken this kind of electronic field trip before, you should introduce the project's various multimedia components.

- Explain that *Live From Mars* is an interactive "electronic field trip" in which students simulate real science, visit real locations, interact with real scientists, in real time. This is achieved through live television broadcasts, hands-on, in-class activities, and the use of the Internet as a tool for collaboration, research and communication.
- Provide time for students to share their prior experiences with the Internet, space exploration and Mars in particular, attitudes towards science, science textbooks, and science television broadcasts in general.
- Share with students your anticipated implementation timeline for *LFM.* Sharing this information with students as you begin validates their active participation as Mission Planners.

Have students access information (via print or on-line) on the history of Mars exploration and organize this information into a timeline.

- There are different ways to organize this Activity. You might assign the research as an independent assignment, or as a cooperative project. It could be worked on during school hours or at home.
- This Activity is easily adapted up or down in grade level and readily lends itself to an interdisciplinary organizational structure, supported in Social Studies (use of timelines), Library Media Center (research skills), Language Arts (preparing a written bibliography of sources), Math (use of spatial measure to show chronological scale of historical events) and Art (use of appropriate design elements for visual displays).

Activity A.1: Mars Mission Logbooks

Teacher Background

Portfolios are generally examples of student work that provide student-generated evidence of progress, accomplishments, or special challenges. The Mars Mission Logbook might include any or all of the following:

- student-selected writing samples
- lab reports (completed Student Worksheets, and other items)
- journals
- drawings
- projects
- photographs
- diagrams
- on-line downloads
- descriptions of favorite WWW sites
- videotapes
- computer disks
- copies of awards or prizes
- copies of written tests or quizzes
- research reports.
- news articles about Mars from current publications (print or on-line)
- weekly student entries regarding new learning
- new vocabulary
- summaries of Activities they disliked, or found boring, with explanations

Objective:

Student will create, organize and maintain a Mars Mission Logbook which may be used by the student, teacher or others to document and assess student involvement in the *Live From Mars* module, and positive or negative outcomes.

Materials: for each student:

1 binder	box	scissors
notebook	crayons	tape
folder	markers,	

SUGGESTED URL

http://cass.jsc.nasa.gov/k12/exmars96.html

Engage

Discuss with students the necessity of tracking their academic progress. Brainstorm, list on the chalkboard and discuss all assessment practices with which students are familiar (quizzes, tests, essays, verbal presentations). Introduce student portfolios and explain their use. Share with your students *your* goals for their learning (and what you yourself hope you will get!) during this unique adventure. Solicit their ideas and input.

Generate with your students a list of the kinds of materials which might be included in each Mars Mission Logbook. You may have a standard set that each student must include, and then let them add more examples which they feel best illustrates their own individual achievements or challenges. Providing students with a written copy of this assessment plan is recommended.

Explore

Procedure:

1. Have the students design covers for their Mars Mission Logbook.
2. Establish assessment/grading criteria.
3. Complete the **KWL** pre-assessment activity below.

"What do I know about Mars?"

Have students start to document this learning experience with the **KWL** Assessment activity. Each student should create a three-column chart, "**Know,**" "**Want to Know,**" and "**Learned.**" In the first column, the student should list all the facts they already know about Mars. Small group discussion is perfectly acceptable, with students "reminding" each other of knowledge otherwise forgotten! After appropriate discussion and writing time, teacher should validate students' knowledge by recording as many individual responses on a whole class chart as time allows. If the hardware is available, hook up a computer to a projection device; class responses can be saved to disk and/or reproduced for students to add to their Mission Logs. There may be disagreement about the validity of certain **Know** items; allow students freedom to state their opinions, but avoid judgments about the absolute correctness of listed items. (But think of ways to provide evidence bearing on misconceptions as the project continues: help students bring evidence to bear, and correct errors or misperceptions with more valid information.) Tell students they should keep an open mind; science is, after all, the continual testing of hypotheses and theories—our "body of knowledge" is changing and evolving.

Similarly, students should also complete the **Want to Know** section, recording their individual questions (this might be completed as a homework assignment, including discussion with family members about this new and different school experience. "My father says why spend all this money in space when there are so many problems down here... My sister heard there was this face on Mars...") Student responses should be added to the class chart. Throughout the electronic field trip, teachers and students may refer to the class **KWL** chart to assess how their ideas have changed, note what questions have been answered, with what kind of information, and what questions remain as a springboard for further learning.

At the end of their *Live From Mars* experience, students will complete their chart by listing what they have **Learned**.

Expand/Adapt/Connect

Insert dividers into the logbook. These dividers might be organized by calendar months of the project, or type of activity, type of assignment, etc.

Add a student generated Glossary, a project-oriented list of words, terms and concepts learned.

Students (in turn) could create a *Live From Mars* Newsletter, applying writing and editing skills to what they read, saw or found on-line. Consider sharing these with other schools you know, or find on-line. Perhaps internationally! At the end of the project, a compendium of these might be contributed to the school library (listing authors and editors) or submitted with an article by the teacher to various education journals—and sent on-line to *PTK*!

Summarize class' responses to "What Do I Know About Mars?" pre-assessment activity and submit them to the *LFM* website: Teachers' Lounge

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

Activity A.2

Become a Member of the Mission to Mars Team

Teacher Background

Each NASA mission has its own statement of Goals. These may be science objectives: Determine the composition of Martian soil. Or they may be engineering goals: Develop a cheaper way to deliver payloads to Mars orbit. These goals may come with other requirements: Complete the mission before the end of this decade. But once the goals are set, it takes teams of people to carry them out. Here are some examples of careers required

Mission Planners

Mission Planners compare different strategies for meeting goals and analyze the costs and benefits of each approach. One approach may be faster and cheaper—but more risky! Another may be very reliable but much more expensive. Yet another may be cheap and safe but take too long. Once a basic strategy has been chosen (such as the innovative new *MGS* aerobraking maneuver) more detailed planning begins. This includes schedules for design, construction, launch and operation of the spacecraft; detailed planning for the package of science instruments; discussions about the inevitable trade-offs between competing requirements. What will be required to make the best use of each instrument? What are the most important observations? The most difficult? How will information be returned to Earth and analyzed? Every aspect of the mission must be studied, understood and incorporated in a Mission Plan.

Project Managers

These specialists create budgets and schedules for the entire project. How many people are required for each task? How long will it take? Where will the spacecraft be built? (*MPF* is built at JPL, but *MGS* at Lockheed Martin Astronautics (in Denver). Who will be responsible for the launch vehicle? (McDonell Douglas builds the Delta IIs, the Air Force is responsible for launching them from Cape Canaveral, and then handing off control to JPL, which communicates with the spacecraft via the Deep Space Network, which has huge radio dishes in the Mojave desert, California, Spain and Australia.) How will components be tested? Who will monitor the "health and safety" of the spacecraft? Many of these are engineering questions, but all have cost and schedule implications and each issue is just a small part of a far larger puzzle that must ultimately fit together perfectly. Managers must choose particular people and personalities for each task, ensure that the required equipment is available at the right time, and monitor progress in each activity area.

The Science Team

This team will have specific detailed science objectives and a "wish list" for the types of instruments that will precisely answer their questions. Some will study radiation, the fields and particles that permeate space. Others will call for images of different wavelengths in the electromagnetic spectrum (visible light, infrared, ultraviolet, etc.)

Engineering Teams

These teams will be concerned with how much power each instrument needs, and how much it weighs. Is the device sensitive to heat or cold? Will radiation affect the measurements? How precisely will the device need to be aimed? Does its operation affect other spacecraft systems? What if some component fails? Can there be a backup or alternative procedure?

The Navigation Team

This team must precisely calculate the position and movement of the spacecraft and its target, then specify changes in attitude via thruster firings. In the case of *Pathfinder,* navigation also includes remotely "driving" a roving vehicle that is millions of miles away and up to 19 minutes in the past! It takes that long for a radio signal, traveling at the speed of light, to get from Mars to Earth, so the "Nav" team has to be sure they're not going to drive over a cliff before they can order the rover to stop or turn.

"OPS" Team

Specialists responsible for *Flight Operations and Spacecraft Systems* formulate the coded electronic commands that tell the spacecraft exactly what to do and when to do it. They also monitor each subsystem: propulsion, power, communications, guidance and control. All operations are controlled by computers that may receive pre-programmed commands months in advance. But complex systems often behave in surprising ways and the "Ops" Team must be prepared to respond immediately to unexpected developments.

Only when all the spacecraft systems and ground systems are working properly can mission goals be met. The payoff is new data for scientists around the world to analyze, a process that may take years after the spacecraft finishes its part of the mission. And by then new missions are already on the drawing boards.

Objective

- Students will identify the various jobs of the Mars Mission Team.
- Students will organize these jobs into categories and write a formal application for a position on the Mars Mission Team.

Materials

▼ chalkboard ▼ paper ▼ pencils	▼ Mars Mission Logbooks ▼ computer attached to projection device (optional)

Engage

Read aloud an excerpt of the most current *Field Journal* you have been able to find on-line ("Why, just yesterday Rob Manning wrote...") or one of the existing excerpts found on page 57 of this Guide. Review with students the position this individual holds on the Mars Mission Team.

Explore

Procedure

1. Working in small groups, students brainstorm the tasks they think are necessary to plan and implement an exploratory mission to Mars, like *MPF* or *MGS*. At the end of 10 minutes, each group will share their list; teacher or student should record results (ideas or questions) on chalkboard or on screen via computer projection setup.

2. When list is completed, ask students if they think all the individual tasks can be grouped together in any way. Discuss ideas. Hopefully, this discussion might lead to the kind of sub-headings listed above for this Activity. However, other reasonable sub-headings are perfectly acceptable.

3. Instruct students to return to their groups and rewrite the list, organized under the appropriate sub-headings. Have each group post (or present) their organizational scheme. Compare and discuss.

Expand/Adapt/Connect

Mars Mission Logbook Entry: Ask students "What position on the Mars Mission Team interests you most? What qualities (of skills, or personality) do you think would be most important in a person applying for this position?"

Go on-line, and identify the various mission members who have volunteered to write *Field Journals* or answer student questions. Print out and add to Logbook some of the comments you find most interesting.

Compare the *Viking* mission to Mars *Pathfinder* and/or Mars *Global Surveyor* in terms of planning time, site, duration and cost.

Read on-line *Field Journals*

Language Arts: Write a formal application for a specific position at NASA or JPL. Include your educational background and state clearly your qualifications ("personal and professional") for the position.

Research and compare cost for the *Viking* Missions with the proposed budgets for Mars *Pathfinder* and Mars *Global Surveyor*.

SUGGESTED URLS

http://spacelink.msfc.nasa.gov/Instructional.materials/Curriculum.Materials/Sciences/Astronomy/Our.Solar.System/Mars/

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

http://spacelink.msfc.nasa.gov/Instructional.materials/Careers/Careers.in.Aerospace/

http://www.jsc.nasa.gov/pao/factsheets/careers.html

Mission Planning: Earth/Mars Comparisons

Teacher Background

Mars *Pathfinder* and *Global Surveyor* will be sending back huge amounts of new images and data to NASA JPL, much of which will be made available not only to scientists, but to students via television, print, and the Internet. For students to understand this data, they need some basic background about what is already known about Mars. A good way to make this information interesting is to compare and contrast conditions on Mars to those on our own planet and/or evident in students' local or regional environments. The next two Activities are intended to both engage and inform students. (See Student Worksheet A.3 for basic Earth/Mars data.)

Atmosphere and Hydrosphere

Earth

Abundant liquid water is what makes our home planet unique in the solar system. Approximately three quarters of Earth's surface is covered by it. Some of this water evaporates and condenses around dust, salt, or pollen grains that are blown into the atmosphere, and these condensation nuclei are the beginnings of clouds. Clouds produce rain and snow and help trap the heat energy that's radiating back from Earth's surface. Carbon dioxide also helps keep heat in the atmosphere—which is known as the greenhouse effect. Clouds and carbon dioxide help moderate the daily temperature fluctuations on Earth, which are at their most extreme in deserts where there is very little water vapor or clouds to trap heat.

Mars

The atmosphere of Mars contains very little water. Conditions on Mars are far too dry for extensive water clouds to form, but even this little amount can condense, forming high, thin, wispy clouds. Early morning fog collects in valleys, and frosts may form on the ground, but these rapidly dissipate as the morning temperature rises. Since Mars is so cold, water is in the form of ice crystals.

The Martian atmosphere is too thin (equivalent to 100,000 feet altitude on Earth) for carbon dioxide to hold in infrared radiant energy and so it has no greenhouse effect as here on Earth. Mars is heated only by the incoming solar radiation, and thus is subject to great day-night fluctuations in temperature.

Storms on Mars are not rain storms as on Earth, but rather dust storms. These occur when the southern hemisphere on Mars is in summer. These dust clouds trap infrared energy and keep it from escaping back into space and so help make Mars' atmosphere a little warmer. (*See MarsWatch 96-97*, p. 29 for why dust storms are of great interest to NASA's Mission Planners.)

Days and Seasons

The rate of spin of a planet (its rotation on its axis) determines the length of its day-night cycle. Earth takes 24 hours to make one complete rotation, which we call a "day". Mars takes 24 hours and 37 minutes, which scientists call a "sol". If you were on Mars, you'd sense a day-night cycle similar to that on Earth. *Sojourner's* baseline mission is 7 sols, though scientists certainly hope it will survive much longer.

The tilt of a planet's axis (relative to its orbit) determines whether or not the planet has seasons and, if so, how severe they might be. Earth's axis is tilted 23 1/2 degrees, and Mars about 25 degrees. Mars, just like Earth, has seasons. *MPF* will land on July 4, summer in Earth's northern hemisphere and summer at the planned Ares Vallis landing site on Mars.

Remember

The distance of a planet from the Sun and the nature of its atmosphere also has a large effect on its weather and climate. Mars is almost one and a half times as far from the Sun as Earth is, and takes about twice as long to travel around the Sun. (A planet's revolution around the Sun determines its year.) Consequently, Mars is colder than Earth and its seasons last about twice as long as ours.

As students will soon discover, however, evidence written in surface channels on Mars, and inferred from its giant volcanoes, make most scientists pretty certain Mars was once quite different, with liquid water on its surface and a thicker atmosphere protecting it from destructive radiation. (See Activities 1.3 and 2.2) Now Mars is cold and dry; its surface too cold for life and scoured by incoming UV rays. One key and fascinating question that will take many missions over many years to answer is whether life—dependent on water and a more clement climate—once existed on Mars?

Objectives

- Students will compare and contrast key characteristics which make Mars similar to, and different from, Earth.
- Student will demonstrate the ability to use appropriate research skills to gather factual data about Mars and Earth.

Materials

- Activity A.3 Student Worksheet
- atlases
- globes
- encyclopedias (CD-ROM or on-line)
- if possible; WWW access
- paper
- pencil

VOCABULARY

atmosphere
axis
canyon
climatology
crater
density
elevation
hydrosphere
physical features
precipitation

Engage

> "Approximately 3.8 billion years ago, Mars and Earth are believed to have been very similar. Understanding what happened to Mars may help us understand our own planet and its future."
>
> — *NASA life scientist Chris McKay, Washington, DC, July 1996*

Ask students to brainstorm a list of physical features on Earth. When they are finished, ask them to place a check-mark next to each physical feature they already know can also be found on Mars. Ask students in what ways knowledge about the Martian environment is important to mission scientists. Explain that in this Activity, they'll be simulating the role of the researchers at NASA and JPL.

Explore

Procedure

1. Organize students into Mission Teams of 3 or 4 students. Their assignment is to research and organize basic data necessary for mission planning. Encourage them to brainstorm team strengths and skills and make decisions about the best cooperative plan for data acquisition. (Be sure each team has solid plans and procedures.)
2. Complete research in teams. Compare data tables with other research teams; discuss any differences, and come up with the most comprehensive Class Data sheet you have time, or wall space, to accommodate.

Expand/Adapt/Connect

Review metric units of measure as related to Mars/Earth stats.

Earth/Mars Comparison Data Sheet

	EARTH	MARS
Land area (in millions)	148 sq. km	144 sq. km
Sea Surface Area	363 sq. km	0
Equatorial Diameter	12,756 km	6,786 km
Distance from Sun (in millions)	147.1 km–152.1 km	206.6 km–249.2 km
Days in a Year	365.25	687.00
Axis Tilt	23.5 degrees	25 degrees
Average Density	5.5 g/cc	3.9 g/cc
Average Precipitation	varies	0

SUGGESTED URLS

http://bang.lanl.gov/solarsys

http://seds.1pl.arizona.edu/billa/tnp/

Activity A.4

Mission Planning—Geography

Objectives

- Students will demonstrate the ability to explain how appropriately or inappropriately researchers, terrestrial or alien, can generalize about a planet's character based on a limited sample of landing sites or observations.
- Students will demonstrate the ability to (1) use latitude and longitude to locate specific locations on Earth, and (2) evaluate that location as a potential landing site for alien space missions.

Materials:

- paper/pencils
- World atlases
- Mars Mission Logbooks
- list of possible and actual Viking Landing sites:

Engage

Have students list reasons scientists might want to explore an unknown planet. Ask them if one landing site on an unknown planet would provide all the data necessary to understand that planet. Tell them that in this Activity they must become alien scientists whose mission is to explore Earth! (See also Activity B.2: "Where Next?")

Explore

Procedure:

1. Hand out or otherwise display the chart showing the Martian latitudes and longitudes which were considered possible landing sites for the *Viking* spacecraft.

2. Working in small teams, students are to address the following challenge:

If MASA (The Martian Aeronautics and Space Administration) sent spacecraft to land at the same latitudes and longitudes on Earth as NASA considered for Mars, where would each spacecraft land? What hazards would be encountered? What might happen to the spacecraft? What would the spacecraft see? Would it detect water? Life? Bacteria? Intelligence?

3. If you were working for MASA, which sites would *you* pick for a landing on Earth? Why? For each site, identify the hazards that your spacecraft lander would have to survive. What would you expect to find?

Organize your information into a chart that you might present at the next MASA Mission Planning meeting.

Possible *Viking* Landing sites: (NASA EB–112)

	Latitude	Longitude
1.	22° N	48° W
2.	20° N	108° E
3.	44° N	10° W
4.	46° N	110° W
5.	46° N	150° E
6.	7° S	43° W
7.	5° S	5° W

Expand/Adapt/Connect

Mars Mission Logbook Entry: Research and find out where *Pathfinder* is scheduled to land and the rationale for choosing this location. See:

http://esther.la.asu.edu/asu_tes/TES_Editor/PATHFINDER/p_f_landingsite_letter.html

for Project Scientist Matt Golombek's discussion of why Ares Vallis was chosen.

- Create a MASA Earth Mission Log: what was your adventure like? Were you scared, excited, curious? What were your first words—back to Mars, or to any Earthlings you met?
- Create a broadcast news report or a front page of the "Mars Daily News" or the "Snows of Olympus Times," reporting this momentous occasion. ("First Close-ups of Earth: Mobile Lifeforms detected. Each bears unique number plate, and belches Carbon Monoxide. Giant Bi-pedal Parasites inside..."). Include vital Earth statistics and factual information about the landing site as well as human-interest reports from the MASA crew. Tape for your school's Science Expo or parent night, share with administrators—and send to *Passport to Knowledge*.
- E-mail other schools involved in *LFM*. Have students plot their locations on a U.S. and/or world map as you receive replies.

SUGGESTED URL

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

Live From Mars Program 1

Countdown

Live Tuesday, November 19, 1996, 13:00-14:00 Eastern

Sites: Cape Canaveral, FL, and Worcester, MA

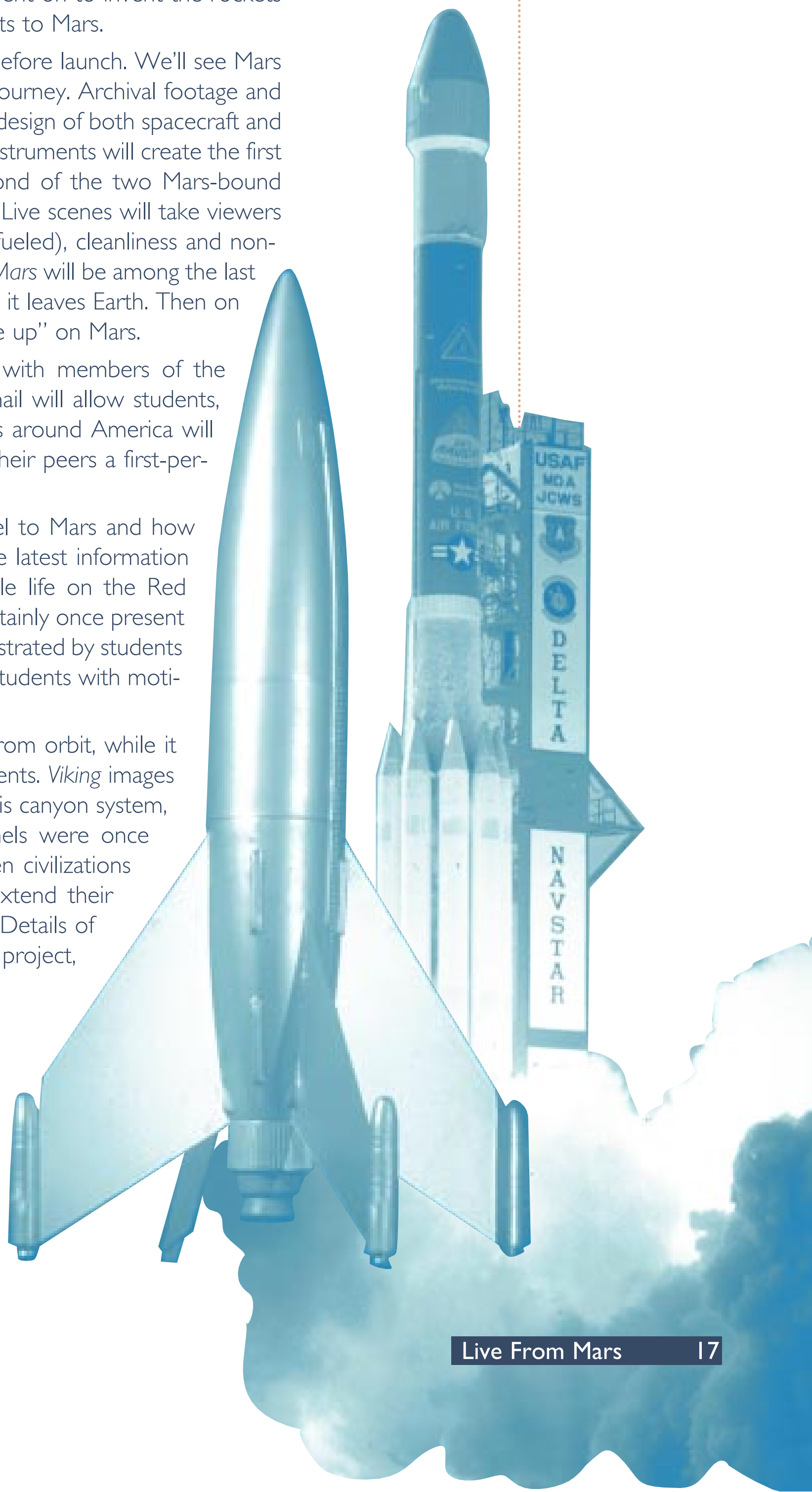
COUNTDOWN will take students, live, behind the scenes at Cape Canaveral, launch site for the entire American space program. It will also visit Worcester, Massachusetts, where in the last years of the 19th Century, the young Robert Goddard first dreamt of space flight, and then went on to invent the rockets that would eventually take humans into space and robots to Mars.

"Countdown" will document the final intense hours before launch. We'll see Mars *Global Surveyor* lift off and the beginning of its 9-month journey. Archival footage and NASA animation provide background: the planning and design of both spacecraft and Mission, what Surveyor is supposed to do, and how its instruments will create the first detailed topographic map of Mars. *Pathfinder,* the second of the two Mars-bound spaceships, will be in final prep. for a December launch. Live scenes will take viewers as close to the rocket as safety (the spacecraft will be fueled), cleanliness and non-contamination measures allow. Participants in *Live From Mars* will be among the last humans to see *Pathfinder* and the *Sojourner* rover before it leaves Earth. Then on July 4, 1997, they can be among the first to see it "wake up" on Mars.

Students in Massachusetts and Florida will interact with members of the *Pathfinder* and *Surveyor* teams, via live 2-way video. E-mail will allow students, anywhere, to participate. Taped questions from schools around America will add other voices and locations. Students will also give their peers a first-person, kids' eye tour of the Cape.

The program will also consider why we should travel to Mars and how Earth and Mars are alike and different. It will review the latest information on Earth's neighbor, including the hot topic of possible life on the Red Planet. Viewers will see how liquid water was almost certainly once present on Mars. Activity 1.3, "Follow the Water", will be demonstrated by students on camera, providing teachers with a model and other students with motivation for their own hands-on work.

"Countdown" will provide the best images of Mars from orbit, while it reviews previous American missions and their achievements. *Viking* images will show the mighty volcanoes, the great Valles Marineris canyon system, and the channels. Students will see how those channels were once regarded as "canals", fueling speculation about past alien civilizations on Mars. The program will show how students can extend their Martian adventure and stay connected via the Internet. Details of *Live From Mars* on-line components and its collaborative project, "The Planet Explorer Toolkit," will be provided.



Activity 1.1.A

Rocket Science 101

Teacher Background

Without the mighty Saturn V rockets, there could have been no Apollo program and no humans on the Moon. Without the smaller, cheaper Delta II rockets, *MGS* and *MPF* would not have been affordable. Weight, cost, thrust, power... all these are critical to the exploration of our Cosmos. This set of Activities will expose your students to some fundamentals of rocket science, and some key principles of physics.

Simple balloon rockets, for example, offer great opportunities for students to explore the Laws of Motion. These laws were first expressed by the English scientist, Sir Isaac Newton (1642-1727).

1 Newton's First Law:

Objects at rest will stay at rest and objects in motion will move in a straight line at constant speed unless acted upon by an unbalanced force.

- (i.e., If something is at rest [not moving], it will stay at rest unless something pushes or pulls on it—that is, exerts a force on it. Also, if something is moving in a straight line at a constant speed, it will continue to move that way unless something pushes or pulls on it.)

2 Newton's Second Law:

Force is equal to mass times acceleration.

$$F = ma$$

- (i.e., If you push or pull on something, that force can change the object's speed and/or direction. The greater the force, the greater can be the resulting change in the object's speed and/or direction. But, for a given force, you will have less effect on a massive object than a less mas-

3 Newton's Third Law:

For every action there is always an opposite and equal reaction.

- (which translates as: if you push on something, it will "push back" with an equal amount of force)

Newton's Laws in rocket motion

To summarize, an *unbalanced force* must be exerted for a rocket to lift off from a launch pad or for a spacecraft to change speed or direction (First Law). The amount of thrust *(force)* produced by a rocket engine will be determined by the rate at which the mass of the rocket fuel burns and the speed of the gas escaping from the rocket (Second Law) OR if you push or pull on something, that force can change the object's speed and/or direction. The harder you push or pull, the greater the effect! The reaction, or motion, of the rocket is equal to and in the *opposite direction* to the action, or thrust, from the engine (Third Law).

In its simplest form, a rocket is a chamber enclosing gas under pressure. A small opening at one end of the chamber allows the gas to escape, and by so doing provides a thrust which propels the rocket in the opposite direction. There's a strong similarity between the mightiest rocket and a humble balloon. The air inside a fastened balloon is compressed by the rubber walls. The air pushes back so that inward and outward forces balance: the balloon does not move. When the nozzle is released, air escapes through it in one direction and the balloon is propelled in the opposite direction.

Objectives

- Students will explore aspects of Newton's First and Third Laws of Motion.
- Students will be able to describe the launch and cruise phases of the *MGS* and *MPF* missions in terms of Newton's First and Third Laws of Motion.
- Students will conduct controlled rocketry experiments and analyze the *MGS* and *MPF* missions in terms of the principles of rocketry.

Materials for each team of 3 or 4 students

- several balloons which, when fully inflated, are 3 to 5 inches in diameter and 1-2 feet long (party time!)
- several plastic drinking straws (milk shake size)
- strong adhesive tape
- nylon fishing line
- stopwatch or timer
- metric measuring tape or meter sticks
- Activity 1.1.A Student Worksheet (one per student)
- Mars Mission Logbooks

Materials for whole class

- Large printed signs of Newton's Laws of Motion

Engage

Show students a video of a rocket or Space Shuttle being launched and continuing up into orbit. (Most NASA Mission films will show this.) Have students note any changes they observe in the rocket's speed and direction. Allow time for discussion and students' sharing of personal experiences with rockets and/or launches.

Explore

Procedure

1. Explain to students that they are going to become flight engineers for NASA, working in small "Rocket Science Teams", and that their mission is to investigate how rockets work. This will involve some fun experiments with rockets made from balloons and, in the process, testing Newton's famous Laws of Motion. Place Newton's Laws of Motion on chalkboard. This Activity will illustrate two of these laws.
2. Demonstrate experimental procedure as outlined on Student Worksheet 1.1.A. Hand out materials, and answer student questions. Then allow Rocket Science Teams time to construct their rockets and complete the experiment, recording data on individual worksheets as well as collecting all the teams' results on a class data sheet or chalkboard.
3. Discuss the results of the balloon rocket experiments with the students. In particular, ask the following:

- Did all teams obtain the same data? How can we explain the differences?
- When did the balloon rockets go the farthest? What caused this? *(A greater unbalanced force was applied for a longer period of time.)* How could they test their ideas?
- Why did the balloon rockets stop? *(There was a counter-acting force called friction between the string and the straw.)*
- If there were no friction between the straw and the nylon string, and no wall in the way, how would the balloon rockets behave? *(They would keep accelerating until all the fuel was gone because there would continue to be an unbalanced force on the balloon.)*
- If there were no friction between the straw and nylon string, no wall in the way, and no air resistance acting against the deflated shell of the balloon, how would the rockets behave after they ran out of fuel? *(They would keep going at the final speed they had when the fuel ran out.)*
- Which Law(s) of Motion does this activity illustrate and why?

Expand/Adapt/Connect

Research (using print or on-line sources) the Delta II rockets chosen by NASA for Mars *Global Surveyor* and Mars *Pathfinder*. When were these rockets designed and built? Have they been used on other space missions? What are their strengths and limitations?

VOCABULARY

acceleration
action/reaction
balanced
force
friction
launch
orbit
payload
rocket

SUGGESTED URL

http://mpf.www.jpl.nasa.gov/mpf/delta.html

Activity 1.1.B

Rockets and Payloads

Objective

• Students will investigate and predict the effect of payload on the amount of energy needed to lift a rocket vertically (thereby working with Newton's Second Law of Motion).

Materials: for each Rocket Science Team of 3 or 4 students

- 2–3 large, long balloons
- balloon pump (available in party stores)
- fishing line
- paper clips (or pennies)
- 1 paper cup
- straws (milk shake size)
- tape
- clothes pins
- metric scale
- Activity 1.1.B Student Worksheet (one for each student)
- Mars Mission Logbooks

Engage

Have Rocket Science Teams brainstorm what equipment they would place on *MGS* or *MPF* spacecraft. Would there be any limitations to the "payload"? (Hopefully, students will suggest that payload weight was a serious constraint to the equipment that could be carried by *MGS* and *MPF* to Mars.)

Explore

Procedure

1. Place large sign with Newton's Second Law of Motion on chalkboard and review the formula (force = mass times acceleration). Have students express this in more colloquial terms, until you are sure all understand the principle involved. Ask: Using the same amount of pushing force, which object could you get to accelerate faster, a Mack truck or a toy wagon? Why? (If F is equal and you have bigger M, you have to have a smaller A to keep the equation balanced.)
2. Distribute materials and Student Worksheets. Review procedure with students and answer any questions.
3. Allow Rocket Science Teams sufficient time to complete investigation and record data.
4. Call all the groups together and have them post the results of each of their trials on a data table on the chalkboard. Draw group conclusions.

   Note: In this experiment students first witness action-reaction. Then they vary the amount of M between the first phase and second phases of the experiments, and should see a corresponding increase in the amount of force required. Acceleration is a variable not addressed, but this should be discussed, along with the effects of not holding the string vertically which adds drag from friction, lowers acceleration and changes results, etc.
5. Have teams share the design principles which made their launches successful and then develop and contribute ideas they think could be used to create an even more successful "heavy-lift" launcher.

Expand/Adapt/Connect

Go on-line and find information giving the specific course that *MPF* and/or *MGS* will follow to travel to Mars. How many trajectory changes will be necessary? How is the spacecraft controlled?

Go on-line, read *Field Journals* and *Biographies* to find out what course to follow to become a rocket scientist.

Explain (in writing or with illustrations) a spacecraft launch, from blast-off through entry into orbit, using Newton's Laws of Motion. Make sure your explanation could be understood by a younger brother or sister!

Graph data from the rocket experiments.

Language Arts: Write a first-person account of a rocket launch as if you were Sir Isaac Newton.

Read a biography of one of the following scientists associated with rocketry: Robert Goddard, Johann Schmidlap, Isaac Newton, Wan-Hu, William Congreve, William Hale, Konstantin Tsiolkovsky, Hermann Oberth. Report this person's contributions to your class.

Research Robert Goddard. Worcester, Massachusetts, will be an uplink site for the first broadcast on November 19, 1996.

Research why launches are held at Cape Canaveral, Florida.

Research the development of rockets from the earliest to the most current designs. Add your own design! Present your report using computer presentation software (HyperCard, HyperStudio, etc.)

Design your own rocket and translate into two-dimensional drawing or three-dimensional model.

SUGGESTED URLS

http://www.jpl.nasa.gov/basics

http://www.nar.org

Mapping the Topography of Unknown Surfaces

Teacher Background: Mapping Mars with Global Surveyor

The *Viking* orbiters provided wonderful pictures, and subsequent image processing created mosaics of most of Mars. But much important information is still missing. An example is something as basic as the elevation of future landing sites. Because Mars' atmosphere is so thin, parachutes are relatively less effective than here on Earth. (There's less resistance to slow the spacecraft down: Newton's Laws, once more!) So, it's critical to know how thick a layer of Martian atmosphere you're traveling through before you reach the surface. If the landing sites are too high up, there'll be too little atmosphere, and you may design a braking system that won't work well enough to slow your descent! Ouch... back to the drawing board. Current uncertainties about Martian elevations are as large as 3 kilometers, enough to make spacecraft designers very nervous. Enter "MOLA."

One of the six instruments on board Mars *Global Surveyor* will be the Mars Orbiter Laser Altimeter (MOLA). MOLA's laser will fire pulses of infrared light 10 times each second. By measuring the length of time it takes for the light to reflect off the Martian surface and return to the spacecraft, scientists can determine the distance to the planet's surface. (Spacecraft navigation data gives the distance of *MGS* from the center of the planet, so putting the two data sets together will yield Martian surface elevation with a precision of a few tens of meters.) MOLA will provide information to construct the first full topographic map of Mars, showing fine details of plains, valleys, craters and mountains.

Note: Since topographic maps use sea level to define zero elevation, we Earthlings measure the height or depth of all landforms relative to sea level. Of course there's no sea on Mars, so scientists describe elevations relative to a zero level that is called the "datum" surface.

Vocabulary

- altimeter
- crater
- datum surface
- infrared
- landform
- laser
- mountain
- plain
- probe
- pulse
- radar
- simulate
- sonar
- terrain
- topographic map
- valley

Objectives

- Students will be able to describe in words and graphic displays the elevation or depression profile of sections of Mars' Olympus Mons and/or Valles Marineris.
- Students will demonstrate the ability to describe the operation of the *MGS* laser altimeter, and simulate its operation.
- Students will be able to explain how orbiting spacecraft build up global maps one data slice at a time.
- Students will use contour maps to create 3-dimensional Martian landforms.
- Students will transform numerical measurements into 3-D representations of hidden landforms.

Materials: for each team of 3/4 students

- 1 shoebox with lid
- scissors
- pencils
- adhesive/scotch tape
- metric ruler
- 1 grid support constructed by gluing one complete 16 cm x 30 cm grid paper onto a piece of cardboard
- Altimeter rod (10 cm length, cut from a coat hanger or wooden skewer)
- an awl, leather punch or other sharp object to punch holes in top of shoebox
- 17 sheets of cm grid paper (16 cm x 30 cm)
- *papier mache*, plaster of paris, or small pieces of rocks, wood, aluminum foil that can be used to make a Martian terrain inside bottom of shoebox
- contour map of Olympus Mons and Valles Marineris (provided with this Guide: duplicate and scale up to give the best "fit" with a standard shoebox); you may wish to duplicate this and cut into "jigsaw puzzle" pieces, covering up place names, in order to increase the challenge aspect of this Activity.

Engage

Explain why NASA needs elevation data from Mars, and how MOLA operates, or have teams go on-line and research MOLA and report back. As noted above, the altitude of a landing site can be crucial for spacecraft safety.

Tell students that they represent a NASA Mission team specializing in mapping the elevation of a little known planet. This Activity simulates the process of gathering data about a surface which can't be measured directly. Working in teams, students will first construct a segment of Mars—in 3 dimensions—from current contour maps, without revealing its exact topography to other teams. This Challenge landscape will be hidden inside a securely-closed shoebox. Each team, in turn, will receive a Challenge landscape created by another team, and unknown to them. Their mission is to collect simulated altimeter data on the Challenge landscape, and create a 3-D paper profile map of what they think is hidden in the box (the "Result" landscape). At the end of the Activity, they'll see how accurately Challenge and Result landscapes match.

Note: Ideally, this is a two stage Activity: you can do just the measuring activity, but the students will benefit both from creating the Challenge and Result landscapes (scaling, plotting, cooperation and model-making skills) which will let them literally get their hands on two sections of Mars.

Explore

Procedure

Making the Challenge landscape

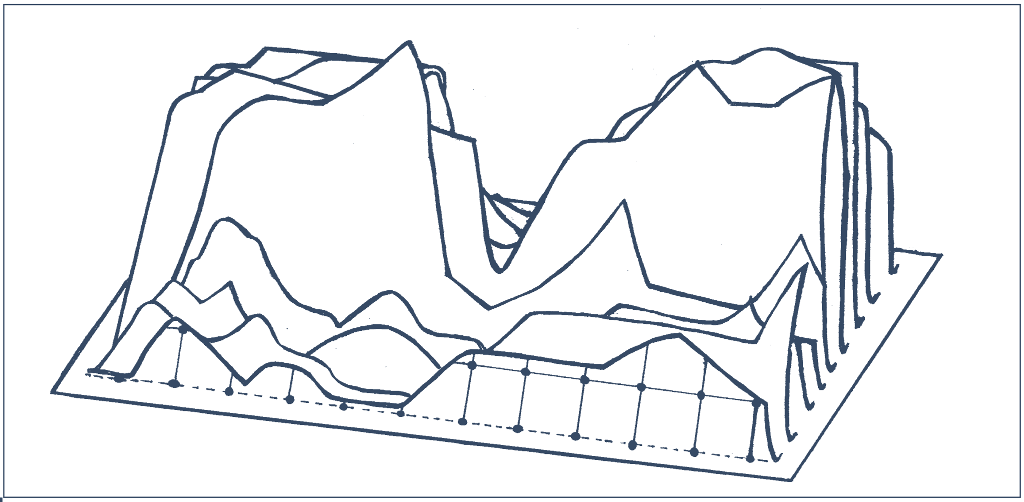
1. Working from the sections of contour maps you provide, each team should make a three-dimensional Mars landscape covering the bottom of the shoebox.
2. Tape or glue a piece of cm grid paper to box lid. Label horizontal and vertical axis 0, 1, 2, 3, etc.
3. Using a sharpened awl or leather punch, punch small holes at intersections of the grid. Be careful!
4. Seal box with tape. Exchange the closed Martian Challenge boxes.

Altimeter Simulation:

Tell students that they will now simulate the Mars Orbital Laser Altimeter using the "Altimeter rod" and collect data representing the Mars terrain hidden in the shoebox.

The teacher might want to demonstrate the following procedure:

1. Find the coordinates (0,0) on the box top.
2. Insert the Altimeter rod into the hole at (0,0), until it comes in contact with the landform inside.
3. Keeping the rod upright, measure how much is showing above the lid. Subtract this from its full 10 cm. length to find the distance from "orbit" (lid) to surface (or use a piece of easily removable paper tape as a marker, and remove and measure the rod.)
4. On the graph paper plotting grid, locate the (0,0) coordinate and count down the number of centimeters which the rod measured. Plot this point on the grid.
5. Repeat this procedure across the row (0,1), (0,2) (0,3), (0,4), etc. to (0,30).
6. Connect the altimeter readings across the row.
7. Cut along this data line.
8. Fold along the dotted line (row 10) and glue on the appropriate row (0,0 for the example above) of the grid support. You now have the first row of your three dimensional Mars landscape. (See Diagram)



Note: to move things along, in a team of 3-4 students, one might be MOLA and collect and measure altitude, one might plot the data points, and another might cut out and assemble the profile sheet once each row of data has been collected. Students should rotate through tasks to expose each of them to all parts of the process.

Repeat this procedure for:

- the second row, coordinates (1,0), (1,1), (1,2), (1,3), (1,4), etc. to (1,30);
- the third row, coordinates (2,0), (2,1), (2,2), (2,3), (2,4), etc. to (2,30); and so on, up to the sixteenth row, coordinates (16,0), (16,1), (16,2), (16,3), (16,4), etc. to (16,30).

After class has completed the hands-on procedure:

1. Look at the Challenge and Result profiles. Ask students to determine which "Result" corresponds to which "Challenge."
2. If you have had students create sections of Valles Marineris and Olympus Mons as the Challenge landscapes, assemble them and enjoy the view!
3. Suggested discussion questions:
   - How could a more detailed map of the surface be made? *(more holes, holes closer together, thinner probes)*
   - Where else could this map-making technique be used? *(other planets and their moons, ocean floors, remote areas that are difficult to reach physically.)*
   - What other techniques beside lasers could be used? *(e.g. radar—as on NASA's Magellan spacecraft which surveyed Venus, or sonar, as in submarines.)*
   - In what ways will future Mars Missions use MOLA information?
4. Locate a topographical map of your area: what is the scale? What symbols are used?
5. Invite a Surveyor (perhaps a student's parent) to class: What tools do they use? Do they ever work with GPS (Global Positioning Satellite) which now provides altitude data, as well as latitude and longitude?
6. Record in Mission Logbooks successes or problems in completing this Activity.

Expand/Adapt/Connect

MOLA's laser will fire infrared pulses every ten seconds. These pulses of energy travel at the speed of light (186,000 miles per second). NASA scientists can determine the distance from the spacecraft to the land form below by timing how long it takes the pulse to travel from the spacecraft to the surface and back to the spacecraft (which you can think of as a kind of echo). Distance = Speed x Time (e.g., travel at 50 miles per hour for 3 hours and you have gone a distance of 150 miles.) If we divide this distance by 2, we have the distance from the spacecraft to the ground.

Teachers of older students might have them calibrate their measuring rods in seconds instead of length. Then, remind students of the velocity of light and have them calculate the distances to the various points in their topographical models. As a starter, *MGS's* orbit is X kilometers (go on-line and find out...) above Mars. Given that the standard shoe box is Y centimeters high (measure one), and that the base of the box can be considered Mars' datum (see above) then each cm on the Altimeter represents Z seconds (here's the math challenge!)

Research how laser altimeters operate and report to class. Construct a visual (poster, 3-D mock-up, etc.) to use in your report.

Research the use of sonar in other technologies and in the animal kingdom (dolphins, whales, bats).

Adapting this Activity to Higher or Lower Grades

Younger students may find this Activity still works well with arbitrary landforms, rather than those modeled on actual Martian topography. In this case, simply have each team create an interesting mountain/valley shape, which then becomes the challenge for other teams to survey and represent.

For a sturdy model which you'll be able to use multiple times, create the surface by crumpling newspaper and covering it with aluminum foil. Pour plaster of paris or apply papier mache over the foil, and spread the plaster all the way to the box sides to anchor the surface. It's best to have 1-3 "mountains" or one complex feature in each box; try to make the highest and lowest points about 10 cm different in length.

SUGGESTED URLS

http://jazzman.gsfc.nasa.gov/737.2pages/mola/mola.htm

http://ltpwww.gsfc.nasa.gov/eib/mola2.html

Activity 1.3

Follow that Water—Investigations with Stream Tables

Teacher Background

Water is essential to life on Earth: its abundant presence on our world drives the weather and shapes the land by rain, runoff and erosion. Whenever we see what looks like evidence of liquid water elsewhere in the Universe, we become especially interested, since water is a requisite for life.

In the late 19th Century astronomers peered at Mars through telescopes and saw lines stretching across its surface: Giovanni Schiaparelli, an Italian, called them "canali" meaning "channels" or "grooves", which was translated into English as "canals." Some interpreted these "canals" as evidence of intelligent life, and even an advanced Martian civilization capable of massive, planet-wide engineering projects. Now spacecraft have looked close-up at Mars, and we know there are no canals built by a Martian Corps of Engineers. But some of the channels do have shapes which look much like those we see on Earth. While it's tempting to think of them as dried-up river beds, most scientists think many of the channels resulted from sudden releases of underground water or sudden melting of underground ice, rather than from sustained rainfall and enduring rivers. How do we know we're not fooling ourselves, or misinterpreting the data, as did some of those 19th century observers?

Scientists use different methods to understand the conditions under which the channels may have been formed. One method involves the use of stream tables, to simulate different rates of flow, from gentle rivers flowing for a long time, to sudden, massive floods. In this Activity, students will have the chance to discover for themselves some of the characteristic shapes created by differing volumes of water, flowing at different rates ("volume over time"). With "educated eyes" they can then turn to study images of Mars and recognize the features and discuss the mechanisms which might have caused them.

VOCABULARY

- avalanche
- delta
- erosion
- flow patterns
- geologist
- meandering
- outflow channels
- simulation
- topographical map

Objectives

- Teams of students will build simple stream tables and other needed equipment.
- Students will vary the angle of the stream tables in order to simulate different flow rates and compare the results.
- Students will observe various features formed in a stream table by flowing water and compare these model features to photos of real features on Mars in order to make inferences about the possibility of water channeling on Mars.

Materials: for each team of students

Please note: if these materials are difficult to secure, consider using only one set for the entire class, and assigning a different Planetary Geologist team per angle, and emphasizing the Image Processing and Data Analysis process for those who must watch. Although there will be less student hands-on time, it might be better to do the Activity in this way rather than foregoing it altogether, so important is the issue of water to Martian science and mission planning.

- Activity 1.3 Student Work Sheet
- 1 wallpaper tray (poke hole about size of a quarter in one end so water can drain into a bucket)
- metric ruler
- two buckets of clean play sand
- a third empty (catch) bucket
- a one gallon plastic water jug
- measuring cup
- 2 plastic funnels: one with a 1/4 in. opening and one with a 1/2 in. opening
- several blocks of wood cut from 2 x 4s, each about 6 in.
- a protractor
- a piece of string and a small weight
- several stones that are flat on top and bottom, about 1/2 to 1 inch in diameter and 1/2 to 1 inch high
- plastic lids from 1-liter soda bottles
- selected images of Martian surface features
- selected images of Earth, featuring dry river beds (**Note:** The *Live From Mars* videos will feature such images. More may be found in the slide set and the *Explorer's Guide to Mars* poster, included in the *LFM* Teacher's Kit.)

Engage

Show students pictures or video of rivers and floods on Earth (perhaps local occurrences in your region). Do they think such conditions could exist on Mars today? Ask if they think Mars could ever have had liquid water. Or consider the question of water on Mars through a discussion on the possibility of life on Mars today in contrast to the distant past. Discuss conditions that seem necessary for life to develop. Cite the August 1996 announcement of the possible discovery of ancient Martian life in a meteorite.

Explore / Explain

Procedure

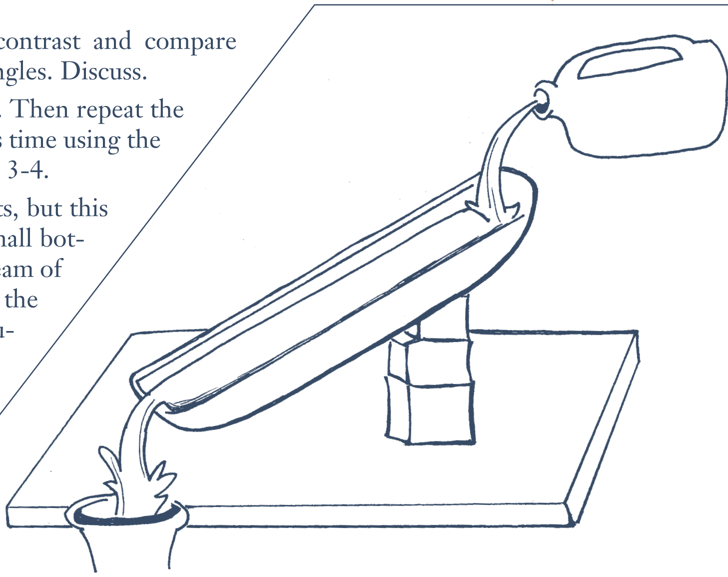
Please note: some details are provided on the Student Work Sheet and its diagram, which you should review along with this procedure.

1. Distribute materials to each student team. Explain that each team is going to work as Planetary Geologists to investigate what can happen to a surface when water flows across it, and that they will share their data to come up with some principles by which water shapes landforms in specific ways.
2. Demonstrate stream table set up and use of the protractor to align the stream table at a given angle. This table should initially be set at an angle of 5 degrees.

   Pour 1 quart of water into the 1/4 inch funnel and allow the water to run down the tray through the groove as the teams watch. Have students describe and sketch the flow pattern which results, carefully noting such things as the shape of the flow pattern including

- whether the channel cut by the water was straight or curved
- how wide the channel became
- how deep the channel became
- how long it took for the jug to empty
- was a small or large amount of sand carried down stream by the water
- whether or not avalanching occurred
- whether or not a delta was formed

3. Assign each team a slant angle (from 5 to 25 degrees) and allow time for basic set up. For the first set of trials, each team should use the plastic funnel with the 1/4 in. opening. Teams should complete Trial # 1 and record results on the Student Worksheet.
4. Before continuing, allow time for teams to contrast and compare results from the stream tables set at different angles. Discuss.
5. Smooth the damp sand back to a uniform layer. Then repeat the same experiment at the same tray angle, but this time using the funnel with the 1/2 inch opening. Repeat Steps 3-4.
6. Again, smooth the sand. Repeat the experiments, but this time tell students to place the stones and the small bottle lids in the tray in such a position that the stream of water will encounter them, working them into the sand and adding a thin layer on top. (This simulates what happens when flowing water meets the elevated rim of an impact crater.) Have students carefully observe and record the appearance of the patterns in the vicinity of the bottle caps and stones at the end of the experiments.



Teacher Background

Students will see that at angles of about 15 degrees and higher, the sand will wash out. Larger volumes of water over shorter time periods (e.g. flood conditions) carve deeper channels with steeper sides. Only at angles of around 5 degrees, simulating gentler processes (e.g. slower flow over longer times) does the water begin to create curves and meanders more typical of terrestrial rivers. *Remind students that most stream beds have slopes that are typically 5 degrees or less but that in this simulation the angle stands for flow rate, not the underlying topography of the planet.* Also note that, as in most simulations, you can't replicate all aspects of the original condition you're trying to understand: for example, results obtained by using sand do not perfectly model rivers running through soil or over rock. But varying the angle does simulate flow rate, one key variable scientists think important for Mars.

7. Challenge students to answer the following questions:
   - At what slope angles (flow rates) do meanders and deltas occur?
   - At which slope angles (flow rates) does the sand wash out completely?
   - How does the slope angle (flow rate) affect the amount of sediment deposited down stream?
   - What happens to the sand immediately after the water starts flowing?
   - What happens to the sand after the water has flowed for awhile?
   - What effect does the volume of water that flows per second have on all of the above?
8. As a last activity, simulate a large scale catastrophic flood by filling the gallon jug with water and carefully creating a uniform "waterfall" along the top of the stream table. Have students try with and without the stones and bottle lids in the flow. Again record and discuss results.
9. Finally, refer to *Viking* images of Mars. Ask students to look carefully at each one and challenge them to compare examples of the different types of patterns they created in their stream table experiments with what they see in the actual images of Mars. Ask them to draw conclusions about the presence of water on Mars in the past and to draw general conclusions about the differing amount and rate of flow of water in the various areas on Mars seen in the images. Ask them to search for signs of liquid water on Mars in the *Viking* images (i.e., on Mars today). Challenge them to hypothesize where they think all the water went.

Expand/Adapt/Connect

Research the various theories as to how water was released onto the Martian landscape at various times in the past and where scientists think it is today.

Have students examine a map showing the geological surface features over the entire surface of Mars. Have them mark the location of outflow channels. Have them do the same with the location of valley networks. Ask them to describe the differences in their geographical distribution and challenge them to explain the reasons for this.

Provide students with the prime landing site for *Pathfinder* as well as the coordinates of the *Viking* 1 and 2 landing sites . Ask students to describe these locations relative to the location of outflow channels and valley networks. Challenge them to hypothesize why scientists chose these particular locations to put spacecraft down on the surface of Mars.

Research meandering streams. What is an oxbow lake and how is it formed? Why does a river bed change over time? Compare and contrast each terrestrial feature to landforms on Mars.

Go on-line and download Mars images. Create a visual display illustrating the various landforms on Mars. If you or your students have documented the flow table experiments, prepare poster displays relating flow rate to surface feature (and submit to *Passport to Knowledge* on-line or in hard copy!)

Read about Giovanni Schiaparelli. Compose a letter he might have written (or e-mailed) to NASA regarding his concerns about the veracity of new data coming from Mars.

Write a news article about the stream bed simulations and report on your data.

Noting the scale of the map, have students measure and calculate the area of some prominent Martian outflow channels. Compare these areas to related places on Earth such as the Nile River Valley, the channeled Scablands region of Washington State or an area of their home state.

Research the Scablands region of Washington State.

Note: this Activity and Activity 2.2 are adapted in part from materials and concepts developed during workshops held by JPL's Mars Exploration Directorate as part of its Education and Outreach Initiative (Meredith Olson, Project Educator.) Related Activities may be found in the series of Student and Teacher Publications created by JPL: to order, contact TERC at 617-547-0430. The first two JPL-TERC modules and a set of Mars and Earth images are part of the *LFM* Teacher's Kit. *LFM* thanks Dr. Olson for her review of the adaptations of the original activities.

SUGGESTED URLS

http://www.msss.com/http/ps/channels/channels.html
http://nssdc.gsfc.nasa.gov/planetary/viking.html
http://www.jsc.nasa.gov/pao/flash

Live From Mars Program 2

Cruising Between the Planets

Live Thursday, April 24, 1997, 13:00-14:00 Eastern

Sites: NASA Jet Propulsion Laboratory, (*Pathfinder* Control) and the Muncie, IN school district planetarium

Cruising Between the Planets airs just days after one of Mars *Global Surveyor's* Trajectory Correction Maneuvers, designed to keep it on track to the Red Planet. We'll hear updates on both spacecraft and consider what it takes—in human as well as engineering terms—to keep them on course.

Paralleling the *Journals* and *Biographies* to be found on-line, we'll get "up close and personal" with the men and women who fly the missions and design the scientific experiments. We'll see the excitement, long hours and hard work, and hear what keeps them—and their spacecraft—pumping. We'll provide more information on the scientific objectives of both missions and also on the high-tech careers which are involved.

JPL is NASA's main center for planetary exploration and the use of robotics to explore our solar system. Mars *Pathfinder* and its *Sojourner* rover were built and tested here. We'll look in detail at what *Sojourner* is designed to do, and use a "spare" to show how it will test new robotic technologies for future, larger roving vehicles.

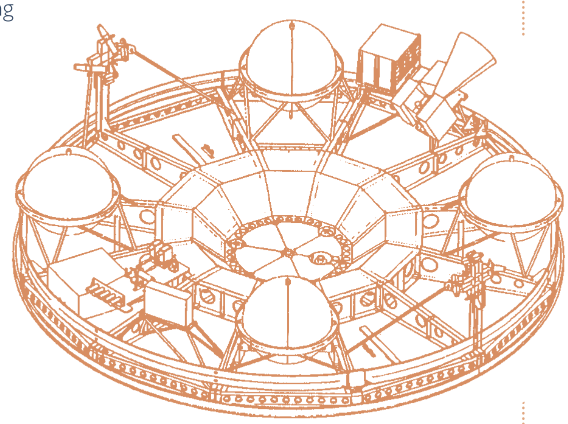
Pathfinder scientists will show us the Mars terrain they've built as a testbed for the lander and rover. They will use this to simulate navigation around the Mars landing site and to deal with any mechanical and engineering problems.

We'll report on MarsWatch '97, a national and international effort to monitor conditions on Mars with terrestrial telescopes. Dust storms and other climatic conditions affect the atmosphere through which both *Pathfinder* and *Surveyor* will have to travel in the final stages of their journey. NASA needs to know how warm or cold or relatively "thicker" or "thinner" the atmosphere has become in order to make final slight adjustments to the entry and descent sequences. During Spring '97, students will be encouraged to work with local amateur or professional astronomers, and we'll see what they've been up to, on-line and in taped reports.

A taped report will show students engaged in building "Rovers from Junk" (see Activity 2.3 p. 36). We'll see further applications of Newton's laws in student-designed balloon and rubber-band rovers, as well as in the real trajectories taking *Surveyor* and *Pathfinder* to Mars.

Live questions will come in to the JPL scientists from Muncie, Indiana and taped questions from across America. Once more, the Internet will connect other schools and students via e-mail. We'll see how the Internet also provides a way to operate model rovers remotely, with participants in different regions and even different countries controlling rovers on model Mars terrains thousands of miles away. We'll see how this hands-on activity parallels the work of NASA's own mission team.

NOTE:
This program falls within NSF's 1997 Science and Technology Week, the theme of which is "The Future of Communications"



For more on National Science and Technology Week, see:
http://www.nsf.gov/od/lpa/nstw/geninfo/start.htm

Observing Mars in the Night Sky

Teacher Background

The 1997 "Opposition Opportunity"

The distance between Earth and Mars varies significantly as the two planets orbit the sun. Every 780 days, Earth and Mars have what—in cosmic terms—counts as a "Close Encounter." At such times, both planets are in a straight line with the Sun, and Mars is at its closest to the Earth. Mars rises in the East as the Sun sets in the West and the two planets are said to be in "opposition." However, because Mars' orbit is quite elliptical, the distance between Earth and Mars at different oppositions isn't always the same. It can be as little as 35 million miles (56 million kilometers) or as great as 61 million miles (98 million kilometers).

In March 1997, the Earth and Mars will once again be in opposition. Mars will appear as a distinctive copper-colored, star-like object in the eastern evening sky that will be brighter than any of the stars around it. This will make it a relatively easy object for students to locate, identify, and track from week to week—while "their" spacecraft are en route to the very place they are observing from down here on Earth. At this time, Earth and Mars will be a little more than 68 million miles (109 million kilometers) apart, but surface markings should be clearly visible, even through moderate sized telescopes. These will include at least one polar cap, pinkish orange deserts and some of the other features which flashed upon the eyes of Schiaparelli and Lowell as they peered at the planet during the "Mars mania" of the late 19th Century. As Mars rotates on its axis, different portions of the planet will be seen from week to week, allowing students the opportunity to map the entire planet. And during the Spring semester here on Earth, seasonal changes can also be looked for on Mars, where it will be summer in the Northern hemisphere and winter in the Southern hemisphere.

From early February through late April, Mars will also go through a very nice retrograde loop (see p. 31)—making a loop-the-loop in the sky against the constellations of Leo and Virgo.

Objectives

- Students will compare and contrast the orbits of Earth and Mars (duration, eccentricity, comparative distances from each other and the Sun), locate the planet Mars in the night sky, and observe and diagram its retrograde motion.
- Students will physically model the orbits of Earth and Mars and derive its characteristic retrograde motion from analyzing their observations.

Materials

- 3 large circular signs, labeled (and appropriately-colored) *Earth*, *Sun*, *Mars*
- Star Chart A (one per student)
- teacher-made transparency of Star Chart A
- Star Chart B (one per student)
- teacher-made transparency of Star Chart B
- Diagram 1 (Earth and Mars orbit) (one per student)
- teacher-made transparency of Diagram 1
- chalk or a spray can of "fake snow"
- a yard stick
- pencil
- a piece of red cellophane about three inches in diameter

Participate in "MarsWatch '97"

Still more exciting is the opportunity for students to use this opposition as a chance to work with local amateur astronomers, or university researchers, as part of NASA's "MarsWatch 97" (see sidebar on p. 29.) Bring an astronomer to your classroom, or take your class out to observe the Red Planet at night, using a larger telescope and more advanced techniques than suggested here. On-line you'll find the latest information about how to connect classroom and the often-enthusiastic amateur star-gazing community.

VOCABULARY

constellation
diameter
ellipse
opposition
orbit
simulation
retrograde

"MarsWatch '97" On-line

For full information and updates on the activity, see the *LFM* Web Site (linked in via Featured Events and Teacher Resources)

Part 1 Modeling Martian Motion

Engage

Ask students to describe differences between stars and planets. Record their answers, and return to them later. Tell students that they are going to *become* stars and planets, and simulate the relative motions of Mars and Earth about the Sun!

Demonstration: Take students to a large open area (a field, school playground, or empty gymnasium). Choose one student (holding large sign) to be the Sun. Using the chalk or spray "fake snow" mark a circle about 20 feet in diameter to represent the orbit of the Earth around the Sun. Next, mark a "twin" (actually an ellipse) about 30 feet in diameter to represent the orbit of Mars. (To accentuate the elliptical orbit of Mars, make sure that the line marking Mars' orbit is at one point approximately twice as *distant* to the line marking Earth's orbit as on the opposite side.)

Choose one student to be the Earth (holding appropriate sign) and another to be Mars (with sign.) Have all the other students form as large an extended group as possible around the sun but well beyond Mars' orbit. Explain that these students represent the distant "fixed stars". Now, have the students who represent Earth and Mars begin to orbit the Sun, one step at a time. Since Earth travels faster around the Sun than Mars, have the student that represents Earth take a large step each time while the student who represents Mars takes a smaller step.

Each time the Earth and Mars take a step, have them stop and ask the student who's representing Earth to call out the name of the student in the outer or "fixed star" circle who can be seen (from the position of Earth) to be closest to Mars. Have all students closely observe what's going on, and record raw data and patterns about the relative motions of Earth and Mars. Back in class, have students debrief, and help them conceptualize their experience as a simulation of how Mars appears to move among the fixed stars as seen from Earth as the two planets orbit the sun.

Explore/Explain

Procedure

1. Distribute copies of Diagram 1 showing the orbits of Earth and Mars to students.

2. Allow time for students to examine diagram. Then ask them to work in small groups to brainstorm and list facts that can be gleaned from the diagram. List facts on chalkboard and discuss.

- *The Earth travels on a closer orbit to the Sun than Mars.*
- *The Earth travels in its orbit faster (completing one orbit in 365 days while Mars takes about 687 Earth days to do the same).*

3. Explain that stars are much farther away from Earth than Mars and the other planets of our solar system, and challenge students to describe Mars' changing position in Earth's skies as the two planets orbit the sun.

4. Ask students to compare and contrast the diagram on their desk with the physical demonstration they completed outside.

The MarsWatch Project 1996–97

This excerpt from the MarsWatch Web Site gives background and rationale for why NASA wants participation from amateur astronomers and others around the world.

To: Friends of Mars
From: Jim Bell
Re: Mars observing campaign, 1996-97

Dear colleague,

I am writing this brief note to solicit potential participation by you or your club or institution in a global network of observations of Mars during the 1996-97 apparition. I think that this is the perfect type of project for small-to moderate-sized telescopes that can obtain good planetary image quality. This project would be very appropriate as a graduate or undergraduate class project, as a "service observing" program carried out by observatory staff, or even as a project organized by skilled amateurs or local astronomy club members. It could also serve as an excellent and timely part of the public outreach and education activity at your institution.

The upcoming apparition (9/96 to 9/97) is particularly important because THREE spacecraft will be traveling to Mars beginning late this year. A U.S. Orbiter (Mars Global Surveyor*), a U.S. Lander (Mars* Pathfinder*), and a Russian Orbiter (Mars-96). The* Pathfinder *lander project is particularly interested in groundbased observations of Mars for two reasons: first, their atmospheric entry profile depends on the atmospheric temperature, which is a critical function of dust and cloud opacity; and second, the lander itself is solar powered, so a substantial amount of dust in the Martian atmosphere will degrade their available power and will affect the lifetime of the mission. Thus, information on the behavior of dust in the Martian atmosphere as a function of time during 1996-97 (such as can be obtained from good multi-color imaging) will be extremely important in the planning and execution of this mission.*

The project will maintain a WWW home page and archive site at JPL in association with the Mars Pathfinder *mission. The goal will be to have participants submit one or more of their images (or entire data sets if they like) to this site for dissemination to NASA Project personnel, professional astronomers, amateur astronomers, news and print media, educators and schoolchildren, and the general public.*

The 1996-1997 MarsWatch Home Page can be found at the URL

http://mpfwww.jpl.nasa.gov/mpf/marswatch.html

Mars: Off the Charts—until YOU put it there!

Engage

With appropriate warnings about night-time precautions, and an invitation to work with parents or other caregivers, invite students to observe the night sky (viewed toward the East) as a homework assignment. (Brainstorm and suggest strategies for determining East from their homes.) Have students share their illustrations; ask them if they were able to distinguish stars from planets.

Explore/Explain

1. Students will be challenged to find Mars in the night sky and carefully track its motion over the coming months.

To be most effective, students should start observing Mars in early January and continue to map its position until mid May. Once they find Mars, their observations will only take a few minutes each time and can be done once every one to two weeks. The exact nights of their observations are not very important so this activity should be easy to schedule. Cooperative learning strategies can link students and parent/caregivers to facilitate coverage during this time. The more "data points" gathered, the more "robust" the results.

2. Project transparency of Star Chart A onto screen and explain that this view of the stars in the Eastern sky will appear about 10 p.m. in mid-January. Point out the constellation Leo, along with its bright star Regulus. Point out that Leo's head and front quarters look just like a "backwards question mark" while his hind quarters and tail are marked by a triangle of stars.

3. Hand out copies of Star Chart A along with pieces of red cellophane. (The red cellophane is to be taped over the end of a flashlight. Red light will allow them to see their chart in the dark, but still allow their eyes to retain "night vision.") Their assignment over the next few nights is to go outside with their star chart and flashlights and find Leo in the sky, using the following procedure:

- Wait outside about 5–10 minutes before looking for Leo, allowing their eyes to adjust to the dark.
- After locating Leo, they should look for a bright point of light in this part of the sky that is **not** on their star chart. This should be Mars!
- Mark the position of Mars on their star chart as accurately as they can; date their observation. (Share success stories and frustrations in class.)

4. During the first class period after students have successfully located Mars in the night sky, project transparency of Star Chart A again and have students confirm their observations. (Mars will move very little from one night to the next.)

5. Pass out Star Chart B; ask students to compare Star Charts A and B (B is more detailed and shows a smaller part of the sky than A). Have students carefully mark the position of Mars on Chart B with a dot and, next to it, write a small number 1 and the date.

Mars, Models and Math

Mars comes closer to Earth than any planet except Venus. Thus, at times, Mars can become as bright or brighter than the brightest stars. Mercury, Venus, Mars, Jupiter and Saturn were all known to ancient watchers of the sky. While they looked just like stars, these five objects were regarded as special because, from week to week, month to month, they slowly moved against the background of the stars as if they had special powers. (Our word for these objects, *planets,* derives from an ancient Greek word meaning "wanderer.')

Why the planets appeared to move against the fixed stars remained a mystery to the ancients. To some, the planets were gods, shrouded in mystery, but to be worshipped. Others tried to create mental pictures, or models, of the universe that explained their movement. One popular notion (suggested by the Greek philosopher Aristotle, 384-322 B.C.) was that the Earth was in the center of the universe and that all objects in the heavens revolved around the Earth. Planets, along with the Sun and Moon were imagined to be carried along on crystal spheres, nested one inside the next, with the Earth at the center. A final sphere, containing the stars, encased all the rest. As the spheres turned at different speeds, the various celestial objects were seen moving across the sky.

Mars, however, as well as Jupiter and Saturn, posed a serious problem. From week to week, these planets would normally move eastward against the stars. But once in awhile, they would stop in their tracks, appear to reverse direction, and move westward for awhile. This was called backwards, or retrograde, motion. Then, they would stop again and resume their easterly trek.

Some ancient astronomers (including Ptolemy who lived in the second century A.D.), cleverly explained this odd planet behavior by suggesting that these planets were actually attached to little sub-spheres that, in turn, were attached to bigger spheres, the original "wheels-within-wheels" concept. As they rotated on these little spheres, revolving around Earth on their larger spheres, these planets would periodically undergo their retrograde motion. Though complex, this idea actually permitted accurate predictions of planetary motion. It was, however, completely wrong.

In 1543 a Polish astronomer, Nicholas Copernicus, showed that Ptolemy's complicated picture of the universe could be made simpler (and the little circles eliminated) if the Sun was in the center of the system rather than the Earth. Now the retrograde motion of Mars (and the other outer planets) could be seen as a consequence of the Earth periodically passing these planets by as it rounds the Sun at a faster speed.

Activity 2.1 allows your students to recapitulate thousands of years of history by observing the night sky, noting Mars' distinctive motion, and deriving the explanations first articulated by Copernicus and then elaborated by Johannes Kepler and Galileo Galilei. Mars fascinated all of them—now it's your students' turn.

6. Students should continue their own MarsWatch once every one to two weeks (you may want to suggest certain nights if the weather forecast calls for clear skies), each time marking Chart B with another dot and number and noting the date in the table. Each week you can have a group discussion and make a master chart with the planet's average position based on all the student observations.

As the weeks go on, discuss the changing position of Mars amid the stars with the students and ask them if—as a by-product of their sky-watching—they also notice any difference in the time that Leo appears in the Eastern sky. (Note: as the Earth continues to orbit the sun, Leo will rise a little earlier each night and thus appear to be higher and higher in the sky at the same Earth time from week to week. This also means that students can make their observations earlier and earlier as the weeks go on.)

Over time, the students will see that Mars moves among the stars in an apparently peculiar way—performing a loop-the-loop as shown in Diagram 1. As Mars is seen to reverse direction, move backwards among the stars and finally reverse direction again, discuss this strange heavenly doh-see-doh with your students. Explain that this strange behavior (technically known as "retrograde motion") really puzzled astronomers until the 16th century.

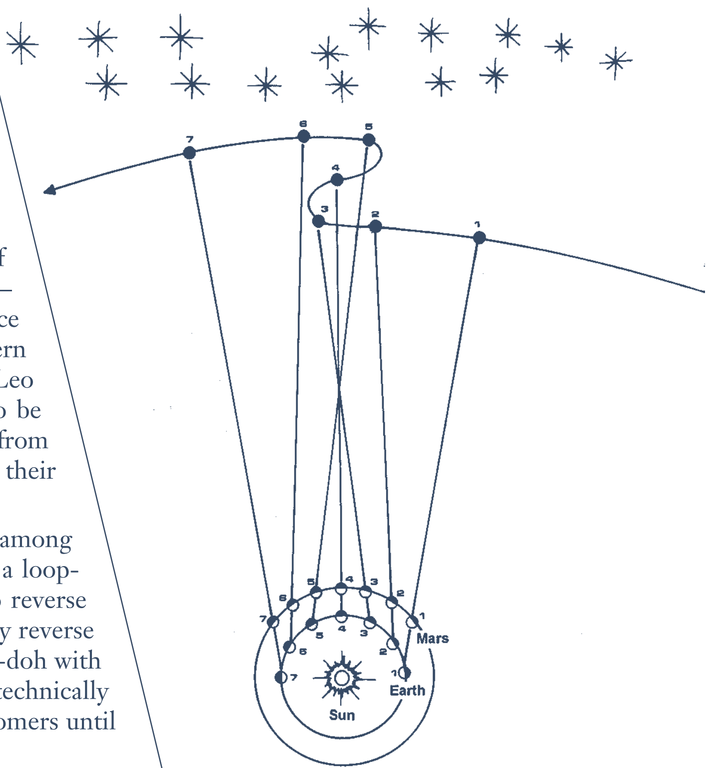


DIAGRAM 1

At the appropriate point in the semester, remind students of their earlier simulation of the Earth/Mars orbit in the school field or playground. Then pass out copies of Diagram 1 and explain that the marked positions of Earth and Mars show corresponding positions for the two planets on the dates given. Have students draw lines connecting corresponding images of Earth and Mars and extend these to the distant stars as shown in your teacher's copy of Diagram 1 in the Teacher Materials. Discuss with students how the apparent loop-the-loop motion of Mars is merely an illusion caused by the Earth passing Mars by as it orbits the sun. (By analogy, a car that you overtake on a highway may look like it's going backwards relative to you).

In addition to observing Mars with the unaided eye, see if you can help the students observe Mars in a telescope. If the school does not own a telescope, try contacting your local planetarium, college or amateur astronomy club. A class visit can be arranged or your local amateur astronomers may be persuaded to bring telescopes to the school.

Have students look at Mars through the telescope(s). Using their red-gelled flash-lights and several blank, three inch circles drawn on white paper, have them carefully sketch what they see and make note of any apparent color of the planet and any individual features they can see. In a follow-up class, compare the sketches and colors. Discuss similarities and differences between the students and the reasons for the differences. Post the best (or most amusing!) observations to the *Live From Mars* project and we'll place them on-line, as motivation to others, and documentation of your students participation in MarsWatch '97. (NASA JPL's plans call for major involvement from Europe and Japan as well as North America, so your students will be participants in a broad, international effort.) Draw students into a discussion of what can be seen of Mars through telescopes from Earth given variations in "seeing" conditions from place to place and day to day, the subjective nature of human eye-brain coordination, and the value of using electronic instruments on board spacecraft in Earth orbit (such as the Hubble Space Telescope) or, better yet, in orbit around Mars itself.

Activity 2.1—Part 2 *(continued)*

Expand/Adapt/Connect

Students with regular access to telescopes may wish to systematically make a Map of the entire surface of Mars as it appears during the late winter and spring of 1997. Because Mars rotates once every 24 hours and 37 minutes (which makes a "Martian day" or "sol"—for Sun), a map can be made by combining drawings completed every few nights for a period of about a month. Gaps due to prolonged inclement weather can be filled in the following month and, over several months, seasonal changes on Mars can be observed, such as the growth or shrinking of a polar cap or a change in the brightness of surface features. Note: Due to the tilt of Mars toward Earth at this time, students will be viewing the physical features of the Northern hemisphere. Maps of Mars showing polar caps and prominent light and dark features will be available on the *Live From Mars* Web Site so students can compare their drawings.

Using your students' observations, or downloading others from on-line, create a "flipbook" that lets you set Mars in motion. (This will be only as smooth as the underlying observations permit, but if you use a standard star chart for all students, you should get an interesting result. You and your students may even want to experiment with "reducing data", literally kicking some data points out of your series in order to arrive at a better animation.)

Go On-line via the *LFM* Web Site, and check out *Mars Today* and you'll find computer graphics showing Mars' relative position to Earth, a depiction of what face of Mars is facing Earth that day... even a weathercast! Advanced students might even want to capture some of these images, and if time, talent and disk-space permit, make their own time-lapse movies.

View *Cosmos*, Program 5, "Blues for a Red Planet", in which astronomer Carl Sagan reviews how "seeing" led many 19th Century astronomers to detect canals on Mars. *(This program also provides an overview of the Viking findings.)*

Have students investigate some of the lore than surrounds the planet Mars, including Percival Lowell's belief that Mars had canals and an advanced race of beings; H. G. Wells, *The War of the Worlds;* Orson Welles' radio broadcast of *War of the Worlds*; novels about Mars by Edgar Rice Burroughs. Have them write a short story about a fictional Mars from these more romantic ages. (A good, easy source for both literature and the 1934 radio broadcast is the *Visions of Mars* CD-ROM, produced by The Planetary Society: see MultiMedia Resources)

Ask students to make believe that they are a member of the first human crew to travel to Mars and ask them to write about their experiences. Suggest their writings take the form of a short story, a personal diary or log, a collection of illustrated poems or a combination of these.

Hold an art contest in which students create works related to Mars. Paintings, sculptures or other forms of expression may relate to Mars as fact or fiction.

Astronomy Clubs

Teachers who are not as comfortable with "eyes-on" astronomy activities *or* who live close to urban areas where outdoor astronomy activities are precluded by light pollution are encouraged to contact their local amateur astronomy club. (see the *LFM* On-line pages under Featured Events and Resources for more information.) Ask a volunteer astronomer, amateur or professional, to visit your classroom to teach your students about Mars' retrograde orbit. Your district may also have, or be able to borrow a Starlab (an inflatable plastic dome and mini-planetarium projector) to simulate night sky watching activities. (See also MultiMedia Resources for suggestions about CD-ROM and other software that can bring the night sky, digitally, to a desktop near you.)

Suggested URLs

http://marswatch.tn.cornell.edu/mars/html
http://www.skypub.com/

Reading the Shapes of Volcanoes on Earth and Mars

What Volcanoes tell us about a Planet

All volcanoes are the result of heat and/or energy interacting with the stuff of which the planet is made. There are volcanoes both on Earth and Mars, but there are many differences as well as similarities. On Earth, volcanoes are a window through the planet's crust to the forces which move continents and raise mountains (plate tectonics). On Mars, they are windows on the past, evidence of a time when the Red Planet was unlike the world we see today.

The Volcanoes of Earth

On Earth, volcanoes occur either close to the boundary between plates (cone), or over hot spots under the crust (shield). These two types are characterized by very different eruptions and distinctive features, including shape, size, and slope angle.

- Cone-shaped volcanoes (such as Mt. Shasta or Mt. Rainier in Washington State's Cascade Range, or Mt. Fuji in Japan, one of Earth's most perfect cones) erupt close to the leading edge of a continental plate. The ash and rock particles spewed into the air by explosive eruptions form the cone which is characterized by a narrow base and steep sides which typically have slope angles of about 30 degrees.
- Shield or basaltic flow volcanoes result from successive flows of very fluid lava over hot spots under the planet's crust. These create gently sloping domes and typically have slope angles of less than 7 degrees. The Hawaiian Islands are the best example of these.

The angle of a volcano's slope is a clue to whether plate tectonics were involved in its formation.

The Volcanoes of Mars

The Tharsis Bulge, located in Mars' northern hemisphere, is a huge dome, rising 10 km above the average elevation, and extending 4000 km from North to South, and 3000 km from East to West. It was probably created more than one billion years ago by the enormous pressure of molten material pushing up on the thin Martian crust. This also caused the giant cracks in the crust which can be seen around the Tharsis Bulge, the most impressive being Valles Marineris, Mars' "Grand Canyon."

There are a number of extinct volcanoes sitting on top of the Tharsis Bulge. They are all shield volcanoes, the largest of which is Olympus Mons. It is the largest volcano in the solar system, 3 times higher than Mount Everest, 2.7 times higher than Mauna Kea (from ocean floor to summit)—all this on a planet about half the diameter of Earth. Its huge size indicates two very important facts. First, the Martian volcanoes must have been active for a very long time (at least hundreds of millions of years). Second, they kept growing bigger and bigger, evidence that the Martian crust did not move much during all that time, indicating an absence of plate tectonics. In contrast, the chain of a hundred Hawaiian Islands shows us that Earth's crust kept moving over a hot spot under the Pacific. Instead of a single large volcano, we find a succession of volcanic mountains in a curving line which traces the motion of the plates.

Martian volcanoes provide important geologic data, but they also offer evidence used in the formulation of hypotheses on the past climate and atmosphere of Mars, and the controversial subject of life. If Martian volcanoes were active for a very long time, a great deal of gas would have been released into the atmosphere. This is part of the evidence that leads scientists to infer that Mars, in the past, had a thicker, warmer atmosphere. Now its thin atmosphere and the planet's deep freeze mean that liquid water cannot exist on the surface. But once, during that time when volcanoes were active, the planet could have been warm enough for liquid water.

Objectives:

- Students will model the different processes which create cone and shield volcanoes.
- Students will identify the kind of volcanoes that exist on Mars (shield) and relate this to the presence or absence of plate tectonics.
- Students will be able to explain why Olympus Mons is the largest volcano in the solar system, and what its size allows us to infer about conditions on early Mars.
- Students will demonstrate the ability to compare and contrast the volcanoes of Earth and Mars.
- Students will measure and compare the slope angles of cone and shield volcanoes to differentiate between the two types.

Materials

For Each Team of Students	For Teacher Demonstration
▼ several cups of clean play sand, kitty litter and thick chocolate and butterscotch syrup ▼ several large paper plates ▼ a protractor ▼ a piece of string ▼ a metal bolt or other small object weighing at least several ounces ▼ cross-sections of Olympus Mons and large Martian volcanoes ▼ pictures of cone shaped volcanoes on Earth	▼ 3 small Pyrex test tubes (app. 18 x 150 mm) ▼ 3 cork stoppers: one with a small hole, one with a medium-large hole, one without a hole ▼ safety goggles ▼ a candle or burner ▼ an insulated test tube holder ▼ a small amount of water ▼ several Alka-Seltzer tablets ▼ world map ▼ graphic showing plate boundaries (from general science or Earth science textbook)

Engage

- Perform the following series of demonstrations in front of the class. (Wear safety goggles and point the test tube away from students. Glass could shatter when heated—please take necessary safety precautions.) Ask students to write a brief description of what they observe in each demonstration.
- First pour a small amount of water into a test tube and add a ground-up Alka-Seltzer tablet. Have students record their observations. *(The chemical interaction of water and tablet releases gases.)* Discuss what happened and challenge students to predict what would happen if the open end of the test tube were partially blocked.
- Place a small amount of water in a second test tube, again add a ground-up Alka-Seltzer tablet, but this time quickly place the stopper with the larger hole in the tube. Have students record their observations and discuss. Challenge them to predict what will happen if the vent hole in the test tube is even smaller. Clean the test tube and repeat using the stopper with the smaller hole.
- Have students predict what would happen if the end of the test tube were completely plugged and ask them to brainstorm and list the geological process being simulated in this demonstration.
- Explain that a planet's internal heat can be a very significant source of pressure. Complete the demonstration: place a small amount of water in a test tube, plug it with the cork without a hole, and heat the test tube over the burner. (Move the tube through the flame to minimize possibility of cracking.) As the water temperature increases to the boiling point, challenge students to explain what's happening inside the test tube, and what will eventually happen to the cork.
- After the cork flies off, discuss the results, and challenge students to relate this to explosive eruptions of volcanoes such as Mt. St. Helens or Mt. Vesuvius. Students should realize that the cones of such volcanoes build up when the erupted materials fall back to earth and gradually pile up around the vent hole.
- Ask students to name famous volcanoes and mark them on a map. Discuss where such volcanoes are located and why. Encourage students to note the clusters of volcanoes and brainstorm why they are not randomly distributed. This should lead to a discussion of plate tectonics, and the formation of cone volcanoes relatively close to plate boundaries.

VOCABULARY

angle
atmosphere
cone
dome
extinct
geology
plate tectonics
pahoehoe
pressure
shield
slope
topographical map
volcano

Explore/Explain

Explain that students are going to investigate volcanic processes by modeling the formation of two types of volcanoes and measuring the resulting slopes.

Procedure

1. Divide students into teams of "Planetary Geologists" and distribute a couple of large paper plates, protractor, string and a weight, and some sand, salt, dry rice and kitty litter to each team. Using a folded piece of stiff paper as a scoop, have students carefully drop sand from a height of 6 inches into the center of the paper plate (to simulate material forming a volcanic cone). Have students record what happens to the sand as they continue to pour.

Instruct students on how to connect their protractors, string and weights to measure angles. Have students measure the slope angle of the sand volcano they have just created. Record the results of each team on the board and have students calculate the average. Challenge students to predict what would happen to the slope angle of their volcanoes if they used more sand and made the pile higher. Have them do so and again record and average the results. Discuss.

Next, have students repeat their experiment using salt, rice and kitty litter. In each case, record and average the results and discuss. (Note: In all cases, the slope angles will probably average between 30 and 35 degrees and not be affected by the height of the cone or the materials used in the Activity.)

2. Show students pictures of cone-shaped volcanoes and have them measure the slope angles using their protractors. Record, average and discuss results.

3. Next, lead students in a discussion of shield or basaltic flow volcanoes and how they are formed. Stress that these volcanoes do not result from large quantities of material being shot high into the sky but instead gradually build up when "pahoehoe", a semi-fluid kind of lava, oozes out of the earth.

Using a clean paper plate, have students simulate this kind of volcanic formation by slowly pouring chocolate syrup into the middle of the plate. After a minute or two, have them measure the slope angle of this volcano. Record and average the results. Repeat with the butterscotch. (Students will note that the slope angles here are much gentler, typically only a few degrees.)

4. Show students pictures of volcanoes on Earth (e.g. the Big Island of Hawaii), but don't characterize them. Have students measure the slope angles. Record, average and discuss. Ask them what they conclude about these volcanoes.

5. Show students cross-sections of Olympus Mons. Again have them measure the slope angle. Record, average and discuss. Tell them these are characteristic of all volcanoes found on Mars and ask, as "Planetary Geologists," what they conclude about the nature of Martian volcanoes.

Based on this, challenge them to draw conclusions about the presence or absence of plate tectonics on Mars. Challenge them to suggest why Mars shows no evidence of plate tectonics.

6. Finally, distribute cross-sections of Olympus Mons and the Hawaiian Islands. Ask them to describe the difference in size. Challenge younger students to compare the difference in heights and base widths of these volcanoes. Challenge older students to estimate by calculation the difference in volume of these volcanoes. Challenge students to explain why the Martian volcanoes are much larger than those in the Hawaiian Island chain.

The Hawaiian Islands resulted from a crustal plate slowly moving over a hot spot and thus, over time, creating a succession or chain of volcanoes. Due to the absence of plate movements on Mars, hot spots remained for long periods of time under the same point in the crust and thus allowed the Martian shield volcanoes to build to a greater and greater size until Mars' interior cooled. Indeed, Olympus Mons is the largest extinct volcano in the solar system.

Expand/Adapt/Connect

Turn the discussion back to the theme of plate movements and relate the Martian volcanoes and their internal sources of heat to the formation of the Tharsis Bulge. Have students measure the total height difference between the top of Olympus Mons and the region of the *Pathfinder* landing site. Have students compare this to the difference in height between the top of Mauna Kea in Hawaii and Mt. Everest to the bottom of the Marianas Trench. Which is the "lumpier" planet and why?

Study of the canyons and valleys on Mars is an obvious extension here. Hands-on activities are available from JPL's Mars Exploration and Public Outreach Program, which is part of NASA's Mars Exploration Directorate.

For further information contact:

Dr. Cheick Diarra/NASA JPL
Mail Stop 180-401
4800 Oak Grove Drive
Pasadena, CA 91109

Create a 3-dimensional contour map of Tharsis Bulge.

Read about famous volcanic eruptions. Write a "You are There" article for a publication appropriate to the time in history.

Review angle measurement.

SUGGESTED URL

http://cass.jsc.nasa.gov/k12/exmars96.html

Activity 2.3

Robots from Junk

Teacher Background

The *Pathfinder* rover, *Sojourner*, was once called the "Microrover Flight Experiment." It was designed to test the design and performance of rovers, as well as to do some interesting science and imaging. It will be the first autonomous vehicle to explore the surface of another planet. (The former Soviet Union successfully operated robot rovers on the Moon, which is a satellite of Earth, not a planet.) *Sojourner* has a mobile mass of 11.5 kilograms. On its top is a flat solar panel 1/4 of a square meter in size which will provide 16 watt-hours of peak power. The rover also has a primary battery that will provide 150 watt-hours of power. The rover has a height of 280 millimeters with a ground clearance of 130 millimeters. It is 630 millimeters long and 480 millimeters wide. Its six wheels are on a rocker-bogie suspension system that permits the rover to crawl over small rocks. *Sojourner* will be able to climb a 30-degree slope in dry sand.

Robots and robotic rovers are fascinating to most students and provide enough material to consume many hours of class time! The Activity suggested here uses simple items and takes just a few class periods. For those who are bitten by the robot bug, however, there are activities that introduce students to sophisticated devices that more closely mimic robots used in space exploration and demonstrate other important scientific and engineering principles. (See "Red Rover, Red Rover," p. 56. The *LFM* Web Site also provides additional resources and contacts.)

This Activity will center around wind (balloon) and rubber band-powered rovers. They are simple, inexpensive and easy to make, but are not as practical for teaching about motion as rovers powered by electric motors. Small, battery-powered motors cost a few dollars and solar cells can be added to investigate rovers powered by solar energy.

Objectives

- Students will construct robots from simple materials and use them to investigate physical concepts including mass, center of mass, torque, and friction.
- Students will explain (infer) how problems they encounter in robot construction relates to the design of planetary rovers.
- Students will research, plan and construct a rover test-bed that simulates the martian environment and the challenge faced by the NASA engineers who built the Mars rover.

VOCABULARY

autonomous
center of mass
lander
robotics
rover

MPF Project Educator Meredith Olson reports students have had great success using round pizza trays and a crutch! Emphasizing the value of learning from experiment, she also had students use a toilet paper tube for a chassis, and push-up yogurt containers for wheels. She writes, "We want students to recognize that ingenious activity can be done everywhere. They do not need to wait to have spiffy equipment to be clever in the way they solve everyday problems... 'Right' answers come from making the materials perform better, not from doing it the way a teacher may say it should be." Push the engineering envelope and your students' imaginations!

Materials: For each Rover Development Team:

- eight 12-inch wooden or plastic dowels
- two 3-inch wooden or plastic dowels
- two 18-inch wooden or plastic dowels
- a couple of square feet of stiff cardboard
- 3-4 balloons
- rubber bands of different strengths and lengths
- several plastic drinking straws
- several bamboo skewers (from grocery store)
- a piece of flexible mesh gutter guard (for house gutters)
- 3/8 inch plastic tubing
- a pair of strong scissors
- several pieces of modeling clay the size of golf balls
- duct tape
- protractor
- large rectangular sponge
- large button with holes
- wooden dowel about 6 inches long

Materials: For the rover test bed (Mars landscape):

- several plywood boards or very stiff pieces of cardboard each at least 1 foot x 2 feet in size
- several pieces of coarse and fine grain sand paper
- several pieces of aluminum foil
- a couple of piles of books
- strong tape
- several rocks or other objects, each an inch or two high and several inches long (to serve as obstacles)

Any other materials students can find at school or home, suggested by them or thought of during an in-class brainstorming session.

Engage

Ask students to demonstrate how big they think the *Pathfinder* rover is. Then show them a box that is roughly the same size as the rover (height: 28 cm, length: 63 cm, and width: 48 cm; about the size of a laser printer, but much lighter). Explain that this is the size of the rover body without its wheels. Discuss.

Explore/Explain

In this Activity students are going to problem solve and simulate the work of a Rover Development Team, creating and testing their own mechanical robotic-rovers. (This Activity can be as open or closed ended as you wish. Some educators may prefer to allow free-form experimentation, relying on student trial and error to arrive at final designs. Consistent with the other Activities in this and previous *PTK* Guides, the following offers step-by-step instructions and hints. These can be passed on to the students from the beginning or used to offer guidance only when they run into difficulty.)

Procedure

1. Distribute the 12 dowels or plastic rods, a piece of stiff cardboard that is 3 x 18 inches, some duct tape, and several pieces of clay each about the size of a golf ball. (Note: commercially available plastic building set materials may also be used if they are sturdy.) Instruct each team to use the dowels/rods, the cardboard and the tape to construct as sturdy a structure as possible. Have them discuss, construct, non-destructively test, and share designs with the class. List key design elements of the most sturdy constructions. Caution students to try to use equal amounts of tape at each of the joints.
2. When they are finished, explain that this structure may be thought of as the framework for an experimental robot rover (Fig. 1). Ultimately, wheels will need to be placed on the frame so it can move, but first they need to experiment with the structure of the frame and develop ideas about where instruments might be placed within. Tell them that in doing this, they must keep in mind the center of mass of the system because that will affect whether the rover might tip over when encountering a large rock.

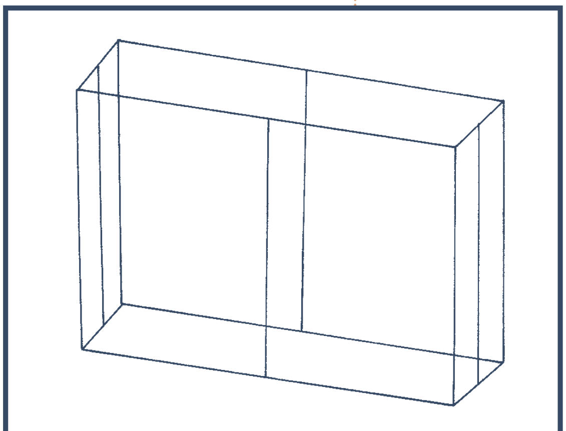


Figure 1

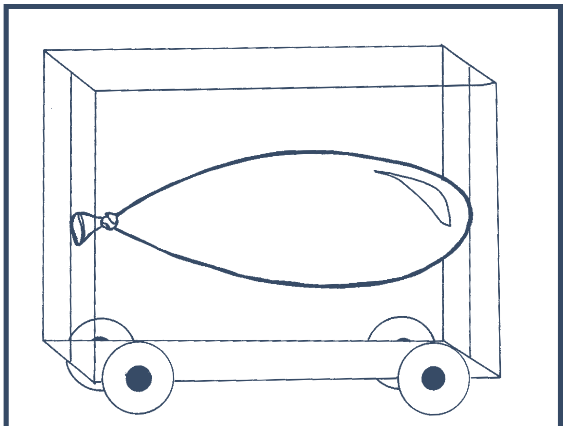


Figure 2

Center of Mass (C.M.) demonstration:

- Explain that all objects have a center of mass—a point at which the object balances. Hold up a meter stick and ask students where you would have to put your finger to balance it. Demonstrate that their likely guess at the 50 cm mark was correct. Next, tape a coin on one end of the stick and repeat the question. Repeat with two coins taped to one end, each time demonstrating the new center of mass. Next move to a 3-dimensional object, like a ball. Hold it in different ways. Lead students to the correct notion that the C.M. is in the center of the sphere.
- Produce a second ball inside which you have inserted a fairly large piece of modeling clay which is securely attached to interior side of the ball. Ask students where the center of mass is. (They will likely answer in the center). Hang this ball by a piece of string from various points. Ask students to infer what is happening. Help them to determine the C.M. of the second ball, and to realize that an object's C.M. is determined by how mass is distributed within that object. Discuss why this concept of center of mass is important to rover design.

3. Explain that the pieces of clay represent instruments to be put in the rover. Have students experiment with attaching a piece of clay near the top of one of the long sides of the frame. Have them determine the new center of mass. Next, have them slowly and carefully begin to tip the frame over so that the clay hangs over the edge of the structure.

4. Using their protractors, have students determine at what angle the structure becomes unstable, i.e., tips over. Record the results. Next have students do the same by placing the same piece of clay near the top of the short side of the frame. Repeat the center of mass determination and the tipping experiment and record the results. Discuss the difference. Challenge students to draw conclusions.

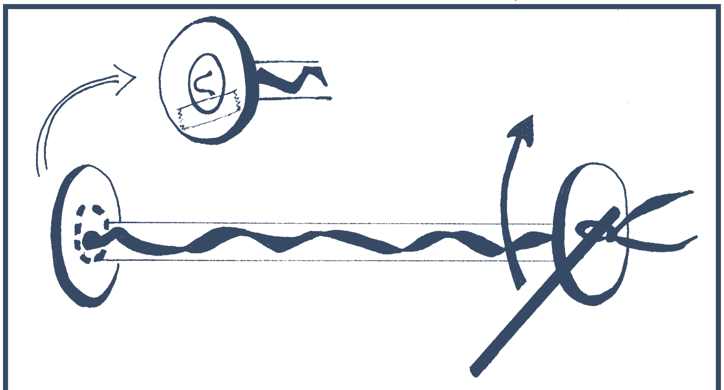


Figure 3

5. Students should repeat the above experiments, this time placing the piece of clay near the bottom of the sides but before they do, challenge them to make hypotheses as to what effect this will have on the center of mass and tip-over angles. Record the results, discuss and re-examine their hypotheses. Discuss. Next, have them place the clay in the center of the bottom of the frame, i.e., in the middle of the piece of cardboard. Again make measurements and discuss. Ask students to conclude where they would place the heaviest instruments within the frame to maximize the stability of the robot when climbing over rocks or other rough terrain. Challenge them to redesign the shape of the frame to increase the overall stability of the rover. (Older students could calculate the volume of the frame and design a new, more stable frame in a different shape but with the same total volume).

6. Discuss wheels. Ask students to draw conclusions as to the best size wheels to use on the original frame and/or their redesigned frame. What advantage do large wheels have? Is there a limit to the size of wheels that can be used for a particular sized frame? Why? If a total of 4 wheels on two axles are to be used, where is the best place to put the axles. Are two axles the best? Why, or why not? Should they be close together or far apart? Should they be right at the front and way in the back? Does the answer depend on the weight distribution of the instruments? Remind them how their decisions will likely affect the C.M. and overall stability of the rover.

7. Distribute more cardboard, scissors, dowels and straws to each team and have them cut out and add the wheels and axles to their frames. Once complete, have them experiment again with the C.M. and determine the tip over angles of their wheeled rovers. What effect did the wheels and axles have on the C.M.? Did they help or hurt the overall stability? Have each team determine how big a rock their rovers can negotiate, under two different conditions: (1) if the rock passes directly under the rover and, (2) if the rock passes under one or more wheels.

Powering the Rovers

Balloon Power:

Procedure

Challenge students in a class discussion or as part of individual design projects to come up with realistic ways of propelling their rovers over rough terrain. Blow up a balloon and let it go, or remind students of their Activity using balloon rockets. Give each team a long balloon and challenge them to figure out a propulsion system that can be attached to their frames (Fig. 3, p. 37).

Ask them to think about where the force of the balloon will be directed and challenge them to apply this knowledge to where, relative to the C.M. of the frame, they should place their balloon for maximum stability. When complete, have each team propel their rovers across the classroom. How could the system be improved? Redesign and test if necessary.

Rubber Band Power:

Give each team a button, a large, strong rubber band and a dowel about as long as the diameter of one of their rover's wheels. Have them disassemble the rear wheels and axle and attach the rubber band as shown in Fig. 3, p. 38 (or challenge them to figure out how to use these materials to power their rovers).

Have students wind up their rubber bands using the dowel attached to one of the wheels and, placing the rover on the floor, have each team test theirs in turn. Redesign, if necessary, for improvements. Note that the tighter the rubber band is wound, the more powerfully and faster energy is transferred to the rear wheels. Is there such a thing as having too much power transferred too quickly? What happens if this occurs? Challenge students to consider and investigate the effects of using different sized wheels, the materials and design of the wheels themselves (see the image of *Sojourner* on the *LFM* poster, and on the accompanying NASA publication) and the nature of the surface on which the rover moves. Make changes if possible including covering the rims of the wheels with coarse rubber or thin strips from a rectangular sponge. This can lead to an important discussion of friction and even torque among older students.

8. After appropriate rover redesigns, clear an area in the hall, gym or play ground and have an "Ares Vallis 500". Award prizes for the teams whose rovers went the farthest and/or the fastest. Discuss with the class the differences in design which led to the winners. Ask them if speed is necessarily a good thing for a planetary rover, especially if it's maneuvering in unknown terrain.

9. Next, have the class design a course for the rovers to navigate. Use appropriate pieces of stiff cardboard, books, tape, different kinds of sand paper, loose sand and rocks. An example is shown below.

Have each team run their rover over the course one at a time. Note which rovers succeeded, which failed, and why. Challenge each team to make adjustments in their rovers (or make overall adjustments to the course if it seems too challenging for most) and run the trials again. Discuss all that was learned.

Expand/Adapt/Connect

Challenge students to take what they have learned from this Activity and use it to design a more advanced robot rover. Tell them that, in this hypothetical case, they might have a budget of a few hundred dollars. Ask them what such a rover could do that their simple rovers could not. Discuss this in light of the fact that a planetary rover is a long distance from Earth where two-way communication can take a long time and the terrain can be very unfamiliar.

Students may also want to investigate and build a Bogie rover with a separate hinged set of wheels. Such designs have advantages in planetary investigations because they add greater capability in helping rovers maneuver over rocks and other uneven terrain. Have them take such a rover by hand over their course, feeling the forces encountered as the rover confronts obstacles. Discuss advantages of the rocker bogie design over the fixed axle designs they built before.

Go on-line and research *Sojourner's* actual design in greater depth.

Discuss how their own rocker bogie design is similar or different.

When running the rover over their Mars terrains, students might want to add a time-delay handicap simulating the time involved in sending messages between Earth and Mars.

Schools might want to collaborate with other schools via e-mail and teleconferencing (CU-SeeMe), exchanging ideas and actually directing rovers at remote locations.

SUGGESTED URLS

http://rics.jpl.nasa.gov

http://www.c3.lanl/~jspeck/Shome.html

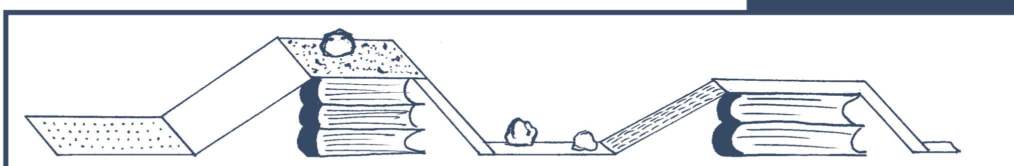


Figure 4

Live From Mars Program 3

Touchdown

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

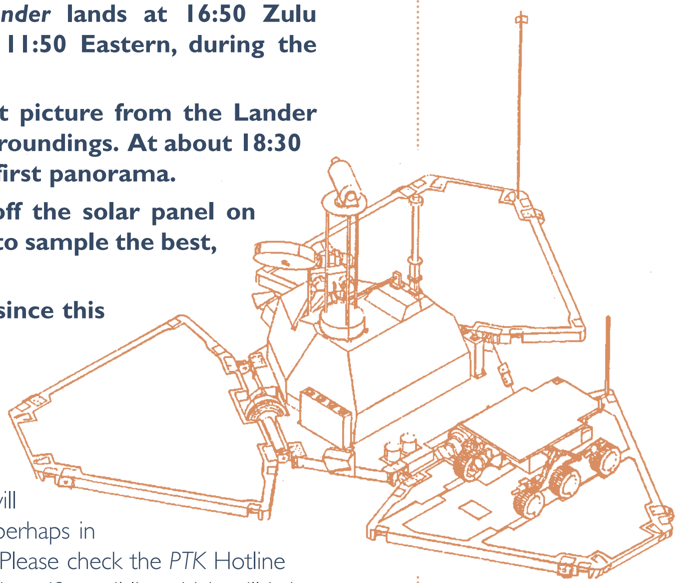
Live Sites: Mars, NASA JPL *Pathfinder* Mission Control, Science Centers and Planetariums

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.

Activity 3.1 *(continued)*

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

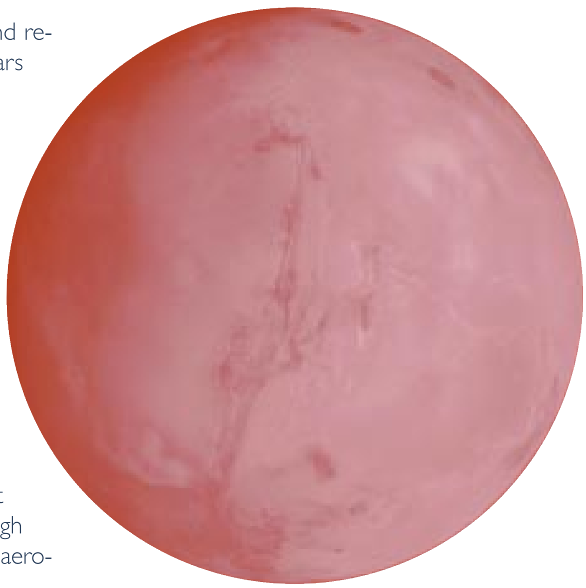
The PBS Teacher Resource Service does not schedule satellite time as far in advance as the publication date of this Guide: broadcast schedule information will be found on-line and via the *PTK* Hotline (1-800-626-LIVE). We anticipate carriage by participating PBS stations and NASA-TV: "Check Local Listings!"

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.

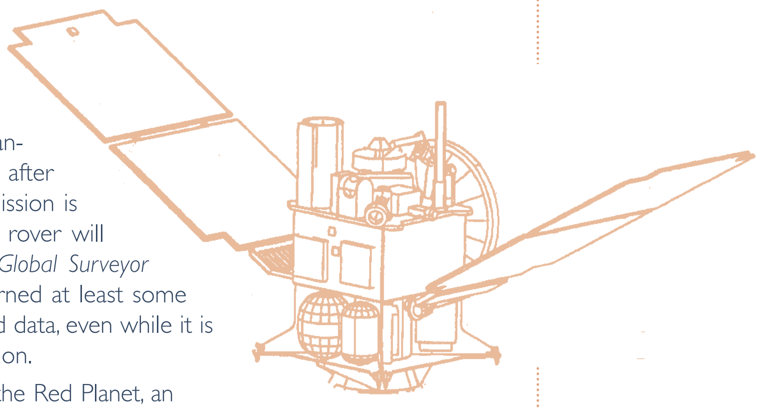
Since the content of the program is a compilation of the "best" of what's gone before, we suggest you choose from the Activities already proposed for Programs 1 through 3. On-line you will find teacher input selected from ***discuss-lfm,*** with comments about how best to implement these Activities in 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 1 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.)

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."

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

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.

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.

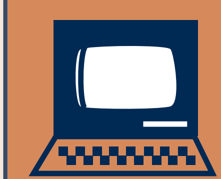
To join the ***updates-lfm*** mail-list, send an e-mail message to:
listmanager@quest.arc.nasa.gov

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: I-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

Bradbury, Ray. *The Martian Chronicles.* Garden City, NY: Doubleday and Company, 1958. ISBN 0-385-03862-3.

Bova, Ben. *Mars.* New York: Bantam Books, 1993. ISBN 0-553-56241-X.

Cattermole, Peter. *Mars, the Story of the Red Planet.* New York: Chapman and Hall, 1992. ISBN: 0-412-41140-3.

Clarke, Arthur C. *The Snows of Olympus: A Garden on Mars*—the illustrated story of man's colonization of Mars. New York: W.W. Norton & Company, 1995. ISBN 0-393-03911-0.

Multimedia

Blues for a Red Planet (Cosmos Series Episode 5) Videotape. Written and narrated by Carl Sagan. Turner Home Entertainment. Atlanta, GA

Duplessis, Claude. Meridian Version 3.9. Shareware software for IBM/Windows. AstroMicro, 1996. ($25.00; E-mail merid@cam.org or download demo at **http://www.cam.org/~merid/downlg.html)**

The Martian Chronicle: A Publication of the Mars Exploration Program at NASA JPL. Electronic newsletter. Edited by David Dubov. Pasadena, CA: NASA JPL. (Distributed via E-mail; contact Cathy Davis at: Catherine.L.Davis@jpl.nasa.gov or call: 1-818-354-6111. Available via the **World Wide Web at http://www.jpl.nasa.gov/mars)**

Our Solar System: Interactive CD-ROM Tour. Produced by Finley-Holiday Film Corp. Whittier, CA: Finley-Holiday Film Corp., 1995. ($24.95; Mac/IBM compatible. #CD-1 Call: 1-800-345-6707)

Viking 1 and 2 at Mars. Slides. Pasadena, CA: The Planetary Society. (40 slides with audio cassette; $13.95 non-members; $12.50 members)

Visions of Mars, The Planetary Society, 1994, (CD-ROM, IBM/Mac) Call: 1-800-969-Mars

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