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.

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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GEOFF HAINES-STILES

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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
GEOFFREY HAINES-STILES, PAT HADDON AND ERNA AKUGINOW

STUDENT ACTIVITIES CONTRIBUTED BY
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CAROL RICHMAN

ILLUSTRATIONS
SASHA HAINES-STILES AND
BRIAN SULLIVAN

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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*.

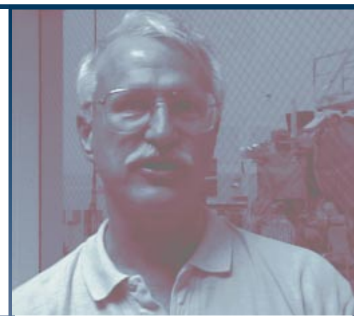
• Personal portraits of the researchers and their lives humanize the hard work of doing science and demystify high-tech careers

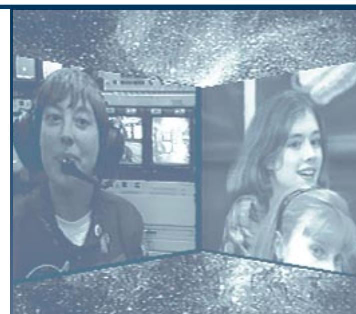
• Cutting-edge telecommunications connects students to remote and otherwise inaccessible locations

• 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.

Activity 1.1: Rocket Science 101

Program 1: "Countdown"

Researcher Q&A, Field Journals from Rocket Scientists, More on Delta Rockets

Thrust, payloads and Newton's Laws

See *Pathfinder* and *MGS* at Cape Canaveral

Visit Worcester, MA, home of rocket pioneer, Robert H. Goddard

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*

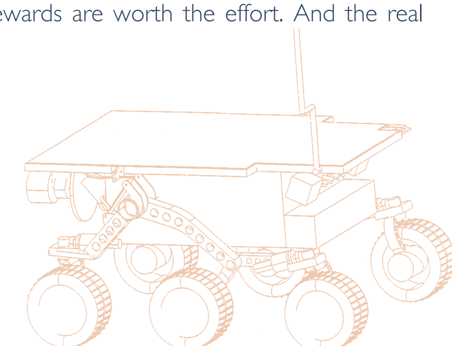
"Hands-On became minds-on. Great stuff for an inner-city school."
— 6th grade teacher, FL

"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 online 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*

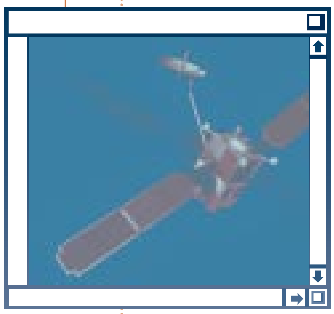
1 to enhance the global understanding of the geology and climate of Mars by characterizing the planet's surface and geological processes… monitoring global weather and the thermal structure of the atmosphere… monitoring surface features, polar caps, polar energy balance, atmospheric dust, and clouds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

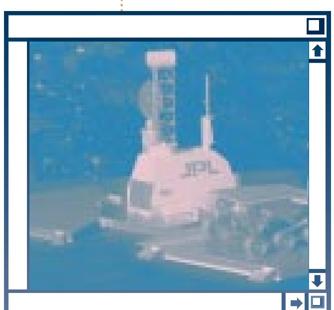


Mars *Pathfinder*

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 notebook folder	box crayons markers,	scissors tape

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

Activity A.3

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.

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

Expand/Adapt/Connect

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

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 Bipedal 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

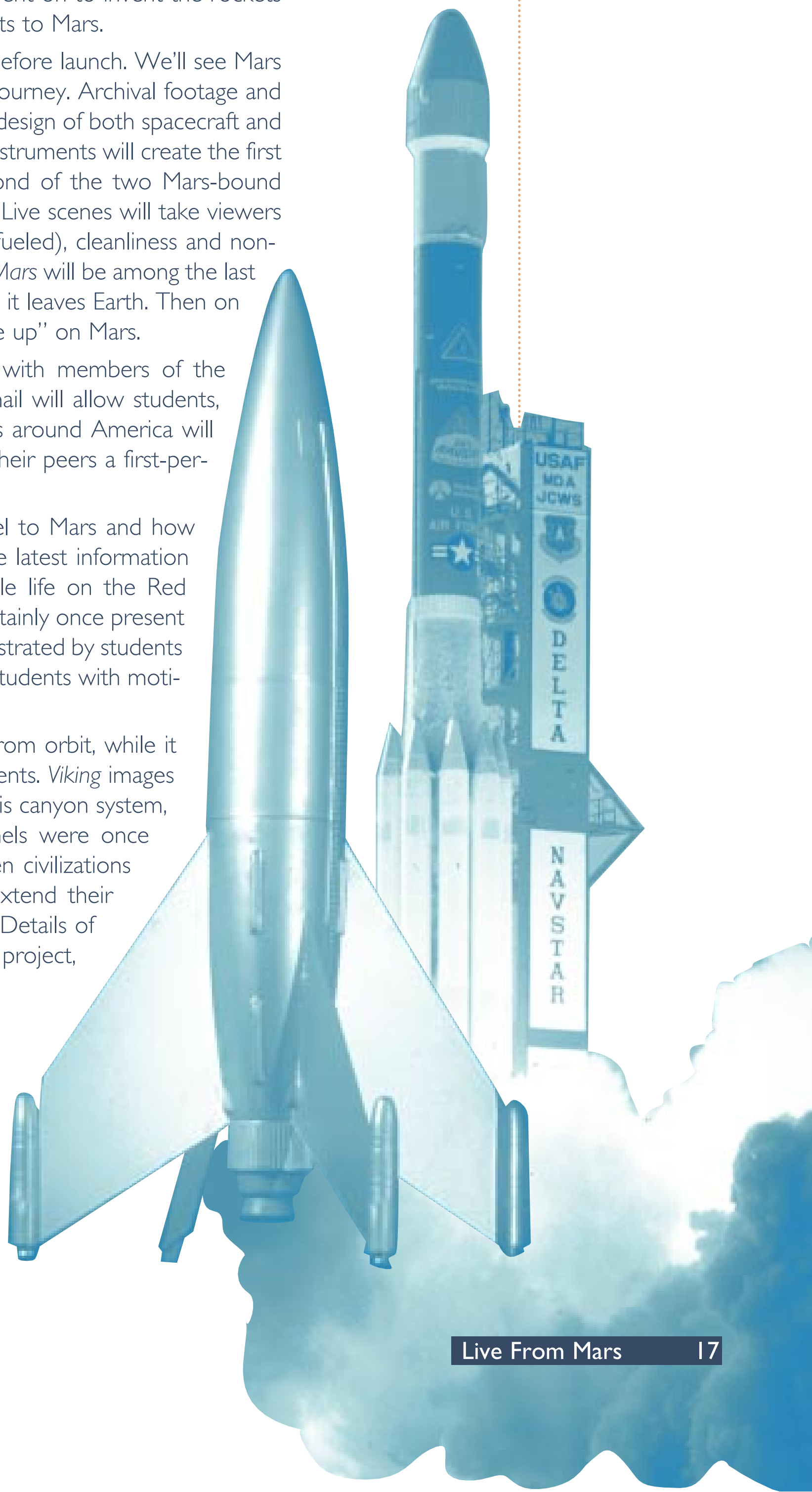
COUNTDOWN will take students, live, behind the scenes at Cape Canaveral, launch site for the entire American space program. It will also visit Worcester, Massachusetts, where in the last years of the 19th Century, the young Robert Goddard first dreamt of space flight, and then went on to invent the rockets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

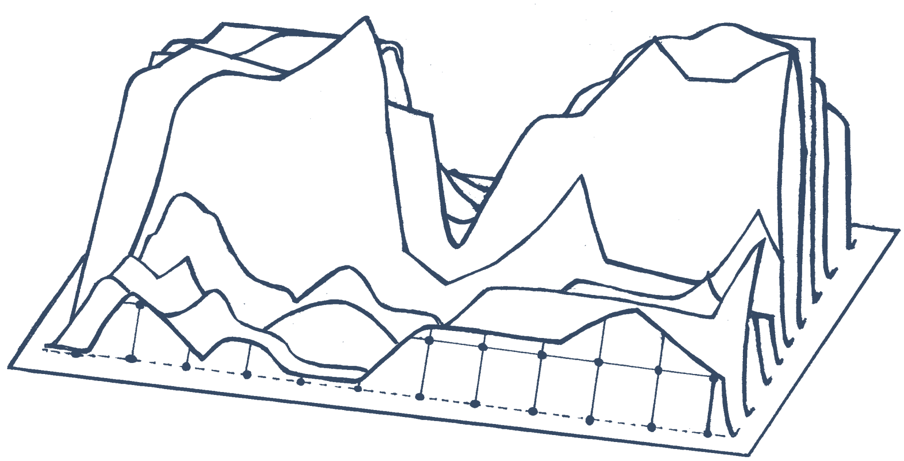
1. Working from the sections of contour maps you provide, each team should make a three-dimensional Mars landscape covering the bottom of the shoebox.
2. Tape or glue a piece of cm grid paper to box lid. Label horizontal and vertical axis 0, 1, 2, 3, etc.
3. Using a sharpened awl or leather punch, punch 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.

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.)

VOCABULARY

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

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

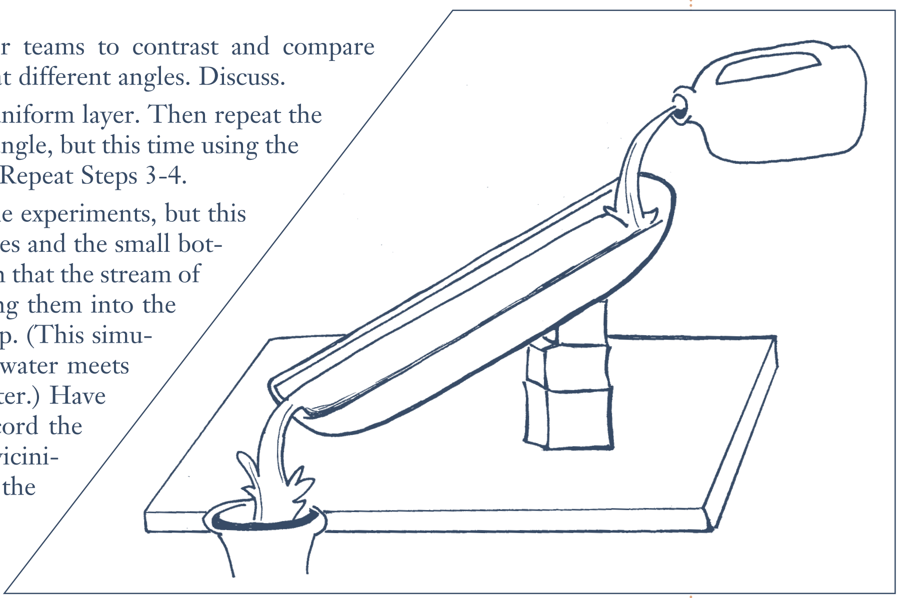
Please note: some details are provided on the Student Work Sheet and its diagram, which you should review along with this procedure.

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.

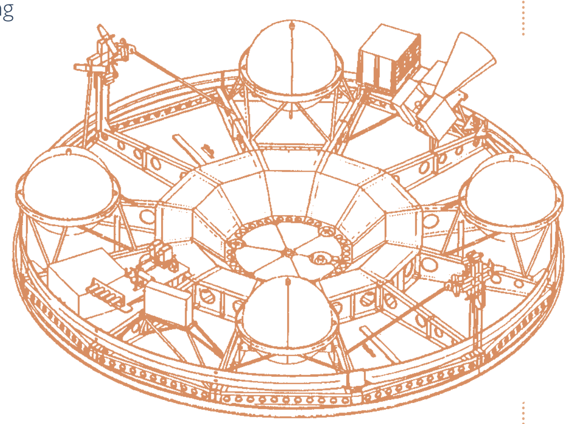
We'll report on MarsWatch '97, a national and international effort to monitor conditions on Mars with terrestrial telescopes. Dust storms and other climatic conditions affect the atmosphere through which both *Pathfinder* and *Surveyor* will have to travel in the final stages of their journey. NASA needs 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.

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

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



Activity 2.1

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.

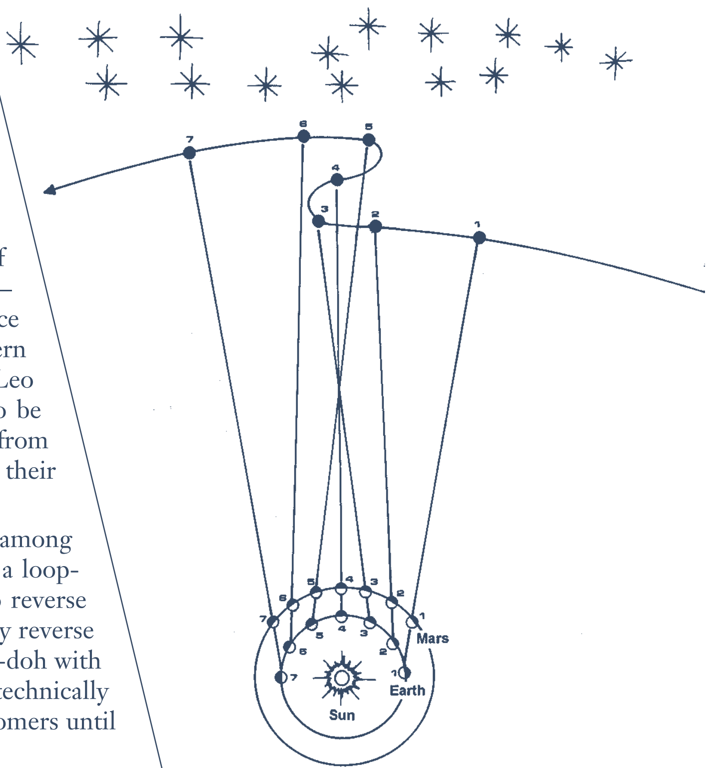


DIAGRAM 1

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.

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.

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.

Activity 2.2 *(continued)*

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.

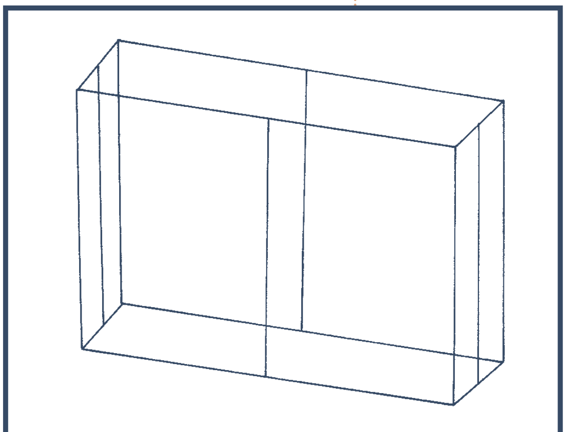


Figure 1

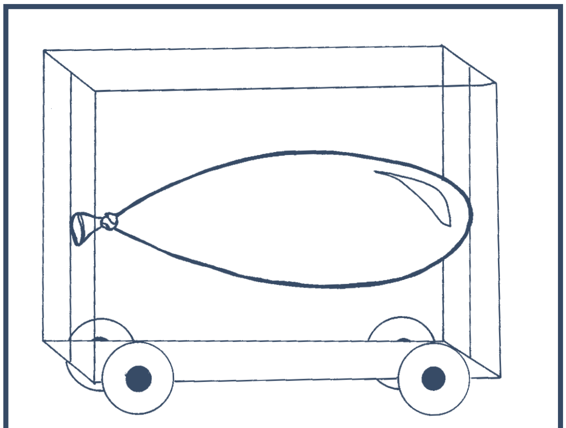


Figure 2

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.

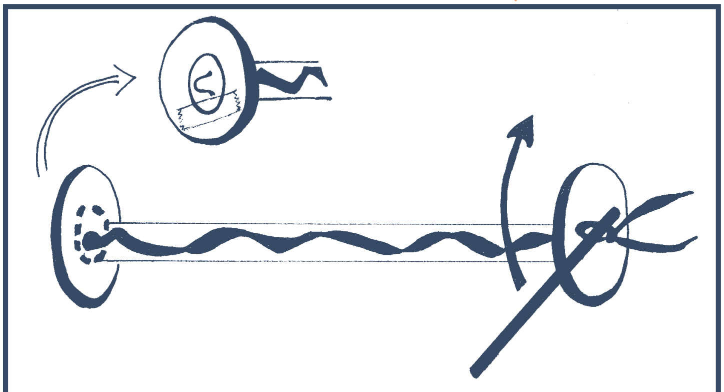


Figure 3

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.

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.

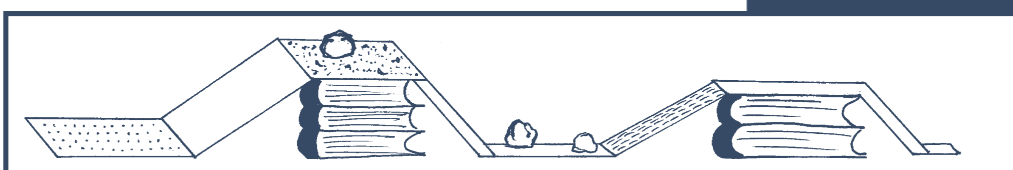


Figure 4

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