Activity 5: What Questions Has This Module Raised?

Purpose
To help students develop an on-going connection to the Mars missions.

Overview
Students reflect on their experiences, generate questions based on their module experiences, and pinpoint specific information they would like to obtain. They then read about the instruments on Mars Global Surveyor and relate the information these instruments will provide to their questions. Finally, students create a calendar for the missions and consider how they will access the information returned by the probes.

Content Goals
- Each Mars mission has specific objectives and the instruments it needs to achieve them.
- Space missions arise out of questions people ask about Mars, and students can generate questions worthy of future study.
- Every mission has a specific timetable, and students can follow the progress of each mission in a number of ways.

Skill Goals
- *Identifying* questions that really interest students.
- *Devising* a plan for answering those questions.

Possible Misconceptions
- Three-meter resolution is not very good.
  Ask: How far away can you discern a three-meter object? How does this compare to the MGS orbit 400 km (250 mi) above the surface of Mars?
- Robotic space exploration is inferior to manned space travel.
  Ask: What would have to change to have people collect this information?
- Space missions are sent up all the time.
  Ask: How often are space missions launched? What prevents NASA from launching as many missions as it wants? How long can scientists find interesting information in a set of images? Do you think that people assume that there are frequent space missions because we see so many pictures from space these days?

Materials
Calendar of the missions, length of paper to make a timeline.

Preparation
Obtain a computer with Web access to visit some of the mission-related sites.

Time
1 class period

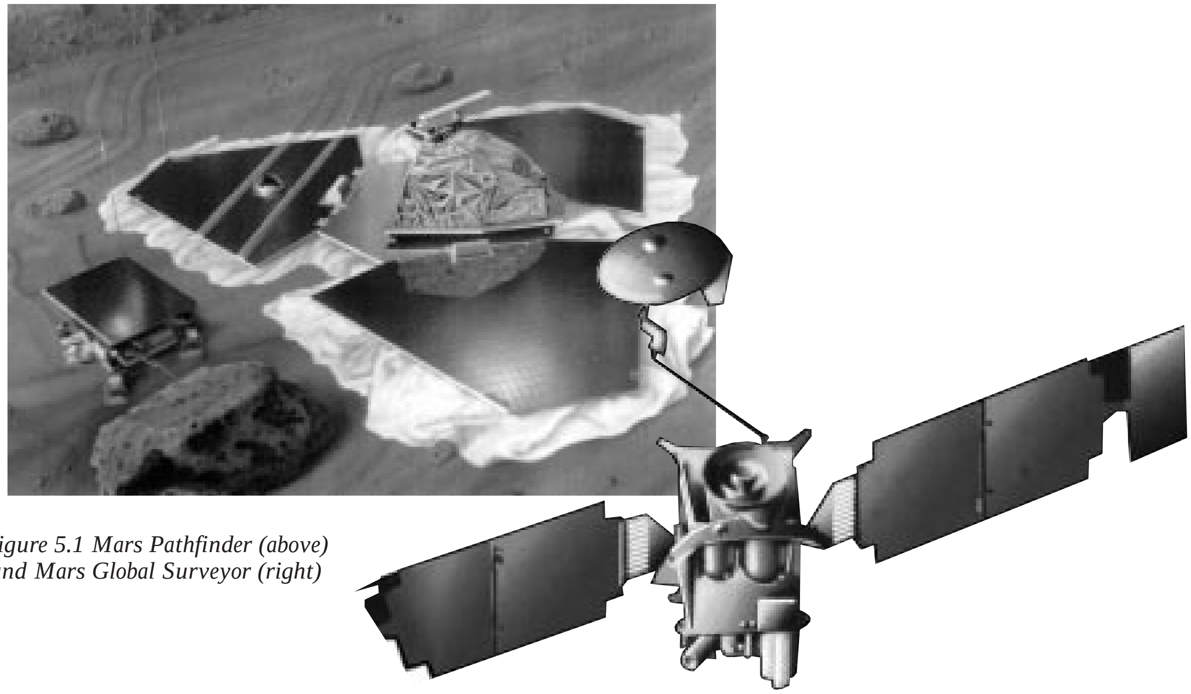


Figure 5.1 Mars Pathfinder (above) and Mars Global Surveyor (right)

At the end of 1996, NASA launched two missions to Mars, the *Pathfinder* and the *Mars Global Surveyor* (*MGS*) (Figure 5.1). *MGS* will study Mars from orbit 400 km (250 mi) above the surface. *MGS* has three cameras with resolutions as high as 3 m (10 ft). This compares to the highest resolution images from *Viking* of 20 m (65 ft). Other *MGS* instruments include:

- a magnetometer/electron reflectometer to study the planet's magnetic field;
- a radio system to study Mars' gravity field and subsurface mass distribution;
- a laser altimeter to study the planet's surface topography and its overall shape
- a thermal emission spectrometer to study the heat coming from the surface and atmosphere. With this information, scientists can create weather maps and identify the size and composition of surface materials.

After a seven-month, 300 million km (190 million mi) journey, *Mars Pathfinder* landed on Mars July 4, 1997. The mission was primarily an engineering experiment to test key technologies and concepts for possible use in future missions employing landers. The lander contained the radio to communicate with Earth, most of the science instruments, and a rover named *Sojourner* (Figure 5.2). *Sojourner* was used to deploy two imagers and an instrument that determined the composition of rocks and minerals. With its instruments, the *Pathfinder* mission was able to investigate:

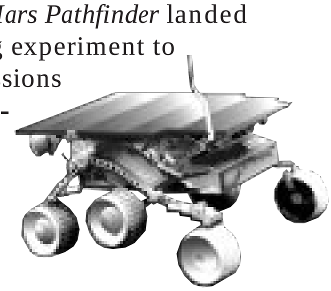


Figure 5.2 The Mars Pathfinder rover, Sojourner.

- the structure of the Martian atmosphere;
- the weather and meteorology on the surface (wind velocity, pressure, and temperature);
- the surface geology;
- the form, structure, and composition of Martian rocks and soil.

Pathfinder Makes Tracks on Mars

Below are examples of the images and information available at the *Pathfinder* Web site. The site is a fascinating window into the mission. It also can link you to other sites that show how questions and hypotheses unfold from data. In fact, students can investigate their own hypotheses, using the images and data to make a case for their ideas.

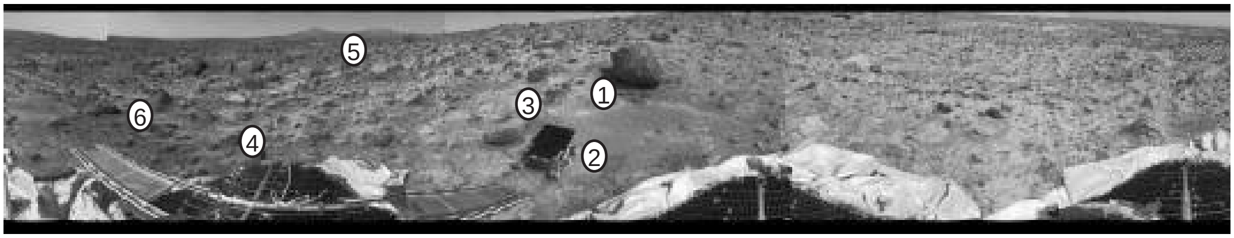


Figure A: A panoramic view of the Martian surface around the Pathfinder landing site. 1) Yogi 2) Sojourner 3) Barnacle Bill 4) Pathfinder's solar panels 5) Twin Peaks 6) Rocks tilted by floods

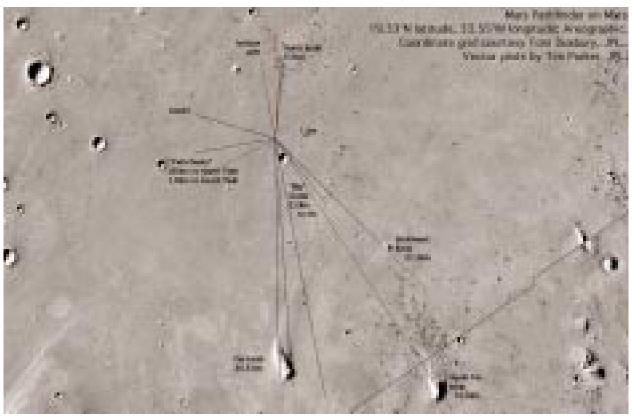


Figure B: NASA determined the location of the landing site by triangulating to known surface features.

After traveling more than 300 million kilometers (190 million miles), *Pathfinder* landed July 4, 1997, 21 years after *Viking I* first touched down on Mars. Cushioned by its 24 airbags, *Pathfinder* bounced 16 times to a near-perfect landing (Figure B).

Figure C: Twin Peaks (1 km away) seen over Sojourner, still mounted on Pathfinder's solar panel.

After opening the solar panels, the cameras took their first look around (Figure C) and several instruments sampled the weather. The sky was clear, the breeze slight, and the temperature -53 ^{o}C (-64 ^{o}F), slightly warmer than temperatures measured during the two *Viking* missions. By having students monitor atmospheric conditions such as wind speed, temperature, and dust levels, they can gain insights into the Martian atmosphere and circulation patterns.

Figure D: Sojourner approaches Barnacle Bill. Yogi is the large rock in the upper right.

Sojourner rolled off the ramp on the second day. It can range 500 m (1625 ft) from the lander before communication degrades. However, there is quite a diversity of rocks to examine within 500 meters! Some rocks are rounded, suggesting transport by water. Others are tabular and angular, indicating a non-aqueous deposition. Initial thinking by *Pathfinder* geologists is that the rounded rocks were deposited by large-scale floods and that the angular rocks were thrown from ancient, nearby impact craters. After examining the Martian soil at the end of the ramp, *Sojourner* examined "Barnacle Bill," a nearby rock (Figure D). Preliminary analysis suggested that Barnacle Bill was composed of andesite, a volcanic rock formed by melting and remelting.

Next, *Sojourner* analyzed "Yogi"(Figure E), a rock five meters (15 feet) from *Pathfinder*. Scientists found that Yogi was a completely different kind of rock than Barnacle Bill. Such a diversity of rock types in a small area suggests that floods swept rocks from areas upstream and deposited them in a jumble on the Chryse Planitia flood plain. The smooth, tilted stack of rocks (#6 in Figure A) lends additional support to the idea of floods. Students can gain insights into the formation of the Martian Surface and into processes that might have altered it by keeping track of the rock types, learning the conditions under which each rock type forms, and examining maps to see where on Mars such rocks might have originated.

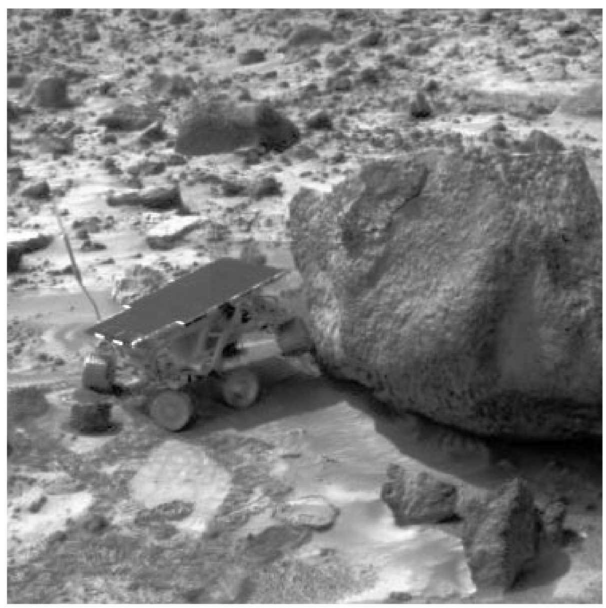
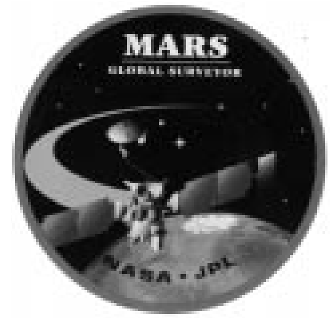


Figure E: Pathfinder approaches Yogi.

The images returned by *Pathfinder* are higher resolution than those returned by the *Viking* missions. In addition, the cameras are in stereo and have 24 filters, giving *Pathfinder* an unprecedented multispectral capability. There are 12 distinct filters for geology, 8 for atmospheric studies, and 2 close-up lenses. To access the images and data collected by *Pathfinder* and *Sojourner* and to learn about the science resulting from the mission, visit the *Pathfinder* Web site: http://mpfwww.arc.nasa.gov/default.html

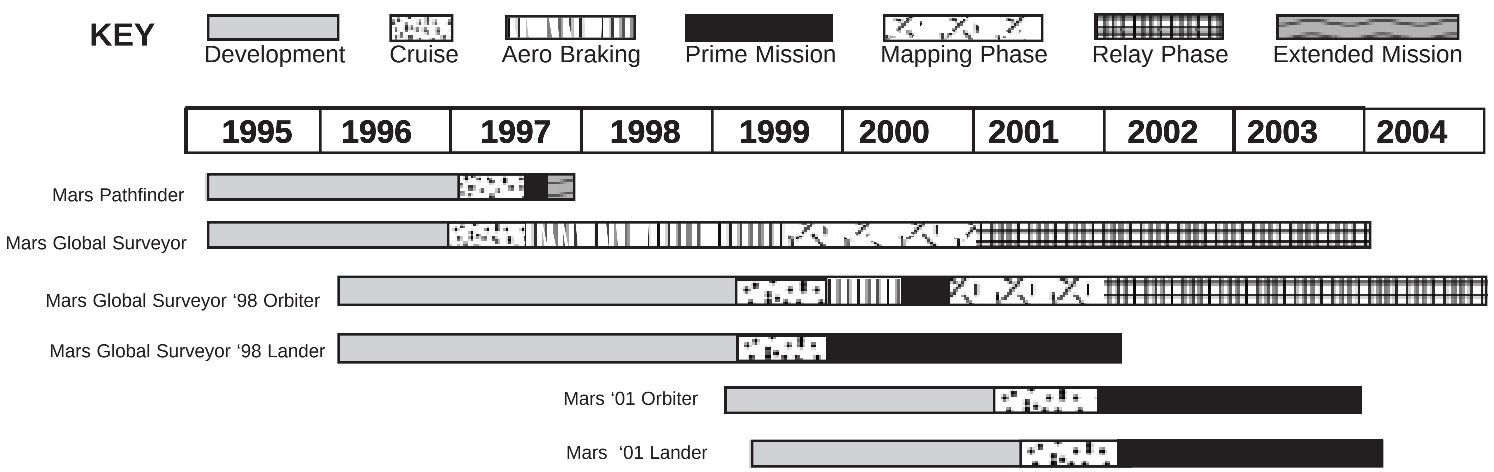
PROCEDURE

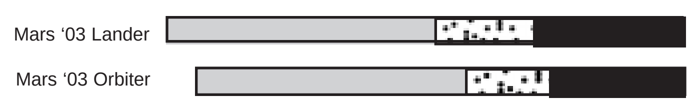


1. Have students reflect on their modeling, image analysis, and experimental work and generate a list of questions. What have they wondered about during the module? What struck them as particularly interesting? What additional information do they wish they had? Which features they would like to see in more detail? Why?

2. Have students read about the instruments on the *MGS* .

3. Review the missions and the instruments. Which instrument(s) can help answer questions about the Martian floods or craters? Which instruments might help answer some of their questions? What instruments would they like to see on a future mission? Could they imagine themselves designing or operating such an instrument?
   Planetary missions take years of preparation. Some of the scientists and engineers have been preparing for the Mars Global Surveyor for over ten years.





4. Show students the calendar for the missions. Ask them:
   - where they expect they might be at these times;
   - how might they access information from the instruments or about the mission.

   Newspapers, magazines, the Web, television, radio, friends.

5. Have each student devise a plan that outlines how he or she might obtain answers to his or her questions.

6. Put a timeline on the wall. Mark the events listed on the calendar to follow the progress of the missions.

7. Explain that NASA will regularly post new sets of images from its current missions on the World Wide Web. Your students will be able to use computers at school or at home to access these images. With these images, your students can build on the questions and excitement these images raise and extend their studies of Mars.

   To learn more about the Mars Exploration Program, explore the following Web pages:
   Mars Global Surveyor: http://mgs-www.jpl.nasa.gov/
   Mars Pathfinder: http://mpfwww.jpl.nasa.gov
   Jet Propulsion Laboratory http://www.jpl.nasa.gov/

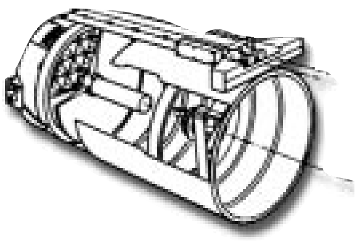
Instruments On Mars Global Surveyor and the Information They Will Provide

(Based on an article by Mike Malin, Principal Investigator on the MGS camera)

In November 1996, NASA launched the *Mars Global Surveyor* (*MGS*). After a ten-month cruise, the spacecraft began its orbit around Mars. For the first year, *MGS* gently dipped into the upper portions of the Martian atmosphere, using atmospheric-drag to slow itself down and shrink its orbit. In mid-March of 1999, it began its two-year mapping mission 400 km (250 miles) above the Martian surface. One of the reasons that the *MGS* mission excites scientists is that it will return a tremendous number of high resolution images as well as the elevation and surface composition data that will help them better understand what those images show. Also, if *MGS* functions as expected over its planned life, it will return over 700 gigabits of information, more than from ALL previous missions to Mars. It would take over 1,200 CD-ROMs to hold that much data!

"There's going to be more data from MGS than anyone can imagine."

Wayne Lee, MGS Mission Planner

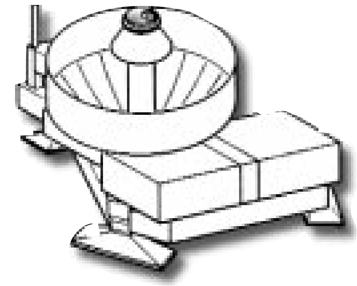


Mars Orbital Camera
to take wide angle and close-up pictures

MGS has two low-resolution cameras capable of recognizing features as small as 500 meters (about 1,600 ft) across and one narrow-angle camera able to see things as small as three meters (10 ft) across. The low resolution cameras will make daily maps of the entire planet enabling scientists to see surface features and dust and ice clouds. The narrow-angle camera, which can see boulders the size of cars, will also image the entire planet and be used to search for traces of beaches and glaciers, the effects of water seeping from canyon walls, and layers in polar deposits that reflect climate changes. It will also take pictures of the two *Viking* landers and the *Pathfinder* lander. These images will finally tie together the ground views these landers have sent us with M*GS*'s views from orbit. Compared to *MGS*, the *Viking* orbiters photographed only about 15% of Mars with a resolution of 100 meters (305 ft), and mapped only two tenths of one percent of the Martian surface in sufficient detail to show objects measuring 20 meters (65 ft) in diameter.

MGS's laser altimeter will tell scientists a great deal about the topography of Mars. Among other things, the altimeter will measure the:

- depths of craters
- heights of volcanoes
- steepness of the cliffs
- slopes of water-carved canyons

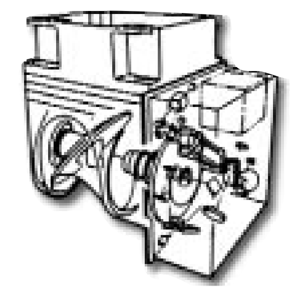


Laser Altimeter
to measure the heights of Mars' physical features

Scientists will also use *MGS*'s laser altimeter in conjunction with other instruments to help determine the size and shape of landforms, the global shape of Mars, and the thickness and strength of the crust.

MGS's Thermal Emission Spectrometer (TES) measures the amount of heat coming from the surface and atmosphere at many different wavelengths. TES will determine:

- the atmospheric temperature and pressure at several different altitudes;
- the concentration of dust both on the surface and throughout the atmosphere;
- the size of particles on the surface, from dust grains to bedrock, by comparing the temperature during the day with that observed at night (the same effect that causes beach sand to be very hot during the day and to be cool at night). The sizes of particles on the surface tell scientists how the particles were moved (e.g., by wind, water, or other processes);
- what the Martian rocks, sand, and dust are made of. TES will be able to discriminate volcanic rocks similar to those found in Hawaii (basaltic) from rocks and ash similar to those erupted by Mount Saint Helens (rhyolitic). TES may tell us if Mars has one or both. It will search for minerals left behind when lakes or other bodies of water dried up, and for minerals that formed when the atmosphere was potentially thicker and wetter than it is today.



Thermal Emission Spectrometer
to measure & map heat emitted by Mars