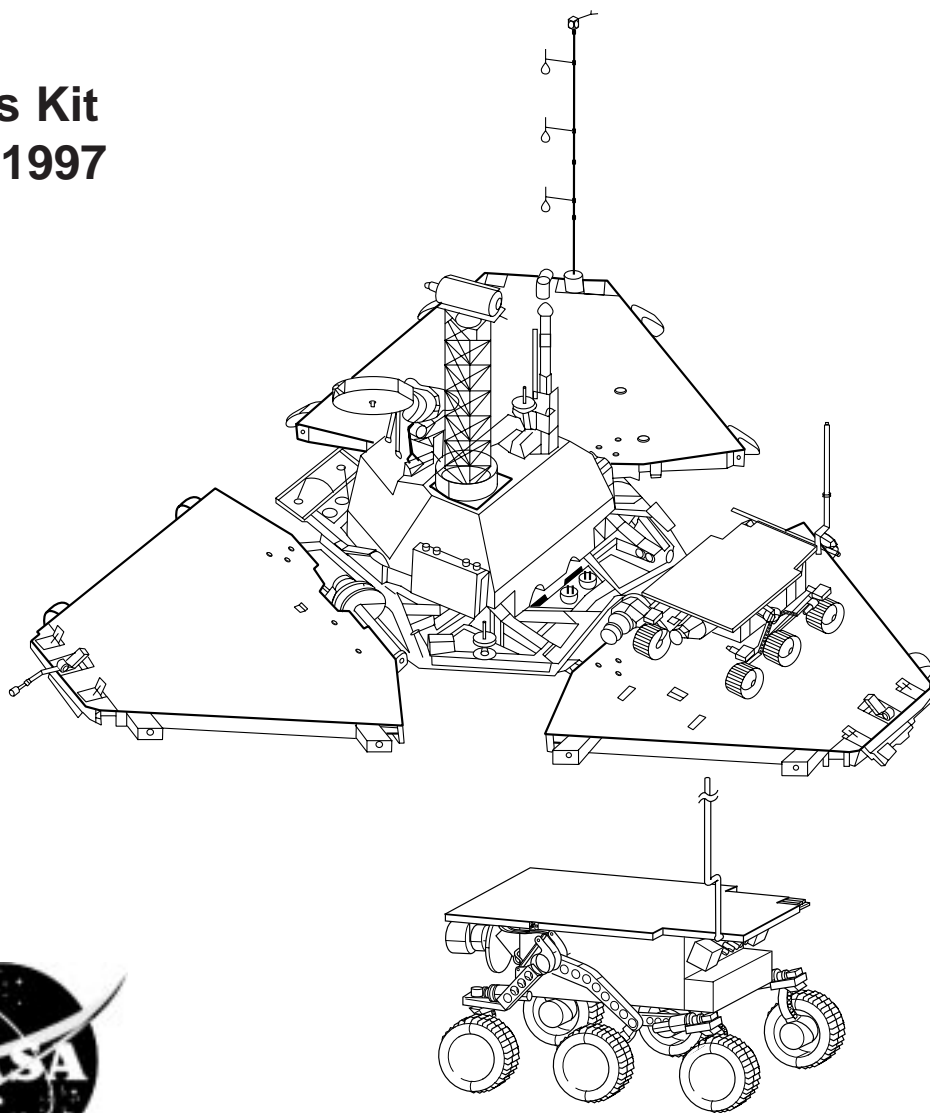


NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

# Mars Pathfinder Landing

Press Kit  
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**RELEASE: 96-207**

## **MARS PATHFINDER SET FOR INDEPENDENCE DAY LANDING**

NASA's Mars Pathfinder mission -- the first spacecraft to land on Mars in more than 20 years and the first ever to send a rover out to independently explore the Martian landscape -- is set for touchdown July 4, initiating a new era of scientific exploration that will lead eventually to human expeditions to the red planet.

Mars Pathfinder is one of the first of NASA's Discovery class of missions, designed to foster rapidly developed, low-cost spacecraft with highly focused science objectives. Pathfinder's purpose is to demonstrate an innovative way of placing an instrumented lander on the surface of the planet. The lander will also carry a free-ranging robotic rover as a technology experiment. Landers and rovers of the future will benefit from the heritage of this pioneering mission.

Pathfinder's atmospheric entry and landing on the Martian surface are the centerpiece of the mission. Once the spacecraft hits the upper atmosphere at 10 a.m. Pacific Daylight Time on July 4, it will begin a 4-1/2-minute, completely automated sequence of events to achieve its landing on the surface of the planet. After a fiery entry, the spacecraft releases a large, billowing parachute to slow its descent through the thin Martian atmosphere. Then a giant cocoon of airbags will inflate seconds before landing to cushion the spacecraft's impact. Along its descent to the ground, Pathfinder will be collecting engineering and atmospheric science data to help scientists profile the Martian environment.

"This is a new way of landing a spacecraft on a planet," said Brian Muirhead, Mars Pathfinder flight system manager at NASA's Jet Propulsion Laboratory, "and the first time a U.S. mission will use airbags to absorb the shock of landing and protect the lander from the rough, rocky terrain."

"The science investigations carried by Mars Pathfinder are going to give us unique insights into the planet's atmosphere and how it varies, and our first detailed understanding of the precise composition of its surface rocks and soils," said Joseph Boyce, Mars program scientist at NASA Headquarters, Washington, DC. "This knowledge is the key to helping unlock many interrelated mysteries about the history and evolution of Mars."

Diving directly into the thin atmosphere at about 26,460 kilometers per hour (16,600 miles per hour), Pathfinder will release its parachute, then jettison the heat shield that protected it from the heat of entry. A tether will be deployed to lower the spacecraft from its backshell; airbags will then inflate about eight seconds before landing. Deceleration rocket engines will fire to nearly halt the craft for an instant in mid-air just before impact.

Once the rockets have been fired, Pathfinder will free-fall up to 30 meters (100 feet) before hitting the ground at a speed of up to 90 kilometers per hour (55 miles per hour). At

impact, the spacecraft, now looking like a huge (5-meter-diameter (15-foot)) beach ball, will bounce many times, possibly as high as a 10-story building, until all impact energy dissipates. The interval between initial impact and complete halt may take as long as several minutes.

The site will be in darkness when Pathfinder lands at 3 a.m. local Mars time (shortly before 10 a.m. PDT; signal would be received on Earth at 10:07 a.m. PDT). After the spacecraft has come to a halt, its first task will be to deflate the airbags and open its petals. "The airbags might begin to deflate immediately after landing if they have been torn by the impact," said Robert Manning, Pathfinder flight system chief engineer at JPL. "If not, each of the bags has vents which will be opened to speed up the process of deflation."

As the Sun rises over the landing site at 12:45 p.m. PDT, Pathfinder will switch over from battery power to solar power. The lander will use its low-gain antenna to transmit critical data on the state of the spacecraft starting at about 2 p.m. PDT.

"By around 3 p.m. Pacific time, we'll have the critical data that we need to determine whether we have a basically healthy spacecraft in reasonably good condition, or whether we'll need to start thinking about contingency operations," Muirhead said. "Frankly, we will be very surprised if everything goes just right, since there are so many conditions that are unknown until we actually arrive at the landing site."

If no significant errors have been detected in the data and the spacecraft is healthy, a sequence will be sent to Pathfinder commanding it to unlock the imager camera head. The imager will first look for the Sun and, if found, the lander will use the location of the Sun to determine its orientation on the surface of Mars. The lander will then autonomously point the high-gain antenna toward Earth. Images of the spacecraft and the region around the rover petal will be taken and sent back to Earth through the high-gain antenna. If the camera, known as the Imager for Mars Pathfinder (IMP), does not successfully locate the Sun, then the mission will continue using the low-gain antenna. If this happens, fewer images will be sent back to Earth because of the antenna's much lower data rate.

Once images of the spacecraft and the rover on its petal have been received on Earth, the flight team will decide whether to deploy the rover ramps. This could take place on the first or second day of the mission. Once either or both ramps are unrolled, images of them and the terrain around the ends of the ramps will be taken and sent to Earth. If conditions are safe, the rover will be commanded to stand up and proceed down a ramp, either forward or backward. The rover should be deployed sometime during the first three days of the mission.

In addition to rover deployment images, Pathfinder's camera will take a panoramic image of its surroundings. If the high-gain communications link is operational, these images will begin to be transmitted as early as the first day of the mission. If the low-gain antenna is being used, these images will be sent down much later. The lander also will be transmitting science data on the temperature, atmospheric pressure and winds on Mars.

Once the rover sets out to explore Mars, it will rely on a toolkit of miniature instruments

to study the composition of rocks and take close-up photos of Martian surface features. The rover is named Sojourner, after American civil rights crusader Sojourner Truth.

"Starting with the lander camera stereo images, we will use special goggles to view the terrain in three dimensions, and look for safe paths to travel along in order for the rover to reach specific rocks and regions to conduct science and technology experiments," said Brian Cooper, the primary rover driver on the mission. "Once the path is decided, we will drive the rover using a set of software instructions that will be uplinked to the rover each day."

The landing site, Ares Vallis, was chosen because scientists believe it is a relatively safe surface to land on and contains a wide variety of rocks washed down into this flood basin during a catastrophic flood. During its exploration of the surface, Sojourner will rely on the lander primarily for communications with Earth and for imaging support.

"Ares Vallis is particularly interesting to geologists because it drains a region of ancient, heavily cratered terrain that dates back to early Martian history, similar in age to the meteorite Allan Hills 84001, which contains scientific evidence suggesting life may have begun on Mars billions of years ago," said Dr. Matthew Golombek, Pathfinder project scientist. "By examining rocks in this region, Pathfinder should tell scientists about the early environment on Mars, which is important in evaluating the possibility that life could have begun there."

Pathfinder's instruments and mobile rover are not designed to provide an answer to the question of life on Mars. They are designed to provide an in-depth portrait of Martian rocks and surface materials over a relatively large landing area, thereby giving scientists an immediate look at some of the crustal materials that make up the red planet. Pathfinder data also will be used to verify observations that are made from space when an orbiter, called Mars Global Surveyor, arrives at Mars in September and later, in March 1998, begins its two-year mapping mission.

The Mars Pathfinder mission, along with Mars Global Surveyor, mark the beginning of a new era in Mars exploration and an ambitious new initiative by the United States to send pairs of spacecraft to the red planet every 26 months in a sustained program of robotic exploration extending well into the next century. This program of robotic exploration will expand scientists' knowledge of Mars in three important areas of investigation: the search for evidence of past life on Mars; understanding the Martian climate and its lessons for the past and future of Earth's climate; and surveying the geology and resources that could be used to support future human missions to Mars. The program will culminate in a robotic sample return mission to be launched as early as 2005.

Mars Pathfinder is the second in NASA's Discovery program of low-cost spacecraft with highly focused science goals. The Jet Propulsion Laboratory, Pasadena, CA, developed and manages the Mars Pathfinder mission for NASA's Office of Space Science, Washington, DC.

[End of General Release]

# Media Services Information

## NASA Television Transmission

NASA Television is broadcast on the satellite GE-2, transponder 9C, C Band, 85 degrees west longitude, frequency 3880.0 MHz, vertical polarization, audio monaural at 6.8 MHz. The schedule for television transmissions during the Mars Pathfinder landing period will be available from the Jet Propulsion Laboratory, Pasadena, CA; Johnson Space Center, Houston, TX; Kennedy Space Center, FL; and NASA Headquarters, Washington, DC.

## Status Reports

Status reports on mission activities for Mars Pathfinder will be issued by the Jet Propulsion Laboratory's Public Information Office. They may be accessed online as noted below. Daily audio status reports are available by calling (800) 391-6654 or (818) 354-4210.

## Pathfinder Newsroom

A newsroom will be operated at the Jet Propulsion Laboratory, Pasadena, CA, from June 30 to July 11, 1997. From June 30 to July 11, the newsroom telephone will be (818) 354-8999. Before that date, media may call (818) 354-5011 for information on credentialing.

## Briefings

A pre-landing briefing on the missions and science objectives of Mars Pathfinder will be held at JPL at 10 a.m. PDT on July 1, 1997. Depending on the Space Shuttle launch schedule, this briefing may be videotaped for later replay on NASA Television. Daily news briefings will continue through the end of the Pathfinder rover's prime mission on July 11. Multiple briefings will be scheduled on landing day, July 4, and as required during the mission.

## Image Releases

Images returned by the Mars Pathfinder lander and rover will be released to the news media in electronic format only during the mission. Images will be available in a variety of file formats at the web address <http://www.jpl.nasa.gov/marsnews> . This site will include files offering the highest spatial and color resolution of images returned by the Pathfinder lander and rover. Images will also be carried on NASA Television during daily Video File broadcasts.

## Internet Information

Extensive information on Mars Pathfinder, including an electronic copy of this press kit, press releases, fact sheets, status reports and images, is available from the Jet Propulsion Laboratory's World Wide Web home page at <http://www.jpl.nasa.gov/marsnews> . The Mars Pathfinder Project also maintains a home page at <http://mpfwww.jpl.nasa.gov> .



# Quick Facts

## Lander

Spacecraft dimensions: Tetrahedron, three sides and base, standing 0.9 meter (3 feet) tall

Weight: 895 kilograms (1,973 pounds) at launch, fueled; 801 kilograms (1,766 pounds) dry

Science instruments: imager; magnets for measuring magnetic properties of soil; wind socks; atmospheric structure instrument/meteorology package.

Power: 160 watts peak power, up to 1,200 watt-hours per day from solar panels, batteries

## Rover

Rover dimensions: 65 cm (2 feet) long by 48 cm (1.5 feet) wide by 30 cm (1 foot) tall

Weight: 10.6 kilograms (23 pounds)

Science instruments: alpha proton x-ray spectrometer, 3 cameras (also technology experiments)

Power: 16 watts peak power, up to 100 watt-hours per day from solar panels, batteries

## Mission

Launch: December 4, 1996, at 1:58 a.m. EST from Cape Canaveral Air Station, FL, on a Delta II launch vehicle

Mars landing: July 4, 1997, at approximately 1700 UTC (10 a.m. PDT)

Speed at atmospheric entry: 26,460 kilometers per hour (16,600 miles per hour)

Speed at surface impact: 70 to 90 kilometers per hour (45 to 55 miles per hour)

Landing site: Ares Vallis, approx 19.4 degrees north latitude, 33.1 degrees west longitude

Sunrise at Martian landing site: 12:45 p.m. PDT

Sunset at Martian landing site: 1:45 a.m. PDT

One-way light time from Earth to Mars: 10 minutes, 35 seconds on July 4;

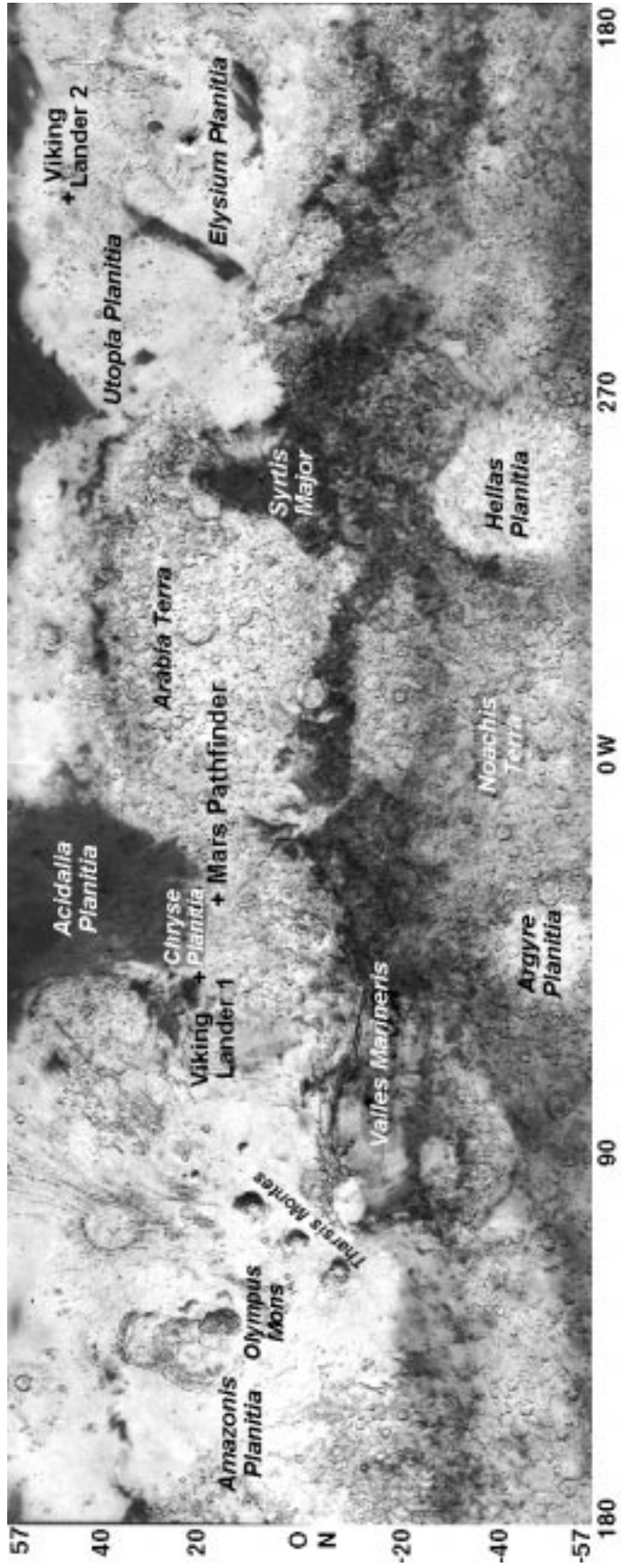
10 minutes, 40 seconds on July 5; 10 minutes, 44 seconds on July 6

Earth-Mars distance on landing day: 191 million kilometers (119 million miles)

Total distance traveled from Earth to Mars: 497 million kilometers (309 million miles)

Primary rover mission: 7 days

Primary lander mission: 30 days



Mars Landing Sites

# Mars at a Glance

## General

- One of 5 planets known to ancients; Mars was Roman god of war, agriculture and the state
- Reddish color; at times the 3rd brightest object in night sky after the Moon and Venus

## Physical Characteristics

- Average diameter 6,780 kilometers (4,217 miles); about half the size of Earth, but twice the size of Earth's Moon
- Mass 1/10th of Earth's; gravity only 38 percent as strong as Earth's
- Density 3.9 times greater than water (compared to Earth's 5.5 times greater than water)
- No magnetic field detected to date

## Orbit

- Fourth planet from the Sun, the next beyond Earth
- About 1.5 times farther from the Sun than is Earth
- Orbit elliptical; distance from Sun varies from a minimum of 206.7 million kilometers (128.4 million miles) to a maximum of 249.2 million kilometers (154.8 million miles); average distance from Sun, 227.7 million kilometers (141.5 million miles)
- Revolves around Sun once every 687 Earth days
- Rotation period (length of day in Earth days) 24 hours, 37 min, 23 sec (1.026 Earth days)
- Poles tilted 25 degrees, creating seasons similar to Earth's

## Environment

- Atmosphere composed chiefly of carbon dioxide (95.3%), nitrogen (2.7%) and argon (1.6%); only trace oxygen
- Surface atmospheric pressure less than 1/100th that of Earth's average
- Surface temperature averages -53 C (-64 F); varies from -128 C (-199 F) during polar night to 17 C (63 F) at equator during midday at closest point in orbit to Sun

## Features

- Highest point is Olympus Mons, a huge shield volcano more than 27 kilometers (16 miles) high and 600 kilometers (370 miles) across; covers about the same area as Arizona
- Canyon system of Valles Marineris is largest and deepest known in solar system; extends more than 4,000 kilometers (2,500 miles) and has 5 to 10 kilometers (3 to 6 miles) relief from floors to tops of surrounding plateaus
- "Canals" observed by Giovanni Schiaparelli and Percival Lowell about 100 years ago were a visual illusion in which dark areas appeared connected by lines. The Viking missions of the 1970s, however, established that Mars has channels probably cut by ancient rivers

## Moons

- Two irregularly shaped moons, each only a few kilometers wide
- Larger moon named Phobos ("fear"); smaller is Deimos ("terror"), named for attributes personified in Greek mythology as sons of the god of war

# Historical Mars Missions

*Mission, Country, Launch Date, Purpose, Results*

Mars 1, USSR, 11/1/62, Mars flyby, lost at 106 million kilometers (65.9 million miles)  
Mariner 3, U.S., 11/5/64, Mars flyby, shroud failed  
Mariner 4, U.S. 11/28/64, first successful Mars flyby 7/14/65, returned 21 photos  
Zond 2, USSR, 11/30/64, Mars flyby, failed to return planetary data  
Mariner 6, U.S., 2/24/69, Mars flyby 7/31/69, returned 75 photos  
Mariner 7, U.S., 3/27/69, Mars flyby 8/5/69, returned 126 photos  
Mariner 8, U.S., 5/8/71, Mars flyby, failed during launch  
Mars 2, USSR, 5/19/71, Mars orbiter/lander arrived 11/27/71, no useful data returned  
Mars 3, USSR, 5/28/71, Mars orbiter/lander, arrived 12/3/71, some data and few photos  
Mariner 9, U.S., 5/30/71, Mars orbiter, in orbit 11/13/71 to 10/27/72, returned 7,329 photos  
Mars 4, USSR, 7/21/73, failed Mars orbiter, flew past Mars 2/10/74  
Mars 5, USSR, 7/25/73, Mars orbiter, arrived 2/12/74, some data  
Mars 6, USSR, 8/5/73, Mars orbiter/lander, arrived 3/12/74, little data return  
Mars 7, USSR, 8/9/73, Mars orbiter/lander, arrived 3/9/74, little data return  
Viking 1, U.S., 8/20/75, Mars orbiter/lander, orbit 6/19/76-1980, lander 7/20/76-1982  
Viking 2, U.S., 9/9/75, Mars orbiter/lander, orbit 8/7/76-1987, lander 9/3/76-1980;  
combined, the Viking orbiters and landers returned 50,000+ photos  
Phobos 1, USSR, 7/7/88, Mars/Phobos orbiter/lander, lost 8/88 en route to Mars  
Phobos 2, USSR, 7/12/88, Mars/Phobos orbiter/lander, lost 3/89 near Phobos  
Mars Observer, U.S., 9/25/92, orbiter, lost just before Mars arrival 8/22/93 (8/21/93 PDT/EDT)  
Mars Global Surveyor, 11/7/96, orbiter, en route to orbit insertion 9/12/97 (9/11/97 PDT/EDT)  
Mars 96, Russia, 11/16/96, orbiter and landers, failed during launch  
Mars Pathfinder, U.S., 12/4/96, en route to landing 7/4/97

# Mission Timeline

All times for events on the spacecraft are given as the time signal would be received on Earth in Pacific Daylight Time (i.e. spacecraft event time plus one-way light time, which is approximately 10 minutes, 40 seconds). All operations events on Earth are in Pacific Daylight Time. Pacific Daylight Time is Universal Time minus 7 hours.

## ***June 30:***

12 a.m.: Mars Pathfinder is approximately 2 million kilometers (1.3 million miles) from Mars, traveling at a velocity of about 19,080 kilometers per hour (12,000 miles per hour) with respect to Mars.

## ***July 1:***

12 a.m.: Mars Pathfinder is about 1.6 million kilometers (982,000 miles) from Mars, traveling at a velocity of about 19,080 kilometers per hour (12,000 miles per hour) with respect to Mars.

## ***July 2:***

12 a.m.: Mars Pathfinder is about 1.1 million kilometers (696,000 miles) from Mars, traveling at a speed of about 19,080 kilometers per hour (12,000 miles per hour) with respect to Mars.

## ***July 3:***

12 a.m.: Mars Pathfinder is about 658,000 kilometers (408,000 miles) from Mars, traveling at a speed of about 19,080 kilometers per hour (12,000 miles per hour) with respect to Mars.

## ***July 4:***

12 a.m.: Mars Pathfinder is about 195,000 kilometers (121,000 miles) from Mars, traveling at a velocity of about 26,460 kilometers per hour (16,600 miles per hour) with respect to Mars.

9:32 a.m.: Cruise stage separation.

10:02 a.m.: Pathfinder enters the upper atmosphere of Mars at 26,460 kilometers per hour (16,600 miles per hour) and begins the sequence of events that will land the spacecraft on the surface. From this point on, the only likely signal from the spacecraft will be the carrier wave, a single frequency radio wave.

The shifting frequency of the carrier, known as the Doppler shift, will provide an indication of the decelerations occurring during entry and parachute deployment. The spacecraft is also

designed to send back a frequency-keyed signal following certain key events; this signal is called a semaphore. The semaphore is very weak, and is not expected to be received in real time. However, careful analysis after-the-fact of the broad frequency spectrum recording of the radio signal will give the operations team considerable information on how events unfolded during the rapid descent to the surface.

Entry, descent and landing (EDL) takes approximately 4.5 minutes and follows the sequence below:

- Spacecraft rapidly decelerates in the atmosphere using the heatshield
- Parachute deploys
- Heat shield separates
- Lander releases from backshell, descends on bridle
- Radar altimeter returns information on altitude
- Airbags inflate
- Rocket-assisted deceleration (RAD) engines fire
- Bridle cable is cut

10:07 a.m.: Landing on surface of Mars in Ares Vallis. Transmitter turned off shortly after landing to save power.

After touchdown, the following sequence will occur:

- Lander bounces and rolls to a stop
- Airbags deflate and are retracted up against the petals
- Petals open

These events of the entry, descent and landing phase will be complete between 11:32 a.m. and 12:33 p.m. PDT. A semaphore signaling the end of this phase may be received via the lander's low-gain antenna.

12:45 a.m.: Sunrise at the landing site. Operations begin for Sol 1 (a Sol is a Mars day, or 24 hours, 40 minutes).

1:56-3:13 p.m.: Transmitter is turned on, and the spacecraft signals Earth through the low-gain antenna. This communications session will contain telemetry from all engineering subsystems including the rover, and the first science data about the atmosphere taken during descent. Carrier is received at 1:55 p.m.; following ground processing, actual first information will probably be received by flight controllers at approximately 2:09 p.m.

### **Nominal Mission Scenario**

If all spacecraft systems are normal, the mission will proceed on its "nominal" plan. On this plan, the following events will occur:

3:20 p.m.: The camera on the lander is released and begins searching for the Sun. The high-gain communications antenna is deployed and pointed toward Earth.

4:13-5 p.m.: First high-gain antenna downlink session. First engineering images of lander, airbags and the region around the lander. The very first image frame will be of a small region including part of the lander and an airbag. Assessment of these first images will tell the operations team about the condition of the spacecraft, the airbags and whether the rover ramps can be deployed. First color images of the region around the rover petal will be sent.

### **Low-Gain Antenna Communications Scenario**

In all likelihood, there will be some condition or conditions of the spacecraft that will be different than the ideal case -- for example, an unusually tilted orientation of the lander due to larger than anticipated rocks, or an airbag draping a solar panel, or some damaged hardware due to a harder than expected landing. At this point the mission team may enter a contingency mode where it uses commands and prepared sequences to further evaluate the health of the lander and improve its ability to continue the mission. Under such circumstances, the highest priority will be to assure the safety of the spacecraft and rover, and to insure enough power for operations and to recharge the battery.

Another possible contingency situation is loss of data due to a spacecraft or ground problem that would require using one of two remaining downlink sessions to retransmit data. Such a situation also will result in replanning the rest of the first day's activities.

Both the lander imager's Sun search and the high-gain antenna deployment must be completed successfully for the images described above to be received. If either activity is not completed fully, the team will intentionally go to a less complex plan of events using the lander's low-gain antenna. The low-gain antenna does not require knowledge of the spacecraft orientation on Mars or active pointing to Earth. This is a contingency scenario that has been well practiced and would proceed on the following timeline (attempts to find the Sun and point the high-gain antenna at Earth would normally resume on Sol 2).

6:06-7:51 p.m.: Low-gain antenna downlink session, including compressed rover ramp deployment images (black-and-white with 80-to-1 compression). Approximately 12 images will be sent. The rover team will evaluate the feasibility of ramp deployment based on these images.

7-8:15 p.m.: During this window, a decision will be made to deploy one or both rover ramps and command the rover to stand up. If more imaging is needed to make this decision, it will be requested at this time.

8:44 p.m.: If the decision is made to deploy either or both ramps, this will occur at this time in the following sequence: activate ramp deploy sequence; release the rover's alpha proton X-ray spectrometer instrument; release the rover from its stowed position; deploy the rover ramps. The rover will then stand up. A semaphore would be transmitted to Earth indicating that the command was received to begin the sequence.

In this low-gain antenna scenario, this is the end of Sol 1 because no more telemetry would be received. The downlink capability ends as the Earth sets to about 30 degrees above the Mars horizon.

### **Nominal Mission Scenario**

If, on the other hand, the high-gain antenna is pointed toward Earth, the following timeline will be followed. It should be remembered that unexpected events can occur at any time which may change this timeline. As always, the highest priority will be to assure the safety of the spacecraft and rover, and to insure enough power for operations and to recharge the battery.

5:40-5:55 p.m.: Command conference to decide whether to deploy the rover ramp.

6 p.m.: Assuming that the rover and project team judge it safe, the ramp deployment sequence will begin at about this time.

6:55-7:57 p.m.: Second high-gain antenna downlink with rover deploy images (black-and-white), showing the ramps deployed. Engineering data, more detailed entry and weather data will be sent. Part of a black-and-white panorama image will be transmitted to Earth.

7:30-8:50 p.m.: Rover and project teams decide whether to deploy rover, based on the position of the ramp(s) on the surface and the expected ability of the rover to safely traverse the area immediately off the end of the ramp(s).

8:58 p.m.: If all conditions are judged acceptable, the rover deploy sequence will be activated and the rover will drive off the lander petal, down a ramp (either forward or backward), and roll out onto the surface of Mars. The alpha proton X-ray spectrometer will be lowered onto the soil to prepare for deployment.

9:24-10:26 p.m.: Third high-gain antenna downlink session. Images should show the rover on the surface of Mars. Based on this imaging, the rover team may decide to deploy the alpha proton X-ray spectrometer. Other images may include a black-and-white 360-degree panorama of the landing site.

10:30 p.m.: Sun sets at landing site, rover goes to sleep. If the alpha proton X-ray spectrometer was deployed, it will be taking measurements of rock and soil composition and storing data all night long.

## ***July 5***

### **Low-Gain Antenna Communications Scenario**

Resuming this scenario in the event that the high-gain antenna is not deployed on the first day:



Night of Sol 1: The flight team processes images of radiometric calibration target, and develops an estimate of the Sun's position. This information may then be used to estimate the lander orientation on the surface and allow the team to manually point the high-gain antenna at Earth on Sol 2. A set of commands will then be sent to the lander on the morning of Sol 2 to update the on-board orientation estimate.

2:20-2:50 p.m.: The first downlink session is conducted using the low-gain antenna. This communication session includes spacecraft health data taken at night. It also includes images acquired following ramp deployment at the end of Sol 1. The lander will then try a brief session with the high-gain antenna using the new pointing information uplinked early on Sol 2. If this communications demonstration is successful, the team will use the high-gain antenna for the second and final downlink on Sol 2. If not, a second low-gain antenna session will occur between 6:30 and 7:30 p.m. After the post-ramp deploy images are received on the ground, the rover team will make an assessment to determine if the rover can be deployed onto the surface. If conditions allow, the rover deploy sequence will be uplinked to the spacecraft and the rover will deploy at about 6:15 p.m. A final set of images of the rover sitting on the surface will then be acquired and downlinked during the final transmit session.

### **Nominal Mission Scenario**

If the mission is on the high-gain communications scenario and the rover was deployed on Sol 1, the following is the sequence of events for Sol 2:

2:20-2:50 p.m.: The first downlink session on the high-gain antenna is conducted. This communication session includes night data and data from the alpha proton X-ray spectrometer.

Key activities on Sol 2 include obtaining and partially returning a color stereo panorama image and performing an extended rover traverse. The rover will conduct several experiments with soil mechanics during this traverse, and may attempt a second measurement with the alpha proton X-ray spectrometer at the end of the day. Additional transmit sessions may occur depending on available power; nominal time for these sessions are 8:20-9:20 p.m. and 10:30-11:20 p.m. Data expected during these sessions include engineering telemetry, weather observations, image data from the stereo color panorama and images acquired by the rover.

# Why Mars?

Of all the planets in the solar system, Mars is the most like Earth and the planet most likely to support eventual human expeditions. Earth's Moon and Mercury are dry, airless bodies. Venus has suffered a runaway greenhouse effect, developing a very dense carbon dioxide atmosphere that has resulted in the escape of all of its water and the rise of torrid, inhospitable surface temperatures of nearly 500 degrees Celsius (about 900 degrees Fahrenheit). Mars, on the other hand, has all of the ingredients necessary for life, including an atmosphere, polar caps and large amounts of water locked beneath its surface. Mars, in fact, is the only other terrestrial planet thought to have abundant water that could be mined and converted into its liquid form to support human life.

Compared to Earth, Mars is about 6,800 kilometers (4,200 miles) in diameter, about half the diameter and about one-eighth the volume of Earth. Mars turns on its axis once every 24 hours, 37 minutes, making a Martian day -- called a "sol" -- only slightly longer than an Earth day. The planet's poles are tilted to the plane of its orbit at an angle of 25 degrees -- about the same amount as Earth, whose poles are titled at 23.3 degrees to the ecliptic plane. Because of its tilted axis, Mars has Earth-like seasonal changes and a wide variety of weather phenomena. Although its atmosphere is tenuous, winds and clouds as high as 25 kilometers (about 15 miles) above the surface can blow across stark Martian deserts. Low-level fogs and surface frost have been observed by spacecraft. Spacecraft and ground-based observations have revealed huge dust storms that often start in the southern regions and can spread across the entire planet.

Early Mars may have been like early Earth. Current theories suggest that, early in its history, Mars may have once been much warmer, wetter and enveloped in a much thicker atmosphere. On Earth, evidence for life can be found in some of the oldest rocks, dating from the end of Earth's heavy bombardment by comets and meteors around 4 billion years ago. Surfaces on Mars that are about the same age show remains of ancient lakes, which suggests that liquid water flowed on the surface at one time and the climate was both wetter and substantially warmer. If this proves to be true, then further exploration may reveal whether life did develop on Mars at some point early in its history. If it did not, scientists will want to know why it didn't. Or perhaps they will be able to determine whether life that began early on in Mars' evolution could still survive in some specialized niches such as hydrothermal systems near volcanoes.

Mars is the most accessible planet on which to begin answering fundamental questions about the origin of life. Scientists want to know if we are alone in the universe. Is life a cosmic accident or does it develop anywhere given the proper environmental conditions? What happened to liquid water on Mars? Could life have begun on Mars and been transported to Earth?

Exploring Mars also will provide us with a better understanding of significant events that humankind may face in the future as Earth continues to evolve. What are the factors involved in natural changes in a planet's climate, for instance? On Earth, one of the most important questions now being studied is whether or not human activities are con-

tributing to possible global warming. Could these climate changes bring about negative environmental changes such as sea level rise due to the melting of the ice caps? Mars provides a natural laboratory for studying climate changes on a variety of time scales. If Mars in the past was warmer and wetter, and had a thicker atmosphere, why did it change?

Layered deposits near the Martian polar caps suggest climatic fluctuations on a shorter time scale. If scientists can learn about the important factors controlling climatic changes on another planet, they may be able to understand the consequences of natural and human-induced changes on Earth.

Mars is an excellent laboratory to engage in such a study. Earth and Venus are active environments, constantly erasing all traces of their evolution with dynamic geological processes. On Mercury and on Earth's Moon, only relatively undisturbed ancient rocks are present. Mars, by contrast, has experienced an intermediate level of geological activity, which has produced rocks on the surface that preserve the entire history of the solar system. Sedimentary rocks preserved on the surface contain a record of the environmental conditions in which they formed and, consequently, any climate changes that have occurred through time.

### **The Search for Life**

After years of exhaustive study of the data returned by the Viking spacecraft from their biology experiments, most scientists concluded that it is unlikely that any life currently exists on the surface of Mars. Centuries of fascination about the possibility of intelligent life on the red planet seemed to fade.

Since that time more than 20 years ago, however, much has been learned about the origins of life on Earth. Biologists learned that the most primitive single-celled microscopic organisms had sprung from hot volcanic vents at the very bottom of Earth's oceans. They found that the most fundamental carbonaceous organic material appear to demonstrate cell division and differentiated cell types, very similar to other fossils and living species. Geologists learned that these organisms could exist in regions along the floors of oceans in environments akin to pressure-cookers, at extremely hot temperatures devoid of light and prone to extreme pressures that no human being could survive. With new technologies and sophisticated instruments, they began to measure the skeletons of bacteria-like organisms lodged deep within old rocks.

Then, in August 1996, a NASA-funded team of scientists announced its findings of the first fossil evidence thought to be from Mars. The findings reignited the age-old question: Are we alone in the universe?

The two-year investigation by a team led by scientists from NASA's Johnson Space Center, Houston, TX, revealed evidence that strongly suggested primitive life may have existed on Mars more than 3.6 billion years ago. Researchers discovered an igneous meteorite in Earth's Antarctica that had been blasted away from the surface of Mars in an impact event; the rock was dated to about 4.5 billion years old, the period when Mars and its terrestrial neighbors were forming. According to scientists on the team, the rock contains fossil evidence of what

they believe may have been ancient microorganisms.

The team studied carbonate minerals deposited in the fractures of the 2-kilogram (about 4-pound), potato-shaped Martian meteorite. They suggested living organisms deposited the carbonate -- and some remains of the microscopic organisms may have become fossilized -- in a fashion similar to the formation of fossils in limestone on Earth. Then, 16 million years ago, a huge comet or asteroid struck Mars, ejecting a piece of the rock from its subsurface location with enough force to escape the planet. For millions of years, the chunk of rock floated through space. It encountered Earth's atmosphere 13,000 years ago and fell in Antarctica as a meteorite.

In the tiny globs of carbonate, researchers found a number of features that can be interpreted as having been formed by possible past life. Team members from Stanford University detected organic molecules called polycyclic aromatic hydrocarbons (PAHs) concentrated in the vicinity of the carbonate. Researchers from NASA Johnson found iron mineral compounds commonly associated with microscopic organisms and the possible microscopic fossil structures.

Most of the team's findings were made possible only because of very recent technological advances in high-resolution scanning electron microscopy and laser mass spectrometry. Just a few years ago, many of the features that they reported were undetectable. Although past studies of the meteorite in question - designated ALH84001 -- and others of Martian origin failed to detect evidence of past life, they were generally performed using lower levels of magnification, without the benefit of the technology used in this research. In addition, the recent suggestion of extremely small bacteria on Earth, called nanobacteria, prompted the team to perform this work at a much finer scale than had been done in the past.

The findings, presented in the August 16, 1996, issue of the journal *Science*, have been put forth to the scientific community at large for further study. The team was co-led by Johnson Space Center planetary scientists Dr. David McKay, Dr. Everett Gibson and Kathie Thomas-Keprta of Lockheed Martin, with the major collaboration of a Stanford University team headed by chemistry professor Dr. Richard Zare, as well as six other NASA and university partners. A variety of papers have been published in the months since that announcement that have argued for and against the claims that the evidence is suggestive of ancient life.

Whether or not the evidence stands up to scientific scrutiny, the suggestion alone has renewed interest in exploring the planets, stars and galaxies outside of the Milky Way galaxy. The questions resound: Does life exist elsewhere in the universe? And why does it exist at all? Did life as we know it originate on Earth or did it spring from other planets, only to be transported to Earth, where it found the most advantageous niche for continuing evolution?

In the year 2005, NASA plans to send to Mars a sample return mission, a robotic spacecraft that will be able to return soil and rock samples to Earth for direct study much as the Apollo astronauts returned hundreds of pounds of lunar rocks to Earth. Additional debate and scientific experimentation with Martian meteorites in the next several years may bring about an answer that may become a turning point in the history of civilization.

# The Multi-Year Mars Program

Launch of the two 1996 missions to Mars -- Mars Pathfinder and Mars Global Surveyor -- ushered in a continuing U.S. program of Mars exploration. The program is designed to send low-cost spacecraft to Mars every 26 months well into the next decade.

Although they were launched within a month of each other in late 1996, Mars Global Surveyor and Mars Pathfinder have their roots in two separate NASA programs. Mars Pathfinder was approved as a stand-alone project under NASA's Discovery program, which was created in 1992 to fund low-cost solar system missions. Mars Global Surveyor, on the other hand, is the first in a multi-year series of missions under the Mars Surveyor program. After 1996, current plans call for two Mars Surveyor spacecraft to be sent to Mars during each launch opportunity in 1998, 2001 and 2003, and a single sample return spacecraft in 2005. The program is expected to continue beyond 2005 on a direction set by results obtained from earlier flights. In addition to the science goals stated, the purpose of these missions is to pave the way for human exploration some time early in the next century.

By 2005, NASA will have had a fleet of small spacecraft with highly focused science goals probing and watching the planet, setting in place a new way of exploring the solar system. Based on the space agency's philosophy of bringing faster, better and cheaper missions to fruition, combinations of orbiters and landers will take advantage of novel microtechnologies -- lasers, microprocessors and electronic circuits, computers and cameras the size of a gaming die -- to deliver an ingenious armada of miniaturized robotic payloads to Earth's planetary neighbor.

U.S. missions to Mars at this point are listed below. (Note: Projected costs are for spacecraft development only and do not include launch vehicles, mission operations after the first 30 days or spacecraft tracking.)

## ***1996:***

☐ Mars Pathfinder (Discovery mission). Demonstrate low cost-entry and landing system, and rover mobility; initiates mineralogy studies; continue study of surface characteristics and Martian weather. Cost: \$171 million (capped at \$150 million in fiscal year 1992 dollars), plus \$25 million for rover.

☐ Mars Global Surveyor. Perform global reconnaissance of physical and mineralogical surface characteristics, including evidence of water; determine global topography and geologic structure of Mars; assess atmosphere and magnetic field during seasonal cycles; provide backup communication relay for the Mars Surveyor '98 lander and communication relay for the Mars Surveyor '98 microprobes. Cost: \$148 million.

### ***1998:***

Mars Surveyor '98 Orbiter. Launch scheduled December 10, 1998. Characterize the Martian atmosphere, including definition of atmospheric water content during seasonal cycles. Provide primary communication relay for the Mars Surveyor '98 lander.

Mars Surveyor '98 Lander. Launch scheduled January 3, 1999. Access past and present-day water reservoirs on Mars; study surface chemistry, topology and mineralogy; continue weather studies. The spacecraft also will deliver two innovative soil microprobes developed under NASA's New Millennium program. Combined cost of both 1998 missions: \$187 million, plus \$26 million for the microprobes.

### ***2001:***

Mars Surveyor '01 Orbiter. Characterize mineralogy and chemistry of surface, including identification of near surface water reservoirs.

Mars Surveyor '01 Lander and Rover. Characterize terrain over tens of kilometers at site selected from MGS and Mars Surveyor '98 orbital observations. Select and gather samples for possible later return. Characterize dust, soil and radiation conditions as they pertain to eventual human exploration. Test components of in-situ propellant production plant. Combined development cost of both 2001 missions: approximately \$250 million.

### ***2003:***

Mars Surveyor '03 Lander and Rover. Characterize terrain over tens of kilometers at a site chosen using earlier orbital observations; select and gather samples for possible later return. Other objectives, related to eventual human exploration, are expected to be added to both 2003 missions.

Mars Surveyor '03 Orbiter: Provide communications and navigation facilities for 2003 and later missions on the Martian surface. Combined development cost of both 2003 missions: approximately \$220 million.

### ***2005:***

Sample Return Mission. Return a sample from one of the two rovers launched in 2001 and 2003. Development cost: approximately \$400 million.

### ***Beyond 2005:***

To be determined. Plans will depend on results of earlier missions.

## **International Cooperation**

International collaboration on all Mars missions will be an important aspect of exploration in the next decade. Many space agencies around the world are considering participation in the planning stages of future missions, including those of Russia, Japan and many European countries. Scientists from the United States are consulting with international partners on the best ways to combine their efforts in Mars exploration. This may result in new proposals for cooperative missions in the first decade of the 21st century.

Among the ongoing programs taking shape is one called "Mars Together," a concept for the joint exploration of Mars by Russia and the United States. The program was initiated in the spring of 1994 and bore its first fruit in the summer of 1995. A Russian co-principal investigator and Russian hardware were incorporated into one experiment, the Pressure Modulator Infrared Radiometer, to be flown on NASA's Mars Surveyor 1998 orbiter. Dr. Vassili Moroz of the Russian Academy of Sciences Space Research Institute (IKI) in Moscow will co-lead the experiment with Dr. Daniel McCleese of NASA's Jet Propulsion Laboratory. The Russian institute also will provide the optical bench for the radiometer. In addition, IKI will furnish a complete science instrument, the LIDAR (Light Detection and Ranging) Atmospheric Sounder, for the 1998 Mars Surveyor lander.

Under Mars Together, NASA is discussing possible collaboration with Russia on a mission in 2001. This possible arrangement involves an additional rover launched and operated by Russia that also would select and gather samples for possible later return. The Mars Surveyor '01 orbiter would provide the communications relay for this rover.

Japan also is building an orbiter, called Planet B, to study the Martian upper atmosphere and its interaction with the solar wind. The spacecraft, to be launched in August 1998, will carry a U.S. neutral mass spectrometer instrument to investigate the upper atmosphere, in addition to a variety of Japanese instruments.

The nations of Europe are considering a mission in 2003 called Mars Express. The tentative plan includes an orbiter carrying one or more small landers and remote-sensing instruments that would study topography and surface minerals. A final decision on this mission is expected before the end of 1998.

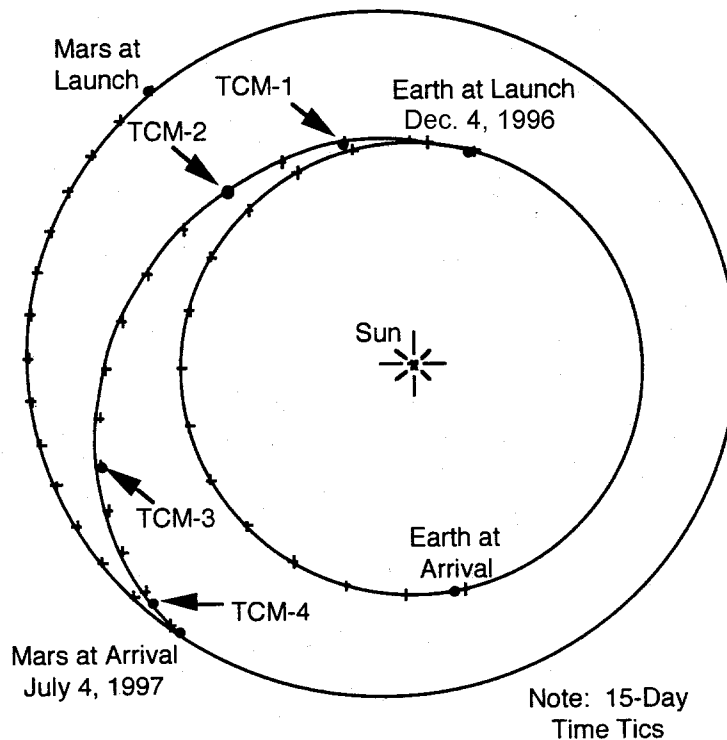
# Mission Overview

Mars Pathfinder will deliver a lander and small robotic rover, Sojourner, to the surface of Mars. The primary objective of the mission is to demonstrate a low-cost way of placing a science package on the surface of the red planet using a direct entry, descent and landing, with the aid of small rocket engines, a parachute, airbags and other techniques. Landers and free-ranging rovers of the future will share the heritage of Mars Pathfinder designs and technologies first tested in this mission. In addition, Pathfinder is studying ancient rocks to understand the nature of the early environment on Mars and the processes that have led to features that exist today.

## Launch and Cruise

Mars Pathfinder was launched December 4, 1996, at 1:58 a.m. EDT atop a Delta II 7925 expendable launch vehicle from launch complex 17B at Cape Canaveral, FL. A PAM-D upper stage booster was used to inject the spacecraft on its interplanetary trajectory. While en route to Mars, the spacecraft spins at a rate of 2 rpm.

During the cruise to Mars, the spacecraft will have completed a total of four trajectory correction maneuvers to refine its flight path, on January 9, February 3, May 6 and June 25, 1997.



*Mars Pathfinder's Earth-Mars trajectory*



During the approach phase of the final 45 days before Mars arrival, spacecraft activities are focused on preparation for entry, landing and descent. The spacecraft continues in a 2 rpm spin-stabilized mode with the spin axis oriented toward Earth. Continuous coverage by NASA's Deep Space Network was required during this phase to support planning and execution of the fourth and final trajectory correction maneuver, and to support final entry preparations.

A final health and status check of the instruments and rover was conducted June 19, some 15 days before Mars entry. All onboard systems were operating normally. In addition, the Pathfinder rover was sent a "wake up" call; it responded normally and accepted minor software changes in preparation for landing. On June 23, the flight team began to load the 370 command sequences required to carry out Pathfinder's entry, descent and landing and initial surface operations.

Four days before Mars entry, on June 30, the spacecraft is scheduled to be turned about 7 degrees to orient it for entry. Commands will be issued to the spacecraft to initiate the software that controls the spacecraft during entry, descent and landing.

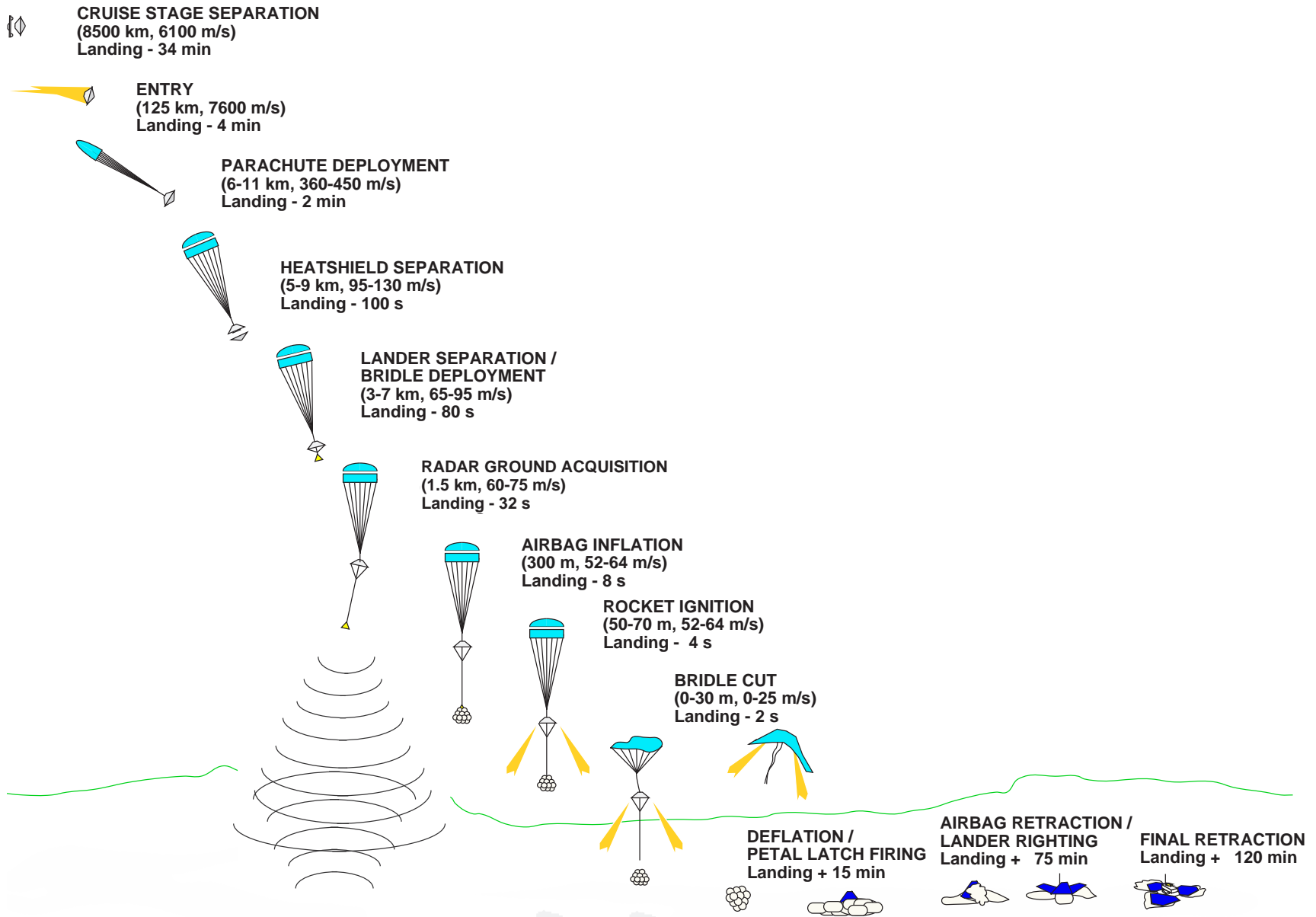
A fifth and final trajectory correction maneuver may be performed during one of two time windows, either 12 hours or six hours before entry into the Martian atmosphere, to insure that the spacecraft lands within its 100- by 200-kilometer (60- by 120-mile) target ellipse. A decision on this maneuver will not be made until a day or two before arrival.

### **Entry, Descent and Landing**

The entry, descent and landing phase begins 1-1/2 hours before Mars arrival and ends when the lander petals are fully deployed. Key activities during this phase include cruise stage separation, entry, parachute deployment, radar altimeter operations, airbag inflation, rocket-assisted deceleration burns, impact, airbag retraction and petal deployment. Real-time communications with the flight system will be possible through impact and, possibly, until the lander petals are deployed, depending on the landing orientation.

The entry trajectory for Mars Pathfinder is a ballistic, direct entry with an initial velocity of 26,460 kilometers per hour (16,600 miles per hour) and a mean flight path angle of 14.2 degrees (downward angle relative to the surface of Mars' atmosphere). The entry velocity is approximately 80 percent faster than that of the Viking landers in the 1970s; the Vikings descended from Martian orbit, whereas Mars Pathfinder will enter the atmosphere directly from its interplanetary trajectory.

The peak aerodynamic deceleration during entry is about 20 g's, and occurs about 70 seconds after entry into the atmosphere (one g equals the normal force of gravity on Earth). A parachute will be deployed between 135 and 190 seconds after entry, at an altitude of between 6 and 10 kilometers (about 4 to 6 miles). The parachute will be deployed by firing a mortar to push the chute out of its canister. Once the parachute is deployed, the flight path angle will begin to bend until the vehicle is descending nearly vertically.



*Mars Pathfinder entry, descent and landing*

The heat shield will be released by a timer signal 20 seconds after parachute deployment to provide sufficient time for the chute to inflate and stabilize. Twenty seconds after heat shield release, the lander will be released and lowered from the backshell on a 20-meter (65-foot) bridle.

The radar altimeter begins measuring the distance to the surface at an altitude of about 1.5 kilometers (1 mile) above the surface. The spacecraft's airbags will inflate two seconds prior to ignition of the rocket-assisted deceleration rockets, and the rockets will fire about four seconds before impact. The total burn time of the rockets is approximately 2.2 seconds, but the bridle is cut prior to the end of the burn to allow enough extra thrust to carry the backshell and parachute away from the lander. This will prevent the backshell and parachute from falling onto the spacecraft. The lander will then free-fall the remaining distance to the ground.

Landing will occur about 4-1/2 minutes after entry into the atmosphere. The imprecision of this time is caused by uncertainties about the altitude at the landing site and possible navigation targeting errors.

The lander could hit the ground in almost any orientation as a result of the rocket burn and bridle cut. At impact, the lander will bounce, roll and tumble until all impact energy dissipates. The interval between initial impact and the spacecraft's complete halt could be as long as several minutes. The airbags completely enclose the lander, so subsequent bounces should not result in high deceleration. Each face of the spacecraft's tetrahedron has a single six-lobed airbag, and energy is dissipated through vents in between the lobes.

## **Post-Landing**

After the lander comes to a complete stop, the next key activities are deflation and retraction of the four airbags, and opening of the spacecraft's petals. Airbag deflation may begin to occur almost immediately after landing due to leaks in the bags. Each of the airbags has deflation patches which will be opened to speed up the process. These patches are opened by Kevlar cords inside the bags which are connected to a retraction motor. Additional cords are attached to other points inside each bag so that the airbags can be retracted after landing.

Flight software will control how the airbags are retracted. In general, the three airbags on the sides facing away from the ground will be retracted first. Once those bags have been retracted, the petals will be partially deployed so that the lander stands itself right side up. The final airbag on the side originally facing the ground will then be retracted before the petals are fully deployed. If the lander comes to rest on a rock, the entire lander may be tilted, but further maneuvering of the petals can be performed during surface operations to lower the overall tilt of the lander.

Telecommunications during entry should provide significant information about the behavior of the entry, descent and landing subsystem. Digital data will not be acquired, however, because of the extremely weak signal.

The amplitude and frequency of the spacecraft will be observed in real-time during entry and descent, and may be seen during petal deployment, depending on the lander's orientation once it comes to a stop on the Martian surface. Changes in amplitude are expected at cruise stage separation, parachute deployment, surface impact and during the airbag retraction and petal deployment. Changes in frequency reflect changes in the spacecraft's speed and will be most pronounced during the period of peak deceleration.

The spacecraft also will deliberately change the frequency of the subcarrier to signal other key events. These include heat shield separation, bridle deployment, crossing the threshold altitude of 600 meters (about 2,000 feet) above the surface, completion of airbag retraction and completion of the petal deployment sequence. These planned frequency changes -- called "semaphores" -- are not likely to be detected in real-time, but can be extracted by post-processing the recorded data. In addition, key spacecraft telemetry data will be recorded and played back after landing.

Other key data to be transmitted to Earth include accelerometer measurements and selected atmospheric structure instrument measurements. The Deep Space Network's 70-meter (230-foot) and 34-meter (110-foot) antennas in Madrid, Spain, will be used to support entry communications.

## **Prime Mission**

Mars Pathfinder's primary mission begins when its lander petals have been fully unfolded and the lander switches to a sequence of computer commands that will control its functions. The spacecraft lands about 2-1/2 hours before sunrise on Mars and will spend the time in darkness retracting its airbags, standing itself upright and opening the petals so that solar panels can be powered up after sunrise.

The lander's first task will be to transmit engineering and science data collected during its descent through the thin atmosphere of Mars. If no errors are detected in these data and the spacecraft is basically healthy, a real-time command will be sent from Earth instructing the lander to unlock the imager camera head, deploy and point the high-gain antenna. If conditions are different than expected, which is not unlikely, the operation team will execute a contingency plan that has been placed onboard the spacecraft in expectation of such conditions.

In the normal plan, the lander's camera will begin taking images -- including a panoramic view of the Martian landscape -- and will begin transmitting the data directly to Earth at 2,250 bits per second. The first images of the Martian landscape will tell engineers whether the airbags are fully retracted and whether the rover's exit ramp can be safely and successfully deployed. Once either or both ramps are deployed, additional images will be acquired to show the terrain beyond the ramps so that engineers can decide on the safest exit route. If the high-gain antenna is not available, data will be sent over the lander's low-gain antenna at a much lower rate of 40 bits per second. In this case, only a few, highly compressed images will be sent.

Once a decision on the route has been made, commands will be sent to deploy the rover. Sojourner will spend about a quarter of an hour exiting its ramp. The rover should be deployed within the first three days after landing.

Driving off onto the floor of an old outflow channel, Sojourner will explore the surface at the command of Earth-based operators, who will rely on lander-based images to select a path and target for the rover. The six-wheeled Sojourner travels at 1 centimeter (0.4 inch) per second, performing mobility tests, imaging its surroundings and deploying an alpha proton x-ray spectrometer designed to study the elemental composition of rocks. During its prime mission, the rover will likely range a few tens of meters (yards) from the lander.

Also mounted on the lander are wind sensors, wind socks and high- and low-gain antennas. Instruments will be used to measure the pressure, temperature and density of the Martian atmosphere. Magnets mounted on the lander will collect magnetic specimens of Martian dust and soil as small as 100 microns (about 1/250th of an inch).

### **Extended Missions**

The primary mission lasts seven Martian days, or "sols," for the rover, and 30 Martian days, or "sols," for the lander. The rover could carry out an extended mission beyond that period, depending on how long its power sources and electronics last; engineers expect that the most probable reason for it to stop functioning is hot-cold cycling of its onboard electronics between Martian day and night.

Sojourner's extended mission activities would include repeating soil mechanics experiments on various soils; additional spectrometer measurements of both rocks and soil; obtaining images of selected areas with the rover camera, including close-ups of the lander; obtaining images of the lander's landing and tumbling path; and traveling longer distances, with the possibility of going over the horizon, up to hundreds of meters (yards).

For the lander, an extended mission lasting up to one year after landing is possible. Lander activities in the extended mission would include continued use of the lander camera to obtain images of the terrain and atmosphere, collection of key engineering telemetry and continued collection of meteorology data.

### **Mission Operations**

All operations for Mars Pathfinder will be conducted at JPL, where the operations and science teams reside. Science data, both raw and processed, will be transferred after a period of validation to NASA's Planetary Data System archive for access and use by the planetary community at large and the general public. The Planetary Data System home page is at [http://pds.jpl.nasa.gov/pds\\_home.html](http://pds.jpl.nasa.gov/pds_home.html) . Images from planetary missions are also available via the web from NASA's Planetary Photojournal at <http://photojournal.jpl.nasa.gov> .

# Spacecraft

At launch the Mars Pathfinder spacecraft weighed about 895 kilograms (1,973 pounds), including its cruise stage, heat shield and backshell (or aeroshell), solar panels, propulsion stage, medium- and- high-gain antennas and 94 kilograms (207 pounds) of cruise propellant. The cruise vehicle measures 2.65 meters (8.5 feet) in diameter and stands 1.5 meters (5 feet) tall. The lander is a tetrahedron, a small pyramid standing about 0.9 meter (3 feet) tall with three triangular-shaped sides and a base.

When Pathfinder is poised to enter the Martian atmosphere, its main components are the aeroshell, folded lander and rover, parachute, airbag system and three rocket engines. Combined, the spacecraft's mass is about 570 kilograms (1,256 pounds) at entry.

Once it has landed and its airbags have been deflated, Pathfinder's mass will be about 360 kilograms (793 pounds). Subsystems contributing to its landed weight include the opening/uprighting mechanism, lander cabling and electronics, instruments and rover. When it is unfolded and lying flat on the surface, the spacecraft will measure 2.75 meters (9 feet) across with a mast-mounted camera standing up about 1.5 meters (5 feet) from the ground.

The lander is controlled by a derivative of the commercially available IBM 6000 computer. This processor and associated components are radiation-hardened and mounted on a single electronics board. The computer has a 32-bit architecture which executes about 20 million instructions per second. The computer will store flight software as well as engineering and science data, including images and rover information, in 128 megabytes of dynamic random access memory.

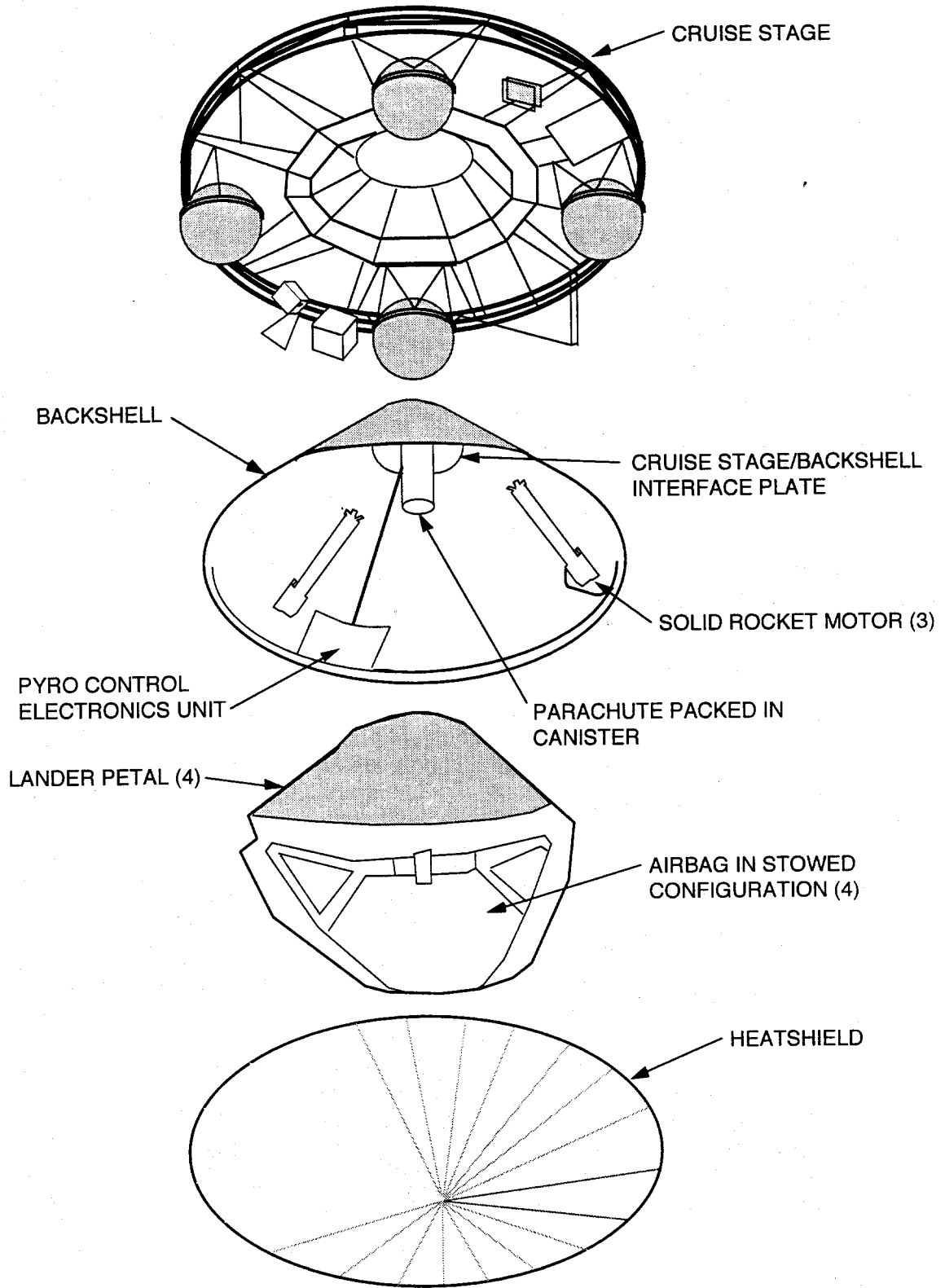
During interplanetary cruise, the spacecraft requires 178 watts of electrical power, provided by 2.5 square meters (27 square feet) of gallium arsenide solar cells.

The lander has three solar panels, with a total area of 2.8 square meters (30 square feet) and supplying up to 1,200 watt-hours of power per day on clear days. At night, the lander will operate on rechargeable silver zinc batteries with a capacity at the beginning of the Mars surface mission of more than 40 amp-hours.

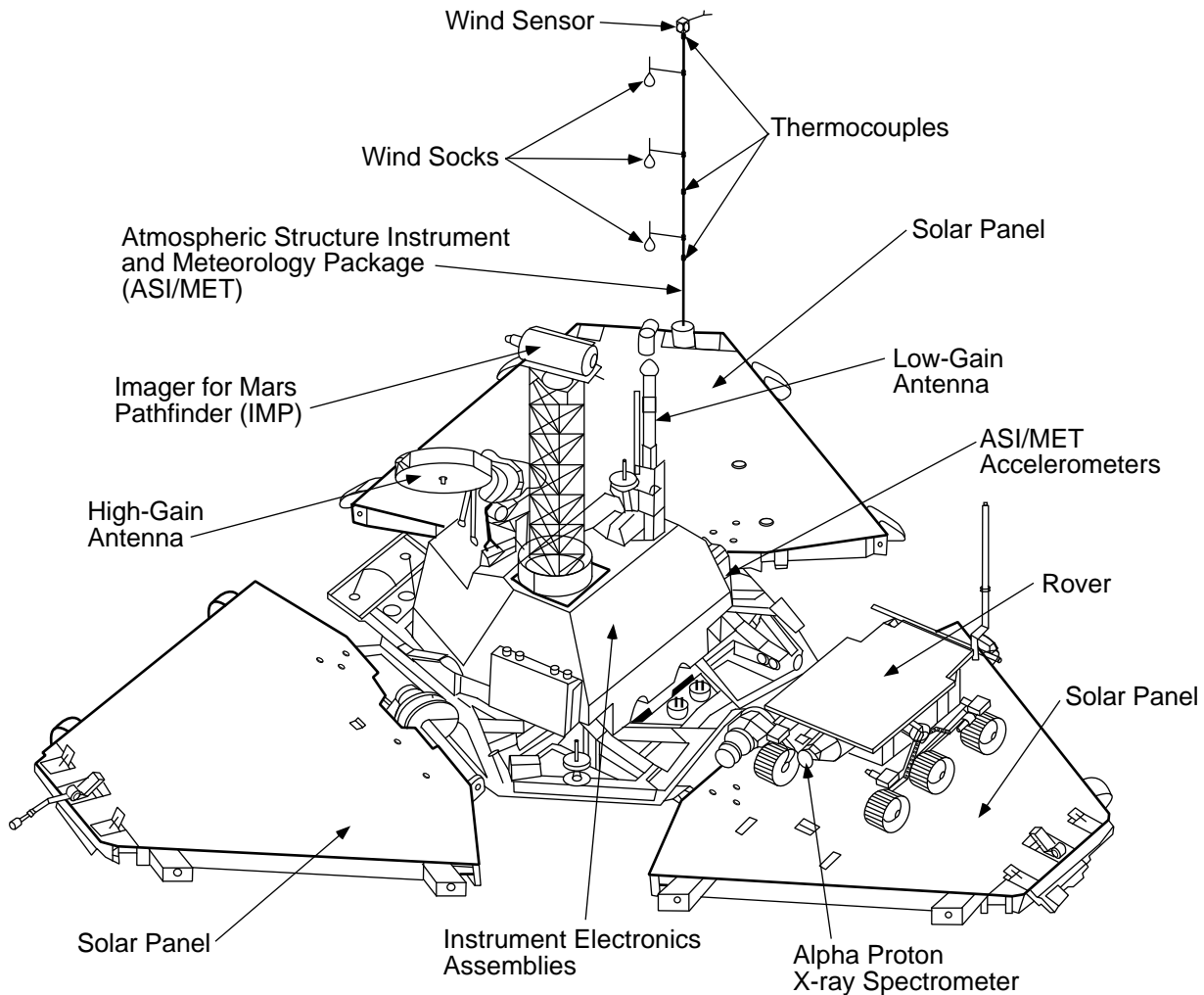
The Pathfinder lander carries a camera on a mast to survey its immediate surroundings. The camera has two optical paths for stereo imaging, each with a filter wheel giving 12 color bands in the 0.35 to 1.1 micron range; exposures through different filters can be combined to produce color images. The camera's field-of-view is 14 degrees in both horizontal and vertical directions, and it will be able to take one frame (256 by 256 pixels) every two seconds.

## **Sojourner Rover**

Sojourner, the small rover onboard Mars Pathfinder, is named after an African-American crusader, Sojourner Truth, who lived during the tumultuous era of the American Civil War and



*Mars Pathfinder flight system*



*Mars Pathfinder lander*

made it her mission to "travel up and down the land" advocating the rights of all people to be free. The name was chosen in July 1995 by a panel of judges from the Jet Propulsion Laboratory and the Planetary Society following a year-long, worldwide competition in which students up to 18 years old were invited to select heroines and submit essays about their historical accomplishments. The winning essay was submitted by Valerie Ambrose, now 14, of Bridgeport, CT. Sojourner Truth was shortened to Sojourner, which also means "traveler."

Sojourner with its mounting and deployment equipment weighed about 15.5 kilograms (34.2 pounds) at launch. Once it is mobile and operating on the Martian surface, it will weigh a mere 10.6 kilograms (23 pounds). The vehicle travels 1 centimeter (0.4 inch) per second and is about 65 centimeters (2 feet) long by 48 centimeters (1.5 feet) wide by 30 centimeters (1 foot) tall. During the cruise to Mars, it was folded in its stowage space and measured only 18 centimeters (7 inches) tall.

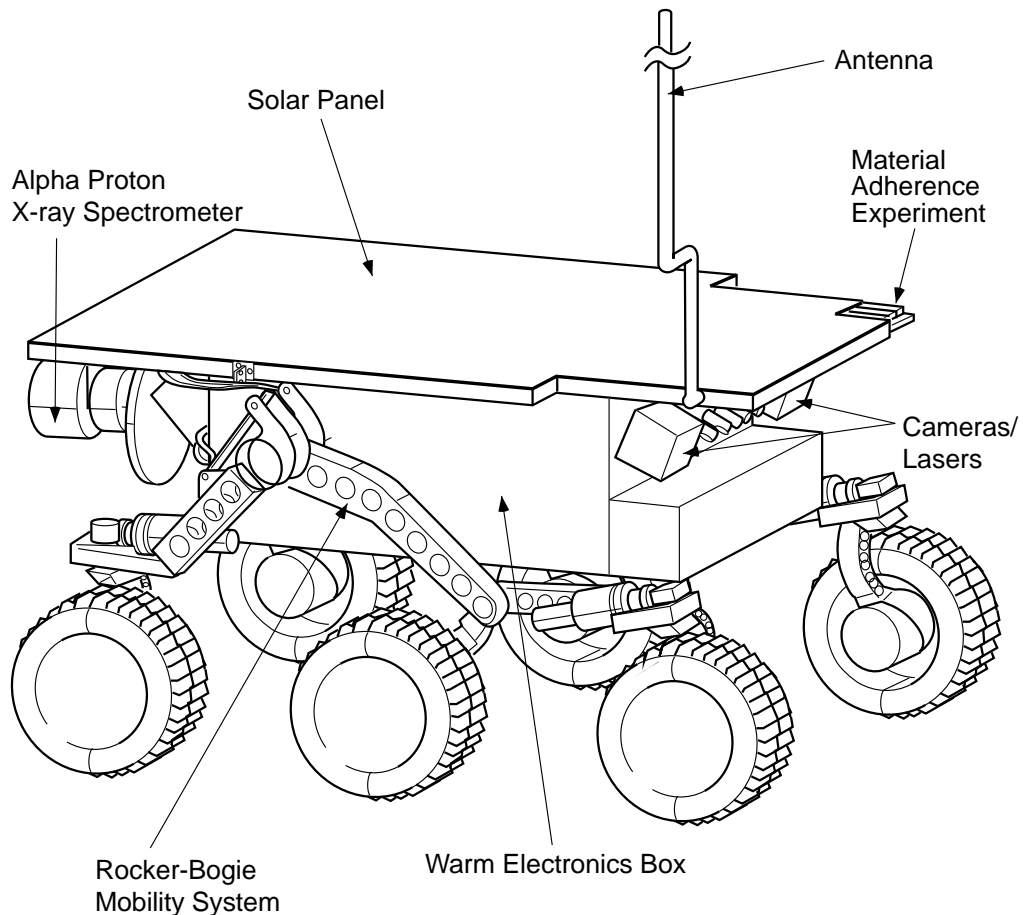
Equipped with three cameras -- a forward stereo system and rear color imaging system



-- the Sojourner rover will take several images of the lander to assess the lander's health. The cameras are used in conjunction with a laser system to detect and avoid obstacles.

Sojourner is powered by a 0.2-square-meter (1.9-square-foot) solar array, sufficient to power the rover for several hours per day, even in the worst dust storms. As a backup and augmentation, lithium thionol chloride D-cell-sized batteries are enclosed in the rover's thermally protected warm electronics box. Thermal insulation is provided by a nearly weightless material called silica aerogel. Three radioisotope heater units (RHUs) -- each about the size of a flash-light C-cell battery -- contain small amounts of plutonium-238 (about 2.6 grams (less than 1/10th ounce) each) which gives off about 1 watt of heat each to keep the rover's electronics warm.

The rover's wheels and suspension use a rocker-bogie system that is unique in that it does not use springs. Rather, its joints rotate and conform to the contour of the ground, providing the greatest degree of stability for traversing rocky, uneven surfaces. A six-wheel chassis was chosen over a four-wheel design because it provides greater stability and obstacle-crossing



*Mars Pathfinder's Sojourner rover*

capability. Six-wheeled vehicles can overcome obstacles three times larger than those crossable by four-wheeled vehicles. For instance, one side of Sojourner could tip as much as 45 degrees as it climbed over a rock without tipping over. The wheels are 13 centimeters (5 inches) in diameter and made of aluminum. Stainless steel tread and cleats on the wheels provide traction and each wheel can move up and down independently of all the others. Three motion sensors along Sojourner's frame can detect excessive tilt and stop the rover before it gets dangerously close to tipping over. Sojourner is capable of scaling a boulder on Mars that is more than 20 centimeters (8 inches) high and keep on going.

The rover also will perform a number of technology experiments designed to provide information that will improve future planetary rovers. These experiments include: terrain geometry reconstruction from lander/rover imaging; basic soil mechanics by studying wheel sinkage; path reconstruction by dead reckoning and track images; and vision sensor performance.

In addition, Sojourner experiments also will determine vehicle performance; rover thermal conditions; effectiveness of the radio link; and material abrasion by sensing the wear on different thicknesses of paint on a rover wheel. All rover communications is via the lander.

Scientists will study adherence of Martian airborne material by measuring dust accumulation on a reference solar cell that has a removable cover, and by directly measuring the mass of accumulated dust on a quartz crystal microbalance sensor.

The rover's control system calls for the human operator to choose targets and for the rover to autonomously control how it reaches the targets and performs tasks. The onboard control system is built around an Intel 80C85 processor, selected for its low cost and resistance to upsets from space radiation. It is an 8-bit processor which runs at about 100,000 instructions per second.

Sojourner also carries an alpha proton X-ray spectrometer which is placed in contact with rocks or soil to measure the elemental composition of the material being studied.

# Science Objectives

Mars Pathfinder carries a suite of instruments and sensors to accomplish a focused set of science investigations. These investigations include: studying the form and structure of the Martian surface and its geology; examining the elemental composition and mineralogy of surface materials, including the magnetic properties of airborne dust; conducting a variety of atmospheric science investigations, examining the structure of the atmosphere, meteorology at the surface, and aerosols; studying soil mechanics and properties of surface materials; and investigating the rotational and orbital dynamics of the planet from two-way ranging and Doppler tracking of the lander as Mars rotates.

In the first few days of the mission, the lander's stereo color imager will take several panoramic photographs of the Martian landscape. Scientists will use the imaging system to study Martian geologic processes and interactions between the surface and atmosphere. The imaging system will be able to observe the general physical geography, surface slopes and rock distribution of the surface so that scientists can understand the geological processes that created and modified Mars. Panoramic stereo imaging will take place at various times of the day, before and after the imager is deployed on its pop-up mast. In addition, observations over the life of the mission will reveal any changes in the scene over time that might be caused by frost, dust or redistribution of sand, erosion or other surface-atmosphere interactions.

The rover also will take closeup images of the terrain during its travels. A basic understanding of soil mechanics will be obtained by rover and lander imaging of rover wheel tracks, holes dug by rover wheels and any surface disruptions that have been caused by airbag bouncing and/or retraction.

The rover's alpha proton X-ray spectrometer -- along with spectral filters of the lander's imaging system and closeup images from the rover -- will measure the elemental composition of rocks and surface soil and infer their mineralogy. These data will provide a "ground truth" for orbital remote-sensing observations being obtained overhead by Mars Global Surveyor. Results will help scientists understand more about the crust of Mars, how it evolved into different feature types, and how weathering has affected surface features. The magnetic properties of airborne dust can also be investigated using a series of magnetic targets on the spacecraft.

During Pathfinder's entry and descent, an atmospheric instrument will profile the pressure, temperature and density of the atmosphere at various altitudes, beginning at 120 kilometers (about 75 miles) above the surface and continuing all the way down to the ground. After landing, a meteorology package records the weather. These weather data will be compared with the last data taken 20 years ago by the two Viking landers. Wind speed and direction will be determined by a wind sensor on top of the lander mast, along with three wind socks on the mast, to reveal more information about the forces present in the Martian atmosphere which act on small surface particles and draw them into the wind. Imaging of the atmosphere can be used to determine properties of aerosol particles such as their size, shape and distribution at different altitudes, as well as the abundance of atmospheric water vapor.

Orbital and rotational dynamics will be studied using two-way X-band ranging and Doppler tracking of the Mars Pathfinder lander by NASA's Deep Space Network. Ranging -- which is achieved by sending radio signals from Earth to the lander and back to Earth, then measuring the amount of time it takes to receive the returned signal -- will provide an accurate measurement of the distance from a tracking station on Earth to Ares Vallis. After a few months of such tracking, scientists expect to know the location of the Pathfinder lander to within a few meters (yards) of accuracy.

Once the location of the lander is known, the pole of rotation of the planet can be determined. Knowledge of the orientation of Mars' pole of rotation will allow scientists to calculate the planet's precession -- the gradual gyration of the planet's rotational axis over the course of many centuries that causes its north pole to point to different locations in space. Such information compared with the same measurement made by Viking should validate or disprove theories about Mars' interior, such as whether the planet has a metallic core, and shed new light on the forces which cycle volatiles such as water and carbon dioxide between the Martian atmosphere and its poles.

### **The Landing Site**

NASA selected an ancient flood plain on Mars as the Mars Pathfinder landing site. Called Ares Vallis, the rocky plain was the site of great floods when water flowed on Mars eons ago. The site -- at 19.4 degrees north latitude, 33.1 degrees west longitude -- is 850 kilometers (about 525 miles) southeast of the location of Viking Lander 1, which in 1976 became the first spacecraft to land on Mars. Pathfinder will be the first craft to land on Mars since the twin Viking landers arrived more than 20 years ago. The spacecraft will land in Ares Vallis at the mouth of an ancient outflow channel chosen for the variety of rock and soil samples it may present.

Some constraints on the location were the result of engineering considerations. Since the Mars Pathfinder lander and Sojourner rover are solar-powered, the best site would be one with maximum sunshine; in July 1997, the Sun is directly overhead at 15 degrees north Martian latitude. The location's elevation had to be as low as possible so the descent parachute would have sufficient time to open and slow the lander to the correct terminal velocity. The landing will be within a 100- by 200-kilometer (60- by 120-mile) ellipse around the targeted site due to uncertainties in navigation and atmospheric entry.

The importance of the landing site on the potential scientific return was the driving factor in the scientific community's choice of a landing site. In 1994, more than 60 scientists from the United States and Europe participated in a workshop to recommend a landing site for Pathfinder. More than 20 individual landing sites were proposed before Ares Vallis was chosen.

A number of potential sites were considered. Among them were Oxia Palus, a dark highlands region that contains highland crust and dark wind-blown deposits; Maja Valles Fan, a delta fan which drained an outflow channel; the Maja Highlands, just south of Maja Valles;

Isidis Planitia, a lowlands site; and Tritonis Lacus, in Elysium Planitia. All of the sites were studied using Viking orbiter and Earth-based radar data.

Ares Vallis met several general criteria. First, it was a "grab bag" location, set at the mouth of a large water outflow channel in which a wide variety of rocks would be potentially within reach of the rover. Even though the exact origins of the samples would not be known, since many rocks washed onto the plain from highlands in ancient floods, the chance to sample a variety of rocks in a small area could reveal much about Mars. In addition, scientists wanted to choose a site that contained highland rocks because they make up two-thirds of the crust of Mars. With highland samples, they would be able to address questions about the early evolution of both the crust and the Martian environment. This was of particular interest to exobiologists, who are interested in beginning their search for evidence of life -- extinct or existing -- by first surveying the rock types in the highlands to find out if Mars had an early environment that was suitable for the beginnings of life.

Once the site was selected, scientists fanned out until they found a geological site very similar to Ares Vallis on Earth which they could study firsthand. In September 1995, planetary scientists traveled to the Channeled Scabland, near the cities of Spokane and Moses Lake, in central eastern Washington State to examine landforms and geologic features created by one or more giant, catastrophic floods which swept through the area as the North American continent thawed from an ice age.

The Scabland formed when waters in glacial Lake Missoula with the volume of Lake Erie and Lake Ontario combined broke through a glacial dam and flooded the region in just two weeks. The flooding carved landforms and geologic features similar to those on Mars' Ares Vallis. The site was an ideal Earth-based laboratory for studying landing site conditions and testing rover mobility.

Mars Pathfinder is the first mission to characterize the rocks and soils in a landing area over hundreds of square meters (yards) on Mars. The new information will provide a calibration point or "ground truth" for remote-sensing observations taken by orbiters that are surveying the planet's surface.

## **Planetary Protection Requirements**

The United States is a signatory to the United Nation's Treaty of Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (12/19/66). Known as the "Outer Space Treaty," this document states in part that exploration of the Moon and other celestial bodies shall be conducted "so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter."

NASA policy establishes basic procedures to prevent contamination of planetary bodies. Different requirements apply to different missions, depending on which solar system object is targeted; the spacecraft or mission type (flyby, orbiter, lander, sample-return and so on); and the

importance of the object to the study of the origins of life. For some bodies such as the Sun, Moon and Mercury, there are no outbound contamination requirements. Current requirements for the outbound phase of missions to Mars, however, are particularly rigorous. Planning for planetary protection begins during pre-mission feasibility planning.

Planetary protection requirements called for Pathfinder's surfaces to contain a maximum of 300 spores per square meter (about 250 spores per square yard) and no more than 300,000 spores total for the entire spacecraft. To meet this requirement, the spacecraft was cleaned to the same level as the Viking landers before they were sterilized. Also by requirement, the final assembly of the spacecraft and its pre-launch processing were performed under special clean room conditions. Technicians continually cleaned the spacecraft throughout development by rubbing down surfaces with ethyl alcohol. Large surface areas, such as the airbags, thermal blankets and the parachute, had to be baked for about 50 hours at 110 degrees C (230 F). The spacecraft was checked constantly during processing at NASA's Kennedy Space Center in Florida and was given a final planetary protection inspection just before its integration with the Delta II launch vehicle.

The result of this effort was an exceptionally clean spacecraft. With the microbiological sampling and assays, the cleaned surfaces had a spore burden density of 43 spores per square meter. By analysis, the partially sterilized surfaces had even lower spore counts. The final total spore count by direct assay and by analysis was less than 24,000 spores.

## Science Experiments

Mars Pathfinder and its rover carry several science instruments that will image terrain in the vicinity of the landing site, explore the composition of rocks and make measurements of the Martian atmosphere. The payload of science instruments includes:

□ **Imager.** The camera on the lander is a stereo imaging system with color capability provided by a set of selectable filters for each of the two camera channels. It has been developed by a team led by the University of Arizona at Tucson, with contributions from the Lockheed Martin Corp., Max Planck Institute for Aeronomy in Katlenberg-Lindau, Germany, Technical University of Braunschweig in Germany and the Orsted Laboratory, Niels Bohr Institute for Astronomy, University of Copenhagen, Denmark. Principal investigator is Peter Smith, University of Arizona, Tucson, AZ.

The imager consists of three physical subassemblies: a camera head with stereo optics, filter wheel, charge-coupled device and pre-amplifier, mechanisms and stepper motors; an extendable mast with electronic cabling; and three plug-in electronics cards which plug into slots in the warm electronics box within the lander. Full panoramas of the landing site are acquired during the mission using the stereo baseline provided by the camera optics. Multispectral images of a substantial portion of the visible surface may be acquired with as many as 13 spectral bands.

A number of atmospheric investigations will be carried out using the imager.

Aerosol opacity is measured periodically by imaging the Sun through two narrow-band filters. Dust particles in the atmosphere are characterized by observing Phobos, one of Mars' moons, at night, as well as the Sun during the day. Water vapor abundance is measured by imaging the Sun through filters in the water vapor absorption band and in the spectrally adjacent continuum. Images of wind socks located at several heights above the surrounding terrain are used to assess wind speed and direction.

A magnetic properties investigation is included as part of the imaging investigation. A set of magnets of differing field strengths will be mounted to a plate and attached to the lander. Images taken over the duration of the lander mission are used to determine the accumulation of magnetic species in the wind-blown dust. Multispectral images of these accumulations may be used to differentiate among likely magnetic minerals.

The imaging investigation also includes the observation of wind direction and speed using wind socks that are located at various heights on a 1-meter-tall (40-inch) mast. The wind socks will be imaged repeatedly by the imager; orientations of the wind socks will be measured in the images to determine the wind velocity at three different heights above the surface. This information can then be used to estimate the aerodynamic roughness of the surface in the vicinity of the lander, and to determine the variation in wind speed with height. Because the Viking landers had wind sensors at only one height, such a vertical wind profile has never been measured on Mars.

This new knowledge will help to develop and modify theories for how dust and sand particles are lifted into the Martian atmosphere by winds, for example. Because erosion and deposition of wind-blown materials has been such an important geologic process on the surface of Mars, the results of the wind sock experiment will be of interest to geologists as well as atmospheric scientists.

□ **Alpha Proton X-ray Spectrometer.** This instrument is designed to determine the elements that make up the rocks and soil on Mars. It is a derivative of instruments flown on the Russian Vega and Phobos missions and identical to the unit that flew on the Russian Mars '96 landers, which were lost shortly after launch. Thanks to the mobility provided by the Mars Pathfinder rover, the alpha proton X-ray spectrometer can take not only spectral measurements of the Martian dust but, more importantly, may be moved to distinct rock outcroppings, permitting analysis of the native rock composition for the first time. The alpha and proton portions are provided by the Max Planck Institute for Chemistry, Mainz, Germany. The X-ray spectrometer portion is provided by the University of Chicago. Principal investigator is Dr. Rudolph Rieder of the Max Planck Institute for Chemistry; co-investigators are Dr. Thanasis Economou of the University of Chicago and Dr. Henry Wanke of the Max Planck Institute for Chemistry.

The instrument can measure the amounts of all elements present except hydrogen, as long as they make up more than about 1/10th of 1 percent of the mass of the rock or soil. The spectrometer works by bombarding a rock or soil sample with alpha particle radiation -- charged particles that are equivalent to the nucleus of a helium atom, consisting of two protons and two neutrons. The sources of the particles are small pieces of the radioactive

element curium-244 onboard the instrument. In some cases, the alpha particles interact with the rock or soil sample by bouncing back; in other cases, they cause X-rays or protons to be generated. The "backscattered" alpha particles, X-rays and protons that make it back into the detectors of the instrument are counted and their energies are measured. The number of particles counted at each energy level is related to the abundance of various elements in the rock or soil sample, and the energies are related to the types of elements present in the sample. A high-quality analysis requires about 10 hours of instrument operation while the rover is stationary; it may be done at any time of day or night.

Most of the instrument's electronics are located on the rover in a container called the warm electronics box. Cables run from that box to the instrument sensor head, which contains the radioactive sources and particle detectors. The instrument sensor head is held by a robotic arm attached to the back of the rover. This arm has a flexible "wrist" and can place the sensor head in contact with rocks and soil at various angles depending on how rough the rocks or soils might be. Sensors on a bumper ring attached to the sensor head indicate to the rover when adequate contact has been made with the sample rock or soil. When the sensor head is in position, it analyzes an area of rock or soil within a circle 5 centimeters (2 inches) across. Additional information about the rock or soil can be obtained by taking pictures of it using a small color camera on the back of the rover, or by rotating the rover and imaging it with stereo cameras on the front of the rover.

□ **Atmospheric Structure Instrument/Meteorology Package.** The atmospheric structure instrument and meteorology package -- or ASI/MET -- is an engineering subsystem which acquires atmospheric information during the descent of the lander through the atmosphere and during the entire landed mission. It is implemented by JPL as a facility experiment, taking advantage of the heritage provided by the Viking mission experiments. Dr. Alvin Seiff of San Jose State University, San Jose, CA, was the instrument definition team leader. The science team that will use the data acquired by the package is led by Dr. John T. "Tim" Schofield of JPL.

Data acquired during the entry and descent of the lander permit reconstruction of profiles of atmospheric density, temperature and pressure from altitudes in excess of 100 kilometers (60 miles) from the surface.

The accelerometer portion of the atmospheric structure instrument depends on the attitude and information management subsystem of the lander. It consists of sensors on each of three spacecraft axes. The instrument is designed to measure accelerations over a wide variety of ranges from the micro-g accelerations experienced upon entering the atmosphere to the peak deceleration and landing events in the range of 30 to 50 g's.

The ASI/MET instrument hardware consists of a set of temperature, pressure and wind sensors and an electronics board for operating the sensors and digitizing their output signals. Temperature is measured by thin wire thermocouples mounted on a meteorological mast that is deployed after landing. One thermocouple is placed to measure atmospheric temperature during descent; three more are located to monitor atmospheric temperatures at heights of 25, 50



and 100 centimeters (about 10, 20 and 40 inches) above the Martian surface after landing. Pressure is measured by a Tavis magnetic reluctance diaphragm sensor similar to that used by Viking, both during descent and after landing. The wind sensor employs six hot wire elements distributed uniformly around the top of the mast. Wind speed and direction 100 centimeters (about 40 inches) above the Martian surface are derived from the temperatures of these elements.

# What's Next?

One month before the launch of Mars Pathfinder, another Mars spacecraft called Mars Global Surveyor was launched toward the red planet. Mars Global Surveyor will reach Mars on September 12, 1997, and be captured in orbit after a 10-month journey to the planet.

At first, the spacecraft will be in a highly elliptical orbit and spend four months dipping into Mars' upper atmosphere using a technique called aerobraking to bring it into a low-altitude, nearly circular mapping orbit over the poles. This critical phase of the mission will be flown in a modified aerobraking configuration to accommodate a solar panel that is not fully deployed. The panel, one of two 3.5-meter (11-foot) wings, is tilted 20.5 degrees from its fully deployed position.

Shortly after launch, ground controllers discovered that a small damper arm -- part of the solar array deployment mechanism at the joint where the inboard panel is attached to the spacecraft -- broke during the panel's initial rotation during the first day of flight. The piece of metal became lodged in a 5-centimeter (2-inch) space in the shoulder joint at the edge of the solar panel.

After completion of a series of diagnostic activities in January and February 1997 to characterize the situation, the Surveyor flight team turned its attention to analyzing the possibility of carrying out the mission in the solar array's current configuration. In late April 1997, the JPL flight team, in collaboration with NASA Headquarters and its partners at Lockheed Martin Astronautics in Denver, decided to perform the aerobraking phase with the tilted solar panel rather than attempt some slight maneuvers to jiggle the debris free and allow the panel to lock in place.

Analysis of the situation indicates that the array, in its current state, will pose little risk to the aerobraking operations or the science goals of the mission. Using a two-axis gimbal drive assembly at the base of the solar array wing, the solar panel can be adjusted to the proper position for aerobraking and mapping. During aerobraking, the panel will be rotated 180 degrees so that the side with the solar cells faces into the direction of air flow as the spacecraft dips repeatedly into the Martian atmosphere.

Once in its mapping orbit, Mars Global Surveyor will complete one orbit around Mars about every two hours. Each new orbit will bring the spacecraft over a different part of Mars. As the weeks pass, the spacecraft will create a complete global portrait of Mars, capturing the planet's ancient cratered plains, huge canyon system, massive volcanoes, channels and frozen polar caps. During its mission, Mars Global Surveyor will pass over the terrain where the two U.S. Viking landers -- separated by more than 6,400 kilometers (4,000 miles) -- have rested for 22 years. The spacecraft also will be passing over the Mars Pathfinder lander and rover, which likely will no longer be operating by then.

By March 1998, Surveyor will be ready to begin data collection, compiling a

systematic database as it surveys the Martian landscape with multi-spectral measurements and high-resolution photographs of unique features, such as giant volcanoes, deep canyons, changing polar caps and Mars' network of sinuous, intertwining river channels. In addition, the spacecraft's altimeter will fire laser pulses that will measure the heights of Martian surface features.

Mapping will begin on March 15, 1998 and last until January 31, 2000 -- a period of one Martian year or 687 Earth days (almost two Earth years). The spacecraft will transmit its recorded data back to Earth once a day during a single 10-hour tracking pass by antennas of the Deep Space Network. During mapping operations, the spacecraft will return more than 600 billion bits of scientific data to Earth -- more than that returned by all previous missions to Mars and, in fact, roughly equal to the total amount of data returned by all planetary missions since the beginning of planetary exploration, with the exception of the Magellan mission to Venus.

Mars Global Surveyor, the first in NASA's decade-long program of robotic exploration, will study Mars' early history, geology and climate. The spacecraft, which will orbit Mars in a near-polar orbit that will take it over most of the planet, carries a suite of sophisticated remote-sensing instruments designed to create a global portrait of Mars by mapping its morphology, mineral composition, topography, magnetism and atmosphere. Some of the instruments are flight spares from experiments flown on Mars Observer, which was lost shortly before Mars arrival in 1993. With this comprehensive archive of the red planet, scientists will be able to address a multitude of questions surrounding the evolution of Mars.

# Program/Project Management

The Mars Pathfinder mission is managed by the Jet Propulsion Laboratory for NASA's Office of Space Science, Washington, DC. At NASA Headquarters, Dr. Wesley T. Huntress is associate administrator for space science. Joseph Boyce is Mars program scientist and program scientist for Mars Pathfinder. Kenneth Ledbetter is director of the Mission and Payload Development Division.

At the Jet Propulsion Laboratory, Norman Haynes is director for the Mars Exploration Directorate. Donna Shirley is manager of the Mars Exploration Program. For Mars Pathfinder, JPL's Anthony Spear is project manager and Brian Muirhead is flight system manager and deputy project manager. Richard Cook is mission manager and Dr. Matthew Golombek is project scientist.

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