NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mars Global Surveyor Arrival

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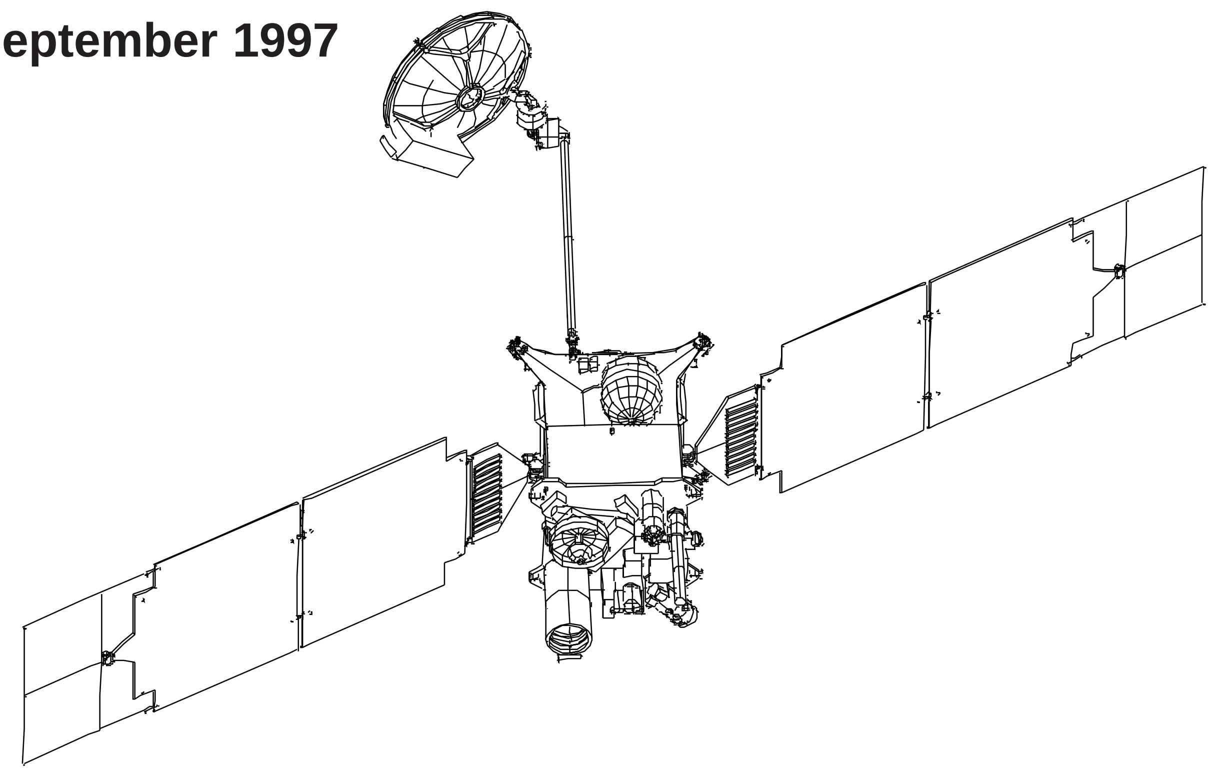

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RELEASE:

MARS GLOBAL SURVEYOR ON TARGET FOR ARRIVAL

NASA's Mars Global Surveyor, the first in a new series of spacecraft destined to explore the red planet, is preparing to intercept the orbit of Mars and begin a two-year mapping mission after a 10-month, 700-million-kilometer (435-million-mile) interplanetary journey.

The orbiter will fire its main engine beginning at 01:17 Universal Time on September 12 (6:17 p.m. Pacific Daylight Time September 11) for 22 minutes to slow its speed enough to be captured in orbit around the planet.

Mars Global Surveyor is a global mapping mission, carrying a suite of science instruments designed to study the entire Martian surface, atmosphere and interior. Measurements will be collected beginning in March 1998 from a low-altitude, nearly polar orbit 378 kilometers (234 miles) above the Martian surface over the course of one complete Martian year, the equivalent of nearly two Earth years.

"Throughout its primary, two-year mission, Mars Global Surveyor will gather information on the geology, geophysics and climate of Mars," said Glenn E. Cunningham, Global Surveyor project manager at NASA's Jet Propulsion Laboratory, Pasadena, CA.

"The mission will provide a global portrait of Mars as it exists today," he said. "This new view will help planetary scientists to better understand the history of Mars' evolution, and will provide clues about the planet's interior and surface evolution. With this information, we will have a better understanding of the history of all of the inner planets of the solar system, including our home planet, Earth."

Mars Global Surveyor continues NASA's long exploration of the red planet, which began more than 30 years ago with the Mariner 4 spacecraft that produced the first pictures of the planet's cratered surface. Following the successful landing of the Mars Pathfinder lander and rover on July 4, 1997, Mars Global Surveyor is the first in a multi-year series of missions called the Mars Surveyor program that will lead to eventual human expeditions to the red planet.

Mars Global Surveyor was launched at 12:00:49 p.m. Eastern Standard Time on November 7, 1996, atop a three-stage Delta II launch vehicle from launch pad 17A at Cape Canaveral Air Station, FL. The third-stage Star 48B solid rocket later propelled the spacecraft out of Earth orbit and on its way to Mars.

Once on course for the cruise to Mars, the spacecraft deployed its two solar panels to begin generating solar power. One of the solar panels did not fully deploy and is tilted about 20 degrees from its intended position; this is not, however, expected to pose a significant risk to the mission. The low-gain antenna was used for initial spacecraft communications, until the spacecraft was far enough away from Earth in early January 1997 to begin using its 1.5-meter-diameter (5-foot) high-gain antenna.

Mars Global Surveyor's six science instruments — the thermal emission spectrometer, laser altimeter, magnetometer/electron reflectometer, ultra-stable oscillator, camera and radio relay system — were calibrated during the cruise to Mars. Three trajectory correction maneuvers were performed to fine-tune the spacecraft's flight path. All spacecraft systems and the instrument payload performed well as Mars Global Surveyor headed for its destination, according to Joe Beerer, Global Surveyor flight operations manager.

When Surveyor reaches Mars, its 660-newton main engine will fire to slow the spacecraft's speed by more than 973 meters per second (2,176 miles per hour) with respect to Mars and allow the craft to be captured by Mars' gravity.

"Mars Global Surveyor will be flying over the north pole when it enters orbit around Mars," said Wayne Lee, Mars Global Surveyor mission planner. "The spacecraft will spend the first six days in this highly elliptical orbit around the planet, completing one orbit around Mars in about 45 hours, or just less than two days."

Instrument calibrations and some science measurements will take place during the elliptical orbit phase, said Dr. Arden Albee, Mars Global Surveyor project scientist.

“The spacecraft will be passing in and out of the planet’s magnetic field, if indeed Mars has one, during the early and larger elliptical orbits around the planet,” he said. “Global Surveyor will be able to make unique observations of interactions of magnetic field lines with the solar wind. In addition, it will make calibrations of the magnetometer and electron spectrometer that would not be possible from the lower-altitude mapping orbit.

“The thermal emission spectrometer and the camera will obtain initial observations on the surface and atmosphere of Mars,” Albee continued. “These will provide valuable insight into changes in the atmosphere that might affect the safety of the spacecraft during aerobraking operations.”

Six days after Mars arrival, the spacecraft will begin an innovative braking process, called aerobraking, to lower itself into a low-altitude mapping orbit. Aerobraking allows a spacecraft to use the drag of a planet's atmosphere to lower its orbit without relying on propellant. The technique was first tested in the summer of 1993, using the Magellan spacecraft orbiting Venus.

During each of its orbits shortly after Mars arrival, Mars Global Surveyor will pass through the upper fringes of the Martian atmosphere each time it reaches periapsis, the point in its orbit closest to the planet. Friction from the atmosphere will cause the spacecraft to be slowed slightly and lose some of its momentum during each orbit. Each time the spacecraft dips into the atmosphere, its one tilted solar panel will be rotated 180 degrees to protect it from folding up. As the spacecraft loses momentum, the apoapsis, or the point in its orbit farthest from

Mars, will also be lowered.

Trimming its orbit from the highly elliptical, 45-hour orbit to a nearly circular, two-hour orbit will take about four months. Five engine burns will accomplish the first orbital adjustments, lowering the periapsis (or closest point to Mars) from about 250 kilometers (156 miles) to about 112 kilometers (69 miles) above the surface.

Next, Mars Global Surveyor will spend about three months adjusting the farthest part of its orbit from 54,000 kilometeres (33,480 miles) to about 2,000 kilometers (1,240 miles). As the spacecraft's orbit is trimmed, the time it takes to make one complete revolution around Mars will diminish to less than three hours.

In the final three weeks of aerobraking, Global Surveyor will raise the closest part of its orbit once again, until it is circling Mars in a 350- by 410-kilometer (217- by 254-mile) orbit, very close to the final mapping orbit. With this adjustment, the spacecraft will be orbiting Mars about once every 118 minutes, and crossing Mars' equator at about 2 p.m. local solar time each orbit.

As the spacecraft continues to circularize its orbit, the 34-meter-diameter (112-foot) antennas of NASA’s Deep Space Network will be used to begin a navigation and radio science experiment, measuring small shifts in the spacecraft's velocity that will tell scientists more about the planet's gravity field.

All of the spacecraft's instruments will be turned on around March 10, 1998, and the mapping mission will begin on March 15. Data from this final checkout phase will allow the spacecraft to obtain one complete global map of the surface — a process that will take seven days — before the dust storm season begins in the spring.

"In 1998 the Martian dust storms occur roughly between February and August, so the atmosphere may be disturbed when mapping begins," Albee said. "But we may have an excellent opportunity to obtain data on the spread of a global Martian dust storm, should one occur next year."

In its final mapping orbit, Mars Global Surveyor will circle Mars at a speed of about 3.4 kilometers per second (7,600 miles per hour) in an orbit that will take it close to both poles. On the day side of the planet, Global Surveyor will be traveling from north to south. On each orbit, it will cross the equator at about 2 p.m. local mean solar time. The spacecraft will always see the surface of Mars on the daylit side as it appears at mid-afternoon. This “sun-synchronous” orbit puts the Sun at a standard angle above the horizon in each image.

Experiment teams will control their spaceborne instruments from their home institutions. Each 24 hours worth of data will be transmitted to Earth during daily, 10-hour tracking passes performed by NASA's Deep Space Network.

The Mars Global Surveyor mission is expected to yield more than 700 billion bits of scientific data, more than the amount of data returned by all previous Mars missions, and exceeded only by the Magellan Venus mission.

Mars Global Surveyor will examine the entire planet — from the ionosphere, an envelope of charged particles surrounding Mars, down through the atmosphere to the surface and deep into Mars' interior. Scientists will glean valuable new information on daily and seasonal weather patterns, geological features and the migration of water vapor from hemisphere to hemisphere over a complete Martian year.

As the primary mission winds down in late 1999, Global Surveyor will be used to relay data from microprobes penetrators beneath the surface of Mars that will have been deployed before arrival by the 1998 Mars Surveyor, and will be used as a backup relay platform for data from the Mars Surveyor '98 lander itself. Depending on its lifetime, Global Surveyor may also serve as a communications relay station for other spacecraft arriving at Mars.

Mars Global Surveyor is the first mission in a sustained program of robotic exploration of Mars, managed by the Jet Propulsion Laboratory, Pasadena, CA, for NASA's Office of Space Science, Washington, DC. JPL is a division of the California Institute of Technology.

[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. Television coverage of the Mars Global Surveyor orbit insertion begins at 5 p.m. Pacific Daylight Time on Sept. 11 and concludes at approximately 8:30 p.m. PDT, following a live news briefing. The schedule for NASA TV programming is 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 Mars Global Surveyor 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.

Briefings

A pre-arrival mission and science overview briefing, originating from the Jet Propulsion Laboratory, will be carried live on NASA TV at 10 a.m. Pacific Daylight Time on Tuesday, September 9. Status briefings will be held at 10 a.m. PDT Wednesday and Thursday, September 10-11. A post-arrival briefing will be held at 7:40 p.m. PDT Thursday, September 11. A briefing presenting initial science findings is tentatively scheduled the week of September 22-26.

Image Releases

Images returned by Mars Global Surveyor will be released to the news media in electronic format only during the mission. The images will be available in a variety of file formats from the JPL home page at **http://www.jpl.nasa.gov** . Images will also be distributed from the Mars Orbiter Camera principal investigator's web site at **http://www.msss.com** .

Internet Information

Extensive information on Mars Global Surveyor — including an electronic copy of this press kit, as well as news releases, fact sheets, status reports, spacecraft and science data and images — is available from the Jet Propulsion Laboratory's World Wide Web home page at **http://www.jpl.nasa.gov** . The Mars Global Surveyor Project also maintains a home page at **http://marsweb.jpl.nasa.gov** . Data from all of the mission's science instruments will be available on the home pages of each instrument's principal investigator; these addresses are linked to the Mars Global Surveyor project's home page.

Quick Facts

Spacecraft

Dimensions: Main structure 1.2 by 1.2 by 1.8 meters (4 by 4 by 6 feet); 12 meters (40 feet) across with fully deployed solar panels
Spacecraft mass at Mars arrival: 767 kg (1,691 lbs)
Science instruments: thermal emission spectrometer; laser altimeter; magnetometer/electron reflectometer; ultra-stable oscillator; camera; radio relay system
Solar arrays: 2 panels, each 3.5 meters (11 feet) long; power 980 watts maximum; cells composed of gallium arsenide and silicon
Radio: 25-watt transmitter, X-band (8 GHz)
High-gain antenna diameter: 1.5 meters (4.9 feet)

Launch/Cruise

Launch: 12:00:49 p.m. Eastern Standard Time (17:00:49 Universal Time) November 7, 1996, from Cape Canaveral Air Station, FL
Cruise: 10 months

Mars Orbit Insertion

Orbit insertion burn: Begins 01:17:16 and ends at 01:39:33 Universal Time on Sept 12, 1997 (6:17 p.m. to 6:39 p.m. Pacific Daylight Time Sept 11, 1997); duration 22 min, 17 sec
One-way speed of light time on arrival day: 14 minutes, 6 seconds
Time burn observed on Earth: Begins 6:31 p.m. and ends 6:53 p.m. PDT Sept 11, 1997
Mars-Earth distance on arrival day: 254.6 million km (158 million mi)
Change in velocity: 973 m/sec (2,176 mph)
Velocity before burn (with respect to Mars): 5.09 km/sec (11,386 mph)
Velocity after burn (with respect to Mars): 4.40 km/sec (9,842 mph)
Average deceleration due to burn: 7/100ths of 1 Earth G
Martian seasons at arrival: Fall in northern hemisphere, spring in south

Aerobraking and Mapping Mission

Period of aerobraking: Begins September 17, 1997; continues for 4 months
Period of initial elliptical orbit: 45 hours, plus or minus 3 hours
Final mapping orbit: period 117 min, mean altitude 378 km (234 mi), polar, sun-synchronous
Primary mapping mission: March 15, 1998 to January 31, 2000; covers 1 Martian year (687 Earth days)
Martian seasons when mapping begins: Winter in northern hemisphere, summer in south

Program

Development time: 26 months
Costs: $148 million pre-launch development; $52.6 million launch; $46.4 million mission ops
Spacecraft industrial partner: Lockheed Martin Astronautics, Denver, CO

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 6,794 kilometers (4,219 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 Earth is
- 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%)
- Surface atmospheric pressure 8 millibars (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 27 C (80 F) at equator during midday at closest point in orbit to Sun

Features

- Highest point is Olympus Mons, a huge shield volcano more than 15,900 meters (52,000 feet) high and 600 kilometers (370 miles) across; has 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 EDT)
Mars Global Surveyor, 11/7/96, orbiter, en route to orbit insertion 9/12/97 (9/11/97 EDT)
Mars 96, Russia, 11/16/96, orbiter and landers, failed during launch
Mars Pathfinder, U.S., 12/4/96, landed 7/4/97, lander and rover, fulfilled all science objectives

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 C (about 900 F). 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 about 25 kilometers (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 contributing 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 re-ignited 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 approximately 2-kilogram (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 could 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 could 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. campaign 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 fulfilling specific science goals, these missions are expected to pave the way for human exploration some time early in the next century.

By 2005, NASA will have launched a series 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.

The current plan for U.S. missions to Mars is listed below. 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 communication relay for the Mars Surveyor '98 microprobes and backup communication relay for the Mars Surveyor '98 lander. 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 (or miles) 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 (or miles) 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 Global Surveyor is a global mapping mission, designed to gather data on the atmosphere, surface and interior of Mars. Global data sets will enable scientists to determine Mars' current state and characterize its evolution. Among a myriad of science objectives, Mars Global Surveyor will study Mars' climate, surface topography and subsurface resources, and map the entire globe. Information from the mission will serve as a foundation for planning future robotic and human missions to Mars.

Launch

Mars Global Surveyor was launched at 12:00:49 p.m. Eastern Standard Time on November 7, 1996, atop a Delta II 7925A launch vehicle from launch pad 17A at Cape Canaveral Air Station, FL. The launch was delayed one day due to clouds and upper level winds on the first day of the launch period.

After liftoff, the first stage of the three-stage Delta rocket and the nine solid-fuel strap-on boosters lifted the spacecraft to an altitude of about 115 kilometers (70 miles) above Earth, and the Delta's second stage then boosted the payload into a circular parking orbit 185 kilometes (115 miles) above Earth. After achieving the parking orbit, the booster and spacecraft coasted for about 35 minutes, then fired to raise the apogee, or high point, of the parking orbit.

Small rockets were used to spin up the Delta's third stage and spacecraft to 60 rpm. The second stage was jettisoned and the third stage, a Star 48B solid rocket, was ignited to complete the trans-Mars injection burn and send Global Surveyor on its way to the red planet.

Solar panel deployment. About an hour after launch, the spacecraft's two 3.5-meter (11-foot) solar arrays were unfolded and a piece of metal called the "damper arm" on one of the panels was broken off during the deployment. (The damper arm is the part of the solar array deployment mechanism at the joint where the entire panel is attached to the spacecraft.) The metal fragment became trapped in the 50-millimeter (2-inch) space between the panel's shoulder joint and the edge of the solar panel, leaving the array about 19 degrees from its fully deployed position.

The damper arm connects the panel to a device called the "rate damper," which functions in much the same way as the hydraulic closer on a screen door acts to slow the speed at which the door closes. In Global Surveyor's case, the rate damper was used to slow the motion of the solar panel as it unfolded from its stowed position.

The operations team studied the problem with engineering data and computer-simulated models over the next two weeks. Two strategies for correcting the problem emerged. The first involved performing several slight maneuvers using the spacecraft's electrically driven solar array positioning actuators to try to gently shake the array and free the trapped debris. These maneuvers were carried out in January and February 1997, to no avail.

The second strategy was to reconfigure the solar panel during aerobraking so that the unlatched side of the panel would not be facing into the direction of the air flow and at risk of folding up on itself. The solar arrays are essential to the aerobraking technique and will be used to provide the drag surface that will slow the spacecraft's orbital speed, transforming its initial elliptical orbit into the final, circular mapping orbit. The technique allows Global Surveyor to carry considerably less fuel to Mars and take advantage of the planet's atmospheric drag to lower itself into the correct orbit.

After testing and analysis, the flight team determined that aerobraking could be safely accomplished by rotating the panel 180 degrees, turning the panel's solar-cell side into the flow of wind each time the spacecraft dips into the Martian atmosphere. By turning the panel's solar-cell side into the direction of the air flow, force will be exerted on the debris that is lodged in the hinge. The force of the air flow on the opposite side of the panel will insure the panel does not close up, and may possibly exert enough force to snap the panel into the latched position.

Cruise

The spacecraft spent 309 days en route to Mars, following what navigators call a Type 2 trajectory. This type of flight path took the spacecraft more than 180 degrees around the Sun and, compared with other types of trajectories, is a slower way to reach Mars. Because the spacecraft has been traveling at a slower velocity, however, it will require less propellant to slow down once it is ready to be captured in orbit around the destination planet.

On the first part of its flight, all spacecraft communications with Earth occurred through Global Surveyor's broad-beam, low-gain antenna. The dish-shaped, narrow-beam high-gain antenna sat on the spacecraft in a stowed, body-fixed orientation during cruise, making communications with Earth through the high-gain antenna impossible unless the spacecraft was turned to point the high-gain antenna directly at Earth.

Outer cruise began on January 9, 1997, when the spacecraft switched from the low-gain to the high-gain antenna for communications with Earth. The switch-over became feasible when the angle between the Sun and Earth as seen from the spacecraft fell to a level low enough to allow the solar panels to collect adequate power while pointing the antenna at Earth.

Three trajectory correction maneuvers were performed along the trip to Mars to fine-tune the spacecraft's flight path. These thruster firings were performed on November 21, 1996, March 20, 1997, and August 25, 1997. Another maneuver had been scheduled for April 21, 1997, but was not necessary and, hence, not performed.

During the last 30 days of approach to Mars, the flight team focused on final targeting of the spacecraft to the proper aim point, and preparations for orbit insertion. On August 19 and 20, the spacecraft's camera took a series of eight images of Mars, at a distance of 5.5 million kilometers (3.4 million miles). With a resolution of about 20 kilometers (12.5 miles) per picture element, these images were processed to create a movie of the planet as it rotated.

Mars Orbit Insertion

Mars Global Surveyor will perform an attitude reorientation maneuver once it reaches the orbit of Mars to turn the spacecraft's main engine toward the direction of its motion, or toward Mars. Then the spacecraft will fire its 660-newton main engine for approximately 22 minutes, 17 seconds, to slow down. The burn will begin at 01:17:16 and conclude at 01:39:33 Universal Time (UT) September 12, 1997 (6:17 to 6:39 p.m. September 11, 1997 Pacific Daylight Time (PDT)). Because it takes 14 minutes, 6 seconds for radio signals to travel from Mars to Earth on arrival day, the beginning and end of the burn will be detected on Earth at 6:31 and 6:53 p.m. PDT, respectively.

Telecommunications with the spacecraft will cease 9 minutes into the burn as Mars Global Surveyor passes behind Mars as seen from Earth. This occultation will last 14 minutes. NASA's Deep Space Network tracking facilities in California and Australia will regain communications with Global Surveyor at 01:57:00 UT (6:57 p.m. PDT), when the spacecraft reemerges from behind Mars.

By completion of the burn, the spacecraft will have slowed down by about 973 meters per second (2,176 miles per hour) with respect to Mars. Global Surveyor will be in a highly elliptical orbit, completing one revolution around Mars every 45 hours, plus or minus 3 hours.

Aerobraking

Selection of the less expensive Delta II booster in order to stay within program costs placed mass limitations on Mars Global Surveyor and prevented it from carrying enough propellant to Mars to directly achieve a low-altitude mapping orbit. An innovative, mission-enabling braking technique known as aerobraking was chosen instead to trim the spacecraft's initial, highly elliptical capture orbit and lower it to a nearly circular mapping orbit.

The Magellan spacecraft at Venus was the first planetary spacecraft to try aerobraking, as a demonstration, in the summer of 1993. The success of this demonstration cleared the way for its implementation in the Mars Global Surveyor mission design.

Global Surveyor's use of aerobraking will differ from that performed with the Magellan spacecraft in two important ways. First, Global Surveyor must aerobrake before it can start its primary mapping mission, whereas Magellan tested aerobraking as an engineering demonstration at the conclusion of its mission. Consequently, Global Surveyor's mission objectives are dependent on successfully aerobraking through the Martian atmosphere until the proper mapping orbit is achieved. Not only must aerobraking be successful, but it must be accomplished so that the spacecraft crosses the equator within a few minutes of 2 p.m. local solar time each orbit. This is called a “sun-synchronous” orbit. These two elements of the aerobraking phase make the Mars Global Surveyor's navigation by far the most challenging of the planetary missions to date.

Mars Global Surveyor
Orbit Insertion Timeline

Thursday, September 11, 1997
All times are Earth-received, Pacific Daylight Time

12:40 p.m.	Deep Space Station 14 at Goldstone, CA, begins tracking
12:40	Deep Space Station 15 at Goldstone, CA, begins tracking
4:31	Gyro #2 turned on
4:35	Deep Space Station 43 in Australia begins tracking
4:35	Deep Space Station 45 in Australia begins tracking
5:01	Spacecraft begins loading maneuver control parameters
5:17	Deep Space Station 15 transmitter off
5:31	Spacecraft begins maneuver command block
5:55	Spacecraft transmitter switches from high-gain antenna to low-gain antenna #1
5:55	Spacecraft's telemetry turned off; transmits only carrier signal
~5:59	Deep Space Stations re-acquire signal
6:01	Thrusters enabled for steering and attitude control during orbit insertion
6:14	Spacecraft starts turn to align rocket engine in burn direction
6:15	Solar arrays begin turning to orbit insertion orientation
6:29	Inertia measurement unit set to supply accelerometer data
6:30	Fuel and oxidizer valves enabled and armed
6:31	Main engine burn begins
6:40	Deep Space Station 45 transmitter on
6:43	Spacecraft passes behind Mars; radio signal lost
6:44	Closest approach to Mars (periapsis #1)
6:53	Main engine burn ends
6:55	Attitude control returned to reaction wheels
6:55	Spacecraft turns to Earth point and resumes array-normal-spin attitude
6:56	Solar arrays moved to array-normal-spin position
6:57	Spacecraft emerges from behind Mars
~6:57 - 7:03	Deep Space Stations acquire spacecraft carrier signal
7:10	Spacecraft transmitter switches from low-gain antenna to high-gain antenna
7:10	Spacecraft resumes transmitting telemetry (data)

During each of its orbits shortly after Mars arrival, the spacecraft will pass through the upper fringes of the Martian atmosphere each time it reaches periapsis, the point in its orbit closest to the planet. Friction from the atmosphere will cause the spacecraft to slow slightly and lose some of its momentum during each orbit. Loss of momentum will lower the spacecraft's apoapsis, or the point in its orbit farthest from Mars.

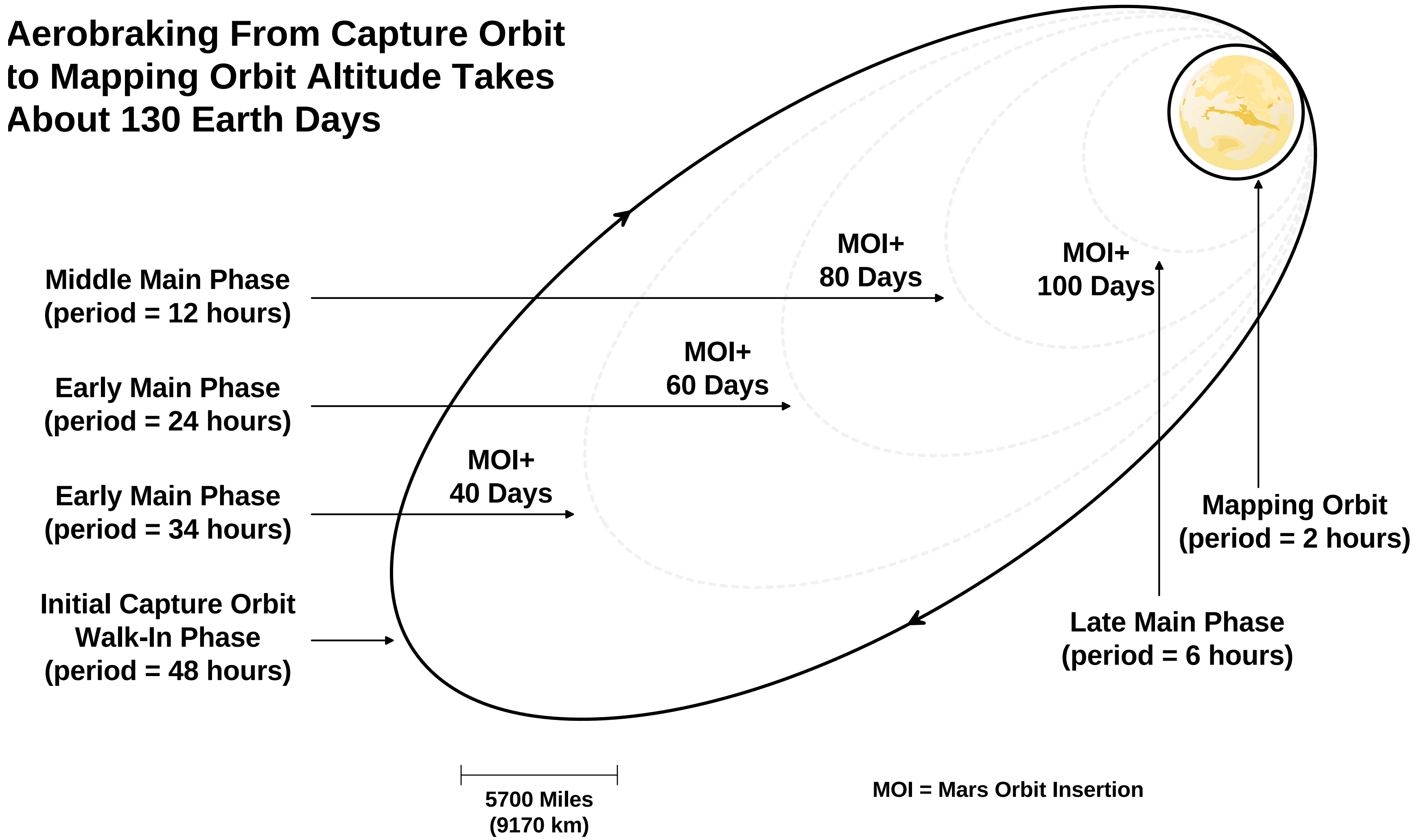
Aerobraking will take place over four months, beginning with an initial "walk-in" phase. After the spacecraft is captured in a 45-hour (plus or minus 3 hours) elliptical orbit around Mars, its apoapsis and periapsis will be gradually adjusted as scientists and engineers learn more about the density of Mars' upper atmosphere. The flight team will be able to gauge atmospheric density and variations from one orbit to another, while the spacecraft is tracked continuously by the 34-meter-diameter (112-foot) antennas of NASA's Deep Space Network, which are designed to both transmit and receive X-band signals.

In the initial walk-in phase, the spacecraft's closest pass over Mars will be lowered from the capture orbit of 250 kilometers (156 miles) above the surface to about 112 kilometers (69 miles) above the surface. This will be done with a series of five propulsive maneuvers, using the spacecraft's thrusters. The first of these propulsive burns, scheduled to take place on September 16, will be the largest and drop the spacecraft's periapsis altitude to 150 kilometers (93 miles). The next four burns, occurring on September 18, 20, 22 and 24, will lower the spacecraft gradually to the 112-kilometer (69-mile) aerobraking altitude.

After completion of the walk-in phase, the spacecraft will spend about three months in the main phase of aerobraking. During this time, Global Surveyor's apoapsis altitude of 54,000 kilometers (33,480 miles) will be dropped to about 2,000 kilometers (1,240 miles). As the spacecraft's orbit is trimmed, the time it takes to make one complete revolution around Mars will drop to less than three hours.

The final three weeks of aerobraking constitute the "walk-out" phase and will reduce the spacecraft's apoapsis to 450 kilometers (279 miles) above the surface of Mars. As Global Surveyor lowers its apoapsis, it will also use its thrusters to gradually raise its periapsis from 112 kilometers (69 miles) to 143 kilometers (89 miles) above the surface. By doing so, the spacecraft will be slowly "walking out" of the atmosphere during each closest approach to Mars. Adjustments in both the farthest and closest points in Mars Global Surveyor's orbit around the planet will be reshaping its flight path from highly elliptical to a nearly circular orbit.

Aerobraking will end with a termination burn performed on about January 18, 1998. This burn will raise Global Surveyor's periapsis one final time, from 143 kilometers (89 miles) to approximately 450 kilometers (279 miles) above the surface of Mars. The spacecraft will then be circling Mars in a 400- by 450-kilometer (248- by 279-mile) orbit, just slightly off from its final mapping orbit. By then Global Surveyor will be orbiting Mars about once every 118 minutes, and crossing Mars' equator at just about 2 p.m. local solar time each orbit.



Mars Global Surveyor aerobraking orbits

Mars Global Surveyor will begin aerobraking in the southern spring, and the historical record of global dust storms suggests that this is the most likely season for such storms to occur. During these storms, the dust itself is not of concern, since there is no evidence that it reaches anywhere near the altitudes at which aerobraking will occur. Scientists are more concerned with the possible increase in atmospheric density at the aerobraking altitude that could be caused by increased heating due to a dustier atmosphere in general.

Data from the highly successful Mars Pathfinder mission provided valuable new information about the density of the Martian atmosphere all the way up to about 120 kilometers (75 miles), which will be used to update the atmospheric models before the start of the Mars Global Surveyor aerobraking phase. Pathfinder also recorded dust activity and pressure and temperature fluctuations during its primary mission in July 1997. If Pathfinder’s lander and rover are still operating by the time Mars Global Surveyor arrives at Mars, surface temperature, pressure and opacity measurements will be monitored to help the Global Surveyor navigation team adjust the spacecraft's orbit.

Several measurements will also be made from the Hubble Space Telescope and from Earth. Hubble will take multiple images of Mars near the start of the aerobraking phase, before Mars gets too close to the Sun as viewed from Earth. Hubble images taken during the week before Pathfinder landed showed local dust activity near the landing site in Ares Vallis. When combined with Earth-based observations made at the Space Science Institute in Boulder, CO, using the National Radio Astronomy Observatory microwave antenna, these measurements will yield a global average atmospheric temperature profile from the ground to about 60 kilometers (35 miles) above the surface.

Scientists have been able to infer that moisture in the atmosphere usually confines Martian dust to lower altitudes, where it has a minimal impact on the densities at higher altitudes. As Mars gets closer to the Sun, atmospheric temperatures rise, along with water vapor content, and allow dust to circulate at higher altitudes. The Hubble and radio astronomy microwave observations will be used to keep a close eye on the Martian atmosphere during aerobraking, not only because the spacecraft's periapsis will have to be raised to survive the effects of a global dust storm, but also because the aerobraking phase coincides with the first half of the dust storm season.

Mars Global Surveyor will also be dipping repeatedly into the Martian atmosphere in a different configuration than was originally planned. Because one of the spacecraft's two solar panels did not fully deploy and latch into place after launch, it is tilted at about 20 degrees from its fully deployed position. After careful analysis, engineers determined that the only risk posed by the tilted panel was the possibility that the panel might fold up on itself if enough wind flow was exerted.

To minimize that risk, the operations team will rotate the unlatched panel 180 degrees each time the spacecraft encounters the strongest air flow, which will be at periapsis. By rotating the panel and turning its solar-cell side into the direction of the air flow, the latch will not be in danger of folding up. The air flow, when exerted on the opposite side of the latch, may, in fact, push the array into the fully locked position. Whether or not that is accomplished, Global Surveyor's new aerobraking configuration does not pose significant risk to the science objectives of the mission.

Science During Aerobraking

Early science measurements conducted during aerobraking will provide the navigation team with enough information to perform alternative aerobraking strategies should the situation arise. Scientists will benefit from new observations of Mars achieved with unique lighting geometry from Global Surveyor's aerobraking orbit. The spacecraft's low-altitude passes will allow scientists to record information from much closer to the planet than will be possible during the mapping period. This 4-1/2-month transition will also give experiment teams time to calibrate their instruments and prepare for continuous mapping operations.

The Mars orbital camera will image the surface of Mars at low Sun elevations between 15 degrees north latitude and 45 degrees south latitude, as the spacecraft slowly unwinds from the aerobraking attitude. Image swaths taken over 100 orbital revolutions will yield more than 5,000 pictures at five times the surface resolution of Viking orbiter imaging.

Data from the thermal emission spectrometer will include 100 atmospheric profiles of temperature and dust content at an unprecedented altitude of about 100 kilometers (60 miles). This will be followed each orbit by mid-latitude infrared measurements with a resolution of 30 to 40 kilometers (19 to 25 miles). In addition, daily global coverage of thermal and compositional properties will be recorded at a resolution of about 300 to 400 kilometers (185 to 250 miles) resolution, in association with unique local times of day and seasons.

As the elliptical orbit shrinks, the magnetometer will complete its primary science objective of determining the existence of a global magnetic field and measuring solar wind interaction with Mars' magnetopause, the boundary beyond which Mars no longer influences space. The electron reflectometer portion of this experiment will observe electron density variations in the ionosphere at the lowest altitude during its two months of operation.

Pointing down at the planet, the laser altimeter will have a unique opportunity during the spacecraft's closest approach to the planet on its third orbit after arrival to obtain a 600-kilometer (373-mile) swath, centered at 30 degrees north latitude, with 200 meters (655 feet) of spatial resolution and 2 meters (6.5 feet) of altitude precision. This orbit also permits the only forward/aft viewing by the thermal emission spectrometer prior to mapping the planet at 5:30 p.m. local solar time.

Finally, as the spacecraft’s orbit is adjusted to achieve a periapsis of 200 kilometers (124 miles) from the surface, the radio science team will see a fourfold improvement in the sensitivity of their measurements when Global Surveyor flies over features known to produce gravity variations, such as the south polar cap.

The Mapping Mission

The final mapping orbit will be nearly circular, at 350 by 410 kilometers (217 by 254 miles), or an average of 378 kilometers (234 miles) above the planet's surface.

After the mapping orbit is achieved, spacecraft systems will be deployed and instruments will be checked out over the next 10 days.

The primary mission begins once the spacecraft has reached its mapping orbit and is completing 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 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 21 years, and over Ares Vallis, home of the Mars Pathfinder lander (or Carl Sagan Memorial Station) and the Sojourner rover.

The primary mapping mission 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 700 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.

As Mars rotates beneath the spacecraft, a suite of onboard instruments will record a variety of detailed information. Detectors will measure radiation — visible and infrared — from the surface to deduce the presence of minerals that make up Mars. These same instruments will record infrared radiation from the thin Martian atmosphere, gathering data about its changing pressure, composition, water content and dust clouds. By firing short pulses of laser light at the surface and measuring the time the reflections take to return, a laser altimeter will map out the heights of Mars' mountains and the depths of its valleys.

The camera system will use wide- and narrow-angle lenses to record land forms and atmospheric cloud patterns. Another sensor will look for a Martian magnetic field. As the telecommunications subsystem transmits information back to Earth, engineers will use the signal of the orbiting spacecraft to derive data about the planet's atmosphere and gravitational field.

By the time global mapping operations are over, Mars Global Surveyor will have obtained an extensive record of the nature and behavior of the Martian surface, atmosphere and interior. Such a record will aid in planning more specialized explorations that might involve robots, scientific stations deployed to the Martian surface, sample return missions and perhaps even human landings. Just as importantly, this record will help scientists understand planet Earth and what the future might have in store for humanity.

Mission Operations

Throughout the two years of Mars Global Surveyor's mapping mission, principal investigators, team leaders and interdisciplinary scientists will have science operations planning computers at their home institutions. All will be electronically connected to the project database at the Jet Propulsion Laboratory in Pasadena, CA, giving them direct involvement in mission operations.

Their computers will be equipped with software that allows the science teams to remotely initiate most of the commands required by their instruments to conduct desired experiments. The teams will be able to access raw science data within hours of their receipt on Earth. This automated operation will provide "quick-look" science data and let investigators easily monitor the health and performance of their instruments.

Many images and other data will be immediately available to the public on the Internet. After a short period of data validation, science data, both raw and processed, along with supplementary processing information and documentation, will be transferred to NASA's Planetary Data System archive for access and use by the broader planetary science community and the general public.

Control and operation of Mars Global Surveyor will be performed by a team of engineers located at JPL and at Lockheed Martin Astronautics Inc. in Denver, CO. Engineers in Denver will be electronically linked to JPL, providing monitoring and analysis of Mars Global Surveyor based on telemetry received from the spacecraft through NASA's Deep Space Network. The team will also develop the sequence of commands that will be sent to the spacecraft via the Deep Space Network. The electronic networking eliminates the costs of relocating mission operations team members during the mission.

The Spacecraft

The main component of the Mars Global Surveyor spacecraft is a rectangular body, or bus, that houses computers, the radio system, solid-state data recorders, fuel tanks and other equipment. Attached to the outside of the bus are several rocket thrusters, which are fired to adjust the spacecraft's path during the cruise to Mars and to modify the spacecraft's orbit around the planet.

At launch, the spacecraft weighed 1,060 kilograms (2,337 pounds), including the science payload and fuel, and stands about 3 meters (10 feet) tall. The bus or main body of the spacecraft measures 1.2 by 1.2 meters (4 by 4 feet) and is 12 meters (40 feet) across from tip to tip when the solar panels are fully unfolded. The high-gain antenna, deployed in the cruise phase, measures 1.5 meters (4.9 feet) in diameter. The high-gain antenna will be deployed on a 2-meter-long (6-1/2-foot) boom.

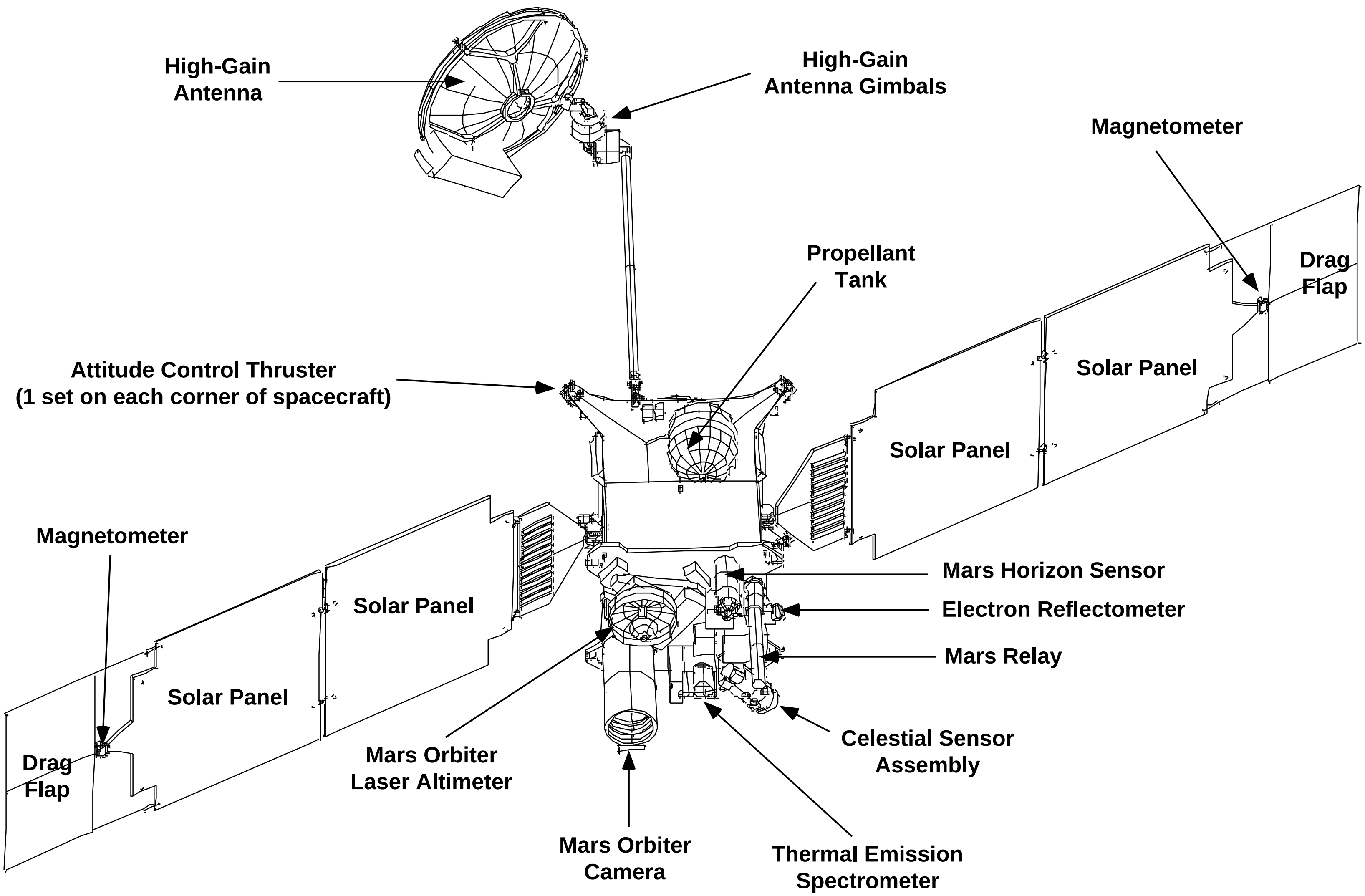
To minimize costs, spare units left over from the Mars Observer mission were used in portions of the spacecraft's electronics and for some of the science instruments. The spacecraft design also incorporates new hardware — the radio transmitters, solid state recorders, propulsion system and composite material bus structure.

Mars Global Surveyor will orbit the planet so that one side of the bus, called the nadir deck, always faces the Martian surface. Of the six science instruments, four — the Mars orbiter camera, the Mars orbiter laser altimeter, the electron reflectometer and the thermal emission spectrometer — are attached to the nadir deck, along with the Mars relay radio system. The magnetometer sensors are mounted on the ends of the solar arrays.

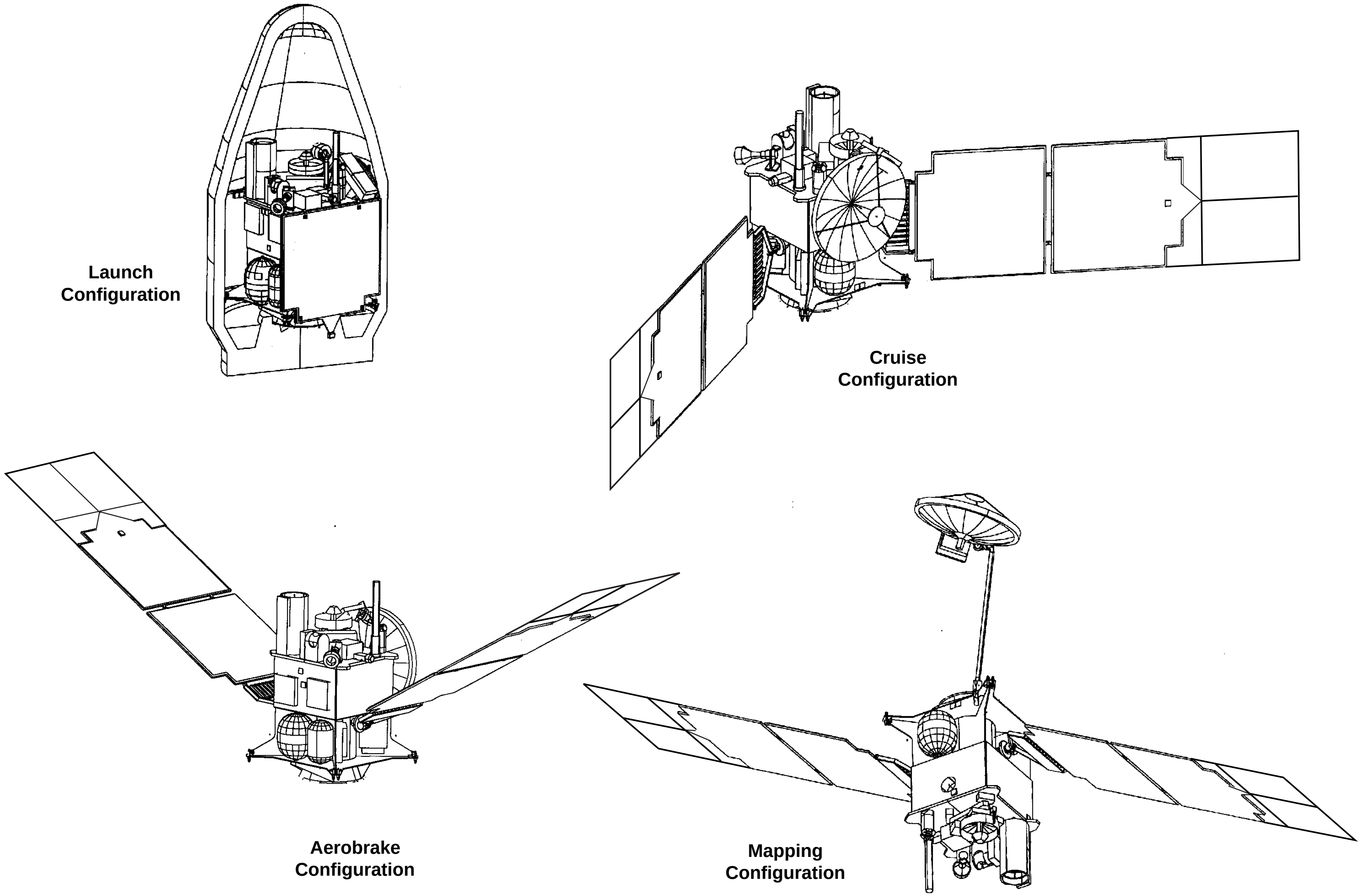
The bus has two solar-array wings and a boom-mounted high-gain communications antenna. The solar arrays, which always point toward the Sun, provide 980 watts of electricity for operating the spacecraft's electronic equipment and for charging nickel hydrogen batteries. The batteries will provide electricity when the spacecraft is mapping the dark side of Mars. To maintain appropriate operating temperatures, most of the outer exposed parts of the spacecraft, including the science instruments, are wrapped in thermal blankets.

In its mapping configuration, the dish-shaped high-gain antenna is deployed on the end of a 2-meter (6-1/2-foot) boom so that its view of Earth will not be blocked by the solar arrays as the spacecraft orbits Mars. Measuring 1.5 meters (4.9 feet) in diameter, this steerable antenna will be pointed toward Earth even though the spacecraft's position will be continuously adjusted during mapping to keep the nadir deck pointed toward Mars. The spacecraft's radio system, including the high-gain antenna, also will function as a science instrument. Researchers will use it in conjunction with NASA's Deep Space Network ground stations for the radio science investigations.

Spacecraft communications with Earth will always utilize X-band frequencies for radio tracking, return of science and engineering telemetry, commanding and the radio science experi-



Mars Global Surveyor spacecraft



Mars Global Surveyor configurations

ments. However, the spacecraft's telecommunications equipment also accommodates Ka-band downlink, which was furnished as an experiment to demonstrate its feasibility for future missions. Primary communications to and from the spacecraft occur through the 1.5-meter-diameter (4.9-foot) high-gain antenna.

From launch through the aerobraking operations, the high-gain antenna remains fixed to one side of the spacecraft, and the spacecraft must be slewed to point the antenna directly toward Earth for communications. Just before the start of mapping, the high-gain antenna will be deployed on the end of a 2-meter (6.5-foot) boom mounted to the same side of the spacecraft. This configuration will allow the antenna to automatically track Earth by using two gimbals that hold the antenna to the boom.

In addition to the high-gain antenna, the spacecraft also carries four low-gain antennas that could be used in the event ground-controllers lose the signal from the high-gain antenna. Two of these low-gain antennas function as transmit antennas, while the other two can receive signals from Earth. Placement of these four low-gain antennas insures that the spacecraft can receive commands and transmit downlink telemetry in a wide range of orientations in space.

The spacecraft's 25-watt radio frequency amplifiers allow Global Surveyor to transmit science and engineering telemetry at data rates between 21,333 symbols per second to 85,333 symbols per second. A symbol is specially encoded bit. It takes approximately 1.147 bits of storage space to encode one bit of raw data with this particular encoding scheme.

Data rates for sending commands to the spacecraft will vary from as low as 7.8 bits per second using the low-gain antennas to as high as 500 bits per second using the high-gain antenna. The standard date rate is 125 bits per second. Global Surveyor can receive instructions from Earth at a maximum rate of 12.5 commands per second.

Science Objectives

Mars Global Surveyor is designed to provide a detailed, global map of Mars that will allow scientists to study its geology, climate and interior. Key science objectives are to:

- ❑ Characterize the surface features and geological processes on Mars.

- ❑ Determine the composition, distribution and physical properties of surface minerals, rocks and ice.

- ❑ Determine the global topography, planet shape and gravitational field.

- ❑ Establish the nature of the magnetic field and map the crustal remnant field. (A crustal remnant field is evidence of magnetism that is detected within the planet's crust or rocks, produced by the planet's own magnetic field at the time of formation.)

- ❑ Monitor global weather and the thermal structure of the atmosphere.

- ❑ Study interactions between Mars' surface and the atmosphere by monitoring surface features, polar caps that expand and recede, the polar energy balance, and dust and clouds as they migrate over a seasonal cycle.

Among the questions scientists wish to answer are those relating to Mars' early atmosphere and the dramatic climate changes which sent the planet into a deep freeze. All the ingredients necessary for life exist on Mars, including water, yet the surface of Mars is totally dry and probably devoid of life today.

Water is fundamental to the understanding of geological processes and climate change. But water cannot exist in liquid form at the low atmospheric pressures that currently prevail on the surface of Mars; it turns into water vapor or ice. Spacecraft have photographed numerous large and fine channels across the surface of Mars, with shapes and structures that indicate, almost beyond a doubt, that they were carved by running water. Where has the water gone? Only a tiny fraction is known to exist in the northern polar cap and in the atmosphere.

Some of it may have escaped into space, but scientists believe that most of it should have remained on Mars. They want to know if water could be hidden in permafrost — thick layers of ice-rock — beneath the surface, just as it is trapped in the polar regions on Earth. The origin and evolution of Mars are still a mystery. Thought to have formed 4.6 billion years ago, in much the same way as the other rocky planets of the inner solar system, Mars has two distinct hemispheres, roughly divided by the equator. The southern hemisphere is badly battered, perhaps the result of an intense bombardment by debris as the planet was forming. This part of Mars may be closest in history and age to the heavily cratered faces of the Moon and Mercury. Other regions of Mars may be widespread plains of volcanic lava, which erupted from within the planet over a long period of time. Similar eruptions spread across Earth's Moon to form the dark areas known as lunar maria, or "seas."

During the last 2 billion or 3 billion years, Mars also developed features that resemble those of Earth rather than the Moon. Geologic activity in the younger, northern hemisphere created huge, isolated volcanoes — most notably Olympus Mons and the other volcanoes along the Tharsis uplift — as the interior of Mars melted and lava rose to the surface. A huge canyon just below the Martian equator, called Vallis Marineris, would dwarf Earth's Grand Canyon, stretching 5,000 kilometers (3,100 miles) across the planet's surface. Many sinuous channels, apparently cut by running water that may have flooded regions of Mars hundreds of millions of years ago, also appear in the northern hemisphere.

Science Experiments

Mars Global Surveyor carries a complement of six scientific instruments which have been furnished by NASA centers as well as universities and industry. They are:

❑ **Thermal Emission Spectrometer**. This instrument will analyze infrared radiation from the surface. From these measurements, scientists can determine several important properties of the rocks and soils that make up the Martian surface: how hot and cold they get during the cycles of night and day; how well they transmit heat; the distribution of rock and grain sizes; and the amount of the surface covered by large rocks and boulders. Scientists will also be able to identify minerals in solid rocks and sand dunes, which will be key to understanding how Martian bedrock has weathered over millions of years and how it might be weathering today. The instrument can also provide information about the Martian atmosphere, especially the locations and nature of short-lived clouds and dust. Principal investigator is Dr. Philip Christensen, Arizona State University.

❑ **Mars Orbiter Laser Altimeter**. This experiment will measure the height of Martian surface features. A laser will fire pulses of infrared light 10 times each second, striking a 160-meter (525-foot) area on the surface. By measuring the length of time it takes for the light to return to the spacecraft, scientists can determine the distance to the planet's surface. Data from this instrument will give scientists elevation maps precise to within about 30 meters (100 feet) from which they will be able to construct a detailed topographic map of the Martian landscape. Principal investigator is Dr. David Smith, NASA Goddard Space Flight Center.

❑ **Magnetometer/Electron Reflectometer**. The magnetometer/electron reflectometer will search for evidence of a planetary magnetic field and measure its strength, if it exists. These measurements will provide critical tests for current speculations about the early history and evolution of the planet. The instrument will also scan the surface to detect remnants of an ancient magnetic field, providing clues to the Martian past when the magnetic field may have been stronger due to the planet's higher internal temperature. Principal investigator is Dr. Mario Acuna, NASA Goddard Space Flight Center.

❑ **Radio Science**. The radio science investigation will use data provided by the spacecraft's telecommunications system, high-gain antenna and an onboard ultra-stable oscillator, which is like an ultra precise clock, to map variations in the gravity field by noting where the spacecraft speeds up and slows down in its passage around Mars. From these observations, a precise map of the gravity field can be constructed and related to the structure of the planet. In addition, scientists will study how radio waves are distorted as they pass through Mars' atmosphere in order to measure the atmosphere's temperature and pressure. Dr. G. Leonard Tyler, of Stanford University, is the radio science team leader.

❑ **Mars Orbiter Camera**. Unlike cameras on spacecraft such as Galileo or Voyager, which take conventional, snapshot-type exposures, the Mars orbiter camera uses a "push-broom" technique that builds up a long, ribbon-like image as the spacecraft passes over the planet. The camera will provide low-resolution global coverage of the planet every day, collecting images through red and blue filters. It will also obtain medium- and high-resolution images of selected areas. The wide-angle lens is ideal for accumulating a weather map of Mars each day, showing surface features and clouds at a resolution of about 7.5 kilometers (4.6 miles). These global views will be similar to the types of views obtained by weather satellites orbiting the Earth. The narrow-angle lens will image small areas of the surface at a resolution of 2 to 3 meters (6.5 to 9.5 feet). These pictures will be sharp enough to show small geologic features such as boulders and sand dunes — perhaps even the Mars Pathfinder lander and the now-silent Viking landers — and may also be used to select landing sites for future missions. Principal investigator is Dr. Michael Malin, Malin Space Science Systems Inc., San Diego, CA.

❑ **Mars Relay System**. Mars Global Surveyor carries a radio receiver/transmitter supplied by the French space agency, Centre National d'Etudes Spatiales, which was originally designed to support the Russian Mars '96 mission, lost during launch. Now it will be used to relay data from the microprobes carried on the 1998 Mars Global Surveyor Lander mission, as well as to serve as a backup to relay data from the lander itself. Data relayed from the surface to Mars Global Surveyor will be stored in the large solid-state memory of the orbiter's camera, where it will be processed for return to Earth. This collaborative effort will maximize data collection. Following support of the Mars '98 mission, the Mars relay system is expected to provide multiple years of in-orbit communications relay capability for future international Mars missions.

Program/Project Management

Mars Global Surveyor is the first mission in a sustained program of Mars exploration — called the Mars Surveyor program — which will send low-cost pairs of orbiters and landers to Mars every 25 months well into the next century.

The Mars Global Surveyor 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. Kenneth Ledbetter is director for mission and payload development. Dr. William Piotrowski is Mars Global Surveyor program executive. Dr. Patricia Rogers is Mars Global Surveyor program scientist.

At the Jet Propulsion Laboratory, Norman Haynes is director of the Mars Exploration Directorate. Donna Shirley is manager of the Mars Exploration Program. Glenn E. Cunningham is Mars Global Surveyor project manager. Dr. Arden Albee of the California Institute of Technology, Pasadena, CA, is Mars Global Surveyor project scientist.

JPL's industrial partner is Lockheed Martin Astronautics, Denver, CO, which developed and operates the spacecraft. Navigation and ground data support are provided by JPL. Science operations will be carried out by NASA’s Goddard Space Flight Center, Greenbelt, MD; Arizona State University, Tempe, AZ; Malin Space Science Systems, San Diego, CA; Stanford University, Palo Alto, CA; and NASA's Jet Propulsion Laboratory, Pasadena, CA.