NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

2001 Mars Odyssey Arrival

Press Kit
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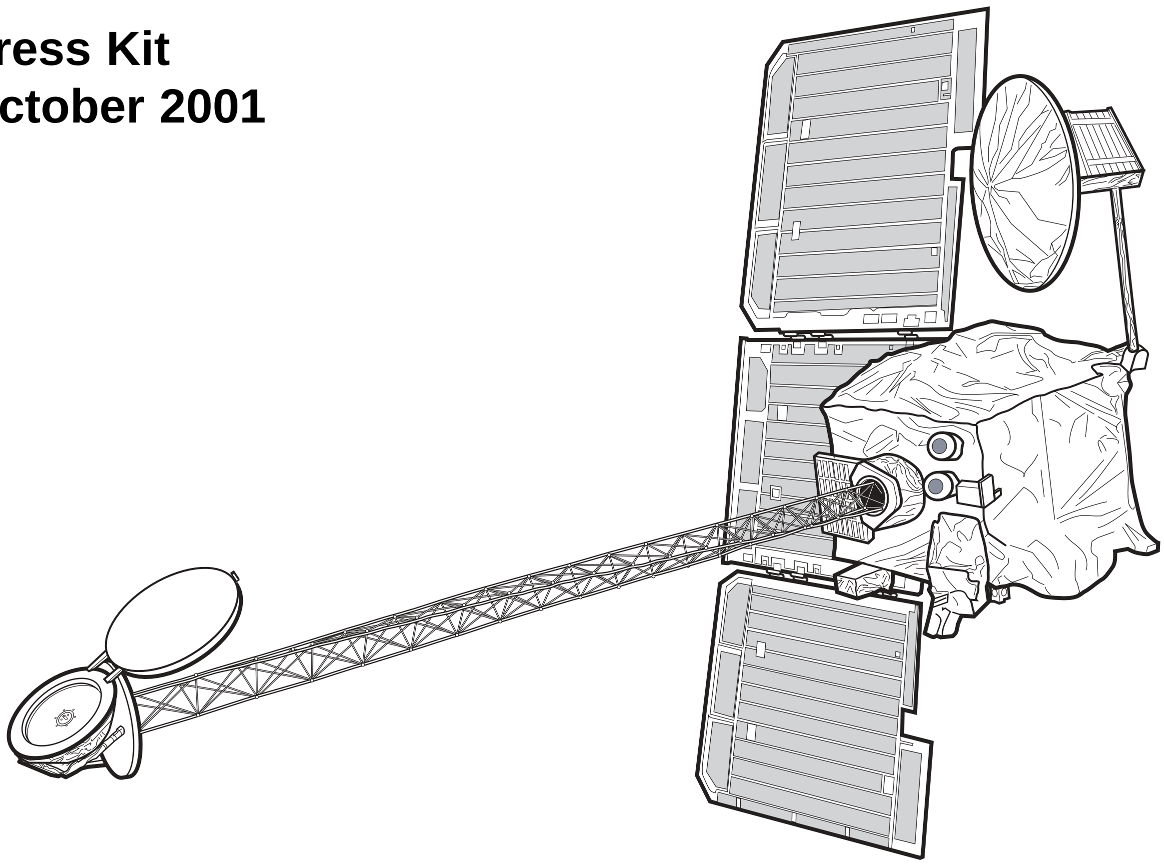

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RELEASE:

NASA'S 2001 MARS ODYSSEY SPACECRAFT POISED TO ARRIVE AT MARS

After 200 days of travel and more than 460 million kilometers (about 285 million miles) logged on its odometer, NASA's 2001 Mars Odyssey spacecraft will fire its main engine for the first and only time Oct. 23 and put itself into orbit around the red planet.

Odyssey was launched April 7 from Cape Canaveral Air Force Station, Fla. Other than our Moon, Mars has attracted more spacecraft exploration attempts than any other object in the solar system, and no other planet has proved as daunting to success. Of the 30 missions sent to Mars by three countries over 40 years, less than one-third have been successful.

"The spacecraft, ground system and flight team are ready for Mars orbit insertion," said Matthew Landano, Odyssey project manager at NASA's Jet Propulsion Laboratory, Pasadena, Calif. "We uplinked the sequence of commands that control the orbit insertion on Oct. 15. Now we will closely monitor the spacecraft's progress as it approaches Mars and executes the orbit insertion burn."

To enter orbit, Odyssey's propellant tanks, the size of big beachballs, must first be pressurized, plumbing lines heated, and the system primed before 262.8 kilograms (579.4 pounds) of propellant is burned in exactly the right direction for 19.7 minutes.

Flight controllers at JPL will see the main engine burn begin a few seconds after 7:26 p.m. Pacific time on the evening of Oct. 23. (Events in space are usually measured in Universal Time -- formerly called Greenwich Mean Time -- under which the Mars arrival occurs on Oct. 24. In the United States, however, the arrival will take place the evening of Oct. 23.)

The spacecraft will pass behind the planet 10 minutes later and will be out of contact for about 20 minutes. The burn is expected to end at 7:46 p.m. Pacific time, but controllers will not receive confirmation until a few minutes later when the spacecraft comes out from behind Mars and reestablishes contact with Earth at about 8 p.m.

The firing of the main engine will brake the spacecraft's speed, slowing and curving its trajectory into an egg-shaped elliptical orbit around the planet. In the weeks and months ahead, the spacecraft will repeatedly brush against the top of the atmosphere in a process called aerobraking to reduce the long, 19-hour elliptical orbit into a shorter, 2-hour circular orbit of approximately 400 kilometers (about 250 miles) altitude desired for the mission's science data collection.

NASA's latest explorer carries several scientific instruments to map the chemical and mineralogical makeup of Mars: a gamma ray spectrometer that includes a neutron spectrometer and a high-energy neutron detector; a thermal-emission imaging system; and a Martian radiation environment experiment.

JPL manages the 2001 Mars Odyssey mission for NASA's Office of Space Science, Washington, D.C. Principal investigators at Arizona State University in Tempe, the University of Arizona in Tucson, and NASA's Johnson Space Center, Houston, Texas, operate the science instruments. Lockheed Martin Astronautics, Denver, Colo., is the prime contractor for the project, and developed and built the orbiter. Mission operations are conducted jointly from Lockheed Martin and from JPL, a division of the California Institute of Technology in Pasadena. NASA's Langley Research Center in Hampton, Va., will provide aerobraking support to JPL's navigation team during mission operations.

- 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 tentative schedule for television transmissions for Mars Odyssey arrival is described below; updates will be available from the Jet Propulsion Laboratory, Pasadena, Calif.; Johnson Space Center, Houston, Texas; Kennedy Space Center, Fla., and NASA Headquarters, Washington, D.C.

Briefings and Television Feed

An overview of Mars arrival will be presented in a news briefing broadcast on NASA Television originating from JPL at 10 a.m. PDT Oct. 18. A live feed of arrival activities from control rooms at JPL and at Lockheed Martin, Denver, Colo., will be broadcast on NASA Television beginning at 7 p.m. PDT Oct. 23; a news conference will immediately follow orbit insertion at about 8:45 p.m. PDT. A news conference broadcast on NASA Television from JPL summarizing the orbit insertion is tentatively scheduled Oct. 24, with the exact time to be announced later.

Status Reports

Status reports on mission activities will be issued by JPL's Media Relations Office. They may be accessed online as noted below.

Mars Arrival Media Credentialing

Requests to cover the Mars Odyssey arrival event in person at JPL in Pasadena, Calif., must be faxed in advance to the JPL newsroom at 818/354-4537. Requests must be on the letterhead of the news organization and must specify the editor making the assignment to cover the launch.

Internet Information

Extensive information on the 2001 Mars Odyssey mission, 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** . The Mars Exploration Program maintains a home page at **http://mars.jpl.nasa.gov** .

Quick Facts

Spacecraft

Dimensions: Main structure 2.2 meters (7.2 feet) long, 1.7 meters (5.6 feet) tall and 2.6 meters (8.5 feet) wide; wingspan of solar array 5.7-meter (18.7-feet) tip to tip
Weight: 729.7 kilograms (1,608.7 pounds) total, composed of 331.8-kilogram (731.5-pound) dry spacecraft, 353.4 kilograms (779.1 pounds) of propellant and 44.5 kilograms (98.1 pounds) of science instruments
Science instruments: Thermal emission imaging system; gamma ray spectrometer including a neutron spectrometer and the high-energy neutron detector; Martian radiation environment experiment
Power: Solar array providing up to 1,500 watts just after launch, 750 watts at Mars

Launch Vehicle

Type: Delta II 7925
Weight: 230,983 kg (509,232 lbs)

Mission

Launch: April 7, 2001, from Cape Canaveral, Fla.
Interplanetary cruise: Approximately six months (200 days)
Earth-Mars distance at launch: 125 million kilometers (77.5 million miles)
Total distance traveled Earth to Mars: 460 million kilometers (286 million miles)
Earth-Mars distance at arrival: 150 million kilometers (93 million miles)

Mars Arrival

Orbit insertion burn: October 24, 2001, from 2:26 to 2:45 Universal Time (October 23, 2001, from 7:26 to 7:45 p.m. PDT) (Earth-received times)
Duration: 19 minutes
One-way speed-of-light time from Mars to Earth on arrival day: 8 minutes, 30 seconds
Velocity before burn (with respect to Mars): 5.422 km/sec (12,129 mph)
Velocity after burn (with respect to Mars): 4.374 km/sec (9,784 mph)
Change in velocity due to burn: 1,427 meters per second (3,192 mph)
Average deceleration due to burn: 1/10 of 1 Earth "G"
Martian season at arrival: Late fall in Mars' northern hemisphere

Aerobraking Phase

Aerobraking period: Begins October 26, 2001, continues for 3 months
Initial orbit: Elliptical with a period of about 19.9 hours, plus or minus 4 hours
Final mapping orbit: Circular with a period of 118 minutes; mean altitude 400 kilometers (249 miles), polar, nearly sun-synchronous
Primary mapping mission: January 31, 2002, to August 5, 2004
Martian season when mapping begins: Early winter in Mars' northern hemisphere

Program

Cost: $297 million total for 2001 Mars Odyssey, comprised of the following:
$165 million spacecraft development and science instruments
$53 million launch
$79 million mission operations and science processing

Mars at a Glance

General

- ❑ One of five planets known to ancients; Mars was Roman god of war, agriculture and the state
- ❑ Reddish color; at times the third 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
- ❑ Same land area as Earth
- ❑ 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 planet-wide magnetic field detected; only localized ancient remnant fields in various regions

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 less than 1/100th that of Earth's average
- ❑ Surface winds up to 40 meters per second (80 miles per hour)
- ❑ Local, regional and global dust storms; also whirlwinds called dust devils
- ❑ 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 about 26 kilometers (16 miles) 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 Mariner 9 and Viking missions of the 1970s, however, established that Mars has channels possibly 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

[Unnamed], USSR, 10/10/60, Mars flyby, did not reach Earth orbit

[Unnamed], USSR, 10/14/60, Mars flyby, did not reach Earth orbit

[Unnamed], USSR, 10/24/62, Mars flyby, achieved Earth orbit only

Mars 1, USSR, 11/1/62, Mars flyby, radio failed at 106 million km (65.9 million miles)

[Unnamed], USSR, 11/4/62, Mars flyby, achieved Earth orbit only

Mariner 3, U.S., 11/5/64, Mars flyby, shroud failed to jettison

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, passed Mars but radio failed, returned no 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 orbiter, failed during launch

Kosmos 419, USSR, 5/10/71, Mars lander, achieved Earth orbit only

Mars 2, USSR, 5/19/71, Mars orbiter/lander arrived 11/27/71, no useful data, lander destroyed

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, lasted a few days

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 8/89 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, lost just before Mars arrival 8/21/93

Mars Global Surveyor, U.S., 11/7/96, Mars orbiter, arrived 9/12/97, made high-detail maps of planet through 1/00, now conducting extended mission

Mars 96, Russia, 11/16/96, orbiter and landers, launch vehicle failed

Mars Pathfinder, U.S., 12/4/96, Mars lander and rover, landed 7/4/97, last transmission 9/27/97

Nozomi (Planet-B), Japan, 7/4/98, Mars orbiter, currently in orbit around the Sun; Mars arrival delayed to 12/03 due to propulsion problem

Mars Climate Orbiter, U.S., 12/11/98, lost upon arrival 9/23/99

Mars Polar Lander/Deep Space 2, U.S., 1/3/99, lander and soil probes, lost upon arrival 12/3/99

Why Mars?

Mars perhaps first caught public fancy in the late 1870s, when Italian astronomer Giovanni Schiaparelli reported using a telescope to observe "canali," or channels, on Mars. A possible mistranslation of this word as "canals" may have fired the imagination of Percival Lowell, an American businessman with an interest in astronomy. Lowell founded an observatory in Arizona, where his observations of the red planet convinced him that the canals were dug by intelligent beings -- a view that he energetically promoted for many years.

By the turn of the last century, popular songs envisioned sending messages between worlds by way of huge signal mirrors. On the dark side, H.G. Wells' 1898 novel "The War of the Worlds" portrayed an invasion of Earth by technologically superior Martians desperate for water. In the early 1900s novelist Edgar Rice Burroughs, known for the "Tarzan" series, also entertained young readers with tales of adventures among the exotic inhabitants of Mars, which he called Barsoom.

Fact began to turn against such imaginings when the first robotic spacecraft were sent to Mars in the 1960s. Pictures from the first flyby and orbiter missions showed a desolate world, pocked with craters similar to those seen on Earth's Moon. The first wave of Mars exploration culminated in the Viking mission, which sent two orbiters and two landers to the planet in 1975. The landers included a suite of experiments that conducted chemical tests in search of life. Most scientists interpreted the results of these tests as negative, deflating hopes of identifying another world on where life might be or have been widespread.

The science community had many other reasons for being interested in Mars, apart from searching for life; the next mission on the drawing boards concentrated on a study of the planet's geology and climate. Over the next 20 years, however, new findings in laboratories on Earth came to change the way that scientists thought about life and Mars.

One was the 1996 announcement by a team from Stanford University and NASA's Johnson Space Center that a meteorite believed to have originated on Mars contained what might be the fossils of ancient bacteria. This rock and other so-called Mars meteorites discovered on several continents on Earth are believed to have been blasted away from the red planet by asteroid or comet impacts. They are thought to come from Mars because of gases trapped in the rocks that match the composition of Mars' atmosphere. Not all scientists agreed with the conclusions of the team announcing the discovery, but it reopened the issue of life on Mars.

Another development that shaped scientists' thinking was new research on how and where life thrives on Earth. The fundamental requirements for life as we know it are liquid water, certain chemical compounds and an energy source for synthesizing complex organic molecules. Beyond these basics, we do not yet understand the environmental and chemical evolution that leads to the origin of life. But in recent years, it has become increasingly clear that life can thrive in settings much different from a tropical soup rich in organic nutrients.

In the 1980s and 1990s, biologists found that microbial life has an amazing flexibility for surviving in extreme environments -- niches that by turn are extraordinarily hot, or cold, or dry, or under immense pressures -- that would be completely inhospitable to humans or complex animals. Some scientists even concluded that life may have begun on Earth in hydrothermal vents far under the ocean's surface.

This in turn had its effect on how scientists thought about Mars. Life might not be so widespread that it would be found at the foot of a lander spacecraft, but it may have thrived billions of years ago in an underground thermal spring or other liquid water environment. Or it might still exist in some form in niches below the frigid, dry, windswept surface.

NASA scientists also began to rethink how to look for signs of past or current life on Mars. In this new view, the markers of life may well be so subtle that the range of test equipment required to detect it would be far too complicated to package onto a spacecraft. It made more sense to collect samples of Martian rock, soil and air to bring back to Earth, where they could be subjected to much more extensive laboratory testing.

Mars and Water

Mars today is far too cold with an atmosphere that is much too thin to support liquid water on its surface. Yet scientists studying images acquired by the Viking orbiters consistently uncovered landscape features that appeared to have been formed by the action of flowing water. Among those features were deep channels and curving canyons, and even landforms that resemble ancient lake shorelines. Added to this foundation is more recent evidence, especially from observations made by Mars Global Surveyor, that suggested widespread flowing water on the Martian surface in the planet's past. On the basis of analysis of some of the features observed by both the Mars Pathfinder and Mars Global Surveyor spacecraft, some scientists likened the action of ancient flowing water on Mars to floods with the force of thousands of Mississippi Rivers.

Continuing the saga of water in the history of Mars, in June 2000 geologists on the Mars Global Surveyor imaging team presented startling evidence of landscape features that dramatically resemble gullies formed by the rapid discharge of liquid water, and deposits of rocks and soils related to them. The features appear to be so young that they might be forming today. Scientists believe they are seeing evidence of a groundwater supply, similar to an aquifer. Ever since the time of Mariner 9 in the early 1970s, a large part of the focus of Mars science has been questions related to water: how much was there and where did it go (and ultimately, how much is accessible today). The spectacular images from Mars Global Surveyor reveal part of the answer -- some of the water within the Mars "system" is stored underground, perhaps as close as hundreds of meters (or yards), and at least some of it might still be there today.

Still, there is no general agreement on what form water took on the early Mars. Two competing views are currently popular in the science community. According to one theory, Mars was once much warmer and wetter, with a thicker atmosphere; it may well have boasted lakes or oceans, rivers and rain. According to the other theory, Mars was always cold, but water trapped as underground ice was periodically released when heating caused ice to melt and gush forth onto the surface.

Even among those who subscribe to the warmer-and-wetter theory, the question of what happened to the water is still a mystery. Most scientists do not feel that the scenario responsible for Mars' climate change was necessarily a cataclysmic event such as an asteroid impact that, say, disturbed the planet's polar orientation or orbit. Many believe that the demise of flowing water on the surface could have resulted from a gradual loss of atmosphere resulting in a climate change taking place over hundreds of millions of years.

Under either the warmer-and-wetter or the always-cold scenario, Mars must have had a thicker atmosphere to support water that flowed on the surface even only occasionally. Mars' atmosphere is overwhelmingly composed of carbon dioxide. Over time, carbon dioxide gas reacts with elements in rocks and becomes locked up in the mineral carbonate, resulting in the atmosphere becoming thinner over time.

On Earth, the horizontal and vertical motions of the shifting tectonic plates that define the crust of our planet are continually plowing carbonates and other widespread minerals beneath the surface to depths at which the internal heat within Earth releases carbon dioxide, which later spews forth in volcanic eruptions. This terrestrial cycle replenishes the carbon dioxide in Earth's atmosphere. Although we are not sure Mars today harbors any active volcanoes, it clearly had abundant and widespread volcanic activity in its past. The apparent absence of a long-lasting system of jostling tectonic plates on Mars, however, suggests that a critical link in the process that leads to carbon dioxide recyling in Earth's atmosphere is missing on Mars.

These scenarios, however, are just theories. Regardless of the history and fate of the atmosphere, scientists also do not understand what happened to Mars' water. Some undoubtedly must have been lost to space. Water ice has been detected in the permanent cap at Mars' north pole. Water ice may also exist in the cap at the south pole. But much water is probably trapped under the surface -- either as ice, or possibly in liquid form if it is deep underground or near a heat source close to the surface.

NASA's next mission to the red planet, 2001 Mars Odyssey, will provide another vital piece of information to the “water puzzle” by mapping the basic elements and minerals that are present in the upper centimeters (or inches) of the planet's surface. Odyssey will be the first spacecraft to make direct observations of the element hydrogen near and within the surface of Mars, and hydrogen may provide the strongest evidence of water on or just under the Martian surface since it is one of the key elements within the water molecule. In addition, the high-resolution thermal emission imaging system on Odyssey might be able to identify hot spots such as hot springs, if any exist, which could serve as prime sites for possible future exploration.

Even if we ultimately learn that Mars never harbored life as we know it, scientific exploration of the red planet can assist in understanding life on our own home planet. Much of the evidence for the origin of life here on Earth has been obliterated by the incredible dynamics of geological processes which have operated over the past 4 billion years, such as plate tectonics and rapid weathering. Today we believe that there are vast areas of the Martian surface that date back a primordial period of planetary evolution -- a time more than about 4 billion years ago that overlaps the period on Earth when pre-biotic chemical evolution first gave rise to self-replicating systems that we know of as "life."

Thus, even if life never developed on Mars -- something that we cannot answer today --scientific exploration of the planet may yield absolutely critical information unobtainable by any other means about the pre-biotic chemistry that led to life on Earth. Furthermore, given the complexity we recognize in Earth’s record of climate change, some scientists believe that by studying the somewhat simpler (but no less bizarre) Martian climate system, we can learn more about Earth. As such, Mars could serve as Mother Nature's great "control experiment" providing us with additional perspectives from which to understand the workings of our own home planet. The 2001 Mars Odyssey mission continues us on the path of understanding the red planet as a "system" by probing what it is made of, and where the elusive signs of surface water may have left their indelible marks.

Lessons Learned

Engineers and scientists working on the 2001 Mars Odyssey project began looking at ways to reduce risks to their mission immediately after the loss of Mars Climate Orbiter and Mars Polar Lander in 1999. In addition to the independent assessments made by the project, the team has also followed recommendations made by the NASA review boards investigating the losses and a NASA "Red Team" assigned to review the project.

Among the risk reduction actions taken are:

- ❑ Identified parameters critical to mission success and did an independent verification of these parameters
- ❑ Listed both imperial and metric units on documentation for hand-off between systems and subsystems
- ❑ Added key staff at both JPL and Lockheed Martin
- ❑ Moved launch to Kennedy Space Center instead of Vandenberg Air Force Base in California to provide additional schedule margin and reduce how much the spacecraft's battery is discharged during launch
- ❑ Prepared mission fault trees and conducted mission risk reviews to formulate risk mitigation actions
- ❑ Conducted an independent verification and validation of the flight software by NASA personnel in Fairmont , West Virginia
- ❑ Conducted additional flight software tests to stress the design under off-nominal conditions.
- ❑ Added check valves in the propulsion system to isolate the fuel and oxidizer until the moment of the Mars orbit insertion main engine burn
- ❑ Conducted additional pyro qualification test firings over a broader set of conditions
- ❑ Conducted additional thruster test firings to demonstrate proper operation under cold starting conditions
- ❑ Conducted life-cycling tests for assemblies in the communication system that are cycled on and off during flight
- ❑ Conducted additional measurements to assess the interference between the relay radio and the orbiter and instrument electronics
- ❑ Changed out suspect capacitors in orbiter electronics based on failures of similar capacitors on another program
- ❑ Added second- and third-shift testing to add operating time and build confidence in orbiter electronics
- ❑ Added ability to receive telemetry from spacecraft during the pressurization process prior to the Mars orbit insertion main engine burn
- ❑ Increased navigation tracking data during cruise
- ❑ Added delta differential one-way range measurements, called "delta DOR," that provide an independent measurement of the orbiter location relative to Mars
- ❑ Moved the point at which recovery from a fault would be impossible closer to Mars orbit insertion to minimize the time the system is not redundant
- ❑ Conducted additional oxidizer burn-to-depletion test to build confidence in and select parameters for the Mars orbit insertion strategy
- ❑ Raised Mars capture orbit design to a higher altitude
- ❑ Conducted additional studies to ensure that there is no fuel migration within the propulsion system that would cause excessive imbalance during the orbit insertion main engine burn
- ❑ Conducted an independent verification of Mars aerobraking by NASA Langley Research Center
- ❑ Adopted a more conservative Mars aerobraking profile to allow for dust storms and wider atmospheric variations
- ❑ Assigned clear lines of responsibility within the organization to improve communication
- ❑ Formalized operations team training
- ❑ Designated personnel to transition from development to operations
- ❑ Added a tracking station in Santiago, Chile, to fill in telemetry gaps after launch and early in cruise phase

Where We've Been and Where We're Going

Incorporating lessons learned from past and ongoing Mars mission successes and setbacks, NASA's revamped campaign to unravel the secrets of the red planet moves from an era of global mapping and limited surface exploration to a much more comprehensive approach in which next-generation reconnaissance from orbit and from the surface will pave the way for multiple sample returns.

Over the next two decades, NASA's Mars Exploration Program will build upon previous scientific discoveries to establish a sustained observational presence both around and on the surface of Mars. This will be achieved from the perspective of orbital reconnaissance and telecommunication, surface-based mobile laboratories, sub-surface access and, ultimately, by means of robotic sample return missions. With international cooperation, the long-term program will maintain a science-driven, technology-enabled focus, while balancing risks against sound management principles and with attention to available resources. The strategy of the Mars Exploration Program will attempt to uncover profound new insights into Mars past environments, the history of its rocks and interior, the many roles and abundances of water and, quite possibly, evidence of past and present life.

The following are the most recently completed, ongoing and near-term future Mars missions of exploration in the NASA program:

❑ **Mars Pathfinder** (December 1996 - March 1998): The first completed mission in NASA's Discovery Program of low-cost, rapidly developed planetary missions with highly focused scientific goals, Mars Pathfinder far exceeded its expectations and outlived its primary design life. This lander, which released its Sojourner rover at the Martian surface, returned 2.3 billion bits of information, including more than 17,000 images, as well as more than 15 chemical analyses of rocks and soil and extensive data on winds and other types of weather. Investigations carried out by instruments on both the lander and the rover suggest that, in its past, Mars was warm and wet, and had liquid water on its surface and a thicker atmosphere. Engineers believed that, in October 1997, a depletion of the spacecraft's battery and a drop in the spacecraft's operating temperature were to blame for the loss of communications with Pathfinder. Attempts to re-establish communications with the vehicle ceased in March 1998, well beyond the mission's expected 30-day lifetime.

❑ **Mars Global Surveyor** (November 1996 - January 2001 primary mapping mission): Orbiting the red planet 8,985 times so far, NASA's Mars Global Surveyor has collected more information than any other previous Mars mission and keeps on going into its extended mission. Sending back more than 65,000 images, 583 million topographic laser-altimeter shots and 103 million spectral measurements, Global Surveyor's comprehensive observations have proven invaluable to understanding the seasonal changes on Mars. Some of the mission's most significant findings include: possible evidence for recent liquid water at the Martian surface; evidence for layering of rocks that point to widespread ponding or lakes in the planet's early history; topographic evidence for a south pole-to-north pole slope that controlled the transport of water and sediments; identification of the mineral hematite, indicating a past surface-hydrothermal environment; and extensive evidence for the role of dust in reshaping the recent Martian environment. Global Surveyor will continue gathering data in an extended mission approved until 2002.

❑ **Mars Exploration Rovers** (2003): Identical twin rovers, able to travel almost as far in one Martian day as Sojourner did over its entire lifetime, will land at two separate sites and set out to determine the history of climate and water on the planet where conditions may once have been

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very favorable for life. By means of sophisticated sets of instruments and access tools, the twin rovers will evaluate the composition, texture and morphology of rocks and soils at a broad variety of scales, extending from those accessible to the human eye to microscopic levels. The rover science team will select targets of interest such as rocks and soils on the basis of images and infrared spectra sent back to Earth. Two different Martian landing sites will be chosen on the basis of an intensive examination of information collected by the Mars Global Surveyor and Mars Odyssey orbiters, as well as other missions. They will use the same airbag landing system demonstrated by Mars Pathfinder.

❑ **Mars Reconnaissance Orbiter** (2005): This scientific orbiter will attempt to bridge the gap between surface observations and measurements taken from orbit. It will focus on analyzing the Martian surface at new scales in an effort to follow the tantalizing hints of water from the Mars Global Surveyor images. For example, the Mars Reconnaissance Orbiter will measure thousands of Martian landscapes at 20- to 30-centimeter (8- to 12-inch) resolution, which is adequate to observe rocks the size of beach balls. In addition, maps of minerals diagnostic of the role of liquid water in their formation will be produced at unprecedented scales for thousands of potential future landing sites. Finally, a specialized, high-resolution sounding radar will probe the upper hundreds of meters (or yards) of the Martian sub-surface in search of clues of frozen pockets of water or other unique layers. Finally, the Mars Reconnaissance Orbiter will finish the job of characterizing the transport processes in the present-day Martian atmosphere, including the planet's annual climate cycles, using a unique infrared sounding instrument, originally carried to Mars on the ill-fated Mars Observer, and then again on Mars Climate Orbiter.

❑ **Smart Lander** (2007): NASA has proposed to develop and launch a next-generation "mobile surface laboratory" with potentially long-range roving capabilities (greater than 10 kilometers (about 6 miles)) and more than a year of surface operational lifetime as a pivotal step toward a future Mars sample return mission. By providing a major leap forward in surface measurement capabilities and surface access, this mission will also demonstrate the technology needed for accurate landing and surface hazard avoidance in order to allow access to potentially compelling, but difficult to reach, landing sites. Its suite of scientific instruments could include new devices that will sample and probe the Martian subsurface in search of organic materials.

❑ **Scout Mission** (2007): NASA has also proposed to create a new line of small "scout" missions that would be competitively selected from proposals submitted by the broader scientific and aerospace community. Exciting new vistas could be opened by means of this innovative approach, either through observations made from airborne vehicles, networks of small surface landers, or from highly focused orbital laboratories. NASA aims to compete these scout missions as often as possible, and potentially every four years, depending on resource availability.

❑ **Mars Sample Return** (earliest launch possibility late 2011): NASA is studying additional scientific orbiters, rovers and landers, as well as approaches for returning the most promising samples of Martian materials (rocks, soils, ices and atmospheric gases/dust) back to Earth. While current schedules call for the first of several sample return missions to be launched in 2014 with a second mission in 2016. Technology development is underway for advanced capabilities including a new generation of miniaturized surface instruments such as mass spectrometers and electron microscopes, as well as deep drilling to 20 meters (about 20 yards) or more.

Mission Overview

2001 Mars Odyssey is an orbiter carrying science experiments designed to make global observations of Mars to improve our understanding of the planet's climate and geologic history, including the search for water and evidence of life-sustaining environments. The mission will extend across more than a full Martian year.

Launch

Odyssey was launched on April 7, 2001, at 11:02 a.m. EST from pad 17A at Cape Canaveral Air Force Station, Florida. The spacecraft launched on a variant of Boeing's Delta II rocket called the 7925 that included nine strap-on solid-fuel motors. Launch occurred during the first launch opportunity.

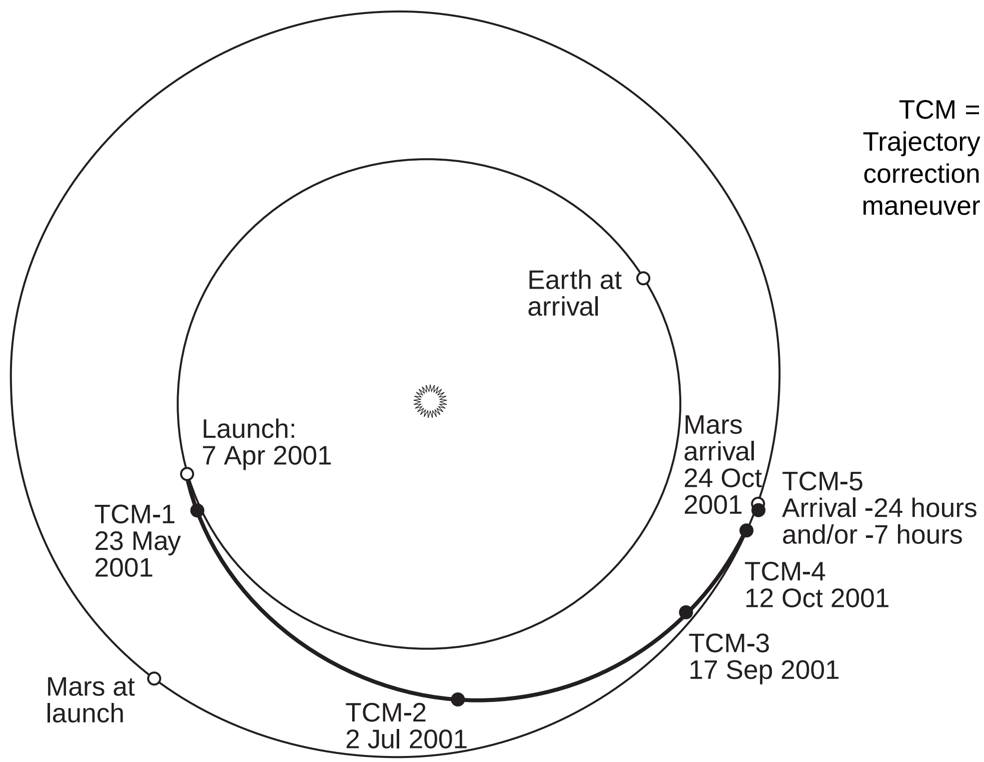
Interplanetary Cruise

Odyssey’s interplanetary cruise from Earth to Mars lasts 200 days. Primary activities during cruise have included checkout and monitoring of the spacecraft and the science instruments, and navigation activities necessary to determine and correct Odyssey's flight path to Mars.

All science instruments were turned on and calibrated during early cruise. Twelve days after launch, the thermal emission imaging system took visible and infrared pictures of Earth and the Moon. The Martian radiation environment experiment, neutron spectrometer, and high-energy neutron detector began taking data within a month after launch. The gamma ray spectrometer’s gamma sensor head began collecting data in late June 2001. The Martian radiation environment experiment was turned off on August 20, 2001, after it failed to respond during a downlink session. Flight controllers expect to continue troubleshooting the problem after Odyssey is in orbit at Mars.

Odyssey's flight path to Mars is what navigators call a “Type 1” trajectory that takes it less than 180 degrees around the Sun. During the first two months of cruise, only the Deep Space Network complex near Canberra, Australia, was capable of viewing the spacecraft. Late in May, California's Goldstone complex came into view, and by early June the complex near Madrid, Spain, was also be able to track the spacecraft. A tracking station in Santiago, Chile, was added to fill in tracking coverage during the first 30 days following launch.

During the early portion of its flight, the spacecraft transmitted to Earth using its medium-gain antenna and received commands on its low-gain antenna. In late May 2001, Odyssey began receiving and transmitting through its high-gain antenna. Computer command sequences to control the spacecraft during cruise were generated and uplinked approximately once every four weeks during one of the regularly scheduled Deep Space Network passes.



Interplanetary trajectory

The spacecraft determines its orientation in space chiefly via a star camera and a device called an inertial measurement unit. The spacecraft generally flies with its medium- or high-gain antenna pointed toward Earth while keeping the solar panels pointed toward the Sun.

The spacecraft is stabilized in three axes and does not spin to maintain its orientation, or "attitude." Odyssey's orientation is controlled by reaction wheels, devices with spinning wheels similar to gyroscopes. These devices are occasionally "desaturated," meaning that their momentum is unloaded by firing the set of smaller thrusters used to control the spacecraft's orientation, or "attitude."

During interplanetary cruise, Odyssey was to fire a set of larger thrusters a total of four or five times to adjust its flight path. The first of these trajectory correction maneuvers was performed on May 23, 2001; the second on July 2; and the third on September 16. Another trajectory correction maneuver on October 12 was used to direct the spacecraft to the proper aim point at Mars. Flight controllers will then have the option of adding final thruster firings 24 hours before arrival and/or seven hours before arrival, as needed. The spacecraft communicates with Deep Space Network antennas continuously for 24 hours around all of the trajectory correction maneuvers. Maneuvers are

Arrival Events

All times are "Earth-received times" in PDT

4:56 p.m.: Commands are sent instructing Odyssey to fire small thrusters to "desaturate," or unload the momentum of, the spinning reaction wheels. These devices are similar to gyroscopes and are used to control the spacecraft's orientation.

6:59: The flight team performs last-minute calculations of any bias in the spacecraft's heading based on accelerometer readings. This is the last opportunity to adjust any orbit insertion activities.

7:06: The catalyst bed heaters, or "catbed" heaters, are turned on to prime the spacecraft's reaction control thrusters in preparation for firing.

7:12: Lines to the main engine fill with propellant, and the propellant system is pressurized.

7:18: Odyssey switches from its medium-gain antenna to the low-gain antenna for receipt of commands from Earth. Odyssey stops sending data to Earth and switches to sending a carrier signal only.

7:19: The Deep Space Network locks on to the carrier signal from the spacecraft. Reaction wheels turn the spacecraft to its proper orientation in preparation for the engine firing.

7:26: Main engine ignites to begin Mars orbit insertion.

7:36: The Deep Space Network loses the spacecraft signal as Odyssey passes behind Mars.

7:36: Still behind Mars and incommunicado, the spacecraft enters the darkness of Mars' shadow (i.e. a solar eclipse) for two minutes.

7:39: Odyssey reaches "periapsis," the lowest point in its first orbit of Mars, at an altitude of about 328 kilometers (203 miles). It is still out of reach of Earth ground stations.

7:45: Main engine concludes firing.

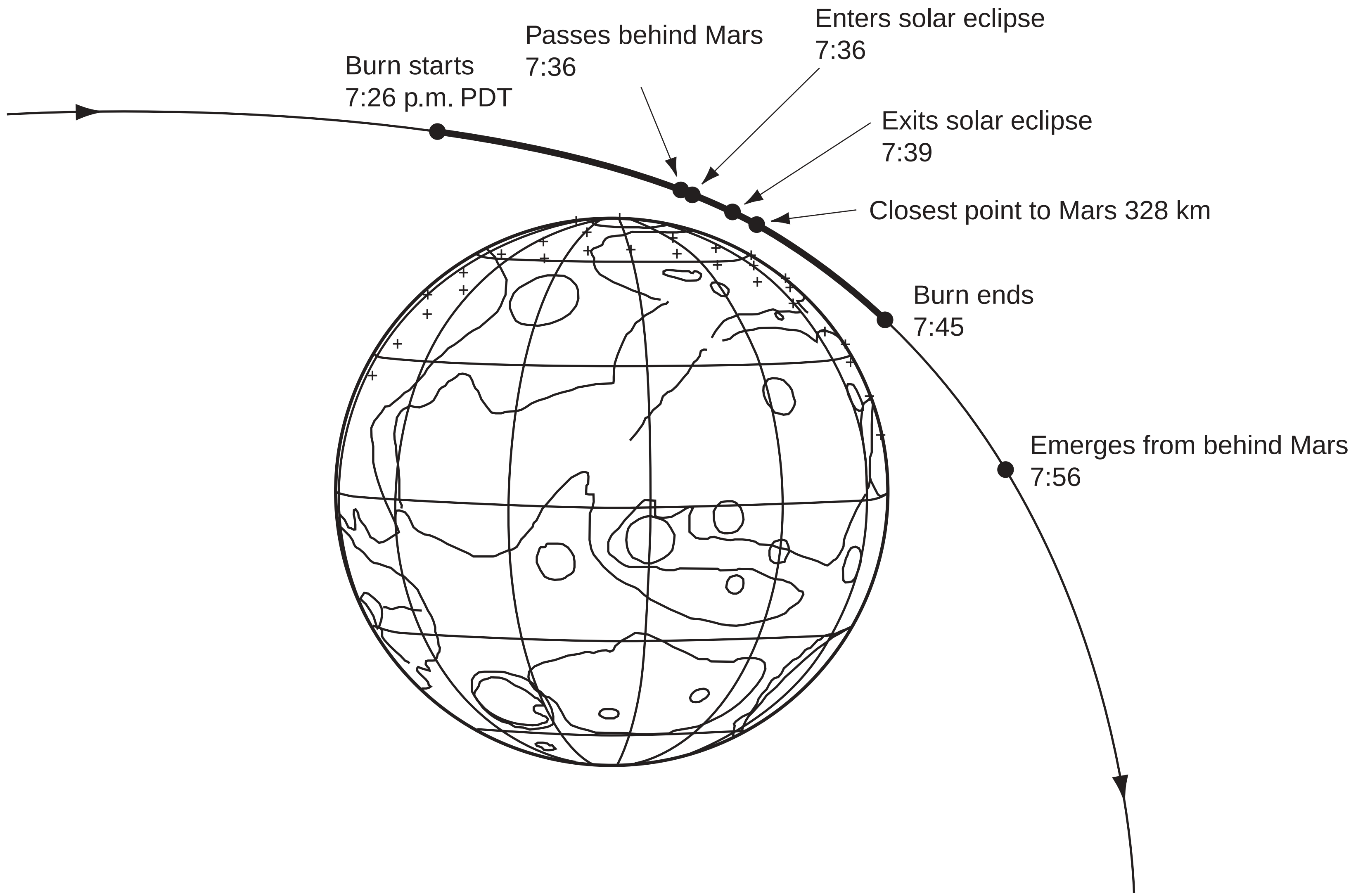
7:49: Still out of touch with the Deep Space Network, Odyssey's reaction wheels turn the spacecraft to point the high-gain antenna toward Earth. Fault protection software that was turned off a day before Mars arrival is turned on again. (Fault protection software is used to help the spacecraft respond to unexpected events by directing Odyssey to stop what it's doing and point its antenna toward Earth to await further commands. Fault protection software is turned off during critical maneuvers such as Mars orbit insertion to prevent relatively small glitches from interfering.)

7:56: Odyssey emerges from behind Mars from Earth's point of view; Deep Space Network antennas seek to lock on to the spacecraft's carrier signal.

8:00: Odyssey's propellant and oxidizer tanks are mechanically isolated from pressurant.

8:01: The spacecraft resumes transmitting data to Earth at 40 bits per second; the Deep Space Network may take several minutes to lock on to the low-rate data stream.

Note on times of events: For consistency, all times stated in this press kit are in "Earth-received time," the time at which signals reporting each event would be received on Earth. Since it takes radio signals 8 minutes, 30 seconds to pass from Mars to Earth at the speed of light on arrival day, each event in space actually takes place that much earlier than the times reported here.



Arrival events

conducted in what engineers are calling a "constrained turn-and-burn" mode. In this mode, the spacecraft turns to the desired burn orientation and fires its thrusters, while remaining in contact with Earth.

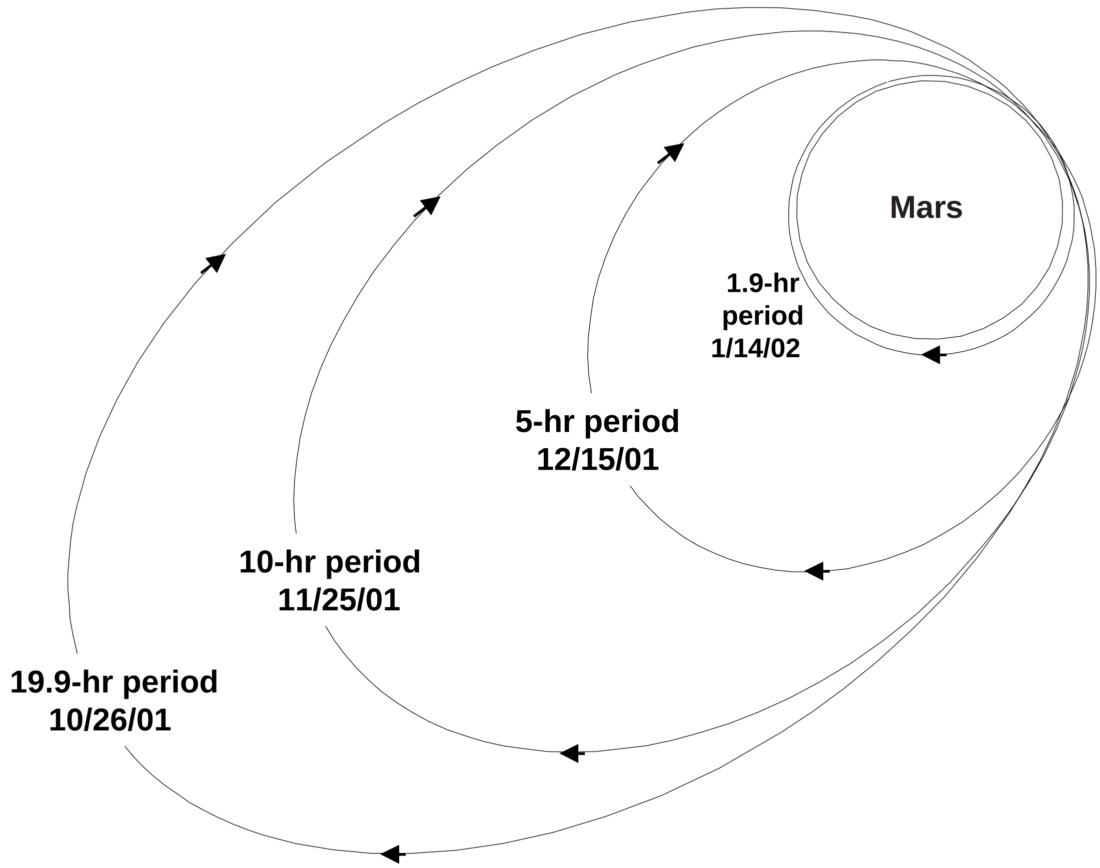
During cruise, engineers have been using several different techniques to track the spacecraft's position and speed. In one of these techniques, called two-way Doppler tracking, a ground station sends a signal to Odyssey and the spacecraft turns around and sends a signal back to Earth. By looking for small changes in the frequency of the spacecraft's signal, engineers can measure Odyssey's velocity in relation to Earth. (The signal's frequency changes with the spacecraft's speed, much like the rising and falling of the siren of a fire truck as it rushes by.)

A second technique used during Odyssey's cruise is ranging. Here, a signal is sent from Earth to the spacecraft, which again turns around and sends a signal back to Earth. By measuring precisely how long the signal takes to make the round trip at the speed of light, engineers can measure the spacecraft's distance from Earth.

For the Odyssey mission, engineers have supplemented those techniques with a third, newer one called "delta differential one-way range," or delta DOR. In this technique, two different ground stations on Earth simultaneously measure signals from Odyssey and from one of several distant quasars in space. Like beacons in the cosmos, quasars provide very stable radio signals. By combining the measured signals using a technique called interferometry, engineers can measure Odyssey's angular or three-dimensional motion relative to Earth. Using this technique improves the accuracy of Odyssey tracking by about a factor of three over what would be possible if the team was using only Doppler and ranging measurements.

The solar array was placed in its stowed position during a June 2001 test. The solar array will be stowed during Mars orbit insertion and aerobraking drag passes. During these operations, the solar array can still collect energy, but during orbit insertion the Sun angle is such that the array's power output is reduced and the spacecraft is largely running off its battery. The test demonstrated that the mechanisms used for stowing the array are operating as expected.

A series of checkouts of Odyssey's UHF radio transceiver have been performed during cruise. The UHF system is not part of the spacecraft's main science mission at Mars; it will be available for use as an orbiting relay to support future Mars landers. In the UHF tests, signals have been sent to and received from Odyssey via a ground antenna at the Stanford Research Institute in California. The tests have shown that Odyssey's UHF receiver is performing as expected. UHF signals transmitted from Odyssey, however, have been received on Earth at a signal strength 6 decibels lower than expected. The project is investigating this discrepancy, but preliminary analyses indicate that even if the UHF transmitter continues to perform at this lower level, planned data rates for support of lander missions will not be impacted.



Aerobraking orbits

Mars Orbit Insertion

Odyssey will arrive at Mars on October 24, 2001, as measured in Universal Time (the evening of October 23 in the United States).

Twenty-two hours before arrival, engineers will disable software sequences known as fault protection that could cause Odyssey to enter “safe mode” in response to unplanned events. Two and a half hours before arrival, a reaction wheel desaturation is performed. Nine and one half minutes before Mars orbit insertion, the propulsion system is pressurized. At that time, telecommunications system is switched so that Odyssey listens for commands from Earth on its low-gain antenna. It stops sending data to Earth and switches to sending a carrier signal only via its medium-gain antenna. The spacecraft will then turn to the desired Mars orbit insertion orientation.

As it nears its closest point to the planet over Mars’ northern hemisphere, the spacecraft will fire its 695-Newton main engine for approximately 20 minutes beginning at

02:26 Universal Time (7:26 p.m. PDT), Earth-received time. This will cause Odyssey to be captured into an elliptical, or egg-shaped, orbit around the planet. This is the only time the main engine is used during the entire mission.

The burn starts 12 minutes, 51 seconds before “periapsis,” the spacecraft's closest point to Mars. The total burn duration is just under 20 minutes. About 10 minutes into the burn, the spacecraft will pass behind Mars as seen from Earth, and the carrier signal will be lost. About 20 minutes later, Odyssey will emerge from behind Mars and, if all goes well, the carrier signal will be reacquired by ground stations on Earth. Shortly thereafter, downlink telemetry will be reestablished, and the flight team will evaluate the spacecraft’s health and status.

It is expected that Odyssey will be captured into an initial orbit that takes it once around Mars every 15 to 25 hours, with an average orbital period expected to be about 20 hours. If the orbital period is greater than 22 hours, the spacecraft will lower it by firing its small thrusters three orbits after arrival. This maneuver will be sized to reduce the orbit period to 20 hours.

Aerobraking

Aerobraking is a gradual process designed to adjust the shape of Odyssey’s orbit over a period of several weeks. Just after arriving at Mars, the spcecraft’s initial orbit is in the shape of an ellipse or loop. In order to fulfill its science mission, the final orbit must be very close to a circle at a uniform altitude above Mars. Aerobraking is a technique that slows the spacecraft down by using frictional drag as Odyssey skims the upper part of the planet's atmosphere with its large solar array.

During each of its long, elliptical loops around Mars, the orbiter will pass through the upper layers of the atmosphere each time it makes its closest approach to the planet. Friction from the atmosphere on the spacecraft and its wing-like solar array will cause the spacecraft to lose some of its momentum during each close approach, known as an "a drag pass." As the spacecraft slows during each close approach, the orbit will gradually lower and circularize.

Aerobraking will occur in three phases that engineers call “walk-in,” the “main phase” and “walk-out.” The walk-in phase includes the first four to eight orbits following Mars arrival. It will serve as a calibration period during which engineers can characterize the flight system performance, validate the flight team's processes and models, and establish the density of Mars’ atmosphere.

The first images will be taken during this early phase of aerobraking when the thermal emission imaging system is tested by taking an initial look at the Martian atmosphere. Odyssey will arrive near the end of the dust storm season, so it is anticipated that a dust storm may be in progress or may arise during the aerobraking period. The Mars Global Surveyor spacecraft currently in orbit at Mars will be used during the Odyssey arerobraking phase to monitor the atmosphere for dust storms. If for some reason Global Surveyor is unavailable for this purpose, Odyssey's infrared camera can be used for atmospheric monitoring of Mars. Before the start of aerobraking, science operations will begin for the neutron spectrometer and the high-energy neutron detector. The neutron spectrometer will operate for a few days until the spacecraft's altitude drops below 180 kilometers (112 miles). The high-energy neutron detector will continue to operate during aerobraking, but its high voltage will be turned off whenever the altitude is less than 180 kilometers (112 miles).

The main aerobraking phase begins once the point of the spacecraft's closest approach to the planet, or the "periapsis," has been lowered to within about 100 kilometers (62 miles) above the Martian surface. As the spacecraft's orbit is reduced and circularized during approximately 380 drag passes in 78 days, the periapsis point will move northward, almost directly over Mars' north pole. Small thruster firings when the spacecraft is at its most distant point from the planet will keep the drag pass altitude at the desired level to limit heating and dynamic pressure on the orbiter.

Aerobraking drag pass events will be executed by stored onboard command sequences. Each drag pass sequence begins with the heaters for the thrusters being warmed up for about 20 minutes. The spacecraft's radio transmitter is turned off to conserve power during the drag pass. Gyroscope-like devices called reaction wheels are used to turn the spacecraft to the proper orientation for aerobraking. Following the drag pass, the spacecraft is reconfigured to transmit data collected during the drag pass back to Earth.

The walk-out phase is the name that engineers use to describe the last few days of aerobraking when the period of the spacecraft's orbit is the shortest. Following aerobraking walk-out, the orbiter will be in an elliptical orbit with a periapsis near an altitude of 120 kilometers (75 miles) and an "apoapsis" -- the farthest point from Mars -- near a desired 400-kilometer (249-mile) altitude. The periapsis point will be near the Martian equator. Odyssey will then fire its thrusters in a maneuver to raise the periapsis, putting the spacecraft in the final 400-kilometer (249-mile) circular science orbit.

The transition from aerobraking to the beginning of the main science mapping mission will take about two weeks. At this time the spacecraft will deploy its dish-shaped high-gain antenna.

Mapping Orbit

The science mission begins in early February 2002 after the spacecraft is captured into orbit about Mars and aerobraking is completed. The primary science phase will last for 917 Earth days, or 2-1/2 Earth years. During the primary mission, Odyssey's orbit is inclined by 93.1 degrees, meaning that it passes very close to Mars' north and south poles. The orbit is also nearly "Sun-synchronous," meaning that Odyssey passes over the same part of Mars at roughly the same local time each day. The spacecraft will orbit Mars once in just under two hours.

During the primary mission, the thermal emission imaging system begin taking pictures. The neutron spectrometers will operate continuously during mapping. Following the start of the science mission, the gamma sensor head door on the gamma ray spectrometer will be opened; about six weeks later, the instrument's boom will be deployed, allowing the instrument to obtain global measurements during all Martian seasons. In addition, a recovery of the Martian radiation environment experiment will be attempted early in the mapping phase. Opportunities for science collection are assigned on a time-phased basis depending on when conditions are most favorable for specific instruments.

Relay Phase

At the end of the first Martian year in orbit (about two Earth years), Odyssey will have completed its main science mission. It will then be available to act as a radio relay to provide communication support for U.S. and international landers and rovers. These are expected to be the twin NASA Mars Exploration Rovers and the European Space Agency's Mars Express Beagle II lander.

Spacecraft

The shape of 2001 Mars Odyssey is not uniform, but its size can most easily be visualized by mentally placing the spacecraft inside of a box. Pictured this way, the box would measure 2.2 meters (7.2 feet) long, 1.7 meters (5.6 feet) tall and 2.6 meters (8.5 feet) wide. At launch Odyssey weighs 729.7 kilograms (1608.7 pounds), including the 331.8-kilogram (731.5-pound) dry spacecraft with all of its subsystems, 353.4 kilograms (779.1 pounds) of fuel and 44.5 kilograms (98.1 pounds) of instruments.

The framework of the spacecraft is composed mostly of aluminum and some titanium. The use of titanium, a lightweight metal, is an efficient way of conserving mass while retaining strength. Odyssey's metal structure is similar to that used in the construction of high-performance and fighter aircraft.

Most systems on the spacecraft are fully redundant. This means that, in the event of a device failure, there is a backup system to compensate. There are some exceptions, such as the main engine.

Command and Data Handling

All of Odyssey's computing functions are performed by the command and data handling subsystem. The heart of this subsystem is a RAD6000 computer, a radiation-hardened version of the PowerPC chip once used on many models of Macintosh computers. With 128 megabytes of random access memory (RAM) and three megabytes of non-volatile memory, which allows the system to maintain data even without power, the subsystem runs Odyssey's flight software and controls the spacecraft through interface electronics.

The interface electronics are computer cards that are used to communicate with external peripherals. These cards slip into slots in the computer's main board, giving the system specific functions it would not have otherwise. For redundancy purposes, there are two identical sets, or “strings,” of these computer and interface electronics, so that if one fails the spacecraft can switch to the other.

Communication with Odyssey's sensors that measure the spacecraft's orientation in space, or "attitude," and its science instruments is carried out via another interface card. A master input/output card collects signals from around the spacecraft and also sends commands to the electrical power subsystem. The interface to Odyssey's telecommunications subsystems takes place through another card called the uplink/downlink card.

There are two other boards in the command and data handling subsystem, both of which are internally redundant. One of them called the module interface card controls when the spacecraft switches to backup hardware and serves as the spacecraft's time clock. A converter card takes electricity produced by the power subsystem and converts it into the proper voltages for the rest of the command and data handling subsystem components.

The last interface card is a single, non-redundant, one-gigabyte mass memory card that is used to store imaging data. The entire command and data handling subsystem weighs 11.1 kilograms (24.5 pounds).

Telecommunications

Odyssey's telecommunications subsystem is composed of both a radio system operating in the X-band microwave frequency range and a system that operates in the ultra high frequency (UHF) range. The X-band system is used for communications between Earth and the Odyssey spacecraft, while the UHF system will be used for communications between Odyssey and future Mars landers.

The spacecraft communicates with Earth through three antennas. The high-gain antenna is a 1.3-meter-diameter (4.25-foot) dish used for high data rates during late cruise and the main mapping mission. The high-gain antenna can simultaneously receive commands from Earth while transmitting science data to Earth. Protruding through the high-gain antenna dish is a 7.1-centimeter-wide (2.8-inch) medium-gain rectangular horn antenna. In emergencies, or at times when the high-gain antenna is not pointed directly at Earth, wide-angle communications coverage for receiving commands from Earth is provided by a 4.4-centimeter-wide (1.75-inch) low-gain antenna. Altogether the telecommunication subsystem weighs 23.9 kilograms (52.7 pounds).

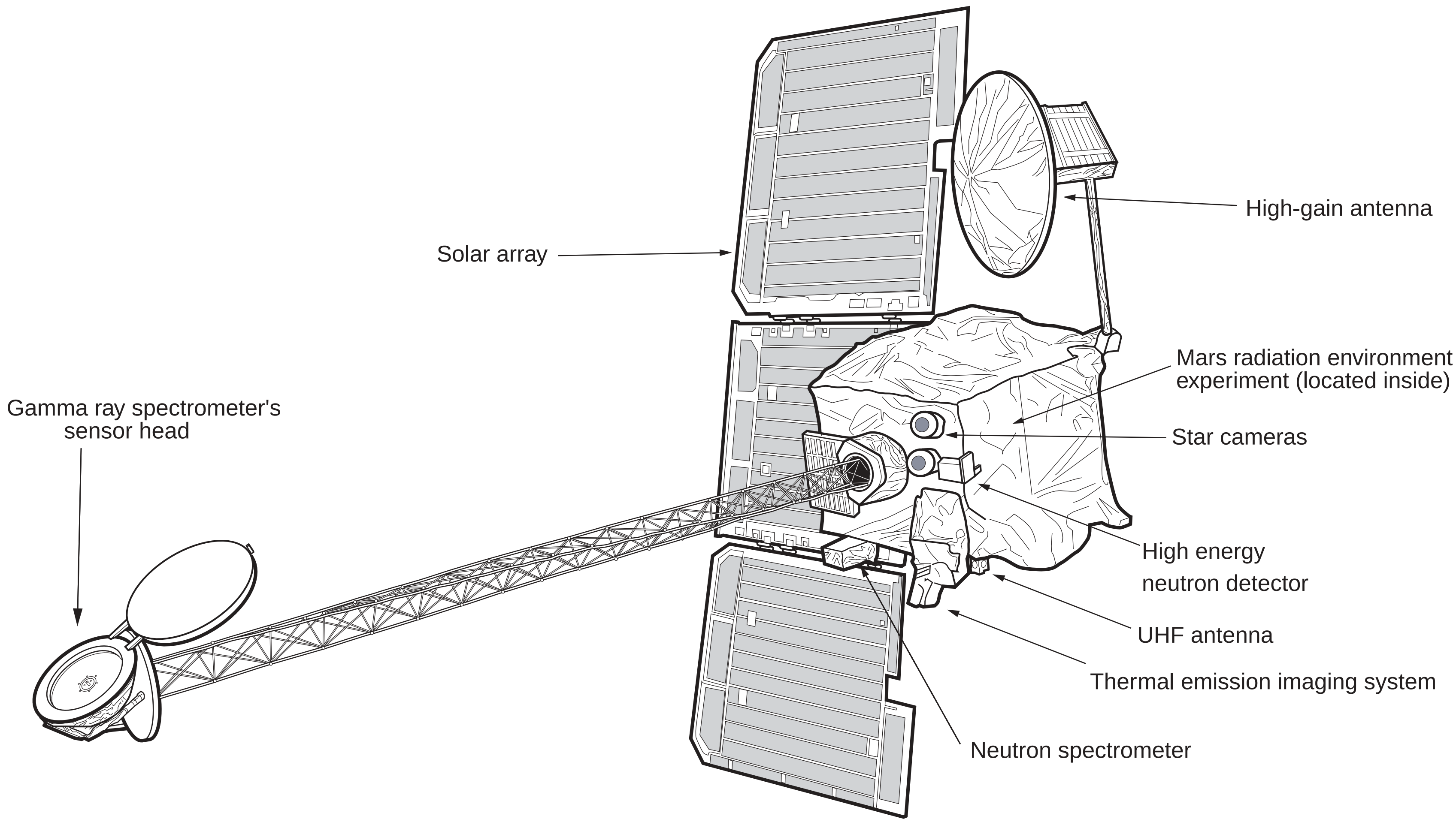
Electrical Power

All of the spacecraft's power is generated, stored and distributed by the electrical power subsystem. The system obtains its power from an array of gallium arsenide solar cells on a panel measuring 7 square meters (75 square feet). A power distribution and drive unit contains switches that send power to various electrical loads around the spacecraft. Power is also stored in a 16-amp-hour nickel-hydrogen battery.

The electrical power subsystem operates the gimbal drives on the high-gain antenna and the solar array. It contains also a pyro initiator unit, which fires pyrotechnically actuated valves, activates burn wires, and opens and closes thruster valves. The electrical power subsystem weighs 86.0 kilograms (189.6 pounds).

Guidance, Navigation and Control

The guidance, navigation and control subsystem determines the spacecraft's orientation, or "attitude," using three redundant pairs of sensors. A star camera is used to look at star fields. A Sun sensor is used to detect the position of the Sun as a backup to the star camera. Between star camera updates, a device called the inertial measure-



2001 Mars Odyssey spacecraft

ment unit collects information on spacecraft orientation.

This system also includes the reaction wheels, gyroscope-like devices used along with thrusters to control the spacecraft's orientation. Odyssey's orientation is held fixed in relation to space ("three-axis stabilized") as opposed to some spacecraft which are stabilized by spinning. There are a total of four reaction wheels, with three used for primary control and one as a backup. The guidance, navigation and control subsystem weighs 23.4 kilograms (51.6 pounds).

Propulsion

The propulsion subsystem features sets of small thrusters and a main engine. The thrusters are used to perform Odyssey's attitude control and trajectory correction maneuvers, while the main engine is used to place the spacecraft in orbit around Mars.

The main engine, which uses hydrazine propellant with nitrogen tetroxide as an oxidizer, produces a thrust of about 695 Newtons (156 pounds of force). Each of the four thrusters used for attitude control produce a thrust of 0.9 Newton (0.2 pound of force). Four 22-Newton (5-pound-force) thrusters are used for turning the spacecraft.

In addition to miscellaneous tubing, pyro valves and filters, the propulsion subsystem also includes a single gaseous helium tank used to pressurize the fuel and oxidizer tanks. The propulsion subsystem weighs 49.7 kilograms (109.6 pounds).

Structures

The spacecraft's structure is divided into two modules. The first is a propulsion module containing tanks, thrusters and associated plumbing. The other, the equipment module, is composed of an equipment deck, which supports engineering components and the radiation experiment, and a science deck connected by struts. The top side of the science deck supports the thermal emission imaging system, gamma ray spectrometer, the high-energy neutron detector, the neutron spectrometer and the star cameras, while the underside supports engineering components and the gamma ray spectrometer's central electronics box. The structures subsystem weighs 81.7 kilograms (180.1 pounds).

Thermal Control

The thermal control subsystem is responsible for maintaining the temperatures of each component on the spacecraft to within their allowable limits. It does this using a combination of heaters, radiators, louvers, blankets and thermal coatings. The thermal control subsystem weighs 20.3 kilograms (44.8 pounds).

Mechanisms

There are a number of mechanisms used on Odyssey, several of which are associated with its high-gain antenna. Three “retention and release devices,” or latches, are used to lock the antenna down during launch, cruise and aerobraking. Once the science orbit is attained at Mars, the antenna is released and deployed with a motor-driven hinge. The antenna's position is controlled with a two-axis gimbal assembly.

There are also four latches used for the solar array. The three panels of the array are folded together and locked down for launch. After deployment, the solar array is also controlled using a two-axis gimbal assembly.

The last mechanism is a latch for the deployable 6-meter (19.7-feet) boom for the gamma ray spectrometer. All of the mechanisms combined weigh 24.2 kilograms (53.4 pounds).

Flight Software

Odyssey receives its commands via radio from Earth and translates them into spacecraft actions. The flight software is capable of running multiple concurrent sequences, as well as executing immediate commands as they are received.

The software responsible for the data collection is extremely flexible. It collects data from the science and engineering devices and puts them in a variety of figurative holding bins. The choice of which channel is routed to which holding bin, and how often it is sampled, is easily modified via ground commands.

The flight software is also responsible for a number of automated functions which the spacecraft performs on its own without explicit commands from Earth. For example, the spacecraft periodically runs routines to control its attitude or orientation in space. It also carries out fault protection, which involves frequent internal checks to determine if any problem has occurred. If the software senses a problem, it will automatically perform a number of preset actions to resolve the problem and put the spacecraft in a safe standby mode awaiting further direction from ground controllers.

Science Objectives

One of the chief scientific goals that 2001 Mars Odyssey will focus on is mapping the chemical elements and minerals that make up the Martian surface. As on Earth, the elements, minerals and rocks that form the Martian planet chronicle its history. And while neither elements (the building blocks of minerals) nor minerals (the building blocks of rocks) can convey the entire story of a planet's evolution, both contribute significant pieces to the puzzle. These factors have profound implications for understanding the evolution of Mars' climate and the role of water on the planet, the potential origin and evidence of life, and the possibilities that may exist for future human exploration.

Other major goals of the Odyssey mission are to:

- ❑ Determine the abundance of hydrogen, most likely in the form of water ice, in the shallow subsurface
- ❑ Globally map the elements that make up the surface
- ❑ Acquire high-resolution thermal infrared images of surface minerals
- ❑ Provide information about the structure of the Martian surface
- ❑ Record the radiation environment in low Mars orbit as it relates to radiation-related risk to human exploration

During the 917-day science mission, Odyssey will also serve as a communication relay for U.S. or international landers in 2004.

The orbiter carries three science payloads comprised of six individual instruments: a thermal infrared imaging system, made up of visible and infrared sensors; a gamma ray spectrometer, which also contains a neutron spectrometer and high-energy neutron detector; and a radiation environment experiment.

Thermal Emission Imaging System

This instrument is responsible for studying the minerals on Mars' surface. Unlike our eyes, which can only detect visible light waves, or a small portion of the electromagnetic spectrum, this instrument can see in both visible and infrared, thus collecting imaging data that would otherwise be invisible to scientists.

In the infrared spectrum, the instrument uses nine spectral bands to help detect minerals within the Martian terrain. These spectral bands, similar to ranges of colors, can obtain the signatures, or spectral fingerprints, of particular types of geological materials. Minerals such as carbonates, silicates, hydroxides, sulfates, hydrothermal silica, oxides and phosphates, all show up as different colors in the infrared spectrum. This multi-spectral method allows researchers to detect in particular the presence of minerals that form in water and understand those minerals in their proper geological context.

Remote-sensing studies of natural surfaces, together with laboratory measurements, have demonstrated that nine spectral bands are sufficient to detect minerals at abundances of five to 10 percent. In addition, the use of nine infrared spectral bands can determine the absolute mineral abundance in a specific location within 15 percent.

The payload's multi-spectral approach will also provide data on localized deposits associated with hydrothermal and subsurface water and enable 100-meter-resolution (328-foot) mapping of the entire planet. In essence, this allows a broad geological survey of the planet for the purpose of identifying minerals, with 100 meters (328 feet) of Martian terrain captured in each pixel, or single point, of every image. It will also allow the instrument to search for thermal spots during the night that could result in discovering hot springs on Mars.

Using visible imaging in five spectral bands, the instrument will also capture 18-meter-resolution (59-foot) images specifically to determine the geological record of past liquid environments. More than 15,000 images each 20 by 20 kilometers (12 by 12 miles) will be acquired for Martian surface studies. These will be used in conjunction with mineral maps to identify potential future Martian landing sites. These images will provide an important bridge between the data acquired by the Viking missions of the 1970s and the high-resolution images captured by NASA’s currently orbiting Mars Global Surveyor.

The instrument weighs 11.2 kilograms (24.7 pounds); is 54.5 centimeters (21.5 inches) long, 37 centimeters (14.6 inches) tall and 28.6 centimeters (11.3 inches) wide; and runs on 14 watts of electrical power.

The principal investigator for the instrument is Dr. Philip Christensen of Arizona State University in Tempe.

Gamma Ray Spectrometer

This payload plays a lead role in determining the elements that make up the Martian surface. Using a gamma ray spectrometer and two neutron detectors, the experiment detects and studies gamma rays and neutrons emitted from the planet's surface.

When exposed to cosmic rays, all chemical elements emit gamma rays with distinct signatures. This spectrometer looks at these signatures, or energies, coming from the elements present in the Martian soil. By measuring gamma rays coming from the Martian surface, it is possible to calculate how abundant various elements are and how they are distributed around the planet's surface.

By measuring neutrons, it is possible to calculate the abundance of hydrogen just under the Martian surface, which in turn likely signals the presence of water or ice. The neutron detectors are sensitive to concentrations of hydrogen in the upper meter of the surface.

Gamma rays, emitted from the nuclei of atoms, show up as sharp emission lines on the instrument's spectrum. While the energy represented in these emissions determines which elements are present, the intensity of the spectrum reveals the elements' concentrations. The spectrometer will take a reading every 20 seconds. These data will be collected over time and used to build up a full-planet map of elemental abundances and their distributions.

The spectrometer's data, collected at 300-kilometer (186-mile) resolution, will enable researchers to address many questions and problems regarding Martian geoscience and life science, including the composition of the planet's crust and mantle, weathering processes and volcanism. The spectrometer is expected to add significantly to the growing understanding of the origin and evolution of Mars and of the processes shaping it today and in the past.

The gamma ray spectrometer consists of four main components: a gamma sensor head, a neutron spectrometer, a high-energy neutron detector and a central electronics assembly. The sensor head is separated from the rest of the Odyssey spacecraft by a 6.2-meter (20-foot) boom, which will be extended 200 days after Odyssey has entered its final mapping orbit at Mars. The sensor head is placed on this boom to minimize interference from any gamma rays coming from the spacecraft itself. The two neutron detectors -- the neutron spectrometer and the high-energy neutron detector -- are mounted on the main spacecraft structure and will operate continuously throughout the mapping mission.

The instrument weighs 30.5 kilograms (67.2 pounds) and uses 32 watts of power. Along with its cooler, the gamma ray spectrometer measures 46.8 centimeters (18.4 inches) long, 53.4 centimeters (21.0 inches) tall and 60.4 centimeters (23.8 inches) wide. The neutron spectrometer is 17.3 centimeters (6.8 inches) long, 14.4 centimeters (5.7 inches) tall and 31.4 centimeters (12.4 inches) wide. The high-energy neutron detector measures 30.3 centimeters (11.9 inches) long, 24.8 centimeters (9.8 inches) tall and 24.2 centimeters (9.5 inches) wide. The instrument's central electronics box is 28.1 centimeters (11.1 inches) long, 24.3 centimeters (9.6 inches) tall and 23.4 centimeters (9.2 inches) wide.

The team leader for the gamma ray spectrometer is Dr. William Boynton of the University of Arizona. Dr. William Feldman of Los Alamos National Laboratory is team leader for the neutron spectrometer, and Dr. Igor Mitrofanov of Russia's Space Institute is principal investigator for the high-energy neutron detector.

Martian Radiation Environment Experiment

This instrument studies the radiation environment on the way to Mars and in the Martian orbit. Since space radiation presents an extreme hazard to human crews of interplanetary missions, the experiment will attempt to predict anticipated radiation doses that would be experienced by future astronauts and help determine possible effects of Martian radiation on human beings.

Space radiation comes from two sources -- energetic particles from the Sun, and galactic cosmic rays from beyond our solar system. Both kinds of radiation can trigger cancer and cause damage to the central nervous system. A spectrometer inside the instrument will measure the energy from these radiation sources. As the spacecraft orbits the red planet, the spectrometer sweeps through the sky and measures the radiation field. The instrument has a 68-degree field of view.

The instrument was to continuously collect data during Odyssey's cruise from Earth to Mars. The experiment operated for four months during cruise and collected 220 megabytes of science data. However, the instrument was turned off on August 20, 2001, after it failed to respond during a downlink session. An investigation team has been troubleshooting the problem, and attempts will be made to recover the experiment early during Odyssey’s main mapping phase.

The instrument weighs 3.3 kilograms (7.3 pounds) and uses 7 watts of power. It measures 29.4 centimeters (11.6 inches) long, 23.2 centimeters (9.1 inches) tall and 10.8 centimeters (4.3 inches) wide.

The principal investigator for the radiation environment experiment was the late Dr. Gautum Badhwar of NASA's Johnson Space Center. Dr. Frank Cucinotta has been appointed as principal investigator.

Program/Project Management

The 2001 Mars Odyssey mission is managed by the Jet Propulsion Laboratory, Pasadena, Calif., for NASA's Office of Space Science, Washington, D.C. At NASA Headquarters, Dr. Edward Weiler is the associate administrator for space science, Orlando Figueroa is the Mars program director, Dr. James Garvin is the lead scientist for the Mars Exploration Program, Mark Dahl is the 2001 Mars Odyssey program executive, and Dr. Michael Meyer is the 2001 Mars Odyssey program scientist.

At the Jet Propulsion Laboratory, Dr. Firouz Naderi is the Mars program manager, Dr. Daniel McCleese is Mars program scientist, Matthew Landano is the 2001 Mars Odyssey project manager and Dr. R. Stephen Saunders is the 2001 Mars Odyssey project scientist.

At Lockheed Martin Astronautics, Denver, Colo., Robert L. Berry is the company's Odyssey program manager.

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