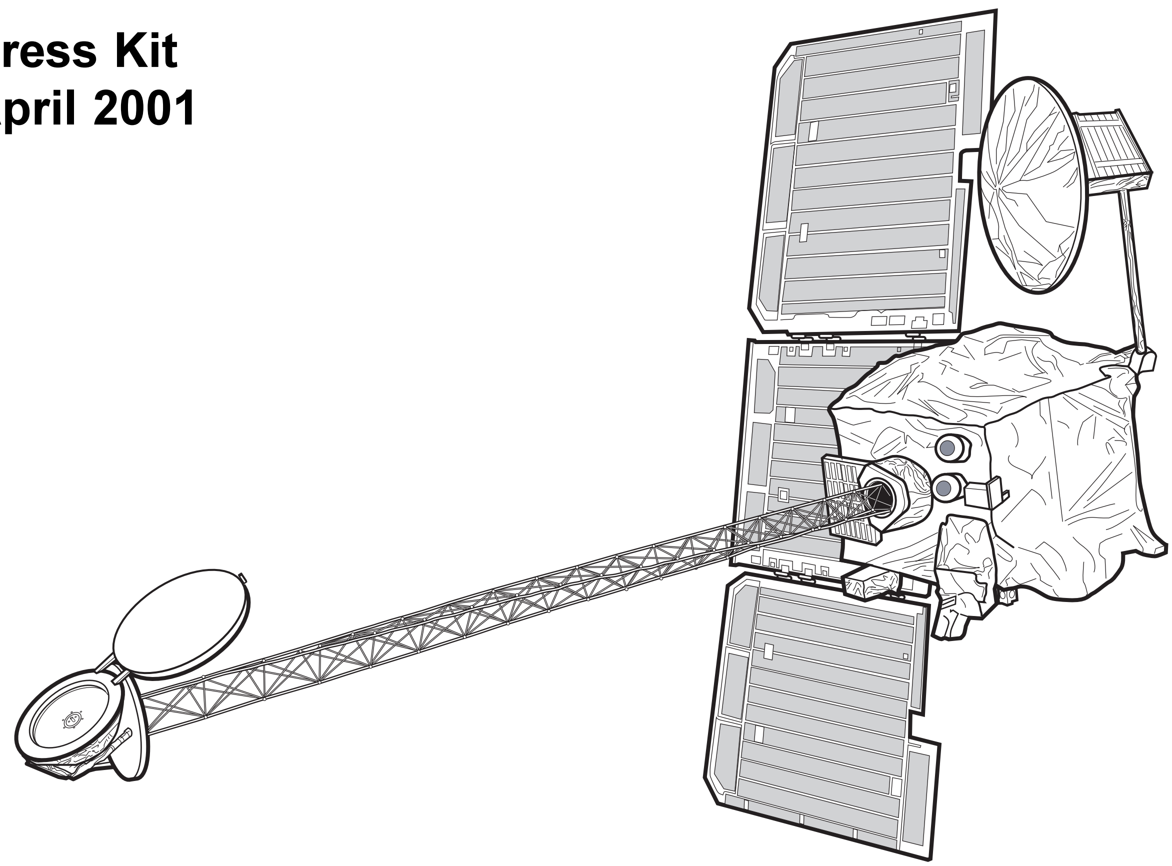
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

2001 Mars Odyssey Launch

Press Kit
April 2001



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RELEASE:

2001 MARS ODYSSEY SET TO FIND OUT WHAT MARS IS MADE OF

When NASA's 2001 Mars Odyssey launches in April to explore the fourth planet from the Sun, it will carry a suite of scientific instruments designed to tell us what makes up the Martian surface, and provide vital information about potential radiation hazards for future human explorers.

"The launch of 2001 Mars Odyssey represents a milestone in our exploration of Mars -- the first launch in our restructured Mars Exploration Program we announced last October," said Dr. Ed Weiler, Associate Administrator for Space Science, NASA Headquarters, Washington, D.C. "Mars continues to surprise us at every turn. We expect Odyssey to remove some of the uncertainties and help us plan where we must go with future missions."

Set for launch April 7 from Cape Canaveral Air Force Station, Fla., Odyssey is NASA's first mission to Mars since the loss of two spacecraft in 1999. 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, fewer than one-third have been successful.

The Odyssey team conducted vigorous reviews and incorporated "lessons learned" in the mission plan. "The project team has looked at the people, processes, and design to understand and reduce our mission risk," said George Pace, 2001 Mars Odyssey Project Manager at NASA's Jet Propulsion Laboratory, Pasadena, Calif. "We haven't been satisfied with just fixing the problems from the previous missions. We've been trying to anticipate and prevent other things that could jeopardize the success of the mission."

Odyssey is part of NASA's Mars Exploration Program, a long-term robotic exploration initiative launched in 1996 with Mars Pathfinder and Mars Global Surveyor. "The scientific trajectory of the restructured Mars Exploration Program begins a new era of reconnaissance with the Mars Odyssey orbiter," said Dr. Jim Garvin, Lead Scientist for NASA's Mars Exploration Program. "Odyssey will help identify and ultimately target those places on Mars where future rovers and landers must visit to unravel the mysteries of the red planet."

NASA's latest explorer carries three scientific instruments to map the chemical and mineralogical makeup of Mars: a thermal-emission imaging system, a gamma ray spectrometer and a Martian radiation environment experiment. The imaging system will map the planet with high-resolution thermal images and give scientists an increased level of detail to help them understand how the mineralogy of the planet relates to the landforms. The part of Odyssey's imaging system that takes pictures in visible light will see objects with a clarity that fills the gaps between the Viking orbiter cameras of the 1970s and today's high-resolution images from Mars Global Surveyor.

Like a virtual shovel digging into the surface, Odyssey's gamma ray spectrometer will allow scientists to peer into the shallow subsurface of Mars, the upper few centimeters of the crust, to measure many elements, including the amount of hydrogen that exists. Since hydrogen is mostly likely present in the form of water ice, the spectrometer will be able to measure permanent ground ice and how that changes with the seasons.

"For the first time at Mars we will have a spacecraft that is equipped to find evidence for present near-surface water and to map mineral deposits from past water activity," said Dr. Steve Saunders, 2001 Mars Odyssey Project Scientist at JPL. "Despite the wealth of information from previous missions, exactly what Mars is made of is not fully known, so this mission will give us a basic understanding about the chemistry and mineralogy of the surface."

The Martian radiation environment experiment will be the first to look at radiation levels at Mars as they relate to the potential hazards faced by future astronauts. The experiment will take data on the way to Mars and in orbit around the red planet. After completing its primary mission, the Odyssey orbiter will provide a communications relay for future American and international landers, including NASA's Mars Exploration Rovers, scheduled for launch in 2003.

The Jet Propulsion Laboratory, Pasadena, Calif., manages the 2001 Mars Odyssey mission for NASA's Office of Space Science, Washington, D.C. Principal investigators at Arizona State University, the University of Arizona and NASA's Johnson Space Center will operate the science instruments. Lockheed Martin Astronautics, Denver, Colo., is the prime contractor for the project, and developed and built the orbiter. Mission operations will be conducted jointly from JPL, a division of the California Institute of Technology in Pasadena, and Lockheed Martin.

- End of General Release -

Media Services Information

NASA Television Transmission

NASA Television is broadcast on the satellite GE-2, transponder 9C, C band, 85 degrees west longitude, frequency 3880.0 MHz, vertical polarization, audio monaural at 6.8 MHz. The schedule for television transmissions for the 2001 Mars Odyssey launch 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.

Status Reports

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

Launch Media Credentialing

Requests to cover the 2001 Mars Odyssey launch must be faxed in advance to the NASA Kennedy Space Center newsroom at 321/867-2692. Requests must be on the letterhead of the news organization and must specify the editor making the assignment to cover the launch.

Briefings

An overview of the mission will be presented in a news briefing broadcast on NASA Television originating from NASA Headquarters in Washington, D.C., at 1 p.m. EST March 19. Pre-launch briefings at Kennedy Space Center are scheduled at 1 p.m. and 2 p.m. Eastern time the day before 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: 725 kilograms (1,598.4 pounds) total, composed of 331.8-kilogram (731.5-pound) dry spacecraft, 348.7 kilograms (768.8 pounds) of fuel and 44.5 kilograms (98.1 pounds) of science instruments
Science instruments: Thermal emission imaging system, gamma ray spectrometer, Martianradiation 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 window: April 7 to April 27, 2001
Earth-Mars distance at launch: 125 million km (77.5 million miles)
Total distance traveled Earth to Mars: 460 million kilometers (286 million miles)
Mars arrival date: October 24, 2001
Earth-Mars distance at arrival: 150 million kilometers (93 million miles)
One-way speed of light time Mars-to-Earth at arrival: 8 minutes, 30 seconds
Primary science mapping period: January 2002 -July 2004

Program
Cost: $297 million total for 2001 Mars Odyssey
$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 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, organic 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 heat 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 hospitable 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 process of climate change taking place over many millennia.

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. If the planet's atmosphere became thinner, then liquid water could not flow without evaporating. Mars' atmosphere today is overwhelmingly composed of carbon dioxide. Over time, carbon dioxide gas reacts with elements in rocks and becomes locked up as a kind of compound called a carbonate.

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, if near a heat source, possibly in liquid form.

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 chemistry 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. The high-resolution imaging system on Odyssey will be able to identify regions such as hot springs, if any exist, which could serve as prime sites in which to refine our surface search for signs of simple biological processes.

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.

❑ **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, options that could move the date sooner to 2011 are presently under detailed examination. 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 three packages of 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 liquid water and evidence of past life. The mission will extend across a full Martian year, or 29 Earth months.

Launch Vehicle

Odyssey will be launched on a variant of Boeing's Delta II rocket called the 7925 that includes nine strap-on solid-fuel motors. Each of the nine solid-fuel boosters is 1 meter (3.28 feet) in diameter and 13 meters (42.6 feet) long; each contains 11,765 kilograms (25,937 pounds) of a propellant called hydroxyl-terminated polybutadiene (HTPB) and provides an average thrust of 485,458 newtons (109,135 pounds) at liftoff. The casings on the solid rocket motors are made of lightweight graphite epoxy.

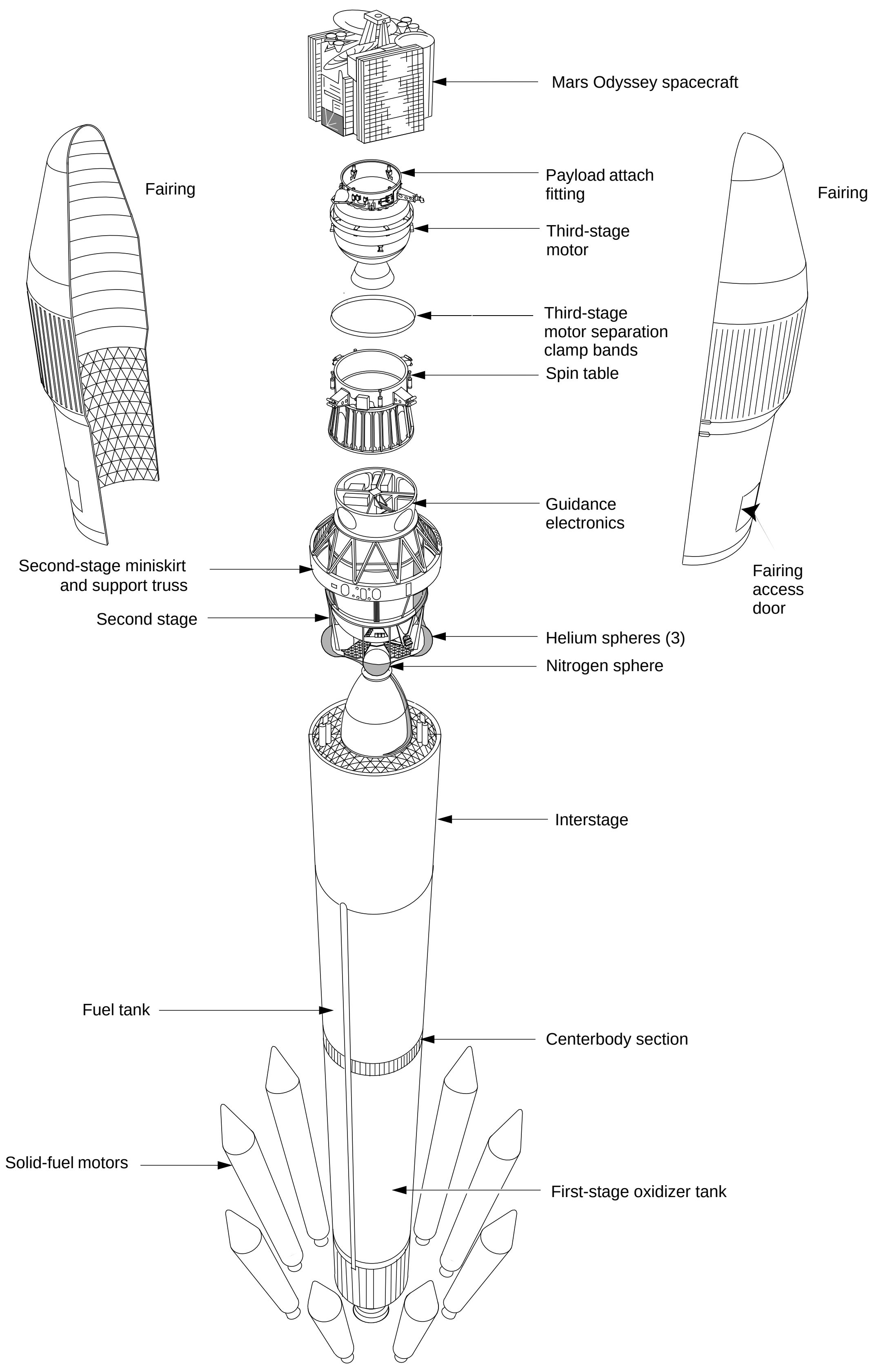
The main body of the first stage houses the Rocketdyne RS-27A main engine and two Rocketdyne LR101-NA-11 vernier engines. The vernier engines provide roll control during main engine burn and attitude control after main engine cutoff before the second stage separation. The RS-27A main engine burns 96,000 kilograms (211,000 pounds) of RP-1 (rocket propellant 1, a highly refined form of kerosene) as its liquid fuel and liquid oxygen as an oxidizer.

The second stage is 2.4 meters (8 feet) in diameter and 6 meters (19.7 feet) long, and is powered by an Aerojet AJ10-118K engine. The propellant is 3,929 kilograms (8,655

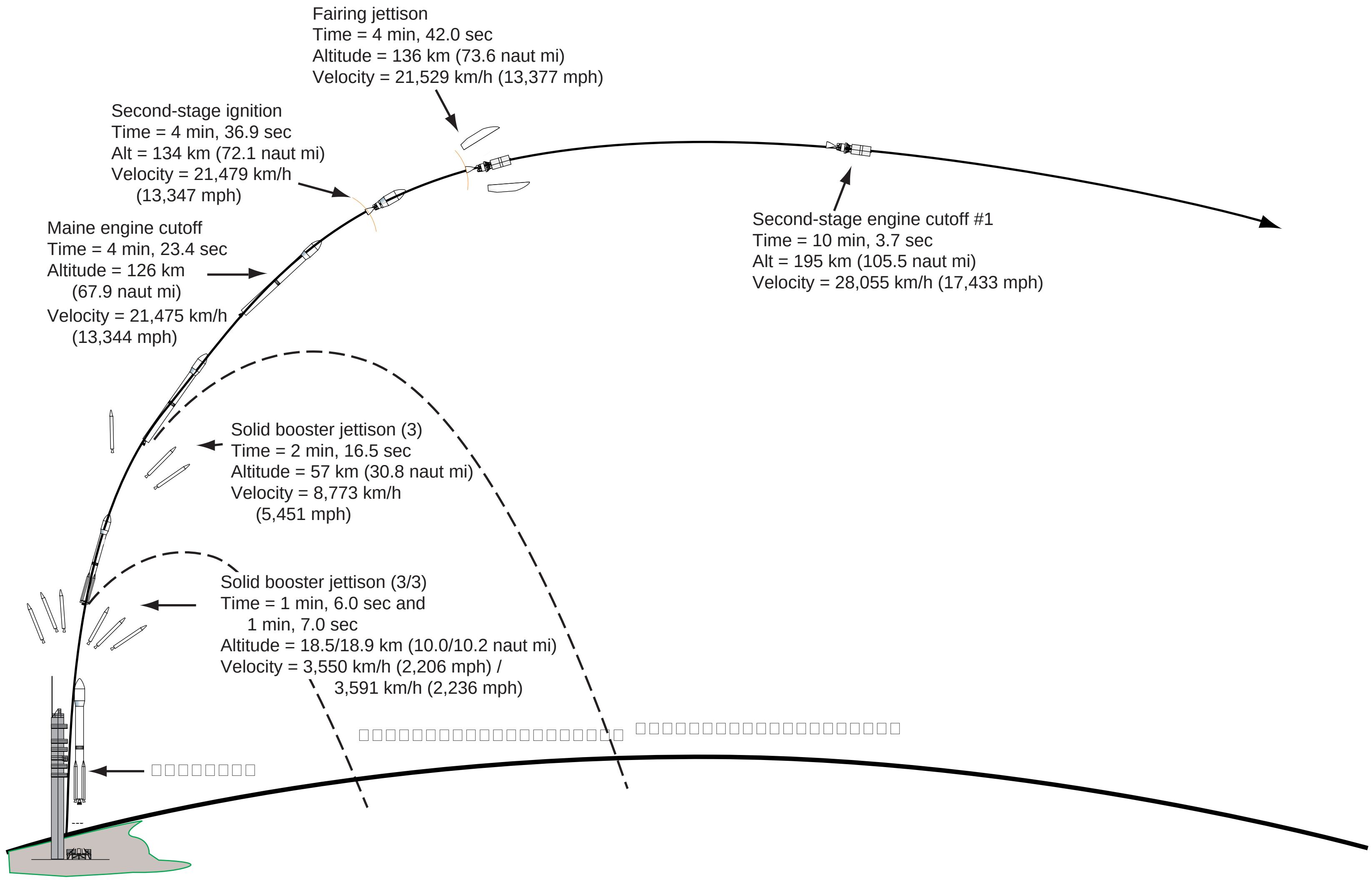
Orbiter Daily Launch Opportunities

The orbiter has two near-instantaneous launch opportunities each day (all times EDT)

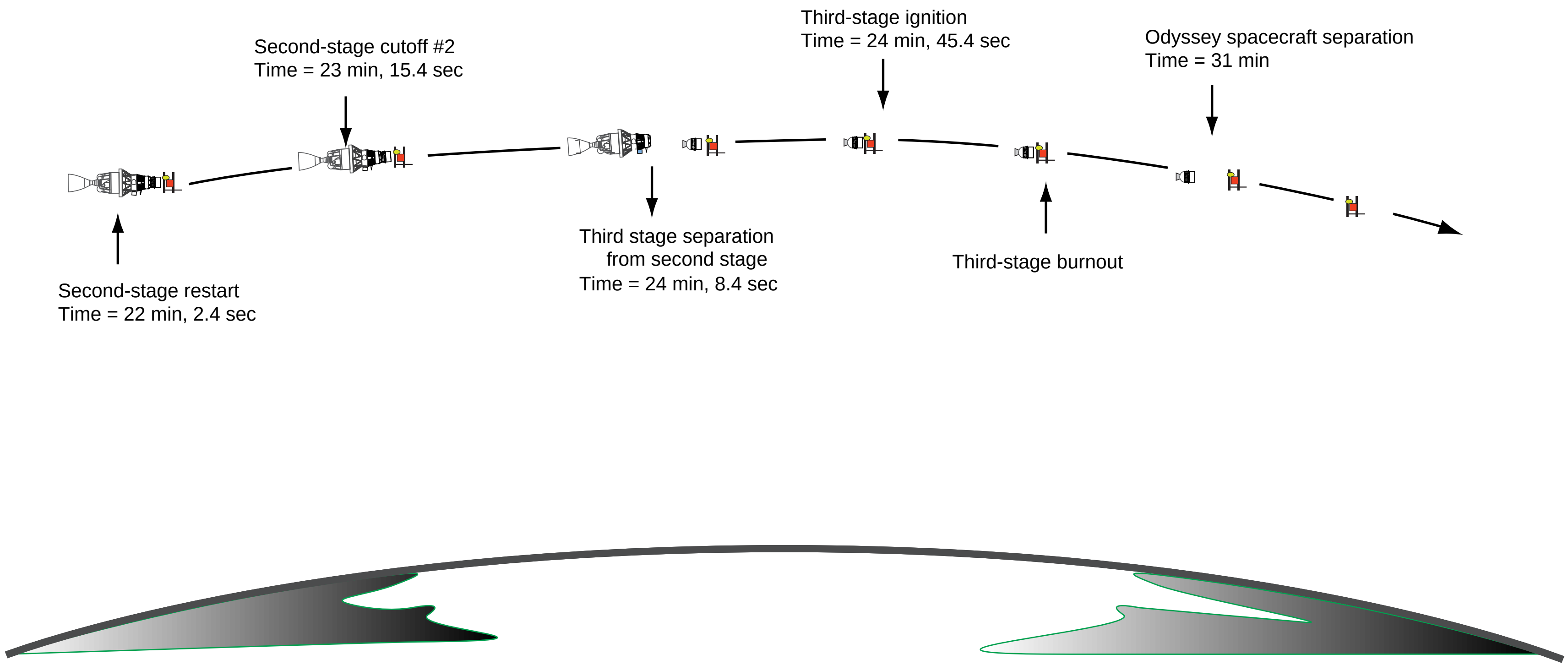
Date	*First Opportunity*	*Second Opportunity*	*Date*	*First Opportunity*	*Second Opportunity*
4/7/01	11:02:22 am	11:32.22 am	4/18/01	7:58:53 am	8:37:50 am
4/8/01	10:29:00	11:29:00	4/19/01	7:38:34	8:14:26
4/9/01	9:57:36	10:57:36	4/20/01	7:29:27	8:04:03
4/10/01	9:33:01	11:01:17	4/21/01	7:23:28	7:57:21
4/11/01	9:19:24	10:27:28	4/22/01	7:15:12	7:48:06
4/12/01	9:00:53	9:57:23	4/23/01	7:07:26	7:39:28
4/13/01	8:45:05	9:35:08	4/24/01	7:00:06	7:31:25
4/14/01	8:31:00	9:16:47	4/25/01	6:53:12	7:23:49
4/15/01	8:22:12	9:05:52	4/26/01	6:46:41	7:16:43
4/16/01	8:10:05	8:51:11	4/27/01	6:40:32	7:10:01
4/17/01	7:58:53	8:37:50			



Delta II launch vehicle



Launch boost phase



Launch injection phase

pounds) of a liquid fuel called Aerozine 50, a 50/50 mixture of hydrazine and unsymmetric dimethly hydrazine. The oxidizer is 2,101 kilograms (4,628 pounds) of nitrogen tetroxide. The engine is restartable and will perform two separate burns during the launch.

The third and final stage of the Delta II provides the final velocity required to place Odyssey on a trajectory to Mars. This upper stage is 1.25 meters (4.1 feet) in diameter and consists of a Star-48B solid-fuel rocket motor with 2,012 kilograms (4,431 pounds) of propellant and a system called active nutation control that provides stability after the motor ignites. A spin table attached to the top of the Delta's second stage supports, rotates and stabilizes the Odyssey spacecraft and Star-48B upper stage before they spin up and separate from the second stage. The Odyssey spacecraft is mounted to the Star-48B by a payload attachment fitting. A yo-yo despin system decreases the spin rate of the spacecraft and upper stage before they separate from each other.

During launch and ascent through Earth's atmosphere, the Odyssey spacecraft and Star-48B upper stage are protected from aerodynamic forces by a 2.9-meter--diameter (9.5-foot) payload fairing that is jettisoned from the Delta II during second stage powered flight at an average altitude of 136 kilometers (73.6 nautical miles).

Launch Period

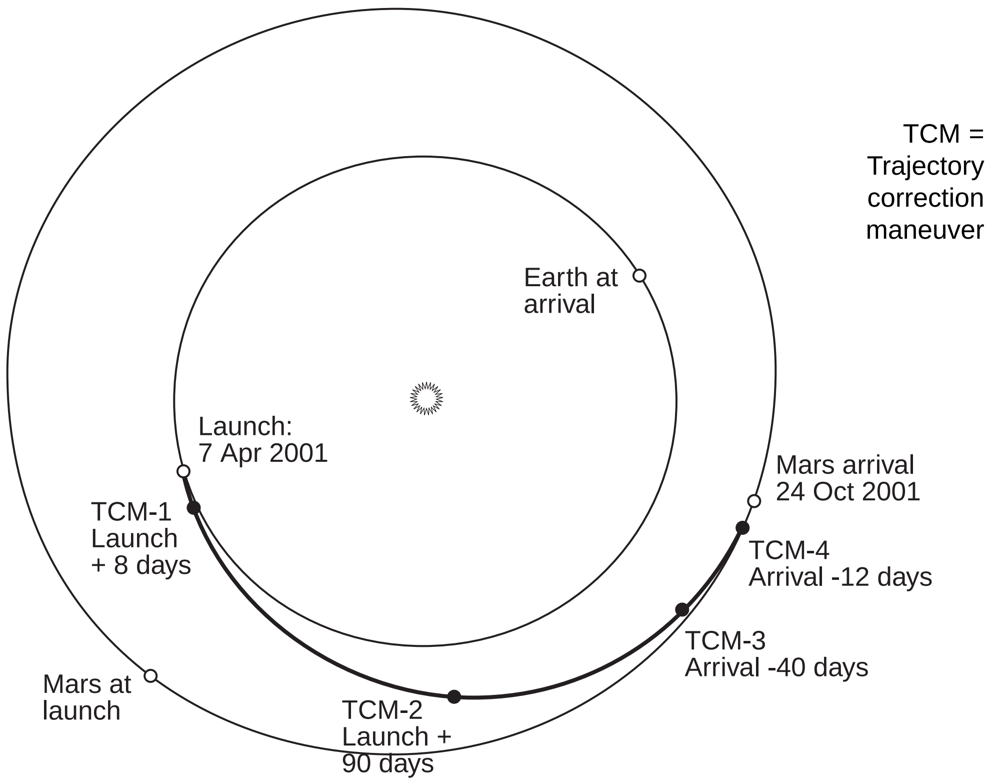
The orbiter launch period extends for 21 days, opening on April 7 and closing on April 27. The first 12 days of the launch period from April 7 through 18 make up what is considered the primary launch period; a secondary launch period runs from April 19 through 27. If Odyssey is launched during the secondary period, science data return at Mars may need to be reduced slightly because of higher arrival speeds and a longer aerobraking periods. Arrival dates at Mars vary with launch dates, and range from October 17 to 28, 2001.

Daily Windows

Two nearly instantaneous launch opportunities occur each day during the launch period each is separated by 30 to 90 minutes depending on the day. On April 7 the first is at 11:02 a.m. EDT and the second is at 11:32 a.m. EDT. The opportunities become earlier each day through the launch period.

Liftoff

Odyssey will lift off from Space Launch Complex 17 at Cape Canaveral Air Station, Florida. Sixty-six seconds after launch, the first three solid rocket boosters will be discarded followed by the next three boosters one second later. The final three boosters are jettisoned two minutes, 11 seconds after launch. About four minutes, 24 seconds after liftoff, the first stage will stop firing and be discarded eight seconds later. About



Interplanetary trajectory

five seconds later, the second stage engine ignites. The fairing or nose cone will be discarded four minutes, 41 seconds after launch. The first burn of the second stage engine occurs at 10 minutes, three seconds after launch.

At this point the vehicle is in low Earth orbit at an altitude of 189 kilometers (117 miles). Depending on the actual launch day and time the vehicle will then coast for several minutes, once it is in the correct point in its orbit, the second stage will be restarted at 24 minutes, 32 seconds after launch.

Small rockets will then be fired to spin up the third stage on a turntable attached to the second stage. The third stage will separate and ignite its motor, sending the spacecraft out of Earth orbit. A nutation control system (a thruster on an arm mounted on the side of the third stage) will be used to maintain stability during this the third stage burn. After that, the spinning upper stage and the attached 2001 Mars Odyssey spacecraft must be despun so that the spacecraft can be separated and acquire its proper cruise orientation. This is accomplished by a set of weights that are reeled out from the side of the spinning vehicle on flexible lines, much as spinning ice skaters slow themselves by extending their arms. Odyssey will separate from the Delta third stage about 33 minutes after launch. Any remaining spin will be removed using the orbiter's onboard thrusters.

About 36 minutes after launch the solar array is unfolded and about eight minutes later it is locked in place. Then the spacecraft turns to its initial communication attitude and the transmitter is turned on. About one hour after launch the 34-meter-diameter (112 foot) antenna at the Deep Space Network complex near Canberra, Australia will acquire Odyssey's signal.

Interplanetary Cruise

The interplanetary cruise phase is the period of travel from the Earth to Mars and lasts about 200 days. It begins with the first contact by the DSN after launch and extends until seven days before Mars arrival. Primary activities during the cruise include check out of the spacecraft in its cruise configuration, checkout and monitoring of the spacecraft and the science instruments and navigation activities necessary to determine and correct Odyssey's flight path to Mars.

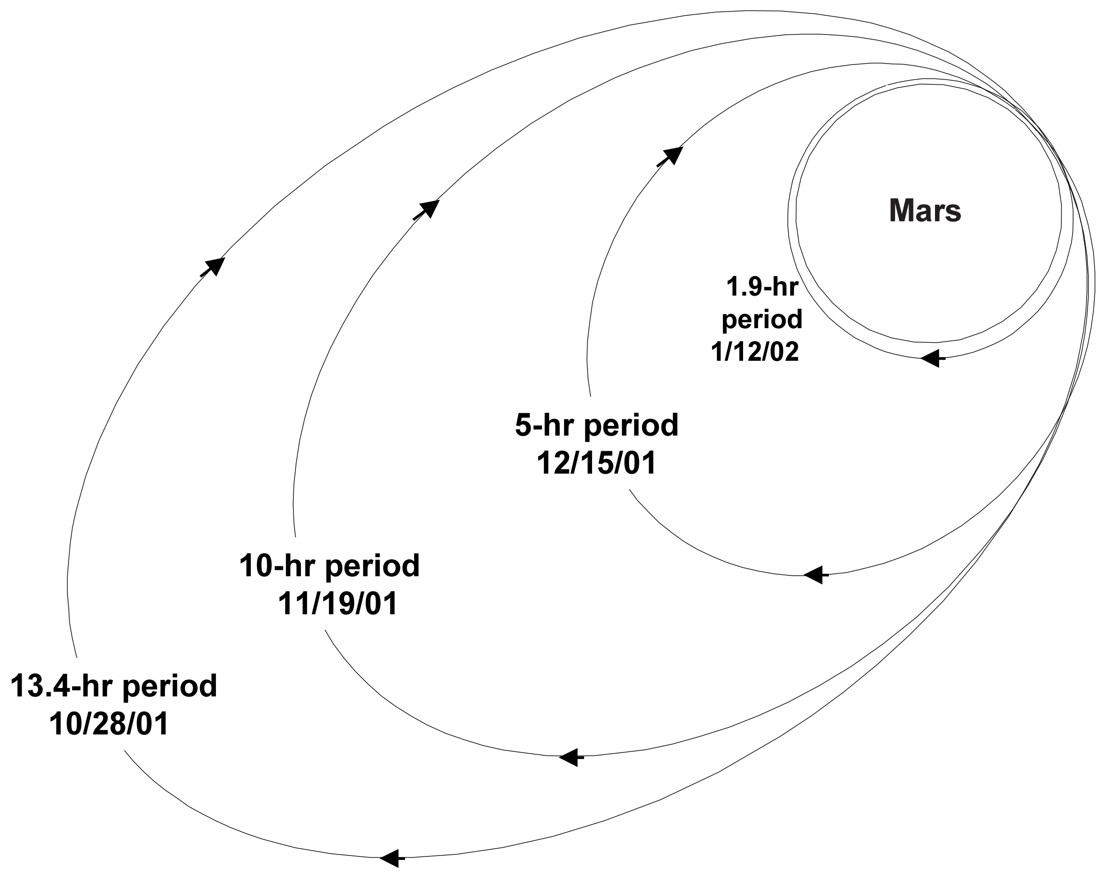
There are science activities planned for the cruise phase including payload health and status checks, instrument calibrations, as well as data taking by some of the science instruments as spacecraft limitations allow.

Odyssey's flight path to Mars is called 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 station in Canberra will be capable of viewing the spacecraft. Late in May California's Goldstone station will come into view, and by early June the Madrid station will also be able to track the spacecraft. The project has also added the use of a tracking station in Santiago, Chile, to fill in tracking coverage during the first seven days following launch.

The orbiter will transmit to Earth using its medium-gain antenna and it will receive commands on its low-gain antenna during the early portion on its flight. At some point during the first 30 days after launch, the orbiter will be commanded to receive and transmit through its high-gain antenna. Cruise command sequences are generated and uplinked approximately once every four weeks during one of the regularly scheduled Deep Space Network passes.

The spacecraft will determine its orientation in space chiefly via a star camera and a device called an inertial measurement unit. The spacecraft will fly with its medium or high gain antenna pointed toward the Earth at all times while keeping the solar panels pointed toward the Sun. The spacecraft is stabilized in three axes and will not spin to maintain its orientation, or "attitude."

The spacecraft's orientation will be controlled by reaction wheels, devices with spinning wheels similar to gyroscopes. These devices will be occasionally "desaturated," meaning that their momentum will be unloaded by firing the spacecraft's thrusters.



Aerobraking orbits

During interplanetary cruise, Odyssey is scheduled to fire its thrusters a total of five times to adjust its flight path. The first of these trajectory correction maneuvers is scheduled for eight days after launch, and will correct launch injection errors and adjust the Mars arrival aim point. It will be followed by a second maneuver 90 days after launch.

The remaining three trajectory correction maneuvers will be used to direct the spacecraft to the proper aim point at Mars. These maneuvers are scheduled at 90 days after launch, 12 days before arrival and seven hours (October 24) before arrival. The spacecraft will communicate with Deep Space Network antennas continuously for 24 hours around all of the trajectory correction maneuvers. Maneuvers will be conducted in what engineers are calling a "constrained turn-and-burn" mode in which the spacecraft will turn to the desired burn attitude and fire the thrusters, while remaining in contact with Earth.

Navigation tracking during cruise involves the collection of two-way Doppler and ranging data. In order to provide additional information for navigation, the project has added a program of delta differential one-way range measurements, called delta DOR, that will be taken periodically during cruise and Mars approach. Delta DOR measurements are interferometric measurements between two radio sources. In this case, one of the radio sources is the DOR tones or telemetry signal coming from Odyssey. The second source will be either a known, stable natural radio source like a quasar or the telemetry signal from the Mars Global Surveyor spacecraft. Each source is recorded simultaneously at two radio antennas. The triangulation achieved through this method provides navigators with much more refined knowledge of the spacecraft's position. With this information, spcecraft operators can more precisely adjust Odyssey's flight path. Delta DOR measurements will be collected and processed for system testing during early and mid-cruise and weekly during the Mars approach phase to provide additional data to the navigation team. For the first 14 days after launch, the Deep Space Network will continuously track the spacecraft. During the quiet phase of cruise when spacecraft activity is at a minimum, only three 8-hour passes per day are scheduled. Continuous tracking will resume for the final 50 days before Mars arrival.

Science instruments will be powered on, tested and calibrated during cruise. The thermal emission imaging system will take a picture of the Earth-Moon system about 12 days after launch if the spacecraft is operating normally. Star calibration imaging is also planned 45 days after launch, while a Mars approach image is planned about 12 days before arrival if the Earth-Moon calibration image is not taken.

Two calibration periods are planned for the gamma ray spectrometer during cruise. Each of the spectrometer's three sensors may be operated during the calibration periods depending upon spacecraft power capabilities. The Mars radiation environment experiment is designed to collect radiation data constantly during cruise to help determine what the radiation environment is like on the way to Mars.

A test of the orbiter's UHF radio system is planned between 60 and 80 days after launch. The 45-meter (150-foot) antenna at California's Stanford University will be used to test the UHF system ability to receive and transmit. The UHF system will be used during Odyssey's relay phase to support future landers, it is not used as part of the orbiter's science mission.

Mars Orbit Insertion

Odyssey will arrive at Mars on October 24, 2001. As it nears its closest point to the planet over the northern hemisphere, the spacecraft will fire its 640-Newton main engine for approximately 22 minutes to allow itself to be captured into an elliptical, or egg-shaped, orbit. If the launch occurs early in the period, Odyssey will loop around the planet every 17 hours. About three orbits after insertion, the spacecraft will fire its thrusters in what is called a period reduction maneuver so that it orbits the planet approximately once every 11 hours.

Aerobraking

Aerobraking is the transition from the initial elliptical orbit to the science orbit where Odyssey will circle Mars at a uniform altitude. It is a technique that slows the spacecraft down by using frictional drag as it flies through the upper part of the planet's atmosphere.

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 primary phases that engineeers call walk-in, the main phase and walk-out. The walk-in phase occurs during the first four to eight orbits following Mars arrival. The main aerobraking phase begins once the point of the spacecraft's closest approach to the planet, know as the orbit's "periapsis," has been lowered to within about 100 kilometers (60 miles) above the Martian surface. As the spacecraft's orbit is reduced and circularized during approximately 273 drag passes in 76 days, the periapsis will moved 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. The walk-out phase occurs during the last few days of aerobraking when the period of the spacecraft's orbit is the shortest.

The aerobraking drag pass events will be executed by stored onboard command sequences. The drag pass sequence begins with the heaters for the thrusters being warmed up for about 20 minutes. The transmitter is turned off to conserve power during the drag pass. The spacecraft then turns to the aerobraking attitude under reaction wheel control.

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. Periapsis will be near the equator. A maneuver to raise the periapsis will be performed to achieve the final 400-kilometer (249-mile) circular science orbit.

The transition from aerobraking to the beginning of the science orbit will take about one week. The high-gain antenna will be deployed during this time and the spacecraft and science instruments will be checked out.

NASA’s Langley Research Center in Hampton, Va., will provide aerobraking support to JPL’s navigation team during mission operations. Langley’s role includes performing independent verification and validation, developing simulation tools and assisting the navigation team with trade studies and performance analysis.

Mapping Orbit

The science mission begins about 45 days after the spacecraft is captured into orbit about Mars. The primary science phase will last for 917 Earth days. The science orbit inclination is 93.1 degrees, which results in a nearly Sun-synchronous orbit. The orbit period will be just under two hours. Successive ground tracks are separated in longitude by approximately 29.5 degrees and the entire ground track nearly repeats every two sols, or Martian days.

During the science phase, the thermal emission imaging system will take multispectral thermal-infrared images to make a global map of the minerals on the Martian surface, and will also acquire visible images with a resolution of about 18 meters (59 feet). The gamma ray spectrometer will take global measurements during all Martian seasons. The Martian radiation environment experiment will be operated throughout the science phase to collect data on the planet's radiation environment. Opportunities for science collection will be assigned on a time-phased basis depending on when conditions are most favorable for specific instruments.

Relay Phase

The relay phase begins at the end of the first Martian year in orbit (about two Earth years). During this phase the orbiter will provide communication support for U.S. and international landers and rovers.

Spacecraft

The shape of 2001 Mars Odyssey is anything but 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 725.0 kilograms (1598.4 pounds), including the 331.8-kilogram (731.5-pound) dry spacecraft with all of its subsystems, 348.7 kilograms (768.8 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 lighter and more expensive 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. The main exception is a memory card that collects imaging data from the thermal emission imaging system.

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 used on most 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.

Interface electronics make use of computer cards 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 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' orientation in space, or "attitude," and its science instruments is done 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 exists through another card called the uplink/downlink card.

There are two other boards in the command and data handling subsystem, both internally redundant. 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. It provides communication capability throughout all phases of the mission. The X-band system is used for communications between Earth and the orbiter, while the UHF system will be used for communications between Odyssey and future Mars landers. The telecommunication subsystem weighs 23.9 kilograms (52.7 pounds).

Electrical Power

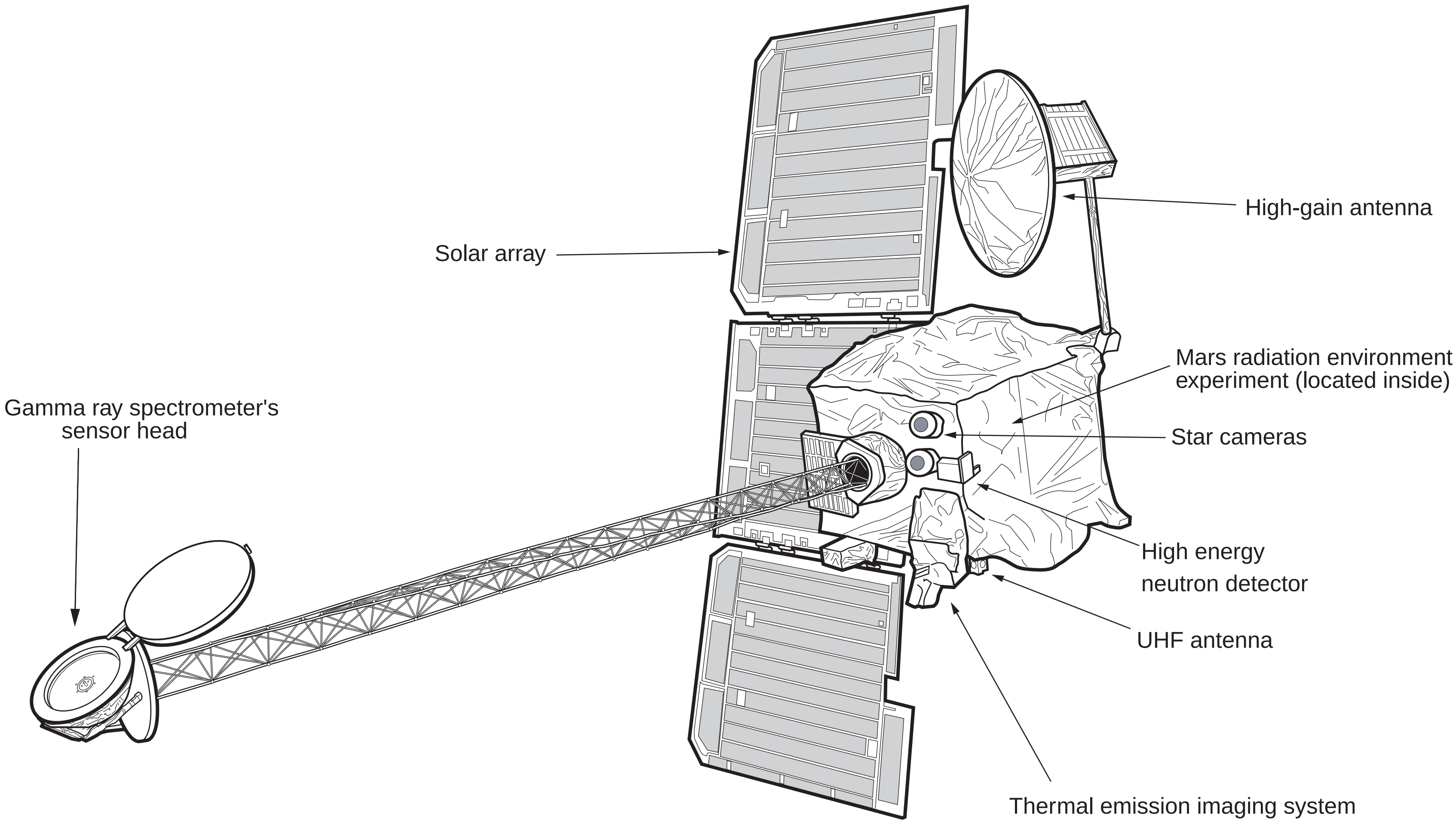
All of the spacecraft's power is generated, stored and distributed by the electrical power subsystem. The system obtains its power from an array of gallium arsenide solar cells on a panel measuring seven square meters (75 square feet). A power distribution and drive unit contains switches that send power 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

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

This system also includes the reaction wheels, gyro-like devices used along with thrusters to control the spacecraft's orientation. Like most spacecraft, Odyssey's orientation is held fixed in relation to space ("three-axis stabilized") as opposed to being stabilized via 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).



2001 Mars Odyssey spacecraft

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 minimum thrust of 65.3 kilograms of force (144 pounds of force). Each of the four thrusters used for attitude control produce a thrust of 0.1 kilogram of force (0.2 pound of force). Four 2.3-kilogram-force (5.0-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 paint. 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 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 retention and release devices 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 retention and release device 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 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 autonomous functions, such as attitude control and fault protection, which involves frequent internal checks to determine if a 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 awaiting further direction from ground controllers.

Science Objectives

One of the chief scientific goals that 2001 Mars Odyssey will focus on is mapping the chemicals and minerals that make up the Martian surface. As on Earth, the geology and elements 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 scientific orbiters and landers in 2003 and 2004. After this period, the orbiter will be available as a communication relay for an additional 457 days, making for a total mission duration of 1,374 days, or two Martian years. Science operations may still continue during the communication relay-only phase depending on remaining orbiter resources.

The orbiter carries three science instruments: a thermal infrared imaging system, a gamma ray spectrometer and a radiation environment experiment.These are all calibrated during the spacecraft's cruise phrase on its way to Mars. Opportunities for data collection are assigned on a time-phased basis depending on when conditions are most favorable for specific instruments.

Thermal Emission Imaging System

This instrument is responsible for determining Mars' surface mineralogy. Unlike our eyes, which can only detect visible light waves, a small portion of the electromagnetic spectrum, the instrument can see in both visible and infrared, thus collecting imaging data that has been previously invisible the scientists.

In the infrared spectrum, the instrument uses 10 spectral bands to help detect minerals within the Martian terrain. These spectral bands, similar to ranges of colors, serve as 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 multispectral 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 10 spectral bands are sufficient to detect minerals at abundances of five to 10 percent. In addition, the use of 10 infrared spectral bands can determine the absolute mineral abundance in a specific location within 15 percent.

The instrument's multispectral approach will also provide data on localized deposits associated with hydrothermal and subsurface water and enable 100-meter (328-feet) resolution 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 experiment will also take 18-meter (59-feet) resolution mineralogical and structural measurements 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 more detailed data will be used in conjunction with mineral maps to identify potential future Martian landing sites. These image will provide an important bridge between the data acquired by the Viking missions and the high-resolution images captured by Mars Global Surveyor.

The instrument weighs 11.2 kilograms (24.7 pounds); is 54.5 centimeters (21.5 inches) long, 34.9 centimeters (13.7 inches) tall and 28.6 centimeters (11.3 inches) wide; and runs on 17 watts of electrical power.

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

Gamma Ray Spectrometer

This instrument plays a lead role in determining the elemental makeup of 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 Mars' hydrogen abundance, thus inferring the presence of water. 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 send a reading to Earth every 20 seconds. This 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 crust and mantle composition, 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 two main components: the sensor head and the central electronics assembly. The sensor head is separated from the rest of the Odyssey spacecraft by a 6-meter (20-feet) boom, which will be extended after Odyssey has entered the mapping orbit at Mars. This is done to minimize interference from any gamma rays coming from the spacecraft itself. The initial spectrometer activity, lasting between 15 and 40 days, will perform an instrument calibration before the boom is deployed. After 100 days in orbit, the boom will deploy and remain in this position for the duration of the mission. 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 mission.

The instrument weighs 30.2 kilograms (66.6 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 principal investigator for the gamma ray spectrometer is Dr. William Boynton of the University of Arizona.

Martian Radiation Environment Experiment

This instrument characterizes aspects of the radiation environment both on the way to Mars and in the Martian orbit. Since space radiation presents an extreme hazard to 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, with a 68-degree field of view, is designed to continuously collect data during Odyssey's cruise from Earth to Mars. It can stores large amounts of data for downlink whenever possible, and will operate throughout the entire science mission.

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 is Dr. Gautum Badhwar of NASA's Johnson Space Center.

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, G. Scott Hubbard is the Mars Program Director, Dr. Jim 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. Dan McCleese is Mars Program Scientist, George Pace 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 Mars Program Director.

3-16-01