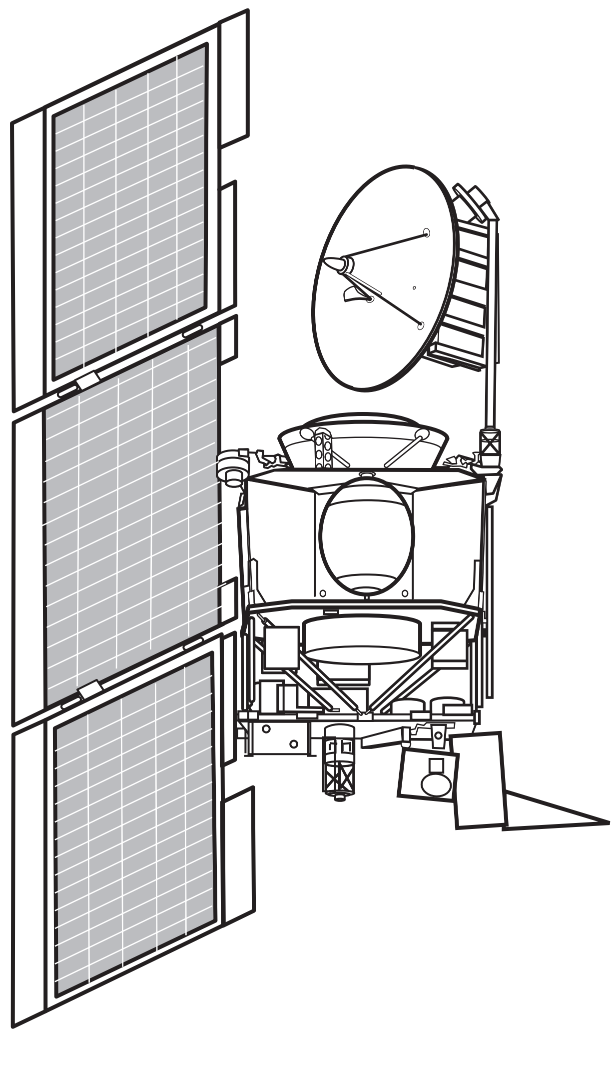
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Mars Climate Orbiter Arrival

Press Kit
September 1999



Contacts

Douglas Isbell Headquarters, Washington, DC	Policy/Program Management	202/358-1753
Franklin O'Donnell Jet Propulsion Laboratory, Pasadena, CA	Mars Climate Orbiter Mission	818/354-5011
Mary Hardin Jet Propulsion Laboratory, Pasadena, CA	Mars Climate Orbiter Mission	818/354-0344

Contents

RELEASE:

NASA'S MARS CLIMATE ORBITER: FIRST MARTIAN WEATHER SATELLITE

Mars Climate Orbiter, the first of two NASA spacecraft to reach Mars this year, is set to go into orbit around the red planet to become the first interplanetary weather satellite and a communications relay for the next lander mission to explore Mars.

The orbiter will fire its main engine at 1:50 a.m. Pacific Daylight Time on Thursday, September 23, 1999, to slow itself down so that it can be captured in orbit around the planet. Signals confirming the event will be received on Earth about 11 minutes later at 2:01 a.m.

"The curtain goes up on this year's Mars missions with the orbit insertion of Mars Climate Orbiter," said Dr. Sam Thurman, flight operations manager for the orbiter at NASA's Jet Propulsion Laboratory, Pasadena, CA. "If all goes well, the happily-ever-after part of the play will be the successful mission of the Mars Polar Lander that begins in December followed by the mapping mission of the orbiter that is set to begin next March."

Once captured in orbit around Mars, the orbiter will begin a period of aerobraking. 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. As the spacecraft slows with each pass, the maximum altitude of the orbit will decrease and the orbit will become more circular.

Mars Climate Orbiter's first assignment after it completes aerobraking will be to serve as the communications relay for its sibling spacecraft, Mars Polar Lander, set to land near the south pole on December 3. After the Lander's surface mission ends in February 2000, the orbiter's science mission begins with routine monitoring of the atmosphere, surface and polar caps for a complete Martian year (687 Earth days), the equivalent of almost two Earth years.

"We're interested in what happens during all the seasons of a Mars year. Weather is what happens from day-to-day and the longterm effect of all of that is climate," said Dr. Richard Zurek, project scientist for the orbiter at JPL. "Mars Climate Orbiter will do what weather satellites do - it will take pictures of clouds, it will look for storms and it will try to understand the atmospheric winds by measuring temperature and pressure and by watching how the atmospheric distributions of dust and water vapor change with time."

Today the Martian atmosphere is so thin and cold that it does not rain; liquid water placed on the surface would quickly freeze into ice or evaporate into the atmosphere. The temporary polar frosts which advance and retreat with the seasons are made mostly of condensed carbon dioxide, the major constituent of the Martian atmosphere. But the planet also hosts both water-ice clouds and dust storms, the latter ranging in scale from local to global. If typical amounts of atmospheric dust and water were concentrated today in the polar regions, they might deposit a fine layer on the ground year after year. Consequently, the top yard (or meter) of the polar layered terrains could be a well-preserved tree-ring-like record showing tens of thousands of years of Martian geology and climatology.

The orbiter carries two science instruments: the Pressure Modulator Infrared Radiometer, a copy of the atmospheric sounder on the Mars Observer spacecraft lost in 1993; and the Mars Color Imager, a new, light-weight imager combining wide- and medium-angle cameras. The radiometer will measure temperatures, dust, water vapor and clouds by using a mirror to scan the atmosphere from the Martian surface up to 50 miles (80 kilometers) above the planet's limb. The radiometer was provided by JPL, supported by Oxford University and Russia's Space Research Institute; its principal investigator is Dr. Daniel McCleese of JPL.

Meanwhile, the imager will gather horizon-to-horizon images at up to half-mile (kilometer) scale resolutions, which will then be combined to produce daily global weather images. The camera will also image surface features and produce a map showing objects the size of a football field with 130-foot (40-meter) resolution in several colors, providing global views that will help create a season-to-season portrait of the planet. The camera was provided by Malin Space Science Systems, San Diego; CA; its principal investigator is Dr. Michael Malin, who also provided the camera for the currently orbiting Mars Global Surveyor.

Mars Climate Orbiter is managed by the Jet Propulsion Laboratory for NASA's Office of Space Science, Washington, DC. Lockheed Martin Astronautics, Denver, CO, is the agency's industrial partner for development and operation of the Orbiter. JPL is a division of the California Institute of Technology.

[End of General Release]

Media Services Information

NASA Television Transmission

NASA Television is broadcast on the satellite GE-2, transponder 9C, C band, 85 degrees west longitude, frequency 3880.0 MHz, vertical polarization, audio monaural at 6.8 MHz.

Status Reports

Status reports on Mars Climate Orbiter mission activities will be issued by the Jet Propulsion Laboratory's Media Relations Office. They may be accessed online as noted below. Audio status reports are available by calling (800) 391-6654 or (818) 354-4210.

Briefing

A summary of Mars Climate Orbiter arrival events will be presented in a news briefing broadcast on NASA Television originating from the Jet Propulsion Laboratory at 8 a.m. PDT September 23, 1999.

Internet Information

Extensive information on Mars Climate Orbiter, 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 Climate Orbiter project maintains a home page at **http://mars.jpl.nasa.gov/msp98/orbiter/** .

Quick Facts

Spacecraft

Dimensions: Main bus 6.9 feet (2.1 meters) tall, 5.4 feet (1.6 meters) wide and 6.4 feet (2 meters) deep; wingspan of solar array 18 feet (5.5 meters) tip to tip
Weight: 1,387 lbs (629 kg) total, consisting of 745-lb (338-kg) spacecraft plus 642 lbs (291 kg) fuel
Science instruments: Pressure Modulator Infrared Radiometer, Mars Color Imager
Power: Solar array providing up to 1,000 watts just after launch, 500 watts at Mars

Launch/Cruise

Launch: December 11, 1998, at 1:45:51 p.m. Eastern Standard Time (18:45:51 UTC) from Launch Complex 17A at Cape Canaveral Air Station, Florida
Launch vehicle: Delta II Model 7425
Cruise: 9-1/2 months
Earth-Mars distance at launch: 158.6 million miles (255.2 million km)
Total distance traveled Earth to Mars: 416 million miles (669 million km)

Mars Arrival

Arrival: September 23, 1999
Engine firing begins: 2:01 a.m. Pacific Daylight Time (PDT) (Earth-received time)
Spacecraft passes behind Mars: 2:06 a.m. PDT (Earth-received time)
Engine firing ends: 2:17 a.m. PDT (Earth-received time)
Spacecraft reappears from behind Mars: 2:27 a.m. PDT (Earth-received time)
Speed before engine firing (relative to Mars): 12,300 mph (5.5 km/sec)
Speed after engine firing (relative to Mars): 9,840 mph (4.4 km/sec)
Change in speed from engine firing: 3,065 mph (1.37 km/sec)
Earth-Mars distance at arrival: 121.9 million miles (196.2 million km)
One-way speed-of-light time from Mars to Earth at arrival: 10 minutes, 56 seconds
Mars seasons at arrival: Fall in northern hemisphere, spring in southern hemisphere

Aerobraking and Mapping Mission

Aerobraking: September 27 to November 10, 1999
Time to orbit Mars once in initial orbit: 12 to 17 hours
Time to orbit Mars once in final orbit: 2 hours
Final orbit: Circular, Sun-synchronous, altitude 262 miles (421 km)
Relay for Mars Polar Lander: December 1999-February 2000
Primary science mapping mission: March 2000-January 2002
Mars seasons when mapping begins: Winter in northern hemisphere, summer in south

Mars ’98 Project

Cost: $193.1M spacecraft development, $42.8M mission operations; total $235.9 million for both Mars Climate Orbiter and the Mars Polar Lander spacecraft (not including launch vehicles or lander’s Deep Space 2 microprobes)

Mars at a Glance

General

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

Physical Characteristics

❑ Average diameter 4,217 miles (6,780 kilometers); 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 128.4 million miles (206.7 million kilometers) to a maximum of 154.8 million miles (249.2 million kilometers); average distance from Sun, 141.5 million miles (227.7 million kilometers)
❑ Revolves around Sun once every 687 Earth days
❑ Rotation period (length of day) 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 80 miles per hour (40 meters per second)
❑ Local, regional and global dust storms; also whirlwinds called dust devils
❑ Surface temperature averages -64 F (-53 C); varies from -199 F (-128 C) during polar night to 80 F (27 C) at equator during midday at closest point in orbit to Sun

Features

❑ Highest point is Olympus Mons, a huge shield volcano about 16 miles (26 kilometers) high and 370 miles (600 kilometers) across; has about the same area as Arizona
❑ Canyon system of Valles Marineris is largest and deepest known in solar system; extends more than 2,500 miles (4,000 kilometers) and has3 to 6 miles (5 to 10 kilometers) 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 65.9 million miles (106 million km)
[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, currently conducting prime mission of science mapping
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; due to enter orbit 9/23/99
Mars Polar Lander/Deep Space 2, U.S., 1/3/99, lander/descent probes; lander to set down near south pole 12/3/99; Deep Space 2 microprobes to smash into surface the same day

Mars, Water and Life

The planet Mars landed in the middle of immense public attention on July 4, 1997, when Mars Pathfinder touched down on a windswept, rock-laden ancient flood plain. Two months later, Mars Global Surveyor went into orbit, sending back pictures of towering volcanoes and gaping chasms at resolutions never before seen.

In December 1998 and January 1999, another orbiter and lander were sent to Mars. And every 26 months over the next decade, when the alignment of Earth and Mars are suitable for launches, still more robotic spacecraft will join them at the red planet.

These spacecraft carry varied payloads, ranging from cameras and other sensors to rovers and robotic arms. Some of them have their roots in different NASA programs of science or technology development. But they all have the goal of improving our understanding of Mars, primarily by delving into its geology, climate and history.

With the announcement in 1996 by a team of scientists that a meteorite believed to have come from Mars contained what might be the residue of ancient microbes, public interest became regalvanized by the possibility of past or present life there. The key to understanding whether life could have evolved on Mars, many scientists believe, is understanding the history of water on the planet.

Mars today is too cold, with an atmosphere that is too thin, to support liquid water on its surface. Yet scientists who studied images from the Viking orbiters kept encountering features that appeared to be formed by flowing water - among them deep channels and canyons, and even features that appeared to be ancient lake shorelines. Added to this are more recent observations by Mars Pathfinder and Mars Global Surveyor that suggest widespread flowing water in the planet's past. Some scientists identified features that they believe appear to be carved by torrents of water with the force of 10,000 Mississippi Rivers.

There is no general agreement, however, 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.

In either case, the question of what happened to the water remains a mystery. Most scientists do not feel that Mars' climate change was necessarily caused by a cataclysmic event such as an asteroid impact that, perhaps, disturbed the planet's polar orientation or orbit. Many believe that the demise of flowing water on the surface could have resulted from gradual climate change over many millennia as the planet lost its atmosphere.

Under either the warmer-and-wetter or the always-cold scenario, Mars must have had a thicker atmosphere in order to support water that flowed on the surface, even only occasionally. If the planet's atmosphere became thinner, liquid water would rapidly evaporate. Over time, carbon dioxide gas reacts with elements in rocks and becomes locked up as a kind of compound called a carbonate. What is left of Mars' atmosphere today is overwhelmingly carbon dioxide.

On Earth, shifting tectonic plates are continually plowing carbonates and other minerals under the surface; heated by magmas, carbon dioxide is released and spews forth in volcanic eruptions, replenishing the carbon dioxide in the atmosphere. Although Mars has no known active volcanoes and there are no signs of fresh lava flows, it had abundant volcanic activity in its past. However, Mars appears to have no tectonic plates, so a critical link in the process that leads to carbon dioxide replenishment in Earth's atmosphere is missing. In short, Mars' atmosphere could have been thinned out over many eons by entrapment of carbon dioxide in rocks across its surface.

That scenario, however, is just a theory. 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, and may 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 well below the surface.

Current and Future Missions

Mars Climate Orbiter and Mars Polar Lander are designed to help scientists better understand the climate history of Mars, not to look for life. They do not, for example, contain any biology experiments similar to the chemistry lab on the Viking landers. However, their focus on Mars' climate and the role of water will have an impact on the life question. Water is also important as a resource for eventual human expeditions to the red planet.

In addition, Mars Climate Orbiter and the currently orbiting Mars Global Surveyor will aid the search for likely sites for future Mars robotic landers. Scientists are interested in three types of Martian environments which are potentially most favorable to the emergence and persistence of life. They are:

- **Ancient groundwater environments.** Early in the planet's history, liquid water appears to have been widespread beneath the surface. During the final stages of planetary formation, intense energy was dissipated by meteor impacts. This, along with active volcanoes, could have created warm groundwater circulation systems favorable for the origin of life.

- **Ancient surface water environments.** Also during early Martian history, water was apparently released from subsurface aquifers, flowed across the surface and pooled in low-lying regions. Evidence of the early climate of Mars and of ancient life, if any, may be preserved in sedimentary rocks in these environments.

- **Modern groundwater environments.** Life may have formed at any time, including recently, in habitats where subsurface water or ice is geothermally heated to create warm groundwater circulation systems. In addition, life may have survived from an early epoch in places beneath the surface where liquid water is present today.

Where to Next?

In 1998 NASA conducted a review of its multi-year Mars program, calling in outside experts to help evaluate and refine the architecture for the future direction of the effort. Some of the details are subject to change as plans evolve, but the following are the basic robotic missions currently planned to Mars:

❑ **December 3, 1999:** Mars Polar Lander sets down near the planet's south pole, equipped with a robotic arm to dig into the soil in search of water ice. Other science instruments will take pictures and study the weather and atmosphere. Two microprobes created under the New Millennium Program's Deep Space 2 project will detach from the lander shortly before arrival and crash into the surface of Mars to test new technologies for probe/penetrators.

❑ **2001:** NASA will launch an orbiter and lander broadly similar to the 1998 Mars spacecraft. The orbiter, equipped with three science instruments, will be the first planetary spacecraft to be launched from the west coast of the United States. The lander will touch down near Mars' equator, carrying a spare Mars Pathfinder rover, a robotic arm and several other science instruments, including three that will return data in support of eventual human exploration.

❑ **2003:** NASA will begin the series of sample-return missions with launch of a lander and rover that will search for soil and rock samples and return them to a mini-ascent vehicle that will loft the samples to Mars orbit. The European Space Agency (ESA), in collaboration with the Italian space agency (ASI), will provide an orbiter. ASI may also provide a drill and other robotic elements for landers beginning in this year. NASA's Human Exploration and Development of Space (HEDS) enterprise, as well as international partners, may also begin providing science and technology experiments for the large lander. As early as this year, NASA and the French space agency, CNES, may also launch a "micromission" spacecraft designed to deliver payloads such as a robotic airplane or a small telecommunications orbiter.

❑ **2005:** NASA and CNES will launch an orbiter, lander and rover on a French-provided Ariane 5 rocket. The lander and rover will search for soil and rock samples, and return them to a mini-ascent vehicle that will loft the samples to Mars orbit. CNES will provide the orbiter spacecraft that will retrieve the 2003 and 2005 samples from Mars orbit and return them to Earth in a vehicle provided by NASA. The samples will reach Earth in 2008. The CNES spacecraft will also carry four miniature landers called "netlanders." In addition, NASA and CNES may collaborate on two "micromissions."

❑ **2007-2009:** As currently envisioned, NASA's strategy will be to continue to collect samples and place them in Mars orbit for later retrieval. In 2007, NASA will launch another lander, rover and ascent vehicle. NASA and CNES may collaborate on two more "micromissions," and HEDS may provide more experiments. In 2009, NASA will launch a lander and rover that will search for soil and rock samples and return them to an ascent vehicle. Current plans call for another orbiter provided by CNES that will retrieve the 2007 and 2009 samples from Mars orbit and return them to Earth in a vehicle provided by NASA.

❑ **2011-2013:** Although plans for these years are uncertain, a repeat of the 2007-2009 strategy is currently envisioned.

These Martian environments can be investigated in several ways. We can get a glimpse of underground environments by using rovers to explore young craters and what appear to be the remains of water-eroded channels, and by drilling from lander spacecraft. Sensors on orbiters will search for the most likely reservoirs of water in these regions.

To investigate these scientific themes, NASA's Mars program will carry out the following implementation strategy for the initial phases of Mars exploration:

- ❑ The Mars orbiters launched in 1996, 1998 and 2001 will provide sufficient information to guide an early sample return from an ancient groundwater environment.

- ❑ Ancient surface-water environments will be explored in greater depth. When a sample-return mission is sent to Mars, it is extremely important to be able to identify minerals formed by water.

- ❑ Ancient and modern sites exhibiting evidence of hydrothermal activity will be studied, followed eventually by efforts to drill as deeply as possible below the surface.

Samples will be collected using rovers capable of extensive searches and of collecting and storing samples of rock and soil. Sophisticated sensors onboard rovers will help insure that diverse rock types are collected. Drills capable of reaching several yard (or meters) below the surface will also be used to analyze subsurface material. It is likely that it will be some time before space technologies will permit drilling to depths of a half-mile (kilometer) and more to access subsurface water.

Samples of the Martian atmosphere will also be brought back to Earth. The possible origin and evolution of life on Mars must be linked to the evolution of its atmosphere.

In 2003, NASA and its international partners will see the first launch of a mission to collect samples and place them in Mars orbit to await their transport back to Earth. A mission in 2005 will include two spacecraft - a lander like the 2003 mission to collect surface samples, and a French-built orbiter to return both the 2003 and 2005 samples to Earth. A series of at least three sample return missions similar to this are expected to be carried out over the following decade.

Even if it turns out that Mars never harbored life, study of the planet can help in understanding life on our own. Much of the evidence for the origin of life on Earth has been erased by movement of the planet's crust and by weathering. Fortunately, large areas of Mars' surface date back to the very earliest period of planetary evolution - about 4 billion years ago, overlapping the period on Earth when pre-biotic chemical evolution first gave rise to life. Thus, even if life never developed on Mars, studies of the planet may yield crucial information about the prebiotic chemistry that led to life on Earth.

Mission Overview

Mars Climate Orbiter carries two science instruments, one a copy of an instrument carried by the Mars Observer spacecraft lost in 1993. Between them, Mars Climate Orbiter and the currently orbiting Mars Global Surveyor carry all but one of the entire suite of science instruments from Mars Observer. In addition, both orbiters will provide radio relay support for Mars Polar Lander.

Launch and Cruise

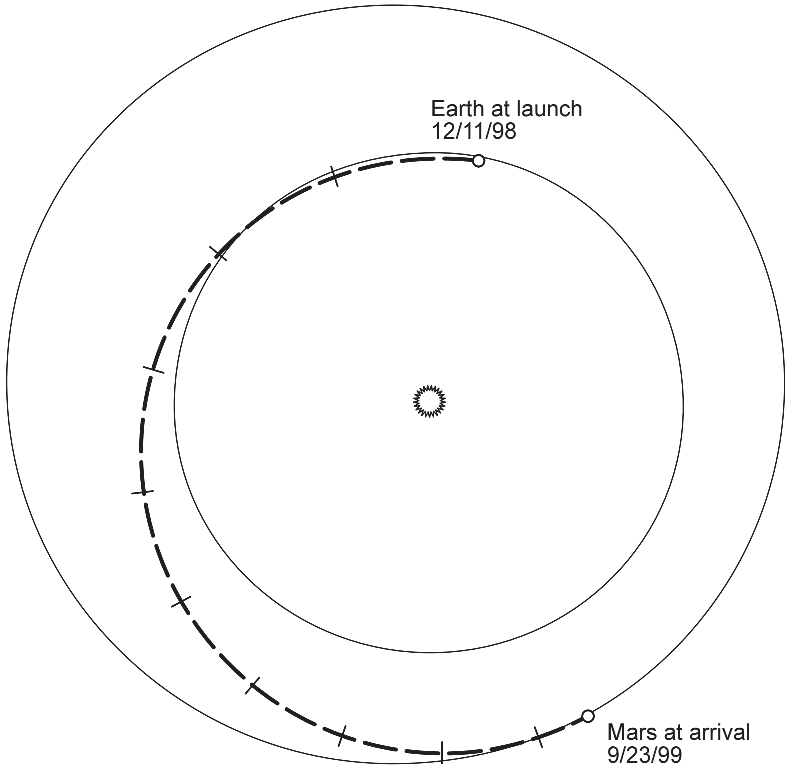
Mars Climate Orbiter was launched aboard a Delta II Model 7425 rocket from Cape Canaveral Air Station's Launch Complex 17 A on December 11, 1998, at 1:45:51 p.m. Eastern Standard Time (18:45:51 UTC).

The spacecraft will have been traveling for 286 days, or about 9-1/2 months, when it rreaches Mars on September 23, 1999. The spacecraft's flight path is called a Type 2 trajectory because it took the orbiter more than 180 degrees around the Sun; this results in a slower speed at Mars arrival. By comparison, the Mars Pathfinder lander, which followed a Type 1 trajectory that took it less than 180 degrees around the Sun, spent only seven months in flight to Mars. During the first leg of its journey, Mars Climate Orbiter flew slightly inward toward the Sun before spiraling out beyond Earth's orbit to Mars.

Arrival Events

Time	*Event*
9/15/99	Final thruster firing to adjust flight path to Mars
9/20/99	Flight team transmits sequence of commands that will control the spacecraft during the arrival burn. Team begins around-the-clock monitoring.
9/23/99	1:41 a.m.: Solar array stowed 1:50 a.m.: Spacecraft turns to orientation for main engine burn 1:56 a.m.: Pyrotechnic devices fired to open valves to begin pressurizing fuel and oxidizer tanks 2:01 a.m.: Main engine begins firing 2:06 a.m.: Spacecraft passes behind Mars, out of view of Earth 2:17 a.m.: Main engine concludes firing 2:19 a.m.: Spacecraft turns to orientation to allow Earth contact when it emerges from behind Mars 2:27 a.m.: Spacecraft emerges from behind Mars, contact reestablished 2:30 a.m.: Solar array unstowed

All times are in Pacific Daylight Time in "Earth-received time," when the signal confirming an event would be received on Earth. Actual events on the spacecraft occur about 11 minutes earlier.



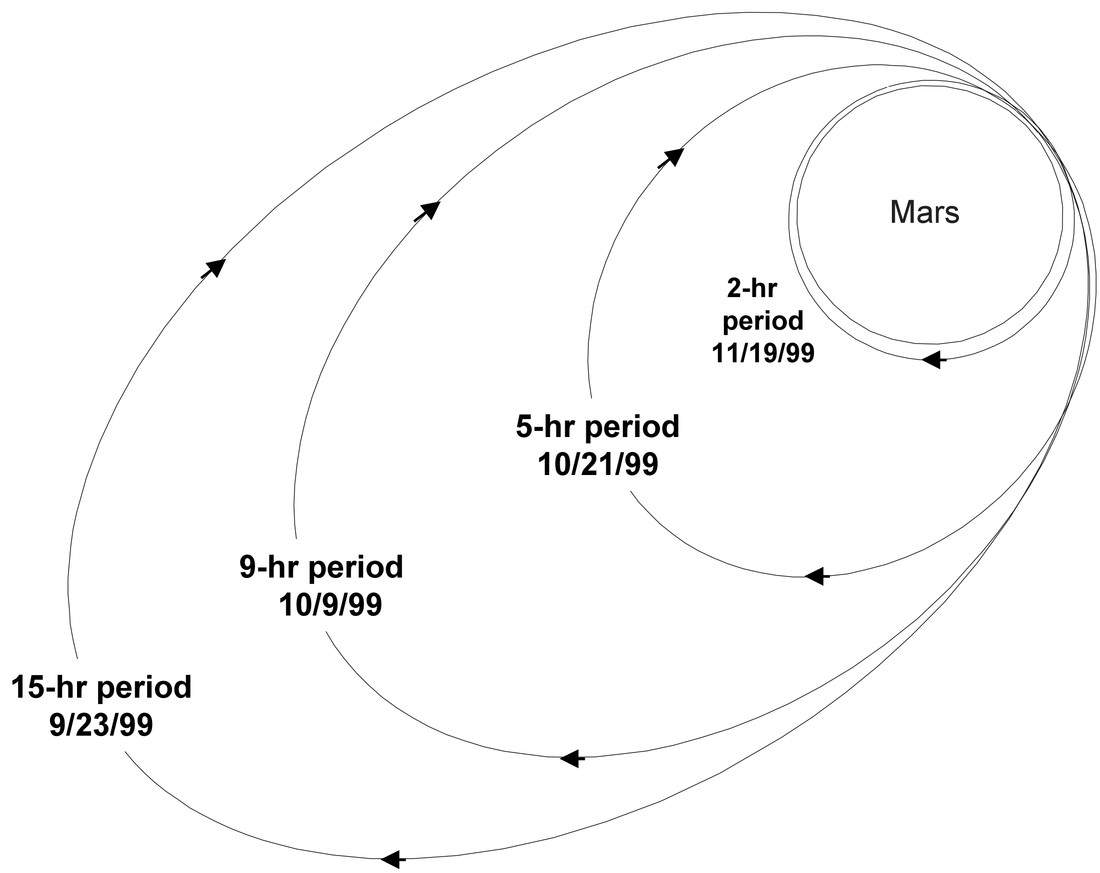
Orbiter's interplanetary trajectory

During the first phase of cruise, the spacecraft maintained contact with Earth using its low-gain or medium-gain antenna while keeping its solar arrays pointed at the Sun. For the first seven days, the spacecraft was tracked 24 hours per day. During the second through fourth weeks after launch, the spacecraft was tracked a minimum of 12 hours per day using the112-foot -diameter (34-meter) Deep Space Network antennas. During quiescent times of the cruise phase, the orbiter was tracked a minimum of four hours each day. The tracking rate increased again to 12 hours per day starting 45 days before the spacecraft is captured in orbit around Mars.

Twelve days into flight, the radiator door on one of the science instruments, the Pressure Modulator Infrared Radiometer, was moved to the vented position to acclimate the instrument's passive radiative cooler to the environment of space.

During interplanetary cruise, the orbiter fired its thrusters a total of four times to adjust its flight path. The first trajectory correction maneuver was carried out 15 days after launch and corrected launch injection errors and adjusted the Mars arrival aimpoint.

The remainder of the trajectory correction maneuvers were used to shape the trajectory and direct the spacecraft to the proper aimpoint for the orbit insertion burn. The second course



Aerobraking orbits

maneuver was conducted 45 days later, on January 25, 1999; the third occurred 60 days before the spacecraft is captured in orbit around Mars, on July 25, 1999; and the fourth took place on September 15, 1999, eight days prior to Mars orbit insertion.

In addition to the course corrections, the science payload was powered on, tested and calibrated during cruise. The Pressure Modulator Infrared Radiometer and Mars Color Imager were calibrated during a week-long checkout 80 days after launch. During this checkout activity the camera was commanded to turn and scan across a specific star cluster as part of a star calibration exercise.

As the spacecraft neared Mars, 16 days before orbit insertion, the camera took a picture of the planet, available at :

http://photojournal.jpl.nasa.gov/cgi-bin/PIAGenCatalogPage.pl?PIA02330

Mars Orbit Insertion

As the spacecraft nears its closest point to the planet, coming in over the northern hemisphere, the spacecraft will fire its 640-newton main engine for 16 to 17 minutes to brake into an elliptical capture orbit. After the burn, the orbiter will loop around Mars once every 12 to 17 hours.

About 22 minutes after completion of the burn, the spacecraft will turn to point its high-gain antenna at Earth. During the first two days after orbit insertion, the spacecraft will communicate continuously with the Deep Space Network's 230-foot-diameter (70-meter) and 112-foot diameter (34-meter) antennas.

Based on the details of the initial capture orbit, the spacecraft will fire its thrusters during its next closest pass by Mars to lower the orbit and reduce the orbit period by two to four hours. The flight team will work to achieve as low an orbit as possible to reduce the amount of time required for aerobraking.

Aerobraking

In aerobraking, a spacecraft is slowed down by frictional drag as it flies through the upper part of a planet's atmosphere. The technique was first tested by NASA's Magellan spacecraft at Venus at the end of its prime mission in 1994 and it was used with great success by the currently orbiting Mars Global Surveyor spacecraft.

Mars Climate Orbiter will be starting from an orbit much lower than Mars Global Surveyor - with an orbit period only one-third as long - so it will require much less aerobraking. The spacecraft will reach its final, low altitude, science-gathering orbit two weeks before its sibling spacecraft -- Mars Polar Lander -- touches down within about 590 miles (900 kilometers) of the southern polar cap.

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 "aeropass." As the spacecraft slows down during each close approach, the orbit will gradually lower and circularize.

Before the beginning of each aeropass, the orbiter's solar wing will be braced against the body of the spacecraft for mechanical stability. The spacecraft there will not receive any solar energy until after the aeropass is over and the solar array can again be turned toward the Sun.

Mars Climate Orbiter may begin aerobraking within a day or two after it enters Martian orbit. The first thruster firing to adjust the orbit for aerobraking may be performed as early as the first time the spacecraft swings away from the planet after entering orbit. During the next several days, the flight team will fire the thrusters each time the spacecraft reaches the point in the orbit most distant from the planet. This will bring the point of its closest approach to Mars down within the planet's upper atmosphere.

The main aerobraking phase will begin once the point of the spacecraft's closest approach to the planet - known as the orbit's periapsis -- has been lowered to within about 60 miles (100 kilometers) above the Martian surface. As the spacecraft's orbit is reduced and circularized over approximately 200 aeropasses in 44 days, the periapsis will move northward from 34 degrees north latitude to 89 degrees north latitude, which will take it almost directly over the north pole. Small thruster firings when the spacecraft is most distant from the planet will keep the aeropass altitude at the desired level to limit heating and dynamic pressure on the orbiter.

Although the orbiter's transmitter can be on continuously during aerobraking, contact with Earth will not be possible during the aeropasses or when the spacecraft passes behind Mars as seen from Earth. As a result, the spacecraft will be out of contact with Earth for 45-to-60 minutes per orbit. The Mars Climate Orbiter will be monitored and tracked during each orbit, but sometimes share Deep Space Network antenna time with Mars Global Surveyor. Concurrent observations from Global Surveyor will provide early warning of dust storms and other atmospheric changes occurring over the planet.

The most challenging part of aerobraking will occur during what the flight team calls the "end game": the last few days of aerobraking, when the period of the spacecraft's orbit is the shortest. At that time, the aeropasses will be occurring most frequently and lasting longer than previous aeropasses.

The final science orbit will be a "late afternoon" orbit that takes the spacecraft over the Martian equator at approximately 4:30 p.m. local mean solar time on the day side of the planet, and at 4:30 a.m. on the night side of the planet.

Lander Approach Navigation

Mars Climate Orbiter's first assignment after it completes aerobraking will be to serve as the communications relay for its sibling spacecraft, Mars Polar Lander. Ground controllers will implement a program of near-simultaneous tracking of Mars Climate Orbiter and Mars Polar Lander to support precision approach navigation for the lander as it prepares for its entry, descent and landing on Mars on December 3, 1999.

The 112-foot-diameter (34-meter) antennas of the Deep Space Network will track the orbiter just before or after tracking the lander. This will allow engineers to reduce effects of errors from locations of ground stations, modeling of solar plasma and other sources. First demonstrated in late 1997 with the Mars Pathfinder and Mars Global Surveyor spacecraft, the technique is expected to increase significantly the spacecraft team's ability to control the entry angle of the lander and thus reduce the size of the landing zone footprint. Mars Global Surveyor may also be used as a navigation aid for the approaching lander.

Mapping Orbit

The orbiter will fire its thrusters in two maneuvers at the end of aerobraking. The first and largest of these maneuvers will raise the spacecraft's periapsis - the point in its orbit where it passes closest to the planet - out of the atmosphere. The second maneuver will place the spacecraft into an orbit designed to fine-tune the timing of the orbiter's passage over the Mars Polar Lander's landing site. Shortly before the lander arrives, additional small maneuvers will be executed to place the orbiter into its final mapping orbit, a nearly circular, Sun-synchronous polar orbit with an average altitude of approximately 262 miles (421 kilometers).

Once the spacecraft has reached the mapping orbit, the high gain antenna will be deployed. The antenna, which was stowed during the nine-and-a-half-month trip to Mars and during aerobraking may require testing to assess its performance in the deployed position.

Lander Support

For the first three months after insertion into the mapping orbit, the orbiter's main task will be to act as a radio relay for Mars Polar Lander. During this time the orbiter will relay commands to the lander, as well as data from the lander to Earth. The orbiter may spend limited time collecting science data and downlinking the information during daily, 10-hour communications sessions. The lander support is scheduled to last through the end of February 2000.

Mapping

From March 2000 through January 2002, the orbiter will carry out its primary science mission making systematic observations of the atmosphere and surface of Mars using its two science instruments, the Pressure Modulator Infrared Radiometer and Mars Color Imager. The length of the science mission was chosen to span one Martian year, or 687 Earth days, so that scientists can observe seasonal variations in the Martian weather. Data will be sent to Earth during the daily, 10-hour communications sessions.

Relay for Future Missions

Once its mapping mission is complete, the orbiter will be available for up to two years as a communications relay for future Mars landers. During this phase, the orbiter will fire its thrusters to increase its altitude. This maneuver fulfills planetary protection regulations by increasing the length of time the spacecraft remains in orbit before eventually entering the atmosphere, breaking up and crashing into the planet's surface.

Spacecraft

Mars Climate Orbiter's main structure, or bus, is 6.9 feet (2.1 meters) tall, 5.4 feet (1.6 meters) wide and 6.4 feet (2 meters) deep. At launch it weighed 1,387 pounds (629 kilograms), consisting of the 745-pound (338-kilogram) dry spacecraft plus 642 pounds (291 kilograms) of fuel.

The framework of the spacecraft bus is made of a combined graphite composite/aluminum honeycomb structure similar to that used in the construction of commercial aircraft.

Most systems on the spacecraft are fully redundant; for example, there are two onboard computers, two radio transmitter/receivers and so on, to compensate in case any device fails. The main exceptions are the electrical battery and the main engine used to brake the spacecraft into orbit upon arrival at Mars.

Onboard Computer

The spacecraft's computer system is greatly simplified compared with computers on planetary spacecraft a few years ago. By the late 1980s, spacecraft boasted the equivalent of onboard local area networks, with a main computer communicating with other computers used to run various subsystems and science instruments. By contrast, the Mars '98 orbiter and lander have a single onboard computer that runs all spacecraft activities (the science instruments contain microprocessor chips but not complete computer systems).

The spacecraft's computer uses a RAD6000 processor, a radiation-hardened version of the PowerPC chip used on some models of Macintosh computers. It can be switched between clock speeds of 5 MHz, 10 MHz or 20 MHz. The computer includes 128 megabytes of random-access memory (RAM); unlike many other spacecraft, the orbiter does not have an onboard tape recorder or solid-state data recorder, but instead stores data in its RAM for transmission to Earth. The computer also has 18 megabytes of "flash" memory that can store data even when the computer is powered off. Eight megabytes of the flash memory will be used to store triplicate copies of high-priority data; when the computer accesses the data later, it will check all three copies of each byte to make sure that information has not become corrupted.

Attitude Control

The attitude control system manages the spacecraft's orientation, or "attitude." Like most planetary spacecraft, the orbiter is three-axis stabilized, meaning that its orientation is held fixed in relation to space, as opposed to spacecraft that stabilize themselves by spinning. The orbiter determines its orientation at any given time using a star camera, two Sun sensors and one of two inertial measurement units, each of which consists of three ring-laser gyroscopes and three accelerometers. The orientation is changed by firing thrusters or by using three reaction wheels, devices similar to flywheels.

During most of the interplanetary cruise, the spacecraft will be in "all stellar" mode, relying only on its star camera and Sun sensors for attitude determination without using the inertial measurement unit. To save wear and tear on their gyros, the inertial measurement units will be primarily used in Mars orbit.

Telecommunications

The spacecraft will communicate with Earth in the microwave X band, using a transponder (transmitter and receiver) based on a design used on the Cassini mission, along with a 15-watt radio frequency power amplifier. It uses a 4.3-foot-diameter (1.3-meter) dish-shaped high-gain antenna to transmit and receive, a medium-gain antenna with transmit-only capability and a receive-only low-gain antenna. A receiver and 15-watt transmitter in the UHF radio band will support two-way communications with Mars Polar Lander and future Mars landers.

Power

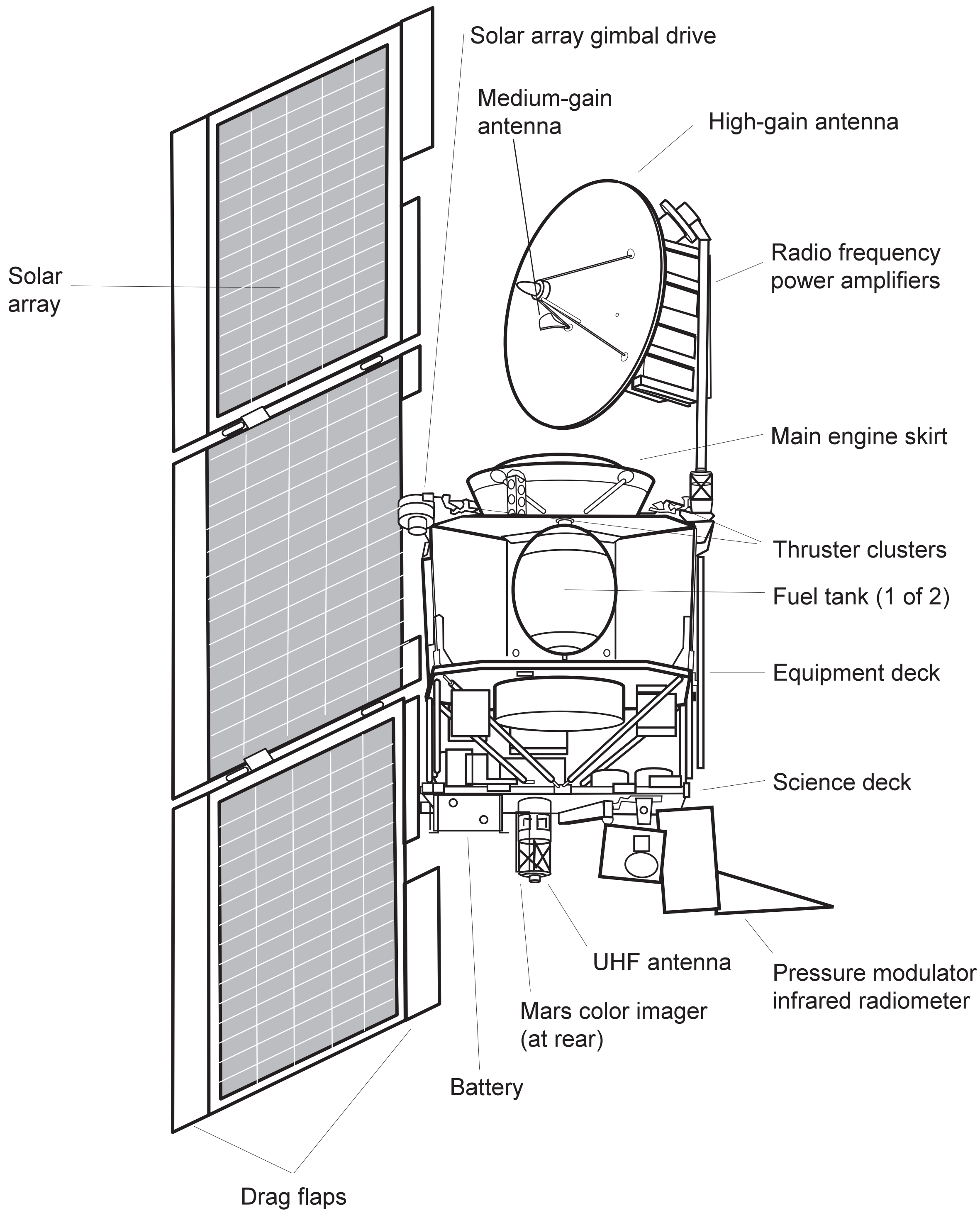
The spacecraft obtains its power from a solar array consisting of gallium arsenide solar cells mounted on three panels that form a single wing spanning 18 feet (5.5 meters) from tip to tip. Shortly after launch, the solar array will provide up to 1,000 watts of power; in Mars orbit it will provide up to about 500 watts. Power is stored in a 12-cell, 16-amp-hour nickel-hydrogen battery. In addition to providing power, the solar array acts as the spacecraft's "brakes" during aerobraking. Wing flaps have been added to the array to increase the amount of surface area and improve aerobraking performance.

Thermal Control

The thermal control system uses electrical heaters, thermal radiators and louvers to control the temperature inside the spacecraft. Multi-layer insulation, Kapton blankets and protective coatings are used to shield electronics from the harsh environment of space.

Propulsion

The propulsion system is similar to Mars Global Surveyor's, featuring both sets of small thrusters for maneuvers as well as a main engine that will fire to place the spacecraft in orbit around Mars. The main engine uses hydrazine propellant with nitrogen tetroxide as an oxidizer to produce 144 pounds (640 newtons) of thrust. The thrusters, which use hydrazine as a monopropellant, are divided into two sets. Four larger thrusters, each of which puts out 5 pounds (22 newtons) of thrust, will be used for trajectory correction maneuvers or turning the spacecraft. Four smaller thrusters producing 0.2 pound (0.9 newton) of thrust each will be used exclusively for attitude control.



Mars Climate Orbiter spacecraft

Science Objectives

One of the chief scientific issues that Mars Climate Orbiter will study is the question of water distribution on Mars. On a planet with temperatures that rarely rise above freezing (32 F or 0 C) and plummet to lows of about -126 F (-88 C), water ice and carbon dioxide ice remain year-round in its permanent polar caps.

Over time, some water has surely been lost to space; some has been added by the infall of comets and meteorites. Water is also likely to be stored in the ground, chemically and physically bound to soil particles and as ice. Models of subsurface temperatures indicate that ground ice should be near the surface in the polar regions.

Instruments onboard the orbiter and lander will analyze the composition of surface materials, characterize daily and seasonal weather patterns and frost deposits, and monitor surface and atmospheric interactions to better understand the planet as a global system.

Other major goals of the mission are:

- ❑ **Study variations in atmospheric dust and volatile materials, such as carbon dioxide and water, in both their vapor and frozen forms.** Mars Climate Orbiter will track these variations over a full Martian year (687 Earth days).

- ❑ **Identify surface reservoirs of volatile material and dust, and observe their seasonal variations.** The orbiter's imager and sounder will be able to characterize surface compositional boundaries and changes that might occur with time or seasons.

- ❑ **Explore climate processes that stir up or quell regional and global dust storms, as well as atmospheric processes that transport volatiles such as water ice clouds and dust around the planet.**

- ❑ **Search for evidence of Mars' ancient climate, which some scientists believe was temperate and more Earth-like with a thicker atmosphere and abundant flowing water.** Layered terrain in the polar regions suggests more recent, possibly cyclic, climate change. Studies of Mars' early climate compared with Earth's may explain whether internal or external factors (such as changes in Mars' orbit) are primary drivers of climate change.

The orbiter carries two science instruments, a radiometer and camera.

Pressure Modulator Infrared Radiometer

This instrument is a sounder that will scan Mars' thin atmosphere, measuring temperatures, dust, water vapor and condensate clouds. It can scan the planet's atmosphere at the horizon or straight down underneath the spacecraft.

The instrument detects radiation in a total of nine channels. One of them detects visible light, while the other eight detect various spectral bands of infrared radiation at wavelengths between 6 and 50 microns. These data will allow scientists to construct vertical profiles of the atmosphere from near the surface to as high as 50 miles (80 kilometers) above the surface. Bands of water vapor and carbon dioxide will be detected, for the first time, at a vertical resolution of 3 miles (5 kilometers). A radiative cooler will keep the detectors located on the instrument's focal plane assembly at temperatures of about -315 F (-193 C).

The instrument weighs 93 pounds (42 kilograms) and uses 41 watts of power. The main instrument box is 9 by 12 by 29 inches (23 by 30 by 74 centimeters); a smaller cooler attached to the instrument is 23 by 26 by 12 inches (58 by 65 by 30 centimeters).

The joint principal investigators for the radiometer are Dr. Daniel McCleese of JPL and Dr. Vassili Moroz of the Space Research Institute (IKI), Moscow, Russia.

Mars Color Imager

The imager combines a wide-angle and a medium-angle camera. Both are designed to snap a series of overlapping frames as the spacecraft sweeps over the planet. Each camera has a charge-coupled device (CCD) detector overlaid with spectral or color filter strips. The camera shutters are electronically controlled at intervals timed so that the spacecraft motion overlaps the filter strips in order to produce a series of color images covering the same surface area.

The wide-angle camera detects light in seven spectral bands - five in the visible spectrum from 425 to 750 nanometers, and two in the ultraviolet spectrum from 250 to 330 nanometers. The camera is capable of taking pictures with a resolution of up to about six-tenths of a mile (1 kilometer) in Mars orbit when the data rate of the communications system allows sending large numbers of images. At other times, the camera will average adjacent pixels together to result in pictures with a resolution as low as 4.5 miles (7.2 kilometers) per pixel. The camera can also image the limb of the planet to detail the structure of clouds and hazes at a resolution of about 2.5 miles (4 kilometers) per pixel.

The medium-angle camera detects light in eight spectral bands from violet to near-infrared (425 to 930 nanometers wavelength). Pointed down at the planet, the camera will take pictures with a resolution of about 130 feet (40 meters) per pixel across a six-degree field-of-view covering 25 miles (40 kilometers).

Once the spacecraft is in its mapping orbit, the Mars Color Imager will provide daily global images of the Martian atmosphere and surface with the wide-angle camera, and monitor surface changes with the medium-angle camera when high downlink data rates are possible. Each of the imager's two cameras is 6 by 6 by 12 centimeters (2.35 by 2.35 by 4.7 inches); together they weigh 2 kilograms (4.4 pounds). The imager uses 4 watts of power.

Principal investigator for the Mars Color Imager is Dr. Michael Malin of Malin Space Science Systems Inc., San Diego, CA.

Program/Project Management

Mars Climate Orbiter is managed by the Jet Propulsion Laboratory, Pasadena, CA, for NASA's Office of Space Science, Washington, DC. At NASA Headquarters, Dr. Edward Weiler is associate administrator for space science. Dr. Carl Pilcher is science director for solar system exploration. Ken Ledbetter is director of the Mission and Payload Development Division, and Steven Brody is program executive for Mars Climate Orbiter. Joseph Boyce is program scientist for Mars Climate Orbiter.

At the Jet Propulsion Laboratory, Mars Climate Orbiter has been operated after launch by JPL's Mars Surveyor Operations Project; Richard Cook is project manager and Dr. Sam Thurman is flight operations manager. Dr. Richard Zurek is project scientist. Dr. John McNamee was project manager for development of Mars Climate Orbiter. At Lockheed Martin Astronautics, Denver, CO, Dr. Edward A. Euler is the company's program director for Mars Climate Orbiter.

9-20-99 HQ