2001 Odyssey Spacecraft Begins Infrastructure Buildup At Mars

by Marsha Freeman

A critical link in the 15-year Mars exploration program under way by the National Aeronautics and Space Administration (NASA), is now safely in orbit around the red planet. In the late evening of Oct. 23, 2001, Mars Odyssey fired its onboard engine, slowed down, and was captured by the gravity of Mars. The spacecraft was launched last April, and after its 285-million-mile interplanetary cruise, made a "bull's-eye" insertion into Mars orbit, to the relief of anxious scientists and engineers. It has been four years since a new spacecraft arrived at Mars, after the back-to-back failures of two missions nearly two years ago.

Odyssey has two major missions to accomplish. The first, its primary science phase, which will begin early next year, is to carry out a mapping of the planet in visible light and infrared, and measure its radiation environment. The second, to commence after one Mars year (nearly two Earth years), is to provide a critical communications link, between the Earth and two Rovers that are scheduled to land on Mars in 2004.

During the planned 917-day science mission, data will be returned by 2001 Mars Odyssey which will also help lay the foundation for future manned flights to Mars. Characterizing the radiation environment, and trying to locate any subsurface water, are two of the prerequisites to human missions. The combination of images and information from Odyssey, and the intrepid Mars Global Surveyor, which has been orbiting the planet since 1997, will also locate any concentrations of minerals, and provide topographical data that could aid scientists in choosing potential human landing sites for Mars exploration.

Aerobraking Into A Science Orbit

When Odyssey arrived at Mars, its highly elliptical orbit at insertion was about 80 miles by 17,000 miles. To carry out its science mission, its orbit must be circular, at 250 miles altitude. When a spacecraft is captured by the gravity of a planet—including satellites launched from Earth—small onboard thrusters are usually fired to circularize the orbit, at the proper altitude.

But another option exists if a spacecraft is to orbit a body with an atmosphere. A series of delicate maneuvers, called aerobraking, can be used to slow the spacecraft down without using any fuel, thus saving weight, which allows increasing the scientific payload. The 2001 Mars Odyssey team has started the aerobraking mission phase, which will last anywhere from 60 days to three months, depending upon atmospheric conditions.

Aerobraking involves sending a spacecraft through the upper layers of a planet's atmosphere, where drag slows it down. This series of maneuvers requires a delicate balance between too shallow an angle, which will increase the number of passes required, or sending it too steeply into the atmosphere, which can damage the satellite as it heats up. For the Mars Odyssey, the engineers estimate that about 400 drag passes through the upper layers of the atmosphere may be required. They estimate that the temperature of the spacecraft could be as high as 350° Fahrenheit during aerobraking.

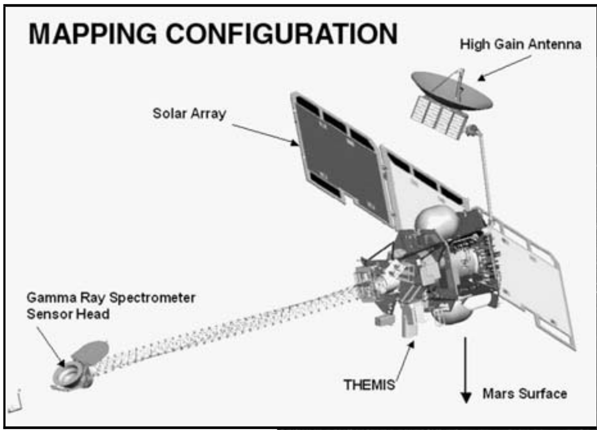
During aerobraking, energy from the spacecraft's orbit "bleeds off," slowing it down. In order to maximize the surface area of the spacecraft that will skim the atmosphere, Odyssey has been oriented with its broad solar arrays facing into the direction of flight. The first aerobraking drag pass took place three days after the spacecraft went into orbit around Mars.

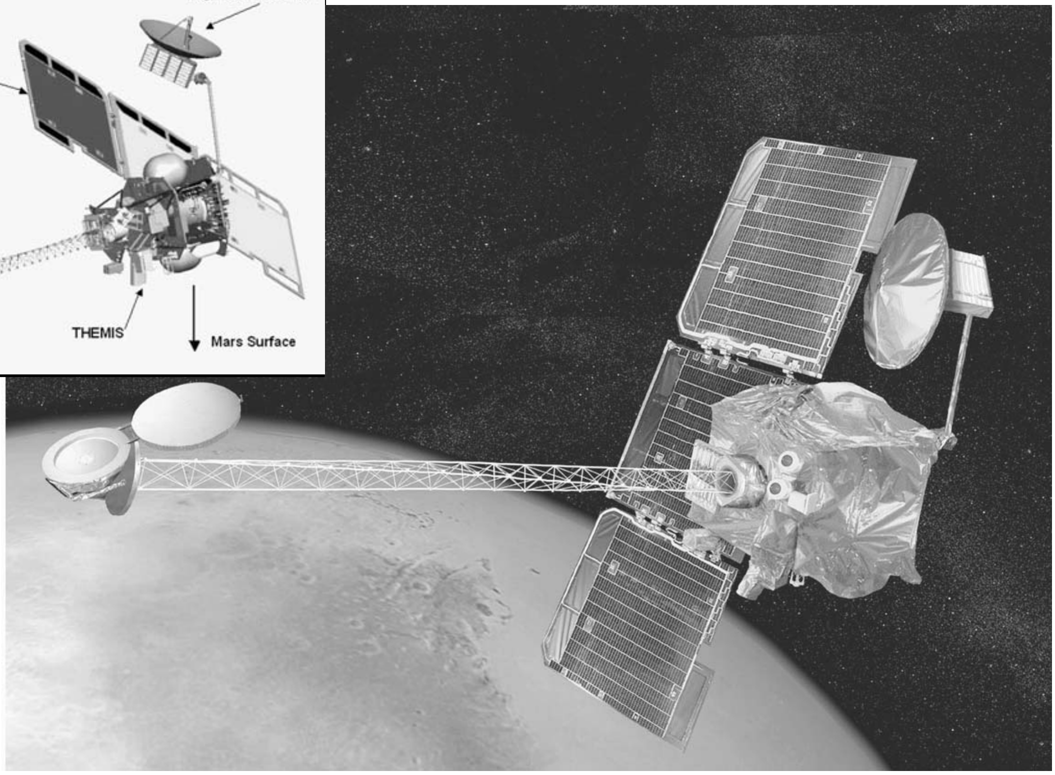
When the Mars Global Surveyor began its aerobraking maneuvers in 1997, one of its solar arrays had been damaged. In order to protect it, the dips into the atmosphere were done slowly and cautiously, over a year and a half. But Odyssey's engineers do not have that option.

The spacecraft must start its scientific mission by early February, so that it will have completed that mission by the time the next mission, which includes the two Rovers, arrives in 2004. At that time, its primary responsibility will shift from science to acting as a communications link between the landers and Earth. Therefore, each drag pass during aerobraking must be carefully planned and precise, because the entire process must be finished when science is scheduled to begin.

Upon orbital insertion, Odyssey was in an 18.5 hour elliptical orbit. Its science orbit will be two hours, and circular at 250 miles. Aerobraking will be carried out in three phases. The "walk-in" phase, occurring during Odyssey's first four to eight orbits, is being used to calibrate the performance of the spacecraft during aerobraking.

In this phase, the aerobraking team, which will work for the next two months on a 24-hour-per-day basis, will determine how closely the model they have of Mars' atmosphere is, to that encountered by the spacecraft. This is no easy task.





The 2001 Mars Odsyssey spacecraft will begin its science mission in early February of next year.

A Meteorologically Active Planet

Mars is a very meteorologically active planet, and for the past four months has been the victim of several raging, planet-wide dust storms. Images taken by the Hubble Space Telescope and Mars Global Surveyor this Summer showed a featureless Mars, shrouded in dust.

Recent dust storms led to a heating of the atmosphere, by as much as 80°F, and although the storms have subsided, scientists fear that they may have kicked up again as Mars reached its closest distance to the Sun in mid-October. The heated atmosphere rises and is denser at a higher altitude, while the surface is cooled by the Sun-blocking dust. These changes in the atmosphere must be constantly monitored, so that the navigational parameters of each drag pass can be adjusted to allow the spacecraft to achieve the required results.

On Oct. 30, the Thermal Emission Imaging System (THEMIS) on board Odyssey took its first infrared temperature image of Mars to determine if the imaging system is working properly. The image of the south pole was taken at nighttime on Mars, to demonstrate the "night-vision" capability of the camera system. THEMIS will perform the critical function of detecting dust storms on Mars during aerobraking. These *in situ,* real-time measurements will be critical to the mission.

When Mars Global Surveyor was carrying out its aerobraking maneuvers, major short-term changes in the density of the upper atmosphere of Mars made it almost impossible for the engineers to predict the conditions that would be encountered on the next orbit. For 10% of the time during aerobraking, the density enountered by the spacecraft on a sweep through the atmosphere was off by more than 70% from the density predicted based on the previous pass!

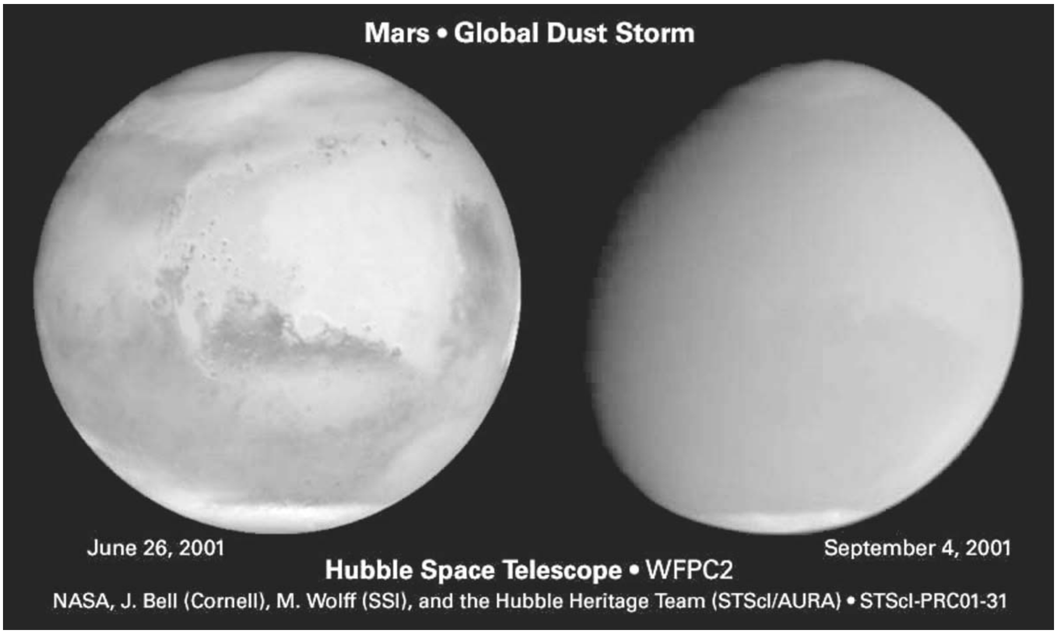
The challenge increases with each aerobraking pass. As the spacecraft's orbit is lowered, its orbital period is reduced, leaving less and less time between passes for the engineers to modify its flight path. At a briefing on Oct. 24, scientists explained that while the time between drag passes will decrease, they will have "more passes under your belt," from which experience to draw on.

The main aerobraking phase will begin when the spacecraft's periapsis (closest distance to Mars) has been lowered to about 60 miles.

The third, or "walk-out" phase will occur during the last few days of aerobraking, when Odyssey's orbit is still elliptical. The periapsis will be about 75 miles, and the most distant point, or apoapsis, will be near the planned 250-mile orbit. Onboard thrusters will raise the spacecraft's periapsis, and circularize the two-hour orbit. Then, Odyssey will be ready for its science mission.

Following The Water

Before there is human life on Mars, one of the most intriguing questions scientists want to answer is, if there were life



These images were taken by the Hubble Space Telescope as a global dust storm began and ended on Mars, obscuring the entire surface, then clearing. Such storms change the atmospheric conditions of the planet, making aerobraking tricky.

on Mars in its past, or if it is even extant. Over the past decade, partly in response to that question, a new search for life has been taking place, *on the Earth*. Peering under Arctic ice caps, inside highly radioactive closed nuclear facilities, and in the driest deserts, scientists have been looking for life in extreme environments. And they have found it everywhere they have looked.

The only prerequisite for life, they have concluded, is access to liquid water, even if it is in the tiniest amounts, and only there on occasion. These discoveries have energized the search for past or present liquid water on Mars.

During the past two years, photographs taken in orbit by the Mars Global Surveyor have indicated more evidence of large bodies of water on Mars in the past, as well as the possibility that even after the planet's climate changed to its present cold, dry state, there may have been underground reservoirs.

In June 2000, a team of scientists studying high-resolution images from Mars Global Surveyor presented evidence that liquid water on Mars may have found its way to the surface more recently than previously believed, and they proposed that seepage of water from below the surface may be continuing even to the present day. Michael Malin, principal investigator for the Mars Orbiter Camera on the spacecraft, along with colleague Ken Edgett, scoured more than 65,000 Global Surveyor images returned over a period of three years, and found that present in about 150 of them are features which, on Earth, are caused by "fluid seepage and surface runoff" of water.

The scientists found about 120 sites where miniature valleys or gorges were excavated from the surrounding cliffs, south polar pits, and crater sides, which they call gullies, indicating that they were created by running water. From the alcove, or source of the seepage, run channels that would have been carved out by water. A fan-like apron is seen at the end of the channels, where debris carried by the water was deposited.

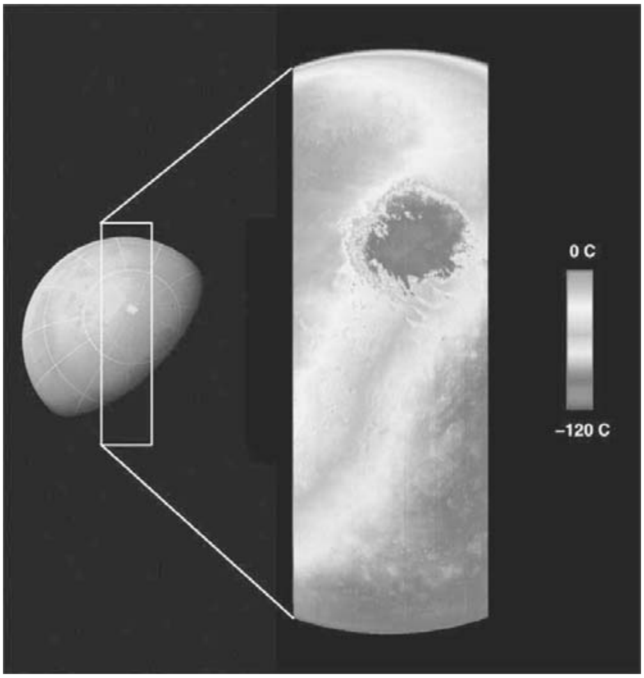
More than 90% of the sites occur south of the Martian equator at high latitudes, nearer the poles in colder regions of the planet. The features are found to occur about two and one-half times more often on colder, polar-facing slopes, as opposed to equator-facing slopes, which would receive more sunlight during the Martian day.

The findings raised a number of questions. First, the scientists estimate that, judging from the features they observe, the water would be 300-1,300 feet below the surface. It has been assumed that any water at that depth would be frozen, since there has been no internal heat source detected in Mars.

Second, it seems peculiar that any seepage would occur in the colder parts of Mars, where liquid water making its way to the surface would evaporate and then freeze instantly. Malin and Edgett propose that when the water emerges and evaporates, the ground is cooled, and the water behind it freezes, producing an "ice dam." Pressure would build behind the dam, and at some point water would break through and send a flood down the gully. Malin believes the gullies formed from repeated outbursts of water and debris, similar to flash floods on Earth.

Evidence Much More Recent

Perhaps the most provocative conclusion from the new research is that the features indicating water seepage and floods seen on Mars, are much more recent than would have seemed possible. The most common, although imprecise, method used to estimate the age of a planetary surface, is to count the number and density of impact craters. The scientists



On Oct. 31, NASA released this first image taken by 2001 Mars Odyssey, which is a thermal profile of the south polar region of the planet. The central polar cap registered at –184°F. The data were taken at night to test the night-vision capability of the Thermal Emission Imaging System, or THEMIS.

report that these 100-plus gully sites have very little cratering, and therefore, are younger surfaces, perhaps millions, rather than billions, of years old.

In addition, there are instances where the apron of debris from the flooding has covered over sand dunes on the surface. Assuming that sand dunes are constantly changing, since dust storms occur during Martian seasonal changes, the gullies could be decades old, or even newer.

After Malin and Edgett released their findings, geologists tried to come up with alternative explanations for the phenomena, disputing the proposition that cold Mars could somehow support underground liquid water. But Richard Hoover, an astrobiologist at NASA's Marshall Space Flight Center, proposed that we not assume that the water on Mars is fresh water, and always freezes at 0° Centigrade. Water containing salt, for example, could stay liquid down to –60°F. Indeed, a recent analysis of a meteorite from Mars which contains ancient crystals of water, suggests that if Mars had oceans, they contained a mix of salts similar to those in the Earth's oceans today. As early as 1976, the Viking landers found that Martian soil contained 10-20% salts.

Another possibility that could explain an underground aquifer on Mars, is that if water keeps moving, it does not necessarily freeze, even when the air temperature is below freezing. This has been observed in Alaska, and at Lake Vostok, which lies underneath an ice sheet in the Antarctic.

Six months later, the scientists presented further evidence that life could have existed on Mars. The new evidence, of widespread sedimentary layering on Mars, lends credence to the view that early in Martian history, conditions there allowed for the existence of large-scale oceans or lakes, for significant periods of geologic time. And with large bodies of water, over time, there could have been life.

What Malin and Edgett compiled from the Mars Global Surveyor images is evidence of widespread layering of what appears to be sedimentary rock, created from the compression and hardening of deposited material, mainly inside craters and in chasms of canyons. Although such layering had been seen since the Mariner 9 mission in the early 1970s, it has never been seen in such great detail or been known to exist so widely across the planet before.

At a press conference in December 2000, Malin stated, "Some of the images of these outcrops show hundreds and hundreds of identically thick layers, which is almost impossible to have without water." Summing up the significance of this latest find, Malin remarked, "On Earth, sedimentary rocks preserve the surface history of our planet, and within that history, the fossil record of life. It is reasonable to look for evidence of past life on Mars in these remarkably similar sedimentary layers. . . . What is new in our work is that Mars has shown us that there are many more places in which to look, and that these materials may date back to the earliest times of Martian history."

Onboard 2001 Mars Odyssey are two instruments that will contribute to answering these questions. It will be the first time there are two spacecraft in orbit at Mars, with different instruments, that will complement each other and work together.

Taking A Closer Look

The Gamma Ray Spectrometer (GRS) will play the leading role in determining the elemental composition of Mars' surface. It will study the gamma rays and neutrons emitted from the planet's surface and, using a gamma ray spectrometer and two neutron detectors, measure the distribution and abundance of about 20 primary elements on the surface.

When chemical elements are exposed to background cosmic rays, gamma rays are emitted from the nucleus, each with a distinct electromagnetic signature. The energy spectrum of the gamma-ray emissions coming from the Mars surface will indicate the presence of various chemicals, and the intensity will indicate their concentrations. The GRS will be able to detect the presence of hydrogen, which scientists assume will imply the presence of water. The neutron detectors are sensitive to concentrations of hydrogen in the upper three feet of the surface.

The sensor head, containing the GRS, is separated from the rest of the Odyssey spacecraft by a 20-foot boom, in order to avoid interference from any gamma rays coming from the spacecraft itself. About 100 days into the mission, the boom will deploy and remain in this position for the remainder of the mission. The two neutron detectors are mounted on the main spacecraft structure.

The GRS was turned on for testing during one of the spacecraft's first orbits of Mars, and found to be in good working order. Scientists reported at a briefing the day after orbital insertion that "all of the detectors are working perfectly."

THEMIS will collect data in the visible and infrared parts of the spectrum. In the infrared, THEMIS uses ten spectral bands to detect minerals such as carbonates, hydroxides, hydrothermal silica, and others that are formed in the presence of water. In addition, silicates, sulfates, oxides, and phosphates will show themselves as different colors in the infrared spectrum, and their concentrations can also be determined. With ten spectral bands, THEMIS will be able to detect minerals at abundances as low as 5-10%.

THEMIS, which will be able to detect temperature differences as small as 1°F, will also be able to search for thermal spots, which could lead to the discovery of hot springs or underground pools of water on Mars. THEMIS will also provide a daily weather report from Mars.

The visible imaging system, in five spectral bands, with 60-foot resolution, will map the mineralogical and structural geology of the planet, to determine the record of past liquid environments. More than 15,000 images will be acquired, which will bridge those of lower resolution from Viking in the 1970s, and the higher resolution images from Mars Global Surveyor.

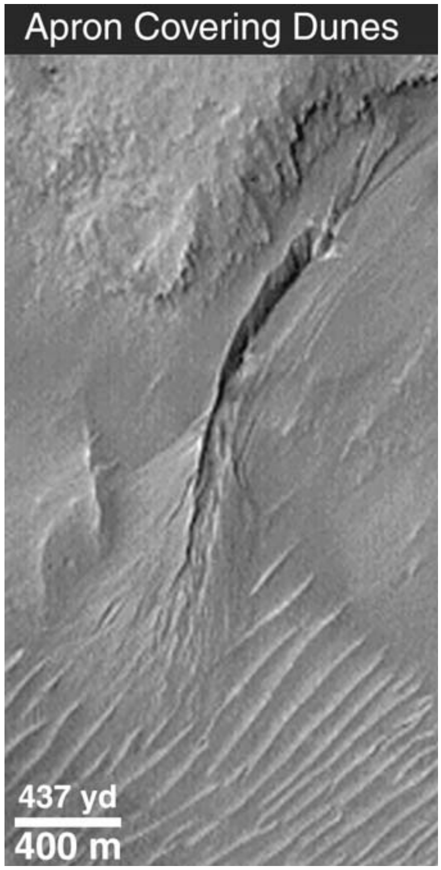
Because Mars has little atmosphere and no protective ozone layer, it is well known that the surface is bombarded by radiation from deep space, and also from the Sun. The third scientific instrument aboard Odyssey is the Mars Radiation Environment Experiment (MARIE). Space radiation can be electromagnetic, such as X rays and gamma rays, or particulate, such as protons and electrons. From Mars orbit, for the first time, MARIE will be able to detect charged particles. It is the particle energy that poses the greatest radiation threat to humans. Protons in space come mainly from activity on the Sun.

Solar flares, which are the most powerful explosions in the Solar System, can shower interplanetary space with protons, which lose their energy in any tissue they come in contact with, and ionize molecules along their tracks. MARIE collected data on the radiation environment during Odyssey's seven-month interplanetary cruise phase. In orbit around Mars, the spectrometer will sweep through the sky and measure the radiation field.

From these data, scientists hope to be able to determine what the radiation environment is on the surface of the planet, so that plans for protecting crews can be made accordingly.

Expanding The Infrastructure

In 2003, NASA plans to send two Rovers to the surface of Mars. During the same launch opportunity, the European Space Agency will send the Beagle lander to the planet as part of its Mars Express program. To make the most of each mission, coordination and shared resources will be needed.



This picture, taken in September 1999 by the Mars Global Surveyor, shows a gully which scientists assume was created by the flow of water. The apron, or fanlike deposit at the end of the channel, covers sand dunes, indicating that the channel is only hundreds of years old, or less.

At Cornell University, in Ithaca, New York, a group led by Professor of Astronomy Steven Squires is participting with an international team in the development of the Athena science package of instruments which will be carried to the Mars surface during the U.S. 2003 Mars Exploration Rover mission.

Although the Mars Global Surveyor, still in orbit around the planet, could provide a communications link with Earth, the ageing spacecraft would be a high-risk back-up. Odyssey is outfitted with a relay antenna that will transmit data directly to Cornell's Space Sciences Building.

Each Rover is a 300-pound mobile scientific laboratory. And one of Odyssey's instruments, THEMIS, will provide data on the mineral composition of soil and rocks that will help scientists better understand the four potential Rover landing sites that have recently been chosen.

The 2001 Mars Odyssey spacecraft is a crucial piece of infrastructure to be put into place at the planet. Over time, NASA plans to build an "interplanetary internet" in orbit around Mars, to increase the data rate and allow it to collect and relay data not only from spacecraft, but also from aircraft and balloons in flight around Mars.