THE INVASION OF MARS

THE LONG JOURNEY OF MARS *ODYSSEY*

by Jordan Strickler

In 1898, H.G. Wells penned the novel *The War of the Worlds*, which portrayed an invasion of Earth by technologically superior Martians desperate for water. This story was reversed starting in 1965 with the flyby of the Red Planet by Mariner 4. It was just the beginning of a long series of Mars probes that continues to this day, making Mars the most visited planet in our solar system.

One of the more successful of the orbiting robots has been Mars *Odyssey*, which set off in 2001 to search for water and survey interesting geological formations on the planet. *Odyssey* can be thought of as a Martian Swiss Army knife—one tool with a host of purposes, from an instrument which has made a multitude of scientific discoveries on its own, to a transmission relay device for multiple landers and rovers (as well as a device to find landing sites for said landers and rovers), and a champion tag-team partner with other spacecraft that have redefined what we know about the planet.

The orbiter, which is currently the longest-serving robot operating near Mars, was named after Arthur C. Clarke's *2001: A Space Odyssey*. That moniker initially ran into some hesitancy due to NASA concerns regarding copyright, but those were soon quelled when Clarke gave his support.

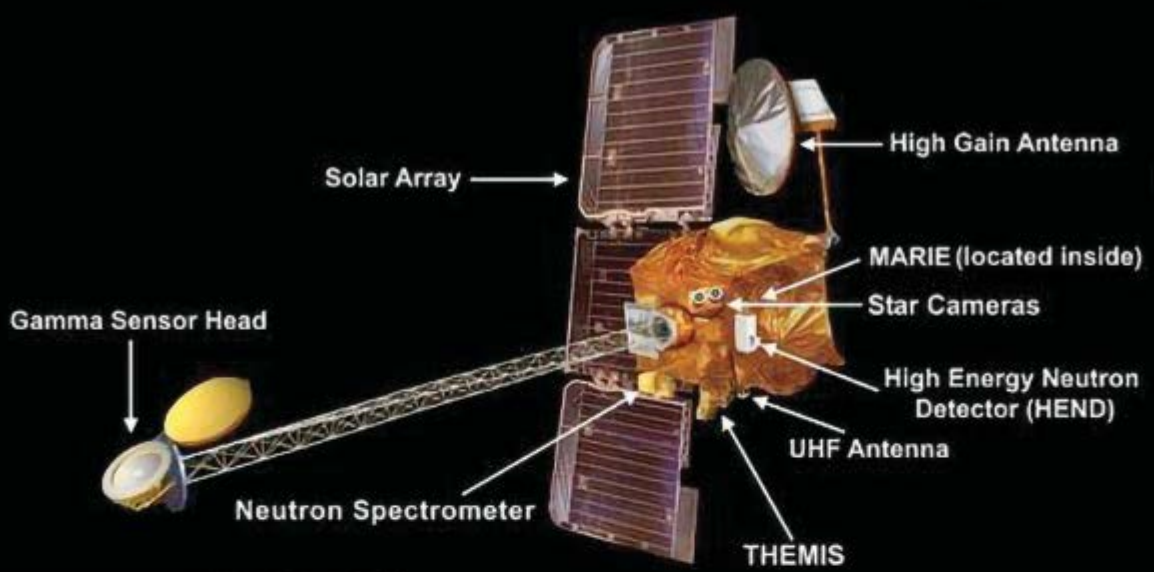
One of the primary goals for *Odyssey* was relatively simple: don't fail. The project was initiated as part of NASA's revamped Mars Exploration Program, which was originally approved in 1993, then restructured in October 2000 after the failures associated with the "faster, better, cheaper" approach the agency was implementing at the time to reduce costs. This approach—established in the early 1990s—was found to have caused two successive Mars missions, the Mars Climate Orbiter and the Mars Polar Lander, to blink out of existence within a three-month span. It got so bad that the Harvard Business Review even published a report in 2004 using "faster, better, cheaper" as an example of how *not* to do business.

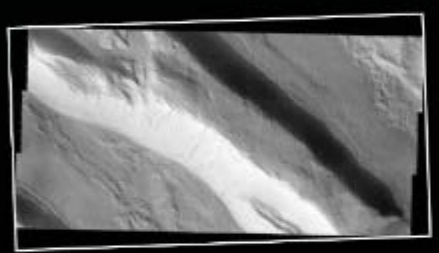
On October 21, 2001, 200 days after launch, *Odyssey* entered orbit around Mars successfully after a 20-minute braking burn. The initial orbit was highly elliptical at about 170 by 16,665 miles (272 by 26,818 kilometers) and would allow the spacecraft one circuit in 18.6 hours.

The second goal of the 297-million-dollar orbiter was to make highly detailed maps of Mars by charting the chemical and mineralogical composition of the Martian surface in visual and infrared wavelengths. Additionally, *Odyssey* would keep an eye out for hydrogen, which could be a key indicator of water ice—a goal which it was able to accomplish with the assistance of the orbiter's Gamma Ray Spectrometer and neutron spectrometers.

To the delight of the scientific community, the discovery of hydrogen came early in the mission when, in May 2002, scientists announced that the probe had indeed identified large amounts of hydrogen in the upper soil. This finding implied the possible presence of ice about a yard (one meter) below the planet's surface.

Credit: NASA





According to Arizona State University, more than 1.2 million cubic miles (five million cubic kilometers) of ice have been identified at or near the surface of the planet. If melted, this is enough to cover the whole planet of Mars to a depth of at least 115 feet (35 meters) and some estimates place this at more than 300 feet (91.5 meters). If you prefer Earth-bound comparisons, that is enough to fill Lake Michigan twice—and that estimate is considered to be conservative.

"This is really amazing," said William Boynton, principal investigator for *Odyssey*'s Gamma Ray Spectrometer suite at the University of Arizona. "This is the best direct evidence we have of subsurface water ice on Mars. We were hopeful that we could find evidence of ice, but what we have found is much more ice than we ever expected."

Prior to *Odyssey*, Mars was thought to mostly be a dry and barren place, but the orbiter rapidly changed the scientific community's mind.

"We clearly identified the presence of hydrogen in the soils of the high latitudes of Mars, which has since been confirmed to be in the form of water ice," explained *Odyssey* Project Scientist Jeffrey Plaut. "We were able very early in our mission to make maps of the locations of ground ice in the upper few feet, or one meter, of the soil. We were able to detect the presence and make estimates of the amount of water in the soil and tally that up, and it was one of the largest known reservoirs of water on Mars along with the water ice that's locked up in the polar cap. It was a huge and historic discovery for *Odyssey* to be able to make those maps of the ground ice."

Just a few years later, the Phoenix lander used its robotic arm to expose some of this ground ice, sample it, and analyze its composition—it was, in fact, water ice. In 2008, satellite imagery from *Odyssey* revealed thick Martian salt deposits across the planet's southern hemisphere, hinting that large amounts of liquid water could have once flowed there.

In February of this year, NASA announced that *Odyssey*—working in tandem with the Mars Reconnaissance Orbiter and the now-retired Mars Global Surveyor—had completed the Subsurface Water Ice Mapping (or SWIM) project, which compiled 20 years' worth of data to locate water. Researchers focused on Mars' northern hemisphere in an effort to locate the best possible place for future human explorers to locate precious, shallow water ice beneath the surface.

Water is not only vital to keeping astronauts alive but can also be used to manufacture other critical goods such as rocket fuel. Mapping efforts in the 2020s could help make crewed missions to Mars possible as early as the subsequent decade.

"The next frontier for Mars is for human explorers to get below the surface and look for signs of microbial life," said Richard Davis, who leads NASA's efforts to find Martian resources in preparation for sending people to the Red Planet. "We realize we need to make new maps of subsurface ice to improve our knowledge of where that ice is for both scientific discovery and having local resources astronauts can rely on."

The gargantuan task of mapping the planet was another test *Odyssey* passed with flying colors. In 2010, NASA released a global map from the orbiter composed of 21,000 images taken over eight years by *Odyssey*'s Thermal Emission Imaging System (THEMIS). This map showed features as small as 330 feet (100 meters)

in size, though *Odyssey* has mapped certain areas at an even higher resolution. That map is now the starting point for almost all geologic studies of the Red Planet.

Over a ten-year period, with the help of the neutron detectors, THEMIS has provided a more accurate picture of the planet's climate, thanks in part to multiple mission extensions due to the probe's hardiness. Researchers have been able to study such changes as the cycle of carbon-dioxide freezing out of the atmosphere in polar regions during each hemisphere's winter. Remarkably, Martian weather and climate stay relatively stable on a yearly basis. "That research was really quite an accomplishment," said Plaut. "No other spacecraft has been able to do that, and it's remarkable how consistent weather patterns have been from year to year."

THEMIS didn't stop there. In 2010, the instrument helped scientists find a series of seven caves on the slope of the volcano Arsia Mons, likely formed due to natural underground stresses near the volcano. While the caves may be too inaccessible for early occupied habitats, the find did spur the hunt for lower-altitude caves and lava tubes. On December 15 of the same year, the orbiter also broke the record for longest serving spacecraft at Mars, with 3,340 days of operation.

More recently, scientists have refocused *Odyssey* on the Martian moon Phobos. Three new views were captured by THEMIS as *Odyssey* drifted in and out of the planet's shadow. While *Odyssey*'s primary objective is the Martian surface, in recent years, the Jet Propulsion Laboratory has developed a process to flip the spacecraft upside-down so it can aim its camera at Phobos. The result has given remarkable insights into the composition and physical properties of the moon.

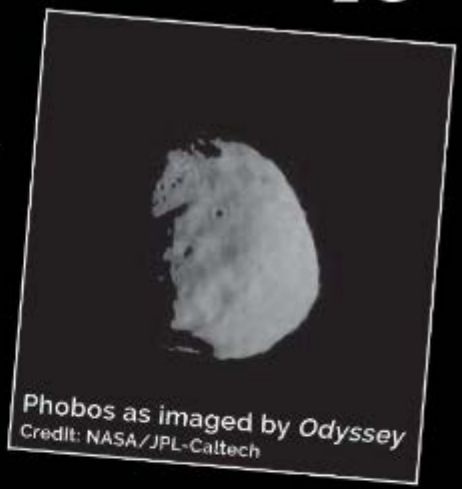
"We're using the unique capability of THEMIS to capture images in the infrared, not only measuring the temperature, but also the spectral behavior of the infrared radiation at different points in the spectrum, which gives us information about the compositions of the soil," noted Plaut. "We're looking at the nature of the moon's soil to see what the composition is, and its texture and density, since it is a planned target for landing and sampling missions."

New images taken December 2019 show Phobos in full-moon phase, when more of the surface is exposed to sunlight, with a maximum temperature of 81 degrees Fahrenheit (27 degrees Celsius). A 2020 photo shows the moon while in eclipse, when Mars' shadow completely blocked sunlight from reaching its surface. This provided some of the coldest temperatures measured on Phobos to date—the lowest a chilly 189 degrees Fahrenheit (123 degrees Celsius) below zero. Another 2020 image showed Phobos exiting an eclipse, with the surface still warming up.

"We're seeing that the surface of Phobos is relatively uniform and is made up of very fine-grained materials," said Christopher Edwards of Northern Arizona University in Flagstaff, Arizona, after the pictures were released. Edwards led the processing and analysis of the Phobos images. "These observations are also helping to characterize the composition of Phobos. Future observations will provide a more complete picture of the temperature extremes on the moon's surface."

With only one other spacecraft actively working near Mars when *Odyssey* arrived on the scene, its tour has surprised many of those who worked on the program. Mike Kelley, Program Scientist for *Odyssey* and the Mars Reconnaissance Orbiter, is impressed with its longevity. "It is the longest-running Mars mission to date," he said. "That provides us with a long timeline of observations and helps us to understand how the atmosphere and climate vary and how the surface of Mars changes over time."

However, two decades have seen the orbiter work through various malfunctions. During the coast to Mars in August 2001, the Mars Radiation Environment Experiment instrument failed to respond but was successfully revived by March 2002. In 2003, a solar flare knocked out another instrument. In 2012, *Odyssey* mysteriously and repeatedly jumped into safe mode, which would hinder its relaying of data from the *Curiosity* rover to Earth and stretch the span longer than the ordinary 14 minutes. The problem was determined to be the loss of one of four reaction wheels, gyros that are responsible for controlling *Odyssey*'s orientation. Fortunately, the three remaining wheels were sufficient to keep *Odyssey* in correct alignment.



Phobos as imaged by *Odyssey*
Credit: NASA/JPL-Caltech

A more politically-driven threat to the craft played out in early February 2020 when President Trump released his 2021 budget request. It slashed funding for *Odyssey* from 12 million dollars to around one million dollars for the fiscal year. The cut would have essentially pulled the rug out from under the program, which needs at least 12 million dollars to operate on a yearly basis. Luckily the budget changes were rejected by Congress and *Odyssey* was spared from the chopping block.

In 2024, the Japan Aerospace Exploration Agency (JAXA), in cooperation with NASA and the European Space Agency, will send a probe to Phobos with the goal of collecting a sample from the surface and returning it to Earth. Called the Martian Moons Exploration probe, their program will be using measurements taken from THEMIS and *Odyssey* for indications of the nature of that soil. *Odyssey* just keeps contributing to our understanding of Mars in ways not anticipated when the mission was conceived.

Odyssey has played an instrumental role in the exploration of the Red Planet. Mars has been mapped, possible water has been discovered, vital rover and lander communication relays have been made, and potential landing sites for past and future missions have been found. Thanks to the orbiter that will be celebrating its 20th anniversary this year, much of what we know about Mars has been forever changed.