The Solar Wind at Mars

The solar wind has slowly eroded the Martian atmosphere for billions of years -- transforming the planet into a barren desert.

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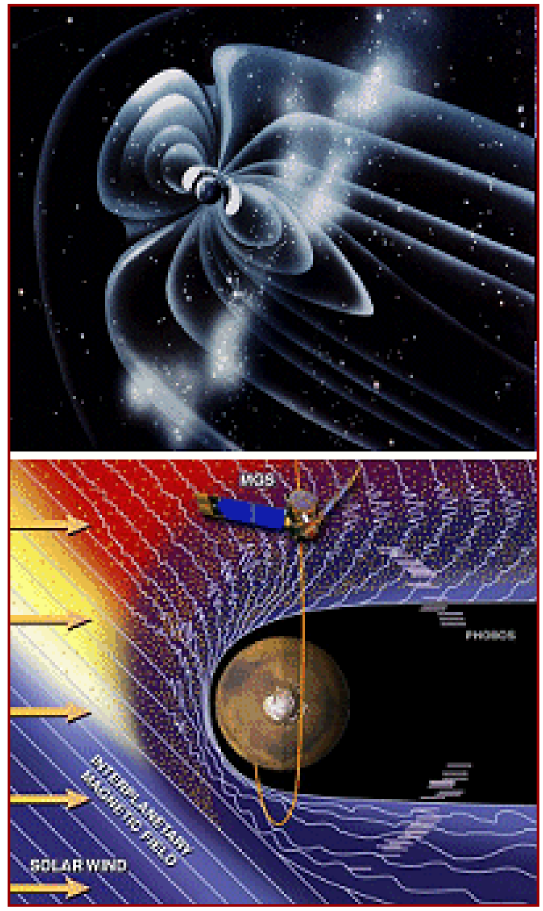
January 31, 2001 -- If it were possible to magically transport a cup of water from Earth to the surface of Mars, the liquid would instantly vaporize. Mars's atmosphere is so vacuous (it's less than 1% as dense as Earth's) that liquid water simply can't exist for very long on the Red Planet.

That's a puzzle to planetary scientists, because Mars's surface is littered with signs of liquid water. Dried up valley networks, sedimentary deposits, and chaotic flood plains hint that billions of years ago Martian water flowed freely and that the atmosphere there must have been substantially thicker than it is now. But where did it all that Martian air go?

New evidence from NASA's Mars Global Surveyor (MGS) spacecraft supports a long-held suspicion that much of the Red Planet's atmosphere was simply blown away -- by the solar wind.



Right, above: Earth is shielded from the solar wind by a magnetic bubble extending 50,000 km into space -- our planet's magnetosphere. **Right, below**: Without a substantial magnetosphere to protect it, much of Mars's atmosphere is exposed directly to fast-moving particles from the Sun. [more]

The solar wind is a fast-moving part of the Sun's outer atmosphere. The solar corona, with a temperature greater than one million degrees C, is so hot that the Sun's gravity can't hold it down. It flows away in all directions traveling 400 to 800 km/s. Every planet in the solar system is immersed in this gusty breeze of charged particles.

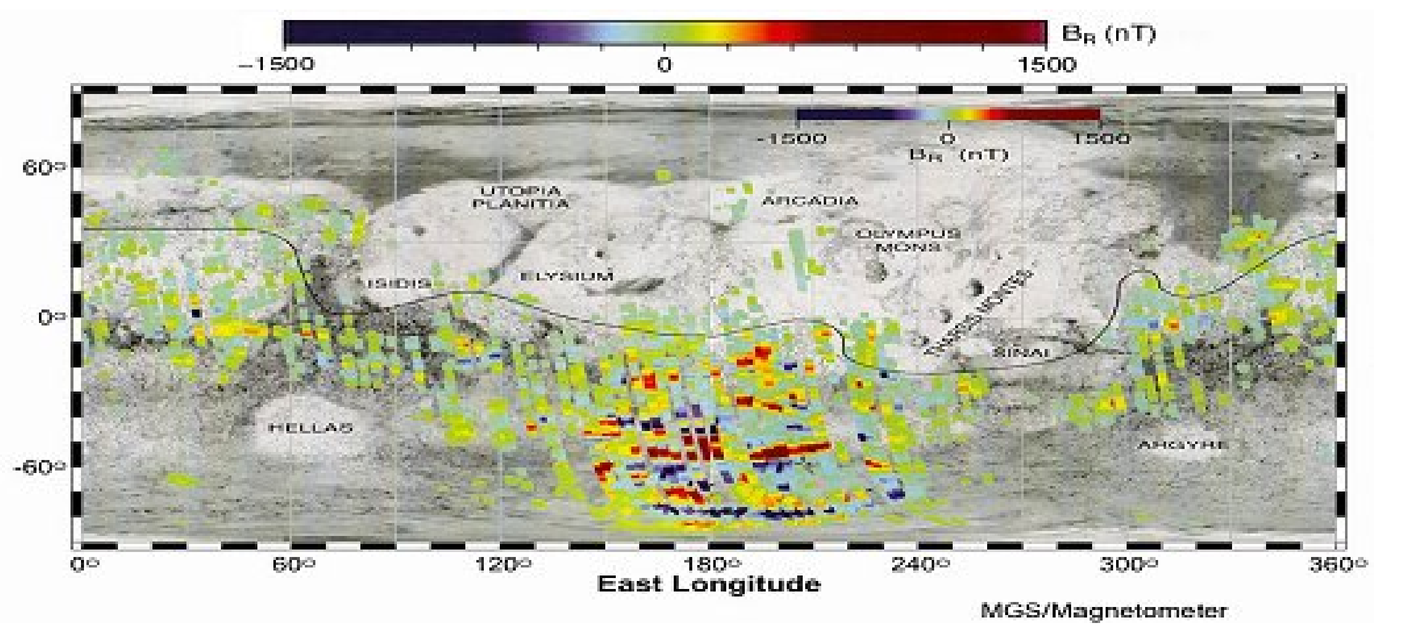
Here on Earth we're protected from the solar wind by a global magnetic field (the same one that causes compass needles to point north). Our planet's magnetosphere, which extends far out into space, deflects solar wind ions before they penetrate to the atmosphere below.

Mars isn't so fortunate. Lacking a planet-wide magnetic field, most of the Red Planet is exposed to the full force of the incoming solar wind. "The Martian atmosphere extends hundreds of kilometers above the surface where it's ionized by solar ultraviolet radiation," says Dave Mitchell, a space scientist at the University of California at Berkeley. "The magnetized solar wind simply picks up these ions and sweeps them away."

"In 1989 the Soviet Phobos probe made direct measurements of the atmospheric erosion," he continued. When the spacecraft passed through the solar wind wake behind Mars, onboard instruments detected ions that had been stripped from Mars's atmosphere and were flowing downstream with the solar wind. "If we extrapolate those Phobos measurements 4 billion years backwards in time, solar wind erosion can account for most of the planet's lost atmosphere."

"To calculate the total loss of atmosphere," he added, "we must take into account how the Sun has changed during the past four billion years. The Sun's ultraviolet output was larger in the past, and the solar wind was probably much stronger. This means that solar wind erosion was likely much more effective in the past than it is today."

Although Mars no longer has a substantial magnetosphere, scientists think it once did and that the remnants of it still exist. In 1998 magnetometers on MGS discovered a network of magnetic loops arrayed across Mars's southern hemisphere. Locally, the magnetic fields arch over the surface like umbrellas, hundreds of km high. "If you were standing on Mars in one of these areas," says Mitchell, "you would measure a magnetic field about as strong as Earth's -- a few tenths of a gauss." Elsewhere on the planet the magnetic field is 100 to 1000 times weaker.

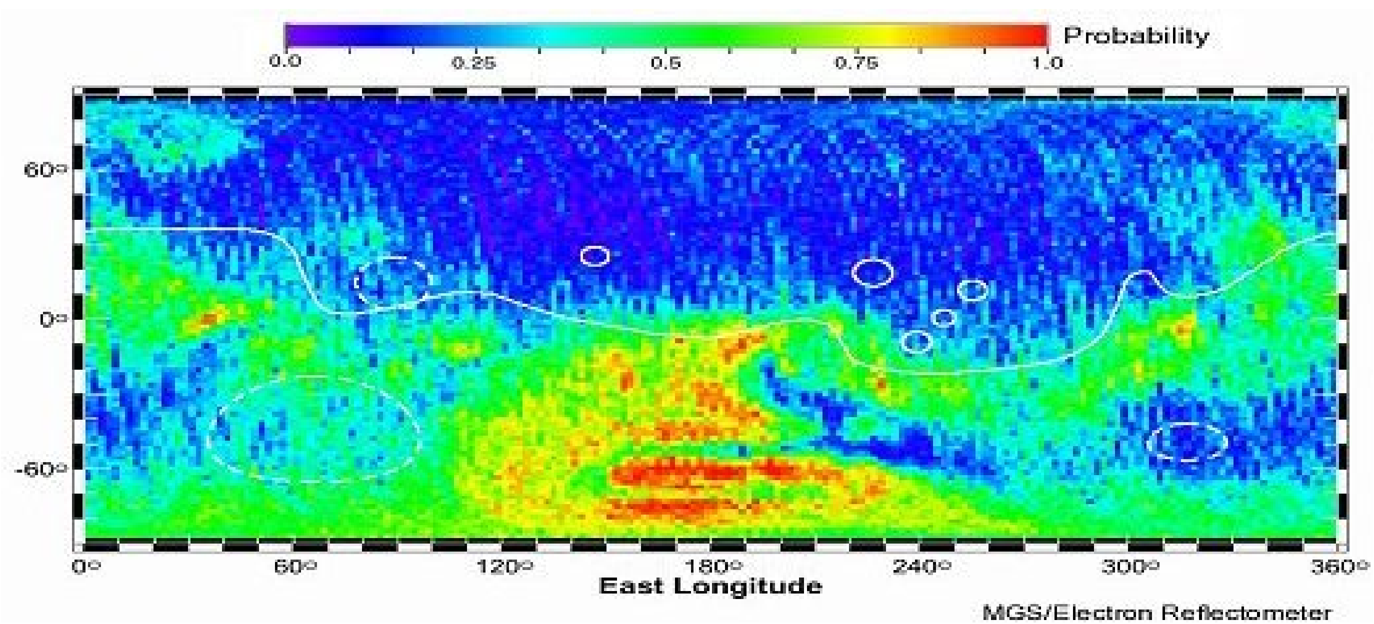


Above: A map of the vertical (radial) component of magnetic fields poking out of the Martian crust. Red and blue areas are zones where stronger-than-average magnetic fields protect the planet from solar wind erosion.

Indeed, it appears that Mars's magnetic umbrellas act like miniature magnetospheres. They ward off the solar wind in their vicinity and harbor pockets of gas ionized by solar UV radiation that would otherwise be blown away.

At a recent meeting of the American Geophysical Union, Mitchell and colleagues unveiled the first-ever global map of the Red Planet's ionosphere (the ionized part of the atmosphere), based on data from the Mars Global Surveyor electron reflectometer. "The ionosphere nicely traces the distribution of the surface magnetic field, and there seems to be a 1-to-1 correspondence," noted Mitchell. Places where magnetic umbrellas deflect the solar wind are also spots where the ionosphere is retained high above the surface of the planet.

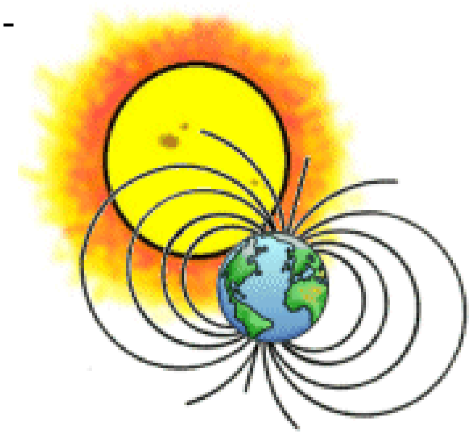
Mitchell cautions that beneath these magnetic umbrellas the neutral atmosphere at Martian "sea level" isn't particularly dense -- they are not oases of air for future colonists! Rather, the mini-magnetospheres are simply places where high-altitude atmospheric losses are relatively low. Most of Mars is still subjected to the full force of the solar wind. To retain a thick atmosphere, a planet-wide magnetic field would be needed.



Above: A map of the ionosphere on Mars. Colors represent the probability that Mars Global Surveyor will be in the ionosphere when orbiting at 400 kilometer's altitude. Blue is a low probability, meaning the spacecraft is usually in the solar wind and the ionosphere is below the spacecraft. Yellow and red show where the ionosphere often protrudes above 400 kilometers altitude. (Credit: David Mitchell, UC Berkeley.)

Earth's global magnetic field comes from an active dynamo -- that is, circulating currents at the planet's liquid metallic core. A similar dynamo once churned inside Mars, but for reasons unknown it stopped working four billion years ago. The patchwork fields we see now are remnants of that original magnetic field.

How do scientists know when the dynamo turned off? "Mars has been kind to us," explains Mitchell. "There are two large impact basins, Hellas and Argyre, about four billion years old that are demagnetized. If the dynamo was still operating when those impact features formed, the crust would have re-magnetized as they cooled. The dynamo must have stopped before then."



Earth also has an ionosphere maintained by solar UV, but on our world --unlike Mars-- the ionosphere envelops the entire planet. It begins at an altitude of about 90 km and stretches thousands of km into space. Because the ionosphere fits safely inside our planet's much-larger magnetosphere, solar wind erosion is not a problem. That's good news for ham radio operators who depend on the radio-reflective ionosphere for over-the-horizon shortwave communications. Living on a magnetized planet has its advantages!

The advantages might be even bigger than amateur radio, though. Planetary magnetic fields could be an essential ingredient for life-bearing worlds circling stars with strong solar winds, worlds that need to retain a substantial atmosphere and liquid water. Indeed, if the Martian dynamo hadn't shut down billions of years ago, the Red Planet might be teeming with Martians today. Instead Mars is a frigid desert, apparently as barren of life as it is of its long-gone magnetic personality!

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Web Links

Sedimentary Mars -- Science@NASA article: New Mars Global Surveyor images reveal sedimentary rock layers on the Red Planet that may have formed underwater in the distant martian past.

The Case of the Missing Mars Water -- Science@NASA article: Plenty of clues suggest that liquid water once flowed on Mars --raising hopes that life could have arisen there-- but the evidence remains inconclusive and sometimes contradictory.

Mars Exploration Program -- from NASA's Jet Propulsion Laboratory in Pasadena, California

Malin Space Science Systems -- the company operating the Mars Orbiter Camera, which took the high-resolution images that revealed the sedimentary regions on Mars

Beagle 2 -- home page

Mars Exploration Rovers -- information from Cornell University on the pair of Mars rovers that NASA plans to launch in 2003

Twin Rovers Headed for Mars -- Science@NASA article: NASA announced plans to launch two large scientific rovers to the red planet in 2003.

Cross-bedding, Bedforms, and Paleocurrents -- an introductory document on methods for interpreting the sedimentary structures mentioned in this article, presented by the U.S. Geological Survey

Movies of computer-simulated sediment deposition -- presented by the U.S. Geological Survey

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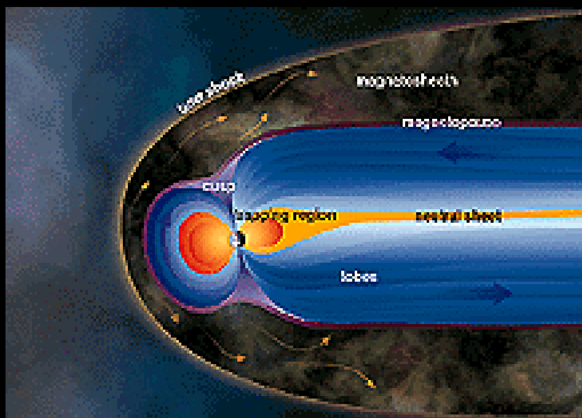
The Earth's Magnetic Field



The Earth has a magnetic field with north and south poles. The Earth's magnetic field reaches 36,000 miles into space.

The magnetic field of the Earth is surrounded in a region called the magnetosphere. The magnetosphere prevents most of the particles from the sun, carried in solar wind, from hitting the Earth.

Some particles from the solar wind can enters the magnetosphere. The particles that enter from the magnetotail travel toward the Earth and create the auroral oval light shows.

The Sun and other planets have magnetospheres, but the Earth has the strongest one of all the rocky planets. The Earth's north and south magnetic poles reverse at irregular intervals of hundreds of thousands of years.

Click on image for full size version (71K GIF)

 Another Image

Photo provided courtesy of NASA

A Magnetosphere

Sun	Mercury	Venus	Earth	Mars	Asteroid	Jupiter	Saturn	Uranus	Neptune	Pluto	Comet
Arts	Cool	Data	Earth	Geology	Life	Missions	Myth	News	People	System	Universe
Ask-Sci	Chat	Comments	Contents	Help	Home	Kids	Preference	Search	Teachers	What's New	Workbook
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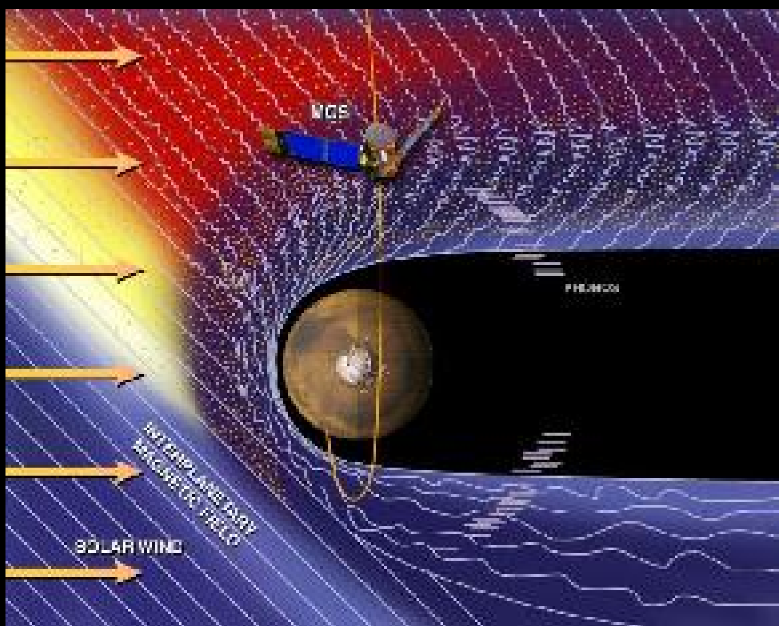
The Martian Magnetosphere



An important new result from the Mars Global Surveyor (MGS) mission is the definite confirmation of the presence of a magnetic field near Mars. The magnetic field leads to the formation of a magnetosphere, as shown in this drawing. A magnetosphere helps protect a planet from the solar wind, however, the Martian magnetosphere may be too small to do that very well. In this picture, MGS can be seen going around Mars.

The magnetosphere can be found outside of, but somewhat overlapping the planet's atmosphere. Particles of the atmosphere can sometimes enter the magnetosphere and particles of the magnetosphere can sometimes enter the atmosphere.

This image illustrates one way in which the magnetometer instrument studies the planet.
Click on image for full size version (53K JPG)
Image from: NASA/JPL

Read more about the Magnetic Field

Return to Martian atmosphere

Last modified March 15, 1998 by the Windows Team

Phobos 2

Mission Overview

The Phobos 2 mission was launched on 12 July 1988 from Baykonur Cosmodrome. The primary objective of the mission, as with its sister probe Phobos 1, was to explore the larger of Mars' two moons, Phobos. In addition to instrumentation to explore the Martian satellites, Phobos 2 also carried instruments to study the Sun, Mars, the interplanetary medium, and gamma-ray burst sources.

The Phobos 2 spacecraft arrived at Mars on 30 January 1989, but was lost while maneuvering in Martian orbit to encounter Phobos on 27 March 1989. The loss was traced to either a failure of the on-board computer or of the radio transmitter (which was already operating on the backup power system).

Instrumentation

Originally, both Phobos spacecraft were to carry identical instrument payloads. Mass limitations required some tradeoffs so that certain instruments were carried by only one spacecraft. Phobos 2 carried a total of 25 instruments. Of those, a few were high energy detectors. A diagram of the Phobos instrumentation is included in the Phobos images page.

- APEX Gamma-ray emission spectrometer.
- LILAS Low-energy gamma-ray burst detector.
- RF-15 X-ray spectrometer.
- VGS High-energy gamma-ray burst detector.

Science

Due to the loss of the spacecraft, much of the original science objectives were not met. However, the two months of data which were obtained did yield a number of important results. These are summarized in Goldman (1990).

A service of the Laboratory for High Energy Astrophysics (LHEA) at NASA/ GSFC
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Science Instruments

Spacecraft
Delta-7925 Rocket
Mission Itinerary

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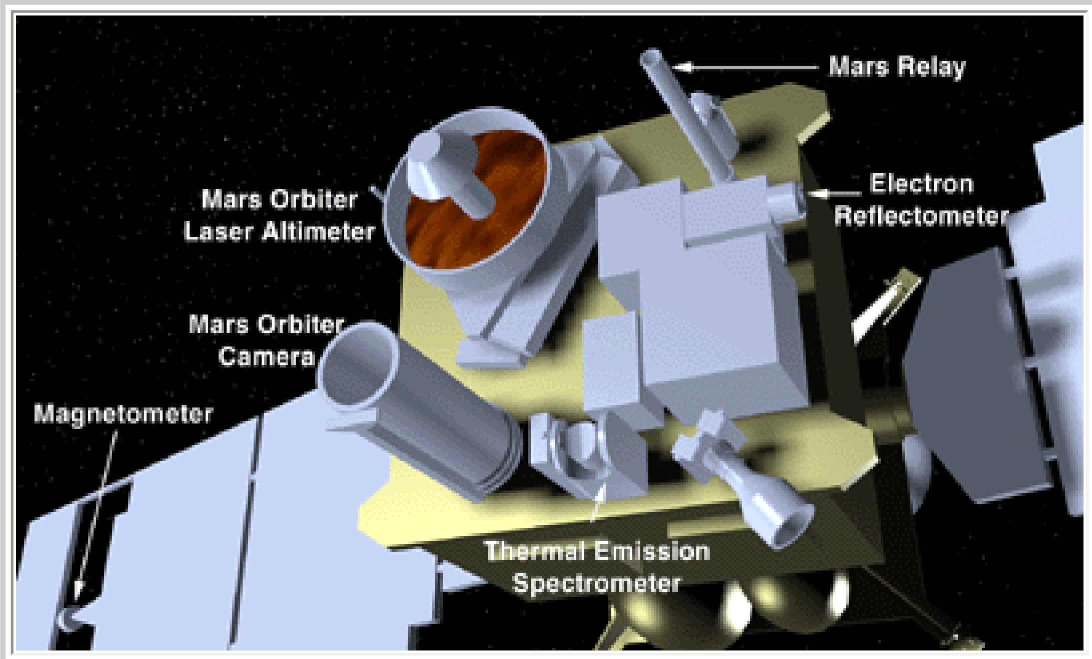

Mapping operations will begin in mid-March 1998 and last until January 2000. During those two years, transmission rates as fast as 85,333 bits per second will allow Mars Global Surveyor's six main scientific instruments to send nearly 83 gigabytes of data back to Earth. The enormous amount of data, enough to fill over 130 CD-ROMs, will contribute to an extremely comprehensive study of the Martian atmosphere, surface features, mineral distribution, and magnetic properties. Click on the red bar containing the title of the science instrument for more information regarding that specific instrument.

Mars Orbiter Camera

The camera will produce a daily wide-angle image of Mars similar to weather photographs of the Earth shown on the nightly news. In addition, the narrow-angle lens will capture images of objects as small as 1.5 meters across.

Mars Orbiter Laser Altimeter

The laser altimeter will bounce beams of light off of the surface to measure the heights of mountains and depths of valleys.

Thermal Emission Spectrometer

The thermal emission spectrometer will scan for heat emitted from Mars to study the atmosphere and to map the mineral composition of the surface.

Magnetomer/Electron Reflectometer

The magnetometer will study the magnetic properties of Mars to gain insight into the interior of the planet.

Mars Relay

The relay antenna will receive data transmitted to Surveyor from future NASA spacecraft that will land on the Martian surface.

Radio Science

An analysis of radio signals sent to Earth from Surveyor will reveal the precise shape of the planet and structure of the atmosphere.