Doppler shift of radio signals sent back to Earth to allow the precise determination of changes in the orbit of the spacecraft. This will allow scientists to construct a model of the Mars gravitational field. As the spacecraft passes over the poles on each orbit, radio signals pass through the Martian atmosphere on their way to Earth. The way in which the atmosphere affects these signals allows determination of its physical properties.

The Magnetic Fields Investigation will determine whether Mars has a magnetic field, and the strength and orientation of the field, if one exists. An electron reflectometer will measure remnant crustal magnetization, and the spacecraft will also have a radio relay system to relay scientific data from the landers that will be deployed by the Russian Mars '96 mission, and future Mars Surveyor landers.

Less than a month after the Mars Global Surveyor is launched, the Mars Pathfinder will be on its way to Mars, taking a shorter path, and arriving before its orbital partner. The Pathfinder will be the first spacecraft to land on Mars in 20 years, and the first one to deploy a rover there.

Because, as part of NASA's Discovery Program, the cap on the cost of the mission is $150 million, new, and somewhat daring, techniques were incorporated into Pathfinder's mission. The mission is primarily an engineering demonstration of key new technologies and concepts, for use in future rover missions to Mars.

Upon arrival at Mars, the spacecraft will enter the Martian atmosphere, and deploy a parachute to help slow its descent. Then, four huge air bags will inflate to surround the lander, to cushion it during a relatively hard landing, which will be at about 35 miles per hour. At a height of about 330 feet, three solid rocket motors, placed inside the top half of the entry vehicle above the lander, will be fired to stop the descent, and the lander will fall to the ground, bouncing and rolling until it stops.

Within an hour of landing on the surface of Mars, the air

Exploration with humans and robots

In a series of interviews with Mars mission scientists, Jonathan Tennenbaum asked Dr. Steven Squyres, from Cornell University, about the limitations of robots in exploration, compared to sending humans. Dr. Squyres responded with an example from his own experience:

I think that the appropriate strategy to adopt is to let robots do what robots do best, and let humans do what humans do best. And have the two work together in . . . the most efficient fashion. What comes to my mind is an experience I had once when I was doing some field work in Antarctica.

I am interested in this problem of lakes on early Mars, and what those environments might have been like. And in the dry valleys of Antarctica, there is a region where there are some lakes that are covered with about four or five meters of ice year-round. So we were studying those lakes. It's a very hostile environment; a very cold place to work, and certainly trying to get into the water column to the bottom of the lakes is a very difficult thing to do.

We had two ways of exploring the bottom. Once we put holes through the ice, we could either put on scuba equipment and go down to the bottom and dive there ourselves, or we could use a small robotic vehicle which we had with us, and put that down and it could dive for us and explore the bottom. We could control it remotely from the surface. We had the opportunity for both human and robotic exploration open to us.

To put a human there is very, very costly and difficult. You have all the life support systems associated with scuba, you have to worry about tanks, you have to worry about compressors that compress the air—it's difficult, it's dangerous, it's time-consuming, and you don't want to do a lot of it if you don't have to. In contrast, the rover, the ROV—the remotely operated vehicle—was much easier to operate, but much less capable.

So once we put a dive hole in, the first thing would be to put the robot down the hole, and we would spend hours surveying the bottom, finding out, basically, what it looks like, making some simple, first-order measurements, doing a simple, basic reconnaissance without using the precious dive resources that we had. Then, once we had answered the simple, first-order questions, and we had really focussed on what the key difficult scientific questions were that the robot couldn't answer, then we put the humans down the hole.

You would answer the questions you went down there to answer, plus, you could look and you could see the environment around you, you could touch it, you could observe it, you could very rapidly formulate a hypothesis and test it right there on the spot, which a robot can't do or certainly can't do very well. And it was only by putting humans in the environment that we really understood it. If we had only the robots to go on, we would have made a lot of mistakes, we would have gotten a lot of things wrong. But, if we had tried to put the humans down first, without doing the robots before them, the humans would not have been able to use the time nearly as efficiently and we wouldn't have come away with this much.