FIRST WHEELS ON MARS

Pathfinder's 25th Anniversary

JORDAN STRICKLER

In 1997, Mars Pathfinder and its 23-pound (10.4-kilogram) Sojourner rover marked a special July 4 celebration. When the pair landed on the surface of Mars, it broke a more than 15-year silence on the Red Planet after Viking 1 completed its mission in 1982, and it had been 21 years to the month since the last machine landed there. Pathfinder, which was formally named the Carl Sagan Memorial Station after touchdown, would spend the next three months analyzing the Martian atmosphere, climate, geology, and the composition of its rocks and soil.

Pathfinder was one of the first projects for NASA's Discovery Missions that emphasized the "faster, better, cheaper" initiative mandated by then-NASA Administrator Daniel Goldin. While some of these programs failed in flight, Mars Pathfinder succeeded brilliantly. Goldin's mandate meant that the lander and rover would have to be completed for under $150 million, less than 10 percent of the Vikings' price tag. Pathfinder's entire budget, including launch, entry, decent and landing, and mission operations, would have to come in under $280 million.

"Low cost was the objective," said Rob Manning, who was the Chief Engineer for Pathfinder and is now the Chief Engineer for all of the Jet Propulsion Laboratory's missions. "We were very strapped for funds," Manning continues. "We had these cheap ramps to get the rover off the lander. We essentially had walkie talkies for the rover and lander to talk to each other. There was a lot of discussion over coffee of how to get some of our costs down."

The spacecraft launched from Cape Canaveral on Dec. 4, 1996 aboard a Delta II booster, just one month after the Mars Global Surveyor was launched. It was the first of a series of missions that included rovers and marked the first successful landing on Mars since the twin Viking landers in 1976. While the planned life expectancies of Pathfinder and Sojourner were anticipated to be a month and a week, respectively, these times were greatly exceeded, with Sojourner roving the landing site for three months.

In a mission full of firsts, Pathfinder marked a novel invention for its landing. Instead of the traditional retrorockets to set the pair onto the planet's surface, the Jet Propulsion Laboratory (JPL) opted instead for a cocoon of airbags. While retrorockets had proven effective in the past, no appropriate throttlable liquid engines had been designed since the 1960s and the cost would have been prohibitive for this mission. "We had to think outside the box," Manning said of the solution. "Just using a regular parachute, you would still come down at 100 miles an hour since the Martian atmosphere is only a tiny fraction of the Earth's."

The airbag system was composed of 24 interconnected inflatable beachball-shaped airbags that would protect the spacecraft and its payload from the impact with the Martian surface.

A view of Sojourner from the Mars Pathfinder lander
Credit: NASA/JPL-Caltech

The pyramid-shaped system measured 17 feet (5.1 meters) on each side, and was fabricated by the same company that had manufactured the Apollo spacesuits. The lander's radar altimeter acquired the surface a little more than 30 seconds prior to landing at an altitude of just under a mile (1.6 kilometers), and the airbags inflated about eight seconds before landing, 984 feet (300 meters) above the surface.

Two pyro firings occurred, the first of which cut the tie cords and released the airbags. The second, a quarter second later, ignited three gas generators that inflated the airbags. The the tether between the airbag-cocooned lander and the parachute was severed, allowing Pathfinder to make its final 75-foot (23-meter) descent. The lander impacted on the surface at a velocity of about 46 feet per second (14 meters per second), generating approximately 18 g's of acceleration. The package bounced at least 16 times before coming to rest—as Manning noted, "We lost count of the bounces!" The small amount of onboard computer could simply not record them all.

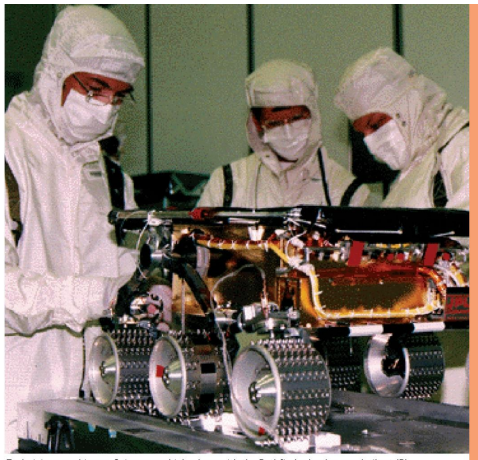
The landing site was an area in Mars' northern hemisphere known as Ares Vallis—an ancient flood plain, chosen because scientists thought it to be a reasonably safe place to land and one that would include a wide variety of rocks dumped during a catastrophic flood early in Martian history (experts believe that the flood plain was cut by a volume of water the size of North America's Great Lakes in just two weeks).

After driving off the lander on the second Martian day, or sol, Sojourner was the first working rover to land on the surface of Mars (the Soviet Union landed two tiny, basic rovers as part of its Mars 2 and Mars 3 missions in late 1971, but neither were successful). The microwave-sized Sojourner rover carried two finger-sized black-and-white cameras in front,

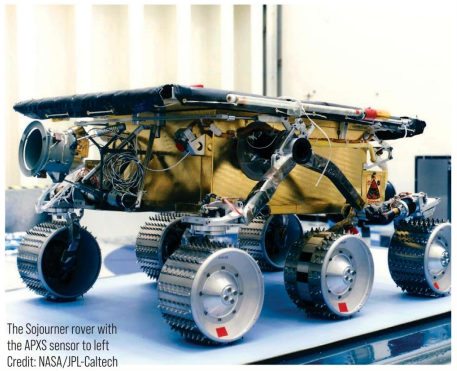
a color camera in the rear, an alpha proton X-ray spectrometer for defining the elemental composition of soil and rocks, and a set of experiments for analyzing material adherence and wheel abrasion. A laser system performed in unison with the two forward cameras to identify and avoid obstructions.

Over the course of 10 weeks, the rover—which traveled a less-than-speedy two feet per minute—collected data on 15 rocks including those with unofficial nicknames such as Yogi, Scooby Doo, and Barnacle Bill (the International Astronomical Union determines official, permanent names for important surface features). It also performed a number of experiments designed to provide information for the design of future rovers, which included terrain geometry reconstruction from lander and rover imaging, basic soil mechanics by studying wheel sinkage, path reconstruction by dead reckoning, and tracking images and vision sensor performance. Other rover experiments studied vehicle performance, rover thermal conditions, effectiveness of the radio link, and material abrasion by sensing the wear on different thicknesses of paint on a rover wheel.

The Pathfinder lander operated for more than 90 days, during which it relayed 2.3 gigabits of data back to Earth, including that gathered by Sojourner. In addition to its communication equipment, Pathfinder carried cameras which transmitted more than 16,500 images—taken with one color and two black-and-white cameras—and 8.5 million measurements of atmospheric pressure, temperature, and wind speed. Pathfinder also marked the first space mission to occur during the internet's adolescence. Throngs of virtual visitors to NASA's website crashed their servers, with an estimated 25 million views on the first day. On July 8, that surged to 47 million (by comparison, that is more than twice the volume of hits received on any one day during the 1996 Olympic Games in Atlanta, Georgia just a year prior). Portions of the web slowed to a crawl.



Technicians working on Sojourner, which, along with the Pathfinder lander, was built at JPL.
Credit: NASA/JPL-Caltech



The Sojourner rover with the APXS sensor to left
Credit: NASA/JPL-Caltech

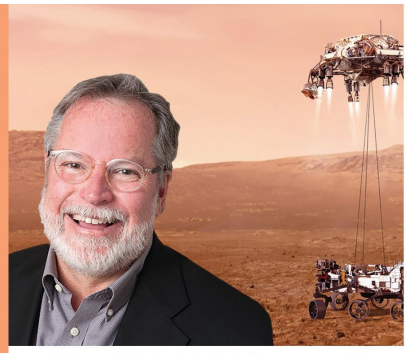
"At that point in time, there had not been a web-based event of such a massive scale in the U.S.," Manning said. "We happened to be one of the first major live events broadcast online—we were essentially the dawn of high traffic events on the internet."

Manning said one of the best parts of the project, aside from the contribution to future exploration, was the informality of it all. "One of the great things about working on Pathfinder was the way in which ideas came," Manning explains. "The fact that you could just run into someone next to the coffee machine and jawbone for an hour, bouncing ideas off of each other and see another person's reactions, was vital in coming up with design concepts."

One example of this informality was how the rover was tested at JPL. Manning needed a place to test the lander and rover together, so he and his team commandeered a conference room, brought in hundreds of pounds of sand (purchased from a local playground supply store), and wandered about a quarter mile to the Arroyo Seco—a dry riverbed that borders the lab—to fetch some river rocks.

To communicate with the Pathfinder/Sojourner testbed, they broke a hole between the conference room and the adjacent lab area to run cabling. Finally, for early tests of the landing bags, they were inflated with a leaf blower pulled from Manning's garage. "My team was sort of flying under the radar on Pathfinder," he adds. "It was only as we got closer to launch that NASA realized the true scope of the mission and began watching more carefully."

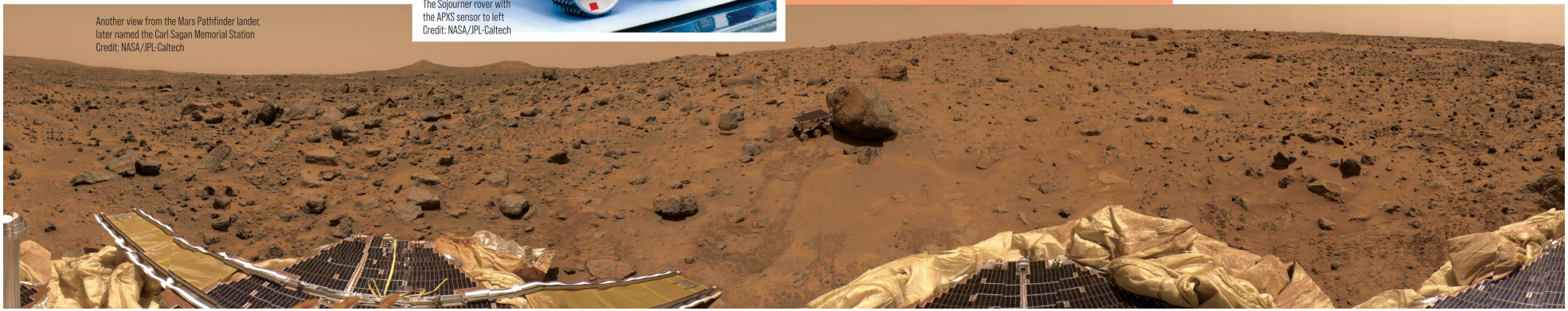
Final contact with Pathfinder was on September 27, 1997. Although mission planners tried to re-establish contact for the next five months, the highly successful mission was officially declared over on March 10, 1998. In 2003, Sojourner was inducted into the Robot Hall of Fame at Carnegie Mellon University.



Rob Manning, Chief Engineer for the Mars Pathfinder mission, now Chief Engineer for the Jet Propulsion Laboratory
Credit: NASA/JPL-Caltech

"Pathfinder was bursting with firsts," Manning said. "A lot of this we were able to carry over to the Opportunity and Spirit rovers," which launched in 2003. "With Pathfinder, we were just trying to put batches of stuff together that had never been together before. It was a really great mission to be a part of."

The Mars Pathfinder mission set the stage for the Mars Exploration Rovers Spirit and Opportunity, and the subsequent Curiosity and Perseverance rovers, both still operating on the Martian surface. Mars Pathfinder remains the most cost-effective planetary exploration mission to date, and is an enduring testament to the power of teamwork under inspired leadership. ■



Another view from the Mars Pathfinder lander, later named the Carl Sagan Memorial Station
Credit: NASA/JPL-Caltech