
GALILEO ENTERS JUPITER’S STRONG MAGNETIC FIELD. THE ATTITUDE CONTROL STAR SCANNER READS TOO MUCH INTERFERENCE. EVEN THE BRIGHTEST STARS IT NORMALLY USED TO PLOT ITS COURSE CAN NO LONGER BE FOUND.

ALL SIGNAL WITH EARTH IS LOST.

NEARLY A FULL 12 HOURS SINCE THE SEQUENCE BEGAN, GALILEO IS CRUSHED. MOVING BLINDLY AT A SPEED OF MORE THAN 100,000 MILES PER HOUR, THE SPACECRAFT DISINTEGRATES IN JUPITER’S INCREDIBLY DENSE ATMOSPHERE. GALILEO IS NOW ONE WITH ITS OBJECT OF STUDY.

JUPITER on my mind
by Matthew Shindell

ASTRONOMERS FIRST TURNED THEIR TELESCOPES TO JUPITER DURING THE 17TH CENTURY. THEY SAW A CONSPICUOUS REDDISH SPOT ON THE GIANT PLANET. THIS GREAT RED SPOT IS STILL PRESENT IN JUPITER’S ATMOSPHERE, MORE THAN 300 YEARS LATER. SCIENTISTS NOW KNOW THAT IT IS A VAST STORM, SPINNING LIKE A CYCLONE. WINDS INSIDE THIS STORM REACH SPEEDS OF ABOUT 270 MPH. WITH A DIAMETER OF 15,400 MILES, THE STORM IS ALMOST TWICE THE SIZE OF THE ENTIRE EARTH AND ONE-SIXTH THE DIAMETER OF JUPITER ITSELF. IMAGES COURTESY NASA
"It's a bitter-sweet sort of thing. On one hand, you're sorry to see the friend go. But at the same time, it's been a great friend who has done great things for us scientifically."
Like the passing of a celebrity, the death of NASA’s Galileo spacecraft made headlines around the world in 2003. The machine was one of the greatest mechanical explorers of our solar system. Its end was spectacular. Rather than sputtering out its remaining fuel and drifting away into the vast emptiness of space, it went down in a deliberate blaze. Ronald Greeley says that Galileo was much more than just a robot. Sure, it had more than its share of glitches. And planetary scientists found that working with the spacecraft could be slow and exasperating. But the machine earned a place in the annals of exploration history.

Greeley is Regents’ Professor of Planetary Geology at Arizona State University. He also is director of NASA’s Regional Planetary Image Facility. Greeley worked with Galileo since its humble beginnings in the 1970s. He lived through its ups and downs.

The Galileo mission was held up several times, before and after liftoff. Once it did make it into space, the spacecraft accomplished many firsts in robotic planetary exploration. It awed scientists with its discoveries on the way to Jupiter. When it finally did arrive at the largest planet in the solar system, it awed everyone again. Galileo’s camera revealed in colorful splendor the unique worlds that are the jovian moons.

As one of 12 members of Galileo’s camera team, Ron Greeley celebrated its triumphs.

As for its death, he didn’t watch.

Greeley was out doing geological fieldwork in the desert when Galileo made its final plunge. He did not tune in to NASA TV for the final Galileo Space Science Update. He did not watch the webcast from the Jet Propulsion Laboratory where Galileo was controlled. Still, the fate of Galileo did cross his mind more than once that day.

The ASU scientist has witnessed nearly every major milestone in NASA’s geologic exploration of the cosmos. Veteran that he is, Greeley knows what went into making planetary geology the vital enterprise it is today. The rocks that Apollo astronauts brought back from the moon were certainly one giant leap. According to Greeley, Galileo and the scientists who worked on the mission made contributions to many areas of science that are just as huge.

“Planning for the Galileo mission started in 1977,” Greeley says. “Planetary geology as a specialized area of study had only been around for about a decade. It was still in its infancy. What we’ve seen since that time is the maturing of a scientific discipline.”

Greeley thinks that Galileo stands out as a significant spacecraft, both for planetary science and for his own life in science. Its loss will be felt in different ways.

“Losing Galileo is sort of like losing an old friend who has lived out his lifetime and now has moved on. In this case, that friend moved downward and deeper into Jupiter,” Greeley says.

“It’s a bitter-sweet sort of thing. On one hand, you’re sorry to see the friend go. But at the same time, it’s been a great friend who has done great things for us scientifically. It served us beyond the call of duty. We’re very proud of the spacecraft.”

The Galileo spacecraft did make some incredible discoveries during its 14-year mission. It also proved that, even in planetary science, getting there is half the fun.

Galileo was launched from the Space Shuttle Atlantis in 1989. But it didn’t have the energy to go directly from the shuttle to the giant planet in a direct flight. To make it, the spacecraft had to first wind its way a couple times through the inner solar system. According to Greeley, several of the mission’s highlights took place during this roundabout trip to Jupiter. The delays only served to make the mission sweeter for geologists.

“The spacecraft had to loop around the sun a couple times. But we were able to do science at the same time,” Greeley explains. “When we made the passes back across Earth, we obtained the first modern data that had been collected of the moon in 20 years. Galileo passed by the far side of the moon and its polar regions and took the first multi-spectral images. None of this was anticipated.”

Venus was another stop along Galileo’s route to Jupiter. The spacecraft’s instruments collected data from deeper inside Earth’s sister planet’s atmosphere than had ever been done during earlier missions by other probes.

Galileo also flew twice through the asteroid belt. On the first time through, Galileo took the first ever spacecraft images of an asteroid. The second time around, Galileo discovered an asteroid named Ida. Ida had a small moon of its own that researchers named Dactyl. “That was pretty exciting stuff,” Greeley says. “We thought that asteroids might have moons. Galileo gave us the chance to test that hypothesis and prove it.”

Even in science, simply being in the right place at the right time can change everything. “It was purely serendipity,” he says. “We didn’t go looking for an asteroid with a moon; we just were lucky enough to find one.”
Planetary Explorer  Ron Greeley got his start in the emerging field of planetary geology in 1967. It was no more than a decade before he successfully proposed the Galileo mission to Jupiter. Today, the ASU professor says he can’t imagine not being a planetary geologist. Yet it was not a career that he set out to pursue. His original training was as a paleontologist.

Greeley wound up working for NASA because his ROTC college scholarship obligated him to two years in the Army. After graduate school, Greeley was assigned to Army Intelligence, where he was supposed to use his geological expertise to help interpret images. The Army trained Greeley to read aerial imagery, as well as images from infrared instruments, radar devices, and other tools of the intelligence community.

That was in the 1960s. The federal government had an abundance of projects for which it needed good geologists.

Greeley initially was scheduled to serve as geologist on the design and construction of a new Panama Canal. But before he could take the job, NASA requested that he take a position as a geologist in the Apollo lunar exploration program. Because Apollo was the top American science priority, NASA got its way.

Before long, Greeley found himself looking at pictures of the lunar surface. He briefed Apollo astronauts on what to expect when they got there.

The ASU scientist’s introduction to planetary geology through a military commitment was not uncommon. But many of those whose talents NASA borrowed from the military left NASA when Project Apollo ended. Greeley stayed. He had fallen in love with planetary work.

Since Apollo, Greeley has been involved with many of the missions that have flown in solar system exploration. It’s difficult to name a mission to a rocky planet in which he didn’t participate. He analyzed data from the Mariner missions to Mars in the 1960s and early 1970s. He was part of the successful Viking orbiter and lander missions to Mars in 1976. And he also participated in the Magellan project that put an orbiter around Venus and gave us our first geological view of our sister planet.

That was just the beginning. All told, Greeley has been chairman or member of more than 30 NASA committees, principal investigator for 17 projects, and a co-investigator or team member for nine other planetary geology projects. The ASU scientist is currently a Science Operations Working Group Chair for NASA’s Mars Exploration Rover mission.

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Galileo went into orbit around Jupiter in 1995. This is where, according to Greeley, the spacecraft made its key contribution to planetary geology. Scientists used Galileo’s instruments to study Europa, Jupiter’s ice-rich moon. They discovered that Europa may in fact have an ocean of liquid water. “The model suggests that there is liquid water at depth,” Greeley explains. “Europa appears to have an icy surface, a liquid ocean, and then a rocky interior.”

Galileo beamed stunning images back to scientists on Earth. The surface of Europa appears as a cracked sheet of thick ice. Icy features appear to have formed and reformed on that surface, perhaps driven by internal planetary activity.

The implications are great. Astrobiologists are scientists who study the possibility of life on other planets. They believe that life requires three primary ingredients. The first ingredient is organic carbon chemistry, which seems to be present throughout our solar system.

The second ingredient is a source of energy. Here on Earth, and perhaps on Mars, it is the sun that provides the energy necessary for life. Jupiter is more than five times farther from the sun than the Earth is. Scientists think that there is not much chance that solar energy fuels whatever life might exist on Europa.

What then is the energy source? Jupiter itself may be the answer. Jupiter is a massive planet. It is the largest of the gas giant planets, which include Saturn, Uranus, and Neptune. All by itself, Jupiter contains about two-thirds of the planetary mass of the entire solar system.

Scientists say that Jupiter contains about the same concentration of hydrogen as the sun itself. It also contains a concentration of materials that are similar to what was found in the solar system when the planets first formed. Jupiter gives off massive amounts of radiation. Here on Earth we receive billions of watts of electrical energy from Jupiter every day.

The final ingredient required for life is liquid water. Europa holds more water than all of the oceans on Earth combined. Scientists are optimistic that some of the water underneath the frozen surface is liquid. They don’t yet know how much.

“If Europa’s ocean is at all liquid, then that raises the potential of favorable habitats for life,” Greeley says. “Europa is now a very high-priority target in the search for life or for habitable zones. It is one of three targets. Mars is another. So is Saturn’s moon Titan.”

During its long mission, Galileo also found suggestions of sub-ice liquid salt water on two of Jupiter’s other moons, Ganymede and Callisto. These two jovian moons now are also considered possible habitats for life, though not to the same degree as Europa. >>>

All cracked up. Jupiter’s moon Europa appears as a thick crescent in this enhanced-color image from the Galileo spacecraft. The colors show the subtle differences in materials that cover the icy surface. The reddish cracks and ridges are thousands of miles long. Scientists think the cracks are caused by the tides raised by Jupiter’s gravitational pull.
During its ninth orbit around Jupiter, Galileo’s cameras made the image at left that shows two volcanic plumes on Io. One plume was captured on the bright limb or edge of the moon. It is erupting over a caldera named Pillan Patera after a South American god of thunder, fire, and volcanoes. The plume is 140 kilometers (86 miles) high. The second plume, seen near the terminator (boundary between day and night), is called Prometheus after the Greek fire god.

The four largest moons of Jupiter are known as the Galilean satellites. These moons were first seen by the Italian astronomer Galileo Galilei in 1610. The moons appear left to right in order of increasing distance from Jupiter. Io is closest, followed by Europa, Ganymede, and Callisto.

“I would have to say it accomplished more than
Galileo detected large amounts of volcanic activity on a fourth moon, Io. Some of Io’s volcanoes erupted lavas that were hotter than what we have here on Earth. Greeley says this indicates that these lavas are different from what we see here today. He says they might be more similar to the lavas that erupted on the early Earth. For scientists, such a finding makes the study of Io significant in understanding the history of our own planet.

Galileo threw researchers a curveball on Amalthea, a fifth moon of Jupiter. Amalthea is a closely orbiting moon. Scientists expected to find that it was rocky, not icy. They believed that the moons closer in would be made from denser materials. What they found was the opposite—a planet made of icy rubble that was less dense than water. It’s a finding that challenges the current models of moon formation.

While in orbit, Galileo also gave researchers a front row seat to a massive collision. They watched as comet Shoemaker-Levy 9 slammed into the atmosphere of Jupiter. The comet’s impact generated more energy within Jupiter’s atmosphere than would have the simultaneous explosion of all of the nuclear weapons on Earth combined.

Greeley says that the loss of Galileo is lessened because the spacecraft did much more than it was ever designed to do.

“\textit{I would have to say it accomplished more than what we had anticipated, primarily because it was such a robust spacecraft. The flexibility that was engineered into it allowed us to deal with problems that popped up along the way.}”

Galileo will be a tough act to follow. The machine answered lots of questions. It also generated many, many more that still need answers.

\textit{NASA supports a variety of planetary geology research projects at Arizona State University. For more information about specific projects, visit the School of Earth and Space Exploration Web site at: } 

\url{http://www.seas.asu.edu/}