Galileo to Jupiter

Gathering treasures on its loop-the-loop journey

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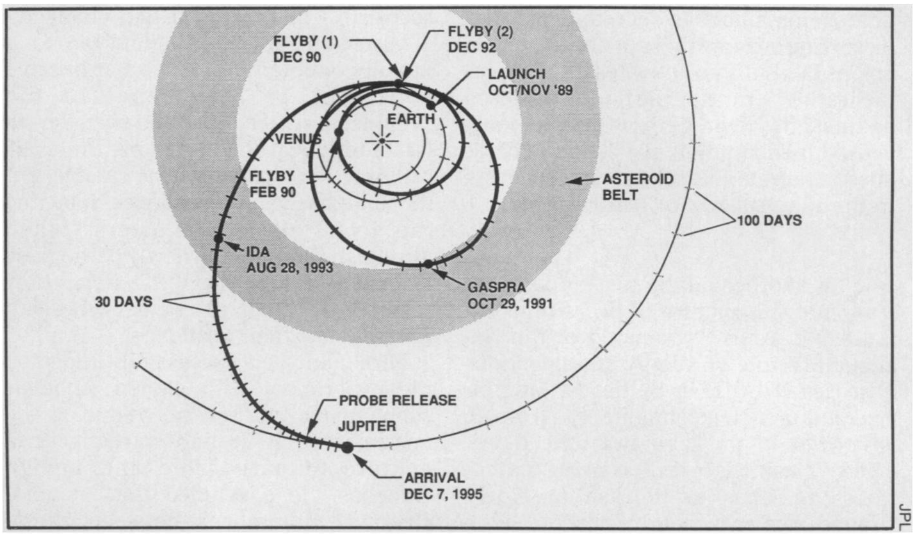

Galileo's route to Jupiter is called VEEGA, for Venus-Earth-Earth-gravity-assist. The craft's roundabout flight path, which first carries it inward to make it go out, will rely on the gravitational influences of other solar-system bodies to accelerate and re-aim Galileo toward Jupiter.

NASA planners devised Voyager 2's string of close encounters with Jupiter, Saturn, Uranus and Neptune to take advantage of a planetary alignment that occurs only once every 175 years or so. The complex trajectory of the upcoming Galileo mission to Jupiter, which will sweep the craft past Venus, Earth, an asteroid, Earth again and another asteroid, emerged largely as a consequence of the Challenger disaster.

Galileo, scheduled for liftoff aboard the shuttle Atlantis as early as Oct. 12, won't arrive at the solar system's largest planet for more than six years. When it does, the two-part craft — an orbiter and a probe that will plunge into Jupiter's stormy atmosphere — should provide a wealth of information about the planet and its fascinating moons. But even before that, scientists expect Galileo to return troves of data as it loops through its 3.86-billion-kilometer tour of space on the way.

After the space shuttle Challenger disintegrated in flight on Jan. 28, 1986, NASA abandoned plans for an upper-stage rocket called the Centaur, intended for use aboard the shuttle. Centaur, fueled by touchy propellants, would have been by far the most powerful booster ever to send shuttle payloads out of their initial, Earth-circling orbits. One of the missions dependent on Centaur was Galileo, originally scheduled to depart Earth in May 1986.

Stuck without an adequate replacement booster, NASA redesigned the mission to fire Galileo using a conventionally fueled but less powerful rocket called the Inertial Upper Stage. To make up for the weaker substitute, Galileo will pick up the speed it needs to reach Jupiter by first heading in toward the sun and flying past Venus next February for a "gravity assist" that will also re-aim its trajectory outward. This will carry Galileo past Earth and onward to fly by an asteroid named Gaspra, making Gaspra the first object of its kind ever approached by a spacecraft. Then the vehicle will head back past Earth again, bend outward to go by a second, more distant asteroid known as Ida, and finally move on to enter the Jupiter-circling orbit that is its ultimate destination.

But Galileo's side trips en route promise more than just an intricate way to reach Jupiter on Dec. 7, 1995. The dates shown below may change if the launching is delayed, but mission officials have planned five separate encounters — each with its own research goals — before Jupiter even enters the picture.

Feb. 9, 1990: *Venus*. The question of lightning on Venus remains unresolved and controversial, with scientists also disagreeing about whether such lightning might signal volcanic activity on the planet. Passing only 15,000 km away, Galileo will search for lightning flashes both by taking pictures of the cloud-shrouded world's night side and by listening for "whistlers," plasma-wave radio emissions associated with lightning.

Photos taken in ultraviolet sunlight reflected from the clouds will focus on small-scale motions of the atmosphere; infrared spectral images and measurements along the planet's edge will address recent questions about whether more water exists at high altitudes than previously believed.

Galileo will not send its Venus data to Earth until October 1990. At the time of encounter, its antennas will be variously covered by protective thermal sunshades or pointed in the wrong direction. For this reason, the data will remain stored on board, to be radioed back long after the spacecraft rushes around Venus.

Dec. 8, 1990: *Earth*. "It was not a foregone conclusion that Galileo would be allowed by NASA management to execute observation sequences during the Earth flybys," according to a written account of the mission plans by Science Data Team Chief Theodore C. Clarke of NASA's Jet Propulsion Laboratory in Pasadena, Calif., and Satellite Working Group Chairman Fraser P. Fanale of the University of Hawaii in Honolulu. One faction did not want to risk even a chance of compromising the Jupiter encounter that is the mission's *raison d'etre* by using its instruments early, particularly when the additional operations would cost an estimated $2 million. The other side included researchers who relished the opportunity of using the sophisticated craft for "a first-ever encounter from deep space with our own planet."

Scientists participating in this primarily Jupiter-bound mission have proposed a host of scientific studies for its two trips past their home world, the first time at a distance of 1,000 km. The craft's Near

Infrared Mapping Spectrometer will map the global distribution of chlorofluorocarbons and other atmospheric gases thought to contribute to global warming through the greenhouse effect. It will also seek thunderstorm-generated clouds punching up into the mesosphere. At the same time, Galileo's Ultraviolet Spectrometer will study the ozone hole over the South Pole and take what Clarke and Fanale call the first measurements of Earth's "airglow," or ultraviolet fluorescence, ever made by a spacecraft coming toward it from deep space.

On the first of Galileo's two Earth encounters it will fly straight up the tail of Earth's magnetic field, allowing a Plasma Science Experiment to measure the electrically charged particles trapped there. Even the mere existence of Galileo's radio beam, independent of whatever scientific data it carries, will be valuable, letting researchers measure subtle changes in the craft's trajectory and thus determine Earth's mass more accurately than has been possible with any past spacecraft.

While passing the Earth, Galileo will probably get good spectral measurements of Earth's moon, enabling comparisons of mineralogical differences between the moon's near and far sides, including photos of a previously unmapped strip on the near side south of huge Orientale basin.

Oct. 29, 1991: ***Gaspra.*** Nine months after the Earth encounter, the craft will take the first close look at an asteroid, passing within about 1,000 km of Gaspra. So far, as with all asteroids, space scientists have little to go on in studying Gaspra except spectral measurements from Earth. They believe the asteroid measures about 15 km in diameter and resembles a stony meteorite in composition. Zipping by at about 29,000 km per hour, Galileo will have time to gather only a few photos and other data. Yet whatever they show will be unprecedented.

Dec. 8, 1992: ***Earth again.*** The first Earth flyby will have placed the spacecraft in an orbit that takes about two years, including the Gaspra visit, to circle the sun. NASA has designed the carefully calculated second Earth trip to enlarge Galileo's orbit into one with a six-year period, big enough to reach all the way to Jupiter. The craft this time will pass only 300 km from Earth.

This flyby will also carry Galileo directly over the moon's north pole, offering a chance to look for signs of what some scientists believe may be ice left in the shaded parts of lunar craters by comet impacts. This controversial idea suggests a possible source of water on the moon, a valuable resource in proposals for a permanently inhabited lunar base.

Aug. 28, 1993: ***Ida.*** Outbound toward Jupiter, Galileo is scheduled to take a close look at the asteroid Ida, about 30 km in diameter (estimated, as in the case of Gaspra, from Earth-based measurements and from assumptions about the composition of its surface). This time the spacecraft will fly past even faster, with mission scientists hoping to grab a few data as the craft hurtles by at about 45,000 kph.

Nearly two more years will pass before Galileo's probe separates from the rest of the craft and heads off in July 1995 for its deep dive into the atmosphere of Jupiter. The dramatic plunge, expected to take place that Dec. 7 and last for perhaps 75 minutes, will be the first such penetration of an outer planet's dense atmosphere. On the same day, the orbiter will make its one close trip past Jupiter's bizarre, volcanically active moon Io, flying only about 1,000 km away and so deep into Jupiter's radiation belts that the spacecraft was modified from its initial design to include "radiation-hardened," solid-state electronic components. Finally, Galileo will settle in for two years of photographing and measuring the Jovian system, including the planet itself and the three other big Galilean satellites – Europa, Ganymede and Callisto.

Jupiter and its moons are the mission's central goal – but getting there should be a rewarding journey. □

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While the detection of genetic differences may seem to complete the puzzle, the one piece that didn't fit won't go away. Garfinkel's DNA probes did show genetic differences between pathogenic and benign zymodemes. But the group also tried its probes on lab zymodemes that appeared to have changed when weaned of bacteria. A DNA probe specific for pathogenic amoebas recognized amoebas that had changed from benign to pathogenic. The benign probe recognized the amoebas of the same zymodeme after they had returned to a benign state among colon bacteria from which they were isolated.

The Israeli DNA probes appear to tell a curious story. Not only had the enzyme pattern changed – a result that could be due to differences in gene expression – but the genes themselves also seemed to have changed. And the researchers found hints that all amoebas may have at least one copy of both pathogenic and benign DNA. Faint traces of the pathogenic probe bound to benign amoeba DNA, and faint traces of the benign DNA probe bound to pathogenic amoeba DNA.

The group acknowledges a slight possibility that the DNA and zymodeme changes arose from an inadvertent mixing of amoeba types in the lab. But they speculate that *E. histolytica* may be able to amplify, or make extra copies of, certain genes in response to differing conditions. "We were intrigued by the idea that the amoeba has master copies [of genes] that it amplifies," Garfinkel says.

Argues Samuelson, "It's a stretch to imagine how an organism can change its genome depending on its environment." He finds the evidence for two strains "overwhelming" and says Garfinkel's paper itself supplies plenty of support for the two-strain hypothesis.

The genetic evidence for two strains has also convinced Tannich. "Now it's clear that there are two genetically different subspecies and that only 10 percent of the infected people have to be treated – only the group that is infected with pathogenic forms," he says.

Mirelman disagrees. "I think it's premature to say that they are genetically distinct until you preclude the possibility that a master sequence is present," he says.

And parasitologists can't ignore Mirelman's odd puzzle piece, contends Martínez-Palomo. Fitting Mirelman's findings into the body of *E. histolytica* research is "the most important question to be solved in amebiasis right now," he says. Mirelman acknowledges that the experiments are difficult to reproduce, and he doesn't yet understand how the switch works. The process seems to have "some sort of magic in it," he muses.

If, in completing the puzzle, researchers find themselves looking at a clear picture of two strains, they may be able to turn their laboratory DNA probes into diagnostic tools to detect virulent infections before symptoms appear. Such a test could precisely identify the 10 percent of infected people whose lives may depend on the expensive treatment.

As a research tool, Tannich's probe is "very sensitive and rapid," he says. But he adds, "I think in developing countries it is not useful at the moment." Parasitologists in several labs, however, are moving ahead with attempts to create a nonradioactive probe that could be used in Third World villages. Reed hopes to develop such a probe within a year and says it should outperform the current "gold standard" of diagnostic techniques – microscopic examination of stool samples.

"That could change completely the way clinicians treat [the] infection," Martínez-Palomo says. NIAID's Diamond remains unpersuaded. "I don't see molecular biology leading to a diagnostic tool," he says. "But it's about the only way we are going to be able to understand what makes [*E. histolytica*] virulent."

As more genetic pieces fall into place, a clearer picture of *E. histolytica* should emerge. Then parasitologists may finally see whether gentle Jekyll has a dangerous double or transforms into the hideous Hyde. □