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Just Passing By Earth

Cassini has completed another flawless gravity assist maneuver en route to the ringed planet Saturn

BASED ON A NASA/JPL PRESS RELEASE

August 18, 1999: Earthlings bid farewell to the Cassini spacecraft last night as the Saturn-bound mission successfully completed a highly accurate pass of Earth at 8:28 p.m. Pacific Daylight Time (03:28 Universal Time August 18). The flyby gave Cassini a 5.5-kilometer-per- second (about 12,000-mile-per-hour) boost in speed, sending the spacecraft on toward the ringed planet more than 1 billion kilometers (almost one billion miles) away.

Right: These images of Earth were captured by the Galileo spacecraft in 1990 as it flew by our planet on its way to Jupiter. [more information]

Engineers at NASA's Jet Propulsion Laboratory confirmed that the spacecraft flew past Earth at an altitude of about 1,171 kilometers (727 miles), passing most closely above the eastern South Pacific at -23.5 degrees latitude and 231.5 degrees longitude. Cassini may have been visible from small islands in that area, such as Pitcairn Island or Easter Island.

Learn more about "Gravity Assist" Flybys

The spacecraft remains in excellent health as it continues along its seven-year-long journey to Saturn. Having completed its cruise among the inner planets, Cassini's future now resides in the cold, dark realm of the outer planets. The spacecraft will pass by Jupiter on December 30, 2000; the giant planet's gravity will bend Cassini's flight path to put it on course for arrival into orbit around Saturn on July 1, 2004.

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Cassini's mission is to study Saturn, its moons, elaborate rings, and its magnetic and radiation environment for four years. Cassini will also deliver the European Space Agency's Huygens probe to parachute to the surface of Saturn's moon Titan. Titan is of special interest partly because of its many Earth-like characteristics, including a mostly nitrogen atmosphere and the presence of organic molecules in the atmosphere and on its surface. Lakes or seas of ethane and methane may exist on its surface.

The Cassini/Huygens program is a joint endeavor of NASA, the European Space Agency and the Italian Space Agency. The Cassini orbiter, built by NASA, and the Huygens probe, provided by the European Space Agency (ESA), were mated together and launched as a single package from Cape Canaveral, Florida, on October 15, 1997. Cassini's dish-shaped high-gain antenna was provided for the mission by the Italian Space Agency. At Saturn, the Huygens probe will detach from Cassini to parachute to the surface of Titan on November 30, 2004.

Nine of Cassini's 12 science instruments were turned on to make observations of the Earth/Moon system. Scientific and engineering data from the Earth flyby will be transmitted by Cassini to receiving stations of NASA's Deep Space Network over coming days.

The Cassini mission is a joint effort of NASA, the European Space Agency and the Italian Space Agency. The mission is managed and the Cassini spacecraft built and operated by NASA's Jet Propulsion Laboratory, Pasadena, CA. JPL is a division of the California Institute of Technology.

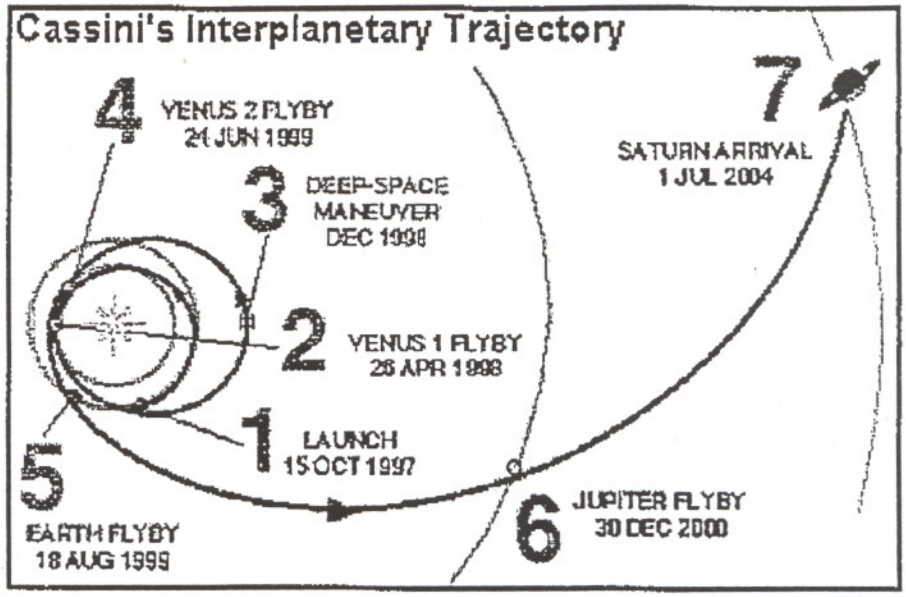
Gravity Assist Maneuvers

or... What happens when a ping-pong ball hits an electric fan?

Based in part on JPL's The Basics of Space Flight by Dave Doody and George Stephan, and on an article by Dave Doody in the May/June 1995 issue of *The Planetary Report* (courtesy of The Planetary Society).

"Gravity assists" make it possible for a spacecraft to reach the distant outer planets without using vast amounts of propellant. Michael Minovitch, a student working at the Jet Propulsion Laboratory in the 1960s, helped develop this marvelous technique. Astronomers had long known that comets' orbits were altered by encountered with planets, but it was Minovitch who first recognized that the principle could be applied to spacecraft trajectories.

Right: This diagram from JPL shows Cassini's circuitous path to Saturn, featuring gravity assist flybys of Earth, Venus and Jupiter. Click for a larger image.



How can gravity assist a spacecraft? Consider the following:

At *point 4* in the diagram pictured right, the spacecraft flies behind Venus. The planet, of course, pulls Cassini with its gravity. But the spacecraft has gravity too, and it pulls on the planet a tiny amount! This causes Venus to lose a little energy from its solar orbit, while Cassini gains the same amount. A small change in energy for massive Venus causes a minute reduction in the planet's speed, but the same energy applied to a tiny satellite causes a great change in speed.

The resulting red arc extends out past the orbit of Mars (Mars's orbit is not depicted). You can think of it as a ping-pong ball hitting an electric fan. The fan blades, whirling around the motor, have lots of angular momentum (as do the planets as they go around the Sun). When the ping-pong ball hits a fan blade, it slows the blade a very small amount, but the ping-pong ball gains lots of speed from the encounter. The ball connects with the blade mechanically, while a spacecraft connects with a planet via mutual gravitation.

Two months after the June 1999 Venus flyby, Cassini proceeds to *point 5* , where it steals energy from Earth's solar orbit, and the spacecraft's resulting arc reaches all the way to Saturn. The Jupiter flyby simply reduces travel time to the ringed planet.

You say tomato, I say tomato...

Gravity assists are well-grounded in classical Newtonian physics, but they can appear paradoxical, as illustrated by this thought experiment posed by JPL's Dave Doody in the May/June 1995 issue of *The Planetary Report* :

"Consider someone bicycling down a road into, and then up out of, a valley. [The hilltops on either side of the valley are the same height.] The cyclist will speed up approaching the valley floor, gaining momentum from the pull of gravity. But just as surely, all that momentum will be lost on the way back uphill, and the cyclist will slow down again when he reaches the crest on the other side. Well, in that case, what good is gravity for interplanetary travel?"

By analogy with the cyclist, a spacecraft would pick up speed -- gaining momentum from gravity -- as it approaches a planet, but it would slow down again as it departs with no net gain of energy. Right?

Not exactly.

The difference between the cyclist passing through a valley on Earth and the spacecraft whizzing by Venus is this: In the example of the cyclist, the bottom of the valley is stationary with respect to the cyclist's destination (the top of the hill on the other side). But, Venus is in motion with respect to Cassini's destination, Saturn. From Saturn's point of view, Cassini can gain energy from an encounter with Venus that will send the spacecraft racing toward the ringed planet.

Doody continues: "Gravity assist can slow you down, too. If you approach Jupiter from behind the planet in its solar orbit ... some of Jupiter's orbital velocity is added to the spacecraft, and the spacecraft receives a boost. On the other hand, if you fly more in front of Jupiter in its orbit, your spacecraft pulls Jupiter slightly in the other direction, causing the planet to speed up ever so slightly and causing momentum to be taken from the spacecraft, slowing it down."

Web Links
Cassini: Voyage to Saturn -- Cassini Mission home page
The Basics of Spaceflight -- from JPL. Includes basic information about gravity assist maneuvers.
Venus: Just Passing By -- Astronomy Picture of the Day, May 1, 1998
Venus's Once Molten Surface -- Astronomy Picture of the Day, Jan. 10, 1999
The Nine Planets: Venus -- from SEDS
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