The Galileo Messenger

Issue 34 June 1994

Ida's Moon Discovered *(See related story next page)*

About 14 minutes before closest approach to Ida, this image was taken by Galileo's charge-coupled device (CCD) camera, illustrating the ~37 to 1 size difference between Ida and its moon (far right). Although the satellite appears to be "next" to Ida, it is actually slightly in the foreground. This image, along with the Near-Infrared Mapping Spectrometer data, helped scientists triangulate the bodies to determine that the satellite is about 100 kilometers from the center of Ida.

From the Project Manager

Galileo's interplanetary "science of opportunity" is nearing completion. It has far exceeded all expectations. Not only did we perform the second asteroid encounter, but that encounter with Ida resulted in the discovery of a satellite of Ida—the first ever sighting of an asteroid satellite. This is science of the first magnitude. And, what an interesting parallel with our namesake's discovery of Jupiter's satellites. In just a few more days, we will complete the playback of virtually all the high-priority Ida data from the spacecraft tape recorder right on schedule thanks to the excellent performance of the DSN, MOSO (Multimission Operations Systems Office), and the Galileo Flight Team.

For our final *en route* encore, Galileo will make the only direct line-of-sight observations of Comet Shoemaker–Levy 9 fragment impacts of Jupiter next month. Most of the Galileo Orbiter science instruments will attempt to measure the effects of these impacts. We have uplinked special software code patches to the visible imaging camera (on-chip-mosaicking) and to the spacecraft central computer (CDS) to help capture these temporally

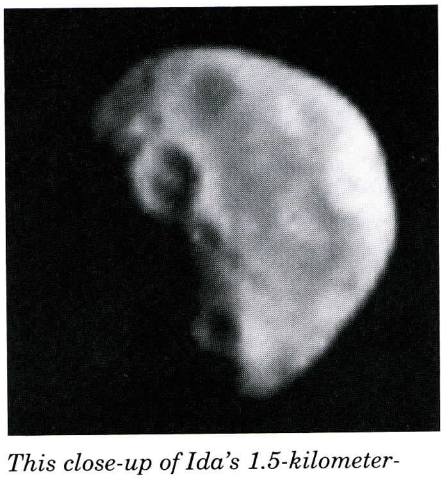
—see page 9

Discovery of Ida's Moon Indicates Possible "Families" of Asteroids

Although Galileo flew by Asteroid Ida last August 28, some of the images it took are just now being transmitted and analyzed. That is why scientists were recently surprised to discover that Ida is not alone in space, but has a moon in orbit around it.

The discovery was first made by Ann Harch of the Galileo camera team, who noticed a bright object near Ida on some new images that were processed on February 17. The team considered and eliminated the possibility that the object was a planet, star, or something other than a moon. A few days later, the Near Infrared Mapping Spectrometer (NIMS) team also noticed some odd data while analyzing Ida's mineral content. They compared notes with the camera team and realized they had, indeed, found a moon.

Using images taken by the two Galileo instruments and comparing sighting angles at different times, the scientists determined the as-yet-unnamed moon is located about 100 kilometers from Ida's center. NIMS data also indicate that the rocks and soil on the surface of the tiny moon (only about 1.5 kilometers long) have roughly equal mixtures of olivine, orthopyroxene, and clinopyroxene, while Ida's surface is predominately olivine with a bit of orthopyroxene. The two are about the same temperature—200 K. More data are needed to determine the characteristics of the moon's orbit, which in turn will help to calculate Ida's density.



This close-up of Ida's 1.5-kilometer-wide moon is the most detailed picture of the recently discovered natural satellite of Asteroid 243 Ida taken by the Galileo Solid-State Imaging camera during its encounter with the asteroid on August 28, 1993.

Shortly after the discovery, Galileo scientists eliminated the idea that the moon is a passing body caught in Ida's gravity. They also doubt that the moon is a piece of Ida knocked loose by a smaller projectile, especially since their bulk compositions differ slightly. Instead, scientists are theorizing that the two are siblings of a "family" of asteroids formed hundreds of millions of years ago when a larger, 100-kilometer-wide asteroid was shattered in a great collision. Instead of fragments shooting straight out from the impact, the exploding asteroid may have produced jets of material carrying two or more objects out together. Those objects would then be captured, gravitationally, around each other. (See "How Can an Asteroid Have a Moon?" on page 4.)

Thus, a family of asteroids could have been created as a result of such an impact. Ida belongs to the Koronis family that travels in the main Asteroid Belt between Mars and Jupiter. Gaspra, the asteroid visited by Galileo in October 1991, is a member of the Flora family.

The discovery of Ida's moon "probably means they [asteroidal moons] are quite common," said astronomer Michael J. S. Belton, who leads the Galileo camera team. Many scientists suspect that a significant fraction of asteroids may have satellites. He noted that scientists believe they are on the verge of answering many questions about the existence and origin of asteroids and their satellites.

Galileo finished transmitting Ida data in June—including additional images of Ida's moon—and scientists expect to be able to determine more about the origin, composition, size, and orbit of Ida's moon, as well as the dynamics of collisions that played a central role in shaping the planets.

Messenger Available Electronically

You can now access the *Galileo Messenger* electronically over the Internet. From within Mosaic, type the following URL:

http://www.jpl.nasa.gov

This brings you to the JPL Home Page from which you can access the *Messenger*.

The latest information on Galileo can be found by selecting "News Flashes" from the Home Page.

If you have comments or suggestions regarding the *Messenger*, you can send email to:

Jeanne.M.Holm@jpl.nasa.gov

Up To Date

During this update period (January 1–June 15, 1994), the spacecraft performed operational activities associated with health and attitude maintenance, telecommunications link characterization, trajectory correction maneuvers, routine science memory readouts, data return from the Ida encounter, and the gravity wave experiment.

Ida Encounter

Four Reserved Box Sequences were uplinked to the spacecraft for the playback of Ida science data. Playback has continued throughout the spring, revealing much more from Galileo's flyby of the asteroid late last summer. An innovative procedure was developed in February and March to process data through the Mission Telemetry System (MTS). The procedure was developed in response to an MTS problem in which lockup occurred on compressed imaging frames sent in jailbox search memory readouts (MROs). The problem occurred because not enough frame headers were included in the sequence design of the MROs.

Data from the Ida encounter have been successfully received from all instruments (except the Heavy Ion Counter, which was not taking data), including almost 30 minutes of fields and particles data acquired just after closest approach. To date, over 98 percent of the data have been successfully received with only minor outages due to weather and short-term ground equipment problems.

Navigation

With the successful completion of Trajectory Correction Maneuver 22A on February 15, which imparted a 0.1-meter/second change to the spacecraft velocity, Galileo is now aimed at a point inside of Jupiter's atmosphere. To be precise, Galileo is targeted inside the atmospheric entry Probe's required entry corridor, which is defined by time of arrival, latitude, and flight-path angle. This is the desired situation, since the Orbiter is responsible for the precise delivery of the Probe, which is scheduled for release on July 13, 1995.

Gravity Waves

The gravity wave experiment ran from April 28 through June 11. Both closed-loop (Doppler tracking) and open-loop (radio science receiver) data were processed.

Routine Operations and Testing

Cruise Science

Six routine Retropropulsion Module 10-N maintenance flushing activities were completed. Regular science data acquisition from the Extreme Ultraviolet Spectrometer, Dust Detector, and Magnetometer has continued successfully in parallel with the Ida data return, using the Command and Data Subsystem (CDS) MRO technique. CDS MROs were also performed between January 15 and 20 to play back selected low-rate science data from the Ida encounter. Preliminary analysis has shown that the data were properly received.

Ultrastable Oscillator

Seven Ultrastable Oscillator (USO) tests were performed between January 4 and April 25 to verify the instrument's health and to collect gravitational red-shift experimental data. Long-term trend analysis is continuing.

Telecommunications—Block V

Six Block V receiver fast-acquisition tests were performed; all six were unsuccessful in demonstrating the Performance Verification Model receiver operation in the suppressed carrier mode. Troubleshooting on the receiver is now highly focused and successful operation is expected this fall.

Anomaly Status

AACS Ida Anomaly Test

Between January 22 and 25, Ida engineering data were played back using CDS MROs. Scientists used

—see page 8

Galileo Mission Summary*

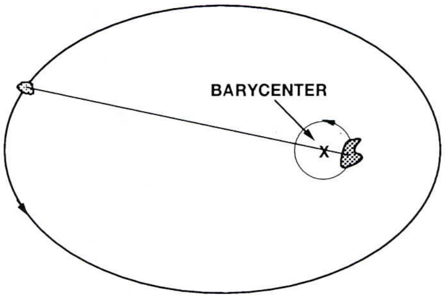
Distance from Earth	536,741,200 km (3.59 AU)
Distance from Sun	669,669,900 km (4.48 AU)
Heliocentric Speed	38,400 km/h
Distance from Jupiter	252,317,900 km
Round-Trip Light Time	59 min, 44 s
System Power Margin	44 W
Spin Configuration	Quasi all-spin
Spin Rate/Sensor	2.89 rpm/Star Scanner
Spacecraft Attitude	Approximately 7 deg off-Sun (leading) and less than 1 deg off-Earth (leading)
Downlink Telemetry Rate	40 bps (coded)
General Thermal Control	All temperatures within acceptable ranges
RPM Tank Pressures	All within acceptable ranges
Powered Science Instruments	Plasma Wave Spectrometer, Extreme Ultraviolet Spectrometer, Ultraviolet Spectrometer, Energetic Particle Detector, Magnetometer, Heavy Ion Counter, and Dust Detector Subsystem
RTG Power Output	505 W
Real-Time Commands Sent	73,306 commands

* All information is current as of June 15, 1994.

How Can an Asteroid Have a Moon?

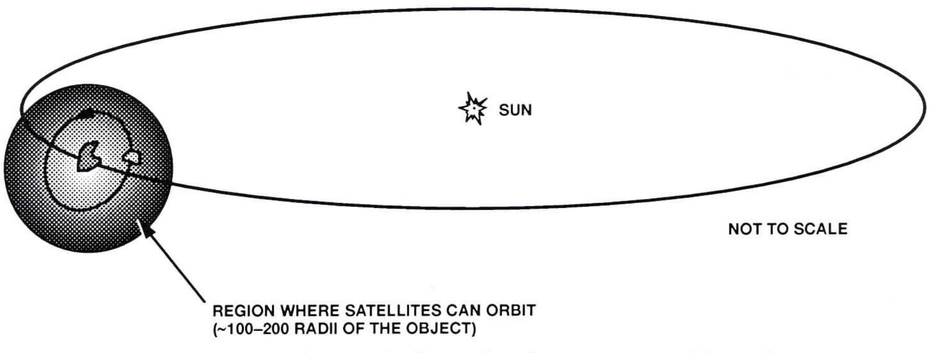
Sir Isaac Newton first described how any two objects, no matter what size or how far apart they are from each other, exert an attractive force upon one another. Since gravity is, relatively, a very weak force (compared to electricity and magnetism, with which we have familiar experiences), we don't recognize that tables, baseballs, buildings, and even people all gravitationally attract each other. These forces are fantastically small, but it is interesting to note that the gravitational attraction between a parent holding a child is stronger than that of any one of the planets (except Earth!) on that child. In other words, even an object with little mass can exert a greater force than another much more massive object, if the smaller object is much closer than the larger one. In mathematical terms, the force of gravity falls off as the inverse of the distance squared. So, if the distance between two objects is doubled, the attractive force is one-quarter the value.

Similarly, Ida and its moon attract each other. Because they are far from other bodies compared to their mutual separation, they influence each other very strongly. Any two bodies under the right circumstances will orbit each other, even if they also orbit about a third body, such as the Sun. (The Sun, of course, is in orbit about the Galaxy, which in turn is in orbit about other galaxies, and so on.) Bodies actually orbit about their mutual center of mass, called the barycenter, which is located along a line connecting their centers, and at a distance from either center inversely proportional to the mass of that object. Calculations have shown that asteroids like Ida can have satellites in stable orbits out to about 100 to 200 times their radius, so Ida could have satellites out to several thousand kilometers. However, only the one moon, 1993 (243) 1, has been seen as yet.



Any two objects, even if small and distant, will orbit one another if they are far from other objects.

— *Jan Ludwinski*
Mission Design Team Chief



If a planet or asteroid is orbiting the Sun, the planet or asteroid can have a satellite if the satellite is close enough that the planet's or asteroid's gravity influences it more than the Sun's gravity.

Name That Moon!

There is no precedent for naming an asteroid's moon. Responsibility for naming Solar System bodies lies with the International Astronomical Union's (IAU) Working Group on Planetary System Nomenclature.

The Galileo Project is now soliciting names for Ida's moon, which currently carries the temporary designation 1993 (243) 1: 1993 is the year Galileo photographed it; 243 is the numerical designation of Ida; and the 1 notes that it is the first satellite discovered around Ida. The name chosen for Ida's satellite should relate in some way to Ida, either through mythology (Ida was a nymph who cared for the infant Jupiter) or similarity in name (Lupino has already been suggested—remember actress Ida Lupino?).

All suggested names and accompanying rationale for the choice must be received by the Galileo Project by **July 31, 1994**. The Project (through the Near Infrared Mapping Spectrometer and Solid-State Imaging teams) will then make a recommendation to the IAU in August. As the discoverers of the satellite, we trust that the IAU will give our recommendation special consideration.

Please send your suggested names to:

Name Ida's Satellite
Project Galileo
Mail Stop 264-419
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

We appreciate and will seriously consider all suggestions.

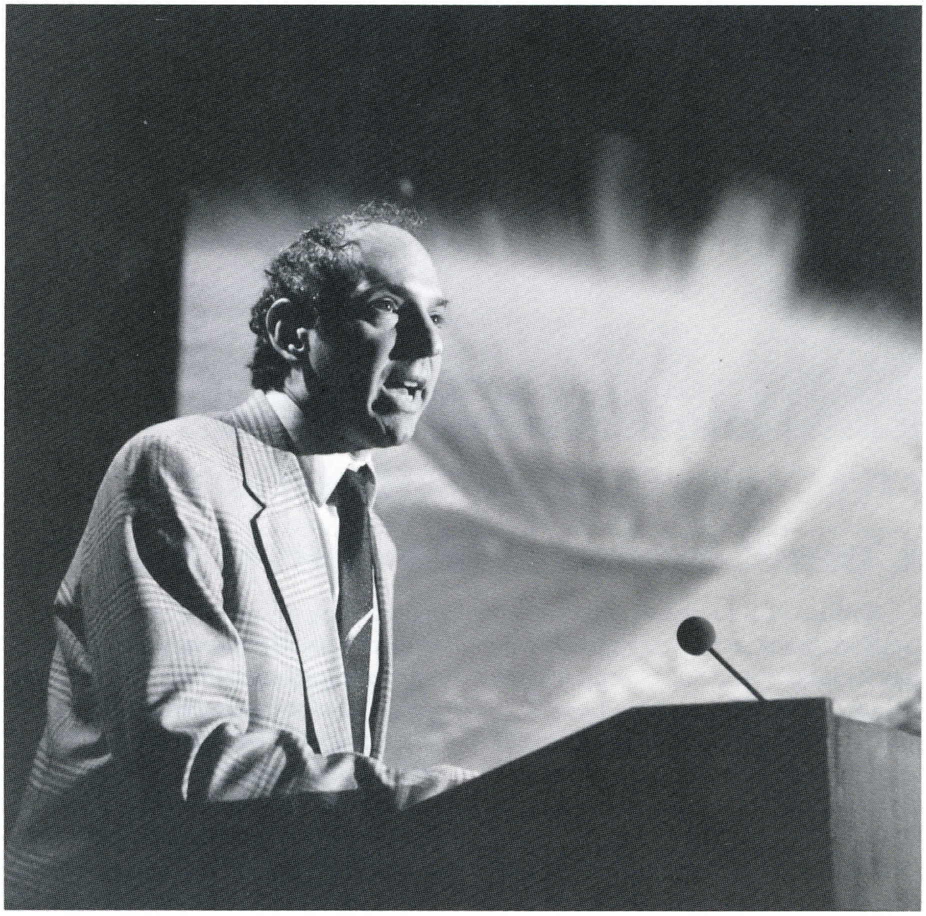
Comet Codiscoverer Speaks at JPL

Literary scholar and inveterate comet hunter David Levy, who is part of the team that discovered Comet Shoemaker–Levy 9 last year, discussed his exciting discovery at JPL's von Karman Auditorium on May 17. Levy used photographs, music, poetry, and humor to bring his subject to life.

As a young man, Levy became captivated by comets after reading *Starlight Nights*, the autobiography of famous comet hunter Leslie C. Peltier. To help explain "what makes a comet hunter tick," he shared the following excerpt from the book:

> *Time has not lessened the age-old allure of the comets. In some ways, their mystery has only deepened with the years. At each return, a comet brings with it the questions which were asked when it was here before, and as it rounds the Sun and backs away toward the long slow night of its aphelion, it leaves behind with us those questions still unanswered. To hunt a speck of moving haze may seem a strange pursuit. But, even if we fail, the search is still rewarding. For in no better way can we come face to face night after night with such a wealth of riches as old Croesus never dreamed of.*

Inspired by these words, Levy began his search for comets at age 17 using a small backyard telescope. Nineteen years later, after moving from Canada to Tucson for better viewing conditions, he was finally rewarded with his first comet discovery in 1984. Since then, he has discovered 20 more comets—8 from his own backyard and 13 with Gene and Carolyn Shoemaker at the Mount Palomar Observatory.



David Levy's talk at JPL was highlighted by dramatic illustrations of what the comet fragment impacts might look like at Jupiter.

His optimism and patience have really paid off this time. Levy recalled how poor the viewing conditions were that evening and how close they had come to calling off their observations. But when the sky cleared briefly, Levy talked the Shoemakers into using a few more sheets of some slightly damaged film. The next afternoon, Carolyn Shoemaker was methodically studying the pictures through her stereomicroscope when she saw the bizarre streak of light not far from Jupiter.

Their joint discovery of the luminous "string of pearls" comet caused a worldwide stir, even before its collision course with Jupiter was charted. Jim Scotti, an astronomer at the University of Arizona's Lunar and Planetary Laboratory in Tucson, confirmed their findings with the powerful 36-in. Kitt Peak telescope. Scotti was astounded; he told Levy, "I've been trying to pick my jaw up off the floor! I'm not taking my telescope off this comet for the rest of the observation period."

Although Levy is hesitant to predict spectacular fireworks when the comet collides with Jupiter, he is thrilled that it is capturing the public's imagination. "This is a marvelous opportunity to increase public awareness of what we [astronomers] do. For the first time in the history of the telescope, we are witnessing the impact of a comet on a planet. I still can't believe how fortunate we are to have this wonderful spacecraft [Galileo] available to us. It is so rare in science to have everything working together. This is truly an event of the first magnitude."

"The Cosmic Event of the Millennium"

Comet Shoemaker–Levy 9 to Crash Into Jupiter

Galileo will have a front-row seat in an extraordinary galactic performance beginning July 16 when Comet Shoemaker–Levy 9 (SL9) collides with the largest planet in our Solar System. The performance will last six days, as some 22 massive chunks of the comet crash into the atmosphere of Jupiter at the average rate of one every six hours. The comet broke into pieces two years ago when its orbit brought it close to Jupiter. This time, scientists anticipate that the impacts will result in large explosions, whose flashes may be visible directly to Galileo and which may be bright enough to be seen by Earth-based observers by reflection off Jupiter's closest moons. The largest piece will collide with the planet on July 20, coincidentally the twenty-fifth anniversary of the Apollo 11 landing on the Moon.

None of this was anticipated when Galileo was launched in October 1989. In fact, SL9 was discovered just over a year ago in March 1993, when astronomers David Levy and Gene and Carolyn Shoemaker spotted the comet from the Mount Palomar Observatory in California. Their discovery sparked the interest of others, and soon many telescopes were tracking the comet and computers were calculating its trajectory. These orbital investigations led to the surprising realization that SL9 was on a collision course with Jupiter.

As luck would have it, Galileo will be well poised to view the celestial fireworks, which will occur on the far side of Jupiter as viewed from Earth and on its night side. No other spacecraft (except Voyager 2, which is currently over 6 billion kilometers from Jupiter), including the Hubble Space Telescope, nor any Earth-based telescope will have that viewing advantage. Those telescopes will have to settle for observing indirect effects, such as the previously mentioned reflections or the aftermath of the damage as the impact areas rotate into view of the Earth. It is important to realize, however, that Galileo is still 240 million kilometers away from Jupiter, and the impacts—***if they are visible at all***—will be only a small dot of light in the Galileo images.

The Challenge and Payoff

Capturing the images and other science data is complicated by several factors, including the limited tape recorder space, the reduced downlink capability, the uncertainty in actual effects of the comet impacts (due to our poor understanding of its size), and the several-minute uncertainty in the actual impact time of each fragment. The science teams have adopted a strategy of using different observing schemes on different impacts so as to cover much of the uncertainty space. For example, the Solid-State Imaging camera will utilize four different schemes to measure light intensity from Jupiter. Scientists hope these data will reveal more about the composition of Jupiter's atmosphere, the origin of the comet, and the implications of a similar impact to our planet.

Some believe the collision will create giant bubbles of hot gas that will bring materials from far below Jupiter's thick cloud cover to the top, where those materials can be analyzed. Others think the impact could even cause changes in the planet's distinctive banded appearance or cause the birth of new spots.

How can a tiny comet have such an impact on the giant planet? "Comparing the mass of SL9 fragments to Jupiter is a bit like comparing a gnat with an elephant," writes Clark Chapman, a senior scientist at the Planetary Science Institute in an article for *New Scientist* (March 5, 1994). "But, just as . . . dust ejecta arising

A String of Pearls. *This composite image of the 22 fragments that make up Comet Shoemaker–Levy 9 was taken by the Hubble Space Telescope in January 1994. The comet was torn into pieces by Jupiter's gravitational pull as it passed the planet in 1992. The Planetary Report calls it "Jupiter's celestial necklace."*

from an impact on Earth changes global climate, so the impacts on Jupiter should profoundly affect that planet's stratosphere." Scientists point out that even a few cubic kilometers of comet ices can overwhelm the dynamics and chemistry of Jupiter's atmosphere locally.

Scientists also hope to learn more about the origin of SL9. From observations of the fragments' brightness and arrangement along their orbits, astronomers believe the comet must have measured between 3 and 9 km in diameter before it fragmented. They also believe that SL9 has been in orbit around Jupiter for 20 to 100 years. Since most comets orbit the Sun, this intriguing finding led to speculation that SL9 began life as either a small satellite of Jupiter, a so-called Trojan asteroid locked into Jupiter's orbit, or a comet captured by the planet's strong gravitational pull.

Ironically, if SL9 had not fragmented, astronomers would never have known it existed; it was too small, dark, and faint. But after its breakup, the long string of fragments and the dust associated with them presented a vastly larger surface area off which to reflect sunlight. When Carolyn Shoemaker first spotted the odd-shaped SL9, she thought it was a "squashed comet." Her team immediately notified colleague Jim Scotti in Arizona, who used a larger telescope equipped with sensitive charge-coupled devices and was able to determine that the object was actually a string of comet fragments.

Finally, SL9's crash will give astronomers a chance to actually witness a comet shaping a planet's future, a process that has been going on since the beginning of our Solar System. Nearly 200 large impact craters still exist on Earth, despite erosion and extensive plate tectonics that have erased many of them. Scientists say that every million years or so an asteroid or comet strikes our planet, which can drastically change our global climate. Every *hundred* million years, one strikes with a size and force that can actually change the course of evolution, like the 10-km-wide fragment that struck the Earth 65 million years ago and is believed to have wiped out the dinosaurs. What SL9 does to Jupiter will give scientists a better idea of what happened on Earth in the past.

Theories aside, "we've never seen anything hit a planet that is even as big as a house," according to Steve Marain, a spokesman for the American Astronomical Society, who was quoted in the April issue of *Aerospace America*. Several SL9 chunks may be as large as small mountains.

Worldwide Interest

Astronomers are comparing this event to the excitement generated by Halley's Comet, which captured the attention of millions of people around the world in 1986. The Planetary Society is setting up a worldwide network of observers to strive for constant coverage from ground-based telescopes during the string of impacts. Under the title "Jupiter Watch," the Planetary Society will publish guides, provide video links from telescopes to classrooms and television stations, and organize Jupiter Watch parties in order to educate the public about astronomy, space, and the origin of life.

All this attention can't fail to put the spotlight on Galileo, with its unparalleled view of the action and its ability to detect the effects of the SL9 impacts through several of its instruments. It will also focus attention on Galileo's arrival at the Jovian system on December 7, 1995, some 17 months after the collision.

(Updates on Jupiter Watch events can be obtained by calling 1-800-9-WORLDS.)

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these data to study the anomalous attitude-control flight fault-protection trip that occurred hours before the Ida encounter on August 28, 1993. Using those data as a guide, an anomaly test sequence was designed to provide insight into the Attitude and Articulation Control Subsystem fault indications by rerunning key parts of the Ida encounter sequence. The test sequence ran from May 9 through 13 without any fault indication.

AC/DC Bus Imbalance

The alternating current (AC) bus imbalance measurement has remained fairly stable since March 1992 and currently reads 4.3 V.

The direct current (DC) bus imbalance measurement has shown significant change. On May 19, the measurement exhibited a gradual drop from ~17 V to near 12.5 V over a 36-hour period. On May 21, it abruptly increased from 12.5 V to near 22.5 V and has since remained stable. Other telemetry measurements also changed during the time period of the bus imbalance change, which included the DC bus current, AC bus current, system DC shunt current, CDS 10-VDC power supply current, SBA temperature, and USO oven current.

The AC/DC anomaly team was convened to verify that these telemetry changes are consistent with the slipping-brush debris model. Preliminary analysis indicates that all telemetry changes seem consistent with clearing a debris path in the SBA. The Project will be briefed on July 12, 1994.

Uplink Generation

The Project has approved the EJ-7 Cruise Plan, which will be executed by the spacecraft starting July 11. This sequence will include the Shoemaker–Levy 9 observations and some early data return.

In Memory of James B. Pollack

James B. Pollack, world-renowned expert in the study of planetary atmospheres and particulates using nongrey radiative transfer techniques, died June 13 from a rare form of cancer. His work led to many advances in our understanding of the Solar System, including evolutionary climate change on all the terrestrial planets and detailed models of the early evolution of the giant gas planets.

Dr. Pollack participated in every major NASA flight mission since Apollo. He made fundamental contributions to the design, development, and implementation of the Mariner Mars series, Pioneer Venus, Viking, Voyager, Galileo, and Cassini, and was a key player in Mars Observer and CRAF. He was a member of the imaging teams of the Mariner 9 orbiter of Mars, the Viking Lander on Mars, and the Voyager spacecraft for the Saturn, Uranus, and Neptune encounters.

His discoveries include the first real evidence that the clouds of Venus are composed of sulfuric acid, and the resolution of a major paradox concerning Saturn's rings. He first conceived that nearly lossless scattering by wavelength-sized particles of water–ice could explain the low microwave emissivity and high radar reflectivity of Saturn's rings. Dr. Pollack also led a team in modeling the luminosity evolution of giant gas planets during their primordial contraction stages. These models were applied to explain the density gradient in the Galilean satellites as a natural outcome of their location relative to luminous proto-Jupiter.

Until his death, he was a senior space research scientist at the NASA Ames Research Center in California.

Ground Data System

Transition from the MTS-based telemetry support to the new Multimission Ground Data System (MGDS)-based support is nearly complete. The MGDS telemetry capabilities, supplied by the Multimission Operations Systems Office, provide workstations for telemetry display and analysis to supplement digital television and printer telemetry display devices. A period of parallel operations started March 31, during which both MTS and MGDS telemetry displays were provided in the Mission Support Area for comparison. In May, MGDS data were declared prime for real-time mission support.

As of this writing, July 1 was the date for the real-time MSA to relocate from one building to another at the Laboratory. At that time, MTS support of real-time operations was to be decommitted. Some problems are continuing with the MGDS non-realtime product support, particularly with the support of imaging data products provided to the Multimission Image Processing System (MIPS). This is the interface used for processing imaging data after Data Memory subsystem MRO from the spacecraft (i.e., Ida images). Decommitment of the MTS–MIPS interface support will be deferred until problems with the MGDS interface are resolved.

GDS integration of the E2.0 software deliveries was completed. In addition to the MGDS telemetry capabilities, the E2.0 build provided Galileo Phase-1 GDS support capabilities.

The software associated with the E3.0 mission build was delivered. As part of the mission build, 12 program sets and two command databases were redelivered. The most significant new capability provided in the E3.0 software was support of the new SSI "on-chip mosaic" capability that will be first used during the Shoemaker–Levy 9 sequencing in July.

—Matt Landano
Deputy Mission Director

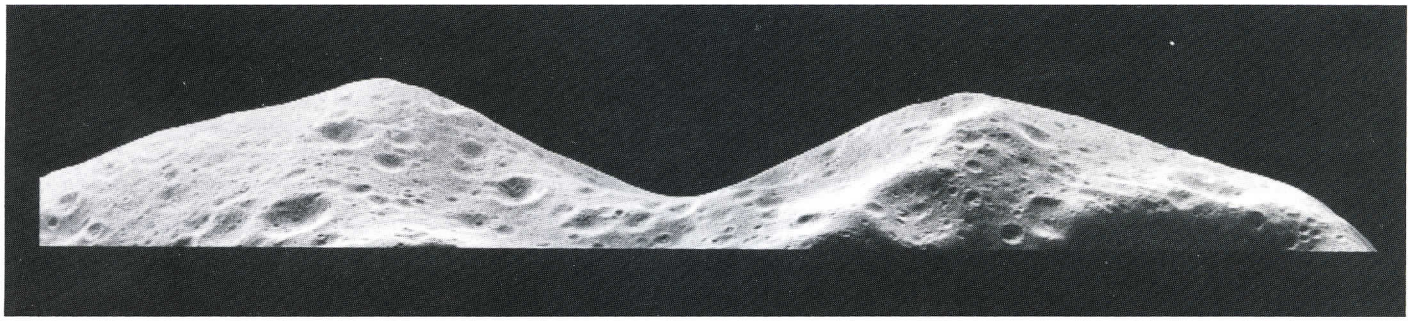
PROJECT MANAGER from page 1

elusive events. The difficulty is that there is tens-of-minutes uncertainty in when the impacts will occur. We must very judiciously program Galileo such that the limited amount of data we can store on the spacecraft for later playback has the best chance of "capturing" the events. Moreover, we can only play back less than 10% of what we record, so close collaboration with terrestrial observers of the aftermath effects will be needed to reduce the "post-facto" timing uncertainty to best determine what data to play back. The Shoemaker–Levy 9 impact observation experiment is much more elaborate and challenging than many of us originally envisioned. We begin uplinking the first phase of the new flight software for Jupiter operations in February so all playback must be completed before then.

The development of the new capabilities for Jupiter operations on the Low-Gain Antenna has been underway for well over a year now and is right on schedule. Over the past several months, the overall Project focus has been shifting to Jupiter preparations. Clearly, proper release of the Probe (July 13, 1995) and successful Probe Relay and Jupiter Orbit Insertion (JOI) on December 7, 1995, are our top priority. From now until JOI completion, we will be most vigilant to ensure that no other Project activities adversely affect our preparations for these absolutely essential events. The preparations include thorough testing of the recently completed new flight software for Relay/JOI (Phase 1) on our Galileo Spacecraft Testbed using the exact sequences that will be sent to the spacecraft. The "critical" sequence that will perform Relay/JOI, as well as the "noncritical" concurrent sequence for collecting arrival day science, are both now in development. In the event of a fault, the "noncritical" sequence will be automatically cancelled by the spacecraft to provide the best chance for successful completion of the "critical" sequence. The "noncritical" sequence will be completed and "frozen" this fall; the final version of the "critical" sequence, next summer. Concurrent development and testing is being done to maximize the reliability and robustness of the flight software and sequences.

While second in priority to Relay/JOI, our biggest effort from here on is Jupiter orbital operations preparations. Development and testing of the new flight and ground software for orbital operations (the Phase 2 software) will be ongoing until late 1995. Next month, we begin the detailed development of the actual spacecraft sequences that will use the Phase 2 flight software to issue the commands onboard the spacecraft to acquire and return the science data during the two-year primary orbital mission of 11 orbits, with targeted Galilean satellite gravity-assist encounters on all but one. The sequence development is scheduled on a "just-in-time" basis to minimize cost. It takes far more time to develop the sequences for an orbit than a typical Galileo orbital period (weeks); we must start now in order to complete the sequences for the final orbit just before they must be sent to the spacecraft. We have a lot to do. We must very carefully manage all our resources—people, spacecraft, and money—to get it all done.

In the last *Messenger*, we noted our puzzlement that a bus reset had occurred in all-spin last September. A very sophisticated computer analysis of the Spin Bearing Assembly (SBA) brush/



The Galileo imaging system captured this picture of the limb of Ida about 46 seconds after Galileo's closest approach on August 28, 1993, from a range of 2480 kilometers. It is the highest resolution image of an asteroid's surface ever captured, showing detail at a scale of about 25 meters per pixel.

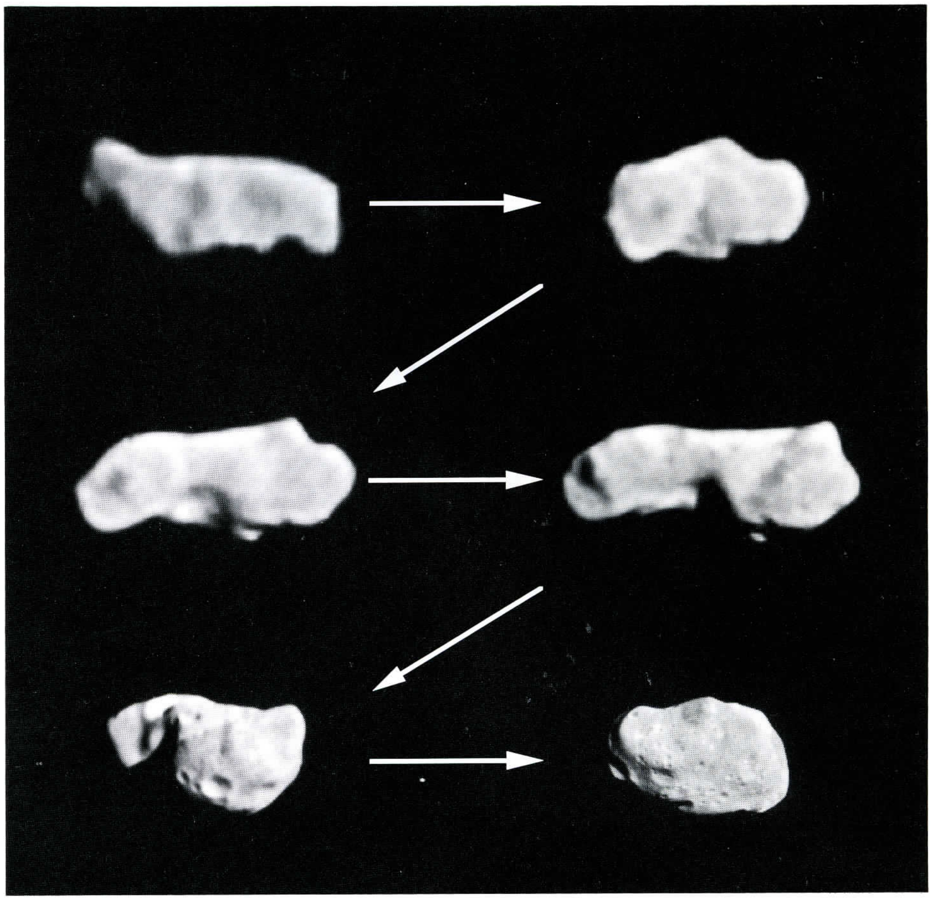
This image is one frame of a mosaic of 15 frames shuttered near Galileo's closest approach to Ida. Since Ida's exact location was not well known prior to the Galileo flyby, this mosaic had only about a 50 percent chance of capturing Ida. Fortunately, this single frame successfully imaged a part of the sunlit side of Ida.

The area in this frame shows some of the same territory seen in a slightly lower resolution full-disk mosaic of Ida returned from the spacecraft in September 1993, but from a different perspective. Prominent in this view is a 2-kilometer-deep "valley" seen in profile on the limb. This limb profile and the stereoscopic effect between this image and the full-disk mosaic will permit detailed refinement of Ida's shape in this region. This high-resolution view shows many small craters and some grooves on the surface of Ida, which give clues to understanding the history of this heavily impacted object.

ring dynamics solved the puzzle. Mechanical dither between the spun and despun spacecraft sections occurs due to the tolerance in the active control loop that operates the SBA torque motors to keep the sections fixed with respect to each other. The dither causes the brushes to rock on the slip rings due to the very slight back and forth motion of the ring surface under each brush. When a brush rocks up on its leading edge (toe) or back on its trailing edge (heel), the electrical contact surface between the brush and ring is drastically reduced—effectively opening the circuit. Thus, the all-spin dither-induced rocking effectively produces the brush "lifts" (i.e., bounce) we have long believed to be an essential part of the spurious bus resets. So, all nine of our resets "fit" the SBA brush-debris-short/brush lift model. Recall that the Relay/JOI critical sequence continues even if a reset occurs, and our new orbital operations (Phase 2) flight software is being built so that any sequence will continue.

Our comprehensive review of the Mars Observer (MO) investigation reports has been completed and endorsed by a select, non-Galileo Review Board. Galileo is very different than MO in heritage, design, FMECA, testing, etc. More specifically, it was objectively concluded on an item-by-item basis that Galileo is not susceptible to the postulated MO failure types. However, the MO loss is causing us to be even more circumspect in our final review of the normal and contingency operating modes of Galileo's 400-N main engine that will be used for the first time to perform the Orbiter Deflection Maneuver (ODM) shortly after Probe Release next summer.

— Bill O'Neil
Project Manager



This composite image shows Ida as seen from Galileo during its approach on August 28, 1993. The asteroid makes a complete rotation every 4 hours 38 minutes; therefore, this set of images spans about three-quarters of Ida's rotation period and shows most of Ida's surface. The asteroid appears to be about 58 kilometers long and about 23 kilometers wide, with a very irregular shape and volume of some 16,000 cubic kilometers.

Beginning in the upper left, the images are arranged in chronological order from a time 3 hours 51 minutes before closest approach through 33 minutes before closest approach. Ida's rotation axis is roughly vertical in these same-scale images, and the rotation causes the right-hand end of Ida to move toward the viewer as time progresses. The first image was taken from a range of about 171,000 kilometers and provides an image resolution of about 1700 meters per pixel (the highest resolution achieved for Ida is about 25 meters per pixel). The second, taken 70 minutes later, is from 119,000 kilometers, followed by 102,000; 85,000; 50,000; and 25,000 kilometers. The features on Ida are less sharp in the earlier views because of the greater distances.

Prominent in the middle views is a deep depression across the short axis of the asteroid. This feature tends to support the idea that Ida originally may have been formed from two or more separate large objects that collided softly and stuck together. Also visible in the lower left view is an apparent linear albedo or reflectance boundary. Color images yet to be returned from the Galileo spacecraft may help resolve the question of whether or not the two ends of Ida are made of different materials.

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Galileo Messenger Readers' Survey

In an effort to improve the *Galileo Messenger* and its usefulness to readers everywhere, we are asking you to take a few minutes to complete this survey. The results will be published in a future issue. Our return mailing address is on the reverse side. Simply fold, staple shut, attach appropriate postage, and mail by August 15, 1994.

1. How do you read this newsletter?
   - ☐ Read all or most
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2. Check the categories of articles of interest to you in your order of preference (1 being of most interest):
   - ☐ Highly technical scientific information
   - ☐ Simplified scientific information
   - ☐ In-depth explanation of scientific concepts relating to Galileo's mission
   - ☐ Commentary from the Project Manager
   - ☐ Description of routine spacecraft operations
   - ☐ Other ______________________________
3. Please answer each question:

YES	NO	
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We would appreciate any further comments you might have (use another piece of paper, if necessary):

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Teachers and educators are asked to complete this section of the survey:

9. Grade level or subject taught ______________________________

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____

11. List the types of articles that have been useful in the past

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12. I would like to see:

- [ ] More charts and other graphics
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