The Galileo Messenger

Issue 44 July 1997

From the Project Manager

First of all, all of us on Project Galileo heartily salute our colleagues on the Mars Pathfinder Project for their spectacular success. As we watched them on July 4th, we certainly could directly relate to their anxieties and ecstasy. Seeing signal from the Pathfinder Lander after landing was the perfect analogy to our Galileo Orbiter signaling to us that it was seeing the Atmospheric Probe signal after entry. And comparisons are natural and countless. Upon reflection, I find it particularly striking that the flight time of Mars Pathfinder from Earth to Mars was almost exactly the same seven months as Galileo's first orbital flight around Jupiter: December 7th vs. 4th to June 27th vs. July 4th—and our arrival at Ganymede-1 would have been July 4th (1996), except that our adaptive navigation strategy resulted in the one-week advance in Ganymede arrival.

It reminds us of the vastness of the Jupiter System our Galileo Orbiter is exploring. It is indeed the "miniature" solar system we refer to, consisting of 16 known natural satellites. And our flights from one of the major satellites (the Galileans: Io, Europa, Ganymede, and Callisto) to the next are completely analogous to interplanetary flights in the inner solar system—the gravity-assist at

—see page 4

Probe Mystery Solved:

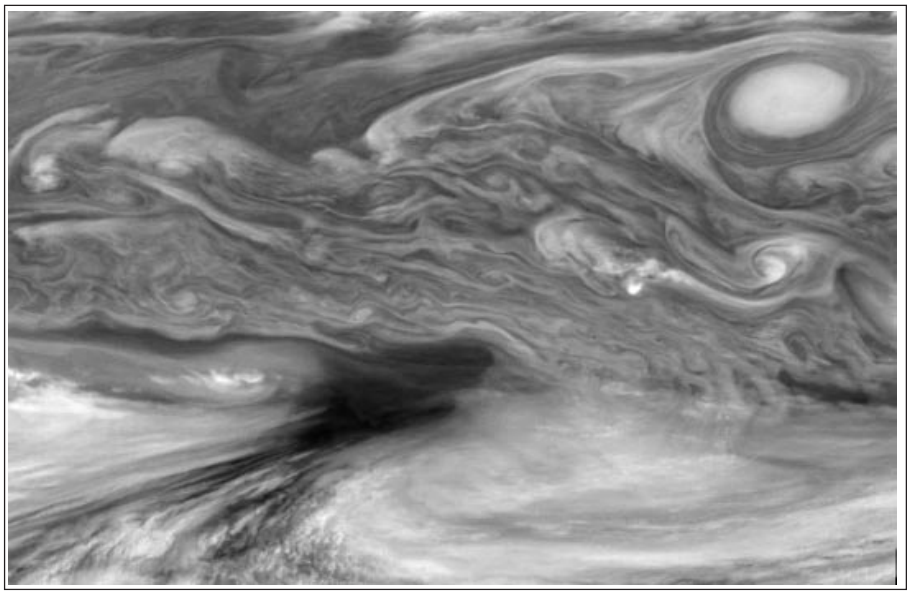
Jupiter as Wet (and Dry) as Earth

Jupiter Atmospheric Science Panel, from left: Dave Seidel [Moderator; JPL], Andrew Ingersoll [Interdisciplinary Scientist (IDS), Solid-State Imaging (SSI) Team; Caltech], Tobias Owen [IDS and Probe Neutral Mass Spectrometer (NMS) Team; University of Hawaii], Glenn Orton [IDS and SSI, Photopolarimeter/ Radiometer (PPR), Probe Nephelometer (NEP) Teams; JPL], Robert Carlson [Principal Investigator (PI), Near-Infrared Mapping Spectrometer Team (NIMS); JPL], Ashwin Vasavada [SSI Team Affiliate; Caltech].

Questions And Answers

The unexpected dryness at its entry site was one of the Galileo Probe Mission's more perplexing mysteries (see "The Probe Story: Secrets and Surprises from Jupiter," *The Galileo Messenger*, Issue 38, April 1996). Was Jupiter globally dry? Was the water everyone expected to see somehow locked in its interior? Or was the weather on Jupiter as varied (and interesting) as on Earth? These were the questions Andy Ingersoll of Caltech and the Galileo Science Team raised at the Galileo Press Conference at the Jet Propulsion Laboratory on June 5 in von Kármán Auditorium. The panel of researchers (pictured above) was most pleased to report that the latter model of a planet with a richly complex and dynamic weather system was the correct one.

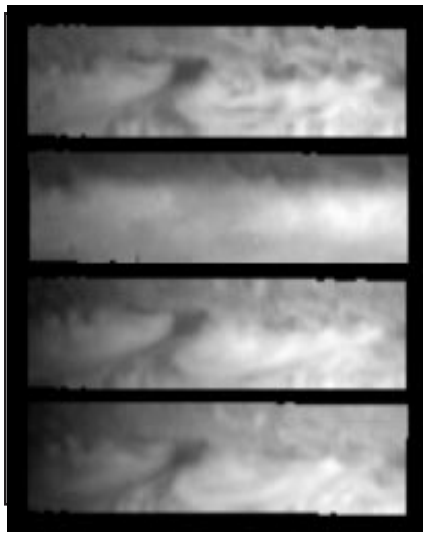
—see page 2



Photomosaic of SSI images showing a 34,000-km-wide swath from the Jovian equatorial region. The dark area is a hot spot—similar to the one that swallowed the Probe—where the air is drawn down to the interior; circulation is counter-clockwise. Bright, white areas are columns of rising air, spinning clockwise and topped by clouds.

Probing Hot Spots

Since the Probe entered at a hot spot, the Galileo Science Team selected other such areas to investigate—like the hot-spot area shown in the SSI image above and in the NIMS view below. Analysis from the output of the SSI (visible light) camera, NIMS, PPR, and the Ultra-violet and Extreme Ultra-violet Spectrometers (UVS/EUV) proved very fruitful.



NIMS swaths showing the same hot spot as in the SSI image above, but in four different IR wavelengths: 2.74, 1.99, 1.61, and 0.76 µm (top to bottom). The 1.99-µm wavelength senses the upper clouds and haze; other wavelengths probe deeper in the atmosphere.

Different atmospheric constituents (both chemical composition and particle size) react differently to different wavelengths of electromagnetic radiation. The NIMS image scanned the same hot spot as SSI, but in many different infrared (IR) wavelengths. The series of such images yields what amounts to a three-dimensional picture of the atmosphere, because different constituents are concentrated at different levels.

Because water absorbs IR, NIMS can generate water maps. Those that NIMS PI Bob Carlson displayed showed both the rare, very dry areas (like the Probe entry zone), with about 1% relative humidity, and more common water-saturated, very wet and likely rainy areas.

Understanding Jovian Weather

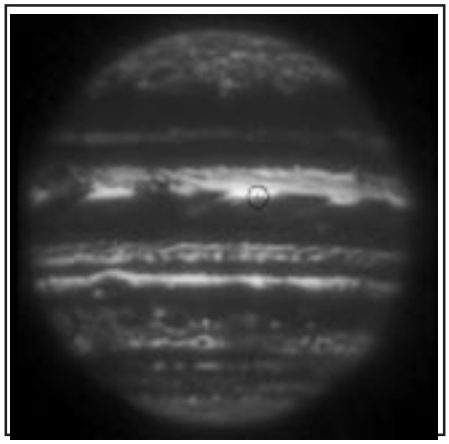
Fundamentally, Jovian weather resembles Earth's, but Jupiter has no solid surface. Its weather is driven by heat (as on Earth), but the source is different; instead of the Sun warming a surface, and the surface heating the air above it, heat in Jupiter is from deep down (as indicated by Probe data).

The atmospheric processes that Toby Owen of the Probe NMS Team described resemble Earth's: a rising column of heated Jovian air (mostly a hydrogen–helium mix) cools with expansion as it rises, then condenses out clouds (water droplets low, ice crystals higher) and rain (or snow). But on Jupiter, the rising air also condenses out hydrogen sulfide as a higher, colored (but wispier) cloud layer and ammonia as the highest cloud layer. Seen from Galileo, the region of updrafts is cloud-topped, and very bright. Above the clouds, the air at the top is very cold, very clear, and dry of all volatiles (which condensed out below).

What Goes Up . . . Comes Down

The high, clear air rolls outward, sinks, compresses, and heats up. Nothing condenses on the way down—the warming air is dry and soaks up any volatiles, so the region of subsiding air is clear. These areas are dark in visible light, but bright in the infrared. The videos that Glenn Orton of the PPR and Probe NEP Teams brought from NASA's 3-m IR telescope in Hawaii showed Jupiter glowing through its hot spots like a colossal cosmic jack-o-lantern (see below).

While the Jovian atmosphere has no real bottom, far below the underside of the water cloud deck is a layer of mixing, where the torrid air is enriched with heavier elements.



Jupiter with Probe entry site (circled). IR image taken at 4.85 µm from NASA's IRTF with the NSFCAM instrument, 11/21/95.

The global atmosphere circulates on a gargantuan scale (almost 500,000 km about the equator): regions of rising air spread around the planet as a system of bright, latitudinal *zones*. Regions of sinking air spread around the planet as a system of dark *belts*, studded with even darker hot spots, clear all the way down to the dark, hot mixing level.

The boundary between the belts and zones is very turbulent; images of these areas through time show wind strength and direction as clouds are blown about. Ashwin Vasavada of Caltech showed such videos of thunderheads moving toward a dark hot spot. His narration of an animated flight between cloud decks around a hot spot was especially interesting.

It was into such a dark, dry hot spot that the Galileo Probe dropped in December 1995. While the area around it was as dry as any desert on Earth, the distant lightning it detected hinted that wetter, stormier weather lay beyond.

Building the Atmosphere

The balance of constituents in the mostly hydrogen–helium atmosphere (carbon, sulfur, etc.) closely match that in comets, so Toby Owen suggested that the Jovian atmosphere, originally so similar in composition to that of the Sun, has been enriched over the eons by cometary bombardment. (Through the impacts of Shoemaker–Levy 9 in 1994, we see this process happening even now.)

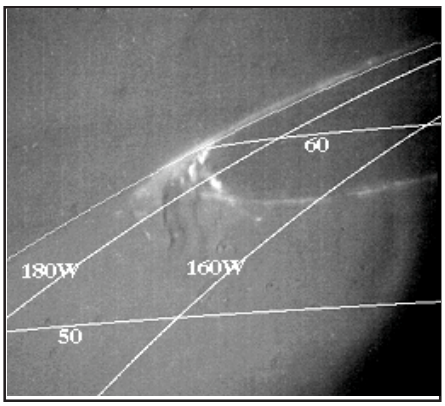
And More

The Jovian Auroras

Also like Earth, Jupiter has auroras. The images that Andy Ingersoll displayed showed a ragged curtain of light circling the north pole where charged particles, streaming down powerful magnetic field lines, slammed into atmospheric molecules in a high, glowing ring some 500 km above the 1-bar level.

Life on Jupiter?

Is there life on Jupiter itself? Toby Owen echoed the consensus opinion that, because there are only clouds and no surfaces, complex molecules would have no place to collect and begin to evolve, but would be cooked when pulled down to the hot mixing level.



The Jovian aurora borealis imaged by the SSI camera in visible light over the night side. The aurora circles the north magnetic pole, reaching down to 57 deg latitude.

—see page 4

Educational Outreach Corner

At JPL, May 20, a warm welcome from Project Manager Bill O'Neil.

Educators fill von Kármán Auditorium to learn about the Galileo Mission.

Scenes From a Galileo Educators' Workshop

The Galileo Mission: Making it Happen workshop featured "take-it-back-to-your-classroom" activities, creative ways that concepts given in the informative talks about how the Galileo Mission works could be conveyed to junior and senior high school students. David Armstrong, 11th and 12th grade math teacher at Marina High School, Huntington Beach, uses our Galileo home page and liked the many classroom applications offered. Bonnie Stefan, 6th grade teacher at Jefferson Middle School, Indio, appreciated the visual and performing arts emphasis. "It was fun!"

Moons orbiting Jupiter.

Europa, B-r-r-r!

Collecting data, a 70-m antenna?

Educational Ambassadors to Jupiter Selected!

Throughout 1997, Galileo's exciting discoveries will be presented to their local communities by **Fred Marschak**, Santa Barbara, CA; **James Beaber**, Lakewood (Denver), CO; **Susan Clavier**, Dover, DE; **Mary Matthes**, Rehoboth Beach, DE; **Charlotte Bihm**, Opelousas (Lafayette), LA; **Don Donovan**, Braintree (Boston), MA; **Betty Paulsell**, Lawson (Kansas City), MS; **Virgil Boehland**, Duluth, MN; **Chelen Johnson**, Minneapolis, MN; **Chuck St. Lucas**, Omaha, NE; **Thomas Estill**, Lyme, NH; **Paul Fisher**, Morristown (Newark), NJ; **Kenn Hitchcock**, Alamorgordo, NM; **John Telesca**, Johnson City (Binghamton), NY; **Bradley Timerso**n, Newark (Rochester), NY; and **Evan Justin**, Vashon Island, WA. These are the 1st-round educational ambassadors selected. The 2nd-round applications will be accepted Aug. 11–Sept. 2.

PROBE MYSTERY SOLVED from page 3

What Does it All Mean?

Understanding Jovian weather is of great value in understanding Earthly weather. Just as medical doctors must understand the comparative anatomy of other animals to make sense of human anatomy, so must meteorologists understand the comparative meteorology of other worlds to make sense of terrestrial weather. Without studying the weather and climate on other planets, there is no way to know just what is peculiar to the Earth, or what may be universal. Jupiter, Ingersoll reflected, is more like the Earth than we thought. But Jupiter is also so much more!

We need more probes!
—Andy Ingersoll

From its broiling, roiling bottomless depths; through multiple cloud decks; to frigid, aurora-lit heights; through endless cloud canyons, searingly dry voids, and centuries-long downpours, Jupiter is an ideal meteorological laboratory.

Our evolving comprehension of this mammoth, kaleidoscopic treasure trove owes so much to the recent, ongoing contributions of the Galileo Orbiter and Probe and also the Hubble Space Telescope, the IRTF on Mauna Kea, Hawaii, and many other instruments and researchers of the Jupiter Watch. But we also have so many more questions. Andy Ingersoll said it best, "We need more probes!" ❖

—Larry Palkovic

PROJECT MANAGER from page 1

a given satellite "launches" Galileo on its trajectory to the next satellite. Indeed each orbit is a mission in itself. And unlike any other orbital mission to date, every orbit is quite unique. Galileo never repeats its path—it is always in new territory—the ultimate explorer!

On June 25th, we performed the eighth satellite encounter of the primary mission tour—Callisto-9. Save just two days, it was exactly one year from our first encounter—Ganymede-1 on June 27, 1996. All eight encounters—or should I say missions—have been grandly successful. We are eight for eight!

Galileo is now in the seminal magnetotail orbit. Second in size only to the seven-month first orbit, this Callisto-9 (C9) Orbit is taking Galileo ten million kilometers into the magnetotail of Jupiter, where no spacecraft has ever been, in order to sample the fields and particles of this unexplored region to help explain the vastness of Jupiter's magnetosphere. This journey into the magnetotail has always been a fundamental element of Galileo's primary mission because it is crucial to one of the three major Galileo objectives, which are to investigate the Jupiter atmosphere, satellites, and *magnetosphere.*

This C9 orbit introduces a new operating feature. At seven key places around this orbit, we are "Recording During Cruise" (RDC). The orbit duration is long enough that we can play back a section of tape, then record new information on that section, subsequently play it back, and repeat this six times. This is particularly important in order to increase the sampling frequency of the fields and particles instruments at these key points in the magnetosphere. The shorter orbital cruise periods of all the other orbits (and greater Earth–Jupiter communication distance, resulting in lower average telemetry bit rates) warrant that we use all of our playback capability to play back the data from the immediately previous encounter.

The Team continues to do a phenomenal job of designing and executing extremely complex sequences, orchestrating the end-to-end data gathering of 11 separate science instruments with very limited (by today's standards) onboard computing capacity and downlink data rates. All 11 instruments are still providing excellent data even though the Photopolarimeter–Radiometer filter wheel is somewhat impaired, one of the 17 Near-Infrared Mapping Spectrometer detectors is not functioning, and another is problematical. The science bounty of Galileo is already tremendous and growing steadily. The preparations for the Galileo Europa Mission (GEM) that will continue operations through the last day of this millennium are well along. In fact, the planning for the last encounter of the primary mission—Europa-11—has now been made an integral part of the GEM planning, so it's a series of nine consecutive, synergistic Europa encounters we are planning. And more and more, we are adopting our GEM techniques/procedures as we near the completion of the primary mission so the transition from primary to GEM will be quite seamless.

Congratulations to the Galileo Team that holds the undisputed record for perseverance in space missions and has skills and ingenuity second to none! ❖

— Bill O'Neil

Editor ..... Jean Aichele
(818) 354-5593
jean.h.aichele@jpl.nasa.gov
Galileo Educational Outreach ..... (818) 354-6710
askgalileo@gllsvc.jpl.nasa.gov
Educator Resource Center ..... (818) 354-6916
Public Information Office ..... (818) 354-5011
newsdesk@jpl.nasa.gov
Project Galileo ..... http://www.jpl.nasa.gov/galileo

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

JPL 410-16-44 7/97