From the Project Manager

With Magellan's successful launch in May, attention is now being focused on Galileo's long-awaited launch opportunity, scheduled for October 12, 1989. How fitting that it falls on Columbus Day. Galileo, also known to some as the "critter," will then be aboard the STS-34 Space Shuttle Atlantis and finally on its way to Jupiter!

In January and again at the May 6 "Galileo Day" we had the pleasure of meeting the STS-34 astronauts. The Atlantis crew will fly under the command of Captain Donald E. Williams with Commander Michael J. McCulley as our pilot; Shannon W. Lucid, Franklin R. Chang-Diaz, and Ellen S. Baker will be the mission specialists. Each of these individuals brings a diverse background to the success of the mission.

Galileo's 1989 VEEGA (Venus-Earth-Earth Gravity Assist) mission offers a wealth of unique scientific opportunities. On February 9, 1990, Galileo will fly by Venus, where we will be studying its lightning, atmospheric dynamics, and cloud composition. Then, in December of both 1990 and 1992, Galileo will have two Earth encounters. During these encounters, we will have an opportunity to observe Earth's geotail, hydrogen corona, and global meteorology, as well as new areas of our Moon and determine the composition of unsampled areas.

In October 1991, Galileo will have the opportunity to be the first spacecraft to encounter an asteroid, Gaspra, and may also fly by Asteroid Ida in August 1993. These passings will allow Galileo to examine the surface geology, composition, size, shape, and mass of the asteroids, and analyze the relation of primitive bodies to meteorites. During its six-year journey to Jupiter, Galileo will also be making measurements of the interplanetary environment.

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Test and integration activities are drawing to a close at Kennedy Space Center as Galileo nears launch. Above, workers are loading the Retropropulsion Modules with propellant.

Happenings at the Cape

Excitement and exertion are playing a balancing game with Galileo's team at the Kennedy Space Center. Excitement grows over the scheduled October 12 launch of the Galileo spacecraft, which for some is a culmination of 15 years of work. And, exertion increases with the remaining test and integration activities necessary to complete in these last few months before launch.

Those activities have kept the team members busy in Florida, where they have completed Phase 1 of the work there -- preparing Galileo for launch in the payload processing facility. Milt Goldfine, who leads the team at the Cape, explained, "Phase 1 was the most technically challenging part of our operations. With Phases 2 and 3 (integrating the spacecraft and the IUS together and then with the shuttle), we have fewer activities to accomplish in a greater period of time."

The Galileo team members have been getting excellent support from their KSC counterparts. With everyone working diligently, all the activities to ready the spacecraft and the Space Shuttle Atlantis are running on schedule.

Integration will continue until August 23. At that time, the Galileo spacecraft, mounted atop the IUS, and loaded into the payload bay of the Space Shuttle Atlantis, will be moved onto its launch pad, awaiting the October morning it will thunder its way to Jupiter.
The PPR: Finding That There Is More Than Meets The Eye

In aerial photography, comparing different colors can highlight ground features that cannot be seen otherwise. Similarly, the Galileo Orbiter has an instrument that views an assortment of spectral bands. The Photopolarimeter-Radiometer (PPR) is in many respects three instruments combined into one: a photometer, a polarimeter, and a radiometer. Combining three major functions into one instrument makes a flexible and powerful experiment, but it required some compromises and a great deal of clever design.

Investigating

The PPR will determine the amounts of radiation at Jupiter and its moons, provide atmospheric temperature profiles in the topmost (smog-like) layer and in the stratosphere just below, and help us understand cloud and haze properties and structures.

At Jupiter, the Probe will measure the atmospheric conditions in its path. PPR data for each area will then be compared with remotely sensed data for the entire planet.

Like Galileo’s Ultraviolet Spectrometer and Near Infrared Mapping Spectrometer, the PPR is aligned with the imaging system. That way, data from all three instruments can be correlated for the object being viewed and can be used to investigate major elements of the Jovian atmosphere.

Performing

A detailed look at the tasks performed by each of the PPR’s functions starts with the Photopolarimeter, whose design comes almost directly from the cloud photopolarimeter on the Pioneer Venus Orbiter.

Cloud particles can play a dominant role in determining the polarization of reflected sunlight. (Polarization is the suppression of the vibration of light waves in a certain direction.) For instance, water droplets in the Earth’s atmosphere produce rainbows with a very strong signature in the polarization as a function of the phase angle (the angle between the Sun, the water droplet/scatterer, and the observer).

Scattering due to the molecules of an atmosphere (Rayleigh scattering) produces a very distinctive polarization signature and is most prominent at shorter wavelengths. (It is this wavelength dependence that makes the sky appear blue on Earth.) An examination of the relative contribution of Rayleigh scattering provides an estimate of how much gas is above the cloud tops. This "optical barometer" technique helps to see variations in the height of the cloud tops associated with major Jovian cloud features. The Photometer investigates at seven narrow bands in the visible and near infrared wavelengths. These channels correspond to the positions of several absorption bands which are due to atmospheric methane and ammonia. The behavior of the intensities of these bands across Jupiter will help deduce the vertical structure of clouds and haze.

The Radiometer’s infrared wavelengths overlap some of those used by the Probe’s Radiometer. They correspond to regions (mainly hydrogen) with different atmospheric absorption, that way the Radiometer can see to different depths and measure each region's brightness temperature.

The PPR has two additional radiometry bands. One of these uses no filter and, thus, observes all radiation from the visible through thermal and solar infrared wavelengths; the other lets through solar radiation only. The difference between the solar-plus-thermal and the solar-only channels gives the total thermal radiation emitted.

For viewing the moons of Jupiter, this Radiometer is the only source of data on direct “temperatures” of the surface. It is expected to be able to make such measurements for many regions, including the interesting "hot spots" near the volcanoes of Io.

Constructing

A 10-centimeter (4-inch) diameter telescope collects the radiation for all three functions of the PPR. Light from the telescope is focused through one point, giving all three functions exactly the same field of view. The light then strikes a filter/retarder wheel, which can step through 32 positions.
A single polarimetry observation requires three wheel positions, each with a filter and a half-wave retarder. After passing through these, the light enters a prism, separating it into beams of vertically and horizontally polarized components. These beams are directed to a pair of photodiode detectors. (These detectors measure the light by converting it into electricity.) Thus, the polarization of the incoming light is determined by rotating the beam itself using the retarder.

Photometry, in which just the intensity of the incoming light is measured, requires only one position on the wheel with an appropriate filter. In principle, this filtered beam could be immediately directed to a detector to measure its intensity. The PPR, instead, passes the beam through a prism and to the silicon detectors used for polarimetry, thus, avoiding the added complexity of an additional optical path and detector. The photometry intensity is then just the sum of the intensities measured by the two detectors.

Another advantage of this design is that some information on the polarization of the observed light is available if the polarization direction is known or inferred from other measurements.

For radiometry (measuring thermal infrared radiation), a separate telescope allows radiation to come in from space (corresponding to a 3 Kelvin blackbody) to provide a reference signal. This beam intersects the incoming light's path just ahead of the filter wheel. Filters are used to select the desired wavelength; then mirrors send the beam to the side. There, it strikes a conical mirror that focuses it onto a pyroelectric detector.

For radiometric calibration, there is a target on Galileo's sunshade, which can be viewed and its temperature monitored by means of platinum resistance thermometers connected to the PPR's electronics. Similarly, the Photometer's response can be checked with an internal calibration lamp.

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Integrating

Trade-offs were crucial to the PPR's design. An actively cooled radiometry detector would have been more sensitive, but would have been incompatible with the photometry and polarimetry requirements. Also, one instrument splitting time among three functions has, of course, less time for any one of them. However, there is a tremendous advantage in having the functions and wavelengths sampled with exactly the same field of view. Despite all its capabilities, the PPR has a mass of only 5.0 kilograms and is less than 0.5 meter on its longest axis. It uses a peak power of 11 watts and an average of 6 watts.

The PPR was designed and built at the Santa Barbara Research Center (SBRC) in California. The SBRC has supplied sensors for Landsats and weather satellites and has built radiometers for many deep space missions.

J.E. Hansen, the Principal Investigator for the PPR, is at the Goddard Institute for Space Studies in New York City, as are investigators M.D. Allison, A.D. Del Genio, A.A. Lacs, W.B. Rossow, and L.D. Travis. Other investigators include G.S. Orton and T. Martin at JPL, P.H. Stone at the Massachusetts Institute of Technology, Y.L. Yung at the California Institute of Technology, and D. Morrison at the University of Hawaii.

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including the distribution of hydrogen in the inner solar system, dust particle characteristics throughout the solar system, measurements of the solar wind, and searches for gravity waves. Some of these data will be collected for the Galileo scientists by our German colleagues using the Weilheim tracking station near Munich.

With the launch delay, problem solving, and VEGA mission changes and their impact on the spacecraft's hardware and software, our collective ingenuity and dedication have been exhaustively tested. I commend each of you for your excellent performance in the face of these challenges. JPL can be very proud of the achievements and accomplishments we have made. The time remaining before launch, as well as the mission, should be most exciting and rewarding for everyone on the Galileo Project.

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Dick Spehalski
Meet the Team

Galileo Chief of Test and Operations, Milt Goldfine, and his team of "free spirits" are responsible for assembling, testing, and launching the Galileo spacecraft. The enthusiasm and expertise which Milt brings to his job have helped to make JPL's spacecraft testing program one of the finest in the aerospace industry.

Milt came to JPL with a background in mathematics from Hunter and Columbia Universities. Before college, Milt served in the Army/Air Corps during World War II, and after graduation he worked for PhilCo for two years. JPL, however, has captivated him since 1954, when he came here to work on the Corporal missile. Over the next several years, Milt searched for suitable sites for the Microlock system (the predecessor receiver of the Deep Space Network), worked on the Re-entry Test Vehicle (the forerunner of Explorer I), and helped test the Sergeant missile at the White Sands Test Facility. He returned to Pasadena to become Test Chief for Rangers I and II. Milt worked through the Mariner and Galileo Projects, and aided the Seasat radar experiment in its testing phase.

JPL's spacecraft testing is unique since the scientists and engineers who develop a subsystem support the spacecraft's testing, rather than transferring the testing to another organization. Milt and his team coordinate all of Galileo's test and launch activities.

"The Test Team and I find the tasks are very challenging and the work gratifying. Equipment and software delays and other problems have to be accommodated for Galileo's fixed launch period," Milt stresses. "One of the nice things about the job is the great exposure Test Team members have with the rest of the Lab and the Galileo scientists." He emphasizes that the cooperation of the groups supplying Galileo's hardware and software is essential for successfully launching on time.

The Test Team activities he directs start at the Spacecraft Assembly Facility (SAF) and conclude with launching the spacecraft from Kennedy Space Center (KSC). Milt and several Test Team members accompanied the spacecraft to KSC this May. Meanwhile, the remainder of the Team is staying at JPL for real-time data analysis of the tests conducted at KSC.

Milt emphasizes his debt to the individuals in the test and operations area. When the launch was delayed, Milt petitioned the Project to hold over the men and women who were working there, "I felt that the expertise in the test area was invaluable and, because the Project wisely maintained this group through the down period, we are now able to smoothly proceed into the VEEGA mission."

Through all his projects, his wife, Jeep, has helped him to persevere and to keep his optimistic attitude. Their son, Bernie, is a teacher. In his spare time, Milt plays handball, reads, works with his computer, and experiments with high-fidelity digital recording on high-quality videotape.

-Dick Spehalski

Editor's Note

Since the last Messenger, the management of the Galileo Project has changed hands. The new Galileo Project Manager is Dick Spehalski; John Casani, the former Manager, is now the Assistant Laboratory Director of the Office of Flight Projects.

Dick "Spe" Spehalski came to JPL from Cornell in 1959. He was the Galileo Flight System Integration Manager before being promoted to Galileo Project Manager. Prior to joining Galileo in 1977, he was the Applied Mechanics Division Representative for Voyager, from inception through launch. His earlier experience began on the Sergeant missile system and continued through the Mariner Venus and Mars missions.

Dick and his wife, Nancy, live in Altadena and have raised three sons, Steve, Mark, and James. An avid sports fan, he likes to spend his spare time fishing, boating, and camping with his family. He also plays handball several times a week and tinkers with his Corvair.

Jeanne Collins

Editor

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