From the Project Manager

We have just had our first Galileo science press briefing. Several Galileo scientists presented and described their first look at the data Galileo obtained at Venus. Recall that we had to store the Venus data on the spacecraft’s tape recorder until Galileo got close enough to Earth to transmit it at a high data rate over one of its low-gain antennas.

The broad spectrum of information about Venus obtained by Galileo in this very limited, "first" encounter is awesome. It is a wonderful confirmation of the ability of the Galileo Orbiter’s instruments to thoroughly investigate the Jovian system.

During the upcoming Earth encounter, Galileo will make extensive measurements of the environment in Earth’s neighborhood in space, and will acquire many exciting observations of the Earth and Moon in the ultraviolet, visible, and infrared spectrums.

Of course, we must remember that the only reason we went to Venus and the only reason for flying past the Earth (twice!) is to get to Jupiter. In that regard, Galileo just completed its last Trajectory Correction Maneuver before Earth encounter. It was performed excellently, just as all the others have been. No further actions are required on the ground or spacecraft to achieve the required first Earth gravity assist; it is already assured. Very

— See page 8

Venus Through Galileo’s Eyes

These are enhancements of four views of the planet Venus taken by Galileo’s Solid-State Imaging Subsystem (SSI) at distances ranging from 1.4 to 2 million miles as the spacecraft receded from Venus. The pictures in the top row were taken two hours apart about four days after closest approach. The faint Venustian cloud features are especially clear. A high-pass filter was applied to bring out broader global variations in tone. The bright polar hoods are a well-known feature of Venus. Of particular interest to planetary atmospheric scientists are the complex cloud patterns near the equator, in the vicinity of the bright subsolar point, where convection is most prevalent.
The Sequence Team: Interpreting for Galileo

Clear, comprehensible communication with the spacecraft is essential to Galileo's mission. However, the written and spoken desires of Galileo's scientists and engineers are incomprehensible to the spacecraft. Ordering, defining, and translating those desires into Galileo's computer language can be quite a challenge—a challenge well met by Galileo's Sequence Team.

The communication cycle generally begins with a request from the Orbiter or Probe Engineering Team or the Science Office. The Mission Design Team (MDT) coordinates all these requests to allow Galileo to do as much as possible without endangering itself or its supplies (for example, propellant). Sometimes the requests find their way to the Sequence Team still written as narrative, but generally the MDT combines all requests into a Cruise Plan file.

The Cruise Plan then comes to the Sequence Team. Because they deal at a greater level of detail than the MDT, often the Sequence Team needs to elicit more information from the originators. The Sequence Team has created a variety of software programs, with automatic checking functions, that begin to translate these Cruise Plans into actual sequences of commands for Galileo. After performing a series of checks and then being satisfied with the sequence of commands, the Team passes the sequence on to others to ensure that additional mission constraints have not been violated and for the scientists to verify that their desires will be met by these commands. The Team takes all that input and creates a second and final iteration.

This scenario is followed for all large sequences. Often, though, sequences need to be created much more quickly, especially when creating a Trajectory Correction Maneuver (TCM) for the Navigation Team and the Orbiter Engineering Team (OET). For a TCM, the Navigation Team requires the spacecraft to obtain a certain change in velocity; the OET then designs how the spacecraft should perform the TCM. In such an instance, the Navigation Team starts the process one to two weeks before Galileo needs to perform a maneuver, after which the OET takes one to four days to design the maneuver. The Sequence Team then "builds" the commands within one to four days, depending on how much time they have.

These processes have served Galileo well over the mission's first year. Jim Erickson, Sequence Team Chief, expressed, "This has always worked very well. In fact, this is the way we generate all commands, except for a few real-time commands sent through the Mission Control Team."

Even with near-real-time commands, the Sequencing Team might get involved. Sometimes the Project needs quick turnaround work. Jim indicated, "In that case, we only perform one iteration. We generally build the commands in a day and the sequence is reviewed in a Command Conference. We send a tape to the Mission Control Team and they send it to Galileo. Especially when the turnaround is so rapid, it's important to check the Project's command constraints because of the possibility of harming the spacecraft or violating constraints and rules."

Each week, the Sequence Team delivers at least one product and is working on two others in parallel. As many as four or five sequences could be with the Team at any
time. During encounter, that number may increase to 12 a week.

For example, in preparation for the upcoming Earth encounter, the Team is preparing TCM-8: a sequence for which the Project only has one week to prepare. The maneuver requires the latest possible navigation data, hence the short turnaround. Because Earth’s gravitational assist will amplify all deviations from a perfect trajectory, a small adjustment at this point could save 500 times the fuel that would have to be expended after flyby if no TCM were performed. As Galileo’s 1995 arrival at Jupiter neared, the time for sequence preparation will compress. Therefore, staying in practice on quick turnaround TCMs is valuable.

“IT is easier between encounters,” Jim commented. “During that time, we prepare for long-range events. We also use this time to create sequences that could be used for any possible contingencies or anomalies. We review past performances, examining what we might have done differently. In general, we sharpen up to get ready for the next encounter or maneuver and for Jupiter operations.”

One such long-range event will be the High-Gain Antenna deployment next April. This is one of the most important sequences the Team has had to develop. Such an event has never occurred before, and no software is available to automatically check this sequence for certain errors. This, coupled with several unique requirements, makes the deployment a certain challenge for the Team. Jim, however, is not worried: “This is an excellent team. I have never worked with a better group of people in my life.”

Each of the thirty-four people on the Team specialize in one of five sequencing functions. One group takes the Cruise Plan and other requests and merges them to create the sequences of commands

These images are two versions of a near-infrared map of lower level clouds on Venus’ night side, obtained by the Near-Infrared Mapping Spectrometer on February 10, 1990. With a spatial resolution of about 13 miles, this is the sharpest image ever obtained of the mid-level clouds of Venus. The image to the left shows the radiant heat from the lower atmosphere (about 400°F) shining through the sulfuric acid clouds, which appear as much as 10 times darker than the bright gaps between clouds. This cloud layer is at about 170°F. This high-resolution map covers a 40-degree-wide sector of the Northern Hemisphere. The several irregular vertical stripes are data dropouts. The right image, a modified negative, represents what scientists believe would be the visual appearance of this mid-level cloud deck in daylight, with the clouds reflecting sunlight instead of blocking out infrared from the hot planet and lower atmosphere. Near the equator, the clouds appear fluffy and blocky; farther north, they are stretched out into east–west filaments by winds estimated at more than 150 mph, while the poles are capped by thick clouds at this altitude.
that will eventually cause Galileo to perform the desired function. Another group keeps an eye on the scan platform and how these proposed commands will affect it. A third group translates these sequences into the binary code, the zeros and ones, that Galileo can understand. Analyzing the telecommunications implications of the sequence falls under the cognizance of other individuals. Yet another group creates a graphic representation of the commands, a timeline, so that the Flight Team knows exactly what Galileo will be doing at any given moment. The Sequence Integration Engineers oversee organizing all this work. Meanwhile, in the background, other members of the Sequence Team work diligently to fine tune the Team’s software.

Jim summed up the group’s outlook: “We are a service organization. We take other people’s desires and create commands to have the spacecraft satisfy those desires.”

Some of Jim’s responsibilities as Team Chief include acting as a liaison with the Engineering Office, and overseeing long-range plans, future training, future staffing for Jupiter operations, budgets, product delivery, and special task preparation. All these tasks involve lots of meetings. Preapproval meetings are required so that the Sequence Team only works on Project-approved sequences. Command Conferences are called to review each Team product, including the semi-monthly Cruise Plans and weekly Team products.

Since Jim keeps his eyes on long-range planning, his Deputy

These images of Venus' clouds were taken by Galileo's SSI on February 13, 1990, at a range of about one million miles. The smallest detail visible is about 20 miles. The top images were taken six hours later than the bottom ones. The two left images show Venus in near-infrared light. Sunlight penetrates through the clouds more deeply at the near-infrared wavelengths, allowing a view near the bottom of the cloud deck. The westward motion of the clouds is slower (about 150 mph) at the lower altitude. The clouds are composed of sulfuric acid droplets and occupy a range of altitudes from 30 to 45 miles. The images have been spatially filtered to bring out small-scale details and de-emphasize global shading. The filter has introduced artifacts (wiggly lines running north–south) that are faintly visible in the infrared image. The two right images show, in violet light, the state of the clouds near the top of Venus' cloud deck. A right-to-left motion of the cloud features is evident and is consistent with westward winds of about 230 mph.
Keeping the Lines of Communication Open

Galileo collects data on its journey to Jupiter and transmits signals that are received by antennas on Earth. Soon after the signals are received, the Project's scientists and engineers receive printouts or computer files of information they can study and analyze. How do those bits of data received at the Deep Space Network become a graph on a scientist's desk? Behind the scenes, the Multimission Control and Computing Center creates the necessary lines of communication.

The Multimission Control and Computing Center (MCCC, or "M-Cubed") Telemetry System acquires raw telemetry data from the Deep Space Network (DSN). After performing an elaborate, first-level processing, data are sent to the Project's printers and monitors, to the Probe Telemetry Processor, and to the Galileo Test Bed. This distribution makes engineering and science "housekeeping" data available to the Mission Control Team, Orbiter and Probe Engineering Teams, Science Teams, and throughout the Project staff. In addition, the low-rate science and engineering data are sent via tape to the MCCC Data Records Subsystem; and the high-rate science data (for example, images) are sent via tape to the Multimission Image Processing Laboratory (MIPL). These Telemetry and Data Records Subsystems, as well as the Multimission Operations Control Subsystem, Multimission Command Subsystem, Multimission Simulation Subsystem, and the General Purpose Computing Capability, are all implemented, maintained, and operated under the management of the Flight Projects Support Office (FPSO).

As its name implies, MCCC supports multiple missions, Galileo being only one of them. Still, MCCC caters to each of its customers, creating specific products and services for each project. For example, several things were done in preparation for Galileo's launch. All tape and disk recorders on the Galileo MCCC Telemetry Subsystem were refurbished or replaced. Most of these had been installed before the Voyager launches in 1977. Edwin Gatz, Flight Projects Support

See page 8

Jose Coito, Ed Gatz, and Mel Pinck view Galileo images of Venus on an MCCC workstation.
Galileo: Up To Date

The Galileo spacecraft continues to perform well. Two Trajectory Correction Maneuvers (TCM-6 and TCM-7) were successfully completed on October 9 and November 13, respectively. Both maneuvers were executed using the axial (Z) and lateral (L) thrusters. Spacecraft performance during these maneuvers was excellent and near predicted levels.

In addition to the maneuvering activity, several other important activities were successfully completed, including loading the VE-9 program, which controls the spacecraft's activities from October 18 through December 7. These activities comprise the retraction of the Plasma Subsystem sunshade; the continued collection of cruise science data; special navigation operations; periodic health and maintenance checks (SATURNs, Retropulsion Module thruster "flushing," and Attitude and Articulation Control Subsystem calibrations); and power on and checkout of the science instruments for the Earth encounter.

The Plasma Wave Subsystem (PWS), Energetic Particles Detector (EPD), Photopolarimeter Radiometer Subsystem (PPR), and Plasma Subsystem (PLS) were successfully powered on. Operations of the PWS and PPR were without incident; power consumption and thermal profiles were near anticipated levels. Shortly after the EPD and PLS were powered on, some unexpected events were observed. One of the EPD's low-energy detectors indicated very high noise counts, possibly indicative of a failing detector. Commands were sent to raise the threshold level of this detector and monitor its performance at the new level. Subsequent analysis by the Principal Investigator resulted in reduced concern for the detector's health and safety, and the threshold was lowered to its original value. The unexpected PLS event was thermal related in that temperatures in excess of predicted levels were observed shortly after power on. The thermal performance was closely monitored by PLS engineers and, subsequent to an intensive analysis, the PLS high voltage was powered off; temperatures were then noted to drop to safe levels. Operation of the PLS during the Earth encounter phase is presently being evaluated by the Principal Investigator.

The Extreme Ultraviolet Spectrometer (EUV) experienced an anomaly evidenced by no photon counts being recorded when the instrument was commanded to its encounter mode. Subsequent memory readouts indicated two bits in a single byte were corrupted. Although the memory locations were different, this memory corruption is similar to that observed in the December 1989 EUV checkout. The Principal Investigator rapidly recreated the same symptoms on the test vehicle at the University of Colorado and requested a test-verified software "patch." The EUV memory was successfully "patched" to reset the instrument to its encounter data-taking mode, and proper operation was restored. The cause of the EUV anomaly is being vigorously investigated by the Principal Investigator.

The AC/DC bus imbalance and the Command Data Subsystem (CDS) power-on reset (POR) telemetry indication anomalies are still being observed. The ninth despun CDS Critical Controller 2A POR occurred. The signature of this event was the same as that observed in the previous occurrences in February, April, and July 1990. Possible causes include a faulty solder joint, electronic part failures, marginal component performance, and slip-ring debris. The POR signal is normally used to inhibit Critical Controller commanding when a real POR signal is present. However, problems in selected electronic circuitry or in the telemetry latch device could produce an anomalous telemetry indication. In all occurrences, recovery from this POR was completely successful, indicating the event was not caused by a permanent failure in the CDS. The CDS personnel recently developed a software method to help determine whether the telemetry latch device is "faulty" or the circuitry is actually detecting a transient "POR signal" on the interface.

The AC/DC bus imbalance measurements continue to exhibit some activity. The AC measurement fluctuations were relatively small, varying between 1 and 3 volts, but always reading above 45 volts, indicating a leakage resistance path to chassis between 100 and 500 ohms. The DC measurement exhibited fluctuations of

Galileo Mission Summary*

<table>
<thead>
<tr>
<th>Distance from the Earth</th>
<th>17,790,470 kilometers (11,054,490 miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from Venus</td>
<td>163,162,570 kilometers (101,584,520 miles)</td>
</tr>
<tr>
<td>One-Way Light Time</td>
<td>1 minute, 4 seconds</td>
</tr>
<tr>
<td>Velocity Relative to the Earth</td>
<td>9.86 kilometers per second (22,050 miles per hour)</td>
</tr>
<tr>
<td>Velocity Relative to the Sun</td>
<td>27 kilometers per second (69,410 miles per hour)</td>
</tr>
<tr>
<td>Spacecraft–Sun Angle</td>
<td>12.5° off</td>
</tr>
<tr>
<td>Spacecraft Spin Rate</td>
<td>3.15 revolutions per minute</td>
</tr>
<tr>
<td>Downlink Telemetry Rate</td>
<td>1.2 kilobits per second (Low-Gain Antenna 1)</td>
</tr>
<tr>
<td>Spin Configuration</td>
<td>Cruise mode, dual spin</td>
</tr>
<tr>
<td>Powered Science Instruments</td>
<td>Dust Detector Subsystem, Energetic Particles Detector, Extreme Ultraviolet Spectrometer, Heavy Ion Counter, Magnetometer, Plasma Subsystem, Plasma Wave Spectrometer, Photopolarimeter Radiometer, and Ultraviolet Spectrometer</td>
</tr>
<tr>
<td>RTG Power Output</td>
<td>545 watts</td>
</tr>
</tbody>
</table>

*All information is as of November 16, 1990.
about 14 volts, dropping from about 18.5 to about 4 volts. These fluctuations occurred over a one-hour period and during a time of no spacecraft electrical load switching, mechanical motion, or thermal environmental changes. All other power-related and subsystem telemetry continues to be normal. Tests to better characterize the Power/Pyro Subsystem telemetry sensor performance under both nominal and faulted conditions are in process.

The Plasma Subsystem pyro-actuated sunshade was successfully retracted on November 1. All spacecraft pyro-related telemetry was as expected. Indication of sunshade retraction was quickly observed by the Attitude and Articulation Control Subsystem acquisition-sensor temperature data and later by PLS temperature measurements.

Special navigation activities, Delta Differential One-Way Ranging (ΔDORs), using all three DSN sites were conducted this fall in support of Earth navigation. Twenty-one of these passes have been successful. A ΔDOR is another navigation data source—used in addition to Doppler and ranging data—to better determine Galileo's exact location.

Several recent activities focused on verifying communications with the spacecraft. A major uplink compatibility test was successfully completed in September. During each of two tests, 16 no-operation (NO-OP) commands were transmitted to the spacecraft from the Weilheim, Germany, tracking station under control of the German Space Operation Center (GSOC). The two uplink tests were nearly identical, except that the second test also included ranging modulation on the uplink. The Galileo Flight Team in the Mission Support Area at JPL used downlink telemetry via the Deep Space Network's (DSN's) Madrid tracking station to confirm that Galileo properly accepted and executed the commands. Starting in September 1991, GSOC will support the cruise science phase of the Galileo mission by tracking the spacecraft for five passes each week, generating Experimenter Data Records, and transmitting noninteractive commands for the fields and particles, low-rate science instruments.

The first combined Ground Data System/Mission Readiness Test for Earth encounter was successfully completed in late October and early November for all these DSN sites. The Test demonstrated the stations' ability to support real-time command and telemetry functions for Earth encounter. In addition, station personnel generated and routed magnetic tapes to the Multimission Imaging Processing Laboratory (for high-rate science) and the Data Records System (for low-rate science) to verify the interfaces.

Four of the planned 10 program sets scheduled for the current software set, C3.2, have been delivered. C3.2 delivery activities have included the successful completion of the acceptance test and delivery reviews for the Experimenter Data Records Generation program set and the Radio Science Closed-Loop Data Validation program set. The Multimission Image Processing System delivery has been delayed pending the fix and retest of problems discovered in acceptance testing. All Project software required for the Earth encounter has been delivered.

—Matt Landano

These images of Venus were obtained by Galileo's SSI at ranges of 1.4 to 2 million miles as the spacecraft receded from Venus. The pictures in the top row were taken about four and five days after closest approach; those in the bottom row were taken about six days out. In these violet-light images, north is at the top and the evening terminator is to the left. The cloud features high in the planet's atmosphere rotate from right to left—from the limb through the noon meridian toward the terminator, traveling all the way around the planet once every four days. The motion can be seen by comparing the last two pictures, taken two hours apart. The other views show entirely different faces of Venus. These photographs are part of the "Venus global circulation" sequence planned by the Imaging Team.
Office Systems Manager for Galileo, commented that "some of the computers are older than the programmers." The new equipment, along with more spares, has increased the reliability of the Subsystem. Software updates for the MCCC Command, Simulation, Operations Control, and Data Records Subsystems were also delivered. In addition to all the changes for launch, MCCC participated in multimission verification tests with the DSN and in Project Ground Data System and DSN Mission Readiness Tests.

More recently, in preparation for Earth encounter, MCCC has made some significant deliveries. The image-processing capability now exists for real-time processing and generating of Experiment Data Records for the Solid-State Imaging, Near-Infrared Mapping Spectrometer, and Plasma Subsystems—all high-rate data-return systems. Also, a new, multimission optical navigation system will answer Galileo's concerns for support during the flyby of asteroid Gaspra. Scientists plan to check out and demonstrate this system during Earth encounter. New hardware goes with these new software programs. The MCCC Telemetry Subsystem has been fitted with new printer-plotters and improved firmware for interface devices for those printers.

One very innovative part of the MCCC support comes in the form of the very latest in workstations for scientific displays—SANTA2 (Science Analysis Near-Term Activity). An adaptation of the VNESSA (Voyager Neptune Encounter Science Support Activity) system, SANTA2 should enable scientists to analyze the data from Galileo more quickly. At Earth encounter, these interactive displays for real-time data analysis should prove exciting. Still experimental, SANTA2 is supported by the Project on a "best-effort" basis. This is a Space Flight Operations Center (SFOC) pilot program to demonstrate application of SFOC-developed technology.

Although under the cognizance of FPSO/MCCC, Ed Gatz dedicates his time to supporting Galileo. He is assisted by Mel Pinck, Data System Project Engineer, and Jose Coito, Facilities and Operations Project Engineer. More than 250 development and operations people provide around-the-clock support in MCCC for all projects. During Earth encounter, for example, most MCCC personnel will be supporting Galileo in some way, and many will be working different shifts to ensure Galileo receives 24-hour support during this critical period.

While many of the personnel are in the Space Flight Operations Facility, others can be found in offices around the Laboratory, and in the Information Processing Center (IPC) at JPL's Woodbury site. IPC houses the Unisys computers that help generate the spacecraft sequence commands and analyze the spacecraft and navigational data.

In the midst of all this, MCCC is undergoing an end-to-end replacement of all telemetry, command, simulation, and operations control equipment, to be completed by April 1992. The main driver for this replacement for Galileo involves the requirements at Jupiter. At Jupiter, the data rate will jump to 134 kilobits per second. MCCC's present system cannot support such high data rates for months on end. The new equipment can meet Galileo's needs and will be more reliable, more flexible, and faster. Presently, passing the data on to the scientists requires physically taking a tape to MIPL and to Data Records. The new system will include high-speed electronic interfaces, taking advantage of the local area network capabilities on Lab. Eventually, there will be less reliance on paper, and more reliance on individual workstations with built-in plotting capabilities.

Each flight project supported by MCCC has some of its own telemetry equipment and pays for a portion of the MCCC budget. The bulk of MCCC is financed out of the Flight Projects Office. Multimission capability is sized to handle multiple projects simultaneously. For example, MIPL is currently processing both Galileo's playback of Venus data and Earth encounter images, as well as Magellan's mapping of Venus.

Shortly, Galileo will be on its way to the first spacecraft encounter with an asteroid—Gaspra on October 29, 1991!

The Galileo Flight Team and spacecraft continue to perform beautifully. What great pride and satisfaction there is for all of us in this great enterprise.

—Bill O'Neil