Up To Date

HGA Actions

Between January and April 1992, the fourth, fifth, and sixth warming and cooling turn activities were performed in an attempt to walk the High-Gain Antenna (HGA) alignment pins out of their receptacles to free the stuck antenna ribs. Another warming-cooling turn activity was completed on July 10. During the warming-cooling turn activities, the temperatures of various Galileo components were monitored. Heaters were turned on and off, as necessary, to keep the hardware within safe temperature limits and to maintain an adequate system power margin. Sun gate data, collected after each cooling or warming turn, indicated that an antenna rib still obscures... — see page 2

This image of Gaspra is a mosaic of two images taken by Galileo on October 29, 1991. Because the High-Gain Antenna has not yet been deployed, this high-resolution image was obtained via one of the low-gain antennas onboard Galileo. In the event the High-Gain Antenna is not deployed before the spacecraft reaches Jupiter, scientists expect to achieve 70% of the original mission, including 100% of the Probe's mission using the low-gain antennas. (P40449)
the sun gate signal, thereby confirming there was no rib release. Also, Attitude and Articulation Control Subsystem gyro-based wobble data showed no change in the wobble angle as a result of the warming and cooling turns, corroborating the sun gate obscuration data. Subsequent to the twelfth HGA anomaly review on May 7, the Project decided to cancel the planned future turn cycles, since it was concluded these remaining cycles would likely provide very little benefit to walking out the stuck pins.

On April 29, an HGA diagnostic motor turn-on sequence activity was performed for approximately two seconds to collect data regarding the HGA’s present configuration. Analysis using the power system shunt current telemetry data collected at the highest possible sample rate indicated that the drive motors stalled approximately 100 milliseconds after turn on, indicating that the HGA drive system is still stalled. The wobble data collected after the turn-on verified that no ribs had been released from the motor action. Additional diagnostic motor turn-on activities are planned for late July and mid-September. Currently, HGA action plans are being developed that will take full advantage of the near-Earth solar environment for tower expansion and motor hammer actions.

An HGA technical workshop was held at JPL in June. The workshop was convened to provide an independent review and assessment of all the HGA anomaly-related efforts performed to date. Members included experts from the aerospace industry, other NASA centers, universities, the European Space Agency, and Department of Defense facilities. No new ideas were offered and no flaws were identified in the JPL problem assessment or action plan.

### Galileo Mission Summary*

<table>
<thead>
<tr>
<th>Distance from the Earth</th>
<th>268,514,000 kilometers (164,417,000 miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance from the Sun</td>
<td>292,085,000 kilometers (178,850,000 miles)</td>
</tr>
<tr>
<td>Distance from Jupiter</td>
<td>1,112,000,000 kilometers (680,917,000 miles)</td>
</tr>
<tr>
<td>Round-Trip Light Time</td>
<td>29 minutes, 36 seconds</td>
</tr>
<tr>
<td>Velocity Relative to the Sun</td>
<td>19.3 kilometers per second (42,600 miles per hour)</td>
</tr>
<tr>
<td>Spacecraft–Sun Angle</td>
<td>12° off Sun</td>
</tr>
<tr>
<td>Spacecraft Spin Rate</td>
<td>3.15 revolutions per minute</td>
</tr>
<tr>
<td>Spin Configuration</td>
<td>Cruise mode, dual spin</td>
</tr>
<tr>
<td>Downlink Telemetry Rate</td>
<td>40 bits per second, coded (Low-Gain Antenna 1)</td>
</tr>
<tr>
<td>Powered Science Instruments</td>
<td>Dust Detector Subsystem, Energetic Particles Detector, Extreme Ultraviolet Spectrometer, Heavy Ion Counter, Magnetometer, and Ultraviolet Spectrometer</td>
</tr>
<tr>
<td>General Thermal Control</td>
<td>All temperatures within acceptable ranges</td>
</tr>
<tr>
<td>RTG Power Output</td>
<td>525 watts</td>
</tr>
<tr>
<td>Real-Time Commands Sent</td>
<td>7961 commands</td>
</tr>
</tbody>
</table>

*All information is as of June 25, 1992.*

### Assessing Anomalies

During the pre-cool phase for the sixth cooling turn when the S-band traveling-wave tube amplifier was commanded to the low-power mode, the Radiometric Calibration Target (RCT) Near-Infrared Mapping Spectrometer nickel transducer telemetry indication went into alarm to a saturation reading of 255 data numbers (DN). However, after return from the cooling turn attitude, the nickel transducer telemetry initially read 201 DN, but then subsequently saturated at 255 DN and has remained there since mid-April. A 255 DN reading may be indicative of an open interface between the transducer on the RCT and the Command and Data Subsystem (CDS).

For the first two months of 1992, the AC/DC bus imbalance measurements remained fairly stable. For instance, at the end of the DSS 43 track on March 7, the AC bus imbalance was reading 223 DN (44.3 volts), where it has generally remained over the last two years. However, at the beginning of the DSS 43 track on March 8, the AC bus imbalance was found to be reading 13 DN (3.1 volts), a change of 210 DN. This was the first large fluctuation observed on the AC imbalance measurement since it began in December 1989. Other AC fluctuations were observed again in May and June, at one point dropping as low as 5 DN (0 volts), and then increasing up to about 3 volts. Such large imbalance fluctuations have been observed before, but only for the DC measurement. All these fluctuations are likely caused by conductive brush wear debris in the Spin Bearing Assembly, causing interface “shorts.” These changes are consistent with the model developed by the AC/DC anomaly investigative team. As a consequence of the large AC measurement change, work was performed to analytically model the AC sensor/circuitry and to characterize the sensor hardware over a wide range of shunt leakage resistances. Additionally, a special test was performed on the spacecraft using the Energetic Particles Detector (EPD) to independently verify the 3.1 volt AC.
imbalance reading. Because of EPD measurement resolution limits, the test was inconclusive in totally substantiating the imbalance reading, but the test did verify that adequate bias was still present on the EPD.

A total of 17 unexpected CDU lock change counts have been observed between September 1990 and December 1991. Three of these are known to be caused by ground procedural/operational errors. The remaining 14 are still under investigation, but are believed due to a single cause. Recent laboratory tests have demonstrated that under conditions of low frequency sweep rates and low uplink transmitter power levels, the spacecraft hardware can normally produce spurious command lock changes; further work is in progress. In no instance did the spacecraft receive a spurious command as a result of these lock-change anomalies.

While Galileo was being reconfigured after the fourth warming turn in January 1992, anomalous command and telemetry signatures were observed. The spacecraft downlink was configured in two way, the telemetry rate was 10 bits per second, the solar range was 2.27 AU, the Earth range was about 3.25 AU, and the spacecraft was about 6.3 degrees from the Sun and moving toward solar conjunction. On January 12, while over DSS 14, the CDs telemetry indicated that uplink bit errors were being detected, and a short time later the ground receiver automatic gain control and signal-to-noise ratio telemetry indicators showed a gradual 6-decibel performance drop, thereby precluding the processing of spacecraft telemetry data. Later that same day, while over DSS 43, similar degraded telemetry performance was observed, but for a short period the telecommunications link improved enough to verify that the spacecraft health was normal. Throughout this period, there was no evidence that the CDs processed or executed a command. An intensive, thorough investigation into the anomaly revealed that a design change made to Galileo's Voyager-inherited radio receiver made the receiver more sensitive to solar-induced noise effects. Later, when beyond the effects of solar conjunction, flight tests were performed that demonstrated all spacecraft command-related hardware is functioning properly.

**Gaspra Science Return**

Last November, four images of asteroid Gaspra were retrieved from the Galileo spacecraft. Data were returned on eight consecutive tracking passes at Australia in mid-November using a modified 40-bits-per-second Data Memory Subsystem (tape recorder) memory read out (DMS MRO) technique originally used at 1200 bits per second after the Venus encounter. The performance of the DSN, the Flight Team, and the Ground Data System were outstanding throughout the data retrieval process. In May and June, the spacecraft transmitted asteroid data to each of the three 70-meter antennas at Goldstone, Madrid, and Canberra, culminating in retrieval of the highest resolution Gaspra image on June 5, also using the DMS MRO technique. The remainder of the Gaspra science data on three tape recorder tracks is scheduled to be returned late this November, when Galileo is close to Earth and higher telemetry data rates are possible.

**Reaching Aphelion**

On January 12, Galileo went through aphelion (the trajectory point at which the spacecraft was farthest from the Sun) at a solar distance of 2.27 AU. Galileo entered the solar conjunction period on January 13 and exited on January 30; the minimum solar conjunction angle of 2.27 degrees occurred on January 22. During the solar conjunction period, telemetry quality was poor, as predicted, and therefore, it was difficult in real time to comprehensively assess the spacecraft thermal status. However, as the Sun–spacecraft angle increased, and the telemetry link improved, it was inferred from trend data that no abrupt thermal changes occurred.

**Attitude Corrections**

Six SITURN's were performed during the first half of this year. A SITURN, on April 27, oriented the spacecraft to a 16-degree off-Earth pointed attitude (Earth-lagging) to improve telecommunications performance. Using real-time commands, the telemetry rate was increased from 10 to 40 bits per second coded telemetry in support of the HGA diagnostic motor turn-on activities in late April.

Periodic maintenance, flushing, of the Retropropulsion Module (RPM) 10-Newton thrusters continues. On March 10 and May 12, ten of the 12 thrusters were flushed; the P-thrusters were not flushed because they were used to perform SITURN activities. Spacecraft response throughout all the flushing exercises was normal.

**Navigation**

During May and June, three navigation cycles were performed. These navigation cycles provided near-continuous acquisition of two-way Doppler and ranging data. These data will improve orbit determination in preparation
for the trajectory change maneuver TCM-14 scheduled for August 4 through 7. The TCM is expected to impart a delta velocity of about 21 meters/second.

**GSOC Activities**

The Operations Plan for the German Space Operations Center (GSOC) Operations Team was completed by GSOC and published in the Galileo Space Flight Operations Plan. The Plan documents the organization, personnel roles, and operating mechanisms to be used by GSOC to provide Galileo cruise science support after the HGA is deployed.

**Ground Computing Activities**

In early April, the Multimission Operations Systems Office (MOSO) IBM 3090/150 computer and the Management and Administrative Support Systems (MASS) IBM 3090/200 computer were merged into one mainframe computing environment configuration. The merge was accomplished without error and did not impact Galileo Data Management Team operations or flight software development activities. As a precautionary measure, the MOSO IBM 3090/150 computer temporarily remains at the Information Processing Center as a backup. A demonstration of the MOSO Galileo Multimission ground data system (MGDS) Command Subsystem Version 17.1 was given to the project on June 3.

On April 27, the Unisys Steering Committee reviewed year-to-date and future costs, as well as cost savings options. The committee decided that with the current version (version 39) of the Unisys operating system, the JPL security requirements cannot be satisfied. Therefore, implementing and testing of the Unisys operating system version 41 are proceeding; all project testing activities are scheduled for completion on August 17. A target date of September 1, 1992, was selected for projects to complete certification of their application software in this new operating system environment. The Galileo Project is now planning for this upgrade and formulating a plan and schedule, based on the availability of personnel and resources, to accommodate this upgrade.

**Software Activities**

On January 8, the Project Change Board approved two Project Change Directives and five Software Change Requests authorizing the Mission Sequence System to implement the remote-sensing looper capability. A remote-sensing looper consists of a remote-sensing science activity sequence that is loaded on Galileo as part of a stored sequence, but whose execution is repeated (looped) one or more times following completion of the activity's first instance. This new looper capability is needed to support remote-sensing science activities at Jupiter. This new capability will be delivered at the C5.1 and D1.0 Project Mission Builds.

The C5.1 and C5.2 software development deliveries, encompassing a total of 22 program sets, were completed on March 26 and June 18, respectively. These deliveries provided updates to capabilities needed for Earth 2 sequence planning and sequence generation activities, as well as downlink support enhancements.

—Matt Landano

**Probe Checkout at Earth 2**

The upcoming Earth 2 activities include a Probe Mission Sequence Test (MST) and an abbreviated Probe Checkout. As defined by the Probe Engineering Team, the normal Probe checkout consists of a systems functional test (SFT) and an MST. The SFT provides a complete functional test at the subsystem level, while the MST thoroughly tests the actual Probe mission sequence, including the operation of the data and command processor and the Neutral Mass Spectrometer (NMS) valves. To date, only the SFT has been performed in flight, once eight days after launch and again at Earth 1. Dr. Hasso Nieman, Principal Investigator for the NMS, requested that the MST be performed periodically to cycle the NMS' valves to ensure its proper operation as the Probe descends through the Jovian atmosphere on December 7, 1995.

A full checkout of the Probe is planned prior to its release in July 1995. However, if the High-Gain Antenna (HGA) is not deployed by that time, in order to reduce the data playback time an abbreviated procedure will check only what is mandatory and could be corrected prior to release. This abbreviated checkout will also be verified at Earth 2. If the HGA is not successfully deployed, the activities at Earth 2 will provide a final thorough test of the Probe, including its scientific instruments. Consequently, the Probe Engineering Team and the Probe Science Team are eagerly anticipating the challenge of the Probe activities at Earth 2.

—Pat Melia
Keeping the Ground Systems Office Running on Track

A large and complex project like Galileo requires a correspondingly large number of complex computer programs and ground system capabilities to support spacecraft operations. The monumental and crucial task of coordinating the developing, implementing, and testing of these ground system capabilities is overseen by the Ground Systems Office (GSO) managed by John McKinney. The GSO coordinates and system engineers new Project and multi-mission data system capabilities that are added to Galileo’s support baseline. The GSO also verifies that these additions are compatible with the Project’s needs. The GSO is a staff-level office that reports to the Mission Director.

The specific tasks of the GSO include Mission Operations System (MOS) engineering (including leading the MOS Design Team, when active), Ground Data System (GDS) engineering, GDS integration and test, Project software management and systems engineering, configuration management, MOS training, Project computer security management, Central Software Library management, and Project documentation support.

Much of the GSO’s work involves managing and system engineering of software funded by the Project. Wayne Sible, the Ground Software Manager, and Susan Braun Alfaro, the Ground Software System Engineer (GSSE)

The Ground Systems Office coordinates the variety of ground support systems necessary to keep Galileo performing well. The GSO staff members are, from left to right, seated, Frederick Melikian, Katrina Walker, Dick Halverstadt, Betty Sword, and Georgia Stufflebeam, and standing, Betsy Wilson, Pat Laubert, Larry Bryant, Ed Garcia, Wayne Sible, and John McKinney. Susan Braun Alfaro is not pictured.
perform these functions. Wayne and Susan are not specifically tasked with developing the software (that is the responsibility of the Galileo Flight Team). Rather, they coordinate the software development, interfaces, and deliveries—no small feat, since the Project software includes nearly 3.4 million lines of code and 193 software interfaces. The software development teams will be rather busy this summer as they must deliver 2.7 million lines of code by September 1992.

As GSSE, Susan conducts the required system integration testing (SIT) to ensure correct data flow and performance for the Project software. Wayne and Susan also conduct the System Engineers’ Monthly Report (SEMR) meeting to review the status and plans for the software development. The SEMR is attended by the office managers and team chiefs and focuses on the development process, accomplishments, problems, high priority failures, action items, plans, and schedules. Susan and Wayne produce a summary report for the Mission Director after each SEMR.

In addition to substituting occasionally for John as acting Office Manager, Wayne was involved in developing the plan for bringing the Project software to the Level 41 operating system on the Unisys computer. He recently completed the task of coordinating the Project testing of the level 41 Unisys upgrade and the testing required to transition the Galileo application software to the new IBM 3090 computer. This activity represented the merging of Flight Projects Office and Administrative Computing into a more cost-effective computing environment.

Once the individual data system capabilities have been developed and tested, it will be necessary to integrate the individual programs and test the overall support capabilities to ensure that Galileo support requirements can be met. GDS Integration Engineer Betty Sword conducts the critical GDS tests to verify the end-to-end data flow from the Deep Space Network (DSN) through the MGDS to the Project, or in the case of cruise science operations, from the German Space Operations Center (GSOC) through the MGDS to the Project. Prior to launch, GDS tests were conducted to demonstrate data flow from the Shuttle system through the MCCC to the Project. Even during times of infrequent Project changes, Betty continues to test new multimission support capabilities introduced by the DSN or MOSO. For example, the DSN has significantly upgraded their computer capabilities to prepare for the launch of Mars Observer. Although there are no new capabilities for Galileo, Betty participates in Multimission Verification Tests to ensure that the new software will support Galileo. She also conducts GDS tests prior to such major mission events as Gaspra and Earth encounters.

Planning and conducting MOS training and operations readiness exercises is the job of Galileo MOS Test and Training Engineer Larry Bryant. Most training on Galileo is the responsibility of the individual teams and offices, but when an exercise involving the entire Flight Team is necessary, Larry steps in to plan and conduct it. This type of exercise usually occurs prior to a major mission milestone, such as launch, or prior
to a significant change in new support capabilities. For example, Larry is currently working on defining and coordinating the training needed to transition the Flight Team to the new MGDS data system capabilities.

Tina Walker, Ed Garcia, and Pat Laubert, the Configuration Management Support Staff, maintain the configuration baseline for Galileo. One of their tasks is to coordinate and run the Project Change Board (PCB). The PCB consists of the Project Manager, Mission Director, and Office Managers, who meet regularly to consider changes to the Galileo support configuration. These changes include Sequence Change Proposals, Software Change Requests, Project Change Directives (document changes), and waivers to Mission and Flight Rules. Tina, Ed, and Pat also maintain the databases and Level 5 software development schedules for the Project.

Documentation changes usually involve updates to the Project documentation, and it is Georgia Stufflebeam who updates the documents, coordinates final drafts with the requester, and manages the final distribution. Examples of documents regularly updated by Georgia include Software Requirements Documents, User Guides, Software Interface Specifications, and Team Operations Plans. She also maintains the Project computer equipment inventory and the team interface database. Frederick Melikian, an academic part-time employee at JPL and a Glendale College student, assists Georgia. He has considerable computer and word-processing expertise and is frequently able to help the people in the Project Office.

In addition to managing the GSO, John McKinney also performs GDS and MOS engineering duties. As GDS Engineer, John defines Project support requirements and coordinates the development and implementation of ground system capabilities with the Project, DSN, GSO, and MOSO. He represents the MOS in Galileo low-gain antenna studies, coordinates the conversion to the new MGDS being developed by MOSO, and works with GSO to coordinate the start of cruise science support after deployment of the High-Gain Antenna. In addition to his many and varied Galileo duties, John also supervises the Ground Data System Engineering Group in Section 317.

John grew up in the small town of Crane, Texas, and attended Texas A&M University, where he earned his master’s degree in mathematics and computer science in 1967. After college (which included ROTC), he signed up with the Air Force and was assigned to the Air Force Satellite Control Center in El Segundo, California. Soon after his arrival in California, he met and married Eileen, who was then working as an executive secretary and administrative assistant. In 1971, after leaving the Air Force, John pursued his lifelong interest in space exploration by applying for a job at JPL. He was hired by none other than Galileo Mission Director Neal Ausman to oversee the development and operations of the Sequence Events Generator Program for the Mariner ’71 Project. Then the Mariner–Venus Project beckoned, and John supported the MOS design and served as a mission controller during operations. After Mercury encounter, John moved on to the Voyager Project to serve as the Mission Sequence System Engineer. Finally, in 1978, he joined the Galileo Project as GDS System Engineer, eventually to become the GSO Manager.

Eileen and John have two sons, Michael and Matthew. Michael graduated from the University of California at Irvine in June and is now enrolled in graduate school at USC. Matthew, an avid follower of the exploits of the crew of the Starship Enterprise, is a third grader at Stowers Elementary School in Cerritos. The McKinneys are active in the PTA (Eileen is a PTA board member), Cub Scouts (Eileen is a Den Leader and John is Pack Treasurer), City League baseball, and soccer. Somehow they also find time to be active members of the JPL Amateur Radio Club as well—John is a past treasurer and president and Eileen has edited the club’s newsletter for the last 11 years. It seems that John is working 24 hours a day, and even many of his leisure activities are extensions of his JPL work. He spends a lot of time at his home computer, and on Saturday mornings he teaches programming to seventh and eighth graders at a school near his home. In addition, his trips to Germany to coordinate GSO support and a passion for classical music have led John to become something of a Mozart fanatic. And, while he reads technical books “just for fun,” during last year’s 200th celebration of Mozart’s death he turned to reading various biographies of the composer. When time permits, John also enjoys fishing and has made several deep-sea fishing expeditions with his son Michael.
at any time since then. Three weeks after EGA2, in the last week of December, we will have the first opportunity to restore the HGA to assembly dimensions. Galileo will be 1.0 AU from the Sun, where a warming turn will expand the tower to assembly length for the first time. While considered unlikely, it is possible that this action alone will free the ribs.

"Hammering" the deployment system is our very best prospect to free the ribs. While performing investigative testing on the flight spare HGA at JPL early this year, it was discovered that pulsing the deploy motors rotated the deployment ball screw substantially beyond its continuous run stall point. Following the extension of the tower, we will hammer the ball screw as far as it will rotate by pulsing the motors. During the April 1991 deploy attempt, the ball screw stalled at 5.1 turns. Our recent ground tests and motor pulse test on the spacecraft indicate we can advance the ball screw 1.5 turns by a combination of running the motors continuously at warm temperatures (windup) followed by about 1000 pulses. This will double the force in the highest loaded rib deploy pushrod. There is a good chance that before reaching the new hammer stall point, the rising force in the pushrod will overcome the rib restraint and pop the rib free. The dynamic effect on the deployment mechanism of this rib springing out could free the other ribs. If this "zipper" action does not occur, then we will resume hammering the now softer system. This will increase the force in the remaining stuck rib pushrods by several factors. The hammering technique has the prospect of actually yielding (permanently deforming) any stuck pins and receptacle surfaces.

While the prospects of freeing the HGA by the above method are good, we must be prepared for the possibility that the ribs will remain stuck. Earlier this year, the Project, in conjunction with the Telecommunications and Data Acquisition (TDA) organization at JPL, studied how to maximize the mission return over the Low-Gain Antenna (LGA). We have always known we could perform the atmospheric entry Probe mission and put the Orbiter into Jupiter orbit without the HGA. The challenge was to return Orbiter science, particularly imaging, over the LGA. The joint Galileo and TDA study determined that improvements in the Deep Space Network (DSN) antennas and arraying of antennas in conjunction with data compression on board the Galileo spacecraft would enable the return of a tape recorder load of data each Jupiter orbit. Each tape load could contain 200 to 400 images, as well as data from all the other lower rate instruments. So, in our primary 10-orbit mission, we could return 2000 to 4000 images. Most of these would be the high-resolution satellite images that have always been a very special feature of the Galileo mission. Fields and particles data would be returned nearly continuously at low rates. Our overall estimated science return for the LGA mission in percentages of the primary HGA mission breaks down as: atmospheric science, 80%; satellite science, 70%; and magnetospheric science, 60%. NASA Headquarters has accepted our recommendation that we proceed with the implementation of the LGA mission on March 1, 1993, if the HGA is not deployed by then. The implementation will include new DSN hardware and software and major new flight software for the Galileo Command and Data Subsystem (CDS) and Attitude and Articulation Control Subsystem (AACS). With or without the HGA, Galileo will be a spectacular mission at Jupiter!

Finally, I am very pleased that an excellent Jupiter satellite tour was designed and selected on schedule, May 1, and, concomitant with the selection, the Project recommended and NASA enthusiastically approved the August 1993 asteroid Ida encounter.

—Bill O’Neil

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