From the Project Manager

We are entering a critical stage in the life of any mission — integration and test. Now comes the “proof of the pudding” — whether all subsystems will fit together and play together as planned and designed.

The Galileo Probe is already undergoing system tests, and has been in integration testing since last spring. Environmental testing — thermal vacuum, vibration, pyro shock, descent pressure and temperature, and entry deceleration (high-g) tests — will begin at Hughes Aircraft Company in January 1983. Problems with the data and command processor have delayed the start of environmental testing by two months, but Hughes still expects to be able to deliver the Probe to JPL in October 1983 for integration with the Orbiter.

Orbiter system test and integration is scheduled to start in February at JPL’s Spacecraft Assembly Facility (SAF). Some of you already may have had an opportunity to view the high-gain antenna assemblies from the high-bay viewing gallery as they undergo testing. Dr. Lew Allen, JPL’s new director, was part of a group on-hand to view the deployment test of the flight antenna on October 15.

The Galileo Orbiter is the most complicated of any JPL system yet devised. The need to fit within the Shuttle’s cargo bay necessitated the furlable antenna and the folding booms for the radioisotope thermoelectric generators and some of the science instruments. The need to provide a steady platform for the optical instruments yet still allow the fields and particles instruments to sweep the entire sky necessitated the dual-spin design. To assure reliable electrical interfacing across the spun-despun section, a hybrid approach was devised, using slip rings for power and grounding and rotary transformers for high rate data signals.

Meet the Team

Asked to describe Galileo’s Flight Systems Integration Manager, one staff member grinned and said, “He’s a Polish mechanical engineer who drives a Corvair he spent a year rebuilding.”

Dick Spebalski, also known as Spe, says he’s been at JPL “all my life,” but he actually came here directly from Cornell in 1959. Spe is responsible for the mechanical engineering aspects of the Galileo Orbiter; integration with the major external interfaces including the Shuttle, Centaur, Department of Energy (RTGs), Federal Republic of Germany (RPM), and the Probe; and Orbiter and Spacecraft system test and launch operations.

“Moving from the expendable launch vehicles to the Shuttle has brought a new set of complex interfaces and exacting safety requirements,” Spe notes. “Integration with the external interfaces has presented a demanding set of tasks. Frequent reprogrammings have kept our own designs and interfaces in a state of upheaval, but meeting the challenges has been interesting and rewarding.”

Prior to joining Galileo in 1977, Spe was the Applied Mechanics Division Representative to the Voyager Project see Page 4

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John Casani

Dick Spebalski
S- and X-Band Antenna

The protoflight and flight units of Galileo's main antenna arrived at JPL in late summer for test and integration. Lou Keeler, technical manager for the antenna system, provided the following summary of its design.

The communications antenna aboard the Galileo Orbiter is a 4.8-meter diameter space-deployable rib and mesh structure. In order to fit in the Space Shuttle's cargo bay, the antenna must be furled during the launch phase. After deployment from the Shuttle, the antenna will unfurl to be nearly 16 feet in diameter; it weighs only slightly more than 76 pounds.

The antenna was designed and developed by the Government Electronic Systems Division of Harris Corporation in Melbourne, Florida, and is designed for S- and X-band frequencies. The predicted gain is 50.1 decibels (dB) at 8418 MHz and 37.6 dB at 2295 MHz, while half-power beamwidths are approximately 0.45 degrees and 1.8 degrees at 8418 MHz and 2295 MHz, respectively.

Testing is now beginning at JPL with radio frequency performance and vibration, acoustic, and thermal/vacuum environmental testing. The antenna is a modified version of that developed for the Tracking and Data Relay Satellites (TDRS), the first of which will be launched on the Shuttle next year.

The Galileo antenna uses 18 rigid graphite fiber-reinforced epoxy ribs to shape and support the reflective mesh surface. The reflector mesh is made of a fine-drawn (1.2 mil diameter), gold-plated molybdenum wire which is knitted into an elastic fabric capable of being folded for the launch configuration and unfolded in orbit while maintaining precise surface contour geometry. The high-accuracy surface contour is achieved through the use of a secondary drawing surface-shaping technique. A series of circumferential multi-strand quartz cords is attached to the rear side of the ribs by adjustable standoff devices, while a second series of circumferential quartz cords runs parallel to the front cords and is attached to the front mesh surface. Fixed-length stainless steel tie wires connect the front and rear cord systems and shape the mesh paraboloid in the circumferential directions. Through a series of rib rotation adjustments, standoff height adjustments, and rear cord length adjustments, the desired shaped paraboloid contour is achieved, with approximately 0.020 inch root mean square (RMS) contour roughness. Small black spots on the mesh are targets for theodolite (surveyor's angles) measurements that are fed into a computer when the surface shape is being adjusted.

The 18 rigid ribs are folded and preloaded around the central feed support tower during the launch phase of the mission. Deployment begins with the energizing of redundant non-explosive initiators which release a central release mechanism, freeing the rib mid-points from their stowed and locked configuration. At this point, a mechanical drive unit begins rotating a ballscrew assembly, causing a ballnut and carrier assembly to begin translating along the antenna boresight axis. As the carrier translates, 18 spring-loaded pushrods begin rotating the ribs outward. Once the ribs have hit pre-set mechanical stops, the drive unit continues raising the carrier assembly, the pushrod springs compress, and an over-center condition is reached with the ribs positively preloaded against their stops and the mesh surface properly tensioned. The mechanical drive unit for this antenna, called the Dual Drive Assembly, was designed and built by JPL design personnel and features fully-redundant brushless DC-type motors driving redundant harmonic gear passes.

Both S- and X-band feed systems are supported from the reflector structure by a six-strut truss system made of lightweight beryllium tubes which allow adjustability in order to align the feeds with the final reflector surface geometry.

The X-band system uses a frequency selective subreflector in a Cassegrain configuration. The S-band system is a focal-point feed reflector system. The frequency selective surface passes S-band energy and reflects X-band energy. This allows the S-band focal-point feed to be located behind the X-band Cassegrain subreflector. The subreflector was specially shaped to optimize X-band performance.

The S- and X-band energy is transmitted through a dual-skin quartz and

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*Ed. note: On a machine that usually knits nylon bosiery.
Nomex honeycomb radome structure. A thin shell beryllium structure atop the radome houses the rib central release mechanism and supports a Kevlar tower on which is installed a low gain antenna and components of the Galileo Plasma Wave Subsystem experiment. The ribs and the central tower are covered by a black material that serves as part of the thermal blankets or as a conductive surface to remove electric charges.

**Potpourri**

Two major Galileo reviews — the design of the fault protection system and the plans for design verification and system test — occupied a full week of the November calendar. The broad scope of the reviews forced an extreme-ly valuable system integration process, and an enormous amount of information was exchanged.

Many of us rejoiced when the reviews were completed, but not solely for the quality of the reviews. We celebrated because the climate has changed on the Project. As we near the start of system testing, the business of engineering now dominates our discussions. After years of delays and reprogramming replete with anxieties about the very survival of Galileo, it is now clear that we have a project. The job we must do now is the one we all know best — build the highest quality spacecraft possible within the cost and schedule constraints, and send it to Jupiter to gather for all mankind the secrets of the giant planet and its fascinating moons.

— Gentry Lee

**Attitude and Articulation Control**

The dual-spin Galileo is a challenging departure from the traditional three-axis stabilized and all-spin spacecraft which have plied the solar system in the past. The configuration combines attributes of both types of vehicle: an inertially stable platform for precisely aiming optical instruments, and the sky-sweeping continuous rotation desirable for fields and particles experiments.

Though gyroscopic stability is a favorable aspect of this system, the dual-spinner poses a unique set of control problems by introducing the complexities of rotational dynamics into the critical pointing control considerations which occur in the three-axis design. Combine these factors with the need for advanced flight software capable of providing autonomous operation and onboard attitude determination, and it is apparent that the Galileo Attitude and Articulation Control Subsystem (AACS) represents the most sophisticated state-of-the-art application of control system technology.

The AACS consists of many individual components, all governed by the Attitude Control Electronics (ACE), the heart of which is an ATAC-16MS 16 bit/word microprocessor. The ACE communicates with the Command and Data Subsystem (CDS) via the spacecraft CDS bus, receiving commands and transmitting telemetry as required. The ACE also controls the Retro Propulsion Module (RPM) via the Propulsion Drive Electronics (PDE) which contain the logic and drive electronics for the thruster valves and latching isolation valves.

The AACS utilizes a Star Scanner (SS) mounted to the spinning part of the spacecraft as its primary source of attitude control data. A photomultiplier tube senses star crossings through a V-slit aperture and lens system, providing information which is processed by the AACS software and compared against an onboard star catalog. This is the basis for Galileo attitude determination relative to an inertial coordinate system. Galileo has adopted the Earth Mean Equator of 1950 (EME-50) as its standard reference frame. Command and control of Galileo is facilitated entirely by the AACS through this reference system.
AACS (contd)

A set of gyroscopes is attached to the scan platform to provide three-axis inertial reference for the platform. This allows the scan platform to compensate for spacecraft motion. Gyro data is also used for spacecraft orientation during periods when the star scanner is not usable as, for example, during maneuvers.

Acquisition sun sensors on the spinning section sweep the sky and generate back-up spin rate and sun direction information. This provides a simple method by which a sun-pointed orientation can be achieved from any random attitude. This is important for attitude recovery in the event of a failure.

Two accelerometers measure spacecraft velocity changes along the spin axis. This is used to control the magnitude of trajectory correction maneuvers as well as for compensation for non-gravitational forces which affect navigational accuracy. Galileo can also perform lateral velocity changes by timed thruster burns.

The Spin Bearing Assembly (SBA) couples the spinning and non-spinning parts of the Orbiter, referred to as the rotor and the stator, respectively. A brushless DC motor provides the torque necessary to spin or de-spin the stator. By counter-rotating the stator at precisely the rotor's rate of spin the stator remains fixed in inertial space. The SBA also provides the means to articulate the scan platform, which is mounted on the stator, about the spin axis or "clock" direction. Electrical interfaces between the stator and rotor are contained within the SBA. These consist of slip rings for power transmission and rotary transformers for data transfer.

The Scan Actuator Assembly (SAS) is a bearing assembly with motor similar to the SBA. It is used to articulate the scan platform about an axis perpendicular to the spin axis, known as the "cone" direction. Thus, the scan platform can be pointed as desired by appropriate combinations of SAS and SBA motion commanded by the attitude control electronics. Both the SAS and SBA contain optical encoders which provide very precise position information. The ACE communicates with the SAS, SBA, gyros and accelerometers through the Despun Control Electronics (DEUCE) unit.

Wobble control of the Orbiter is achieved by changing the angle at which the RTG booms are canted to the spin axis. This is controlled by Linear Boom Actuators (LBA) which utilize stepper motors driven by the ACE.

The AACS must satisfy very stringent requirements imposed by the Galileo mission. In order to provide communication with Earth, the High Gain Antenna (HGA), which is aligned with the spin axis, must be pointed accurately. Control of the spin axis orientation is also important for the science instruments. Those on the scan platform must be pointed in a manner which corrects for spacecraft motion (wobble, nutation, etc.) as well as the relative angular motion between the spacecraft and a scan platform target (target motion compensation). Additionally, the fields and particles instruments mounted on the rotor require that the spin rate be carefully controlled. Probe release is initialized at a specific attitude and rate, also under the control of the AACS.

The AACS provides measurements of the Orbiter and scan platform attitudes and rates. Particularly remarkable is the fact that the AACS corrects this data for known errors that affect Orbiter and scan platform orientation and converts the information to the EME-50 coordinate system before it is telemetered (sent to Earth). This allows simplification of ground support systems, both in command preparation and pointing reconstruction, thus reducing operational costs.

The design of the AACS incorporates the ability to detect failures and switch to redundant components in order to continue as normal an operation as is possible in an anomalous situation. As was the case with other advanced planetary spacecraft such as Voyager, this is necessary because of the enormous distances and the attendant communications delays which could result in the loss of the spacecraft if there were no provision for self-diagnosis and correction.

— Ed Litty
George Carlisle

Spebalski (contd)

from inception through launch. He gained his earlier experience starting on the Sergeant missile system and continuing through the Mariner Venus and Mars missions.

Spe 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 (both lake and deep sea), boating, and camping with his family. He also plays handball several times a week to keep in shape, and tinkers with the old Corvair.

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