From the Project Manager

While awaiting NASA’s final decision on the launch date for the Galileo mission, many important events have occurred. We all regret the departure of Al Wolfe, who is now Chief Engineer of Flight Projects for the Laboratory. Al had been with Galileo since 1977 as the Deputy Project Manager. Al’s professionalism, thoroughness, and dedication will be missed, but we wish him well in his new position.

Over the past few months there have been mission changes, as well as management changes. As you may recall, most early plans for Galileo called for direct flights to Jupiter. The Centaur upper stage provided sufficient energy to place the spacecraft on a direct trajectory.

After the Challenger tragedy on January 28, 1986, NASA placed severe new constraints on shuttle operations and cancelled the shuttle/Centaur program. Without the Centaur, a direct flight to Jupiter was impossible. Investigation of a new launch-vehicle configuration began in concert with new trajectory options to see which would allow Galileo to arrive at Jupiter and perform a mission with the greatest possible science return. Those studies included Vega trajectories, various shuttle/upper-stage combinations, and expendable launch vehicles.

Dr. Roger Diehl began to investigate a new series of low-energy launch options. He soon realized the way to get to Jupiter using a low-energy launch was to go first to Venus — the Venus-Earth-Earth Gravity Assist (VEEGA) trajectory concept, nicknamed the “Solar Cruiser.”

This new trajectory requires a series of modifications to the spacecraft for thermal protection, telecommunications requirements, and the six-year-long cruise.

Galileo was designed to operate between 1 AU and 5 AU from the Sun (1 astronomical unit (AU) = 150,000,000 kilometers or

— see page 4
Radio Science

There are three separate radio science experiments planned for the Galileo mission: radio propagation, celestial mechanics, and gravitational wave search. Although all have certain hardware in common, they utilize different radio signals at various times.

Measuring Radio Waves

The radio propagation team will investigate Jovian atmospheric temperatures, pressures, and structures, and will search for ionospheres of the satellites. In addition, the team will study the solar wind and Jupiter's inner magnetosphere.

The radio propagation experiments measure the minute changes in frequency, power, time delay, and polarization of the spacecraft's radio signal, left over after the speed and position of the Orbiter are removed. The experiments can be conducted when anything is between the Earth and the spacecraft: a planet, a satellite, the Sun, or the solar wind. These are usually times when the signal is too noisy for navigation or celestial mechanics experiments (although there is occasionally some overlap).

As Jay Breidenthal, the science coordinator for radio propagation, says, "one man's noise is another man's data."

For example, when Jupiter's atmosphere is between Galileo and the Earth, a signal emitted from the spacecraft will travel through the Jovian atmosphere in order to get to Earth-based antennas. As a consequence, the radio signal received is slightly different than the signal originally sent. "This is due, in part, to bending of the radio waves, as well as the effects of layering, turbulence, and bubbles of hot and cold gas in the atmosphere upon the radio signal," explains Breidenthal.

A related atmospheric experiment will be conducted during the descent of the Probe. Using the radio signal between the Probe and the Orbiter, the team hopes to observe changes in the wind speed with altitude and to gain some understanding of whether heat is moving downward or upward through the atmosphere.

Another radio propagation experiment will study the solar corona. When Jupiter, and consequently the spacecraft, are on the side of the Sun opposite from Earth, a signal sent from the spacecraft must travel through the solar corona before reaching the Deep Space Network's (DSN's) antennas. Therefore, scientists will study the Sun with the same techniques they will use at Jupiter.

One interesting but puzzling phenomenon scientists hope to better understand is the acceleration of the solar wind. At the surface of the Sun, the solar wind is traveling very slowly. Yet, by the time it reaches the orbit of Mercury, it has accelerated enough to escape the Sun's gravitational pull.

The signals from Galileo will be filled with "noise" from a variety of radio sources and will be incredibly weak (about a billion times fainter than the sound of a transistor radio in New York as heard from Los Angeles), and the effects are very minute (about the same as measuring the distance between New York and Los Angeles to an accuracy of a human hair). Needless to say, these measurements are difficult. So much signal power is lost cutting through Jupiter's atmosphere that the ordinary receivers used for telemetry will no longer function. However, the team plans to continue recording even after the signal appears to stop. With subsequent computer enhancement, they will be able to extract another hour's worth of data — about a 30% increase in data acquisition for each occultation.

For Galileo radio science, it proved advantageous to put about 80% of the measuring equipment at the DSN stations, quite unlike the other experiments which have nearly all of their equipment on the spacecraft itself. Emphasizes team leader H. Taylor Howard, "Our ground-based equipment is both a curse and a blessing. It is complex and requires careful adjustment; but if there is a failure or we find something surprising, we don't have to pack up and go home — repairs and changes can always be made."

The U.S. team has joined forces with the Deutsche Forschungs- und Versuchsanstalt für Luft und Raumfahrt (German Institute for Aerospace) for studies of the Sun during Galileo's cruise to Jupiter.

Partially in preparation for the Galileo radio propagation studies, the DSN is building several new

When Galileo's radio transmitter beams a signal through Jupiter's atmosphere, the changes in the signal allow scientists to estimate the atmospheric density, temperature, and pressure.

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antennas and receiving systems. The new equipment will be able to continuously detect and calibrate the slowly rotating, linearly polarized signal from Galileo. Existing antennas either were too inefficient or could follow only a few turns before losing the signal, and existing receivers were not accurate enough.

Involved in the radio propagation task are five scientists dedicated to radio propagation, as well as several other team members who work on all three radio science experiments. The team leader for the experiments is Professor H. Taylor Howard from Stanford University.

Performing Celestial Mechanics

The Celestial Mechanics (CM) and Relativity experiment on the Galileo spacecraft will more exactly determine the orbits and will reveal information about the interior compositions of Jupiter and its satellites (whether there are definite boundaries of rock and ice or whether they are homogeneous throughout).

The gravity fields of the planet and satellites will be measured. Much as our moon affects ocean tides on the Earth, so any large body influences another near it. Jovian gravitational fields will affect the flight of the spacecraft, and Earth-based observers can measure that effect.

To do this, a two-way radio link will be established between Galileo and the ground stations on Earth. A signal sent from Earth to the spacecraft, in either the S-band or X-band, will then be returned by the spacecraft to Earth. Because of the tugging of gravitational fields upon the spacecraft, the radio signal will be altered slightly. The difference between the signal received and the one sent will give valuable data to the science team.

Often the radio signal will be scintillated. Such outbursts denote interference from a variety of sources, including interplanetary media and the particle environment around Jupiter.

The CM team will utilize an S-band uplink, a transponder, and a 5-m parabolic dish antenna to send simultaneous, clear downlink signals at two different frequencies. The CM is a part of the radio science system onboard Galileo. The team leader for the CM experiment is Dr. John Anderson.

Searching for Gravitational Waves

A very different aspect of the celestial mechanics experiment involves a search for gravitational waves. Gravitational waves are extremely faint perturbations in the interstellar medium caused by momentous occurrences.

The idea behind the Gravitational Wave Search (GWS) is that there is constant gravitational radiation from the cosmic background. Very rarely, when stellar or galactic catastrophes happen, this background is overwhelmed and a “pop” may be heard at very low frequencies (with periods of about 20 minutes). The GWS will hear three “pops” at the Earth-based detectors — one at the Earth, its echo, and one from the spacecraft.

For example, if two black holes were to collide, the collision would set up a gravitational rippling in the interstellar medium. That ripple would eventually reach the radio signal stretched between Galileo and the Earth. Scientists would detect three “pops” as the ripple passed through and interfered with the signal. The Ulysses spacecraft, also in that region of space, could possibly then confirm the detection.

John Anderson explains, “We will only see catastrophic events, perhaps the collapse of an object with 10,000,000 times the mass of the Sun. While we hope to actually detect gravitational waves, the absence of any waves will still give us valuable information.”

The problem for searchers today involves the limits of the length of Earth-based detectors. Ideally, a detector would be several billion miles long. Galileo presents a unique opportunity, because the detector will be the radio signal stretched between the spacecraft and the Earth: a detector about 2 billion miles long. If gravitational waves exist, as scientists surmise, then there is about a 40% chance of detecting these waves on Galileo’s cruise to Jupiter. Different events will have different radio signatures — a black hole will “sound” distinctly different from a binary pulsar.

When such waves are detected, the GWS team, led by Dr. Frank Estabrook, can help ground-based observers scan the skies for visual confirmation and identification of the source of the waves.
The May 1986 launch plan included a flyby of the asteroid Amphitrite. The Amphitrite opportunity is lost, but since Galileo will make two passes through the asteroid belt the prospects for finding another asteroid target are good.

Our crew at the Kennedy Space Center has finished the electrical testing on the Orbiter. Most of the crew returned home for the Thanksgiving holiday, and will remain here until just before launch in 1989. The spacecraft, originally planned for return to JPL last August, is being kept at the Cape for further software testing and troubleshooting. We are decontaminating the retropropulsion module oxidizer tanks which had been filled for the May 1986 launch. The spacecraft will then be returned to JPL in February 1987 for VEEGA modifications. Following this work, Galileo will undergo a new series of system-level environmental tests in 1988.

The Probe was sent to JPL from Hughes last month. The science instruments have been removed and are being upgraded. Re-integration of the Probe and instruments is scheduled for early 1988.

— J.R. Casani

Meet the Team

Many people have been with the Galileo Project for a number of years; however, few can say they started earlier than David Smith. In 1973, as Trajectory Mission Design Group Supervisor, Dave Smith co-authored a paper entitled "Jupiter Orbiter Probe Tour Mission." This was the first complete description of what was to become the Galileo Mission.

As manager of JPL’s Spacecraft Data Systems Section, Dave is responsible for the Galileo Orbiter’s Command and Data Sub-system (CDS). Recently, John Casani, Galileo Project Manager, asked Dave to prepare an additional CDS (with over 12,000 components) for Galileo, a job which will take Dave’s section over 12 months to complete. Galileo’s spare was slightly modified and given to Magellan without the despun section.

Dave began his scientific career at the University of West Virginia in 1958, majoring in aerospace engineering. He received his master’s degree from USC in 1965, and then went to TRW. He has been with JPL since 1971 in a variety of capacities including the Low-Thrust Navigation Team leader, Magellan and Halley Science and Mission Design Manager, and Mission Design Section (312) Manager. His diversity of jobs reflects his personal strength, “I’m well-rounded . . . not too specialized, but competent at many things.”

His first job at the Lab had nothing to do with deep space missions. JPL had a contract with the Department of Transportation to develop a personalized rapid transit system (a robotic system like the automated tram that used to be at JPL). The system would become a part of “Morgantown” at Dave’s alma mater. “It was very exciting, returning to West Virginia to meet and work with the people back there,” he remembers.

A man of many interests (a member of the JPL Gun Club, a chess player, and a bridge player), he is perhaps most passionate about sports. In high school, he was an all-state player in baseball, basketball, and football. In fact, he was once tempted to pursue a career coaching college football instead of engineering. And, although he did play semi-professional football with the California Razorbacks (a member of the Western Football League), the Galileo Project is pleased he chose to remain in science.

Dave and Nancy, his wife of 27 years, have three children. When asked about future plans, Dave quipped, “My only plan is to deliver a CDS to John Casani.”

David B. Smith