From the Project Manager

The launch of the Galileo spacecraft, that momentus event on which our collective energy was focused for such a long time, is now history. We shall continue to look forward to the many tasks that must be successfully accomplished to obtain the scientific knowledge that we seek from the Galileo mission. However, the act of launching and successfully achieving our flight path to Venus is of such significance that it merits some special attention while it still lingers in our memories.

The Galileo launch, to many of us, represents a culmination of years of personal and team efforts and of sacrifices. The emotions present within each of us at such an event defy description. To some, the launch represents the completion of a challenging spacecraft development, to others the start of an exciting mission. To many, it is a shift from one to the other, but nevertheless a soul-stirring event.

From my perspective as Project Manager, I was fortunate to witness the coming together of such a diverse set of activities that it boggles the mind. The professionalism, teamwork, and dedication visible in this process was truly inspiring to behold.

To those of you that will not continue the mission with us, I thank you and wish you great success in your future endeavors. To those continuing on with us, I am certain we will have challenges to fully exercise our talents. To all, I thank you and wish you God-speed.

— R. J. Spebalski

Launch at Last!

Launch to Landing

At 9:54 A.M. Pacific Daylight Time (PDT), on October 18, the Space Shuttle Atlantis was launched under a sky filled with puffy, white cumulus clouds. The Galileo spacecraft, destined for Jupiter, began its six-year journey.

At the Kennedy Space Center and at JPL, Flight Team members and their families nervously watched the launch. Applause erupted at the moment of lift-off and again as the Solid Rocket Boosters separated from the Shuttle. As the mission progressed, tension was visibly released.

It seemed as though Galileo was fated to be delayed. Worries over whether Hurricane Hugo would come onshore at the Kennedy Space Center mounted until, at the last moment, the destructive force of the storm swept north of the launch site. Engineers relaxed as the decision to leave Atlantis and Galileo on the launch pad proved to be well-founded.

As the first day of the launch period approached, excitement mounted on both coasts as the long-awaited day neared. On Monday night, October 9, technicians discovered a glitch in the Shuttle's second main engine controller. The decision was made the next day to replace the faulty computer, thereby delaying the
scheduled October 12 launch until sometime the following week. The new lift-off date of October 17 looked good all around. The Shuttle was performing well, Galileo was nestled in its payload bay, and the astronauts boarded Atlantis. As time passed, however, the clouds began to multiply. Countdown continued until the last possible second, when the Launch Director scrubbed the launch because of the inclement weather.

Weather conditions around the globe can affect the Shuttle's lift-off because, if the Shuttle needed to return to the Earth shortly after launch it could do so at several sites: Ben Guerir, Morocco; Moron, Spain; Banjul, The Gambia; Edwards Air Force Base, California; White Sands Space Harbor, New Mexico; or at KSC itself. Because of the inclement weather at the Cape, that landing site was not available and the launch was delayed again.

As the Galileo team looked forward to launch the next day, disaster struck Northern California. A 7.1 earthquake, centered just 15 miles south of Sunnyvale, caused evacuation of the Inertial Upper Stage (IUS) control center there, which was crucial to mission operations. The crew recovered as the night progressed and JPL was receiving the required data as launch neared.

Even as the moment of final launch approached, the clouds looked ominous over the Kennedy Space Center. However, at last, nature cooperated and STS Mission 34 was under way.

At about 4:15 P.M. PDT, Mission Specialist Shannon Lucid initiated Galileo's deployment. As deployment finished, STS-34 Commander Donald E. Williams declared, "Galileo is on its way to another world. It's in the hands of the best flight controllers in this world — fly safely."

One hour later, the IUS rocket ignited, propelling Galileo toward its first encounter, Venus. As the second stage of the IUS fell away from the spacecraft, Galileo was finally on its own, its destiny in the hands of the Flight Team.

It seemed to be a mission of accomplishment in the face of adversity. Even after deploying the spacecraft, the landing proved to be a concern. Heavy winds were forecast for the California desert, and so the landing time was accelerated by two orbits (three hours). An hour or two before landing, the fog was rolling off the hills into the dry lake bed. Then, the skies cleared just before the Shuttle was scheduled to land. As the Space Shuttle Atlantis touched down in a picture-perfect landing at Edwards Air Force Base, the crowds cheered. It was a strange blend of viewers — Galileo Flight Team members, reporters, a host of people (some of whom had retired years ago) who had at some time helped to design and construct Galileo, and, most important, the American public who paid for the mission.

The Acting Associate Administrator for Space Flight summed up the feelings of many, "Galileo is on its long, multiyear odyssey to Jupiter. Before, we have gotten a fleeting glimpse [of Jupiter]. This time we will be stopping. This is the real crowning accomplishment of this mission, to get Galileo on its way."
Galileo: 
Up to Date

The Galileo spacecraft is performing without a significant flaw. Just a few days after the Shuttle Atlantis propelled Galileo on its way to Jupiter, the Mission Operations Team began sending commands to the spacecraft. As of October 27, over 250 commands had been sent to the spacecraft in "real time." In general, the spacecraft is operated using sequences transmitted from the ground and stored for later execution. Real-time commands, however, are transmitted on an as-needed basis to change the content of the spacecraft’s memory.

"The Heavy Ion Counter is powered on and is detecting high-energy ions from solar flares," stated Matt Landano, Deputy Mission Director. These solar flares are energetic enough to cause single event upsets (SEUs) in sensitive equipment. However, there have been no SEU events detected by Galileo. SEU incidences, which plagued earlier spacecraft, were analyzed by the Project and specific design changes were made, consisting of shielding and hardened electronic components.

The Solid-State Imaging and Near Infrared Mapping Spectrometer instruments were both successfully checked out in late October. Data from these activities were stored on the Data Memory Subsystem tape recorder and played back later, consistent with telemetry link capabilities. When Galileo encounters Venus, Earth, the asteroids, and Jupiter, it will make extensive use of the tape recorder to capture precious science observations. The Energetic Particle Detector (EPD) instrument cover is open and its protective sunshade is in place. The Retro Propulsion Module 10-newton thrusters were fired and monitored as part of its periodic maintenance plan, and showed temperatures ranging from 66°C to 112°C, well below the 150°C limit.

The spacecraft is tracked by the Deep Space Network (DSN) system of antennas located in California, Australia, and Spain. Overall, the support from the DSN has been splendid. However, minor problems have occurred at the Madrid, Spain station. Two hardware failures and an antenna pointing error have caused the Flight Team to work around problems without any significant loss of data. In addition, the German Space Operations Center successfully received both high- and low-rate data at S-band via its Wilhelm tracking station.

Checking Out the Probe

Shortly after launch, the Flight Team began systematically checking each of the spacecraft’s systems and subsystems to make sure all were functioning properly. The first system checked out was the Probe.

"We wanted to verify the health and safety of the Probe," explained Pat Melia, Probe Engineer for Ames Research Center, which manages the Probe project. During launch activities, vibrations from Atlantis and the Inertial Upper Stage booster rocket could have "flipped" some of the electrical relays, turning on relays which should have remained off. If that had happened, some of the systems on board the Probe could have begun draining the limited resources of its lithium battery. Because this battery is not rechargeable, this checkout was extremely important. Without power at Jupiter, the Probe would not have been able to function.

The Systems Functional Test (step two in a three-step checkout) showed flawless results. None of the relays had been flipped. If they had, mission operations personnel would have been able to easily correct the problem from the ground. Such tests are planned annually during cruise, with the next test scheduled during the first Earth flyby, in December 1990.

In addition, the Probe checkout afforded an opportunity to pump out any gas which might have accumulated around the Neutral Mass Spectrometer (NMS), one of the Probe’s six science instruments. The NMS will help to determine the chemical constituents of Jupiter’s atmosphere. After the checkout was completed, the Probe was turned off.

Galileo Mission Summary*

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<th>Metric</th>
<th>Value</th>
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<tbody>
<tr>
<td>Distance from the Earth</td>
<td>3,041,000 kilometers (1,890,000 miles)</td>
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<tr>
<td>Distance from Venus</td>
<td>149,069,000 kilometers (92,627,000 miles)</td>
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<td>One-Way Light Time</td>
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<td>Veolcity Relative to the Sun</td>
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<td>Spacecraft Sun Angle</td>
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<tr>
<td>RTG Power Output</td>
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*all information is as of October 27, 1989
What's in an RTG?

Once at Jupiter, Galileo will begin an exhaustive study of the Jovian environment. This furious activity will test the limits of Galileo's Flight Team, as well as its hardware. In spacecraft terms, a great deal of energy will be required to run the instruments with which Galileo will probe the Jovian depths. In the past, spacecraft that travel at or within Earth's orbit have utilized solar energy to power their instruments. However, at the great distance of Jupiter, the only feasible power source involves the use of Radioisotope Thermoelectric Generators (RTGs).

The RTGs power the spacecraft through the radioactive decay of plutonium-238. This decay emits heat, which is converted into electricity for the spacecraft to "see, sense, hear, and speak." This power supplies a reliable, long-lasting source of electricity that is insensitive to the chilling cold of space and virtually invulnerable to high radiation fields, such as Earth's Van Allen belts and Jupiter's magnetosphere.

An RTG consists of two parts: a source of heat and a system for converting the heat to electricity. The heat source contains a radioisotope, such as plutonium-238, that becomes physically hot from its own radioactive decay. This heat is converted to electricity by a thermoelectric converter that uses the Seebeck effect, a basic principle of thermoelectricity discovered in 1822. An electromotive force, or voltage, is produced from the diffusion of electrons across the joining of two different materials (like metals or semiconductors) that then form a circuit when the ends of the converter are at different temperatures.

Each RTG contains 18 separate heat source modules, and each module encases four plutonium-238 pellets. The modules are designed to survive a range of postulated accidents: launch vehicle explosion or fire, reentry into the atmosphere followed by land or water impact, and post-impact situations. An outer covering of graphite provides protection against the structural, thermal, and eroding environments of a potential reentry. Additional graphite components provide impact protection, while iridium cladding of the actual fuel cells provides post-impact containment. The fuel is in the form of plutonium-238 dioxide, a ceramic material that is resistant to fracturing.

One of Galileo's two RTGs undergoes some of the myriad tests for safety and operations.

As the launch of Galileo neared, antinuclear groups, concerned over what they perceived as risks to the public safety from Galileo's RTGs, sought a court injunction prohibiting Galileo's launch.

From the outset, the Project understood the need to safely operate an RTG-powered spacecraft and had developed appropriate safety-related data. The RTGs themselves were carefully designed and extensively tested. And, in fact, RTGs have been safely used for years in planetary exploration. The Lincoln Experimental Satellites 8/9, launched by the Department of Defense, had 7% more plutonium on board than does Galileo, and the two Voyager spacecraft each carried 80% of the plutonium Galileo does.

After the Challenger accident, a study considered additional shielding. Additional shielding was not adopted, even though it would offer some protection near the launch area, because the great complexity of such a design significantly increased the risk of mission failure. If a failure on orbit occurred, additional shielding would significantly increase the consequences of a ground impact. The two close flybys of Earth had raised questions about the possible inadvertent reentry of Galileo into Earth's atmosphere.

Exhaustive studies were made by JPL and were independently reviewed regarding the safety of the Venus-Earth-Earth Gravity Assist (VEEGA) mission. These studies showed that the Galileo team had designed the spacecraft and its trajectory to keep the probability of an inadvertent reentry at Earth to less than one in two million. Over the course of the Project, millions of dollars were spent to improve the safety of shuttle flights and the Galileo mission. The Department of Energy, as required by law, completed a mission risk analysis, with full disclosure of those results to State and local governments. The Interagency Nuclear Safety Review Panel completed an independent Safety Evaluation Report, and the Office of Science and Technology Policy approved the mission. As a result of the Project's testing and rationale for the Galileo mission, the Court found in the Project's favor and the launch was a splendid success.

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