On July 20, John Casani called an “all-hands” meeting of the Galileo team at JPL to announce the latest reprogramming developments. As of now, “stop work” orders have been placed on all injection module subcontract activity, and phase-down of the in-house activity will be complete by the end of this fiscal year. Work has begun on re-integrating the Centaur stage for an ’86 launch. A condensed version of the talk is given below.

On July 18, President Reagan signed a supplemental appropriations bill which directs NASA to develop the wide-body Centaur as a Shuttle upper stage and to launch Galileo with it in 1986. I’d like first of all to give you the background that has brought us to this point and then describe where we go from here.

At the Project’s inception in 1977, Galileo was scheduled to be launched in January 1982 aboard the Space Shuttle using the NASA three-stage version of the Inertial Upper Stage (IUS). Due to Shuttle development and schedule problems, Galileo was redirected, in 1979, to a 1984 split launch, with the Orbiter and Probe launching about a month apart. The split launch was required because the increased launch energy requirements could not be satisfied with a single Shuttle/IUS launch in 1984.

In 1981, NASA dropped development of the three-stage IUS due to escalating costs and adopted the Centaur as the high-energy upper stage. The launch schedule was slipped to 1985 to allow time for the necessary development and integration effort. However, the improved upper stage performance allowed the Orbiter and Probe to be recombined for a single direct launch.

Funding for the Centaur was in the budget for fiscal year 1982 (FY82) sent by the Administration to Congress. However, in December 1981, due to federal budget problems, the Centaur was deleted from the FY83 budget. At this point, a revised FY82 operating plan, dropping Centaur funding and adding funds for a planetary version of the USAF two-stage IUS and the Injection Module, was sent to Congress. Although no specific approval for the revised operating plan was given, the Administration directed that work on the Injection Module, the planetary two-stage IUS, and the Galileo ΔV-EGA mission begin.

The ΔV-EGA mission would have launched in May 1985, about one month later than the ’85 Centaur mission. It would have required a single launch of a combined Orbiter and Probe, a two-year orbit around the Sun with a large propulsive maneuver about one year out, and an Earth reencounter. Earth gravity assist would then boost the spacecraft on to Jupiter with arrival in late 1989. The large propulsive maneuver would have depleted much of the Galileo propellant, causing a major redesign and greatly reduced margins for the Orbiter’s tour of the Galilean satellites.

In recent months, Congress has been working on the so-called FY82 Urgent Supplemental Appropriations Bill to provide funding for various agencies that otherwise could not operate through the remainder of the year.

A provision of the bill directs NASA to restart development of the Centaur for launching Galileo and the International Solar Polar Mission in 1986. The language states that no more funds are to be obligated for any other upper

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A mass spectrometer in the Galileo Probe will directly and repeatedly sample Jupiter's atmospheric gases at different altitudes as the Probe descends.

Remote sensing instruments flown on previous Jupiter flyby missions have provided valuable information on wind patterns and physical composition in the planet's upper atmosphere, but they have only "scratched the surface." Such instruments cannot precisely study the vertical mixing of gases. The Probe's mass spectrometer will provide a detailed analysis of the chemical composition of the atmosphere and aid in understanding the processes resulting in the complex, colorful clouds.

The Jovian atmosphere is star-like—some scientists believe its elemental abundances are virtually identical with those on the Sun. Comprised primarily of 90 percent hydrogen and 10 percent helium, it also includes minor amounts of the inert gases neon, argon, krypton, and xenon, and non-inert gases such as water, methane (CH₄), ammonia (NH₃), hydrogen sulfide (H₂S), acetylene (C₂H₂), and ethane (C₂H₆) as well as other trace constituents.

Unlike remote sensing instruments, Probe instruments can make measurements in the lower atmosphere, where clouds form. The Probe is expected to pass through at least two cloud layers composed of water and ammonia during its projected 60-minute lifetime.

Jupiter's wild colors originate deep in the atmosphere, and it may be possible to explore the role of sulfur in generating the colors.

The mass spectrometry measurements will also aid in understanding the processes involved in the formation of the solar system. The noble gases—helium, argon, krypton, and xenon—are chemically inert; that is, they do not combine with other elements to form other compounds. They do not settle out of a planetary atmosphere by liquefying or freezing, but remain in the gaseous state. Therefore, there should be the same abundances of them now as there was at the beginning of the solar system. Cosmic abundances of krypton and xenon are poorly defined, so the Probe's mass spectrometry offers the first opportunity to measure these elements in a single undisturbed reservoir. The results can be used to calibrate a very large mass of data on noble gas abundances in meteorites, the Earth, and the inner planets.

Voyager's discovery of lightning on Jupiter raises anew the possibility that organic compounds (the basis of life on Earth) may be formed in the Jovian troposphere. A classic laboratory experiment several decades ago showed that organic compounds can be formed when a spark is struck in a mixture of gases. Galileo will search for samples of organic compounds such as hydrogen cyanide and acetonitrile.

Abundances of photochemically-produced gases and other trace constituents will also be evaluated.

The mass spectrometer identifies gases by measuring the mass of the ions produced when the gas is ionized by an electron beam. As gas is admitted to the ionization region of the ion source, it is ionized by an electron beam. The beam energy can be varied. The ion beam is then directed into a quadrupole analyzer, a set of four hyperbolically-shaped rods 15 centimeters long. A radio frequency voltage is applied to the rods to filter the incoming ions. The voltage and frequency can be varied so that only ions of a chosen mass and charge can travel the length of the rods and be counted at the ion detector.

Atmospheric gases will enter the mass spectrometer through two inlet ports at the apex of the Probe. These ports will be sealed by metal-ceramic devices and kept under vacuum until the Probe enters the Jovian atmosphere. Pyrotechnic devices will then release the covers, allowing atmospheric gases to enter and be pumped to the test cells.

With its broad mass and sensitivity range, the instrument measures almost everything that enters it, making it ideal for this exploratory mission. The normal range of ion masses to be covered will be from 1 to 52 AMU (atomic mass units) with occasional sweeps from 1 to 150 AMU to search for heavier compounds.

A small fraction of the gas goes directly to the ionization region where the composition of the total sample is measured. One task of the spectrometer will be to separate the hydrogen from the gas samples to raise the relative abundances of the remaining gases in the sample. The instrument includes two "enrichment" cells and one "purification" cell. Some gas passes through the enrichment cell where substances called getters adsorb trace gases such as hydrogen sulfide, phosphine, and complex hydrocarbons until only the noble (inert) gases remain. The noble gases are admitted to the ion source for analysis. The enrichment cell is then heated, the adsorbed gases are desorbed, and the gases are admitted to the ionization region for analysis of the more complex compounds.

Galileo's mass spectrometer is a "state-of-the-art" instrument. Particularly difficult problems and choices in designing the instrument relate to the "plumbing": the inlet lines, gas handling, pressure reducing, and pumping systems. A special problem was designing a pumping system that could efficiently remove one of the major components, helium (which is typically difficult to "pump"), without contaminating the spectrometer from the pumping system itself.

The instrument is being built at the Goddard Space Flight Center. The engineering unit will be delivered August 1, 1982 and the flight unit is in fabrication now. The instrument weighs 11.8 kilograms and consumes about 25 watts, about half of which is consumed in pumps and heaters in the pumping systems.

Dr. Hasso B. Niemann of NASA's Goddard Space Flight Center, Greenbelt, Maryland, heads a team of seven other investigators.

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**Dr. Hasso B. Niemann**
A great milestone was reached on July 17 with the successfull balloon drop of a test model of the Galileo Probe. The following is condensed from an article by Don Kindt, Galileo's Probe Spacecraft System Integration Manager at JPL.

The Galileo Probe is designed to be carried to Jupiter by the Galileo Orbiter and then released to enter the Jovian atmosphere on its own. After a fiery, red-hot entry, the Probe will shed its protective heatshield and descend by parachute through the atmosphere of Jupiter, sending data back to the Earth to make sure that it will work at these altitudes, but they had to blow fast enough to carry the balloon over White Sands before the batteries ran out onboard the Probe and the supporting Air Force gondola. The drop also had to occur in daylight so the events could be recorded on film. (Ed. note: Photographs were not available at press time.)

The Probe was held in the Air Force gondola, which is like an upside down basket. The gondola provided pre-drop power, heating, movie cameras, and other balloon-related equipment. The gondola (with its Probe cargo) was rolled out of the hangar, hoisted on a portable test crane for weighing, and then transferred to the huge portable launch crane to hang suspended above the ground until the moment of launch.

Meanwhile, the 400-foot-long polyethylene balloon was carefully unpacked from its six-foot-square container and stretched out along the deserted runway at Roswell, N.M. Inflation with helium began about one hour before launch, until the 5.14 million cubic foot balloon expanded, rose, and tugged at its tether. (After launch, at 100,000 feet (19 miles) altitude, its diameter expanded to about 234 feet.)

As the launch command was given shortly after dawn, a minor hitch in the release mechanism required a sledge hammer. The problem solved, the payload crane truck (with its dangling payload) was driven in the direction of the wind until the truck was directly under the rising balloon and the payload was towed skyward by the rapidly ascending balloon.

Wind conditions were monitored carefully until the right conditions existed for the test. Not only did the winds have to blow from east to west at these altitudes, but they had to blow fast enough to carry the balloon over White Sands before the batteries ran out onboard the Probe and the supporting Air Force gondola. The drop also had to occur in daylight so the events could be recorded on film. (Ed. note: Photographs were not available at press time.)

The balloon was destroyed by command several minutes after Probe release, and the gondola drifted to the desert floor on its recovery parachute. A crew was sent to pick up the parts of the Probe and to recover the gondola for future use on other Air Force jobs.

All the data and pictures will have to be analyzed to confirm that everything worked according to design. If so, the next stop is Jupiter!
stages, and only current obligations and termination costs are allowable. It also requires NASA to advance the operational readiness state of the second Shuttle launch pad to January 1986 to allow both the Galileo and ISPM launches in 1986.

The first two versions of this bill were vetoed by the President. He signed the third version of the bill into law on July 18, 1982, and NASA has begun the process of implementing the Centaur provision.

Why in the face of so many objections, did Congress reinstate the Centaur? There are several reasons as I see it. First, there is high regard within Congress for the achievements of the Planetary Program, and concern by many that the future of the Program would be severely eroded if constrained to the existing launch vehicle capability. Second, the Air Force will require a higher energy stage in a few years and Congress was reluctant to abandon the 20 years of development investment, proven reliability, and maturity in exchange for a major new development program with a new round of development cost risks. Third, Congress wanted NASA to have responsibility for the upper stage development and this might not have happened if a new high energy upper stage development with heavy Air Force requirements was started. Lastly, and perhaps most significantly, Congress is concerned about the exodus of commercial customers to the European Ariane launch vehicle. Arianespace’s stated objective is to capture 30 percent of the commercial market through 1985 — already they have booked nearly that amount. The Centaur’s recurring costs have been stated as about half those of the IUS with twice the launch capability, which has led some to believe that with the Centaur it would be possible to keep or recapture more of the commercial market.

As for Galileo, we must stay on our present development and test schedules for both the Orbiter and Probe.

To control the cost and maintain the stability of the ongoing activities, it is mandatory that absolutely no changes be made to the spacecraft; i.e., to any hardware on the spacecraft side of the IM/spaceraft adapter interface. All necessary interface accommodations will be confined to an assembly consisting of a new intermediate adapter which should “look like” the IM at the forward end and “like” the old Centaur ‘85 spacecraft adapter at the other end.

As for the Injection Module, that work must stop.

I want to personally thank, on behalf of the Project and the Laboratory, Joe Savino and each of the people working on the Injection Module Team for the fine job they did in the past six months. It has been a truly remarkable effort. An incredible amount of quality work has been accomplished, with everything clicking off right on schedule. It is keenly disappointing to do a job well, with intensity and dedication, only to have it terminated so abruptly for reasons totally beyond your control. Nonetheless, we must bring this work to an orderly close now, and get to work reintegrating with the Centaur and with reprogramming to the 1986 mission.

The Injection Module and ΔV-EGA mission design work was important because it demonstrated our resourcefulness, our ingenuity, and our adaptability to rapidly changing circumstances. We must reach for those same qualities again as we begin the process of adapting to the ’86 launch. We must always remember that our ultimate objective is to deliver a fully functional Galileo spacecraft — Orbiter and Probe — to Jupiter. With the reinstatement of the Centaur we can achieve that goal in 1988, one year earlier than we could have with the ΔV-EGA mission, even though the launch is one year later. The Centaur will not only get us there faster, but with more propellant in our tanks, which means higher assurance of obtaining our science and mission objectives.

All in all, the change is good. The promise Galileo holds is greater than ever and, with your continued support and enthusiasm, the payoff will be there.

Getting from here to there is the daily business of Galileo’s Mission Design Manager, Bob Mitchell. The simplest task of his day is walking to JPL from his home in La Canada–Flintridge. After that, things get more complicated.

“Mission design is the process of generating trajectories (flight paths) and plans for implementing a mission within the constraints imposed by the Project and the laws of celestial mechanics,” explains Bob. “There are certain kinds of trajectories and tours that best meet the mission objectives, and we have varying degrees of flexibility in designing these trajectories. It becomes a matter of determining options and tradeoffs.”

Each time the Project has undergone reprogramming by NASA, Bob and his co-workers in JPL’s Mission Design Section have generated a new mission design, identifying the best route to Jupiter and the orbital tour that will return the most science data. Besides the official baseline missions, they have studied other options. Trajectory choices are complicated by matters such as launch vehicle performance, spacecraft propellant utilization, solar conjunctions, occultations, ring plane crossings, Probe entry speeds, aspect angles, and numerous other requirements levied by the navigation and science teams.

Bob holds an undergraduate degree in electrical engineering, and graduate degrees from the University of Arkansas in electrical engineering and mathematics. Were it not that a spur-of-the-moment resume to JPL produced a job offer, he might now be designing automatic control systems for Caterpillar tractors.

Since joining JPL, Bob has worked on Mariners ’67, ’69, and ’71, and on Viking, primarily in the maneuver and trajectory areas.

Bob and his wife Vineda (pronounced Vin e’ da) are active in challenge level square dancing. They have two teenage sons and a younger daughter. Bob also likes to ride dirt bikes with his sons in the desert and the mountains of Mexico. Having developed some degree of fluency in Spanish, he enjoys visiting with the locals as much as finding new roads to explore.