LESSONS FROM THE PIONEER VENUS PROGRAM

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Good evening. It is indeed a pleasure to address a group of scientists and engineers who share my enthusiasm for space exploration. When Bernie Bienstock, tonight's host from Boeing, first asked me to be a keynote speaker tonight he suggested I tell war stories about Pioneer Venus. Well, for a veteran like me, that's a tempting offer. And it's a temptation I don't intend to resist. So my remarks tonight will be more of a personal Pioneer Venus memoir then a program history. As the Hughes Program Manager for the Pioneer Venus project, I gained a perspective on what it takes to design, build, test, launch and fly planetary missions.

Before beginning, let me extract a few lessons from my experience in the planetary exploration program and as program manager of the Pioneer Venus Program. I feel it is the job of experienced veterans to convey to younger members of the scientific and engineering community the problems and issues that were encountered, and how we resolved them.

First, I learned the importance of a continuous, relatively low cost robotic exploration program to complement large scale expensive robotic and manned missions. Funding such programs is an unnatural act for Congress, especially today with the emphasis on manned space flight. I believe it is the responsibility of groups like you to give substance to the idea and be effective advocates for these types of missions.

Second, I learned the importance of mission success. Those of you building instruments or spacecraft should not be beguiled by "faster, better, cheaper." Those ideals only come after quality, the paramount requirement. Your efforts will be quickly forgotten if focus on schedule, cost and innovative ideas does not result in mission success. Keep your eyes on the goal.

A key part of any mission should be an extensive test program. Theory and engineering will indeed produce an impressive spacecraft, but unless it can be proven to operate per specification in the required environment, you may not achieve success. Testing innovation, to simulate the representative environments, is required.

Third, I learned from Pioneer Venus how satisfying it is to be involved in the excitement of the Planetary Programs. I've been associated with many programs over my long career, but none has been more satisfying than my six years heading up the Pioneer Venus program for Hughes.

My planetary exploration experience began in the early 70's with the Outer Planets Grand Tour. At that time, the alignment of the outer planets presented a unique opportunity to fly a single spacecraft to Jupiter, Saturn, Uranus, Neptune and Pluto. In fact, this opportunity was singled out by President Nixon as a major national objective, in much the same way President Bush has announced the missions to the Moon, Mars and beyond as part of his Vision for Space Exploration in February, 2004. In response to Nixon's announcement, JPL planned to begin a major contract procurement. At Hughes I was asked to form a team to compete for this contract and I succeeded in enlisting our best and brightest. As the planning began, and the cost estimates developed, NASA rapidly determined that the Grand Tour was too expensive. As a result, Congress balked and refused to fund the effort.

In an effort to salvage this exciting mission, JPL decided to build the spacecraft in-house as the Mariner Jupiter Saturn (MJS) Program. Thus my Hughes team found itself without an objective. Ultimately the MJS program morphed into the very successful Voyager program that flew two spacecraft to all the outer planets except Pluto and returned extraordinary science data and spectacular photos, testimony to JPL's technical and budgetary creativity.

It was during this period that the idea of the Pioneer Venus program developed. Richard Goody and Mike McElroy of Harvard, Tom Donahue of Michigan, Don Hunten of Arizona and other scientists sold the concept of a series of exploration missions to Venus with comparative planetary atmosphere science as its centerpiece and a launch every few years. The mission was assigned to the Ames team who had been so successful with the Pioneer Program over many years, most recently a flyby of Jupiter, beating JPL to the punch with an amazingly inexpensive mission.

Ames had historically relied on TRW, now NGST, as their contractor. Even though Ames wanted to continue with TRW, since they had an excellent track record, NASA insisted on a competition for the Pioneer Venus program. We had a good team already assembled and the competition for the contract was fierce, but in the end Hughes was awarded the contract. Ironically the major difference between Hughes and TRW was our superior approach to science integration. Since we believed it was our weak point we worked extra hard on the science objectives and overachieved!

The Pioneer Venus program we won was really two missions; an Orbiter to orbit Venus for one Venusian Day (about 9 earth months) and a Multiprobe Bus. The later spacecraft consisted of a probe carrier that, in turn, transported one Large probe and three Small Probes to Venus and released them on a ballistic trajectory for descent through the Venusian atmosphere. As an additional incentive to sell the program to Congress, NASA defined the Pioneer Venus program as a "management experiment" designed to develop and test ways to reduce the cost of planetary programs by streamlining programmatics. If this sounds familiar, think "faster, better cheaper."

All the appropriate executives, including the heads of NASA, Ames and Hughes, agreed with this noble objective for the Pioneer Venus Program, with one very important exception, Ames Pioneer Program Manger Charlie Hall. Charlie and his team had been very successful over the years by paying scrupulous attention to detail. He was committed to making sure the Pioneer Venus program was a technical success, and he was not about to allow Hughes or any other hardware-provider to cut corners in order to save money. Thus Charlie's philosophy was in direct conflict with the management's experiment objective.

We began the Pioneer Venus contract in late 1974 with a planned launch of the Orbiter in May 1978 and the Multiprobe in August 1978. Because we had four years, we thought there was plenty of time. As it turned out, we barely made the launch dates.

The Orbiter was relatively straightforward, compared to the Multiprobe Bus and Probes that had to survive descent through the harsh Venusian atmosphere. To help overcome our many Multiprobe problems we formed a strong global team. The GE reentry team in Philadelphia, experienced in designing vehicles to enter the earth's atmosphere, was assigned the responsibility for the Probe entry system, including protective heat shielding and parachute design to extract the science-laden Large Probe pressure vessel and control its descent through the Venusian clouds. Since the Probes had to remain stable as they descended through the Venus atmosphere, we used the aerodynamic expertise at the Hughes Missile Division, NASA's Ames Research Center and the Langley Research Center. Since the pressure at the surface of Venus was equivalent to an ocean depth of 3300 feet, we went to the Navy's David Taylor Research Center for their deepsea expertise. To test the pressure vessel at the high pressure and temperatures anticipated at Venus we went to the only facility capable of simulating the Venus surface environment, the Southwest Research Institute in San Antonio, Texas. We had dozens of subcontractors all over the world.

As we developed our design, we began an extensive program to validate the ability of our Probe hardware to withstand the Venus environment. During this testing, we encountered numerous problems, mostly associated with adapting earth-based hardware to operate in the anticipated Venus environment. For example, the Large Probe pressure vessel imploded with a very loud bang the first time we tested its ability to withstand the high pressure and temperature on the Venusian surface. We had to go back and redesign, increasing the pressure vessel wall thickness. In addition, during the first tests of the parachute system, our parachute system ripped apart and had to be redesigned. Finally, at the aptly named test range in Truth or Consequences, New Mexico, we successfully demonstrated the parachute design by dropping it from a helium filled balloon at 100,000 feet.

The first time we tested the Small Probe's ability to withstand the hot temperature of Venus we found the interior overheated. Although the Large Probe thermal control was successful with an internal nitrogen atmosphere, this technique did not allow the Small Probe thermal design to close. After much experimentation, we determined that nitrogen gas was too conductive for the Small Probe and needed to be replaced with xenon, a much heavier inert gas.

Design of the probe penetrations and windows was an equally challenging problem, especially for the Large Probe Infrared Radiometer. The only material that would meet the requirements of this instrument at the high temperatures and pressures was natural diamond. We went to the South African diamond company, DeBeers, to find a diamond large enough for our needs. They came up with a 200 carat diamond which was then polished to a _ inch window. The company that processed the diamond was so excited about being part of planetary exploration that they issued an impressive brochure explaining how the window was produced. As difficult and expensive as that process was, it was even more challenging and expensive to determine out how to attach this window to the titanium pressure vessel. We finally developed a brazing process that provided a leak-proof seal.

Resolving these problems, and many more like them, put us behind schedule. By the end of the program, our teams were working 24/7 in order to accomplish the final assembly, integration and test of our multiple spacecraft. The outcome was a real cliffhanger but at the end, with an all-out effort, we launched the Orbiter in May 1978 and the Multiprobe in August 1978, exactly on the original schedule set 6 years earlier

Even after launch there were problems. Our onboard computer on both the Orbiter and Multiprobe Bus experienced single event upsets from high-energy particles. We redesigned the firing sequence of the Orbiter solid motor many times, to find the optimal programming sequence. It was fired by an autonomous onboard timer, with no direct control from the ground stations. If the firing occurred too early, the Orbiter would miss Venus altogether. Too late, and the Orbiter would enter the Venusian atmosphere. In addition, the Orbiter developed a small nutation which could have affected the solid rocket motor firing. Thus we needed to spin-up the Orbiter to make it more stable. In the end, we resolved these last problems and on December 4, 1978 the Orbiter solid rocket motor fired and injected the spacecraft into Venus orbit – exactly as planned.

And five days later, on December 9th, five spacecraft, including the Multiprobe Bus, the Large Probe and 3 Small Probes, approached Venus. They had separated 3 weeks earlier to target 5 different landing sites on Venus. In order to conserve battery power, the one Large and three Small Probes that communicated directly with Earth did not begin transmitting until approximately 20 minutes prior to entry, presumably enough time for the DSN to acquire the transmissions from all probes. Since the probes had been dormant for 4 months, we had no idea of their health status or for that matter whether they were still working. Furthermore, with the need to acquire four probes in a few minutes, there was limited room for DSN error. Needless to say, we were a very anxious group in mission control. The specter of 6 years' work going down the drain was quite real. As you can imagine, there were loud cheers in mission control and around the world as cheerful Aussie operators at the DSN station in Tidbinbilla announced "probe acquired" shortly after the onboard timer turned the probes on. The probes transmitted scientific and engineering data for the one-hour descent to the surface. Even though there was no plan to survive landing, one Small Probe continued to transmit data from the surface for over another hour before being consumed by the heat at the surface.

In the post-mission press conference, I was honest in saying I was delighted that everything worked the first time we tried it at Venus, since almost nothing worked the first time we tested it on Earth. Both the Orbiter and Probe missions were very successful. Most of the desired Probe data was returned and the Orbiter, required to operate for one Venus day (9 months), continued to operate for over 10 years.

The management experiment was a limited success. Charlie Hall was correct in his vision that mission assurance was more important than squeezing the last dollar out of costs. Nevertheless, with our efforts to complete the program efficiently, the total spacecraft cost for the two missions was approximately $100M for 6 spacecraft or about $300M in today's dollars. NASA got good value. After much personal conflict with Charlie over how the program was to be executed, we eventually became good friends with the common objective of a successful outcome. Our final award fee was close to 100%.

Subsequently the Planetary Program fell on bad times, partially due to NASA's focus on the Space Shuttle and International Space Station. Planetary launches declined to once per decade instead of one every few years, with programs like Galileo or Magellan absorbing most of the limited funds. The original plan, to continue visiting Venus with Probes, was abandoned. In fact, the next probe to enter a planetary atmosphere was the Galileo probe, 17 years later.

My company, Hughes, reduced its efforts on planetary exploration and redirected the focus on communication satellites, becoming the world leader in this field. Several members of the Pioneer Venus team went on to develop the satellite direct-to- home service, DirecTV, which became a huge financial success for Hughes.

I'm pleased to note that there is now a renaissance in the Planetary Programs. Under Dan Goldin's leadership, the Discovery Program has resurrected lower cost, smaller programs like the Mars lander, Sojourner, which was enormously successful and captured the public's imagination. Today, there are two robots exploring the surface of Mars, the Genesis spacecraft is on its way to Earth, the Casini spacecraft is now orbiting Saturn and the Huygens Probe is due to enter the Titan atmospheric early next year. Maybe it's even time to return to Venus!

Thank you for inviting me to speak. Good luck to all of you. You are in an interesting field at an interesting time.

My thanks to Bernie Bienstock for inviting me to the Probe Conference and helping me prepare this paper.

Finally, preparing this paper reminded me how much of a privilege it was to work with an outstanding team at Hughes, Ames, JPL, our subcontractors and the scientific community. I salute them all. They made Pioneer Venus a success.