RETURN TO MERCURY: THE DISCOVERY-MERCURY POLAR FLYBY MISSION Paul D. Spudis, *Lunar and Planetary Institute, Houston TX 77058*; Jeffrey B. Plescia, *Jet Propulsion Laboratory, Pasadena CA 91109*; Alan D. Stewart, *The Boeing Company, Seattle WA 98124*

Mercury is one of the last pieces of unknown real estate in the Solar System. There have been no missions to Mercury since the three flybys of Mariner 10 two decades ago. That spacecraft mapped about 40 percent of Mercury's surface and determined that the planet possesses a weak global magnetic field [1]. Since then, the planet has been studied with Mariner data and through Earth-based optical and radar observatories. These studies have demonstrated that Mercury possesses a tenuous sodium atmosphere [2], has surface properties comparable to the moon [3], and apparently has polar caps composed of water ice [4]. As near-infrared spectra are ambiguous [5], the surface composition of Mercury, a key parameter towards understanding the chemistry of the Solar System [6], is completely unknown. We are proposing a polar flyby mission to Mercury. In accordance with the philosophy of the *Discovery* Program, our scientific objectives are focused: 1) Investigate the physical and compositional state of Mercury's polar caps; and 2) Complete the geological reconnaissance of Mercury begun by Mariner 10 by mapping the morphology and composition of units on the previously unseen hemisphere of the planet. To conduct this exploration, our payload consists of neutron, X-ray fluorescence, and thermal infrared spectrometers, a radar scatterometer, and a narrow angle camera.

We believe that a flyby mission is adequate for achieving the most significant science objectives and requires a simpler and less costly spacecraft. Such a mission simplifies requirements for the spacecraft thermal design because spacecraft perihelion is close to Mercury's aphelion (thermal flux = 4.6 suns), whereas an orbiter must be designed to survive Mercury perihelion (thermal flux = 10 suns, as well as receiving thermal radiation from the planet's surface). Moreover, a flyby spacecraft does not have to carry fuel to burn into orbit and its propulsion subsystem is smaller and much simpler; the additional mass available to a flyby spacecraft as compared to an orbiter is on the order of 300 kg. Such a mass margin permits a much larger, more robust, and diverse payload to be flown, greatly increasing the scientific return of the mission.

Launch opportunities for MPF occur every two years, but to observe the hemisphere opposite to the one seen by Mariner 10, our baseline windows occur in 1996 and 2000. The MPF mission uses a Venus gravity assist to achieve a solar-resonant orbit, thus permitting multiple flybys of the planet at little propulsive cost. The nominal MPF mission consists of three flybys, each at about 500 km altitude. The first encounter occurs approximately 10 months after launch and subsequent encounters take place approximately every 6 months; thus, the entire mission of three flybys will be completed in less than 2 years, thus greatly lowering operations cost. The first Mercury flyby will be across Mercury's north pole, seen only obliquely by Mariner 10. This pass allows us to address our primary science goal, the extent and properties of the polar cap, in addition to imaging the heretofore unseen hemisphere of Mercury. The second flyby is equatorial and completes the mapping of the hemisphere opposite the one studied by Mariner 10. The third encounter will continue these observations over the south pole of Mercury.

The MPF spacecraft is 3-axis stabilized with a scan platform to support and point the science instruments (Figure 1). The design includes articulated solar arrays, hydrazine propulsion, X-band communications, modular structure with 8 avionics bays, and a rigidly mounted, pre-deployed sun shade. The bus combines flight-proven, off-the-shelf subsystems and components along with high-technology items (such as the use of composite materials and solid state data recorders) into a simple, low-cost versatile design. The spacecraft has a dry mass of about 400 kg (including science payload and margins), produces up to 470 watts of power, and has about 1500 m/s total delta-v capability. This design provides significant growth margin and flexibility in meeting the mission requirements.

The principal science goals of the MPF mission are addressed through the analysis of multiple data sets. On all passes, both approach and departure imaging will thoroughly map the unknown hemisphere of Mercury. We will obtain full disk images of the planet at eight wavelengths between 200 and 1000 nm, permitting major color provinces to be mapped across the planet. Image mosaics will complete the surface mapping of the planet and will have an average resolution of about 200 m/pixel, comparable to existing Mariner 10 coverage of the other hemisphere. Closest approach (from about 1000 to 500 km) will yield selected images of the surface at resolutions of 5-10 m/pixel.

For the polar deposits, we want to know their extent, composition, and physical properties; from these observable facts, we hope to be able to determine deposit origin and evolution through time. On the polar passes (encounters 1 and 3), the neutron spectrometer will permit us to identify and measure hydrogen if present in amounts greater than 100 ppm. The radar scatterometer will transmit pulses in right circularly polarized (RCP) radiation and receive pulses in both RCP and left circularly polarized (LCP) modes. The ratio of LCP/RCP in the reflected power is diagnostic of surface material -- ratios greater than unity are characteristic of ice, whereas ratios of much less than unity (0.1) represent silicates [4]. Thus, the radar instrument will determine the presence and map the extent of the Mercurian polar ice caps. The thermal emission spectrometer (TES) will measure the physical properties of the polar deposits, including temperatures, which are around 60° K in the permanently shadowed areas of the Mercurian pole.

On the equatorial pass (encounter 2), geoscience will be emphasized by mapping the composition and morphology of the unknown hemisphere of Mercury. An X-ray fluorescence spectrometer will determine the abundance of the principal rock-forming elements in the crust; Al, Mg, and Si are easily measured to about 10% precision and during periods of active Sun (our year 2000 opportunity), we anticipate also determining Ca, Fe, and possibly Ti to about 20% precision. The TES will obtain mid-IR spectra for the variety of terrain units observed on the planet from which we can identify and determine the abundance of the major silicate minerals of the mercurian crust. Both of these data sets will characterize the chemistry and mineralogy of the color provinces mapped during approach and departure by imaging, thus permitting a complete assessment of the composition and stratigraphy of Mercury's surface.

Through the use of the heritage provided by the Mariner 10 spacecraft and mission design and the use of off-the-shelf instruments, we have created a low-cost, *Discovery*-class mission that effectively does the job of a *Mariner*-class mission, which would probably cost over half a billion dollars in today's fiscal climate. In contrast to some limited objective *Discovery* missions that return a few pieces of first-order information, the MPF mission will obtain hemispherical, multi-wavelength data sets for an entirely unmapped and unknown region of the Solar System. The Mercury Polar Flyby mission blazes new trails in the exploration of the planets by mapping and characterizing one of the last unknown and mysterious members of the solar family.

References [1] Mariner 10 special issues: *Science* v. 185, no.4146, 12 July, 1974; *JGR* vol. 80, 2341-2514, 10 June, 1975. [2] Potter A. and Morgan T.H. (1985) *Science* 229, 651. [3] Clark P.E. et al. (1987) in *Mercury*, Univ. Arizona Press, 77; Harmon J.K.and Campbell D.B. (1987) in *Mercury*, Univ. Arizona Press, 101. [4] Slade M.A. et al. (1992) *Science* 258, 635. [5] McCord T. B. and Adams J. B. (1972) *Science* 178, 745; Villas F. (1987) in *Mercury*, Univ. Arizona Press, 59. [6] Taylor S.R (1992) *Solar System Evolution*, Cambridge Univ. Press, 307 pp.

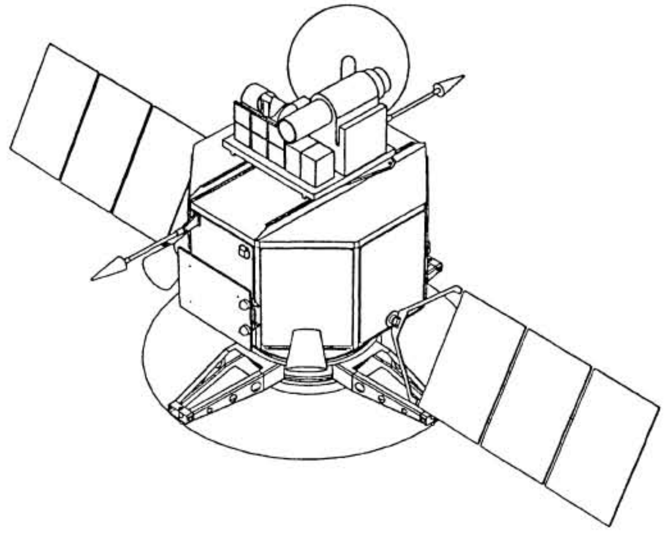

Figure 1. Spacecraft configuration, *Discovery* Mercury Polar Flyby Mission