The Mercury MESSENGER

Issue 5 — The newsletter concerned with exploration of the planet Mercury — May 1993

TWO MERCURY MISSIONS SELECTED FOR STUDY IN DISCOVERY SERIES

NASA Discovery Mission Initiative Proposal Selection

Recently the announcement of opportunities to propose small, scientifically focused, low-cost, state-of-the art missions for NASA's Discovery Mission Initiative resulted in the submission of seven proposals for a Mercury mission. The seven proposals and their principal investigators were (1) *MISE: A Mercury Interior, Surface and Environment Mission Concept* (Robert Reedy, Los Alamos National Laboratory); (2) *IPSIS: Inner Planet Spectrographic Imaging Telescope* (Faith Vilas, NASA Johnson Space Center); (3) *Mercury Mapping Orbiter Mission* (Albert Metzger, Jet Propulsion Laboratory); (4) *Mallcu: A Mercury Polar Orbiter Mission* (Bruce Bills, NASA Goddard); (5) *Ulysses: A Return to the Hadley Apennine* (David Scott, Scott Science and Technology, Inc.); (6) *Hermes Global Orbiter—A Mission to Mercury* (Robert Nelson, Jet Propulsion Laboratory); and (7) *Mercury Polar Flyby* (Paul Spudis, Lunar and Planetary Institute).

The latter two proposals were selected to receive mission definition study money, and will be described below. These summaries are based on material in each proposal.

Hermes Global Orbiter

The Hermes Global Orbiter will perform remote sensing observations of the planet's surface, atmosphere, and magnetosphere. The plan is to use a Delta II vehicle to launch the 300-kg, three-axis-stabilized, class C craft in 2002. Using two Venus and two Mercury gravity assists along a heliocentric flight trajectory, the spacecraft would arrive at Mercury in three years, to be maneuvered into a polar, elliptical, 12-hour orbit with a 200-km periapsis and a 15,000-km apoapsis. Thermal control is achieved with a Mercury shade and passive radiation coupled with spacecraft orientation. The plane of the polar orbit will be aligned such that periapsis will occur at the terminator or on Mercury's darkside when the planet is at perihelion. The proposal team believes that the severe thermal environment (due to the combination of 10 times greater solar flux plus Mercury's thermal emission) precludes consideration of a low circular orbit.

Figure 1 is a drawing of the proposed spacecraft. The approach of the proposal team in designing this mission has been to develop a forefront mission that is low cost by using significant heritage in hardware and simplifying the development and management process.

The payload, which has considerable heritage, will consist of three subsystems. An optical observation facility will include both a Nd:YAG dual wavelength laser altimeter/active photopolarimeter and a telescope with an attached 10° field of view visible/near-IR camera that has flown on SDIO missions. An ultraviolet spectrometer, a simplified version of the one flying on Galileo, is coaligned with the telescope axis. The boom-deployed magnetometer is similar to one that has flown on Galileo and Pioneer Venus.

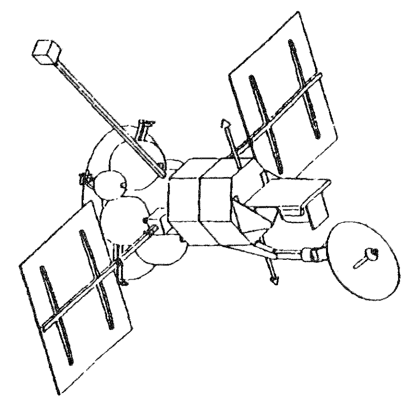

Fig. 1. Hermes Global Orbiter.

The goal of the mission is to understand Mercury's significance in planetary formation and early solar system history by (1) determining Mercury's surface topography, composition, texture, and mineralogy; (2) searching for condensates at Mercury's poles; and (3) constraining Mercury's interior composition and structure as well as the probable composition and thermodynamics of the interior of the protoplanetary accretion disk. Specific investigations will be designed to answer the following questions:

1. What is Mercury's surface composition? This is probably the most important question, because virtually no information is available about the composition of the planet's crust (see Issue 1 of this newsletter). Iron bands from major mafic minerals are too weak to be identified from groundbased or earlier flyby observations. A multispectral camera and UVS capabilities of the proposed orbiter will be necessities.

2. To what extent are volcanic units present on the surface, and to what degree are these units representative of the interior? What is the role of impact cratering in determining surface morphology? Data from the complete multispectral camera coverage and the laser altimeter will help to resolve the origin of the plains terrains of Mercury and unravel

the planet's complex history.

3. What is the relationship between interior structure and topography? What is the nature of the interior and its relationship to spatial and temporal variations of the magnetic field? Data from the magnetometer, spacecraft radio science, and altimeter will allow the history and structure of the planet's interior to be characterized to a much greater extent than ever before.

4. What is the nature of the mercurian regolith? Is ice present near the poles, as radar observations have suggested? The photopolarimetry experiment can determine whether ice is present and can characterize ice, particle size, and agglutinate distribution in the regolith.

5. What are the composition, evolution, and dynamics of Mercury's atmosphere? A number of mechanisms have been proposed for the origin and dynamic interaction of the atmospheric constituents with the planet's surface. Ultraviolet and visible wavelength experiments will be used to identify as-yet-undiscovered constituents and provide the basis for a working atmospheric model.

The following datasets will be obtained: (1) complete photographic coverage at 1 km or better, much of the coverage at 100-m resolution; (2) multispectral imaging; (3) spatial variations in mineralogy, ice content, and the physical nature of the regolith; (4) gravitational and magnetic field maps; (5) map of ionized sodium in the atmosphere; and (6) determination of spatial and temporal behavior of known atmospheric constituents and search for other constituents.

Mercury Polar Flyby

The Mercury Polar Flyby is designed primarily to characterize the recently discovered polar caps on Mercury. The Mercury environment presents both thermal and gravitational challenges, which translate into particularly limited payload capacities for an orbiter. Thus, the mission proposed here involves multiple flybys with a three-axis-stabilized spacecraft from the Boeing Defense and Space Group, the designers of Mariner 10. The spacecraft, based upon a design for the Lunar Resource Mapper proposed by Boeing to NASA/JSC, was chosen with the idea of keeping the spacecraft and mission as simple as possible.

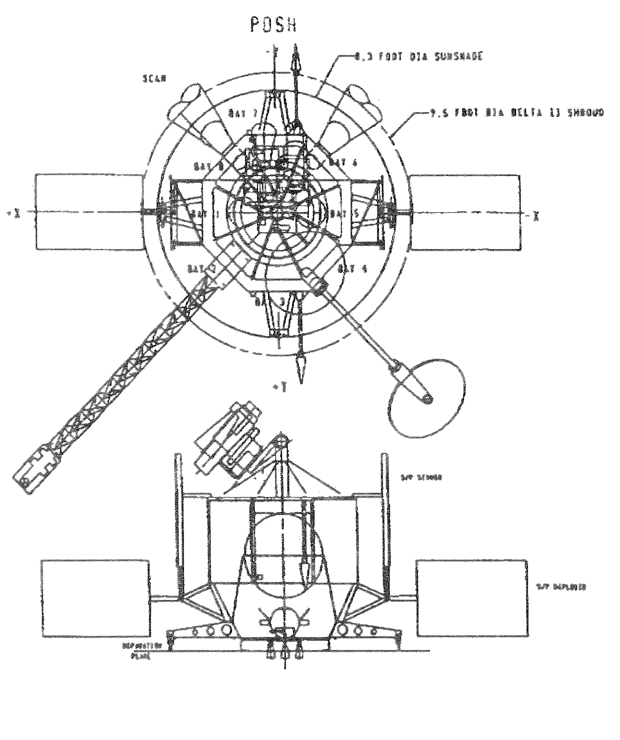

Fig. 2. Mercury Polar Flyby.

The payload will be optimized for limited science objectives in keeping with the philosophy of the Discovery Program, and the 400-kg spacecraft will use only off-the-shelf hardware with Mariner 10 heritage to minimize risks and financial investment. Figure 2 is a drawing of the proposed spacecraft. After the 1996 or 2000 launch, the first flyby will take the spacecraft directly across the north pole only 18 months after launch. An equatorial pass will occur six months later, followed by encounters at six-month intervals.

To quote, the proposed investigation team believes that "although some in the planetary science community contend that an orbiter must be the next step in the exploration of Mercury, flying a less capable (and much less costly) spacecraft to Mercury is more desirable than designing an extremely capable orbiting spacecraft that never leaves the drawing boards."

The spacecraft requires one gravity assist from Venus to get to Mercury, and then achieves a heliocentric orbit with a 2:1 resonance (one orbit during two Mercury years). Closest approach will be in the range of 1000 km. Each encounter will occur when Mercury is at aphelion. The minimum mission, with one encounter at the pole and the next at the equator, will be accomplished in two years.

The scientific payload will consist of three instruments. A solid-state imager, similar to the one proposed for the Clementine Mission will provide images to be used for mapping Mercury's surface and for determining broad compositional units. The Thermal Emission Spectrometer, identical to one flown on Mars Observer, will allow mapping of the thermal properties and physical nature of the regolith. The radar scatterometer and neutron/gamma ray spectrometer will allow determination of the extent and purity of the polar deposits. A flight-proven magnetometer, to study interaction between the planet's magnetic field and the solar wind, may be added if mass, power, and fiscal margins permit.

The primary goals of this mission are to characterize the poles, as well as complete the reconnaissance of the planet's surface, in particular the unmapped hemisphere, and to determine the bulk composition. The investigation will focus on addressing the following questions using the indicated instruments:

1. What is the composition of Mercury's polar caps? The neutron/gamma ray spectrometer will be combined with the radar scatterometer to address this question. The shape and intensity of the thermal neutron signal will determine whether or not water ice is present, even if it is buried to a depth of 1 m. If no water ice is present, the radar scatterometer will allow characterization of other volatiles, such as ammonia, carbon dioxide, and methane, to a similar depth.

2. What is the temperature, extent, and purity of the polar ice? The thermal infrared spectrometer will allow temperature mapping. These data will be combined with radar scatterometer and Earth-based radar data to estimate the temperature and extent of ice on and below the surface, and thus the total ice volume. This amount will be compared to the supply rate for volatiles from cometary bombardment in the inner solar system. The extent to which the radar pulses are scattered will allow determination of the purity of ices or clathrates.

3. What is the geological setting of the polar deposits? Images from the narrow-angle camera combined with thermal maps from the infrared spectrometer and data from the radar scatterometer instrument will indicate the most likely locations for the polar

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GROUNDBASED RADAR INDICATES POLAR ICE ON MERCURY

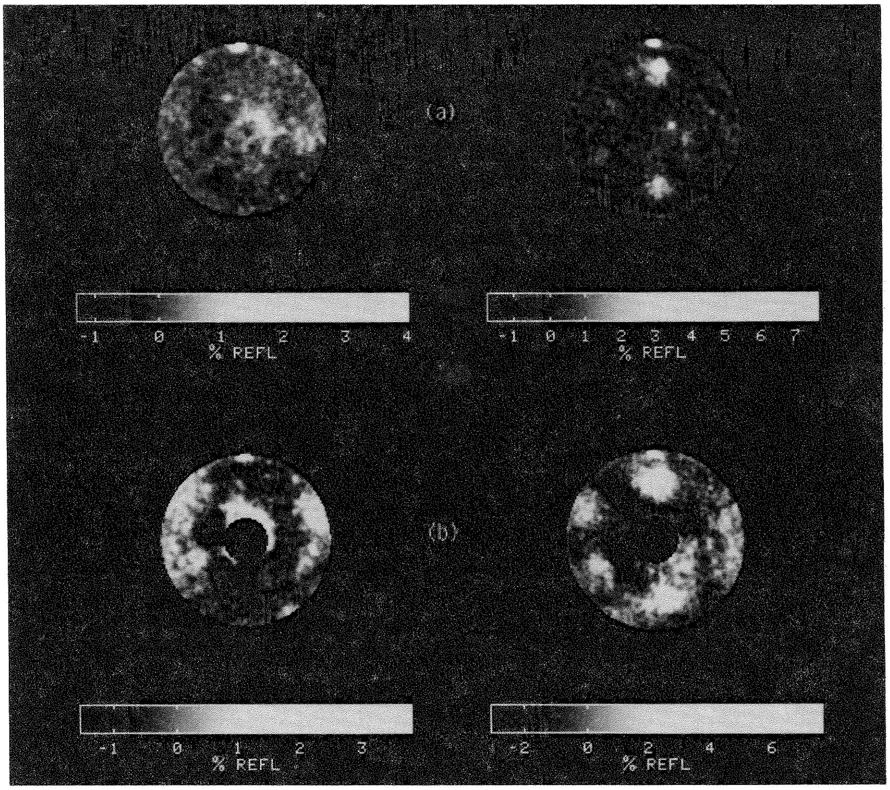

Fig. 3. VLA/Goldstone Mercury Radar Image. Residual radar images of Mercury for two days. These images are obtained by subtracting a model from the actual measured reflectivities in an attempt to enhance variations across the disk. Images on the left are for August 8, and those on the right are for August 23. (a) SS (same sense) images. (b) OS (opposite sense) images. For the OS images, the interior has been blanked (incidence angles less than 15°) in order to see the more interesting variations at larger incidence angles.

Included among the goals of both missions proposed above is the confirmation and characterization of the evidence from groundbased radar observations of polar caps on Mercury [Slade et al. (1993) *Science, 258*, 635–640; Harmon and Slade, ibid., 640–643].

Evidence for the polar ice was seen on the first unambiguous full-disk radar maps of Mercury at 3.5 cm (Slade et al.) and confirmed by a series of observations at 12.6 cm (Harmon and Slade). Both sets of observations clearly showed polar features whenever a pole was in view.

The 3.5-cm observations were taken on two days in August 1991. This experiment was designed to image the hemisphere not photographed by Mariner 10, as well as the north pole of the planet. The observations were made by transmitting with the Goldstone 70-m antenna and receiving with the Very Large Array. The 12.6-cm observations were made at Arecibo Observatory for 28 days during three consecutive inferior conjunctions. Viewing conditions for the 12.6-cm data varied: At different times, the north, south, or both poles could be viewed.

Mercury, which has been studied by only one flyby mission, Mariner 10, has been a relatively difficult object to observe due to its proximity to the Sun; groundbased radar observations have therefore played a major role in our understanding of that planet, and have been instrumental in changing the view that Mercury has a relatively uninteresting surface (it has been referred to as "the boring planet") very similar to the Earth's Moon.

The experimenters were in for an astounding surprise: A highly reflective region was clearly visible in depolarized (transmission and receipt in the same polarization) images of each pole when that pole was in view. Figure 3 is a depolarized 3.5-cm radar image showing such a feature at the north pole. The radar brightness of the pole was far higher than the brightness in any other part of the image. For the 3.5-cm data at the north pole, the radar reflectivity ratio, a rough estimate of the ratio of diffusely reflected to specularly reflected signal, is 1.0 to 1.4, compared to the <0.1 values associated with typical terrestrial planetary surfaces. Such high values for the ratio have also been observed for icy regions of Mars and outer planetary satellites. Thus, although other explanations were considered, the most likely candidate for the highly reflective areas was believed to be polar ice. According to another recent study [Paige et al. (1993) *Science, 258*, 643–646], conditions at the poles are predicted to be adequate for long-term survival of water ice in shadowed areas of impact craters.

The reflectivity ratio is actually the ratio of circularly polarized signal received in the same-sense polarization used for transmission to signal received at the opposite-sense polarization used for transmission. The radar signal received at the opposite-circular polarization from transmission is largely a specularly reflected signal; the polarization is reversed when waves are directly reflected off a "hard surface" that is relatively smooth on the scale of the radar wavelength and lies roughly perpendicular to the radar beam. Radar signal received at the same circular polarization as transmitted is the result of diffuse scatter from a surface that is rough on the scale of the radar wavelength; this surface reflects and randomizes polarization of the returning beam. The large diffuse-scattering component of water ice, which is relatively transparent to radar at this wavelength and does not present a smooth, hard surface, arises from coherent backscattering due to volume scattering from density fluctuations, cracks, voids, and particles embedded in the ice.

The same-sense reflectivity is far higher for the martian polar features than for Mercury's poles, probably as a result of some combination of less purity, smaller thickness, and greater surface covering of polar ice on Mercury.

These experimenters recommended further investigations from orbit and from Earth to determine the extent of ice. Passive radio observations can determine where the temperature regimes that are required for ice to remain stable are actually found. ☿

MERCURY MISSIONS (continued)

deposits. At a minimum, the form in which the deposits exist (whether as true surface "caps" or mixed with soil and buried) will be determined. Further constraints will be placed on the origin and evolution of the polar deposits.

4. What is the geology of Mercury, based on imaging of both imaged and previously unimaged hemispheres? The Mariner 10 mission to Mercury, which photographed only 40% of the planet's surface and one hemisphere, left many unanswered questions. Is the other hemisphere like the imaged hemisphere? By providing images for the entire surface, this mission will allow us to determine the planet's volcano-tectonic history and the extent to which volcanic or basin terrain exists.

Future Issues

Our next issue will focus on theoretical physics, and we hope to include in future issues more results of groundbased observations, including studies of the atmosphere of Mercury and the possible existence of polar ice. If you would like to contribute or suggest a topic for a future issue, please contact the editor or one of the co-editors. Send contributions or requests to the editor at the following address: Pamela Clark, c/o Rita Clark, Code 691.0, NASA Goddard Space Flight Center, Greenbelt MD 20771. If you would like to be added to the mailing list, send your name and address to Mercury Messenger, Publications and Program Services Department, Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058.

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