The MESSENGER Mercury Dual Imaging System (MDIS): Imaging Strategy at Mercury

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Introduction

The MESSENGER (**ME**rcury **S**urface, **S**pace **EN**vironment, **GE**ochemistry, and **R**anging) spacecraft will launch in March of 2004, beginning a 5-year journey to Mercury. Mercury has been visited by only one spacecraft, Mariner 10, making it the least explored terrestrial planet. Mercury is an endmember planet in terms of position, density, and composition, and knowledge of its geology and geophysics is fundamental to understanding the evolution of the inner solar system. The spacecraft will make two flybys of the planet, in July of 2007 and April of 2008, before settling into a year-long orbital mission in April of 2009. MESSENGER will carry a set of miniaturized instruments optimized to investigate such key science questions as the origin of Mercury's high density, the composition and structure of its crust, the physical properties of its core, the planet's tectonic and volcanic history, the nature of the radar bright deposits found in craters near the pole, and the characteristics of the planet's thin atmosphere and miniature magnetosphere [1]. The Mercury Dual Imaging System (MDIS), a narrow-angle and wide-angle multispectral imager, will map landforms, surface spectral variations, and topographic relief [2].

Mercury's thermal environment poses a challenge to the design of the spacecraft, with the intensity of the solar radiation varying from about 4 - 10 times the total irradiance falling on the Earth. Because of this severe environment, a sunshade protects the spacecraft from direct solar illumination, thus constraining its range of pointing [3]. To compensate for this limited pointing capability, the dual cameras of MDIS are able to pivot about a common axis. The pivot platform design enables the instrument to acquire optical navigation (OpNav) images and star field calibrations, and greatly increases opportunities to image key features with minimal impact on spacecraft pointing. The nominal scan range of the platform is 40˚ in the sunward direction to 50˚ planetward.

The wide-angle camera (WAC) has a 10.5˚ field-of-view (FOV) and consists of a refractive telescope having a collecting area of 48 mm. A 12-position multispectral filter wheel provides color imaging over the spectral response of the CCD detector. Ten spectral filters are defined to cover wavelengths diagnostic of different surface compositions and have bandwidths from 10 - 40 nm over a range of 415 nm to 1020 nm. A medium-band filter provides short integration for high-resolution imaging when the spacecraft is close to the surface (~300 km), and the last filter is panchromatic for OpNavs. The narrow-angle camera (NAC) has a 1.5˚ FOV and uses a reflective design with a single medium-band filter with a passband identical to the one used in the WAC (650 - 850 nm). Each image will include four columns of dark reference pixels in order to correct for changes in background signal due to variations in operating temperature. Both cameras have identical detector electronics contained in a modular focal plane unit (FPU). Due to thermal constraints, only one camera will operate at a time.

The primary science goals for the MDIS instrument are to produce a global monochrome map at 500 m/pixel resolution, and a global color map at 2 km or better with high SNR. In actuality, we expect to obtain about 90% of the monochrome map at resolutions as high as 250 m/pixel, and about 60% of the global color map at ~1 km/pixel, in all 11 filters. In addition, images of selected areas of the planet will be obtained at resolutions of up to 20 m/pixel, and a global topographic map will be constructed from stereo images at ~2 km/pixel. MDIS will be taking measurements complementary to those obtained by other instruments, including the Mercury Laser Altimeter (MLA), the Mercury Atmospheric and Surface Composition Spectrometer (MASCS), the X-Ray Spectrometer (XRS) and the Gamma and Neutron Spectrometer (GRNS) [2].

Mercury Flyby Imaging

The two Mercury flybys will provide the majority of the global color data. Each flyby will view a different hemisphere of Mercury, resulting in nearly 76% coverage of the planet at an average of 2 km/pixel. The first flyby is scheduled for July of 2007. MESSENGER will approach Mercury at a phase angle of 113˚, passing the planet on the night side, and departing at a phase angle of ~50 degrees. The subsolar point of the first flyby is ~174˚ E longitude. The second flyby, scheduled for April 2008, has an approach phase angle of 135˚ and a departure phase angle of 32˚. The subsolar point on the second flyby is 5˚ E longitude, nearly 180˚ from the first flyby, thus allowing mapping of the other Mercury hemisphere. Both flybys pass the equator and enable excellent mapping of the surface from ~50˚ S to 50˚ N latitude. The polar region will be mapped during the primary orbital mission.

At each flyby, a 3-color approach movie will be acquired, beginning 30 hours before the encounter and ending about 1 hour before closest approach. A departure movie, also in 3 colors, will be obtained at corresponding times on the way out from Mercury. Color images will be acquired in all 11 filters during approach and departure, at about 5 km/pixel, and a high resolution (1-km/pixel) 11-color mosaic will be obtained near to closest approach. In addition, a color photometry sequence of the same surface location will be taken at a range of phase angles. Monochrome mosaics of the surface will be acquired at resolutions of 500 m/pixel during approach and departure, and up to 60 m/pixel at closest approach.

In total, ~75% of the planet, including the previously unseen hemisphere, will be imaged in monochrome at a resolution of ~500 m/pixel, and in color at 2.4 km/pixel or better.

Mercury Orbital Imaging

MESSENGER will be placed in a highly elliptical orbit with an initial periapse altitude of 200 km and initial latitude of periapsis of approx. 60˚N. The average periapse throughout the orbital mission is ~64˚. The orbit has a 12-hour period and is inclined 80˚ to the planet's equatorial plane, to protect the spacecraft surface from thermal radiation (Fig. 1). This elliptical orbit results in a 10x difference in image resolution between the southern and northern hemispheres for a single camera. The NA camera will be used to image the southern hemisphere at a resolution comparable to imaging of the northern hemisphere acquired by the WA camera, thus resulting in a global basemap with nearly uniform resolution. The NA camera can also be used in the northern hemisphere to obtain swaths at very high resolution down to scales of 20 m/pixel. The spacecraft will be in orbit for 1 Earth year, equivalent to ~2 Mercury solar days, or ~4 Mercury years. MDIS will image the entire planet twice: once looking as close as possible to nadir, and the second time viewing ~20˚ off nadir. This strategy will allow for analysis of the same areas with identical illumination to facilitate stereo matching.

As MESSENGER's orbit evolves, it passes through two extreme cases: a near-terminator (dawn - dusk) orbit, and a near-noon-midnight orbit. When in near-terminator orbits, the spacecraft must continuously roll around the Sun line in order to keep the planet in nadir view. In near-noon-midnight orbits, the spacecraft maneuvers as far as possible to maximize planet coverage while still keeping the spacecraft bus behind the sunshade [3]

Color imaging while in orbit is designed to fill in gaps in the global map obtained during the flybys. About 50% of the surface will either not have been imaged in color during the flybys, or will have been seen at unfavorable viewing geometries. Color images of these areas will be acquired in at least 4 filters at resolutions of 1 - 2 km/pixel.

Multi-spectral photometric phase function sequences will be acquired of one spot in the southern hemisphere as it rotates from terminator to subsolar longitude. We plan to image this location at 11 phase angles in 10˚ increments, from 130˚ to 30, thus enabling a detailed characterization of Mercury's phase function.

MDIS stereo derived topography of the southern hemisphere will be merged with MLA topography of the northern hemisphere resulting in a global topographic map to be made at a resolution of ~2 km/pixel. Radio occultation measurements and earth-based radar data will provide absolute topographic control in the southern hemisphere.

References: [1] Solomon, S. C., and 20 others (2001). The MESSENGER Mission to Mercury: Scientific Objectives and Implementation, Plan. and Space Science, 49, 1445-1465. [2] Gold, R.E., and 29 others (2001). The MESSENGER Mission to Mercury: Scientific payload, Plan. Space Sci., 49, 1467-1479. [3] Santo A.G., and 25 others (2001). The MESSENGER Mission to Mercury: Spacecraft and mission design, Plan. Space Sci., 49, 1481-1500.

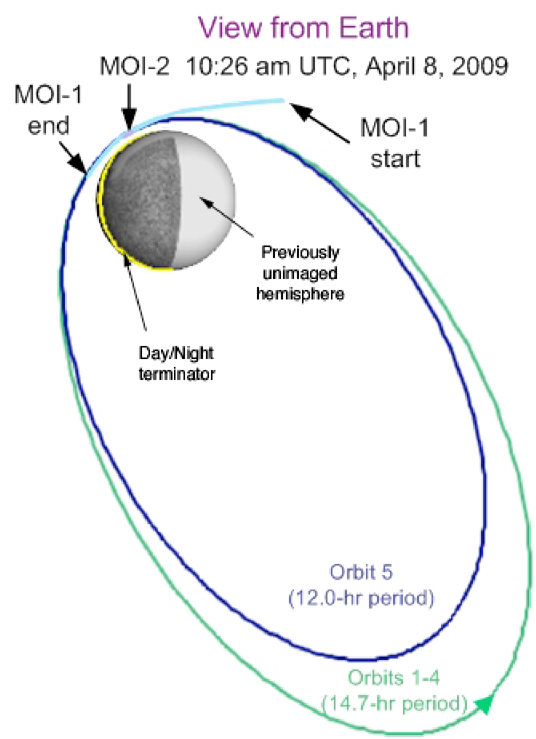

Figure 1: Mercury Orbit Insertion (MOI) showing MESSENGER's highly elliptical orbit. Initial orbits in green, first 12 hour orbit in blue.