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Mercury after six months of MESSENGER orbital observations

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1. Introduction

The MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft, launched in August 2004 under NASA's Discovery Program, became the first spacecraft to orbit the planet Mercury in March 2011 [1]. Here we summarize findings from the MESSENGER mission after its three Mercury flybys in 2008-2009 and its first six months in orbit about the innermost planet.

2. Early orbital operations

The scientific questions that underpin the MESSENGER mission led to a set of mission measurement requirements that are being achieved by the seven payload instruments and the radio science experiment [1]. Interweaving the full set of observations in a manner that maximizes the opportunity to satisfy all mission requirements and yet meets all spacecraft pointing and thermal constraints was a complex optimization problem that was solved with a software tool (SciBox) that simulates science observations and tracks progress toward meeting each objective [2]. The orbital science plan, as the outcome of that optimization process, includes an array of observational sequences now underway.

MESSENGER's Mercury Dual Imaging System (MDIS) [3] is acquiring three global mosaics: (1) a cartographic mosaic of monochrome images obtained viewing nadir to characterize the distribution and stratigraphy of landforms and geological units; (2) a stereo complement of the monochrome mosaic to determine the forms of volcanic constructs, tectonic features, and craters; and (3) a multispectral mosaic at wavelengths from 395 to 1040 nm to characterize surface materials (e.g., Figure 1). Targeted observations provide increased resolution of key features identified from prior observations and special measurement sets that require specific pointing (e.g., photometric characterizations). MDIS is also acquiring repeated images of the south pole to map permanently shadowed regions and an orchestrated set of limb images of the southern hemisphere to constrain long-wavelength topography.

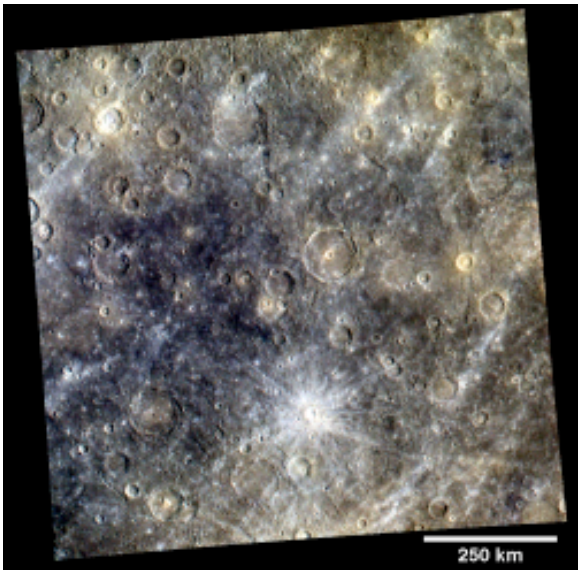

Figure 1. A portion of the MESSENGER's color base map of Mercury's surface. This image, acquired on 15 April 2011 and centered at 3.5°S, 275.7°E, was constructed from images obtained with eight color filters on the MDIS wide-angle camera [3].

MESSENGER's elemental remote sensing instruments, including the Gamma-Ray and Neutron Spectrometer (GRNS) [4] and X-Ray Spectrometer

(XRS) [5], are gathering observations to determine the average abundances of most major and some trace elements (Si, Mg, Fe, Ca, Al, Ti, S, H, K, U, Th). Maps of composition are being obtained for Mercury's northern hemisphere; the highest resolution is attained by XRS, particularly during times of high-intensity solar X-ray flux.

The Visible and Infrared Spectrograph (VIRS) channel of MESSENGER's Mercury Atmospheric and Surface Composition Spectrometer (MASCS) [6] is acquiring global observations of spectral reflectance from 300 to 1450 nm. For targeted areas, observations at wavelengths from 115 to 600 nm by the Ultraviolet and Visible Spectrometer (UVVS) channel of MASCS complement those by VIRS.

The UVVS portion of MASCS is recording the emission lines of many neutral and ion species and mapping the distributions of species within the exosphere. Several spacecraft pointing sequences are being used to examine different regions of the exosphere, including dayside radial limb profiles to provide full local-time coverage and probe important dusk-dawn asymmetries, polar scans over both poles during each dawn-dusk orbital season, mapping scans at high altitudes to provide spatial coverage on the day and night sides, and ride-along opportunities for further measurements.

MESSENGER's Mercury Laser Altimeter (MLA) [7] is acquiring topographic profiles when the spacecraft altitude is 1800 km or less. Altimetric coverage by MLA encompasses the northern hemisphere, including the north polar region, and some near-equatorial portions of the southern hemisphere. MLA profiles have an along-track resolution of 0.8–1 km and a vertical precision <1 m. Southern hemisphere topography is being derived from stereo imaging, radio occultations, and limb profiles.

MESSENGER's radio science experiment [8] is determining Mercury's gravity field from range-rate data between the spacecraft and ground stations of the Deep Space Network (DSN). Doppler tracking data are being acquired on every downlink pass and through every periapsis pass on downlink orbits. The tracking data are also giving precise occultation entry and exit times when Mercury blocks the spacecraft as viewed from Earth. The spacecraft radio frequency system is operating continuously in orbit to maximize the utility of additional DSN coverage.

MESSENGER's Magnetometer (MAG) [9] is measuring the vector magnetic field at a field resolution of 0.05 nT and at the highest instrument sampling rate (20 samples/s) for as much of every magnetospheric transit as possible, to characterize Mercury's magnetic field and magnetospheric structure. When continuous high-rate sampling is not possible, triggered high-rate burst-mode sampling is used to capture magnetospheric boundaries.

During each spacecraft orbit, both within Mercury's magnetosphere and in Mercury's solar wind environment, the Fast Imaging Plasma Spectrometer (FIPS) sensor on the Energetic Particle and Plasma Spectrometer (EPPS) [10] is acquiring wide angular sampling of ions with species discrimination for energies from 50 eV to ~10 keV per charge. These data are allowing specification of plasma composition within the magnetosphere. The Energetic Particle Spectrometer (EPS) sensor of EPPS is monitoring higher-energy ions and electrons, from ~25 to ~2700 keV, to investigate access of solar energetic particles to the planetary surface and identify magnetospheric acceleration processes inferred from Mariner 10 observations but not seen during the MESSENGER flybys.

3. Status after six months in orbit

The first six months of orbital observations span more than 350 orbits and a full Mercury solar day. The combined global observations from all of MESSENGER's instruments are markedly revising our understanding of the solar system's innermost planet.

References

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