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Dawn at Vesta

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Abstract

The Dawn spacecraft begins it's Vesta mission in 2011. The exploration of this protoplanet that has survived largely intact since it's birth at the dawn of the solar system, and which is thought to be the source of the HED meteorites, will provide important clues as to the factors that influence the variability in planetary bodies of our solar system. The comparison of the characteristics of 4 Vesta and dwarf planet 1 Ceres will elucidate the role of water, impacts, time of formation, heliocentric distance, and initial composition in producing these two neighboring but diverse protoplanets.

1. Introduction

The ion-propelled Dawn spacecraft entered the main asteroid belt on November 13, 2009 after gaining a gravity assist from Mars on February 19, 2009. It will be captured into orbit around Vesta in August of 2011, after spending roughly three months approaching the protoplanet. Dawn will spend roughly one year orbiting Vesta and collecting data in three orbit subphases. The Survey orbit is at 3000 km radius, the High Altitude Mapping Orbit (HAMO) is at 950 km radius, and the Low Altitude Mapping Orbit (LAMO) is at 460 km radius. The spacecraft arrives at Vesta during austral summer and departs as the Sun is crossing the equator. A revised Vesta rotation pole is expected in June 2010, the result of analysis of new WPC3 Hubble data collected in February 2010, which may change the illumination conditions during the encounter. HAMO is repeated during the departure phase to observe the newly illuminated terrain in Vesta's northern hemisphere, a phase referred to as HAMO-2. Figure 1 illustrates the orbit subphases and provides their characteristics. All orbit adjustments will be accomplished via thrusting with the ion propulsion system. Following departure from Vesta, Dawn will continue thrusting outward in the Main Belt and rendezvous with Ceres in February of 2015, where it will carry out a nominal five month mission and then enter a quarantine orbit.

Vesta exhibits an ancient differentiated surface and appears to be the most geologically diverse of the large asteroids. Spectroscopic observations indicate a basaltic crust. A large impact crater near the south pole may have exposed the interior (mantle) of the asteroid. Distinctive light and dark areas have been observed with the Hubble Space Telescope which may represent distinct geologic units. A goal of the Dawn mission is to develop a contextual framework for understanding Vesta as the parent body for the H-E-D suite of meteorites, which are thought to have been excavated by the large impact that created the south polar basin.

Dawn carries three instruments and a radio science package. Dawn carries two redundant framing cameras (FC: 1024 x 1024 pixels, and 7 color filters plus clear); a visible and infrared mapping spectrometer (VIR: UV to 5 microns) and a Gamma Ray and Neutron Detector (GRaND). These were provided by Germany (MPS and DLR), Italy (INAF and ASI), and LANL. Topography of the bodies will be determined from multi-angle image data to 100 m spatial resolution at Vesta. Radiometric tracking is used to map the gravity field of the bodies. For Vesta, the gravity field will be determined to degree 10 (< 90 km half-wavelength resolution). The instrument fields-of-view and sensitivity regions are shown in Figure 2.

2. Science Plan

Dawn will spend 17 days in Survey orbit, completing six orbits. The angle between the orbit plane and the sun (beta angle) was chosen as 10 degrees to optimize low-incidence-angle lighting conditions for VIR while maintaining a safe operational margin against entering eclipse. VIR will be operated in a pushbroom mode in the equatorial latitudes, where the lighting results in the VIR slit being at a high angle to the spacecraft groundtrack (Dawn's y-axis, which is aligned with the VIR slit, is controlled by the attitude control system to always keep the massive solar array pointed towards the Sun). The VIR scan mirror will sweep across the groundtrack to obtain image cubes along the orbit in most of the northern hemisphere and in the higher southern latitudes, where the slit is more parallel to the spacecraft groundtrack. Complete coverage with VIR at 600 m resolution of the adequately illuminated surface is expected. The FC will also collect mosaics and ride-along images, including limbs, which will fully cover the surface and provide a landmark control network for the image-derived topography.

The High Altitude Mapping Orbit is designed to allow efficient global mapping with the FC in the clear and multiple filters with < 100 m horizontal spatial resolution. HAMO comprises 60 orbits in six sets of ten orbits each. Each ten orbit cycle completes one global mapping of the body. A beta angle of 30 degrees balances incidence angle and coverage. Coverage of the body of >90% is expected. Two cycles are devoted to nadir imaging in clear and at least 5 filters. Four cycles are devoted to imaging at various off-nadir viewing angles in the clear filter to assemble the data needed to derive the topographic model. VIR data will be collected as ride-along in HAMO, achieving a spatial resolution of about 175 m with coverage mainly in the southern hemisphere (south pole crater).

During the departure phase, the spacecraft will stop in an orbit similar to the initial HAMO, but at a beta angle of 45 degrees to collect image data of the newly illuminated northern polar region. Distinct morphologic features related to the impact that created the south pole basin are expected in the north. Additional off-nadir data will be collected to extend the topographic mapping to high northern latitudes, and improve the height accuracy.

The Low Altitude Mapping Orbit is primarily for GRaND and gravity mapping. GRaND will accumulate events over 70 days with a duty cycle of 80% to allow confident identification of elemental abundances, enabling assessment of contributions of major HED end-members in the bulk Vesta composition and for smaller regions of the surface. Gravity data will be derived from the radiometric tracking obtained using the High-Gain Antenna (HGA) while pointed at Earth, or using a Low-Gain Antenna to a 70-m Deep Space Network station. Full gravity mapping coverage is obtained in about 40 days of tracking in LAMO. The FC will obtain nearly complete coverage at high resolution (20-m IFOV) for geologic mapping, and to refine the crater size distribution.

3. Figures

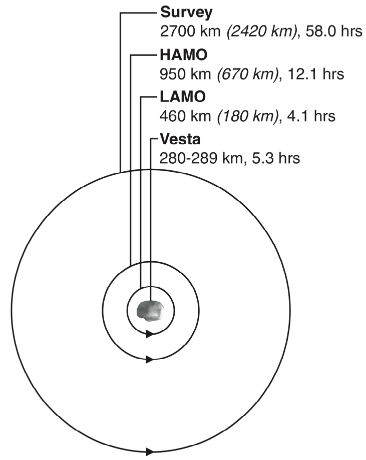

Figure 1. Dawn orbit subphases at Vesta. Orbit radii and periods are indicated, along with Vesta's radii and rotation period.

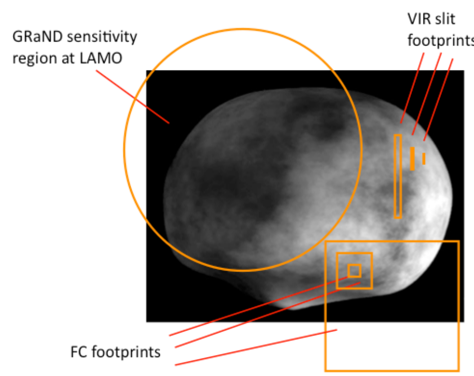

Figure 2. Instrument fields-of-view (FC and VIR) and sensitivity region (GRaND) shown for each orbit altitude on Vesta's shape model.