DAWN'S EXPLORATION OF VESTA C. A. Raymond[1], C. T. Russell[2], M. D. Rayman[1] and R. A. Mase[1], and the Dawn Team. [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109-8099, USA, [2]UCLA, Institute of Geophysics, Los Angeles, CA 90095-1567, USA. Carol.A.Raymond@jpl.nasa.gov

Introduction: The Dawn spacecraft will reach Vesta in mid-2011 and begin a comprehensive geological and geophysical characterization to investigate the geologic history, interior structure, and evolution of this minor planet in the Main Asteroid Belt [1]. Analyses of the suite of basaltic achondrite howardite-eucrite-diogenite (HED) meteorites, linked spectrally to Vesta, indicate that Vesta underwent igneous differentiation and has a metallic core. As such, Vesta represents a diminutive end-member of the differentiated terrestrial planets. Recent work by Weiss et al. (Science, 322, 2008) on the angrite (basaltic achondrite) meteorites suggests that planetesimal differentiation and short-lived planetesimal dynamos was likely common in the early solar system. Thus, Vesta may be representative of a class of objects that differentiated early, and were later incorporated into the terrestrial planets or shattered by impacts. The geochemical and geophysical data that Dawn will obtain at Vesta aims to test whether Vesta's crust and mantle formed by the fractional crystallization of a magma ocean or by serial magmatism. To characterize the magmatic processes that shaped Vesta's surface and interior, Dawn will map the morphology, surface age, and surface mineralogical composition of Vesta using its Framing Cameras and Visible-Infrared Mapping Spectrometer, and map elemental composition using its Gamma Ray and Neutron Detector (GRaND). High accuracy navigation will determine the gravity field to constrain the crustal structure, the core radius/core and mantle density tradeoff, and the compensation state of the south polar crater to estimate roughly its age. Multi-angle imaging data will be used to construct a model of Vesta's topography and map the surface morphology. The large south polar crater on Vesta is the likely source of many HED meteorites, and existing spectral data suggest it may be floored by olivine-rich material, either mantle rocks or cumulates of the lower crust. The degree to which the material excavated from the south polar crater (Vestoids and HEDs meteorites) is representative of the entire body can be addressed with Dawn data.

Vesta Mission: The Vesta mission begins with the Approach Phase, illustrated below in terms of range, phase angle and sub- spacecraft latitude. Approach activities with the framing camera include Opnav imaging, Rotational Characterizations, and a Moon search. VIR scan-mirror image cubes and FC mosaics are acquired to test integration times. The three dedicated orbits are shown in the figure below. In the 17-day Survey Phase, VIR acquires global coverage @ ~600m resolution using pushbroom imaging and scan-mirror image cubes. Multiple FC mosaics with full rotational phase coverage @ ~270 m/px resolution are obtained. In HAMO-1 (High-Altitude Mapping Orbit-1, 31 days), two nadir FC global mappings in clear and 7 filters @ ~70 m/px resolution are collected, as well as four off-nadir FC global mappings in the clear filter for topography. VIR collects scan image cubes in the north and pushbroom imaging in the south @ < 200m res. The Low-Altitude Mapping Orbit (LAMO) achieves 70 days of GRaND nadir observations at 80% duty cycle and global tracking coverage for gravity mapping at < 30 km equatorial spacing. Near-global FC imaging in clear and selected filters at ~20m resolution is also acquired. As Dawn spirals out for departure, it stops at HAMO-2, where one FC nadir mapping with filters and three off-nadir clear mappings are acquired, along with VIR pushbroom, of newly illuminated terrain.

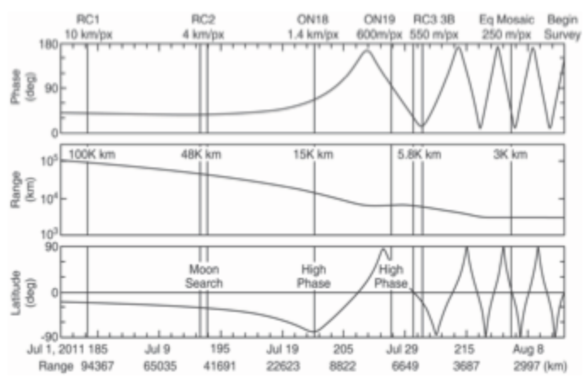

Figure 1: Approach activity timeline

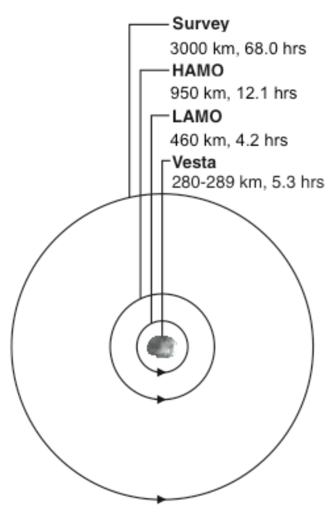

Figure 2: Dawn's orbits at Vesta

Expected Results: During the Approach Phase, the rotational characterizations will refine knowledge of Vesta's rotation pole, while the Moon search will characterize Vesta's environment. A new rotation pole (RA=307.5º±3.1º, Dec=43.1º±1.2º, 1-σ error)[3] has been estimated combining all previous data with new Hubble data. Existing data obtained using Hubble Space Telescope and Palomar rule out satellites ≥ 45m outside of 14 Vesta radii (3700 km) but permit objects of ≥ 5km within Survey orbit and ≥ 20 km within HAMO orbit. The first major improvement to the Vesta photometric model will be achieved with the approach data.

In the Survey Orbit, a global spectral mapping of the surface will be conducted @~600m resolution with the Visible-Infrared Mapping Spectrometer (VIR) when the solar phase is at the lowest of the entire mission (minimum phase of 10-15º). Over 35,000 spectral frames are collected in pushbroom mode and as cubes obtained using the scan mirror to complete the global coverage. Dense coverage will be obtained with the Framing Camera (FC) @~270m/px resolution in the clear and seven color filters, over a range of phase angles. These data will produce the first Vesta shape model and landmarks for optical navigation.

The High-Altitude Mapping Orbits (HAMO-1 and -2) are dedicated to global high-resolution mapping with the FC to produce global image mosaics at <100m resolution in panchromatic and seven color filters, as well as high-resolution spectral mapping with VIR of selected regions. Co-located VIR and FC data will provide strong constraints on surface composition, mineralogy, surface properties and weathering. HAMO-1, with a minimum phase of 30 º, provides coverage to ~58 º N latitude. By the time of HAMO-2, which takes place eight months later during departure, the subsolar point has moved from it's maximum southern latitude to an equatorial position, allowing viewing of newly illuminated terrain in the northern polar region, and viewing of the surface with different illumination conditions. In HAMO-1, two mapping cycles of 5 days each will be dedicated to nadir mapping, while four 5-day cycles will be used for off-nadir mapping in the clear filter only, yielding a total of >6000 images. The off-nadir data are used to construct the first topographic model of Vesta after HAMO-1. The sun-synchronous orbit delivers the near-constant-illumination image pairs that optimize stereophotogrammetry. Thus in HAMO-1 our data acquisition geometry optimizes the data for stereo processing. The different illumination conditions during HAMO-2 produce a combined HAMO-1/HAMO-2 data set that is optimal for stereophotoclinometry, which will also be used to produce an independent topographic model after HAMO-2. The height data from both techniques will be reconciled and merged with the gravity reference frame to produce the final Vesta topographic model at ≤100 m horizontal spatial resolution and ≤10 m height accuracy.

VIR will collect >70000 spectral frames in HAMO, mainly in the southern hemisphere, with limited coverage of the northern terminator and northern latitudes.

In HAMO-2, a similar plan will be executed, but with only four 5-day cycles. One nadir with filters and three off-nadir cycles will be obtained to fill in the northern polar cap and complete the topographic mapping.

In the Low-Altitude Mapping Orbit (LAMO), the Gamma-Ray and Neutron Detector (GRaND) is sensitive enough to detect spatially-resolved elemental abundances of major rock forming minerals and the radiometric tracking system used for navigation on the spacecraft yields high-accuracy gravity data from coherent Doppler tracking. In the nominal 70 days in LAMO GRaND builds up statistically significant counts to resolve the presence and concentrations of HEDs end-members on the Vesta surface, and to identify possible K-rich areas. The gravity spherical harmonic model is developed to degree and order 20 or more, providing a means to probe the interior structure of Vesta and confirm the presence of an iron core.

Dense high-resolution (~25 m/px) imaging coverage with limited three-filter mapping is obtained in LAMO to enable accurate age dating of individual geologic units. Combined with the sparse but globally distributed high-resolution VIR cubes, the image data will reveal tectonic fabric and geologic boundaries to further enrich understanding of Vesta's geologic history.

Summary: The Dawn spacecraft will produce comprehensive data sets that will reveal the geologic history and interior evolution of protoplanet Vesta, providing a view into the conditions and processes occurring at the earliest epoch of solar system history.

References: [1] Russell, C. T. et al. (2007), Earth, Moon, and Planets, 101, Issue 1-2, pp. 65-91. [2] Weiss, B. et al. (2008), Science, 322, 713. [3] Li, J-Y, et al., in press, Icarus.