GEOPHYSICAL EXPLORATION OF VESTA. C. A. Raymond[1], S. W. Asmar[1], A. S. Konopliv[1], R. S. Park[1], R. Jaumann[2], F. Preusker[2], C. T. Russell[3], D. E. Smith[4], M. J. Toplis[5], and M. T. Zuber[4], [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA (carol.a.raymond@jpl.nasa.gov), [2]DLR, Inst. of Planetary Research, Berlin, Germany, [3]UCLA, Los Angeles, CA, USA, [4]MIT, Cambridge, MA, USA, [5]Uni. de Toulouse, France.

Introduction: Dawn's year-long stay at Vesta allows comprehensive mapping of the shape, topography, geology, mineralogy, elemental abundances, and gravity field using it's three instruments and high-precision spacecraft navigation. In the current Low Altitude Mapping Orbit (LAMO), tracking data is being acquired to develop a gravity field expected to be accurate to degree and order ~20 [1, 2]. Multi-angle imaging in the Survey and High Altitude Mapping Orbit (HAMO) has provided adequate stereo coverage to develop a shape model accurate to ~10 m at 100 m horizontal spatial resolution. Accurate mass determination combined with the shape yields a more precise value of bulk density, albeit with some uncertainty resulting from the unmeasured seasonally-dark north polar region. The shape and gravity of Vesta can be used to infer the interior density structure and investigate the nature of the crust, informing models for Vesta's formation and evolution.

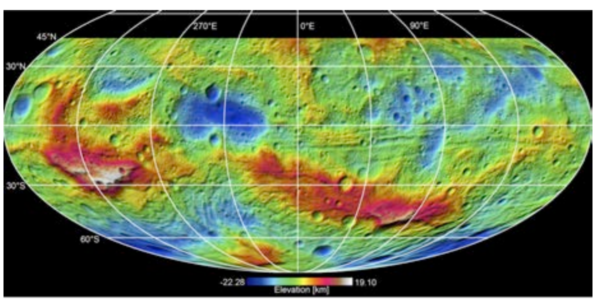

Figure 1: Shape model of Vesta derived from stereo image data and relative to a best-fit ellipsoid of dimensions 282x283x230 km [4].

Shape of Vesta: Figure 1 shows a shape model of Vesta, derived using stereophotogrammetry methods using data from the Survey orbit at ~2700 km altitude. The spatial resolution of this model is ~450 m/pixel and heights are accurate to ~30 m. Above 45°N the illumination conditions in Survey did not permit retrieval of heights. A more accurate, higher-resolution shape model is being derived from HAMO-1 data, and a second HAMO orbit during departure will image the northern regions as illumination returns there. The shape of Vesta is dominated by the large Rheasilvia impact basin at the south pole, and the high topography (terra) surrounding the Rheasilvia basin and associated with its ejecta. Also apparent are many other large impact basins [3], as well as a marked difference in the dynamic range of the topography between the northern and southern hemisphere, likely due to Rheasilvia.

Gravity Field: A degree and order 8 gravity field has been determined from tracking data through HAMO, and a higher-order field is currently being derived using LAMO tracking data. Major features of the gravity map shown in Figure 2 are the large positive anomalies associated with the northern polar cap, high topography near 30°S and 245°E, the central mound of the south polar Rheasilvia basin, and negative anoamlies over the deep portion ofhte Rheasilvia basin and several putative large impact basins in the north. Weaker positive anomalies are correlated to the equatorial cratered and equatorial trough terrains that appear to be influenced by Rheasilvia's ejecta blanket. These anomalies remain after Bouguer correction using a crustal layer of mean density ~3.0 and ~19 km thickness, indicating there are significant density anomalies within Vesta's crust.

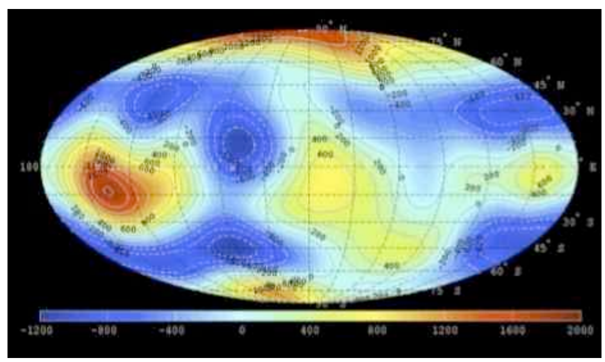

Figure 2: Radial Acceleration (mGal) on a 290x265 ellipsoid [1].

Bouguer anomalies over the Rheasiliva basin (Fig 3) show a clear correlation of the positive Bouguer anomalies with the high terrain along the crater rim, and the central mound. The higher density implied for the central mound is in agreement with the presence of diogenitic material identified in VIR data [5]. The low over the second, older impact basin is consistent with the signatures apparent in the northern hemisphere. Modeling of these gravity anomalies with higher resolution gravity and topography data will allow inferences about the crustal thickness and density variations.

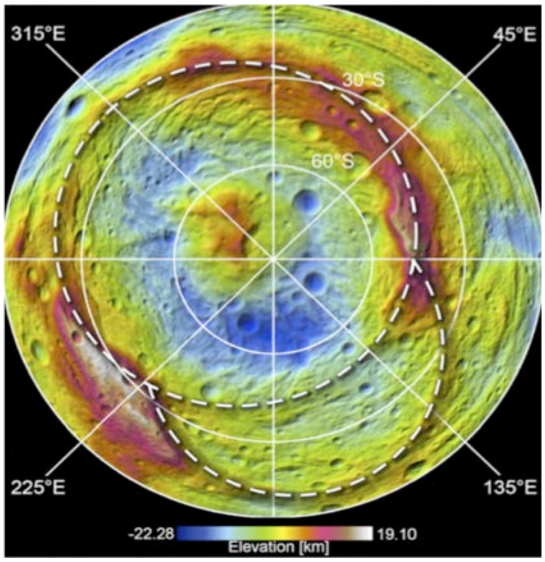

Figure 3a. Topography of the south pole with outlines of Rheasilvia and an older underlying impact basin.

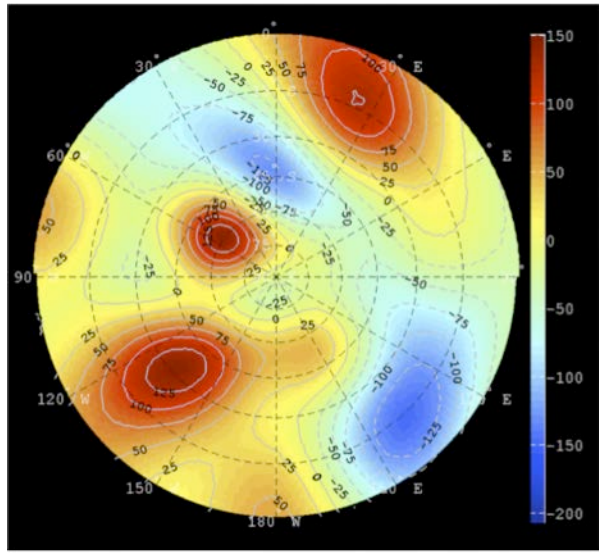

Figure 3b. Bouguer gravity of the south pole impact basin, contoured in mGal.

Vesta's Core: The bulk density estiamte has been combined with Dawn's measurement of 0.03178 for the gravitational moment J_2 to explore the range of models of Vesta's interior that are consistent with the geophysical and geochemical constraints. The J_2 predicted from Vesta's shape for a homogenous density is 0.0350, thus the measured J_2 confirms the presence of a central mass concentration. We investigate a range of two-layer models of Vesta's internal structure to obtain constraints on the size of the core. Core and bulk silicate densities, and core radii, were varied within geochemically constrained ranges to derive the range of expected core size. Core densities of 3900, 6000, 7000 and 8000 kg m^{-3} were used, representing possible asteroid evolution models from low-degree partial melting to crystallization in a magma ocean. Values between 7000 and 8000 kg m^{-3} are consistent with densities of iron meteorites expected for a fully differentiated body, while density of 3900 kg m^{-3} is consistent with a partial melting scenario in which the central "core" is a mixture of sulfides, metals and the residue of partial melting. For each core density, core size and bulk silicate density are derived that can reproduce $J_{2.}$ The core size and silicate density that fits J_2 is narrowly constrained for core densities between 6000 and 8000 kg m^{-3}. The range of core densities associated with the iron meteorites (7000-8000 kg m^{-3}) yields an average core size (equivalent spherical core size) of 105-114 km, resulting in a core mass fraction (~18%) similar to that deduced from the meteoritic data [5, 6] . The core size expands to 126 km for lower density FeS 6000 kg m^{-3}). The core size and shape are only weakly dependent on the core density; rather the density of the silicate fraction controls the fit for a given flattening The core density associated with an undifferentiated interior allowed by partial melting models requires bulk silicate (crustal) densities that are very low. We have been able to rule out a partial melting scenario in which a very light crust (~2000 kg m^{-3}) overlays a denser chondritic mantle (3900 kg $\cdot$ m^{-3}), because such models do not match J_2.

While it is possible to have a core of FeS with minor metal in a chondritic body, if that were true on Vesta it would result in significant sequestering of both chalcophile and siderophile elements in the core, and corresponding depletions in the eucrites and diogenites; such chalcophile depletion is not observed in the HEDs. Hence, the core size constrained by the densities of iron meteorites, the HEDs, and petrogenetic models of the Vesta's interior evolution indicate an iron core of size 105-114 km, that is consistent with a magma ocean scenario. Modeling of Dawn's higher-order gravity field will help constrain Vesta's crustal thickness and crust and upper mantle density, providing further constraints on Vesta's interior structure.

References: [1] Asmar, S. W. et al. (2012) *LPS XLIII.* [2] Konopliv A. S. et al. (2011) *Space Sci. Rev.,163,* doi: 10.1007/s11214-011-9794-8. [3] Marchi S. et al. (2012) *LPS XLIII.* [4] Preusker F. et al. 2012) *LPS XLIII.* [5] De Sanctis, M. C. et al., (2012) *LPS XLIII* [6] Ruzicka A. et al. (1997) *Meteor. Planet. Sci. 32,* 825-840. [7] Righter, K. and M. J. Drake, (1997) *Meteor. Planet. Sci., 32,* 929-944.