Geophysical Research Abstracts
Vol. 12, EGU2010-3321, 2010
EGU General Assembly 2010

Dawn Virtual Vesta: Topographic Stereo Mapping Using Simulated FC Data

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The initial exploration of any planetary object requires a careful mission design guided by our knowledge of that object as gained by terrestrial observers. This process is very evident in the development of the Dawn mission to the minor planets 1 Ceres and 4 Vesta. This mission was designed to verify the basaltic nature of Vesta and to explore its geologic evolution. Hubble Space Telescope observations have determined Vesta's size and shape, which, together with masses inferred from gravitational perturbations, have provided estimates of its density. These investigations are the basis for choosing the appropriate instrumentation, design and orbital operations at Vesta and prepare for a precise data evaluation. In particular, as the estimation of Vesta's topography is crucial for understanding its surface processes and geological evolution, photogrammetric stereo processing of simulated Dawn FC (Framing Camera) data (Virtual Vesta) has been performed to constrain topographic accuracies and to optimize the observation scenario. The stereo-photogrammetric derivation of a digital terrain model (DTM) relies on area-based multi-image matching of two or more images. The resulting tie point coordinates are combined with the interior camera geometry (camera calibration) and information of the orbit position and pointing. By three-dimensional forward ray intersection an irregular grid of object points is built up, which is used to interpolate a final raster DTM. Generally, the quality of DTMs strongly depends on the accuracy of the orientation data. While the interior camera geometry of FC is well defined by laboratory calibration measurements, photogrammetric block adjustment is used to improve Dawn orientation data. The Virtual Vesta dataset consists of simulated observations of Vesta for the Survey & High Altitude Mapping Orbits (HAMO), based on the current mission image acquisition strategy, including S/C trajectory and camera orientation. The simulated Vesta surface is based on the HST-derived global shape by Thomas 1997, 2005, with the addition of craters with diameter range of 0.4 - 100 km and surface perturbations at wavelengths from few 100 m to 10s of km. The resolution of the Vesta model is 10 m/pixel with a height accuracy of ~1 m, 1-sigma. The simulated trajectory and camera orientation data contain errors whose magnitude is consistent with what is expected at a post-processing stage; 1 FC pixel 1-sigma, random orientation error per image, and correlated position errors that range from a few km in Survey to few 100s m in HAMO. Both orbits consist of highly variable illumination geometry (Sun azimuth: 0-360°, incidence: 0-90°) for the illuminated part of Vesta (i.e. the southern hemisphere up to low northern latitudes) at the time period of the respective orbits:
- Survey orbit (up to ~53° N): 507 images, mean image resolution 250 m/pxl
- HAMO (up to ~58° N): 2,005 images, mean image resolution 60 m/pxl
Particularly for HAMO an observation strategy has been worked out, in order to fulfill the following geometry and illumination requirements for efficient stereo processing:
- the stereo angle between stereo images should be >15° and <65°
(to provide sufficient vertical and horizontal accuracy) and
- the phase angle for each image segment should be >2°
(to avoid influence from opposition effect) and
- the incidence angle for each image segment should be >20° and <60°
(to provide sufficient contrast and to minimize the amount of cast shadow areas) and
- the emission angle for each image segment should be <75°
(to exclude near-limb image segments) and
- the variation of the illumination direction of stereo images should be <10°(to minimize mismatching caused by

variable illumination).
For both datasets, DTMs with sub-pixel accuracy can be derived.
Ref. Thomas et al., 1997, Science 277, 1492-1495; Thomas et al., 2005, Nature 437, 224-226.