OPTICAL NAVIGATION FOR THE DAWN MISSION AT VESTA

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ABSTRACT

The Dawn S/C was launched in September 2007 towards asteroids Vesta and Ceres, in order to conduct various remote sensing observations of their surface, interior and elemental composition with a payload consisting of optical and infrared instruments and a gamma ray and neutron detector. In addition radiometric data will be collected to determine the gravity field of each asteroid.

After 3 ½ years of interplanetary cruise, mostly with its Ion Propulsion Engines, Dawn began its final approach operations phase towards Vesta in May 2011 and was captured by Vesta in July 2011. Subsequently it has entered 3 science orbits, at progressively lower altitudes, each with distinct orbital characteristics, scientific goals and duration; Survey, High Altitude Mapping Orbit 1 (HAMO-1) and Low Altitude Mapping Orbit (LAMO). Currently Dawn had successfully completed operations at LAMO and is on its transfer to the final, HAMO-2, science orbit, with an expected Vesta departure date near the end of August 2012.

An important navigation component is optical navigation (OpNav), which has been conducted at all mission phases with the exception of the transfer to HAMO-2. Optical data are complementary to the traditional radiometric range and Doppler data and often allow visibility in directions perpendicular to those. In addition to supporting real-time navigation operations, optical navigation will be used to determine some key physical characteristics of Vesta, such as the asteroid's pole & shape, and to assist mission design & science operations.

In this work we present an overview which includes the optical navigation plan, camera calibration, imaging, methodology, data types, expected performance, testing and verification as well as the key interfaces and procedures in OpNav processing. We also include our up to date results and some comparisons between the expected and actually achieved overall plan and performance.

The relative size of Vesta, which exceeds the camera field of view for most of the duration of the mission necessitates use of surface-relative OpNav methods. Landmarks are the most important data type. They are used extensively starting with the middle of the approach phase and are at the focus of OpNav processing. Landmarks are control points on the surface of the asteroid, centered on a small digital terrain and albedo model of a small patch of the surface, or landmark map. They are constructed with stereo-photoclinometry, a method that combines aspects of stereo and

more traditional photoclinometry techniques. The association of landmarks with topographic models brings significant advantages in processing accuracy, speed, automation and allows for a large volume of optical measurements to be included in the orbit determination process. In turn, the use of landmarks also influences the overall image acquisition plan from late approach and in the various science orbits. Although landmarks have been used in the past for reconstruction and topographic investigations, this is the first effort to use them in real-time navigation, i.e., orbit determination, trajectory design and on-board ephemeris and sequence updates.