DAWN AT CERES – SHAPE MODEL AND ROTATIONAL STATE. Frank Preusker[1], Frank Scholten[1], Klaus-Dieter Matz[1], Stephan Elgner[1] Ralf Jaumann[1], Thomas Roatsch[1], Steve P. Joy[2], Carol A. Polanskey[3], Carol A. Raymond[4], Christopher T. Russell[2], [1]German Aerospace Center, Institute of Planetary Research, D-12489 Berlin, Germany (Frank.Preusker@dlr.de), [2]UCLA, Institute of Geophysics, Los Angeles, CA 90095-1567, USA, [3]Bear Fight Institute, Winthrop, WA, USA, [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109-8099, USA,

Introduction: In 2012, the Dawn mission completed its 14-month observation campaign at asteroid (4) Vesta and entered in March 2015 successfully into the orbit around its final target – the dwarf planet Ceres. The mapping strategy at Ceres is similar to the strategy successfully applied at Vesta and is divided into three different altitude orbits Survey, High Altitude Mapping Orbit (HAMO), and Low Altitude Mapping Orbit (LAMO) [1]. At the moment, Dawn has completed its Survey and High Altitude Mapping Orbit (HAMO) phases at Ceres and is currently in its Low Altitude Mapping Orbit (LAMO). In June 2015, Dawn started its Survey orbit and acquired about 880 clear filter images using the onboard camera Dawn FC [2] with a resolution of about 400 m/pixel in eight different cycles. In August 2015 Dawn started its HAMO orbit. The Dawn FC acquired about 2350 clear filter images with a resolution of about 135 m/pixel in six different cycles. In each cycle, Ceres was mapped completely under similar illumination conditions (Sun elevation and azimuth), but different viewing conditions (by slewing the spacecraft off-nadir). This stereo constellation allows us to construct digital terrain models (DTMs) and to analyze the rotational state of Ceres.

Methods: The stereo-photogrammetric processing for Ceres is based on a software suite that has been developed within the last decade. It has been applied successfully to several planetary image data sets [3-7] and covers the entire workflow from photogrammetric block adjustment to digital terrain model (DTM) and map generation.

Results: We constrained all HAMO clear filter images with our stereo requirements (Table 1) and achieved at least triple stereo image coverage for the entire illuminated surface. In total, about 10,000 independent multi-stereo image combinations were used to determine selected image tie points by multi-image matching for the set-up of a 3D control network of ~30,000 surface points. The control point network defines the input for the photogrammetric least squares adjustment where corrections for the nominal orientation data (pointing and position) are derived. The three-dimensional (3D) point accuracy of the resulting ground points have been improved from ±200 m to ±16 m (0.12 pixel). We have also refined Ceres' spin axis orientation, formerly determined from Earth-based observations [8], to: right ascension = 291.431° ± 0.01°, declination = 66.761° ± 0.01°. Furthermore we have refined the spin rate, formerly as well determined from Earth-based observations [9] to W1 = 952.15323 +/- 0.00005 degree per day. In conclusion we changed W0 to 170.488° ± 0.01° that the IAU approved tiny crater 'Kait' (Figure 1) is located at zero longitude [10].

Finally, 10,000 individual multi-image matching processes at full image resolution were carried out to yield ~2.8 billion object points. The achieved mean forward ray intersection accuracy of the ground points is ±16 m. Finally, we have generated a DTM with a lateral spacing of 135 m/pixel (60 pixel/degree) and a vertical accuracy of about 10 m (Figure 2). The HAMO DTM covers approximately 98% of Ceres' surface (few permanently shadowed areas near the poles required interpolation). Based on the HAMO DTM, we determined a best-fit ellipsoid (482.8/480.6/445.0 km) with its body long axis at 45.9°E.

Differences in illumination	<10°
Stereo angle	15-55°
Incidence angle	10-90°
Emission angle	0-55°
Phase angle	10-180°

Table 1. Requirements for stereo processing.

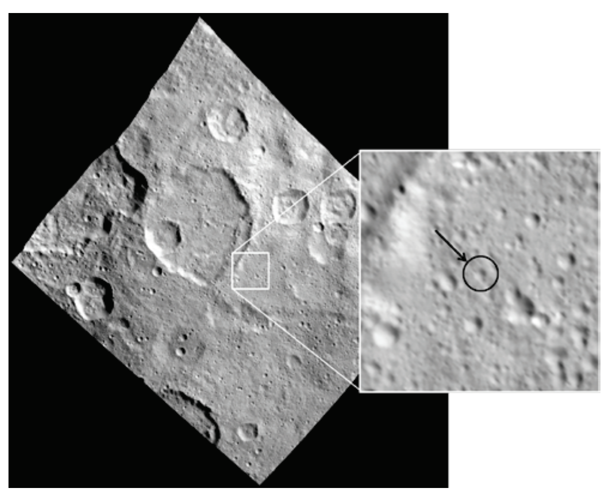

Figure 1. Crater Kait in HAMO image FC21A0042363

Finally, using adjusted orientation data and the HAMO DTM as the topographic reference, ortho-rectified HAMO clear filter images, clear filter image mosaics, and a HAMO atlas of Ceres have been derived [10, 11].

Outlook: A final version of the Ceres DTM and an overall re-assessment of Ceres' geophysical properties can be expected from the analysis of the entire Dawn FC image dataset of Ceres (from Survey, HAMO, and LAMO orbit) when the Dawn mission will finish its mapping observations.

References: [1] Russell C.T. et al., (2011), *Space Sci. Review*, 163/1-4. [2] Sierks H. et al., (2011), *Space Sci. Rev., 163*, 263-327. [3] Giese B. et al., (2006) *Planetary and Space Science*, 54, 1156–1166. [4] Gwinner K. et al., (2009) *Photogrammetric Engineering Remote Sensing, 75*, 1127–1142. [5] Preusker F. et al., (2011*), PSS, 59*, 1910–1917. [6] Scholten F. et al., (2012) *JGR*, Vol. 117. [7] Preusker F. et al., (2015) *A&A*, 583, A33. [8] Thomas P.C. et al., (2005), *Nature* 437, 224-226. [9] Chamberlain M.A. et al., (2007), *Icarus* 188, 451-456. [10] Roatsch T. et al. (2015) *Planetary and Space Science*, in press. [11] Roatsch T. et al., (2016) *this meeting*.

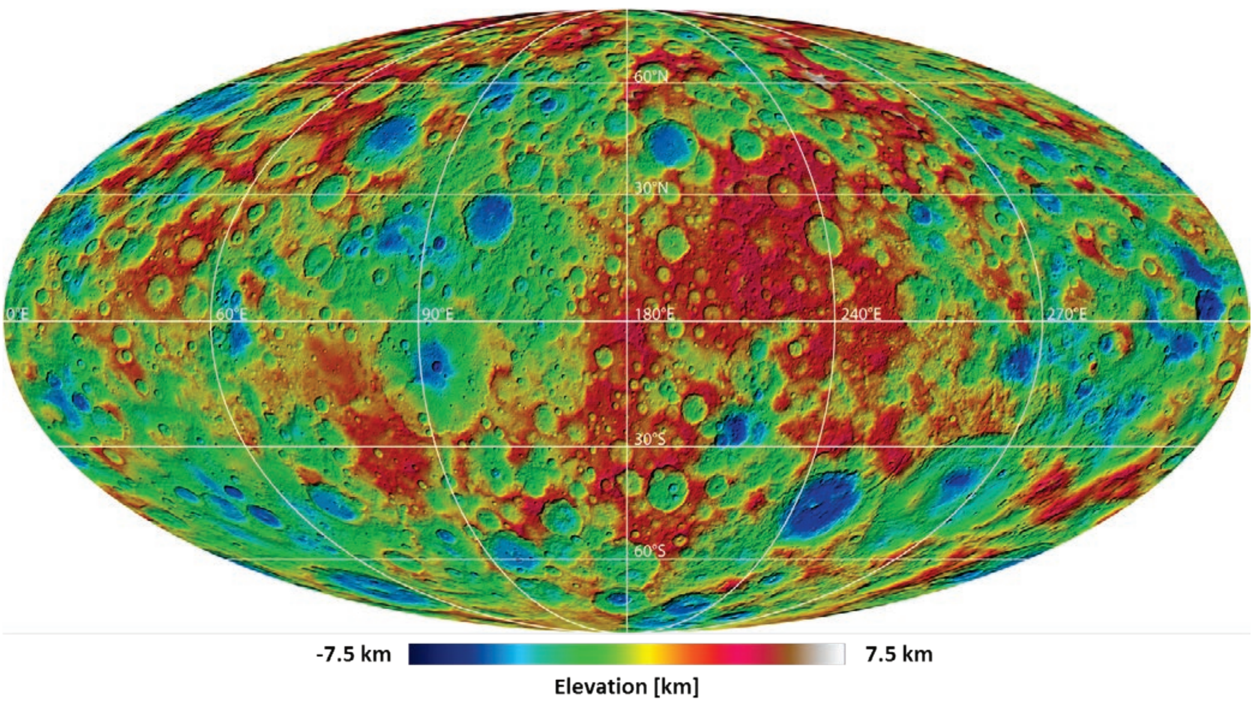

Figure 2. Global HAMO DTM of dwarf planet Ceres centered at 180° with a lateral spacing of about 135 m/pixel (hill-shaded color-coded heights) in Mollweide Projection (equal-area). Elevations refer to a biaxial ellipsoid (482x482x446 km).