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New astrometric observations of Phobos and comparisons of different data reduction schemes

A. Pasewaldt (1), J. Oberst (1,2), B. Beisembin (2), K. Willner (2), H. Hoffmann (1), K.-D. Matz (1), T. Roatsch (1), and V.Lupovka (3)
(1) German Aerospace Center, Berlin, Germany, (2) Technische Universität Berlin, Berlin, Germany , (3) Moscow State University of Geodesy and Cartography, Moscow, Russia (Andreas.Pasewaldt@dlr.de / Fax: +49 30 67055-402)

Abstract

From April 2008 until August 2011, the Mars Express (MEX) spacecraft carried out about 80 Phobos flybys, during which more than 240 images of this Martian satellite were acquired. These images were used in order to derive the position of the moon's center-of-figure (COF)[1]. Throughout each flyby the inertial pointing of the camera was controlled by measuring the relative positions of background stars. The position of the natural satellite was determined by means of the limb-fit method (191 obs.) and/or by measuring the positions of surface features (210 obs.). The results are 239 positions of Phobos' center in right ascension and declination coordinates in the S/C-centered J2000 coordinate system.

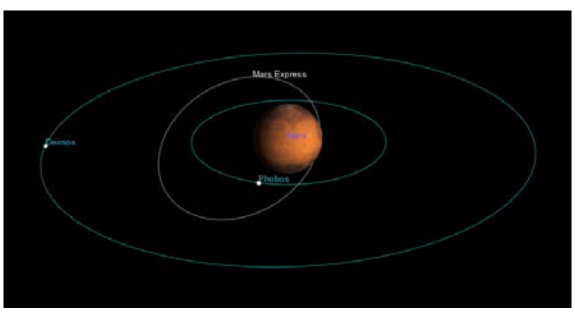

Figure 1: Mars Express in the Martian system.

1. Introduction

Phobos, the larger and inner of two Martian moons, revolves in a mean distance of 9,376 km from Mars' center in a near-equatorial, near-circular orbit. Its sidereal orbital period is 7.65 hours. Phobos is tidally locked to its parent planet. Because it is moving far inside the synchronous orbit, it is subject to tidal acceleration.

[1] In this investigation it is assumed that the deviations between Phobos' COF and center-of-mass (COM) are small and therefore can be neglected.

The evolution of the Phobos orbit is generally derived from analytical and numerical orbit models that help us exploring the moon's in the past and future. Astrometric observations or positional measurements of Phobos' center constitute the main input data to these models [2,4].

2. Data and methods

The MEX spacecraft carries seven scientific instruments, among them the HRSC/SRC camera. While the HRSC is a push-broom line scanner, the SRC is a frame camera with Maksutov-Cassegrain optics (focal length: 988.6 mm; f/11) and a 1,024 × 1,024 CCD array. The MEX spacecraft is in a highly elliptical orbit about Mars with a periapsis of 250 km and an apoapsis of 10,100 km above the Martian surface. Its orbital period is about 6.721 hours and therewith similar to that of Phobos [2,3,4].

2.1 Background star measurements

During each flyby the SRC camera is pointing at a fixed position on the celestial sphere, while Phobos is crossing the field-of-view. A contiguous sequence of eight images is taken, of which the first and the last image are long-time exposures in order to catch the faint light of background stars. For these images the pointing can be verified and improved by comparison with the positions of reference stars from a catalogue. Between the first and the last image, a linear pointing drift is assumed [4].

2.2 Limb-fit measurements

At a given image time Phobos' limb can be predicted and projected onto the image plane. The prediction has to take into account the current models of Phobos' position, orientation, size, and shape as well as the illumination (Sun) and observation (camera) geometry.

It is represented by a number of limb points, whose positions are defined relative to the moon's COF. By using a semi-automatic work flow the predicted limb can be fitted to the observed limb such that predicted limb points match with observed limb pixels. As a result the position of the COF is stored as new position of Phobos [1,2].

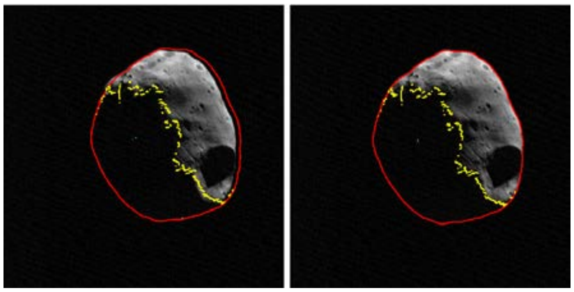

Figure 2: Fitting of predicted to observed limb.

2.3 Control point measurements

In the same way the positions of points of a control network (665 points) [5] can be predicted and projected onto the image plane. If we identify and measure the positions of the corresponding observed control points, we can set up a system of equations in order to calculate the transformation parameters between predicted and observed control points. From at least two pairs of corresponding points we can solve for the parameters of a 2-D similarity transformation. If we apply these parameters on the predicted center-of-mass (COM), we obtain a new position of Phobos [4].

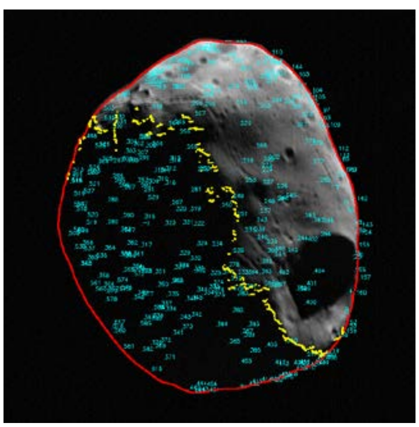

Figure 3: Phobos' control points.

3. Results and discussion

The image coordinates of Phobos are first corrected for the pointing offset and then transformed to J2000 coordinates. The results are 239 positions of Phobos' center in equatorial coordinates in the S/C-centered, J2000 coordinate system [2,4].

The observation errors are calculated as sum of the error of the resp. measurement method, the error in camera pointing, and the error in S/C position [1,2,4].

$$\sigma = \sqrt{\sigma_a^2 + \sigma_b^2 + \left(arctan\left(\frac{\sigma_c}{d}\right)\right)^2}$$

Acknowledgements

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References

[1] Duxbury, T. C. and Callahan, J. D.: PHOBOS and Deimos astrometric observations from Mariner 9, Astronomy and Astrophysics, Vol. 216, pp. 284-293, 1989.

[2] Oberst, J., Matz, K.-D., Roatsch, T., Giese, B., Hoffmann, H., Duxbury, T., Neukum, G.: Astrometric observations of Phobos and Deimos with the SRC on Mars Express, Astronomy and Astrophysics, Vol. 447, pp. 1145-1151, 2006.

[3] Oberst. J, Schwarz, G., Behnke, T., Hoffmann, H., Matz, K.-D., Flohrer, J., Hirsch, H., Roatsch, T., Scholten, F., Hauber, E., Brinkmann, B., Jaumann, R., Williams, D., Kirk, R., Duxbury, T., Leu, C., Neukum, G.: The imaging performance of the SRC on Mars Express, Planetary and Space Science, Vol. 56, pp. 473-491, 2008.

[4] Willner, K., Oberst, J., Wählisch, M., Matz, K.-D., Hoffmann, H., Roatsch, T., Jaumann, R., Mertens, V.: New astrometric observations of Phobos with the SRC on Mars Express, Astronomy and Astrophysics, Vol. 488, pp.361-364, 2008.

[5] K. Willner, J. Oberst, H. Hussmann, B. Giese, H. Hoffmann, K.-D. Matz, T. Roatsch, T. Duxbury: Phobos control point network, rotation, and shape, Earth and Planetary Science Letters, Vol. 294, pp. 541–546, 2010.