Observations of Phobos and its shadow: Implications for the Phobos orbit. K. Willner, J. Oberst, M. Wählisch, K-D. Matz, T. Roatsch. German Aerospace Center, Institute of Planetary Research, Rutherfordstrasse 2, 12489 Berlin, konrad.willner@dlr.de.

Introduction: The orbit of Phobos deep in the gravity field of Mars is strongly affected by various parameters of the Mars interior. The orbit of the small satellite is therefore complex and undergoing a particulate tidal evolution. Our early analysis of images from High Resolution Stereo Camera / Super Resolution Channel (HRSC/SRC) on Mars Express (MEX) [4] have shown stark discrepancies between orbit models and observations of up to 12 km, a fact which renewed the interest in more detailed astrometric analysis of Phobos data to constrain the orbit models. Since these early studies, we have made a number of new astrometric measurements using new image data and upgraded measurement techniques. The Mars Express spacecraft has continued its Phobos flyby maneuvers and has obtained many more SRC images of the satellite. In addition, the shadow of Phobos was captured on several occasions by the HRSC and the Mars Orbiting Camera (MOC) on the Mars Global Surveyor, which all had not been analyzed yet. These shadow observations provide further constraints on the orbit of Phobos not affected by uncertainties in the spacecraft orbit and camera pointing. In the presentation, we will report on first preliminary results of our ongoing study titled „Geodesy and Cartography of Phobos“, funded by DFG.

Shadow observations: We evaluated the MOC wide- and narrow image data base to search for transits of Phobos` shadow through the camera's field of view over the course of the long mission, beginning in 1997. 334 candidate images, presumed to contain the shadow, were found. The majority of images were taken by the MOC wide angle camera with pixel resolutions between 1 km and 7.5 km. The images differed greatly in quality of the shadow and the image data itself. Thus we classified the images being left with 19 'excellent', 88 'very good', 100 'good' and 127 'low quality' images. On the other hand, there are 9 HRSC images from 5 orbits of different channels available which contain the Phobos shadow in pixel resolution of 100m; all these have excellent quality (Fig. 1).

We only considered the 19 'excellent' MOC images and the 9 HRSC shadow observations for analysis. To determine the position of Phobos in the stellar sky we determined the exact position of the shadow center, the height above a reference body and we extracted the exact time from the image data. We projected all images into an equidistant map projection on a Mars Orbiter Laser Altimeter (MOLA) reference sphere and registered the images to the Mars digital Image Map (MDIM) 2.1. Thus a direct measurement of the ellipse center with an ellipse-fit method was possible. The corresponding height of the surface was extracted from the Mission Experiment Gridded Data Record (MEGDR) of the MOLA –dataset. The stellar position of the sun at the time of the observation of the Phobos shadow center equals the stellar position of Phobos at the time. All Phobos position results were compared with the recent orbit model of Lainey et al., 2005 [3]. Results from HRSC images show that Phobos is ahead of its predicted position by an average value of 3.5km with an accuracy of ±0.8 km. The across-track offsets varied between 0.2 km and 10.6 km ±0.3km. In contrast, results from MOC images show discrepancies of 1 km to 18 km in along-track and 1 km to 4.5 km in across-track direction with accuracies of ±5.9km and ±1.6km, respectively.

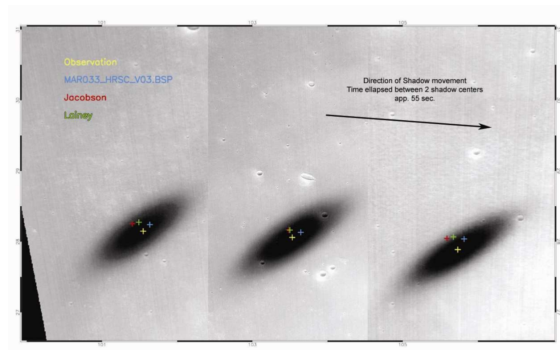

Figure 1: Three shadow images taken during the MEX orbit no. 2345. The HRSC imaged the shadow in green, nadir and blue channel (from left to right). The marks show different orbit model calculations in comparism with our observations.

Phobos flyby observations by SRC: We have made several improvements [5] over our previous measurement techniques [4]. Also, many more Phobos images from 44 flybys were available compared to what was available in our previous studies. Background star images before and /or after the Phobos encounter were used to control the pointing uncertainties of the camera such that smaller offsets between model and observation can be identified than was possible before. Also, we use control point measurements rather than limb fits to determine the position of the Phobos center of figure/mass (COF/COM) in the image. Control points from the catalog of Duxbury and Callahan [1] – all of them craters – were identified in the images, and their line/sample coordinates were measured in SRC images from flybys. These were compared with the theoretical image coordinates for each control point computed from the Phobos orbit model and corrected camera pointing. The transformation parameters - a translation vector, scale and rotation - between observation and theoretical image coordinates were then computed by using an iterative least-squares analysis involving all identified surface features of one image at a time. The obtained transformation parameters were applied to the nominal COF of Phobos image coordinates. From the corrected pointing of the camera, we obtained the stellar position of the Phobos COF.

Results: The early discrepancies between predicted and observed Phobos positions have motivated new studies of the Phobos orbit by various teams. On the basis of our reported astrometric data [4], Lainey et al. [3], have produced an updated Phobos orbit model, involving parameters describing higher-order gravity field parameters of Phobos and updated values for the tidal Q of Mars. A second new Phobos orbit model has been produced at Jet Propulsion Laboratory [2]. Our new data show that these models and our understanding of the orbit of Phobos have indeed much improved. However, distinct small offsets between models and observations remain. Our astrometric measurements during Phobos flybys consistently show that Phobos is being ahead of its position by 1km to 2.5km compared to the prediction from Lainey's model. The accuracy of our new data allows us to show that these differences depend on the position of Phobos in its orbit, an observation which may be the basis for further improvement of the models. The Phobos shadow measurements which constitute an attractive independent verification of the results are in agreement with these data, but unfortunately show much larger scatter, for which the reason is still being investigated.

References: [1] Duxbury T. C. and Callahan J. D. (1989), Phobos and Deimos control networks. Icarus, 77:275-286 [2] Jacobsen, pers. communication [3] Lainey V. et al. (2005), New ephemerids of the Martian moons. EOS Trans AGU, G51A-0802 [4] Oberst J. et al. (2006), Astrometric observations of Phobos and Deimos with the SRC on Mars Express. A&A, 447:1145-1151 [5] Willner K. et al. (2007), Workshop "Advances in Planetary Mapping 2007", LPI, Houston, Mar 2007, submitted