

**NEW OBSERVATIONS OF PHOBOS AND ITS SHADOW WITH THE HRSC/SRC ON MARS EXPRESS.**

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**Introduction:** The Mars Express (MEX) spacecraft is in an elliptic near-polar orbit and occasionally approaches the Martian satellite Phobos. As the ratios in orbit periods of MEX and Phobos are similar, there are typically multiple flybys in consecutive orbits, followed by a period without encounters. For example, a total of 3 Phobos flyby maneuvers were executed within one November week, 2005, alone. The spacecraft is equipped with the HRSC (High Resolution Stereo Camera), a pushbroom scanner for multispectral stereo mapping of the planet surface, and the SRC (Super Resolution Channel), a panchromatic 1K x 1K framing camera, suited for astrometric observations. During 25 individual flybys (as of Jan 10, 2006), Phobos was observed by HRSC and SRC from ranges between 5000 km and 150 km (Table 1 and Fig. 1). In addition, the Phobos shadow was captured on four occasions by several of the nine viewing channels of the HRSC (Fig. 2).

**Flyby Observations:** While results from the first Phobos flybys have been reported previously [1,2], more data from recent flybys have been obtained since. Data from the first encounters have been used for topographic modeling of Phobos [1] as well as for astrometric measurements of the satellite position [2]. The positional data differed substantially from the various available predictions, which had been based on images from the early Mariner, Viking and Phobos missions [3,4,5], and the discrepancy therefore motivated the beginning of renewed Phobos orbit modeling efforts [6]. The new flyby observations confirm the updated orbit models of Phobos and can be used to further improve the accuracy of the models, which bear important implications on tidal dissipation and internal structure of Mars, possibly even on the higher-order terms of the Phobos gravity field [6].

**Shadow Observations:** The recent shadow observations by HRSC are used as an independent check on the orbit models, as the shadow locations are not affected by uncertainties in spacecraft trajectory- and pointing data. The positions of the shadow were measured in HRSC images that were reprojected to the MOLA (Mars Orbiting Laser Altimeter) Mars shape model, using the nominal MEX orbit and camera pointing data. Comparisons of the reprojected images with MOLA shaded relief maps of the corresponding area are used to verify that the navigation data including time tags in the HRSC images are correct. Also, measurements were made for the size,

elongation, orientation, and brightness of the shadow. We estimate that the position of the (diffuse) shadow can be estimated to within approx. 10% of the shadow width. The measured positions were compared with the predictions of the shadow position, which were computed on the basis of the new Phobos ephemeris and the known lighting geometry. Predictions and observations appear in agreement within the measurement accuracy of the shadow position.

**Table 1: Phobos Observations**

Flybys:

Orbit	Date and Time	M. Anomaly	Flyby Dist.
413	2004-05-18T08:34	32.02°	1881 km
649	2004-07-23T12:40	185.11°	1834
682	2004-08-01T18:35	178.02°	1465
715	2004-08-11T00:30	171.36°	1207
748	2004-08-20T06:25	164.77°	1239
756	2004-08-22T12:06	169.14°	147*)
1064	2004-11-16T14:22	114.14°	4676
1163	2004-12-14T08:06	94.43°	3815
1212	2004-12-28T01:18	91.70°	1966*)
1558	2005-04-03T23:51	40.59°	3588
1574	2005-04-08T11:21	53.57°	3797
1607	2005-04-17T17:15	47.54°	3977
1769	2005-06-02T03:41	202.77°	1440*)
1901	2005-07-09T03:25	181.73°	3109
2151	2005-09-16T23:24	136.73°	3825
2192	2005-09-28T11:02	131.80°	2924*)
2233	2005-10-09T23:50	127.02°	2111
2381	2005-11-20T09:06	94.23°	3169
2397	2005-11-24T20:39	100.80°	1672
2405	2005-11-27T02:15	106.72°	1426
2446	2005-12-08T13:44	96.60°	2026
2463	2005-12-13T08:03	75.12°	4233
2479	2005-12-17T19:26	83.87°	2913
2487	2005-12-20T01:15	89.69°	2571
2501	2005-12-24T00:51	272.40°	4745

\*) no SRC images

HRSC Shadow Observations

2239	2005-10-11T16:36	318.13°	n/a
2345	2005-11-10T08:40	317.10°	n/a
2451	2005-12-10T00:39	312.01°	n/a
2549	2006-01-06T11:02	309.23°	n/a

**Plans:** On December 1, 2005, Mars Express entered its Extended Mission, during which more Phobos flybys and shadow observations are being planned. We will develop schemes that allow us to use HRSC images for the astrometric measurements. These are lower in resolution than the SRC images (where we currently accomplish a measurement accuracies of 0.5

– 5 km), however, the multiple viewing angles of HRSC will allow us to determine the trajectory of Phobos relative to MarsExpress in three dimensions during one single flyby. These new observations will further improve the Phobos ephemeris to accuracy levels of better than 5% of the Phobos size. Also, the large number of added observations by both, HRSC and SRC, will allow us to update the current Phobos shape models.

**References:** [1] Giese B. et al. (2005) *Zeitschrift für Photogrammetrie, Fernerkundung und Geoinformation*, **5**, 435-440. [2] Oberst J. et al. (2006) *Astron. Astrophys.*, in press. [3] Duxbury T. C. and Callahan J. D. (1988) *Astron. Astrophys* **201**, 169-176. [4] Duxbury, T. C. and Callahan J. D. (1989) *Astron. Astrophys.* **216**, 284-293. [5] Kolyuka Y. et al. (1991) *Astron. Astrophys.* **244**, 236-241. [6] Lainey V. et al. (2005), *EOS Trans AGU*, G51A-0802.



**Figure 1:** SRC images of Phobos obtained during flybys in MEX orbits 1901, 2151, and 2381 (from left to right).



**Figure 2:** Images of the Phobos shadow as it moves across the Mars surface, captured consecutively, 10s of seconds apart, by the HRSC green, nadir, and blue channels (from left to right). Images were obtained in orbit 2345.