Studies of Phobos' Orbit, Rotation, and Shape Using Spacecraft Image Data

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Introduction: Images obtained by the HRSC (High Resolution Stereo Camera) and the SRC (Super Resolution Channel) on the European Mars Express (MEX) spacecraft have renewed the interest in Phobos, the larger of the two Martian satellites. We are involved in a comprehensive study in geodesy and cartography of this small (13.4 x 11.2 x 9.2 km) satellite. We focus on astrometric measurements to refine and validate the current Phobos orbit models, and on an update of the Phobos control point network to study rotational and global shape parameters.

Astrometric measurements: We carried out astrometric measurements in SRC data. Earlier, a 12km discrepancy between orbit predictions and observations was noted (Banerdt & Neumann, 1999; Bell et al., 2005; Oberst et al., 2006) and updated orbit models have been released (Jacobson & Rush, 2006; Lainey et al., 2007). We now validate the Phobos positions against these new models.

Camera pointing errors have a major influence on the accuracy of the astrometric measurements. To control the nominal pointing of the camera with respect to the stellar background, background star observations are typically included in most SRC images. We compared observed positions of stars with star catalog entries and corrected camera pointing accordingly.

The position of Phobos in the stellar coordinate system is estimated using control points from the network by Duxbury & Callahan (1989). These control points are identified in the SRC images, and their line/sample coordinates are measured. All of the control points are craters (or more precisely: the control point is at the center of the crater lid), the coordinates of which can be conveniently be determined using an ellipse fit method. From the known Phobos-fixed coordinates of the control points and the navigation information, we computed their predicted line/sample coordinates. Finally translation vectors between predicted and observed line/sample coordinates are computed using an iterative least-squares analysis on the functional basis of a Similarity transformation. The obtained transformation parameters were applied to the predicted position of the Center of Mass (COM) of Phobos.

Results: Initially, 117 SRC images from 42 flybys were considered for the analysis. On average, 11 control points were observed per image giving us well-controlled information for the COM of Phobos. As some image suffered from smear, lack of identifiable control points, insufficient surface coverage, or lack of background star observations, we only considered observations of 69 images from 28 orbits. Phobos positions were observed with an estimated accuracy of ±0.1km and ±0.5km, depending on the distance of the satellite from the spacecraft. The computed translation vectors were studied in the Phobos across-track (radial towards/away from Mars and out of orbit plain) and along-track direction. While no significant offsets were found across-track, small systematic offsets ranging from 1.5km to 2.6km, depending on the orbit model used, were observed in the along-track direction

Control point Network: SRC images cover 78.2% of Phobos' surface with resolutions better than 50m per pixel, 69.2% better than 20m per pixel. Observations in Viking Orbiter Images were incorporated into the analysis to fill the coverage gap of SRC images. We are in the process of establishing a new control point network, which currently consists of 632 points observed in 53 SRC images and 12 Viking images.

Small impact craters were chosen as control points. Craters were included in our list that could be observed in at least 3 images. In contrast to the point definition in Duxbury & Callahan (1989) we measured the estimated center of each crater floor. To detect gross errors in the position and orientation data of MEX or Viking Orbiter, we first performed block adjustments for each data set independently. For Viking, the iterative adjustment process failed to converge, suggesting that the Viking orientation data had to be pre-corrected by means of a limbfit prior to the adjustment. A bundle block adjustment was then performed with both Viking and SRC observations.

Results and Outlook: For a number of Viking orbits, gross errors in the position and orientation data were found. For example, the images of Viking orbit 244 could not be used. The navigation data on MEX orbits was good with only a few minor errors. Coordinates of object points are determined with rms errors of ±35m and ±120m to ±150m per cartesian coordinate for SRC and Viking observations, respectively, when computing the block adjustment for the data sets separately. When combining both data sets to one image block, an overall object point accuracy of ±40m per cartesian coordinate can be reached. Further improvements in the residuals were observed when the rotational parameters of Phobos were slightly modified. An in-depth analysis is yet to come.

SRC and Viking images are of limited use when it comes to automatic determination of conjugate points for the generation of DTMs, as image matching software often relies on contrast differences. However, first tests showed that similar object point accuracies can be obtained for measurements in HRSC images obtained during close flybys. We will attempt to use the available and the expected data from planned flybys to generate a DTM of Phobos by extending the already existing patch (Giese et al., 2005). Results will be reported in the full paper and at the Conference.

References

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