IMPROVED DETERMINATION OF PHOBOS AND DEIMOS MASSES FROM VIKING FLY-BYS

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The masses of the Martian moons, Phobos and Deimos, have been redetermined from the Viking Orbiter 1 and 2 (VO-1 and VO-2) fly-by tracking data. These estimates are improved over previous analyses[1,2] due to improvements both in the moon ephemerides and in the filter techniques used to reduce the spacecraft tracking data. The ephemeris improvements were based on simultaneous reduction of all Phobos and Deimos imaging from the two Viking Orbiters. Since the moons caused gravitational perturbations on the spacecraft trajectories, least squares parameter estimation techniques were used to determine each moon's mass directly from two-way doppler tracking obtained during the closest approaches of VO-1 and VO-2 to each body.

The Phobos mass estimate is based on a series of eight consecutive fly-bys by VO-1 during February, 1977. The radius of closest approach from Phobos to VO-1 during this sequence of encounters ranged from about 100 km to 209 km. The mass estimate was obtained by optimal combination of the information obtained from separate fits of VO-1 tracking data obtained during each encounter. By contrast, the Deimos mass was obtained from a single close fly-by performed by VO-2 on October 15, 1977. The radius of closest approach for this encounter was less than 40 km. Gravitational mass, μ, and density, ρ, estimates for each moon were found to be as follows:

$$\text{Phobos}: \quad \mu_P = 8.5 \pm 0.7 \times 10^{-4} \quad km^3/s^2, \qquad \rho_P = 2.2 \pm 0.2 \quad gm/cm^3$$
$$\text{Deimos}: \quad \mu_D = 1.2 \pm 0.1 \times 10^{-4} \quad km^3/s^2, \qquad \rho_D = 1.7 \pm 0.2 \quad gm/cm^3$$

where density estimates are based on nominal volumes of 5751 km^3 for Phobos and 1052 km^3 for Deimos.

The above results assumed that the gravitational attraction of each moon was properly modeled by an equivalent point mass acceleration. In reality, the extended shape of each moon causes their surrounding gravitational field to be non-symmetric. This, in turn, causes systematic trends in the post-fit tracking data residuals when using the point mass model. Harmonic expansions for both Phobos and Deimos gravity fields have been determined from their corresponding topographical features. Thus, further improvements in the mass estimates are expected when these harmonic expansions are incorporated into the data reduction. This is expected to further reduce systematic trends in the near encounter data residuals by a factor of two or more.

1. Christensen, E. J., G. H. Born, C. E. Hildebrand, and B. G. Williams, "The Mass of Phobos From Viking Flybys," *Geophysical Research Letters*, **4**, No. 12 (1977), pp. 555-557.

2. Hildebrand, C. E., G. H. Born, and T. C. Duxbury, "The Deimos Mass Experiment: Planning and Preliminary Results," in *Natural and Artificial Satellite Motion*, ed. Nacozy and Ferraz-Mello (Austin, TX: Univ. of Texas Press, 1979), pp. 353-368.