THE MASS OF MARS, PHOBOS, AND DEIMOS, FROM THE ANALYSIS OF THE MARINER 9 AND VIKING ORBITER TRACKING DATA; *D.E. Smith*[1], *F.G. Lemoine*[1,2], and *S.K. Fricke*[3] [1]Laboratory for Terrestrial Physics, NASA/Goddard Space Flight Center, [2]Astronomy Department, University of Maryland, College Park, MD 20742, [3]RMS Technologies Inc., Landover, MD 20706.

We have estimated the mass of Phobos, Deimos and Mars using the Viking Orbiter and Mariner 9 tracking data. We divided the data into 282 arcs, and sorted the data by periapse height, by inclination and by satellite. The data were processed with the GEODYN/SOLVE orbit determination programs, which have previously been used to analyze planetary tracking data[1,2]. The *a priori* Mars gravity field applied in this study was the 50th degree and order GMM-1 (Goddard Mars Model-1) model [2]. The subsets of data were further carefully edited to remove any arcs with close encounters of less than 500 km with either Phobos or Deimos. Whereas previous investigators have used close flybys (less than 500 km) to estimate the satellite masses[3-6], we have attempted to estimate the masses of Phobos and Deimos from multiday arcs which only included more distant encounters. The subsets of data were further edited to eliminate spurious data near solar conjunction (November-December 1976, and January 1979). In addition, the Viking-1 data from October through December 1978 were also excluded because of the low periapse altitude (as low as 232 km) and thus high sensitivity to atmospheric drag.

During the Mariner 9 mission, the majority of Phobos flybys were at distances of 3,750 to 4,500 km whereas the Deimos flyby distances averaged 5,500 to 7,000 km. In contrast, the flyby distances between Viking 1 and Phobos ranged mostly from 1,000 to 4,000 km, whereas the encounter distances between Viking-1 and Deimos ranged mostly from 6,000 to 13,000 km. Nevertheless, during 17 arcs (out of approximately 150 arcs), the flyby distance between VO-1 and Deimos reached 1,000 to 5,000 km. Our solutions indicate that the Viking Orbiter 2 arcs at 300 km periapse altitude are only weakly sensitive to both Phobos and Deimos, an apparent consequence of a poor flyby geometry, and large residual signals from both Mars gravity and atmospheric drag.

In units of km^3/s^2, we find that the *GM*, or universal constant of gravitation multiplied by the planet or satellite mass, for Mars, Phobos, and Deimos are:

Satellite & Periapse Ht.	Mars (km^3/s^2)	Phobos (10^{-3} km^3/s^2)	Deimos (10^{-3} km^3/s^2)
VO-1 1500 km (30 arcs)	42828.40205 ± 0.052	0.539 ± 0.046	0.061 ± 0.072
Mariner 9 (32 arcs)	42829.30448 ± 0.57	0.562 ± 0.065	0.157 ± 0.109
VO-2 1500 km, 55 deg inclin., (12 arcs)	42820.93202 ± 31.04	0.696 ± 0.095	0.046 ± 0.285
VO-2 1500 km, 75 deg inclin., (6 arcs)	42787.98356 ± 21.37	0.619 ± 0.306	1.282 ± 0.646
VO-2 800 km (51 arcs)	42832.05436 ± 4.85	0.770 ± 0.581	0.103 ± 0.291
VO-1 300 km (81 arcs)	42828.23235 ± 0.071	1.172 ± 0.871	1.053 ± 0.859

The Viking-1 spacecraft dominates the determination of the Mars *GM* because of the tight standard deviations. The solutions from the Viking-1 300 km, and Viking-1 1500 km data are close to those found by Null [7] from the Mariner 4 hyperbolic flyby of 42828.32 ± 0.13 km^3/s^2 and Anderson et al. [8] from the Mariner 6 Mars hyperbolic flyby of 42828.22 ± 1.83 km^3/s^2. The Mariner 9 data manifests a large bias in the Mars *GM* estimate with respect to the values from Null [7] and the Viking-1 Orbiter estimates. We believe this bias may be an artifact of an as yet unidentified force or measurement modeling error associated with the Mariner 9 Doppler data.

It is interesting that the subset solutions utilizing the distant encounters yield estimates of the Phobos *GM* reasonably close to the published values from Christensen et al. [3] of (0.66 ± 0.08) 10^{-3} km^3/s^2, and from Koluyka et al. [6] of (0.722 ± 0.005) 10^{-3} km^3/s^2. Using the Phobos volume estimate of 5,680 ± 250 km^3 from Duxbury [9], our high altitude periapse Phobos *GM* estimates yield a density ranging from 1.42 to 1.83 g/cm^3. The solutions for Deimos from the distant encounters are intrinsically weaker. If the data from the high altitude (1500 km and 800 km periapse orbits) are combined we obtain a Deimos *GM* of (0.076 ± 0.055) 10^{-3} km^3/s^2. Conversion of this *GM* to an estimate of satellite density is more problematical given the large uncertainty in the estimate for the volume of this satellite [9]. This estimate agrees with the value of (0.12 ± 0.01) 10^{-3} km^3/s^2 from the close flybys [4,5]. Nevertheless, we find that analysis of the distant encounters provides more robust estimates of the Phobos *GM* than the Deimos *GM*.. We also find that the estimates for the *GM* of Mars are largely uncorrelated with the *GM* 's for the natural satellites, since the satellite values change minimally whether or not the Mars *GM* is adjusted in any of the subset solutions.

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