MERLIN: Mars-Moon Exploration, Reconnaissance and Landed Investigation.

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Background: The compositions, origins, and geologic histories of Mars' moons Phobos and Deimos are poorly understood. Their albedos, spectra and densities resemble D-type bodies, which are common in the outer solar system but rare in the inner solar system [1-3 and references therein]. Both moons have been interpreted as captured from the outer asteroid belt or outer solar system, but viable methods for capturing outer solar system objects into Mars orbit are dynamically difficult [4]. Alternatively the moons have been suggested to have formed *in situ* from material like that forming bulk Mars, or from reaccreted ejecta of large impacts early in Mars' history [2-4 and references therein]. The moons are on the flexible path for human exploration, and an understanding their geology is required to plan human-enabled science.

D-type objects are widely considered to be "ultraprimitive", rich in organics and possibly volatiles, and a possible source of carbon and volatiles to the early terrestrial planets [5]. However D-type bodies' composition is uncertain, and volatile-poor compositions are also consistent with remote measurements [6]. Dynamical models such as the "Nice model" suggest that D-type objects may have bombarded the terrestrial planets early in solar system history [7]; if they are volatile-rich, they may have been an important volatile source for the terrestrial planets.

Mission Concept: A submitted Discovery mission concept, the Mars-Moon Exploration, Reconnaissance and Landed Investigation (MERLIN), would obtain both rendezvous and landed measurements with sufficient accuracy to resolve Mars' moons' composition and origin. Although either moon could be targeted, MERLIN's nominal target is Deimos because of lower ΔV requirements and large exposures material less affected by space weathering ("albedo streamers"). The measurement objectives of MERLIN are to:

- determine Deimos' elemental and mineralogical composition,
- investigate its volatile and carbon content, and
- characterize processes that shaped its geology.

Mission Overview: A Type IV interplanetary trajectory lessens propulsion requirements by >600 m/s, enabling launch on an Atlas V 401. Following Mars Orbit Insertion (MOI), MERLIN executes trajectory correction maneuvers to fly nearly in formation with Deimos, completing about 5 months of global mapping and radio science measurements, summarized in Fig. 1. A multispectral wide-angle camera (WAC) and panchromatic narrow-angle camera (NAC) based on MESSENGER/MDIS put the landing site into context by characterizing Deimos' physical geology, regolith distribution, and spectral heterogeneity. A landing site on fresh material in an albedo streamer is characterized and certified as safe for landing. Following the rendezvous phase, the spacecraft descends to the surface and completes ~90 days of landed measurements (including margin). During the landed phase, MERLIN measures surface material with arm-mounted instrumentation including elemental composition with an alpha particle X-ray spectrometer (APXS), mineralogical composition with a Raman spectrometer, and regolith texture with a microscopic imager. An operational stereo camera (OpsCam) and a terrain-imaging camera (TerrainCam), based on MER's Hazcam and Navcam, support tactical planning of landed measurements and characterize geology of the landing site. These measurements also provide valuable precursor information for future human exploration of the Mars system. Optional additional instrumentation to augment precursor information includes a dosimeter to characterize the radiation environment and a dust counter to characterize the debris environment near the moons' orbits. Spacecraft design and instrument accommodation are shown in Fig. 2.

MERLIN's measurements would distinguish different origins for Mars' moons, addressing NASA's science theme of understanding the first billion years of solar system history and the initial stages of planet and satellite formation. MERLIN would determine the inventory of carbonaceous materials on Deimos and the moon's relationship to D-type bodies, addressing NASA's science them of the history of solar system volatiles and organics. MERLIN would characterize the geology and internal structure of Deimos, addressing NASA's objective to understand processes that shape planetary bodies.

References: [1] Grundy, W. M. *et al*. (1991) *Aseteroids, Comets, and Meteors 1991,* 215-218. [2] Murchie, S. and S. Erard (1996) *Icarus*, *123*, 63–86. [3] Rivkin, A. S. *et al*. (2002) *Icarus*, *156*, 64-75. [4] Burns, J. A. (1992) in *Mars* (Kieffer, Jakosky, Snyder, Matthews eds.), U. of Ariz. Press, Tucson. [5] Hiroi, T. *et al*. (2001) *Science, 293,* 2234-2236. [6] Emery, J. and R. Brown (2003) *Icarus*, *164*, 104. [7] Gomes, R. *et al*. (2005) *Nature*, *435*, 466.

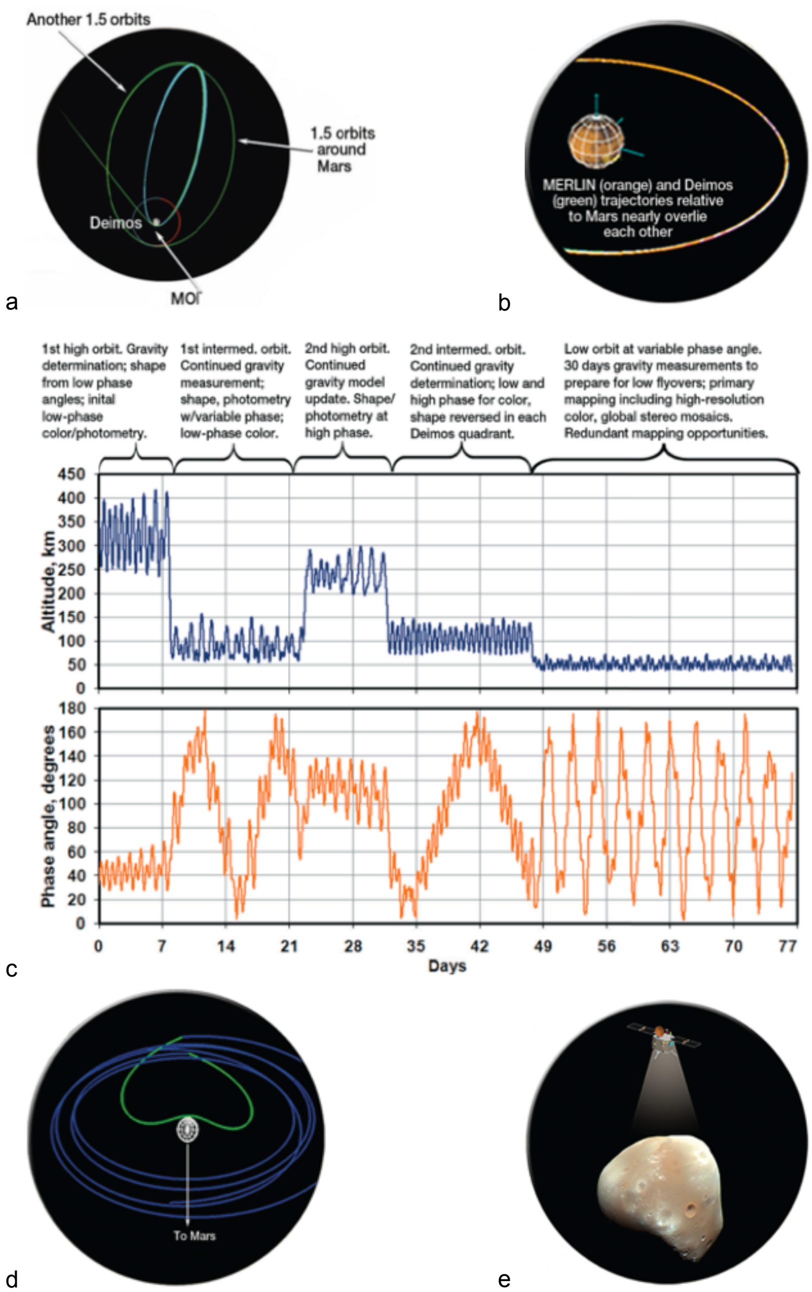

Fig. 1. Profile of the rendezvous phase of the MERLIN mission. (a) During 1.5 or more elliptical orbits after MOI, OpNav images refine Deimos' ephemeris and both moons' environment is explored. Two more maneuvers, separated by another 1.5 or more orbits, circularize MERLIN's orbit at Deimos. (b) MERLIN and Deimos are then nearly co-orbital; the spacecraft flies in formation with the moon and acquires color and stereo images, and mass/volume measurements. (c) During the first 11 weeks of Deimos "proximity operations" MERLIN cautiously decreases altitude while Deimos' gravity field and shape are being refined. Illumination geometries built into designs of the initial orbits support shape determination as well as color and photometric mapping. (d) During 6 more weeks at 50-km altitude, several 1- to 2-km altitude flyovers certify the landing site with color and morphology imaging and terrain modeling. (e) MERLIN is delivered to a point above Deimos, then navigates to landing using onboard closed-loop processing of descent images. The spacecraft can "hop" to and explore 1 or 2 more nearby sites. Depending on use of propellant margin, enough may remain to re-ascend to orbit and continue low flyovers to compile high-resolution coverage in preparation for future exploration.

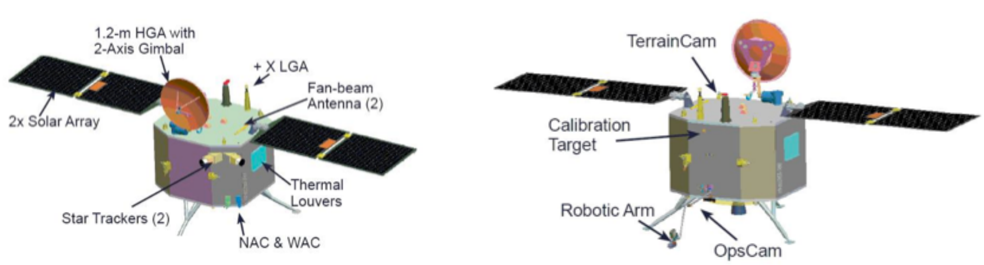

Fig. 2. MERLIN spacecraft configuration showing accommodation of science instrumentation.