THE MARS-MOONS EXPLORATION, RECONNAISSANCE AND LANDED INVESTIGATION. Scott L. Murchie[1], Nancy L. Chabot[1], Julie C. Castillo-Rogez[2], Raymond E. Arvidson[3], Debra L. Buczkowski[1], Douglas A. Eng[1], Artur B. Chmielewski[2], Justin N. Maki[2], Ashitey Trebi-Ollenu[2], Bethany L. Ehlmann[4], Patrick N. Peplowski[1], Harlan E. Spence[5], Mihaly Horanyi[6], Goestar Klingelhoefer[7], John A. Christian[8], Carolyn M. Ernst[1]. [1]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA (scott.murchie@jhuapl.edu); [2]Jet Propulsion Laboratory, Pasadena, CA 91109, USA; [3]Washington University, St. Louis, MO 63130, USA; [4]California Institute of Technology, Pasadena, CA 91125, USA; [5]University of New Hampshire, Durham, NH 03824, USA; [6]University of Colorado, Boulder, CO 80303, USA; [7]University of Mainz, Germany; [8]West Virginia University, Morgantown, WV 26506.

Introduction: The Mars-Moons Exploration, Reconnaissance and Landed Investigation (MERLIN) is a proposal to NASA for a Discovery mission to explore Mars' moons and land on Phobos as the first U.S. mission to conduct an *in situ* investigation of a primitive D-type body. Understanding Phobos and Deimos provides key information for understanding the history and evolution of the solar system. MERLIN performs 9 months of detailed orbital reconnaissance of Phobos and Deimos, characterizing their global geology and a landing site on Phobos. Once landed, MERLIN performs 90 days of *in situ* scientific measurements. MERLIN's dual orbital and landed data yield high-priority science, while simultaneously addressing strategic knowledge gaps (SKGs) to prepare for future human exploration of the Mars system.

Addressing Decadal Survey Goals: MERLIN directly addresses small-body science goals in the Decadal Survey [1]. The goal to understand how solar system objects formed and evolved is addressed by landed compositional measurements; these test models for the origin of the martian moons, which predict different compositions [e.g., 2,3]. The same measurements investigate the inventory of C, OH, and H_2O in Phobos' surface and subsurface, addressing the distribution of volatiles and organics in the solar system and resources available for human explorerers. MERLIN addresses the goal of understanding processes that shape planetary bodies, with several measurement objectives: measuring particle size-frequency distribution in the moons' hypothsized "dust belts" to test models of the belts' formation [4]; testing models for formation of Phobos' grooves using color variations and morphology [e.g., 5,6]; testing models for the moons' internal structures by measuring density and libration [e.g., 7,8]; quanitfying effects of space weathering including changes in composition with depth; and quantifying texture of the regolith including grain size, packing, cohesion, and angle of internal friction.

Outer Solar System Science in the Inner Solar System: Phobos' location in Mars' orbit enables a Discovery-class mission to investigate, *in situ*, a D-type body [9,10]–a class of objects common in the outer solar system, thought to be ultraprimitive. MERLIN's landed compositional measurements test this hypothesis.

Science Mission Profile: MERLIN's science mission is summarized in Fig. 1. For 4 months after Mars orbit insertion in January 2024, MERLIN's elliptical orbit crosses that of both moons. Deimos is imaged multispectrally and in stereo, yielding an improved shape model and new insights into geology and internal structure. A radiation monitor and dust counter characterize radiation and particulate environments in Mars orbit. In June 2024, the orbit is circularized at Phobos, and MERLIN begins formation flying with Phobos. Multispectral 8 m/pixel and stereo 1-2 m/pixel imaging characterize geology, regolith properties, and test models for the origin of Phobos' surface features. Radio science investigates heterogeneity of the moon's interior. During two low flyovers, 40 cm/pixel color stereo and 5 cm/pixel high-resolution imaging provide morphologic and spectral evidence for regolith processes. These data are used to identify a landing ellipse. Imaging of Phobos from past missions provides *a priori* knowledge that enables pre-planning a high-fidelity proximity and landed investigation, minimizing risk associated with the first planned landing on a rocky small body.In October 2024, the spacecraft lands on Phobos' redder unit [9,10]. Color stereo imaging characterizes the regolith and provides geologic context for compositional measurements by instruments on a robotic arm. γ-ray and α-particle X-ray spectroscopy measure abundances of elements diagnostic of proposed origins, and of C and H to ascertain volatile content. A microscopic imaging spectrometer measures abundances of minerals, including mafic silicates, hydrated phases and organics [11]. In an extended mission, MERLIN can ascend and land in the bluer unit, comparing the composition and mineralogy of the two spectral units.

Preparing for Future Human Exploration: MERLIN's science investigations address SKGs required to prepare for orbital human exploration of the Mars system [12]. To further prepare for future human missions, MERLIN tests Deep-Space Optical Communication (DSOC) in Mars orbit, using both test data and real-time video of the moons from MERLIN's imagers.

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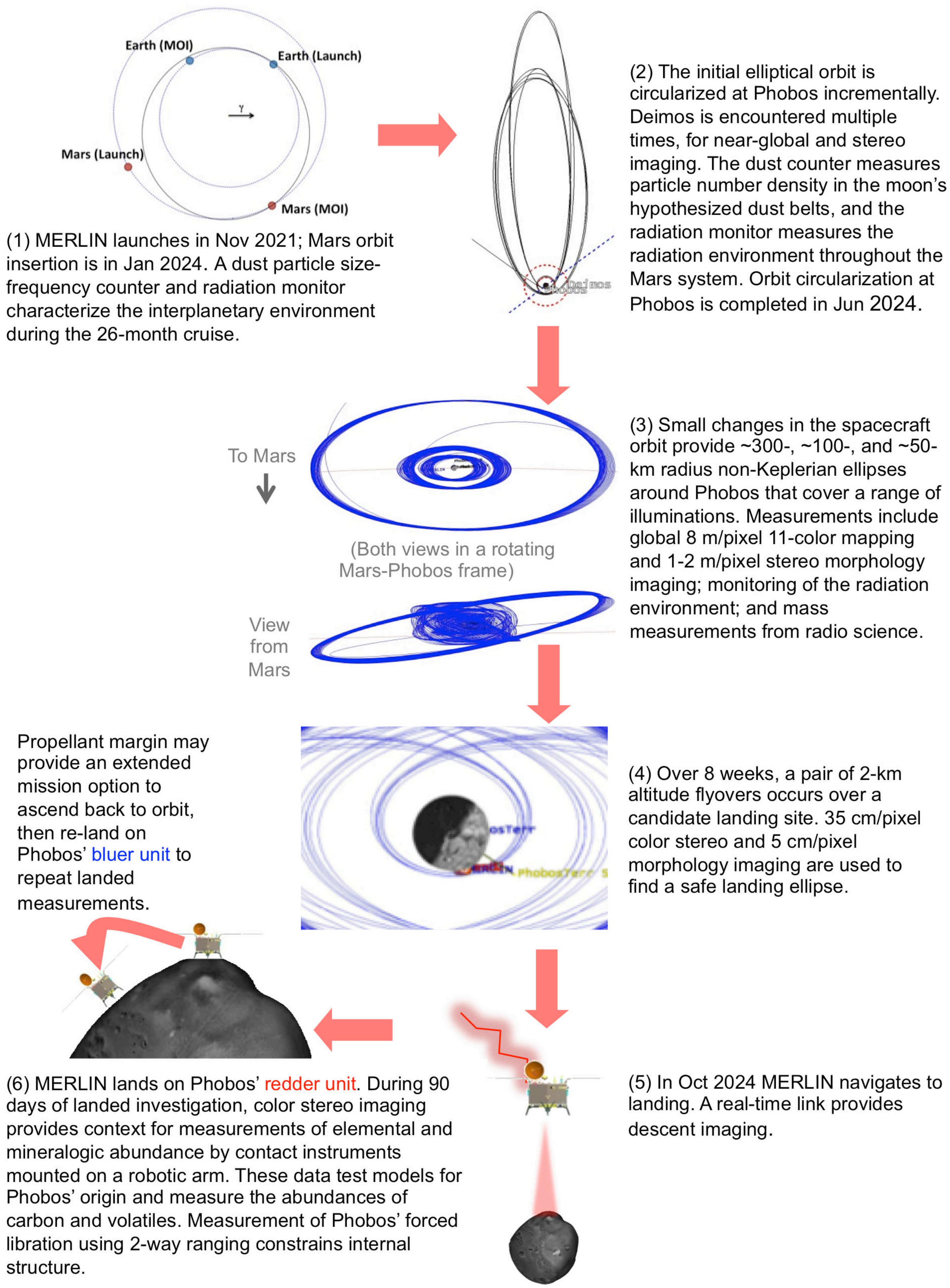

Figure 1. Graphical summary of MERLIN's science mission profile.