Mars-Moons Exploration, Reconnaissance, and Landed Investigation

SSERVI Exploration Science Forum

• Proposed to Discovery Program (2010, 2015) to:
  – Explore the second terrestrial planet satellite system
  – Take the first *in situ* measurements of a D-type body
  – Close strategic knowledge gaps for human exploration of Mars’ moons
Morphologies & densities indicate different evolutions

2 color units:
- redder unit on both moons
- bluer unit on Phobos

Mapping the moons’ morphology and color will yield new understanding of small-body geologic processes

**Phobos**: heavily cratered, grooves; \( \rho = 1.87\pm0.02 \text{ g/cm}^3 \)

**Deimos**: lightly cratered, mantled; \( \rho = 1.49\pm0.19 \text{ g/cm}^3 \)
• Both are D-type and bracket the range of D-types’ spectral variability
• D-types thought to be C-, volatile-rich
• Hypothesis: Phobos and Deimos are captured primitive bodies
• Also could be space-weathered bodies co-accreted with Mars, or reaccreted Mars basin ejecta
• Determining the moons’ compositions constrains their origin, providing insight into early solar system processes
MERLIN Science Questions

1. What are the moons’ compositions and origins?
2. Are they rich in C and volatiles?
3. What geological processes affect their surfaces and environment?
4. What are the moons’ interior structures?

Measurements Close Strategic Knowledge Gaps

- Elemental and mineralogical composition
- C and H for In Site Resource Utilization (ISRU)
- Regolith mechanical properties
- Particulate / radiation environments around Mars
- Moons’ shapes and gravity fields
# MERLIN science measurements:

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<th>Visions and Voyages Questions</th>
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<td>Phobos’ and Deimos’ compositions and origin</td>
<td>Initial stages, conditions, processes of solar system formation</td>
<td>Elemental composition, Mineral composition, Spectral heterogeneity</td>
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<td>Content, forms of water and carbon</td>
<td>Supply of water to inner planets, Primordial sources organic matter</td>
<td>Occurrence of hydrated minerals, Abundance of C and H, Types, abundances of C phases</td>
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<td>Geological processes that affect moons’ surfaces and environment</td>
<td>Chemical and physical processes that shaped the solar system over time</td>
<td>Regolith landforms, Groove formation processes, Effects of space weathering, Orbital particulate environment, Shape and volume, Mass and mass distribution</td>
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Two Views of Spacecraft Show Science & Exploration Payload

Orbital instruments

- Radiation monitor (not visible)
- Deep-Space Optical Communication
- Orbital imaging system
- Dust particle counter
- Turret has an APXS, microscopic imaging spectrometer
- Mini-GRS on forearm
- Landed stereo camera
- Robotic arm supports landed science
Mission Profile: Cruise Phase

Launch is in Nov 2021 on an Atlas V 401. MOI is in Jan 2024
Deimos is encountered at 4 locations for near-global imaging. The dust counter measures Phobos’ and Deimos’ hypothesized dust belts.
Non-Keplerian orbits around Phobos cover a range of illuminations over 2.5 months, for global stereo and color imaging.
Global 1 m/pixel stereo imaging is comparable to best from NEAR

100 m

Global 8 m/pixel color imaging is comparable to HiRISE but in 11 colors

500 m
2-km altitude flyovers provide 5 cm/pixel high-res and 40 cm/pixel color stereo images

In Oct 2024 MERLIN navigates to landing in a small, targeted ellipse
Landing Enables Robust Science

Robotic arm with contact instruments

Stereo imager
Gamma-ray Spectrometer

- Major elements and C are measured to 10’s cm depth
- Distinguishes major compositional types

Gamma-rays support “indirect neutron spectroscopy” to detect H to 100’s ppm [Peplowski et al. 2015]
• Major and minor elements are measured in top 10’s µm
• Discriminates among closely similar analog compositions
• Comparison of volatile K, S with γ-ray results at depth constrains chemical effects of space weathering
Microscopic Imaging Spectrometer

- Analog materials also have differing abundances of major and minor minerals, most of which are “lost” in spectra of large areas
- Instrument is prototyped and lab-tested
- Test results demonstrate that point counts of minerals grains test & corroborate interpretations from elemental measurements
MERLIN Accomplishments

- First U.S. dedicated small-body lander
- First *in situ* exploration of Mars’ moons
- First mission to a D-type body
- Closes strategic knowledge gaps for human exploration of the Mars system