

NASA's Evolvable Mars Campaign: Mars' Moons Robotic Precursor

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Human exploration missions to the moons of Mars are being considered within NASA's Evolvable Mars Campaign (EMC) as an intermediate step for eventual human exploration and pioneering of the surface of Mars. A range of mission architectures is being evaluated in which human crews would explore one or both moons for as little as 14 days or for as long as 500 days with a variety of orbital and surface habitation and mobility options being considered. Relatively little is known about the orbital, surface, or subsurface characteristics of either moon. This makes them interesting but challenging destinations for human exploration missions during which crewmembers must be able to effectively conduct scientific exploration without being exposed to undue risks due to radiation, dust, micrometeoroids, or other hazards. A robotic precursor mission to one or both moons will be required to provide data necessary for the design and operation of subsequent human systems and for the identification and prioritization of scientific exploration objectives. This paper identifies and discusses considerations for the design of such a precursor mission based on current human mission architectures. Objectives of a Mars' moon precursor in support of human missions are expected to include: 1) identifying hazards on the surface and the orbital environment at up to 50-km distant retrograde orbits; 2) collecting data on physical characteristics for planning of detailed human proximity and surface operations; 3) performing remote sensing and in situ science investigations to refine and focus future human scientific activities; and 4) prospecting for *in situ* resource utilization.

These precursor objectives can be met through a combination of remote sensing (orbital) and in-situ (surface) measurements. Analysis of spacecraft downlink signals using radio science techniques would measure the moon's mass, mass distribution, and gravity field, which will be necessary to enable trajectory planning. Laser altimetry would precisely measure the moon's shape and improve the accuracy of radio science measurements. A telescopic imaging camera would map the moon at submeter resolution and photograph selected areas of interest at subcentimeter resolution and a visible and near-infrared (0.4-3.0 μm) imaging spectrograph would produce a global map of mineral composition variations at a resolution of tens of meters and maps of selected areas of interest at meter resolution. Additional remote sensing capabilities could include a thermal infrared imager (heat flow, thermal inertia, and grain size distributions), a gamma-ray and neutron detector (atomic composition), a ground-penetrating radar (internal structure), and a magnetometer and Langmuir probe (magnetic properties and plasma field). Once on the surface of Phobos or Deimos, necessary instrumentation would include a penetrometer (regolith compressive strength), a motion-imagery camera (to observe the penetrometer tests before, during, and after contact), a dust-adhesion witness plate and camera (dust levitation), a microimager (dust particle sizes and shapes), and an alpha-proton-X-ray, X-ray fluorescence, Mössbauer, or Raman

spectrometer (atomic and mineral composition of surface materials) and an optional temperature probe (regolith thermal properties).

A variety of robotic mission design options to enable both orbital and surface measurements are being considered that include fully integrated and modular approaches. In-situ measurements from at least one surface location would be required, with additional measurement locations possible through use of multiple landers, through propulsive relocation of a single lander, or through electromechanical surface translation by a walking or hopping lander vehicle, which could also serve to evaluate such mobility capabilities for subsequent human missions. Preliminary orbital analysis suggests that remote sensing would likely be performed while in a distant retrograde orbit around the target moon. Mission design options to enable characterization of both Mars' moons in a single mission are also being studied.