MARS MOON SAMPLE RETURN FOR SCIENCE AND SEGUE TO POTENTIAL HUMAN PRESENCE AT MARS. M. E. Lisano[1], D. Britt[2], J. Castillo-Rogez[3], D. Kring[4] [1]Jet Propulsion Laboratory, California Institute of Technology (4800 Oak Grove Ave, Pasadena CA 91109, michael.e.lisano@jpl.nasa.gov, julie.c.castillo@jpl.nasa.gov) [2]Dept. of Physics, Univ. of Central Florida (P.O. Box 162385, Orlando FL 32816, britt@physics.ucf.edu), [4]Lunar & Planetary Institute (3600 Bay Area Blvd, Houston TX 77058, kring@lpi.usra.edu).

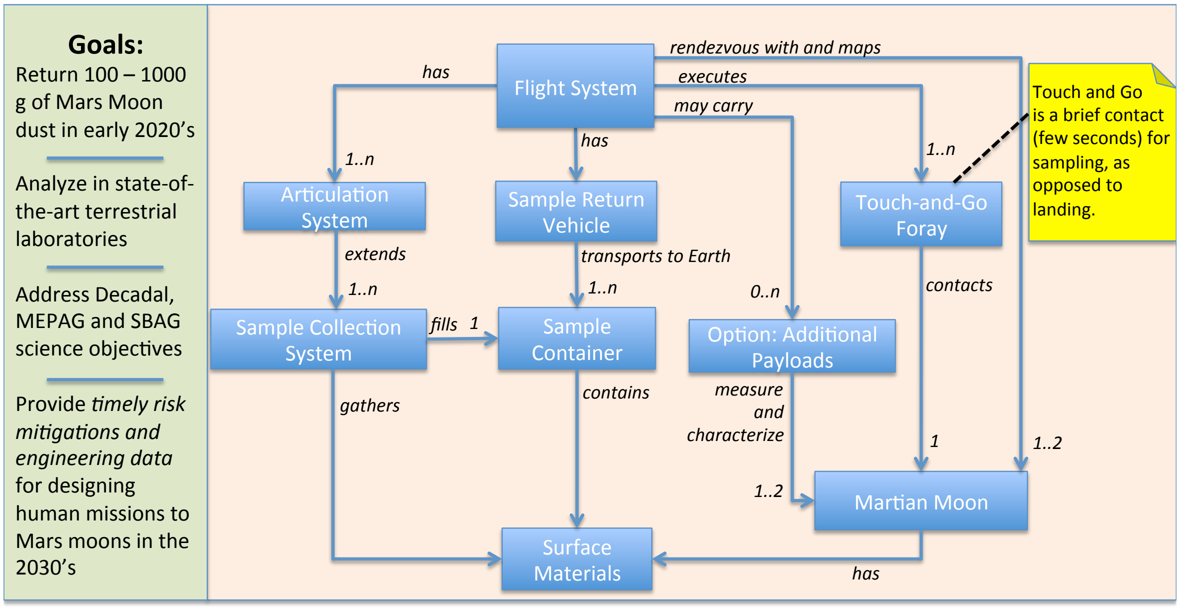

Figure 1: Block Diagram of Key Elements for a Mars Moon Sample Return Mission

Introduction: We recommend that the next step on the path to a near-term, sustainable human presence in Mars orbit - particularly traveling to or establishing a crewed base on a Martian moon – be a 2018 mission to perform a detailed robotic mapping and mineralogical reconnaissance of the martian moons, and also return a multi-gram (or greater) sample from a moon of Mars to Earth, for analysis in terrestrial laboratories. Besides furnishing key data in ***a timely way to retire key risks with 2030's potential human exploration at Mars' moons***, the mission addresses key Decadal, Mars Exploration Program Assessment Group (MEPAG) and Small Bodies Assessment Group (SBAG) science objectives, and importantly, provides the potential to obtain Mars **surface** materials that have been accreted to the Mars regolith, *c.f.* [1]. We describe here the rationale and top-level architecture for a low-cost, low-risk NASA robotic mission concept to carry out this reconnaissance and sample return from the moons of Mars. Our mission concept is based on the *Gulliver/SAM* (Sampling Ancient Mars) mission [2] we have proposed in prior Discovery and Mars Scout calls, focusing on *sample return as the primary mission objective* (i.e. threshold mission success is the return of a multi-gram Mars moon sample).

The threshold minimum mission concept (sample-return from Deimos only) is low-cost, i.e. Discovery-Scout class, and our mission implementation approach, based on the flight system architecture described in the block diagram of Fig. 1, has been rated by NASA Technical-Management-Cost (TMC) review as Low Risk. The mission scope can be expanded to support additional measurement and exploration objectives - e.g., adding a spectrometer, a mini-dosimeter, or delivering and relaying communications with a small (several-kg), agile surface rover. These additional payload options would be chosen based on *complimentarity plus non-interference* with the primary sample return objective, while keeping mission cost compliant with program requirements.

Science Traceability and Mission Rationales: *Rationale for Sample Return vs. In-Situ Analysis:* Major advances in planetary science have been achieved by analyzing extremely small amounts of trace elements or low percentage minor species and returned samples in terrestrial laboratories [3]. In-situ or remote sensing instruments tend to be limited very strongly to bulk analysis of a few major elements or minerals. For Phobos and Deimos some of the most critical analyses would require detailed laboratory measurements of trace elements and minor species to determine the presence of water, geotechnical properties of surface materials, and geochemical evolution of the regolith.

Science – Decadal Traceability: A sample returned from either Phobos or Deimos would address Decadal, MEPAG and SBAG science objectives. Results from

ESA's Mars Express mission suggest that Phobos/Deimos is likely composed in part of re-accreted material ejected from Mars' surface early in its history, and also phyllosilicates and possibly carbonaceous chondrite materials. Mission objectives relative to the sample itself would include: • determining the origins, age and bulk composition of Phobos and Deimos through elemental, isotopic, and noble gas analysis, to identify whether Phobos/Deimos are re-accreted Mars ejecta, or captured outer-solar-system planetessimals (suggested by their type-D spectral properties) • evaluating the presence, age, and provenance of Mars-surface-native materials, possibly representative of Mars' early history (> 4Ga) • identifying organic and/or hydrated matter in the sample • and identifying protosolar material traces (with isotope ratios). Lateral composition variations can be obtained from mapping images and secondary payloads, e.g. a spectrometer.

Risk Reductions for Human Missions to Mars Orbit and Mars Moons. A Mars moon sample return mission would mitigate major mission risks associated with potential human visits to and operations on Mars' moons. On such visits, the Phobos/Deimos regolith material would likely permeate the crew capsule (per Apollo experiences) and be breathed and swallowed for months during operations and Earth return. Given the moons' milli-gravity, regolith perturbed during surface activities would likely form dust clouds of unknown extent, duration, and sunlight-obscuring (and power-reducing) character. Mitigating these human mission risks requires measuring regolith composition, including trace chemistry and minor element compositions, as well as particle size and morphology distributions. These can only be determined to useful precision in terrestrial laboratories with sample return.

High-precision terrestrial laboratory analysis of returned surface material could definitively answer a range of geotechnical and safety questions for future exploration such as particle size, dust environment, angle of repose, compression, compaction, particle abrasion and biological hazards. Sampled material could be tested for effectiveness as a radiation shield, to minimize dose over long-duration occupation of Phobos or Deimos – potent design information, if combined with in-situ mini-dosimeter data (*c.f.* [4]). While some regolith properties can be measured in-situ, each would require separate instrumentation; the result would be far less precise than terrestrial laboratories. Having sample-based data in hand by ~2022, along with high-resolution maps of potential landing site, would help constrain spacecraft, spacesuits and equipment designs for potential human 2030's visits to Phobos/Deimos. The sample return mission itself would also return a high-resolution gravity map of the moon(s), reduce/retire technology risk for Mars moon rendezvous and landing, and reduce risk of navigating from Mars orbit to atmospheric entry at Earth.

Mission Architecture - Design Concept Description: Referring to Fig. 1, our mission concept features a single flight system, solar powered and chemically-propelled, with dry mass of ~500-600 kg. It includes at least one sampling system (a collector for gathering up to 100 - 1000 g of material, on an articulation system e.g. robotic arm). Launched in 2018, it would enter Mars orbit, then target martian moon rendezvous. If the mission were scoped for encounter with a single moon, delta-V requirements would be in family with many recently proposed sample return missions; electrical propulsion would be considered if both moons were to be visited.

During Mars moon approach, the moon would be imaged and mapped, using both wide- and narrow-area cameras, e.g. to survey sites for astronaut forays. A mini-rover, if featured (e.g. a "Tumble-bot" rover designed for mobility in milli-gravity while measuring radiation levels and soil mechanics for several days, *c.f.* design by Pavone et al [5]) would be deployed, and the spacecraft would relay data during mini-rover activities. Next, the spacecraft would fly to a near-moon staging point, and makes one or more Touch-and-Go forays to obtain a regolith sample during brief surface contacts (~a few seconds) at targeted sites. The sample would be stowed in the Sample Return Vehicle (SRV); then the spacecraft would depart the Mars system and returns to Earth in 2020 or 2021. The SRV would enter Earth's atmosphere and land, after which the sample would be retrieved for lab distribution, and curation.

Key Early Mission Trades and Decisions: Done early in the development life-cycle, four foundational, design-driving architectural trade studies would establish the overall mission architecture and cost. These trades are: • number of individual samples to return • which site(s) to sample (i.e. on Phobos, Deimos, or both) • baseline sample amount and "margin" over the threshold sample • and choosing our non-sampling objectives, including selection of secondary (U.S. or international) payloads. Follow-on design decisions include configuration, power and propulsion design.

Take-away: A 2018 Mars moon sample return mission would offer high return in Decadal science, at low cost, plus timely data and crucial risk reductions potential 2030's human visits to Mars' moons.

References: [1] D. Kring and B. Cohen (2002), *JGR*, 107, E2, 5009. [2] Britt et al (2005), *68th Meteoritical Soc Mtg*, LPI [3] Swindle et al. (1991) *EOS, 72,* No. 44, pp 473-488. [4] Mazur et al (2011), *Space Weather*, doi:10.1029/2010SW000641 [5] Pavone M. et al (Mar 2012) *NIAC Symposium*.