SCIM: SAMPLE COLLECTION FOR INVESTIGATION OF MARS, A LOW-COST, LOW-RISK CONCEPT FOR THE FIRST MARS SAMPLE RETURN MISSION.

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Introduction: SCIM—**S**ample **C**ollection for **I**nvestigation of **M**ars—is a revolutionary concept for a low-cost, low-risk sample return from Mars that will fundamentally advance our knowledge of the geology, climate and habitability of Mars. As the first sample return from another terrestrial planet, SCIM would provide a unique data set and a comparative basis for understanding how the rocky inner planets formed and why they have evolved so differently from each other. In addition, as the first round-trip to Mars and the first Mars Sample Return mission, SCIM would be a scientific, technological and operational pathfinder for future surface sample return as well as future crewed missions to Mars. As such, it is uniquely positioned to address the current interest in a mission that both makes progress towards surface sample return, and supports future human missions to Mars.

Using an innovative mission design, SCIM will gather samples of martian dust and atmosphere during a Mars aeropass, without landing or even entering orbit around Mars. Using experience gained from the Stardust and Genesis missions, these samples would then be returned to Earth. Samples returned to terrestrial laboratories by SCIM would be analyzed with state-of-the-art instrumentation providing unprecedented insight into the origin and evolution of Mars and its development relative to other bodies in our Solar System.

The baseline payload for this mission concept consists of a Dust Collection Experiment (DuCE) with aerogel collector modules (similar to those successfully flown by Stardust), an Atmospheric Collection Experiment (ACE) consisting of two separate gas collection tanks, and a Camera Experiment (CamEx). SCIM would incorporate critical planetary protection features that ensure that collected martian material is sterilized onboard prior to targeting the Earth for sample return. After the aeropass, deep space maneuvers would retarget SCIM back to Earth, where the Sample Return Capsule would descend by parachute in an identical manner to the Stardust mission.

The Relevance of SCIM in the Context of the NRC Planetary Science Decadal Survey: NASA's systematic Mars exploration approach over the previous decade has deployed missions that have studied martian processes with increasing precision, resolution, and specificity. The next major step is returning samples to terrestrial laboratories for analysis, where the variety and precision of measurements far exceed practical in situ or remote sensing capability. Sample return missions provide the analytic capability required to achieve high-priority science as defined by the science community, and to answer questions raised by remote observations. Considering the overarching goals of the Mars Exploration Program (Life, Climate, Geology, Preparation) [1], and the limitations of Mars meteorite samples, MEPAG recommendations are for three types of materials to be returned from Mars: (1) selected rocks from carefully chosen sites, (2) regolith fines, and (3) atmospheric gas. SCIM would deliver the last two of these three advocated sample types.

Surface sample return missions to Mars are necessarily faced with significant challenges of entry, descent, landing, surface operations, followed by launch and orbit rendezvous, and planetary protection, which result in high mission risk and cost. SCIM uses a novel, innovative mission design to eliminate many of these challenging steps to return the first martian samples with a much lower risk. Recently returned Stardust and Genesis samples illustrate the value of applying high precision, cutting edge terrestrial laboratory instruments to extraterrestrial materials collected and returned to Earth. SCIM will likewise provide *fundamental new constraints on martian hydrologic, sedimentary, volcanic, and climatic processes*, and *a unique comparative basis for understanding how and why Mars has evolved so differently from Earth*. In doing so, SCIM would be responsive to two of the three themes identified in the recent NRC Planetary Science Decadal Survey [2] to be of particular interest for the next decade, i.e., (1) Planetary habitats—searching for the requirements for life, and (2) Workings of solar systems—revealing planetary processes through time. The particular priority questions within these themes that would be addressed include: (a) Did Mars or Venus host ancient aqueous environments conducive to early life, and is there evidence that early life emerged?; (b) Can understanding the roles of physics, chemistry, geology and dynamics in driving planetary atmospheres and climates lead to a better understanding of climate change on Earth?; (c) How have the myriad chemical and physical processes that shaped the solar system operated, interacted and evolved over time?

SCIM Science Goals: Key science questions would be answered by sample analysis using modern laboratory instruments. The identification and characterization of μm- to nm-scale minerals (and poorly crystalline phases), precise analyses of trace element and isotope abundances in dust and gas, and characterization of minute amounts of organic matter can be done only in terrestrial laboratories. The return of even a small amount of martian fines now would complement the future return of a cache of diverse geologic samples, as advocated by MEPAG, because airborne dust represents the bulk crust (as opposed to a specific, compelling landing site), and a sample of the upper atmosphere would allow comparison with atmospheric composition at the surface (as determined by MSL, for example). SCIM science goals are identified in **Table 1**. The number of dust particles and amount of atmospheric gas to be collected would be driven by the type and variety of analyses required to address the science goals, and would include margins for measurement reproducibility, investigation of new hypotheses, and curated samples for future studies.

Table 1. SCIM Science Goals.

I	Quantitatively characterize the chemical, isotopic, and mineralogical composition of martian crustal materials as represented by the global dust
II	Investigate aqueous alteration processes and environments that have affected or produced martian surface materials
III	Understand Mars' volatile reservoirs, hydrologic and atmospheric cycles, and climate evolution
IV	Synthesize data from remote-sensing and Earth-based laboratory investigations of martian materials to provide "ground truth" for past and future remote sensing observations of Mars

SCIM Dust Science: The martian atmosphere typically contains 10-400 billion metric tons of dust [3], ranging in diameter from <1 to >10 μm [e.g., 4,5]. This dust samples the only planetary regolith besides Earth's known to have been exposed to hydrolytic, atmospheric, and possibly even biologic weathering processes. Spectroscopic studies demonstrate that airborne dust is nearly indistinguishable from pervasive, bright regions of the martian surface [6], and several decades ago it was proposed that winds had homogenized, distributed, and deposited a global blanket of dust over the entire planet 7,8]. Soils at the Viking, Mars Pathfinder, and MER landing sites are strikingly similar in chemical and mineralogic composition and appear to be a global representative of the exposed crust [9-14]. These soils likely represent regionally derived sands, mixed with aeolian dust. The sand particles at several sites are reasonably well characterized, and their mineralogies (mostly olivine, pyroxenes, plagioclase) indicate they are physically comminuted basaltic rocks [10,12]. In contrast, the dust is not well characterized because of its fine grain size and it is likely to be too dispersed to be acquired by rover sampling systems (which may also restrict its characterization by MSL's CheMin experiment). Because of its global nature, the martian dust provides an opportunistic sample of crustal materials, likely including both primary igneous and secondary altered materials. Dust is the very material that may carry the most complete and interesting geologic record, and about which we know the least.

SCIM Atmosphere Science: The science rationale for determining the composition of atmospheric species, particularly for carbon, oxygen, krypton, and neon isotopes, is discussed in the 2008 ND SAG report on Mars Sample Return [15]. Specific atmospheric composition investigations for SCIM would provide a significant increase in precision, accuracy, and sensitivity relative to current and planned investigations, and in several cases enable first-ever measurements. SCIM would provide a gold-standard ground-truth for a majority of high precision isotopic measurements of martian atmospheric species.

Relevance to Human Space Exploration: SCIM would advance the goals of human space exploration of Mars through both its systems and its science. It would bring into sharp focus our ability to perform a round-trip to Mars, and would do so while traversing deep into the atmosphere, allowing "aerocapture-like" atmospheric parameters to be measured in the process. However, the entry angle and streamlined shape of SCIM's aeroshell would not allow it to be captured, but rather it will exit the atmosphere and retain enough velocity to return to Earth. The SCIM shape, more slender than blunt, is comparable to the vehicle designs that may be flown to Mars for crewed missions. SCIM would allow NASA to gain experience flying such vehicles now. Finally, understanding in detail the composition of martian dust would help mitigate both health and engineering concerns that could otherwise unnecessarily drive the design and costs of human missions.

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