Mars Sample Return at 6 Kilometers per Second: Practical, Low Cost, Low Risk, and Ready.

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Introduction: The technology for a practical sample return is available now. For about 20% of the cost of a complex robotic mission that would return rock and soil samples in, perhaps, fifteen years, we could return samples of atmospheric dust and gases in five years using the SCIM mission concept [1].

SCIM proposes to return samples of both martian dust and atmosphere without ever landing on the martian surface. A robotic mission that doesn't land is low risk with lots of options for contingencies. The small, dispersed solid-portion of the sample SCIM targets is relatively easy to sterilize *in situ*, thereby avoiding planetary protection concerns for the first Mars Sample Return. Moreover, there will be enough martian dust and atmosphere returned to give us an immense science return, providing data for a new, global view of Mars (See Table 1). SCIM can also provide ancillary engineering and chemical data necessary for successfully planning future sample-return missions.

Role in Science/Engineering/Human flight: SCIM will collect and return atmospheric solids that will provide a well-mixed sample of martian crustal components from the hemisphere(s) over which the craft flies. Therefore, we will glean information about weathering, oxidation state, hydration, bulk and trace element chemistry. SCIM atmospheric samples will allow isotope and noble-gas geochemistry to provide constraints on martian history, including primordial and current atmospheric composition, surface-atmosphere interactions, and the degassing history through time. Moreover, we can concurrently collect data on atmospheric and structural parameters for engineering models of landing missions, and health-issues (e.g., Cr^{+6}) for astronauts without diluting the science return.

Mission design: The SCIM mission design is a venture in flexibility; its exact structure can be modified with respect to the science-goals, institutional partnerships, and the budget at hand.

Basic Mission. The heart of the mission is a high-speed aeropass of Mars with a periapsis below ~45 km, near the equator, at a dusty time of year. Gas is collected when ram-air enters a small opening in the nose; dust is collected as it passes through the rarified bow-wave and impacts aerogel-filled collectors in the body of the spacecraft. The gas and dust collectors are launched in place and require only the removal of simple covers to activate them for the collection processes. After the aeropass, the solar-panels redeploy and the spacecraft resumes cruise configuration. The dust collectors are heated for a few hours to sterilize the samples, eliminating planetary-protection concerns [3], and then stowed for a STARDUST-like return and analysis.

An example Scout-level mission based on the SCIM concept is shown in Fig. 1. This basic mission was designed to collect <u>at least</u> 1000 dust particles of diameter 10 microns or greater, along with millions of smaller particles, and at least one liter of martian atmosphere. For perspective: returning 1000 cometary particles (and no gas) was the goal of the highly-successful STARDUST mission [4], and NASA's prized cosmic dust collection is comprised of only ~250 particles.

Using current Earth-based instrumentation, one thousand 10 micron diameter dust particles would provide sufficient experimental material for many thousands of scientific analyses (Fig. 2). Similarly, the 1 liter atmospheric sample allows for multiple replicate isotopic analyses.

Variations on the basic mission: SCIM can be tailored to various scenarios and even upgraded for increased science return on a higher (but still low-cost) budget. Possible modifications include:

- Non-silicate / non-oxide aerogel and/or 29Si aerogel for analysis or more elements and mineralogical structures
- Passive instrumentation of aeroshell to collect data for CFD and other engineering models
- Double aeropasses to sample both hemispheres
- Rotating collectors/covers to separate dust particles as a function of depth in the atmosphere
- "Piggy-back" probe / small orbiter / camera for collecting remote data in addition to aeropass
- International cooperation: parsing space-craft, dust collector(s), launch vehicle, and "piggy-back" instrument.

We emphasize that SCIM is not intended to replace a future full-scale robotic-landed (or even crewed) mission. Rather, it is a practical near-term step that can provide valuable scientific and engineering data.

References:

[1] Leshin, L. A., et al., (2003) LPS XXXIV Abstract #1288; [2] Jurewicz, A. J., et al., (2002) LPS XXXIII Abstract #1703; [3] Clark, B. C., (2003) LPS XXXIV Abstract #1797; [4] Brownlee, D., et al. (2006) *Sci., 314,* 1711-1716; [5] Wiens, R. et al, (2003) LPS XXXIV Abstract #1199.

Table 1. SCIM Science Goals are achievable because Martian dust and gas are well mixed below the troposphere; moreover, aerogel capture particles "intact" and, after capture, will protect it thermally during the aeropass [2].

I. Quantitatively characterize the chemical, isotopic, and mineralogical composition of martian crustal materials

II. Investigate aqueous processing mechanisms that have affected or created martian surface materials

III. Discover evidence relevant to Mars' original volatile inventory, hydrologic and atmospheric cycles, and climate evolution

IV. Provide "ground truth" for past and future remote sensing observations of martian materials

V. Confirm that martian (SNC) meteorites are indeed samplesof Mars

Fig. 1. An example of a SCIM mission architecture for Mars sample collection and return. This design is for an economical (e.g., SCOUT-cost) mission, an expedient, low risk, Mars sample return that addresses global issues and can also be considered "reconnaissance" for robotic-landing or crewed missions [1].

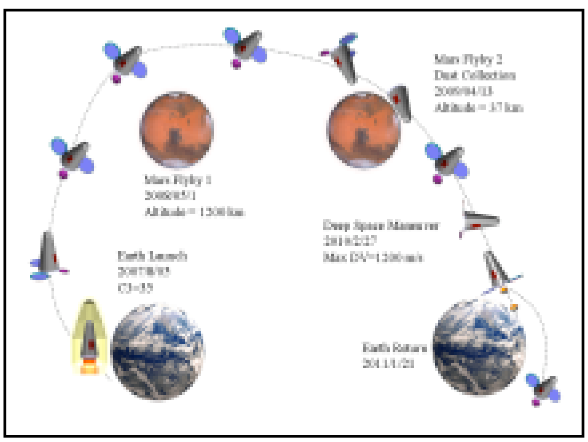
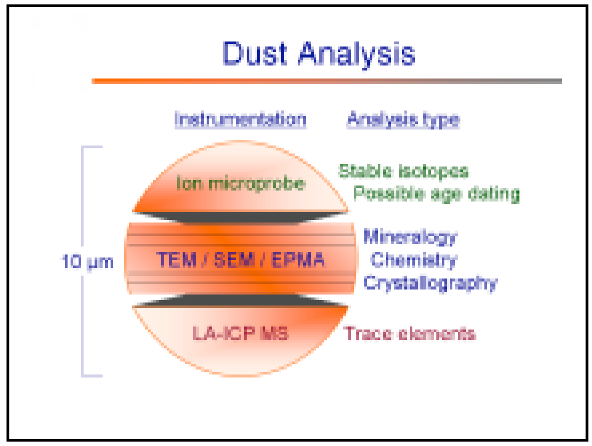


Fig. 2. Scientific importance of dust and atmospheric Samples.

(A) Shows how a 10 micron grain can be allocated for further scientific research after examination using non-destructive analytical techniques. Note: the Mars dust particles could easily be sectioned into multiple pieces and distributed to international laboratories having complementary instrumentation. Accordingly, each returned dust particle will provide material for numerous studies, as per STARDUST [4].



(B) Overview of how the isotopes in a well-mixed martian atmospheric gas sample can be used to probe fundamental questions about martian history [5]. We expect all of these investigations to be addressed with a SCIM 1 liter sample.

Species	Investigation
$^{18}O/^{17}O/^{16}O$	Total volume of water on Mars; Evolution of atmospheric oxygen over time by comparison with SNC silicate and alteration products
$^{14}C/^{12}C$	Very recent (4x10[illegible] yr) cryosphere-atmosphere exchange; or indicator of nitrate deposits present on Mars' surface
$^{3}He, ^{4}He$	Recent degassing history (past 10[illegible] yr)
Ne isotopes	Degassing history over past 10[illegible] yr
$^{36}Ar/^{38}Ar$	Degassing history over 4.5x10[illegible] yr Atmospheric escape history/modeling
$^{40}Ar, ^{129}Xe$	Interior processes / early degassing history
$^{128}Xe, ^{80}Kr$	Possible constraint on near-surface (paleo-ocean-deposited?) Br, I, from cosmic-ray-induced neutron capture Kr, Xe
$^{136}Xe, ^{134}Xe$	U/Pu ratio in Mars' interior
Kr, Xe isotopes	Formation of Mars from solar nebula; solar nebula processes
D/H	Precise composition of present atmosphere; Atmosphere-cryosphere exchange; Atmospheric chemistry & escape processes
$^{13}C/^{12}C$	Present atmospheric composition; Atmosphere-cryosphere exchange; Atmospheric chemistry & escape processes
$^{15}N/^{14}N$	Present atmospheric composition; Balance between degassing and escape; Atmospheric escape processes