STERILIZED SAMPLE RETURN: BREAKING THROUGH THE MARS SCIENCE BARRIERS

B.C. Clark, Lockheed Martin Astronautics, P.O. Box 179, MS S-8000, Denver, CO 80201

Introduction: For over three decades, a wide variety of science advisory committee's have strongly endorsed the critical importance of Mars Sample Return (MSR). For a brief review of this history, see [1]. During and prior to this time, MSR mission implementations have been under serious analysis by JPL and NASA Centers (LaRC, JSC), through both internal and contracted studies. NASA currently has no approved date for the first Mars surface sample return, but studies are underway. It is now becoming apparent that MSR is needed in a timely manner to prevent stagnation of martian science due to lack of critical data.

The Science Barriers: Increasingly ambitious Mars missions are firmly planned for orbital remote sensing (Mars Reconnaissance Orbiter, MRO; Mars Express, MEx) and landed *in-situ* investigations (Mars Exploration Rovers, MER; Beagle 2; Mars Science Laboratory, MSL). Following in the footsteps of Pathfinder, MGS and Odyssey, an enormous data base on Mars is being amassed. Without concomitant investigation at the scale used for modern laboratory attacks on geological problems, these observations of the surface will not necessarily mean that scientists always will "know what they are looking at." Complex weathering environments, for example, are notoriously difficult to disentangle. Straight-forward lab techniques such as thin sections, SEM mounts, and chemical processing are far beyond the expected capabilities of upcoming missions. *In-situ* isotope and microprobe work are unlikely, and even if instruments were provided, the data bottleneck would severely limit the ability to search through numerous samples at the microscale for rare, pivotal evidence on petrogenesis, physical weathering, and alteration sequences and products.

MER science is a major step forward from Pathfinder and Viking, and will provide critical mobility, but obtains compositional information at the scale of cm, not petrographic or electronic microscopy. Examining a foreign geologic setting at the level of the hand lens and bulk chemical analysis is to modern geochemical methods as Sherlockian sleuthing is to modern forensic science. Micro-forensics has proven over and over again that circumstantial evidence at the *macro* level alone, and the speculation it encourages, can result in false conclusions (innocent persons wrongly jailed, criminals wrongly freed). Lack of micro-compositional, mineralogic, and isotopic data on the materials of Mars is rapidly becoming an ultimate barrier to progress in understanding a most mysterious planet.

Cost and Risk Factors: Engineering and policy barriers to MSR have been the primary reason these missions have not yet begun. Recent approaches and concepts may provide the necessary breakthroughs.

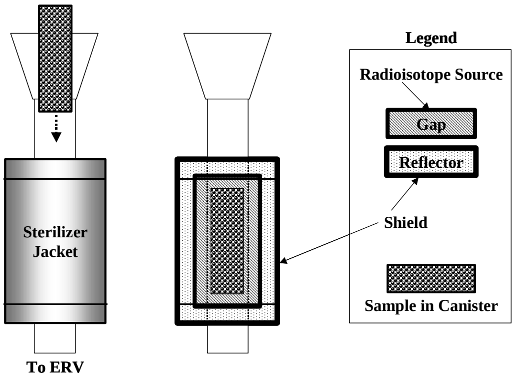
Cost Barriers. The relative cost for MSR has decreased significantly over the decades, due to improvements in productivity in the aerospace disciplines, and to advances in avionics, propulsion, guidance, as well as the availability of proven subsystems, which can be reflown for MSR missions. Meanwhile, the economic resources of those nations now engaged in space exploration have increased many-fold during the past 30 years, so that the fractional national investment to accomplish an MSR mission has plunged. Yet, space policy makers (primarily OMB and the Congress) have recently favored much smaller cost caps for critical missions in space exploration. Current independent studies have indicated the first surface-MSR to be somewhat above one B$, but not including the planetary protection (PP) Receiving Facility (estimated as high as 250-350 M$ [2, 3]).

Risk Factors. More recently, concern has been raised over the reality that a sample return mission from the surface of a planetary-sized body requires about twice the critical activities of a lander mission to the same body. Overall mission reliability calculations, although notoriously difficult to perform on an absolute scale, imply about double the system failure probability as a lander mission alone. On the other hand, the only new components of such a mission are the Mars ascent vehicle (MAV), a quasi-autonomous sample transfer and the back-contamination protection. Ascent via rocket invokes only propulsion, and does not require complex, heavy heatshields and parachute systems of a lander (not to speak of airbags, legs, petals, etc.). Both MAV and sample transfer can be developed and demonstrated in the Earth's vicinity prior to major expenditures on the mission. The proposed SCIM [4, 5] and Gulliver [6] missions bypass these complexities altogether by avoiding landing and rendezvous/handoff.

Savings by Sterilized Sample Return: By sterilizing the samples prior to return to Earth, the full test and assurance program for *stringent* sample isolation and containment (1E-6 probability level for avoiding inadvertent release of a single 200 nm particle, the current guideline [7]) could be selectively tailored to reduce cost and to *use the sterilized MSR mission itself* as part of the demonstration of the effectiveness of the engineering techniques chosen. Likewise, PP and EIS, and other plans and approvals could be obtained at potentially far less cost and effort. Pre-launch testing of non-mission critical tasks, such as some aspects of PP itself, could be reduced or eliminated. The Receiving Laboratory functions could be performed by modestly upgraded curatorial facilities already in use for Lunar and interplanetary particle samples. Ultra-sensitive analyses for organic materials and possible biomarkers could be performed in existing state-of-the-art laboratories instead of a new, costly and dedicated facility whose capabilities may prove to be moot because of negative evidence for life forms in the samples. Sterilizing in space also reduces mission *risk* by avoiding unnecessarily complex sample handling due to perceived difficulties in containment.

Heat Sterilization: Currently approved NASA standards specify heat sterilization at 500ºC for >0.5 sec [8]. In-progress NASA research may provide data at lower temperatures. Medical practice routinely employs dry heat sterilization at temperatures as low as 140ºC, from which temperature-time sterilization functions can be derived [9]. However, numerous groups have recommended radiation over heat sterilization for samples that may contain weak hydrous or other heat-labile mineral phases [10-12].

Radiation Sterilization: Doses of 15-20 Mrad have been recommended. This technique, using x- or gamma-rays, does minimal damage to geological specimens, as is well known from general radiation effects and geological testing [11]. Furthermore, all SNC meteorites have received in-space doses exceeding 25 Mrad [13], yet have been successfully subjected to a wide range of studies [14]. Although life forms will be reproductively inactivated, metabolic activity of some enzymes should remain; most organic compounds will be intact; PCR probes for DNA and other sensitive biochemical tests can be conducted.



Implementation of In-Space Irradiation Sterilization (ISIS). An example design uses radioisotope sources (such as Gd-153 or Co-57) with relatively low gamma energies and no extraneous emissions. Radiotoxicity of such sources is much less than that of trans-uranium radioisotopes. In the accompanying figure, the sample canister is a cylinder, 5 cm in diameter, and is placed inside a sterilizer jacket for several months during the return trip to earth. An internal layer of isotope irradiates the sample, while an external shield protects sensitive spacecraft components.

Impact Sterilization: The SCIM SR mission [3-4] proposes to collect dust and gas during a 6 km/s fly-through of the martian atmosphere. Laboratory experiments at 4-5 km/s by Burchell et al. (utilizing porous ceramic impactors doped with the hardy bacterium, *Rhodococcus erythroplis*) showed no detectable survival into aerogel, glass or metal, except for a few cases of splashback for rock impacts [15]. Furthermore, survival may have been enhanced by the use of moist projectiles [16], which does not simulate the martian situation for SCIM. The Stardust mission has already been classified as an Unrestricted Earth Return (6.1 km/s impact velocities at the time of collection).

Application Scenarios: The SCIM and Gulliver missions seek to collect samples from the atmosphere and from the moons of Mars, respectively. Each can be accomplished for a fraction of the cost and at less risk than surface MSR, and could provide first demonstrations of a roundtrip and return of martian material. In both cases, there are arguments to be made that their samples have already been rendered sterile by their environment, but in-flight sterilization could still be provided. For surface MSR, sterilizer hardware need not be taken to the surface. Whether heat or radiation is used, sterilization would be optional via command, so that as confidence is gained in the engineering systems, this step can be skipped to provide eventually for pristine sample return. In the meantime, extremely valuable information on the nature of contemporary samples from Mars could be obtained to allow better life detection testing, safe-guarding, and preservation in an eventual fully implemented Receiving Facility.

References: [1] Belton, M. et al. (2002), NRC Decadal Study, Planetary Exploration. [2] Beatty, D. (2002), MEPAG Briefing. [3] Bell, M.S. et al. (2002), World Space Congr/COSPAR Abs 01223. [4] Leshin, L.A. et al. (2002), Lunar Planet. Sci. XXXIII, #1721. [5] Op.cit. (2003), this volume. [6] Britt, D.T. et al., *Meteorit. Planet. Sci. 37*, A25. [7] Rummel, J. (1999), Lett to MSR Project. [8] NASA NPG 8020.12B. [9] Clark, B. (2002), World Space Congr/COSPAR Abs 02263. [10] Gooding, J.L. et al. (1990), NASA TM 4184. [11] Allen, C.C. et al. (1999,*) J. Geophys. Res. 104*, 27,043. [12] MSHARP-99, Carr, M.H. et al. (1999), NASA/TM-1999-209145. [13] Clark, B.C. (1999), *Orig. Life Evol. Biosph. 31*, 185-197. [14] McSween, H.Y. (2002), *Meteor. Planet. Sci.37*, 7. [15] Burchell, M.J. et al. (2001), *Adv. Space Res. 28*, 707. [16] Ahrens, T., pers. comm., 8/02.