CHALLENGES OF A MARS SAMPLE RETURN MISSION FROM THE SAMPLES' PERSPECTIVE – CONTAMINATION CONTROL, PRESERVATION, AND PLANETARY PROTECTION.

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Introduction: The main point of any sample return mission is laboratory analysis. Everything must be designed, built, and operated to get the highest quality samples to the best laboratories. In order to preserve the research value of these precious samples, chemical and organic contamination must be minimized, understood, and documented. The samples must also be preserved – as far as possible – from physical and chemical alteration. In addition, spacecraft targeted to the surface of Mars, as well as spacecraft and samples returned from that planet, carry unique requirements for planetary protection.

Contamination Control

Contamination control starts with mission design. Samples will never be cleaner than the tools and containers used to collect, transport, and store them. Samples, tools, containers, and contamination witness materials for a Mars sample return mission will carry unique requirements for both inorganic and organic contamination control. Tools, equipment, and operating procedures must minimize the introduction of contamination onto sample surfaces. Cross-contamination among samples must be prevented. Unavoidable contamination must be understood and documented.

Sample acquisition tools and storage containers must be made of well-characterized materials. Specific elements are considered critical to the geochemical interpretation or age dating of martian samples, and these elements may be excluded from sampling tools and containers. Maximum allowable abundances for minor and trace elements in tools and containers have been recommended, based on the abundances of these elements in martian meteorites. Separate requirements for the maximum allowable organic contamination on tools and containers will be established to address the concerns of both basic research and planetary protection.

Cross-contamination among samples in also a critical concern, especially for materials collected from a diverse set of geochemical environments. Recent mission designs incorporate separate, sealed containers for each rock and soil sample. Such a design is important for contamination control, and also for planetary protection.

Materials that come into contact with the samples must be not only carefully selected but also well-documented. Witness coupons of these materials, as well as samples of coatings and lubricants, must be collected and preserved for the duration of the mission and subsequent sample analysis.

Sample Preservation

A separate concern, also critical to detailed analysis and interpretation, is the preservation of the samples from physical alteration. A key factor is the degradation of samples due to temperature cycling.

A Mars sample return mission may well encounter temperature-sensitive minerals. Much of the martian surface and essentially all of the near subsurface areas remain below 0˚C, and the minerals in rocks and soils are tolerant of those conditions. However, ices and minerals such as the multiply hydrated sulfates recently discovered on Mars are extremely temperature sensitive. A temperature rise of a few tens of degrees during the course of acquisition, storage on Mars, interplanetary flight, or Earth entry could seriously alter such samples. While some temperature cycling may be unavoidable, it should be minimized and must be well understood.

Sample heating may also lead to significant loss of adsorbed atmospheric gases, particularly from fine-grained dust and soil. Degassing changes the physical and chemical characteristics of the sample, and can also lead to rapid pressure increases. Sample containers must be designed and constructed to deal with degassing and internal pressure changes.

Planetary Protection

Every spacecraft destined for the martian surface or orbit is extensively cleaned, and contamination witness materials are collected and preserved, in order to minimize and document possible biological contamination of Mars. International treaties and national planetary protection policies place strict limits on the allowable bioloads of all Mars missions. These requirements will be the most stringent for sample return missions, not only to protect Mars from forward contamination but also to insure against false positive indications of life in the returned samples.

In addition, extreme precautions must be taken to insure that samples from Mars are not allowed to pose a threat of "back contamination" to the Earth's biosphere. Spacecraft hardware, as well as flight and recovery operations, must insure containment of the samples. The mission must be designed and operated to "break the chain of contact" with Mars, to prevent uncontained martian material from reaching Earth.

The assessment of possible life and biohazard in martian samples – while preserving these samples pristine enough for a wide range of geological and geochemical research – will require an unprecedented collaboration among policy makers, mission engineers, and researchers. For the first time since Apollo, sample science will interact closely with microbiological analysis and hazard assessment. The research community must be prepared to answer the key life and biohazard questions, and must be prepared for the full range of possible answers.

The exploration of Mars is being carried out by many countries, and recently Mars sample return missions have been specifically studied as a joint effort between NASA and the European Space Agency, with the possible inclusion of additional partners. As planning develops, these initial studies will be updated and will form the basis for the engineering, operations, and science of this incredibly challenging international mission.