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# THE MARS SAMPLE RETURN CONTEXT FOR EARTH ENTRY, DESCENT, AND LANDING

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The first Mars Sample Return mission to be launched in 2005 presents significant challenges to the design of the Earth entry, descent, and landing system for the Martian sample. These challenges are driven by low vehicle mass, high entry velocity, and very high reliability, the latter being due the the unknown biohazard potential of the Martian material. The challenges include a passive landing system that maintains sample containment, and the qualification of a high-performance thermal protection system at entry velocities exceeding the Earth entry vehicle experience to date.

## Introduction

The first Mars Sample Return (MSR) mission will be launched in 2005 as part of the ongoing Mars Surveyor Program. It will be the first of a series of Mars sample returns planned to explore and characterize in detail possible geological environments for past and current life on Mars. Each mission will collect and return a few hundred grams of Martian surface materials, with the first sample returning in 2008. The full arsenal of Earth's laboratories can be applied to the samples, resulting in cost-efficient, rapid, and adaptive Mars science that would not be affordable or even possible with in situ instrumentation.

The Mars Surveyor Program is preparing for the MSR missions with a series of orbiters and landers launched at every Earth-Mars opportunity, approximately every 26 months. It began with the Mars Global Surveyor mission launched in 1996 and continues with the Mars Climate Orbiter and Mars Polar Lander, both to be launched this Winter. An orbiter launched in 2001 will complete the global survey needed to select the first MSR landing sites on Mars. Landers launched in 2001 and 2003 will provide ground truth for the orbital observations, and will lay the groundwork, so to speak, for the local site characterization and sample selection and collection techniques that will be needed by the MSR missions, as well as to gather data and perform experiments in preparation for eventual human missions to Mars. In parallel, the Mars Surveyor Program is making significant investments in technology developments to enable a low cost implementation of Mars Sample Return.

The current baseline mission mode for MSR, Mars orbit rendezvous, uses two spacecraft to deliver the mission elements to Mars: a lander containing the sampling rover and Mars Ascent Vehicle (MAV) capable of reaching low Mars orbit; and an orbiter carrying an Earth entry vehicle that is capable of entering a low Mars orbit and then injecting on a trajectory to Earth. The sample is collected and launched on the MAV into low Mars orbit, and then the orbiter performs a rendezvous with the sample, transfers it into the Earth entry vehicle, and departs for Earth.

## The Earth Entry Vehicle

All of the possible mission modes considered for Mars Sample Return assume for mass efficiency that the vehicle carrying the Martian sample enters directly into Earth's atmosphere from the hyperbolic approach trajectory and then lands at the selected site for recovery. This part of the mission poses unique challenges and requires new technologies to enable the mission. The entry velocities range from 11.5 to 12.5 km/s, depending on the mission opportunity and the landing site. These velocities are higher than any previously experienced by Earth entry vehicles. Furthermore, the entry vehicle's mass is limited to

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allow the mission to fly on low cost Earth launchers, which leads to the consideration of new materials that have not flown before in real environments. The MSR design reference mass target for the Earth entry vehicle is 25 kg (30 kg allocated), including a 2.7 kg payload.

One of the most significant drivers on the Earth entry vehicle as well as on other mission elements is Planetary Protection. In particular, it must be assured with high confidence that there will be no inadvertent release of Martian material into Earth's ecosphere during entry, descent, landing, and recovery. This comes from recommendations by the National Research Council to NASA.[1] That report states that while the chance of returning a viable replicating Martian organism with pathogenic or ecological effects is low, the risk is not zero. They recommend that no uncontained Martian material be returned unless it has been sterilized, including any spacecraft surfaces exposed to the Martian environment, that the containment of Martian materials be monitored en route, and that the containment be maintained from entry through transfer to a receiving facility. Unsterilized samples are not to be removed from containment until it has been rigorously determined that the material does not contain a biological hazard.

## Design Challenges

What this means for the Earth entry vehicle is that it must protect the sample container from being breached during entry heating and the landing impact, and that the landing must be accurate enough for the sample to be found by the recovery team before anyone else finds it. Therefore, the heat shield and entry environment must be well characterized through the experiments and analyses needed to assure that the vehicle will protect the descent and landing system and sample container. The entry and landing must be robust to plausible failure modes of the vehicle, such as any mechanical actuation or deployment failures. The landing system must protect the container from impact at the landing site adequately to prevent a breach. Lastly, the landing site must be selected to avoid losing the sample in plausible weather conditions, and to prevent others from gaining access to the sample container while the recovery team searches for it.

Since most landing systems involve mechanical deployments, specifically a parachute, the most obvious design consequence is that containment must be maintained in the event of a parachute failure. So the vehicle must be designed to work completely passively from entry to landing well enough to prevent a breach. Another consequence is that landing in a very large body of water in bad weather conditions, even if the sample were designed to float, could result in a loss of the sample. It could then be found by someone who might open the container and expose Earth's environment to its contents before the absence of any biological hazard in the sample could be verified. These two consequences result in the challenge of a passive landing system that can hit solid ground and reliably maintain containment.

The low mass allowed for the entry vehicle combined with the high velocity of entry creates another significant challenge, which is the assurance of the performance of the MSR entry vehicle during hypersonic entry using a high performance thermal protection system (TPS). Since the first use of the MSR entry vehicle in actual conditions will contain Martian samples, the challenge will be to understand the environment that that vehicle will be exposed to and the behavior of the TPS in that environment with enough fidelity to define margins in such parameters as TPS thickness that provide high assurance that the MSR entry heat shield will work. This understanding will require careful planning of the approach to affordable experiments and analyses that provide the necessary fidelity.

## Conclusion

Mars Sample Return presents significant challenges to the design and qualification of its Earth entry vehicle due to the limited mass available for the vehicle, the high entry velocity, and planetary protection concerns. These challenges include the design of a passive landing system that can impact solid ground, and the characterization of new TPS materials in the MSR entry environment. These challenges do not represent obstacles, but rather opportunities for the community represented here today to contribute to the exploration of Mars, to new insights into the origin of life, and ultimately to a better understanding of ourselves and our place in the universe.

## Acknowledgement

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## Reference

1. K. H. Nealson, et al, "Mars Sample Return Issues and Recommendations," National Academy Press, Washington, D.C., 1997.