Session IX: Sample Return Challenges
Multi-Mission Earth Entry Vehicle Design Trade Space and Concept Development Strategy

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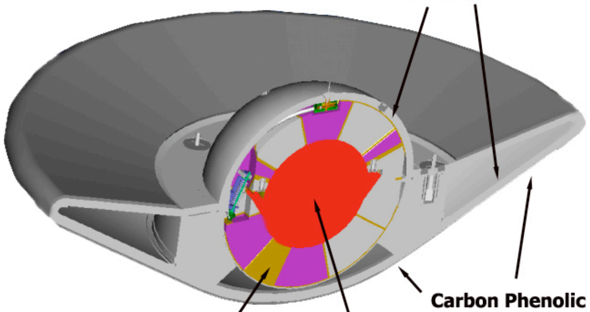
Introduction

- This goal of this presentation is to outline an approach to develop a flexible Earth Entry Vehicle (EEV) design which can be utilized by multiple sample return missions.
- The multi-mission EEV concept will be based on the Mars Sample Return (MSR) EEV design which is driven by minimizing risk associated with sample containment.
- This vehicle, by necessity, is designed to be the most reliable space vehicle ever developed.
- Such a high reliability concept provides a logical foundation by which individual missions can build upon in optimizing an EEV design which meets their specific needs.
- By preserving key common elements, the multi-mission EEV concept will provide a platform by which technologies, design elements, processes, etc., can be developed and flight tested prior to implementation on MSR.
- This approach could not only significantly reduce the risk and associated cost in development of the MSR EEV, but also by leveraging common design elements, all sample return missions will benefit.

A Starting Point: Mars Sample Return

- Basic EEV design was developed in the 1999-2001 time frame for the 2003/2005 MSR Project.
- Development continued in 2001-2004 through focused technology development activities.
- The EEV baseline design has not changed dramatically since 2001, but future modifications are anticipated as new technologies, processes, etc. are made available.
- Basic design tenets will remain unchanged:
  – Design is guided by the mission's Probabilistic Risk Assessment (PRA)
  – Planetary Protection / sample containment requirements are the driver
  – Eliminate or minimize active systems
  – Seek to use heritage, high TRL elements



EEV Baseline Design Parameters

- 0.9 m, 60° sphere-cone aeroshell
- 44 kg entry mass, including 3.6kg for 16cm diameter Orbiting Sample (OS)
- Earth entry at 12km/s, -25° FPA
- Peak heating ~1500 W/cm^2
- Peak entry deceleration ~ 130 g's
- No parachute for terminal descent
- 41 m/s landing velocity at UTTR

MSR EEV Development History

Langley Research Center

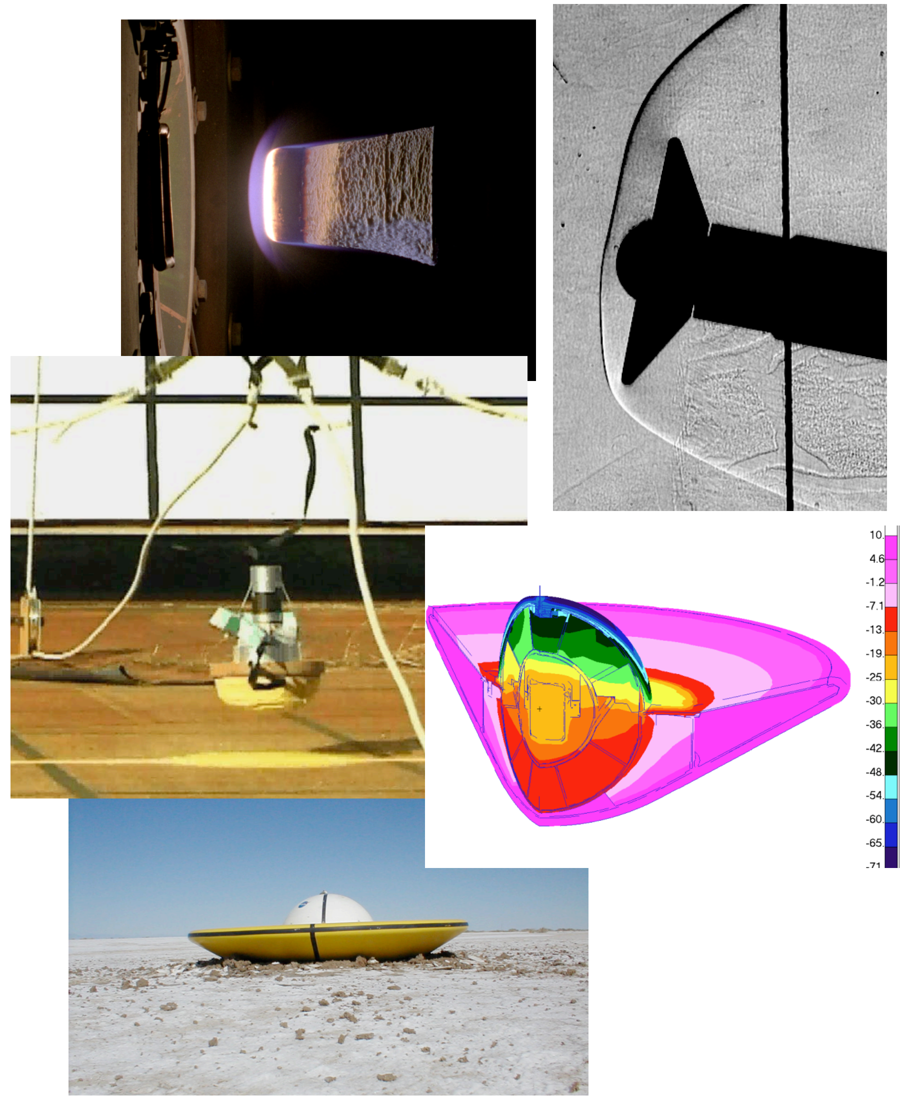
LaRC has extensive development and testing experience with this EEV design.

Aerodynamic stability:
- extensive 6-DOF simulation development
- hypersonic wind tunnel testing
- ballistic range and subsonic stability tests

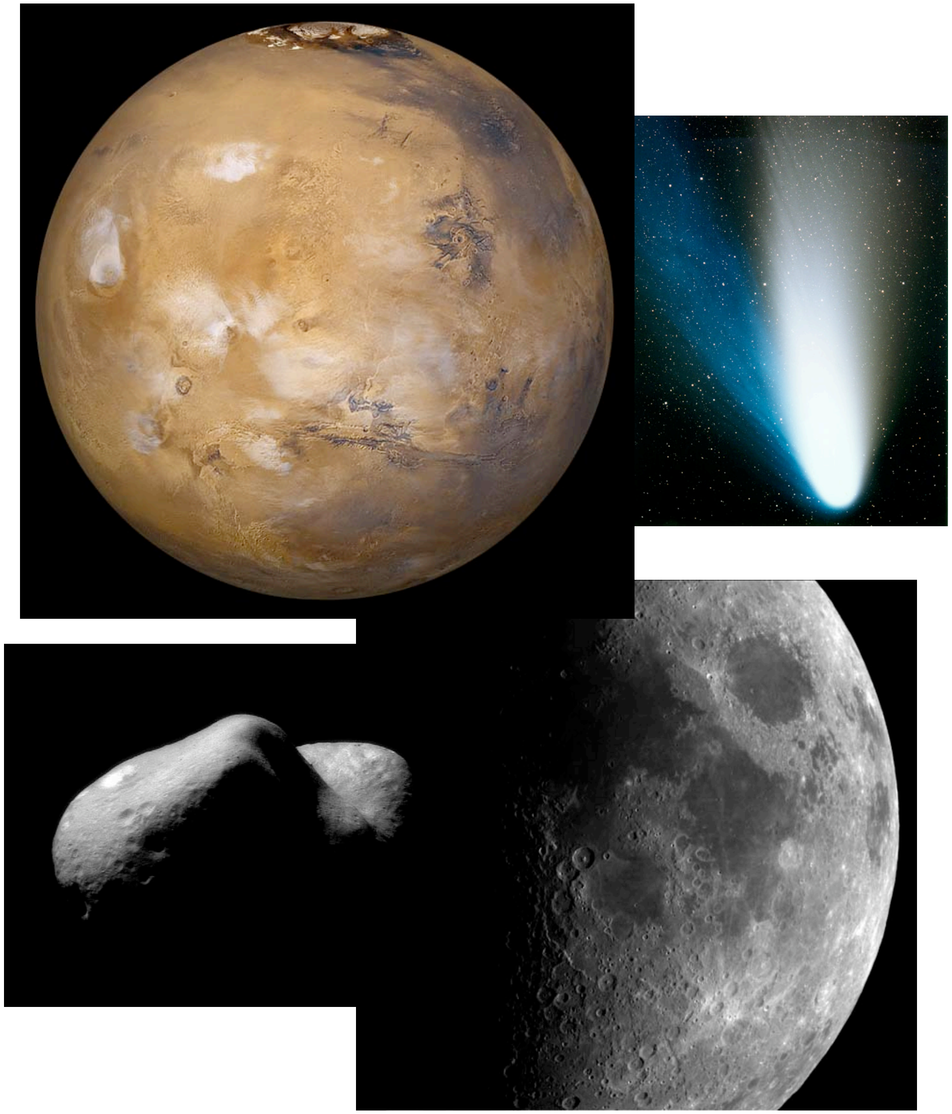
Thermal Protection System:
- PRA drove the selection and development of fully dense carbon phenolic (FDCP)
- arc-jet testing performed
- re-creation of heritage fabrication processes

Thermal Analysis:
- PATRAN model was developed to analyze the thermal environment of the entire vehicle from exo-atmospheric, through EDL, and post-landing

Impact Protection System:
- UTTR terrain characterization
- UTTR full scale drop tests
- cellular sphere impact tests
- LS-DYNA analysis and model validation



Sample Return MMEEV Applications



- Not all sample return missions will need to meet the rigorous planetary protection requirements of MSR.
- By definition, the MSR EEV concept is designed to be the most reliable sample return system feasible. This provides a logical basis by which any EEV design can be built upon.
- Optimize the EEV design for each mission, while also providing a platform by which technology development and risk reduction can feed forward to future sample return missions, particularly MSR.

Fundamental Principles to Preserve

- The high reliability of the EEV concept can be traced back to two design principles which will be preserved in the Multi-Mission EEV development:

- Chute-less design
  - Combined reliability of parachutes and automated deployment systems ~ 10^{-3} (even multiple parachute design).
  - Parachute system adds aft mass and increases capsule ballistic coefficient:
    - Increases aero-heating and risk to heat shield
    - Exacerbates ground impact event in the event of parachute failure
    - Reduces aerodynamics stability
  - Packaging of parachute system interferes with sample transfer and placement
  - Introduces premature parachute deployment event that could remove aft TPS prior to heat pulse.
  - Landing footprint is slightly increased due to greater sensitivity to winds.
  - Requires power, sensors, flight computer, sensors, pyros, etc.

- Aerodynamic stability
  - Provides hypersonic re-orientation capability, even when spin-stabilized 180º backwards or tumbling, in the event of entry attitude failures due to spacecraft separation or meteoroid impact.
  - Provides robust performance against a wide range of entry condition dispersions, as well as atmospheric uncertainties.
  - Extensive aerodynamic database development and testing has been compiled for the 60º sphere-cone forebody shape.

Trade Space / Optimization Parameters

- Depending on the destination, some MMEEV design requirements may vary greatly across possible sample return missions.
  - Payload accommodations / volume / mass
    - drives overall EEV diameter, mass / ballistic coefficient
    - could also impact aft body shape
  - Entry conditions
    - entry velocities at Earth return can range from ~10 km/s for lunar or near-Earth missions to ~16 km/s for some comets
    - entry flight path angle will drive trade between aerothermal environments the vehicle will encounter versus landing accuracy
  - TPS material selection
    - size (and velocity) DOES matter when it comes to turbulent flow and radiative heating!
    - nose radius can be used to mitigate some aeroheating issues
    - with recent developments of PICA (MSL, Orion, etc.), this may be a reliable option which can save both mass and cost
    - ultimately, any TPS flight data will significantly reduce the risk for MSR (whether aerothermal or meteoroid)

Tracking MMEEV Performance

- In keeping with the goal of maximizing commonality and feed-forward between different applications of the MMEEV, including MSR, several performance attributes will need to be tracked while optimizing the MMEEV design for a specific sample return mission.
  - Aeroheating
    - will be key in selecting appropriate TPS material
    - will also impact post-landing (soak back) thermal environment, which may be critical for sample preservation with respect to science
  - Aerodynamics
    - stability will be driven by such things as ballistic coefficient, center of mass location, vehicle configuration (e.g. aftbody shape)
    - strong desire to stay within the bounds of the current aero-database
  - Impact loads
    - for MSR, and possibly other missions, the impact requirements are driven by sample containment
    - science may also impact requirement with respect to sample preservation (e.g. stratigraphy)

Concept Development Strategy

- During early mission concept studies, or even prior to this, a "design map" will be developed which will look across the likely range of MMEEV optimization parameters and provide a suite of candidate vehicle classes or configurations to select from for each sample return mission based on its unique requirements.
- During mission development, this concept can then be modified as needed, as long as those MMEEV fundamental principles are preserved.
  - This will insure maximum commonality and feed-forward for other users.
  - The natural tendency should be NOT to stray since, by definition, the basis of the design is high reliability.
  - New technology, processes, and lessons learned during both development as well as in-flight can be implemented not only to other MMEEV designs within that class, but across all MMEEV implementations.

Conclusions

- The vast experience with the Mars Sample Return Earth Entry Vehicle design has laid a very strong foundation for the development of a very reliable EEV which can be used for various sample return missions.
- The fundamental principles of a chute-less design and aerodynamic performance, in the areas of self-righting and passive stability, were identified by MSR as keys to providing a highly reliable EEV system.
- The MMEEV provides a flexible platform by which technology development and flight test experience can be applied (either as cross-feeding or feed-forward) to other sample return missions, reducing both risk and cost.
- This will be true particularly for MSR which may ultimately be the most challenging sample return mission in the foreseeable future (other than human spaceflight).

Acknowledgement

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