Multi-Mission Earth Entry Vehicle Design Trade Space and Concept Status (Version 2.0)

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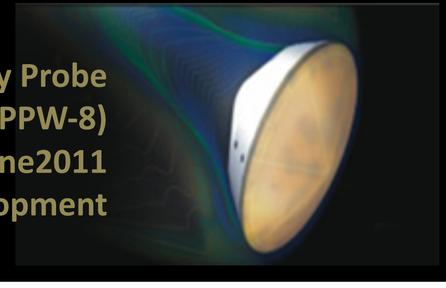
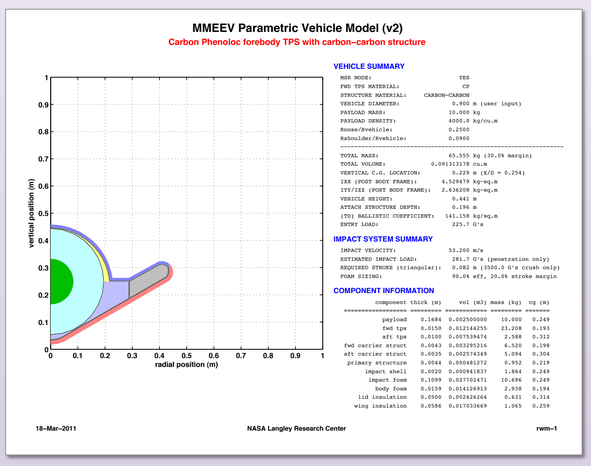
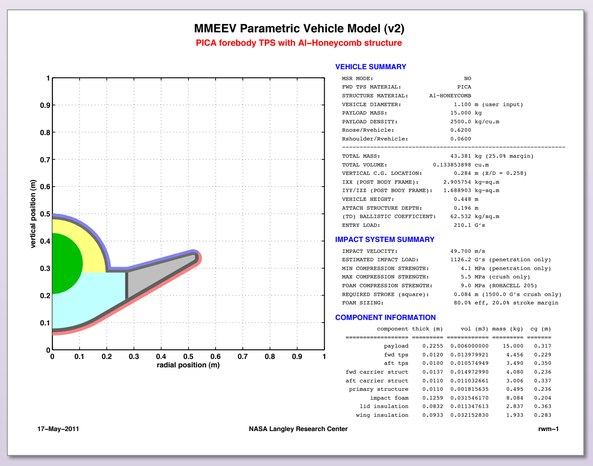


What is the Multi-Mission Earth Entry Vehicle (MMEEV)?

- A vehicle design concept based on the Mars Sample Return EEV design.
- Was first introduced at IPPW-6 in 2008; Version 1.0 summary provided at IPPW-7 in 2010.
- Development is directed by NASA's In-Space Propulsion Technology Program.
- Provides a reliable foundation upon which any sample return mission can optimize an EEV design which meets their specific needs / requirements.
- Preserves key design elements which lower risk.
  - "Chute-less" design: reduces risk and complexity of EEV.
  - Aerodynamic stability: provides robust performance using well understood aerodynamics; includes re-orientation capability prior to heat pulse.
- MMEEV Provides a common platform by which key technologies can be identified, designed, developed and flight proven prior to implementation on MSR, providing significant risk and development cost reductions to any sample return mission.

Parametric Vehicle Model Version 2.0:





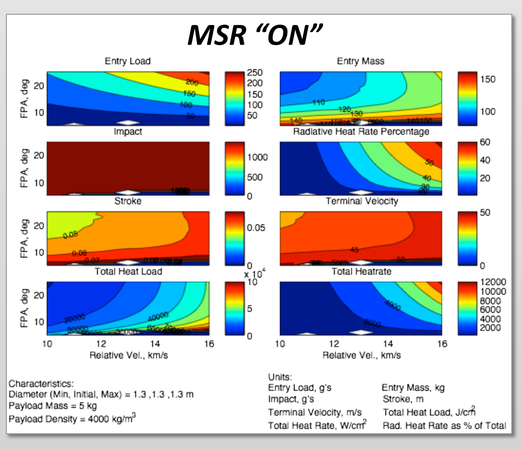
- MMEEV parametric vehicle model handles both MSR impact architecture as well as a more simplified impact attenuation approach.
- New inputs include payload size, nose radius, and shoulder radius. Also allows for selection of PICA (with Al-honeycomb carrier structure) or Carbon-Phenolic (with Advanced Carbon-Carbon carrier structure).
- Given the large number of inputs and associated geometric relationships, several rules and constraints are used to assist in the iterative / convergence process.
  - simple constraints (i.e. minimum and maximum allowed values) on such parameters as structure or TPS thickness are sufficient
  - the complex geometry required the enforcement of several other rules in order to ensure the vehicle model would converge to a usable solution (e.g. if input vehicle diameter is too small to accommodate the payload, the vehicle will be resized to the smallest possible).
- Includes a 1-D energy balance model for estimating impact stroke and foam thickness requirements.
- A simplified structural scaling model is also included to determine structure thickness as a function of maximum entry loads (ACC structures only).

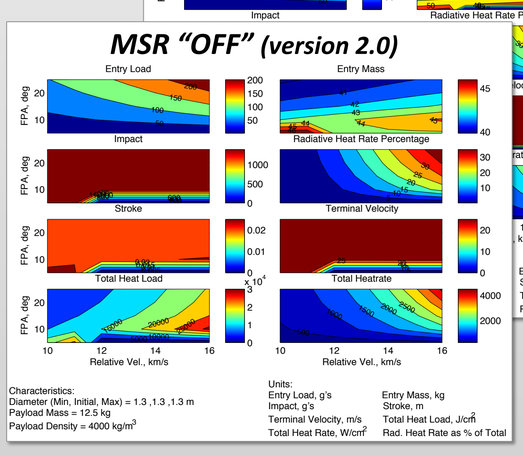
MMEEV Version 2.0 Performance Summary:

- For Version 2.0 of the trade space analyses, the parametric vehicle model and forebody TPS MERs were integrated into NASA LaRC's Program to Optimize Simulated Trajectories (POST2) 6-DOF simulation software.

Payload Accommodations	
Payload Mass	5 to 30 kg
Payload Density	500 to 10,000 kg/m^3
Vehicle Diameter	0.5 to 2.0 m
Entry Conditions	
Inertial Velocity	10 to 16 km/s
Inertial Flight Path Angle	-5° to -25°

- For each set of entry conditions, the parametric vehicle model, EDL trajectory, and flight environments were iterated until the required forebody TPS thickness converged.



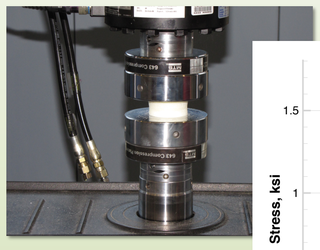


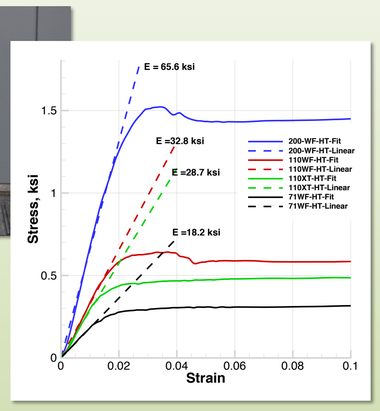
- The entire mission and vehicle trade space was run using the Version 2.0 models, for both an MSR-like architecture (CP/ACC) and simplified architecture (PICA/Al-honeycomb).
- Results for the simplified architecture agree well with the Version 1.0 results, providing continuity in the MMEEV analyses as the models become higher fidelity and more capable, and the trade space grows.

Significant Changes from MMEEV Version 1.0:

- The focus of the Version 2.0 development was to provide an update to the trade space analyses provided in Version 1.0 with improvement to key MMEEV models.
- SIGNIFICANT improvements were made to the parametric vehicle model, including:
  - ported to MATLAB from Pro-E to provide significant improvements in optimization convergence; Pro-E still used for model validation
  - increased scope and fidelity of user inputs
- Updates to forebody PICA TPS Mass Estimating Relationship (MER) and development of forebody Carbon Phenolic TPS MER.

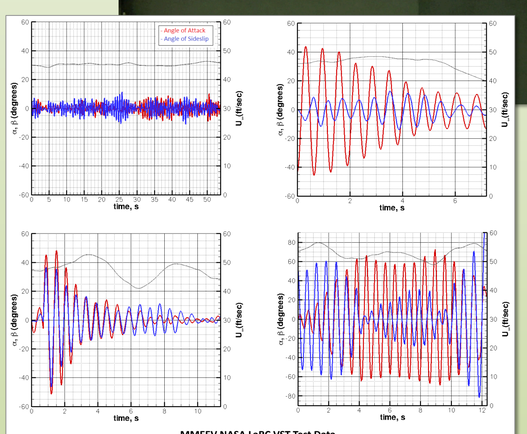
Impact Foam Materials Testing:





- Rohacell® foams are credible candidates for MMEEV energy absorbing materials.
- A series of static tests was conducted to characterize the mechanical properties of four high performance Rohacell® foams: 200 WF-HT, 71 WF-HT, 110 WF-HT, and 110 XT-HT.
- Followed ASTM D1621 (Standard Test Method for Compressive Properties of Rigid Cellular Plastics); allows for comparison with manufacturer provided data.
- This test data will be used to develop models for material properties suitable for finite-element analysis.

Aerodynamic Testing – NASA LaRC Vertical Spin Tunnel (VST):

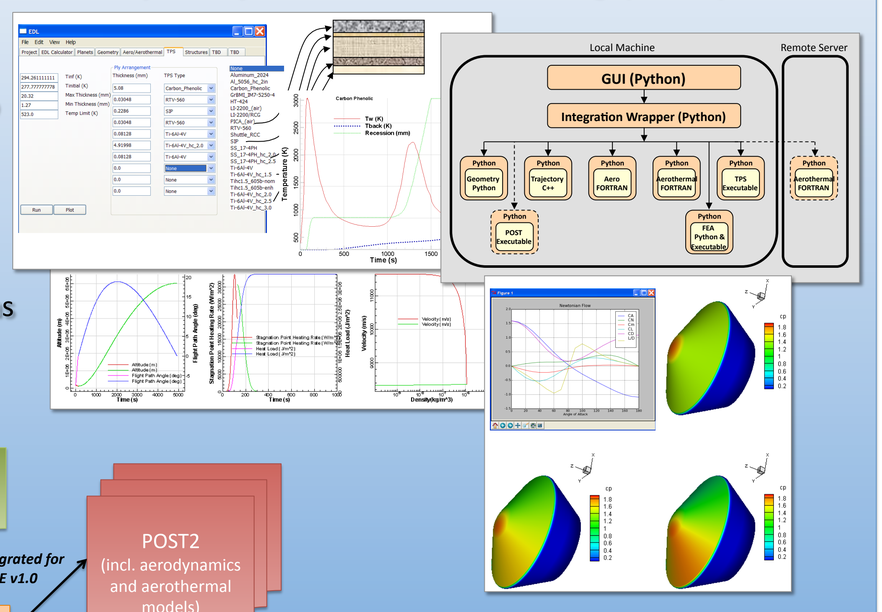


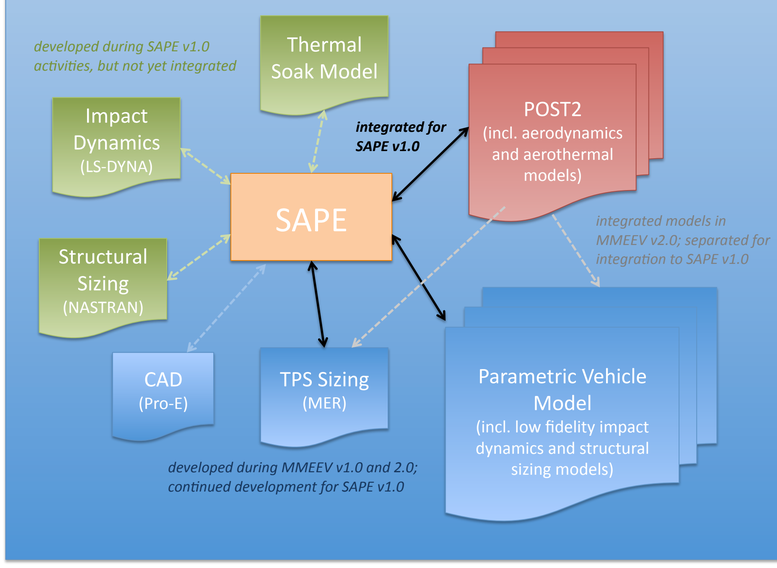
MMEEV NASA LaRC VST Test Data
[upper left = baseline CG, unperturbed oscillation, lower left = baseline CG, perturbed oscillation; upper right = aft CG, unperturbed oscillation, lower right = aft CG, perturbed oscillation]

- The largest source of uncertainty in MMEEV aerodynamic performance is the low speed regime; much of MMEEV descent is subsonic (near vertical) with no stability assist.
- CFD predictive capability is credible for static aerodynamics, but not demonstrated for dynamics.
- A test in the NASA LaRC VST was executed in FY 2010, to determine free-flight dynamics of a scaled capsule at subsonic velocity and to assess dynamics over a broad parameter space (vehicle size, CG placement, inertias) and the sensitivity to payload-driven uncertainty in CG placement.
- The results indicated that the MMEEV configuration is stable for all chosen CG locations, and the vehicle dynamics do not appear to depend significantly on surface roughness or vehicle inertias.

Systems Analysis for Planetary Entry Descent and Landing (SAPE) tool:

- Prototype EDL system analysis tool has been developed for missions to celestial bodies with atmosphere.
- Python, a platform independent language, is used for tool integration as well as Graphical User Interface.





- Plan includes integrating MMEEV tools and models into SAPE during FY 2011.
- SAPE will then be used as the centralized data flow manager and project requirements interface to MMEEV concept studies, including MSR, expected to begin in FY 2012.