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Introduction and Objective

• A new tool called the “Multi Mission System Analysis for Planetary Entry Descent and Landing” or M-SAPE is being developed as part of NASA’s In-Space Propulsion Technology program

• Part of M-SAPE’s development requires mass estimating relationships (MERs) to determine the vehicle’s required Thermal Protection System (TPS) for safe Earth entry

• The objective of the current work is to develop MERs using FIAT1-based correlations with as high an accuracy to FIAT prediction as possible

• Forebody MERs are the ablators PICA and Carbon Phenolic atop ACC, and for the aftbody are the insulators SIRCA, Acusil II, SLA-561V, and LI-900.

How the flight trajectories and aerothermal environments were created:

<table>
<thead>
<tr>
<th>Vehicle Geometry Space</th>
<th>Flight Trajectory Space</th>
<th>Methodology</th>
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<tbody>
<tr>
<td></td>
<td>Flight Trajectory Parameter</td>
<td>Range of Values</td>
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<tr>
<td></td>
<td>Entry Velocity [km/s]</td>
<td>10-16</td>
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<tr>
<td></td>
<td>Entry Flight Path Angle [abs. deg.]</td>
<td>5-25</td>
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<tr>
<td></td>
<td>Ballistic Coefficient [kg/m²]</td>
<td>41.95-128.74</td>
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<tr>
<td></td>
<td>Total Number of Trajectories</td>
<td>840</td>
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<td>Resolution = smallest unit used in range of values</td>
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How the TPS response was modeled and how the MERs were created:

FIAT Modeling

• The maximum temperature at the bottom face of the top material was 250°C

• The material stack up had an adiabatic back face

• The surrounding environment was at 21.3°C (for radiation from the spacecraft surface)

• The surface was modeled as a 1D planar geometry using FIAT version 3.0

MER Constraints/Modeling

• No margins were added to the thickness

• For the forebody ablators, 15% of the trajectories were so mild as to have little or no material recession and were therefore discarded

• Curve fits were used to create the MERs

Sample Calculation of MER Fit

Results Summary and Future Work

• The MERs are accurate to within 14% of FIAT prediction at one standard deviation (SD)

• The worst-case possible under-prediction of TPS thickness is 18.7%

• TPS materials can be manufactured to much a much greater thickness than given in these MERs

• Future work would be in the development of MERs for additional materials and for entry into different planetary atmospheres