National Aeronautics and Space Administration

MPCV Aerothermodynamic Database

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MPCV Aerothermal Database Philosophy

Our Mantra: As accurate as possible, as conservative as necessary.

- **Accuracy** - Model all physically relevant phenomenon as accurately as possible.

  Examples:

  - Simulate all aspects of reacting gas chemistry with best-available models.
  - Choose turbulence models based on best representation of ground test data.
  - Develop a vehicle-specific combined blowing reduction/roughness augmentation model for convective heat transfer.

- **Conservatism** - Make conservative design assumptions when reality is uncertain.

  Examples:

  - Assume convective heating is turbulent.
  - No catalytic relief in turbulent boundary layers.
  - Low wavelength radiative intensity - UV/VUV spectral contributions.

We necessarily take a pay-as-you-go approach to buy down conservative assumptions - some will require Orion-specific flight test data input.

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MPCV Aerothermal Database Philosophy

Process

1. **Define "baseline" environment for a smooth outer mold line vehicle.**
   - The baseline is our predicted environment for a flight scenario with modeling assumptions.
2. **Define a local augmentation factor and/or increments to account for:**
   - Local geometry effects.
   - Phenomenon not captured in the baseline.
   - Known deficiencies in predictive capability.
3. **Define a margin for the combined (baseline) x (augmentation factor) + (increment).**

Design Environment = (margin) x ((baseline) x (augmentation factor) + (increment))

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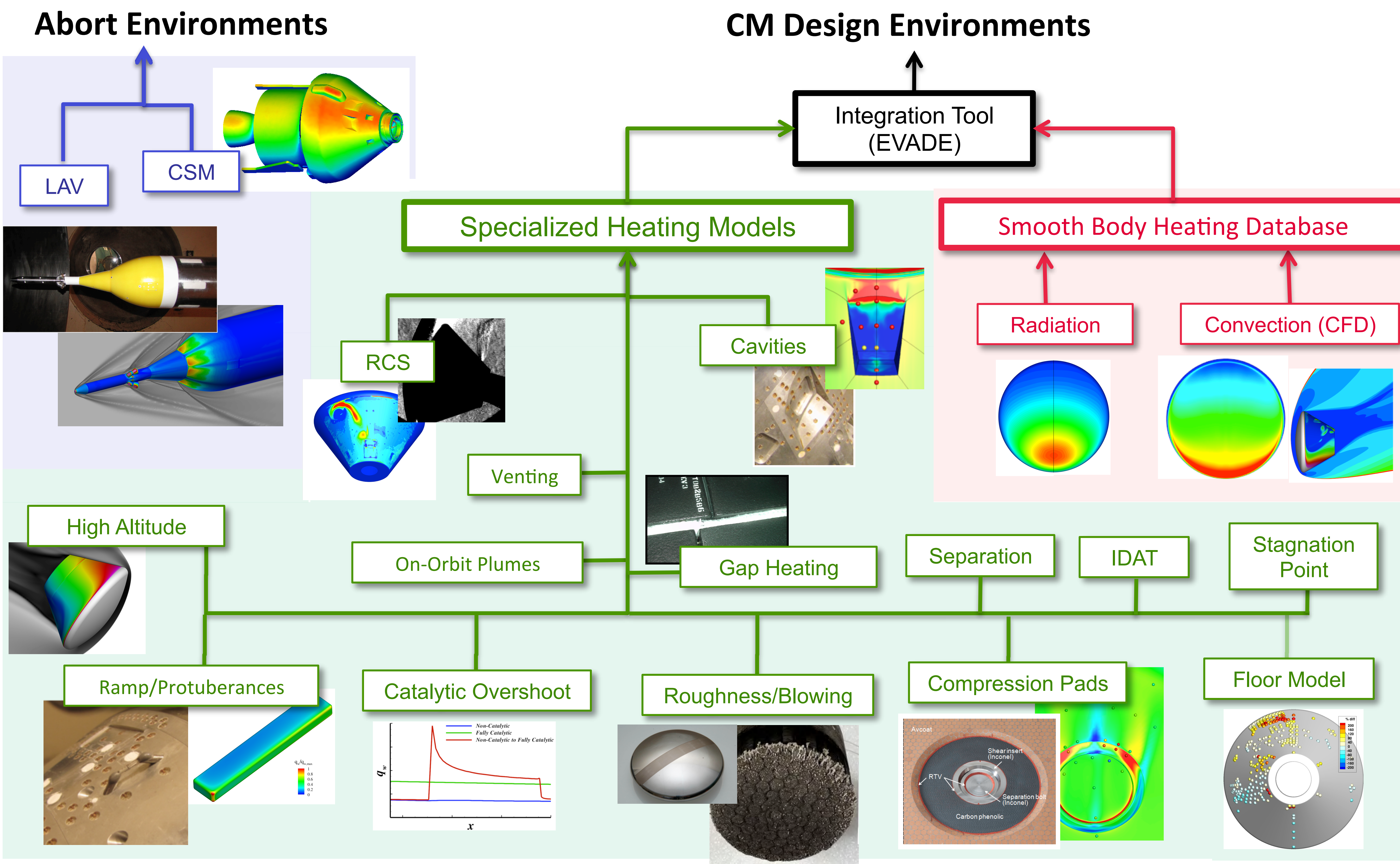
Database Construction



MPCV Transitional Aerothermal Database

- **Pay-as-you-go approach initially allowed transition modeling to fall off the analysis plate as development costs were deemed too high.**
- **Recent vehicle weight analysis showed MPCV Crew Module is too heavy for SLS launch vehicle and current parachute capabilities.**
  - Weight sensitivity to many vehicle parameters and design assumptions performed.
    - Modeling assumptions (fully turbulent convective heating, roughness augmentation, recession)
    - Thermal protection system bondline temperature limits
    - Carrier structure design
  - Fully turbulent convective heating assumption showed largest weight sensitivity.
    - Hundreds of pounds of heatshield mass could be saved by assuming a conservative Re_θ-based transition criteria.
- **MPCV Program is now providing some resources to develop a transitional aerothermal database for heatshield.**
  - Includes:
    - Transition Onset Criteria
    - Laminar local heating augmentation models

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MPCV Transitional Aerothermal Database

- **Transition onset model being developed to switch between laminar database environments and fully turbulent database environments.**
  - Developed using currently available MPCV CM ground test data in conventional supersonic and hypersonic test facilities.
- **Transition Model Development Methodology**
  - Observe transition onset location in ground test data.
  - Compute momentum thickness Reynolds number (Re_θ) at the observed transition location with computational tools.
  - Spatial correlation of Re_θ at transition onset along streamlines from stagnation point developed.
  - Apollo flight data used to assess effects of blowing at heat shield surface to add margin to smooth body transition prediction model.
- **Extensive boundary layer stability analysis or mechanism-based transition predictions not currently feasible due to limited available resources.**
  - Preliminary predictions indicate MPCV CM heatshield is dominated by first mode instabilities, while attached backshell region is dominated by second mode instabilities. (Need to do this quick analysis and not sure that I'll have time before the meeting, but wanted to include this statement for review and approval in case I end up with this information)

Backup Charts

MPCV Aerothermal Database Philosophy

The Complementary Roles of Simulation & Experiment

- **Developing the MPCV Aerothermal Database (ATDB) was necessarily a bootstrapping process:**
  - Initial versions were almost exclusively computational products and relied heavily on Apollo, Shuttle, and other historical data and tools.
  - Earliest test series were designed to assess uncertainties in computational predictions and relevance to heritage tools.
- **As vehicle design matured - and limitations in computational techniques became more well defined - the process necessarily evolved.**
- **In its present form, the ATDB is developed both from extensive simulation, empirical/engineering models, and experimental testing techniques.**
  - As always, the overarching goal is to define the aerothermal environment as accurately as necessary and practicable, given the evolving maturity of the vehicle and limitations of budget, schedule, and resources.
- **Due to inherent limitation in both ground testing and simulation for aerothermodynamic quantities of interest, there will continue to be a hybrid computational/experimental approach required for the foreseeable future.**