CAP Aerothermodynamics Lessons Learned

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Background

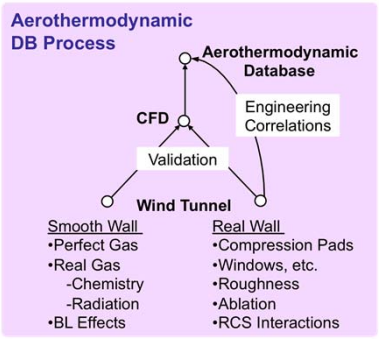
The CEV Aeroscience Project (CAP) aerothermodynamics team provide aerothermodynamic environments for ascent abort and reentry using high fidelity computation, ground testing and flight testing

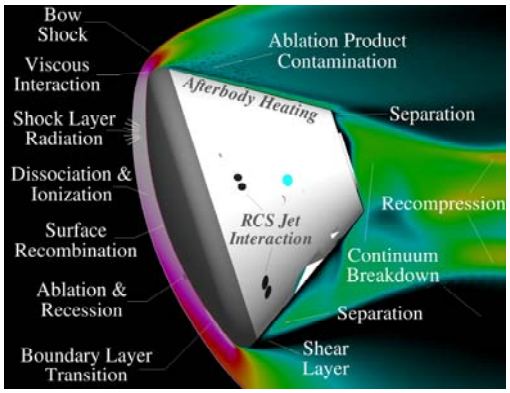
- At the start of the project, the intention was to rely heavily on computational methods, however wind tunnel testing and engineering methods have been used heavily in the construction of the database
- The database is versatile to cover a wide range of trajectories and to an extent, changes in geometry

Background

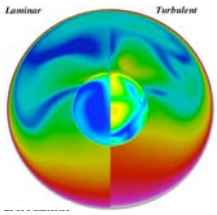
Re-entry Aerothermodynamic Environments

Environment is simulated in ground test facilities by designing tests to investigate specific phenomenon

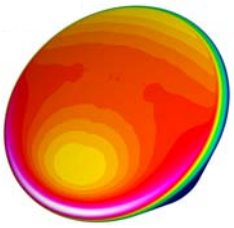




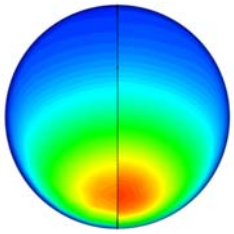
Aerothermodynamics Analysis



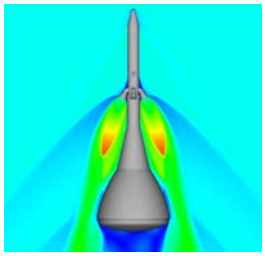
CM Smooth Backshell Heating
Computational Fluid Dynamics



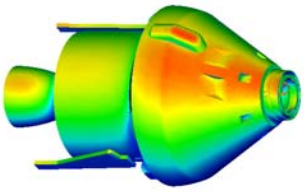
CM Smooth Heatshield Heating
Computational Fluid Dynamics



Smooth Body Radiative Heating



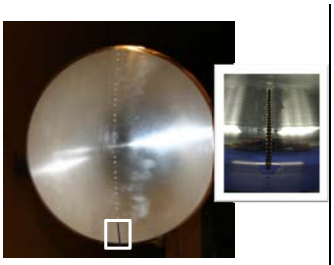
LAV Computational Fluid Dynamics

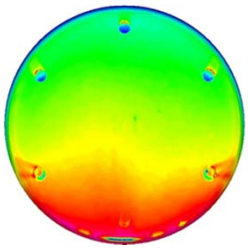


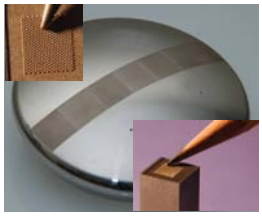
CSM Ascent Abort Direct Simulation
Monte Carlo

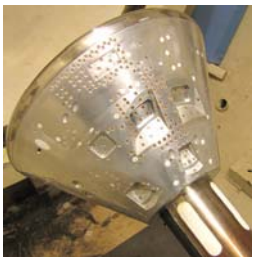
Aerothermodynamic Testing

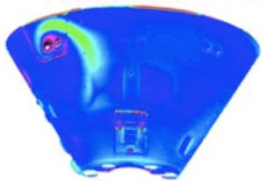
Heatshield Features


High Gradient Regions

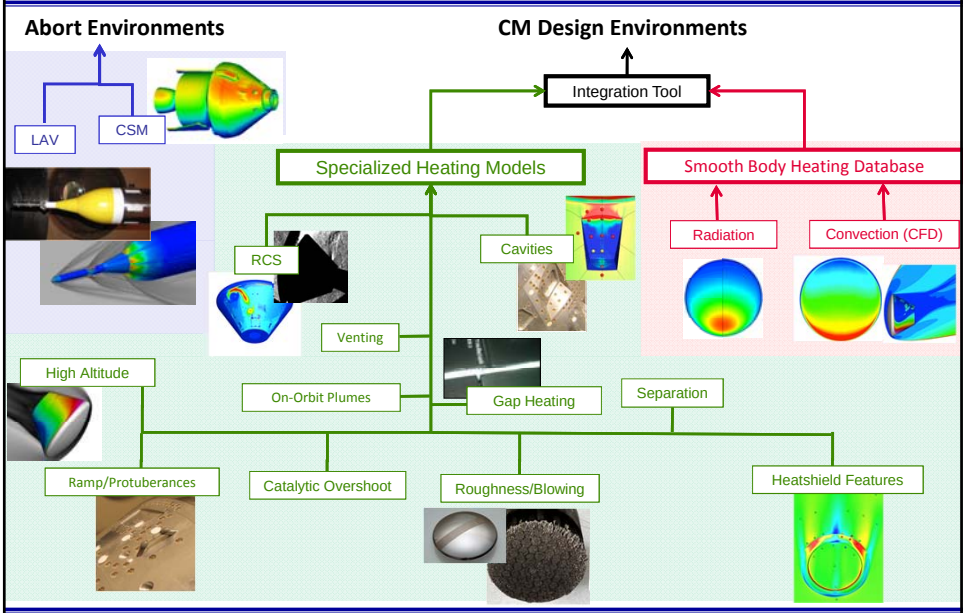

Heatshield Features


Heatshield Roughness


Backshell Features


Reaction Control Jets

Database Construction



Major Database Components

Component	Type	Validation Source
Smooth Body Convective	CFD derived/Engineering	Orbiter, Apollo, Wind Tunnel Testing
Smooth Body Radiation	High Fidelity	Wind Tunnel Testing, Heritage
Cavity Heating	Empirical/Engineering	Orbiter heritage, Wind Tunnel Testing
RCS Heating	Empirical/RGD-DSMC/Empirical	Apollo, Wind Tunnel Testing
Venting	Engineering	Heritage
High Altitude	RGD-DSMC	Heritage
Gap Heating	Empirical	Orbiter
Ramps/Protuberances	Empirical/Engineering	Heritage, Wind Tunnel Testing
Catalytic Overshoot	CFD derived	Orbiter data
Roughness/Blowing	Empirical/Engineering	Wind Tunnel Testing
Heatshield Features	CFD/Empirical	Wind Tunnel Testing
Separation Line	CFD derived	Wind Tunnel Testing

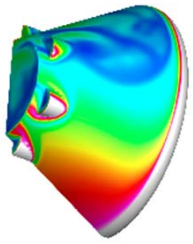
Lessons Learned

Integration with trajectory design is critical – environment indicators included in trajectory design help guide vehicle assessment

Integration with the Thermal Protection System design and assessment is critical

- TPS design and environment derivation are coupled for ablative material
- Know how the aerothermodynamic environments are being used
- Understand a design environment versus a realistic environment and when to use both

Be an active participant in vehicle trade studies or designs like this will come to fruition



Lessons Learned

Protuberances, penetrations, gaps, local chemistry, control jets, roughness…all effect the system, do not underestimate their contributions to the total heat load and peak heat rate

Lessons Learned

CFD has a place in trade studies, predicting environments for smooth bodies and ground to flight traceability, but it isn't ready for non-smooth component analysis or highly unsteady wake flow

- Keystone wind tunnel test with more than 400 discreet measurements on the capsule backshell to understand penetrations/protrusions/RCS environments