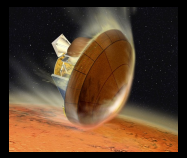
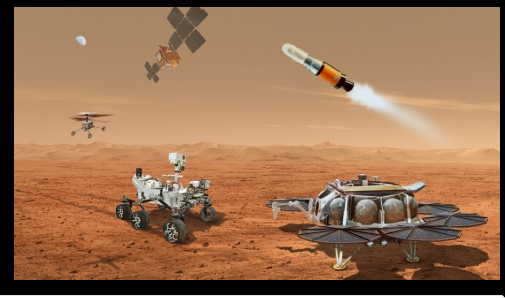


Simulations of Coupled Shoulder Ablation of a Conceptual Aeroshell

Prakash Shrestha[a], Olivia Schroeder[a], Georgios Chatzigeorgis[a], Joseph Schulz[a], Grant Palmer[a], Eric C. Stern[b], Christopher Johnston[c]

[a]Analytical Mechanics Associates, Inc. at NASA Ames Research Center, Moffett Field, CA 94035, USA
[b]NASA Ames Research Center, Moffett Field, CA 94035, USA [c]NASA Langley Research Center, Hampton, VA, 23681

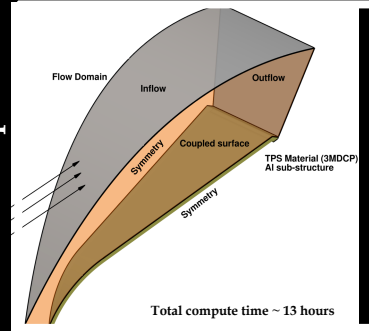


The current study explores how coupled numerical simulations of flow dynamics and material response affect ablation of the shoulder region of an entry capsule used in space missions like the Mars Sample Return (MSR) project. A new computational tool named Ares, developed at NASA Ames Research Center, is applied to carry out the coupled simulations by connecting US3D (flow solver) and Icarus (material response solver). The material considered is three-dimensional mid-density carbon phenolic (3MDCP). Particularly, this work extends the uncoupled analysis of Shrestha et al. 2022 by incorporating the coupling mechanism across the ablating surface between fluid and the capsule geometry. For simplicity, an axisymmetric geometry of the entry system is considered. Mission-relevant parametric studies, such as angles of orientation of the material layers with respect to the streamwise direction, backshell boundary conditions, and alteration of convective heat-transfer coefficients, are investigated to essentially explore Ares capability with the primary focus on shoulder location.

Introduction

- The NASA's MSR program has selected 3MDCP as the heatshield thermal protection system (TPS) material for the forebody of its Earth Entry System (EES)
- Due to the nature of the aerothermal environment the spacecraft faces during Earth entry, a coupled ablation modeling is applied to simulate surface recession with particular focus on the shoulder region
- The newly built US3D-Icarus interface named Ares is used for the simulation

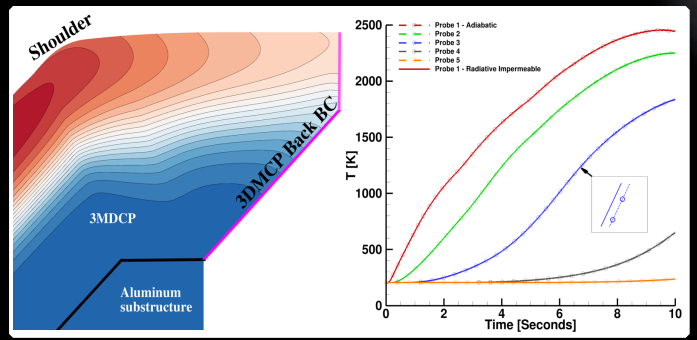
Setup



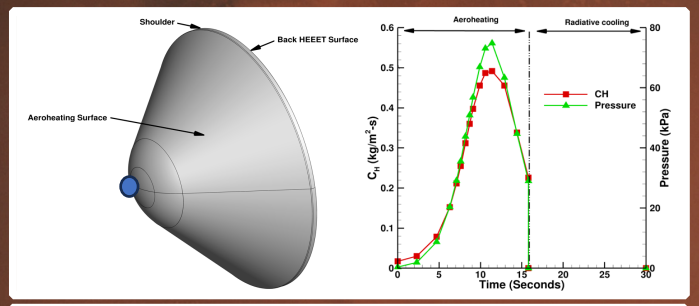
Total compute time ~ 13 hours

- Physical Time: 10 seconds
- 61,000 material cells
- 5 processors in solid
- 74,000 fluid cells
- 60 processors in fluid
- Laminar Navier-Stokes
- Smooth wall
- CH-based ablation with blowing gas correction
- Species: N2, O2, N, O, NO

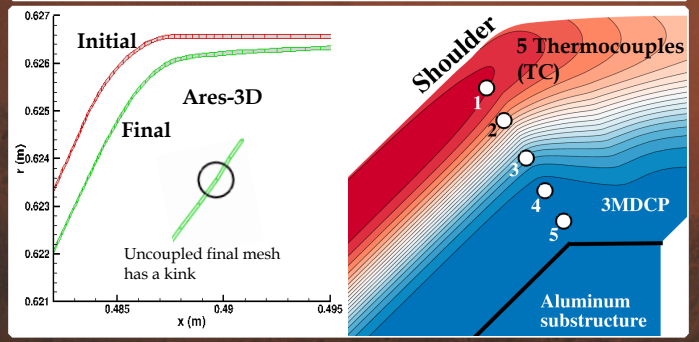
3MDCP Back BC



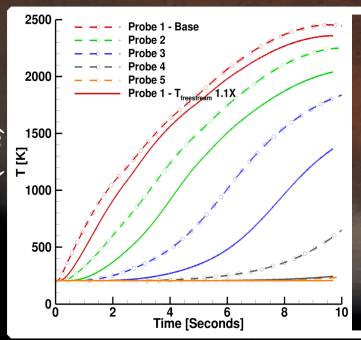
Flight & Geometry Conditions



Base Results

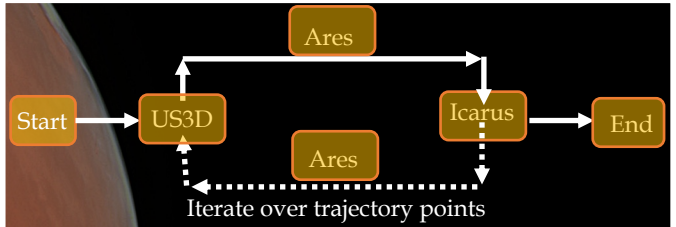


CH (T_∞)



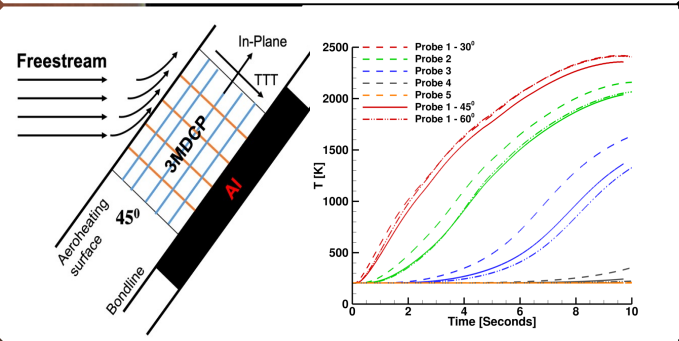
- $Q_{wall} = CH^* (H_{wall} - H_\infty)$
- $\Delta H \sim \Delta T = T_{wall} - T_\infty$
- T_∞ is altered by +10%
- Q_{wall} lowers and less heat is conducted into the 3MDCP material
- However, opposite observations (high TC data) are expected when reducing T_∞ by -10%

Basic model of Ares



Start from a converged CFD data per 1st trajectory point

Angles of Material Orientation



Summary

- Axisymmetric coupled ablation modeling is carried out for a conceptual MSR-EES aeroshell using 10 seconds of a flight-like trajectory and the 3MDCP material response model.
- Coupled ablation modeling results in smoother mesh deformation compared to an uncoupled approach
- Other than the 3MDCP back face boundary condition, modeling parameters tested to date have minimal impact on near-bondline thermal response
- As future work, a comparison between uncoupled and coupled simulations will be carried out

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References: Prakash Shrestha, Olivia Schroeder, Christopher O. Johnston and Eric Stern. "Simulations of A Conceptual MSR-EES Shoulder Recession and Thermal Response," AIAA 2023-0961. AIAA SCITECH 2023 Forum. 2023.