New Stagnation Arc Jet Model Design for Testing ADEPT 3-D Carbon Cloth
1 NASA ARC; *NASA Inc.- Moffett Field, CA

1: Background

The Adaptive Deployable Entry and Placement Technology (ADEPT)

- A mechanically deployable desorator is being considered as an entry, descent and landing (EDL) system to enable Human Mars class missions.
- Ground rules for the Mars studies required aerocapture, orbit, and then entry.
- Utilizes a 3-D woven carbon cloth fabric as both heatshield and primary structure.
- Design guidelines required 6 layers remaining after all entry events.

The Problem

- The peak heating predicted for the ADEPT carbon cloth is <15 W/cm² and resulting temperatures were predicted to be <1400K.
- Predictions for carbon mass loss were performed using equilibrium thermochimistry, which is only accurate for T=2000K.
- Carbon oxidation is kinetically controlled at T=2000K, and mass loss drops off considerably from equilibrium values.
- Equilibrium predictions resulted in a 13-layer carbon cloth design, with the cloth representing 70% of the TPS mass.

- Design of the cloth thickness and mass would be significantly reduced if kinetics were considered, but development of the kinetic constants for Carbon in CO₂ would be costly and difficult to implement in the trade studies.

The Solution (This project in red)

- Develop an engineering model to describe the recession rate of the carbon as a function of the partial pressure of monatomic oxygen, which could easily be implemented in the trade study computational stream.
- The AHF uses Nitrogen, Oxygen and Argon rather than Air and Argon (like the IHF) for testing.
- Develop a stagnation test article design that can be used in the AHF with varying levels of Oxygen.
- Develop a relationship for the recession as a function of the oxygen concentration.

2: Design Approach

The Approach

- Repurpose an existing nearly square fabric tensioning design from earlier ADEPT testing (Bilaterally Loaded Ablation Model [BLAM]) that was used in a wedge holder to evaluate the response of the cloth in shear while under load.
- Simplify the design by removing the load cell and therefore negating the need for a water cooled part.
- Place an insulating collar around the tensioning section and a new back plate.
- Build a prototype (in process)

3: Analysis

Analysis Approach

- CFD analysis of a typical AHF test condition on model with a target of ~70 W/cm² [2x predicted entry environments]
- Very conservative 3-D Finite Element model developed for the new carbon cloth design
  - 20,000 hex elements, 12814 nodes
  - 100 W/cm² and 50 W/cm² constant heatflux applied to top surface for 5 minutes, followed by 10 minute cooldown
  - Only top and bottom surface radiating to the environment, all other surfaces adiabatic
  - Transverse-isotropic properties included for thermal modeling
  - Carbon cloth has much higher conductivity in-plane than through the thickness
- Future analysis work would include the L2020 collar and the graphite frame beneath the cloth

The Results

- Analysis shows that the collar material will survive heating due to the carbon cloth in proximity (Tcooling+Tmax≤7200K), as will all other materials in contact.
- This design should work well in the AHF in-flows with heatfluxes at or below 100 W/cm² with no loss of material integrity

4: Summary

A new stagnation test article has been designed for developing an engineering model representing the mass loss of carbon cloth as a function of the partial pressure of monatomic oxygen for more reasonable predictions of carbon cloth thickness requirements in low heating environments.

5: Acknowledgements

- This work was funded by NASA Ames FY17 Director’s Discretionary Fund.
- The Human Mars ADEPT analysis was funded by STMD GCD.
- The original BLAM design was funded by STMD GCD.