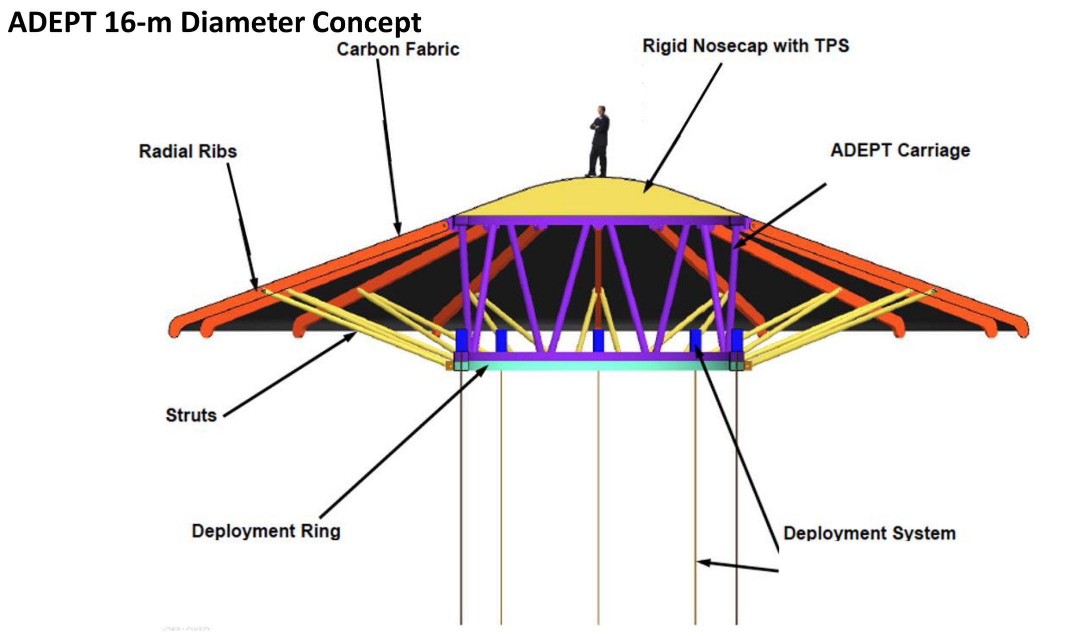
New Stagnation Arc Jet Model Design for Testing ADEPT 3-D Carbon Cloth

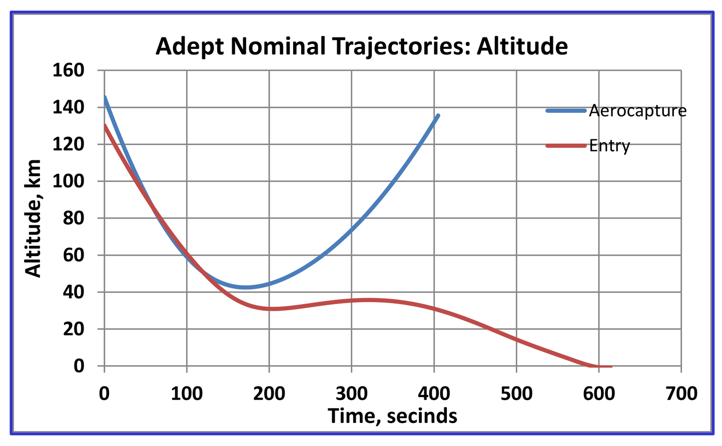
R.Beck§, Y-K Chen§, P. Wercinski§, P. Agrawal*, J. Chavez-Garcia*

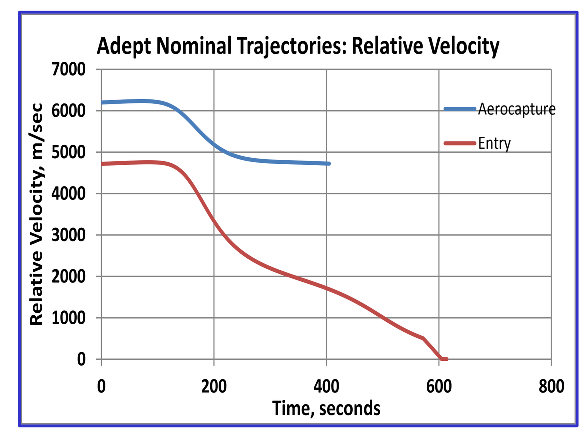
§ NASA ARC; *AMA Inc.-Moffett Field, CA

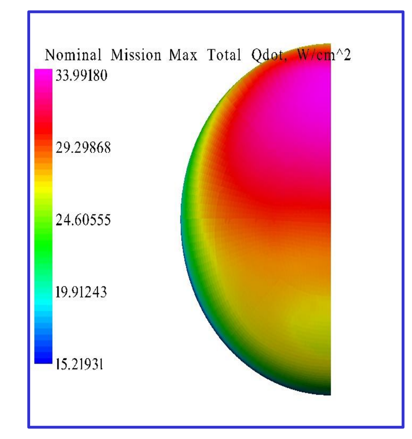
1: Background

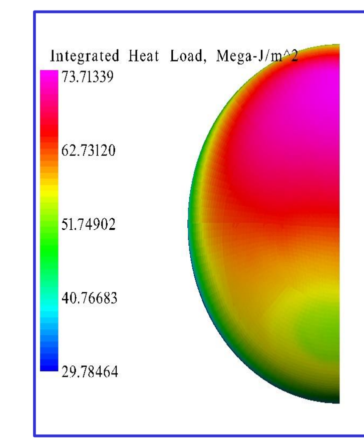
ADEPT 16-m Diameter Concept

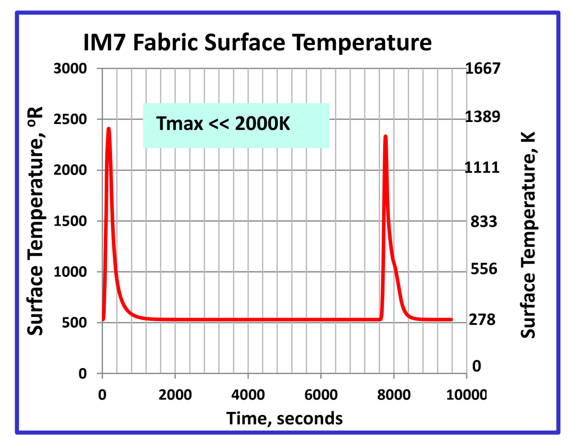


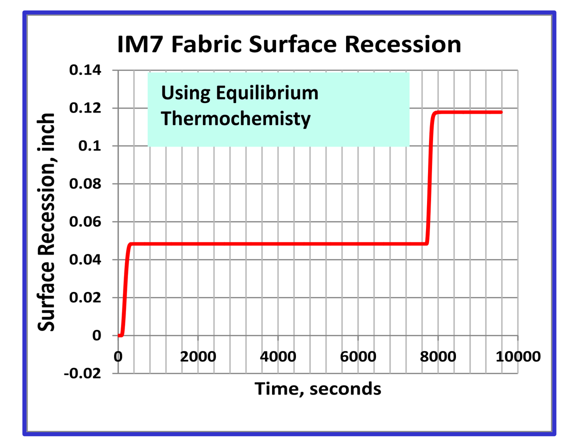


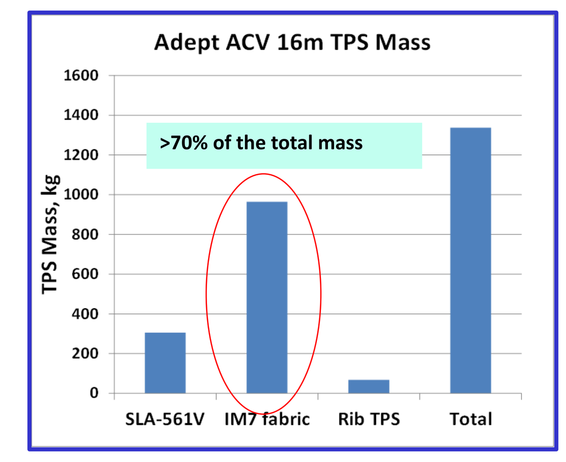












Figures from a report by Jeffrey Bowles (ARC), Steven Tobin (LaRC) and Stanley Bouslog (JSC)

The Adaptive Deployable Entry and Placement Technology (ADEPT)

- A mechanically deployable decelerator 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 <35 W/cm2 and resulting temperatures were predicted to be <1400K
- Predictions for carbon mass loss were performed using equilibrium thermochemistry, 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 15-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 CO_2 would be costly and difficult to implement in the trade studies

The Solution (This project in red)

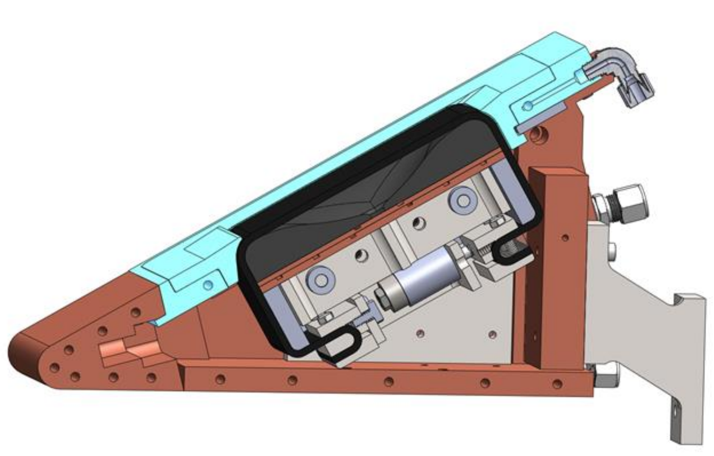
- Develop an *engineering model* to describe the recession rate of the carbon as a function of the partial pressure of monotomic oxygen, which could easily be implemented in the trade study computational stream
- The AHF uses Nitrogen, Oxygen and Argon rather than Air and Argon (like the IHF) for testing
- 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

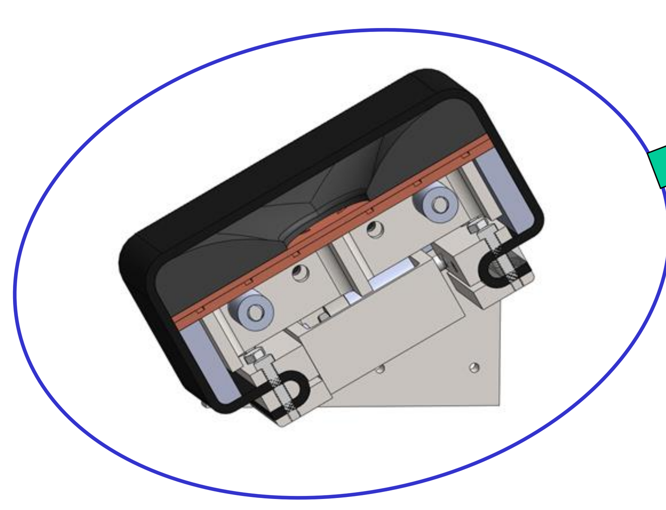
2: Design Approach

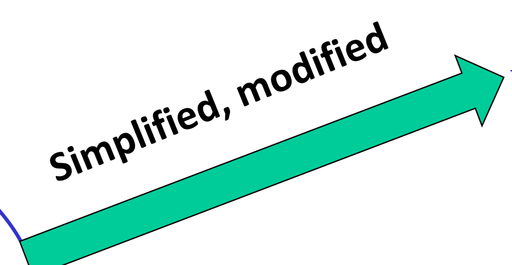
The Approach

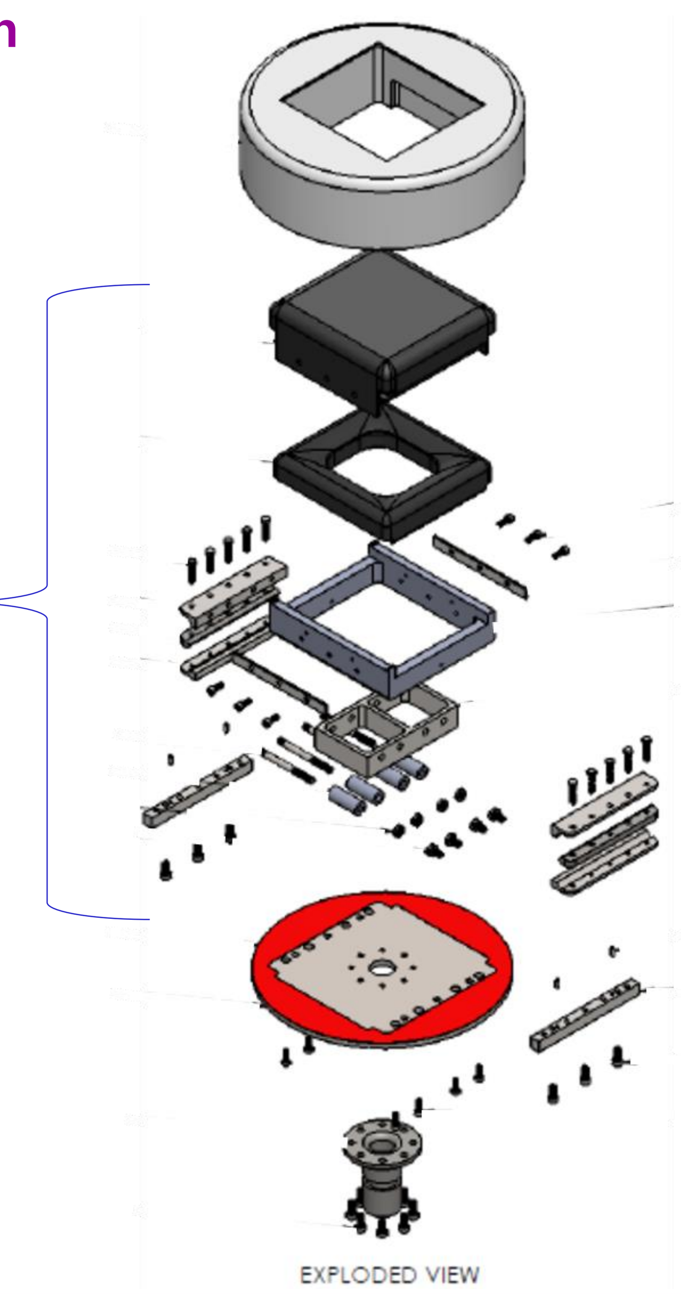
- Repurpose an existing nearly square fabric tensioning design from earlier ADEPT testing (Bilaterally Loaded Ablation Model [BLAM]) that was used in a wedge holder to evaluate the response of the cloth in shear while under load
- Simplify the design by removing the load cell and therefore negating the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

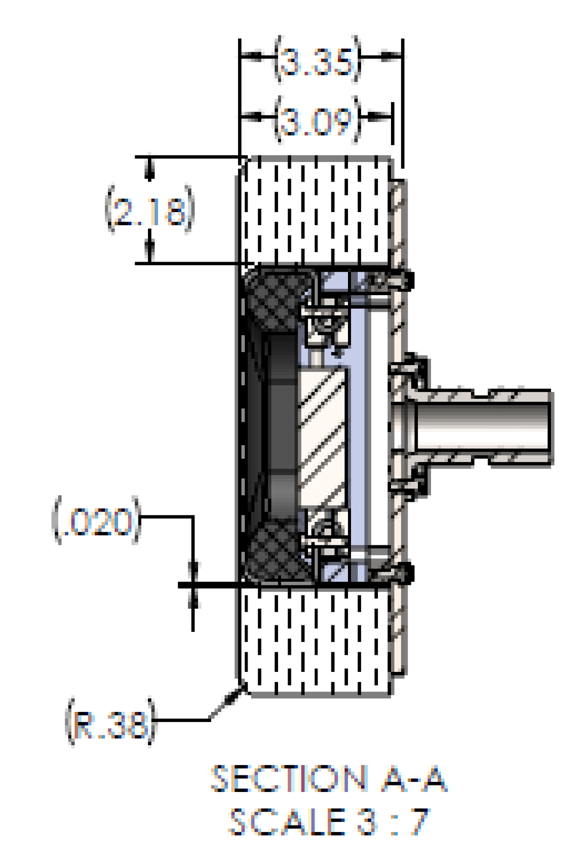
Original ADEPT BLAM design



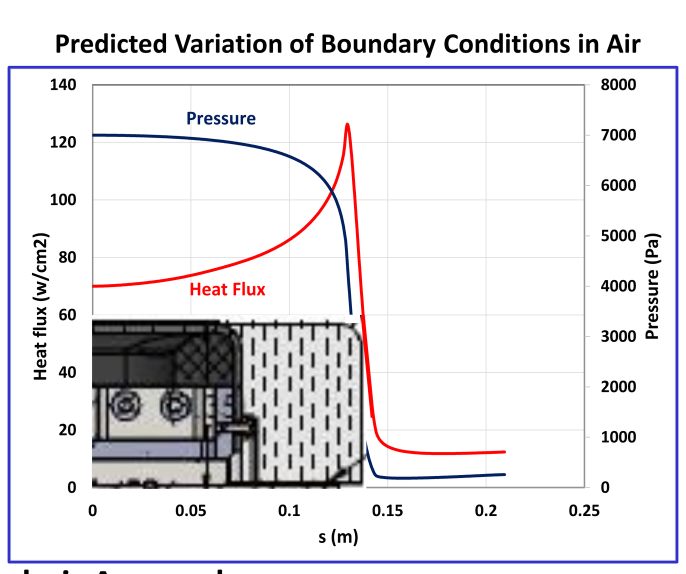


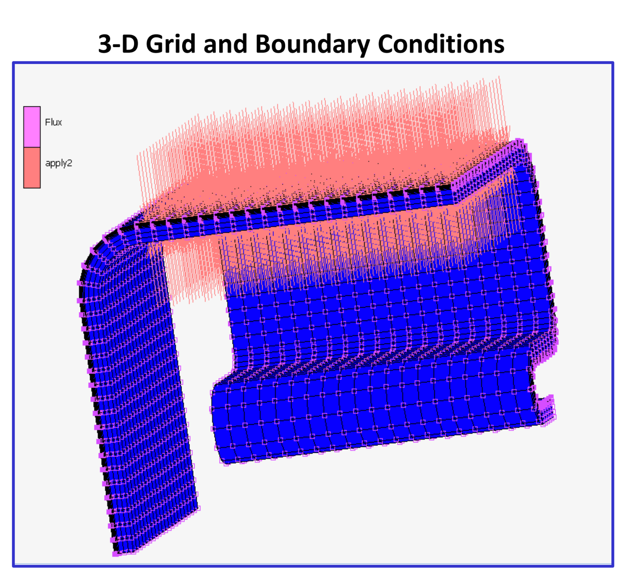






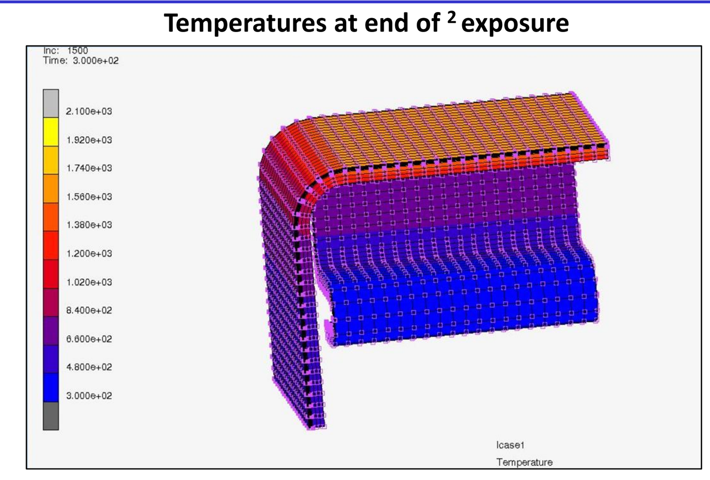
3: Analysis



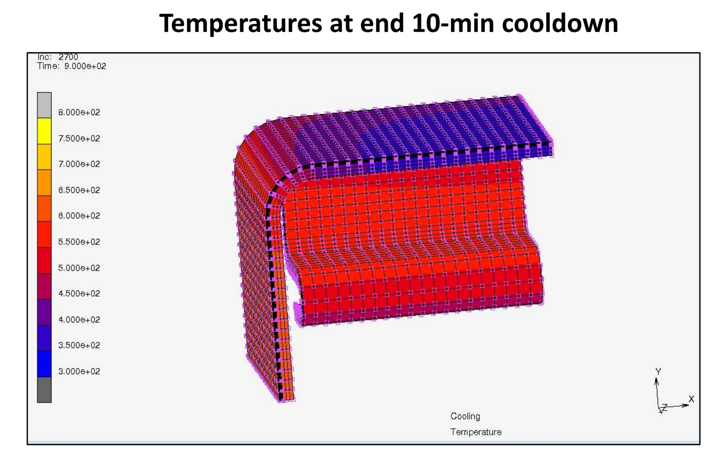


50 W/cm², 5-min

Temperatures at end of ² exposure

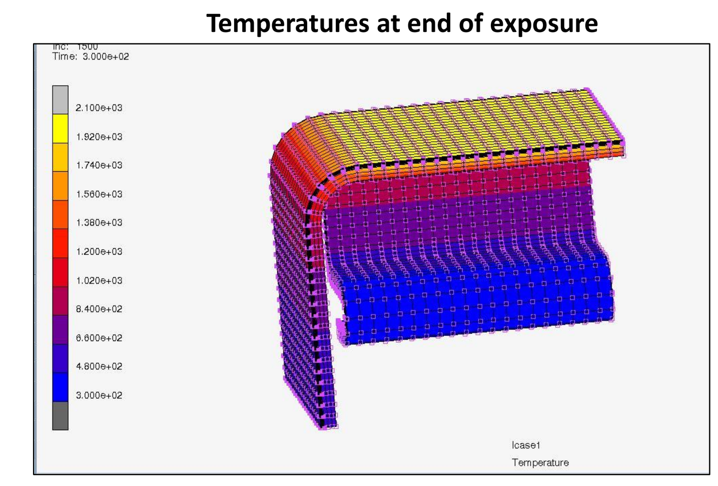


Temperatures at end 10-min cooldown

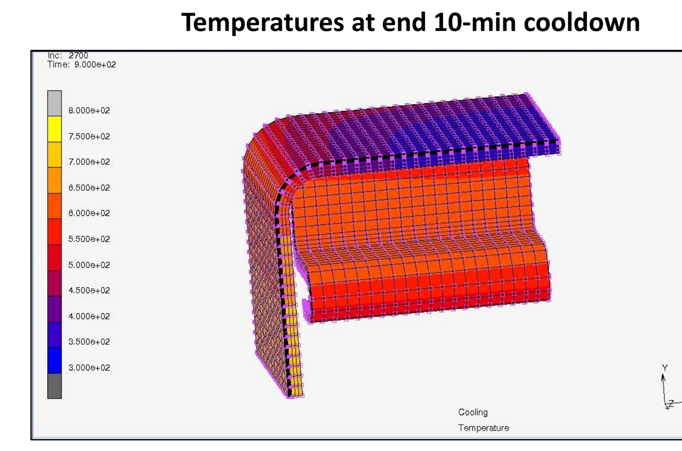


100 W/cm², 5-min

Temperatures at end of exposure



Temperatures at end 10-min cooldown



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
  - 20,800 hex elements, 23814 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 re-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 LI2200 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 (T_{carbon}<<T_{melt} LI2200), 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