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# Hypersonic non-equilibrium Computational Fluid Dynamics (CFD) analysis and effect of underbelly shape on a conceptual lifting body spaceplane

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## APPENDICES

### Theoretical stagnation point wall temperature

Sutton-Graves correlation:

$$q_{stag} = k \left( \frac{\rho}{r_n} \right)^{\frac{1}{2}} * V^3$$

where Sutton-Graves coefficient  $k$  for Earth =  $1.7415 \times 10^{-4}$

$$\rho = 1.03 \times 10^{-3} \text{ kgm}^{-3}$$

$$r_n = 4 \text{ m}$$

$$\text{Therefore } q_{stag} = 39.29 \text{ Wcm}^{-2}$$

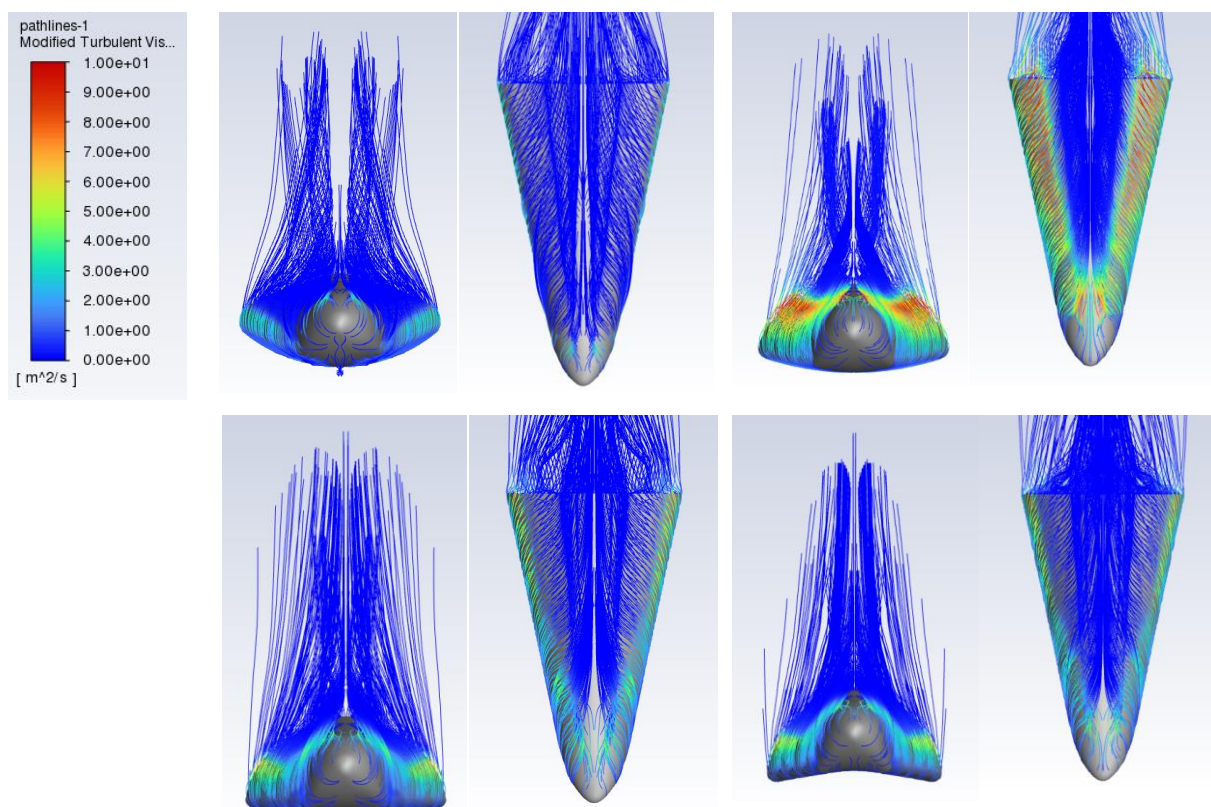
Assuming  $q_R = 0$  from Tauber-Sutton for Earth and applying Stefan-Boltzmann law, both from (NASA TFAWS, 2012), to find the stagnation point wall temperature (assuming a TPS emissivity of 0.85 (same as the Space Shuttle TPS, from (Gnanasekaran, 2017)):

$$q_{rad} = \epsilon \sigma T_w^4$$

$$T_w = \frac{39.29 e^4}{0.8 * 5.67 e^{-8}}^{0.25}$$

$$T_w = 1715.6 \text{ K}$$

### BILBO turbulent viscosity pathlines



**Figure 1:** Turbulent viscosity pathlines for all BILBO shapes