# Aerothermodynamics for Dragonfly's Titan Entry

## Presented by Aaron Brandis

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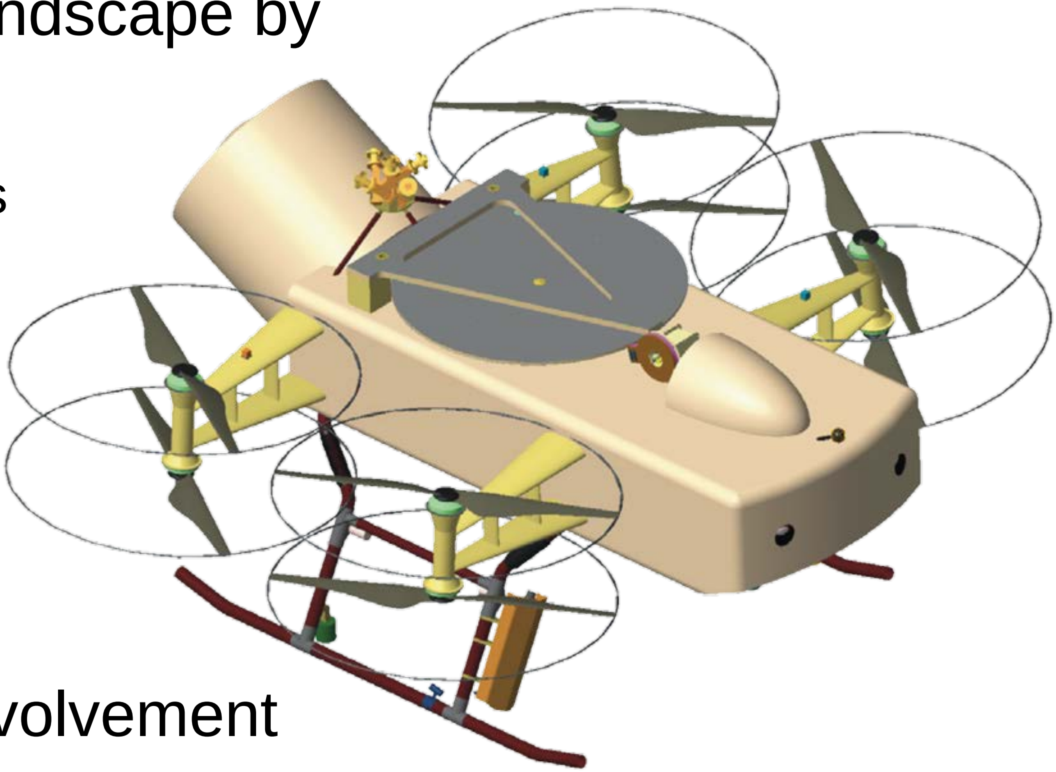
NASA Langley Research Center

Johns Hopkins Applied Physics Laboratory

# Introduction

DRAGONFLY

- Address Titan’s diverse landscape by using rotorcraft.
  - Conduct surface experiments
  - Obtain aerial images
  - Go to the interesting material



**R. Lorenz & D. Adams from APL have more detailed talks about the mission on Friday**

- NASA Ames & Langley Involvement
  - Partnering as the leads for the entry system to provide the completed EDL Assembly.
  - Provides an opportunity for continued development of Titan entry capability
  - Leverages unique capabilities at both LaRC and ARC

# Titan Arrival

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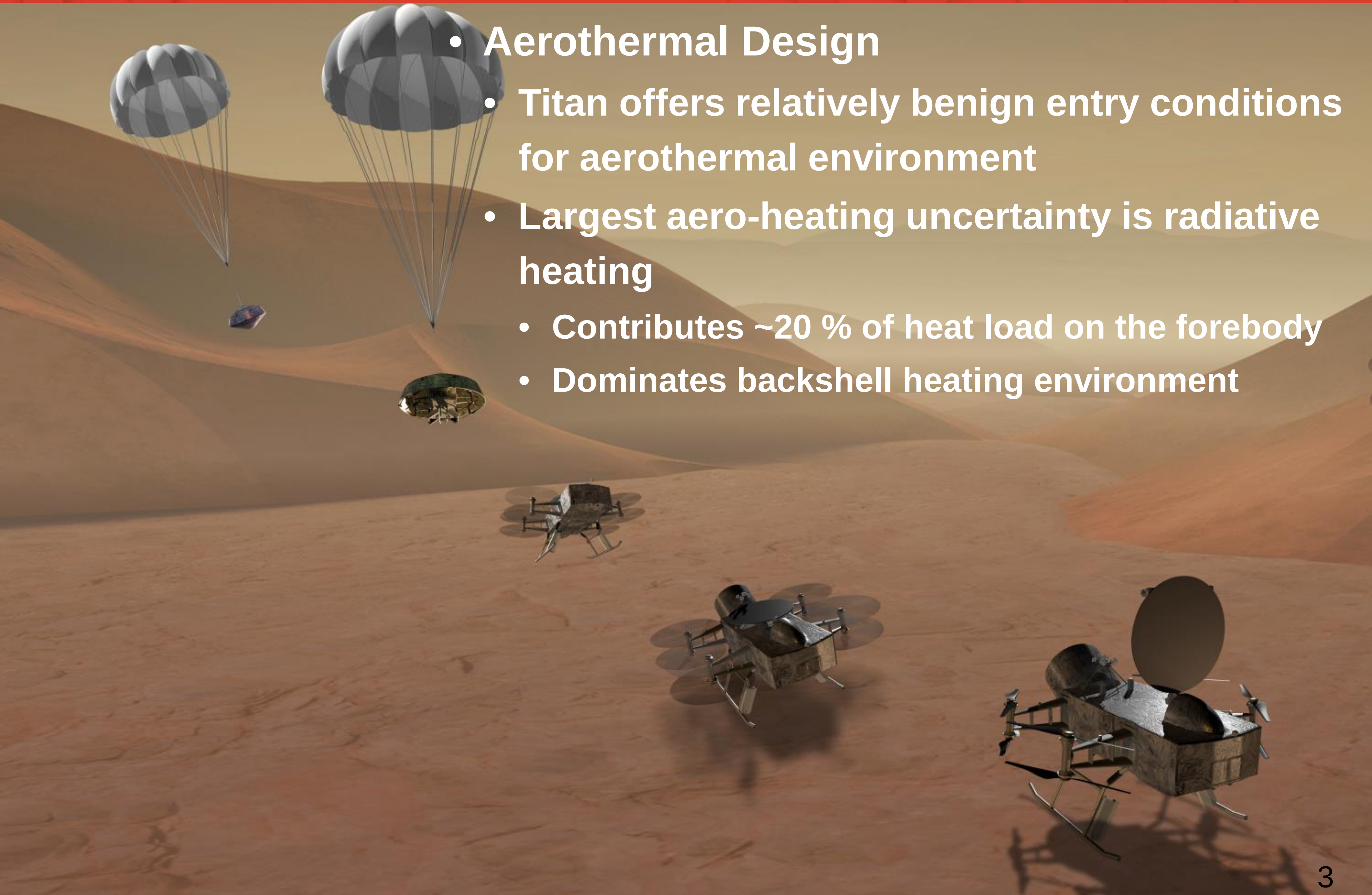
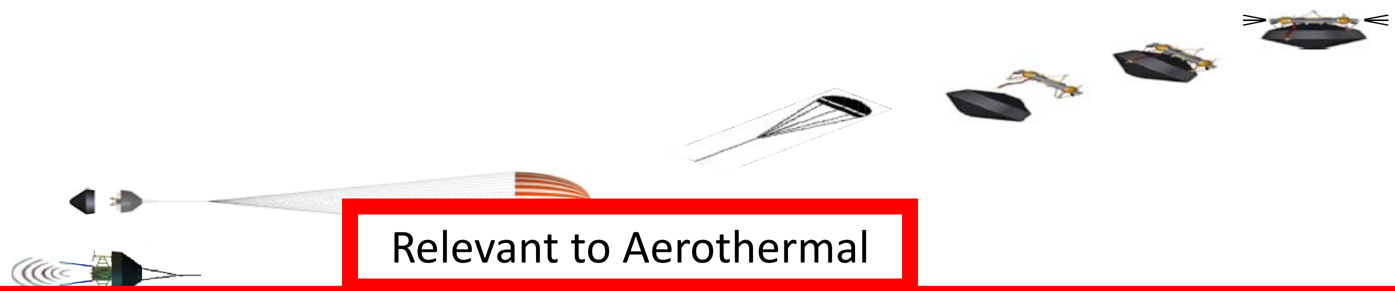


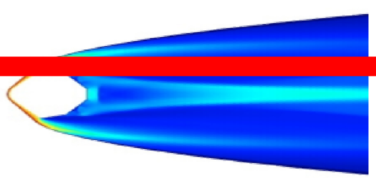
- Aerothermal Design
  - Titan offers relatively benign entry conditions for aerothermal environment
  - Largest aero-heating uncertainty is radiative heating
    - Contributes ~20 % of heat load on the forebody
    - Dominates backshell heating environment

# Entry and Descent



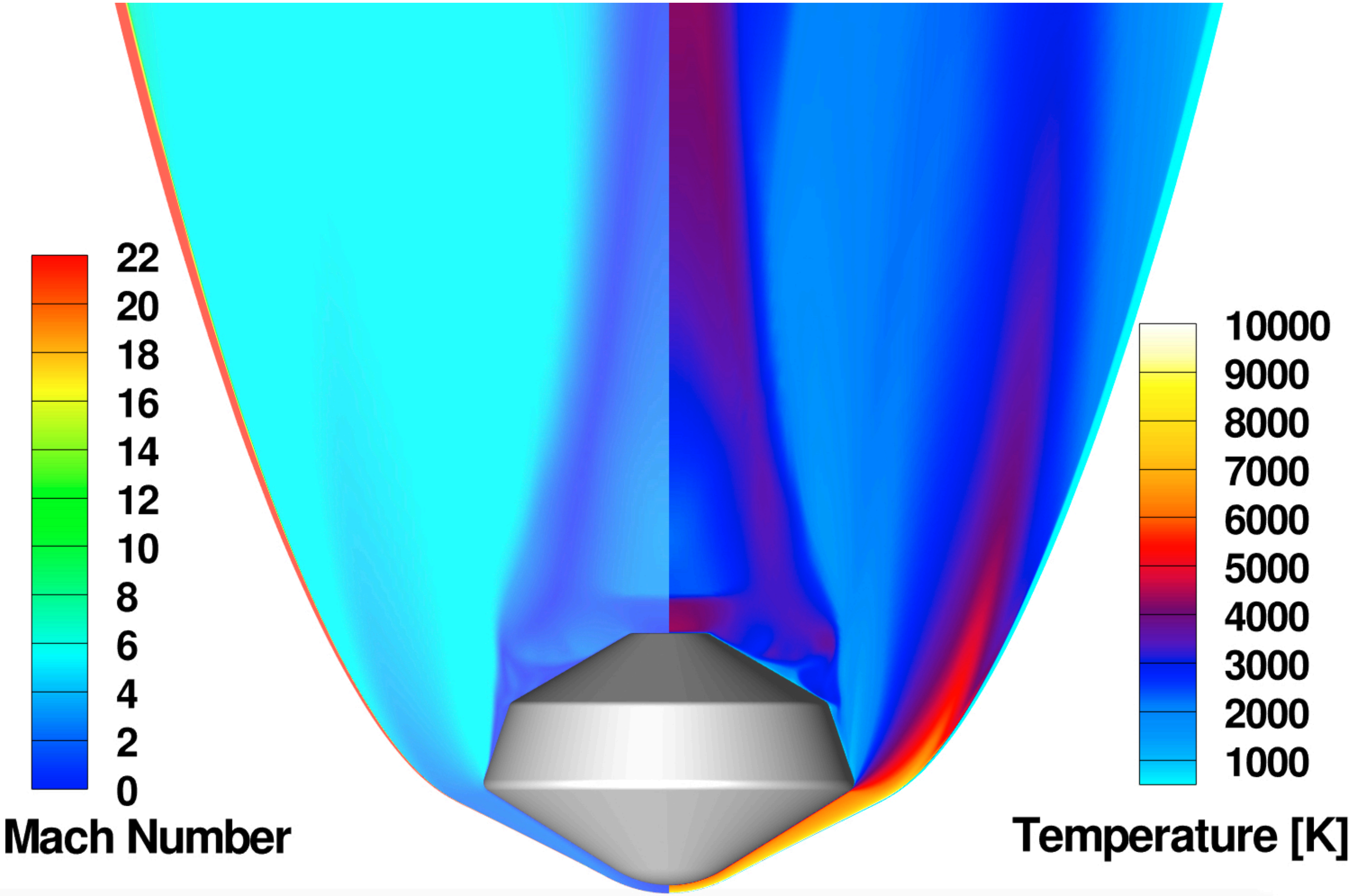
Relevant to Aerothermal

Lander release



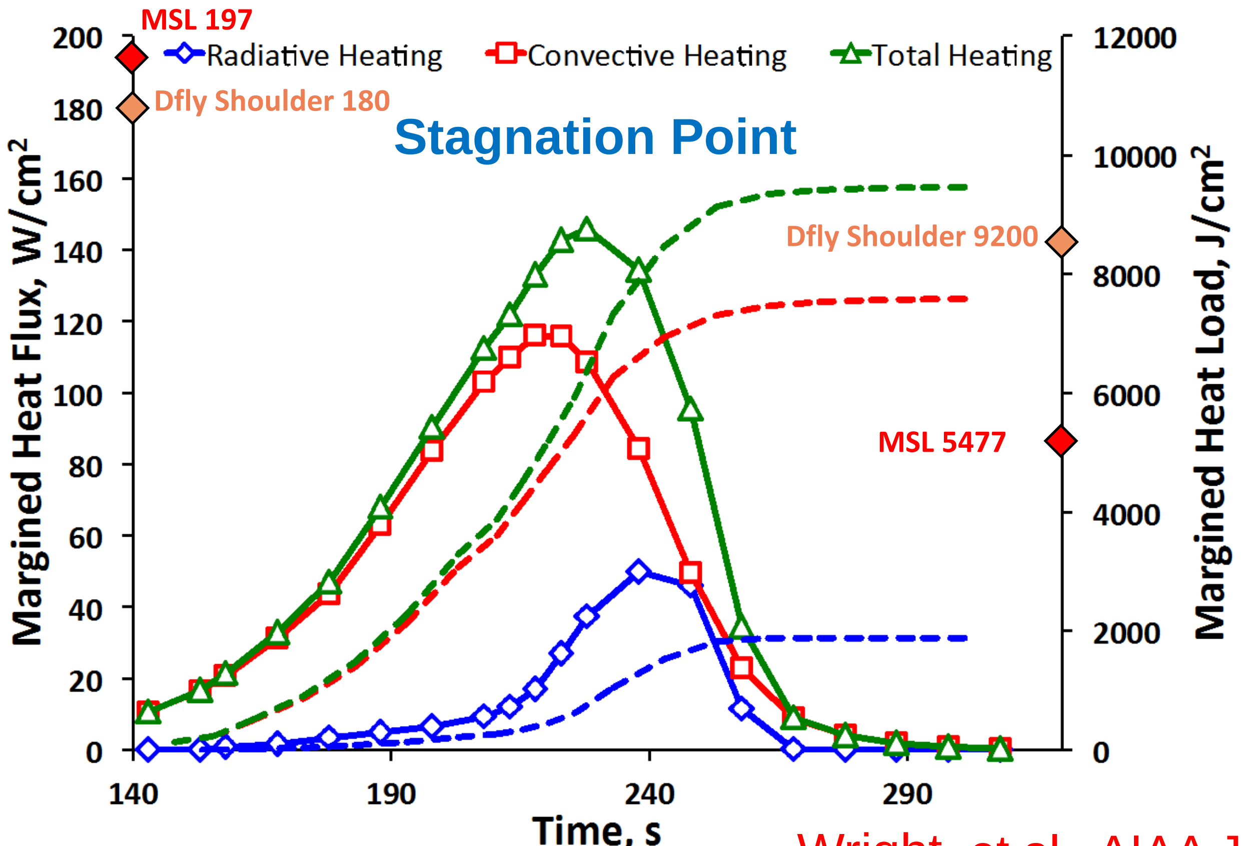
# Entry and Descent (pre Phase A)

- Relatively benign Titan ballistic entry at EFPA of -47.7° and 7.3 km/s
- Genesis scaled 60° 3.7m sphere cone heatshield / biconic backshell geometry
- In terms of TPS materials, Forebody: Tiled PICA. Aftbody: Acusil-II.



# Forebody Heat Loads (Pre Phase A)

DRAGONFLY




Wright, et al., AIAA JSR 2014

- Peak margined heat flux ~ 145 $W/cm^2$
- Margined heat load ~ 9.5 $kJ/cm^2$
- Even though shoulder loads were higher, stag point was driving TPS sizing location
- In family with MSL environments and thus similar TPS thickness
  - PICA is flight proven for such fluxes/loads and more than capable

# Preliminary Phase A Aerothermal V&V

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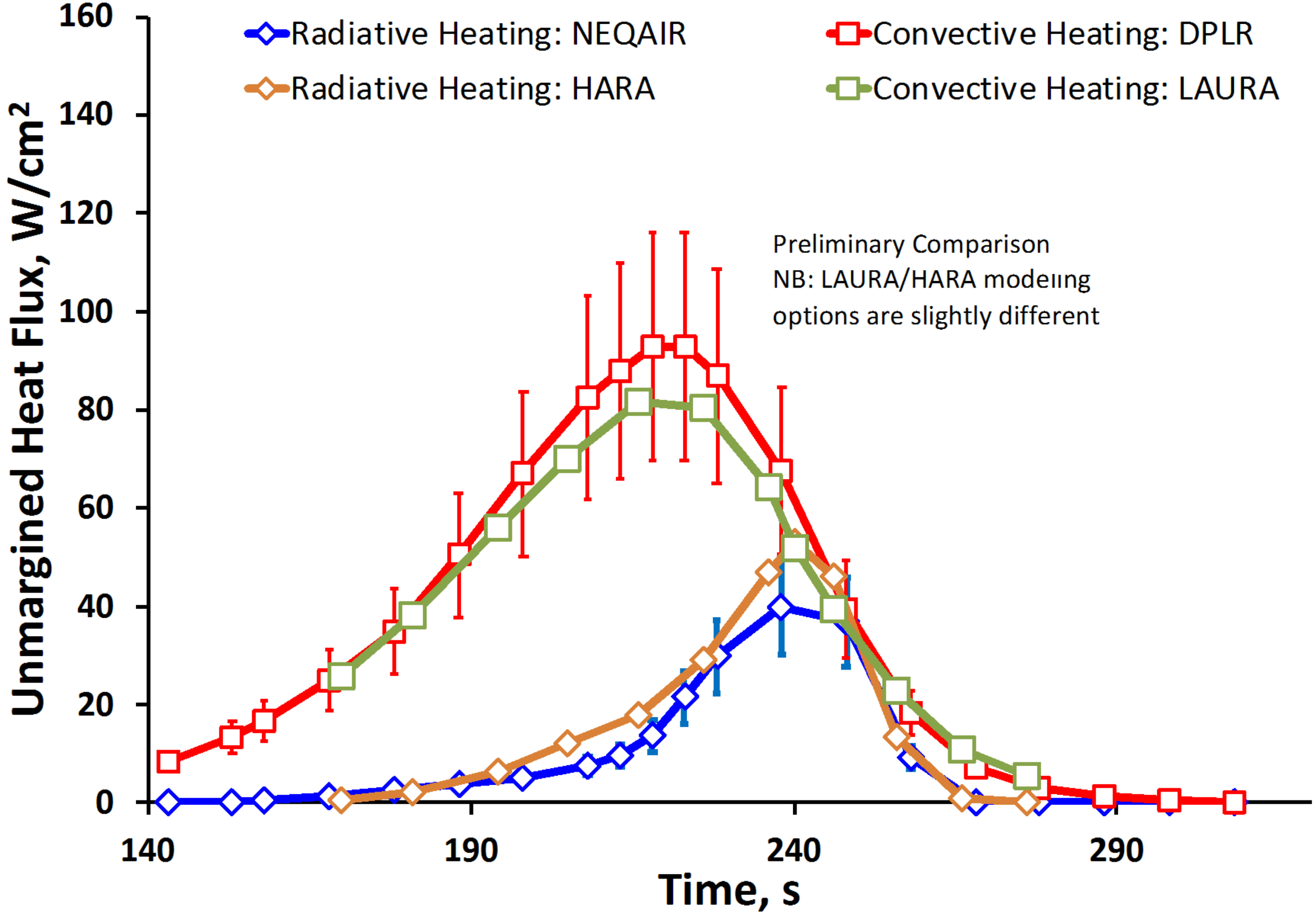

# Aftbody Heat Flux (Pre Phase A)

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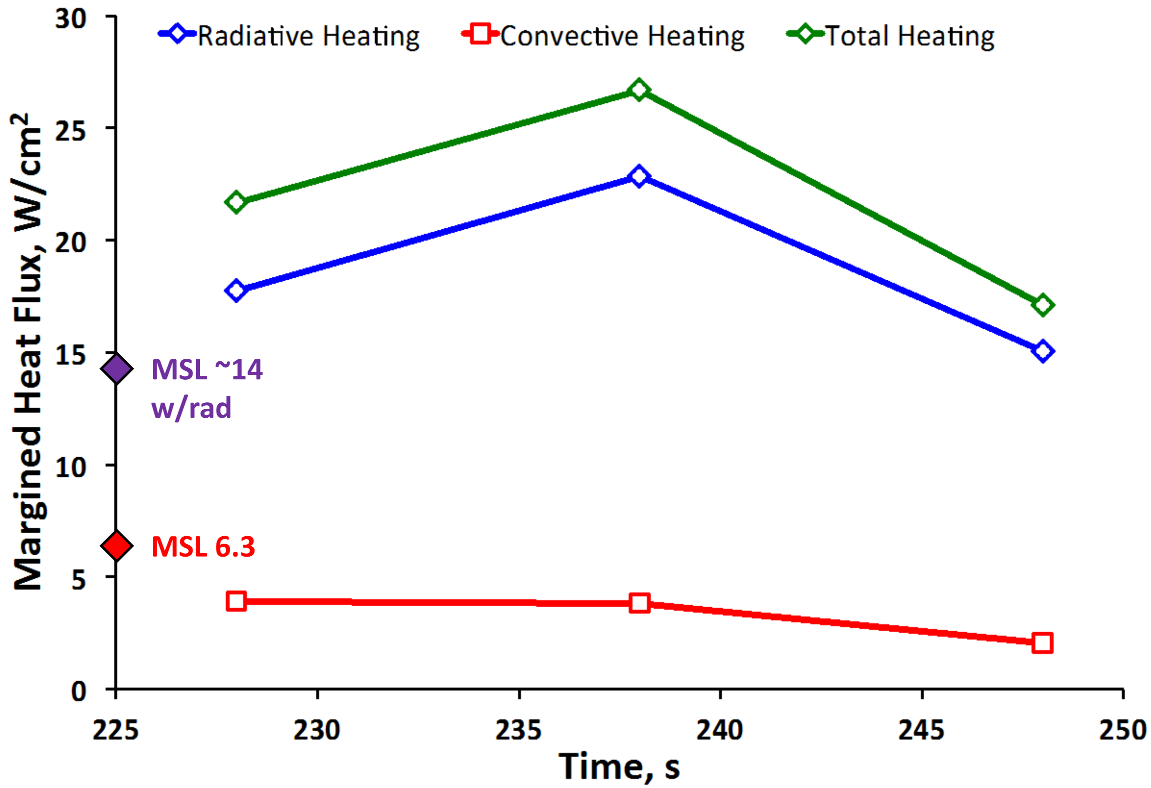


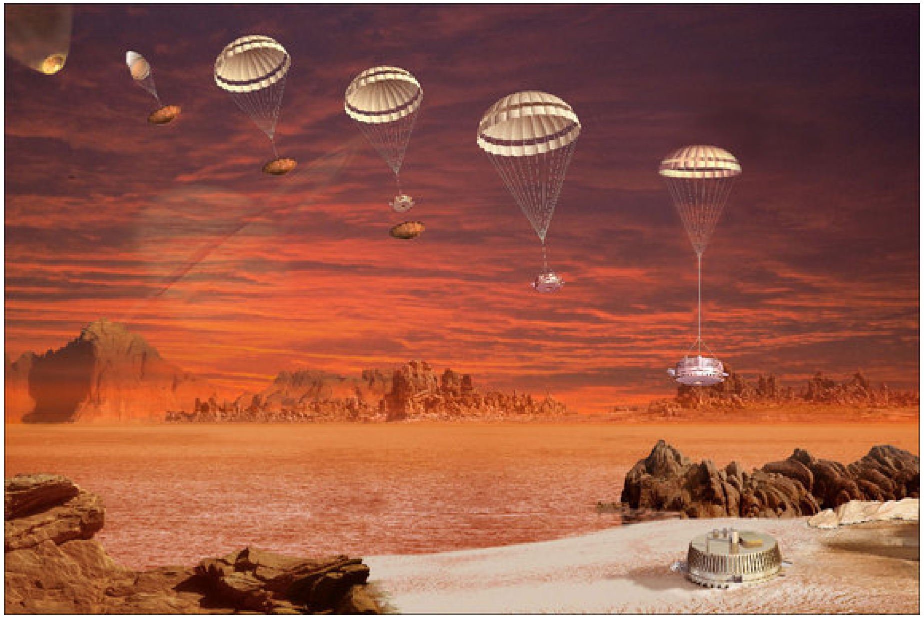

- Heat flux calculated at shoulder seal for zero degree angle of attack
- Peak margined heat flux ~ 25 $W/cm^2$
- Preliminary analysis suggests these environments are relatively insensitive to the increase in mass and size.
- Trade study currently taking place for aftbody TPS material

# Previous Titan Radiation Studies

- The joint NASA/ESA Cassini/Huygens mission resulted in significant efforts to understand radiative heating for Titan.
- Post flight simulations were conducted assuming a Boltzmann distribution of CN excited states
- Consequently, experiments were performed in shock tubes and QSS/CR models developed.

- Reasons to believe there were issues with previously reported Titan (pre-upgrade) EAST data.
- Warranted to update previously published data:
  - Advanced mission proposals to Titan
  - Improvements available with the current EAST set up

Brandis, et al., AIAA JTHT 2010



# Previous Titan Radiation Studies

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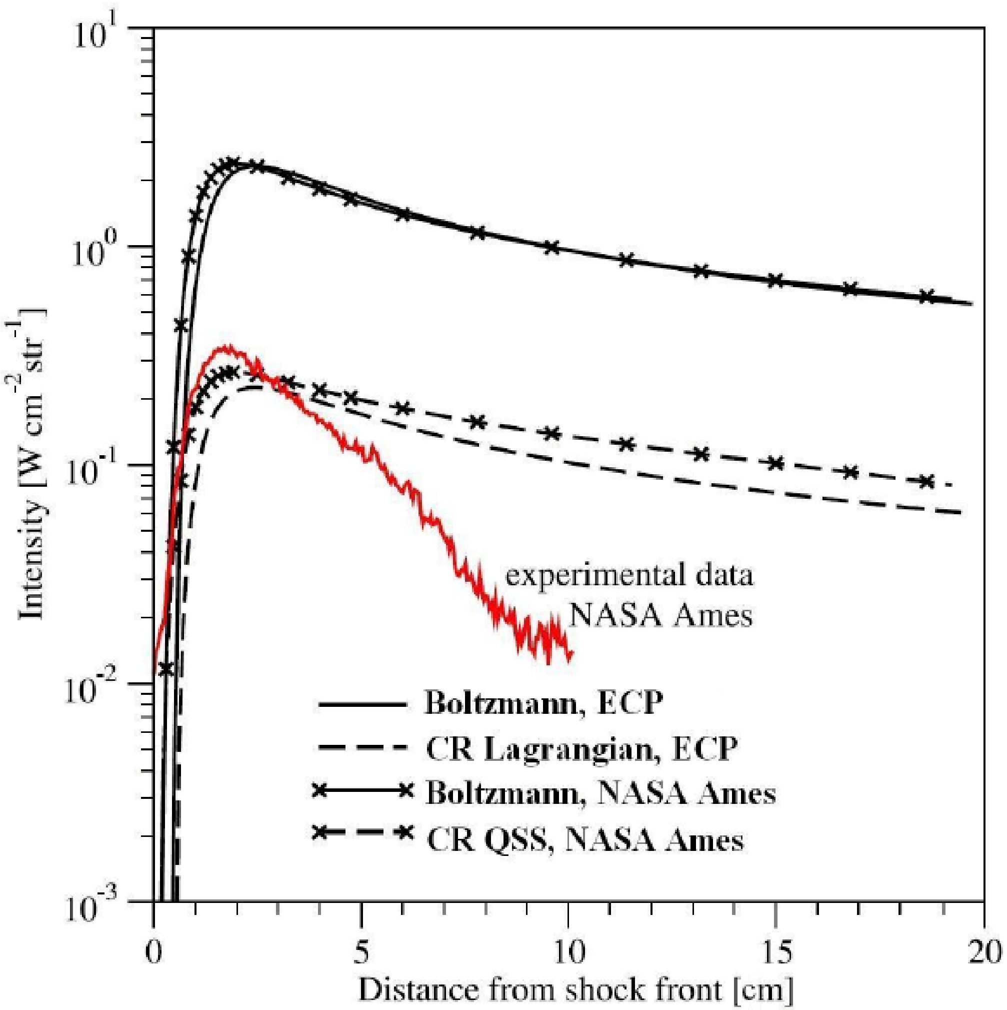
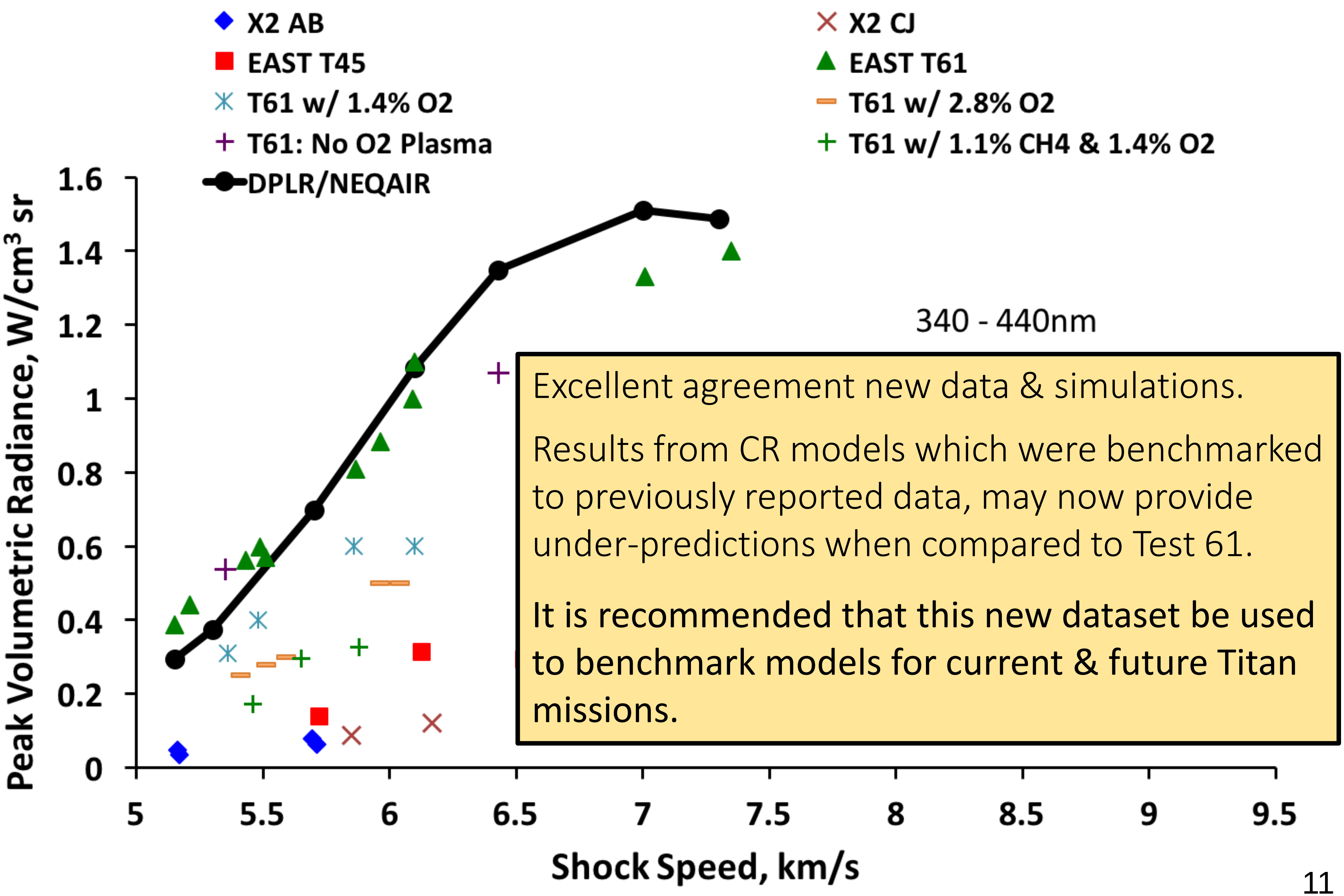
5.15 km/s, 98% $N_2$ : 2% $CH_4$, 0.1 Torr, 400 – 430nm. EAST T43-25




- Two shock tube facilities:
  - EAST at NASA Ames
  - X2 at U. Queensland
- Test 43 & 45 from EAST (2003 to 2005)
- Boltzmann predictions shown to substantially over-predict
- CR models deemed to adequately match peak (within a factor of ~2)
- Simulations showed slower decay rate than experiment

# Comparisons To Previous Data: X2, Test 45
## New Test 61 EAST data funded by NASA's ESM project




Excellent agreement new data & simulations.

Results from CR models which were benchmarked to previously reported data, may now provide under-predictions when compared to Test 61.

It is recommended that this new dataset be used to benchmark models for current & future Titan missions.

# Future Work

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- Aerothermal indicator update in progress for Titan entry to aid picking a worst case design trajectory.
- Run aerothermal analysis for Phase A study, including analyzing heating on the long gain antenna on the backshell at an angle of attack.
- Perform a parametric study for relevant CFD and radiation parameters to inform design margins.
- With updated aerothermal environments and informed margins, the Phase A TPS sizing will take place.
- There is also an Engineering Science Investigation (ESI) study happening simultaneously along side the aerothermal work with the goal of obtaining aerothermal flight data.

# Conclusion

- Dragonfly is a proposed mission that would send a rotorcraft to Titan in order to study prebiotic chemistry and extraterrestrial habitability.

- Aerothermal analysis from both Ames and Langley's suite of codes has been run for Dragonfly, with good agreement shown.

- Models for radiative heating have been validated by recent shock tube testing in the EAST facility.

- The entry conditions are relatively benign and can readily be accommodated with a tiled PICA heatshield similar to MSL and a number of flight proven materials for the backshell.

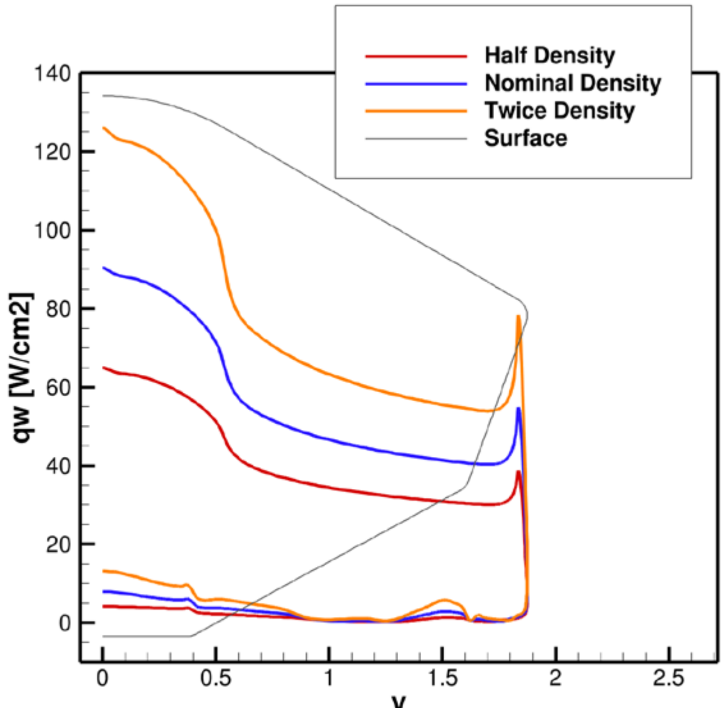
# Questions?

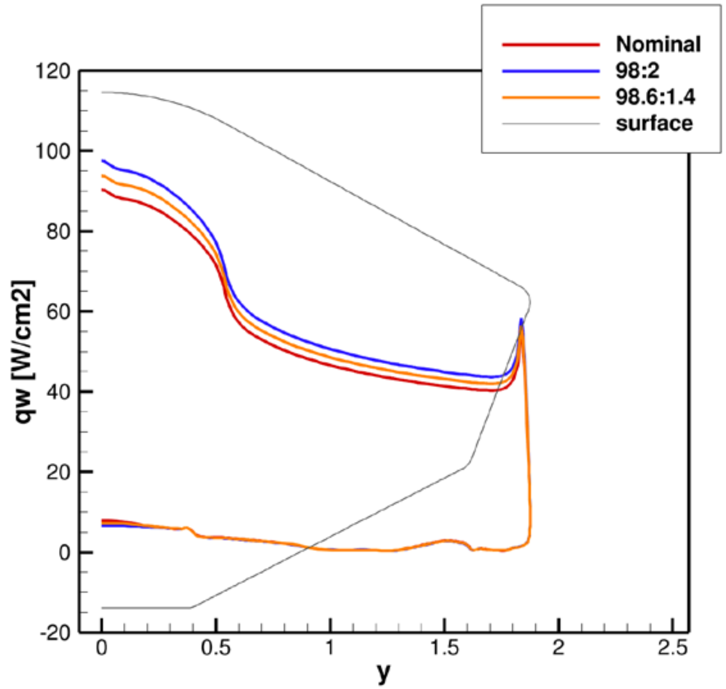
- Reminder for Friday
  - 10:08am: Ralph Lorenz “Sample acquisition and transfer for a Titan lander”
  - 11:06am: Doug Adams “Dragonfly: Rotorcraft landing on Titan”

# Backup

# Effect of Density & Chemical Composition

**Time 223s, Velocity 6.25 km/s, nominal density 3.17 e-4 kg/m3**




- Plots show effects of freestream density and composition on the surface aerothermal environment at peak convective heating.
- Pre phase A nominal chemical composition was 98.2$N_2$ : 1.6 $CH_4$ : 0.1 $H_2$ : 0.1 Ar, the present trade study looked at 98:2 and 98.6:1.4 variation of $N_2$ and $CH_4$.
- Future analysis will be based on expected maximum values for methane in the upper atmosphere, so will be running a composition of 97.8 $N_2$ : 2.2 $CH_4$
- These simulations will be used to determine heating indicators for turbulent shoulder locations, and for points of interest on the backshell.