

AEROTHERMAL ANALYSIS OF THE DRAGONFLY TITAN ENTRY.

C. Naughton², D. Saunders², and A. Brandis¹. ¹NASA Ames Research Center, Moffett Field, CA 94035 (christopher.w.naughton@nasa.gov, aaron.m.brandis@nasa.gov). ²AMA, Inc., NASA Ames Research Center, Moffett Field, CA 94035 (david.a.saunders@nasa.gov).

Author Biography: Christopher Naughton is an engineer working in the Aerothermodynamics branch of NASA Ames Research Center (ARC) where he supports projects such as Dragonfly, the Commercial Crew Program, and AERACEPT.

Introduction: The Dragonfly mission will send a rotorcraft lander to the surface of Saturn's moon Titan as part of the New-Frontiers program [1]. This will be the first spacecraft to land on Titan since the Huygens probe's descent in January of 2005 and only the second spacecraft to enter Titan's atmosphere. The Dragonfly entry capsule is significantly larger than the Huygens probe and will experience higher aerothermal environments. This poster will provide an overview of the aerothermodynamic models used in the Dragonfly aeroshell design process.

Planetary Destination: Titan provides a unique entry environment that has several fundamental differences from the environments at the more common entry destinations of Earth and Mars. The lack of atmospheric oxygen significantly reduces heatshield recession (expected to be negligible), which simplifies material response analysis but also reduces the efficiency of the thermal protection system. The atmosphere is composed of mostly nitrogen and trace amounts of methane. During hypersonic entry this methane dissociates and leads to the formation of the molecule CN, which is known to radiate strongly in the shock layer [2]. Current Dragonfly heating predictions estimate that radiation contributes about 50% of the total heat flux along the forebody and up to 90% on the aftbody, making radiation a key element of aerothermal analysis. To properly address the importance of radiation, a unique radiative-heating correlation was developed that incorporates normal-shock equilibrium chemistry predictions based on work from the Mars 2020 program [3]. These new heating correlations agree well with Computational Fluid Dynamics (CFD) predictions and enable large-scale trajectory analyses by providing rapid heating predictions along candidate trajectories.

Aerothermal Modeling: Dragonfly aerothermal environments are generated with the Data Parallel Line Relaxation (DPLR) finite-volume Navier-Stokes solver alongside the Nonequilibrium Radiative Transport and Spectra (NEQAIR) radiation transport code. DPLR produces shock-aligned flowfields that incorporate the effects of both chemical and thermal nonequilibrium while NEQAIR solves the radiation transport equations along lines-of-sight through the flowfield solutions to

predict the radiative heating on the aeroshell. Titan's atmosphere produces complex thermal and chemical nonequilibria and so classical radiation approximations that extrapolate from a single line-of-sight, such as the Tangent-Slab method, were found to overpredict peak radiative heat fluxes by 10-20%. Therefore, all radiative heating is directly calculated using 3-D transport for both the forebody and aftbody to reduce unnecessary conservatism. A 21-species finite-rate chemistry model, including electrons and ionized species, is used in the CFD to ensure accurate vehicle heating predictions (the level of ionization is particularly important for accurate radiative flux predictions).

Scope: This poster will cover: 1) The models and assumptions used to simulate entry into Titan's atmosphere, 2) Dragonfly aerothermal engineering correlations alongside statistical heating values, and 3) Driving aerothermal considerations for a Titan entry such as CN formation and radiation-flowfield coupling.

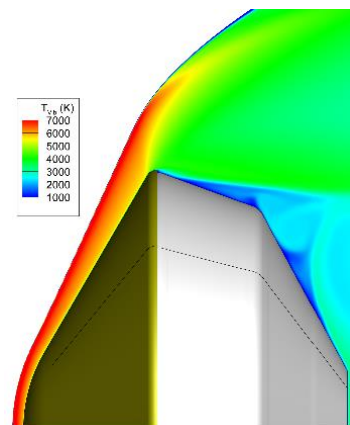


Fig. 1: Temperature contours of the simulated flow-field around the Dragonfly capsule during entry.

References:

- [1] J. Barnes et al. (2021). *Science Goals and Objectives for the Dragonfly Titan Rotorcraft Relocatable Lander*. The Planetary Science Journal, 2:130, August.
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- [3] A. Brandis, C. Johnston, and K. Edquist. (2018) *Radiative Heating Indicators and Uncertainty Analysis for Mars2020*. [Presentation]. AIAA Aviation Forum, 25-29 June, Atlanta, Georgia. <https://ntrs.nasa.gov/api/citations/20180007851/downloads/20180007851.pdf>