URANUS PROBE ENTRY AND DESCENT MISSION CONCEPT. J. Monk[1], D. Prabhu[2], G. Allen[3], J.M Thornton[4], H. Hwang[5], A. Pensado[6], S. Dutta[7] , [1]NASA Ames Research Center, Moffett Field, CA 94035, joshua.d.monk@nasa.gov, [2]AMA, Inc. at NASA Ames Research Center, Moffett Field, CA 94035, dinesh.k.prabhu@nasa.gov, [3]AMA, Inc. at NASA Ames Research Center, Moffett Field, CA 94035, gary.a.allen@nasa.gov, [4]AMA, Inc. at NASA Ames Research Center, Moffett Field, CA 94035, john.m.thornton@nasa.gov, [5]NASA Ames Research Center, Moffett Field, CA 94035, helen.hwang@nasa.gov, [6]Analytical Mechanics Associates, 21 Enterprise Pkwy., Suite 300, Hampton, VA 23666, alejandro.r.pensado@nasa.gov, [7]NASA Langley Research Center, Hampton, VA 23681, soumyo.dutta@nasa.gov,

Introduction: Uranus was identified as the third highest priority flagship mission in the 2012-2022 Planetary Science Decadal Survey. This latest concept study was requested by the Decadal Survey panel to determine NASA's planetary science priorities from 2022-2032. This study focused on the probe's entry and descent aspects and associated trades for viable trajectory options.

Uranus Mission and Descent Probe: The proposed Uranus Orbiter and Probe (UOP) Flagship mission will investigate Uranus and its surrounding moons using an orbiting spacecraft with a Uranus descent probe. Unlike previous studies [1,2] the probe release will occur after orbit insertion allowing sufficient separation of critical events during the orbit insertion burn. The probe will be released at an altitude that allows one hour of in situ atmospheric readings that will be relayed to the orbiter. Afterwards the orbiter will transition to the moon tour phase of the mission.

The configuration chosen for the entry aeroshell was a 45° sphere-cone. This shape has been used in the past in the Pioneer Venus Galileo missions [3]. However, the nose radius considered in the present study differed from the values used in either of the previous configurations, primarily to reduce the heat flux at the stagnation point [4].

A two-step approach was used in the development of flight trajectories for the chosen configuration.

In the first step, the trajectory code POST2 [5] was used to screen the thousands of entry states provided by interplanetary trajectory simulations, which were terminated at an altitude of 2000 km from the reference surface (1 bar) of Uranus. The screening criteria were: (i) optimization of the communication geometry between the entry probe and orbiter to ensure at least 1 hour of science measurements, (ii) peak stagnation point pressures to be less than six bar, (iii) peak heat fluxes to be less than 5 kW/cm^2; the latter two constraints being the limits of ground-test capabilities of the arc jets at NASA Ames Research Center. The entry team investigated two trajectories that met the criteria above, a shallow entry (high heat load ~44 kJ/cm^2) and a steeper entry (high heat rate ~1950 W/cm^2).

In the second step, the two bounding candidate entry states from the POST2 screening process were used in developing flight trajectories using TRAJ [6] coupled with FIAT [7] (a materials thermal response and sizing code) and a margins policy [8] to determine a *margined* uniform thickness (hence mass) of the forward heatshield material based on the aerothermal environments at the stagnation point.

Since the combination of TRAJ and FIAT size the TPS based on stagnation point environments only, flow field computations using DPLR [9] were necessary to determine turbulent aerothermal environments on the conical flank, and the augmentation of these environments due to surface roughness. The environments at select locations on the forward heatshield were then used to size the thermal protection material, with the largest thickness value then used to estimate the mass.

The newly developed woven thermal protection material – HEEET (Heatshield for Extreme Entry Environments Technology) [10] – was considered for the forward heatshield and PICA (Phenolic-Impregnated Carbon Ablator) [11] was considered for the backshell. These NASA-developed materials are at TRL 6 and TRL 9, respectively. Furthermore, two options were considered for the HEEET material: (i) a dual-layer option with a denser recession layer on top and an insulative layer underneath it, and (ii) a single layer option consisting of the insulative layer alone.

Results: It is clear that probe entry states are feasible and the selected TPS options are able to perform in the predicted aerothermal environments thus enabling the mission to meet of the descent probe portion of this flagship mission.

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