Atmospheric entry to Earth and other planetary bodies

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Challenges for Hypersonic Vehicles

UNIVERSITY OF OXFORD

TIME

High speed → over 4000 MPH!

AERODYNAMICS

Large range of conditions & manoeuvrability

HEATING

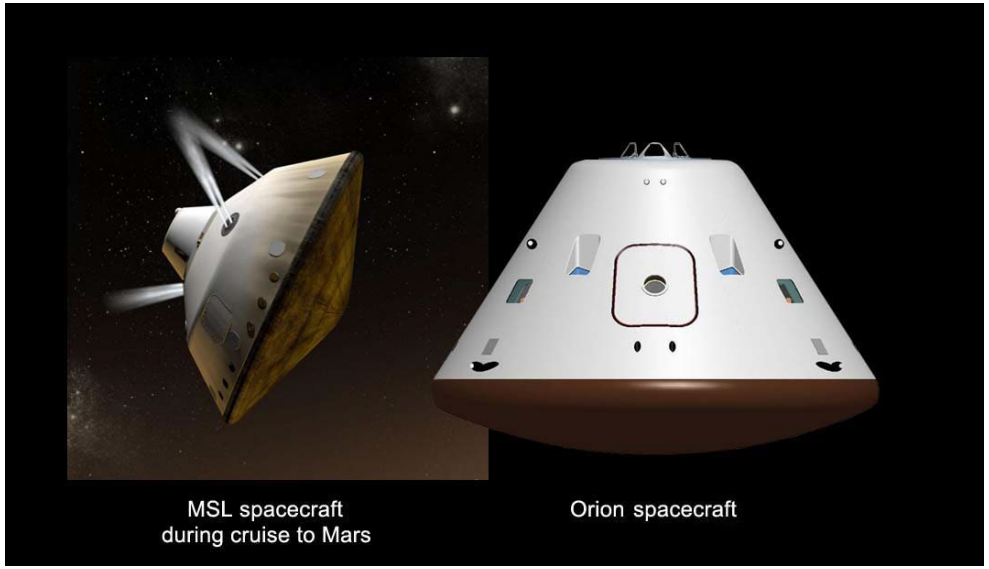
Air becomes hotter than the sun's surface (>5000 K)

THERMOCHEMISTRY

Complex and coupled physics and chemistry

SIMULATION & EXPERIMENTS

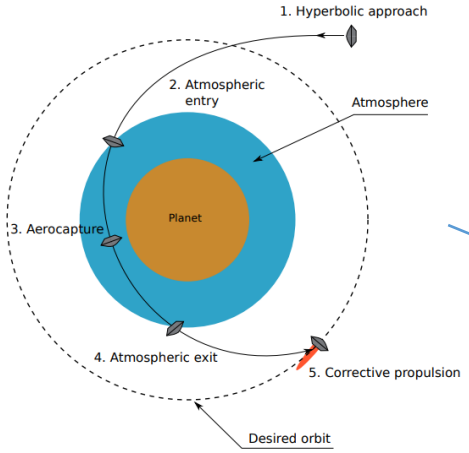
Numerical simulations prohibitively expensive & wind tunnel testing @ true flight conditions is impossible

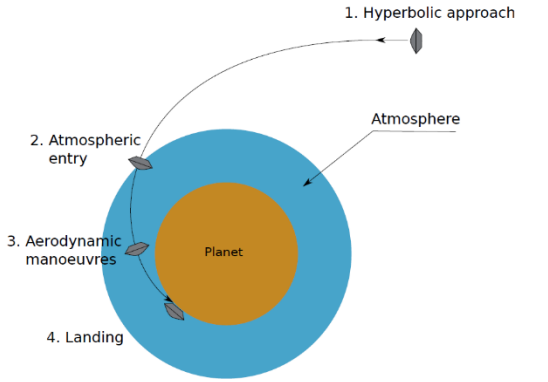


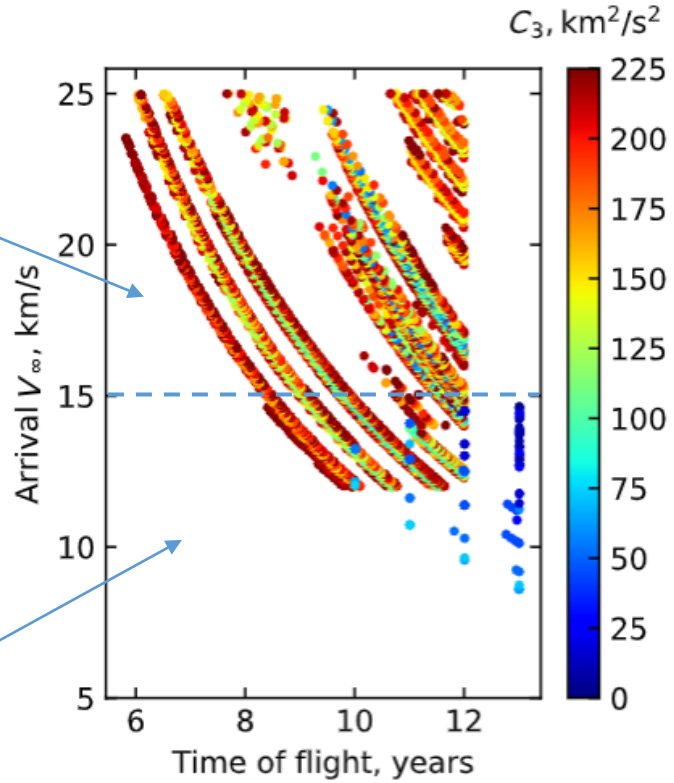
NASA Space vehicles. Source: NASA.

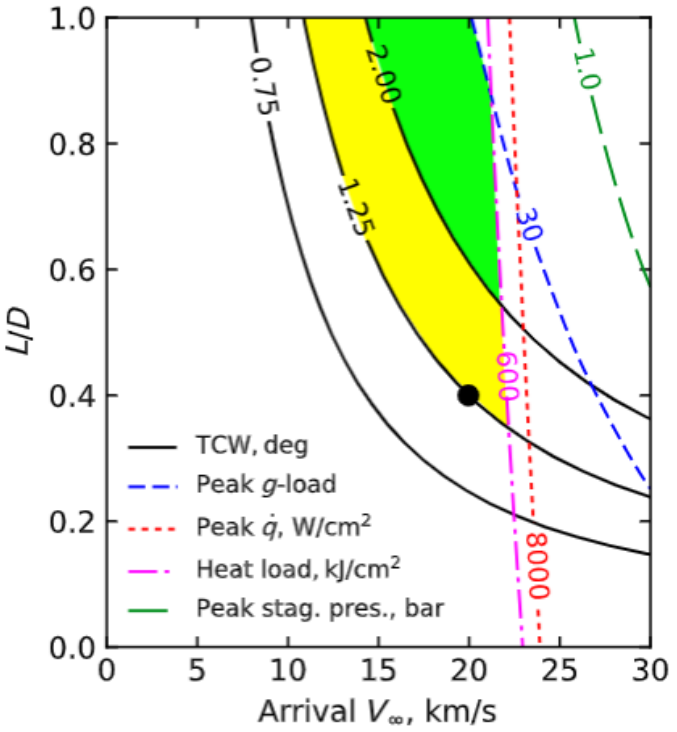
But haven't we successfully entered Earth and other planets atmospheres since the 60's?

Entry, Decent and Landing



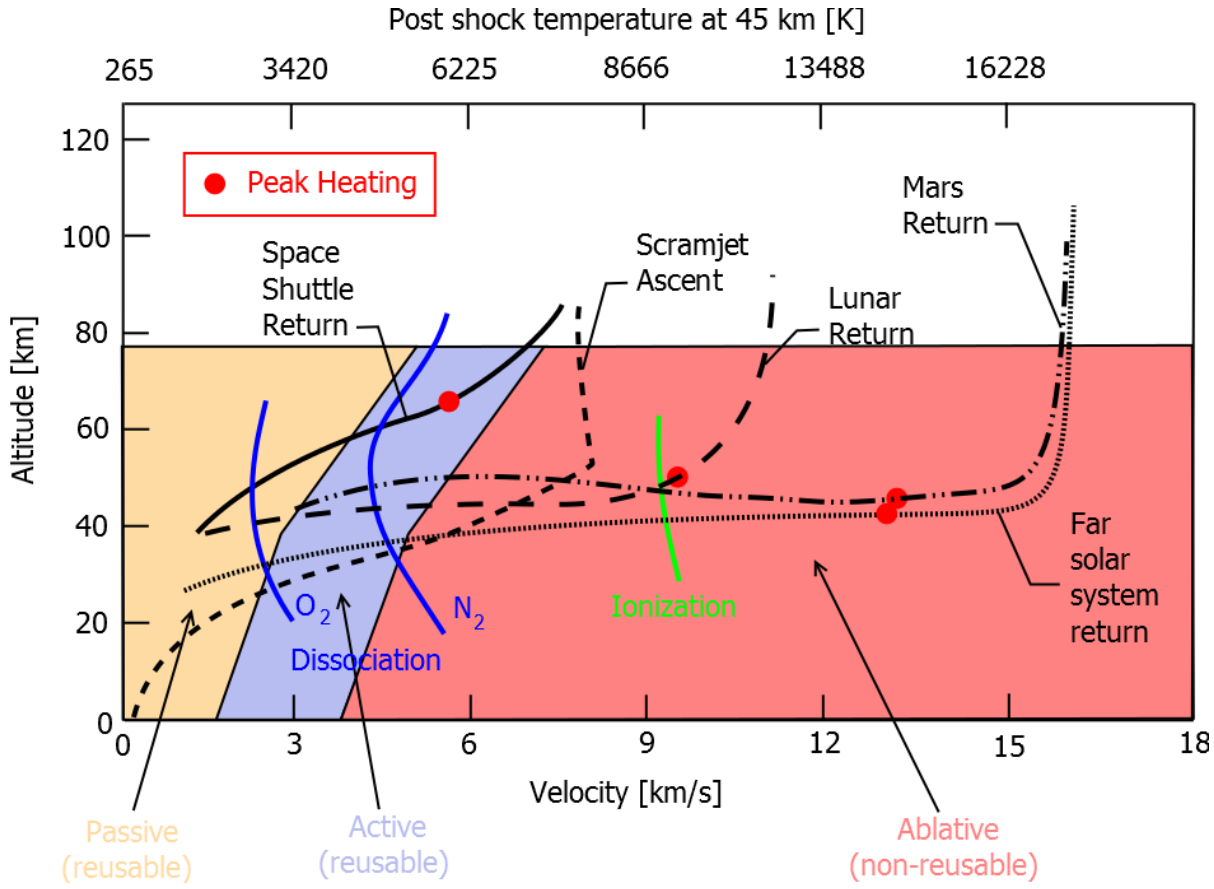


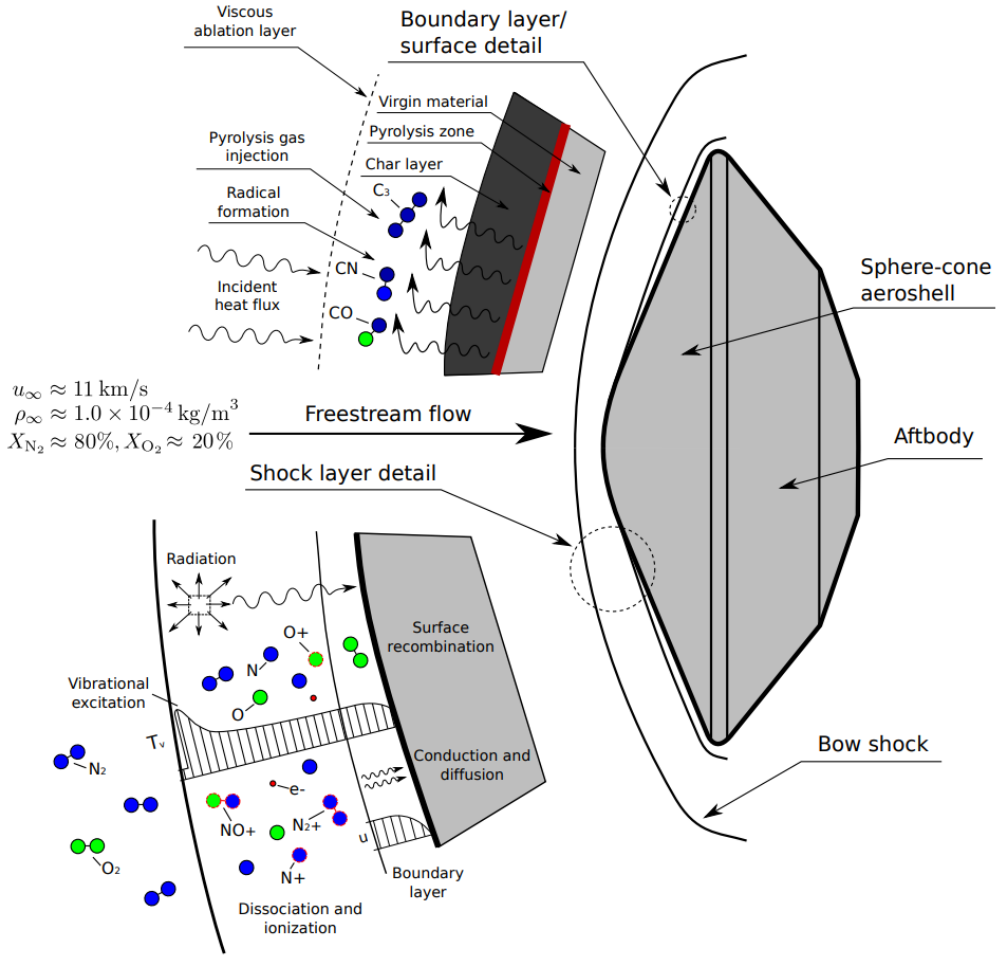




Neptune trajectory calculations.
Source: Girija et al. 2022.

Thermal Protection System





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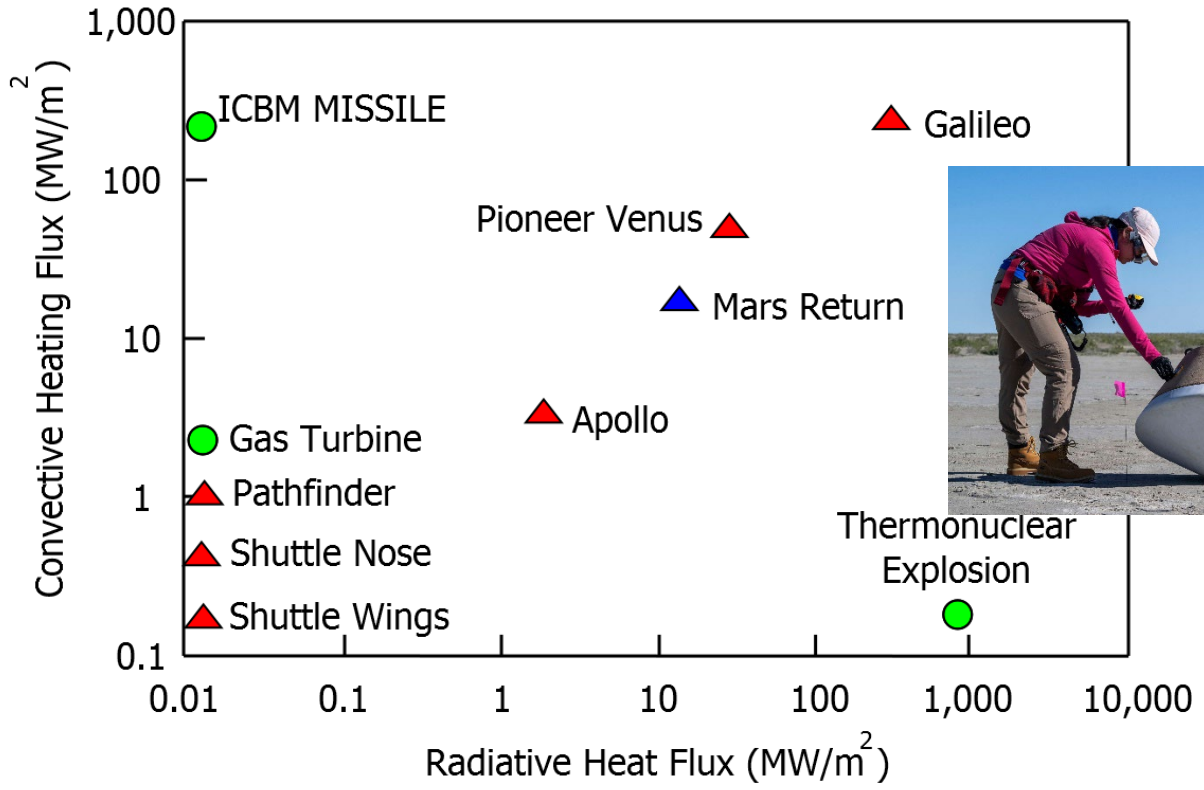
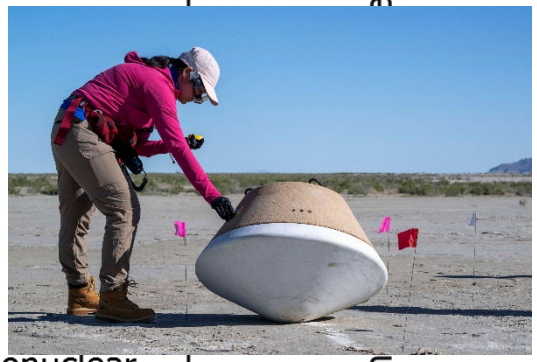
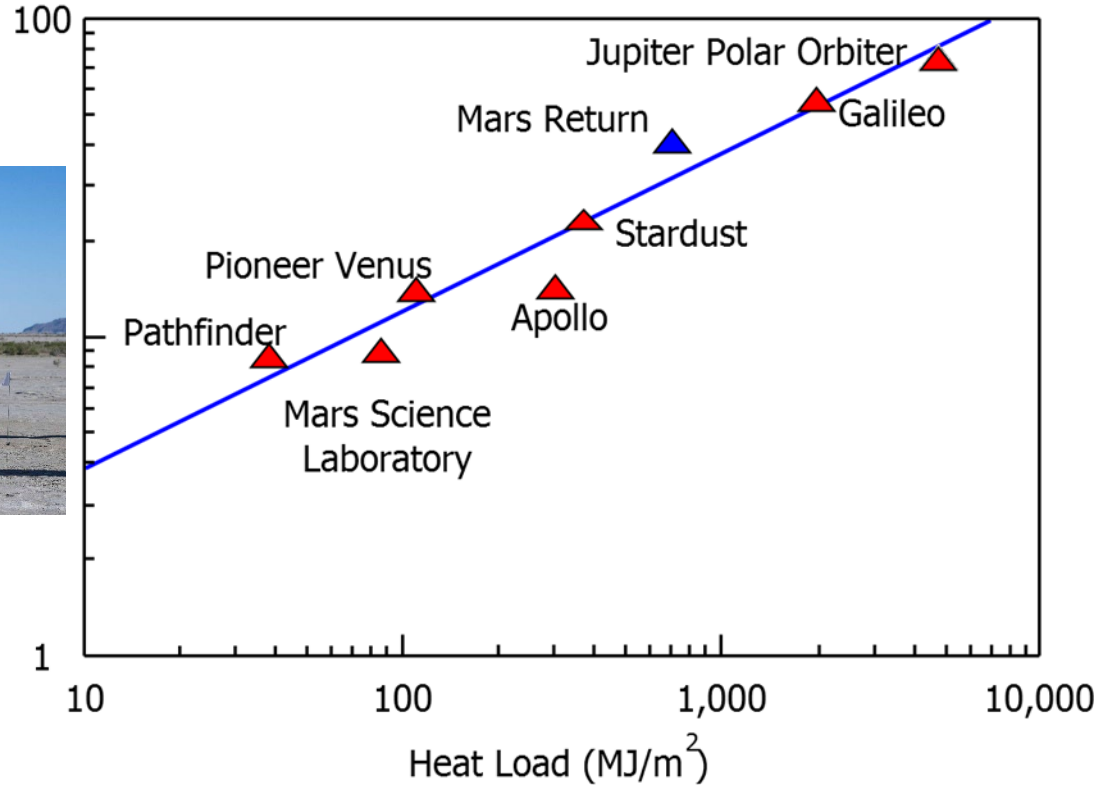
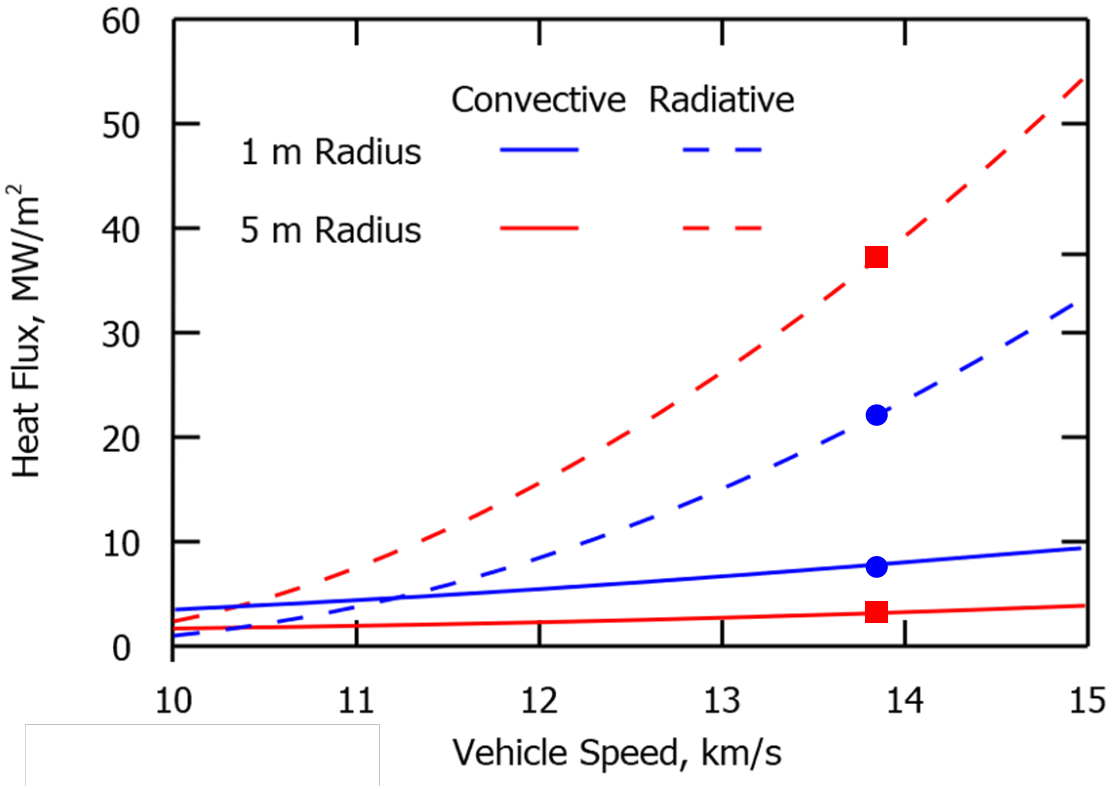






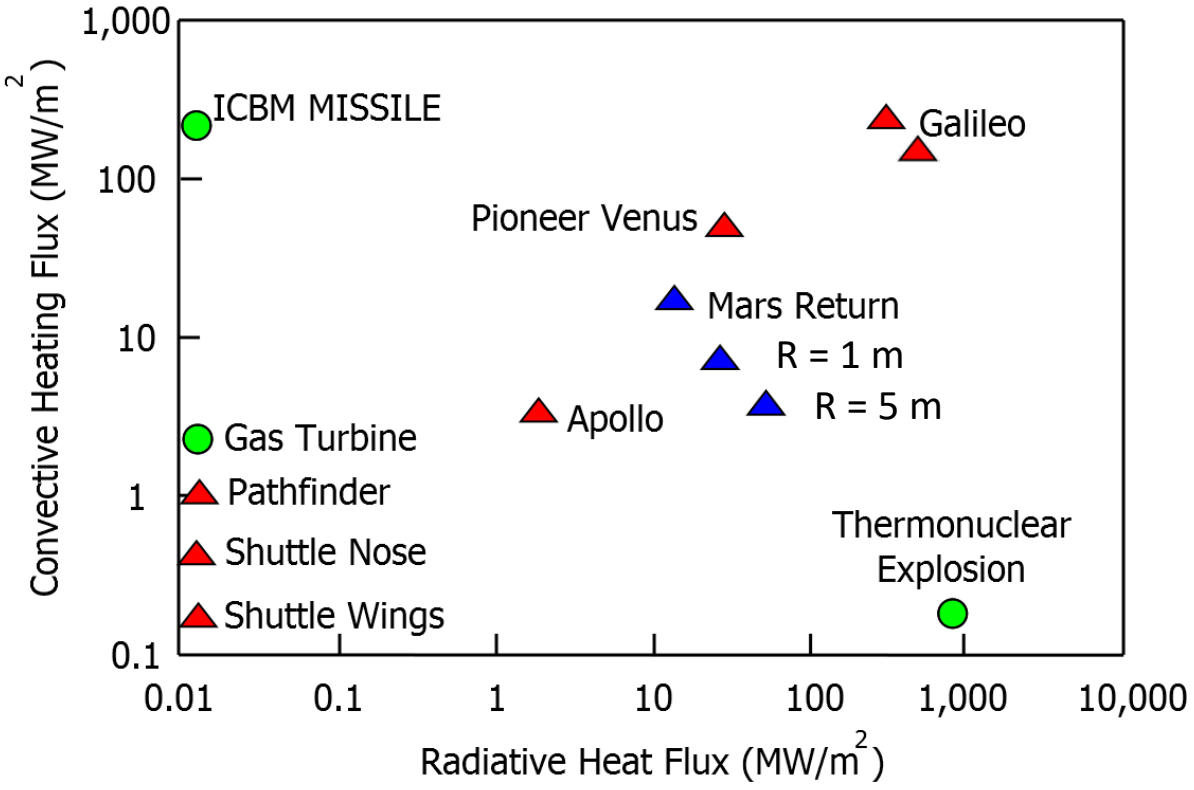
Thermal Protection System

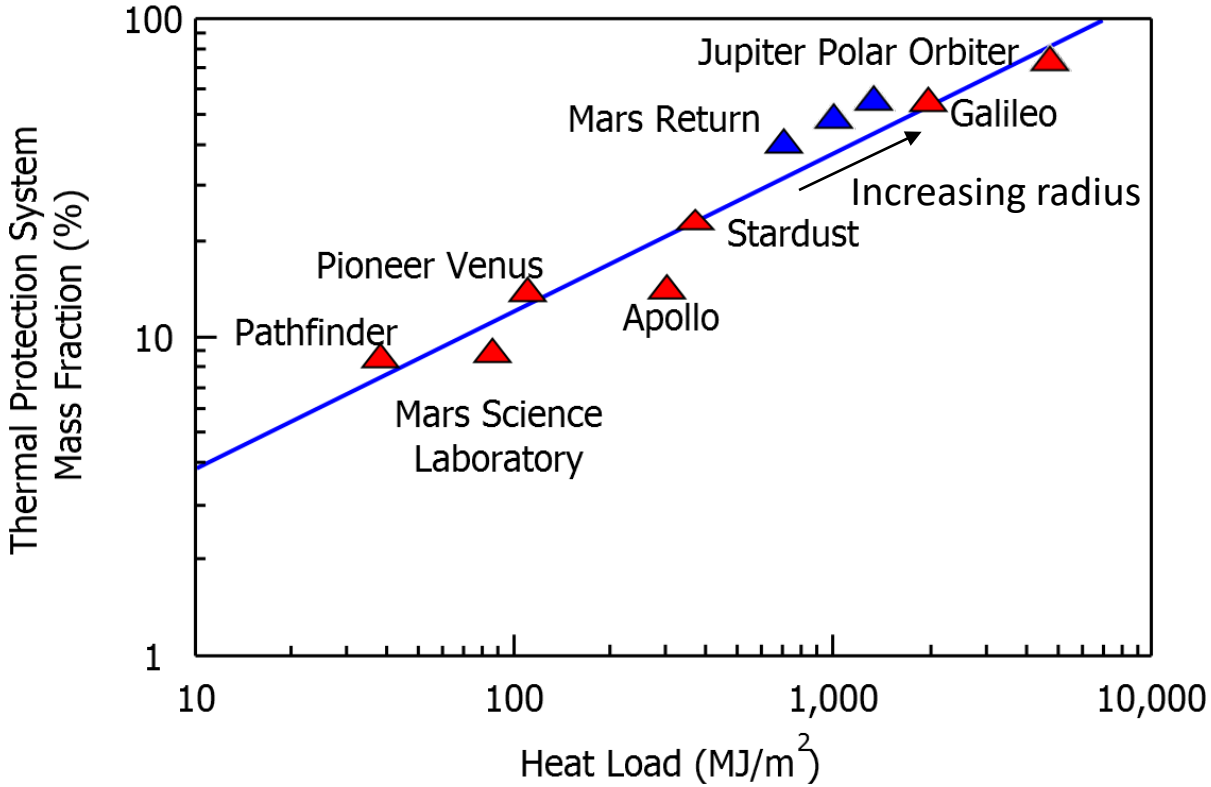
Mercury return capsule, 1 m radius



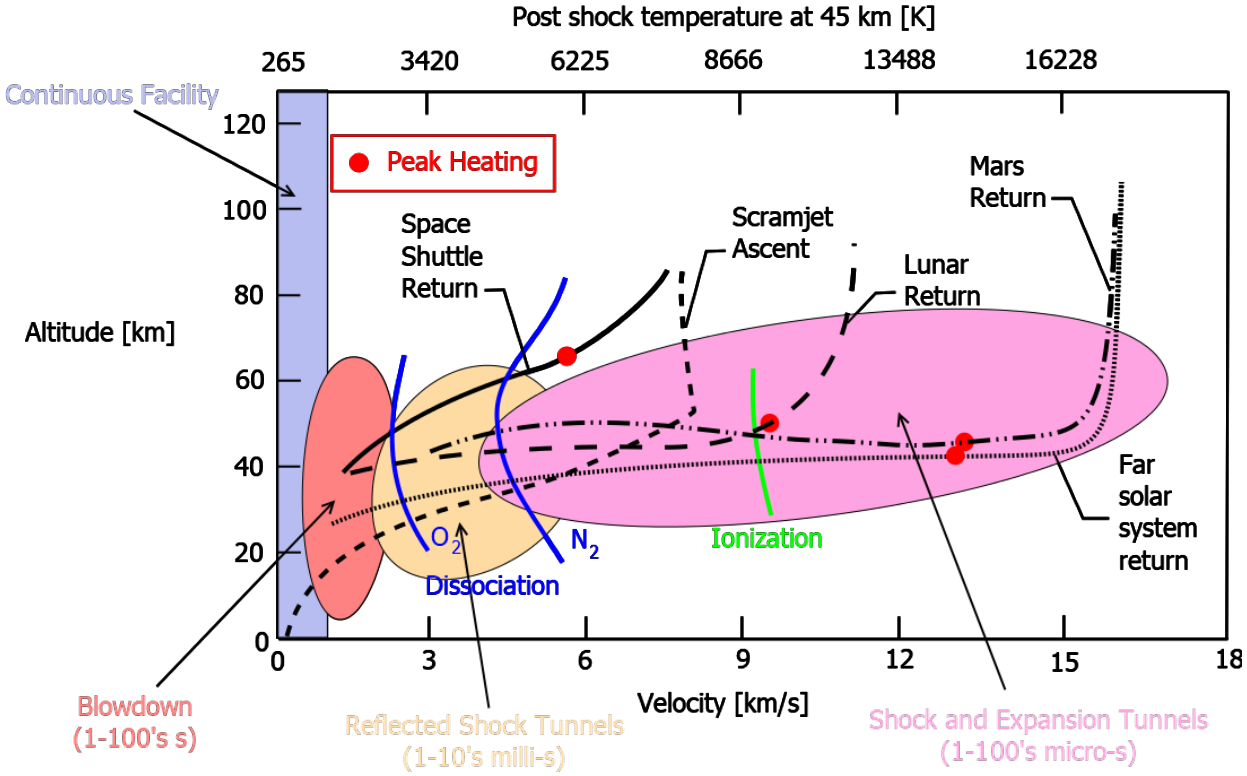
Starship, 5 m radius

Thermal Protection System





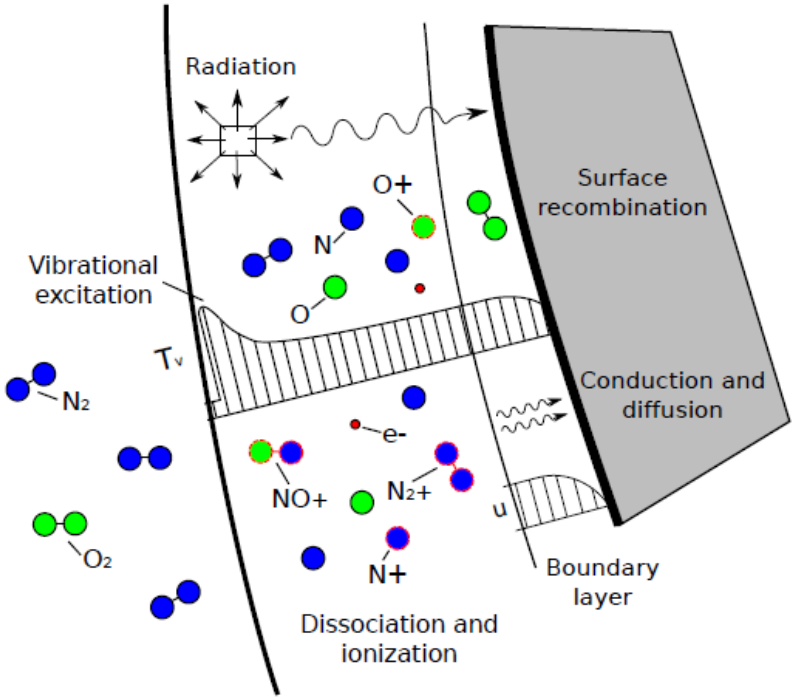
Hypersonic Wind Tunnels



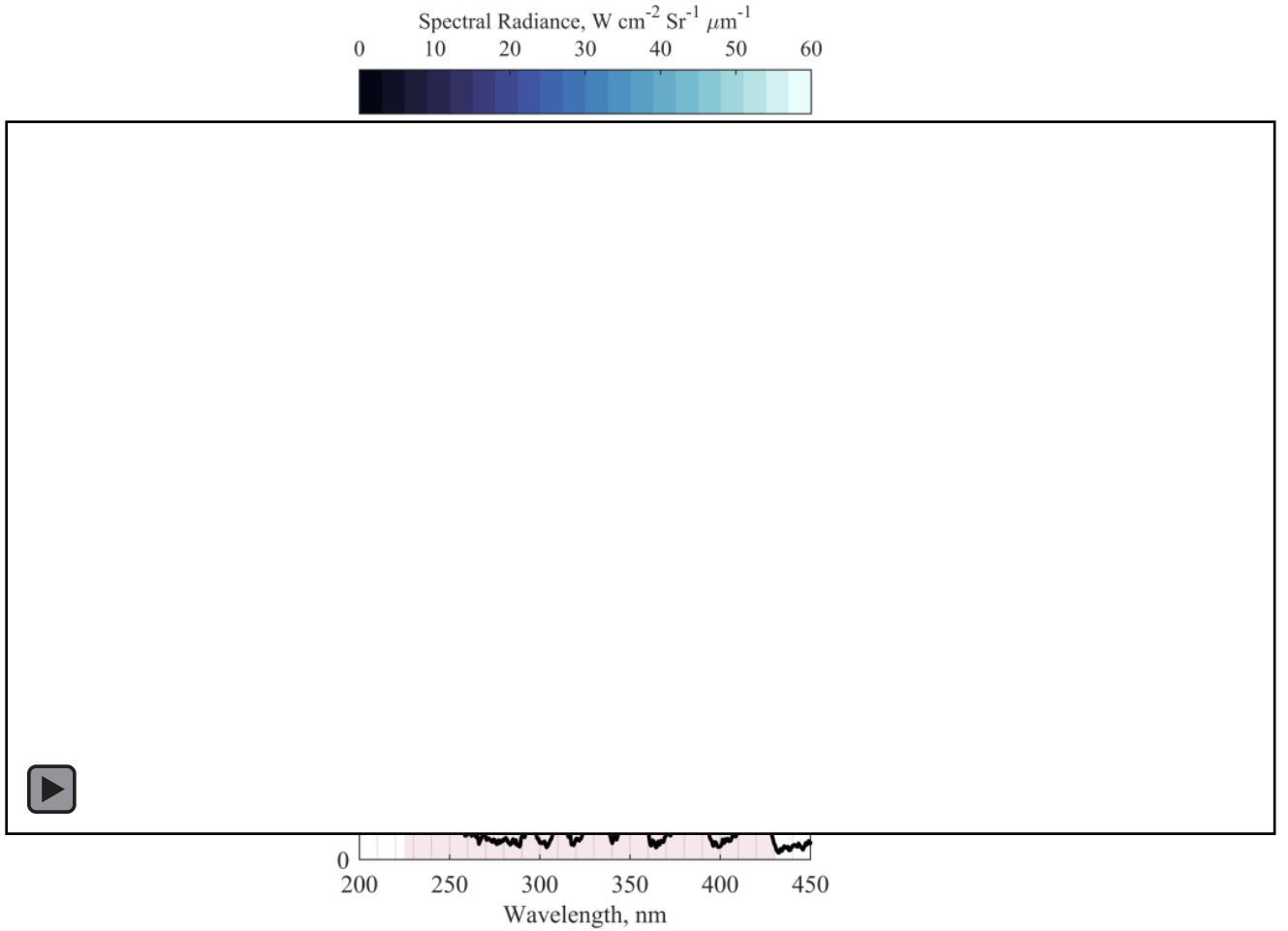
Hypersonic flight replication in wind tunnels.

Oxford Hypersonic Wind Tunnels. T6 is on the left and the High Density Tunnel on the right .

Thermochemistry

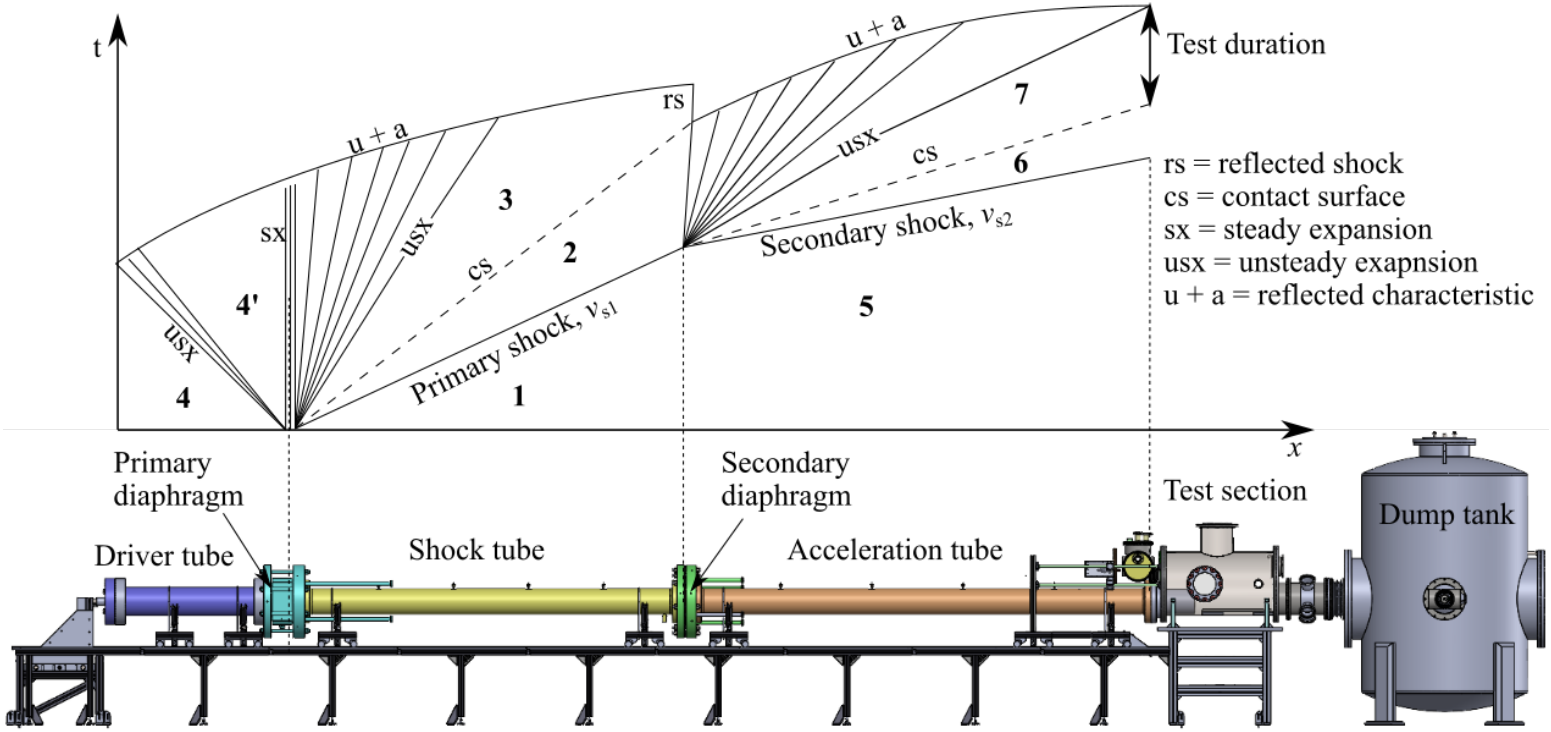


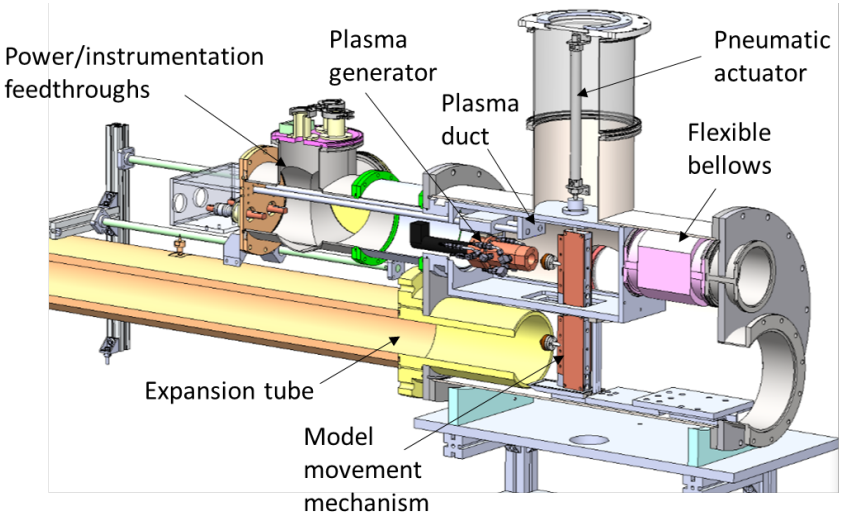
Thermochemical processes in the shock and boundary layer for high speed vehicles.



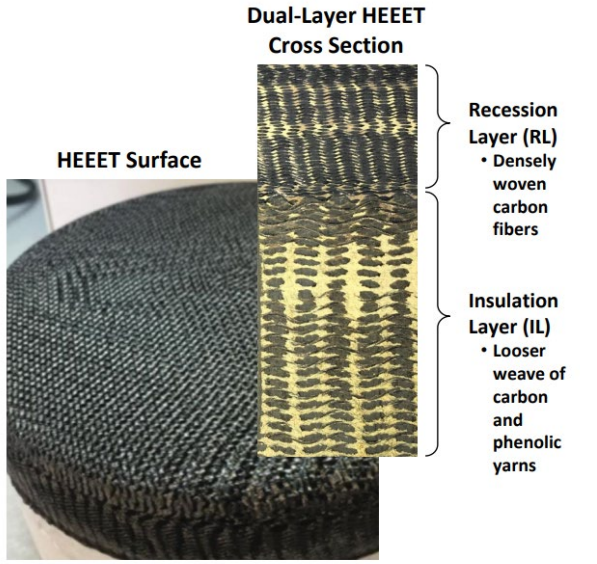
Test in Oxford T6 tunnel in shock tube mode of air at 10 km/s @ 58 km altitude. Slow motion at 1/8th true speed.

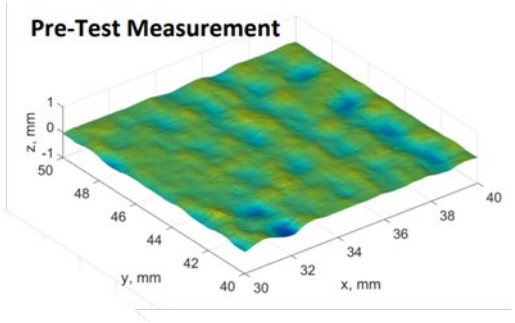
Ablation – Flowfield Coupling

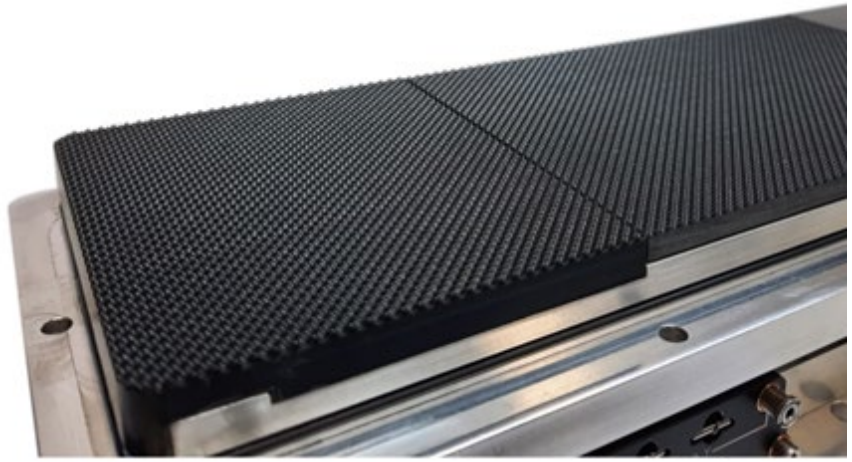


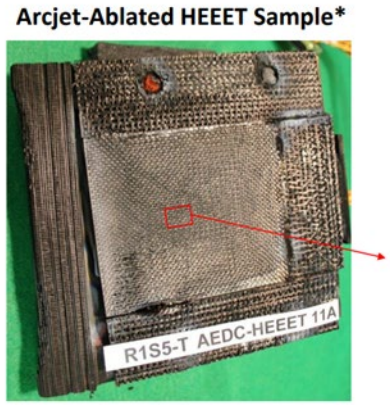


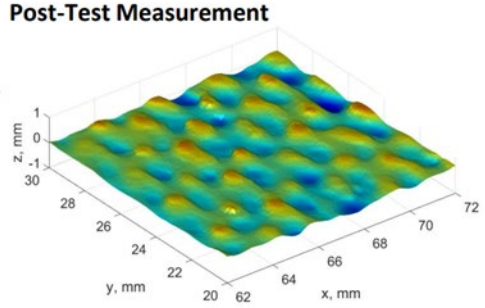
Roughness Convective Heating Augmentation



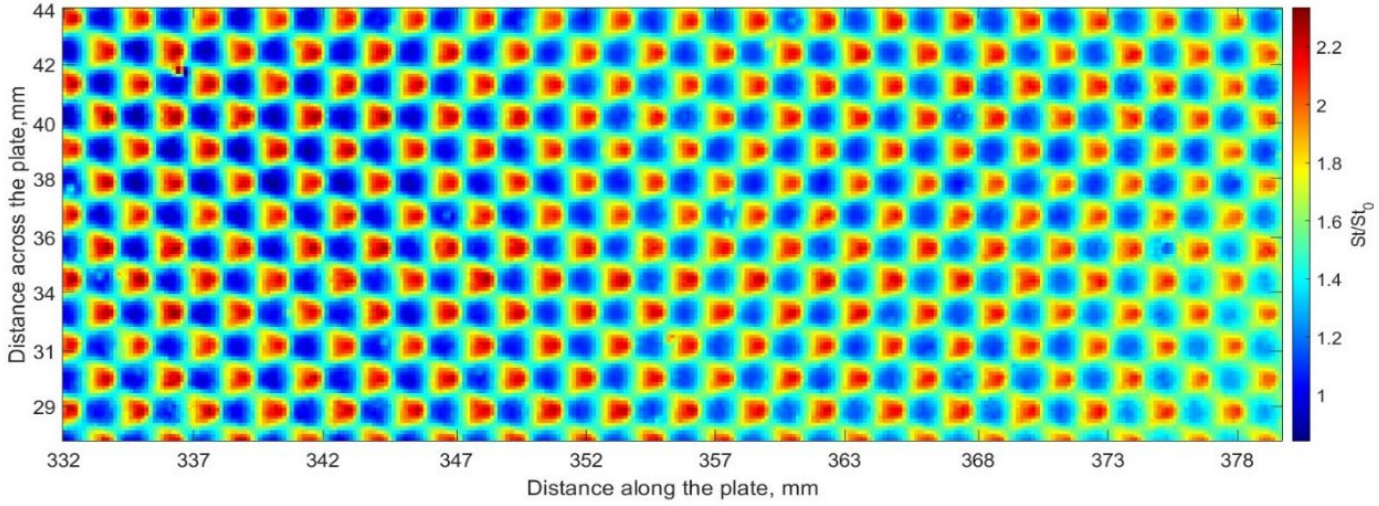




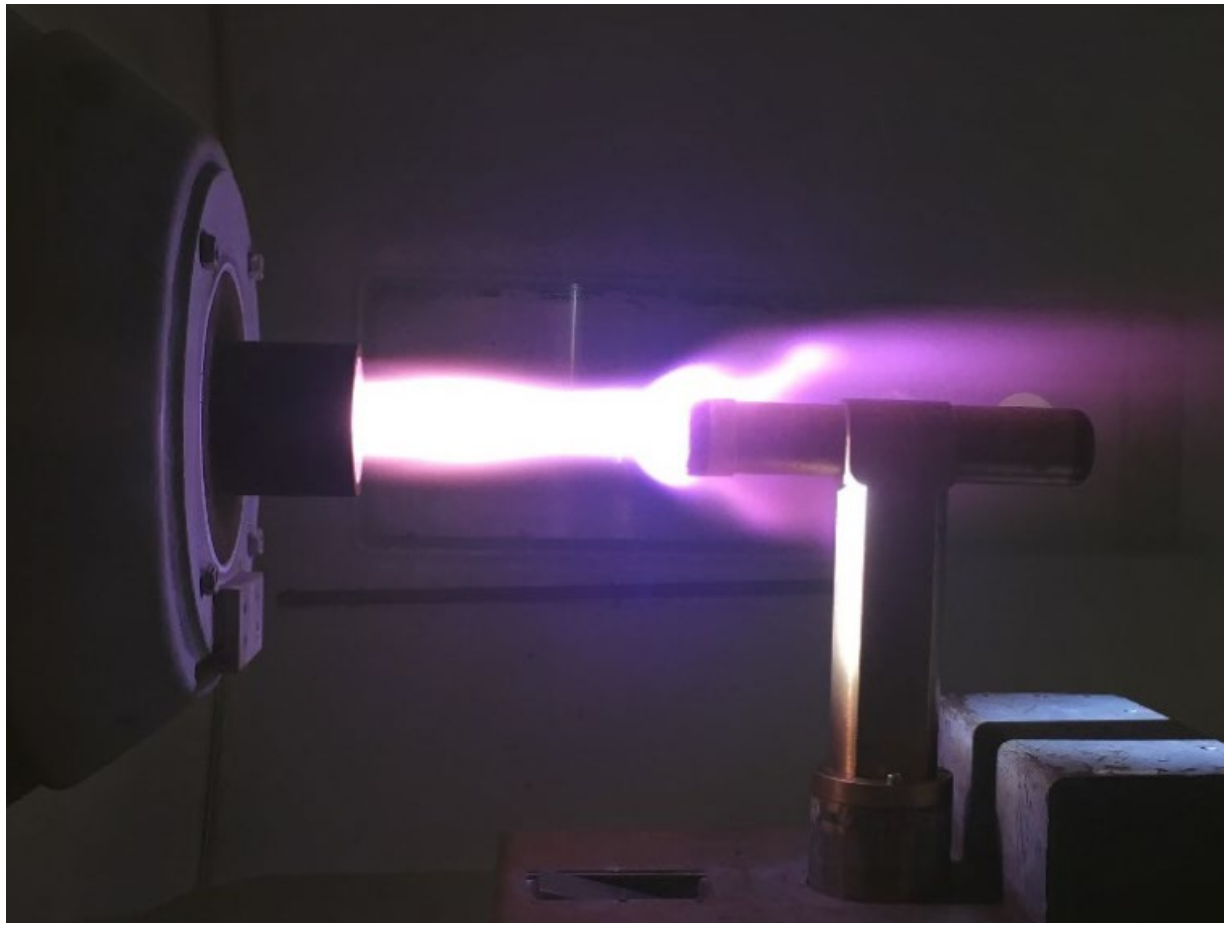


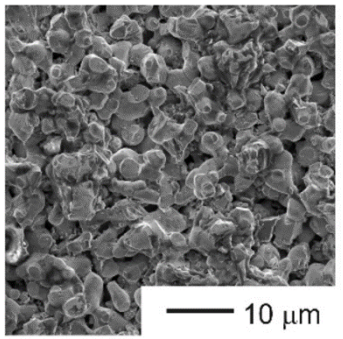


[1]Venkatapathy, E., *et al.*, "TPS for Outer Planets," Outer Planets Assessment Group (OPAG) Technology Forum; 21-22 Feb. 2018

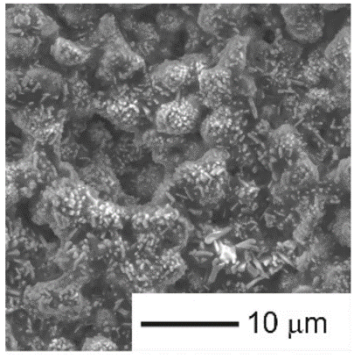


Active Cooling - UHTC



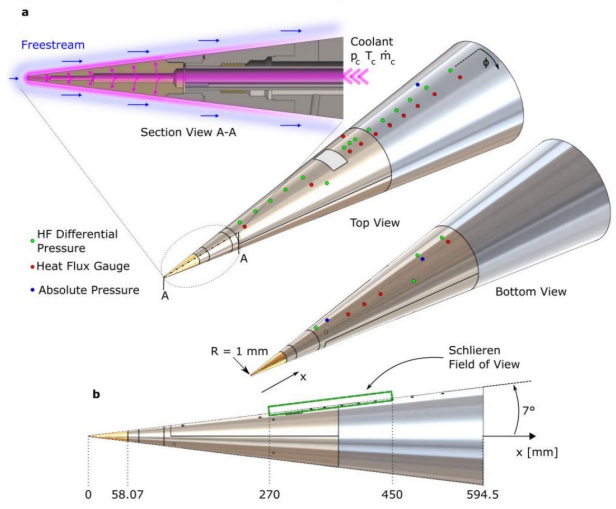


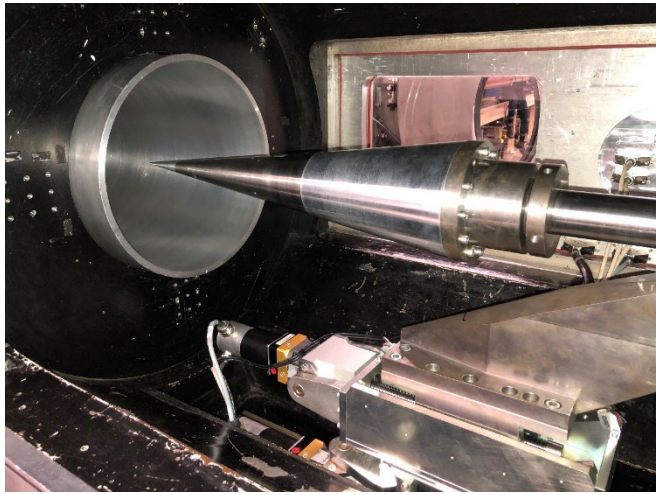
Before testing

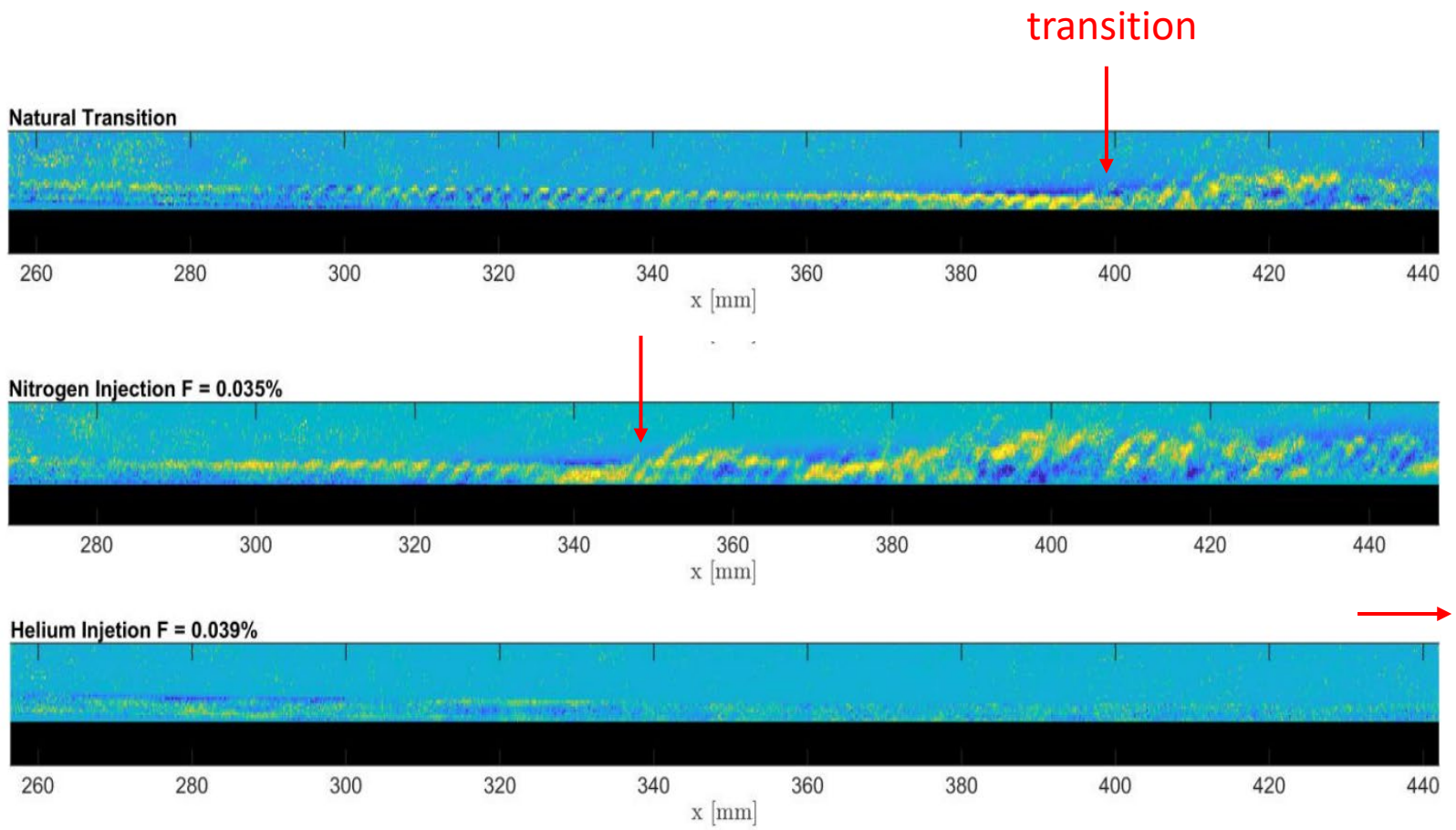


N_2 cooled

Active Cooling – Boundary Layer Transition







World's fastest champagne cork

Oxford T6 Stalker Tunnel, 13.2 km/s.

Thank you - any questions?