16th International Planetary Probe Workshop

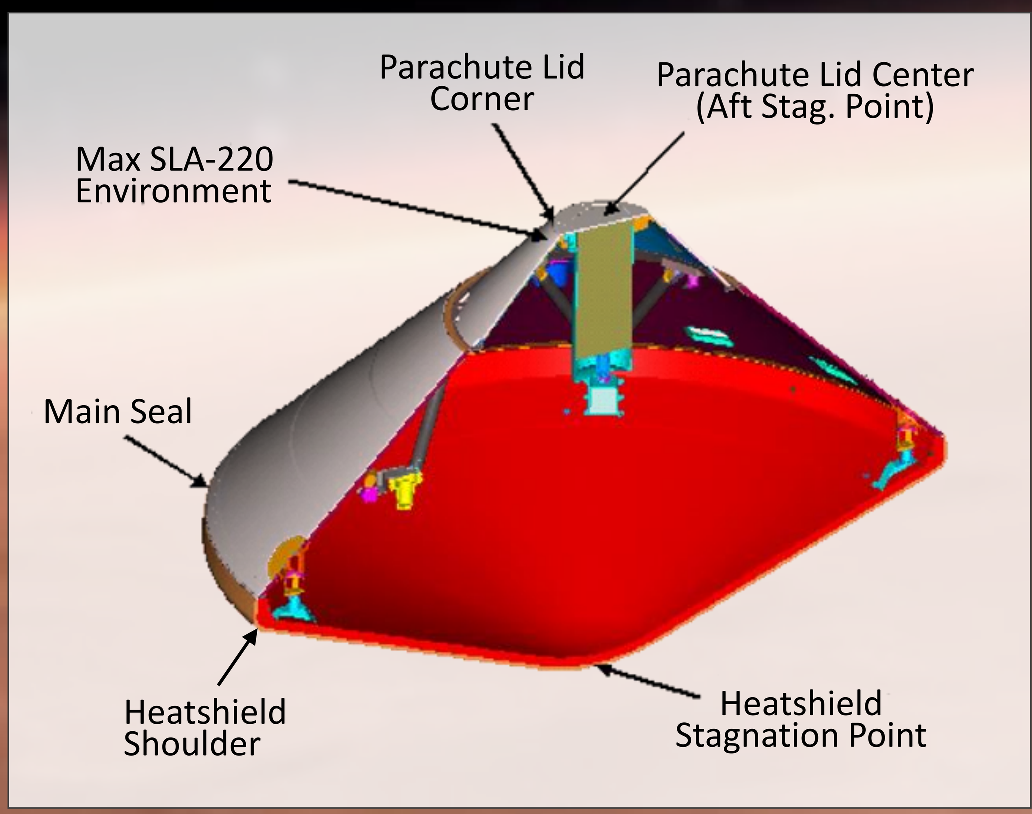
InSight's Reconstructed Aerothermal Environments

J. T. Songer[1], R. A. Beck[2], C. E. Szalai[3], D. A. Saunders[2], K.T. Edquist[4], C. Karlgaard[4],
[1]Lockheed Martin Space, [2]NASA Ames Research Center, [3]Jet Propulsion Laboratory, California Institute of Technology, [4]NASA Langley Research Center

InSight EDL

InSight Aeroshell Heritage and Challenges

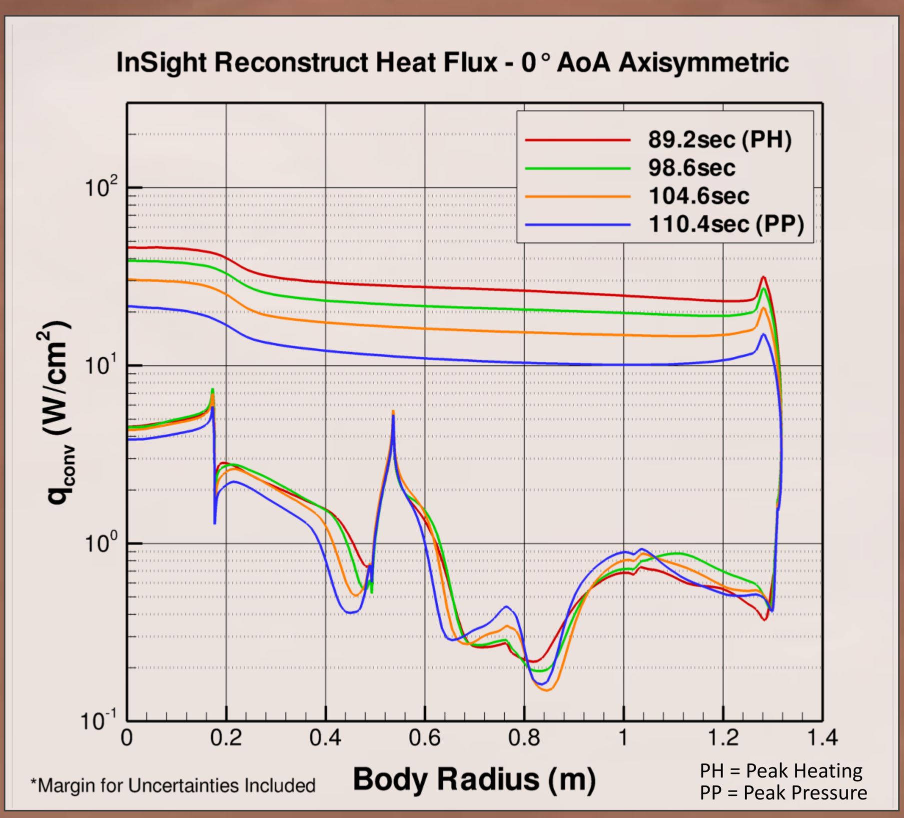
- InSight was intended to be a Phoenix Lander "Build-to-Print" aeroshell
- Identical aeroshell Geometry
- Same TPS materials with thickness increases only where required.
- Initially, InSight convective heating environments exceeded Phoenix values:
  - Phoenix peak q_{dot} = 70 W/cm^2
  - InSight peak q_{dot} = 84 W/cm^2 (2016 launch date)
- Increased analysis complexity for InSight

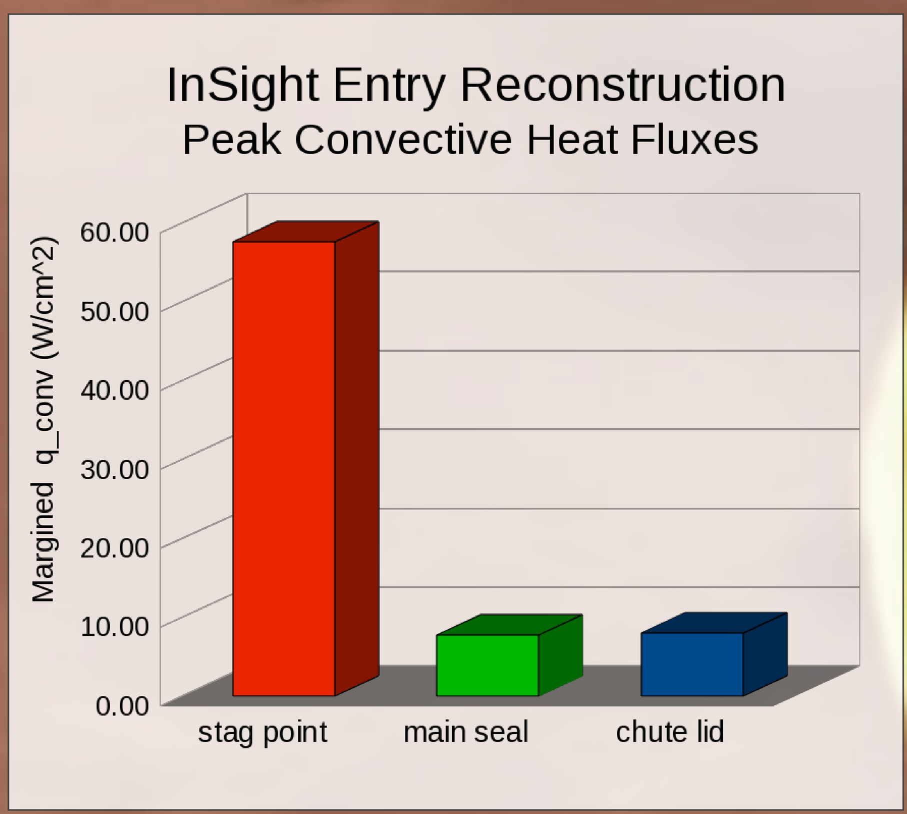


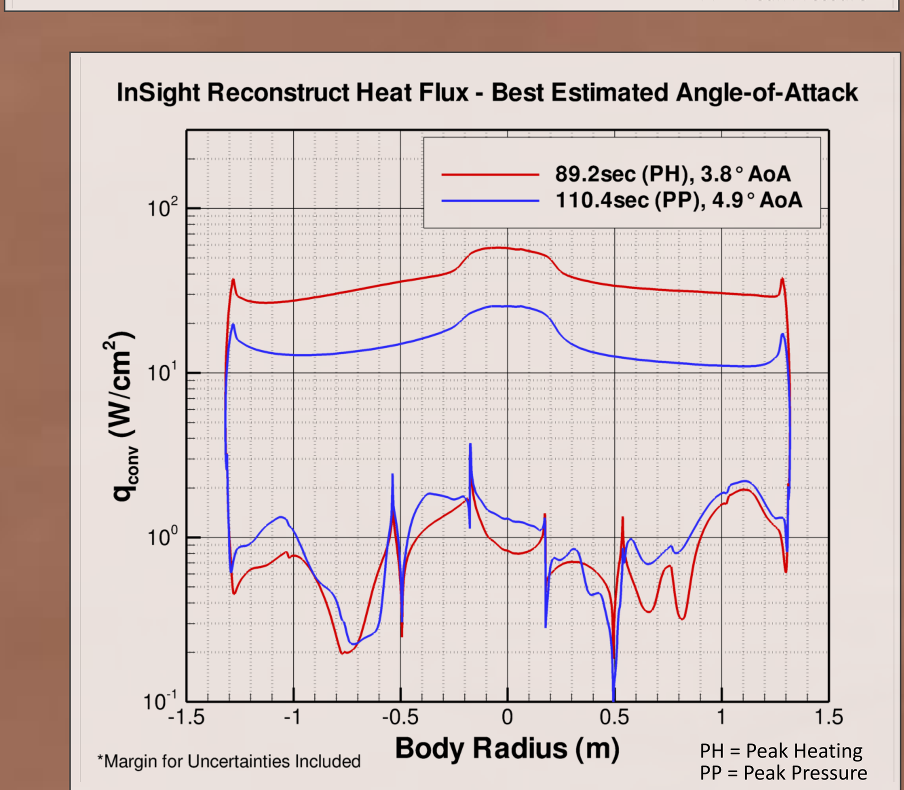
- Additional challenges arose during design:
- Entry during dust storm season
  - Potential thermal protection system erosion due to dust required thicker heatshield TPS
  - Wider range of heat fluxes/heat loads due to atmos.
- Radiative heating to aeroshell afterbody
  - Recent test data indicated non-negligible effect
  - New radiation models incorporated for CO_2 mid-wave IR; InSight first in U.S. to include this in design.
- Possibility of earlier turbulent transition on the forebody than predicted for Phoenix

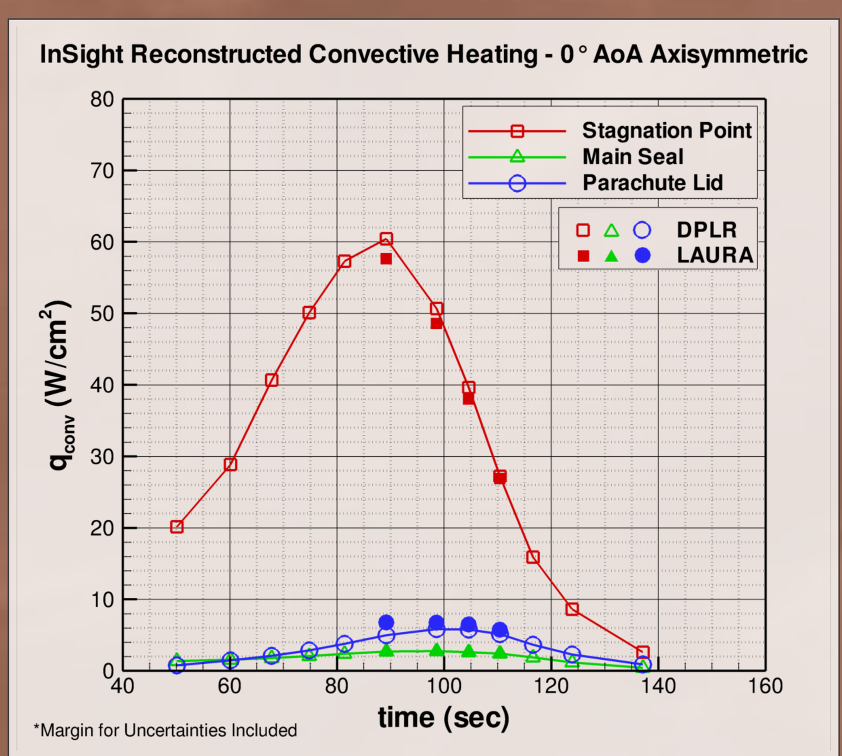
Convective Heating

- Aerothermal reconstruction computations performed with a combination of DPLR v4.04 and LAURA v5.5 solvers.
  - 8-species, non-equilibrium Mars chemistry with super-catalytic, radiative equilibrium wall boundary.
- Total of 16 axisymmetric (0° AoA) solutions at 12 unique trajectory times on BET for comparison to InSight design environments
- Two solutions at reconstructed AoA for main seal heat flux assessment
  - 10° design case drove maximum flux conditions at this location.
  - Non-zero trim angle-of-attack was observed in trajectory reconstruction





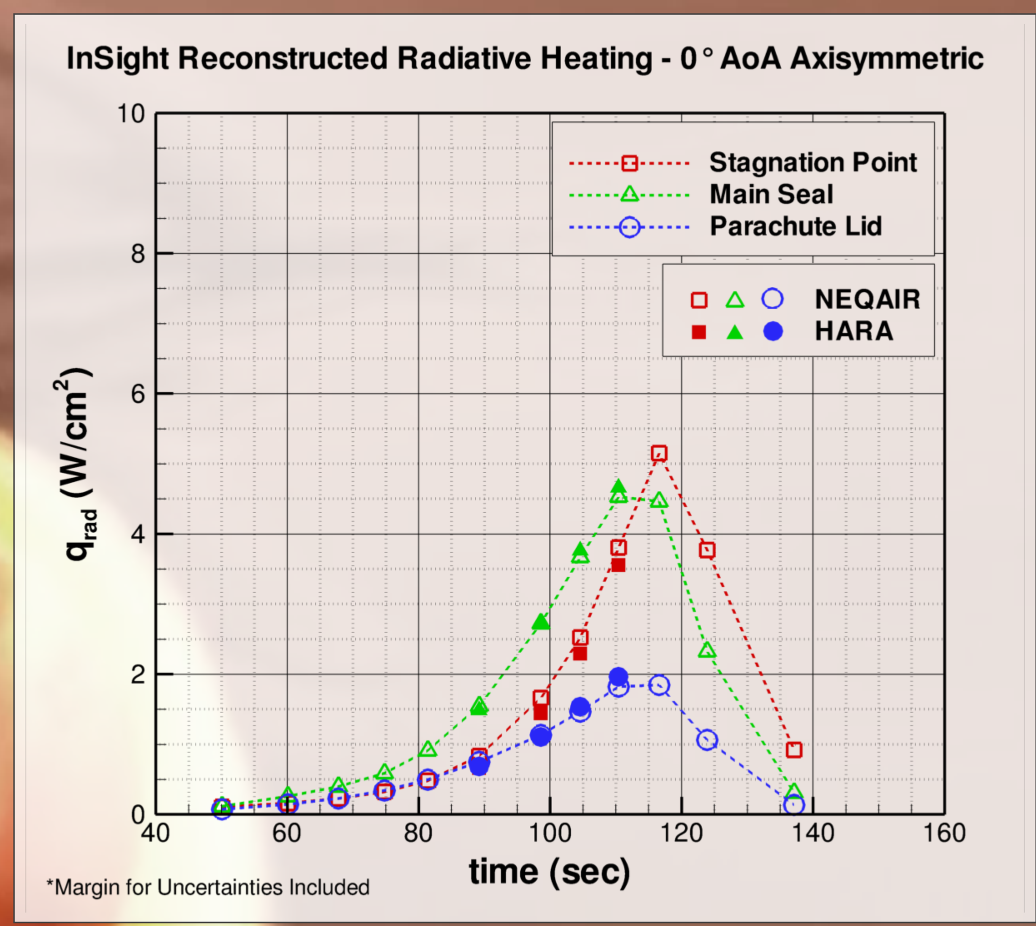


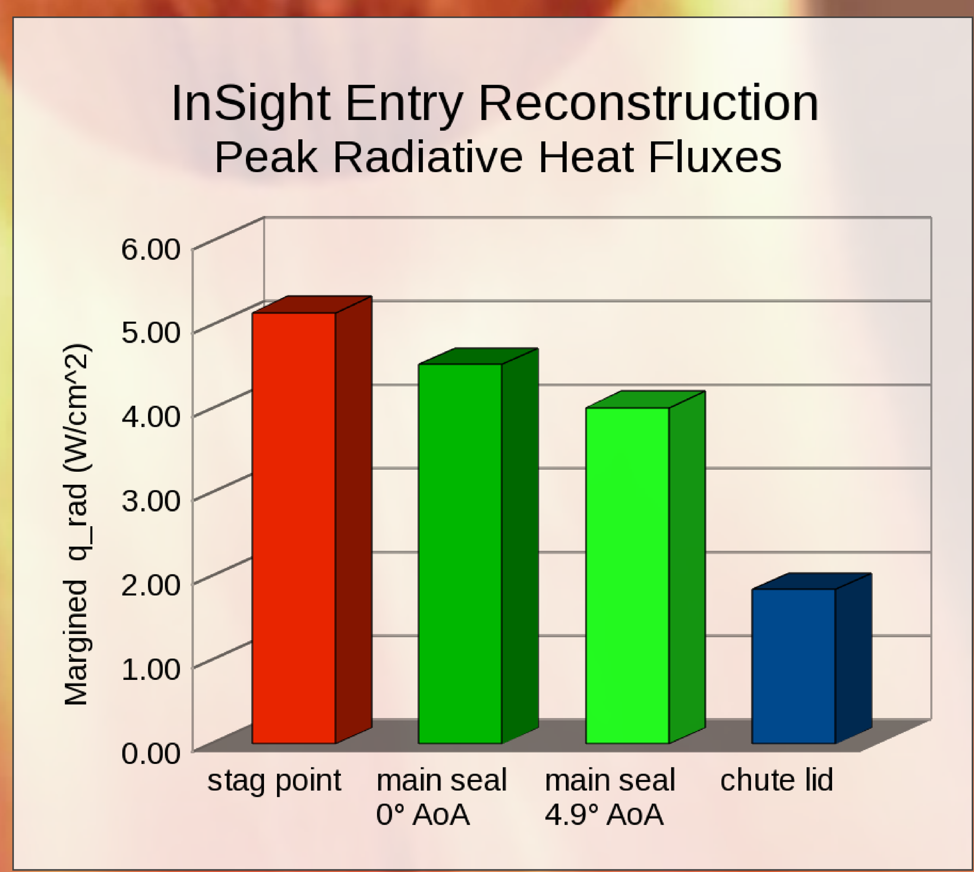


Radiative Heating

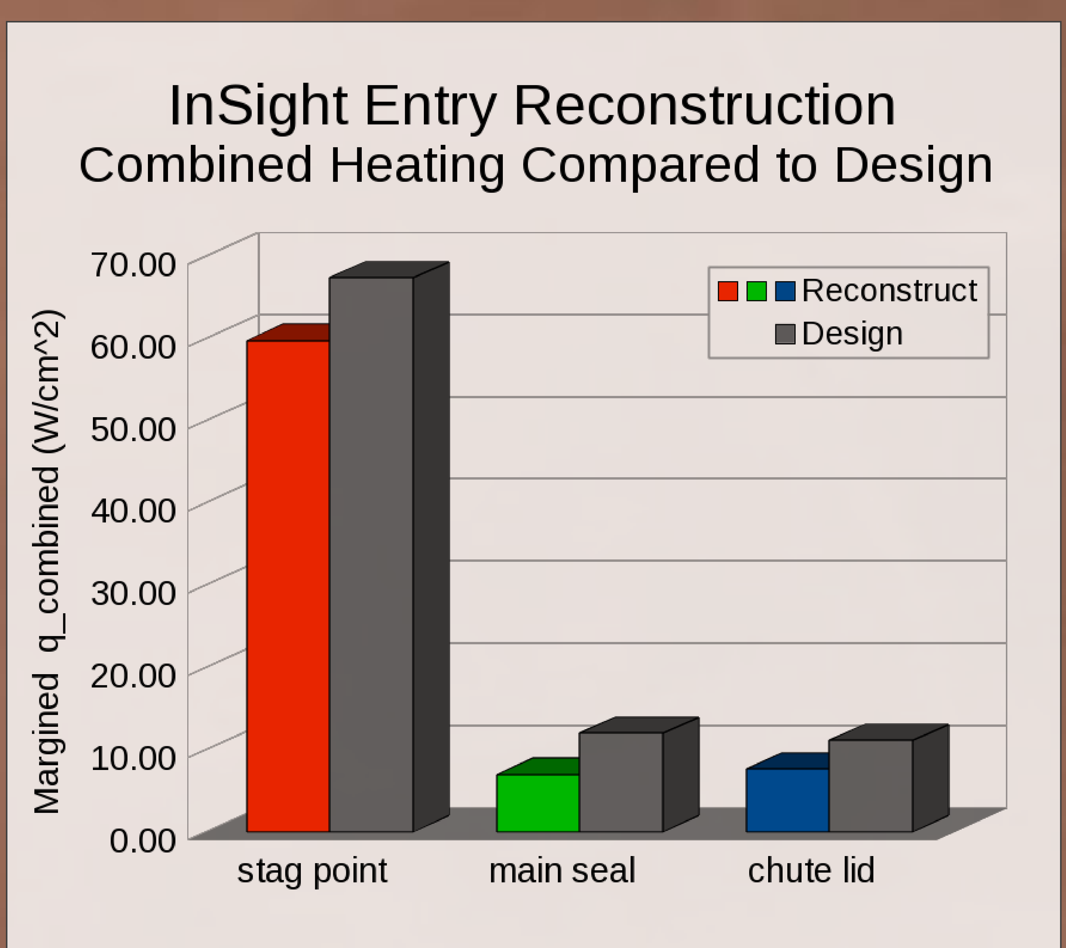
- Radiative heating for environment reconstruction computed with NEQAIR and HARA codes using hemi-integration/ray-tracing methods.
- Solutions for radiative heating at all time points for 3 body locations

InSight radiative heat flux peaks at all locations approximately 110 to 115 seconds from entry interface. Radiative heat pulse significantly lags forebody convective heat pulse but adds to afterbody heat pulse.



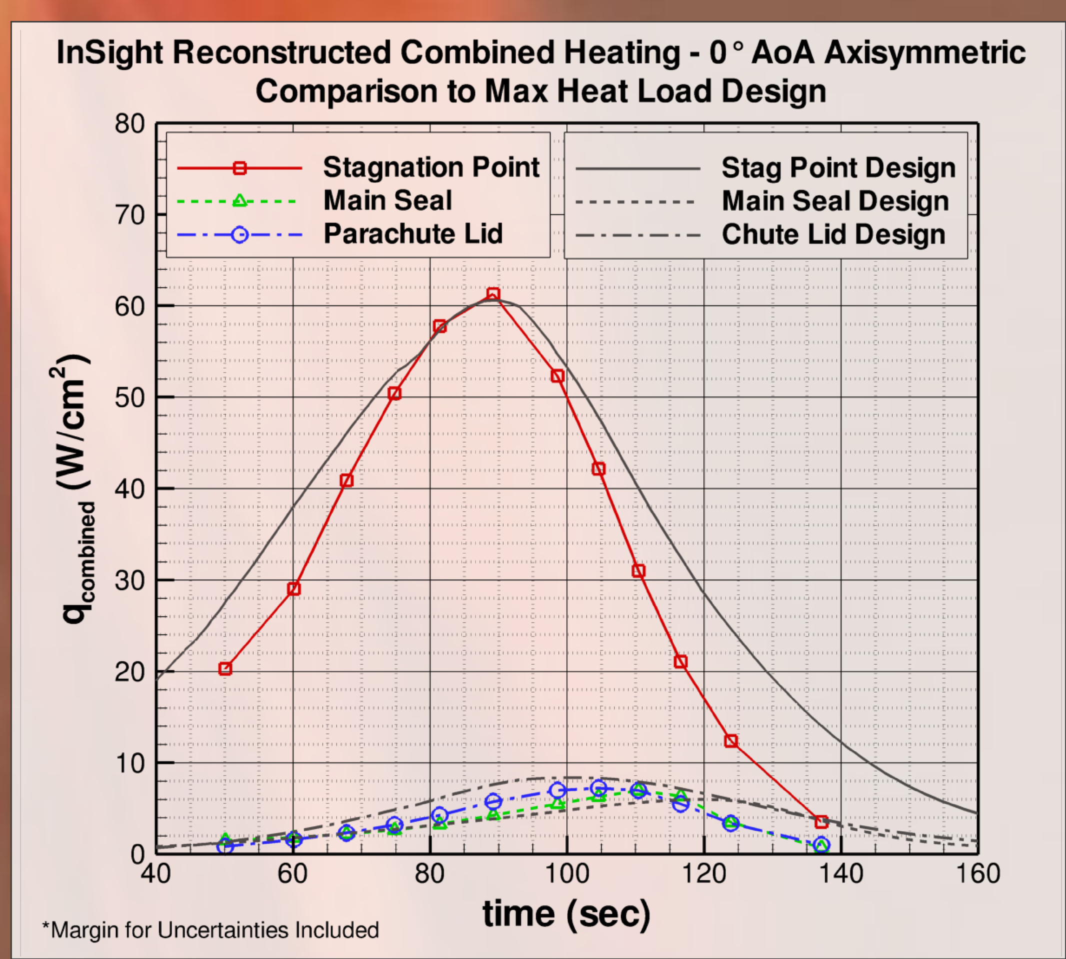


Comparison of radiative flux at main seal for both 0° and 4.9° AoA indicates little impact of flight dynamics on main seal environment. Stagnation point and chute lid are even less sensitive to AoA due to view factor.



How Did Flight Compare to Design?

- Peak heat fluxes during entry were enveloped by the max heat rate (MHR) design environment, and comparable to the max heat load (MHL) design trajectory fluxes.
- Integrated heating was within design environ.
- The main seal combined max heat flux was significantly lower than design with 10° AoA
- As expected, radiative heating computed for afterbody locations on the aeroshell is of the same order as the convective heat flux.



• Flight environments are computed using an InSight reconstructed trajectory, as described in IPPW2019 "Mars InSight Trajectory and Atmosphere Reconstruction"