



Emerging Technologies for Mars Exploration: Entry, Descent, and Landing

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MARS MISSIONS

OPERATIONAL 2001–2017

2018 AND BEYOND



Follow the Water

Explore Habitability

Seek Signs of Life

Prepare for Future Human Explorers

U.S. Missions

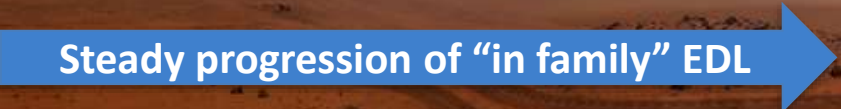
non-U.S. Missions

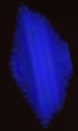
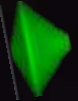
Viking 1/2 Pathfinder MER A/B Phoenix
 & InSight MSL



Diameter (m)	3.505	2.65	2.65	2.65	4.5
Entry Mass (kg)	930	585	840	602	3151
Landed Mass (kg)	603	360	539	364	1541
Landing Altitude (km)	-3.5	-1.5	-1.3	-3.5	-4.4
Peak Heat Rate (W/cm ²)	24	106	48	56	~120
Max Thrust (kN)	2.6			3.5	25
Landing Ellipse (km)	280x130	200x70	150x20	100x20	20x6.5

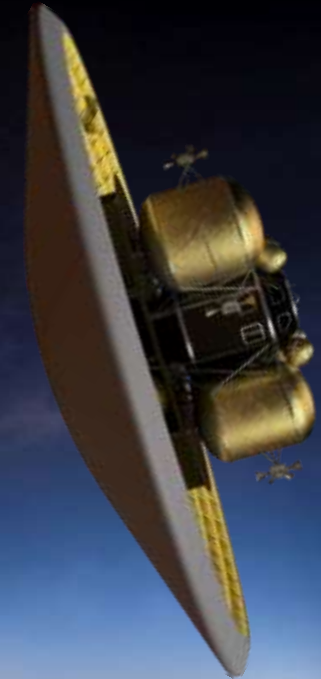
Steady progression of “in family” EDL



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Human Scale Lander (Projected)

Diameter (m)	16-19
Entry Mass (kg)	47-62 t
Landed Mass (kg)	36-47 t
Landing Altitude (km)	0
Peak Heat Rate (W/cm ²)	~120-350
Max Thrust (kN)	~800-960
Landing Ellipse (km)	0.1x0.1



Steady progression of “in family” EDL

New Approach Needed
for Human Class
Landers

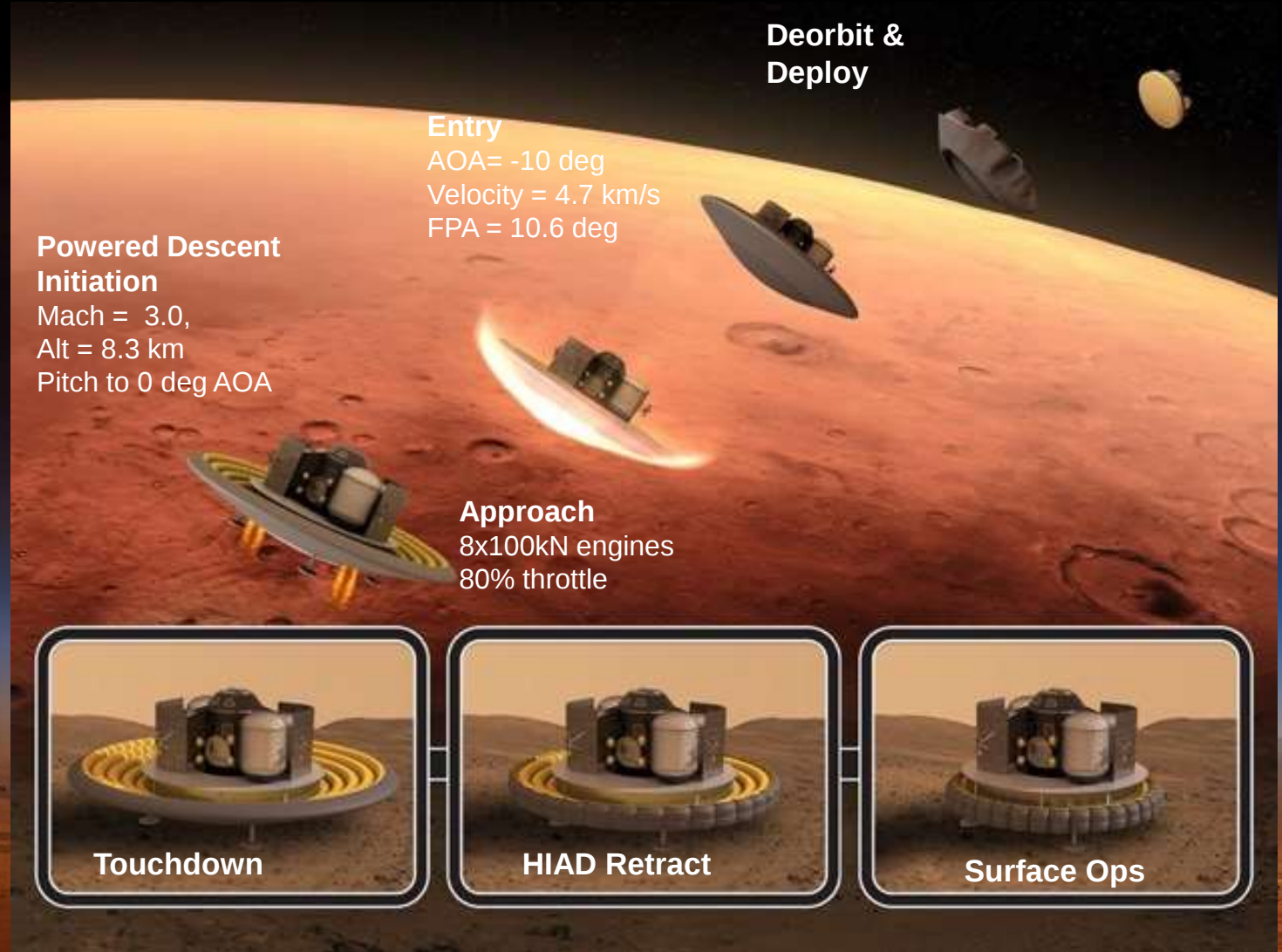


Human Mars Missions EDL Concept Maturation Status

- **Studies continue to inform near-term investments in technology and capabilities**
- **Recent work has led to significant EDL technology decisions:**
 - Parachutes are not viable for human class missions
 - Supersonic retro-propulsion must be employed
 - Precision landing is a must (< 50 m radius footprint)
 - Separation events during entry should be minimized
 - Hypersonic deceleration methods have been bounded; for further study
- **Simulation capability has matured further than ever (including “real” payloads, 6-DOF detail, sensor models)**

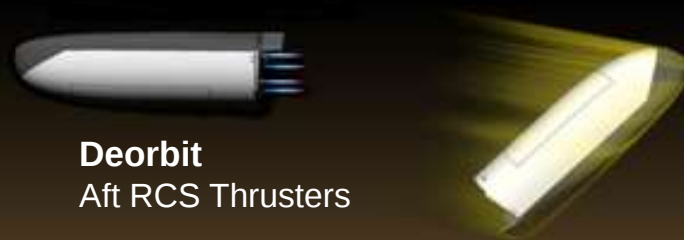
Deployable Decelerators:

Hypersonic Inflatable Aerodynamic Decelerator (HIAD) pictured below or
Adaptable Deployable Entry and Placement Technology (ADEPT)



Rigid Decelerators:

Mid Lift to Drag Ratio vehicle (pictured below) or Capsule



Deorbit
Aft RCS Thrusters

Entry

AOA= 55 deg
Velocity = 4.7 km/s
FPA = -10.8 deg



Powered Descent Initiation

Mach = 1.98, Alt = 3.2 km
Pitch up to 90 deg AOA

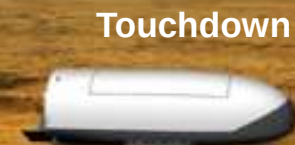


Approach

T/W = 1.25 Earth g
8x125kN engines
80% throttle
10 deg outward cant



Ground Operations

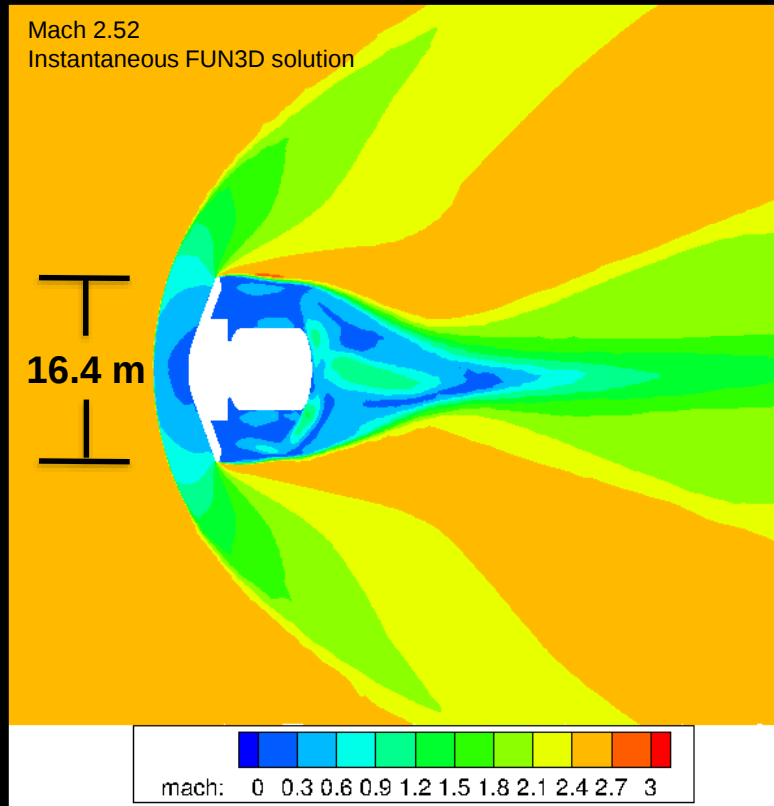


Touchdown

Supersonic Retro Propulsion

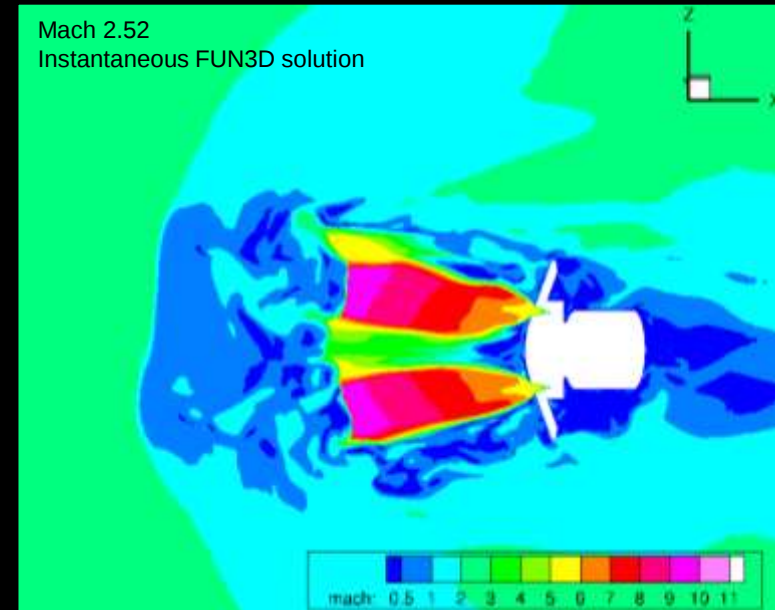


Engines Off



- Strong, detached shock near vehicle
- Heatshield is the flow obstruction
- Dominant forces and moments are steady
- Well-defined scaling relationships

Engines On

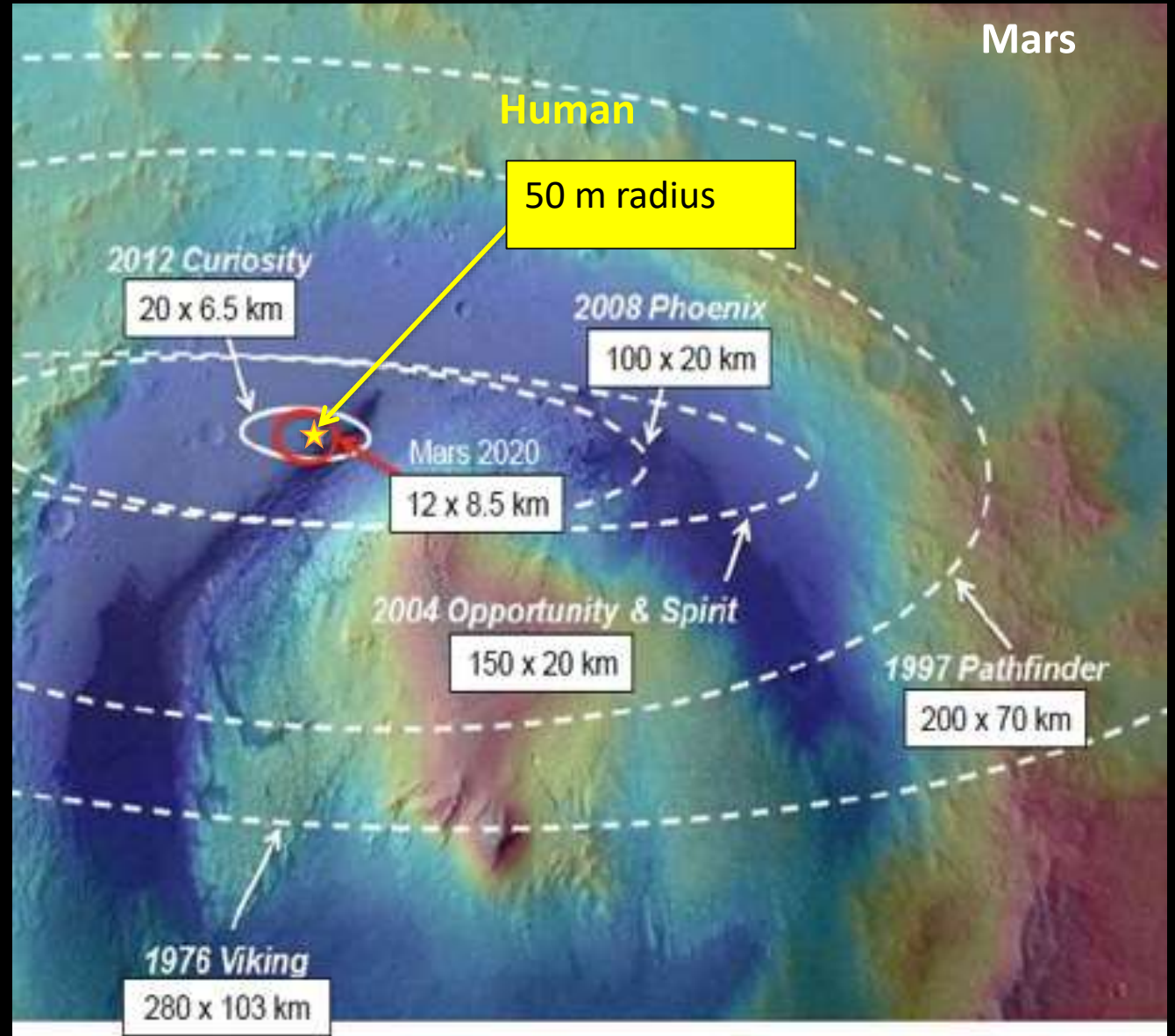


Source: A. Korzun (NASA LaRC), FUN3D solution, 2018.

- Shock displaced far upstream
- Complex, unsteady plume structure is part of the flow obstruction
- Aerodynamic forces and moments can be unsteady
- Less confidence in scaling relationships

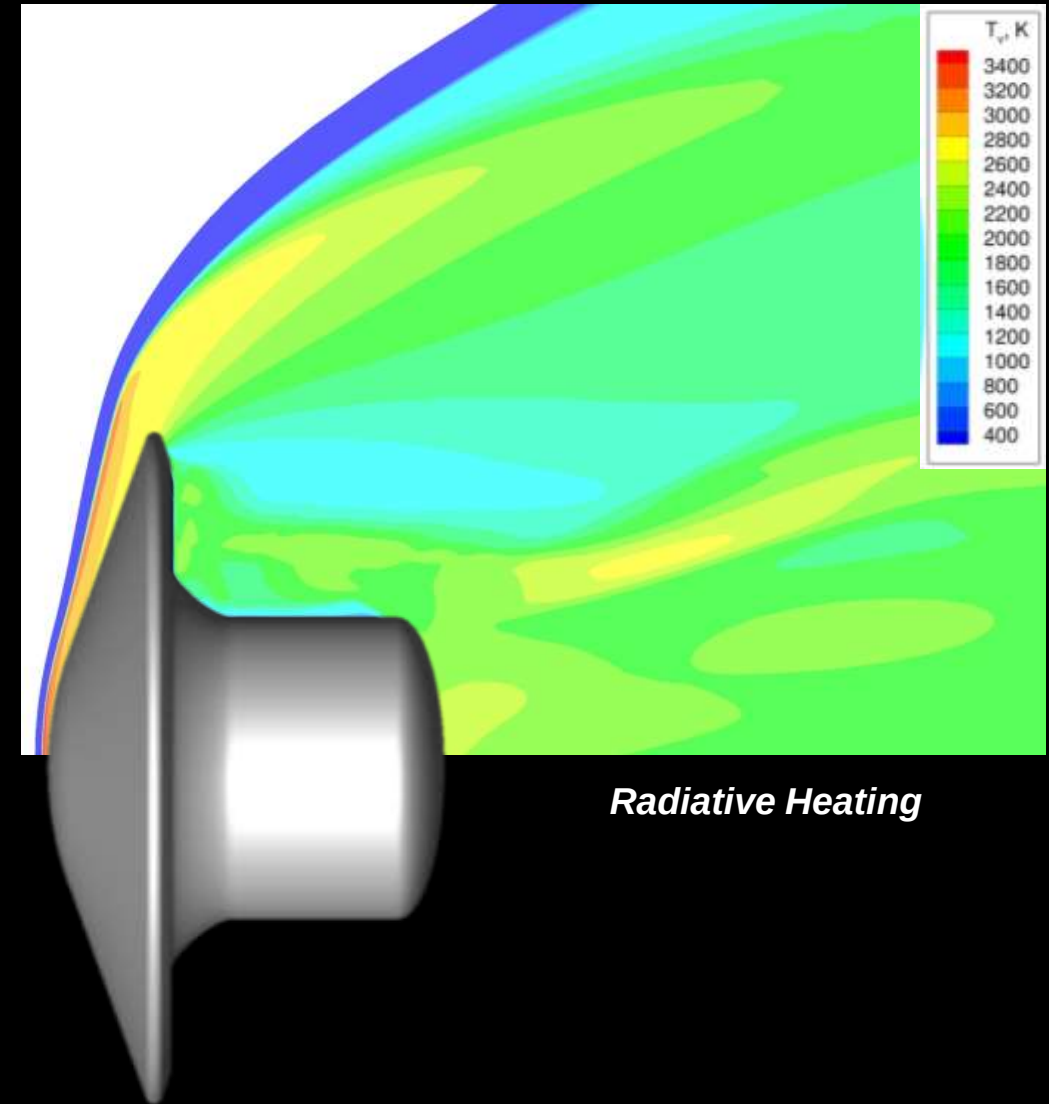
Precision Landing

- Landing precision is improving with each mission
- To get to the current state of the art system changes have been made along the way:
 - MSL had the first active hypersonic guidance
 - Mars 2020 employs a range trigger on the parachute, and uses Terrain Relative Navigation
- Human missions will need integrated guidance, improved velocimetry, and hazard detection/ avoidance



Vehicle and Payload Protection: Aft Body Heating

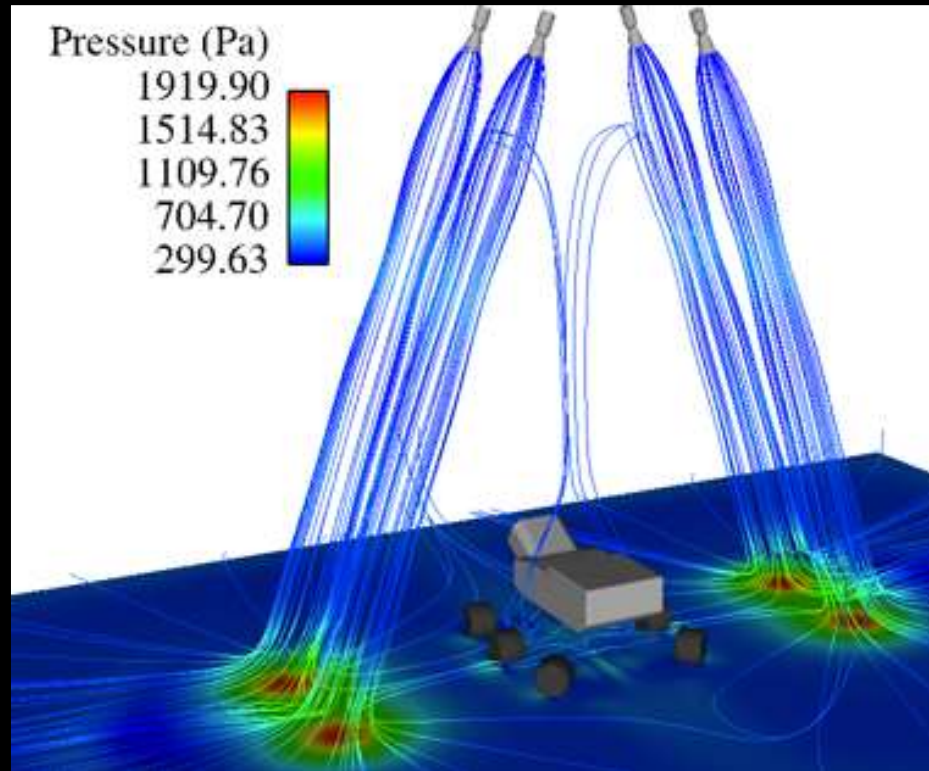
- Increase payload delivery and access by eliminating ridged backshell and using thin flexible TPS over payloads.
- Direct flow impingement can be avoided by limiting the angle of attack
- Significant uncertainty in aft body environments for radiative and convective heating could be reduced with additional backshell measurements on future flights



Vehicle and Payload Protection: Plume-Surface Interaction



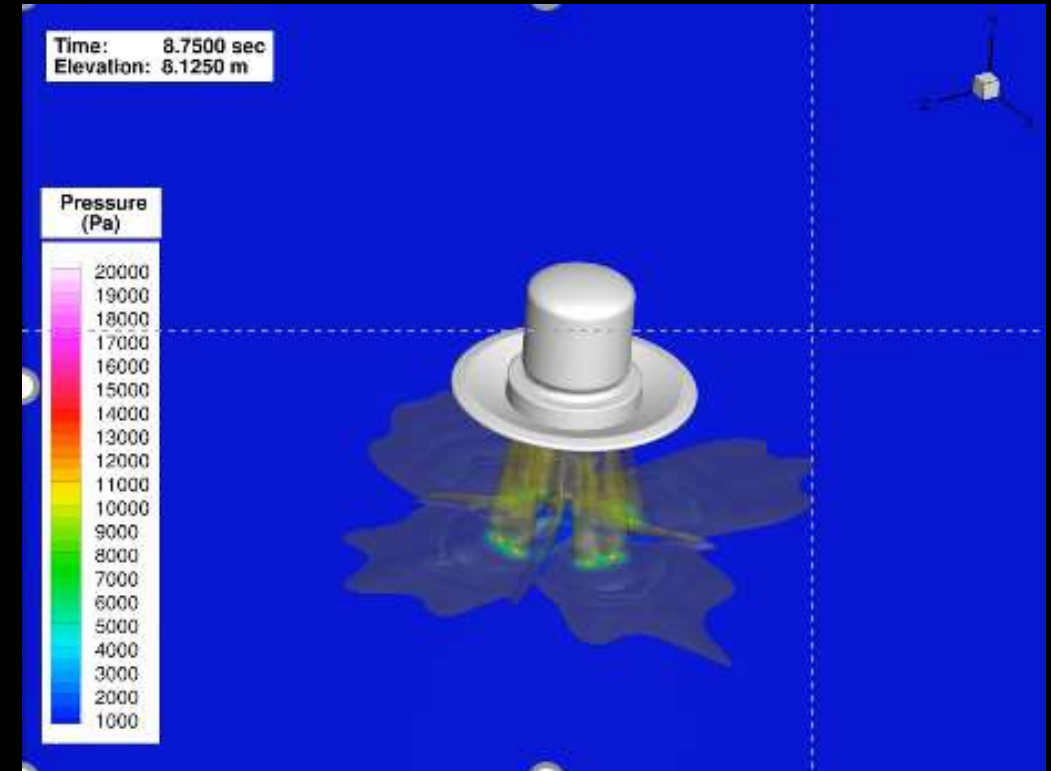
MSL/Curiosity



**5,600 → 700 lbf of thrust, 60+ft from surface -
Damaged instrument**

Est surface pressure ~ 2,000 Pa

Human Mars Lander



**180,000 lbf → 36,000 lbf of thrust, 10+ft from
surface - in proximity to other assets**

Est surface pressure peaks ~ 140,000 Pa

50x greater thrust

70x greater surface pressure



