National Aeronautics and Space Administration

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

IEEE Aerospace Conference

March 6, 2019

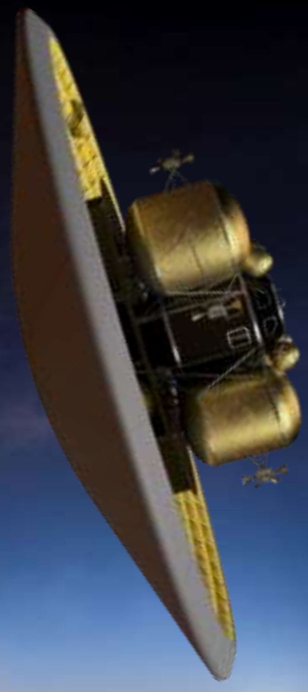
Tara Polsgrove
NASA Marshall Space Flight Center
with special thanks to Michelle M. Munk & Alicia Dwyer Cianciolo


MARS MISSIONS
OPERATIONAL 2001–2017
2018 AND BEYOND
Mars Odyssey (2001)
Mars Express (ESA) (2003)
Mars Reconnaissance Orbiter (2005)
MAVEN (2013)
Mars Orbiter Mission (ISRO) (2013)
Trace Gas Orbiter (ESA/RSA) (2016)
HOPE (UAE)
MMX (JAXA)
Mars Orbiter (China)
Mars Sample Return Orbiter
Mars Lander & Rover (China)
Mars Sample Return Lander
Opportunity Rover (2003)
Curiosity Rover (2011)
InSight
Mars 2020 Rover (NASA)
Mars Sample Return (China)
ExoMars Rover (ESA/RSA)
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

	Viking 1/2	Pathfinder	MER A/B	Phoenix & InSight	MSL	Human Scale Lander (Projected)
Diameter (m)	3.505	2.65	2.65	2.65	4.5	16-19
Entry Mass (kg)	930	585	840	602	3151	47-62 t
Landed Mass (kg)	603	360	539	364	1541	36-47 t
Landing Altitude (km)	-3.5	-1.5	-1.3	-3.5	-4.4	0
Peak Heat Rate (W/cm^2)	24	106	48	56	~120	~120-350
Max Thrust (kN)	2.6			3.5	25	~800-960
Landing Ellipse (km)	280x130	200x70	150x20	100x20	20x6.5	0.1x0.1



Steady progression of “in family” EDL

New Approach Needed for Human Class Landers

Human Mars Missions EDL Concept Maturation Status

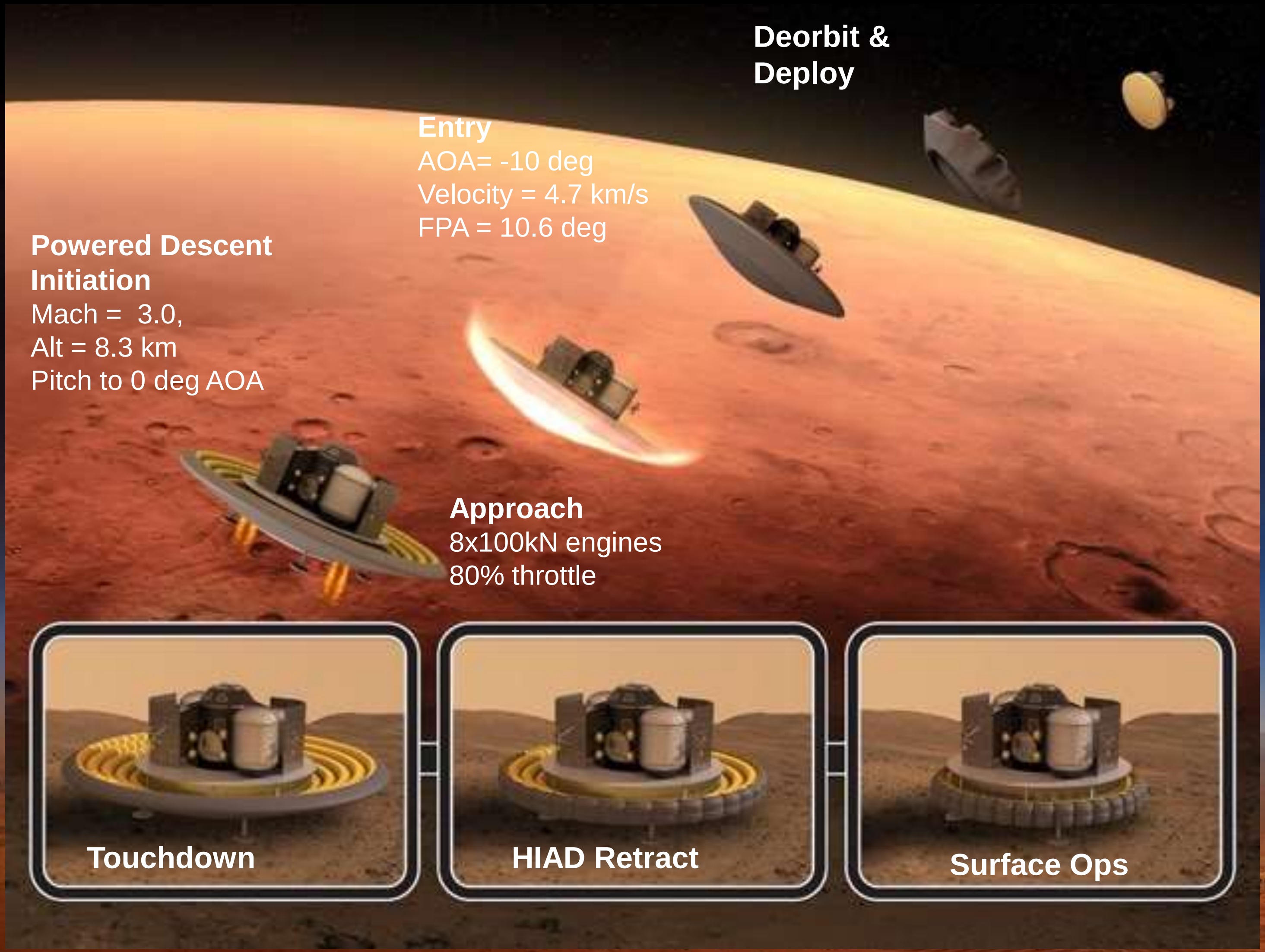
- **Studies continue to inform near-term investments in technology and capabilities**

- **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)**

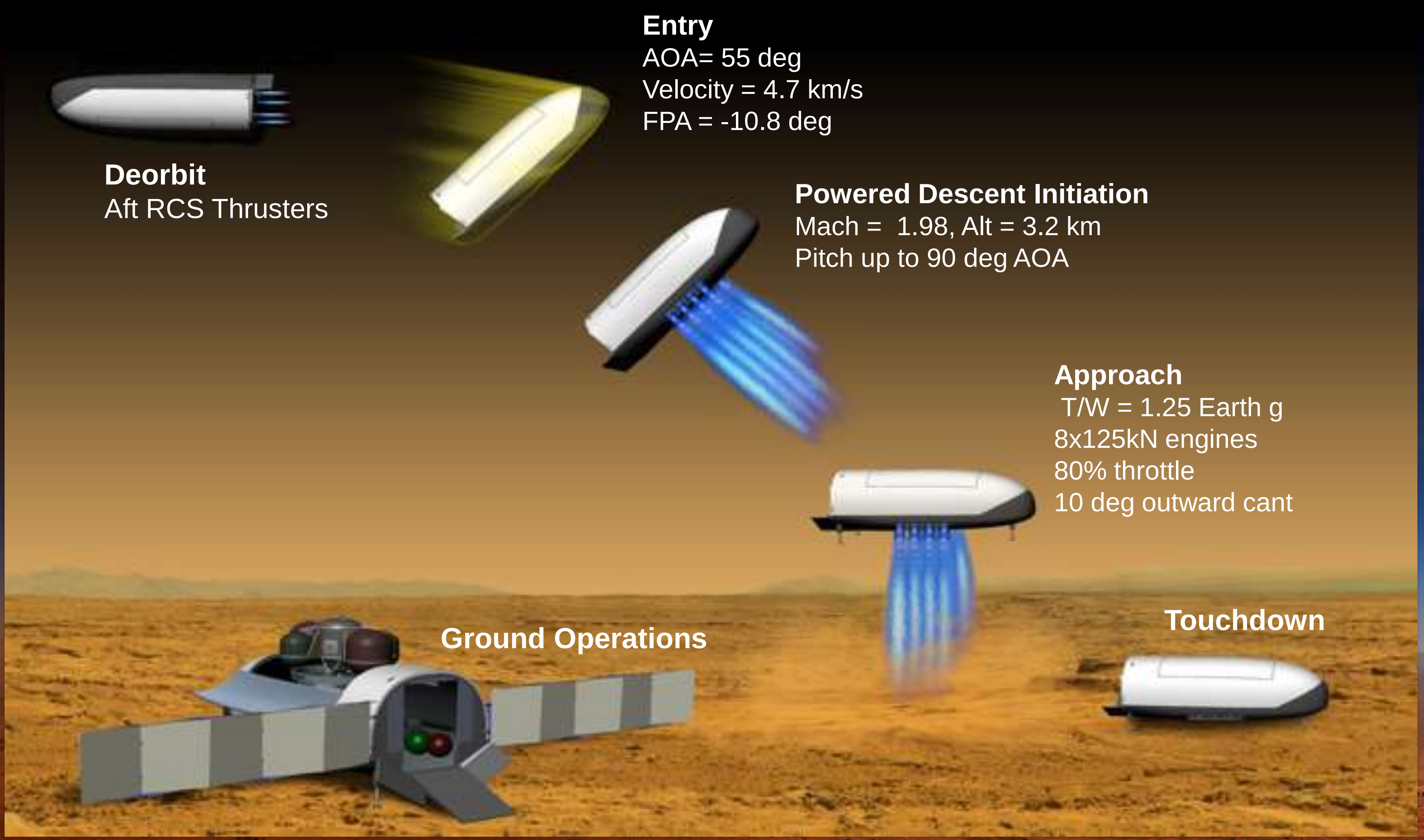
Deployable Decelerators:

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



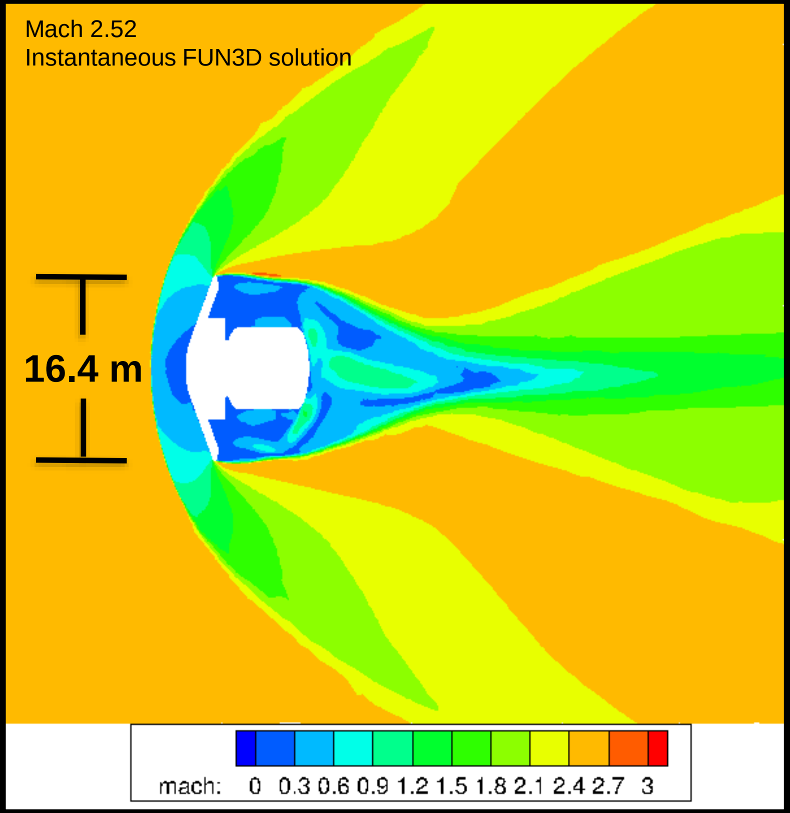
Rigid Decelerators:

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



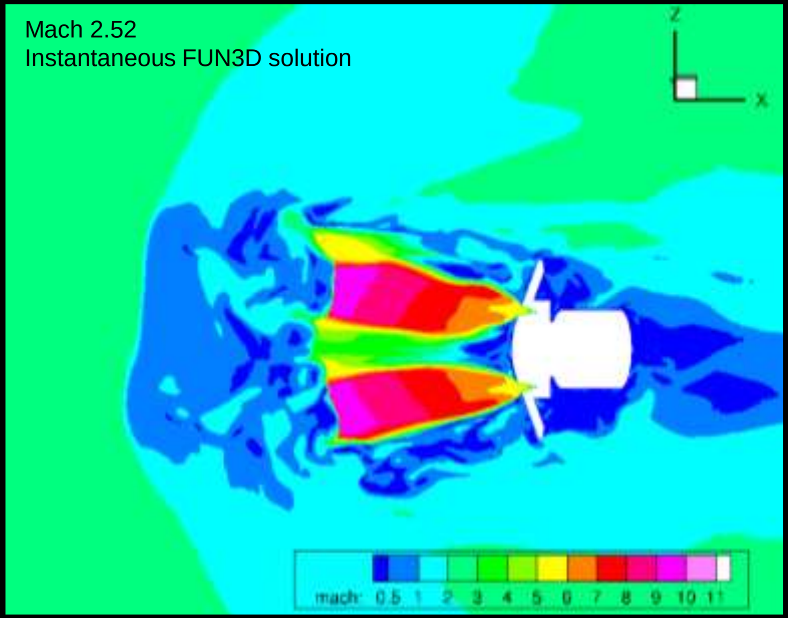
Supersonic Retro Propulsion

Engines Off



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

Engines On

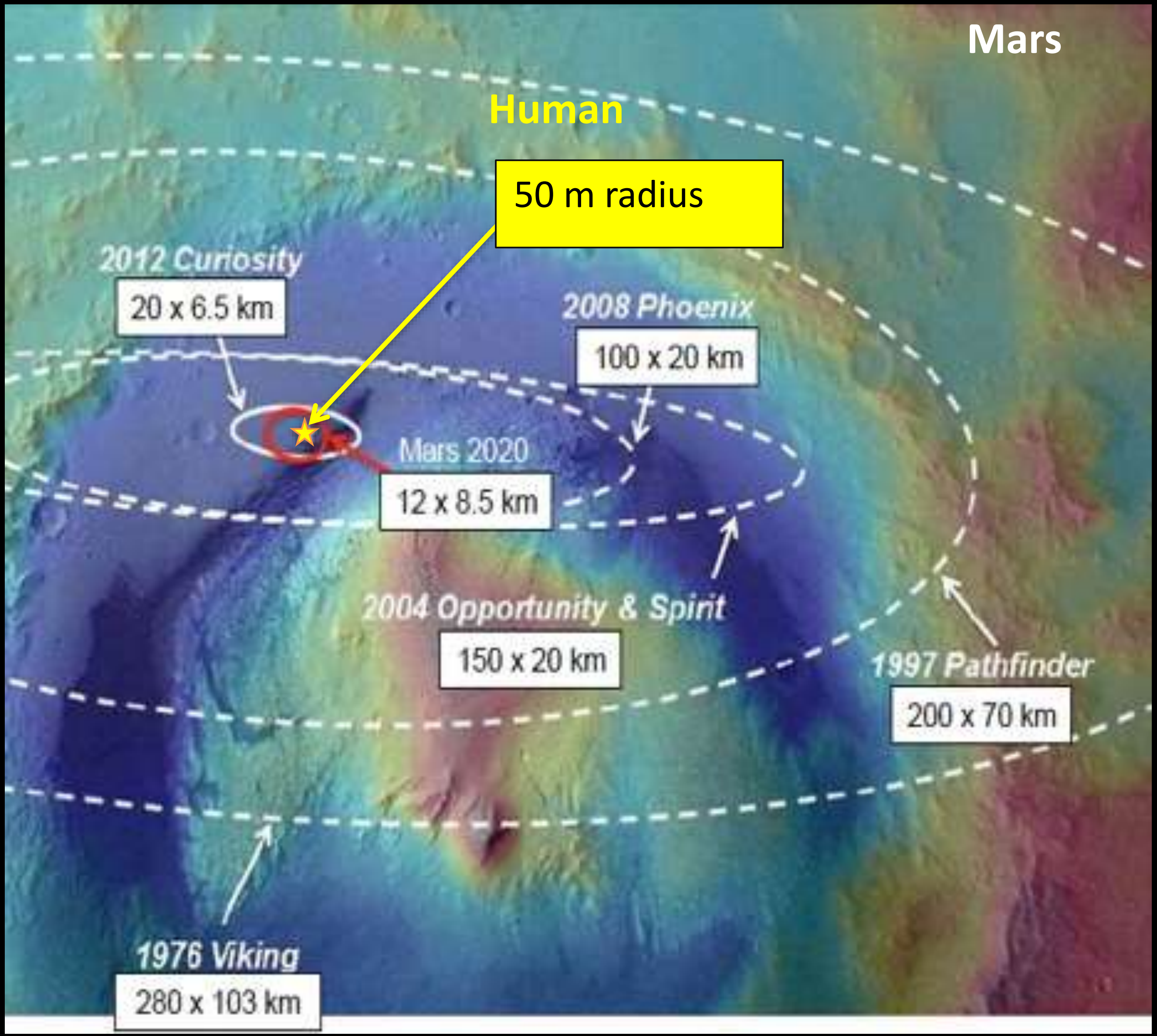


Source: A. Korzun (NASA LaRC), FUN3D solution, 2018.

- 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**

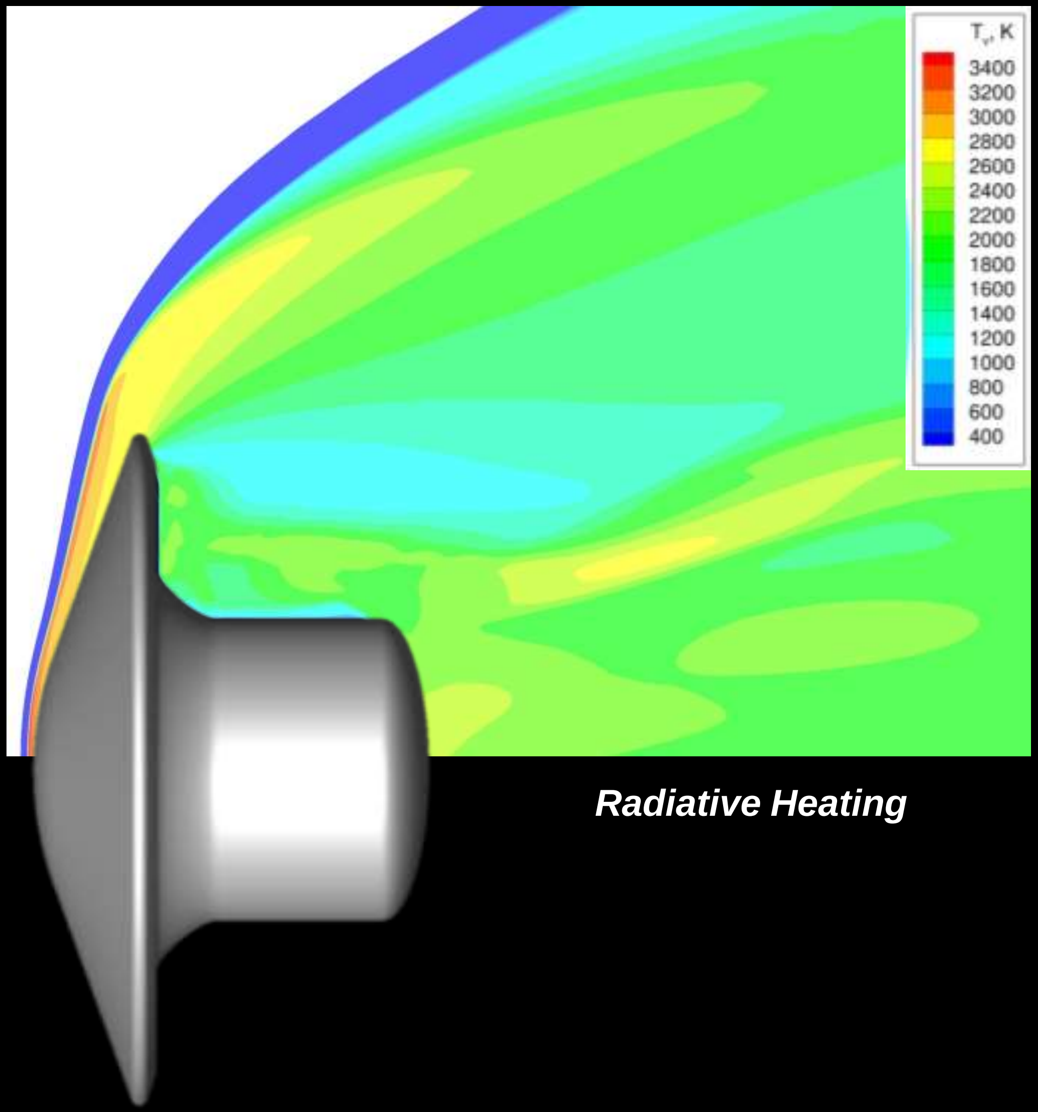


Vehicle and Payload Protection: Aft Body Heating

- **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**

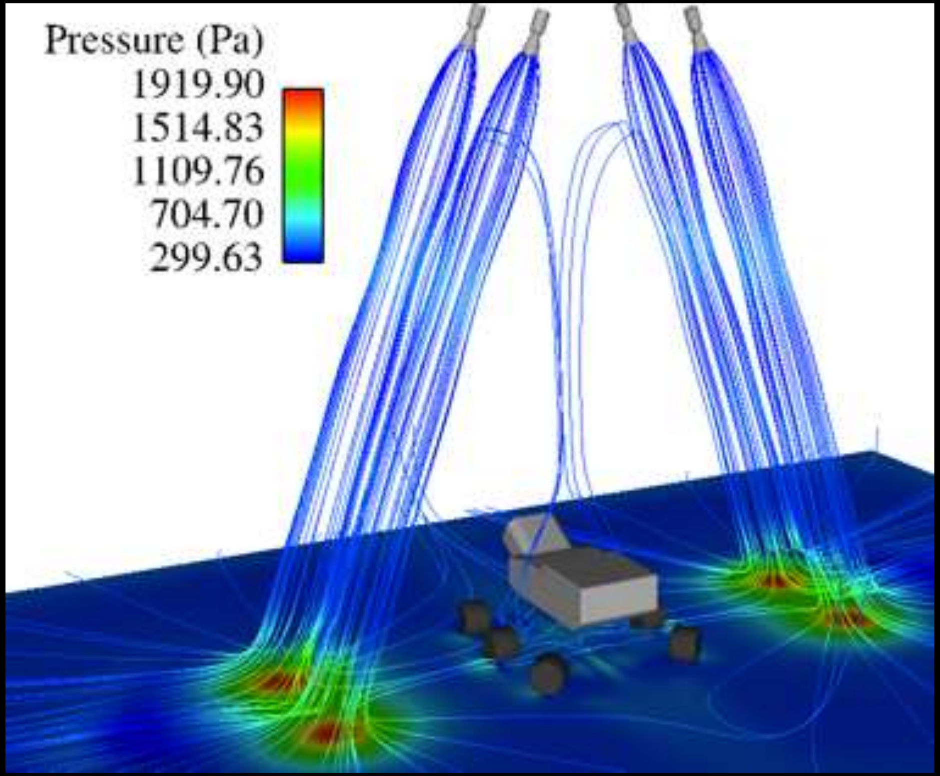
- **Significant uncertainty in aft body environments for radiative and convective heating could be reduced with additional backshell measurements on future flights**



Radiative Heating

Vehicle and Payload Protection: Plume-Surface Interaction

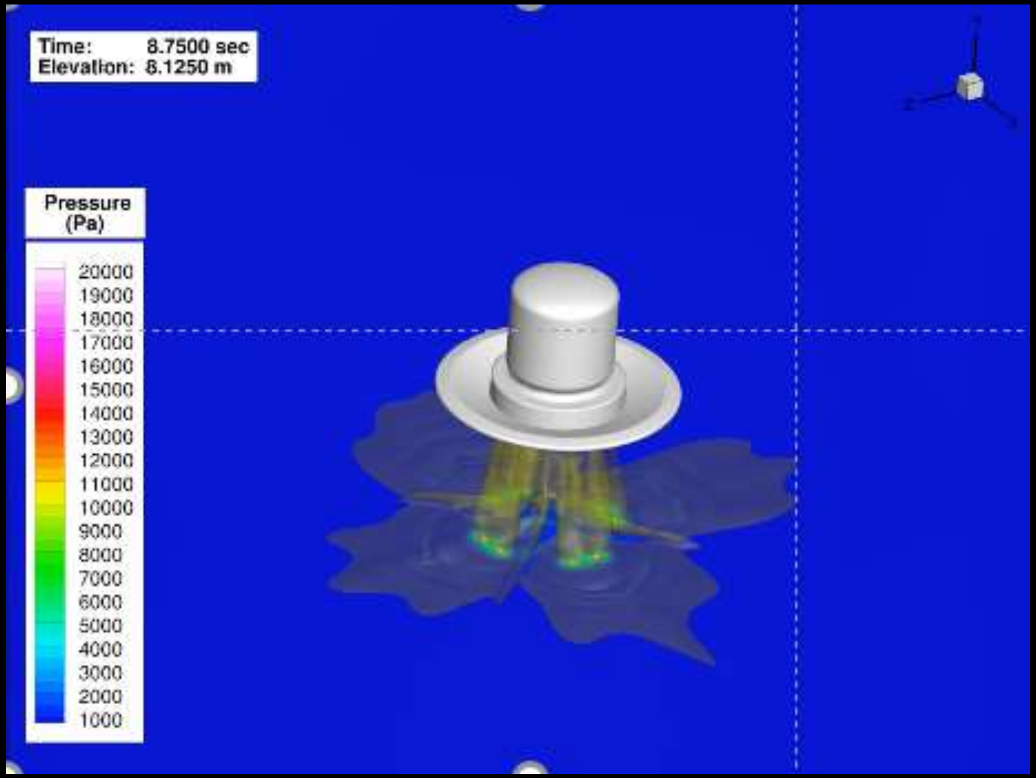
MSL/Curiosity



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

NASA