Advances in Entry System Technologies – Continuing the Ames' Innovation Heritage

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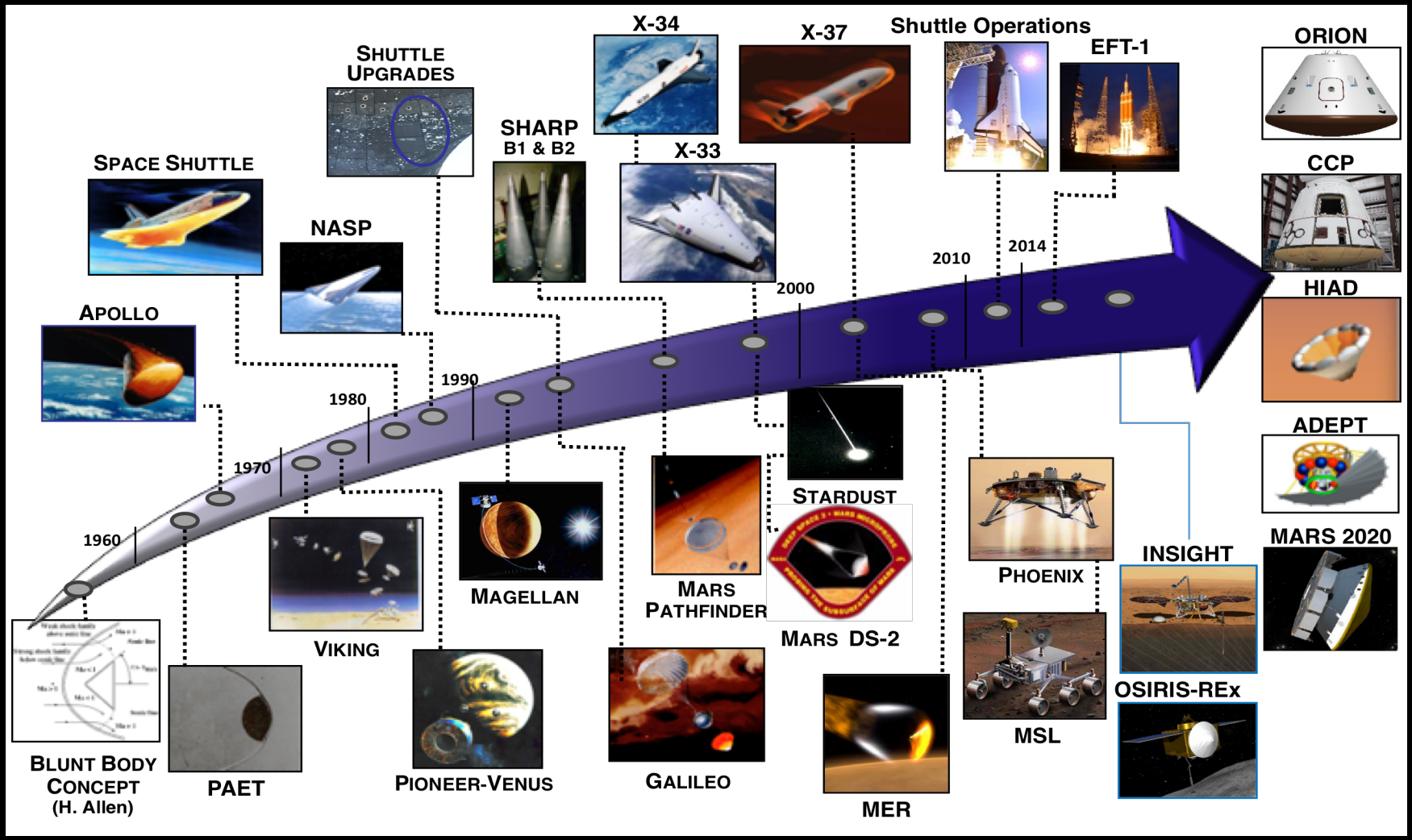
What is this talk about?

- Ames has a **long history of innovations** and **contributions** towards enabling NASA missions
  - Entry Systems and Technology Division at Ames, leveraging the past successes, is continuing this tradition.
- This talk highlights some of the recent innovations that are enabling current missions and laying the ground work for future scientific and human exploration "**as only Ames can**".

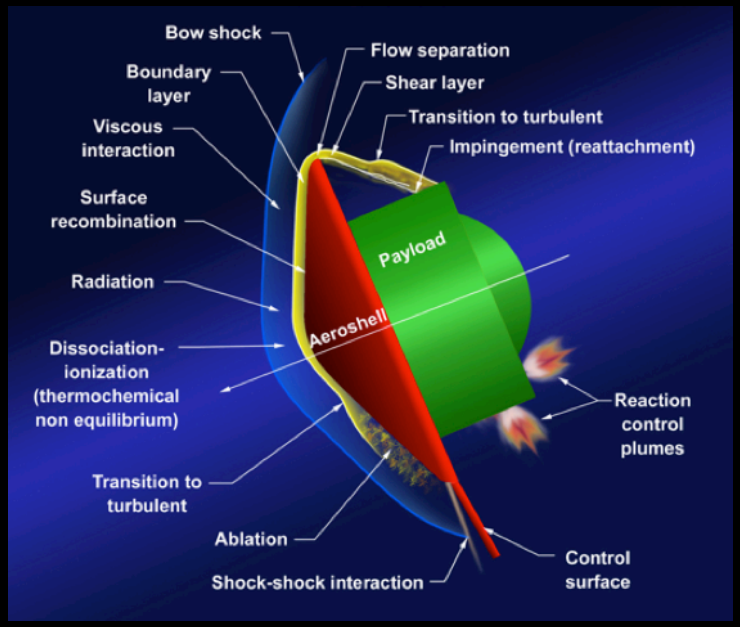
Ames' Heritage and Continuing Contributions



*** H. Julian Allen and Al Eggers, "A Study of the Motion and Aerodynamic Heating of Ballistic Missiles Entering the Earth's Atmosphere at High Supersonic Speeds," NACA-RM-A53D28, 1953 / NACA-TR-1381, 1958.**

Hypervelocity Entry is a Hard Problem !

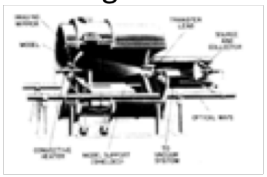
Use of atmospheric drag is the most efficient way to slow down. Protection from the entry heating demands comprehensive understanding of the hypervelocity, reacting flow (aero-thermodynamics), and selection, design, testing and verification of the integrated entry system, especially thermal protection system.

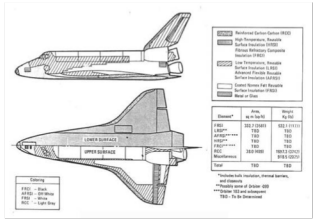


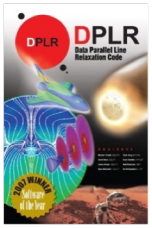
Entry and Thermal Protection System have to be fail-safe, mass efficient and robust.

NASA Ames Entry Systems Inventions

Advanced Entry Heating Simulator

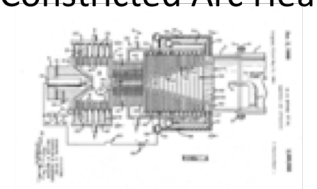






ADEPT

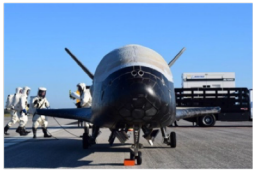
Constricted Arc Heater



RCG, LI-2200
FRCI, AFRSI
AETB, TUFI

SIRCA

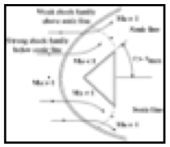
TUFROC

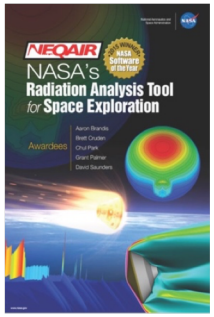


3DMAT

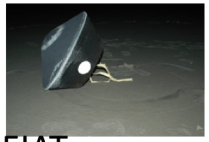
1960 1970 1980 1990 2000 2010 2020

Blunt Body Concept* (1951)

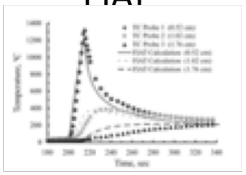




PICA

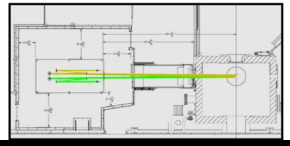


FIAT



HEEET

Laser-Enhanced IHF

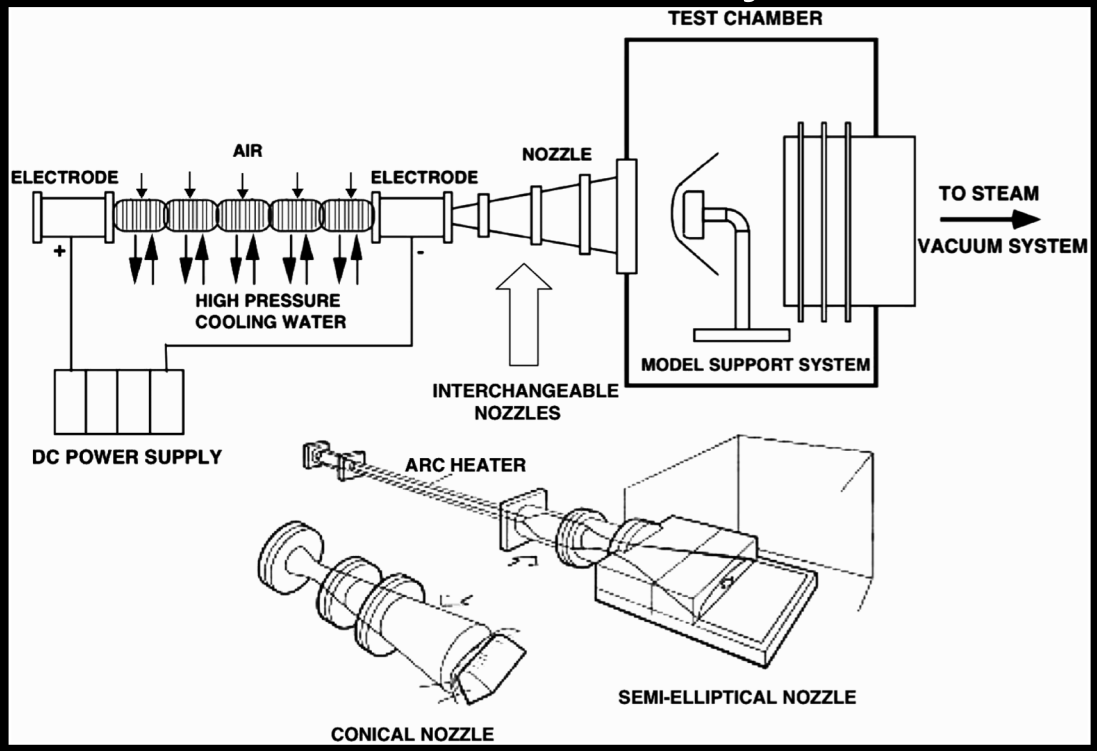


Recent Innovations

- Laser Enhanced Arc Jet Testing
- 3-D MAT
- HEEET
- ADEPT

Laser Enhanced Arcjet Facility (LEAF)

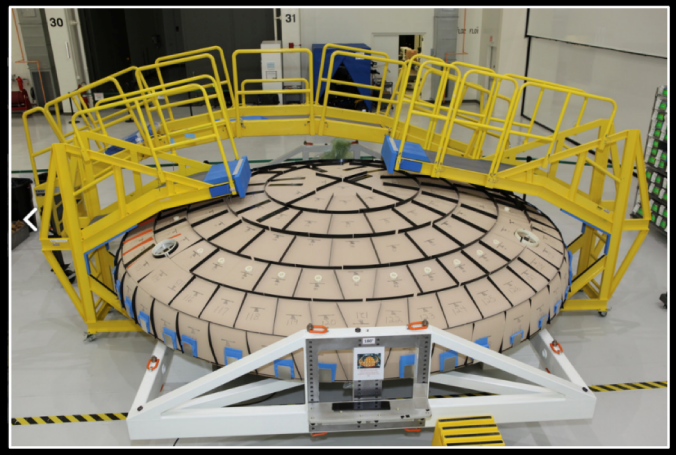
Conventional arc jet

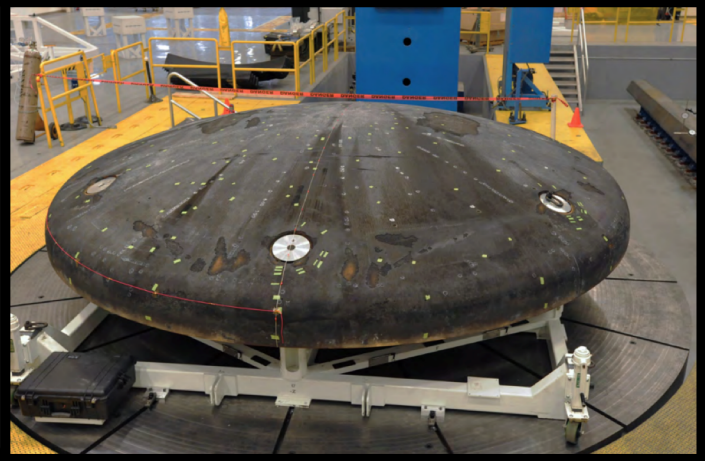


- **Why Laser Enhanced arc jet?**
- **LEAF system at Ames**
- **Exploratory tests with Orion heat-shield material**

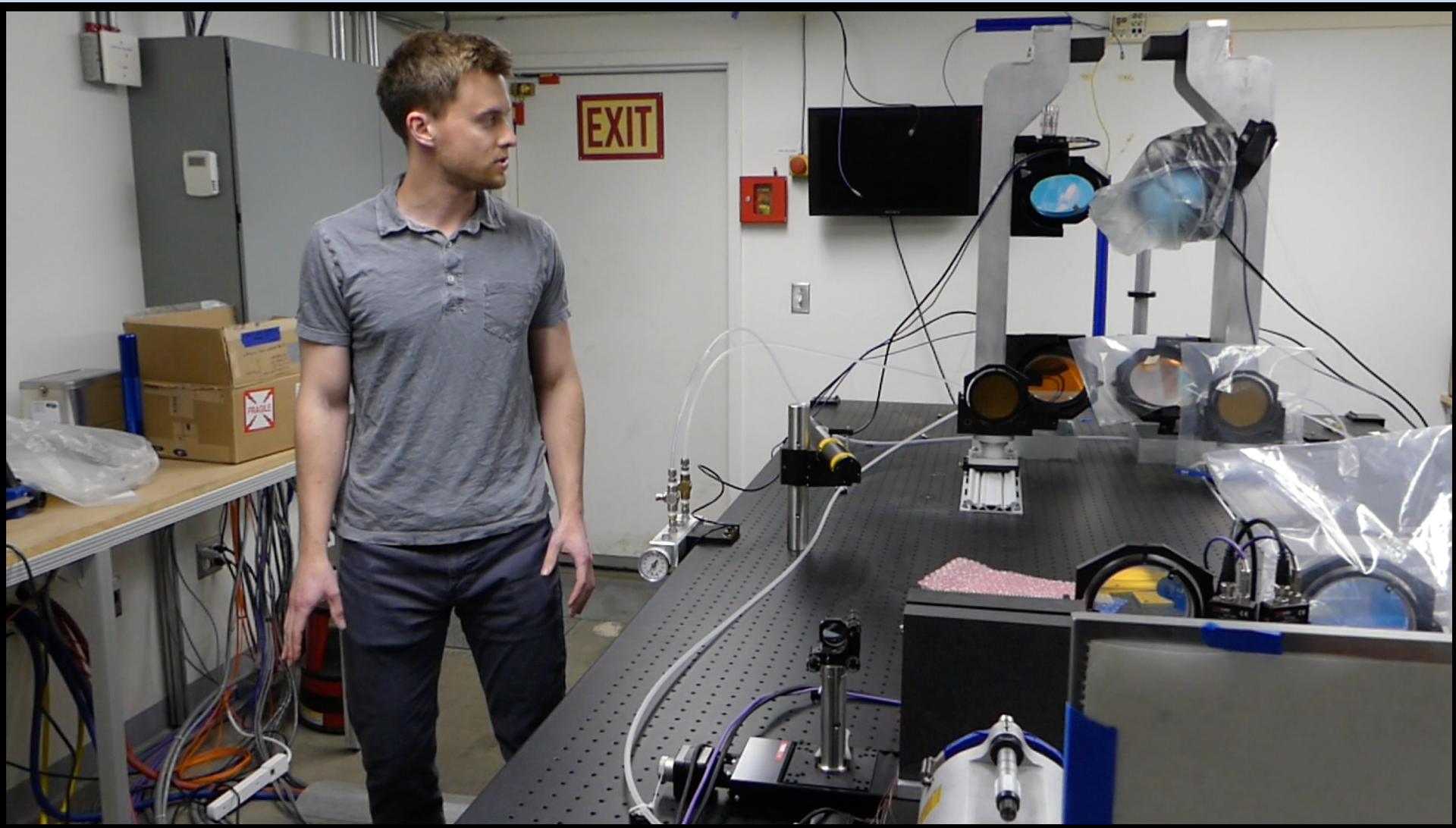
Why do we need a Laser Enhanced Arcjet Facility (LEAF) ?

- Orion Heat shield design has to withstand both shock layer radiation and convective heating
- Heat Shield System Certification Challenges
  - Tiled System with gap-filler
  - Compression-pad region

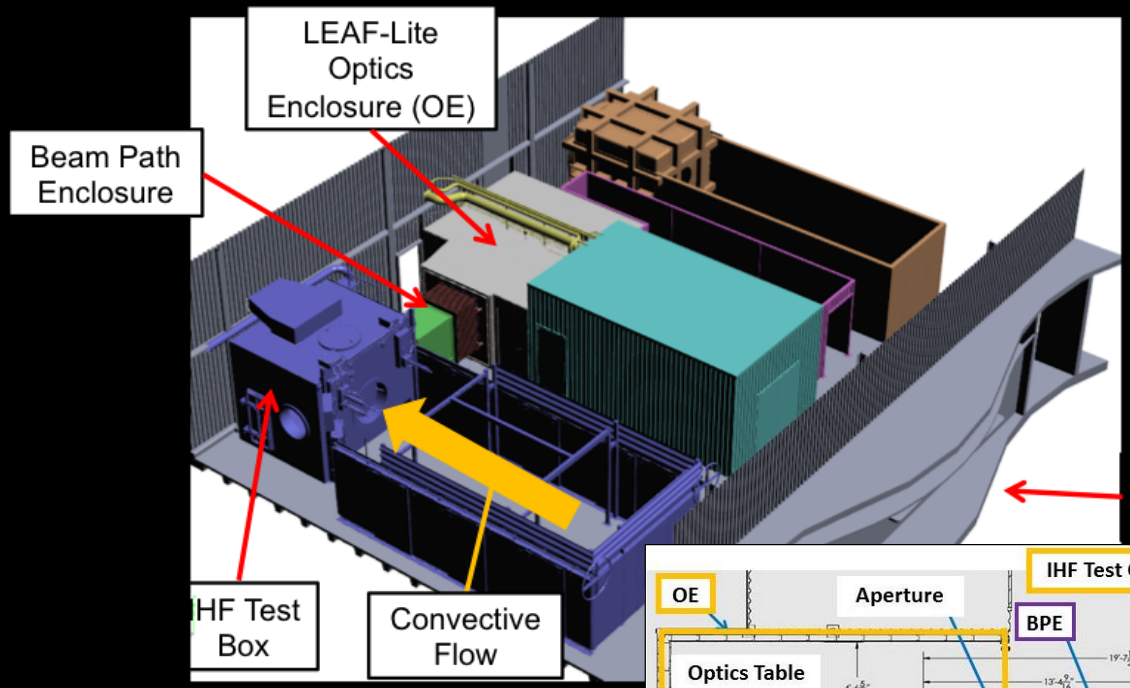


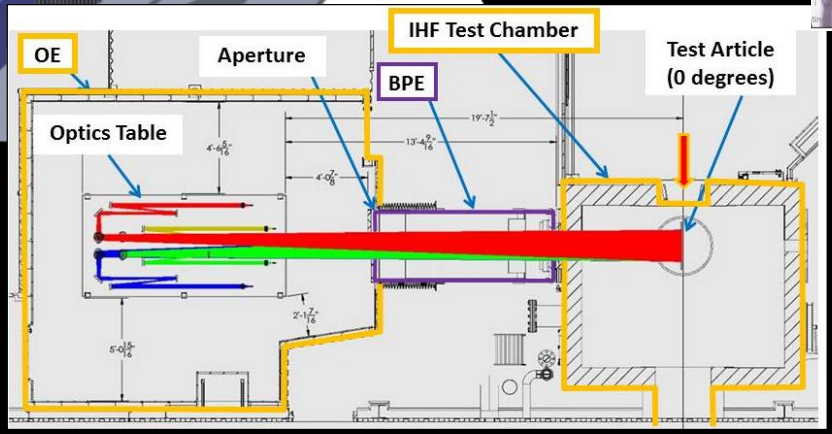


LEAF Explained (by the Lead Engineer)



Integrated IHF and LEAF Setup

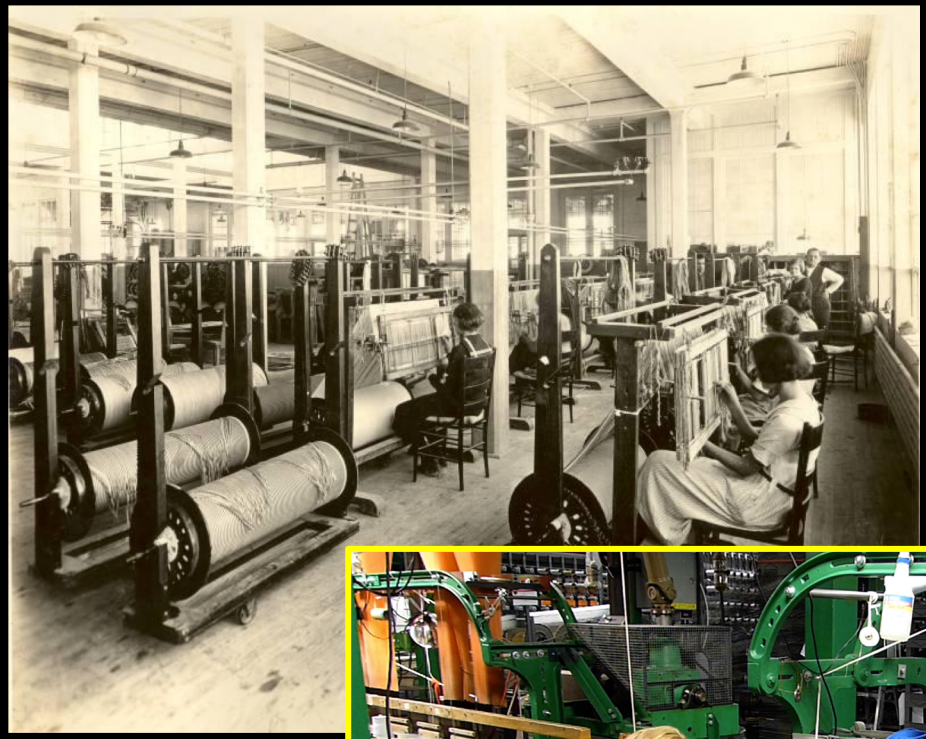


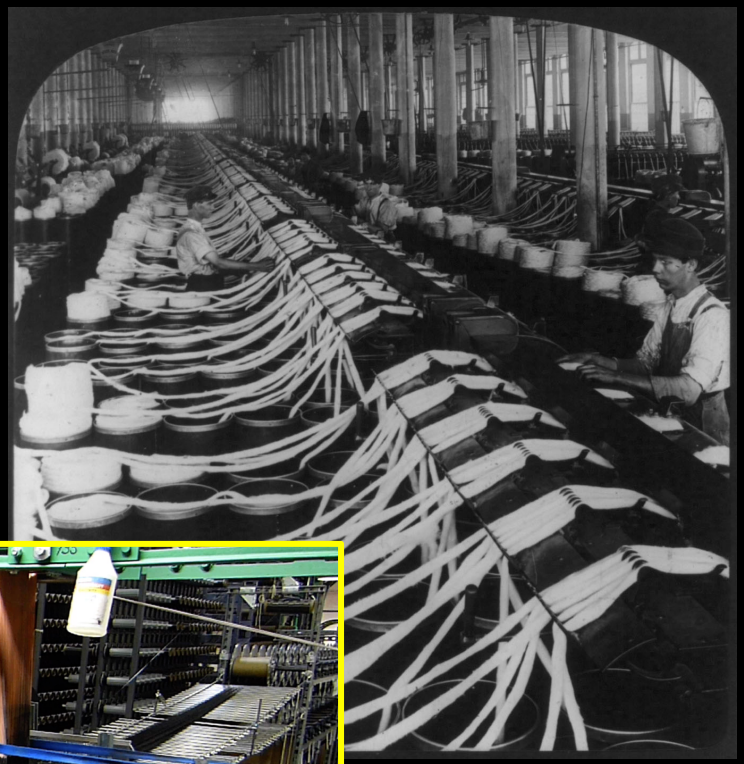


Up to 200 kW laser power with 60 MW arc jet provides unique test capability

Avcoat: Arc jet flow on – Laser on Combined Heating

Weaving Technology

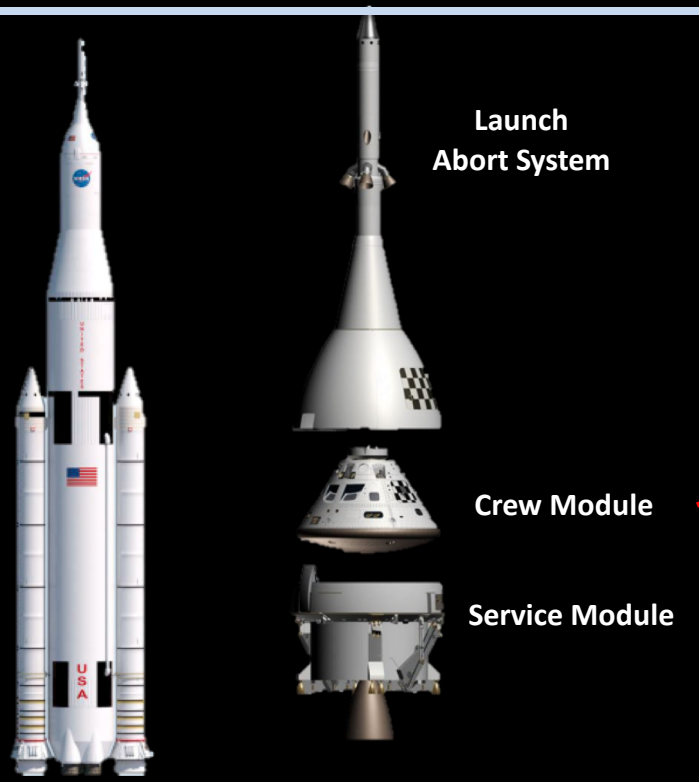


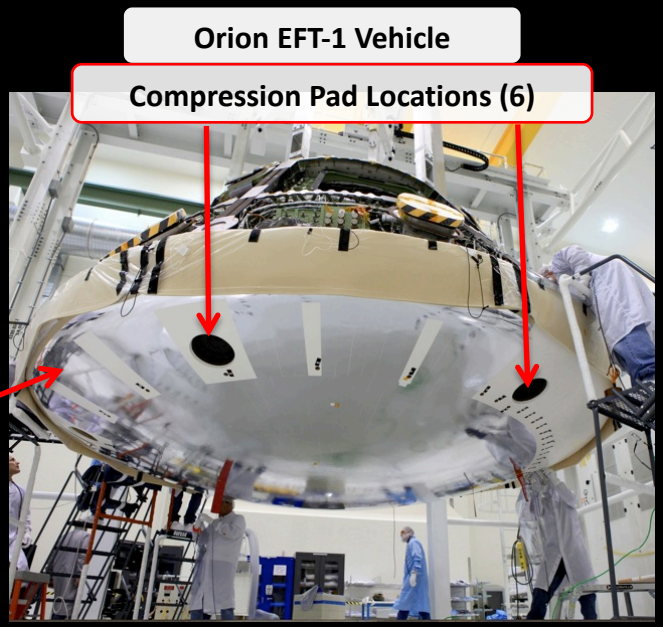


3-D Weaving

3-D Multi-functional Ablative TPS (3-D MAT) Enabling Orion

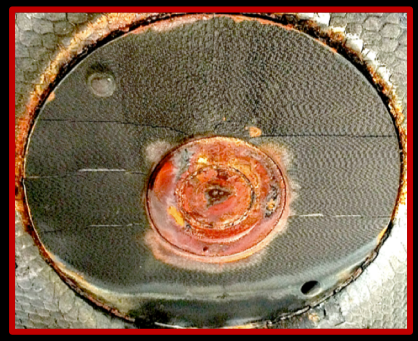
Background: Orion Compression Pad





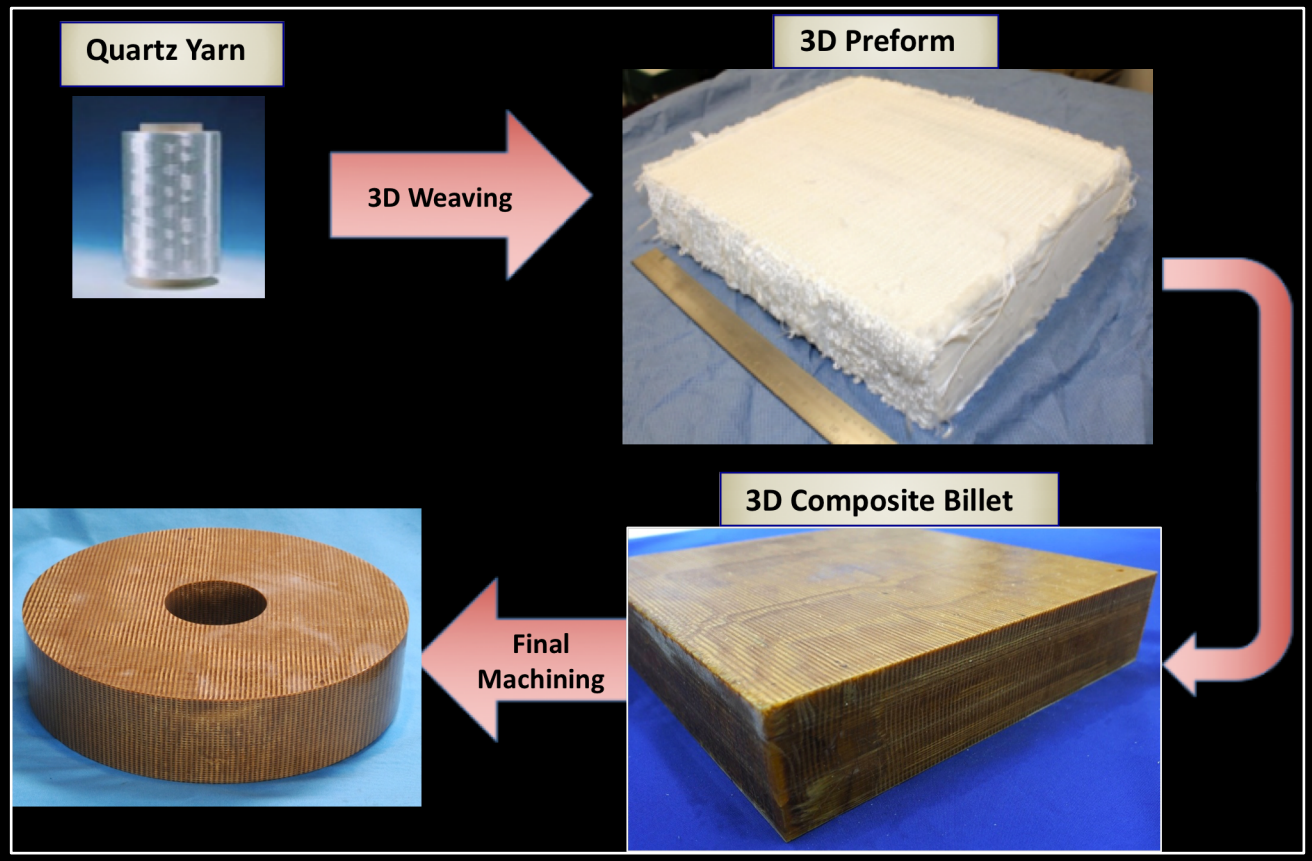
Orion compression pads are the interface between Crew Module (CM) & Service Module (SM) Required to withstand:

- **Launch & ascent structural loads**
- **Pyro-shock (CM/SM separation event)**
- **Earth re-entry (high heating, ablation)**



All EFT-1 carbon phenolic pads contained inter-laminar cracks post-flight

Two Technical Challenges Need to be Addressed – Weaving and Resin Infusion

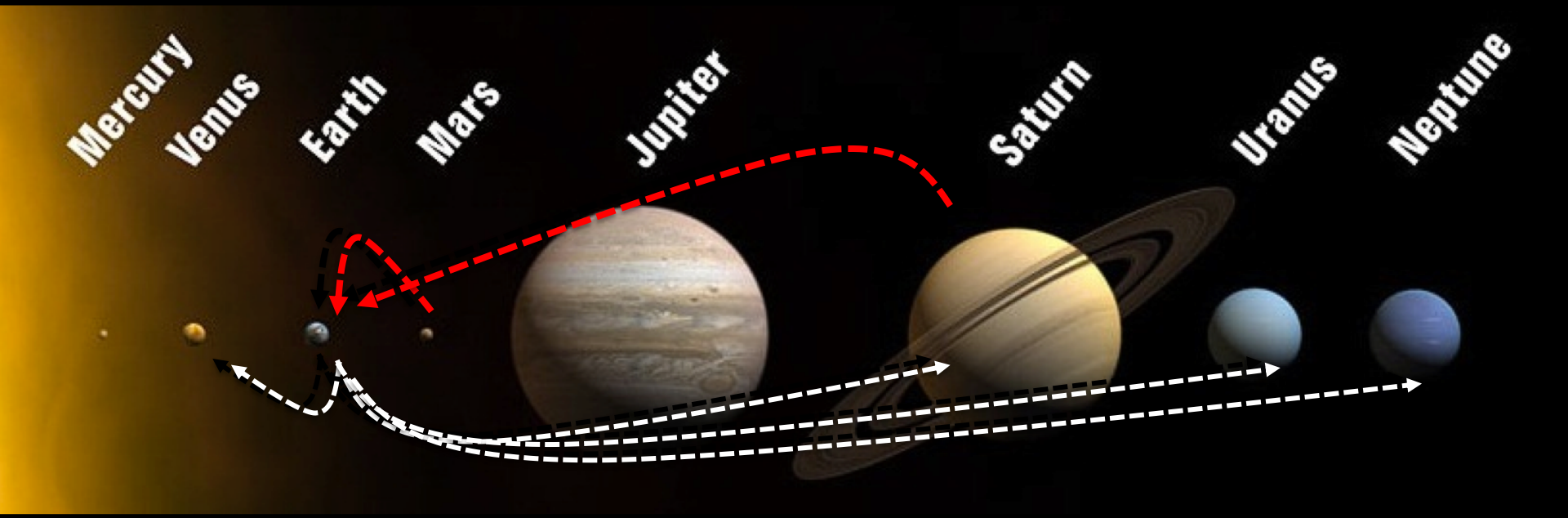


- **Bigger Challenge: Establishing partnership with industry (weaving and resin infusion), experimenting, testing, design assessment and demonstrating the capability for mission adoption in less than 36 months and under $3M.**

Arcjet testing of 3-D MAT

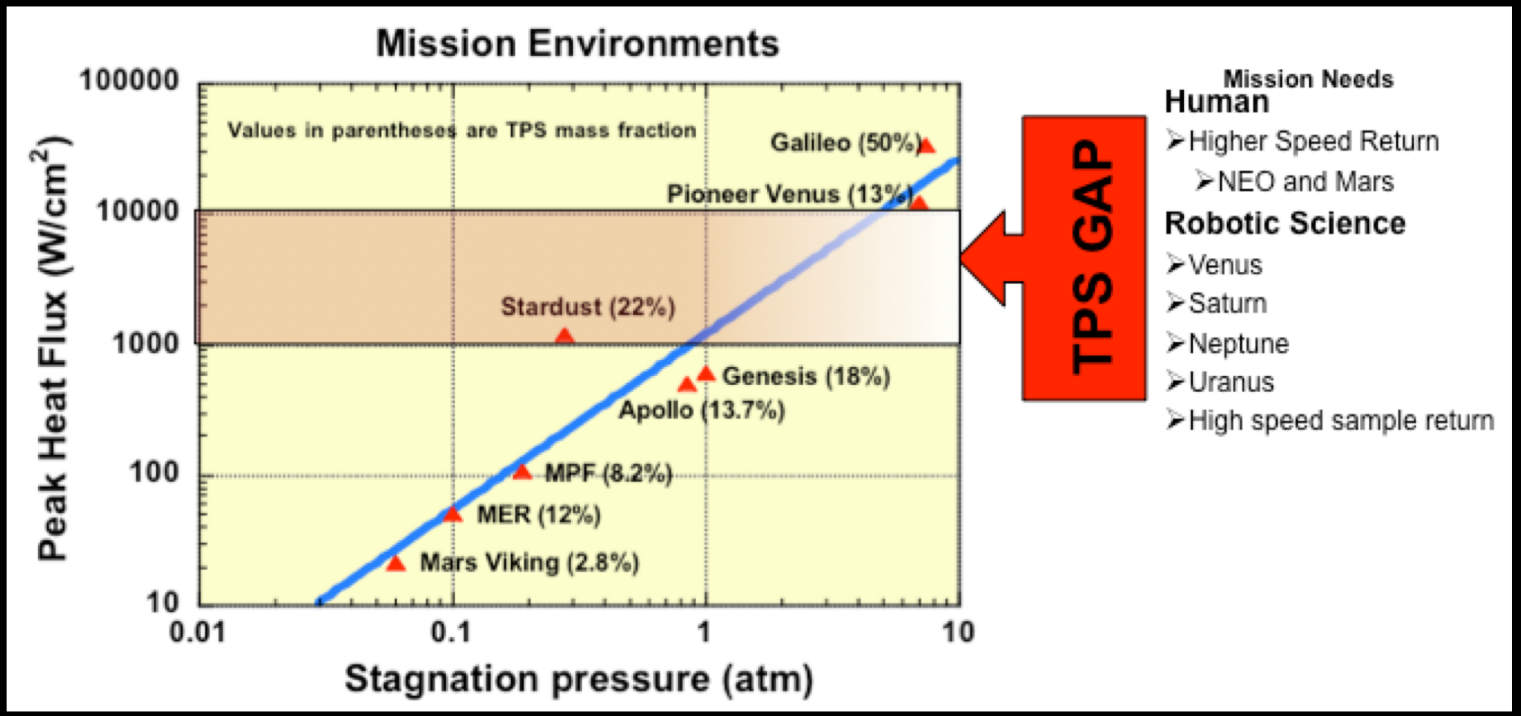
3-D Multi-functional Ablative TPS (3-D MAT)

Heatshield for Extreme Entry Environment Technology (HEEET)



Enabling Missions in the Coming Decades

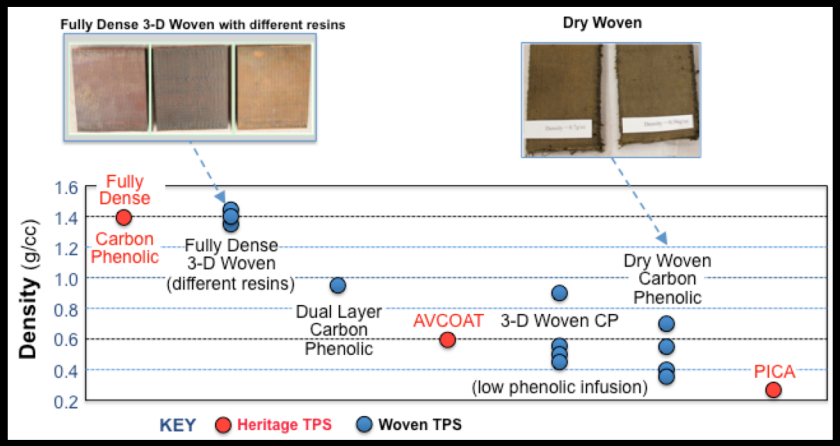
- **Decadal Survey Recommended Missions (NF) require:**
  - **Revival of heritage carbon phenolic (HCP), or**
  - **Development of advanced TPS that is superior in performance to HCP, as robust as HCP and sustainable in the longer term**

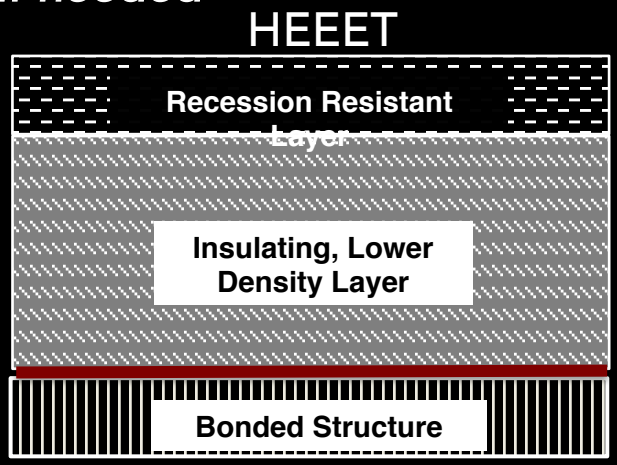


Current ablative TPS State of the Art

3-D Woven TPS and HEEET

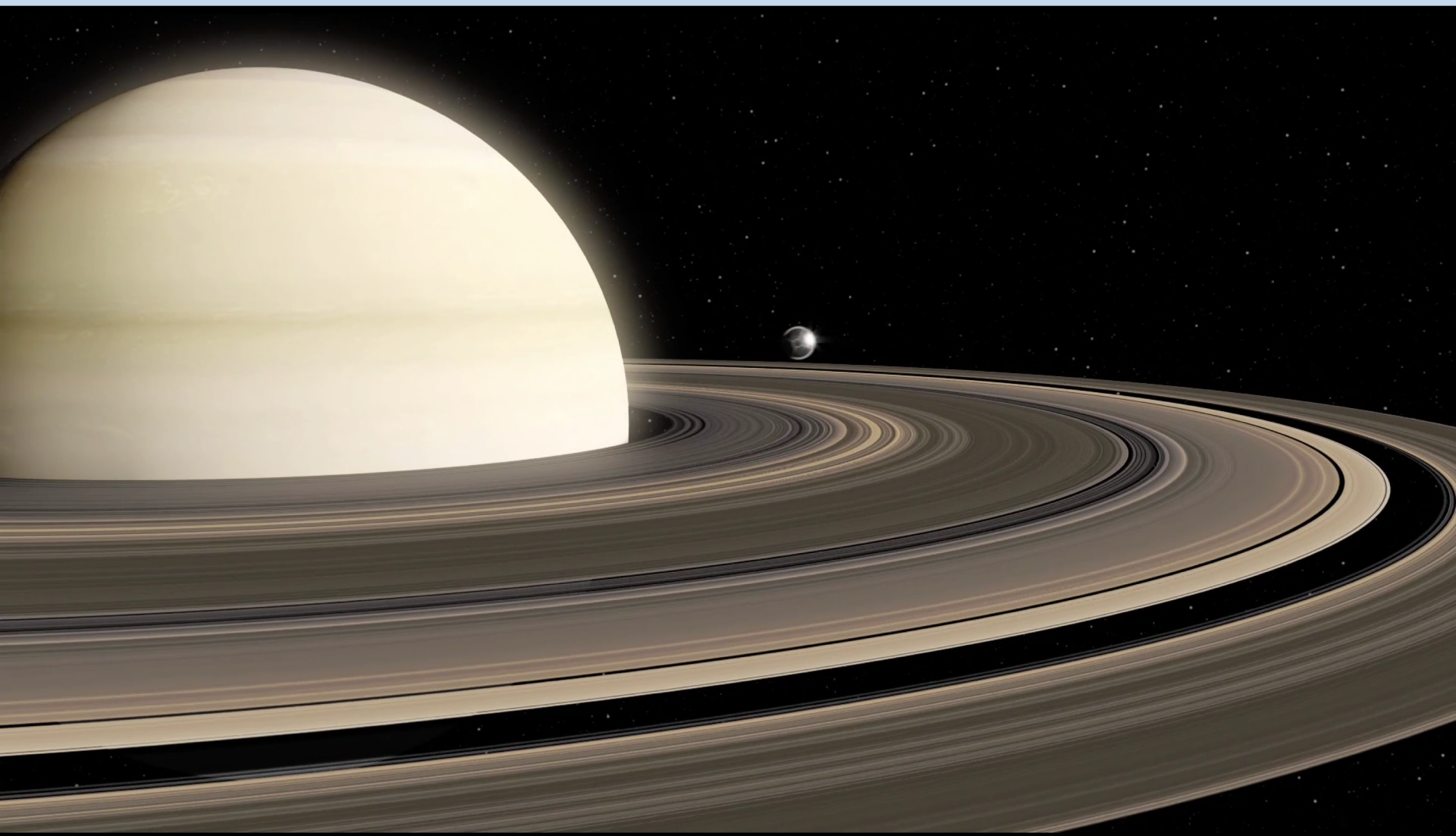
- 3-D Woven TPS, not a single system but a family :
  - *Woven TPS: An approach to the design and manufacturing of ablative TPS by the combination of 3-D weaving that allows precise placement of fibers in an optimized manner and resin infusion if needed*



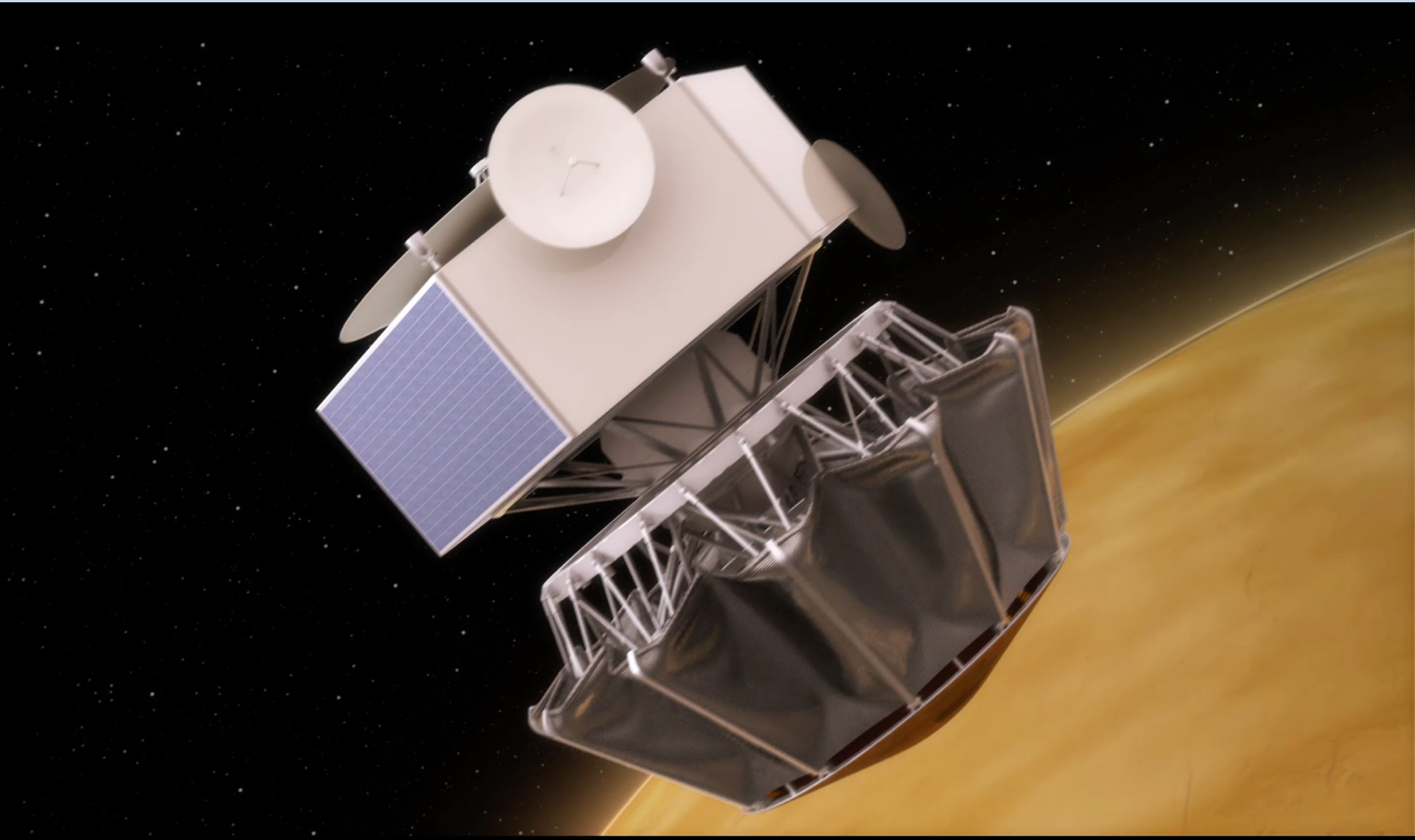


- System/Manufacturing
  - Molding flat panels
  - Seams
  - Resin Infusion at scale
- Integration with aeroshell sub-structure

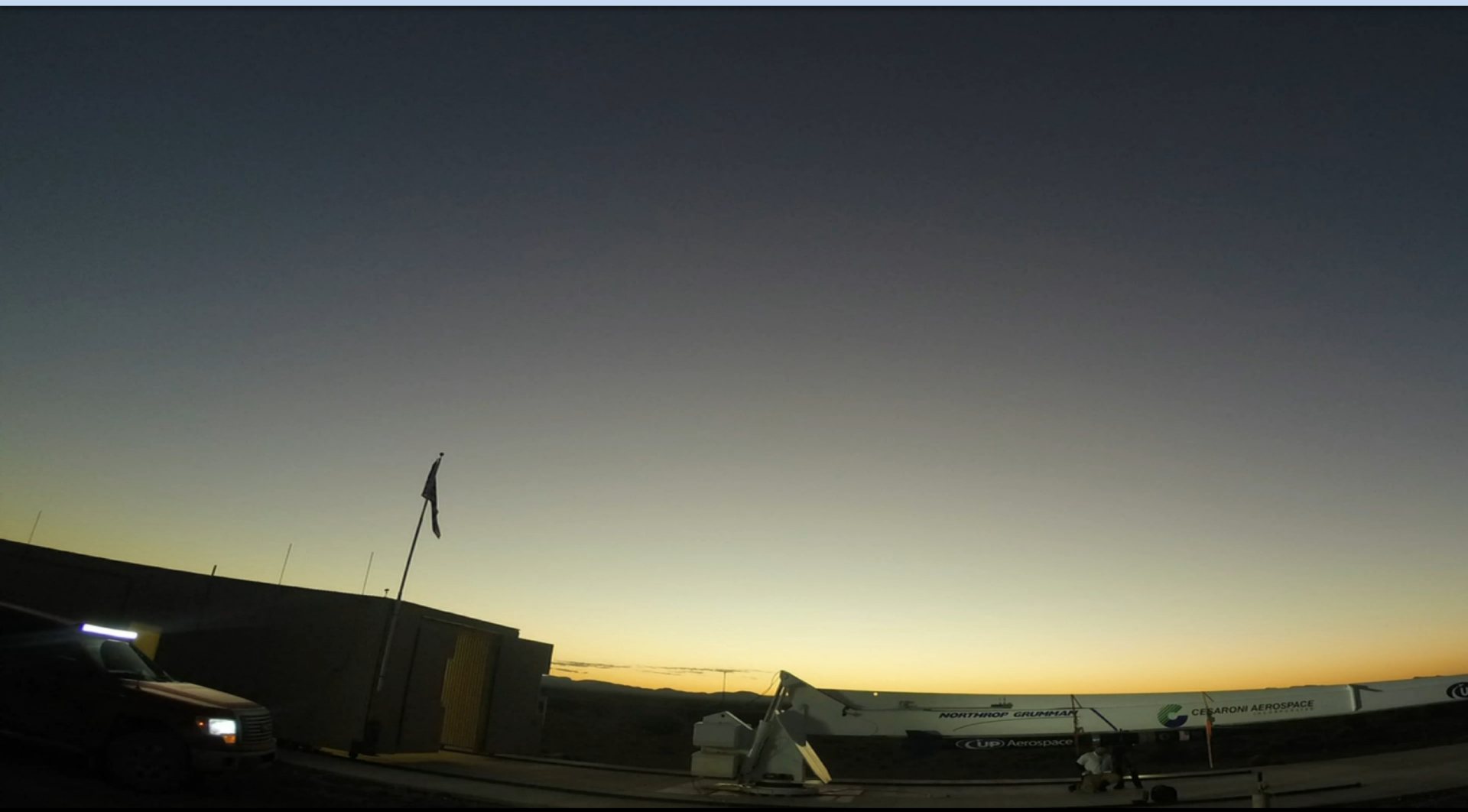
HEEET



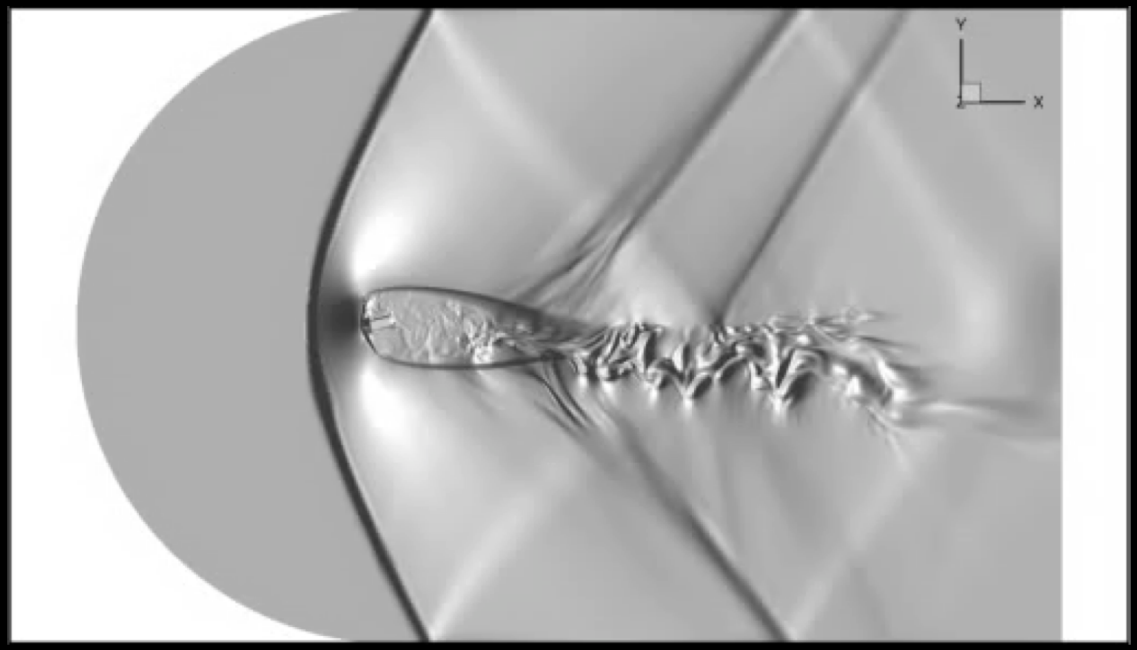
ADEPT

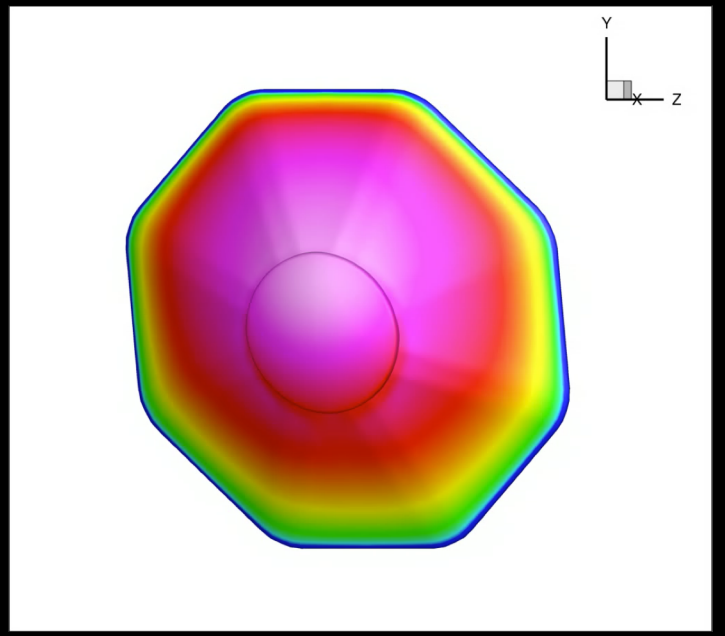


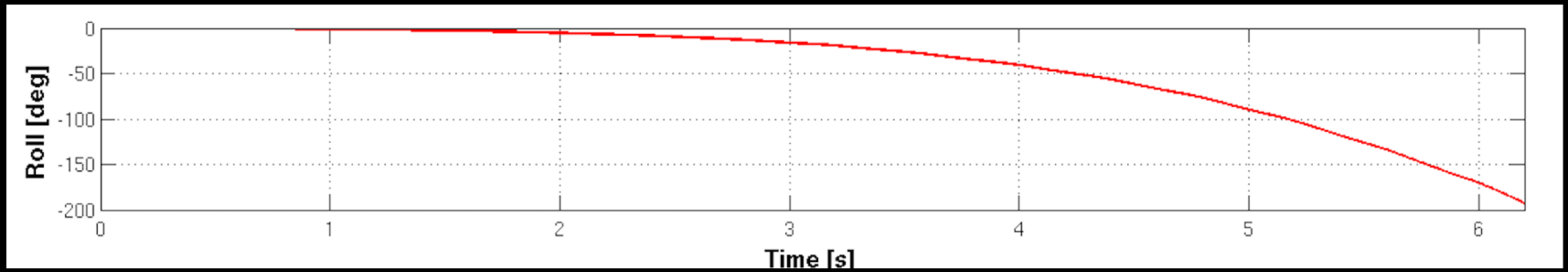
ADEPT Flight Test



SR-1 Flight Trajectory Simulations - Free Flight CFD

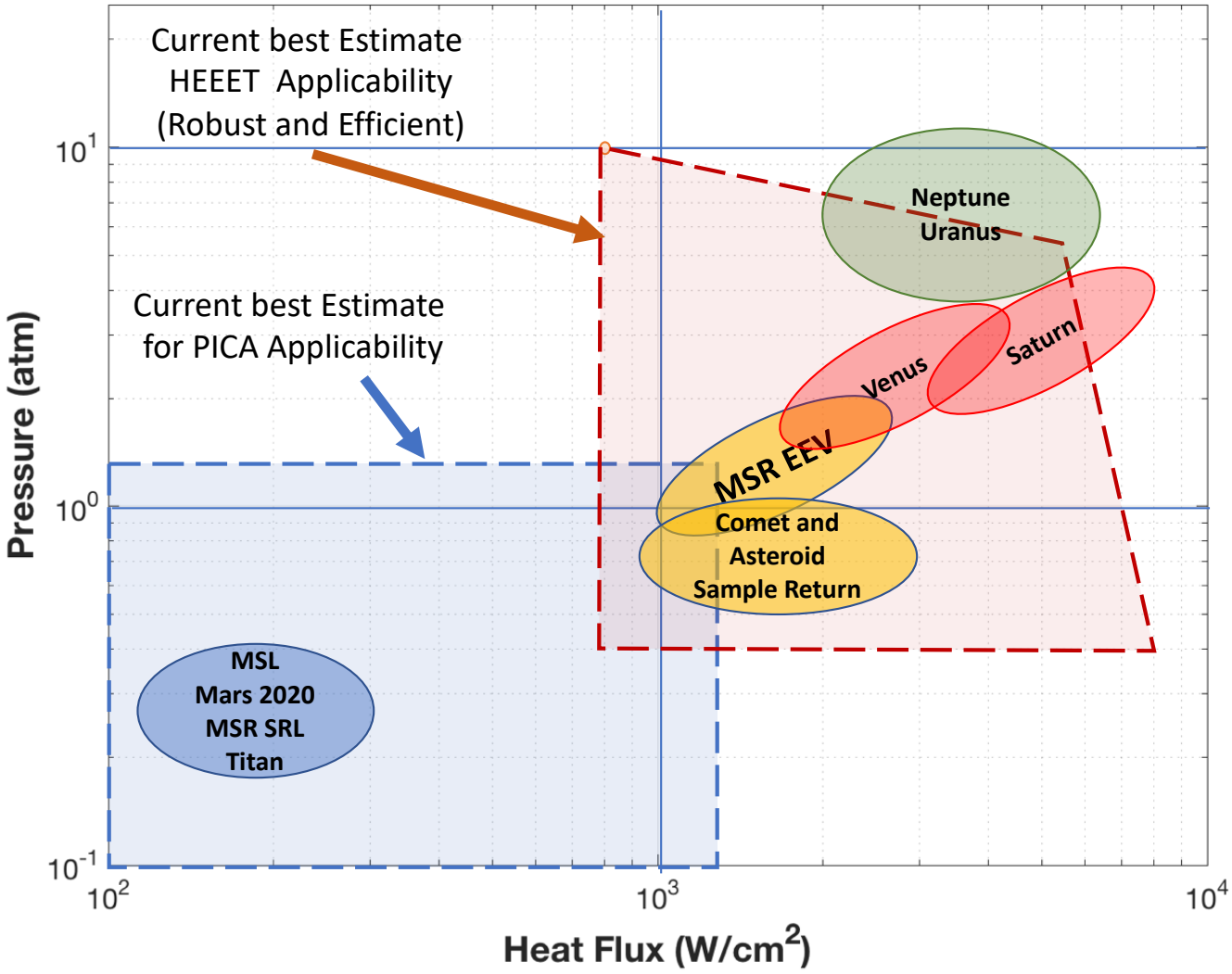






- **Free-flight simulations showed damped oscillations below ~15deg in total a.o.a. for high-altitude portion of trajectory**
- **Undamped oscillations up to 20deg in total a.o.a. for lower portion of trajectory**

NASA Ames Invented PICA and HEEET Adequate to Enable all Future Science Missions



Thank you for the Privilege of your time

Questions?