Entry Technologies: Enabling Ocean Worlds Missions

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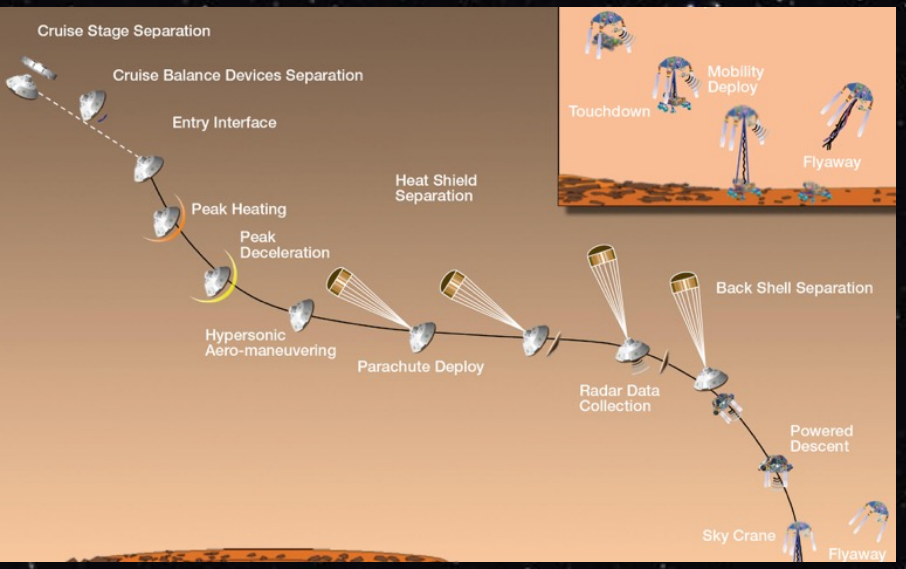
Introduction: Entry Technologies



Proposed White Papers on Thermal Protection System (TPS) Materials

Thermal Protection System Materials for Titan and Mars Missions

- Multiple missions need a PICA heatshield.
- Heritage PICA is no longer available
- PICA-D (domestic) being developed as a replacement, while addressing long term sustainability

Thermal Protection System Materials for Outer Planet Missions

- Challenging missions to Ice Giants need capable TPS material; Carbon Phenolic unavailable
- Sustained support and development recently culminated in TRL 6 for HEEET
- HEEET will enable ice giants missions; sustainability (of knowledge and materials) a key part of HEEET's development.

Entry Systems and TPS technologies are mission critical for in situ Science and sample return missions.

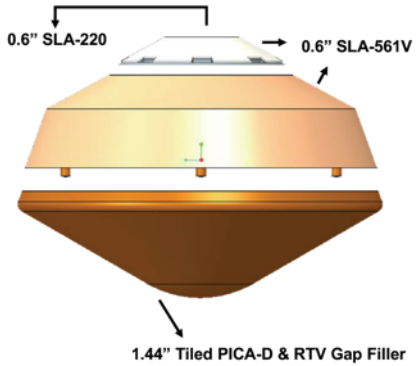
Destination	Gravity	Atmosphere	Implications to Entry
Titan	Low ($0.14\ g_{earth}$)	Dense	Atmosphere provides sufficient Deceleration Need Suitable Thermal protection System
Enceladus, Europa, Ceres, Ganymede, Callisto	Low ($0.02 - 0.15\ g_{earth}$)	Tenuous	Absence of Atmospheric Deceleration Entry Heating is not a concern
Mars	$1/3\ g_{earth}$	Less Dense	Some Atmospheric Deceleration Need Suitable Thermal Protection
Outer Planets (Neptune, Uranus)	$0.85 - 1.14\ g_{earth}$	Dense	Atmosphere provides Deceleration Entry Heating is a challenge

Background

- NASA missions are unique, TPS are unique
- Technologies not sustained without market
- New TPS development needs time and investment
  (e.g. HEEET: 10's $M and nearly a decade)

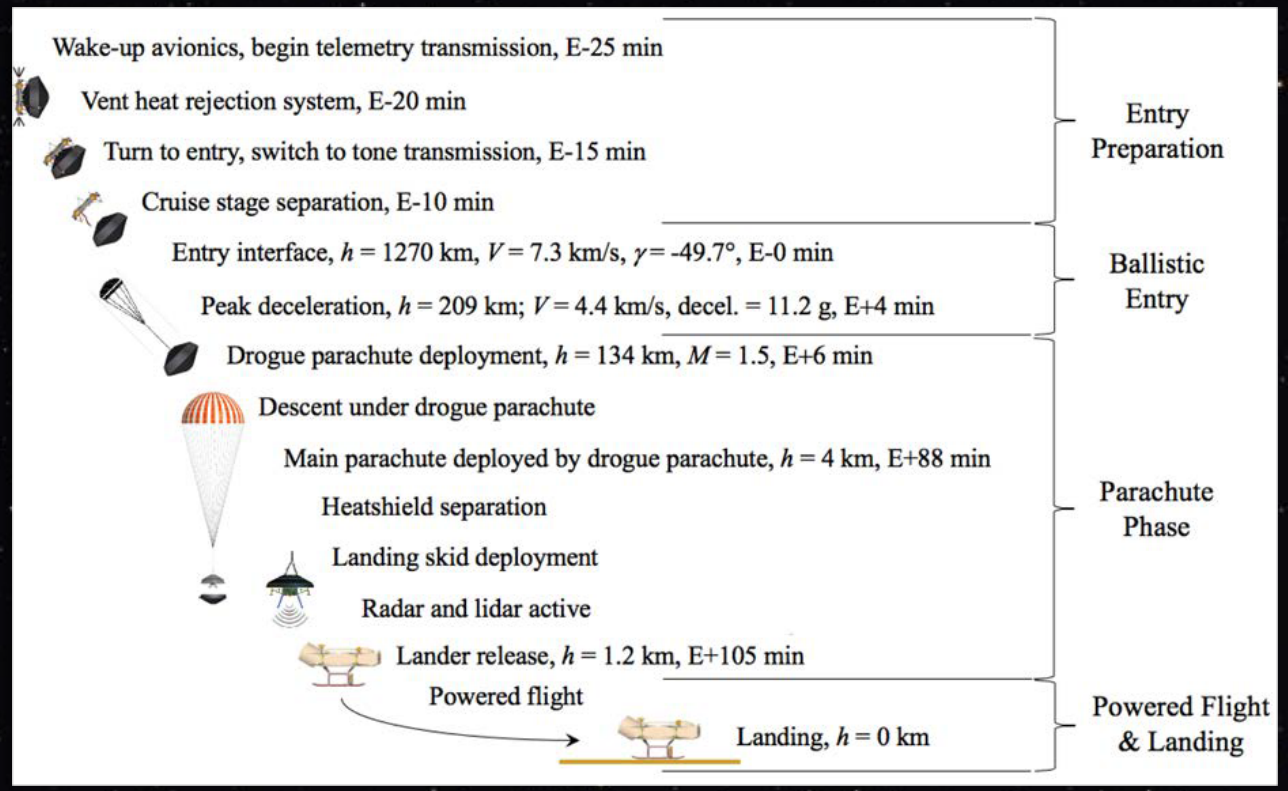
Need White Papers Directly Relevant to Future Missions

Entry at Titan: Dragonfly



- Aeroshell constructed of three TPS materials (high TRL, well-tested, performance-proven)
- Forebody heatshield made of PICA-D
  - ESA probe Huygens used AQ60 as the forebody TPS
- Analysis and Processes are mature, lean on MSL/M2020/Orion experience

- Dragonfly carries instruments to drill, extract and analyze samples (at various locations) at Titan
- Mission features traditional Atmospheric Entry and Descent
  - 250 second Heat Pulse peaking at 250 W/cm^2
  - Capsule spends a long time (80+ min) under the drogue
  - Heritage TPS materials suitable
- All three TPS materials are likely to be available for the next decade and more (Mars Sample Return, Dragonfly)



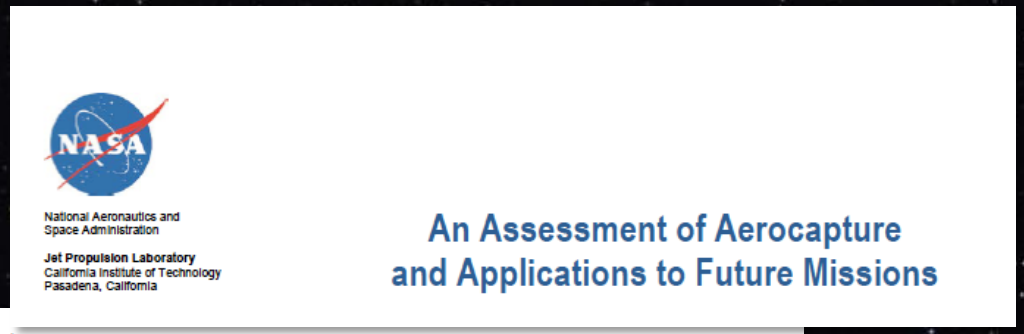
Aerocapture for Ocean World and Outer Planet Missions

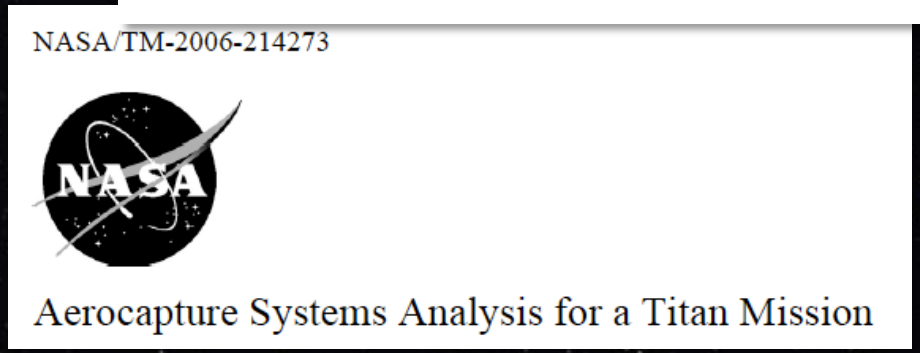
Proposed White Paper on Aerocapture

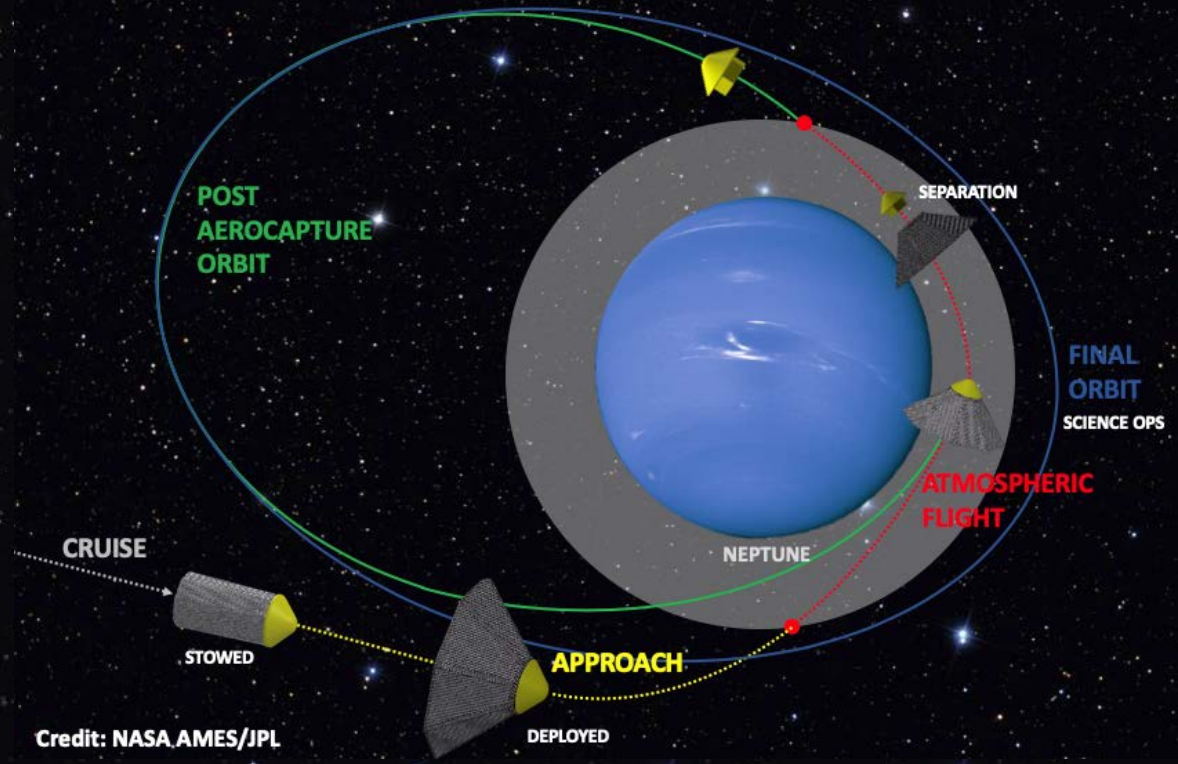
Aerocapture for Solar System Exploration

- Aerocapture delivers more payload mass to orbit
- Aerocapture decreases the trip time from launch (at Earth) to orbit (at destination)
- Missions to ice giants benefit the most from using Aerocapture

A Neptune Orbiter Concept using Drag Modulated Aerocapture (DMA) and the Adaptable, Deployable Entry and Placement Technology (ADEPT)







Takeaways for Ocean Worlds Exploration

- Entry Architecture and Thermal Protection System is a key engineering component of any science mission
- Entry Technologies (e.g. aerocapture) are being proposed/developed that enable flagship missions to Ocean Worlds
- Thermal Protection System Materials (e.g. PICA-D, HEEET) are being developed to enable future missions with a strong emphasis on sustainability (of knowledge, materials, testing facilities)
- Plans underway to author several white papers in support of the Decadal Survey
  - Aerocapture for solar system exploration
  - TPS Materials for Titan and Mars Missions
  - TPS Materials for Outer Planets Missions

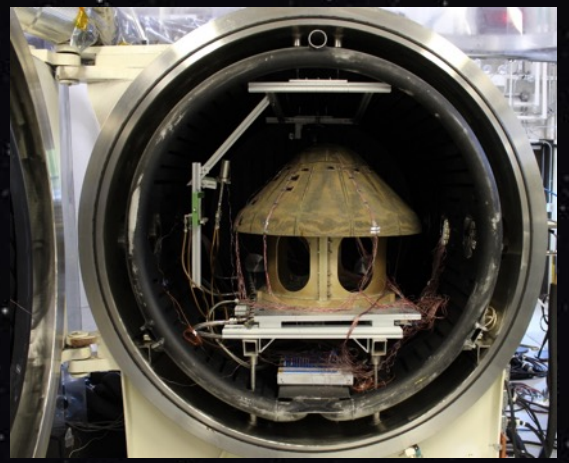
We seek your input into these white papers, and your support for advocacy !

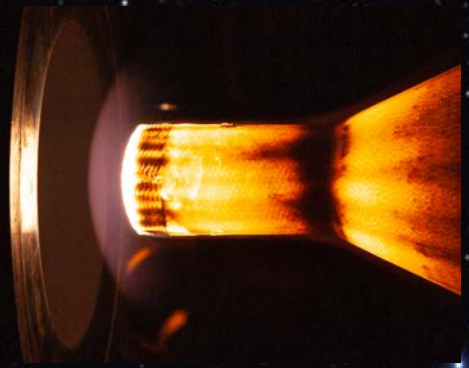
Please contact suman.muppidi@nasa.gov or helen.hwang@nasa.gov with comments/suggestions or opportunities of collaboration

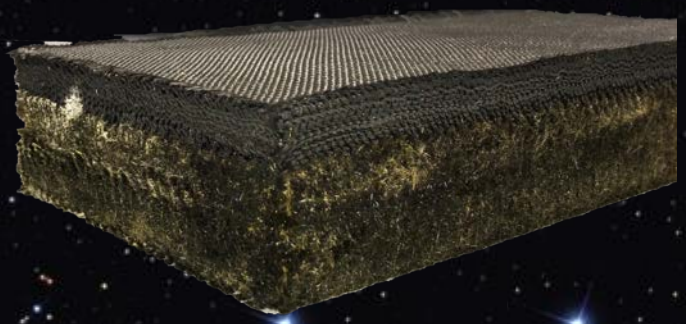
Backup Slides

Enabler: Heatshield for Extreme Entry Environment(HEEET)

Development of HEEET to TRL 6 is complete. Ready for Mission Infusion





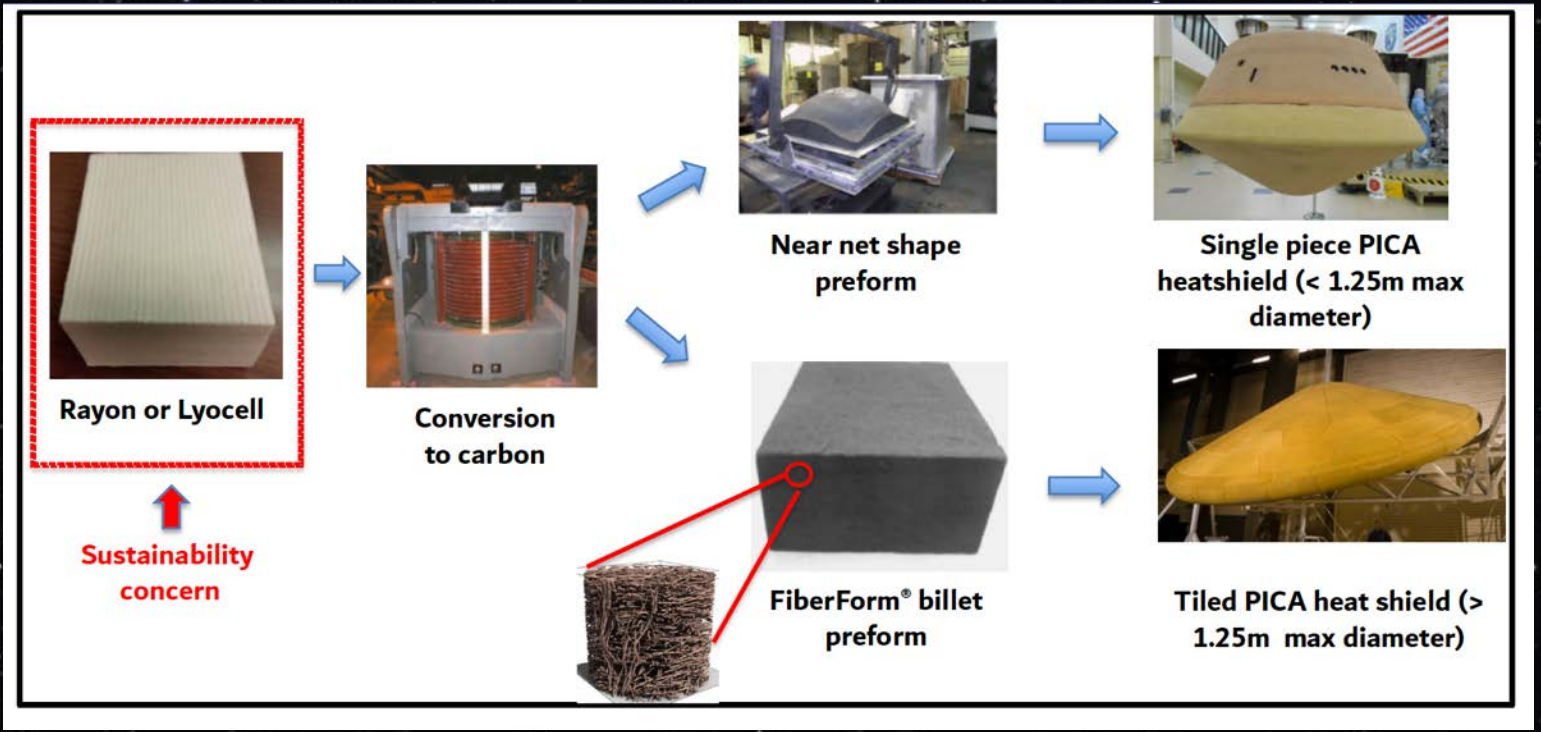


Lori Glaze, Eugene Tu, Jim Reuter at the
HEEET Project Closeout (May 17, 2019)

But don't just take our word for it:

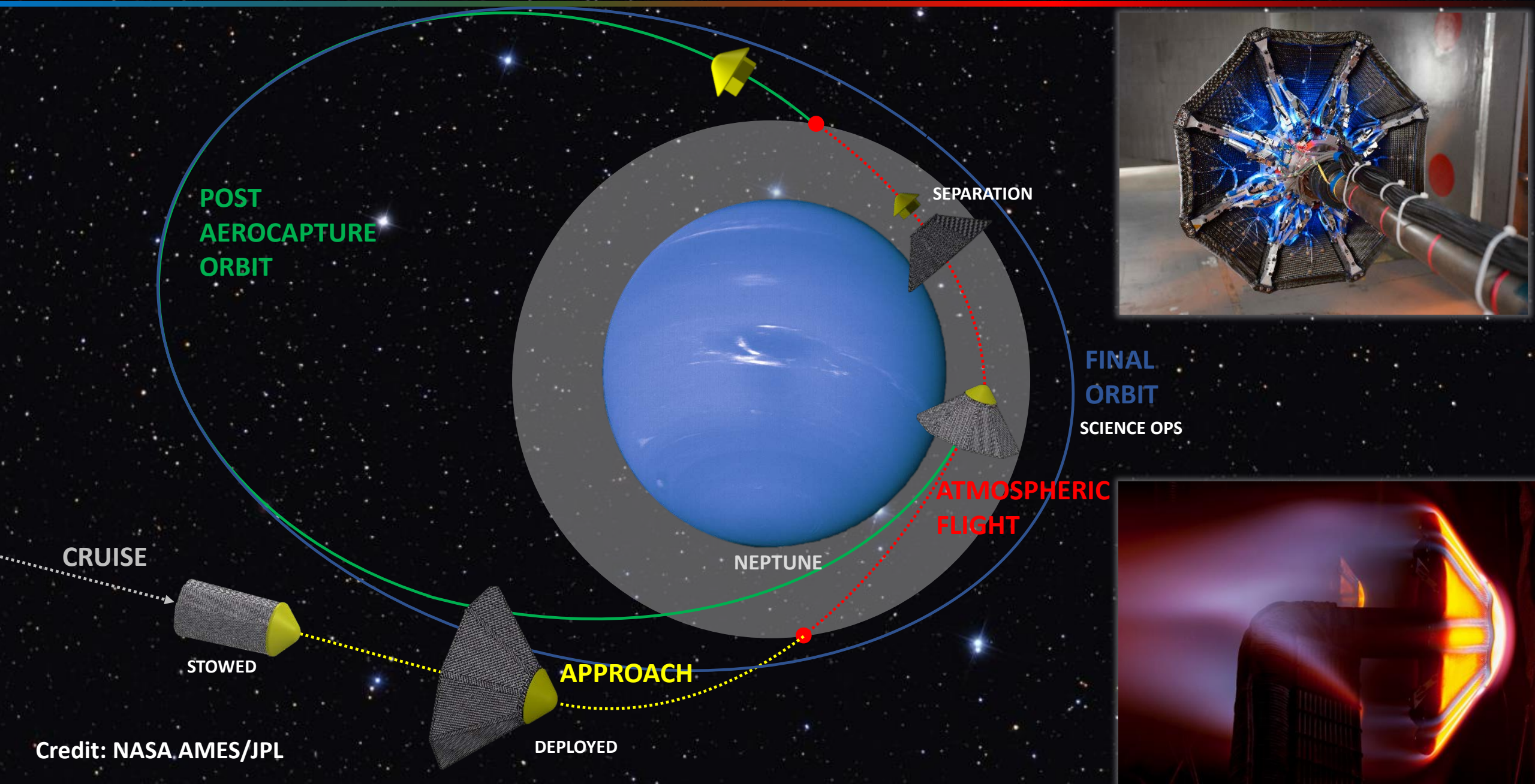
"The Independent Review Board concurs […] that the overall objective of achieving TRL 6 has been completed

Enabler: PICA-D (Domestic Rayon) as a Replacement for Heritage PICA



- Exciting future NASA missions need PICA (MSR SRL, MSR EEV and Dragonfly) and NASA TPS sustainability effort will have a direct benefit for these missions
- PICA has become a workhorse TPS for NASA and sustainment is essential
  - With support from NASA SMD-PSD, NASA ARC / FMI are working together addressing material sustainability.

Enabler: Drag Modulated Aerocapture for Ice-Giants



Credit: NASA AMES/JPL