

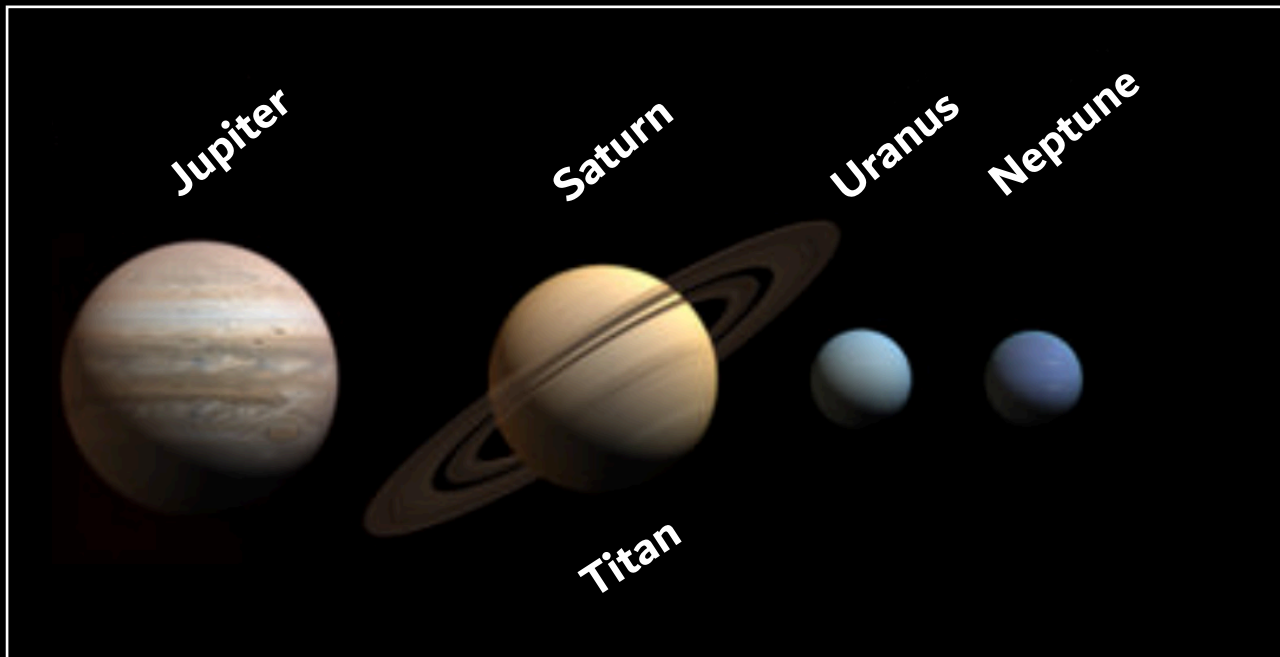
TPS for Outer Planets

Ethiraj Venkatapathy,

D. Ellerby, P. Gage, M. Gasch, H. Hwang,

D. Prabhu, M. Stackpoole, and Paul Wercinski

Entry Systems and Technology Division, NASA ARC



Probes / Landers

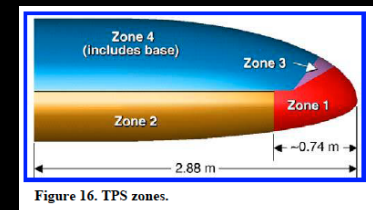
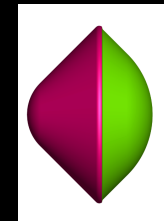


Figure 16. TPS zones.

Aerocapture

OPAG – Technology Forum
February 23, 2018 Hampton, VA

Objective and Outline

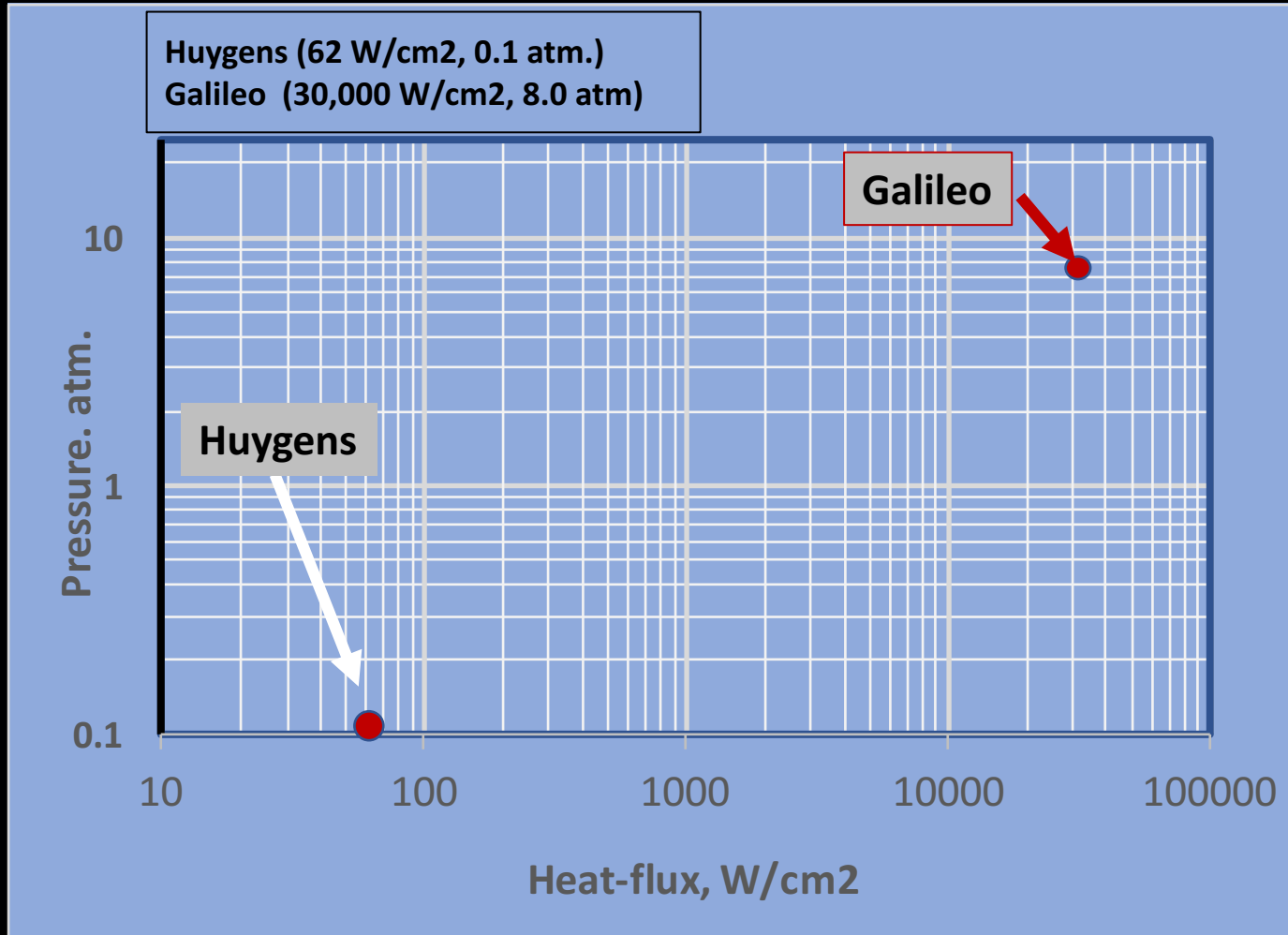
To provide insight into what TPS is needed and the current state of readiness to enable future Outer Planet Missions

- **Mission Science Drivers for TPS**
 - Modest environments for Titan
 - Severe to extreme environments for Icy/Gas Giants
- **Current state of readiness**
 - PICA
 - HEEET
- **Sustainability**
 - Challenges and solutions

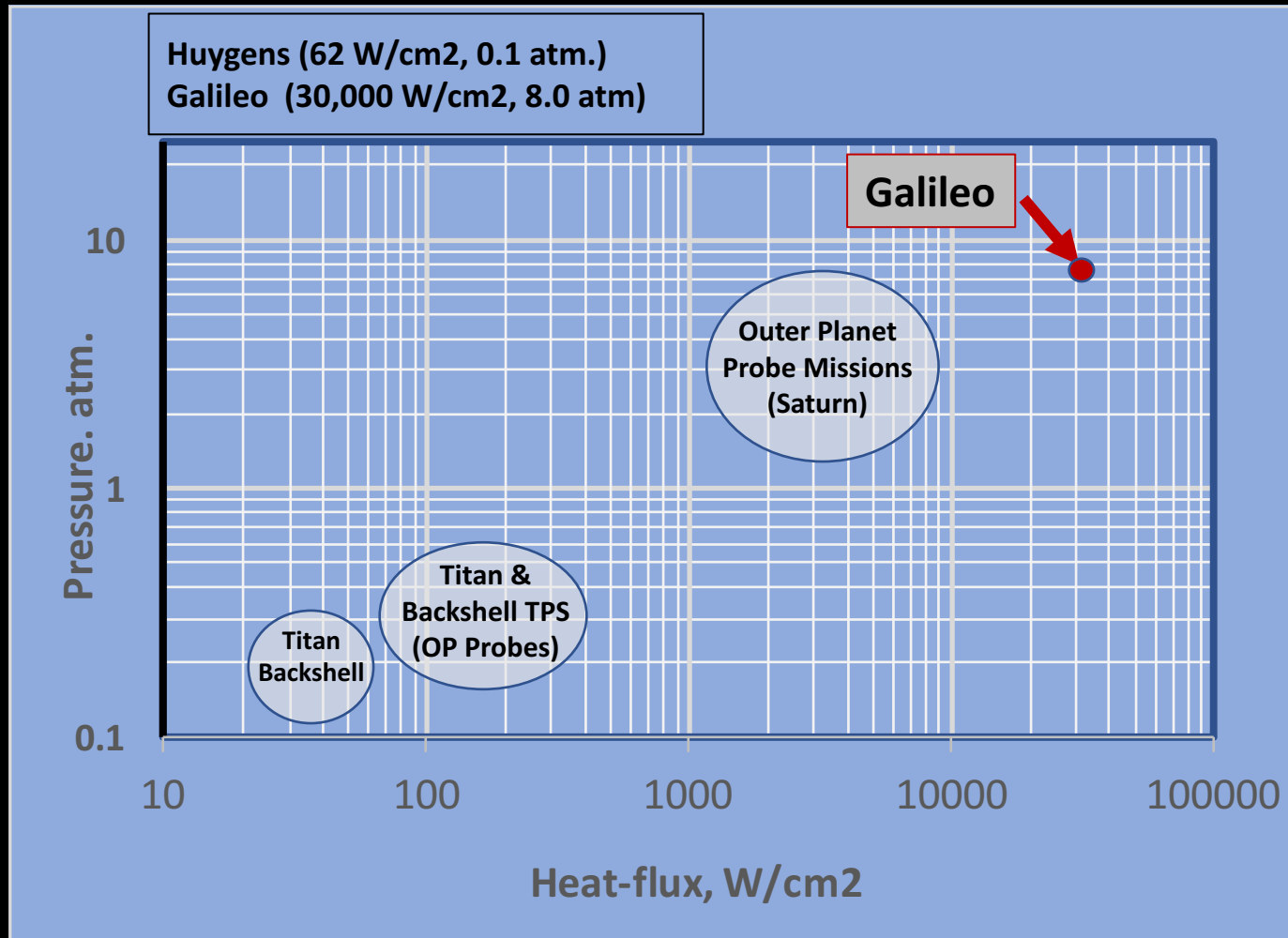
Science, Mission Design and Entry Environment Considerations for TPS Selection

- **Destinations**
 - Jupiter, Saturn, Titan, Uranus and Neptune
- **In Situ Science**
 - Probes at Ice/gas Giants,
 - (Aerial Platforms, Landers, Boats, and Submarines) at Titan
- **Mission Architecture and Vehicle**
 - Ballistic, Direct Entry
 - Lift Guided Entry (Direct or Aerocapture followed by Entry)
 - Rigid Aeroshell (for both ballistic and lift guided)
 - Deployable may be applicable to Titan
 - ADEPT and HIAD are at Low TRL – out of scope in this talk
- **TPS must not fail during entry**
 - Must be manufacturable at relevant scale including thicknesses to withstand heat-load

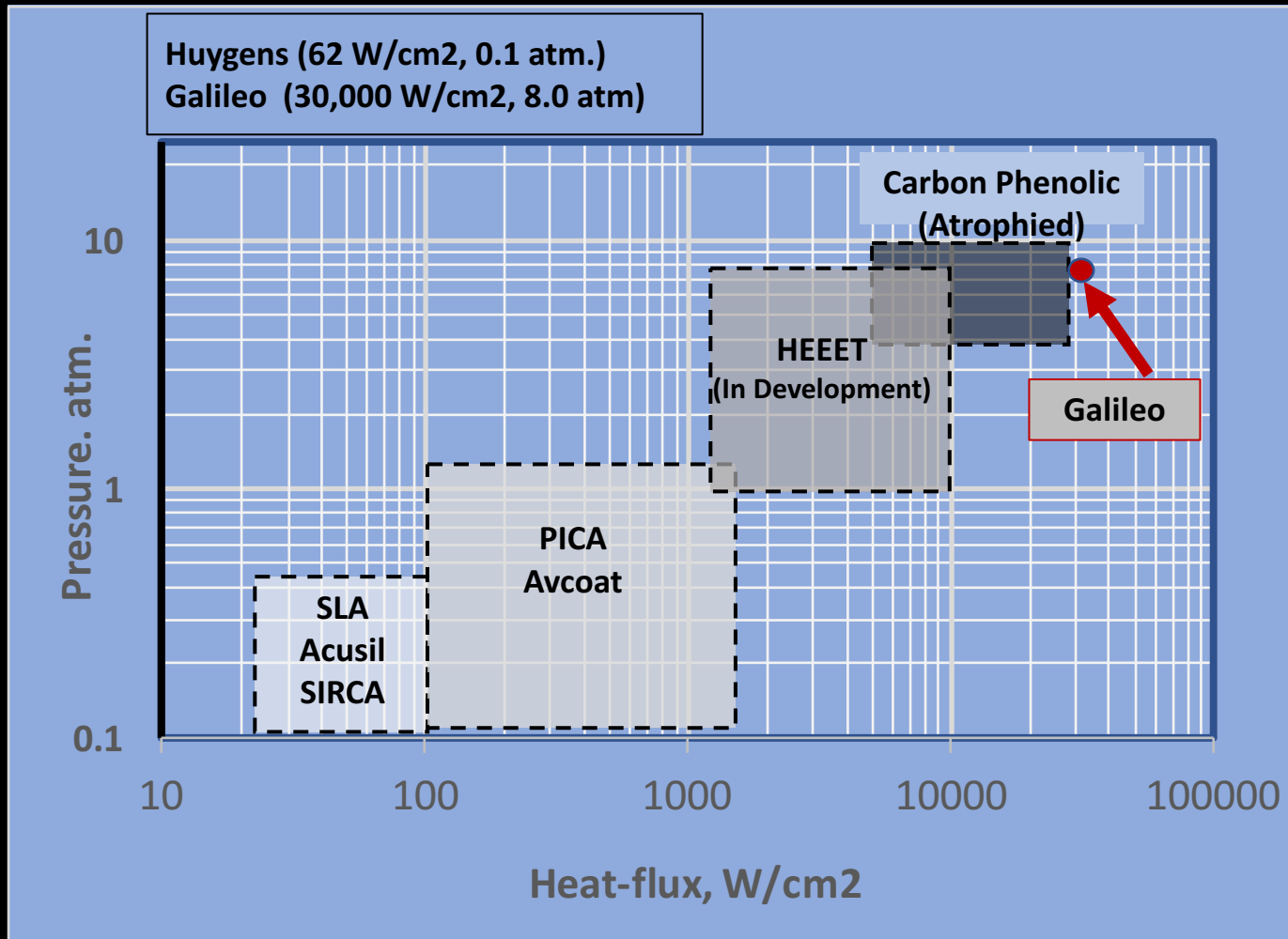
Past Outer Planet Missions and Entry Environment



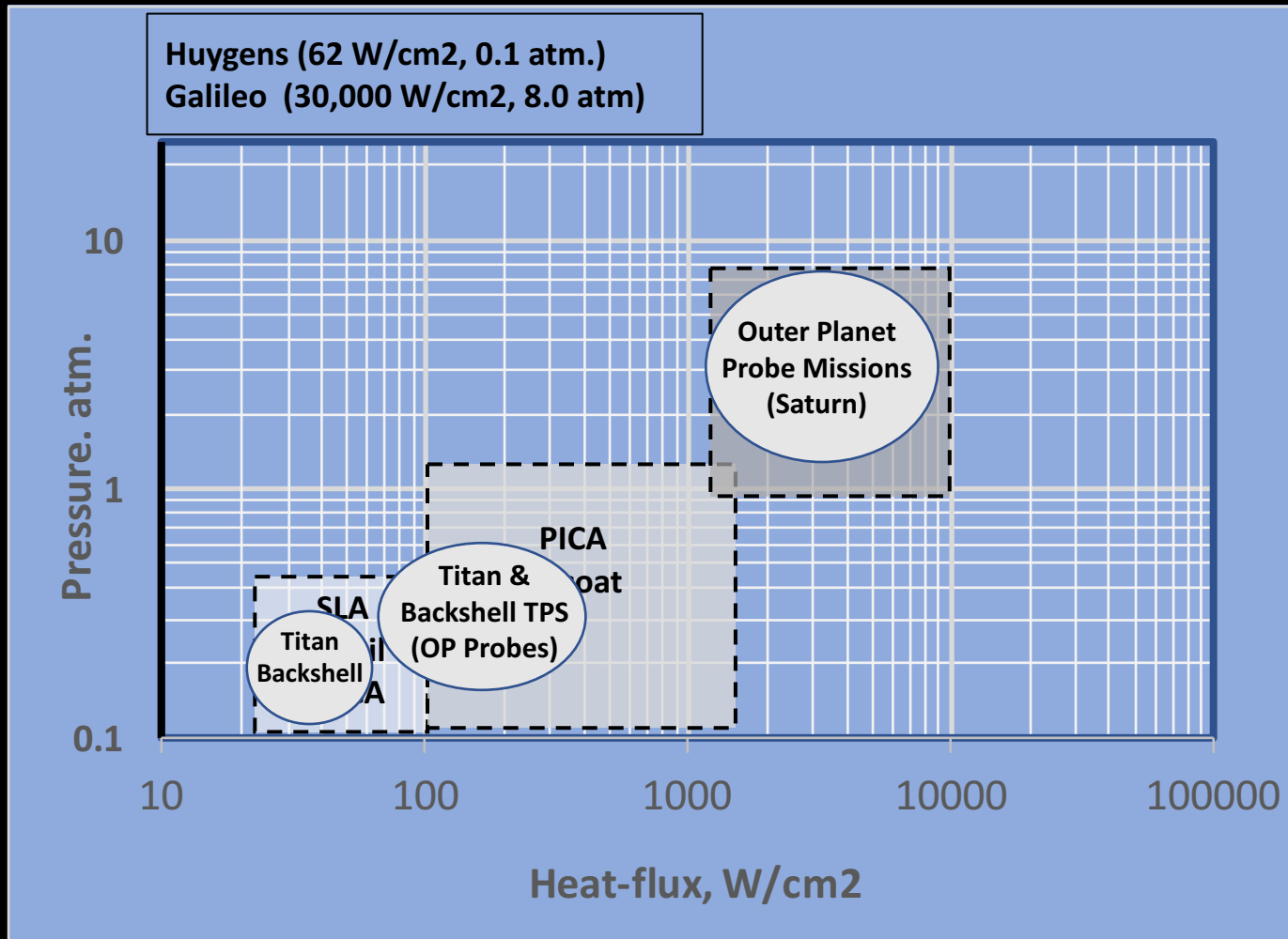
Future Outer Planet Missions and Entry Environment Considered for TPS Development



Current TPS Capability to Support Outer Planet Missions



Outer Planet Missions and Current TPS



PICA Readiness

(More details can be found in the PICA Poster presented earlier)

- In 2016 NASA ARC learned that the heritage rayon utilized in PICA was stopping production, leading to a flight-qualified PICA sustainability challenge

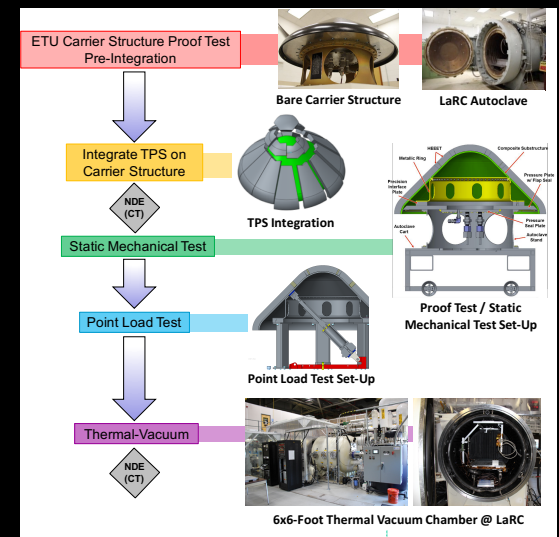
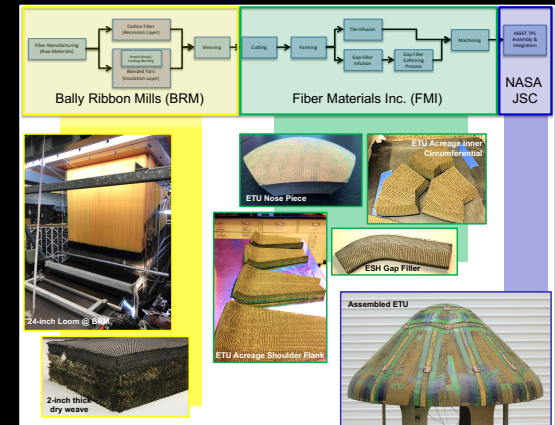
Heatshield Peak Conditions		Pressure atm	Heat Flux W/cm2	Heat Load kJ/cm2
Titan	Titan 1	0.17	150	9.5
	Huygens	0.1	62	3.5
Mars	MSL	0.33	225	6.4

- In FY16/17, NASA ARC was funded by SMD/PSD to address PICA rayon sustainability
- **Lyocell Based PICA (PICA-D) was manufactured and limited testing performed**
 - **Limited data and comparison indicated PICA-D to be good candidate for potential drop-in replacement for heritage PICA**
- **SMD-PSD has initiated two tasks (CY18 and CY19) to:**
 - **Establish PICA-D as a Drop-in replacement for Heritage PICA**
 - **Establish the Expanded Capability (Extensibility) of PICA-D**
- Successful completion of the above tasks are targeted towards:
 - Titan (& Mars) heatshield TPS and backshell for Outer Planet (& Venus) probes
 - Enable higher speed sample return missions from Comets and Asteroids
- Recent NF-4 Mission study (Dragonfly) compared to Huygens and MSL

HEEET Readiness

(More details can be found in the HEEET Poster presented earlier)

- Thermal and thermo-mechanical performance of acreage and seam have been established; Material property database developed; Thermal response model completed
 - > 5000 W/cm² and > 5 atm. capable
 - Efficient and Enabling
 - All NF-4 proposals able to target < 50g entry
 - Flight design tools validation on going
- All basic manufacturing steps have been developed and transferred to industry to establish supply chain for future missions
- All manufacturing and integration operations have been demonstrated.
 - 1m scale MDU/ETU can be scaled to larger dia.
 - Loom capable of thicker weaving (current MDU/ETU has 0.5" recession layer and 1.1" insulating layer)
- Current plans are to complete MDU/ETU testing, AEDC and LHEML testing, design tool validation and documentation in CY'18



Assessment of HEEET Development for Outer Planet Probe Missions

- **Current HEEET Capability is Scalable**
 - In areal dimension (funding limitations required us to focus on areal scalability)
 - HEEET system demonstrated at 0.5” thick recession layer (RL) and 1.1” insulating layer (IL) on the 1m diameter MDU/ETU
- **Recent Outer Planet mission studies show more severe entry environments**
 - Ice-Giants may require seam performance assessment (pressure > 10 atm.)
 - Outer Planet (Neptune and Saturn) missions may require thicker recession layer (~2 X to 3X)
 - Current loom is capable of ~0.7” RL & 0.8” IL (or 0.6” RL & 1.2 ” IL)
 - For thicker than 0.5” RL, manufacturing and integration need to be demonstrated at the system level.
 - The loom capability can be expanded to weave much thicker recession layer, (1.5” – 2.5”) recession layer.
- **Common Probe study is reassessing and may provide a better bounding thickness**
 - Integrated system needs to be demonstrated at bounding thickness levels

Heat-shield Environment from Recent Mission Studies		Pressure	Heat Flux	Heat Load
		atm	W/cm2	kJ/cm2
Jupiter	Galileo	7.31	32000	200
Saturn	Saturn 1	2	2000	250
	Saturn 2	8	8000	75
Uranus	Uranus 1	12	3500	44
	Uranus 2	9	2500	41
Neptune	Neptune 1	25	9600	82
	Neptune 2	11.5	5500	109
	Neptune 3	6.8	4400	134

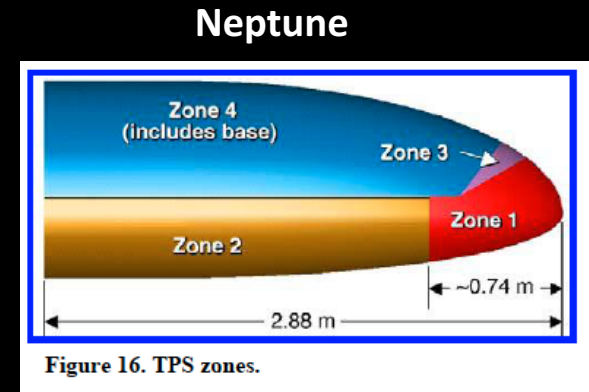
	Stag Point		Flank (Shoulder)	
	Recession Layer, in	Insulation Layer, in	Recession Layer, in	Insulation Layer, in
Saturn			1.03	0.91
Uranus	0.33	0.877	TBD	TBD
Neptune	0.69	1.1	TBD	TBD

Aerocapture: Configurations and TPS

- **Entry Environment and Configurations**

	Neptune	Titan	Mars
Entry Velocity, km/sec	29	6.5	5.7
Atm. Scale Height	49	40	10.5
L/D	0.8	0.25	0.25
M/CdA	895	90	148
Convective Heating, W/cm ²	8000	46	30
Radiative Heating, W/cm ²	(4000- 8000)	(93 - 280)	~ 0
Time of Flight (min)	10	42	10

Ref: Neptune Aerocapture Systems Analysis, Mary Kae Lockwood, AIAA 2004-4951

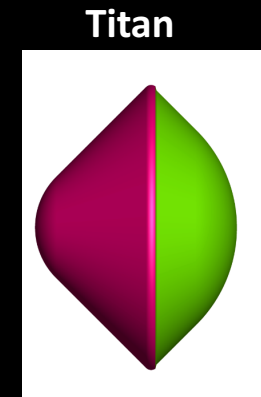


- **Neptune:**

- Multiple TPS needed for optimizing payload mass fraction
- HEEET, PICA and (SIRCA/SLA/ACUSIL/Tile)

- **Titan: Benign**

- TPS: Within the current TPS SOA (e.g. PICA/SLA/SIRCA/ACUSIL)



Addressing TPS for ballistic, direct entry will address aerocapture needs

Sustainability of TPS for OP Missions

- **Why worry?**
 - Missions are few and far between
 - TPS capability is critical and NASA unique
- **PICA and HEEET**
 - Simple compositional systems and manufacturing is automated
 - Both are essentially carbon and phenolic composition
 - PICA uses rayon. HEEET does not (by choice)
 - Technology capability has been transferred to industry
 - Raw material and processing – off the shelf – need to keep an eye
 - Multiple vendors and processing involved
 - Raw material to processing/manufacturing to assembly and integration
 - NASA has to assess the risk of atrophy periodically
- **Approaches to addressing capability availability in the future**
 - Periodically assess and take risk mitigation action for sustaining the capability
 - HEEET and PICA are NASA IP and NASA can transfer the technology at any time
 - Build and store a common aeroshell design capable of missions at multiple destinations

Common Probe Study



- **Could a common atmospheric probe design be used for missions to Venus, Jupiter, Saturn, Uranus, and Neptune? Could we build multiple units and address sustainability concern?**
 - Study funded by SMD-PSD
 - Typical designs have been 45deg sphere cones with high density TPS
 - Study will address inefficiencies or limitations that a common design cause for missions to these destinations
 - 4 NASA Centers involved (ARC, LaRC, GSFC, and JPL)
- **Approach:**
 - Strawman instrumentation payloads defined for each target based on science community input
 - Shallow and steep entry g-loads defined for each destination based on instrument sensitivity
 - TPS and carrier structure analysis and trades being conducted, including long term storage issues
 - Rough costing for design(s)
- Findings and recommendations to be presented at OPAG, VEXAG, and IPPW
- Final report to be delivered to PSD and published by summer 2018

Concluding Remarks & Recommendations

- **TPS needs for Outer Planet Missions falls into two distinct groups**
 - **Moderate to low heat-flux missions (Titan) – PICA**
 - Drop-in replacement for heritage PICA is funded and in progress (Completion by CY'20)
 - **Extreme Entry Environment – HEEET**
 - HEEET is more efficient, robust and capable
- **PICA Replacement and Extensibility development in progress**
- **HEEET development for Saturn, Uranus or Neptune missions**
 - Require thicker recession layer
 - Continued development will meet the future OP mission needs
- **Sustainability is critical for extreme entry environment missions**
 - Periodic assessment necessary
 - Common Probe – build and store multiple copies – may be a solution