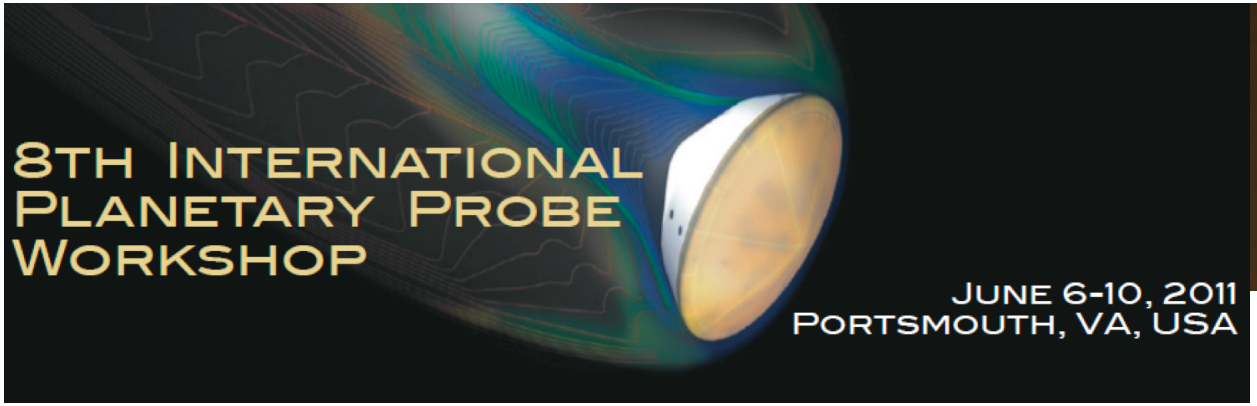
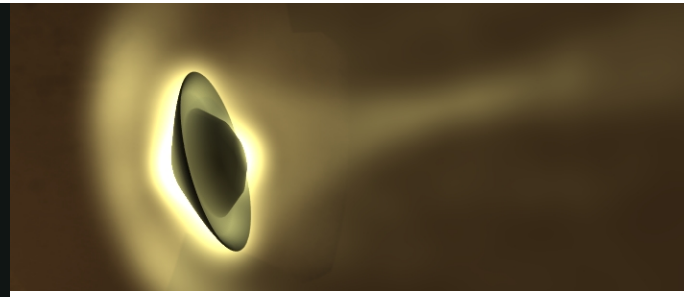
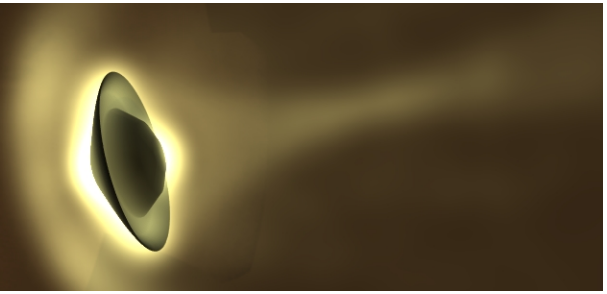


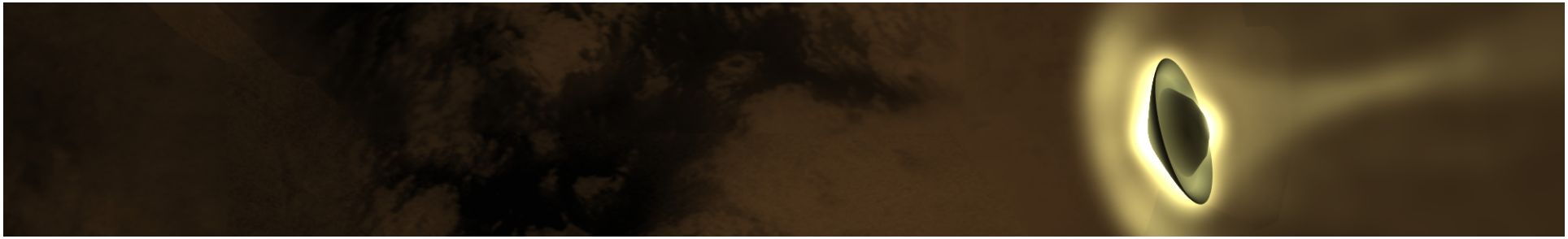


Welcome to session 7A: Advances in TPS Technology for Planetary Probe Design

Schedule



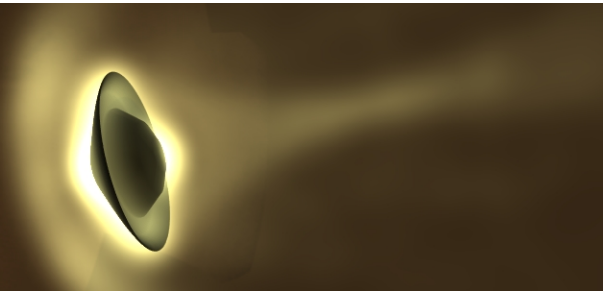
14:30	15:00	D. Ellerby (NASA Ames Research Center): Challenges with Thermal Protection Material Development and Implementation: Lessons Learned from Recent NASA Experience
15:00	15:30	H. Ritter (ESA): Ongoing European Developments on Entry Heatshields and TPS Materials
15:30	15:50	T. White (ERC Inc): MEDLI Aerothermal Environment Reconstruction Efforts
15:50	16:10	T.J. Kowal (NASA Johnson Space Center): Orion Flight Test-1 Thermal Protection System Instrumentation
16:10	16:30	J.O. Arnold (NASA Ames Research Center): Flexible Ablators: Applications and Arc Jet Testing
16:30	17:00	Coffee ☺
17:00	17:30	R.A.S. Beck (NASA Ames Research Center): Overview of Initial Development of Flexible Ablators for Mars EDL
17:30	17:50	G. Pinaud () and Tom van Eekelen (): Aerofast: Development of Cork TPS Material and a 3D Comparative Thermal/Ablation Analysis of an Apollo & a Biconic Sled Shape for an Aerocapture Mission
17:50	18:10	W. Congdon, ARA: Modular Manufacturing of Honeycomb-Reinforced Charring Ablator Systems for the Aeroshells of Large EDL Vehicles
18:10	18:30	Round table discussion



Round Table Discussion

- TPS Needs to support current decadal survey
- Challenges for TPS instrumentation

TPS for Mars and Titan Entries
(courtesy Ethiraj Venkatpathy)

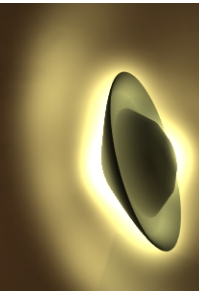


Density	TPS	Supplier	Flight Qual or TRL	Potential Limit		Entry at Mars			Earth Return‡	Titan	
				Heat flux, W/cm^2	Pressure atm	MPF Class	MSL Class	Aero-capture		Direct	Aero-capture
FOREBODY HEAT SHIELD											
Low-Mid	SLA 561V	LMA	Mars	< 120 (<300)*	< 1	●	✖	◡	✖	●	●
	PICA	FMI	Stardust	~ 1200	< 1	■	●	●	✖	●	●
	BPA	Boeing	TRL 3-4	~ 1000	~ 1	■	◡	◡	✖	◡	◡
	Avcoat	Textron	Apollo	~ 1000	~ 1	■	●	●	✖	●	●
	AQ60#	EADS	Huygens	~ 250	< 1	◡	✖	◡	✖	●	◡
	Acusil® II†	ITT	DOD MSL	100	< 1	✖	✖	◡	✖	◡	◡
	SRAM Family	ARA	TRL 5-6	~ 300*	~ 1	◡	◡	◡	✖	◡	◡
	Lower density Phen-Carb	ARA	TRL 5-6	< 2000	~1	■	◡	◡	✖	◡	◡
Mid	ACC	LMA/C-Cat	Genesis	> 2000	> 1	■	■	■	✖	■	■
	Mid-density PhenCarb	Several	TRL 4-5	~ 2,000-4000	> 1	■	■	■	✖	■	■
High	3DQP	Textron	DOD	~ 5000	> 1	■	■	■	✖	■	■
	Heritage Carbon phenolic	None today but several can	Venus, Jupiter	10,000-30,000	>> 1	■	■	■	●	■	■

● Fully capable ◡ Potentially capable, qual needed ■ Capable but heavy ✖ Not capable

†RF transparent #European Supplier * (heat flux limit is lower with high shear, higher at low shear)

TPS for Giant Planet Entries
(courtesy Ethiraj Venkatpathy)



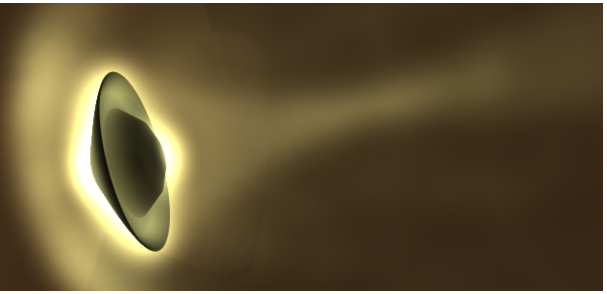
Density	TPS	Supplier	Flight Qual or TRL	Potential Limit		Mission Set				
				Heat flux, W/cm²	Pressure, atm	Saturn Pro-grade	Saturn Retro-grade	Neptune Direct	Neptune Aerocapture	Jupiter High Latitude (Pro-grade)
FOREBODY HEAT SHIELD										
Low-Mid	PICA	FMI	Stardust	~ 1200	< 1	✖	✖	✖	✖	✖
	Avcoat	Textron	Apollo	~ 1000	~ 1	✖	✖	✖	✖	✖
Mid	ACC	LMA/ C-Cat	Genesis	> 2000	> 1	◡	✖	✖	✖	✖
	Mid-density carbon phenolic (0.8-1.0 g/cm³)	Several capable, none active	TRL 3	> 2000 < 5000	> 1	◡	✖	✖	✖	✖
	PhenCarb family	ARA	TRL 5-6	> 2000 < 5000	> 1	◡	✖	✖	✖	✖
High	3D Woven QP	Textron	DOD TRL 3	≥ 5000	> 1	◡	✖	✖	✖	✖
	Heritage Carbon Phenolic (TWCP & CMCP)	Several capable, none active	Venus, Jupiter	10,000-30,000	>> 1	●	●	●	●	✖
BACKSHELL TPS										
Low-Mid	PICA	FMI	Stardust	~ 1200	< 1	●	✖	◡	◡	✖
	Avcoat	Textron	Apollo	~ 1000	~ 1	●	✖	◡	◡	✖
	SLA-561V	LMA	Mars	~ 300*	< 1	◡	✖	✖	✖	✖
	SRAM family	ARA	TRL 5-6	~ 300*	~ 1	◡	✖	✖	✖	✖
	PhenCarb family	ARA	TRL 5-6	> 2000 < 5000	> 1	◡	◡	◡	◡	◡
	SIRCA†	Ames	Mars	< 150	< 1	✖	✖	✖	✖	✖
	Acusil® II†	ITT	DOD	< 100	< 1	✖	✖	✖	✖	✖
High	Teflon (PTFE)†	Several	Various	> 500	> 1	●	✖	●	●	✖
	AD3DQ†	Textron	DOD	< 2500	> 1	●	✖	✖	✖	✖

● Fully capable ◡ Potentially capable (qual needed) ■ Capable but heavy ✖ Not capable

*For low shear environments

†RF transparent

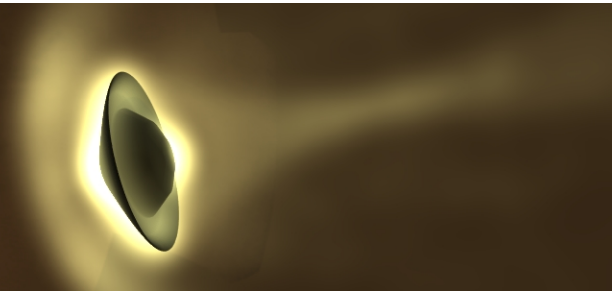
TPS for Sample Return
(courtesy Ethiraj Venkatpathy)



Density	Forebody Heat Shield	Supplier	Flight Qual or TRL	Potential Limit		Entry velocity, km/s		Other Potential Missions
				Heat flux, W/cm^2	Pressure, atm	<13	>13	
FOREBODY HEAT SHIELD								
Low-Mid	PICA	FMI	Stardust	~1200	< 1	●	◒	SR, CEV, Mars
	Avcoat	Textron	Apollo	~ 1000	<1	●	✖	Venus (aerocapture)
	ACC	LMA/C-Cat	Genesis	> 2000	> 1	◒	◒	SR, CEV, Mars
	BPA	Boeing	TRL 3-4	~ 1000	~ 1	◒	✖	Venus (aerocapture)
	PhenCarb Family	ARA	TRL 5-6	(1000 – 4000)	>1	◒	◒	MSR, CEV, Venus, Earth
High	3DQP	Textron	DOD (TRL4)	~ 5000	> 1	■	■	SR, Venus
	Heritage Carbon phenolic	Several capable, none active	Venus, Jupiter	(10,000 – 30,000)	>> 1	■	■	MSR, Venus, Jupiter, Saturn, Neptune

● Fully capable ◒ Potentially capable, qual needed ■ Capable but heavy ✖ Not capable

TPS for Venus Entries
(courtesy Ethiraj Venkatpathy)



Density	TPS	Supplier	Flight Qual or TRL	Potential Limit		Venus Mission Design		
				Heat flux, W/cm^2	Pressure, atm	Direct	Aerocap	From Orbit
FOREBODY HEAT SHIELD								
High	Heritage Carbon phenolic (CMCP) & (TWCP)	Several	Venus, Jupiter	10,000-30,000	>> 1	●	■	■
	3DQP	Textron	DoD TRL 3	~ 5000	> 1	✖	▬	▬
Low-Mid	PhenCarb family	ARA	TRL 4-5	2000-4000	> 1	✖	▬	▬
	ACC	LMA/C-Cat	Genesis	> 2000	> 1	✖	▬	■
	PICA	FMI	Stardust	~ 1200	< 1	✖	●	●
	Avcoat	Textron	Apollo	~ 1000	~ 1	✖	▬	▬
	BPA	Boeing	TRL 3-4	~1000	~1	✖	▬	▬
BACKSHELL TPS								
Low-Mid	PICA	FMI	Stardust	~ 1200	< 1	●	■	■
	Avcoat	Textron	Apollo	~ 1000	~ 1	●	■	■
	PhenCarb family	ARA	TRL 5-6	2000-4000	> 1	▬	▬	▬
	BPA	Boeing	TRL 3-4	~1000	~1	▬	▬	▬
	SRAM Family	ARA	TRL 5-6	~ 300*	~ 1	▬	▬	▬
	SLA-561V	LMA	Mars	~ 300*	< 1	▬	●	●
	SIRCA†	Ames	Mars	~ 150	> 1	▬	▬	▬
	Acusil II†	ITT	DoD	100	< 1	▬	▬	▬
High	Teflon†	Several	Various	> 500	> 1	■	■	■

● Fully capable ▬ Potentially capable (qual needed) ■ Capable but heavy ✖ Not capable

*For low shear environments †RF transparent