

# **Thermal Protection System: What is hot and what is not ?**

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# Thermal Protection Systems Technology

Space Technology Division

Thermal Protection Materials & Systems Branch

SSE Missions	Existing/ Evolving Materials	Sample Return Missions			Direct Entry						Aerocapture					
		Lunar SR	Comet/ Ast. SR	Mars SR	Mars	Titan	Venus	Saturn	Neptune	Jupiter	Mars	Titan	Venus	Saturn	Neptune	Jupiter
Ablative TPS Material Classes																
Low-density silicones	SLA-561V, SIRCA, SRAM, BLA	X	X	X	●	◐	X	X	X	X	◐	◐	X	X	X	X
Low-density phenolics	PICA, PhenCarb	●	●	◐	○	○	X	X	X	X	○	○	X	X	X	X
Mid-density phenolics and others	PhenCarb, BPA, Avcoat	◐	◐	◐	○	○	X	X	X	X	○	○	X	X	X	X
Carbon-based multilayer	C-C /Fiberform®	◐	●	◐	○	○	X	X	X	X	○	○	○	○	○	○
High-density phenolics	Carbon phenolic	○	○	○	○	○	●	●	●	●	○	○	○	○	○	○

- Fully capable and demonstrated;
- ◐ Capable, but not demonstrated;
- Potentially capable but with large TPS mass penalty
- X Not applicable; conditions too severe

# TPS SOA

- ◆ Current inventory of flight qualified TPS for future SMD missions are limited to Carbon-Phenolic, PICA, AVCOAT, SLA 561V and C-C and each impose mission constraints and some are mission limiting.
- ◆ Heritage Carbon-Phenolic, with limited quantity in hand, is the only material proven for expected entry heating at Venus, Saturn, Sample Return Missions (MSR, high speed Comet/Asteroid).
- ◆ A number of materials under development (ISP, ARMD, ESMD) have the potential to enable and enhance future SMD Missions.

# Carbon-Phenolic (CP): Background

- Pioneer Venus used fully dense carbon phenolic (FM-5055) for forebody TPS (also used later on Galileo)
  - ◆ Developed in the late-60s by USAF for strategic RV heat shields (**very specific processing/fabrication specs**)
  - ◆ Tape-wrapped fabrication employed on conical forebody
  - ◆ Fabrication/processing specs for chopped molded nose-cap developed under P-V by NASA
- “Heritage” carbon phenolic is **no longer made anywhere**
  - ◆ Avtex went out of business ~ 1980
  - ◆ Carbon fabric derived from Avtex continuous rayon precursor
  - ◆ Heritage CP used CCA-3 (1641B) carbon fabric derived from carbonization of Avtex rayon (1970s)

# Why is CP important?

- At the time, fully dense CP ( $1442 \text{ kg/m}^3$ ) was the *only* material demonstrated to handle heat fluxes in the range  $1\text{-}10 \text{ kW/cm}^2$  at pressures in the range  $1\text{-}10 \text{ atm}$  (Venus entry  $\sim 7 \text{ kW/cm}^2$  and  $7 \text{ atm.}$ )
  - ◆ Major investment by USAF in the 70s to develop heat shields for Minuteman RVs leveraged by NASA
  - ◆ Extensive ground and flight test data (\$\$\$\$)
- Are there better or equivalent materials today?
  - ◆ No. Neither DoD nor NASA has invested in ablative TPS materials development for the past 30 years
  - ◆ 3-D Carbon-carbon can *potentially* handle these environments, but it has not been demonstrated and it is expensive
- CP Enables NASA missions – No other choice at this time
  - ◆ Venus entry probes (Current NF and Discovery Proposals )
  - ◆ Saturn and Neptune entry probes (Next New Frontier Call 2011)
  - ◆ MSR (Next Decade or beyond)
  - ◆ Others (Jupiter, Saturn, Venus Flagship)

# Current supply status

- USAF realized ~ 6 years ago that they may need to qualify a *new* CP
  - ◆ Heat-shields on MMIII RVs certified for 30 year lifetime (built in mid-late 70s)
- NASA hasn't done much about CP since Galileo
  - ◆ Heritage CP baselined for Mars Sample Return since it is the only material with a database sufficient to satisfy the  $10^{-6}$  reliability requirement
  - ◆ U.S. Navy SSPO has/had a very limited supply of the heritage Avtex rayon
    - USAF has none
  - ◆ Navy SSPO transferred xxxx yards of heritage rayon to Ames (2001)
    - Carbonized to heritage carbon fabric (CCA-3) for potential use on MSR
    - In storage at Ames
  - ◆ Navy SSPO transferred the last remaining (6000+ yards) heritage rayon to Ames (2003)
    - In storage as white goods

# Raiders of the Last Arc: Avtex Rayon Stored in the Same Place



ARC received 13 crates of AVTEX rayon



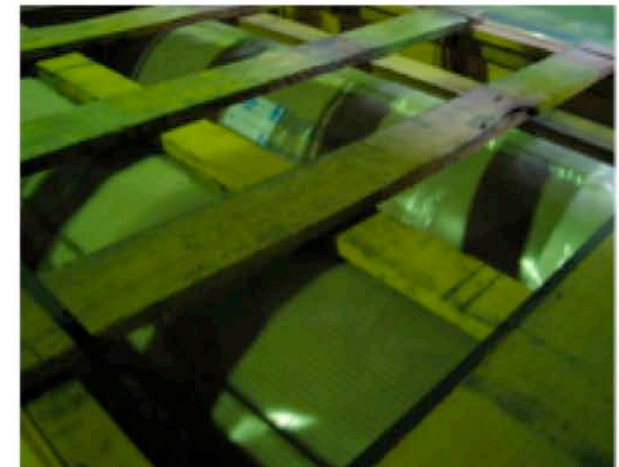
Paul Wercinski, Bernie Laub, and Raj Venkatapathy standing by one of the rayon crates

## Heritage carbon phenolic processing stages

- Precursor material is heritage rayon fabric, called AVTEX rayon.
- Producing carbon fabric from the AVTEX rayon (done by HITCO)
- Carbon fabric then gets the heritage designation of CCA3(1641B)
- CCA3(1641B) infused with phenolic resin in sheets which makes up the carbon phenolic pre-preg
- Pre-preg is then processed and molded into either chop-molded carbon phenolic for the heatshield nose, or laying up the tape-wrapped carbon phenolic for the frustum.



Identification label of heritage rayon fabric



Top view of one crate showing two rolls of rayon fabric

# Recommendations

- Need to Demonstrate that heritage CP can still be made with performance consistent with heritage database
  - ◆ Carbonize heritage rayon & Fabricate TWCP and CMCP billets
    - CMCP hasn't been made since Galileo and those people are gone
  - ◆ Validate material fabrication and performance
  - ◆ Upgraded test facilities
- Establish Alternative to heritage C-P