



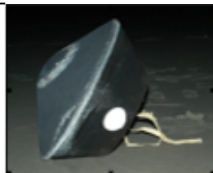
# Progress in Manufacturing & Characterizing Domestic Lyocell PICA (PICA-D) and Comparison to Heritage PICA

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## 1. Background – PICA and PICA Sustainability

### State of the Art Low Density Carbon Phenolic Ablators

- Phenolic Impregnated Carbon Ablator (PICA) is a low density (~ 0.27g/cm<sup>3</sup>) ablator first used as the forebody heatshield for the Stardust sample return capsule where it was used as a single piece heatshield
- Since Stardust, PICA was used on the Mars Science Lab (MSL) in a tiled configuration, on the OSIRIS-REx sample return capsule as a single piece and slated for Mars 2020 as a tiled configuration
- In 2016 NASA ARC learned that the heritage rayon utilized in PICA was stopping production, leading to a flight-qualified PICA sustainability challenge
- 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 showing it to be a good candidate as a potential replacement for heritage rayon



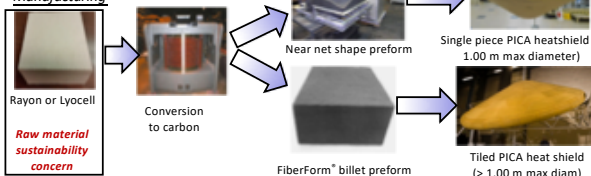
Stardust SRC post flight with PICA forebody heat shield (0.8m max. diameter)

## 2. Establishment of PICA-D as a Replacement for Heritage PICA

- In FY17, SMD-PSD funded ARC to manufacture and perform limited property and aerothermal characterization of Lyocell-based PICA
  - FY17 task successfully completed limited testing that indicated the viability of PICA-D as a potential replacement for heritage PICA

### Role of Rayon/Lyocell in PICA

#### Manufacturing



Lyocell is a sustainable domestic source of a “rayon alternative” fiber that can be used in the manufacture of carbon FiberForm®, the precursor to PICA.

### Material Property Characterization

- In FY17, 3 billets of PICA-D were manufactured to support testing
  - Limited In-plane (IP) tension, through-thickness (TT) tension, and through thickness thermal conductivity at 100F and 350F were conducted and compared to heritage rayon PICA
- Overall these results are in family with production rayon PICA – however additional testing is needed as only a few coupons were evaluated
  - Limited property data had substantial scatter – detailed testing planned for FY18/19

#### Mechanical Property Comparison

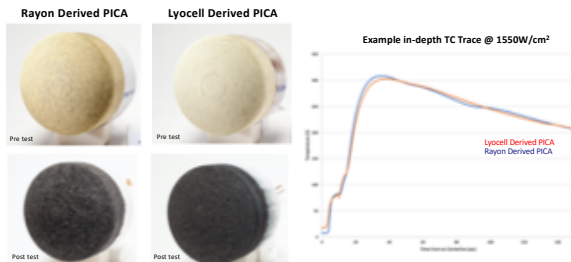
	Density (g/cc)	Failure Stress (psi)
Average Lyocell IP properties	0.28	246.48 (vs 190 for rayon PICA)
Average Lyocell TTT properties	0.28	44.03 (vs 49.6 for rayon PICA)

#### Thermal Property Comparison

	Billet ID	Specimen ID	Thermal Conductivity (BTU-in/hr-ft <sup>2</sup> -°F) at 100°F	Thermal Conductivity (BTU-in/hr-ft <sup>2</sup> -°F) at 350°F
Average Lyocell TTT properties			0.939	1.32
Average Rayon TTT properties			1.22	1.66

## Arc Jet Characterization

- 3 arcjet conditions were tested in FY17
  - NF proposers provided guidance on test conditions
  - All conditions will be repeated in FY18/19 to demonstrate data repeatability

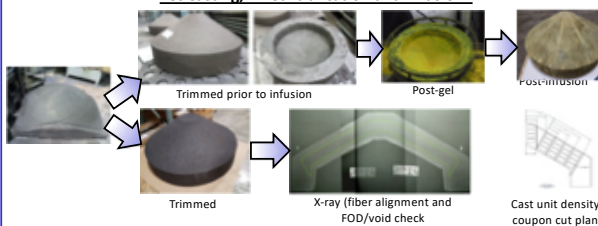


For a given test condition (same run time) initial results indicate that recession and in-depth temperature between a Lyocell derived PICA and a heritage rayon-derived PICA are comparable

## 3. Establishment of PICA-D Expanded Capability

- 9 billets of FiberForm were manufactured in FY17 to optimize the process using Lyocell fibers
  - Billets spanned the spec density range and billet FiberForm target densities were achieved
- Development and fabrication of 3 0.8-m net-shaped FiberForm heatshield blank (OSIRIS REX scale) were also completed in FY17
  - Density targets in all 3 net cast blanks were achieved
- Process refinements and lessons learned have been documented
- Limited Non Destructive Evaluation (NDE) completed on the Lyocell near net shape FiberForm unit to evaluate fiber alignment and check for off-nominal features
- FY18/19 work will expand on the work performed in FY17 and demonstrate repeatability as well as increase single piece net cast dimensions to >1.2-m

### Net Casting, Billet Fabrication and Infusion



## Acknowledgements

PICA sustainability activities are funded by NASA’s Planetary Science Division of the Science Mission Directorate

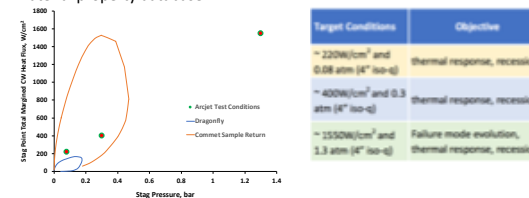
## 4. Exploration of Lyocell PICA (PICA-D) for Future Missions

In FY18/FY19, NASA Ames is leading an effort funded by SMD-PSD to characterize and extend the capability of PICA-D to Establish Lyocell PICA as a Drop-In Replacement for Heritage PICA

- Establishing PICA-D as a “drop in replacement” will allow missions to depend on and design missions with PICA without any risk typical of a replacement.
- Establishing the extended capability of PICA-D will allow Sample Return Missions with higher entry speed that were not considered before.

### Task 1: Establish PICA-D as a Drop-in replacement for Heritage PICA

- Develop comprehensive material property database
  - Perform comprehensive material property testing (range of temperatures) for thermal and mechanical properties
- Perform comprehensive arcjet test campaign
  - Test at multiple conditions, including different material lots
  - Testing to include thermal response, instrumented stagnation and wedge shear coupons
- Develop PICA-D Thermal Response Model utilizing arcjet test data and new material property database

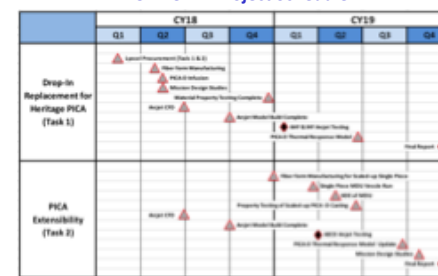


### Task 2: Establish the Expanded Capability (Extensibility) of PICA-D

- Demonstrate Manufacturing and Scale-Up of a Single Piece Heatshield at a Scale of > 1.2m Diameter
  - Perform comprehensive characterization and evaluation of single piece FiberForm casting
  - Characterize fiber alignment, mechanical properties and non-destructive evaluation (NDE)
- Establish Expanded Design Space of PICA-D
  - Perform arcjet testing and heat flux / pressure conditions beyond which PICA has previously been tested and / or flown

Publish all PICA-D Data for current and future missions

## 5. PICA-D Project Schedule



## 6. Summary

- NASA ARC is working with SMD-PSD to address PICA rayon sustainability concerns
- In FY16/17, Lyocell Based PICA (PICA-D) was manufactured and limited testing performed showing it to be a good candidate as a potential replacement for heritage rayon
- Establishing PICA-D as a “drop in replacement” will allow missions to depend on and design missions with PICA without any risk typical of a replacement.
- Establishing the extended capability of PICA-D will allow Sample Return Missions with higher entry speed that were not considered before.