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

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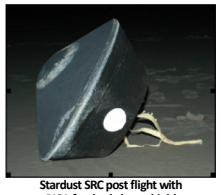
## 1. Background – PICA and PICA Sustainability

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

- Phenolic Impregnated Carbon Ablator (PICA) is a low density (~ 0.27g/cm$^3$) 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



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

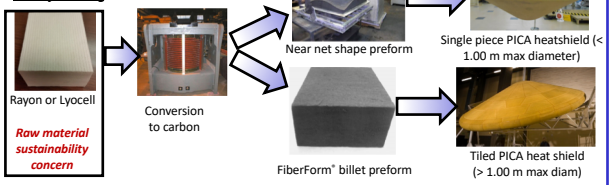
- In 2016 NASA ARC learned that the heritage rayon utilized in PICA was stopping production, leading to a flight-qualified PICA sustainability challenge
- In FY16/17, NASA ARC was funded by SMD/PSD to address PICA rayon sustainability
- Lyocell Based PICA (PICA-D) was manufactured and limited testing performed showing it to be a good candidate as a potential replacement for heritage rayon

## 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

**PICA Processing Steps**

*Role of Rayon/Lyocell in PICA Manufacturing*

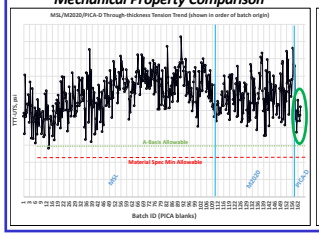



**Lyocell is a Sustainable Domestic Source of a "Rayon Alternative" Fiber that can be Used in the Manufacture of Carbon FiberForm®, the Precursor to PICA.**

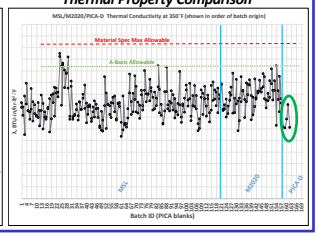
**Material Property Characterization**

- FY17, (3) billets of PICA-D were manufactured to support preliminary testing
- FY18, (9) additional billets were fabricated
  - 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
  - Results are in family with previous production rayon PICA and data is well within Spec limits required for flight hardware

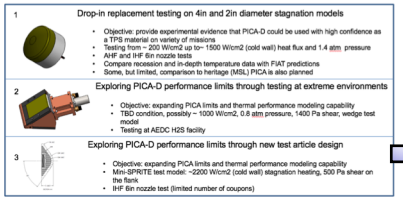
***Mechanical Property Comparison***



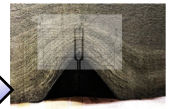

***Thermal Property Comparison***




## Approach to PICA-D Arc Jet Testing




Mini-SPRITE Test Casting with arcjet model superimposed

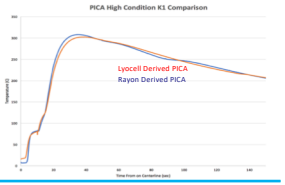


- FY17 - 3 Arcjet Conditions were Tested in Air
  - NF proposers provided guidance on test conditions
  - All conditions will be repeated in FY19 to demonstrate data repeatability

**Rayon Derived PICA**


**Lyocell Derived PICA**


**Example in-depth TC Trace @ 1550W/cm²**




- FY18 – 2 Arcjet Conditions were Tested in Nitrogen
  - Previous testing of PICA with RTV seams was only done in air under MSL and Orion programs
  - In support of Dragonfly Phase A study, PICA-D built 2 wedge shear models with RTV seams for testing in a nitrogen environment

Pre-test Photo

Post-test

**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, in Both Oxygen and Nitrogen.**

## 3. Establishment of PICA-D Expanded Capability

- 9 billets of FiberForm were manufactured in FY18 to optimize the FY17 fabrication process using Lyocell fibers
  - Billets spanned the spec density range and billet FiberForm target densities were achieved
- In FY17 fabrication of (3) 0.8-m Near Net-Shaped (NNS) FiberForm heatshield blanks (OSIRIS REx scale) was completed
  - Density targets in all 3 net cast blanks were achieved
- In FY18, work was done expand on the work performed in FY17 and demonstrate repeatability as well as increase single piece net cast dimensions to 1.5-meter
  - Fabrication of (4) 1.5-m diameter NNS FiberForm heatshields completed in December 2018
- Limited Non Destructive Evaluation (NDE) on the 1.5-m Lyocell NNS FiberForm units underway, (1) unit to be PICA infused (in progress as of March 2019)

**Near Net Shape (NNS) Casting**

Near Net Shape PICA-D Casting Tool

1.5-m Single Piece Unit (1 of 4)

Trimmed 1.5-m Casting

## Acknowledgements

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

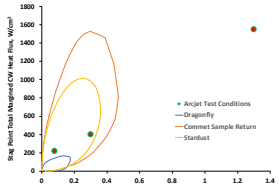
## 4. Exploration of Lyocell PICA (PICA-D) for Future Missions

**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

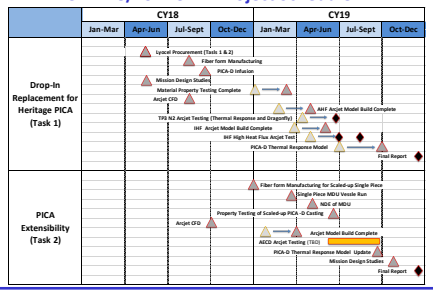



| Target Conditions | Objective |
|---|---|
| ~ 220W/cm$^2$ and 0.08 atm (4" iso-q) | thermal response, recession |
| ~ 400W/cm$^2$ and 0.3 atm (4" iso-q) | thermal response, recession |
| ~ 1550W/cm$^2$ and 1.3 atm (4" iso-q) | Failure mode evolution, thermal response, recession |

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

- Demonstrate Manufacturing and Scale-Up of a Single Piece Heatshield at a Scale of ~1.5-meter 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. FY18/19 PICA-D Project Schedule




## 6. Summary

- NASA ARC is working with SMD-PSD to address PICA rayon sustainability concerns
- Lyocell Based PICA (PICA-D) was first manufactured in FY16/17, and limited testing was performed.
- In FY18/19 additional billets were fabricated and tested. Recent results (FY18) confirm initial testing (FY 17) that, Lyocell-based PICA is a good candidate as a potential replacement for heritage rayon-based 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.