

Sustaining PICA TPS for Future NASA Robotic Science Missions

Mairead Stackpoole, Ethiraj Venkatapathy, and Matthew Gasch, NASA Ames Research Center, Moffett Field, CA 94035
 Steve Violette, Fiber Materials Inc., Biddeford, ME 04005

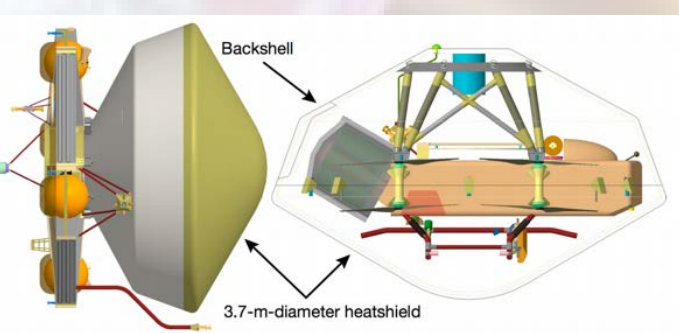
1. Background – PICA and PICA Sustainability

State of the Art Low Density Carbon Phenolic Ablators

- Phenolic Impregnated Carbon Ablator (PICA) is a low density ($\sim 0.27\text{g/cm}^3$) ablator first used as the forebody heatshield for the Stardust sample return capsule (single piece heatshield)
- Since Stardust
 - PICA was used on the Mars Science Lab (MSL) in a tiled configuration
 - OSIRIS-REx sample return capsule (single piece)
 - Slated for Mars 2020 (tiled configuration)
- Based on successful mission use across destinations ranging from Earth return to Mars, PICA has been proposed as the TPS option for numerous New Frontier and Discovery missions
- 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)



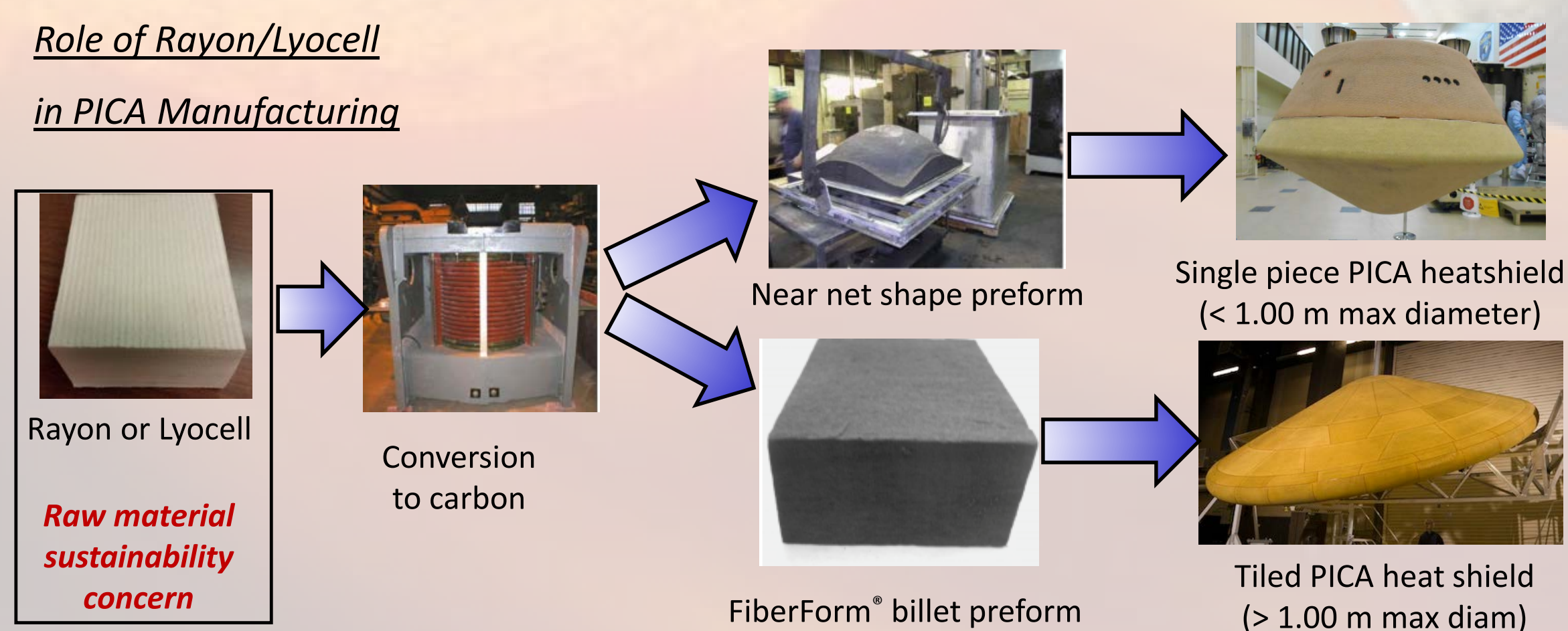
Dragonfly forebody TPS (~3.7 m diameter) Currently NF – Phase A

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

- 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

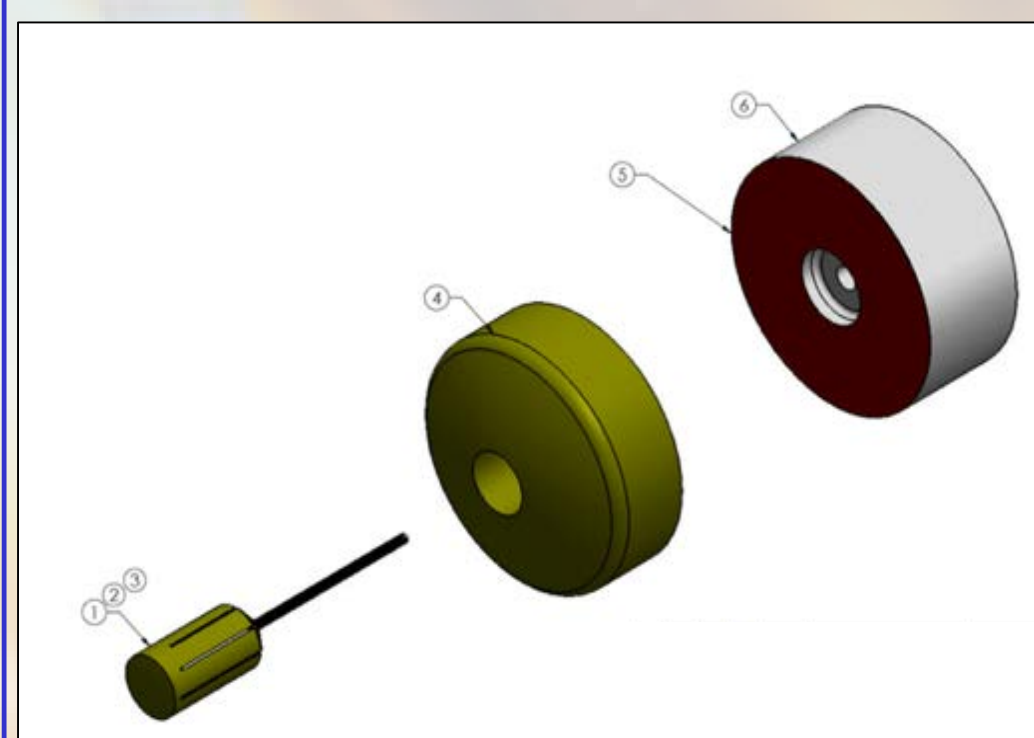
Mechanical Property Comparison

Thermal Property Comparison

	Density (g/cc)	Average Failure Stress (psi)	Thermal Conductivity (BTU-in/hr-ft ² -°F)	
			at 100°F	at 350°F
Average Lyocell PICA IP properties	0.28	246 160 - 255 for rayon PICA	0.94	1.32
Average Lyocell PICA TTT properties	0.28	44 43 to 54 for rayon PICA	1.0 - 1.5	1.5 - 2.1

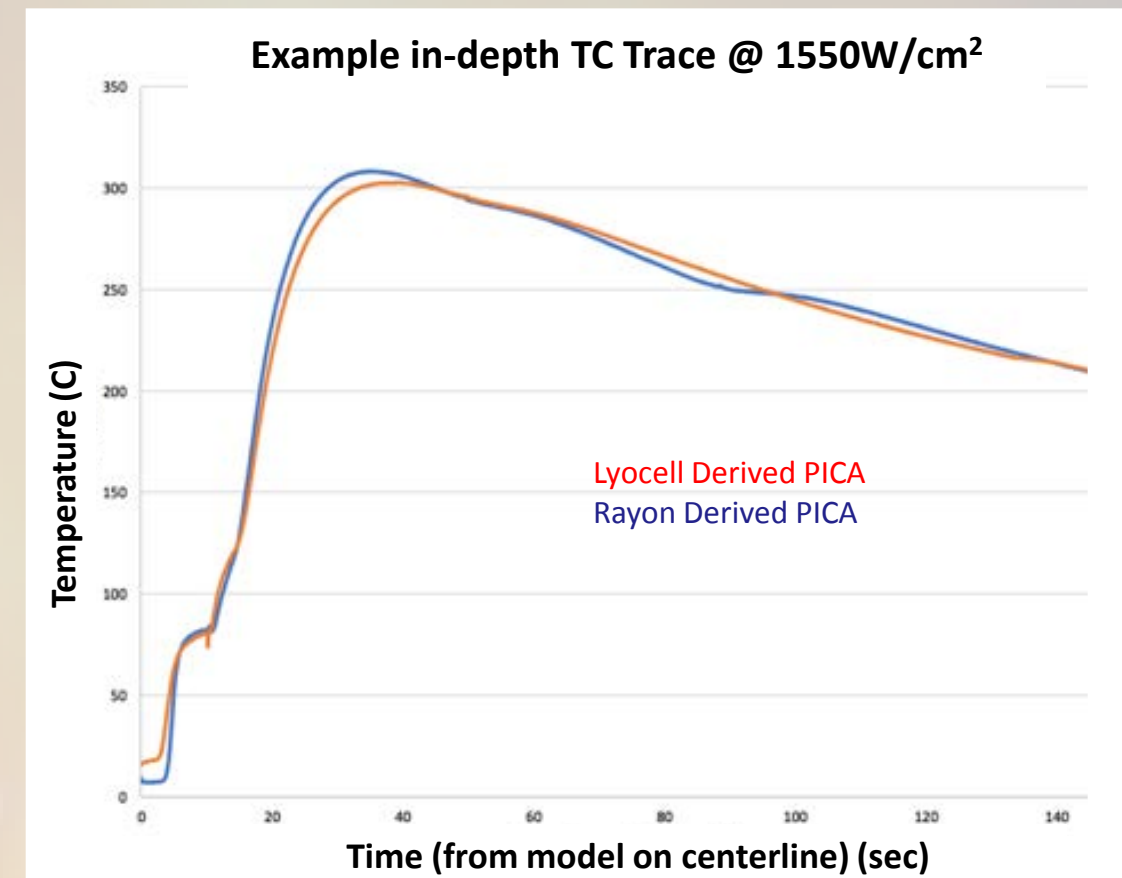
3. Arc Jet Characterization

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



Coupon Geometry

- 4" iso-q coupons
- Each coupon instrumented with a plug containing 5 in-depth thermocouples consisting of 2 type-R and 3 type-K



Recession Comparison

Material	Average centerline recession (1550W/cm ² and 1.3 atm)	Average centerline recession (400W/cm ² and 0.3atm)	Average centerline recession (220W/cm ² and 0.08atm)
Lyocell Derived PICA	4.0 mm	6.0 mm	3.8 mm
Rayon Derived PICA	4.2 mm	6.0 mm	3.9 mm

Pre/ Post Test Model Comparison (1550W cm² condition)

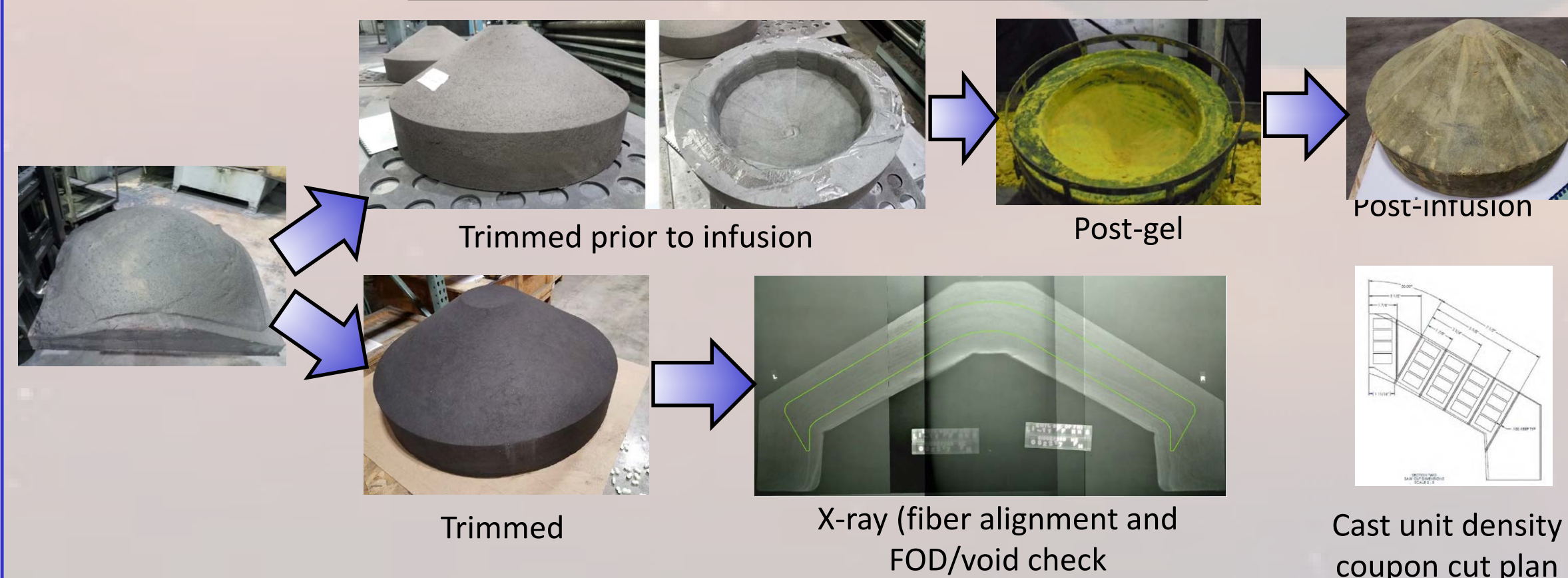


For a given test condition (same run time) initial results indicate that recession and in-depth temperature between a Lyocell derived PICA and a heritage rayon-derived PICA are comparable

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 three 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. Authors acknowledge Y-K Chen, D. Ellerby, G. Gonzales, M. Olson D. Prabhu, and K. Skokova.

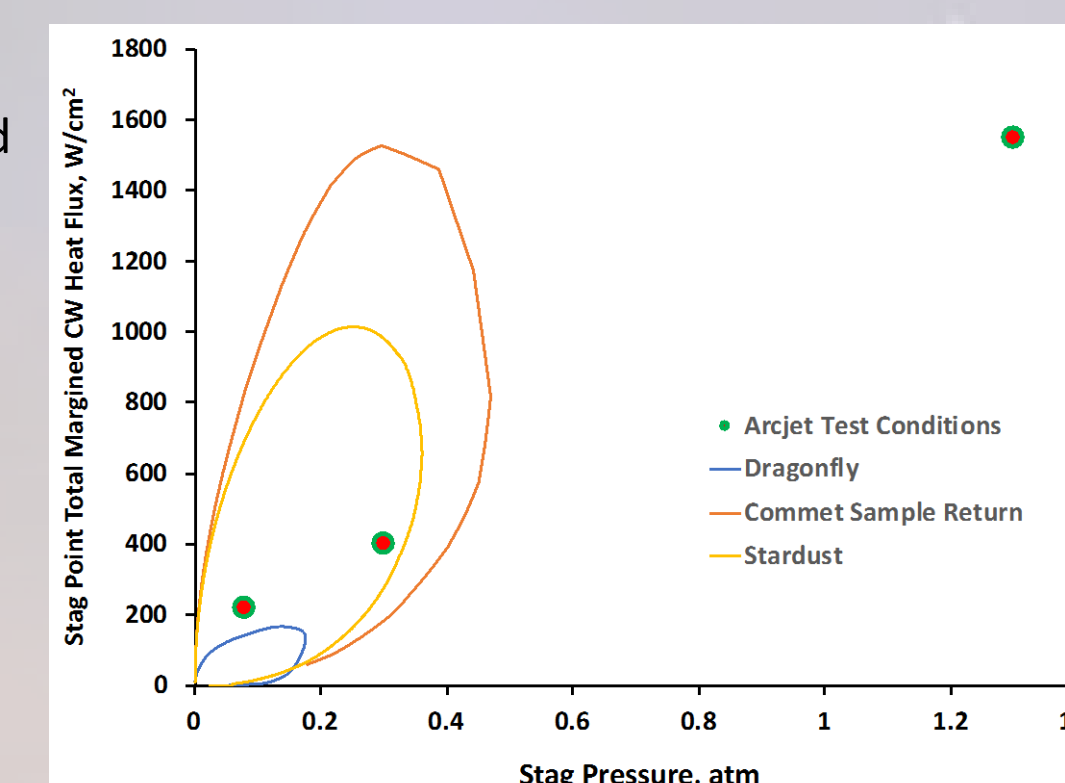
4. Exploration of Lyocell PICA (PICA-D) for Future Missions

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 the risks 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

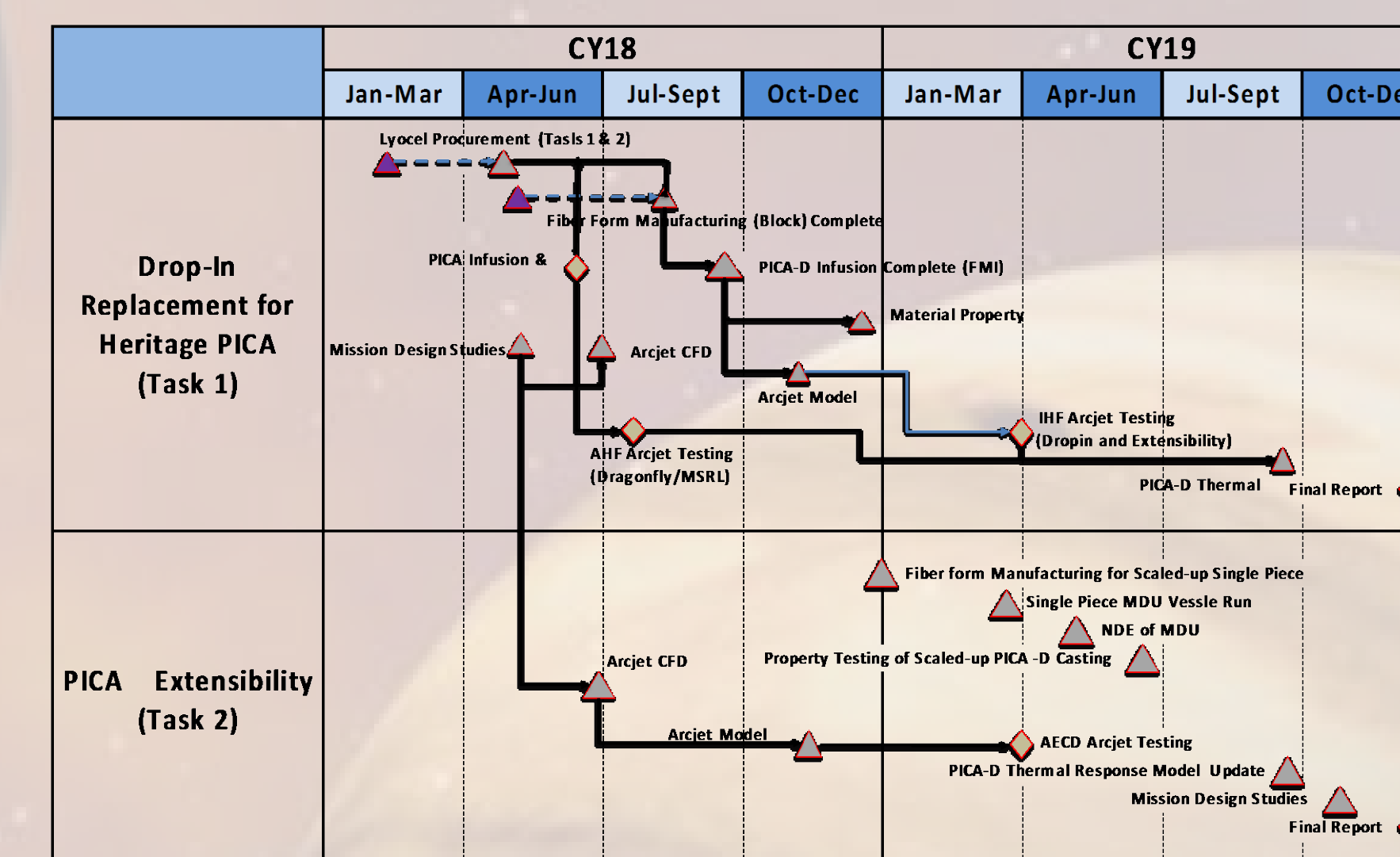
- Develop comprehensive material property database
- Perform comprehensive material property testing (range of temperatures) for thermal and mechanical properties
- Perform comprehensive arcjet test campaign
- Test at multiple conditions, including different material lots
- Test to include thermal response, 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 / FMI is working with the Planetary Science Division of the Science Mission Directorate to address PICA rayon sustainability concerns
- In FY16/17, Lyocell Based PICA (PICA-D) was manufactured and limited testing performed show it to be a good candidate replacement for heritage rayon
- Establishing PICA-D as a “drop in replacement” will allow missions to design with PICA-D without any competitive disadvantage over other competing proposals.
- Establishing the extended capability of PICA-D will allow Sample Return Missions with higher entry speeds not considered before.