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/cm³) 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.
- NASA ARC recently learned that heritage rayon utilized in PICA has stopped production leading to a flight-qualified PICA sustainability challenge.
- NASA ARC is funded by SMD to address PICA rayon sustainability
  - Two approaches are being pursued:
    - Secure the remaining heritage (Sniace) rayon.
    - Develop and implement plans to certify a Lyocell based PICA

Feasibility of Sustainable Domestic Lyocell PICA

Lyocell is being evaluated as a "rayon alternative" FiberForm® precursor – Lyocell is a sustainable domestic source and previous work indicates Lyocell is a feasible alternative to SMD-PIC respund ARC to manufacture and perform limited property and aerothermal characterization of Lyocell based PICA
- Fabrication of PICA billets & a near net shape heatshield using Lyocell based FiberForm®. Activity supports tiled heatshield & smaller scale single piece heatshield designs. Target drop-in replacement for heritage PICA
- Characterization includes thermal /mechanical properties and arc jet testing of instrumented coupons - NASA ARC worked with NF proposing orgs to ensure arc jet testing is at mission relevant conditions

Status - Net Casting, Billet Fabrication and Infusion

- 7 billets of fiberform manufactured to optimize the process using lyocell fibers – billets span the spec density range – fiberform target densities achieved
- Development and fabrication of 1 relevant scale, net-shaped FiberForm heatshield blank (OSIRIS-REx scale) completed – density targets in net cast 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

PICA Processing Steps
Manufacturing
- Rayon or Lyocell Raw material
- Conversion to carbon
- FiberForm® billet preform
- Near net shape preform
- Single piece PICA heat shield (< 1.00 m max diam)
- Tiled PICA heat shield (> 1.00 m max diam)

Status – Property Testing

- 3 billets of PICA manufactured to support testing - these represent the material's density varying through the range of specification limits on billet density
- 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 limited coupons were evaluated

Mechanical Property Comparison

<table>
<thead>
<tr>
<th></th>
<th>Density (g/cc)</th>
<th>Failure Stress (ps)</th>
<th>Billet ID</th>
<th>Specimen ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyocell IP properties</td>
<td>0.28</td>
<td>246.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lyocell TT properties</td>
<td>0.28</td>
<td>190.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rayon Derived PICA</td>
<td>0.939</td>
<td>1.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rayon Derived PICA</td>
<td>1.22</td>
<td>1.66</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Thermal Property Comparison

<table>
<thead>
<tr>
<th></th>
<th>Thermal Conductivity (BTU-in/hr-ft²°F) at 100F</th>
<th>Average Lyocell TTT properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lyocell IP properties</td>
<td>44.03</td>
<td>15.00</td>
</tr>
<tr>
<td>Rayon Derived PICA</td>
<td>48.07</td>
<td>18.00</td>
</tr>
</tbody>
</table>

Summary

- NASA ARC is working with SMD-PIC to address PICA rayon sustainability concerns
- Remaining Sniace heritage rayon has been procured by NASA and is being stored for future SMD-PIC mission – enough heritage rayon available to support a single mission (OSIRIS-REx scale)
- NASA is also evaluating a domestic rayon alternative (Lyocell) for qualifying a replacement PICA thereby providing a sustainable domestic source that is more certain for long-term availability
- Limited initial testing and property dataset indicate that Lyocell derived PICA is a potential drop in replacement for rayon derived PICA

Future Work – 2 Focus Areas

PICA for NF, Discovery and Mars Missions with Expanded Capabilities:
- Recommend that SMD/PIC initiate a tasks for drop in replacement for heritage PICA
  - Comprehensive property database, complete arc jet testing (including shear testing) on multiple samples at NF relevant conditions demonstrating we have a drop in replacement for heritage PICA
  - Evaluate single piece PICA manufacturing scale-up (up to 1.5m uni-piece heatshield)
  - Identify PICA expanded capability limits:
    - Current recommended use based on flight (~ 1000W/cm², 0.5 psi and ~ 600Pa)
    - Potential PICA use limit (heat flux, pressure, shear) (~1700W/cm², ~1.3 atm and 1200Pa?)

Acknowledgements

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

Presented at VEXAG, November 14–16, 2017, APL, Laurel, Maryland