FAMILY SYSTEM OF ADVANCED CHARRING ABLATORS FOR PLANETARY EXPLORATION MISSIONS

ISPT AEROCAPTURE PROJECT – NASA/MSFC

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ADVANCED ABLATORS PROGRAM OBJECTIVES

FLIGHT-READY (TRL-6) ABLATIVE HEAT SHIELDS FOR DEEP-SPACE MISSIONS
DIVERSITY OF SELECTION FROM FAMILY-SYSTEM APPROACH
MINIMUM WEIGHT SYSTEMS WITH HIGH RELIABILITY
OPTIMIZED FORMULATIONS AND PROCESSING
FULLY-CHARACTERIZED PROPERTIES
LOW-COST MANUFACTURING

DEFINITION AND INTEGRATION OF CANDIDATE LIGHTWEIGHT STRUCTURES

TEST AND ANALYSIS DATABASE TO SUPPORT FLIGHT-VEHICLE ENGINEERING

RESULTS FROM PRODUCTION SCALE-UP STUDIES AND PRODUCTION-COST ANALYSES
ADVANCED ABLATORS FOR FOREBODY AND BACKSHELL HEATING

- Probe Forebody
- Probe Afterbody
- Windward Heating
- Leeward Heating
<table>
<thead>
<tr>
<th>Ablator</th>
<th>Abbreviation</th>
<th>Density</th>
<th>Resin System</th>
<th>Fillers</th>
<th>Heating Range</th>
<th>EDL Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRAM-14</td>
<td>S14</td>
<td>14 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>90 to 140 W/cm²</td>
<td>Forebody</td>
</tr>
<tr>
<td>SRAM-17</td>
<td>S17</td>
<td>17 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>110 to 120 W/cm²</td>
<td>Forebody</td>
</tr>
<tr>
<td>SRAM-20</td>
<td>S20</td>
<td>20 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>140 to 270 W/cm²</td>
<td>Forebody</td>
</tr>
<tr>
<td>SRAM-24</td>
<td>S24</td>
<td>24 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>180 to 350 W/cm²</td>
<td>Forebody</td>
</tr>
<tr>
<td>PhenCarb-20</td>
<td>P20</td>
<td>20 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>200 to 500 W/cm² -sec</td>
<td>Forebody</td>
</tr>
<tr>
<td>PhenCarb-24</td>
<td>P24</td>
<td>24 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>300 to 700 W/cm² -sec</td>
<td>Forebody</td>
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<tr>
<td>PhenCarb-28</td>
<td>P28</td>
<td>28 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>400 to 900 W/cm² -sec</td>
<td>Forebody</td>
</tr>
<tr>
<td>PhenCarb-32</td>
<td>P32</td>
<td>32 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>500 to 1100 W/cm² -sec</td>
<td>Forebody</td>
</tr>
<tr>
<td>PhenCarb-36</td>
<td>P36</td>
<td>36 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>600 to 1300 W/cm² -sec</td>
<td>Forebody</td>
</tr>
<tr>
<td>Hyperlites</td>
<td>S11</td>
<td>11 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>10 to 40 W/cm²</td>
<td>Afterbody</td>
</tr>
<tr>
<td>Hyperlites</td>
<td>S12</td>
<td>12 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>30 to 70 W/cm²</td>
<td>Afterbody</td>
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<tr>
<td>Hyperlites</td>
<td>S13</td>
<td>13 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>40 to 100 W/cm²</td>
<td>Afterbody</td>
</tr>
</tbody>
</table>
ADVANCED ABLATORS MANUFACTURING METHODS

Honeycomb Packing (1.0-In. Large Cells)

Strip-Collar Bonding Approach (SCBA)
SRAM-17 ARC-JET SAMPLES FROM DIFFERENT PROCESSING

- Monolithic Molding
  - Sample 3105
  - 119 W/cm² – 125 sec

- Honeycomb Packing
  - Sample 3119
  - 67 W/cm² – 200 sec

- Strip-Collar Bonding
  - Sample 3085
  - 119 W/cm² – 125 sec

- Monolithic Molding
  - Sample 3105
  - 119 W/cm² – 125 sec
SRAM-20 TPS 20 lb/ft$^3$ Candidate for Titan Mission (140 to 270 W/cm$^2$)

Robust Char Layer - Low Recession and Radiation Opacity from Carbon Loading

114 W/cm$^2$-sec for 150 sec
Sample 1545 - NASA/JSC Test

SRAM-20 Thermal Model
Match to Arc-Jet Data
**SRAM-20** Test Sample Performance at 245 W/cm² and 310 W/cm²

- **245 W/cm²-sec for 40 sec**
  - Sample 3151 - NASA/ARC Test
  - Recession 0.185 in.

- **311 W/cm²-sec for 30 sec**
  - Sample 3152 - NASA/ARC Test
  - Recession 0.203 in.

- Iso-Q Sample Design
  - 1.5-In. Thickness
**SRAM-20** Test Sample Performance at 362 W/cm$^2$ and 411 W/cm$^2$

- **362 W/cm$^2$-sec for 25 sec**
  - Sample 3153 - NASA/ARC Test
  - Recession 0.233 in.

- **411 W/cm$^2$-sec for 20 sec**
  - Sample 3154 - NASA/ARC Test
  - Recession 0.221 in.

**Iso-Q Sample Design**
1.5-In. Thickness
**SRAM-17** Ablator 17 lb/ft\(^3\) Candidate for MSL Mission (110 to 200 W/cm\(^2\))

Durable Char Layer - Low Recession and Radiation Opacity from Carbon Loading

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**SRAM-17 Thermal Model**
Match to Arc-Jet Data

114 W/cm\(^2\)-sec for 150 sec
Sample 1541 - NASA/JSC Test
**SRAM-14** Ablator 14 lb/ft$^3$ for MPF-Type Missions (90 to 140 W/cm$^2$)

Very Lightweight Ablator with Excellent Thermal Insulation

![Ablator Image]

114 W/cm$^2$-sec for 100 sec  
Sample 1538 - NASA/JSC Test

**SRAM-14 Thermal Model**  
Match to Arc-Jet Data
**PhenCarb-28** Ablator in Carbon H/C – IHF Test at 411 W/cm²

**Iso-Q Sample Design**
1.5-In. Thickness

**Sample 3171** – 411 W/cm² for 80 sec

Recession 0.071 in.

**Sample 3170** – 411 W/cm² for 40 sec

Production Using ARA Lightweight Carbon-Phenolic Honeycomb

Recession 0.178 in.
### ADVANCED ABLATORS CURRENT ARC-JET TEST PROGRAM

<table>
<thead>
<tr>
<th>Series</th>
<th>Date</th>
<th>Heating Range</th>
<th>Samples</th>
<th>Status</th>
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<tbody>
<tr>
<td>IHF-1</td>
<td>Mar 03</td>
<td>Up to 153 W/cm²</td>
<td>32 Tested</td>
<td>Completed</td>
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<tr>
<td>IHF-2</td>
<td>Sep 03</td>
<td>Up to 182 W/cm²</td>
<td>32 Tested</td>
<td>Completed</td>
</tr>
<tr>
<td>IHF-3</td>
<td>Mar 04</td>
<td>Up to 182 W/cm²</td>
<td>60 Tested</td>
<td>Completed</td>
</tr>
<tr>
<td>IHF-4</td>
<td>Aug 04</td>
<td>Up to 411 W/cm²</td>
<td>34 Tested</td>
<td>Completed</td>
</tr>
<tr>
<td>IHF-5</td>
<td>Sep 04</td>
<td>Up to 1200 W/cm²</td>
<td>32 Ready</td>
<td>Future</td>
</tr>
<tr>
<td>ARMSEF-1</td>
<td>May 05</td>
<td>Up to 720 W/cm²</td>
<td>70 Ready</td>
<td>Future</td>
</tr>
</tbody>
</table>

**SRAM-14** Sample 3061
67 W/cm² - 200 sec
ADVANCED ABLATORS THERMAL RADIATION TEST PROGRAM

211 individual heliostats occupying 8.0-acre site. Each heliostat contains 25 mirrors of 16 ft² each. Can achieve test flux of 300 W/cm².

200-ft tower with additional 50 ft below surface. Occupies 1.0-acre site.
RESPONSE OF *SRAM-20* TO THERMAL RADIATION AT ~100 W/cm²
ADVANCED ABLATORS MECHANICAL PROPERTIES TEST PROGRAM

ARA Lab

SRAM-17

PhenCarb-20

ARA Ablatives Laboratory
OVERVIEW OF ABLATOR TESTING PROGRAMS

ARC-JET TESTING AT NASA/ARC AND NASA/JSC
THERMAL RADIATION TESTING AT SOLAR TOWER
MECHANICAL PROPERTIES TESTING
THERMAL PROPERTIES TESTING
NDI AND REPAIR TESTING
ACCOUSTIC TESTING

SRAM-20 Sample 3070
119 W/cm² - 125 sec
SUMMARY DISCUSSION ADVANCED ABLATORS PROJECT

GOAL IS ADVANCED ABLATORS READY FOR FLIGHT BY 2006

EXTENSIVE ARC-JET TESTING OF MORE THAN 260 SAMPLES

60 THERMAL-RADIATION TESTS IN INTENSE SOLAR SPECTRUM

GENERATING LARGE MATERIAL-PROPERTIES DATABASE

THERMAL-RESPONSE MODELS IN ADVANCED DEVELOPMENT

ABLATORS SHOWING EXCELLENT PERFORMANCE FOR DIVERSE MISSIONS