FAMILY SYSTEM OF ADVANCED CHARRING ABLATORS FOR PLANETARY EXPLORATION MISSIONS

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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
### FAMILY SYSTEMS OF ABLATORS – KEY MATERIALS

<table>
<thead>
<tr>
<th>Ablator</th>
<th>Density</th>
<th>Resin System</th>
<th>Fillers</th>
<th>Heating Range</th>
<th>EDL Location</th>
<th>Abbreviation</th>
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</thead>
<tbody>
<tr>
<td>SRAM-14</td>
<td>14 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>90 to 140 W/cm²</td>
<td>Forebody</td>
<td>S14</td>
</tr>
<tr>
<td>SRAM-17</td>
<td>17 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>110 to 120 W/cm²</td>
<td>Forebody</td>
<td>S17</td>
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<tr>
<td>SRAM-20</td>
<td>20 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>140 to 270 W/cm²</td>
<td>Forebody</td>
<td>S20</td>
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<tr>
<td>SRAM-24</td>
<td>24 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>180 to 350 W/cm²</td>
<td>Forebody</td>
<td>S24</td>
</tr>
<tr>
<td>PhenCarb-20</td>
<td>20 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>200 to 500 W/cm²-sec</td>
<td>Forebody</td>
<td>P20</td>
</tr>
<tr>
<td>PhenCarb-24</td>
<td>24 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>300 to 700 W/cm²-sec</td>
<td>Forebody</td>
<td>P24</td>
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<tr>
<td>PhenCarb-28</td>
<td>28 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>400 to 900 W/cm²-sec</td>
<td>Forebody</td>
<td>P28</td>
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<tr>
<td>PhenCarb-32</td>
<td>32 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>500 to 1100 W/cm²-sec</td>
<td>Forebody</td>
<td>P32</td>
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<tr>
<td>PhenCarb-36</td>
<td>36 lb/ft³</td>
<td>Phenolic</td>
<td>Carbon / others</td>
<td>600 to 1300 W/cm²-sec</td>
<td>Forebody</td>
<td>P36</td>
</tr>
<tr>
<td>Hyperlite-C</td>
<td>11 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>10 to 40 W/cm²</td>
<td>Afterbody</td>
<td>S11</td>
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<tr>
<td>Hyperlite-B</td>
<td>12 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>30 to 70 W/cm²</td>
<td>Afterbody</td>
<td>S12</td>
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<tr>
<td>Hyperlite-A</td>
<td>13 lb/ft³</td>
<td>Silicone</td>
<td>Silica / others</td>
<td>40 to 100 W/cm²</td>
<td>Afterbody</td>
<td>S13</td>
</tr>
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</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
  - $119 \text{ W/cm}^2$ – 125 sec

- **Honeycomb Packing**
  - Sample 3119
  - $67 \text{ W/cm}^2$ – 200 sec

- **Strip-Collar Bonding**
  - Sample 3085
  - $119 \text{ W/cm}^2$ – 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/cm² and 411 W/cm²

362 W/cm²·sec for 25 sec
Sample 3153 - NASA/ARC Test

Recession
0.233 in.

411 W/cm²·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

114 W/cm\(^2\)-sec for 150 sec  
Sample 1541 - NASA/JSC Test

**SRAM-17** Thermal Model  
Match to Arc-Jet Data
**SRAM-14** Ablator 14 lb/ft$^3$ for MPF-Type Missions (90 to 140 W/cm$^2$)

Very Lightweight Ablator with Excellent Thermal Insulation

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 3170 – 411 W/cm² for 40 sec

Recession
0.071 in.

Sample 3171 – 411 W/cm² for 80 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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<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>
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<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>
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</table>

**SRAM-14** Sample 3061  
67 W/cm² - 200 sec
211 individual heliostats occupying 8.0-acre site. Each heliostat contains 25 mirrors of 16 ft$^2$ each. Can achieve test flux of 300 W/cm$^2$.

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

**4017**

**4018**

FLOW

4017 – 108 W / 60 s

4018 – 105 W / 90 s
ADVANCED ABLATORS MECHANICAL PROPERTIES TEST PROGRAM

ARA Lab

PhenCarb-20

SRAM-17
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