2ND INTERNATIONAL PLANETARY PROBE WORKSHOP

FAMILY SYSTEM OF ADVANCED CHARRING ABLATORS FOR PLANETARY EXPLORATION MISSIONS

ISPT AEROCAPTURE PROJECT – NASA/MSFC

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NASA Johnson Space Center
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
<table>
<thead>
<tr>
<th>Ablation System</th>
<th>Density (lb/ft³)</th>
<th>Resin System</th>
<th>Fillers</th>
<th>Heating Range (W/cm²)</th>
<th>EDL Location</th>
<th>Abbreviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRAM-14</td>
<td>14</td>
<td>Silicone</td>
<td>Silica  / others</td>
<td>40 to 100</td>
<td>Forebody</td>
<td>S14</td>
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<tr>
<td>SRAM-17</td>
<td>17</td>
<td>Silicone</td>
<td>Silica  / others</td>
<td>110 to 120</td>
<td>Forebody</td>
<td>S17</td>
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<tr>
<td>SRAM-20</td>
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<td>Silica  / others</td>
<td>140 to 140</td>
<td>Forebody</td>
<td>S20</td>
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<tr>
<td>SRAM-24</td>
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<td>Silica  / others</td>
<td>180 to 350</td>
<td>Forebody</td>
<td>S24</td>
</tr>
<tr>
<td>SRAM-28</td>
<td>28</td>
<td>Silicone</td>
<td>Silica  / others</td>
<td>200 to 500</td>
<td>Forebody</td>
<td>S28</td>
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<tr>
<td>SRAM-32</td>
<td>32</td>
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<td>Silica  / others</td>
<td>300 to 700</td>
<td>Forebody</td>
<td>S32</td>
</tr>
<tr>
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<td>Silica  / others</td>
<td>400 to 900</td>
<td>Forebody</td>
<td>S36</td>
</tr>
<tr>
<td>SRAM-40</td>
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<td>Silicone</td>
<td>Silica  / others</td>
<td>500 to 1100</td>
<td>Forebody</td>
<td>S40</td>
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<tr>
<td>PhenCarb-20</td>
<td>20</td>
<td>Phenolic</td>
<td>Carbon  / others</td>
<td>600 to 1300</td>
<td>Forebody</td>
<td>P20</td>
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<tr>
<td>PhenCarb-22</td>
<td>22</td>
<td>Phenolic</td>
<td>Carbon  / others</td>
<td>700 to 1400</td>
<td>Forebody</td>
<td>P22</td>
</tr>
<tr>
<td>PhenCarb-24</td>
<td>24</td>
<td>Phenolic</td>
<td>Carbon  / others</td>
<td>800 to 1500</td>
<td>Forebody</td>
<td>P24</td>
</tr>
<tr>
<td>PhenCarb-28</td>
<td>28</td>
<td>Phenolic</td>
<td>Carbon  / others</td>
<td>900 to 1600</td>
<td>Forebody</td>
<td>P28</td>
</tr>
<tr>
<td>PhenCarb-32</td>
<td>32</td>
<td>Phenolic</td>
<td>Carbon  / others</td>
<td>1000 to 1800</td>
<td>Forebody</td>
<td>P32</td>
</tr>
<tr>
<td>PhenCarb-36</td>
<td>36</td>
<td>Phenolic</td>
<td>Carbon  / others</td>
<td>1100 to 2000</td>
<td>Forebody</td>
<td>P36</td>
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<tr>
<td>PhenCarb-40</td>
<td>40</td>
<td>Phenolic</td>
<td>Carbon  / others</td>
<td>1200 to 2200</td>
<td>Forebody</td>
<td>P40</td>
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</table>

**FAMILY SYSTEMS OF ABLATORS – KEY MATERIALS**
ADVANCED ABLATORS MANUFACTURING METHODS

Honeycomb Packing (1.0-In. Large Cells)

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

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

- **Honeycomb Packing**
  - Sample 3119
  - 67 W/cm² – 200 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/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/ft³ for MPF-Type Missions (90 to 140 W/cm²)

Very Lightweight Ablator with Excellent Thermal Insulation

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**SRAM-14** Thermal Model Match to Arc-Jet Data

114 W/cm²·sec for 100 sec

Sample 1538 - NASA/JSC Test

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**ARA** Ablatives Laboratory
PhenCarb-28 Ablator in Carbon H/C – IHF Test at 411 W/cm²

Sample 3170 – 411 W/cm² for 40 sec

Production Using ARA Lightweight Carbon-Phenolic Honeycomb

Recession 0.178 in.

Sample 3171 – 411 W/cm² for 80 sec

Recession 0.071 in.

Iso-Q Sample Design
1.5-In. Thickness
# 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>
</tr>
</thead>
<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>
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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>
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<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 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
ADVANCED ABLATORS MECHANICAL PROPERTIES TEST PROGRAM
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
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