Applications of Multifunctional Structures to Small Spacecraft

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Projects involving small spacecraft and constellations of small spacecraft can be highly constrained

- They may have the tightest cost, schedule, mass, volume, and footprint requirements
- They may require the most efficient approaches *in all disciplines* to be successful

An integrated solution is needed to the combined challenges of structure, thermal, and component integration

- Low cost approach that produces spacecraft structure in quantity
- Low mass approach that significantly increases the payload/instrument mass fraction
- Integration approaches that move tasks to lower levels of assembly
- Design solutions that addresses multiple challenges simultaneously rather than multiple solutions layered on top of one another

**Composite Multifunctional Structure has been developed to address this challenge**
Our approach to composite multifunctional structure is based on compression molded thermoset composites

- Simple tooling, capable of high rate production at low recurring costs
- Uses molding compounds to achieve complex part geometry and fiber orientation control and permits post-molding machining if necessary
- Takes advantage of new carbon fiber/epoxy molding compounds
  - Strengths exceeding aluminum
  - 45% mass reduction
  - Near-zero CTE
  - Improved stiffness
- Allows functional elements to be precisely located in mold and embedded within structure
  - Flex-print circuitry
  - Thermal inserts
  - Layered radiation shielding
  - Thin batteries
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Material Properties

Composites have a wide range of structural, thermal, and electrical properties that offer the possibility of increased performance AND flexibility over aluminum.

<table>
<thead>
<tr>
<th>Property</th>
<th>6061-T6 Aluminum</th>
<th>Molding Compounds</th>
<th>Tapes and Prepregs</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.7 g/cm³</td>
<td>1.45 g/cm³</td>
<td>1.61 g/cm³</td>
<td>1.60 g/cm³</td>
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<tr>
<td>Density</td>
<td></td>
<td>MS4A</td>
<td>MS2D</td>
<td></td>
</tr>
<tr>
<td>Strength</td>
<td>36 ksi</td>
<td>45 ksi</td>
<td>28 ksi</td>
<td>175 ksi</td>
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<tr>
<td></td>
<td></td>
<td>MS4A</td>
<td>MS2D</td>
<td></td>
</tr>
<tr>
<td>Modulus</td>
<td>10 Msi</td>
<td>9 Msi</td>
<td>19 Msi</td>
<td>40 Msi</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MS4A</td>
<td>MS2D</td>
<td></td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>167 W/m-K</td>
<td>3 W/m-K</td>
<td>144 W/m-K</td>
<td>3 - 380 W/m-K</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MS4A</td>
<td>MS2D</td>
<td></td>
</tr>
<tr>
<td>CTE</td>
<td>13.1 ppm/°F</td>
<td>3.5 ppm/°F</td>
<td>0 - 1.5 ppm/°F</td>
<td>0 - 15 ppm/°F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MS4A</td>
<td>MS2D</td>
<td></td>
</tr>
<tr>
<td>Electrical Conductivity</td>
<td>4.0E-08 Ω-m</td>
<td>9.6E-05 Ω-m</td>
<td>9.0E-06 Ω-m</td>
<td>3.0E-06 Ω-m</td>
</tr>
</tbody>
</table>

If necessary, surface coatings can be applied to increase electrical conductivity for improved EMI/EMC performance:

- Conductive paints
- Copper/Nickel plating
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Electrical Power Chassis
- Graphite/epoxy composite flight unit and aluminum development unit
- Four-slot, 3U cPCI chassis
- 60 W of dissipated power from electronics
- Mounting location for one four-slot backplane
- Composite enclosure mass is 35% lower than the aluminum enclosure
- Completed random vibration and thermal cycling testing

Propulsion Instrumentation
- Sensor platform, electron probe, ion energy spectrometer enclosure, and propulsion electronics enclosure
- Very low mass components using composite and low cross-sections
- Thermal conductivity tailored to application (1 W/m-K to 400 W/m-K)

Selected Products (1 of 2)

Approach Can Be Applied To Produce Components And Instruments That Have Requirements That Can Not Be Met With Traditional Materials And Designs
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Selected Products (2 of 2)

Thermal Insert Embedded Within Structure To Allow Increased Packaging Density Without Sacrificing Thermal Performance
- Low thermal conductivity bulk molding compound
- Two very high thermal conductivity (1500 W/m-K) pyrolytic graphite inserts embedded with the structure

Flex-print Circuits Embedded Within Structure to Replace Traditional Wiring Harness
- Two flex circuits embedded within the structure
- Surface mounted micro-connectors
- Embedded flex circuit part is approximately 60% lighter than the aluminum version
- More surface area is available for component mounting

Thermal Performance Can Be Tailored To Provide Isothermal Areas, Create Distinct Heat Paths to Radiator, or Maintain Thermally Isolated Areas

Volume and Footprint Available For Payloads and Components Is Increased While Mass And Cost For Harnessing Is Decreased
We are working toward the next generation of composite multifunctional structure

- Modular spacecraft bus structure with embedded electronics and components
- Layered radiation shielding within structural elements
- Integrated sensor/electronics/structure unit for distributed networks of microsensors
- Embedded programmable wire harness
- Embedded thin film battery cell
- Structural integrity monitoring
- Actuators for active vibration control
- Integrated power system – photovoltaics, batteries, electronics, and wiring

Compression Molded Multifunctional Structure Has Been Demonstrated To Meet Space Flight Requirements – The Technology Is Ready To Enable The Most Challenging Instrument And Small Spacecraft Projects
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