Carbon-Carbon Radiator Summary

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The New Millennium Program (NMP) Earth Observing-1 (EO-1) spacecraft uses six passive radiators, each consisting of sandwich panels constructed with aluminum honeycomb cores. Five of the six radiator panels use standard aluminum facesheets. On the sixth radiator panel, as an EO-1 technology demonstration item, the aluminum facesheets were replaced with an experimental panel that utilized Carbon-Carbon (C-C) material for its facesheets. The objective of this technology validation was to demonstrate that Carbon-Carbon could be a cost efficient facesheet material for honeycomb core radiator panels that also function as part of the spacecraft primary structure.

The Carbon-Carbon Radiator (CCR) panel is 28.62 in. x 28.25 in. in size. As are the standard panels, it is a composite panel but consists of two 0.022-in.-thick C-C facesheets, rather than the standard aluminum facesheets, bonded to a 1-in. 5056 aluminum honeycomb core. The internal surface of the CCR panel is coated with an epoxy encapsulate to prevent particle contamination of sensitive instruments on board EO-1 and provide additional strength to the panel. The external surface of the panel is coated with silver Teflon as required by the EO-1 spacecraft thermal design. Photographs of the flight panel are shown in Figures 1 and 2. Panel interior construction details are shown in Figures 3-5.

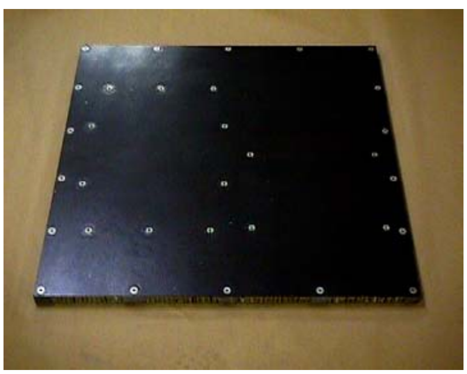

Figure 1.
Carbon-Carbon Panel Internal Surface

Figure 2.
Carbon-Carbon Panel External Surface

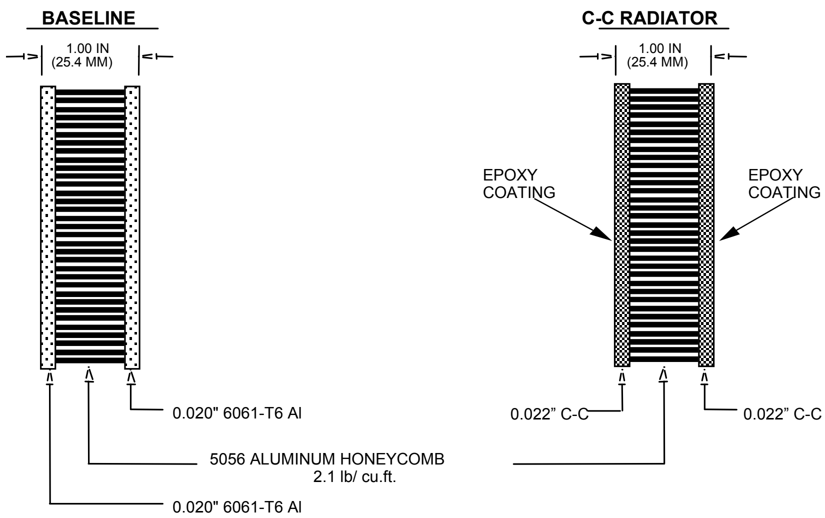

Figure 3. Carbon-Carbon and Baseline Cross-Sections

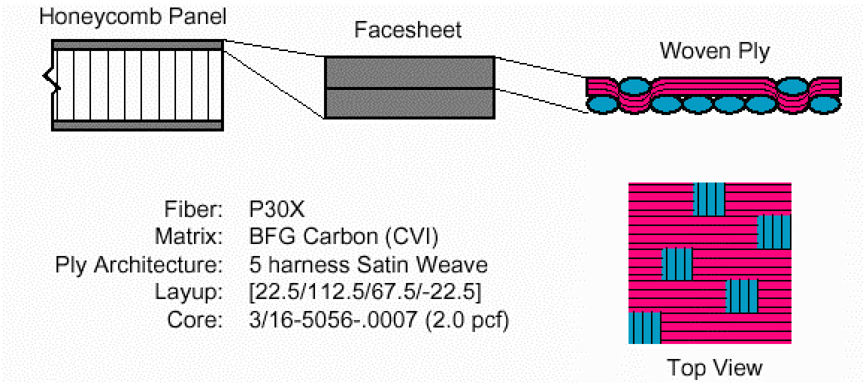

Figure 4. Carbon-Carbon Radiator Facesheet Construction

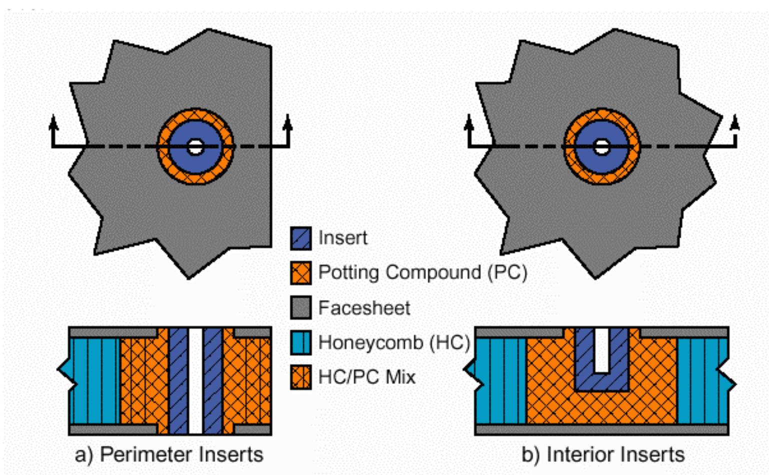

Figure 5. Carbon-Carbon Radiator Panel Insert Design

The use of high conductivity fibers in C-C fabrication yields composite materials that have high stiffness and high thermal conductivity. Since C-C density is lower than that of aluminum, significant weight savings may be realized by replacing aluminum panels with such panels. A C-C material also has a markedly higher specific thermal efficiency than aluminum and thus offers improved performance for lower volume and mass. Also, since Carbon-Carbon is a structural material, it may serve a dual purpose as both a structural and a thermal management material. The primary thermal function of the EO-1 CCR was to radiate the 27.8 watts generated by the EO-1 Power Supply Electronics (PSE) and the 16.3 watts (peak power) generated by Linear Etalon Imaging Spectral Array/Atmospheric Corrector (LEISA/AC) electronics boxes. The panel also served as a primary structural member and was required to support the combined weight of the PSE (50 lb) and the LAC (10 lb) boxes while being subjected to severe thermal and mechanical launch and on-orbit environmental loading conditions. A design summary for the CCR is given in Table 1.

Table 1. Bay 4 Carbon-Carbon Radiator Design Summary

PSE Box Dissipation	DCE	Standby	Safe
	27.8W	27.8W	27.0W
LEISA/AC Box Dissipation	16.3W	0.0	0.0
Heater Resistance	75.7 ohms		
Heater Power	21V	28V	35V
	5.8W	10.4W	16.2W
External Radiator Size	= 1408.59 sq cm = 194 sq in. (12.0 x 16.25)		
Thermal Design Description	Box is black anodize, chotherm at box/panel interface, AgTe radiator		

Prior to spacecraft-level testing, the CCR panel was subjected to four thermal vacuum cycles each consisting of a hot soak at 60°C for four hours and a cold soak at –20°C for four hours. A thermal balance test was performed at the completion of the thermal vacuum cycle test. In addition to the component level thermal vacuum/balance testing, the CCR also went through two spacecraft-level thermal vacuum tests. The first test included a comprehensive thermal balance test. Both tests had the CCR panel in the flight configuration. Thermal model test predictions and test results agreed within 1 degree, as shown in Figure 6, and thereby verified the component thermal model.

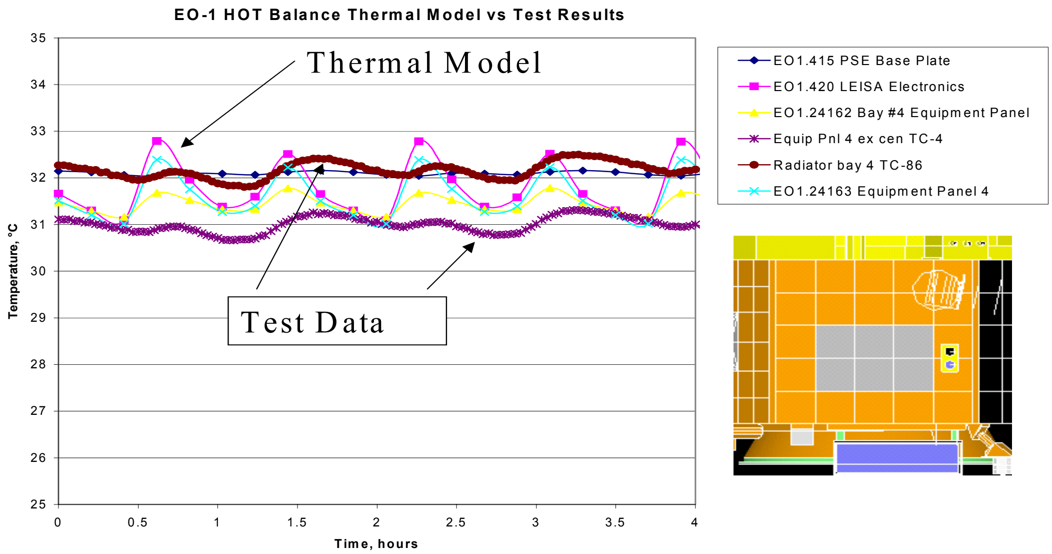

Figure 6. EO-1 Spacecraft Thermal Balance Test Results

The CCR panel flight temperature measurements correlated extremely well with the predicted values obtained from the EO-1 spacecraft thermal model (Figure 7). The excellent correlation results can be attributed to the knowledge obtained during the spacecraft-level thermal vacuum test and understanding of the interfaces and power consumption of the flight electronics. On-orbit thermal performance of the CCR panel was excellent throughout the mission. Review of the flight data for the first 12 months showed only a small change in temperature values (<1.5ºC rise). This small temperature change can be attributed to optical property degradation of the silver Teflon radiator panel or possibly an increase in power. However, such a small change indicates the CCR panel on-orbit performance was excellent.

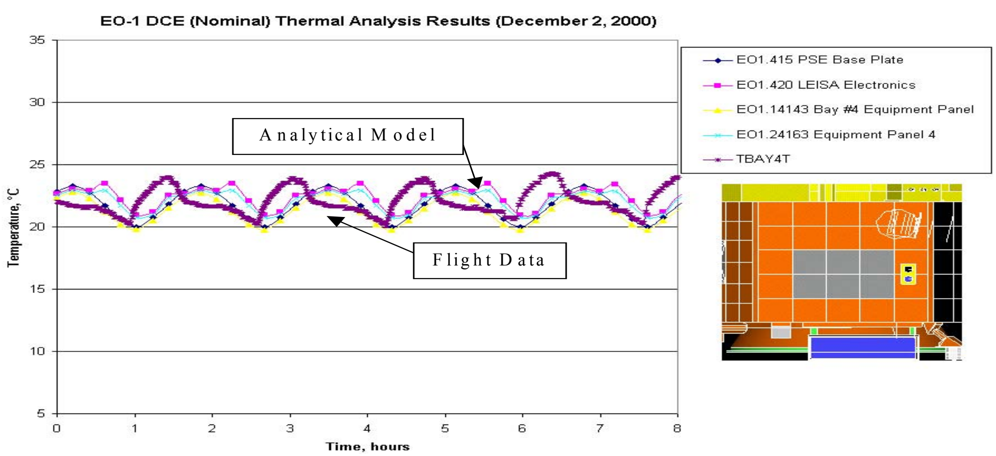

Figure 7. Comparison of Flight Data with Analytical Model Data

The EO-1 mission has demonstrated that use of Carbon-Carbon facesheet material, for fabricating honeycomb sandwich panels, is a viable option for accommodating both thermally and structurally demanding application requirements into a single design.