Section 20a

Carbon-Carbon Radiator (CCR)

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Carbon-Carbon (C-C)

- **Carbon-Carbon (C-C)** - Composite material that uses carbon for both the fiber and the matrix material
  - produced in a high temperature furnace in a lengthy process
- C-C has high thermal conductivity, good strength, and is lighter than Aluminum
- C-C used in high temperature applications
  - Aircraft brakes, Space Shuttle wing leading edge
- Limited applications elsewhere to date, primarily due to cost and production lead time
C-C Spacecraft Radiator Partnership (CSRP)

- CSRP started by Howard Maahs of NASA Langley and Elizabeth Shinn of Wright Patterson Air Force Base to promote the use of C-C as a radiator material.
- CSRP was an informal partnership with members from government and industry:
  - NASA Langley, NASA/Goddard, Air Force at Wright Patterson and Phillips Lab, Naval Surface Warfare Center,
- The New Millennium Program’s EO-1 mission provided an opportunity for the CSRP to fly a C-C radiator:
  - C-C radiator provided by CSRP at “no cost” to NMP.
C-C Radiator on EO-1

- The C-C radiator replaces one of six structural panels on the EO-1 Spacecraft - it is both a radiator and a structural member

- C-C Radiator consists of 1” Al honeycomb with 0.020” C-C face-sheets, approximately 28” by 28”
  - Utilizes two plies of P30X carbon fibers with carbon matrix established by Chemical Vapor Infiltration
  - Epoxy coated for strength and contamination protection
  - Aluminum inserts bonded to honeycomb core for mounting of electronics boxes and attachment to the S/C
  - Exterior coated with Silver Teflon for heat rejection

- CSRP delivered one flight unit and one spare to GSFC
  - Flight qualification testing completed at GSFC
EO-1 C-C Radiator
CCR Technology Validation (Thermal)

- Verify thermal performance of C-C material meets S/C requirements, evaluate any degradation of thermal conductivity (none expected)
  - Thermal conductivity measured by testing (coupon level and panel level Thermal Vacuum (T/V) tests)
  - Thermal cycling verified panel integrity
  - Thermal model correlated to test results and flight data
  - S/C level T/V test provided additional verification, comparison for C-C flight thermistor readings
  - Monitor C-C thermistor data on-orbit, along with S/C attitude data
  - Correlated flight data with C-C thermal model to verify proper C-C radiator performance
CCR Technology Validation
(Structural / Other)

- **Coupon Level Tests** - verify material integrity and strength
- **Panel Level Tests/Analysis**
  - Vibration and Strength
    - Structural Analysis and Modeling
  - Mass Properties
  - Non-destructive examination (radiography) conducted before and after qualification testing
- **Spacecraft Level Testing**
  - Vibration
  - Thermal Vacuum
  - EMI
C-C Radiator Thermistor Layout

Removed to accommodate Calorimeter

TRADCC2T

TRADCC3T

TRADCC4T

TRADCC5T

TRADCC6T
C-C Radiator (Bay 4T)
C-C Radiator (TRADCC2T)

CC Radiator - TRADCC2T

- Hot Orbital Season
- Cold Orbital Season
- Launch Day

Graph showing temperature changes over time.
EO-1 Hot Balance Thermal Model vs. Test Results

Thermal Model

Test Data

Temperature, °C

Time, hours

- EO1.415 PSE Base Plate
- EO1.420 LEISA Electronics
- EO1.24162 Bay #4 Equipment Panel
- Equip Pnl 4 ex cen TC-4
- Radiator bay 4 TC-86
- EO1.24163 Equipment Panel 4
EO-1 DCE Thermal Analysis Results (December 2, 2000)

Thermal Model

Flight Data
CCR Technology Transfer / Lessons Learned

- C-C Radiator technology was successfully validated
  - C-C radiator panels can be used to reduce S/C weight
  - They can also be used as part of the S/C structure
- C-C has a niche, especially for high temperatures
  - Application on the Solar probe
- C-C still needs further development (my opinion)
  - Reduction in fabrication time and cost - high conductivity “traditional” composites are competitive
  - CTE Interface issues with heat pipes
- Redundancy a good idea - we flew the spare panel
- Possible follow-on missions: C-C foam for low CTE mirrors/optical benches
Summary

- CSRP was a success - informal inter-agency partnership
  - Thanks to all who contributed - this was a fun job
- CSRP no longer in business, but manufacturers of Carbon-Carbon are still operating, i.e. B.F. Goodrich, Amoco
- Thanks to EO-1 project and Swales for this opportunity