TRAINING

SPACECRAFT THERMAL CONTROL SUBSYSTEM

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PRESENTED BY:

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PRESENTATION OVERVIEW

Topics

- Component Layout
- Thermal Design Overview
- Thermal Hardware Summary
- Operational Considerations/Constraints
- Operational Contingencies
- Summary
- Appendix A - Pictures of Heaters, Thermostats and Temperature Sensors
- Appendix B - Typical Temperature Profiles
  - Model Predicts
  - TVAC Test Data

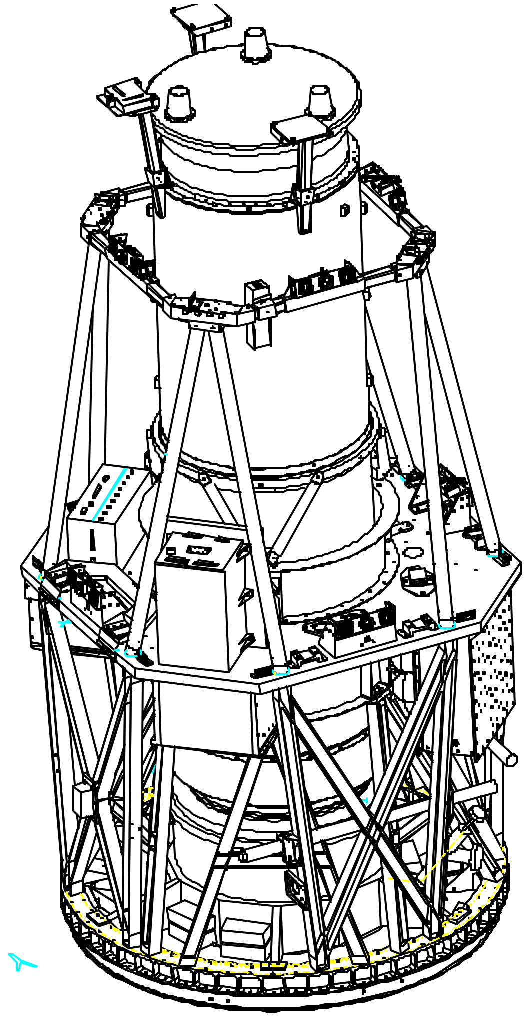
HESSI

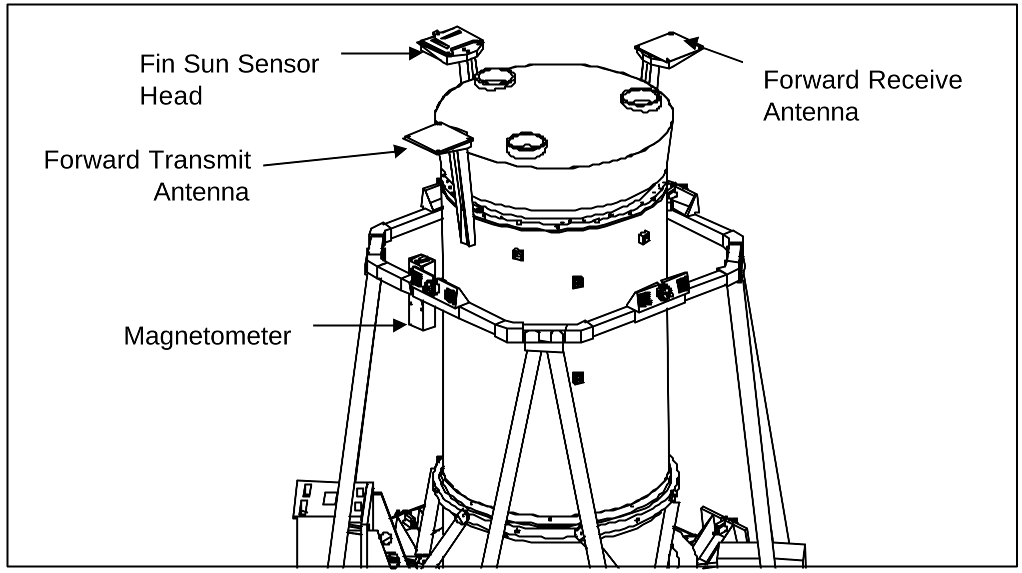
High Energy Solar Spectroscopic Imager

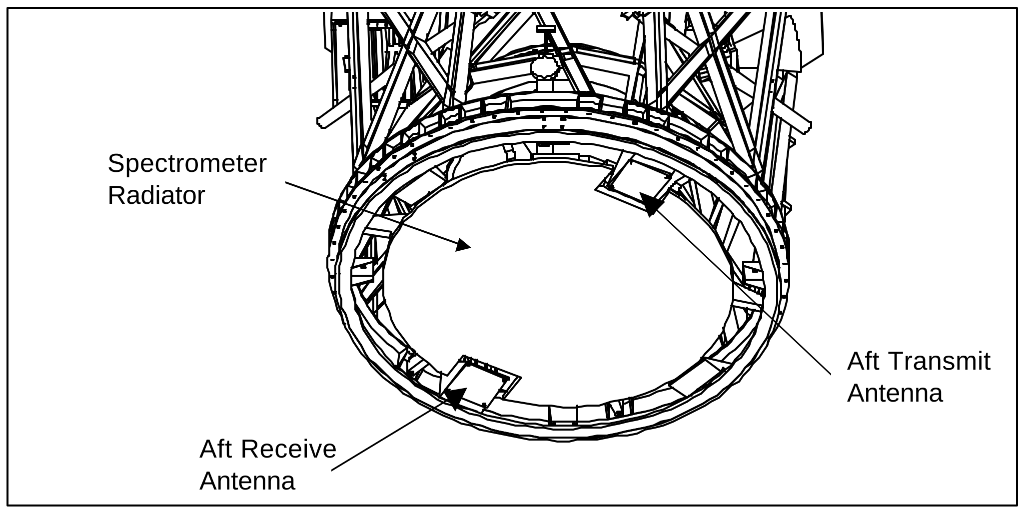
COMPONENT LAYOUT

SPECTRUMASTRO

Spacecraft Shown Without Solar Array Panels







THERMAL DESIGN OVERVIEW

The Thermal Design is Cold Biased to Maintain Bus Components Within Flight Allowable Temperatures

- Design Emphasizes Passive Thermal Design Techniques
- Only Active Design Feature is Heaters on Thermostatic Control
- Waste Heat Rejected by Radiators
  - Silver Coated Teflon Used as Radiator Coating
  - Stable Material That Minimizes Differences Between BOL & EOL Environments and Degradation
- Non-Radiator Surfaces Are Blanketed
  - 15 Layer MLI Blankets to Reduce Heat Losses from Unheated Portions of the Bus
  - 2 Mil, ITO Coated, Second Surface Kapton Outer Layer

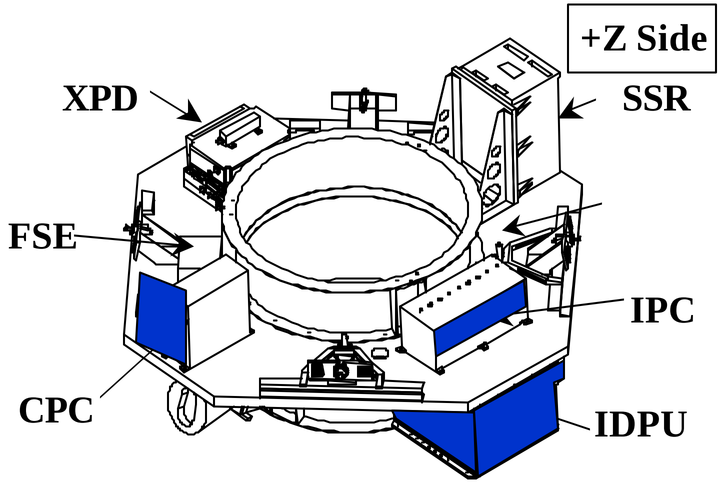
THERMAL DESIGN OVERVIEW

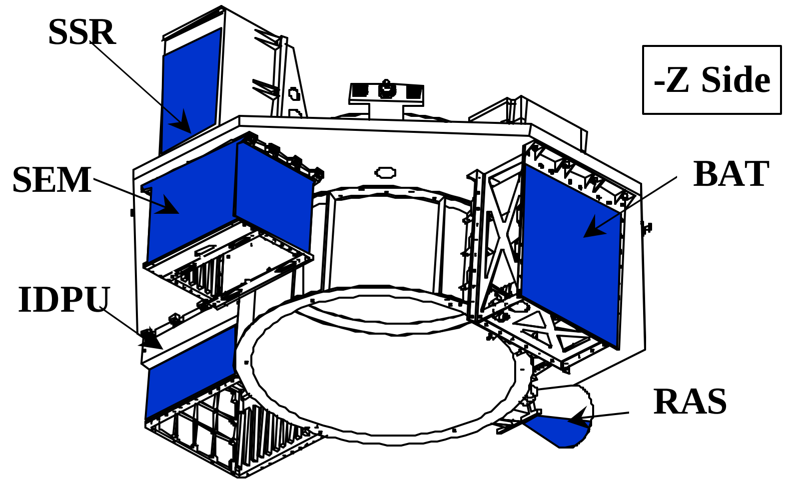
RADIATORS

- Reject Waste Heat From S/C
- 10 mil Thick Silver Coated Teflon Tape

All Remaining Surfaces Covered With MLI Blankets

Denotes Radiator Locations





Summary of Temperature Sensors, Thermostats and Heaters

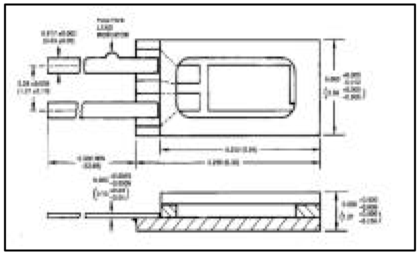
Item #	Description	Total Flt. Qty	Part Number	Distributor	Manufacturer	Comments
Temperature Sensors						
1	Temperature Sensors	7	118MK2000A	Rosemount Inc	Rosemount Inc	Solar Arrays & Batteries
2	Temperature Sensors	17	AD590MF/883B	Avnet	Analog Devices	All Remaining Locations
Coatings						
1	Tape, ITO Coated, Silvered Teflon, 10 mil	1 Rolls	147449-002	Sheldahl	Sheldahl	
2	Tape, Aluminzed Kapton, 2 mil	AR				Kapton Facing Outward
3	Tape, Aluminum Foil, 2 mil	AR				
Thermostats						
1	Thermostats, Battery	4	3200-2-437	Elmwood Sensors	Elmwood Sensors	Close: -5.0°C, Open: 0.0°C
2	Thermostats, SEM & SSR	2	3200-2-484	Elmwood Sensors	Elmwood Sensors	Close: -17.0°C, Open: 11.4°C
3	Thermostats, FSE & XPD	2	3200-1-46	Elmwood Sensors	Elmwood Sensors	Close: -12.0°C, Open: -2.0°C
4	Thermostats, Torque Rods	3	3200-2-525	Elmwood Sensors	Elmwood Sensors	Close: -30.0°C, Open: -25.0°C
5	Thermostats, Dampers	8	3200-2-343	Elmwood Sensors	Elmwood Sensors	Close: 11.1°C, Open: 16.1°C
Heaters						
1	Heater, SEM	1	642-7447-1	Tayco Engineering	Tayco Engineering	49 Ohms, Power: 15 W @ 27 VDC
2	Heaters, XPD & SSR	2	642-7447-2	Tayco Engineering	Tayco Engineering	60 Ohms, Power: 12 W @ 27 VDC
3	FSE Heater	1	642-7447-3	Tayco Engineering	Tayco Engineering	90 Ohms, Power: 8 W @ 27 VDC
4	Torque Rod Heaters	3	642-7447-4	Tayco Engineering	Tayco Engineering	242 Ohms, Power: 3 W @ 27 VDC
5	Damper Heaters	8	642-7447-5	Tayco Engineering	Tayco Engineering	1460 Ohms, Power: 0.5 W @ 27 VDC
6	Heaters, Battery (Supplied by Battery)	21				xx Ohms, Power: xx W @ 27 VDC
Adhesives						
1	RTV 566	2 Kits, AR				Thermal Interface Material
2	Eccobond 285	AR				Thermally Conductive Adhesive
3	EA9394	AR				Structural Adhesive (Tstats & Solar Array Temperature Sensors)

PACI TEMPERTURE SENSORS

Summary of Temperature Sensors That are Processed by the S/C PACI Board

Description	Mounting Location	Part Number	AD590 Analog #	Hardware Telemetry List Function Number
Solar Array 1 - Back	Inboard Panel	118MK2000A		004-006-004
Solar Array 2 - Back	Inboard Panel	118MK2000A		004-006-005
Solar Array 3 - Back	Inboard Panel	118MK2000A		004-006-006
Solar Array 4 - Back	Inboard Panel	118MK2000A		004-006-007
Battery, Chassis	Chassis, Near Interface	118MK2000A		004-006-008
Battery, Cell Temp 1	On Cold Cell	118MK2000A		004-066-021
Battery, Cell Temp 2	On Hot Cell	118MK2000A		004-066-022
Fine Sun Sensor Elec	Housing, External	AD590MF/883B	01	006-007-006
IAD, X	Mounting Bracket	AD590MF/883B	02	001-006-003
IAD, Y	Mounting Bracket	AD590MF/883B	03	001-006-004
SEM, Chassis	Housing, External	AD590MF/883B	04	006-006-010
SEM, DC-DC Converter	Converter Case, External	AD590MF/883B	05	006-006-011
SEM, OCXO Precision Clock	Clock Case, External	AD590MF/883B	06	006-006-012
Solid State Recorder	Housing, External	AD590MF/883B	07	006-006-009
Torque Rod, X	TSTAT Bracket on Torque Rod	AD590MF/883B	08	006-007-013
Torque Rod, Y	TSTAT Bracket on Torque Rod	AD590MF/883B	09	006-007-014
Torque Rod, Z	TSTAT Bracket on Torque Rod	AD590MF/883B	10	006-007-015
Transponder, Housing	Housing, External	AD590MF/883B	11	002-006-004
Transponder, Power Amp	**Internal**	N/A		002-006-009
Transponder, Power Supply	**Internal**	N/A		002-006-010
MLI	Deck, Outer Layer, Sun Side	AD590MF/883B	12	001-006-005
IDPU	Housing, External	AD590MF/883B	13	006-021-001
IPC	Housing, External	AD590MF/883B	14	006-021-003
CPC	Housing, External	AD590MF/883B	15	006-021-002
Spectrometer	Base Ring, +Z Side	AD590MF/883B	16	006-021-015
RAS	Housing, External	AD590MF/883B	17	006-021-004
Paticle Detector	Housing, External	AD590MF/883B		Not Assigned Yet
Imager	Mounting Interface, Near Battery Mount	AD590MF/883B		Not Assigned Yet
Magnetometer, Housing	Mounting Bracket	AD590MF/883B		Not Assigned Yet
Magnetometer	**Internal**	N/A		006-007-012

AD590



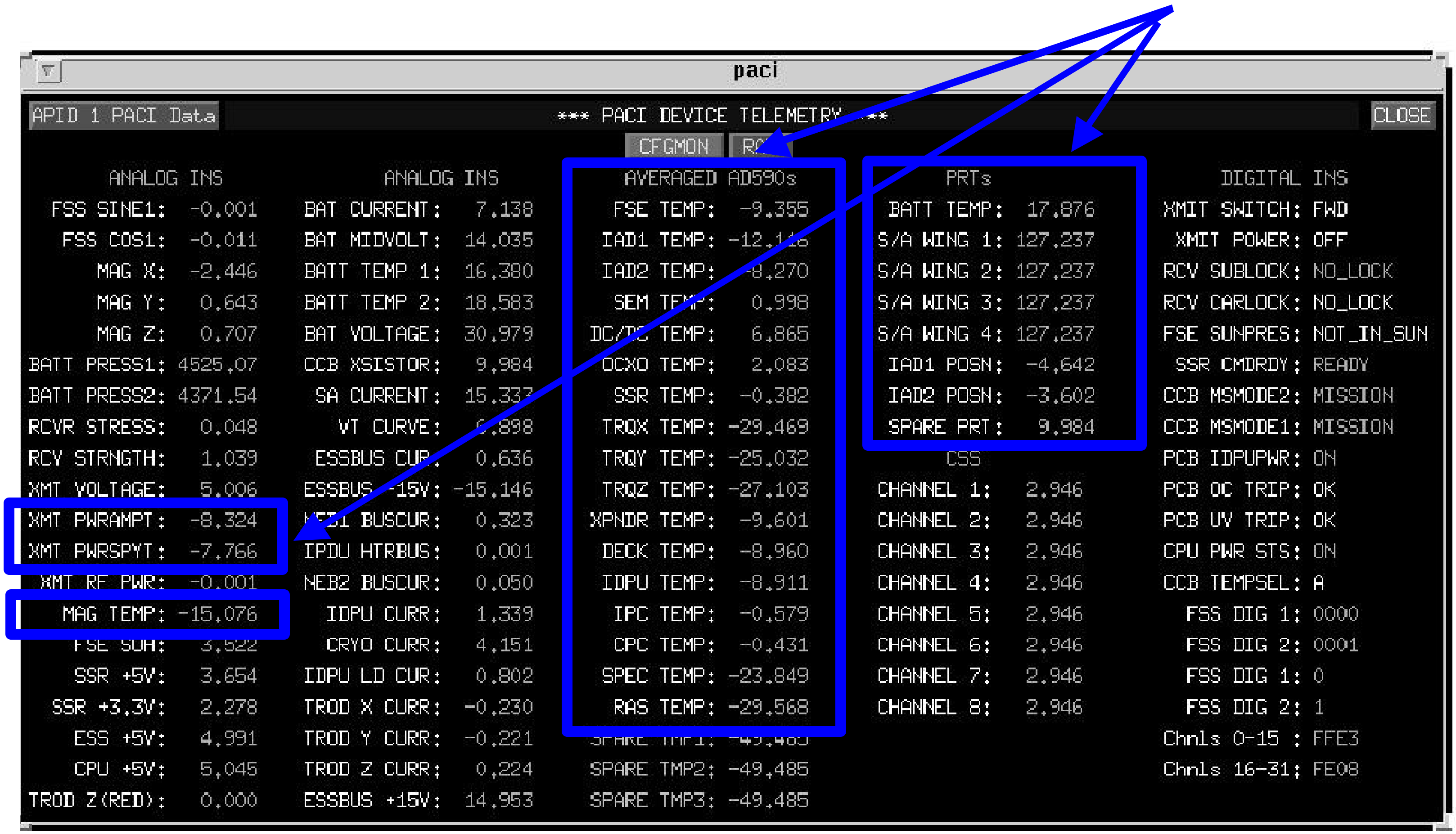
PRT

PACI TEMPERTURE TELEMETRY

SPECTRUMASTRO

“Snap” of Flight Ops Display Window Showing the PACI Temperature Sensor Telemetry

S/C Bus Temperature Sensors



S/C BUS HEATER CIRCUITS

Heater Switches

- Switches Merely Enable or Disable Heater Circuit (I.e, Does not Indicate Whetheror Not the Heater is Actually Drawing Power)
- Nominally All S/C Bus Heaters Should Be Enabled at All Times. The Only exception is the Damper Heaters (i.e., SAD), which Should Be Disabled/Turned OFF Once it has Been Verified That the Solar Arrays Have Been Fully Deployed
- S/C Bus Heaters are Thermostatically Controlled. Heaters Automatically Turn ON When Temperature Drops Below the “Close” Set Point and Turn OFF When Temperature Rises Above the “OPEN” Set Point). Note: All Bus Thermostats Have Fixed Set Points (i.e, They are Not Programmable.)

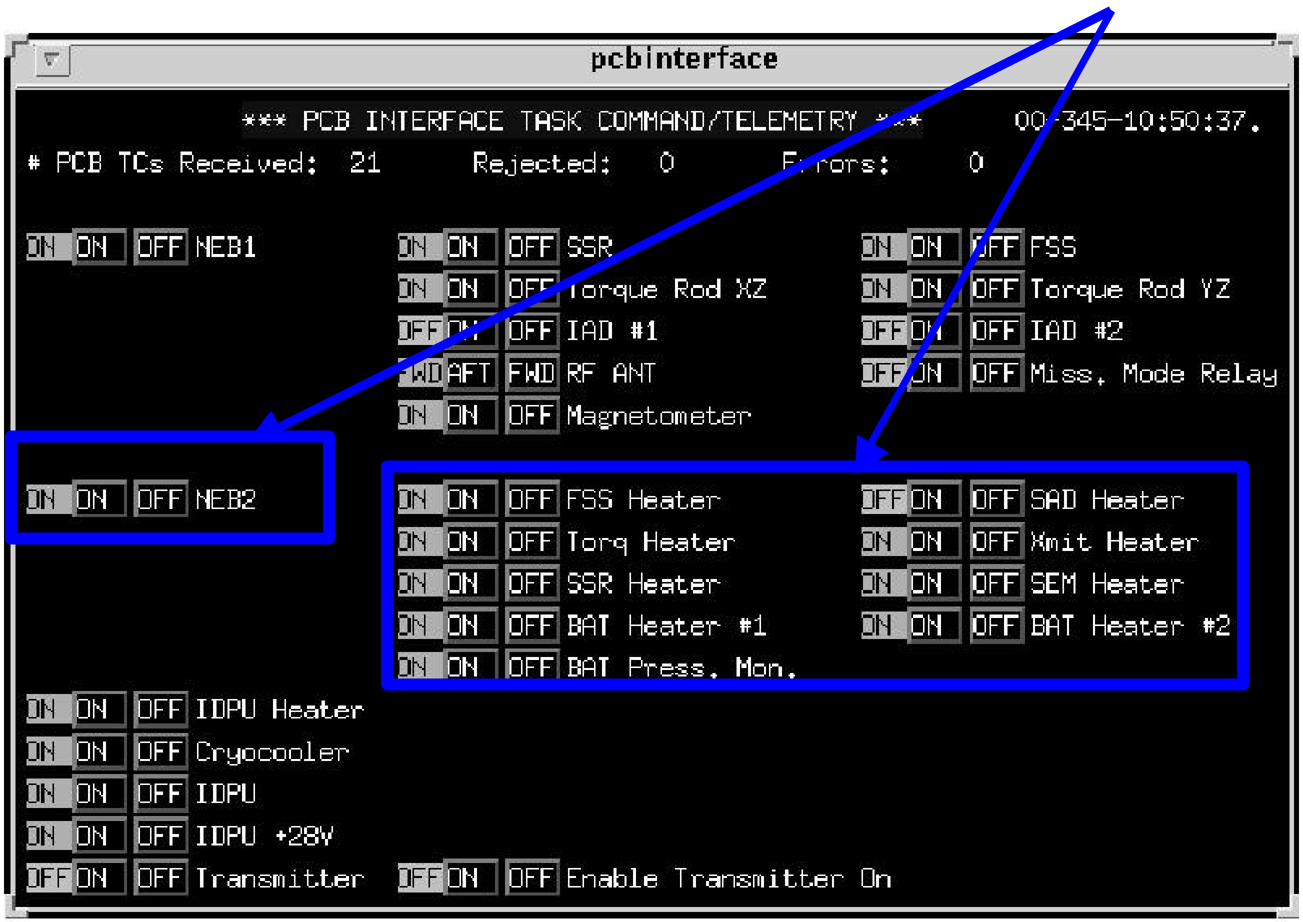
Heater Circuit Telemetry

- For the S/C Bus Heater Circuits, There is no Direct Indication of the Whether or not the Heater Circuit is Actually Drawing Power. Must Rely on Other Data to Determine Whether or not a Heater Circuit is Drawing Power. Specifically, a Change in Temperature or Change in the Current (Amps) are Good Indicators.
- UCB Components, However, are Equipped With Telemetry to Directly Indicate Heater Performance and Status

HEATER SWITCHES

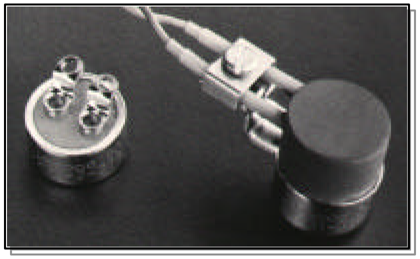
“Snap” of the Heater Switch Flight Ops Display Window

S/C Bus Heater Switches

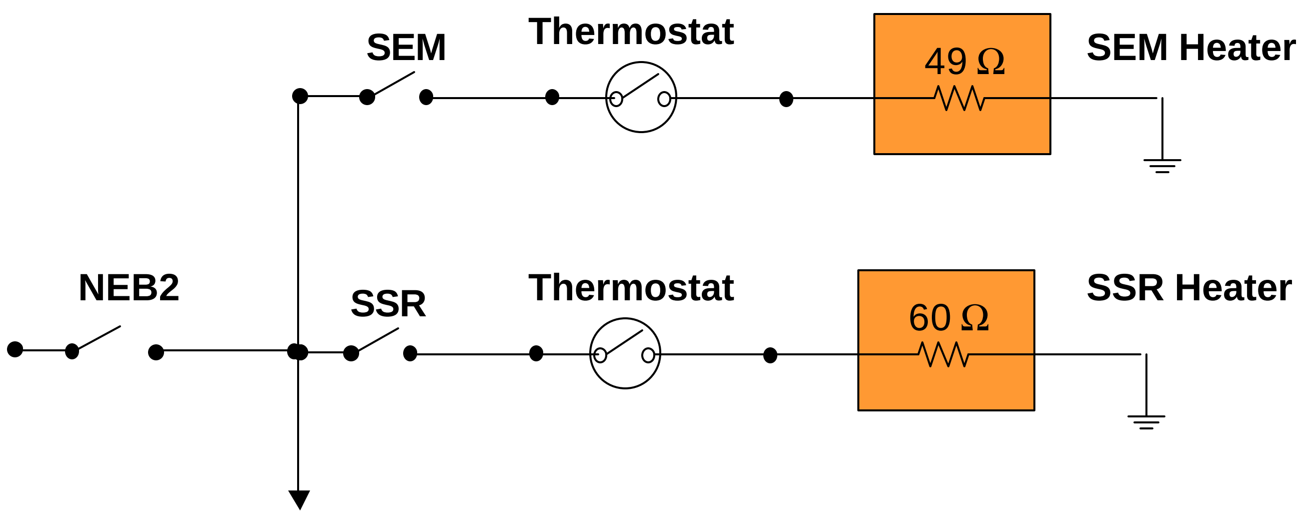


S/C Bus Heater Circuits are Thermostatically Controlled

Thermostats



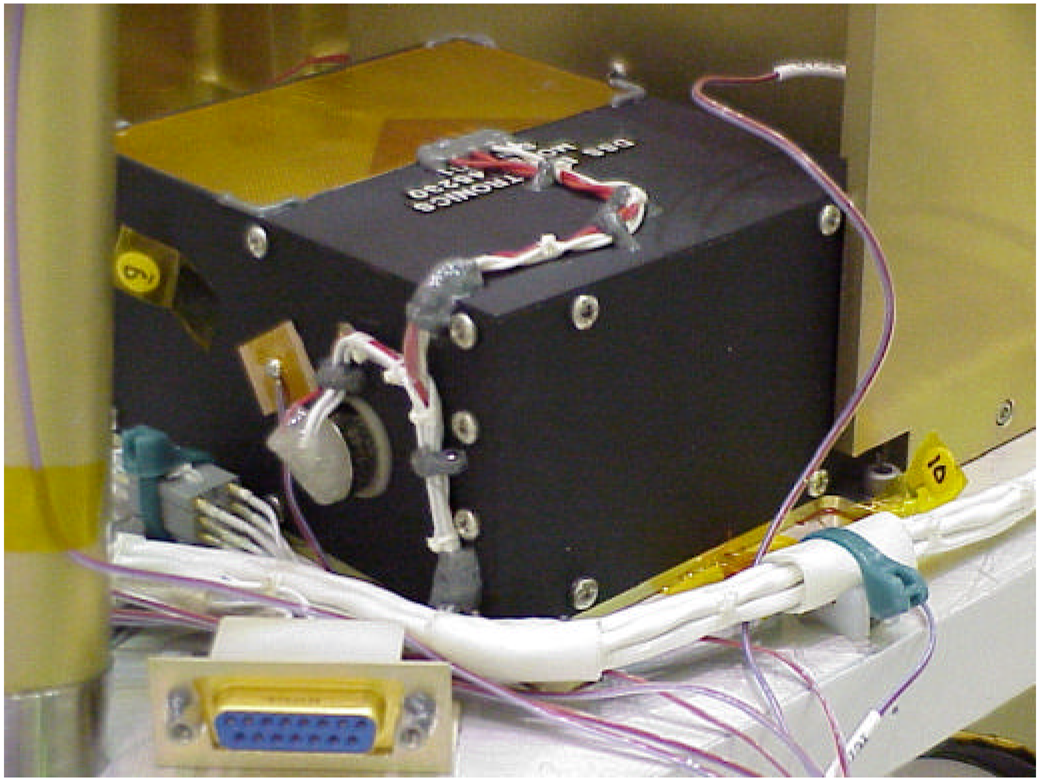
Heaters



Example of Actual Heater, Temperature Sensor and Thermostat Locations

- More Pictures of Other Bus Thermal Hardware Contained in Appendix A

Fine Sun Sensor Electronics



Other Heater Circuits

In Addition to the S/C Bus, the UCB Instrument Components are Equipped with Several Heater Circuits.

Summary of UCB Instrument Heater Circuits

- Deck-Mounted Components
  - CPC, IPC, IDPU, RAS
- Imager
  - Upper grid tray heaters
  - Lower Grid Tray Heaters
- Spectrometer
  - Cryocooler Collar
  - Detector Cold Plates

Key Operational Considerations and Constraints for S/C Bus

- Battery
  - Narrow Operating Temperature Range. Likes to Run Cold (I.e., 5C to -5C)
  - Autonomous Heaters Protect Battery from Ever getting too Cold (< -6C)
  - At Launch Batteries Start out Warm (10C to 15C). There are basically two Options for
  - VT Curve Selection Affects Battery Temperature (Lower VT => Lower Temp)
- Transponder
  - Designed to Accommodate up to Two (2) 15-Minute Downlinks per Orbit. Once the On-Orbit Operation has Been Characterized, It may be possible to Perform More Than Two Downlinks if Temperature Permits.
  - During Downlinks, Temperature May Increase Rather Quickly by as much as 8C. Consequently, the Transponder Should Have at a minimum 8C margin to the Yellow Limits.

CONTINGENCY PLANS - HOT

Possible Options for Component(s) Exceeding Hot Limits:

- Put Component or Neighboring Components Into a Lower Power Mode
- Turn Component or Neighboring Components OFF
- Disable Heater (Thermostat may have Failed in the ON Position)
- Lower V/T Curve (For Battery Only)
- Shut Off Transmitter
- Limit Transponder Downlink/Transmitting Operations (I.e., Decrease or eliminate the number of Downlinks per Orbit)

CONTINGENCY PLANS - COLD

Possible Options for Component(s) Exceeding Cold Limits:

- Put Component or Neighboring Components Into a Higher Power Mode
- Turn Component or Neighboring Components ON
- Enable Heater/Verify Heater Enabled
- (Thermostat may have Failed in the OFF or Position)
- Raise V/T Curve Selection (For Battery Only)
- Turn ON Transmitter
- Increase Transponder Downlink/Transmitting Operations

SUMMARY

Summary

- **Transponder Temperatures Increase Rapidly and Significantly During Downlinks (i.e., Transmitting). Should Adhere to the 2 Downlinks per Orbit Design Limit.**
- **Battery Temperatures Rise When Discharging and When Overcharging. Should the Battery Experience Significant Overcharging, Lowering the VT Curve Selection Should Alleviate the Problem.**
- **Since the S/C is Continuously Pointed at the Sun and Rolling, the Thermal Environment that HESSI is Subjected to is Relatively Stable . Consequently, the Temperatures Should be stable as well.**
  - Nominally, Sinusoidal Temperature Variations Will Occur Due to the Cyclical Transitions Between Shadow and Sunlight, Repeating Approximately Every 95 Minutes
  - In Addition, Seasonal Changes Will Slightly Alter the Thermal Environment, Which in Turn Will Cause Minor Shifts in Temperatures
- **Highly Recommend becoming Familiar With the Component "Yellow" and "Red" Temperature Limits, which are Listed by Mnemonic on the HESSI Website.**

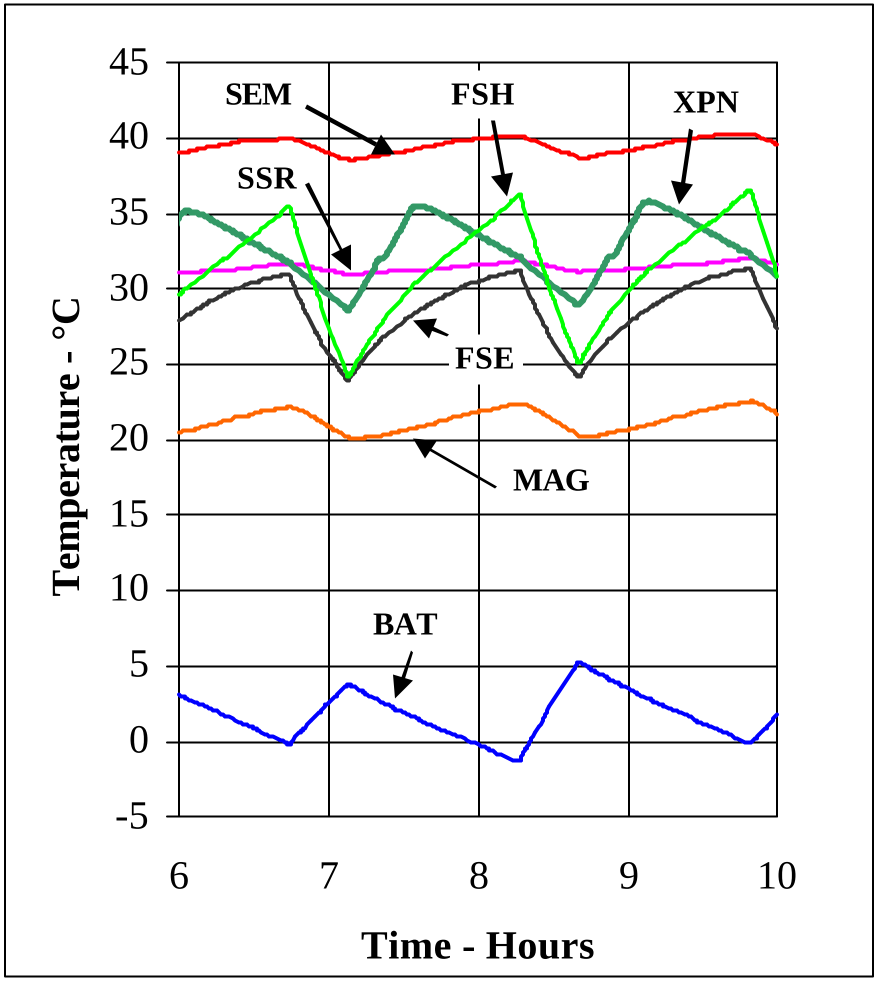
Pictures of Heaters, Thermostats and Temperature Sensors

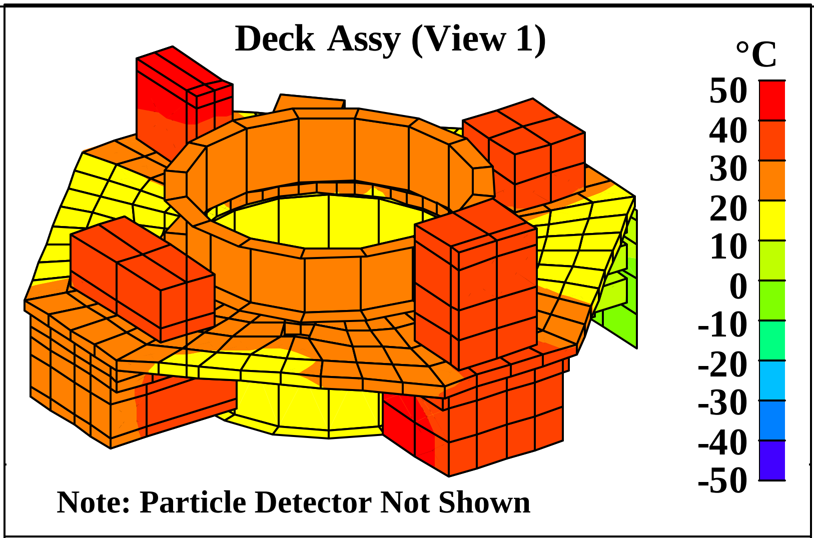
Typical Temperature Profiles

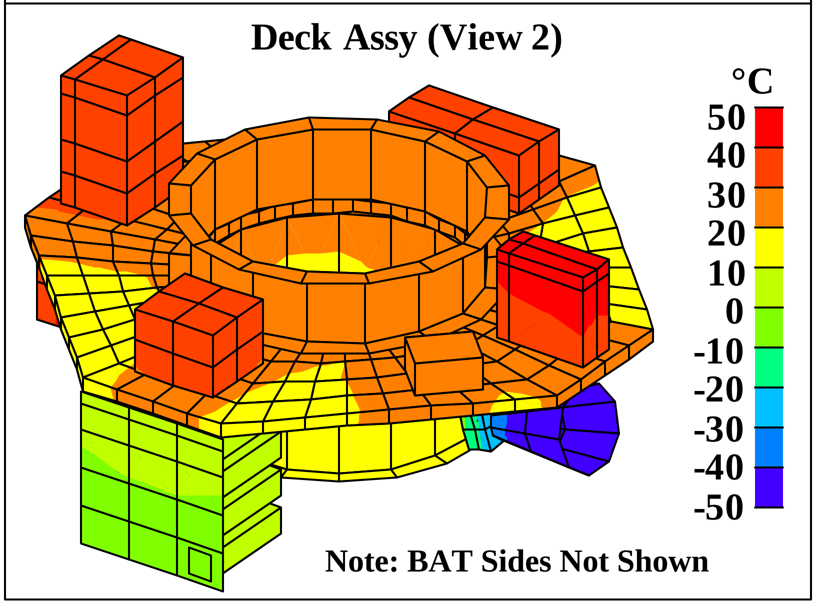
COMPONENTS ON DECK

TEMPERATURE PROFILES - HOT

THERMAL CONTROL SUBSYSTEM
HOT CASE MODEL RESULTS, β = 61°



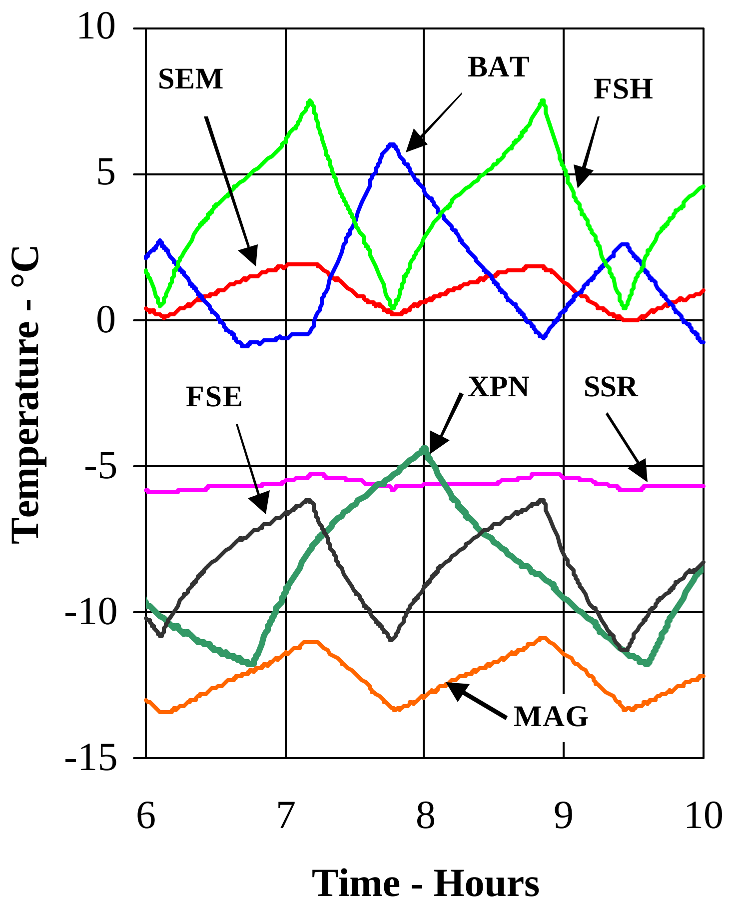


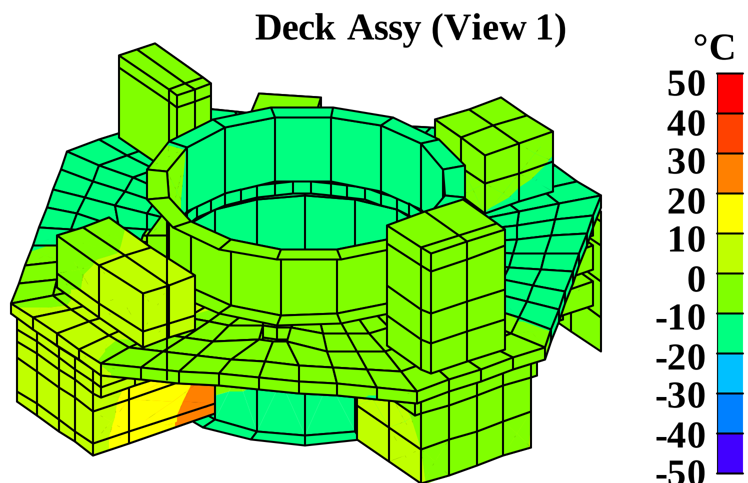


TEMPERATURE PROFILES - COLD

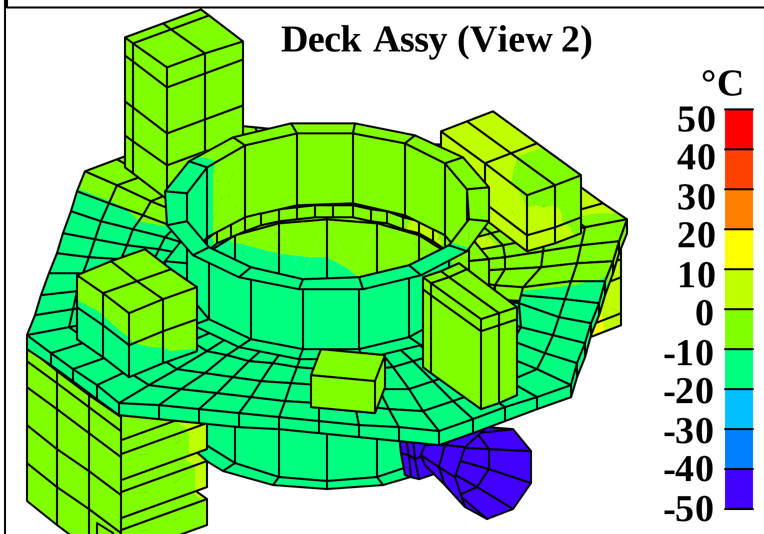
SPECTRUMASTRO

THERMAL CONTROL SUBSYSTEM
COLD CASE MODEL RESULTS, $\beta = 0°$





Note: Particle Detector Not Shown



Note: BAT Sides Not Shown