IMPACT/SEP Thermal Design

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SEP Thermal
Presentation Outline

- **Thermal Requirements**
- **Thermal Environment**
- **Thermal Model**
  - Instrument Interfaces
  - Temperature Limits
  - Thermal Cases
- **Thermal Design**
  - MLI
  - Radiators
  - Coatings
- **Temperature Predictions**
- **Conclusions**

SEP Temperature Limits (^{O} C)

Component	Design Operating	In-Spec Operating	Survival
HET			
Detectors	-25 to +25	-25 to +35	-40 to +40
Electronics	-20 to +25	-20 to +40	-40 to +50
CENTRAL ELEC	-20 to +30	-20 to +40	-40 to +50
LET			
Detectors	-25 to +25	-25 to +35	-40 to +40
Electronics	-20 to +25	-20 to +40	-40 to +50
SIT			
Detectors	-25 to +10	-25 to +30	-35 to +35
Electronics	-20 to +25	-20 to +40	-40 to +50
SEPT			
Detectors	-25 to +10	-25 to +35	-30 to +50
Electronics	-25 to +10	-25 to +40	-40 to +50
SEPT N/S			
Detectors	-25 to +10	-25 to +35	-30 to +50
Electronics	-25 to +10	-25 to +40	-40 to +50

Component Interface Requirements

- Spacecraft operational panel interface temperature range of -13C to +45C
- Spacecraft survival panel interface temperature range of -18C to +50C
- Components are thermally isolated on brackets
- Components are thermal blanketed at spacecraft interface

STEREO Thermal Environment

Early Orbit:

Ahead Spacecraft: Maneuvers for up to first 60 days can off-point from sun-pointing by up to 45 degrees for up to 105 minutes (single lunar swing-by)

Behind Spacecraft: Maneuvers for up to first 90 days can off-point from sun-pointing by up to 45 degrees for up to 105 minutes (two lunar swing-bys)

Extreme mission orbit conditions:

Ahead S/C: Perihelion = 0.879 AU, Aphelion = 1.040 AU

Behind S/C: Perihelion = 0.960 AU, Aphelion = 1.131 AU

Nominal orbit:

Ahead S/C: Perihelion = 0.943 AU, Aphelion = 0.979 AU

Behind S/C: Perihelion = 1.003 AU, Aphelion = 1.083 AU

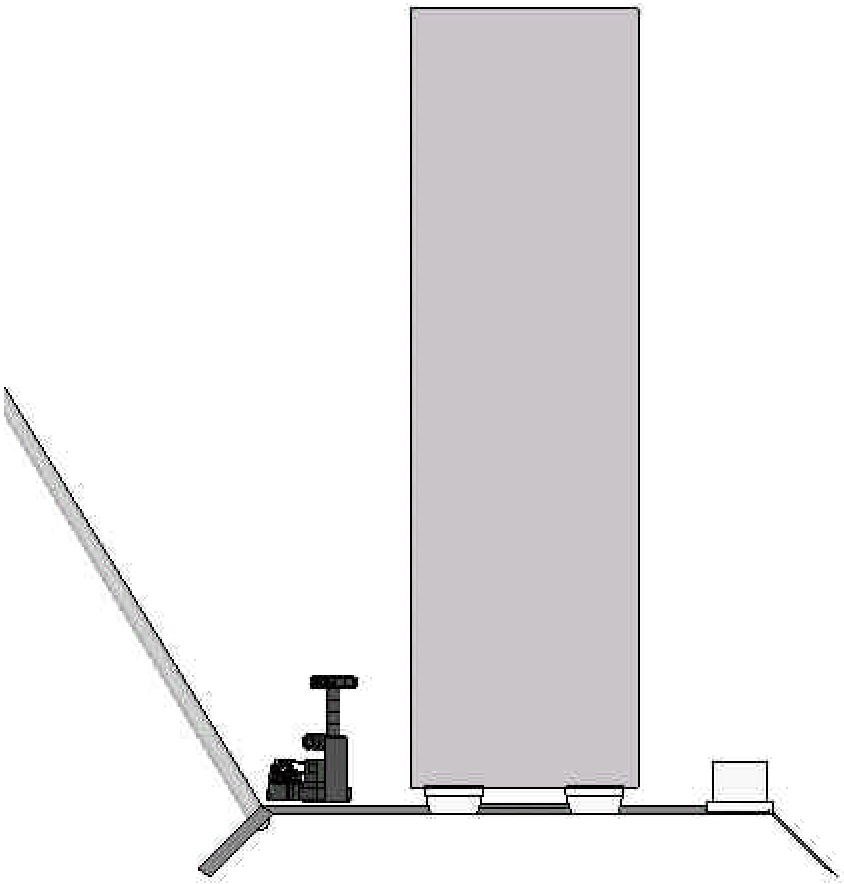
Environmental Heat Inputs

- **Incident Solar Flux Determined by Spacecraft Perihelion and Aphelion**
  - **Solar Flux at 1 AU: 1366.5 W/m^2**

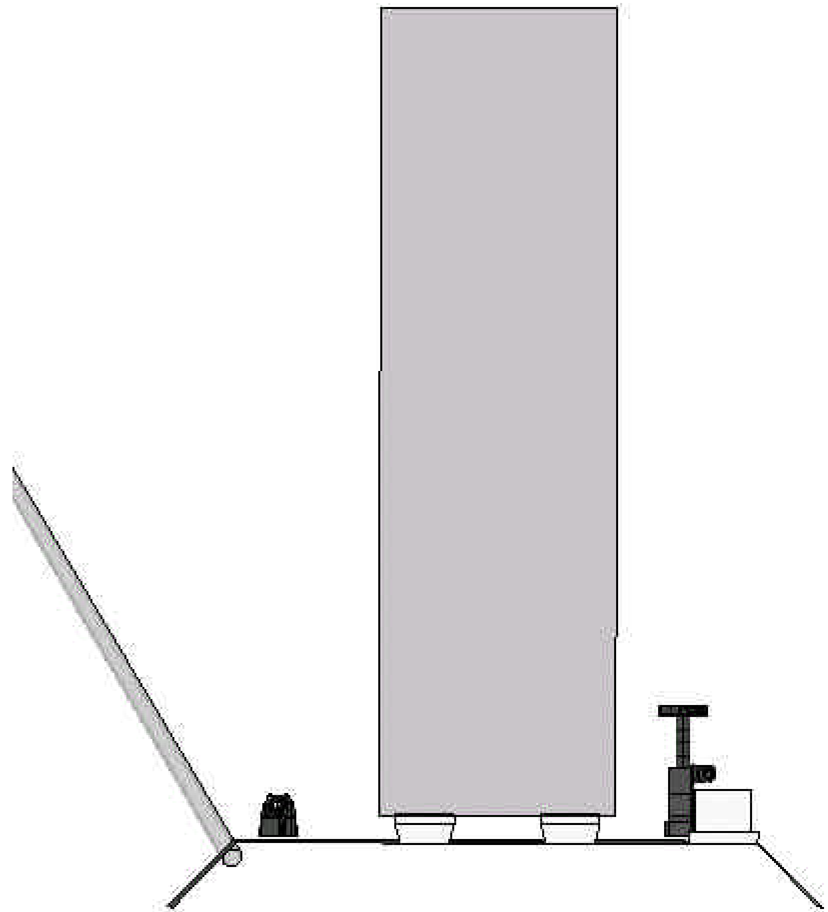
Ahead S/C	Extreme Solar Flux	
Perihelion	0.879 AU	1768.6 W/m^2
Aphelion	1.040 AU	1263.4 W/m^2

Behind S/C	Extreme Solar Flux	
Perihelion	0.960 AU	1482.7 W/m^2
Aphelion	1.131 AU	1068.3 W/m^2

Ahead And Behind Thermal Models

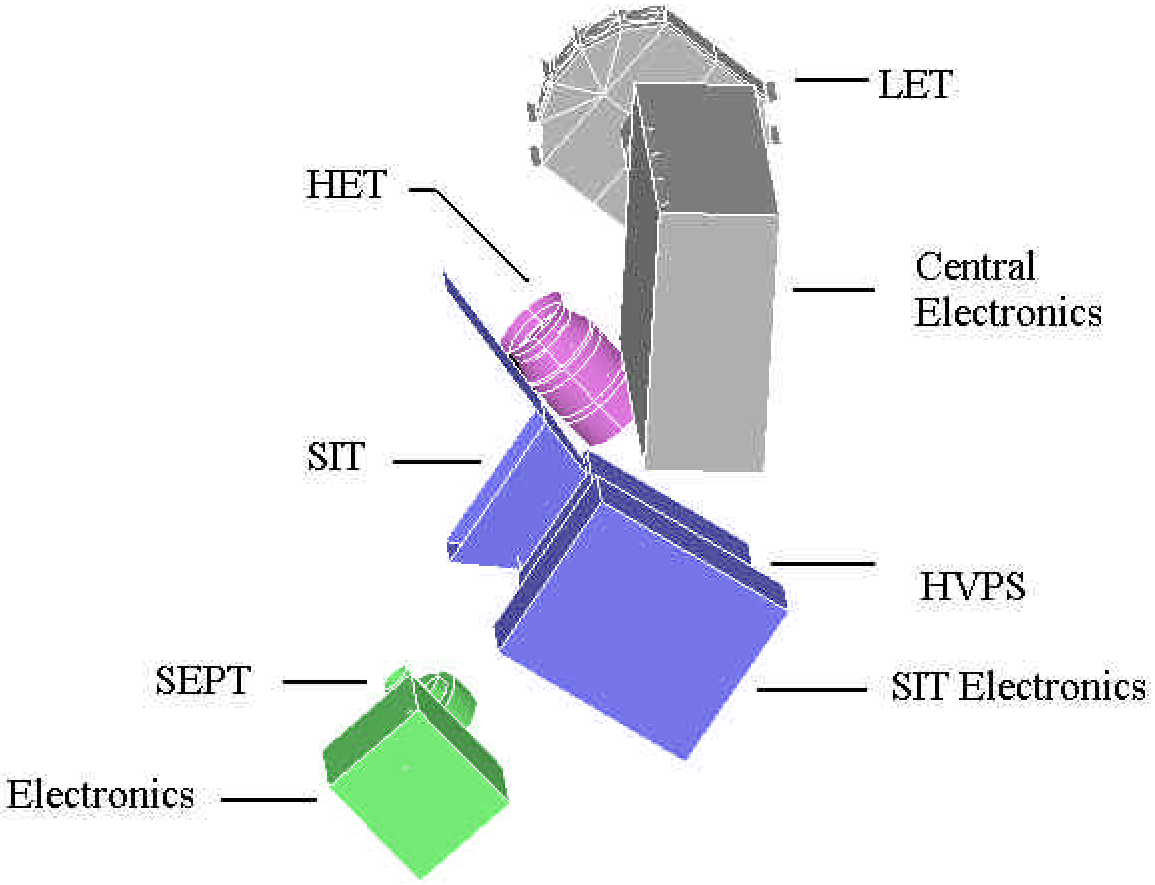


Ahead



Behind

Ahead Thermal Model



Instrument To Spacecraft Interface

- SEP Central Electronics Isolated:
  - 6 Fasteners = 0.065 W/°C
  - Grounding Strap = TBD W/°C
  - TOTAL > 0.05W/°C
    - Studying alternate attachment configurations
- SIT Electronics Isolated:
  - 4 Fasteners = 0.039 W/°C
  - Grounding Strap = TBD W/°C
  - TOTAL < 0.05W/°C
- SEPT-E/SEPT-NS Isolated:
  - 4 Fasteners = 0.039 W/°C
  - Grounding Strap = TBD W/°C
  - TOTAL < 0.05W/°C

Power Dissipation in Each SEP Subsystem

Component	Power Dissipation (W)
LET	0.71
SIT	1.02
SEPT-E	0.51
SEPT-NS	0.51
HVPS	0.33
Cent. Elec	
HET	0.29
SEP Common Elec.	0.61
SEP LVPS	2.15
TOTAL	**6.13**

Thermal Cases

- **On Station**
  - **Operational Hot**
    - **Ahead and Behind**
  - **Operational Cold**
    - **Ahead and Behind**
  - **Survival Hot**
    - **Ahead and Behind**
  - **Survival Cold**
    - **Ahead and Behind**
- **45° Off-Pointing Cold (Instruments Shaded For 105 Minutes)**
  - **Ahead and Behind**
- **45° Off-Pointing Hot (Sun On Instruments Radiators For 105 Minutes)**
  - **Ahead and Behind**

Early Orbit Thermal Case Assumptions

- All Aperture Doors Closed Until After All Maneuvers
- Instruments At Operational Temperatures With Doors Closed Until Immediately Prior To 45 Degree Off-pointing
- Solar Flux at 1 AU: 1366.5 W/m^2
- BOL Optical Properties
- Worst Case Cold
  - Instruments Shaded For 105 Minutes
- Worst Case Hot
  - Sun On Instruments Radiators For 105 Minutes

Thermal Blankets

- ITO coated silver conductive composite (Goddard Composite) deposited on Kapton
- Goddard Composite Outer Layer Blanket to be coated by GSFC
- 10-18 layer except at tight bends (~ 600 g/m^2)
- MLI to be fabricated by APL per GSFC designs

Optical Properties				Effective Emittance (ε^*)
$a_{(bol)}$	$\varepsilon_{(bol)}$	$a_{(eol)}$	$\varepsilon_{(eol)}$	0.05 - 0.02
0.1	0.68	0.2	0.64	

Thermal Blanket Alternatives

- Goddard Composite deposited on Aluminum or Stainless Steel Substrate
  - Additional Mass
  - Electrical Conductivity Requirement Not Yet Tested
- Aluminum Grid Deposited On Goddard Composite
  - Lower Emissivity
  - Additional Mass
  - Electrical Conductivity Requirement Not Yet Tested

Thermal Coatings

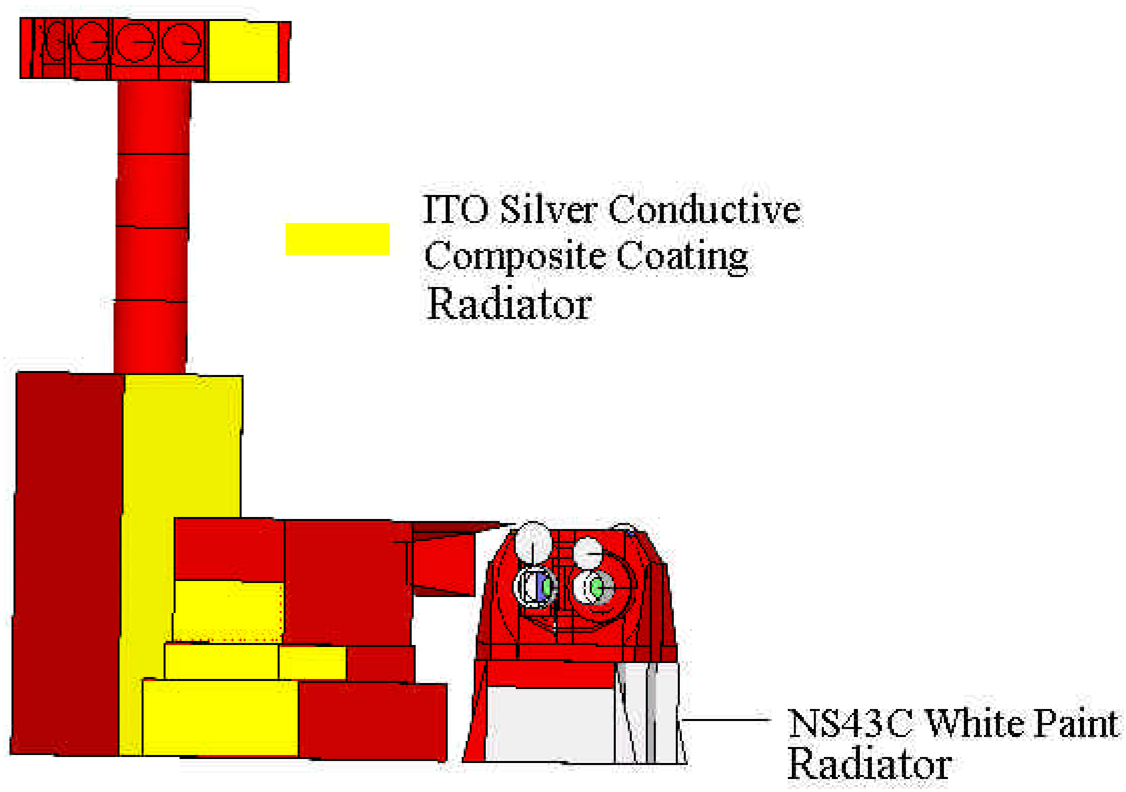
Optical Properties

	$\alpha_{(bol)}$	$\varepsilon_{(bol)}$	$\alpha_{(eol)}$	$\varepsilon_{(eol)}$
ITO Goddard Composite	0.1	0.68	0.2	0.64
MSA94B Black Paint	0.97	0.89	0.97	0.89
NS43C White Paint	0.2	0.92	0.45	0.89

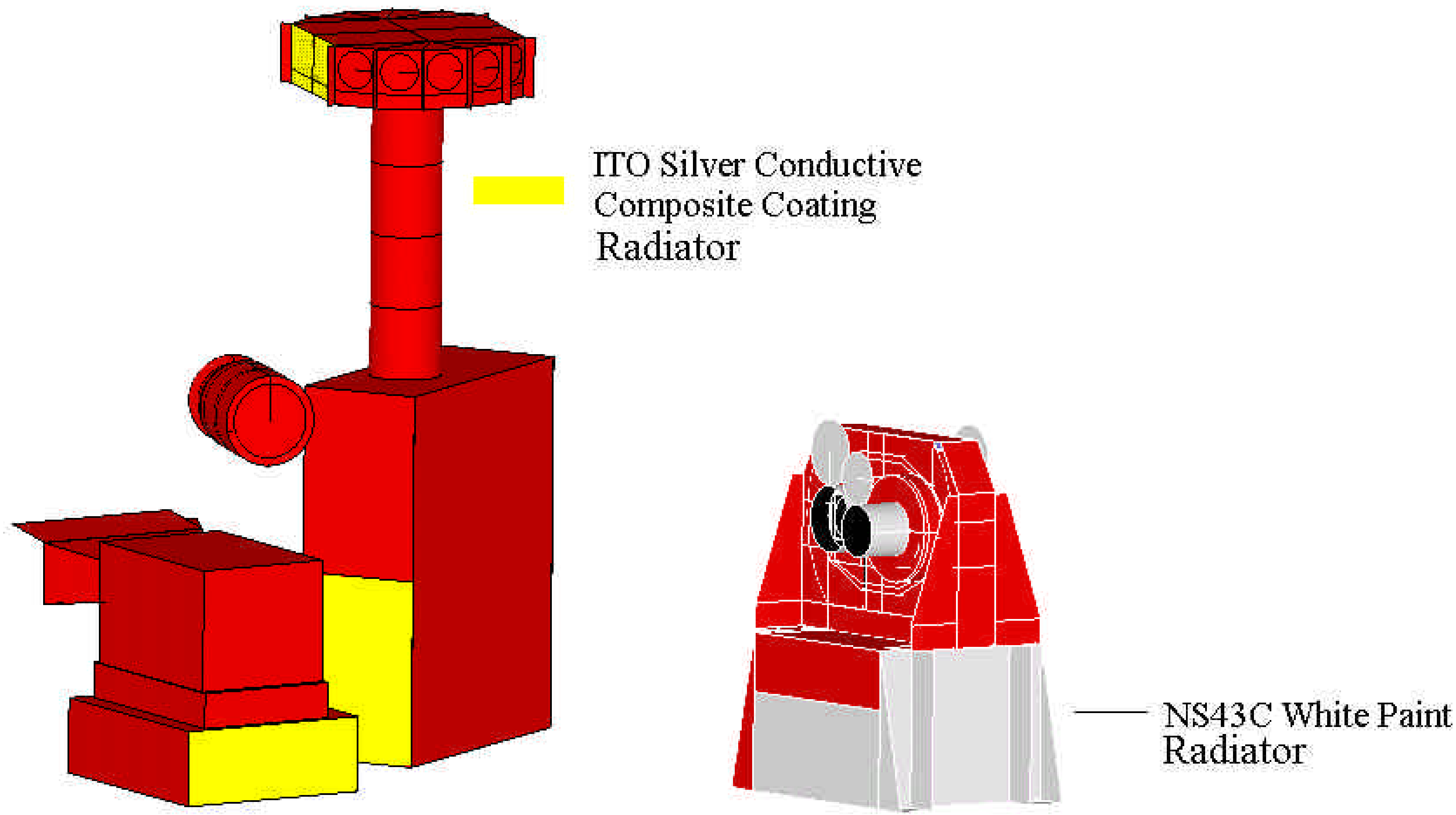
Radiators

- ITO Silver Conductive Composite Coating
  - Deposited on Kapton and Bonded to Aluminum or Deposited Directly on the Aluminum
- NS43C White Paint
  - Painted Directly on SEPT

Ahead Thermal Model Radiator Areas



Behind Thermal Model Radiator Areas



Heater Sizing

- **Operational heaters sized at 75 % duty cycle at 30.5 V**
- **Instrument survival heaters sized for 100% duty cycle at 25 V**

INSTALLED HEATER POWER (Watts)

Component	Ahead S/C		Behind S/C	
	Operational	Survival	Operational	Survival
HET	-	0.1	-	0.3
LET	1.0	2.5	0.7	2.8
SIT				
Detectors	0.3	0.8	0.6	0.8
Electronics	0.2	0.9	0.0	0.6
SEPT/E	1.9	3.0	2.0	2.9
SEPT/NS	1.6	2.2	1.7	2.2
Central Electronics	-	0.7	-	0.3
TOTAL	**4.9**	**10.1**	**5.0**	**9.9**

Installed heater power results in max 75% duty cycle for operational heaters, 100% for survival heaters

Ahead Spacecraft Operational Temperature Predicts

Temp (^oC)	Operational Limits		Operational Predicts			
Component	Design	In-Spec	Hot	Margin	Cold	Margin
HET						
Detectors	-25 to +25	-25 to +35	24.2	10.8	-12.7	12.3
Electronics	-20 to +25	-20 to +40	25.3	14.7	-10.4	9.6
LET						
Detectors						
Sun facing	-25 to +25	-25 to +35	27.9	7.1	-10.4	14.6
Shaded	-25 to +25	-25 to +35	10.4	24.6	-20.6	4.4
Electronics	-20 to +25	-20 to +40	21.2	18.8	-11.2	8.8
SIT						
Detectors	-25 to +10	-25 to +30	7.9	22.1	-20	5.0
Electronics	-20 to +25	-20 to +40	25.1	14.9	-14.8	5.2
SEPT-E						
Detectors	-25 to +10	-25 to +35	11.0	24.0	-19.9	5.1
Electronics	-25 to +10	-25 to +40	11.1	28.9	-16.6	8.4
SEPT-NS						
Detectors	-25 to +10	-25 to +35	7.9	27.1	-19.8	5.2
Electronics	-25 to +10	-25 to +40	14.3	25.7	-13.8	11.2
Central Electronics	-20 to +30	-20 to +40	25.3	14.7	-10.4	9.6

Cold predictions with heater power

STEREO IMPACT

Ahead Spacecraft Survival Temperature Predicts

Component	Survival Limits	Hot	Margin	Cold	Margin
HET					
Detectors	-40 to +40	6.9	33.1	-34.9	5.1
Electronics	-40 to +50	16.4	33.6	-34.9	5.1
LET					
Detectors					
Sun facing	-40 to +40	12.4	27.6	-26.6	13.4
Shaded	-40 to +40	-1.6	41.6	-39	1.0
Electronics	-40 to +50	8.8	41.2	-32	8.0
SIT					
Detectors	-35 to +35	21.6	13.4	-30	5.0
Electronics	-40 to +50	33.5	16.5	-35.9	4.1
SEPT-E					
Detectors	-30 to +50	29.4	20.6	-24.9	5.1
Electronics	-40 to +50	36.1	13.9	-21.8	18.2
SEPT-NS					
Detectors	-30 to +50	25.9	24.1	-25	5.0
Electronics	-40 to +50	32.7	17.3	-19.6	20.4
Central Electronics	-40 to +50	16.4	33.6	-34.9	5.1

Cold predictions with heater power

Behind Spacecraft Operational Temperature Predicts

Temp (^{o}C)	Operational Limits		Operational Predicts			
Component	Design	In-Spec	Hot	Margin	Cold	Margin
HET						
Detectors	-25 to +25	-25 to +35	25.4	9.6	-11.3	13.7
Electronics	-20 to +25	-20 to +40	26.8	13.2	-8.79	11.2
LET						
Detectors						
Sun facing	-25 to +25	-25 to +35	26.5	8.5	-10.8	14.2
Shaded	-25 to +25	-25 to +35	10.8	24.2	-20.2	4.8
Electronics	-20 to +25	-20 to +40	22.6	17.4		20.0
SIT						
Detectors	-25 to +10	-25 to +30	10.2	19.8	-19.8	5.2
Electronics	-20 to +25	-20 to +40	26.4	13.6	-15.5	4.5
SEPT-E						
Detectors	-25 to +10	-25 to +35	9.1	25.9	-20	5.0
Electronics	-25 to +10	-25 to +40	10.8	29.2	-16.1	8.9
SEPT-NS						
Detectors	-25 to +10	-25 to +35	5.2	29.8	-20.5	4.5
Electronics	-25 to +10	-25 to +40	12.3	27.8	-14.4	10.6
Central Electronics	-20 to +30	-20 to +40	26.8	13.2	-8.79	11.2

Cold predictions with heater power

Behind Spacecraft Survival Temperature Predicts

Temp (°C)	Survival Limits	Survival Predicts			
Component		Hot	Margin	Cold	Margin
HET					
Detectors	-40 to +40	10.1	29.9	-35.1	4.9
Electronics	-40 to +50	13.7	36.3	-30.9	9.1
LET					
Detectors					
Sun facing	-40 to +40	10.3	29.7	-23.5	16.5
Shaded	-40 to +40	-4.2	44.2	-34.4	5.6
Electronics	-40 to +50	6.2	43.8		40.0
SIT					
Detectors	-35 to +35	24.1	10.9	-29.4	5.6
Electronics	-40 to +50	32.9	17.1	-34.8	5.2
SEPT-E					
Detectors	-30 to +50	29.1	20.9	-25.1	4.9
Electronics	-40 to +50	35.8	14.2	-21.7	18.3
SEPT-NS					
Detectors	-30 to +50	25.9	24.1	-25	5.0
Electronics	-40 to +50	32.7	17.3	-19.6	20.4
Central Electronics	-40 to +50	13.7	36.3	-30.9	9.1

Cold predictions with heater power

HEATER CIRCUIT DESIGN

No Redundancy, Not Single Fault Tolerant

- **Survival Heaters**
  - **Thermostatically controlled**

- **Operational Heaters**
  - **Thermostatically controlled**
    - **SIT**
  - **Microprocessor controlled**
    - **LET**
    - **SEP central**
    - **SEPT**

Component Level Thermal Analysis Methodology

- **Analyzing components dissipating more than 20 mW**
- **Conformal Coating on boards** e **= 0.80**
- **Interior of Electronic boxes**
  - **Black Anodized**
  - **Black Paint**
- **If the junction to case resistance,** q_{jc}**, unavailable used the value recommended by Mil-M-38510**
- **The first analysis considers only radiation from the component case**
  - **If the resulting temperature is unacceptable, conduction through the leads and/or bonding the component to the board should be considered**

SEPT Component Level Thermal Analysis

Digital Board				
Dissipation mW	Local Board Temperature (C)	Case Temperature (C)	Junction Temperature (C)	Derated Junction Temperature (C)
140				
Operating	25.6	51.6	52.7	110.0
Qualification	51.7	72.6	73.7	110.0
80				
Operating	25.6	74.6	76.4	100.0
Qualification	51.7	92.1	93.9	100.0
Analog Board				
Dissipation mW	Local Board Temperature (C)	Case Temperature (C)	Junction Temperature (C)	Derated Junction Temperature (C)
67				
Operating	20.9	60.8	62.2	100.0
Qualification	48.0	80.3	81.8	100.0
67				
Operating	21.1	60.9	62.4	100.0
Qualification	48.2	80.4	81.9	100.0

Component Level Thermal Analysis Needed

- **SEP Central, SIT Electronics**
  - **Once final component layouts are identified , analyze each component to verify that the temperatures are within the derated limits**
- **Verify junction to case resistances, q_{jc}, used in analysis meet manufacturers specifications**

Conclusions

- SIT, SEPT-E, And SEPT-NS Aperture Doors Must Remain Closed Until After All Maneuvers
- Instruments Should Remain Operational Until Immediately Prior To 45 Degree Off-pointing
  - Instruments Potentially Completely Shaded
- Full Sun On Lightweight Foils And Detectors Behind Open Aperture Doors During 12 Minute On Station Failure Mode
  - Foil Temperatures Rise Rapidly In Sun

Conclusions continued

- Have Flown Detectors Configured Like The LET L1 Detectors Before But They Were On Spinning Spacecraft
  - Here We Have Some Detectors With Their Foils Staring At The Sun And Others Never Seeing The Sun
  - Foils Staring At The Sun Run As Much As 60 °C , Detectors Never Seeing The Sun Run As Cold As -106 °C
- System Level Allocation Must Support Survival And Operational Heater Power?

Future Work

- Thermal Balance and Thermal Vacuum Test Planning
- May Need Some Tests On The Foils To Make Sure That They Won't Break Due To Contraction When Going Cold
- Additional Component Level Analysis
  - Verify case qualification temperatures