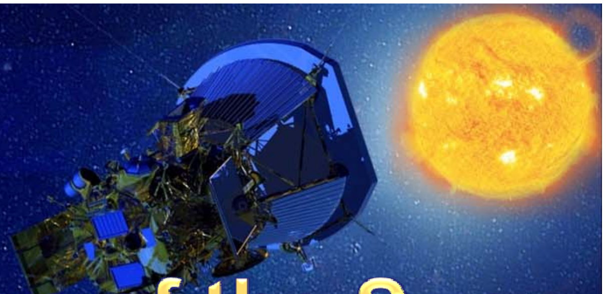
Solar Probe Plus

A NASA Mission to Touch the Sun



Integrated Science Investigation of the Sun Energetic Particles

Preliminary Design Review

05 – 06 NOV 2013

ISIS Thermal

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ISIS Thermal Lead (SwRI)

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Outline

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- Driving Instrument Thermal Requirements
- Thermal Design and Implementation
  - Thermal Management
  - Heaters and Sensors
  - MLI Design
  - Materials and Finishes
- Predicted Performance and Margins
  - Thermal Model Details
  - Design Cases
  - Optical Properties and Power Dissipation
  - Predictions and Margins
- Plans for Thermal Verification
- Summary

Requirements (1/2)

- Design Temperature Limits

EPI-Hi

Component	Hot Op. (°C)	Cold Op. (°C)	Cold Surv. (°C)
EPI-HI HET	40	-25	-40
EPI-Hi LET1	40	-25	-40
EPI-Hi LET2	40	-25	-40
EPI-Hi DPU	40	-25	-40
EPI-Hi Bias	40	-25	-40
EPI-Hi LVPS	40	-25	-40
EPI-Hi HET Tel	30	-25	-40
EPI-Hi LET 1 Tel	30	-25	-40
EPI-Hi LET 2 Tel	30	-25	-40

EPI-Lo

Component	Hot Op. (°C)	Cold Op. (°C)	Cold Surv. (°C)
Detector	35	-30	-45
Anode Board	55	-30	-45
Event Board	55	-30	-45
Power Board	55	-30	-45
Dome	35	-30	-45

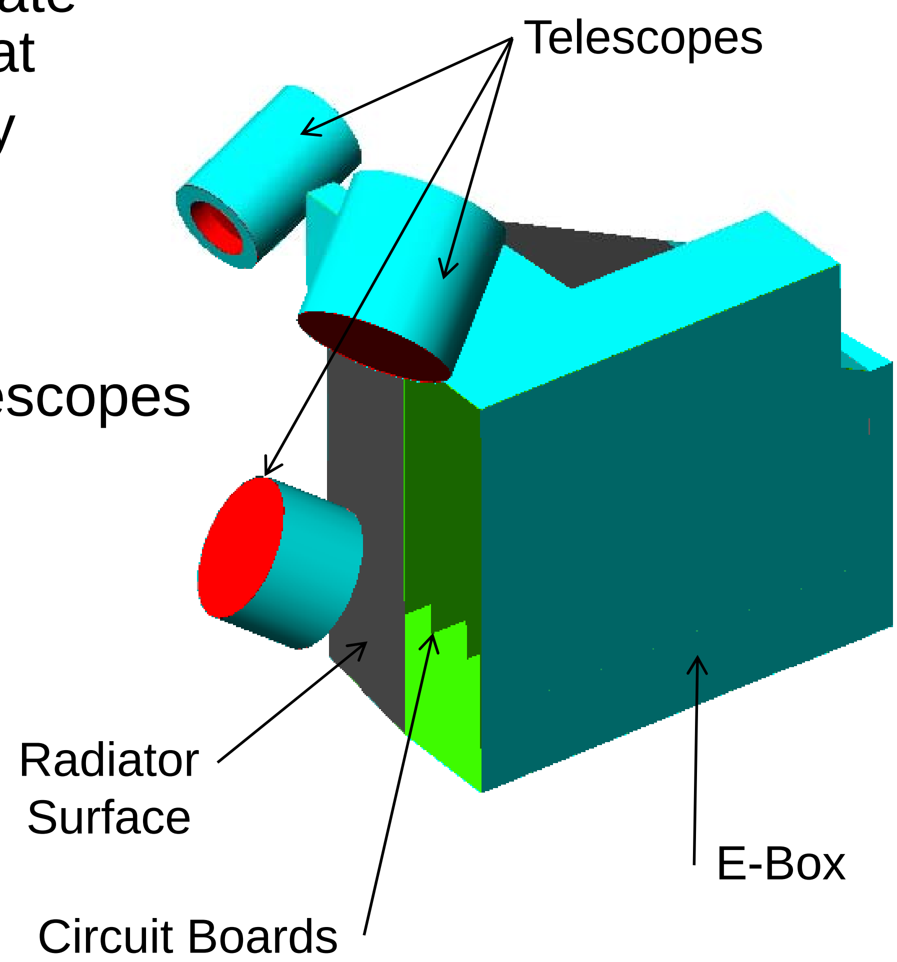
- Margin Guidelines – Includes Test and Model Uncertainty
  - Hot Limits 10 C and Cold Limits 5 C (Heater Controlled)

Requirements (2/2)

- Interface Temperatures
  - Operational: -25 / +65 C
  - Non-Operational: -30 / +70 C
- Heaters
  - 75% Maximum Duty Cycle
  - Resistance Determined at 26 V

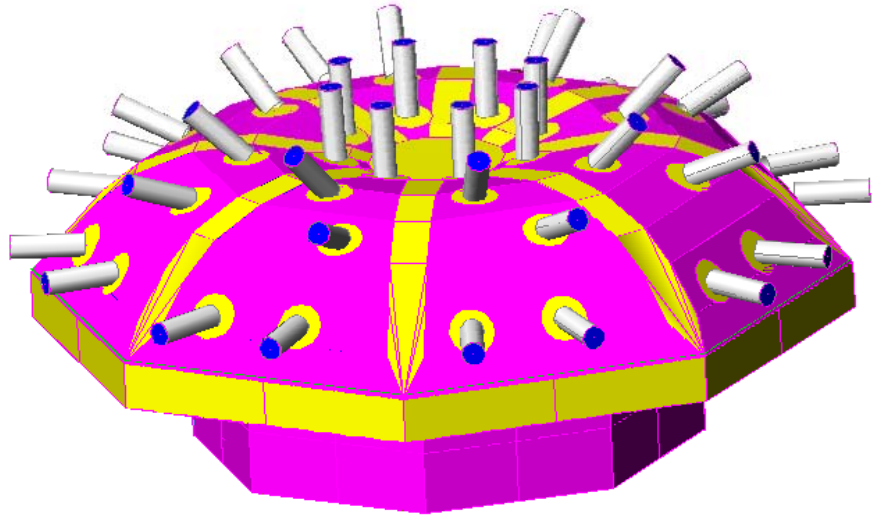
Design (1/3)

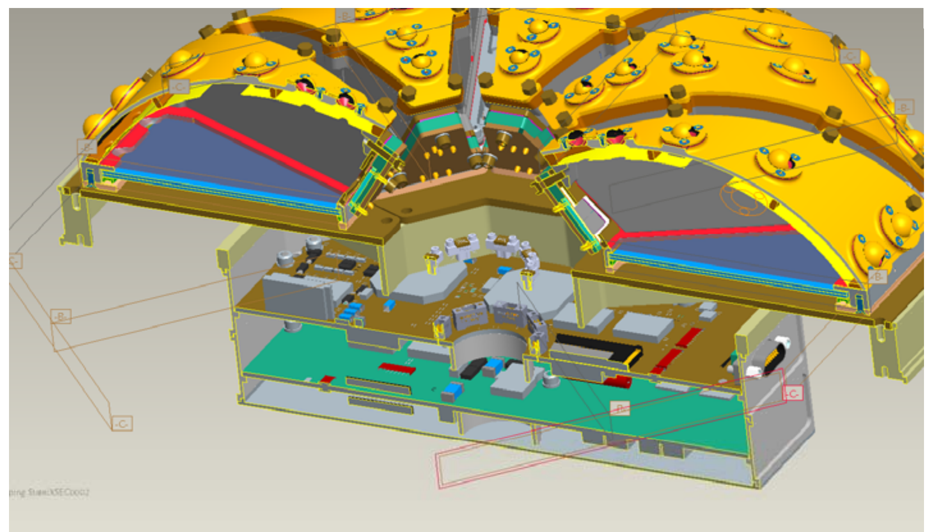
- EPI-Hi
  - E-box Radiator to Dissipate Internally Generated Heat
  - Telescopes Conductively Isolated from E-box
  - Operational Heaters on Telescopes
  - Survival Heaters on Telescopes and E-box
  - MLI on Surfaces Except Apertures, Radiator, and Bottom (S/C Facing)



Design (2/3)

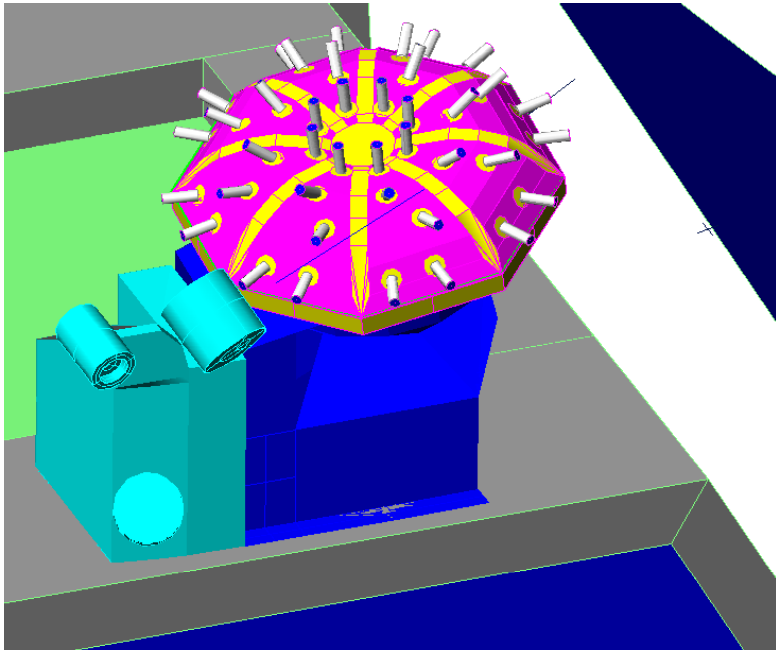
- EPI-Lo
  - Wedge Radiators (8) to Dissipate Internally Generated Heat
  - Eight Survival Heaters (One on Each Wedge)
  - MLI on Surfaces Except Apertures and Radiators

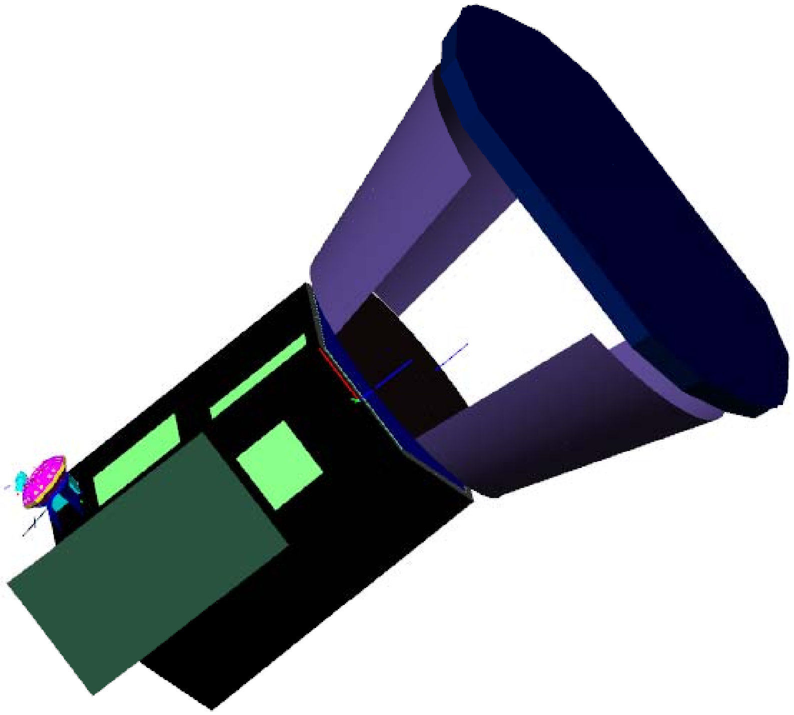




Design (3/3)

- ISIS
  - EPI-Hi and EPI-Lo are Thermally Isolated from the Bracket
  - Bracket is Thermally Isolated from the S/C





Heaters and Sensors (1/2)

- EPI-Hi Heater Operations
  - One S/C Thermistor on Each Telescope and Two S/C Thermistors on E-box (Primary and Redundant)
  - Operational Heaters on Telescopes are All on One S/C Service, but Controlled by E-box
  - Survival Heaters on Telescopes and the E-Box are All on One S/C Service and Controlled by S/C with Sense Location Currently Baselined as the E-box
  - Survival Heaters Also Used to Warm Instrument to Cold Operational Temperature for Cold Turn On by using Different Set Points

Heaters and Sensors (2/2)

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- EPI-Lo Heater Operations
  - Two (Primary and Redundant) S/C Thermistors on Dome for Heater Control and One More (To Be Positioned)
  - All Survival Heaters are on One S/C Service (Separate from EPI-Hi) Controlled by S/C with Sense Location Currently Baselined as One of the Wedges
  - Survival Heaters are Used to Warm Instrument to Cold Operational Temperature for Cold Turn On by Using Different Set Points
  - Survival Heaters are Also Used to Maintain Minimum Cold Operating Temperature During Low Power Operating Conditions

MLI

- Coverage
  - Entire Instrument Other than Apertures, Radiators, and Under EPI-Hi Electronics
- Specifications/Construction
  1. Outer Layer #1: 1.6 Mil Germanium Black Kapton with Nomex Scrim (Germanium facing space and Black facing Spacecraft)- 1 Layer
  2. Outer Layer #2: 2 Mil VDA1 Kapton (Aluminum facing space and Kapton facing Spacecraft)- 1 Layer
  3. Internal Layers: 10 layers of .25 Mil VDA2 Mylar altered by 11 layer of Dacron B4A netting.

  - Each Separate Blanket Grounded with Wire to S/C
  - Vented Using Edge Mesh Screens Directed away from Apertures
  - Edges and Seams Sealed using GBK Tape
  - Blankets Secured using G-10 Buttons and SS Snap Rings

Materials and Finishes

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- Radiators
  - Z-93 Conductive White Coating
- MLI
  - Germanium Black Kapton (GBK)
- Apertures
  - EPI-Hi: Metalized Polyimide
  - EPI-Lo: Z-93
- Thermal Isolators
  - G-10 Fiberglass

Thermal Model

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- EPI-Hi Modeled by Vertex Aerospace
  - Rommel Zara and Santino Rosanova
- EPI-Lo Modeled by APL
  - Shawn Begley
- Bracket Modeled by Vertex Aerospace
- ISIS Model Integrated by Vertex Aerospace
- All Models Created using Thermal Desktop Software
- Pre-PDR Model Delivered to S/C in June
- Good Correlation between Instrument and S/C Results

Design Cases

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- Hot Operational
  - +65 C I/F Temperature
  - EOL Power and BOL Optical Properties
  - Low MLI e* = 0.03
- Cold Operational
  - -25 C I/F Temperature
  - BOL Power and BOL Optical Properties
  - High MLI e* = 0.05
- Cold Non-Operational
  - -30 I/F Temperature
  - BOL Optical Properties and e* = 0.05
- Hot Non-Operational
  - 1.02 AU with +70 I/F Temperature
  - EOL Optical Properties and e* = 0.03

Optical Properties

- Radiator: Z-93 White Coating
  - BOL: a = 0.15, e = 0.91
  - EOL: a = 0.45, e = 0.91
- MLI Exterior: GBK
  - BOL: a = 0.49, e = 0.81
  - EOL: a = 0.55, e = 0.78
- EPI-Hi Apertures
  - HET BOL: a = 0.31, e = 0.46
  - LET BOL: a = 0.35, e = 0.35

Power Dissipation

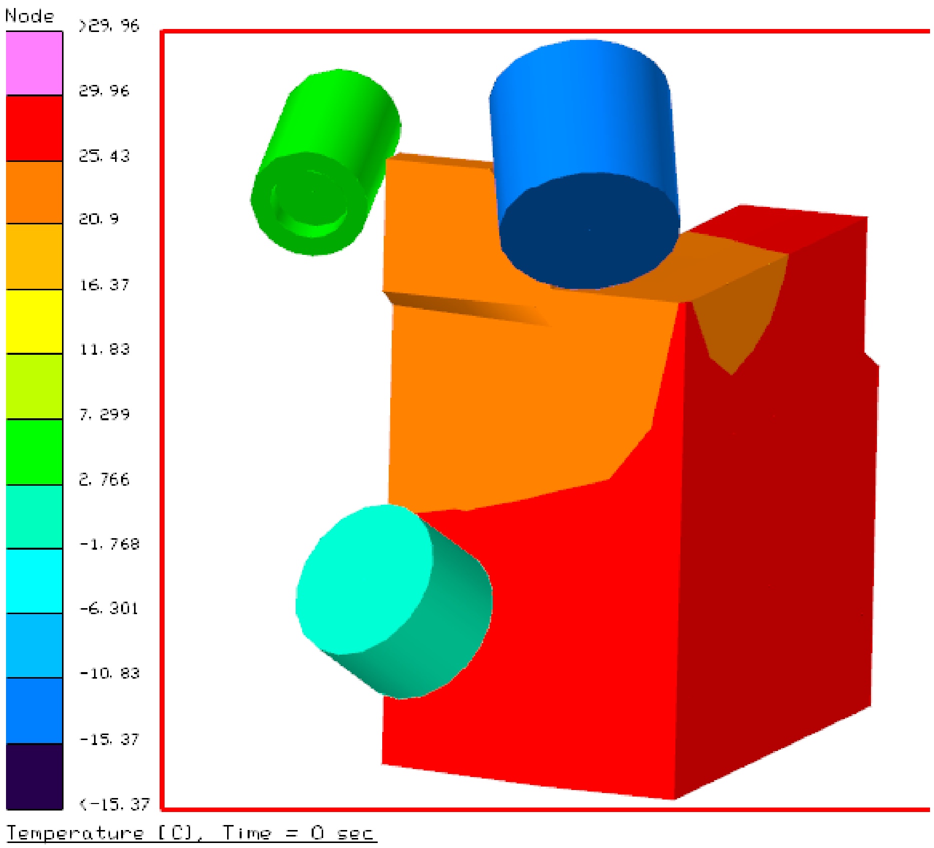
- ISIS Power Distribution
  - Cold Case uses CBE, Hot Case uses CBE+Cont.

EPI_HI Heatloads	Cold CBE, W	Hot w/Contingency, W
Bias Supply	0.14	0.38
DPU	0.71	0.79
HET	1.10	1.22
LET 1	1.19	1.32
LET 2	0.90	1.00
LVPS	1.77	2.06
Total	**5.81**	**6.77**

EPI_LO Heatloads	Cold CBE New, W	Hot w/Contingency New, W
Detector	0.20	0.24
Event	1.13	1.36
Power Supply	1.94	2.33
MCP	0.52	0.62
Anode	0.38	0.46
Total	**4.17**	**5.00**

Predictions (1/9)

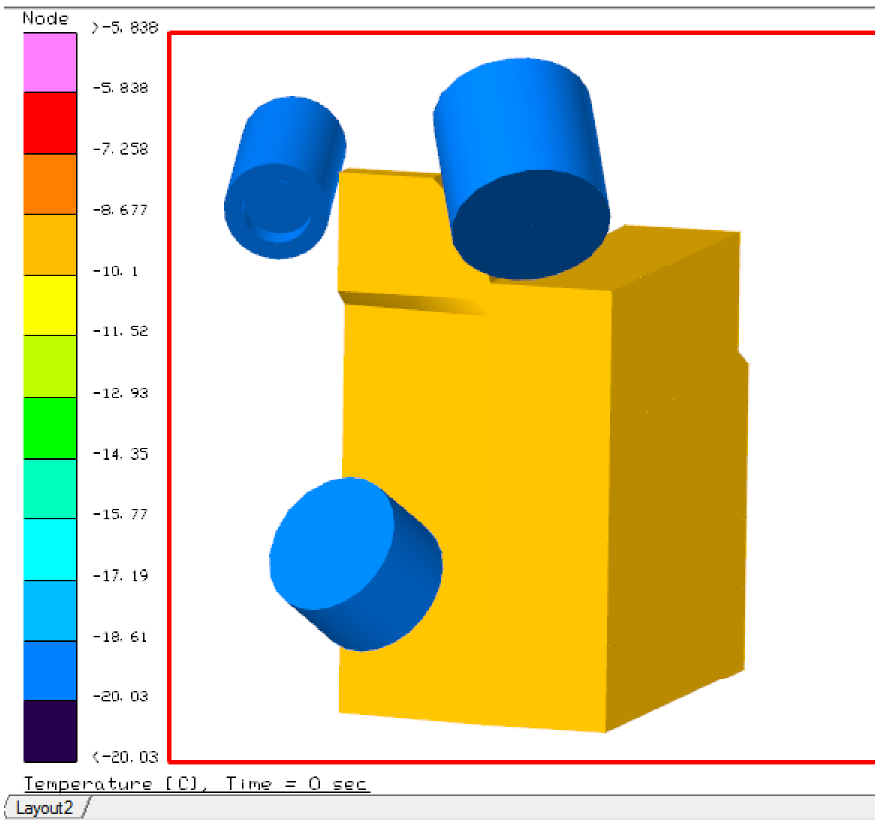
- EPI-Hi Hot Operational



Component	Limit (°C)	Predict (°C)	Margin (°C)
EPI-HI HET	40	29.4	10.6
EPI-Hi LET1	40	29.5	10.5
EPI-Hi LET2	40	27.3	12.7
EPI-Hi DPU	40	28.2	11.8
EPI-Hi Bias	40	28.6	11.4
EPI-Hi LVPS	40	29.6	10.4
EPI-Hi HET Tel	30	3.5	26.5
EPI-Hi LET 1 Tel	30	-15.0	45.0
EPI-Hi LET 2 Tel	30	-0.5	30.5

Predictions (2/9)

- EPI-Hi Cold Operational

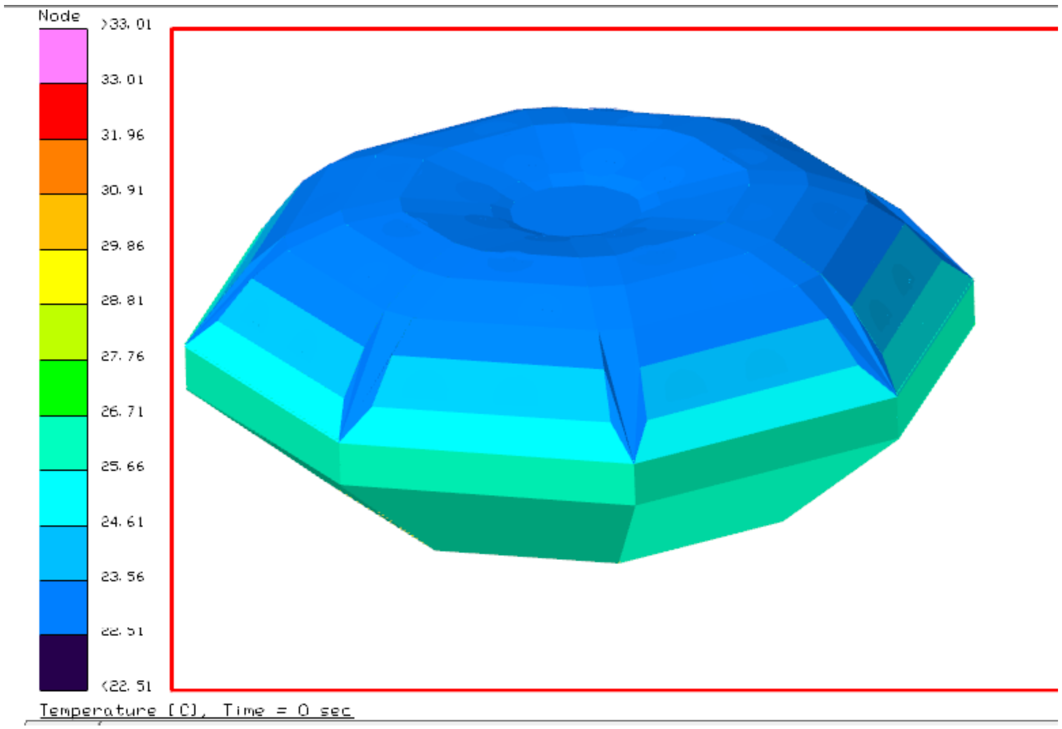


Component	Limit (°C)	Predict (°C)	Margin (°C)
EPI-HI HET	-25	-2.9	22.1
EPI-Hi LET1	-25	-2.9	22.1
EPI-Hi LET2	-25	-4.8	20.2
EPI-Hi DPU	-25	-4.1	20.9
EPI-Hi Bias	-25	-3.8	21.2
EPI-Hi LVPS	-25	-2.6	22.4
EPI-Hi HET Tel	-25	-20	5
EPI-Hi LET 1 Tel	-25	-20	5
EPI-Hi LET 2 Tel	-25	-20	5

Heater Location	Heater Power(W)
EPI-Hi HET TEL	0.05
EPI-Hi LET1 TEL	0.08
EPI-Hi LET2TEL	0.32
TOTAL	0.45

Predictions (3/9)

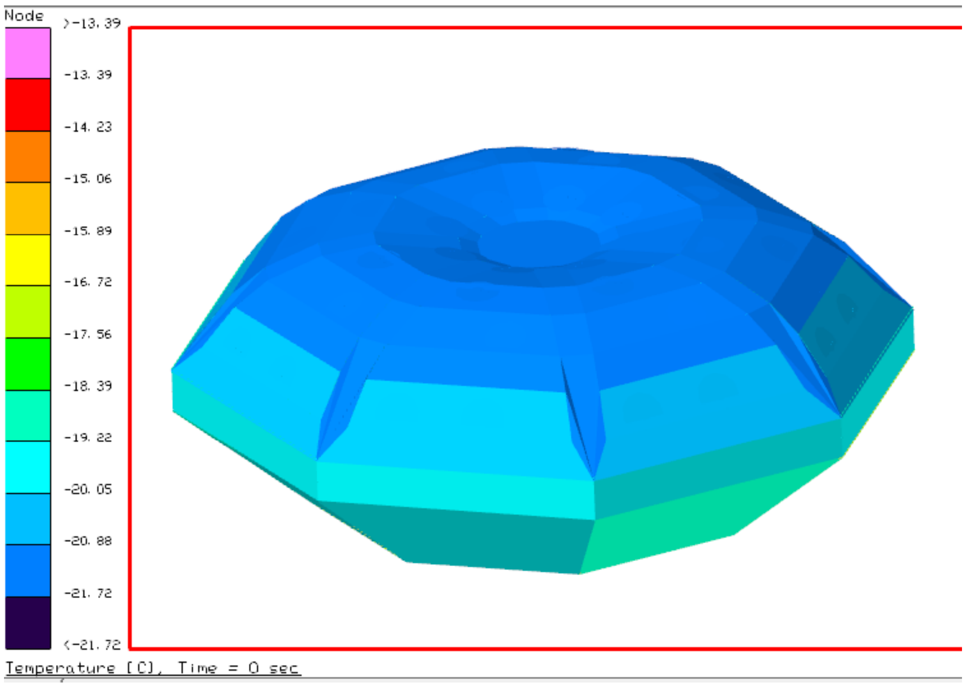
- EPI-Lo Hot Operational



Component	Limit (°C)	Predict (°C)	Margin (°C)
Detector	35	24.8	10.2
Event	55	27.2	27.8
Pwr. Supply	55	28.9	26.1
MCP	55	25.2	29.8
Anode	55	23.8	31.2

Predictions (4/9)

- EPI-Lo Cold Operational



Component	Limit (°C)	Predict (°C)	Margin (°C)
Detector	-30	-10.0	20.0
Event	-30	-8.4	21.6
Pwr. Supply	-30	-7.0	23.0
MCP	-30	-8.8	21.2
Anode	-30	-11.1	18.9

Predictions (5/9)

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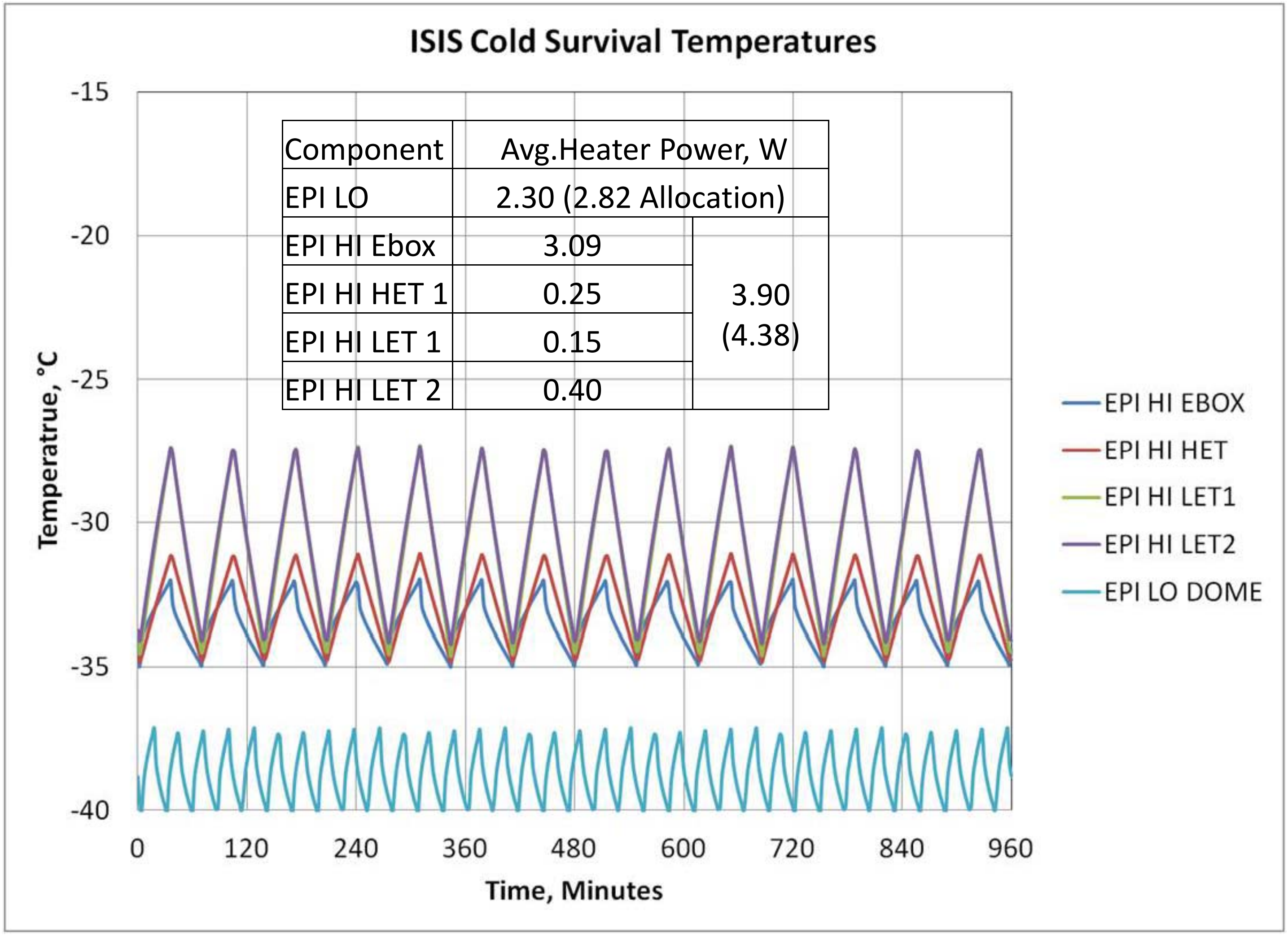
- ISIS Heater Sizing
- EPI-Lo Operational CBE Power of 4.17 W is Duty Cycled at 75% for a Heater Instantaneous Power of 5.56 W (26 V).
  - Temperature Setpoints of -25°C/-22°C (Operational)
  - Temperature Setpoints of -40°C/-37°C (Non-Operational)
- EPI-Hi Operational CBE Power of 5.81 W is Duty Cycled at 75% for a Heater Instantaneous Power of 7.74 W (26 V).
  - HET TEL: 0.3 W
  - LET1 TEL: 0.8 W
  - LET 2 TEL: 0.5 W
  - EBOX: 6.15 W
  - Temperature Setpoints of -20°C/-17°C (Operational)
  - Temperature Setpoints of -35°C/-32°C (Non-Operational)

Predictions (6/9)

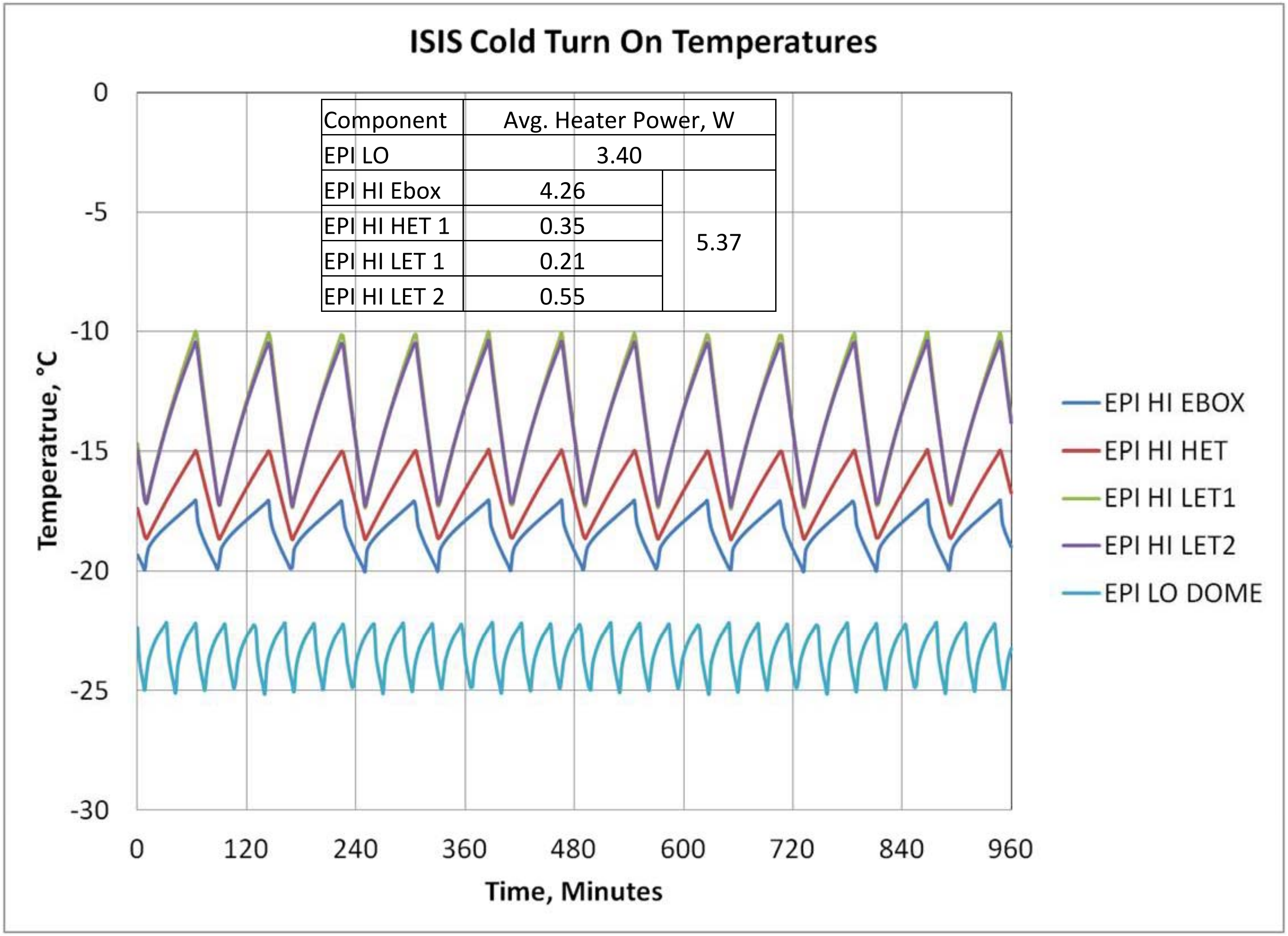
- ISIS Cold Non-Operational Temperatures



Component	Avg.Heater Power, W	
EPI LO	2.30 (2.82 Allocation)	
EPI HI Ebox	3.09	3.90 (4.38)
EPI HI HET 1	0.25	
EPI HI LET 1	0.15	
EPI HI LET 2	0.40	

Predictions (7/9)

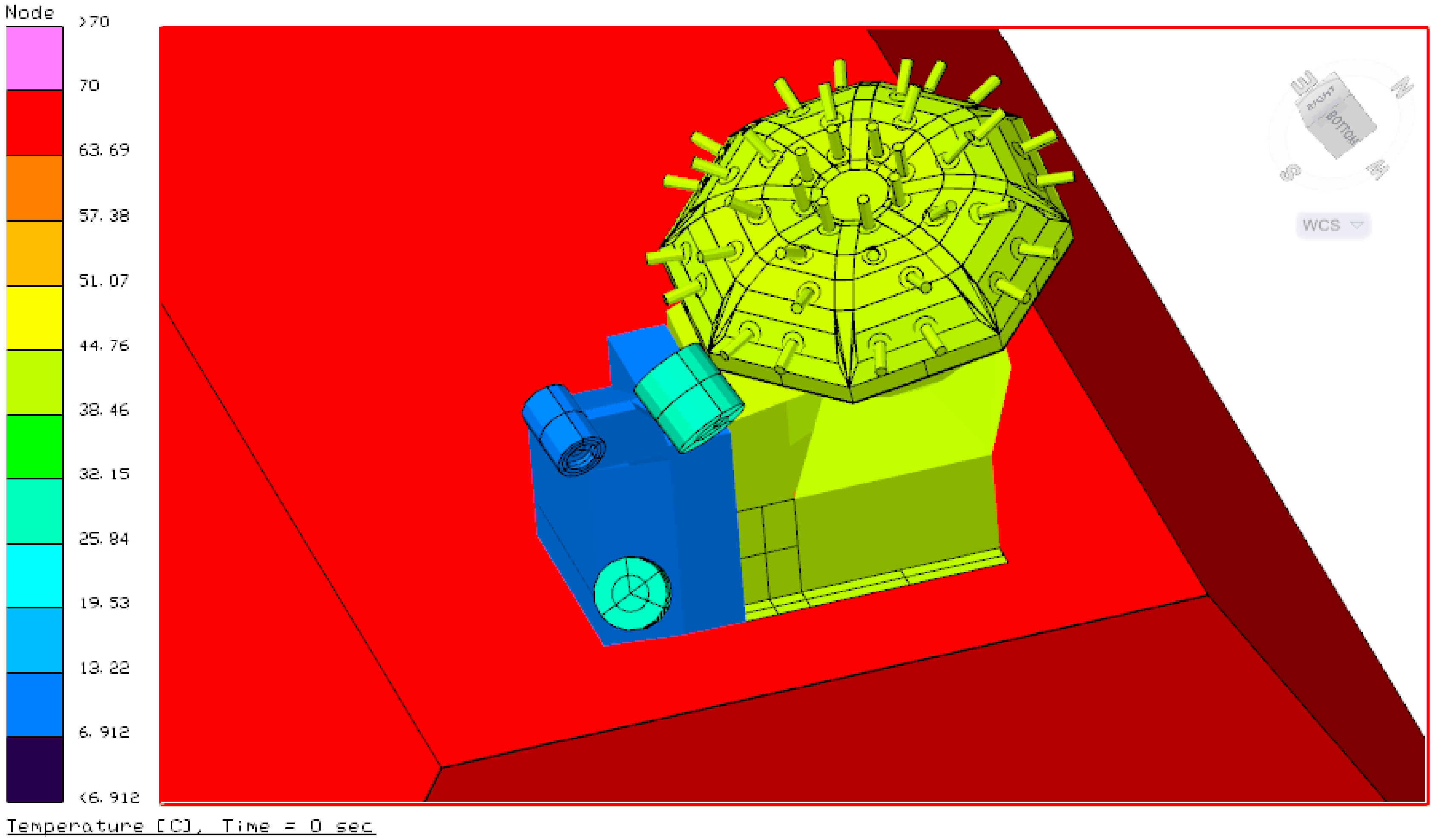
- ISIS Warm Up Temperatures



Component	Avg. Heater Power, W	
EPI LO	3.40	
EPI HI Ebox	4.26	5.37
EPI HI HET 1	0.35	
EPI HI LET 1	0.21	
EPI HI LET 2	0.55	

Predictions (8/9)

- ISIS Hot Non-Operational Temperature Plot



Predictions (9/9)

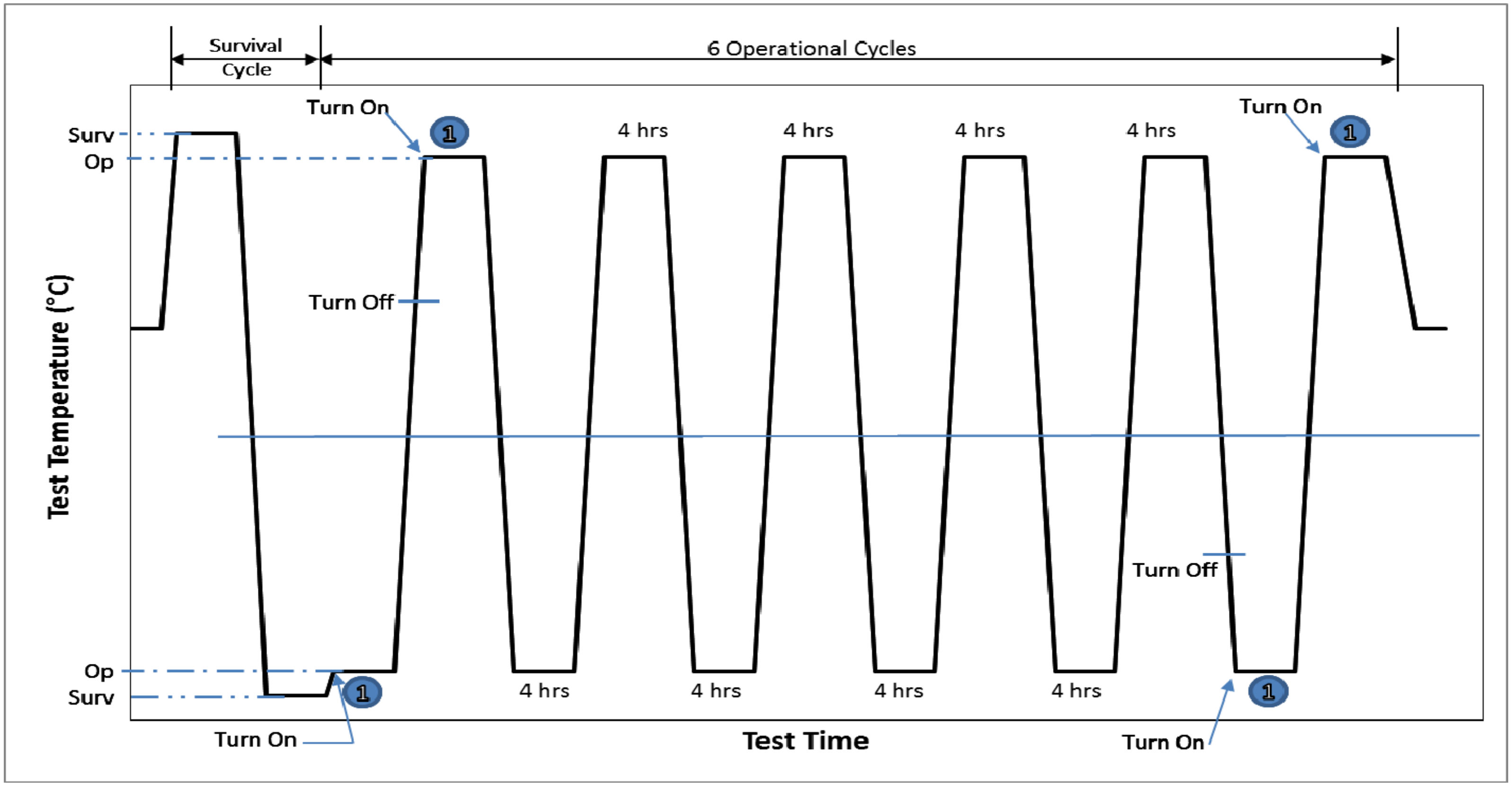
- ISIS Hot Non-Operational Temperature Table

Component	Hot Surv Predict, °C	Hot Surv Limit, °C	Margin, °C
IS_ISIS_TEL_HET	7.0	55.0	48.0
IS_ISIS_TEL_LET1	26.8	55.0	28.2
IS_ISIS_TEL_LET2	30.8	55.0	24.2
IS_ISIS_EPI_HI_BIAS	8.9	55.0	46.1
IS_ISIS_EPI_HI_DPU	9.1	55.0	45.9
IS_ISIS_EPI_HI_HET	8.9	55.0	46.1
IS_ISIS_EPI_HI_LET1	8.9	55.0	46.1
IS_ISIS_EPI_HI_LET2	9.1	55.0	45.9
IS_ISIS_EPI_HI_LVPS	9.2	55.0	45.8

Component	Hot Surv Predict, °C	Hot Surv Limit, °C	Margin, °C
IS_ISIS_EPI_LO_DETECTOR	42.5	55.0	12.5
IS_ISIS_EPI_LO_EVENT	42.2	55.0	12.8
IS_ISIS_EPI_LO_PWR_SUPPLY	42.1	55.0	12.9
IS_ISIS_EPI_LO_MCP	42.3	55.0	12.7
IS_ISIS_EPI_LO_ANODE	42.2	55.0	12.8
IS_ISIS_EPI_LO_DOME	42.7	55.0	12.3

Verification (1/2)

- ISIS Thermal Vacuum Profile
  - Six Operational Cycles
  - One Survival Cycle



Verification (2/2)

- ISIS Thermal Balance
  - Three Cases: Hot Operational, Cold Operational, and Cold Survival
  - Temperature Controlled Baseplate to S/C I/F Temperature Limits
  - Radiators with View to LN2 Cooled Chamber Shroud
  - Verify Heater Duty Cycle
  - Verify Interface Conductances
  - Correlate Thermal Model

Summary

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- Instrument Requirements (Temperature Limits) are Defined
- Thermal Environments and Interfaces are Defined
- Resources (Heater Power) have been Iterated and Baselined
- The Thermal Design Presented and Analyzed Meets all Requirements in the Specified Environments within the Allocated Resources