Thermal Design and Analysis

Critical Design Review
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Bruce Williams
301-953-6000 x3721 (voice)
301-953-6556 (fax)
bruce.williams@jhuapl.edu

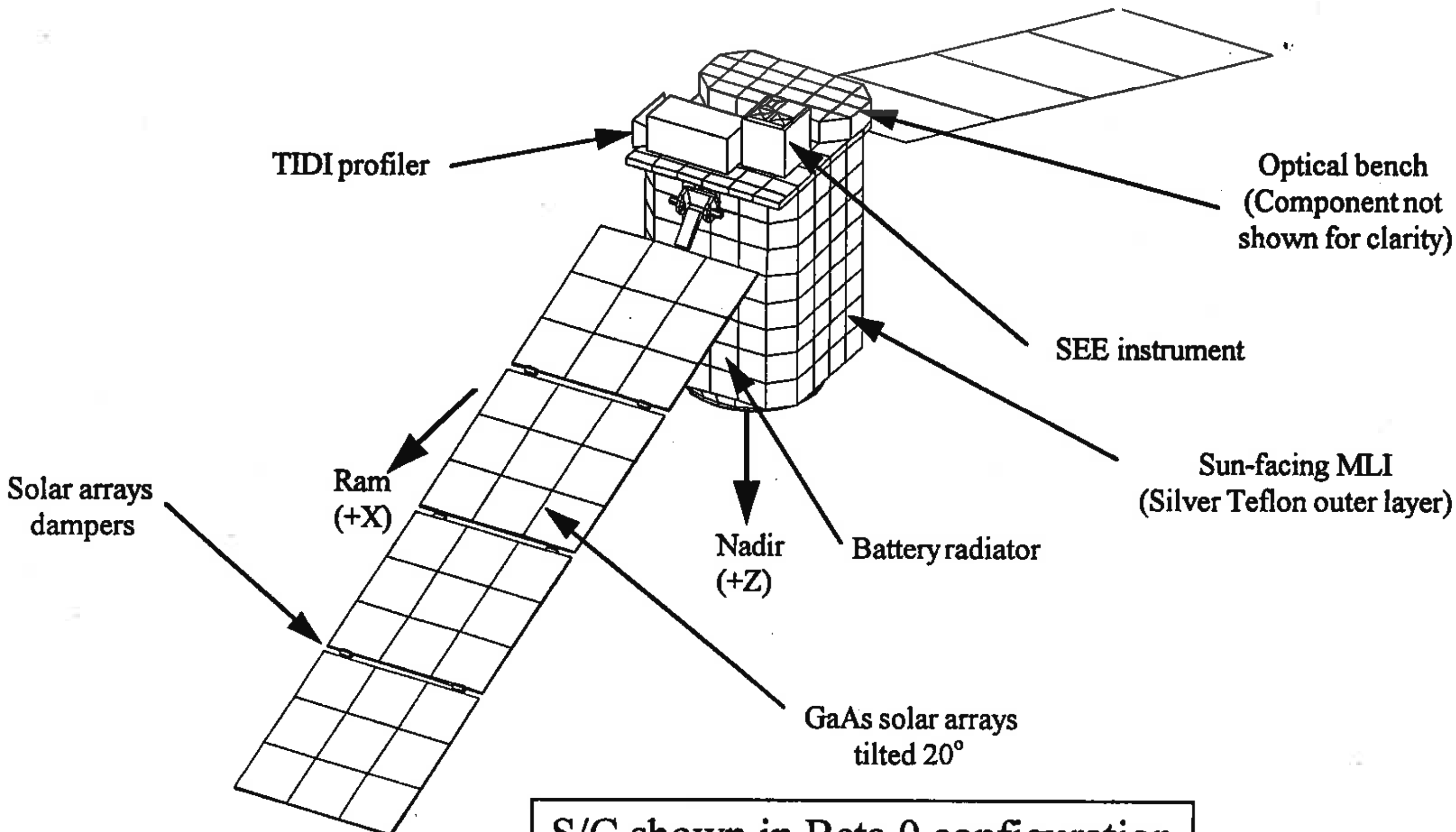
Presentation Outline

- Requirements
- Instrument Summaries
- Changes Since PDR
- Design Overview
- Thermal Model Description & Analysis Parameters
- Detailed Battery Analyses Results and Testing
- Heat Pipe Analysis
- Launch Mode Analyses
- Results
- Thermal Hardware Status
- Issues & Concerns

S/C Thermal Design Requirements

- TIMED S/C attitude:
  - +Y side solar keep-out. Yaw Maneuver
  - +Z to Nadir
  - +/- X to ram (solar array)
  - One RPO
- 2 year design lifetime.
- Orbit: circular *625* km, *74.1*° inclination (2 deg/day precession)
- Package temperature limits.
- Instrument interface temperature limits.
- Package internal heat dissipations.

S/C Thermal Control Design Summary

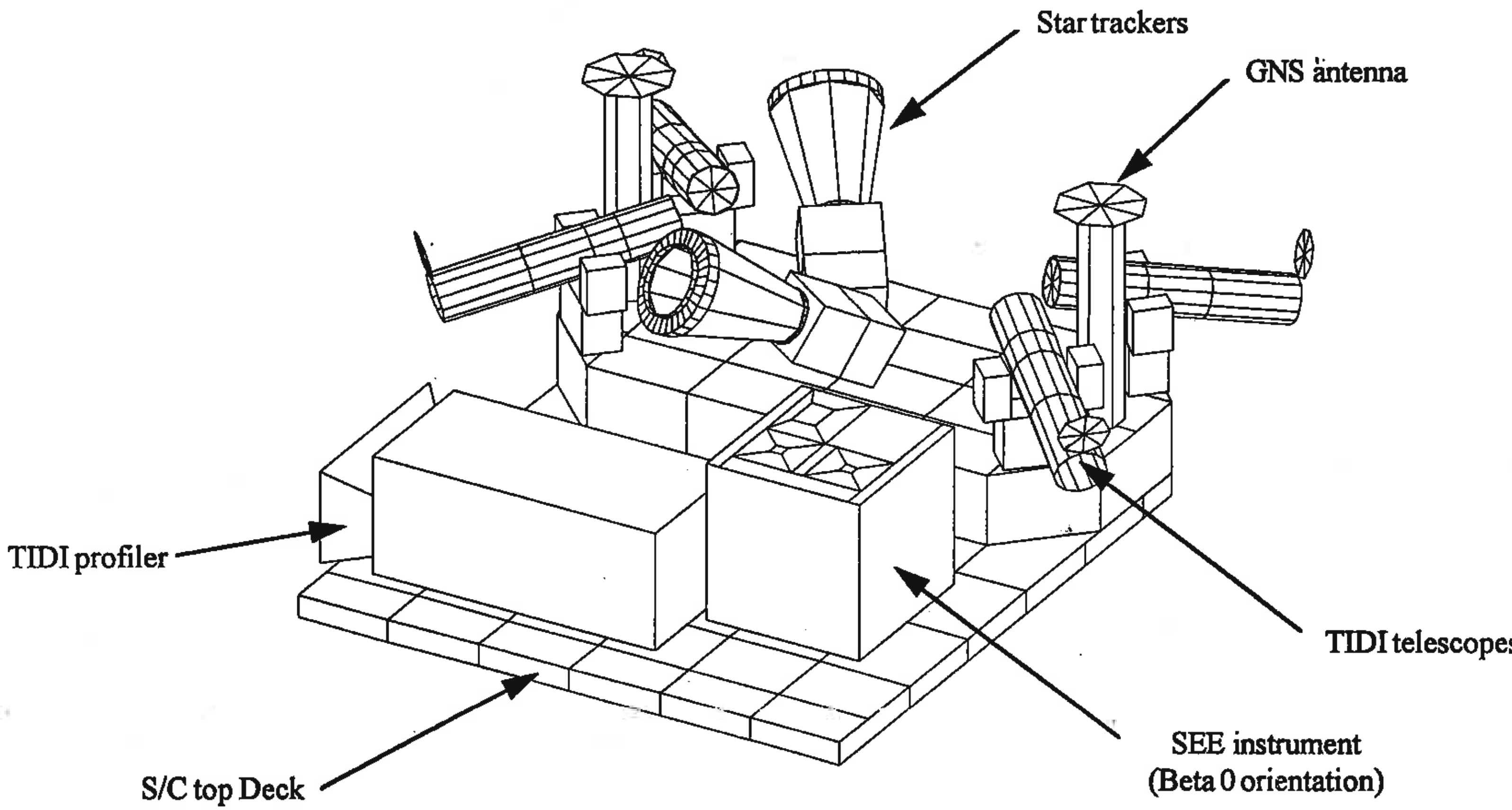


S/C shown in Beta 0 configuration
Sun in Orbit Plane

TIMED

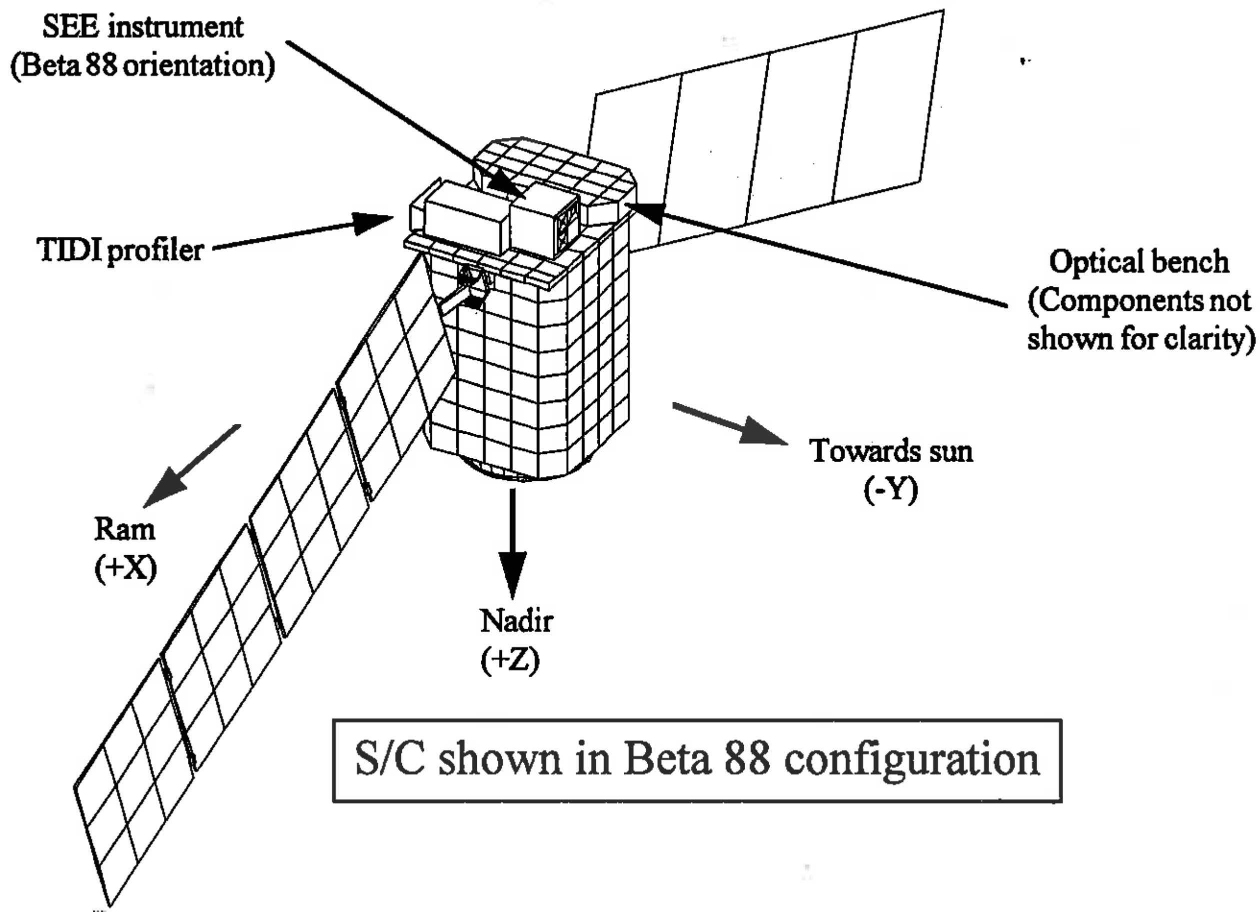
Thermosphere • Ionosphere • Mesosphere • Energetics and Dynamics

S/C Thermal Control Design Summary



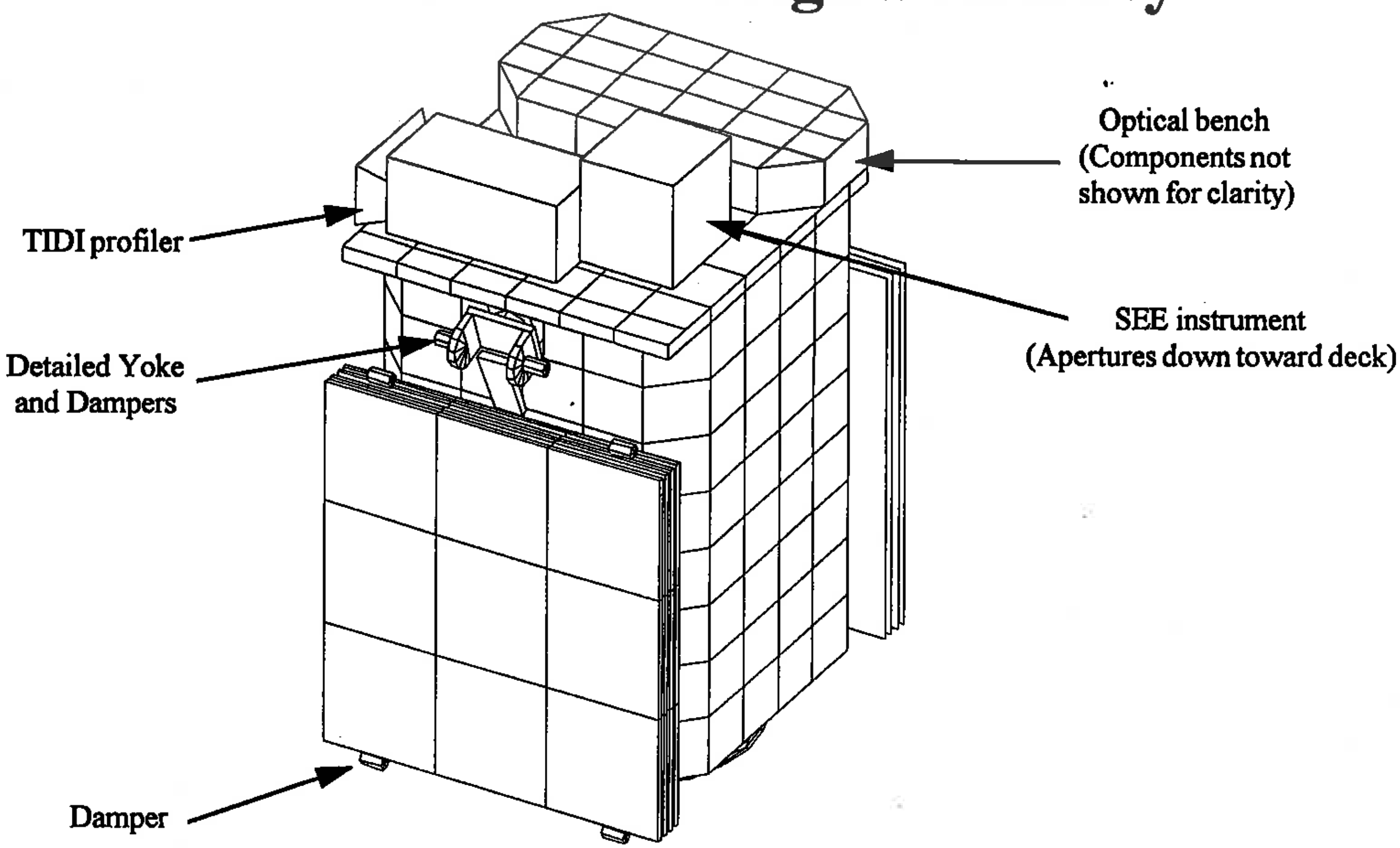
S/C +Z Deck and Optical Bench With Attached Components

S/C Thermal Control Design Summary



S/C shown in Beta 88 configuration

S/C Thermal Control Design Summary



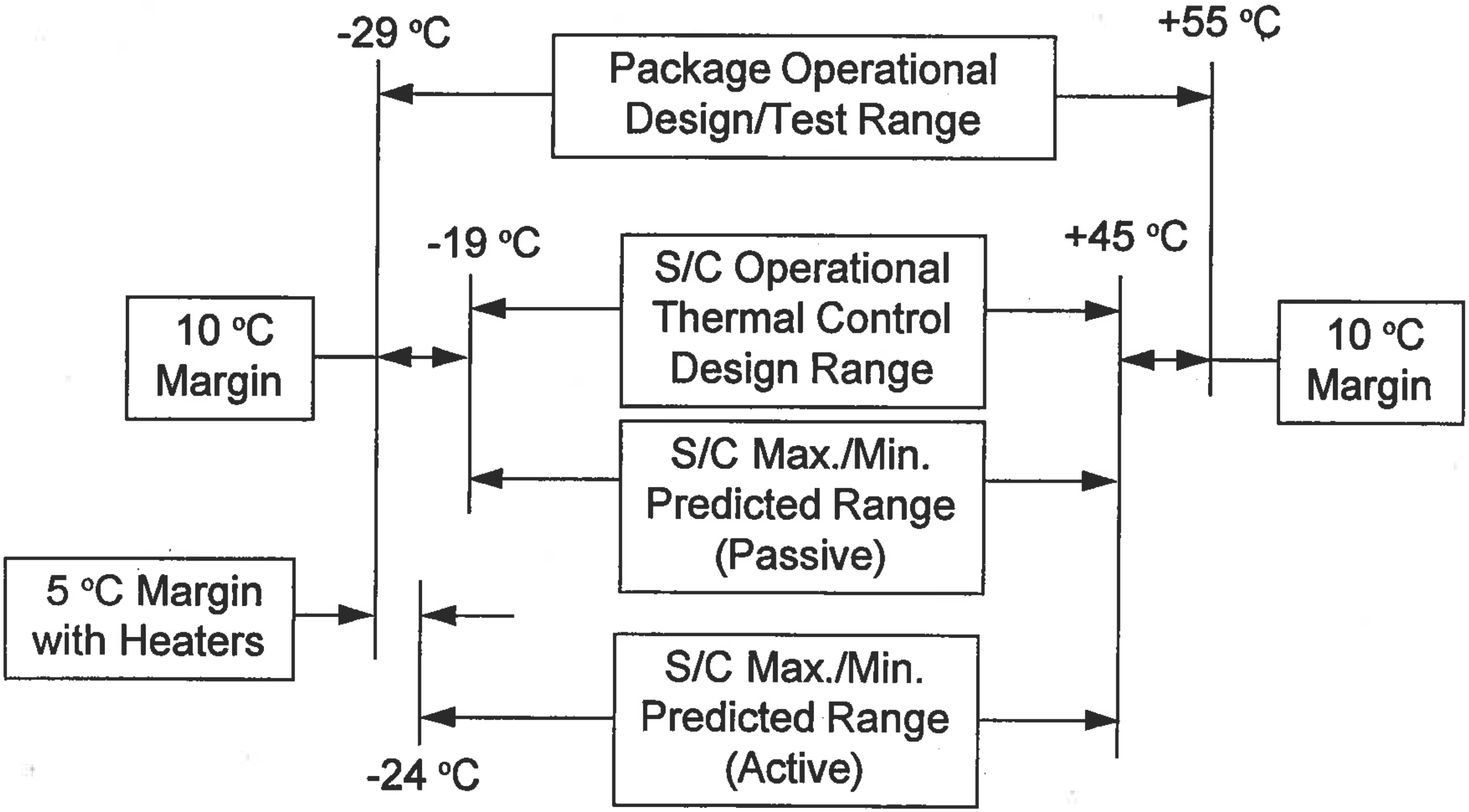
S/C shown in launch configuration

Temperature Limits and Margins

- Test range defines the package baseplate test temperature limits (e.g. -29 to +55 °C).
- Reduce test range by 10 °C to obtain Thermal Control Design Range. (e.g. -19 to +45 °C). This is the margin. A 5 °C margin can be used on the cold end with heaters.
- Thermal Control Design Range defines the maximum and minimum on-orbit allowable temperature prediction range, which is the worst case combination of environments, dissipations, optical properties and blanket effectiveness.
- Thus, temperature predictions can be as wide as the Thermal Control Design Range and be acceptable.

- Derived temperature requirements result from worst case analyses, then adding 10 °C to each end to reach test range. (e.g. Optical Bench, Solar Arrays)

Temperature Limits and Margins



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S/C Temperature Limits By Panel

Location	Thermal Control Design Range		Package Test Range	
	Operating Temperature (Deg. C) *	Non-Operating Temperature (Deg. C) *	Operating Temperature (Deg. C)	Non-Operating Temperature (Deg. C)
+X Panel	-14 to +45	-19 to +50	-24 to +55	-29 to +60
-Y Panel	-19 to +45	-24 to +50	-29 to +55	-34 to +60
-X Panel	-19 to +45	-24 to +50	-29 to +55	-34 to +60
+Y Panel (@ IEM)	-19 to +45	-24 to +50	-29 to +55	-34 to +60
-Z Deck (@ IMU)	*-20 to +60*	*-30 to +65*	*-30 to +70*	*-40 to +75*
+Z Deck	-13 to +45	-19 to +50	-23 to +55	-29 to +60
Optical bench [d]	*-5 to +35*	*-20 to +30*	*-15 to +45*	*-30 to +40*
Star Trackers	*-25 to +40*	*-30 to +45*	*-30 to +50*	*-35 to +55*
Batteries	-5 to *+10*	-15 to +20	-10 to *+20*	-20 to +30
Solar arrays [d]	-70 to +90	-70 to +90	-80 to +100	-80 to +100
Antenna	-90 to +65	-90 to +65	-100 to +75	-100 to +75

* 10 °C margin for passive thermal control. Except Battery and Star Cameras which use 5 °C with heaters.
d - Derived based on worst case analyses plus 10 C margin.

Instrument Interface Temperatures

Instrument	Thermal Control Design Range		Test I/F Range	
	Operating I/F Temperature (Deg. C) **	Non-Operating I/F Temperature (Deg. C) **	Operating I/F Temperature (Deg. C)	Non-Operating I/F Temperature (Deg. C)
SABER - Isolated	-19 to +20	*-29** to +50	-29 to +30	-34 to +60
SEE - Isolated	*-10 to +45*	-24 to +50	*-20 to +55*	-34 to +60
TIDI telescopes - Isol.	*-5 to +35*	*-20 to +30*	*-15 to +45*	*-30 to +40*
TIDI profiler - Isolated	-19 to +30	-24 to +50	-29 to +40	-34 to +60
TIDI E-box - Cond.	-19 to +45	-24 to +50	-29 to +55	-34 to +60
GUVI SIS - Isolated	-14 to +45	-19 to +50	-24 to +55	-29 to +60
GUVI electronics	-14 to +45	-19 to +50	-24 to +55	-29 to +60

* 5 °C margin applied with heaters

** 10 °C margin applied to test range to obtain thermal design range.

Instrument designers use the Test I/F Range to design and test instrument thermal control.
S/C uses Thermal Control Design Range as max. allowable prediction at S/C interface to instrument.

TIMED COMPONENT TEMPERATURE LIMITS

COMPONENT	Thermal Design Range Operating (Deg. C)	Thermal Design Range Non-Operating (Deg. C)	Test Range Operating (Deg. C)	Test Range Non-Operating (Deg. C)
INSTRUMENTS				
GUVI SIS E-box(Outside)	-14 to +45	-19 to +50	-24 to +55	-29 to +60
GUVI FPE #1 (Outside)	-14 to +45	-19 to +50	-24 to +55	-29 to +60
GUVI FPE #2 (Outside)	-14 to +45	-19 to +50	-24 to +55	-29 to +60
GUVI HVPS, 2 stacked (Outside)	-14 to +45	-19 to +50	-24 to +55	-29 to +60
GUVI SIS interface*	-14 to +45	-19 to +50	-24 to +55	-29 to +60
GUVI ECU (Inside)	-14 to +45	-19 to +50	-24 to +55	-29 to +60
GUVI Op. Heater	N/A	N/A	N/A	N/A
GUVI Surv. Heater	N/A	N/A	N/A	N/A
SABER Instrument interface *	-19 to +20	-29 to +50	-29 to +30	-34 to +60
SABER Op. Heater	N/A	N/A	N/A	N/A
SABER Surv. Heater	N/A	N/A	N/A	N/A
TIDI Profiler Interface *	-19 to +30	-24 to +50	-29 to +40	-34 to +60
TIDI E-Box	-19 to +45	-24 to +50	-29 to +55	-34 to +60
TIDI Telescope interface *	-5 to +40	-20 to +30	-15 to +50	-30 to +40
TIDI Op. Heater	N/A	N/A	N/A	N/A
TIDI Surv. Heater	N/A	N/A	N/A	N/A
SEE Interface *	-10 to +45	-24 to +50	-20 to +55	-34 to +60
SEE Op. Heater	N/A	N/A	N/A	N/A
SEE Surv. Heater	N/A	N/A	N/A	N/A
POWER SUBSYSTEM				
Power System Electronics	-19 to +45	-24 to +50	-29 to +55	-34 to +60
Peak Power Tracker Conv. Mod.	-19 to +45	-24 to +50	-29 to +55	-34 to +60
Battery 1*	-5 to +15	-15 to +20	-10 to +25	-20 to +30
Battery 2*	-5 to +10	-15 to +20	-10 to +20	-20 to +30
Solar Array Drive Electronics	-19 to +45	-24 to +50	-29 to +55	-34 to +60
Solar Array Drive Motor #1	-19 to +45	-24 to +50	-29 to +55	-34 to +60
Solar Array Drive Motor #2	-19 to +45	-24 to +50	-29 to +55	-34 to +60
Solar Array #1	-70 to +90	-70 to +90	-80 to +100	-80 to +100
Solar Array #2	-70 to +90	-70 to +90	-80 to +100	-80 to +100
ATTITUDE SUBSYSTEM				
IMU (Gyros)	-20 to +60	-30 to +65	-30 to +70	-40 to +75
AIU (1 &2)	-19 to +45	-24 to +50	-29 to +55	-34 to +60
Reaction Wheels (All 4)	-13 to +45	-24 to +50	-23 to +55	-34 to +60
Reaction Wheel Electronics	-13 to +45	-24 to +50	-23 to +55	-34 to +60
Torque Rod #1 (X)	-30 to +50	-40 to +70	-40 to +60	-50 to +80
Torque Rod #2 (Y)	-30 to +50	-40 to +70	-40 to +60	-50 to +80
Torque Rod #3 (Z)	-30 to +50	-40 to +70	-40 to +60	-50 to +80
Flight Computer 1 & 2	-19 to +45	-24 to +50	-29 to +55	-34 to +60
Star tracker 1*	-25 to +40	-30 to +50	-30 to +50	-40 to +60
Star tracker 2*	-25 to +40	-30 to +50	-30 to +50	-40 to +60
RF SUBSYSTEM				
Nadir S-Band Antenna 1 & 2 (Outside)	-90 to +65	-90 to +65	-100 to +75	-100 to +75
Zenith S-Band Antenna 1 & 2	-90 to +65	-90 to +65	-100 to +75	-100 to +75
GPS Antenna 1, 2 & 3 (Outside)	-90 to +65	-90 to +65	-100 to +75	-100 to +75
GPS filter/pre-amp 1, 2 (In IEM)	-19 to +45	-24 to +50	-29 to +55	-34 to +60
RF Switch 1 & 2 (Outside)	-19 to +45	-24 to +50	-29 to +55	-34 to +60
IEM # 1	-19 to +45	-24 to +50	-29 to +55	-34 to +60
IEM # 2	-19 to +45	-24 to +50	-29 to +55	-34 to +60
Optical Bench (Outside)*	-5 to +30	-5 to +30	-15 to +40	-15 to +40
THERMAL SUBSYSTEM				
HEATERS: OPERATIONAL	N/A	N/A	N/A	N/A
HEATERS: SURVIVAL	N/A	N/A	N/A	N/A

* Thermally isolated from S/C

S/C and Inst. Internal Heat Dissipation by Panel

Component	Hot Case Internal Heat Diss. Beta=0 (Watts)	Hot Case Internal Heat Diss. Beta=90 (Watts)	Cold Case Internal Heat Diss. Beta=0 (Watts)	Cold Case Internal Heat·Diss. Beta=90 (Watts)
+X Panel	62.7	45.5	48.7	35.1
-Y Panel	1.0	1.0	0.0	0.0
-X Panel	51.6	35.8	47.1	34.8
+Y Panel	54.7	54.7	42.4	42.4
+Z Deck	33.3	33.3	33.3	33.3
-Z Deck	43.6	43.6	43.6	43.6
Corner Panels	2.6	2.6	1.6	1.6
Optical bench *	1.5	1.5	1.5	1.5
Star cameras (2) *	25.0	25.0	25.0	25.0
Batteries (2) *	33.0	16.0	33.0	16.0
GUVI SIS Motor	4.0	4.0	4.0	4.0
GUVI SIS *	0.4	0.4	0.4	0.4
SABER *	56.7	56.7	56.7	56.7
SEE *	15.3	15.3	14.4	14.4
TIDI telescopes *	1.2	1.2	1.2	1.2
TIDI profiler *	0.8	0.8	0.8	0.8
Total Heat	382.2	332.2	348.5	305.6

* Thermally isolated from S/C.

TIMED HEAT DISSIPATION SUMMARY

COMPONENT	Design Case A Heat Dissipation (Hot, Orbit Max.) Beta=0 (WATTS)	Design Case B Heat Dissipation (Hot, Orbit Max.) Beta=90 (WATTS)	Design Case C Heat Dissipation (Cold, Orbit Min) Beta=0 (WATTS)	Design Case D Heat Dissipation (Cold, Orbit Min) Beta=90 (WATTS)	Peak Heat Diss. (WATTS)
Peak Power Tracker Conv. Mod. 1 ***	23.4	7.5	19.8	7.5	60.0
Flight Computer 1 & 2	10.0	10.0	10.0	10.0	10.0
RIU #2 (111/121)	0.3	0.3	0.3	0.3	0.3
GUVI ECU	17.0	17.0	17.0	17.0	17.0
Torque Rod #2 (Y)	1.0	1.0	0.0	0.0	3.0
Solar Array Drive Motor #1	0.0	0.0	0.0	0.0	6.3
Solar Array #1	0.0	0.0	0.0	0.0	0.0
-X S/C Panel Subtotal	**51.6**	**35.8**	**47.1**	**34.8**	**96.5**
Battery #2 *, ***	16.5	8.0	16.5	8.0	37.5
-X Battery Subtotal	**16.5**	**8.0**	**16.5**	**8.0**	**37.5**
IEM # 1	36.5	36.5	36.5	36.5	66.0
IEM # 2	18.2	18.2	5.9	5.9	66.0
+Y S/C Panel Subtotal	**54.7**	**54.7**	**42.4**	**42.4**	**131.9**
SABER Instrument *	56.7	56.7	56.7	56.7	70.7
+Y SABER Panel Subtotal	**56.7**	**56.7**	**56.7**	**56.7**	**70.7**
Torque Rod #1 (X)	1.0	1.0	0.0	0.0	3.0
-Y Panel Subtotal	**1.0**	**1.0**	**0.0**	**0.0**	**3.0**
Peak Power Tracker Conv. Mod. 2 ***	23.4	7.5	19.8	7.5	60.0
Power System Electronics ***	28.3	27.0	17.9	16.6	30.0
AIU (1 & 2)	11.0	11.0	11.0	11.0	22.0
Solar Array Drive Motor #2	0.0	0.0	0.0	0.0	6.3
Solar Array #2	0.0	0.0	0.0	0.0	0.0
+X S/C Panel Subtotal	**62.7**	**45.5**	**48.7**	**35.1**	**118.3**
Battery 1 *, ***	16.5	8.0	16.5	8.0	37.5
+ X Battery Subtotal	**16.5**	**8.0**	**16.5**	**8.0**	**37.5**
Reaction Wheels (All 4) w/ Elect	26.0	26.0	26.0	26.0	40.0
Magnetometer Sensors 1 & 2 (Outside)	0.0	0.0	0.0	0.0	0.0
RIU #3 (112/122) (Outside)	0.3	0.3	0.3	0.3	0.3
+Z S-Band Antenna 1 & 2 (Outside)	0.0	0.0	0.0	0.0	0.0
GUVI SIS E-box (Outside)	0.3	0.3	0.3	0.3	0.3
GUVI FPE #1 (Outside)	1.7	1.7	0.0	0.0	1.7
GUVI FPE #2 (Outside)	0.0	0.0	1.7	1.7	1.7
GUVI HVPS, 2 stacked (Outside)	1.0	1.0	1.0	1.0	2.0
GUVI SIS Scan Motor (Outside)	4.0	4.0	4.0	4.0	5.0
GUVI SIS (Outside)*	0.4	0.4	0.4	0.4	1.0
+Z Panel Subtotal	**33.3**	**33.3**	**33.3**	**33.3**	**51.0**
IRU (Gyros)	31.3	31.3	31.3	31.3	31.3
TIDI E-Box	9.2	9.2	9.2	9.2	9.2
Solar Array Electronics Control Unit	2.8	2.8	2.8	2.8	20.0
RIU #5 (114/124)	0.3	0.3	0.3	0.3	0.3
-Z S-Band Antenna 1 & 2 (Outside)	0.0	0.0	0.0	0.0	0.0
RF Switchs and Diplexers	0.0	0.0	0.0	0.0	12.0
SEE (Outside) *	15.3	15.3	14.4	14.4	18.0
TIDI Profiler (Outside) *	0.8	0.8	0.8	0.8	2.8
Optical Bench (Outside)*	1.5	1.5	1.5	1.5	1.5
-Z S/C Panel Subtotal	**43.6**	**43.6**	**43.6**	**43.6**	**72.8**
Star Tracker 1*	12.5	12.5	12.5	12.5	16.5
Star Tracker 2*	12.5	12.5	12.5	12.5	16.5
RIU #6 (115/125)	0.3	0.3	0.3	0.3	0.3
TIDI Telescopes (All 4)*	1.2	1.2	1.2	1.2	1.2
GPS Antenna 1 & 2 (Outside)	0.0	0.0	0.0	0.0	0.0
Optical Bench Subtotal	**1.5**	**1.5**	**1.5**	**1.5**	**1.5**
Torque Rod #3 (Z)	1.0	1.0	0.0	0.0	3.0
RIU #4 (113/123)	0.3	0.3	0.3	0.3	0.3
+X/-Y Corner Subtotal	**1.3**	**1.3**	**0.3**	**0.3**	**3.3**
RIU #1 (110/120)	0.3	0.3	0.3	0.3	0.3
Magnetometer Electronics 1 & 2	1.0	1.0	1.0	1.0	1.0
-X/+Y Corner Subtotal	**1.3**	**1.3**	**1.3**	**1.3**	**1.3**
-X/-Y Corner Subtotal	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
S/C Internal Subtotal	**274.5**	**224.5**	**241.7**	**198.8**	**549.4**
S/C Heaters Subtotal	0.0	46.0	37.0	74.0	167.6
S/C Int & Heater Subtotal	**274.5**	**270.5**	**278.7**	**272.8**	**717.0**
GUVI Internal Heat	24.4	24.4	24.4	24.4	28.7
GUVI Heaters	0.0	0.0	0.0	6.0	13.6
GUVI Total	**24.4**	**24.4**	**24.4**	**30.4**	**42.3**
SABER	56.7	56.7	56.7	56.7	70.7
SABER Heaters	0.0	0.0	8.7	9.7	21.9
SABER Total	**56.7**	**56.7**	**65.4**	**66.4**	**92.6**
SEE	15.3	15.3	14.4	14.4	18.0
SEE Heaters	5.0	10.0	5.0	10.0	22.6
SEE Total	**20.3**	**25.3**	**19.4**	**24.4**	**40.6**
TIDI	11.2	11.2	11.2	11.2	13.2
TIDI Heaters	6.0	7.0	9.0	10.0	22.6
TIDI Total	**17.2**	**18.2**	**20.2**	**21.2**	**35.8**
Inst. Internal Subtotal	107.6	107.6	106.7	106.7	130.6
Inst. Heater Subtotal	11.0	17.0	22.7	35.7	80.8
Inst. Int & Heater Subtotal	**118.6**	**124.6**	**129.4**	**142.4**	**211.4**
S/C & Inst. Internal Subtotal	**382.0**	**332.0**	**348.4**	**305.5**	**680.0**
S/C & Inst. Heater Subtotal	**11.0**	**63.0**	**59.7**	**109.7**	**248.4**
S/C & INST. TOTAL	**393.0**	**395.0**	**408.1**	**415.2**	**928.4**
HARNESS LOSSES (1.5%)	5.9	5.9	6.1	6.2	13.9
TOTAL	**398.9**	**401.0**	**414.2**	**421.4**	**942.3**

* Thermally isolated from S/C. Heat NOT included in subtotals, only in total heat. All other heat is thru conductive mounts

*** Heat Dissipations are Beta angle dependant

TIMED HEAT DISSIPATION SUMMARY

COMPONENT	LAUNCH MODE (Cold, Orbit Min.) Beta=90 (WATTS)	Attitude SAFE MODE (Cold, Orbit Min.) Beta=0 (WATTS)	Attitude SAFE MODE (Cold, Orbit Min.) Beta=90 (WATTS)	Hard Power SAFE MODE (Cold, Orbit Min.) Beta=0 (WATTS)	Hard Power SAFE MODE (Cold, Orbit Min.) Beta=90 (WATTS)	Peak Heat Diss. (WATTS)
Peak Power Tracker Conv. Mod. 1 ***	7.5	19.8	7.5	19.8	7.5	60.0
Flight Computer 1 & 2	0.0	10.0	10.0	0.0	0.0	10.0
RIU #2 (111/121)	0.3	0.3	0.3	0.0	0.0	0.3
GUVI ECU	0.0	0.0	0.0	0.0	0.0	17.0
Torque Rod #2 (Y)	0.0	0.0	0.0	0.0	0.0	3.0
Solar Array Drive Motor #1	0.0	0.0	0.0	0.0	0.0	6.3
Solar Array #1	0.0	0.0	0.0	0.0	0.0	0.0
-X S/C Panel Subtotal	7.8	30.1	17.8	19.8	7.5	96.5
Battery #2 *, ***	11.7	16.5	8.0	16.5	8.0	37.5
-X Battery Subtotal	11.7	16.5	8.0	16.5	8.0	37.5
IEM # 1	36.5	36.5	36.5	5.9	5.9	66.0
IEM # 2	18.2	5.9	5.9	5.9	5.9	66.0
+Y S/C Panel Subtotal	54.7	42.4	42.4	11.8	11.8	131.9
SABER Instrument *	0.0	0.0	0.0	0.0	0.0	70.7
+Y SABER Panel Subtotal	0.0	0.0	0.0	0.0	0.0	70.7
Torque Rod #1 (X)	0.0	0.0	0.0	0.0	0.0	3.0
-Y Panel Subtotal	0.0	0.0	0.0	0.0	0.0	3.0
Peak Power Tracker Conv. Mod. 2 ***	7.5	19.8	7.5	19.8	7.5	60.0
Power System Electronics ***	23.3	17.9	16.6	17.9	16.6	30.0
AIU (1 & 2)	22.0	11.0	11.0	11.0	11.0	22.0
Solar Array Drive Motor #2	0.0	0.0	0.0	0.0	0.0	6.3
Solar Array #2	0.0	0.0	0.0	0.0	0.0	0.0
+X S/C Panel Subtotal	52.8	48.7	35.1	48.7	35.1	118.3
Battery 1 *, ***	11.7	16.5	8.0	16.5	8.0	37.5
+ X Battery Subtotal	11.7	16.5	8.0	16.5	8.0	37.5
Reaction Wheels (All 4) w/ Elect ****	0.0	26.0	26.0	26.0	26.0	40.0
Magnetometer Sensors 1 & 2 (Outside)	0.0	0.0	0.0	0.0	0.0	0.0
RIU #3 (112/122) (Outside)	0.3	0.3	0.3	0.0	0.0	0.3
+Z S-Band Antenna 1 & 2 (Outside)	0.0	0.0	0.0	0.0	0.0	0.0
GUVI SIS E-box (Outside)	0.0	0.0	0.0	0.0	0.0	0.3
GUVI FPE #1 (Outside)	0.0	0.0	0.0	-0.0	0.0	1.7
GUVI FPE #2 (Outside)	0.0	0.0	0.0	0.0	0.0	1.7
GUVI HVPS, 2 stacked (Outside)	0.0	0.0	0.0	0.0	0.0	2.0
GUVI SIS Scan Motor (Outside)	0.0	0.0	0.0	0.0	0.0	5.0
GUVI SIS (Outside)*	0.0	0.0	0.0	0.0	0.0	1.0
+Z Panel Subtotal	0.3	26.3	26.3	26.0	26.0	46.0
IRU (Gyros)	0.0	31.3	31.3	31.3	31.3	31.3
TIDI E-Box	0.0	0.0	0.0	0.0	0.0	9.2
Solar Array Electronics Control Unit	0.0	2.8	2.8	2.8	2.8	20.0
RIU #5 (114/124)	0.3	0.3	0.3	0.0	0.0	0.3
-Z S-Band Antenna 1 & 2 (Outside)	0.0	0.0	0.0	0.0	0.0	0.0
RF Switchs and Diplexers	0.0	0.0	0.0	0.0	0.0	12.0
SEE (Outside) *	0.0	0.0	0.0	0.0	0.0	18.0
TIDI Profiler (Outside) *	0.0	0.0	0.0	0.0	0.0	2.8
Optical Bench (Outside)*	0.0	0.0	0.0	0.0	0.0	1.5
-Z S/C Panel Subtotal	0.3	34.4	34.4	34.1	34.1	72.8
Star Tracker 1*	0.0	12.5	12.5	0.0	0.0	16.5
Star Tracker 2*	0.0	0.0	0.0	0.0	0.0	16.5
RIU #6 (115/125)	0.3	0.3	0.3	0.0	0.0	0.3
TIDI Telescopes (All 4)*	0.0	0.0	0.0	0.0	0.0	1.2
GPS Antenna 1 & 2 (Outside)	0.0	0.0	0.0	0.0	0.0	0.0
Optical Bench Subtotal	0.3	0.3	0.3	0.0	0.0	0.3
Torque Rod #3 (Z)	0.0	0.0	0.0	0.0	0.0	3.0
RIU #4 (113/123)	0.3	0.3	0.3	0.0	0.0	0.3
Misc Subtotal	0.3	0.3	0.3	0.0	0.0	3.3
RIU #1 (110/120)	0.3	0.3	0.3	0.0	0.0	0.3
Magnetometer Electronics 1 & 2	1.0	1.0	1.0	1.0	1.0	1.0
Misc Subtotal	1.3	1.3	1.3	1.0	1.0	1.3
Misc Subtotal	0.0	0.0	0.0	0.0	0.0	0.0
S/C Internal Subtotal	141.1	229.2	186.3	174.4	131.5	549.4
S/C Heaters Subtotal	8.0	62.0	80.0	94.0	114.0	258.2
S/C Int & Heater Subtotal	149.1	291.2	266.3	268.4	245.5	807.6

COMPONENT	LAUNCH MODE (Cold, Orbit Min.) Beta=90 (WATTS)	Attitude SAFE MODE (Cold, Orbit Min.) Beta=0 (WATTS)	Attitude SAFE MODE (Cold, Orbit Min.) Beta=90 (WATTS)	Hard Power SAFE MODE (Cold, Orbit Min.) Beta=0 (WATTS)	Hard Power SAFE MODE (Cold, Orbit Min.) Beta=90 (WATTS)	Peak Heat Diss. (WATTS)
GUVI Internal Heat	0.0	0.0	0.0	0.0	0.0	0.0
GUVI Heaters	0.0	3.0	3.0	3.0	3.0	6.8
GUVI Total	0.0	3.0	3.0	3.0	3.0	6.8
SABER	0.0	0.0	0.0	0.0	0.0	
SABER Heaters	0.0	25.3	25.3	25.3	25.3	57.3
SABER Total	0.0	25.3	25.3	25.3	25.3	57.3
SEE	0.0	0.0	0.0	0.0	0.0	
SEE Heaters	0.0	14.0	14.0	14.0	14.0	31.7
SEE Total	0.0	14.0	14.0	14.0	14.0	31.7
TIDI	0.0	0.0	0.0	0.0	0.0	
TIDI Heaters	0.0	7.0	7.0	7.0	7.0	15.9
TIDI Total	0.0	7.0	7.0	7.0	7.0	15.9
Inst. Internal Subtotal	0.0	0.0	0.0	0.0	0.0	0.0
Inst. Heater Subtotal	0.0	49.3	49.3	49.3	49.3	111.7
Inst. Int & Heater Subtotal	0.0	49.3	49.3	49.3	49.3	111.7
S/C & Inst. Internal Subtotal	141.1	229.2	186.3	174.4	131.5	549.4
S/C & Inst. Heater Subtotal	8.0	111.3	129.3	143.3	163.3	369.9
S/C & INST. TOTAL	149.1	340.5	315.6	317.7	294.8	919.3
HARNESS LOSSES (1.5%)	2.2	5.1	4.7	4.8	4.4	13.8
TOTAL	151.3	345.6	320.3	322.5	299.2	933.1

* Thermally isolated from S/C. Heat NOT included in subtotals, only in total heat. All other heat is thru conductive mounts

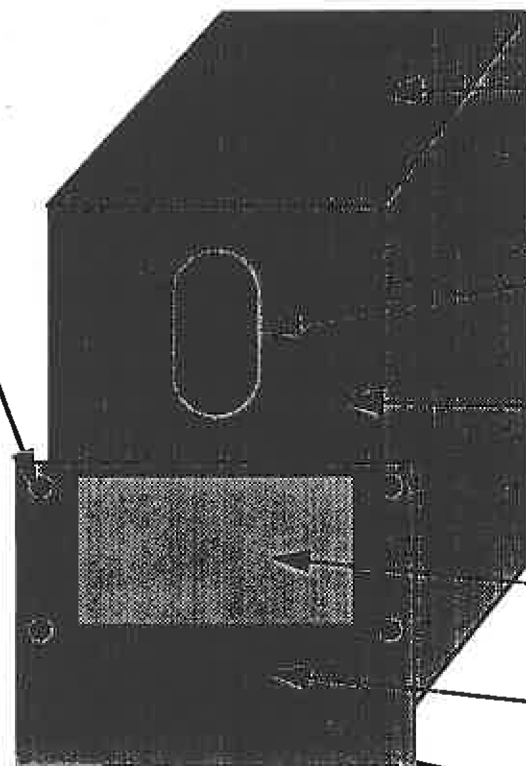
*** Heat Dissipations are Beta angle dependant

**** Reaction Wheels and Electronics will be turned on tsep-3min

Instrument Thermal Summary

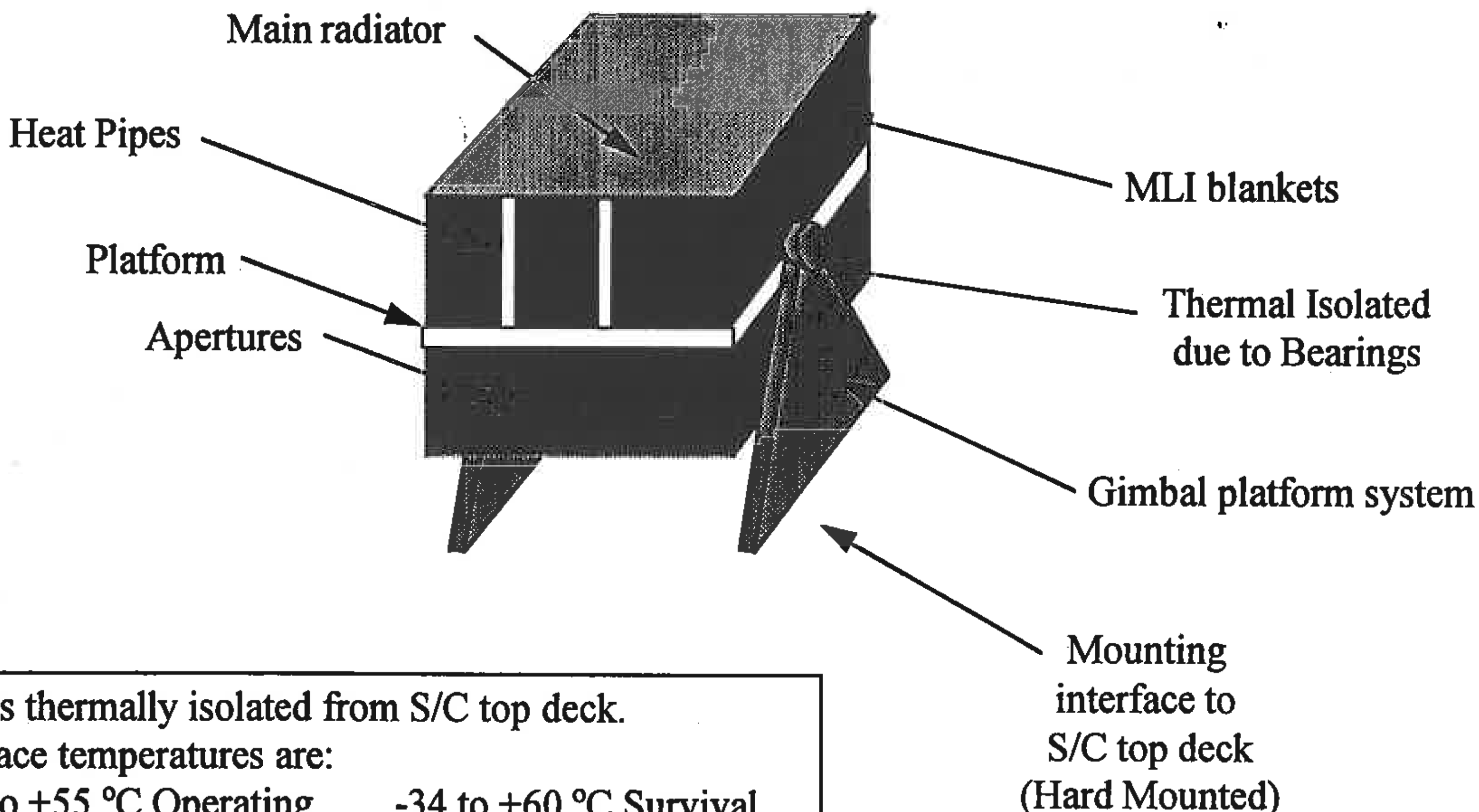
- All instruments have completed successful Preliminary Design Reviews. SABER has completed CDR.
- Instrument internal heater dissipation, heater power and interface temperature requirements have been incorporated into the S/C design.
- Instrument teams are performing their own thermal control designs.
- All instrument thermal design requirements have been met to date.
- Preliminary models have been exchanged with the instrument thermal engineers. Will update S/C model with instrument models closer to instrument CDR's.

SABER Thermal Control Interfaces



- SABER is thermally isolated from S/C +Y side.
- Interface temperatures are:
  - -29 to +30 °C Operating
  - -34 to +60 °C Survival
- S/C Internal Radiation Temp.:
  - -29 to +50 °C Operating
  - -34 to +60 °C Survival
- 0.1 C/min. rate at I/F

SEE Thermal Control Interfaces



- SEE is thermally isolated from S/C top deck.
- Interface temperatures are:
  -20 to +55 °C Operating   -34 to +60 °C Survival
- Deck Gradient Between Feet = 16 °C

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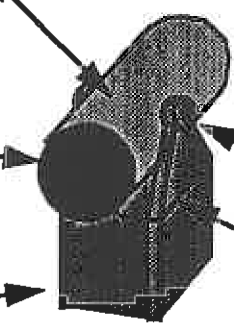
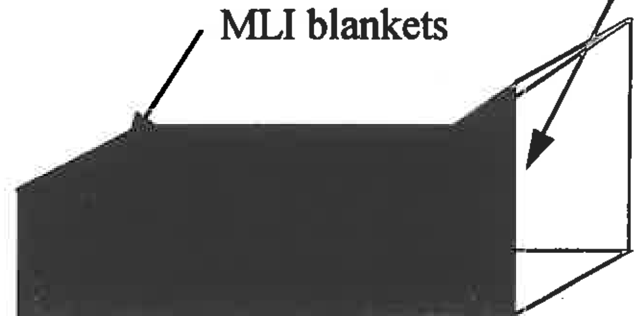
TIDI Thermal Control Interfaces



TIDI telescopes (4)

TIDI E-box



TIDI profiler

- Telescopes are assumed isolated from bench at Bearings.
- Telescope interface temperatures are:
  - -15 to +45 °C Operating   -30 to +40 °C Survival

- TIDI E-Box is conductively tied to underside of top deck.
- E-Box interface temperatures are:
  - -29 to +55 °C Operating   -34 to +60 °C Survival

- Profiler is thermally isolated from top side of top deck.
- Profiler interface temperatures are:
  - -29 to +40 °C Operating   -34 to +60 °C Survival

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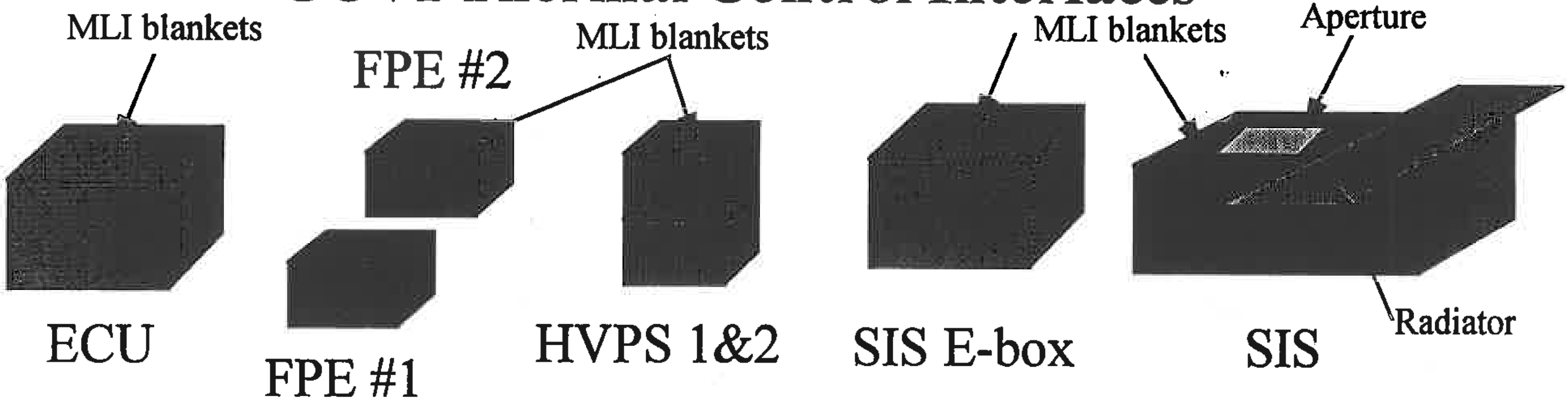
GUVI Thermal Control Interfaces



- All GUVI E-boxes conductively tied to S/C bottom deck, inside adapter ring.
- ECU is conductively mounted to inside of the S/C +X panel.
- SIS is thermally isolated from deck with at least 20 °C/W resistance.
- SIS Scan Motor is conductively strapped to +Z deck. Motor heat is 4 watts.
- All interface temperatures are:
  -24 to +55 °C Operating   -29 to +60 °C Survival
- Temperature gradient of 15 °C between SIS mounting feet.

Thermal Changes Since PDR

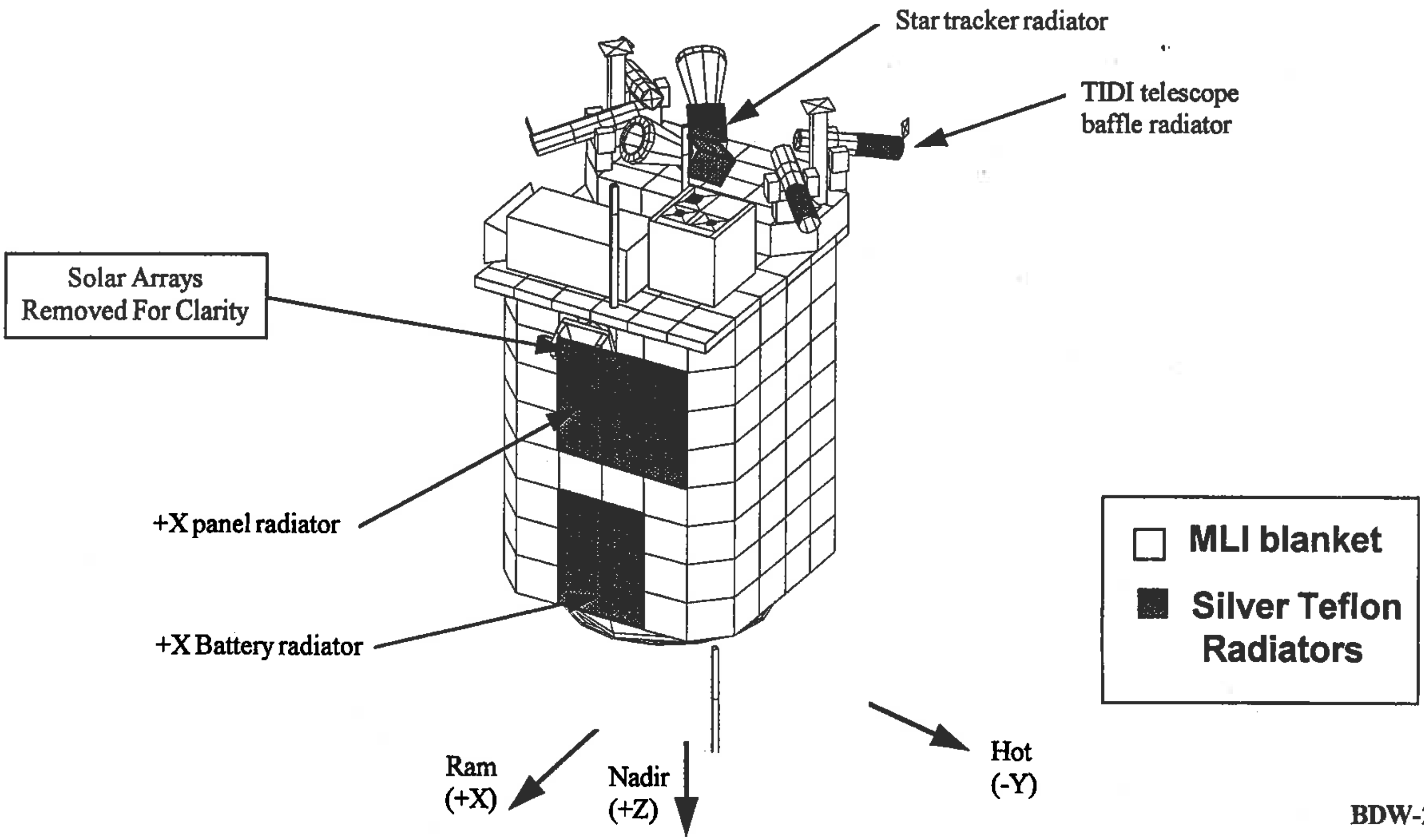
- **Instrument Changes:**

Instrument	Currently	Was
TIDI telescopes	Isolation is Bearing only. No G10	G10 in bracket
SEE	Isolation is Bearing only. No G10	G10 at deck
GUVI SIS Scan Motor	Copper strap to deck. Isolated from SIS Housing	Conductive to SIS housing

- **S/C Changes:**

Component	Currently	Was
+Z h/c deck	Heat Pipes added to cool wheels	Wheels were mounted in corners of S/C machined deck
Optical Bench	No MLI between bench and deck	MLI between bench and deck
Adapter Ring	Use as radiator for wheels	All MLI

S/C Thermal Design Overview



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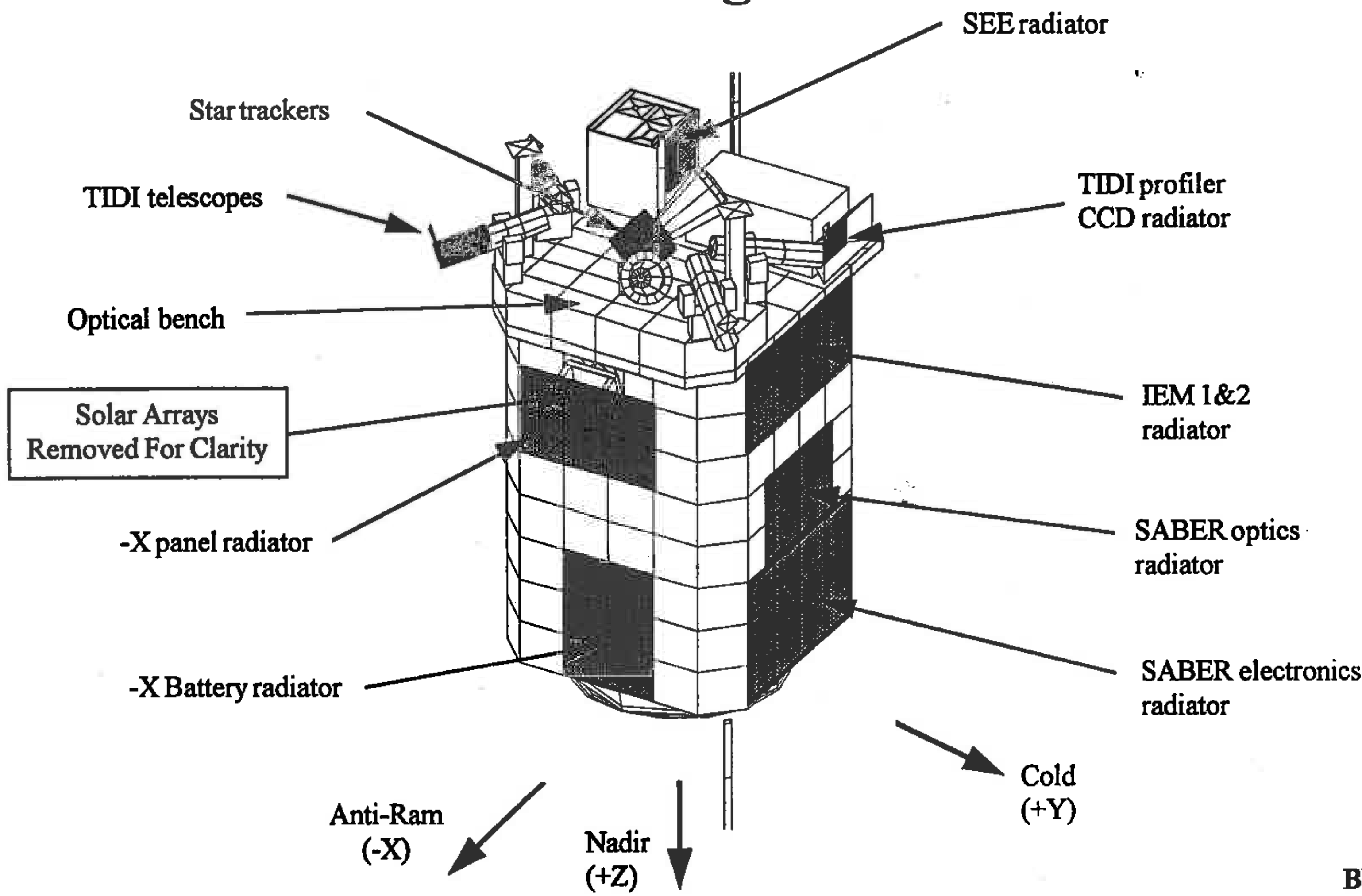
S/C Thermal Design Overview



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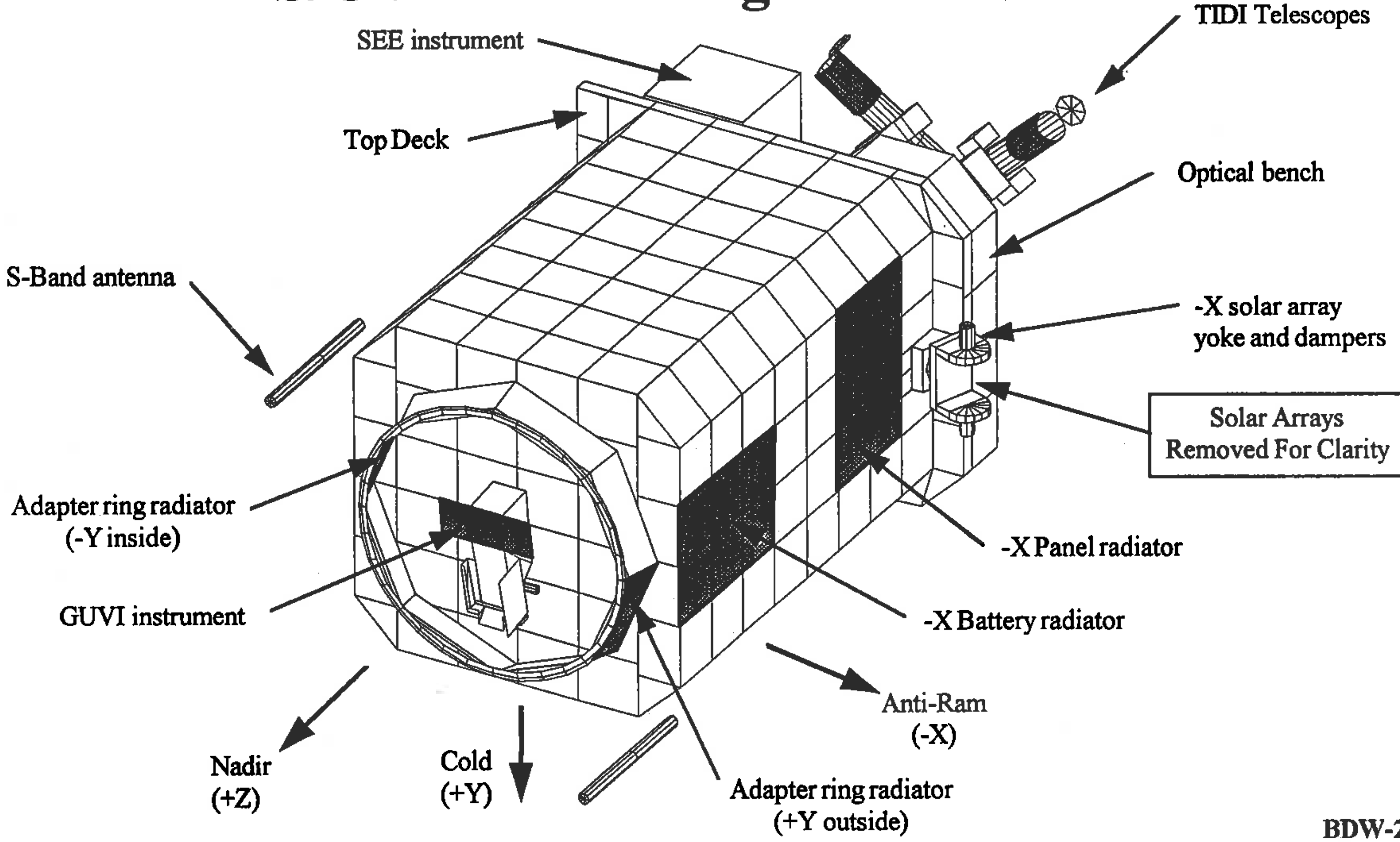
S/C Thermal Design Overview



S/C Thermal Design Approach

- The Following Components are Isolated from the S/C with the listed isolation values:

  Battery Halves: 12 °C/W predicted.
  Optical Bench: 10 °C/W predicted.
  Star Trackers: 45 °C/W predicted
  TIDI Profiler: 20 °C/W predicted.
  TIDI Telescopes: TBD based on bearing test. Assume 20 °C/W
  SEE: TBD based on bearing test. Assume 11 °C/W
  SABER: 5.5 °C/W predicted.
  GUVI SIS Housing: 20 °C/W predicted.

S/C Thermal Design Approach

- Cho-therm placed under conductively mounted boxes.
- Ground straps used to electrically tie boxes to S/C.
- Ground all MLI inner layers to S/C chassis with straps.
- Silver Teflon used as outer layer of MLI blankets.
- Silver Teflon used as S/C radiator surfaces.
- Antenna radomes painted with Aeroglaze A276 White.
- Star tracker sun shades painted with A276.
- No ESD coatings on S/C external surfaces. See charging analysis.
- Use adapter ring as radiator. Account for clamp band keep out zones.

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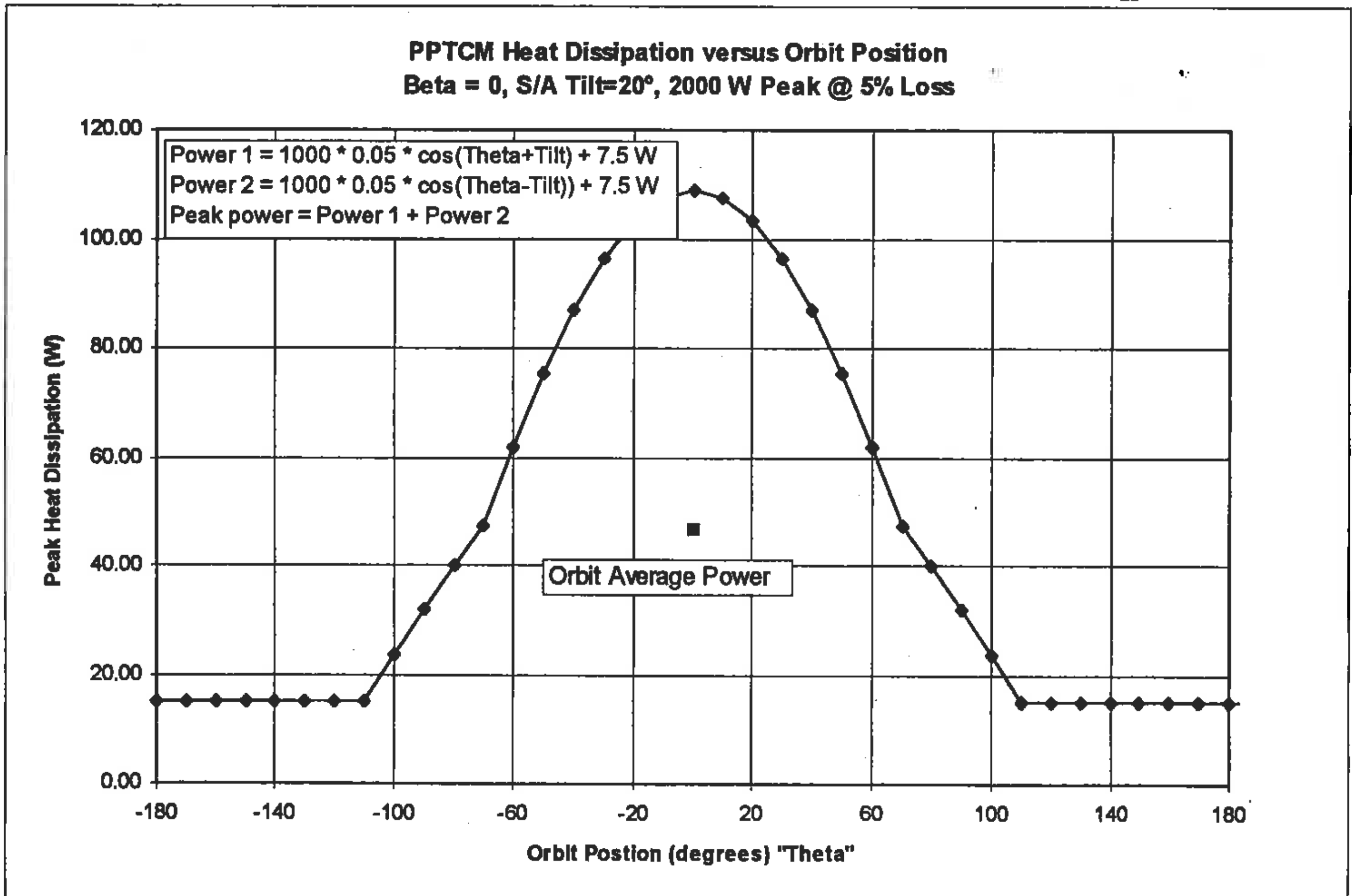
S/C Thermal Analysis Parameters

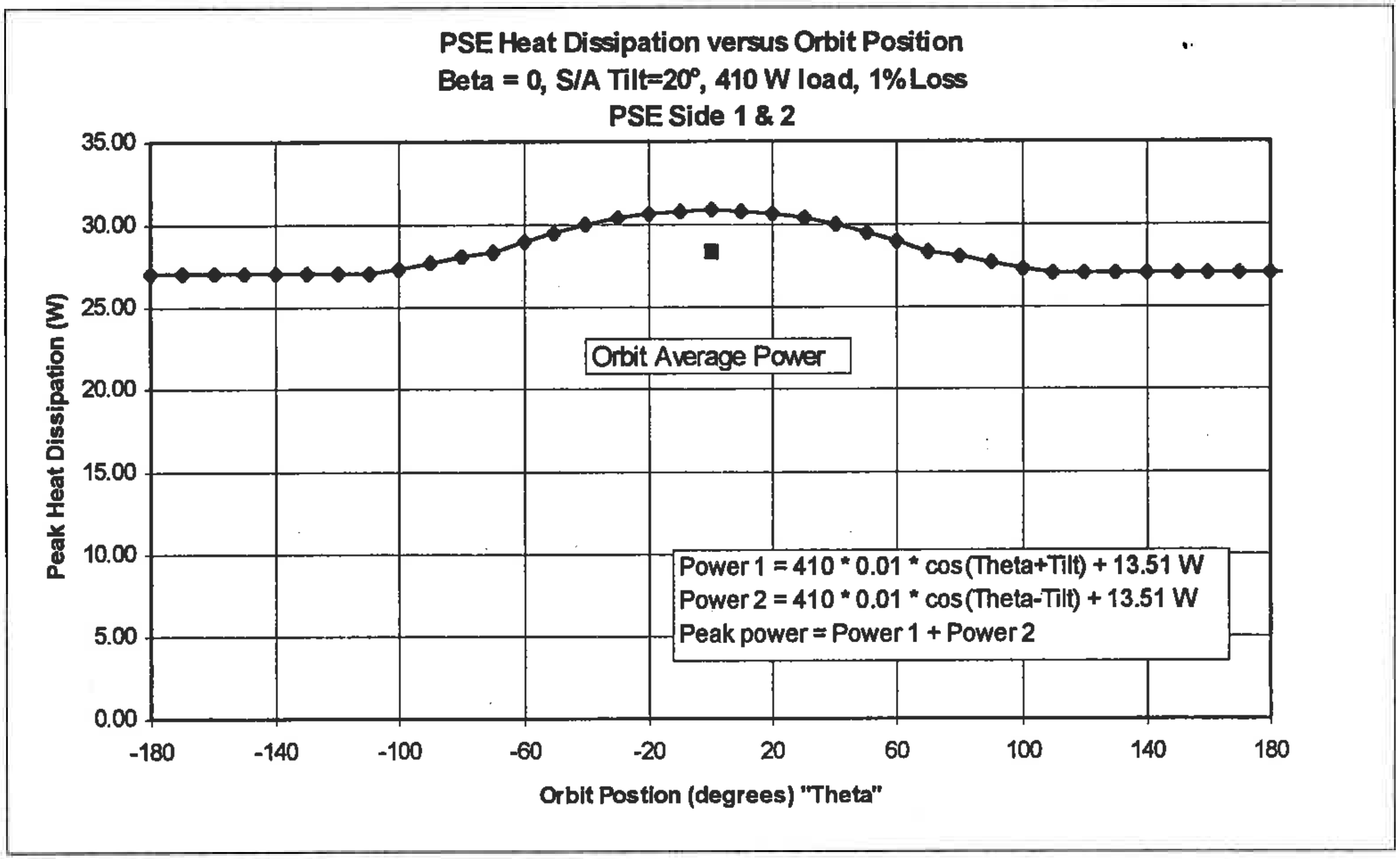
Parameters	Hot Case	Cold Case
Beta angle (degrees)	0 to 88	0 to 88
Solar constant (Btu/hr-ft^2)	450	408
Albedo	0.4	0.2
Earth shine (Btu/hr-ft^2)	85	60
Optical properties	EOL	BOL
MLI effective emittance (sun side)	0.03	0.01
MLI effective emittance (cold side)	0.01	0.03
MLI effective emittance (Small blankets)	0.05	0.05
Internal heat dissipations	Max. orbit avg.	Min. orbit avg.

PSE, Battery and PPTCM internal heats varies with time and beta angle.
Environmental fluxes vary with time and beta angle.
IEM internal heat varies with transmitter operation (15 min/orbit)

PPTCM Time Dependant Heat Dissipation



PSE Time Dependant Heat Dissipation



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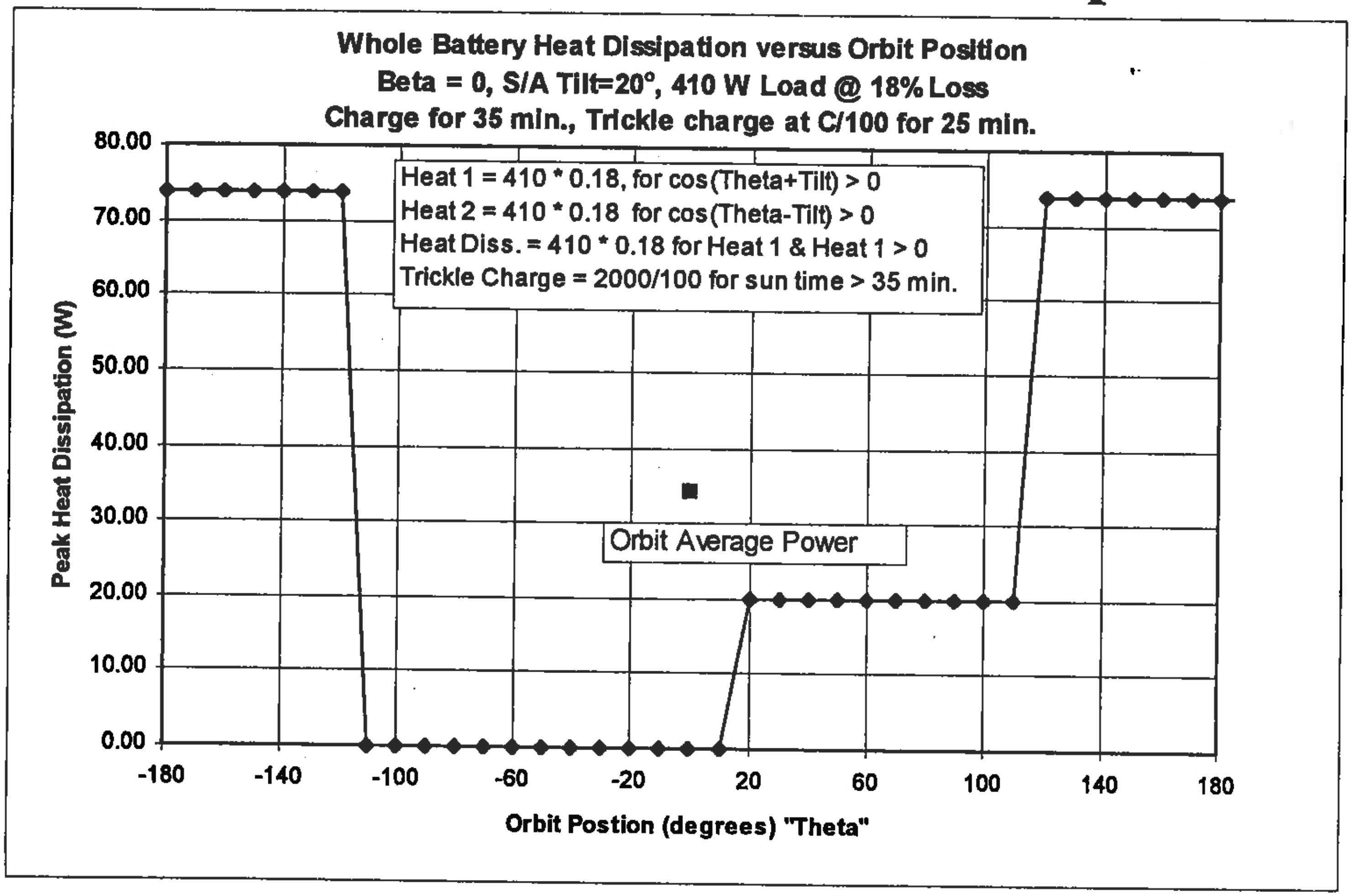
Battery Time Dependant Heat Dissipation



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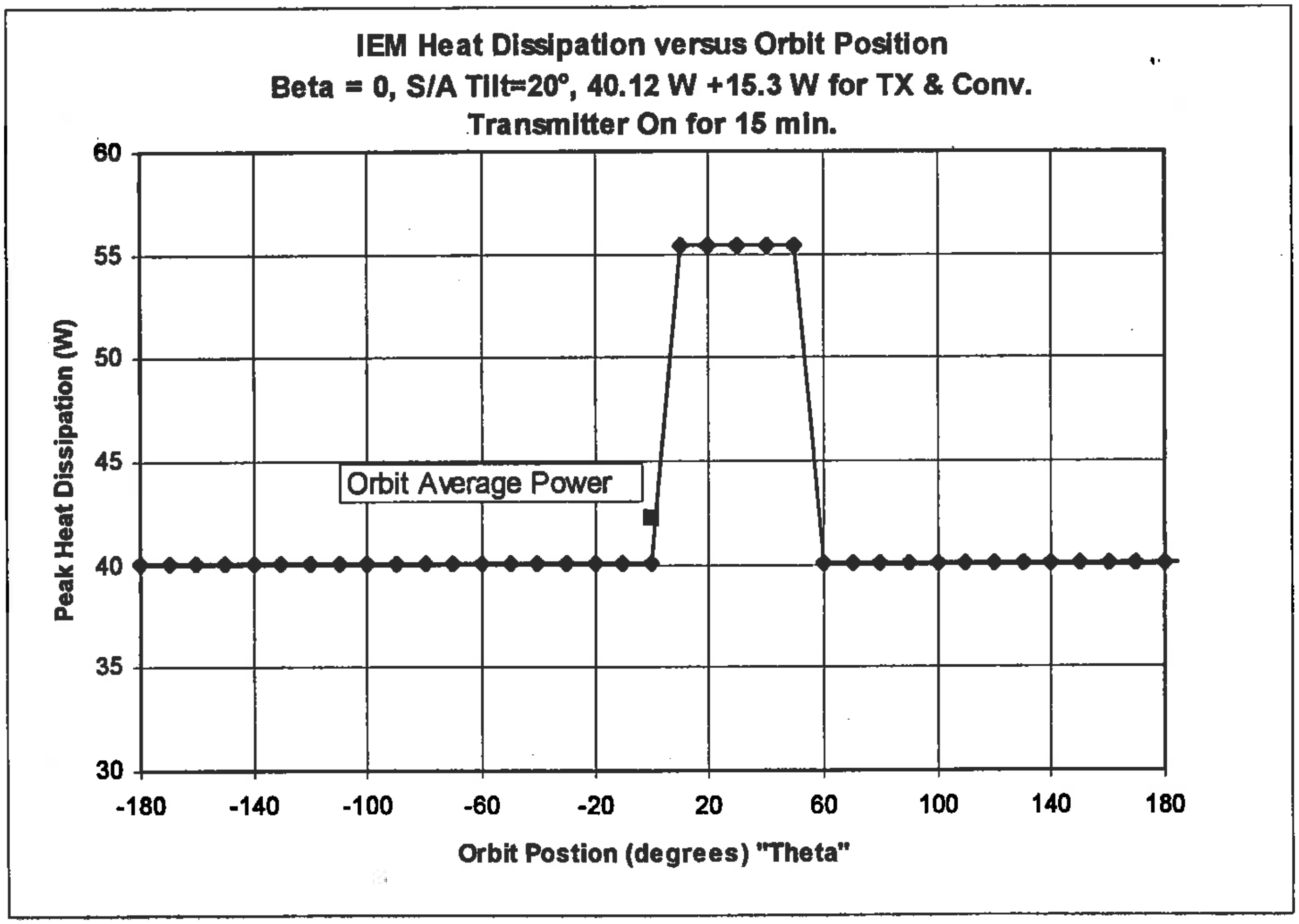
IEM Time Dependant Heat Dissipation



S/C Detailed Thermal Model Description

- **Detailed S/C geometry model contains 894 surfaces.**
- **S/C environments generated for beta angles 0, 30, 40, 50, 67 & 88.**
- **Simplified instrument geometry included.**
- **S/C thermal model contains 975 nodes.**
- **Bulk instrument nodes included.**
- **Conduction only. No internal radiation connections, except under Bench.**
- **Steady state orbit average and transient analyses completed.**

- **Cases run with S/C Detailed model include:**
  - **Launch Scenario (Worst Case Cold, Qenv=0 , Transient)**
  - **Safe Modes (Hot and Cold, S.S. and Transient, Attitude and Hard)**
  - **Normal Operations (Hot and Cold, S.S. and Transient)**

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Other Detailed Thermal Models Created

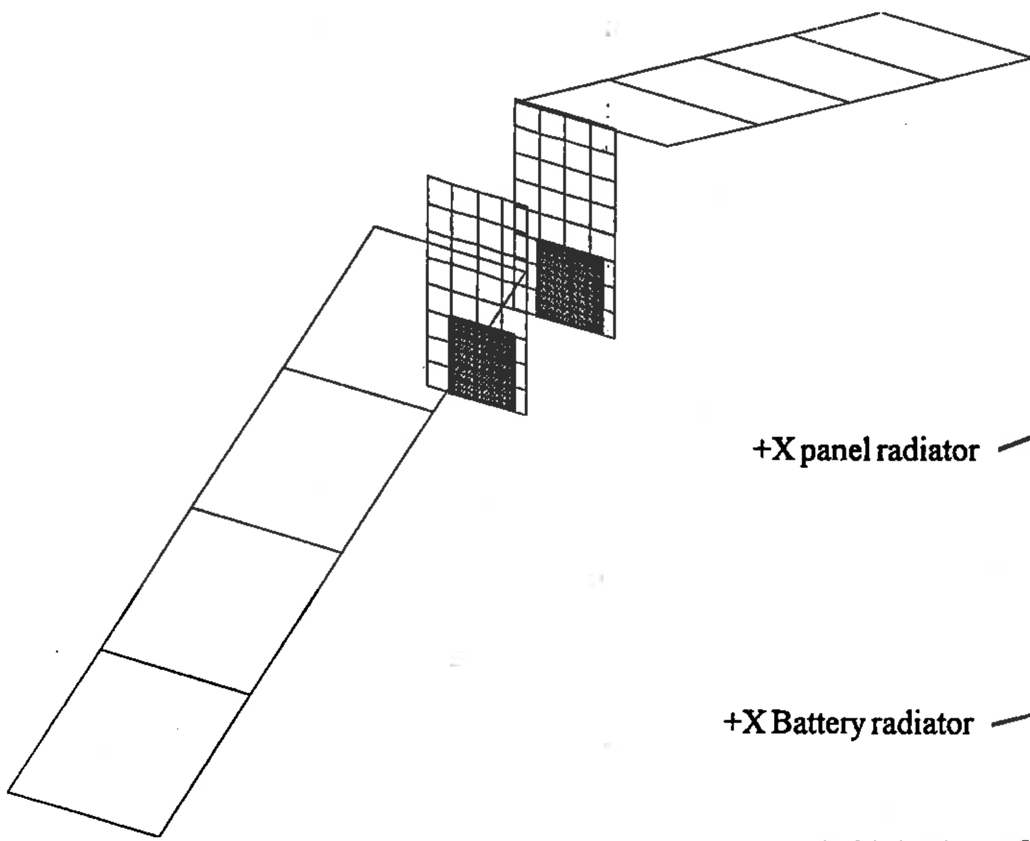
- Several separate detailed models were created, which include:
  - Battery Halves (On-Orbit and Test)
  - Solar Arrays with Dampers and Yokes (Stowed and Deployed)
  - Adapter Ring/Bottom Deck with Embedded Heat Pipes
  - Optical Bench

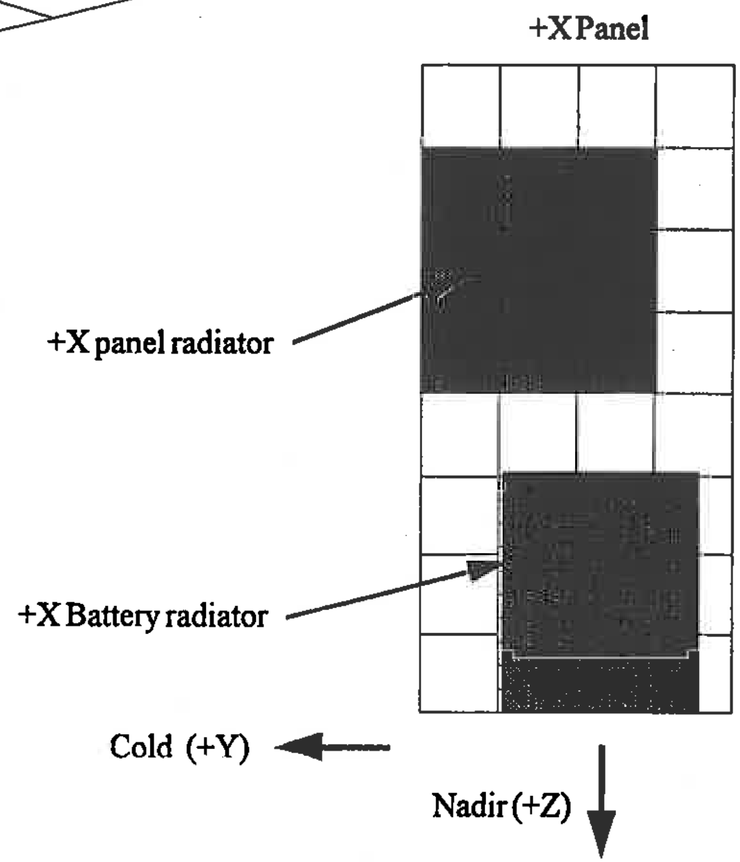
- Box/Card level thermal design and analyses performed:
  - Power Switching Electronics (PSE)
  - Peak Power Tracker Converter Module (PPTCM)
  - Integrated Electronics Module (IEM)
  - Flight Computer
  - Attitude Interface Unit (AIU)
  - Remote Interface Unit (RIU)
- Box analyses use 55 °C mounting plate test condition as interface.
- Junction temperatures maintained below 100 °C.

Detailed Battery Thermal Design

- **Requirements:**
  - **Cell operating temperature range: -5 to +10 °C**
  - **Cell top to bottom maximum ΔT: 5 °C**
  - **Cell to Cell maximum ΔT at same height location: 3 °C**
  - **Battery heat dissipation:**
    - **Beta 0 to 50 = 33 W orbit average**
    - **Beta 67 to 88 = 16 W orbit average**
    - **Heat varies with orbit position due to charge & discharge.**
- **Thermal control approach:**
  - **Thermally isolated battery halves from the S/C with 12 °C /W**
  - **Use heaters to control stability and minimum temperature.**
  - **Require 8 heater circuits, 2 bulk and 2 differential with 2 primary and 2 redundant.**
  - **Require small dead band (<1.0 °C)**

Detailed Battery Thermal Design





Detailed Battery Thermal Design

- **Preliminary results:**

  Each battery radiator area is 2.75 ft^2.
  Maximum cell temperature is 8.2 °C at Beta = 40.
  Maximum cell top to bottom ΔT is 3.2 °C < 5 °C
  Cell to Cell maximum ΔT is 1.8 °C < 3 °C.

- **Require 40 Watts of heater power at Beta=0.**

- **Require 75 Watts of heater power at Beta=88.**

- **The baseplate thickness, cell sleeve thickness and bolt interface resistance were optimized.**

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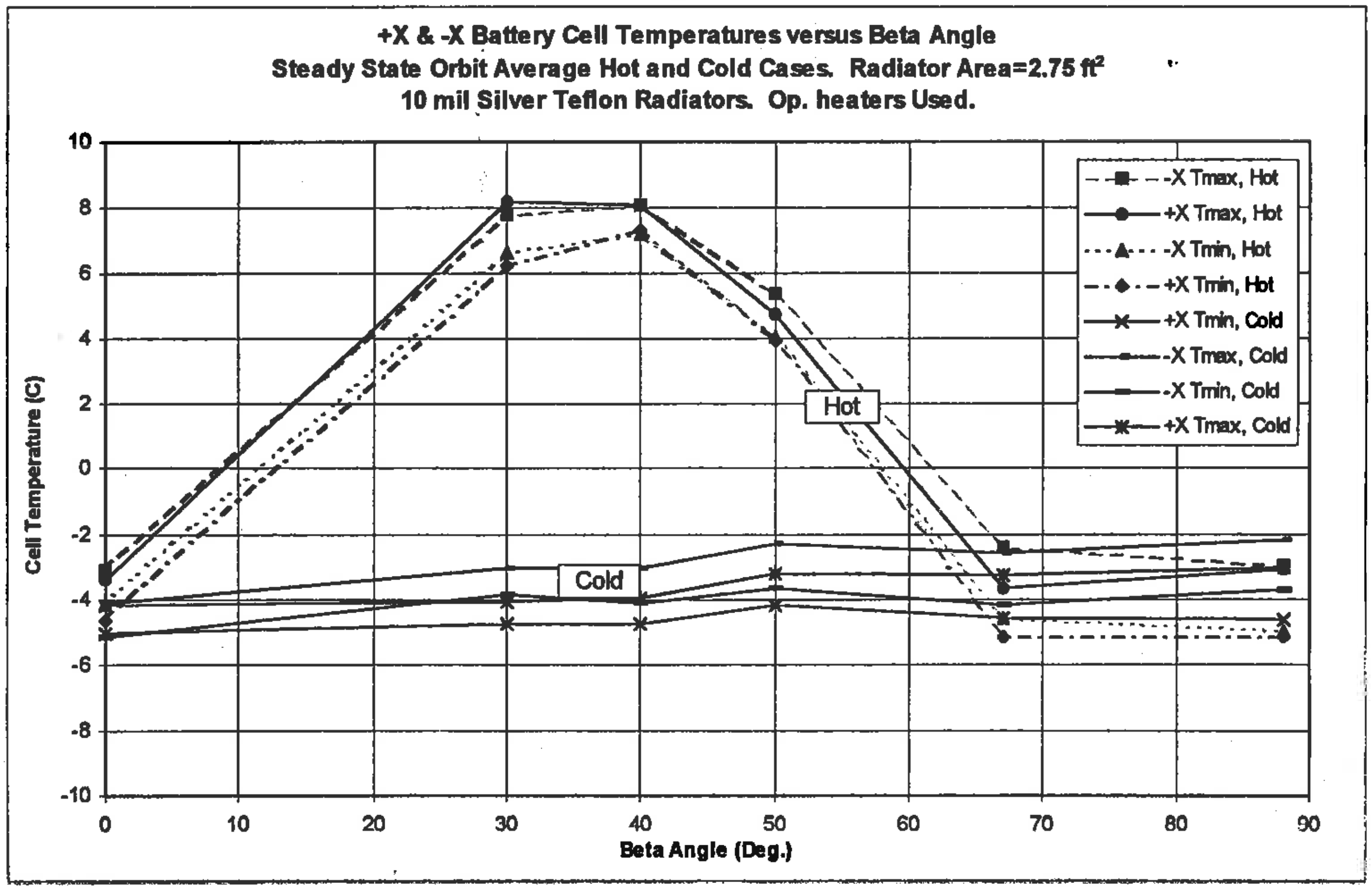
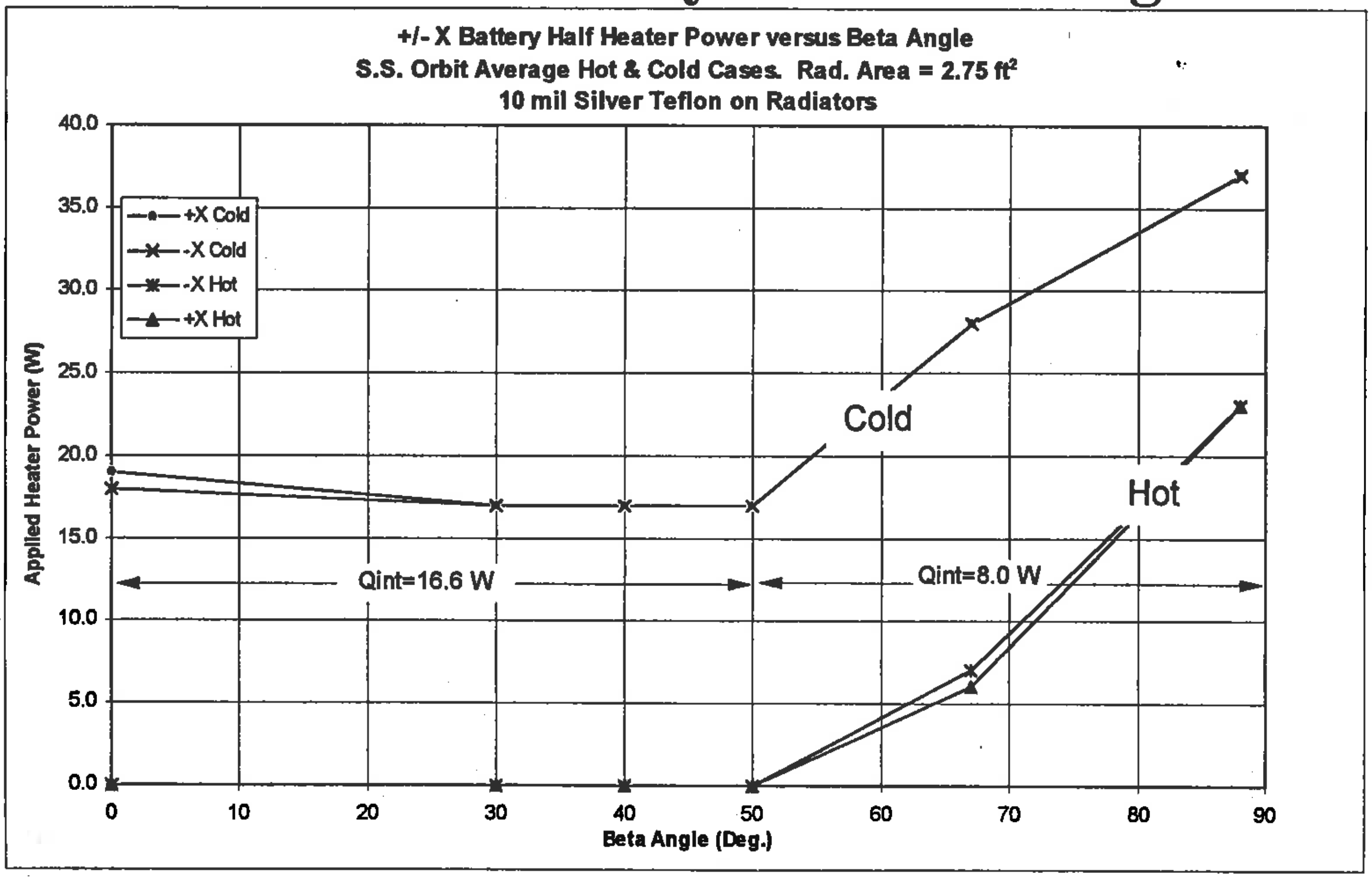
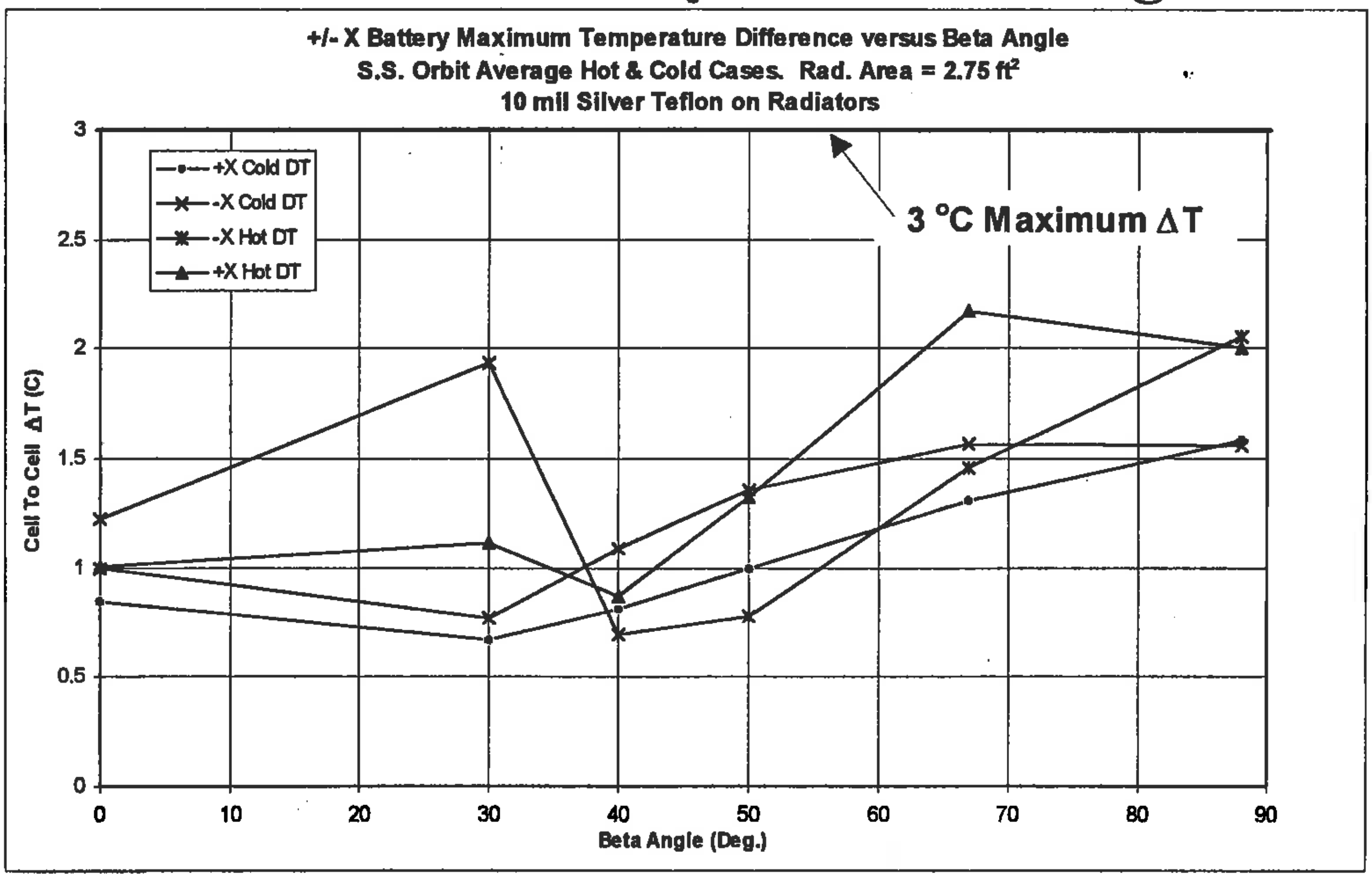
Detailed Battery Thermal Design



Detailed Battery Thermal Design



Detailed Battery Thermal Design



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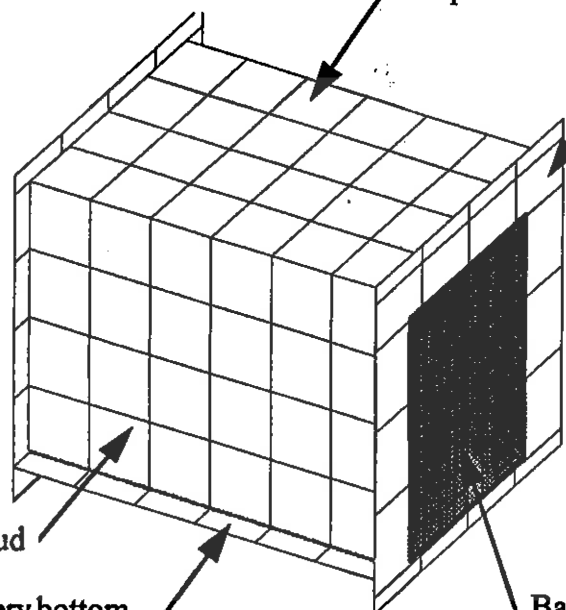
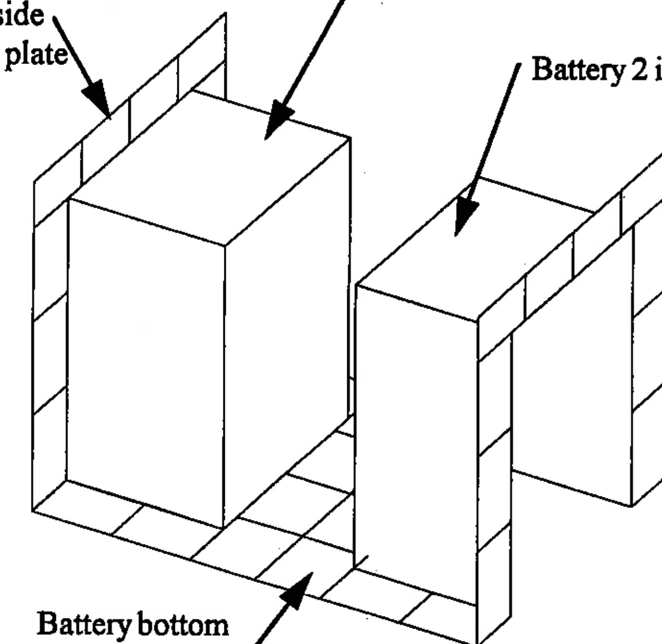
Detailed Battery Thermal Vacuum Testing



Test Battery External Model

(Chamber Not Shown)



Test Battery Internal Model

(Top, Left and Right Shroud Not Shown)

Detailed Battery Thermal Vacuum Testing

- Battery thermal vacuum balance test on Flight-Like Ni-H_2 cells to be completed in December 1997.

- Test will verify thermal control design of battery, which includes:
  - Required heater power
  - Required radiator area
  - Maximum internal temperature differences

- Test will validate heater controller circuit under vacuum conditions.

- Test results will be used to correlate detailed battery model.

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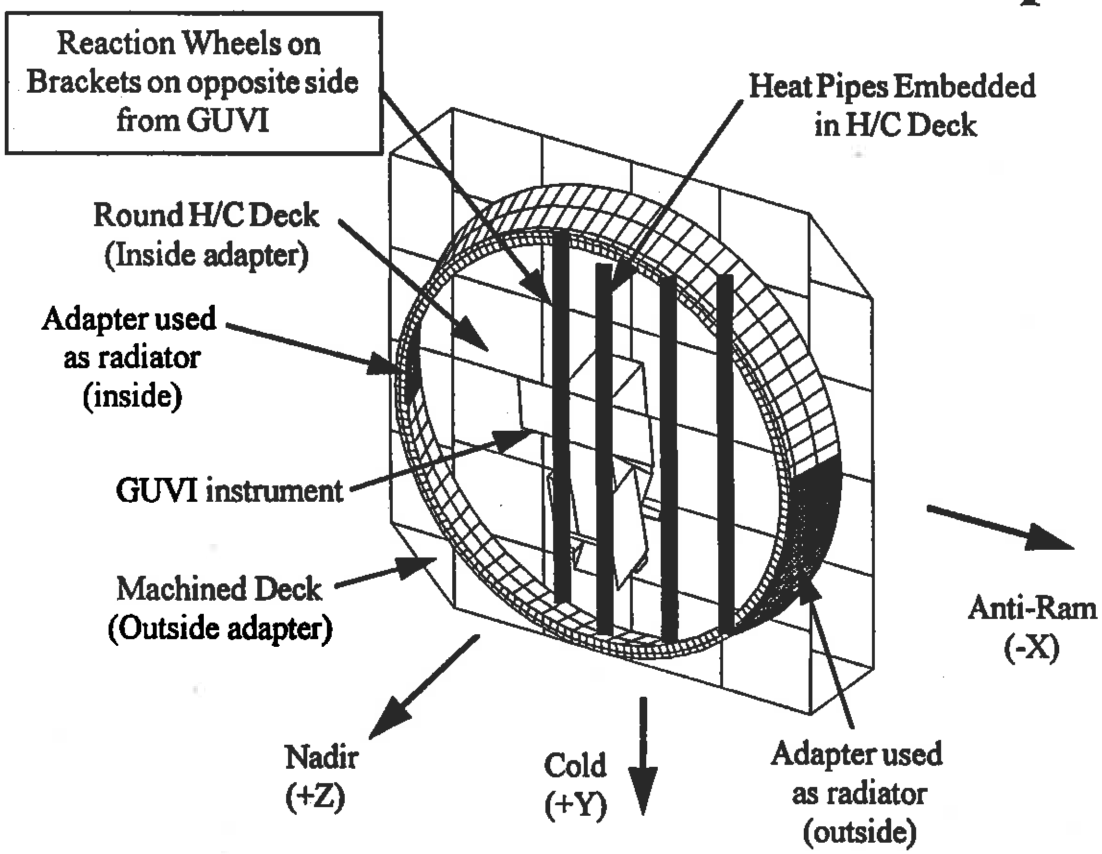
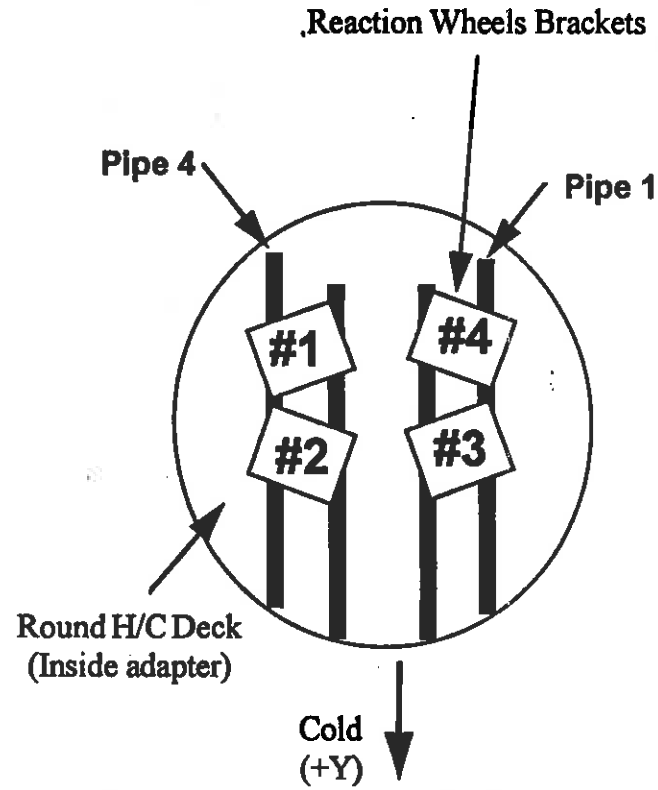
Bottom Deck Heat Pipe Thermal Design



External Model Of Adapter Ring with GUVI Bottom View



Sketch of Wheel Locations Top View

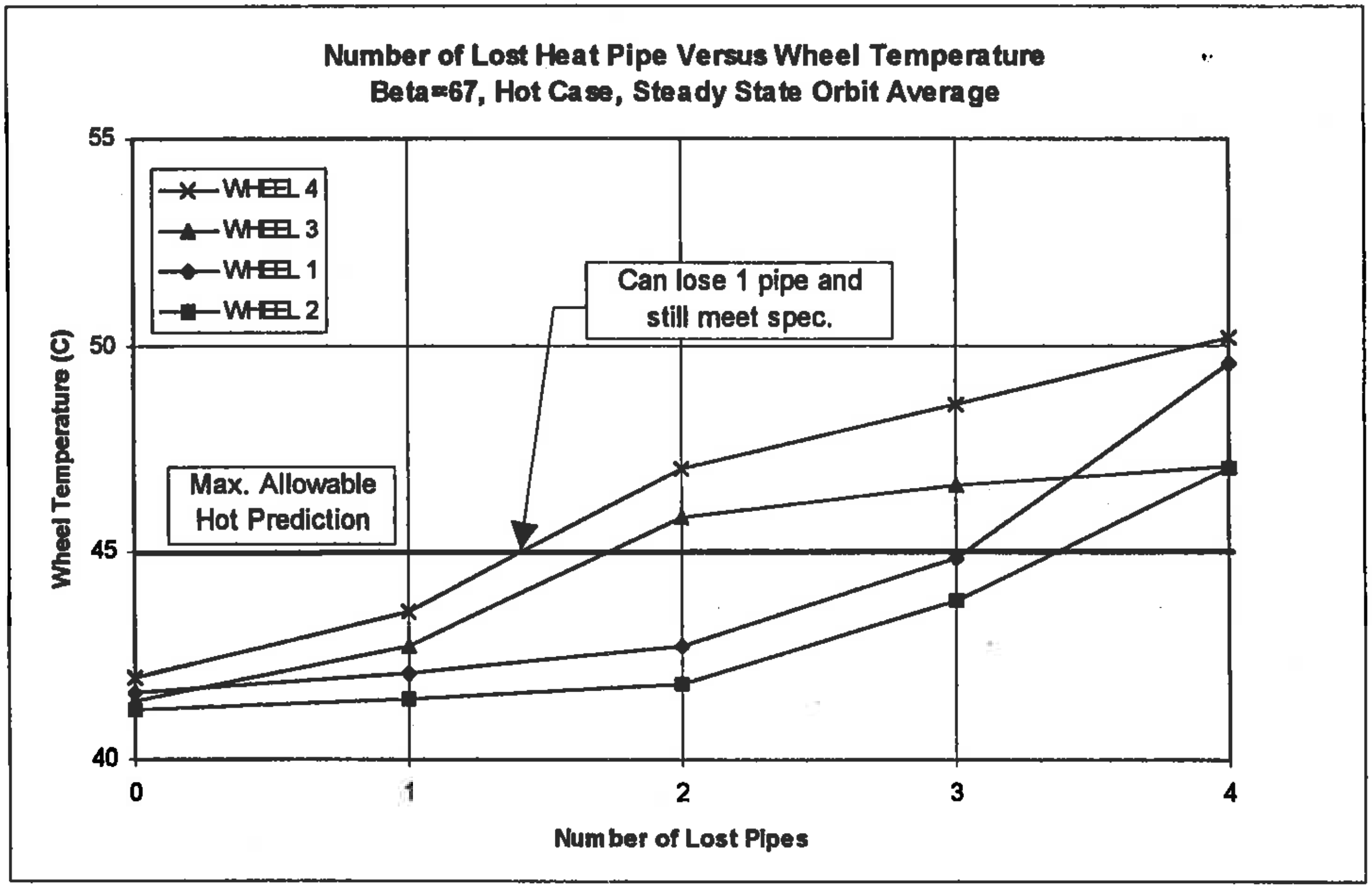
Bottom Deck Heat Pipe Thermal Design

- Reaction Wheels used to be on brackets in the corner of the S/C on the bottom machined deck (+Z). Since heat was distributed around deck, no thermal control required.

- However, due to volume constraints, the reactions wheel and their attach brackets were moved to the round honeycomb deck inside the adapter ring.

- To maintain the reaction wheels below their maximum allowable predicted operating temperature of +45 °C, 4 heat pipes are required to transport the 26 Watts orbit average heat to +Y adapter ring radiator.

Bottom Deck Heat Pipe Thermal Design



S/C Launch Analysis

- Launch cool down for heater power predictions. Set Qenv=0.
  - Solar arrays
  - Battery Halves
  - Star trackers
  - Dampers

- Battery halves require no heater power.

- Star trackers require 10 watts for the last 2 hours of 5 hour run.

- Dampers require 8 watts of heater power.

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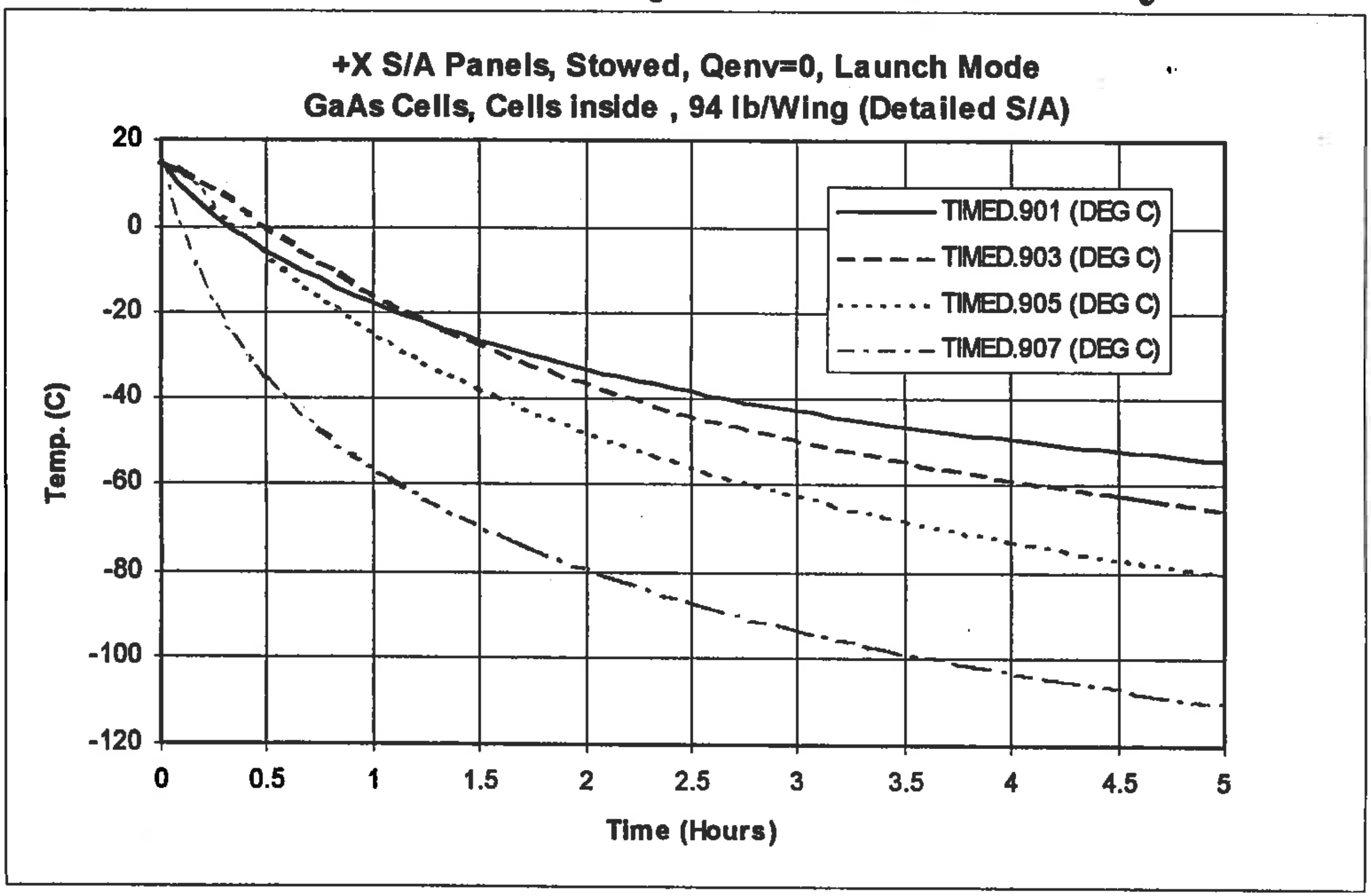
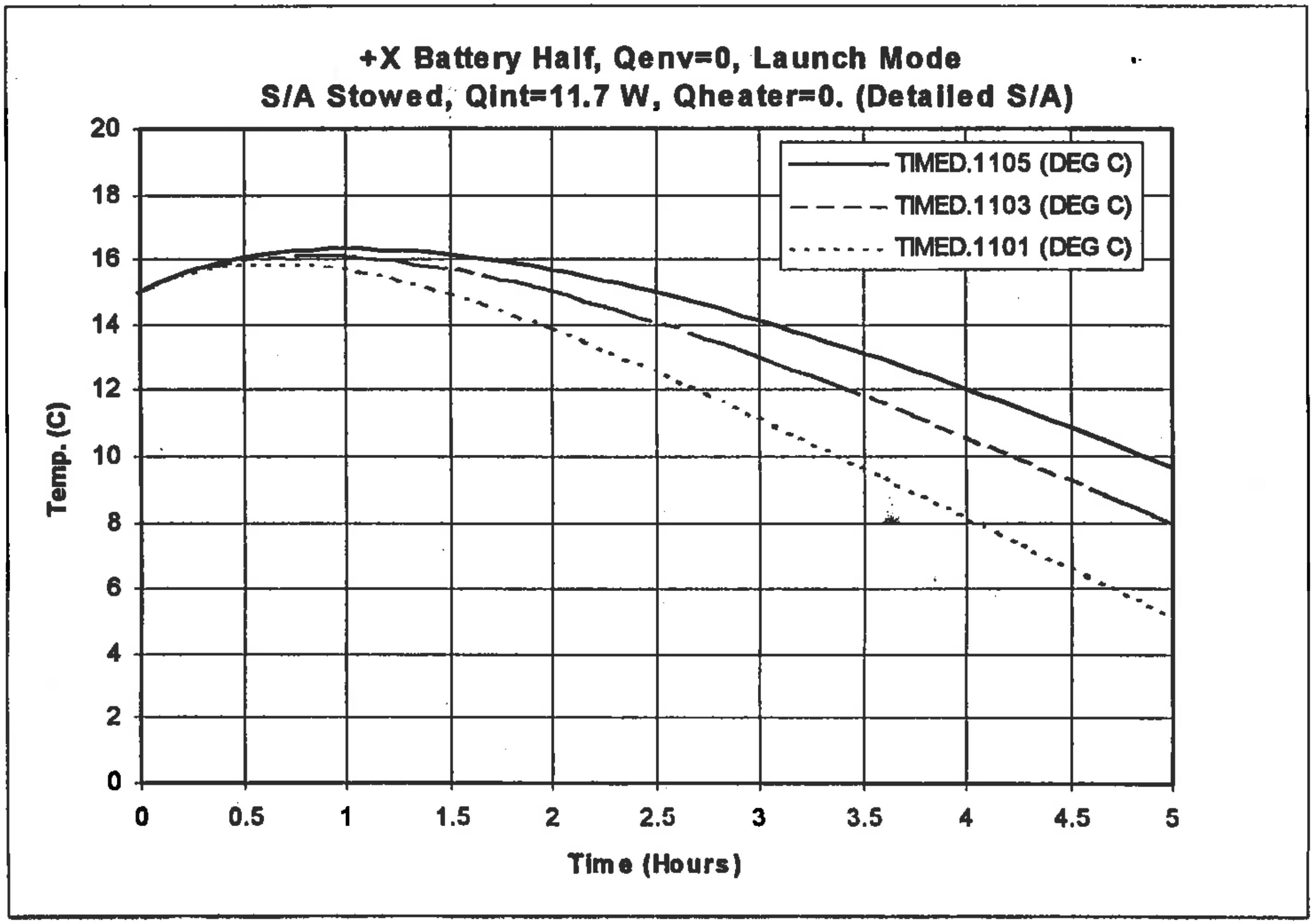
S/C Launch Analysis - Solar Arrays



S/C Launch Analysis - Battery



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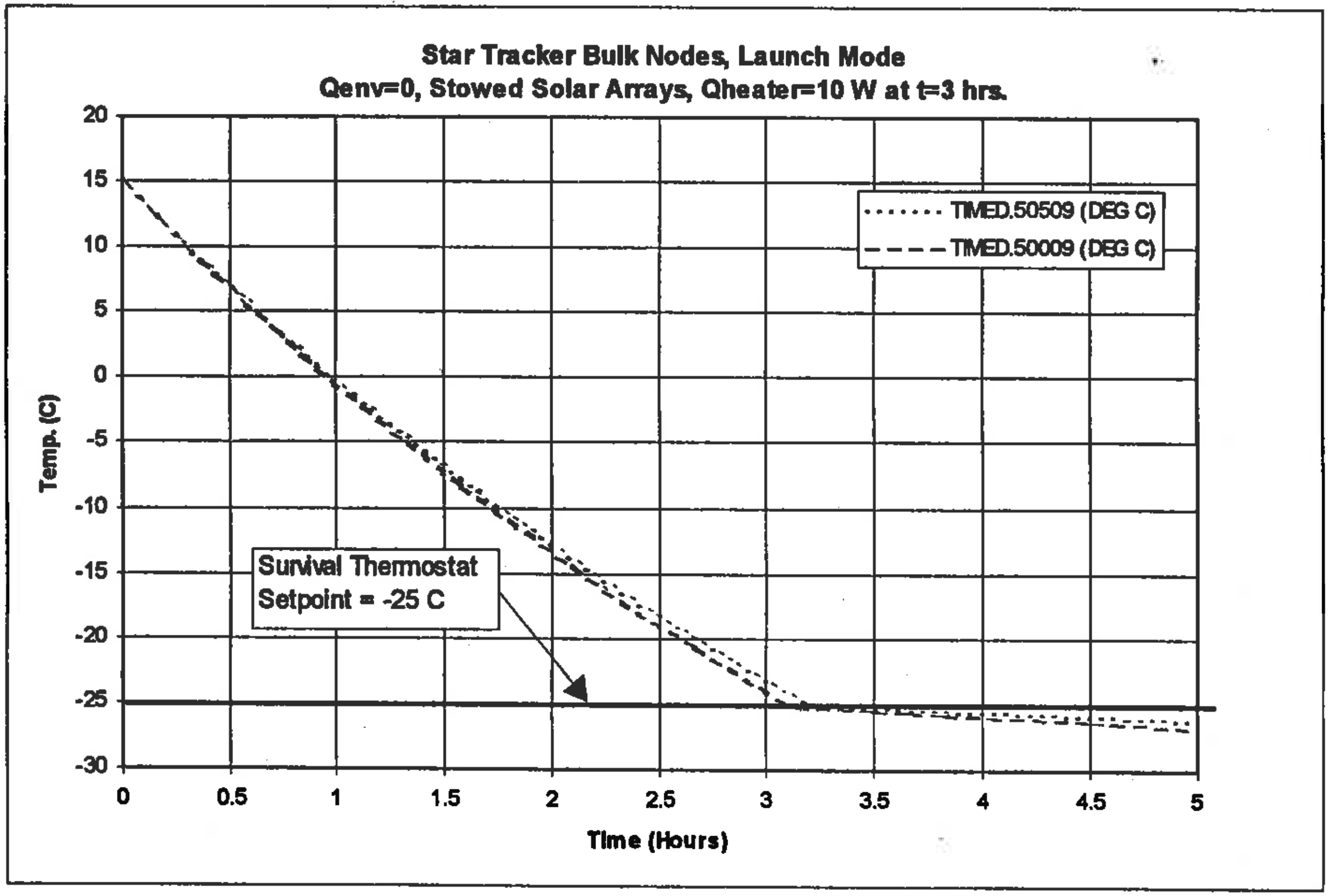
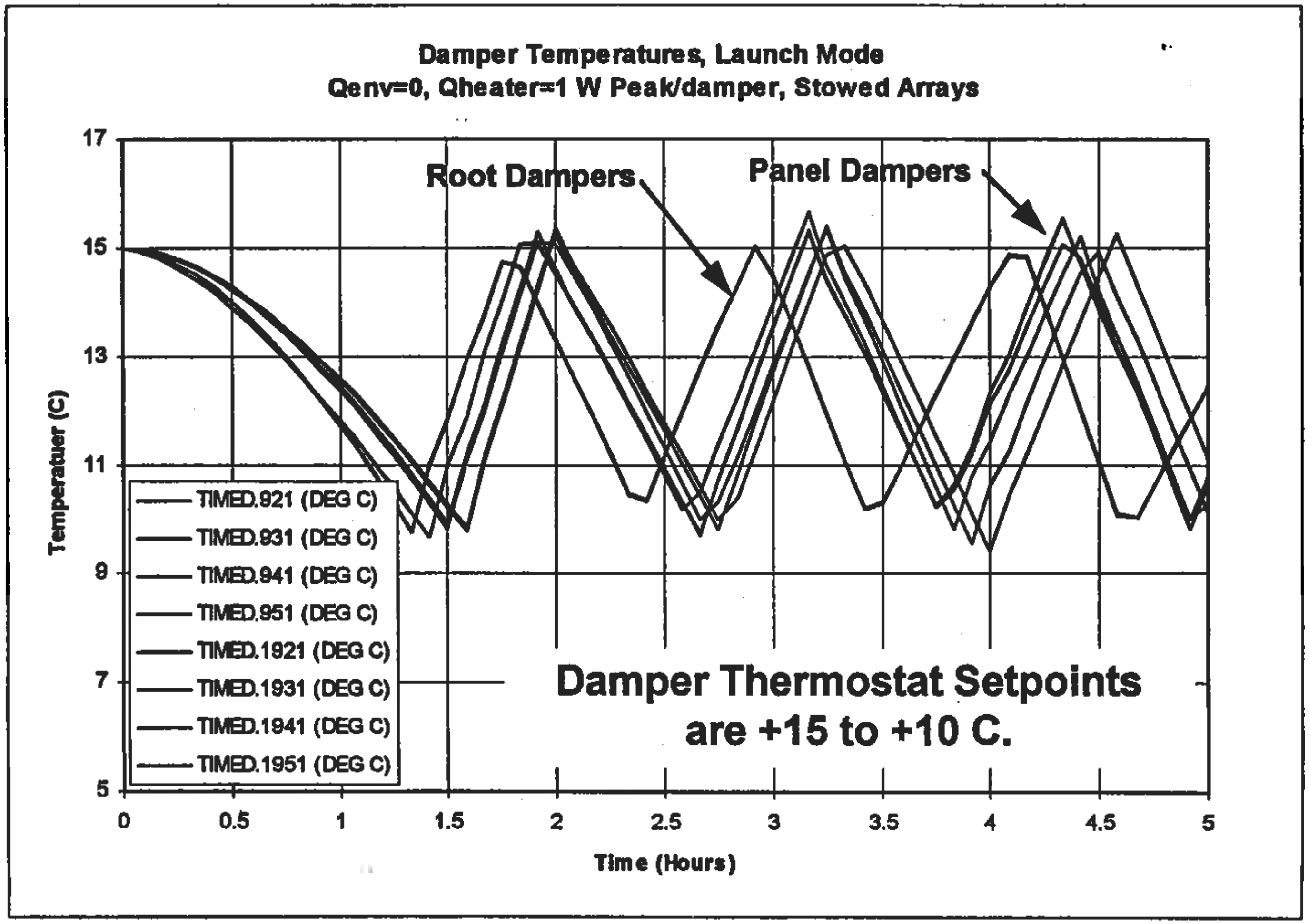
S/C Launch Analysis - Star Trackers



S/C Launch Analysis - Dampers



Optical Bench Thermal Design

•Requirements:

Maintain thermal distortions of bench below 30 arcsec.

•Thermal Design Approach:

Thermally isolate bench from S/C.

Thermally isolate TIDI Telescopes and Star Trackers from bench.

Recommend a totally passive thermal design.

No heaters or radiators . Cover bench externally with MLI.

Allow Bench to radiate to top deck. (Paint top deck under bench)

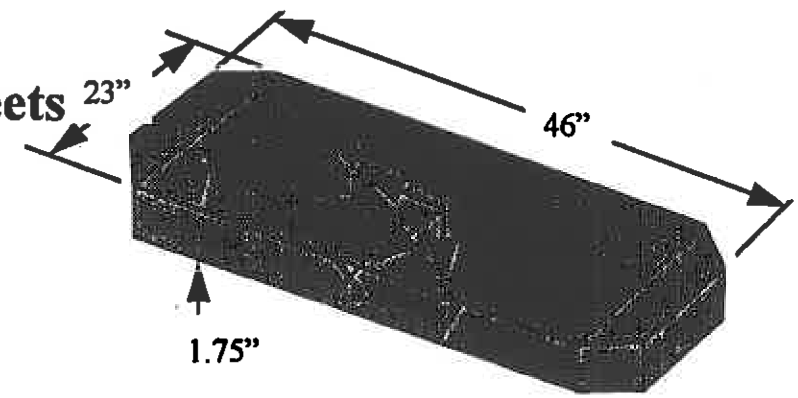
•Current configuration:

Two 0.03" Graphite Epoxy facesheets

Aluminum core (3.1 lb/ft^3)

23" X 46" X 1.75" thick.

Attachment isolation > 10 °C/W



Optical Bench Thermal Design

- Currently predicting a bulk orbit average operating temperature change over the beta angle cycle and hot to cold of +33.8 to -0.2 °C.
- Currently predicting a bulk orbit average SAFE mode temperature change over the beta angle cycle and hot to cold of +13 to -17 °C.

- Currently predicting the following temperature gradients in the bench:
  - ΔT_x (max) = 3.2 °C (across 23")
  - ΔT_y (max) = 13.5 °C (along 46")
  - ΔT_z (max) = 0.71°C (thru 1.75")

- Thermal distortion calculations predict 11.3 arcsec << 30 arcsec.
- Transient analysis reveals 4 °C Peak-to-Peak variation at Beta 0. Beta 88 has no variations.

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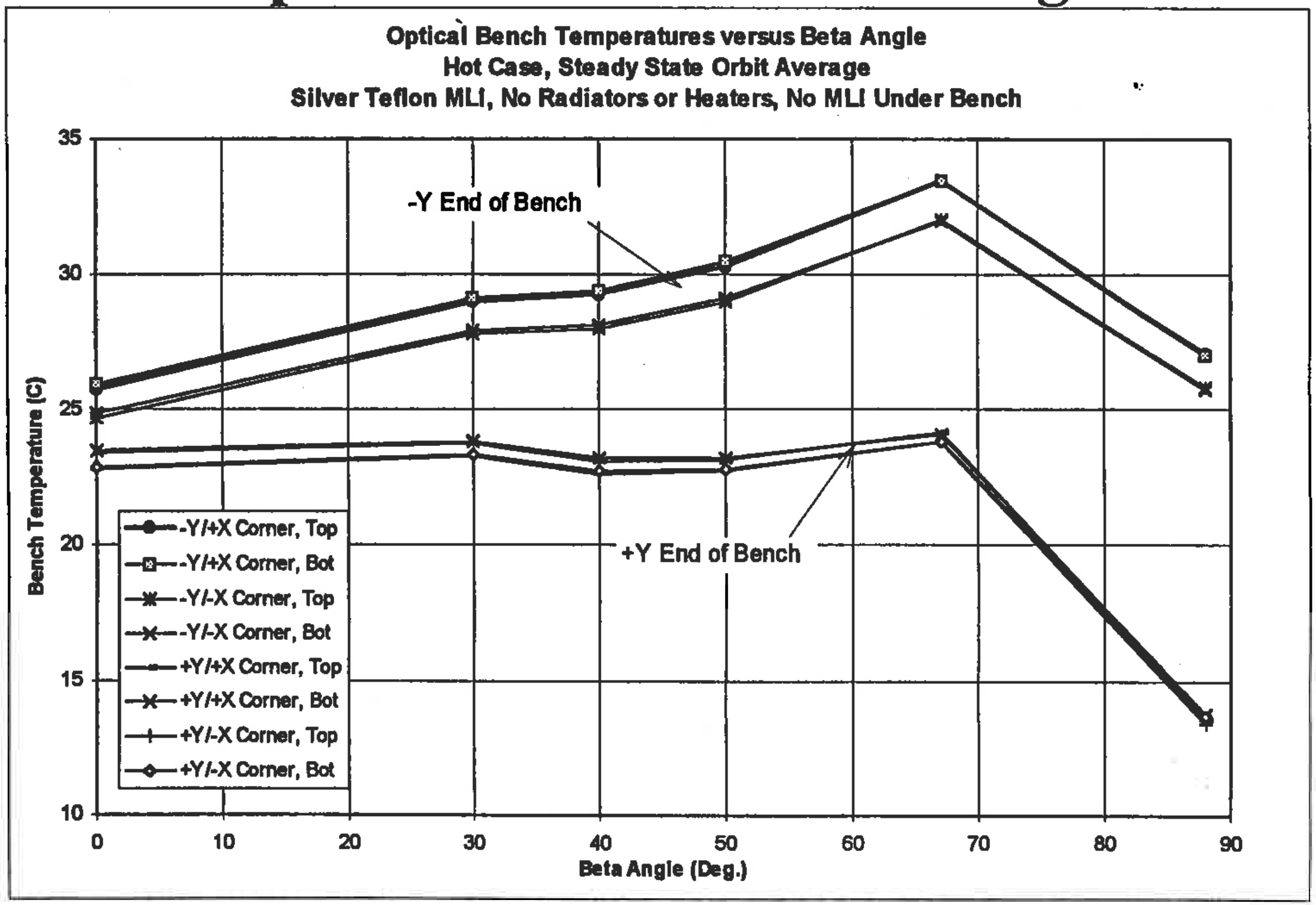
Optical Bench Thermal Design



S/C Thermal Results Summary

- Design meets all instrument and S/C thermal requirements with margin.
- All required heater power has been accounted for in the power system design.
- Heaters, thermostats, temperature sensors and relay designs exist.
- Heat pipes provide required cooling for reaction wheels with some redundancy.

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S/C Operating Temperature Predictions

S/C Orbit Average Temperatures

Component	Max. Oper. Temp. (C)	Max. Temp. Pred. (C)	Min. Oper. Temp. (C)	Min. Temp. Pred. (C)
+X Panel	45.0	34.5	-14.0	-10.9
-Y Panel	45.0	38.3	-19.0	-4.9
-X Panel	45.0	43.1	-19.0	-7.9
+Y Panel (@ IEM)	45.0	26.6	-19.0	-16.8
-Z Deck (@ IMU)*2	*60.0*	47.0	*-20.0*	-5.5
+Z Deck	45.0	40.8	-13.0	-12.0
Optical bench	*35.0*	33.8	-5.0	-0.2
Batteries (2 halves)	*10.0*	8.2	-5.0	-4.5*1
Star Trackers (2)	40.0	30.4	-25.0	-1.6
Solar Array	90.0	77.6	-70.0	-13.6
Nadir S-Band antenna	65.0	-5.7	-90.0	-46.0
Zenith S-Band antenna	65.0	-1.4	-90.0	-57.0
GNS antenna	65.0	-16.0	-90.0	-76.6

*1 Temperature predictions with heater power

*2 Doubler added to spread heat.

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S/C Operating Temperature Predictions

Instrument Interface Orbit Average Temperatures

Component	Max. Oper. Temp. (C)	Max. Temp. Pred. (C)	Min. Oper. Temp. (C)	Min. Temp. Pred. (C)
SABER I/F	20.0	18.4	-19.0	-12.0
SEE I/F	*45.0*	39.0	*-10.0*	0.5
TIDI telescope I/F	*35.0*	33.5	-5.0	0.7
TIDI profiler I/F	30.0	24.3	-19.0	-5.5
GUVI SIS Hsg I/F	45.0	40.8	-14.0	8.0

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S/C and Instrument Operational Heater Power

Component	Orbit Average Heater Power, Beta=0 (Watts) @ 26 Volts	Orbit Average Heater Power, Beta=90 (Watts) @ 26 Volts
Batteries (2 halves)	37.00	74.00
Star Trackers (2)	0.00	0.00
S/C subtotal	37.00	74.00
SABER	8.70	9.70
SEE	5.00	10.00
TIDI telescopes (4)	5.00	6.00
TIDI profiler/CCD	4.00	4.00
GUVI SIS Housing	6.00	6.00
Inst. subtotal	28.70	35.70
Total	65.70	109.70

S/C Operating Temperature Predictions

S/C Max./Min. Transient Temperatures

Component	Max. Oper. Temp. (C)	Max. Temp. Pred. (C)	Min. Oper. Temp. (C)	Min. Temp. Pred. (C)	Heater Duty Cycle (%)
+X Panel	45.0	45.1	-14.0	-11.0	
-Y Panel	45.0	38.3	-19.0	-5.0	
-X Panel	45.0	41.6	-19.0	-10.5	
+Y Panel (@ IEM)	45.0	32.0	-19.0	-16.9	
-Z Deck (@ IMU)**	*60.0*	46.2	*-20.0*	-5.5	
+Z Deck	45.0	41.5	-13.0	-12.0	
Optical bench	*35.0*	35.6	-5.0	-0.5	
Batteries (2 halves)	*10.0*	9.7	-5.0	-5.4*	64
Star Trackers (2)	40.0	33.2	-25.0	-1.8	
Solar Array	90.0	78.2	-70.0	-66.2	
Nadir S-Band antenna	65.0	0.6	-90.0	-57.0	
Zenith S-Band antenna	65.0	1.5	-90.0	-65.0	
GNS antenna	65.0	-11.8	-90.0	-77.2	

* Temperature predictions with heater power

** Doubler added to spread heat.

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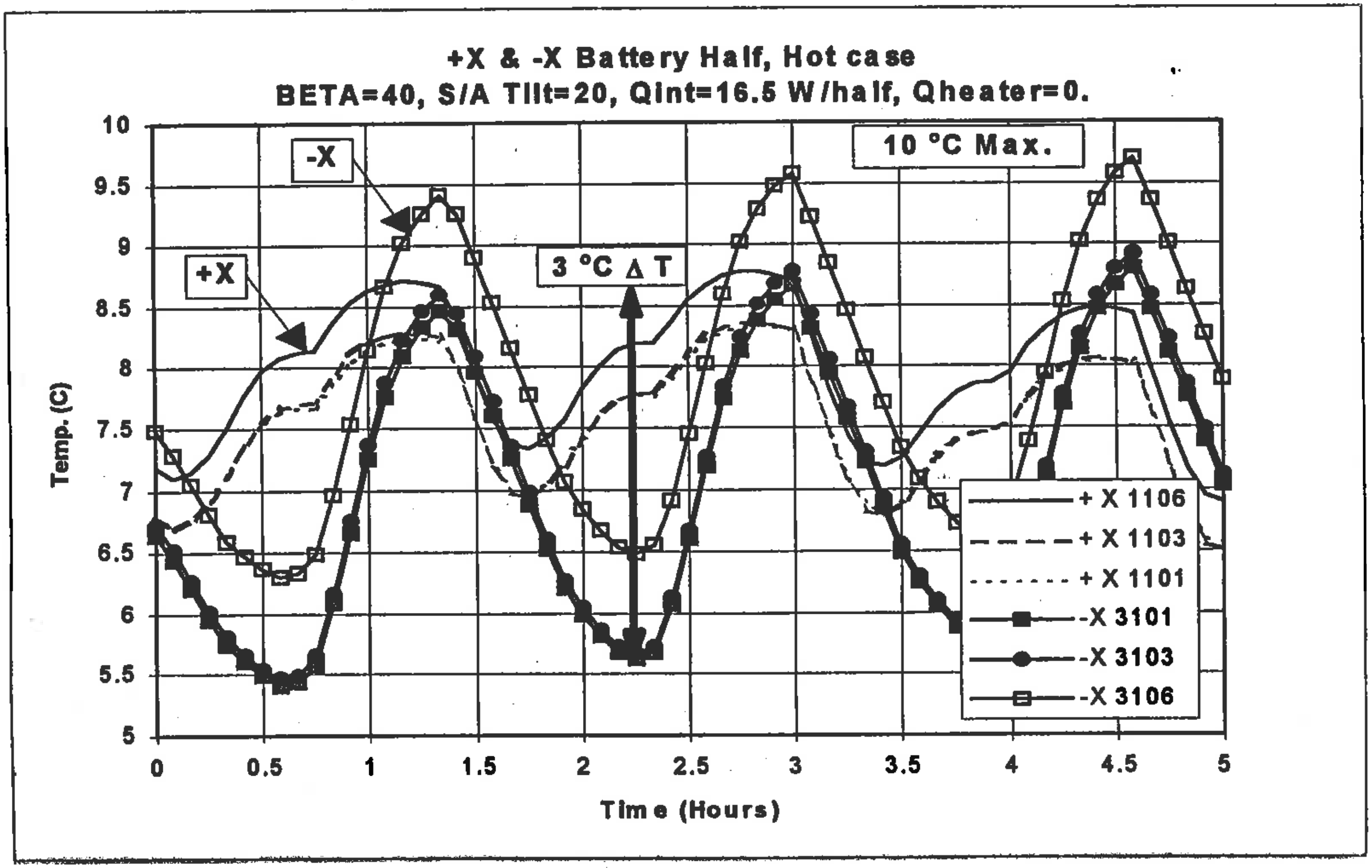
S/C Operating Temperature Predictions

Instrument Interface Max/Min Transient Temperatures

Component	Max. Oper. Temp. (C)	Max. Temp. Pred. (C)	Min. Oper. Temp. (C)	Min. Temp. Pred. (C)
SABER I/F	20.0	19.8	-19.0	-12.1
SEE I/F	*45.0*	39.6	*-10.0*	0.5
TIDI telescope I/F	*35.0*	33.5	-5.0	0.3
TIDI profiler I/F	30.0	24.5	-19.0	-5.5
GUVI SIS Hsg I/F	45.0	41.5	-14.0	8.3

S/C Operating Transient Predictions



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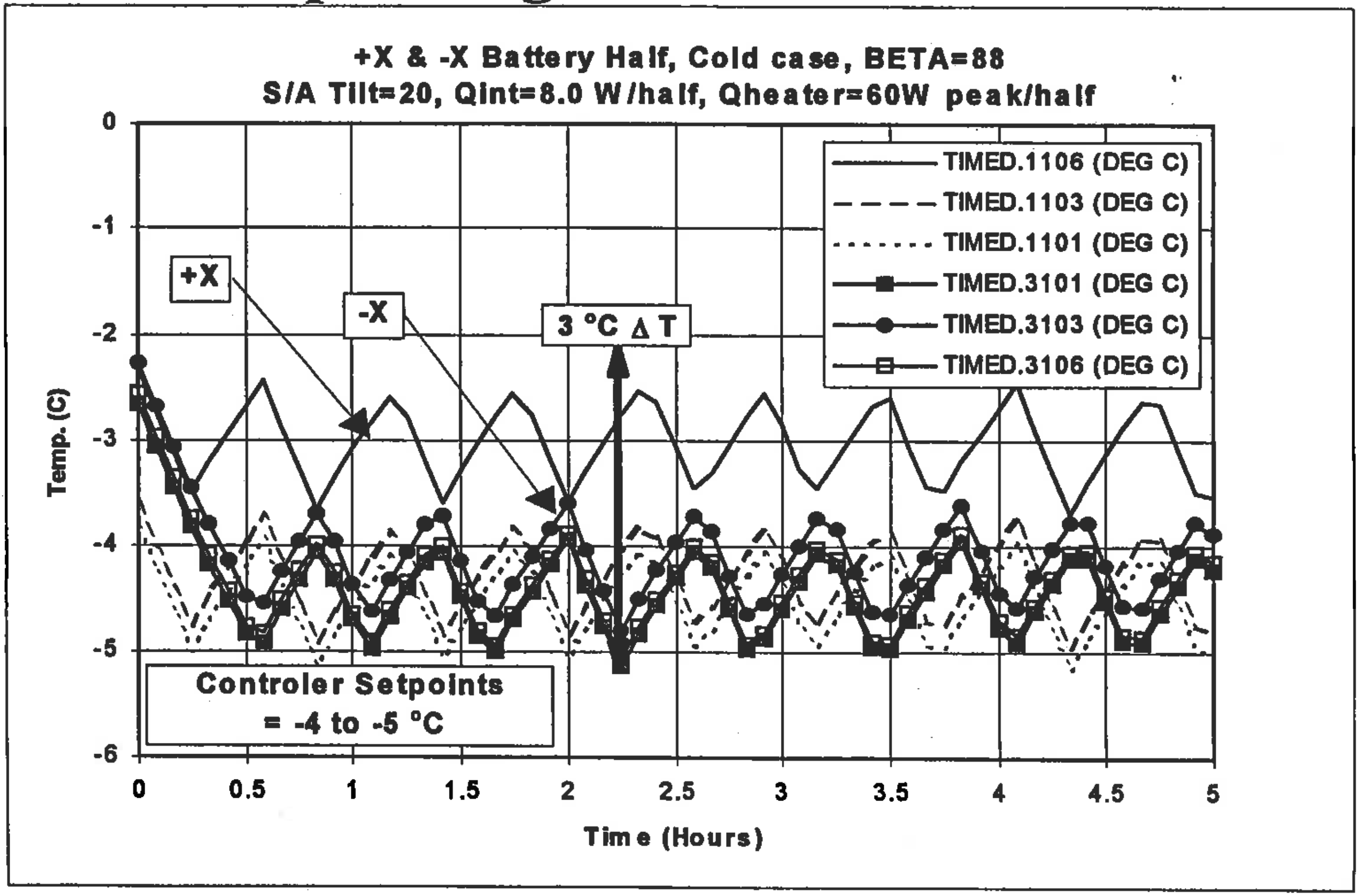
S/C Operating Transient Predictions



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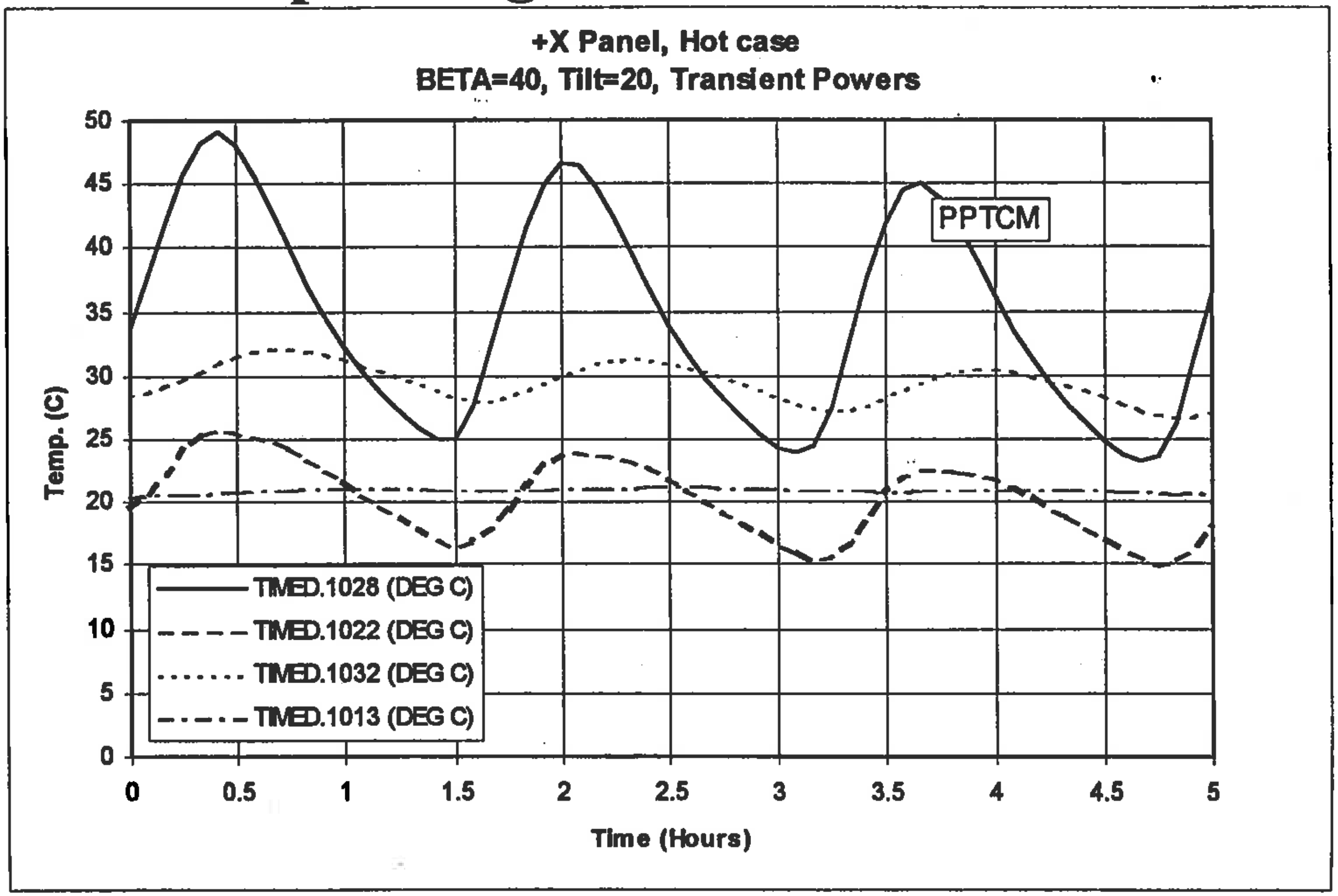
S/C Operating Transient Predictions



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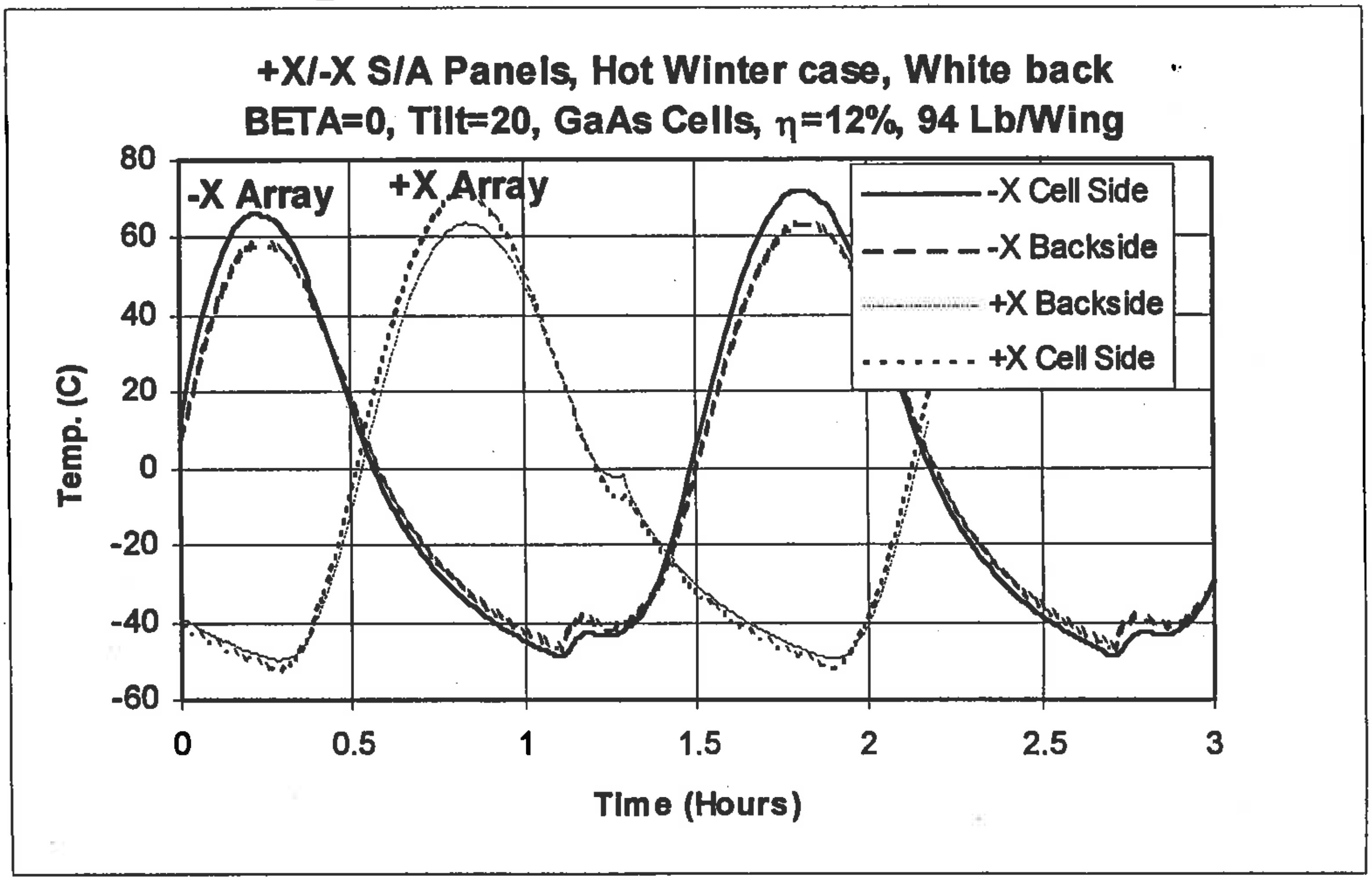
S/C Operating Transient Predictions



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S/C Safe Mode Temperature Predictions

S/C Orbit Average Temperatures

Component	Max. Safe Temp. (C)	Max. Temp. Pred. (C)	Min. Safe Temp. (C)	Min. Temp. Pred. (C)
+X Panel	50.0	22.9	-19.0	-14.7
-Y Panel	50.0	17.4	-24.0	-13.2
-X Panel	50.0	0.8	-24.0	-22.2*
+Y Panel (@ IEM)	50.0	23.1	-24.0	-23.8*
-Z Deck (@ IMU)	65.0	34.9	-30.0	10.1
+Z Deck	50.0	2.6	-19.0	-24.0*
Optical bench	30.0	13.5	-20.0	-16.7
Batteries (2 halves)	20.0	-4.5*	-15.0	-4.5*
Star trackers (2)	45.0	26.0	-30.0	-25*
Solar array	90.0	78.1	-70.0	15.6
Nadir S-Band antenna	65.0	6.3	-90.0	-45.2
Zenith S-Band antenna	65.0	3.5	-90.0	-35.0
GNS antenna	65.0	-25.3	-90.0	-73.0

* Temperature predictions with heater power

Note: Max. Safe Temp.. predicts are from Attitude Safe Hot
Min. Safe Temp predicts are from Hard Power Safe Cold

Safe mode is defines as -Y to sun, -Z north, Inertially Fixed, Solar Array rotated to 88°

S/C Safe Mode Temperature Predictions

Instrument Interface Orbit Average Temperatures

Component	Max. Surv. Temp. (C)	Max. Temp. Pred. (C)	Min. Surv. Temp. (C)	Min. Temp. Pred. (C)
SABER I/F	50.0	-12.8	*-29.0*	-29*
SEE I/F	50.0	17.4	-24.0	-10.2
TIDI telescope I/F	30.0	15.0	-20.0	-16.7
TIDI profiler I/F	50.0	12.9	-24.0	-13.5
GUVI SIS Hsg I/F	50.0	2.5	-19.0	-14.2

* Heater power used to protect minimum interface temperature.

Note: Max. Safe Temp. predicts are from Attitude Safe Hot
Min. Safe Temp predicts are from Hard Power Safe Cold

S/C and Instrument Safe Mode Heater Power

Component	Orbit Average Heater Power, Beta=0 (Watts) @ 26 Volts	Orbit Average Heater Power, Beta=90 (Watts) @ 26 Volts
+X Panel	0.0	0.0
-X Panel	5.0	5.0
+Y Panel	10.0	14.0
+Z Deck	10.0	10.0
-Z Deck	0.0	0.0
Batteries (2 halves)	55.0	75.0
Star Trackers (2)	14.0	10.0
S/C subtotal	94.0	114.0
SABER	25.3	25.3
SEE	14.0	14.0
TIDI telescopes (4)	3.0	3.0
TIDI profiler/CCD	4.0	4.0
GUVI SIS Housing	3.0	3.0
Inst. subtotal	49.3	49.3
Total	143.3	163.3

Note: Heater power predicts are from Hard Power Safe Cold

S/C Thermal Hardware - Thermostats

- Thermostats: Total = 44 thermostats. (prim/red)
  - 2 heater circuits on the star trackers = 4 thermostats
  - Survival heater zones on the following panels:
    - +X and -X panels = 4 thermostats
    - +Y panel (on each IEM) = 4 thermostats
    - -Z panel (near IMU)= 4 thermostats
    - +Z panel = 4 thermostats
  - Damper heater circuits (2 each X 10) = 20 thermostats
  - Battery high/low mechanical backup = 4 thermostats

S/C Thermal Hardware - Heaters

- **Heaters: Total = 76 dual-element heaters.**
  - **3 survival heaters per thermostat = 20 heaters.**
  - **2 heaters per battery cell = 44 heaters.**
  - **1 heater per solar array damper = 10 heaters.**
  - **1 heater per star trackers = 2 heaters**
  - **All heater resistances sized to 26 V. Peak Power reported @ 35 V.**

- **Deutsch blocks for thermostats and heaters connections.**

- **Instruments are purchasing their own thermostats and heaters.**

S/C Thermal Hardware - Temperature Sensors

- **61 S/C temperature sensor pairs are required for the S/C housekeeping and thermal assessment on-orbit. Currently using a 1000 Ohm platinum thermistors for all S/C temperature sensors, which provide -100 to +100 C range (#S100480PFY72B).**

- **Instruments will be supplied 13 S/C-monitored temperature sensors mounted to the instrument:**
  - **GUVI - 2**
  - **SABER - 4**
  - **SEE - 2**
  - **TIDI - 5**

S/C Thermal Hardware - Relays

- **Total of 8 S/C thermal relays.**
  - **2 Battery heater relays required:**
    - **Primary/Redundant heaters (10 A).**
  - **2 Damper heater relays required (2 A):**
    - **Primary/Redundant relays for solar array deployment.**
  - **2 survival relays required, Prim/Redund (10 A):**
    - **Mechanical thermostats on critical components and distributed around S/C bus to provide minimum survival temperatures (Always enabled).**
  - **2 S/C operational heater relays required:**
    - **Primary/Redundant for star trackers (2 A).**

S/C Thermal Hardware - Heat Pipes

- 4 flight and 1 spare heat pipe will be used.

- Heat pipes will be embedded in +Z honeycomb deck.

- Heat pipes are designed to leak before burst.

- Heat pipes are designed to operate between -40 and +40 C with 0 to 50 Watts of heat transport.

- Heat pipes are designed to survive exposure to -55 and +125 C.
  (pipes must survival panel cure temperature)

- Heat pipes are on schedule for delivery to panel developer.

Instrument Thermal Hardware - Relays

•All instruments will be provided one survival heater relay to protect instrument when unpowered = 4 relays.

•SABER requires 1 operational heater relay.

S/C Future Thermal Tasks

- **Purchase most thermal hardware in the next 2-3 months. (Heat pipe contract already in place)**
- **Update instrument models with CDR versions.**
- **Perform battery thermal vacuum balance test.**
- **Correlate battery thermal balance test results with model.**
- **Integrate thermal hardware onto S/C as required.**
- **Prepare for S/C Thermal Vacuum testing over a GSFC.**

S/C Thermal Issues and Concerns

- **Launch environments are schedule for delivery to APL by Dec. 5, 1997. APL will perform launch transient analysis based on new DPAF environment.**

- **To date, worst case heater power estimates have been used for S/C design with Qenv=0 for 4.5 hours for launch phase. (see cool downs)**