GIFTS
Blackbody Subsystem
Critical Design Review

University of Wisconsin
Space Science and Engineering Center

9 March 2004

GIFTS Blackbody Subsystem CDR Agenda

University of Wisconsin, Space Science and Engineering Center
9 March 2004

8:30	**Introduction**	**Hank Revercomb**
8:35	**Overview**	**Fred Best**
8:45	**GIFTS System Level Calibration Requirements Flowdown** GIRD GIFTS Level Calibration Error Budget and Modle	**Hank Revercomb**
9:00	**Top-level Blackbody Requirements Flowdown** Blackbody Level Calibration Error Budget Overview of Top Level Blackbody Subsystem Requirements	**Fred Best**
9:15	**Blackbody Controller** Controller Performance Requirements and Design Overview Changes Since PDR Controller Operation Electronic Error Budget Power Budget Supporting Analysis Part Selection Engineering Model Test Results Controller Verification Plans Callibration Overview	**Scott Ellington**
10:25	**Break**	**All**
10:40	**Blackbody Controller - Digital Interface & Controller Logic** Key Requirements Changes Since PDR Detailed Design Supporting Analysis Testing Results Verification Plans Overall Controller Interface Review	**Mark Werner**
11:30	**Blackbody - Mechanical** Key Requirements Changes Since PDR Detailed Mechanical Design Mechanical Analysis Mass Budget Verification Plans Interface Review and Alignment Tool	**Doug Adler**
12:00	**Blackbody - Thermal** Key Requirements Changes Since PDR Detailed thermal Design Thermal Analysis	**Doug Adler**

	Power Budget Verification Plans Interface Review	
12:45	**Lunch**	**All**
13:30	**Blackbody - Thermistors** Thermistor Selection and Packaging Thermistor Test Plan Thermistor Cavity Integration / Heat Sinking Long Term Test Plan	**Doug Adler**
13:50	**Temperature Uncertainty Budget and Calibration** Temperature Measurement Error Budget Calibration Plans	**Fred Best**
14:10	**Emissivity Modeling and Uncertainty Budget** Monte Carlo Modeling Emissivity Uncertainty Budget	**Bob Knuteson**
14:30	**Development Plans, Logistics, and Facilities** Build Plan and Status, Including Spares Performance Verification Plan and Status Contamination Control Assembly, Integration, and Test /Flow Facilities	**Fred Best**
15:15	**Project Plan Status** Cost Schedule Procurement Plan and Status Resources Configuration Management Status Product Assurance Plan Safety	**Fred Best / Evan Richards**
16:00	**RFA Status**	**Fred Best**
16:20	**Action Item Review**	**All**
17:00	**Adjourn**	

GIFTS
Blackbody Subsystem
Critical Design Review
Overview

Fred Best

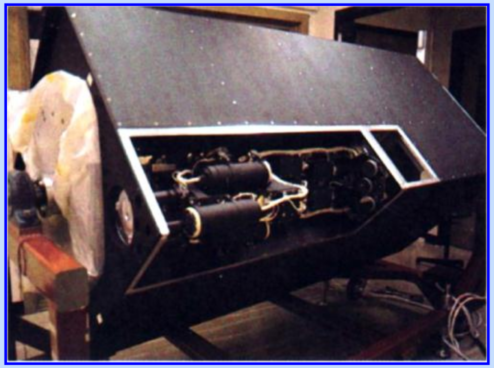
9 March 2004

Topics

- Review agenda
- UW SSEC Heritage
- What are we building - the big picture
- Program status
- Key changes since PDR

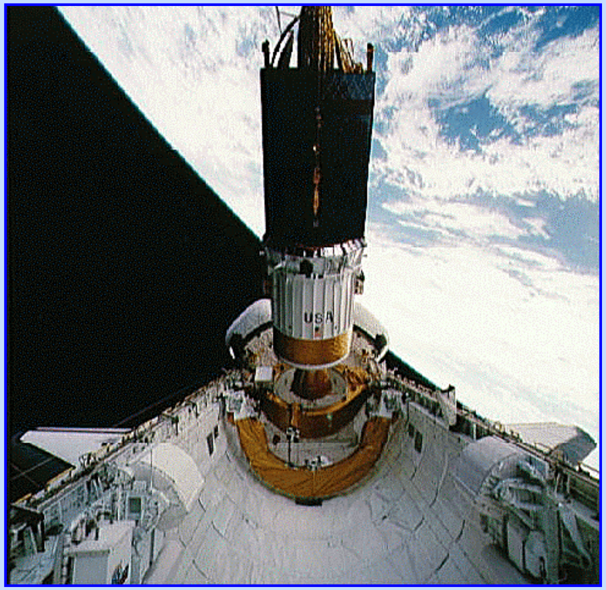
SSEC Major Space Flight Programs

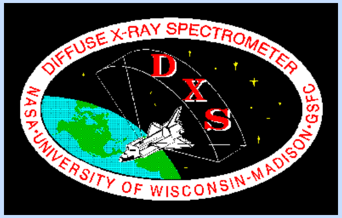
High Speed Photometer



Hubble
1990-93

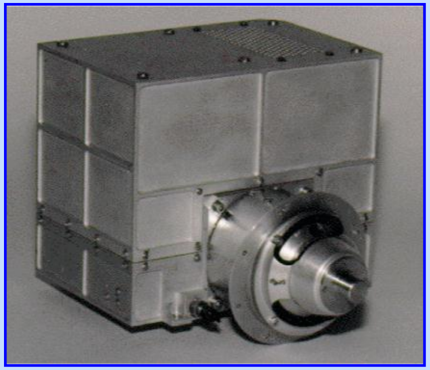
Diffuse X-ray Spectrometer





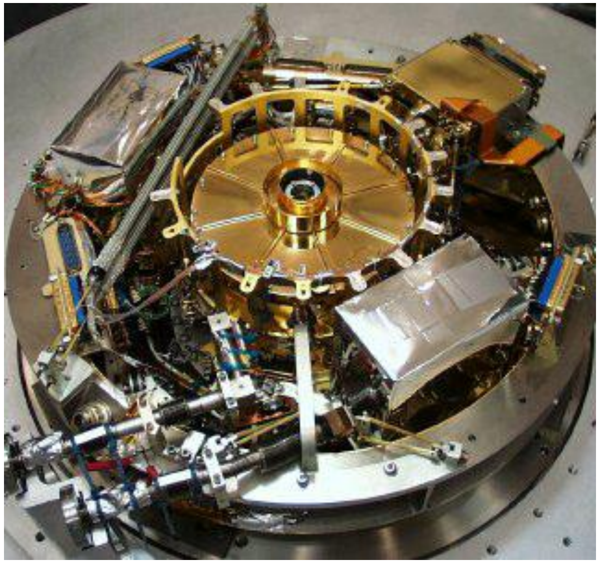
STS-54
1993

Net Flux Radiometer



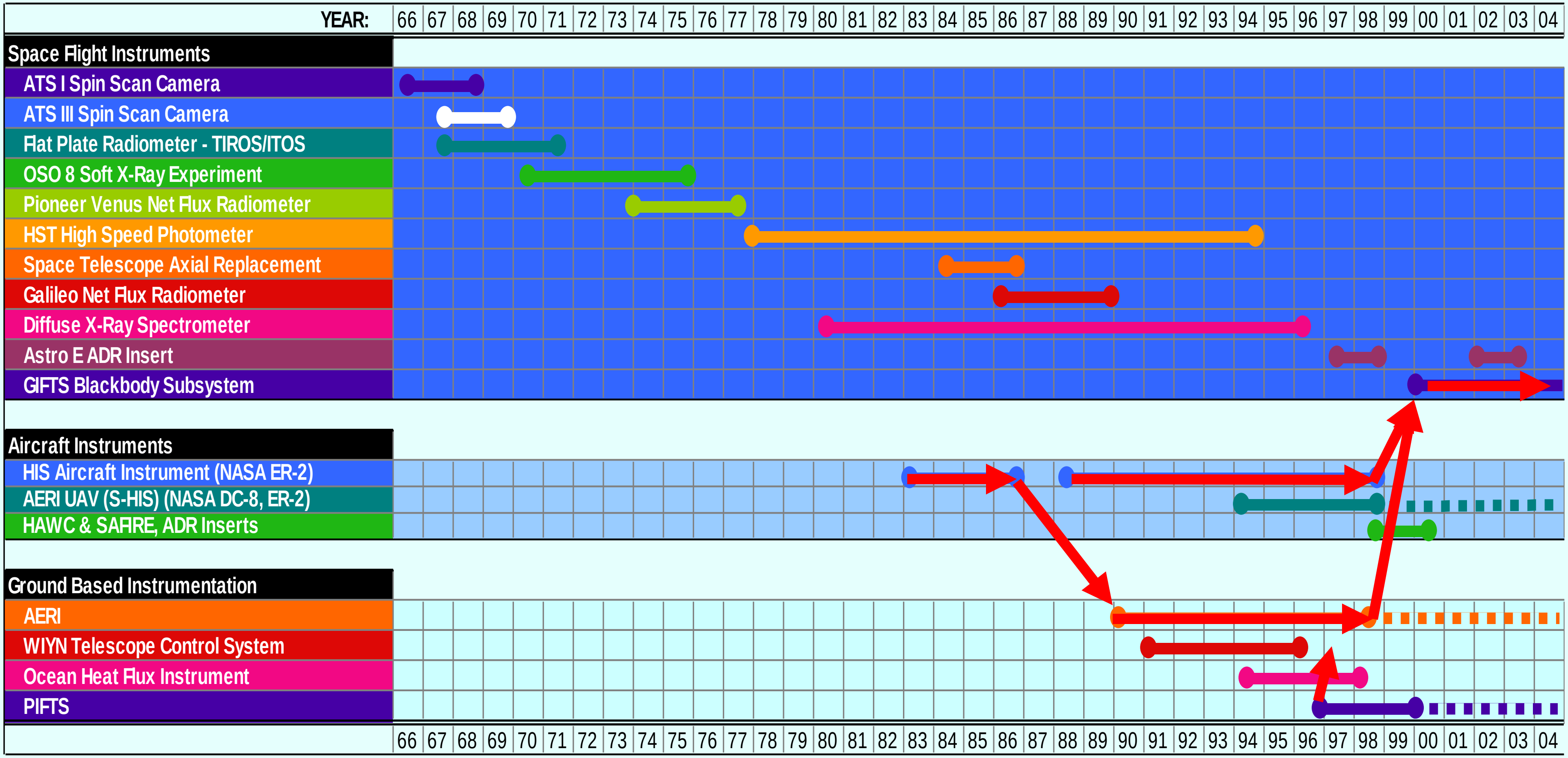
Galileo Entry Probe
7 December 1995

For ASTRO-E & E2 X-Ray Spectrometer



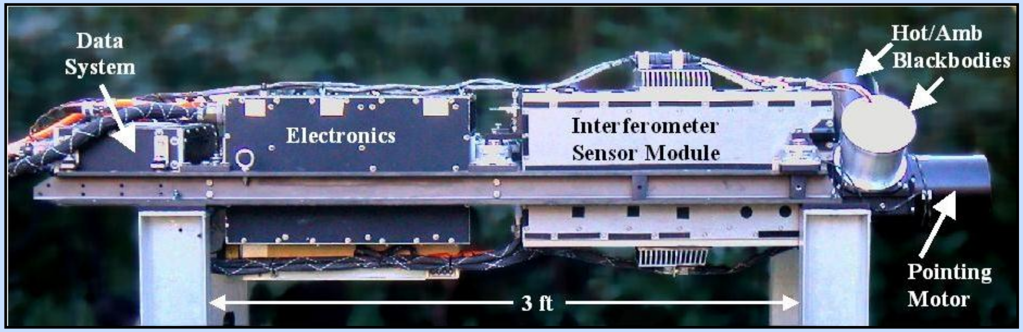
Holds detectors at 0.06 K

UW FTIR Radiometric Calibration Heritage



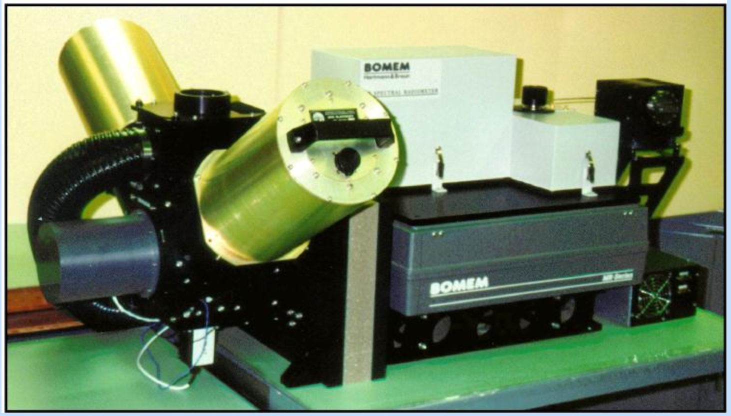
SSEC Aircraft and Ground-based IR

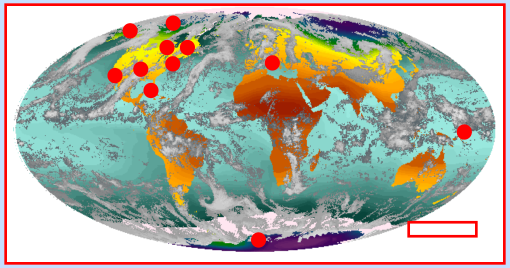
Scanning HIS
(High-resolution Interferometer Sounder)



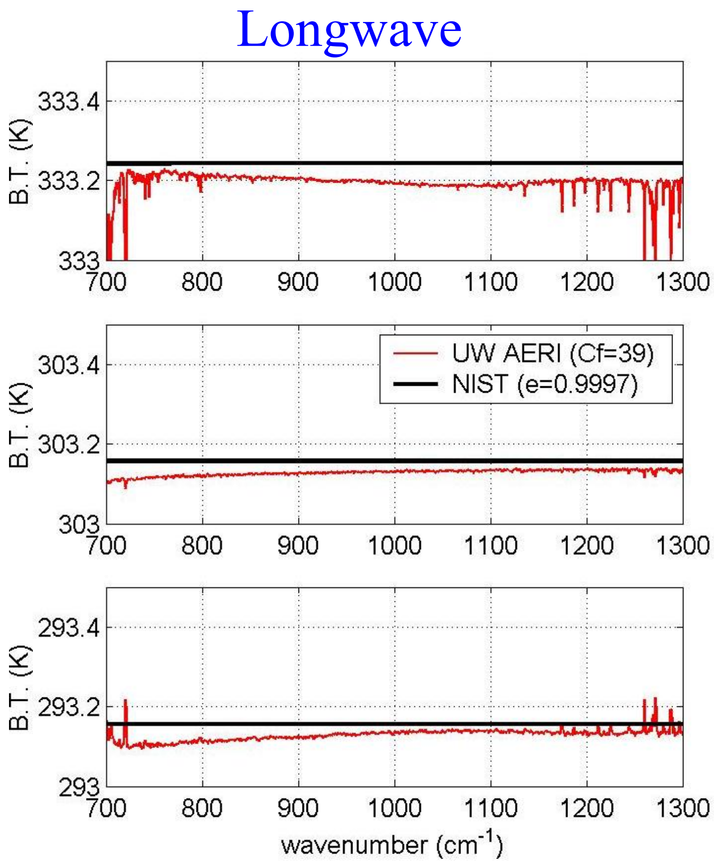
NASA DC-8 & ER2

AERI
(Atmospheric Emitted Radiance Interferometer)



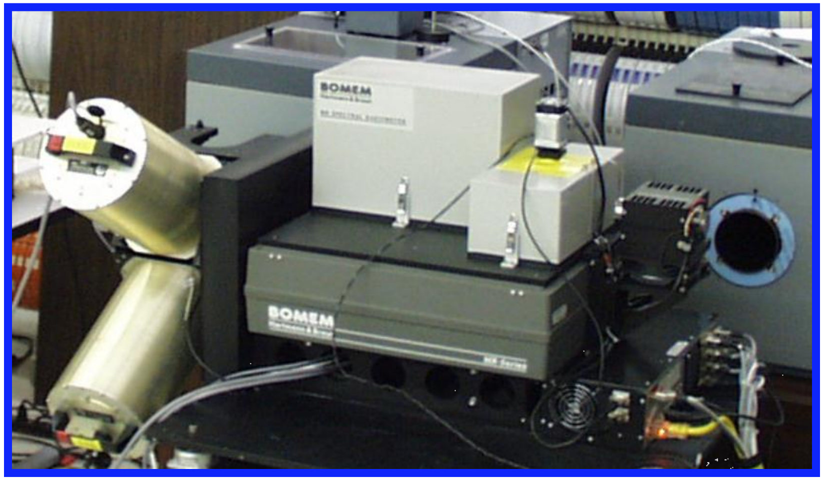


MAERI Intercomparison With NIST Blackbody



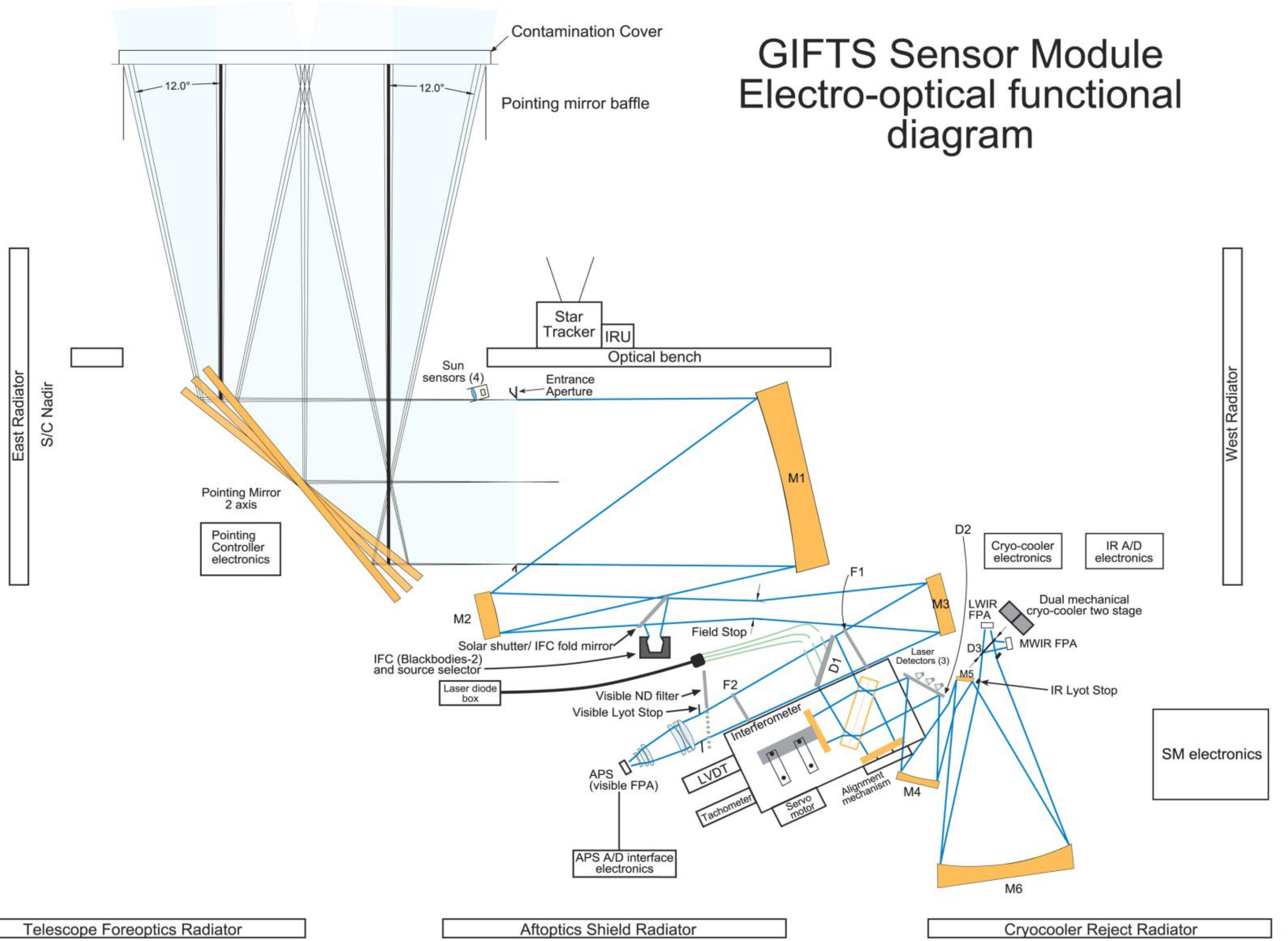
Max Error @ 333 K <0.055K
Max Error @ 303 K <0.050K
Max Error @ 293 K <0.050K

Miami IR Workshop: 3-4 March 1998



NIST has since procured a MAERI instrument to be used as a Radiance transfer standard

GIFTS Electro-optical Diagram



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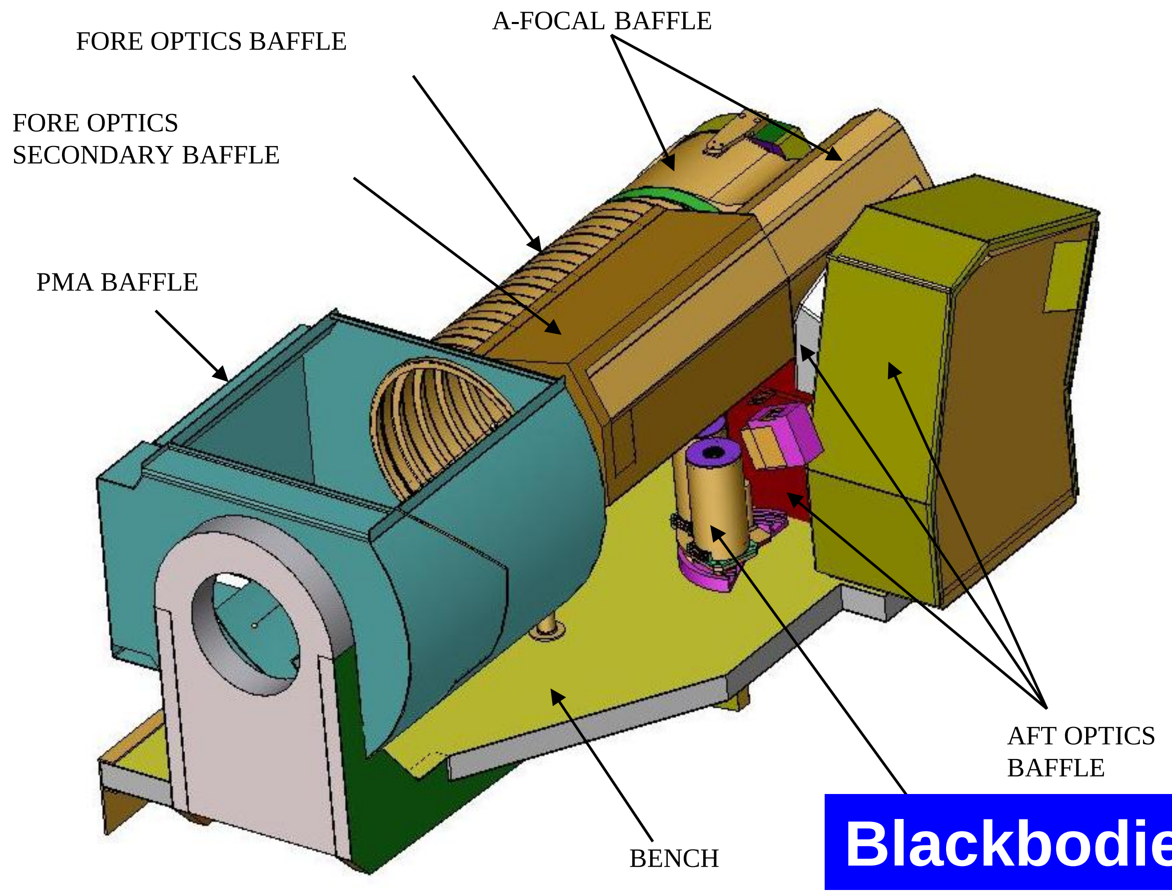
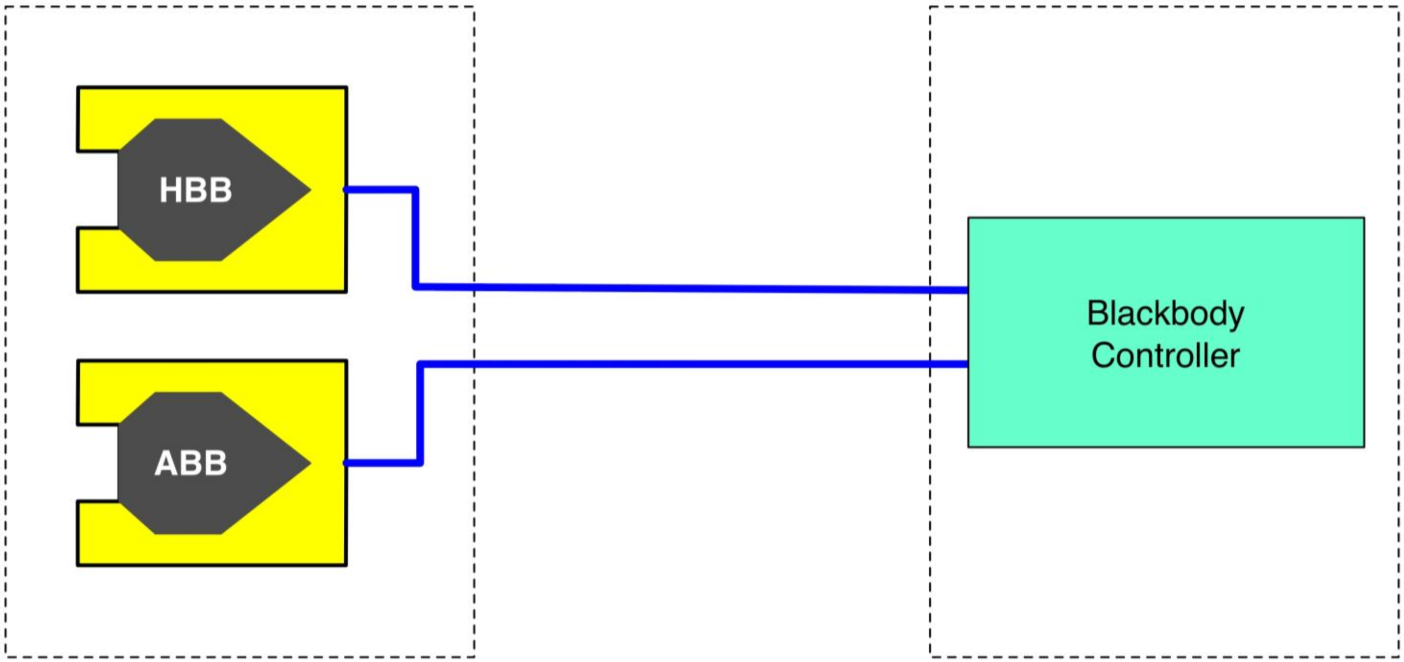
GIFTS Sensor Module



Blackbodies

Aperture stop image at blackbody aperture

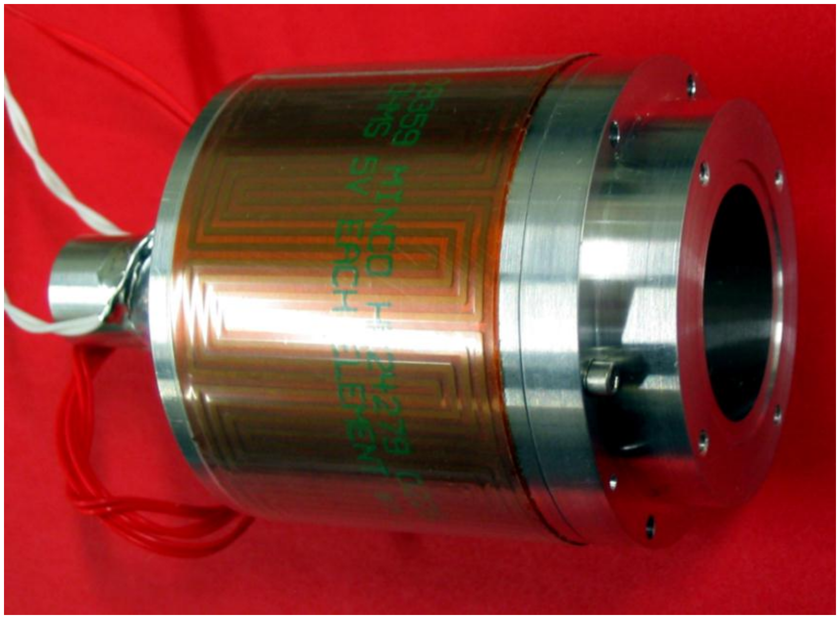
Top Level Block Diagram

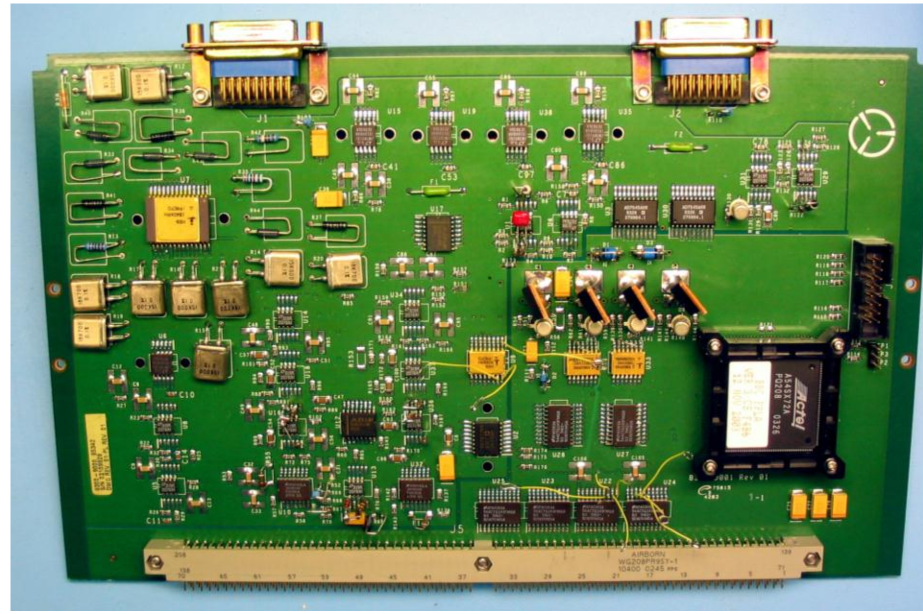


Sensor Module Optics Bench

Sensor Module Electronics Box

Engineering Model Testing





Blackbody Cavity

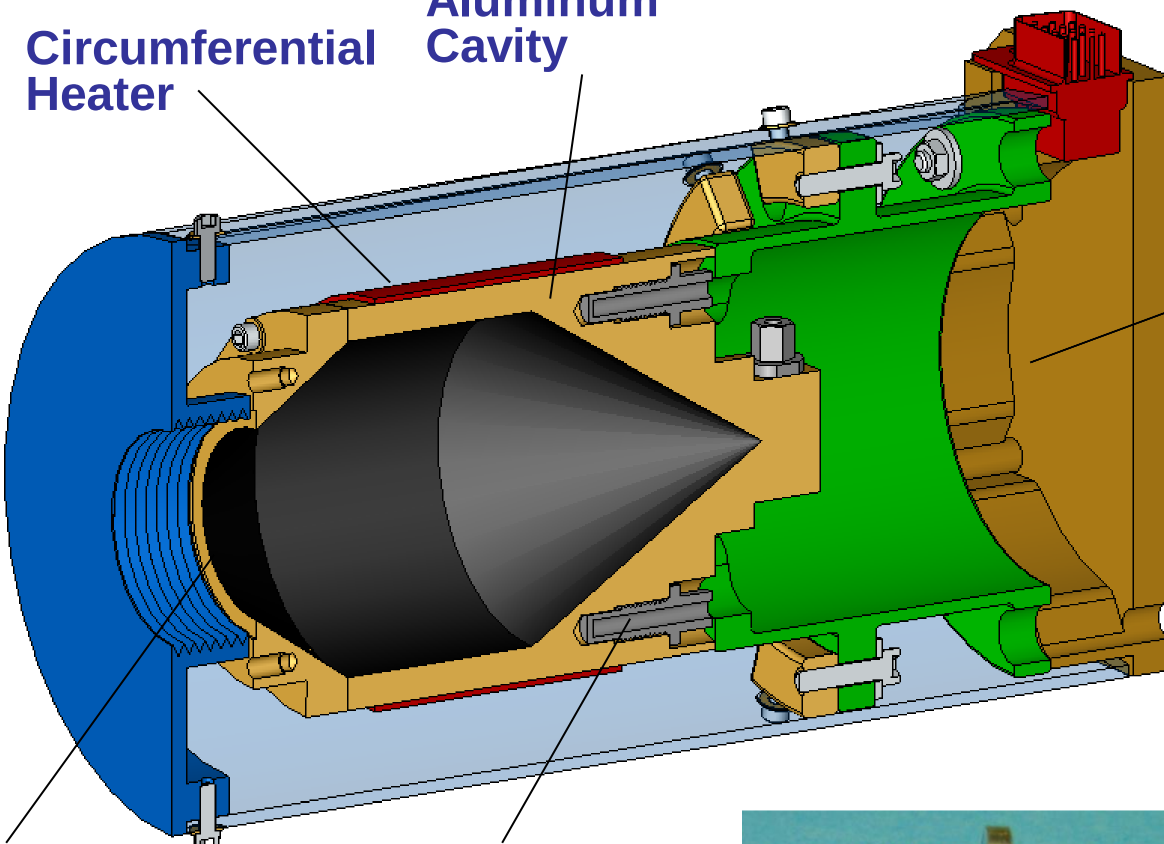
Controller Electronics Engineering Model

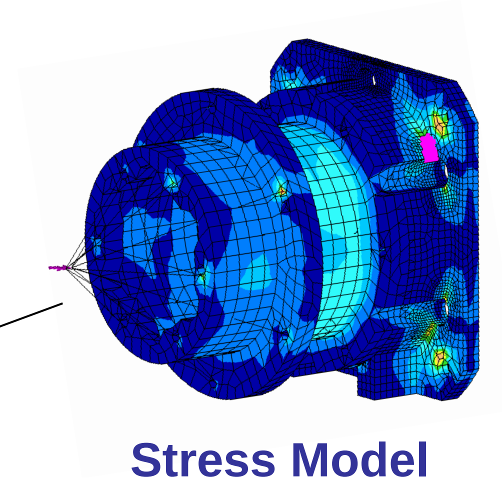
Temperature Sensors

Blackbody Overview

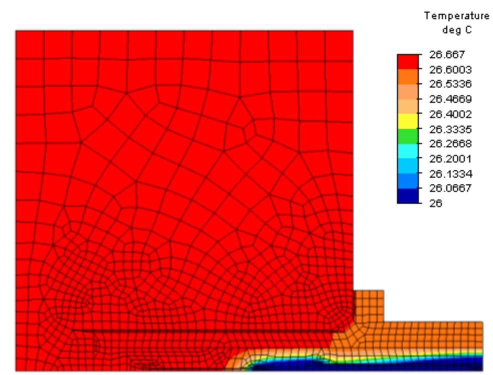
Circumferential Heater

Aluminum Cavity





Stress Model of Base



Blackbody Aperture (1”)

Temperature Sensors

Thermal Model of Installed Sensor

Program Status

- Detailed Design Complete
- Controller Board
  - Breadboard fabricated and tested and meets requirements.
  - Engineering Model -1 fabricated & tested and meets requirements.
  - Engineering Model-2 (closely represents flight) fabricated & ready for test.
  - Flight parts ordered.
- Blackbody
  - Detailed mechanical and thermal design complete and supported by detailed analysis.
  - Engineering Model cavity used for controller testing.
  - Engineering Model thermistors tested using EM cavity.

Key Changes Since PDR

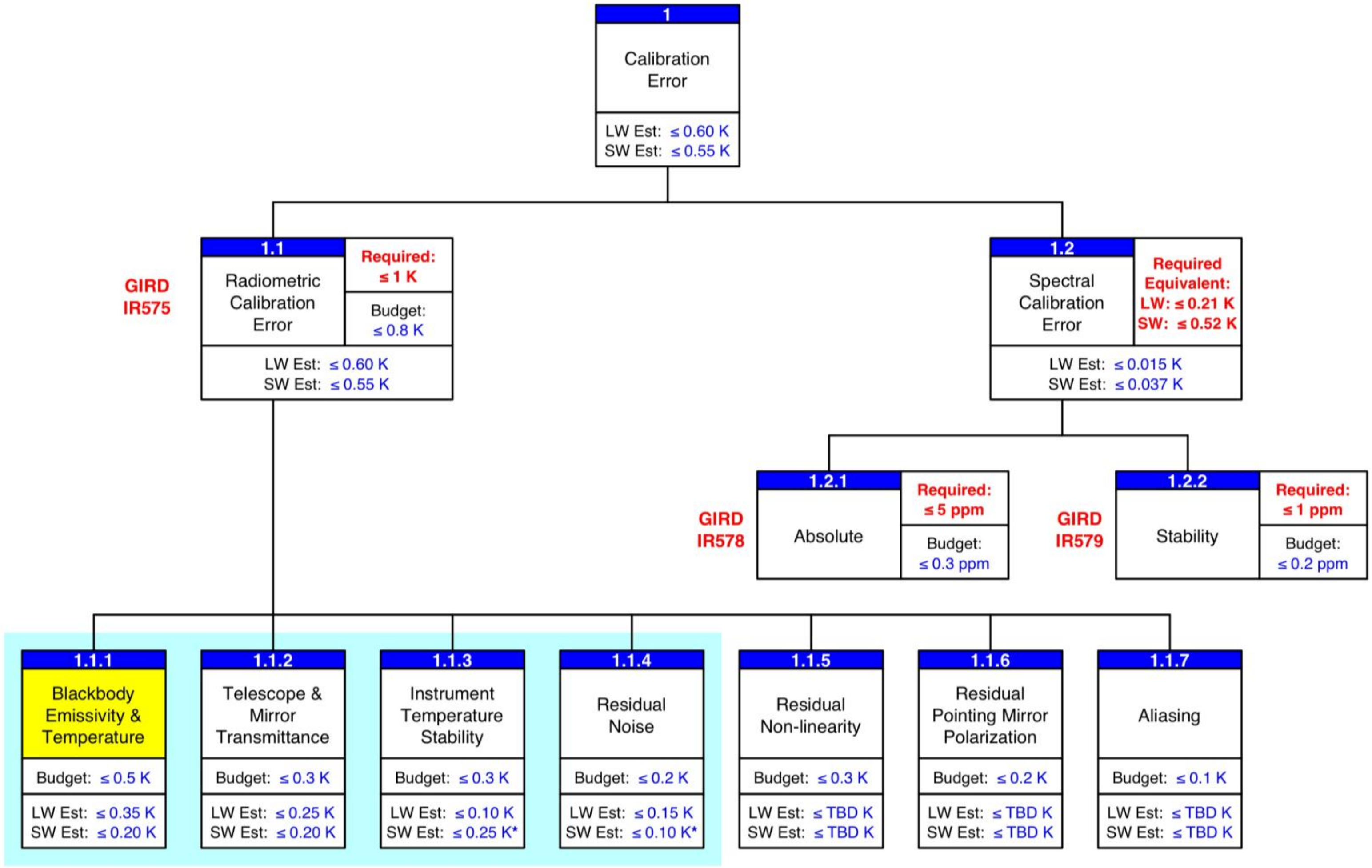
- Thermal interface significantly changed:
  - At PDR the surrounding environment was isothermal and at 265 K.
  - Current baseline is that we are mounted to a 200 K bench, with a restriction on heat loss to the bench (<0.5 W), and with variable baffle temperatures (140 K to 300 K)
  - A survival temperature of 180 K was defined.
- Thermal and mechanical design was modified to accommodate the above.
- Temperature control added to both blackbodies.
- Maximum total power increased from 3.0 to 5.2 W.
- Nominal set point temperature lowered 10 K: HBB is now 290 K, ABB is now 255 K.
- Thermistors were selected to take advantage of SABER program heritage.

GIFTS System Calibration Requirements Flowdown

Hank Revercomb

9 March 2004

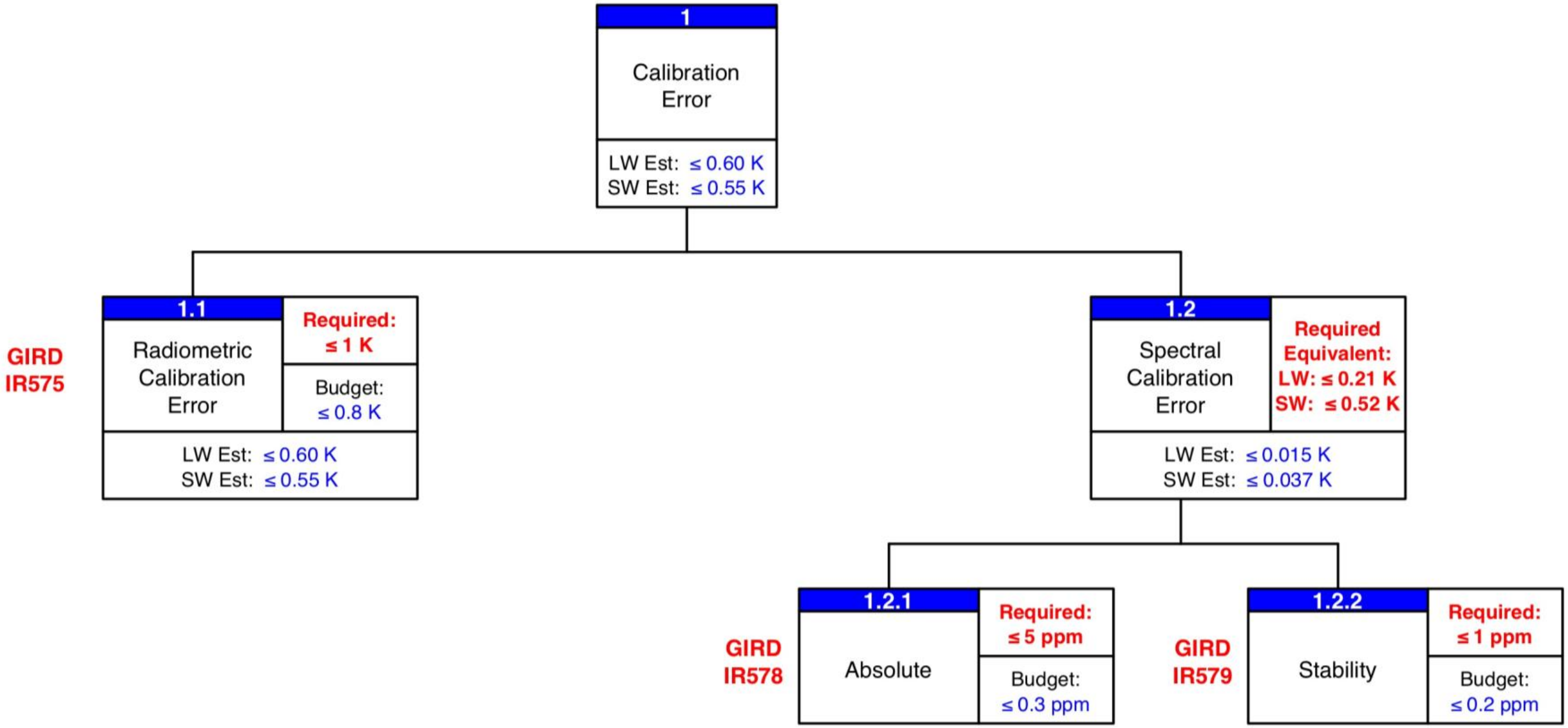
GIFTS Overall Absolute Calibration Budget



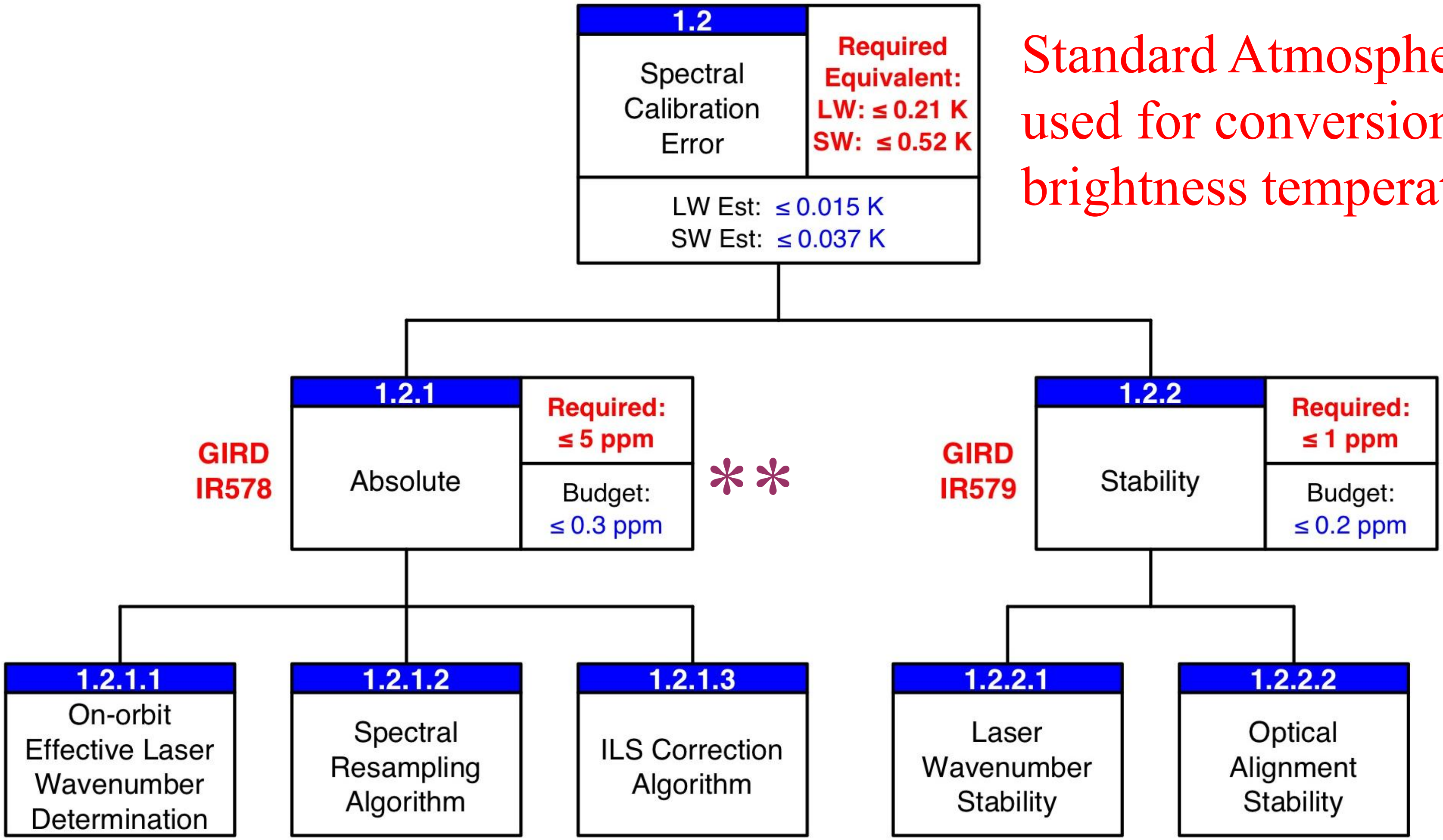
Notes:
* : @ 220 K Scene Temperature

Subject of BB CDR

GIFTS Top-level
Absolute Calibration Budget



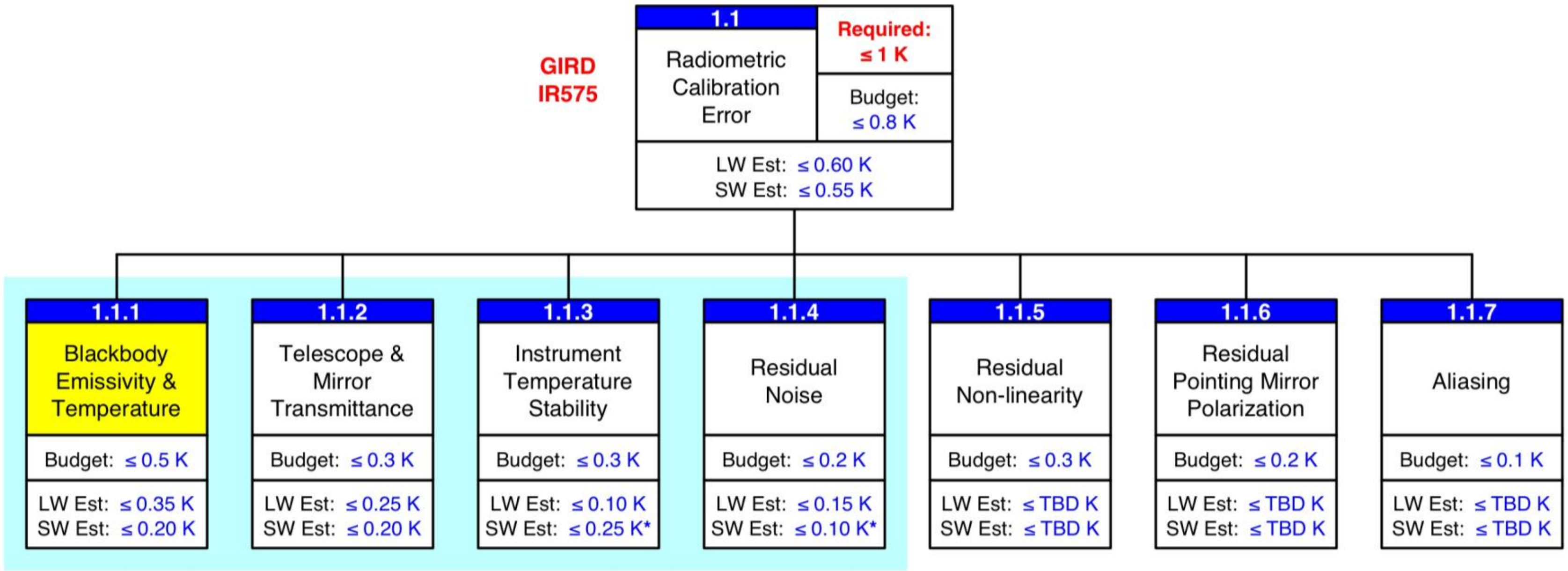
GIFTS Spectral Calibration Budget



Standard Atmosphere used for conversion to brightness temperature

**3-sigma for single sample is 3 ppm-100 sample average assumed

GIFTS Radiometric Calibration Budget (Absolute)



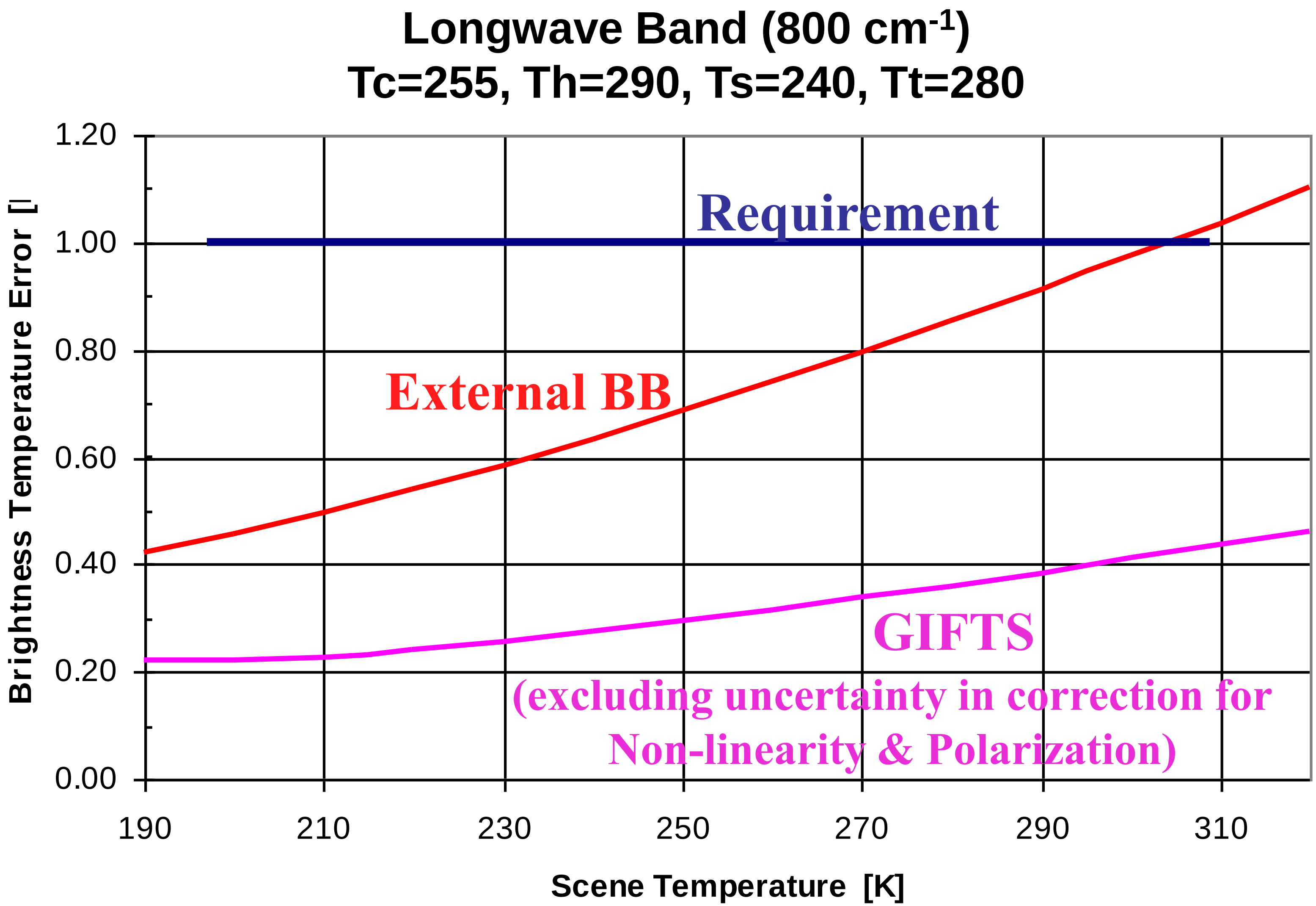
Notes:
* : @ 220 K Scene Temperature

GIFTS Radiometric Calibration Equation: Basis for Uncertainty Modeling

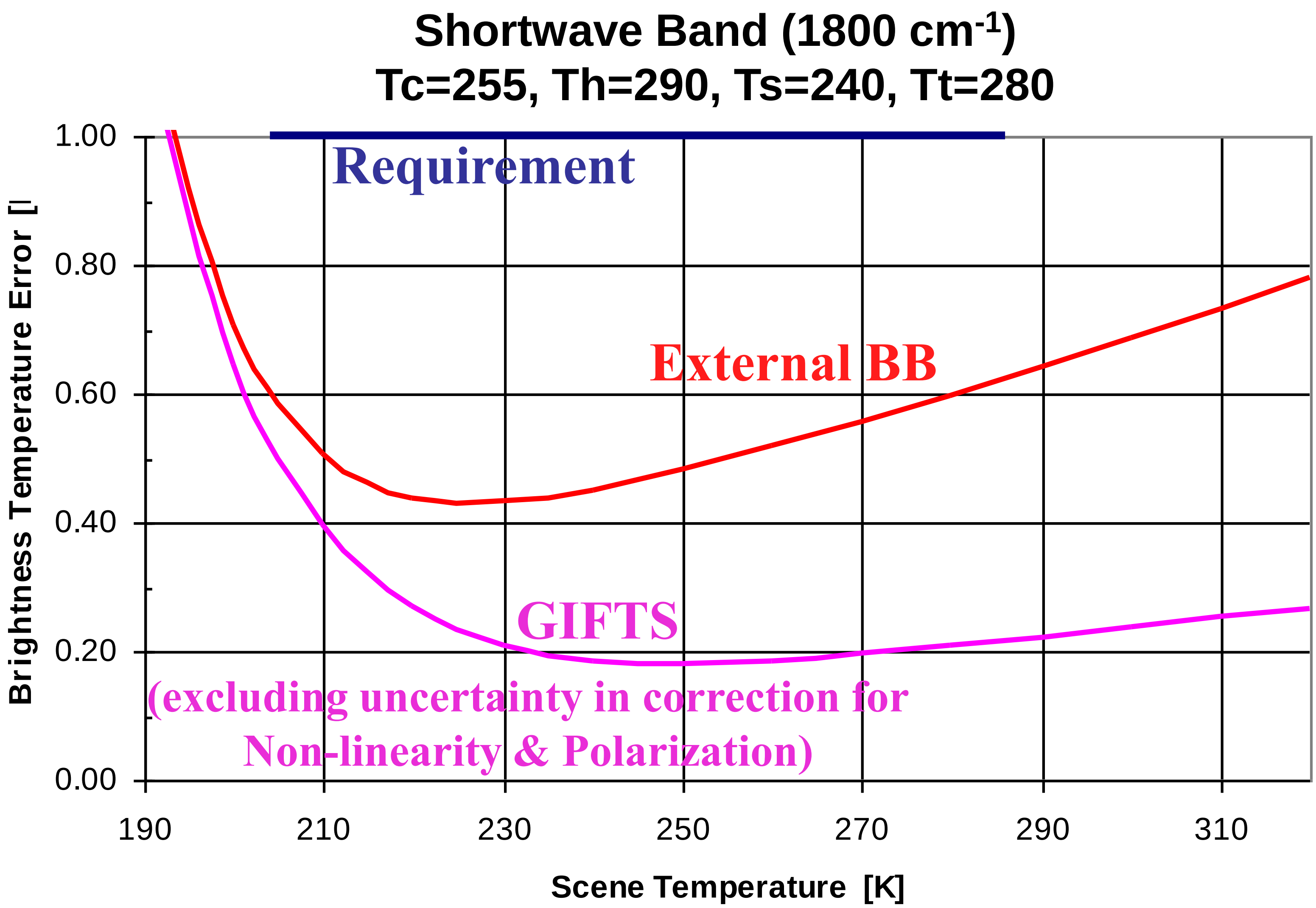
$$N = \left(\frac{\tau_m}{\tau_t}\right)(B_H - B_C)\,\mathrm{Re}\left(\frac{C_E - C_S}{C_H - C_C}\right) + B_S$$

- Radiance N derived from raw spectra of Earth (C_E), Space (C_S), and the internal Hot (C_H) and Cold (C_C) Blackbodies
- τ_t is the signal transmission of the telescope mirrors & τ_m is the transmission of the Blackbody pick-off mirror
- B_i is the Radiance from the Hot, Cold, and Space References [eg. $B_H = \varepsilon_H B(T_H) + (1-\varepsilon_H) B(T_{str})$, where B(T) is the Planck function and Tstr is the effective structure temperature for reflection]

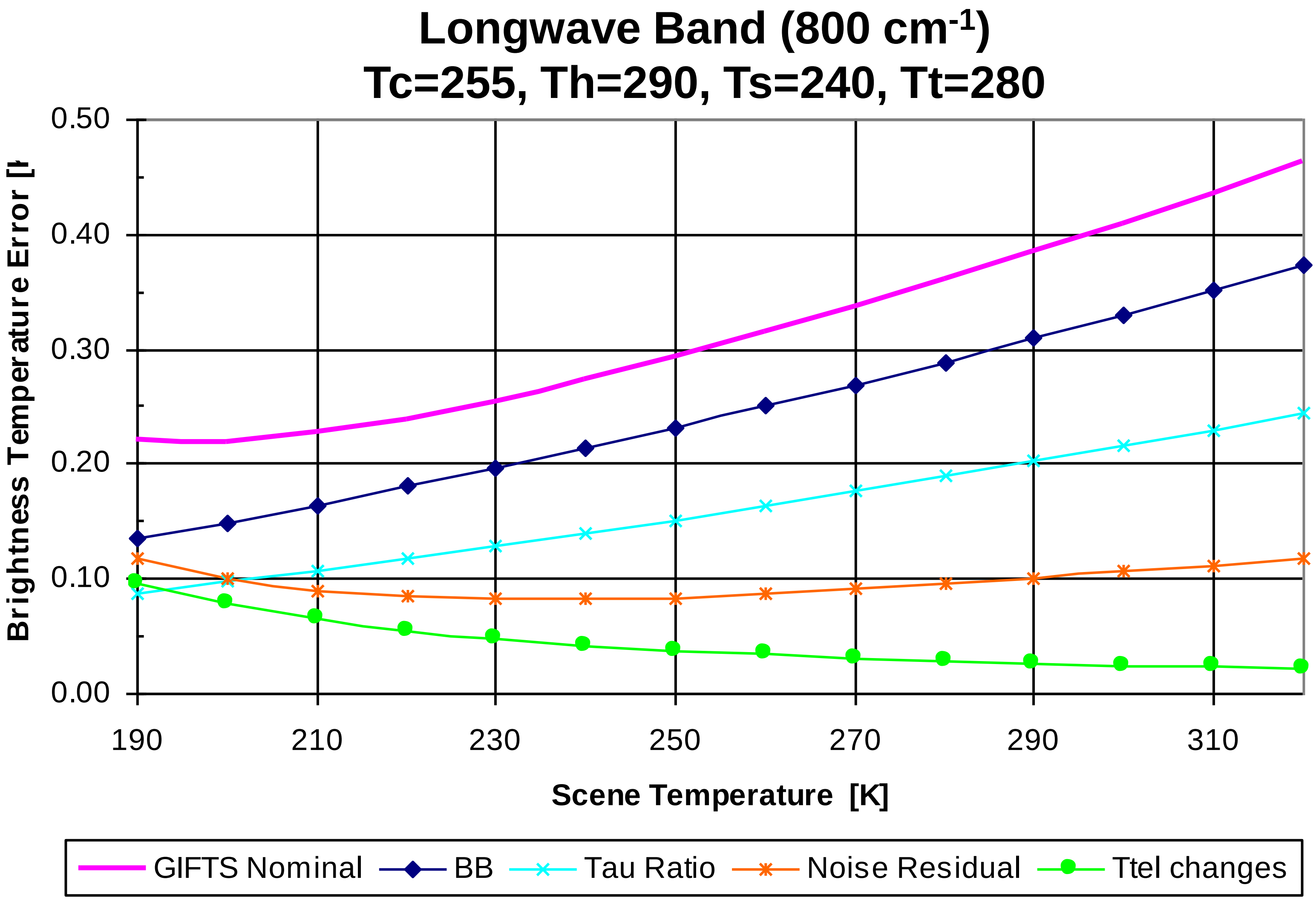
GIFTS Absolute Calibration-Longwave



GIFTS Absolute Calibration-Shortwave

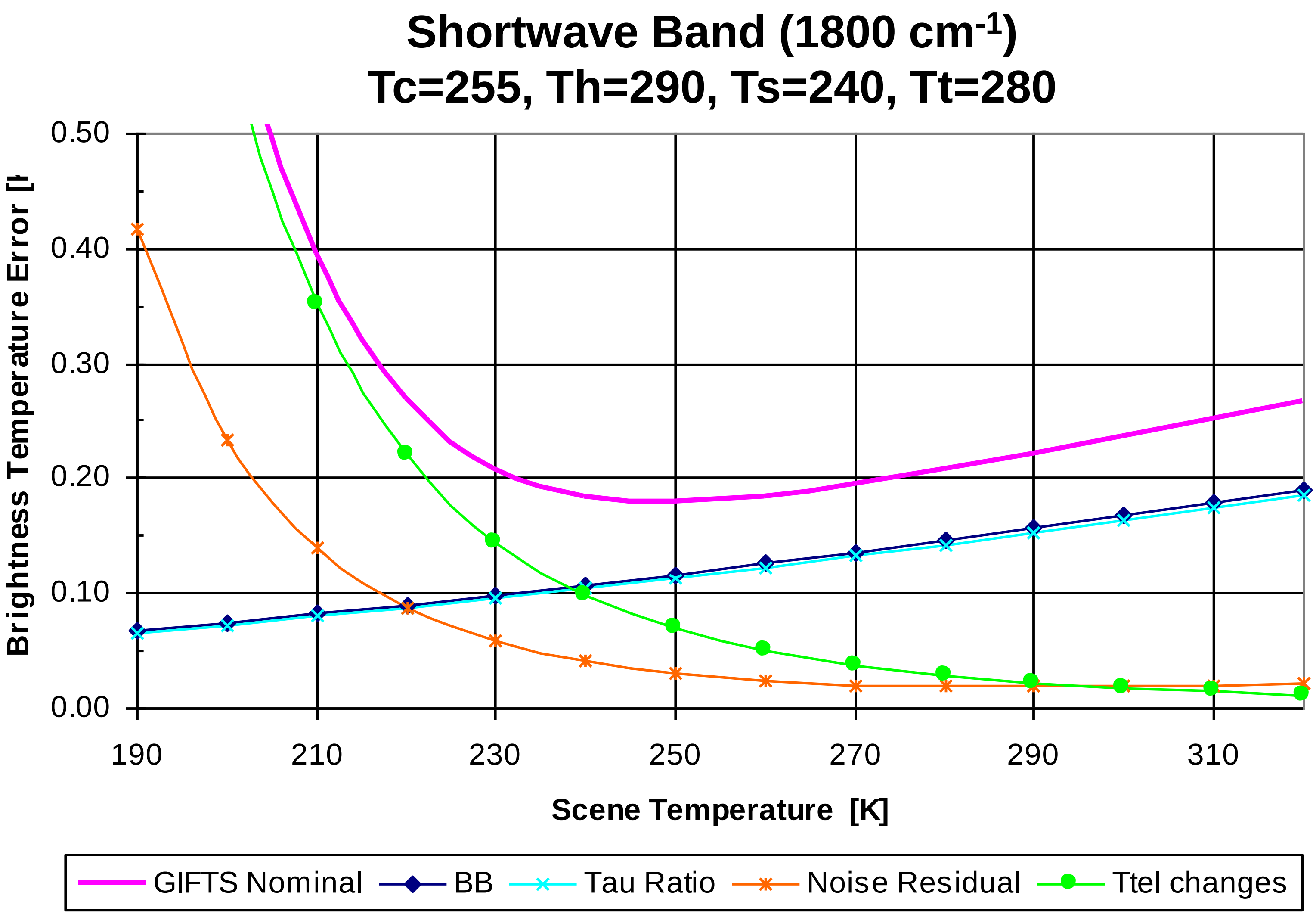


GIFTS Calibration Error Sources-LW



0.3% NEN/4=0.05 0.3 K

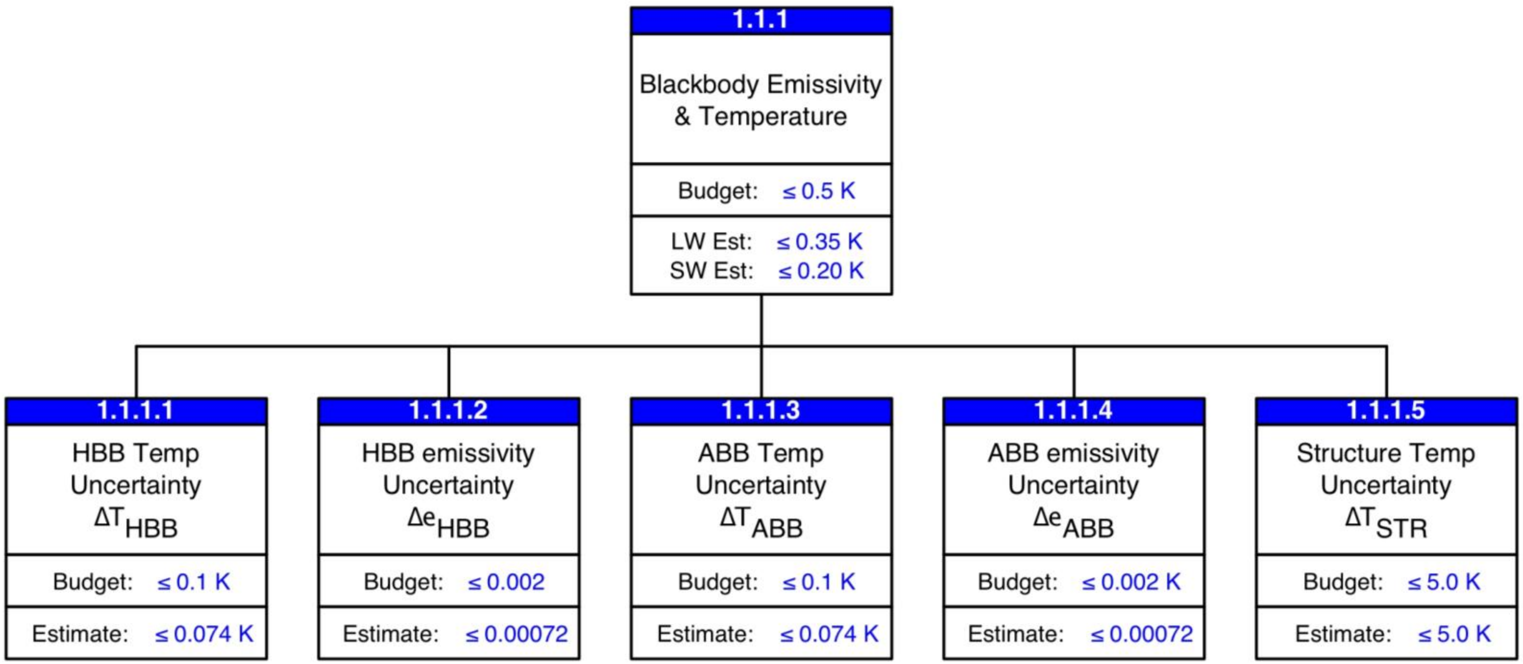
GIFTS Calibration Error Sources-SW



0.5% NEN/4=0.0025 0.3 K

GIFTS Blackbody Budget

Subject of this BB Subsystem CDR:
Budget is 0.5 K 3-sigma Absolute &
0.1 K 3-sigma Reproducibility, by analogy



GIFTS
Blackbody Subsystem
Critical Design Review
Blackbody Requirements Flowdown

Fred Best

9 March 2004

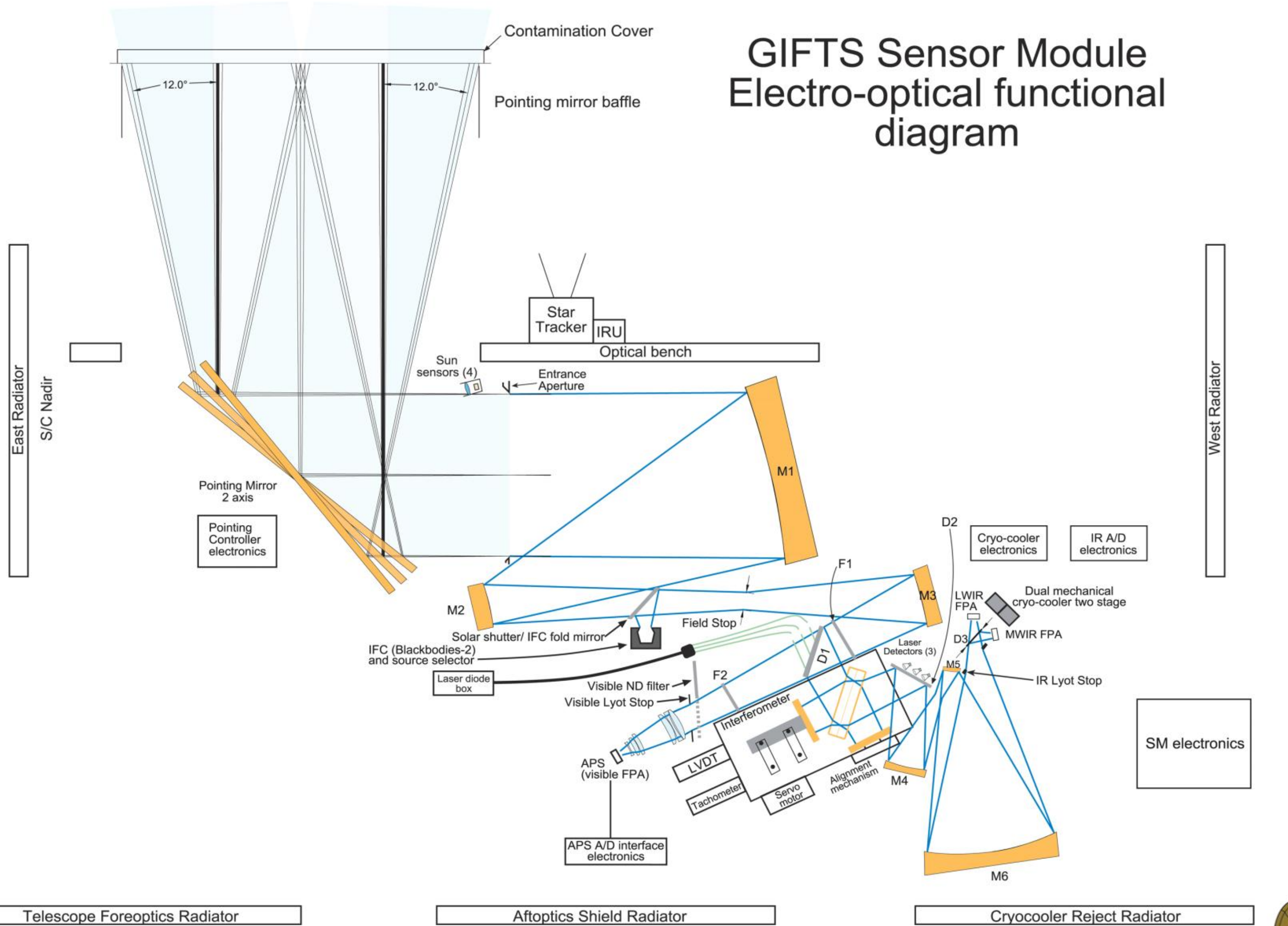
Topics

- GIFTS Calibration Scheme
- Flowdown of requirements
- Blackbody Error Contributions to GIFTS Calibration
- Overview of Top Level BB Subsystem Specifications

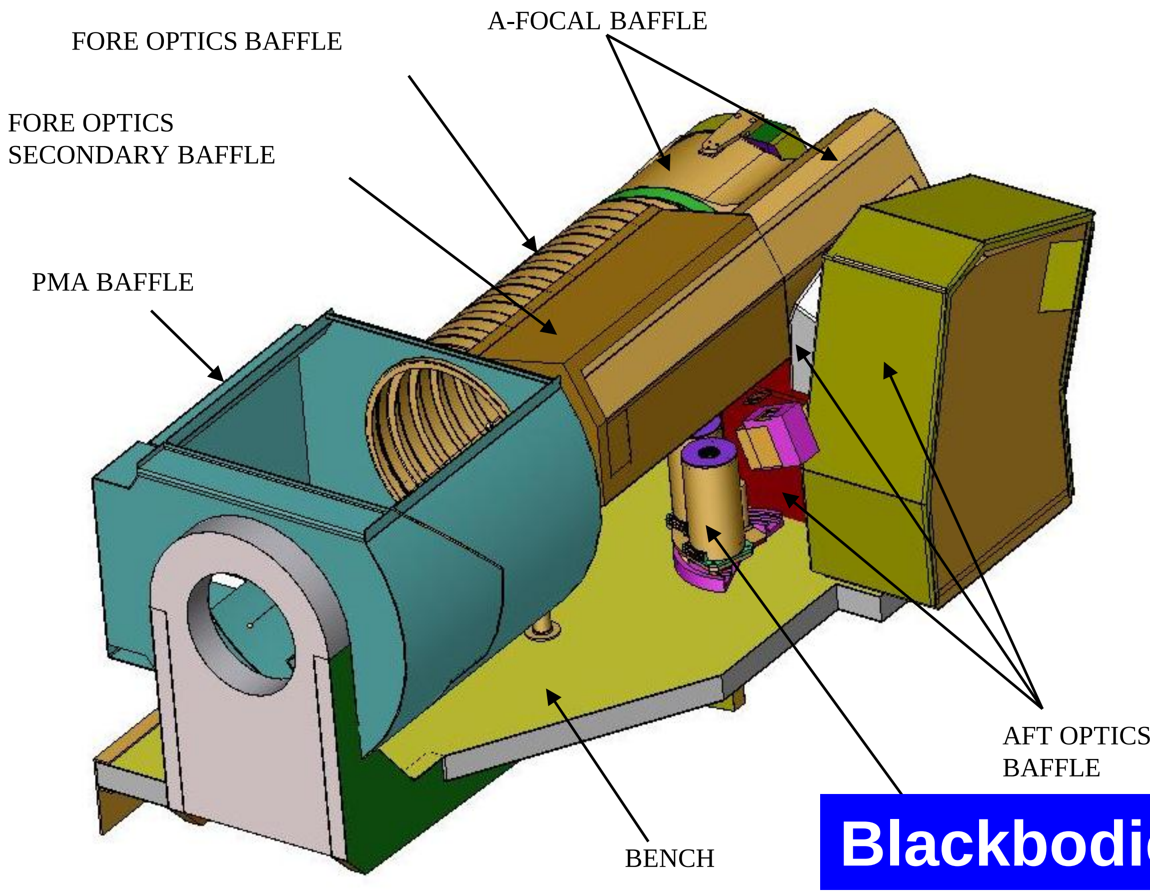
GIFTS Radiometric Calibration Concept

- Two small reference Blackbodies located behind telescope, combined with Space View.
- Blackbody design is scaled from the UW ground-based AERI and NAST / S-HIS aircraft instruments.
- Constraints on original S/C prevented traditional external large aperture blackbody configuration.
- Advantages compared to large external blackbody:
  (1) higher emissivity is practical with small size
  (2) protection from solar forcing.

GIFTS Electro-optical Diagram



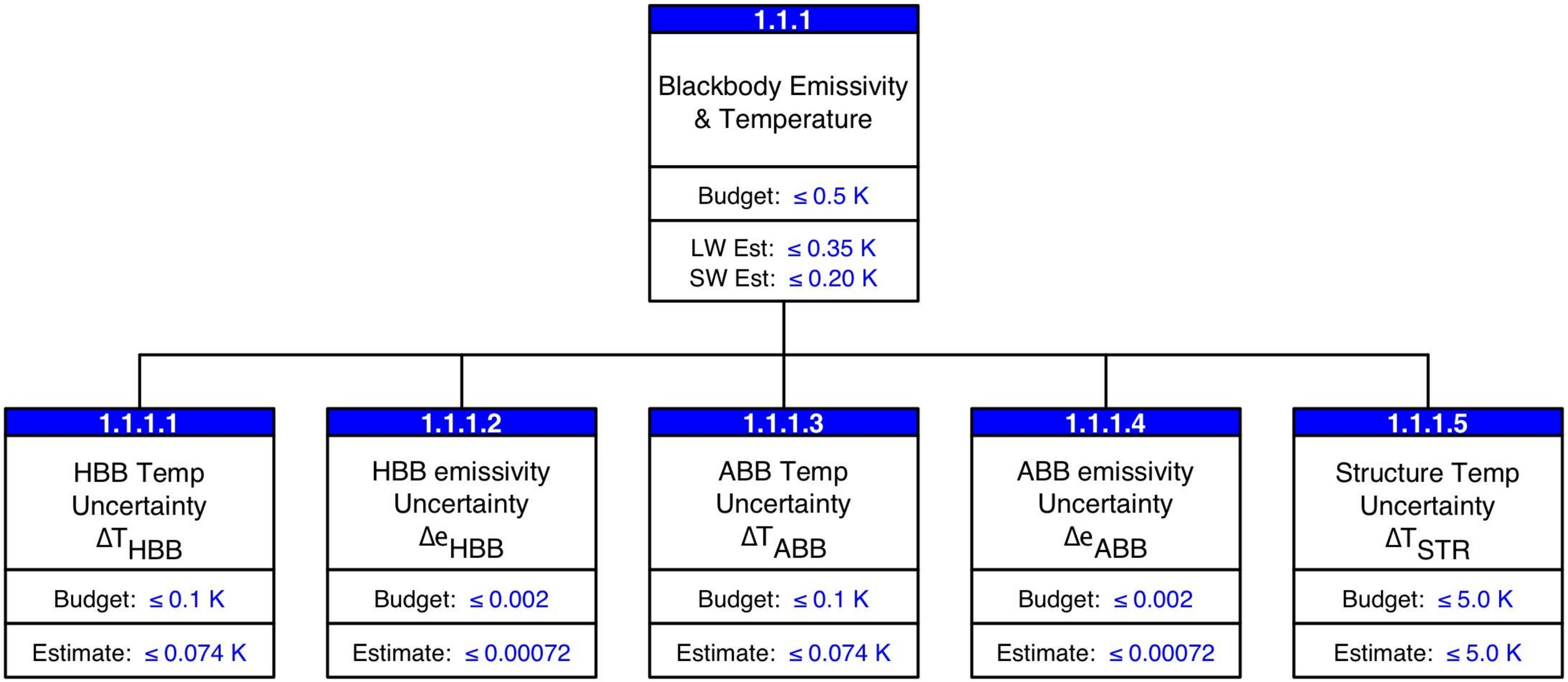
GIFTS Sensor Module



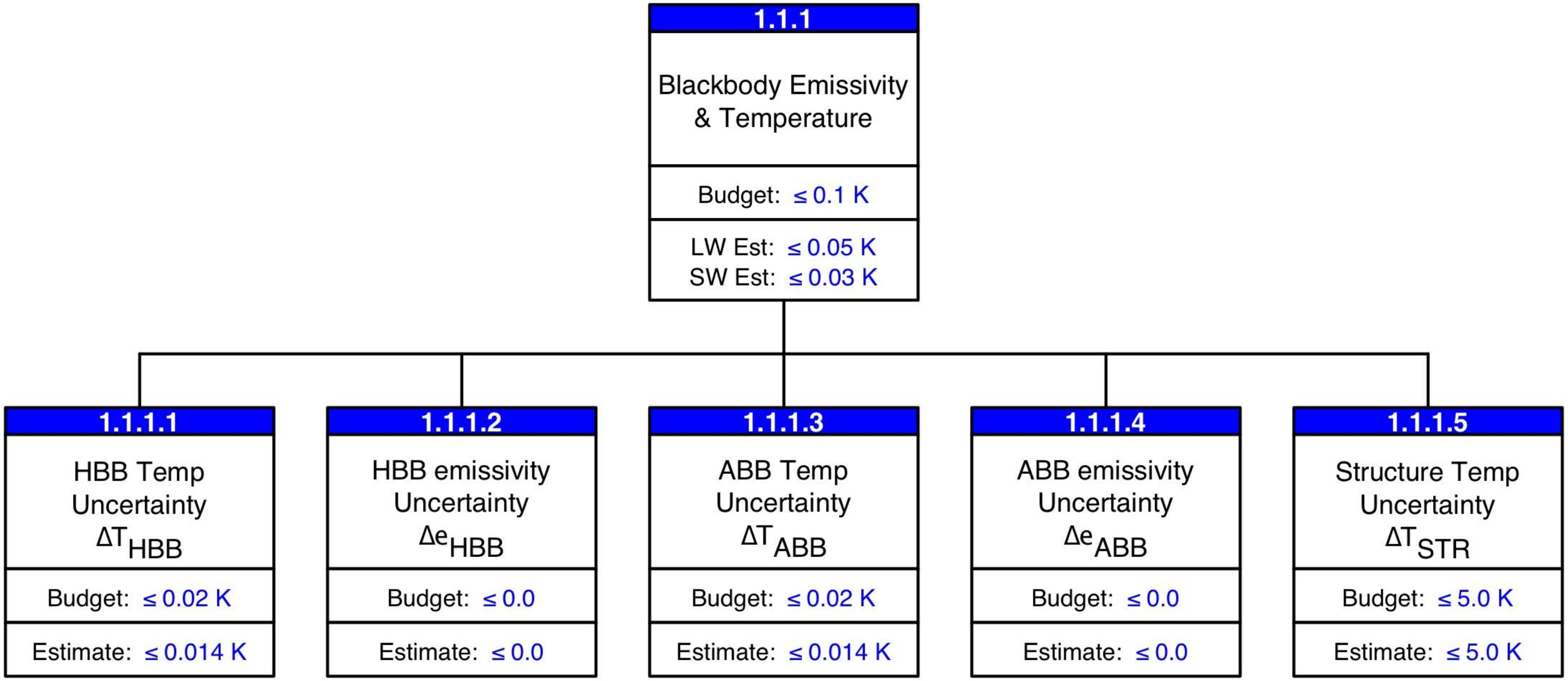
Blackbodies

Aperture stop image at blackbody aperture

GIFTS Blackbody Absolute Calibration Budget



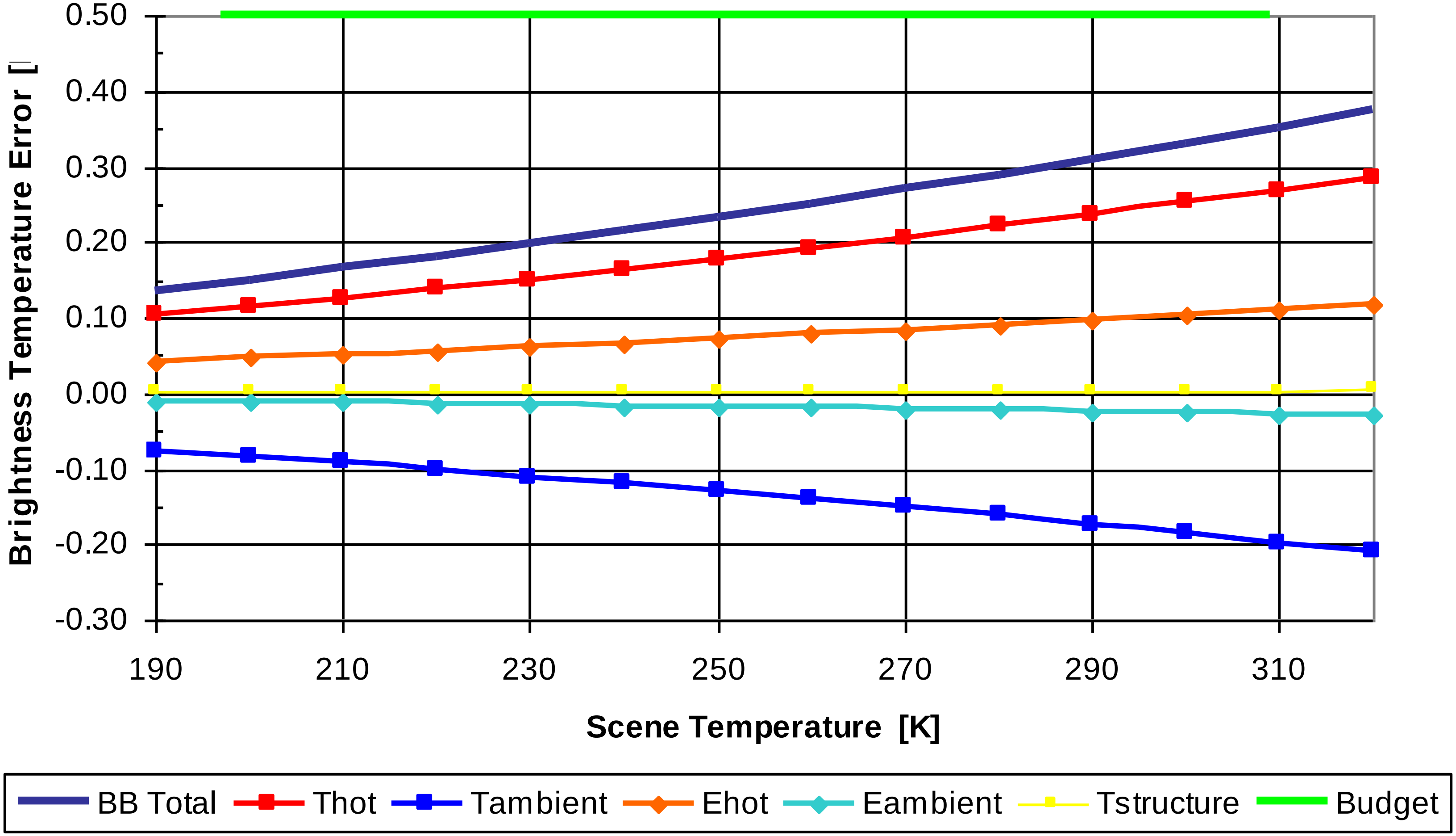
GIFTS Blackbody Reproducibility Calibration Budget



GIFTS Blackbody Error Sources-LW

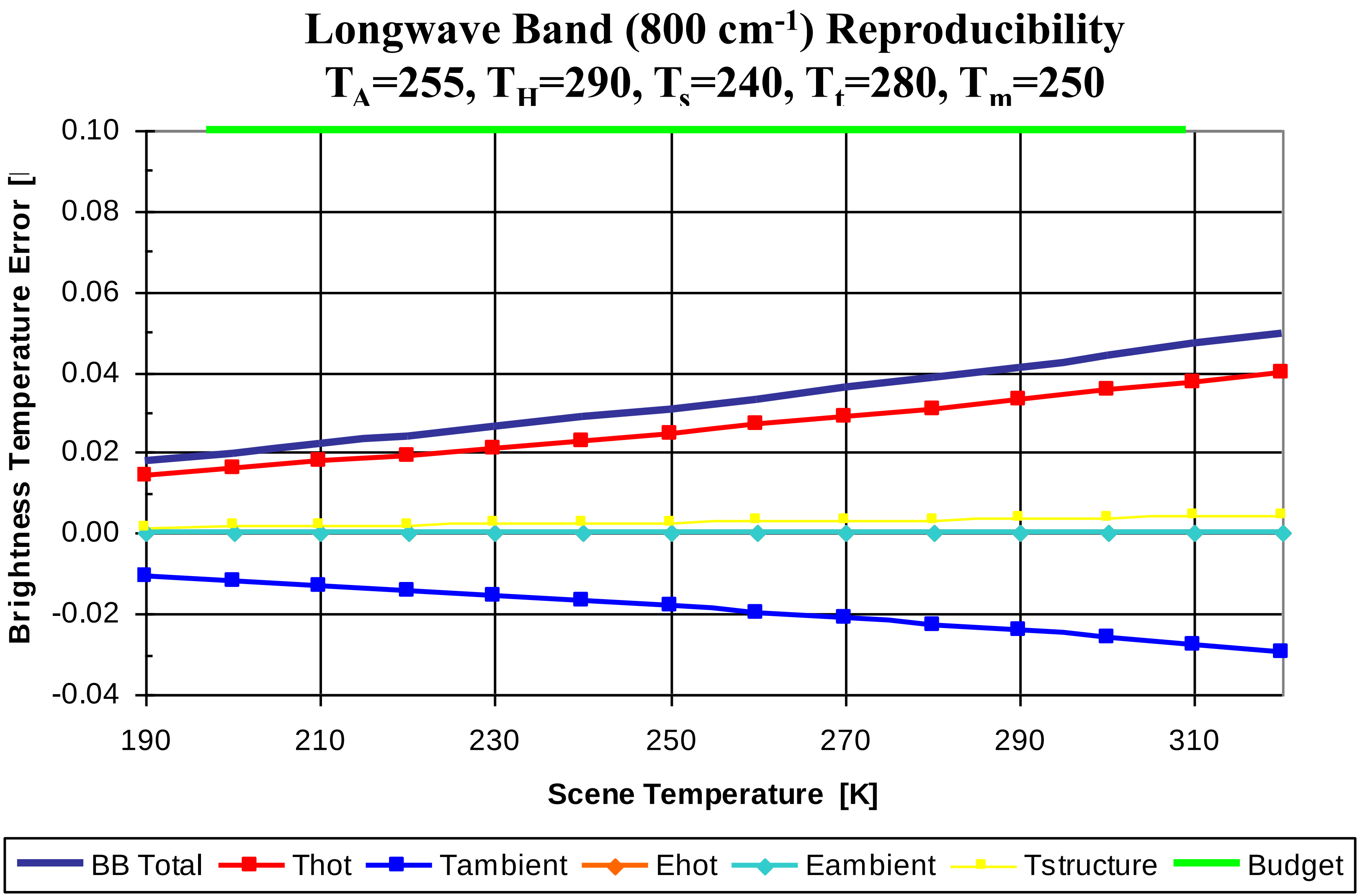
Longwave Band (800 cm^{-1}) Absolute

T_A=255, T_H=290, T_s=240, T_t=280, T_m=250



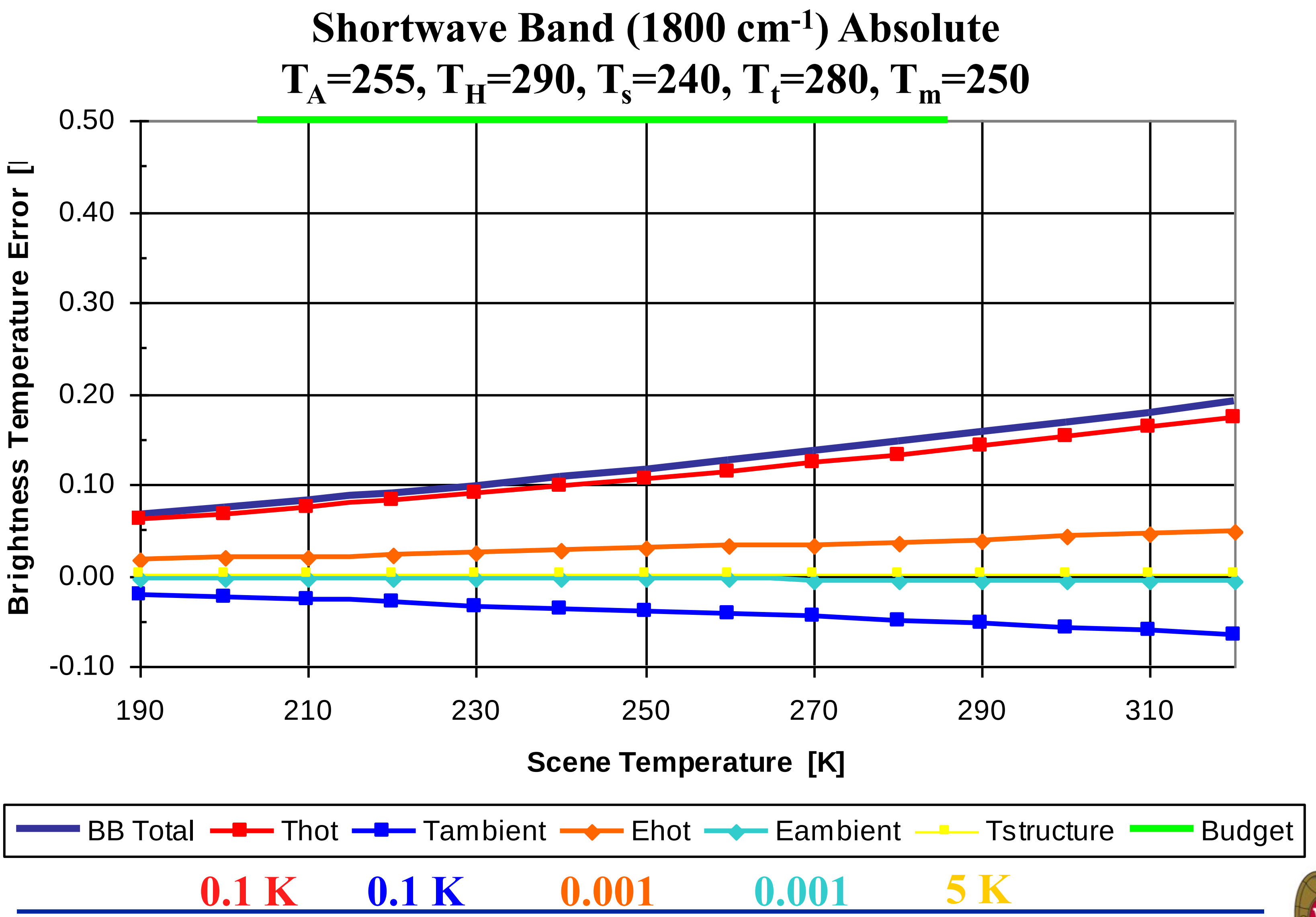
0.1 K 0.1 K 0.001 0.001 5 K

GIFTS Blackbody Error Sources-LW

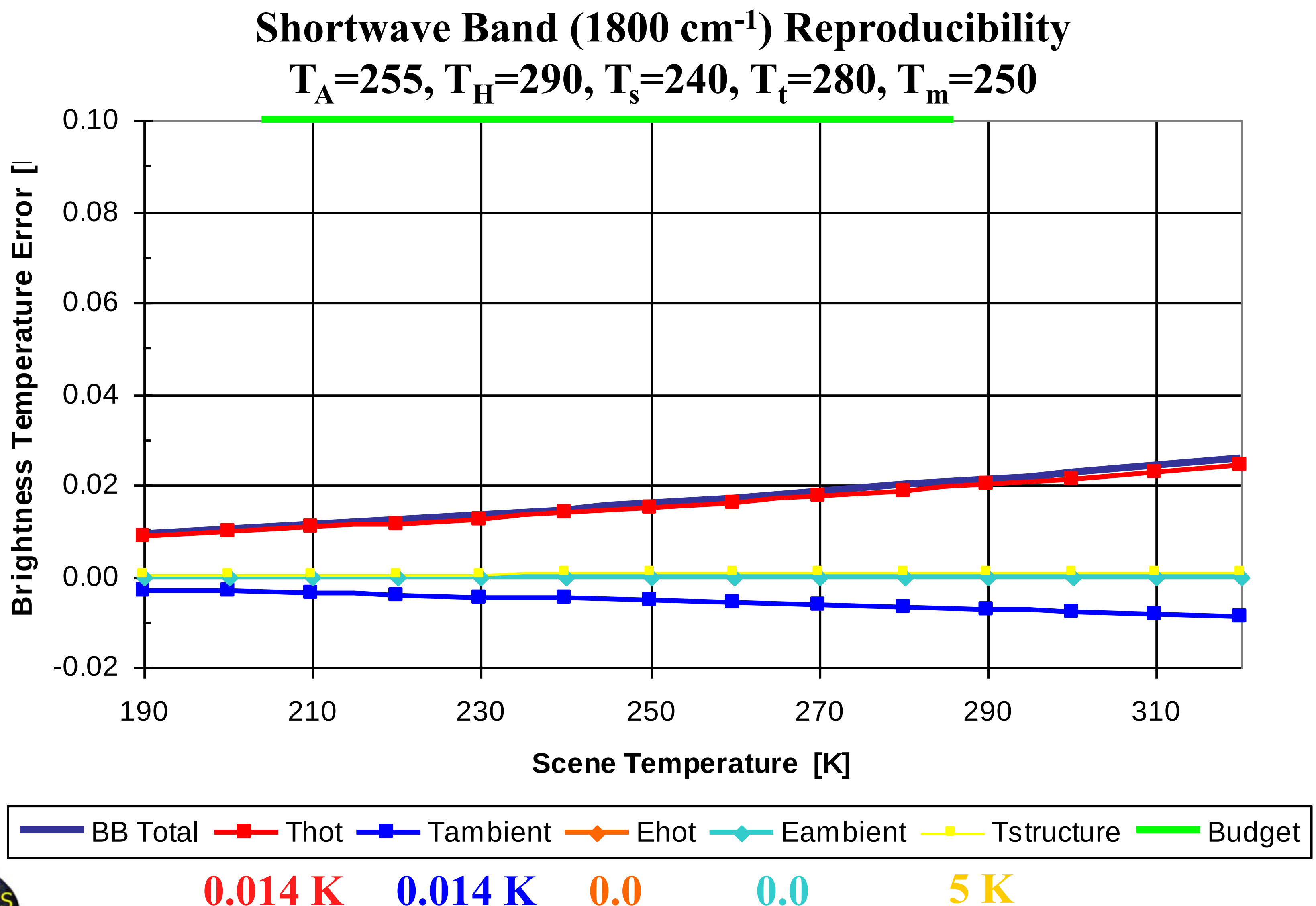


0.014 K 0.014 K 0.0 0.0 5 K

GIFTS Blackbody Error Sources-SW



GIFTS Blackbody Error Sources-SW



Summary of Top Level BB Requirements

	Specification*	Current Best Estimate
Ambient Blackbody Nominal Set Point	255 K	255 K
Hot Blackbody Nominal Set Point	290 K	290 K
Temperature Measurement Uncertainty	< 0.1 K (3 sigma)	< 0.074 K (3 sigma)
Ambient Blackbody Emissivity	> 0.996	> 0.998
Hot Blackbody Emissivity	> 0.996	> 0.998
Emissivity Uncertainty	< 0.002	< 0.00072 (3 sigma)
Wavelength	680 - 2,300 cm^{-1}	680 - 2,300 cm^{-1}

*Derived From GIRD Using Radiometric Model

Summary of Top Level BB Requirements

	Specification*	Current Best Estimate
Source Aperture	2.54 cm	2.54 cm
Source FOV (full angle)	> 10°	> 10°
Mass (two blackbodies plus controller board)	< 2.4 kg	< 2.1 kg
Power: average/max	< 2.2/5.2 W	< 2.2/5.2 W
Envelope	< 8 x 8 x 15.5 cm	< 8 x 8 x 15.4 cm

*Imposed by GIFTS Sensor Module Design

GIFTS
Blackbody Subsystem
Critical Design Review
Blackbody Controller

9 March 2004

Scott Ellington
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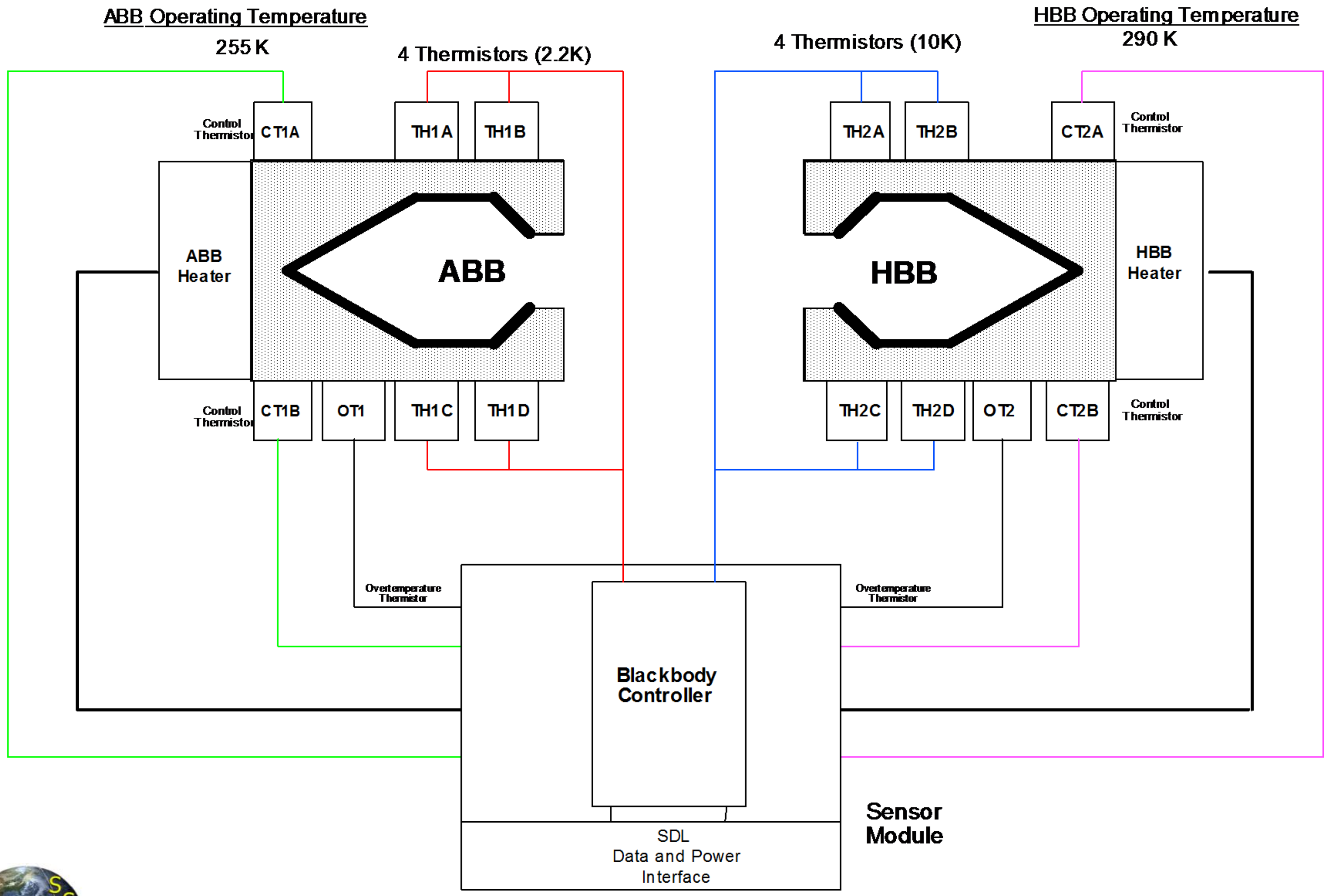
Blackbody Controller

- Performance Requirements and Design Overview
- Changes since PDR
- Controller Operation
- Electronics Error Budget
- Power Budget
- Supporting Analysis
- Part Selection
- Engineering Model Test Results
- Controller Verification Plan
- Calibration Overview

Subsystem Block Diagram



Key Electronics Requirements

- Blackbody Temperature Measurement
  - Hot Blackbody Range 0 to +40˚C
  - Ambient Blackbody Range -40 to 0˚C
  - Long-term accuracy ±0.03˚C (Electronics only)
  - Measurement Update Rate 2.7 Hz

- Blackbody Temperature Control
  - Constant Temperature and Constant Power Modes
  - HBB Control Temperature Range 0 to +40˚C
  - ABB Control Temperature Range -40 to 0˚C
  - Set Point Resolution ≤ 0.2˚C
  - Set Point Drift ≤ 0.005˚C, for a Controller board temperature change of 1°C

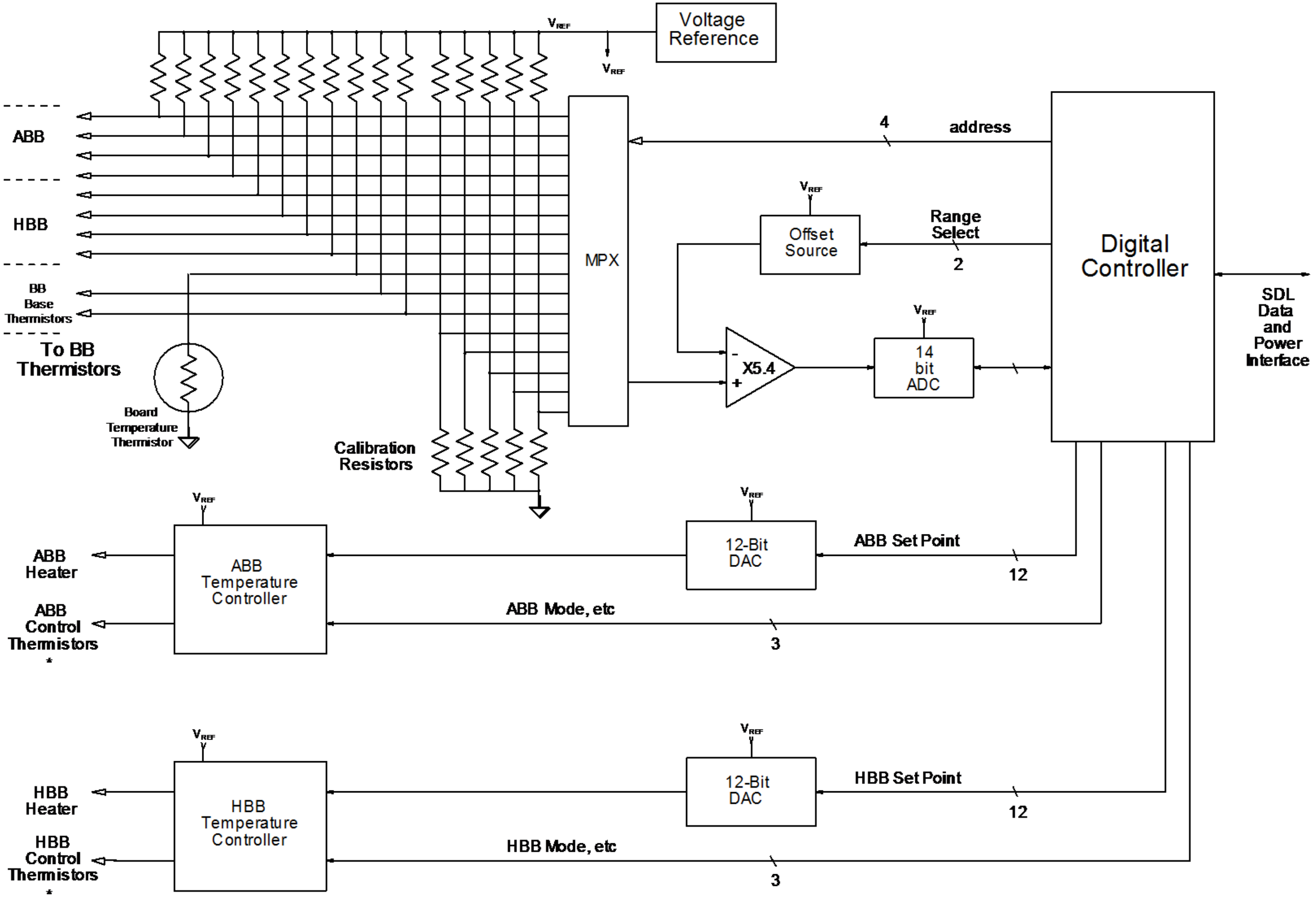
- Electronics Power
  1.2 W, maximum

Changes Since PDR

- Control of both blackbodies
- Maximum total power increases from 3.0 to 5.2 W

- Redundant heater drivers deleted, dual heaters retained
- Add low power "Reset" mode
- Default operation for both blackbodies is constant temperature
- Add autoranging of temperature measurement ranges
- Change ±15V supplies to ±12V
- Add primary overtemperature protection
- Increase measurement update rate from 2.0 to 2.7 Hz
- Command and data interface modified as necessary
- Blackbody thermal environment is colder
- Increase electronics power from 1.0 to 1.2 W
- Change controller operating temperature range to
  -55 to +50°C. (Accuracy guaranteed -40 to +30°C only)

Blackbody Controller Operation



* HBB Control Thermistors are redundant.
Redundant circuitry not shown.

Operational Commands

- Blackbody Modes
  - Constant Temperature
  - Constant Power
- Set Points
- Control Thermistor Select
- Temperature Measurement Range
  - Range Select
  - Autorange On/Off
- Reset Mode

Electronics Error Budget Summary

Error Source	Worst-Case Temperature Error (mK)	
	HBB	ABB
Calibration Networks	0.8	0.8
Half-Bridge Resistor (R3)	1.0	0.9
ADC and Amplifiers	10.2	9.6
Leakage Current	9.2	11.4
Misc. Errors	1.9	1.9
Total	**23.1**	**24.6**
Aging and Radiation Component	11.3	11.3
"At Delivery"	11.8	13.3

Misc. Errors	mK	Notes
Thermal EMF	0.1	3 Pairs of Cu-Cu junctions, gradient <1°C within pair
Cable Resistance Change	0.5	Assume 100°C change in cable temperature from calibration temperatu
Self-heating Uncertainty	1.3	Assume initial self-heating of 0.5mK and a 25% change in thermistor thermal resistance during mission
Total	1.9	

Notes:
1. HBB Range 0 to +40° C
2. ABB Range -40 to 0° C
3. Electronics temperature range -40 to +30° C
4. Calibration at electronics temperature of -5° C only
5. All BBC calibration resistor networks VH102K, ±0.5 ppm/°C tracking
6. Half-bridge Resistors VH102K, ±1 ppm/°C
7. Exclusive of thermistor errors
8. Multiplexer and op amp leakage current 10 nA, maximum
9. HBB Thermistors 10K at 25° C, ABB Thermistors 2.2K at 25° C
10. 7-year long-term drift estimate included
11. Initial calibration uncertainty not included

Power Budget Summary

Load	Current (mA)					Power (mW)					
	+2.5V	+3.3V	+5V	+12V	-12V	+2.5V	+3.3V	+5V	+12V	-12V	Total
Electronics	115	0	72	18	21	316	0	380	231	263	1191
ABB Heater	0	0	366	0	0	0	0	1922	0	0	1922
HBB Heater	0	0	366	0	0	0	0	1922	0	0	1922
Total	115	0	804	18	21	316	0	4223	231	263	5034

All values worst case maximum

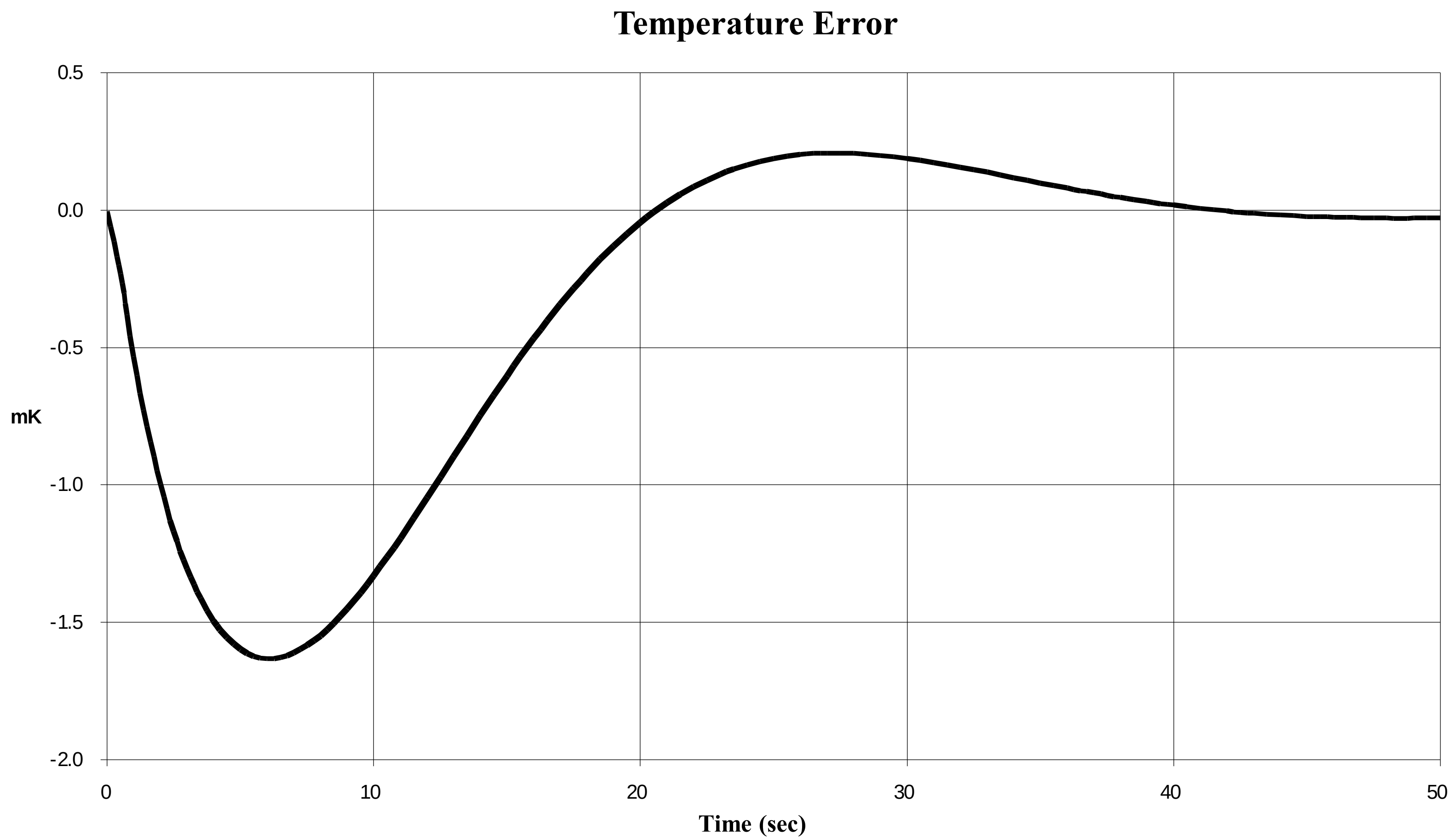
Steady-State Heater Power

Heater	Set Point (°C)	Power (mW)
ABB	-40	244
	0	562
HBB	0	562
	40	989
Total	(Maximum)	1551

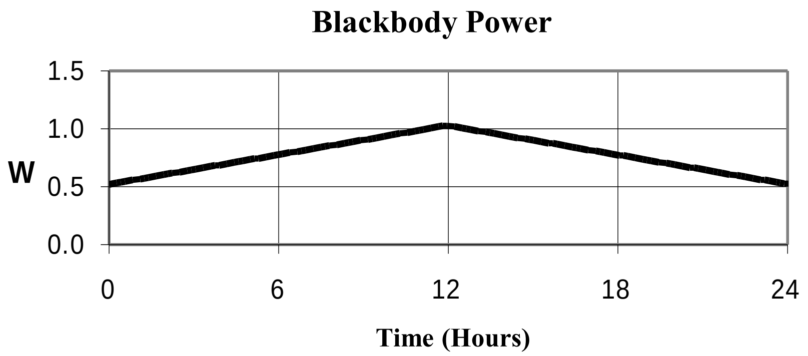
Worst-case for cold side of orbit

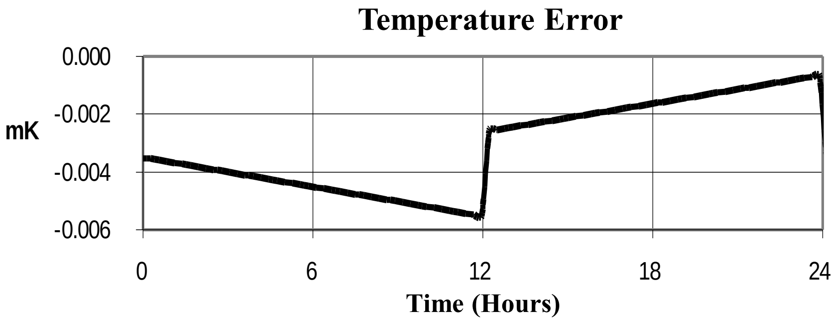
Model Transient Response

0.14 W Blackbody Power Step

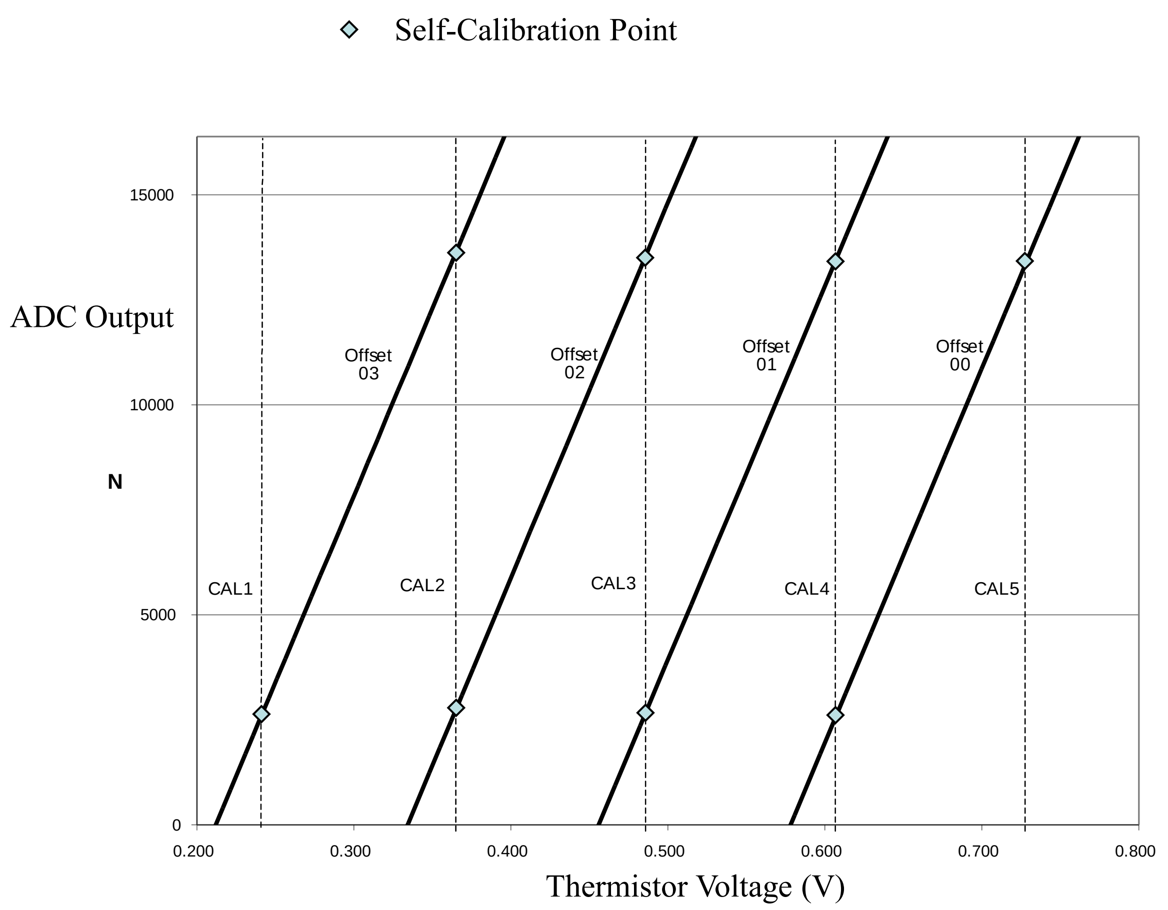


Model Orbital Response

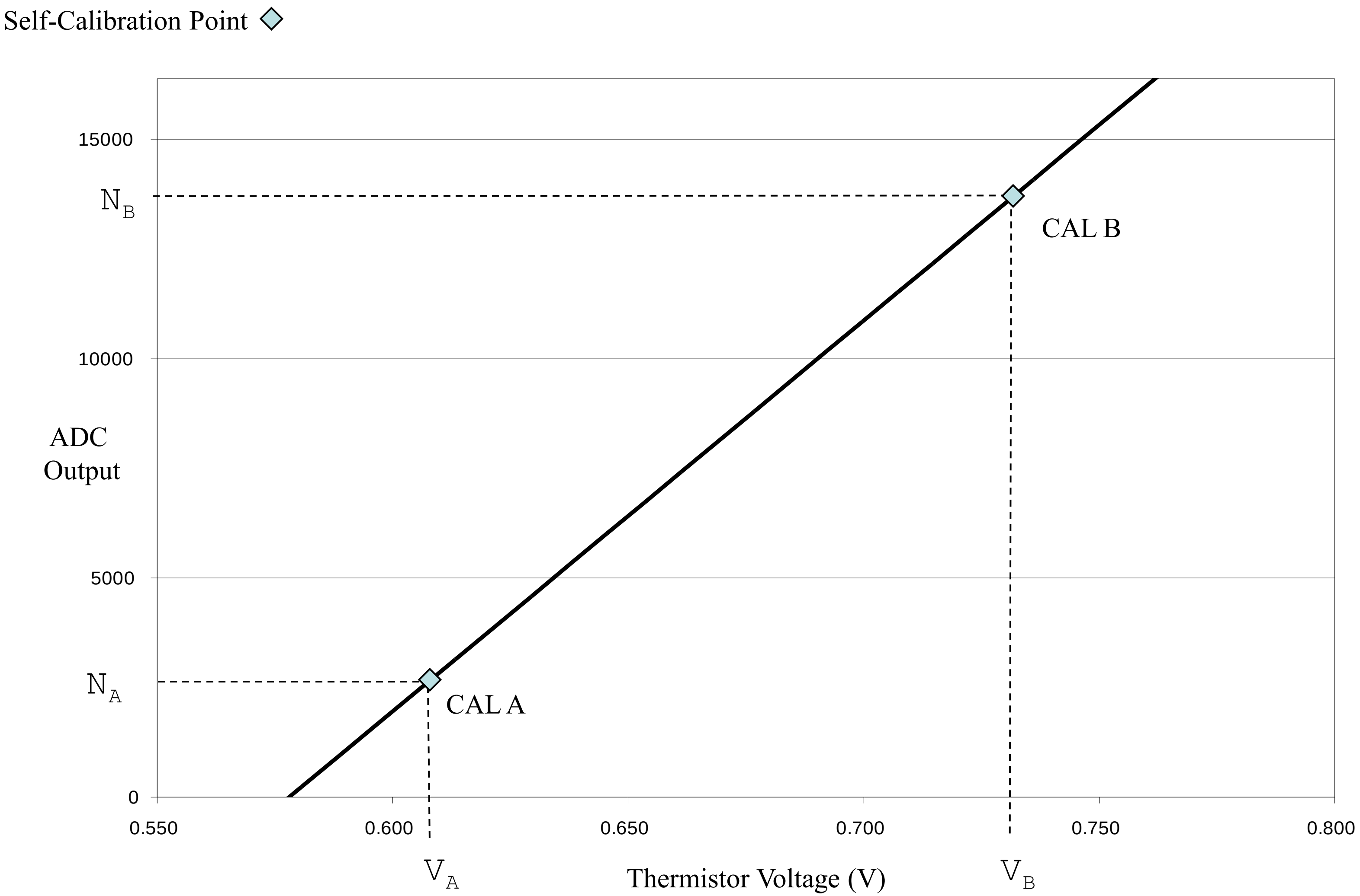




Measurement Ranges and Self-Calibration



Self-Calibration Example



Self-Calibration

Self-calibration corrects for drift of gain and offset in electronics
Residual error depends mainly on stability of precision resistors

N_A = Value at self-calibration point A
N_B = Value at self-calibration point B
V_A = Voltage at self-calibration point A (known)
V_B = Voltage at self-calibration point B (known)
K_1 = Gain constant
K_2 = Offset constant
N = Value at measurement of unknown temperature
V = Thermistor voltage at unknown temperature

T = Blackbody Temperature

$$K_1 = \frac{N_A - N_B}{V_A - V_B} \qquad K_2 = N_A - K_1 \cdot V_A$$

$$V = \frac{N - K_2}{K_1}$$

$$T = F(V)$$

Controller Parts Selection Summary

Reference	Description	Quantity (1)	Flight Part Number	SMD/QPL (Flight Only)	Vendor	Package (Flight)	Notes
1	Rectifier	2	JANS1N5811US	MIL-PRF-19500/477	Micro-Semi	E-MELF	
2	MPX, 1X16	1	HS9-1840ARH-Q	5962F9563002VYC	Intersil	CDFP3-F28	
3	MPX, 3X2	2	HS9-303RH	5962R9581301VXC	Intersil	CDFP3-F14	
4	MPX, 1X8	1	HS9-508BRH-Q	5962F9674202VXC	Intersil	CDFP4-F16	
5	Op Amp	5	RH108AW		LT	GDFP1-F10	
6	Small Signal Diode	4	JANS1N6661US	MIL-PRF-19500/587	Micro-Semi	A-MELF	
7	Dual Op Amp	13	RH1078MW		LT	GDFP1-F10	
8	Quad Comparator	1	HS9-139RH-Q	5962F9861301VXC	Intersil	CDFP3-F14	
9	D/A Converter	2	7545ARPFS		Maxwell	20 LDFP	
10	A/D Converter	1	7872RPFS		Maxwell	16 LDFP	
11	SMT Resistors	142	RM1005	MIL-PRF-55342/3		RM1005	
12	SMT Ceramic Capacitors	83	CDR05	MIL-C-55681/2		CDR05	
13	Tantalum Capacitors	7	CWR09	MIL-PRF-55365		CWR06 (G)	
14	Power MOSFET	4	IRHNJ579034SCS		IR	SMD-0.5	
15	Tantalum Capacitors	2	CWR09	MIL-PRF-55365		CWR06 (C)	
16	Precision Resistor	21	VH102K		Vishay	VHK102K	(4)
17	Thermistor	1	TBD				(4)
18	FPGA	1	RT54SX72S-1CQ208E	5962-0151504QYC	Actel	208 CQFP	
19	8 Bit Transceiver	8	54ACTQ245WRQMLV	5962R9218701VSA	National	CDFP4-F20	
20	Bus Connector	1	WG208PR9SY-1		AirBorn		
21	3 test points	1	MTMM-103-07-G-S-255		Samtec		
22	SMT Resistors	6	RM2208	MIL-PRF-55342/3	SOA	RM2208	
23	PNP Transistor	5	JANS2N2907AUB	MIL-PRF-19500/291		(SMT)	
24	Quad Nand Gate	2	HCS132KMSR	5962R9572601VXC		CDFP3-F14	
25	26-Pin Connector	2	SDD26F4R200G		Positronix		
26	Zero Ohm Resistor	8	H1005CPX-000		State of the Art, Inc.	RM1005	
27	16 Pin Connector	1	Not used for flight.				(6)
28	Fuse	2	FM08A125V2A	MIL-PRF-23419/8			(4)
29	SMT Ceramic Capacitors	9	CDR01	MIL-C-55681/1		CDR01	
30	SMT Ceramic Capacitors	10	CDR03	MIL-C-55681/1		CDR03	

Notes:

(1) Quantity per board
(4) Through-hole component.
(6) Not used on flight board

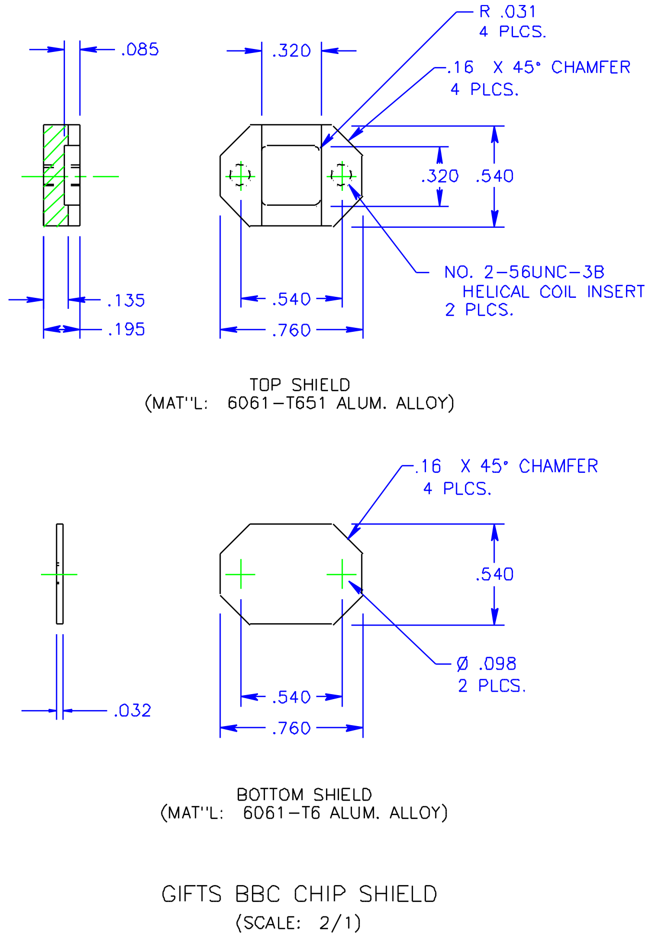
Non-Standard Parts

GIFTS Blackbody Controller Non-Standard Parts — 1 March, 2004

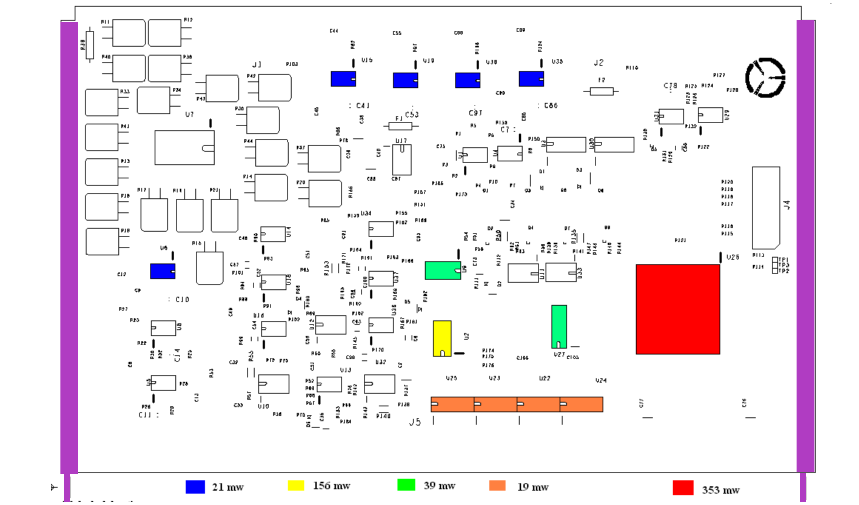
Description	Quantity	Part Number	Vendor	Notes
Op Amp	5	RH108AW	LT	NSPAR not requred
Dual Op Amp	13	RH1078MW	LT	Procured by SDL
D/A Converter	2	7545ARPFS	Maxwell	Procured by SDL
A/D Converter	1	7872RPFS	Maxwell	NSPAR not requred
Power MOSFET	4	IRHNJ579034SCS	IR	NSPAR Submitted by SDL
Precision Resistor	21	VH102K	Vishay	NSPAR Submitted to SDL
3 test points	1	MTMM-103-07-G-S-255	Samtec	NSPAR not requred
Zero Ohm Resistor	8	H1005CPX-000	State of the Art, Inc.	NSPAR not requred

Radiation and Shielding

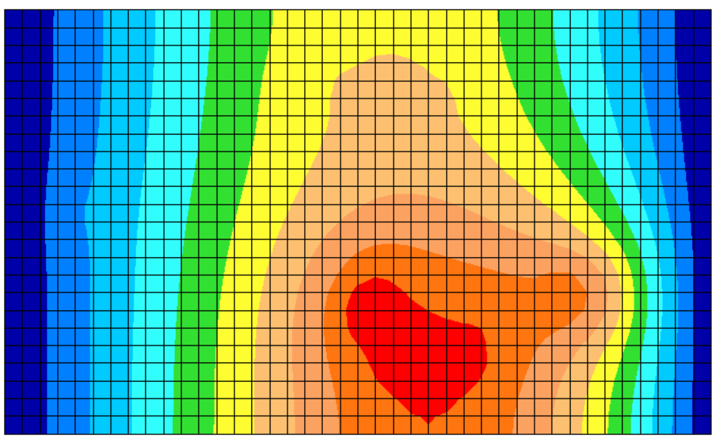
Total mission radiation dose assumed to be 100K Rad, including X2 safety factor
RH108A (Op Amp) requires additional shielding to 20K Rad
7872RPFS (ADC) and HS9-1840 (Mpx) performance improves with additional shielding
110 mils (2.8mm) of additional aluminum shielding is provided for these parts



PWB Thermal Analysis



Board layout



Temperature results

- Neglected radiation, assumed conduction only to edges at 50°C
- Modeled board as single layer with equivalent lateral conductivity based on copper and polyimide layer thicknesses
- Heat flux into board assumed uniform over each component's area
- Total power dissipation is 1.2W
- Components shown total 0.81W, remaining 0.39W evenly distributed over remaining board surface
- Heat to left edge is 0.43W, heat to right edge 0.77W

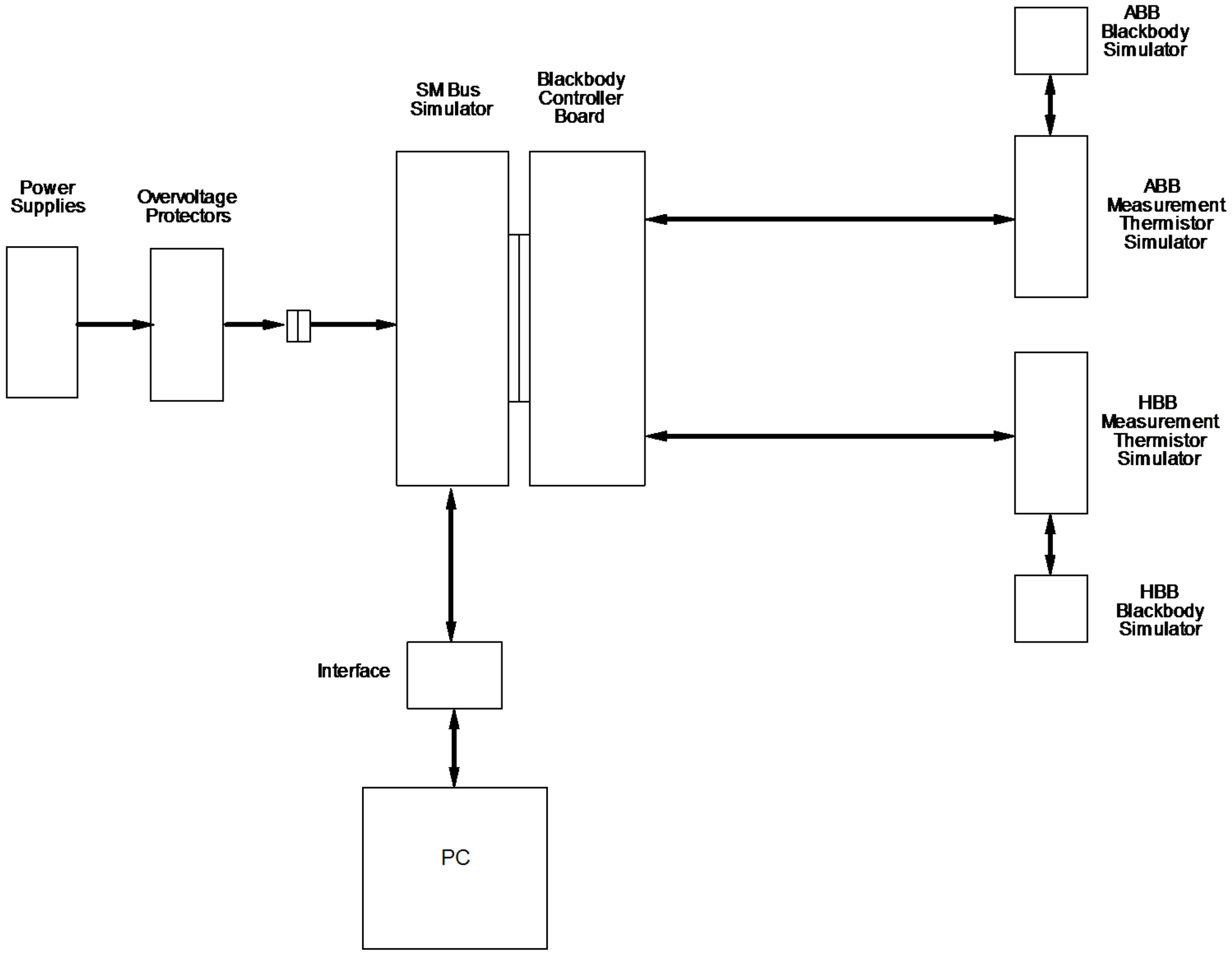
- **Maximum temperature is 54°C**

Parts Derating Summary

Component	Parameter	PPL-21 Limit	Worst Case
Ceramic Capacitor	Voltage	60%	52%
Solid Tantalum Capacitor	Voltage	50%	37%
Film Resistor	Voltage	80%	65%
	Power	60%	29%
Analog Microcircuit	Power Dissipation	75%	4%
	Supply Voltage	90%	75%
	Input Voltage	90%	71%
	Junction Temperature	93.5°C	70°C
Digital Microcircuit	Power Dissipation	80%	19%
	Supply Voltage	90%	90%
	Input Voltage	90%	88%
	Output Current	80%	6%
	Junction Temperature	100°C	66°C
Transistor	Power Dissipation	60%	7%
	Current	60%	3%
	CE/DG Voltage	75%	22%
	Gate-Source Voltage	60%	64%
	Junction Temperature	80%	47%
Diode	Inverse Voltage	70%	6%
	Forward Current	50%	7%
	Junction Temperature	80%	37%
Connector	Voltage	25%	5%
Fuse	Current	50%	25%

Note: Maximum PWB temperature 55°C

Engineering Model Test Set-up

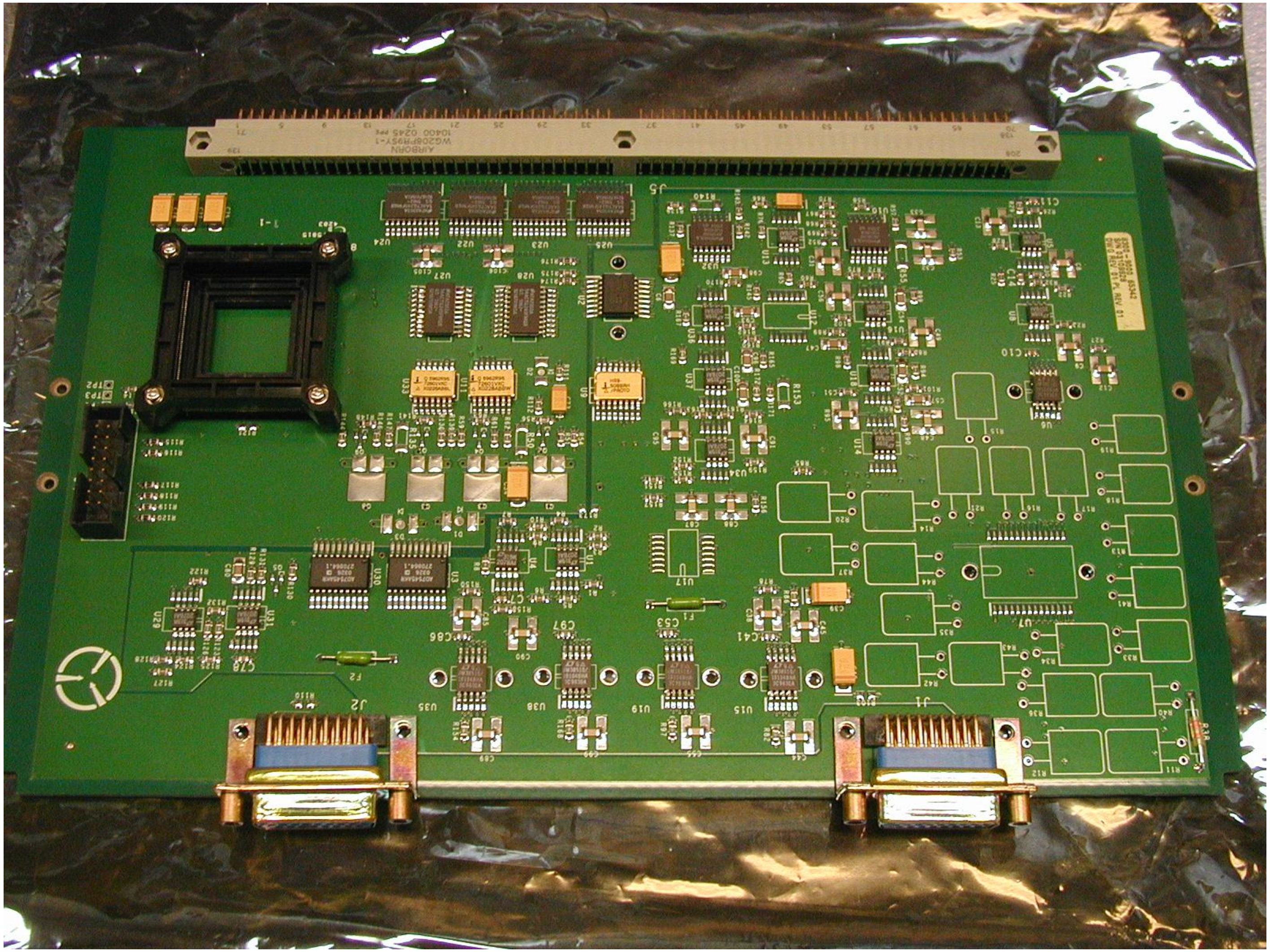


Engineering Model Test Results

- Tested at +25° C only
  - Data Interface
  - Resistance Measurement
  - Temperature Control

- Preliminary results meet specifications

Engineering Model 1 Photograph



Flight Unit Acceptance Test Plan

Pre-coat Tests

BBC Visual Inspection

Solder joint integrity
Solder splashes
Component part numbers, polarity

+25¡C Electrical Test (with Blackbody Simulators and EM Blackbodies)

Post Conformal Coat Tests (with Blackbody Simulators and EM Blackbodies)

Vibration

Thermal Cycling

+25¡C Electrical Test

-55¡C Electrical Test

+50¡C Electrical Test

Calibration (with Flight Blackbodies)

-3¡C (tbr) Calibration

Cold Calibration (if required)

Hot Calibration (if required)

Note: All temperatures refer to Controller board temperature

Electrical Test Outline

Initial Tests

Bus Simulator Safe-to-Mate

BBC Power/Ground isolation measurement

Supply current measurement (heater outputs open)

Reference Voltage Measurement

Logic Array Tests

SDL bus transactions

- Test semaphore bit function
- Read status byte
- Read remainder of registers
- Write and read command registers
- Verify frame count

Temperature Measurement

Resistance Measurement (with blackbody simulators)

- Reference Voltage Measurement
- Channel selection
- Sampling rate
- Measurement range versus offset
- Measurement accuracy and linearity
- Power supply sensitivity

Auto offset mode (with blackbody simulators)

- Verify enable/disable
- Measure range switching points

Measurement noise (with blackbody simulators and EM blackbodies)

Temperature Controller Tests

Constant Power Mode (with blackbody simulators)

- PWM Frequency Measurement
- Duty cycle versus commanded value
- Power supply sensitivity
- Heater voltage and slew rate
- Overtemperature Test

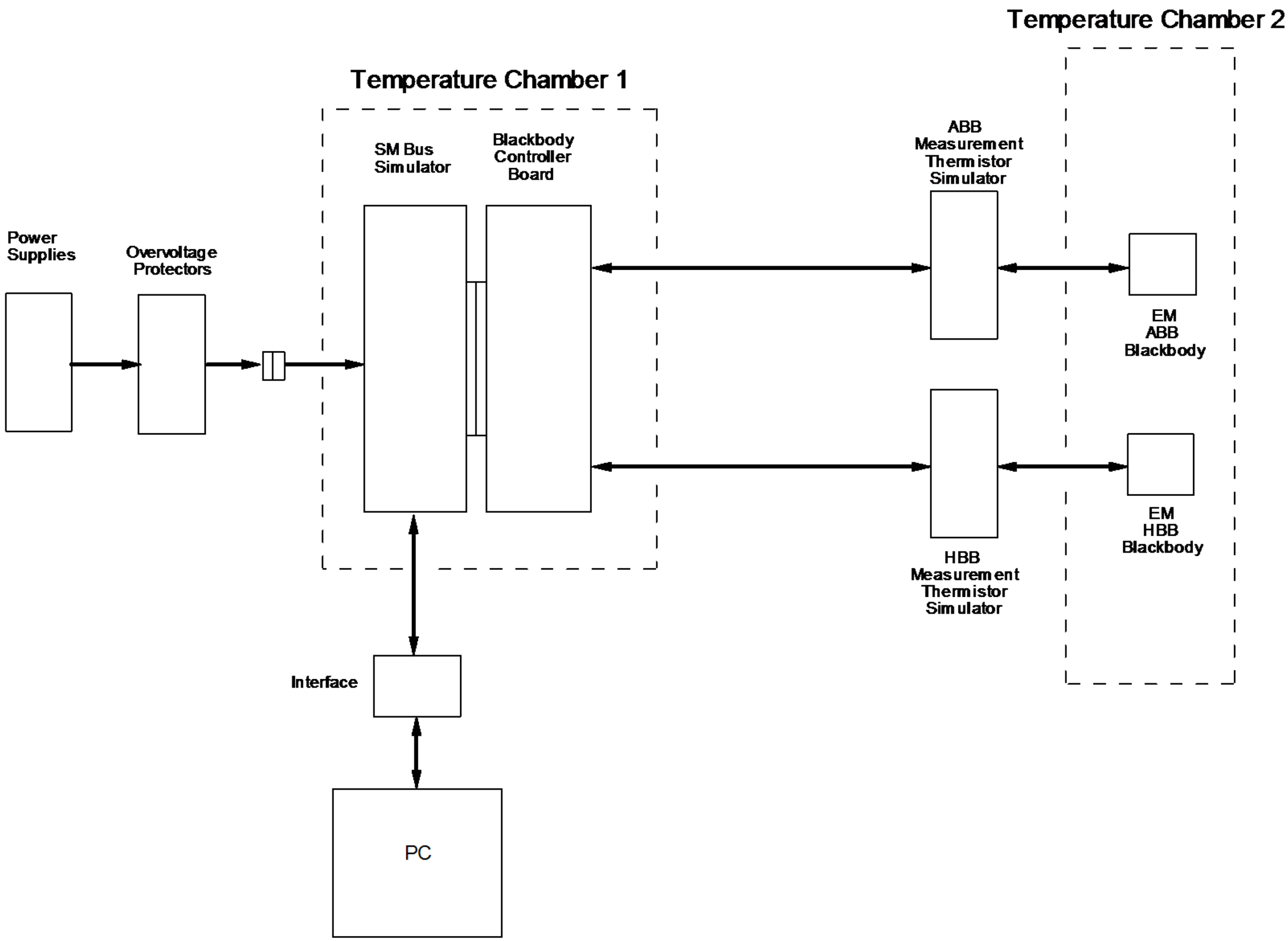
Constant Temperature Mode (with blackbody simulators and EM blackbodies)

- Set point range
- Redundant control thermistor switching
- Temperature Stability
- Power supply sensitivity
- Dynamic Response
- Reset and Initialization
- Single heater operation

Additional Tests

- Temperature Error Monitors
- Board Thermistor
- Operational supply current measurements
- Reset mode operation

Flight Test Set-up



Testing Issues

- SDL Bus Simulator built with commercial components may not allow testing of Blackbody Controller over entire temperature range.
  - SDL Bus Simulator required for all electrical tests
  - SDL Bus Simulator and Blackbody Controller must be installed on the common motherboard in close proximity
  - Temperature Tests of Blackbody Controller require SDL Bus Simulator to operate over the same temperature range
- Motherboard does not allow direct measurement of Blackbody Controller power supply currents.

Calibration Overview

- Direct Temperature Calibration Only
- No Temperature to Resistance or Data to Resistance Calibration
  - Would require extremely precise resistance references
  - Intermediate calibration allows accumulation of errors
  - Interchangeability is not an issue
- Acceptance Test Resistance Measurements
  - Verify measurement ranges
  - Linearity

GIFTS
Blackbody Subsystem
Critical Design Review

Digital Interface & Controller Logic

Mark Werner

9 March 2004

Key Requirements

- Interface to SDL Bus
  - Address decode
  - Generate strobes for writes of control parameter registers
  - Generate enables for reads of control parameters, status and data

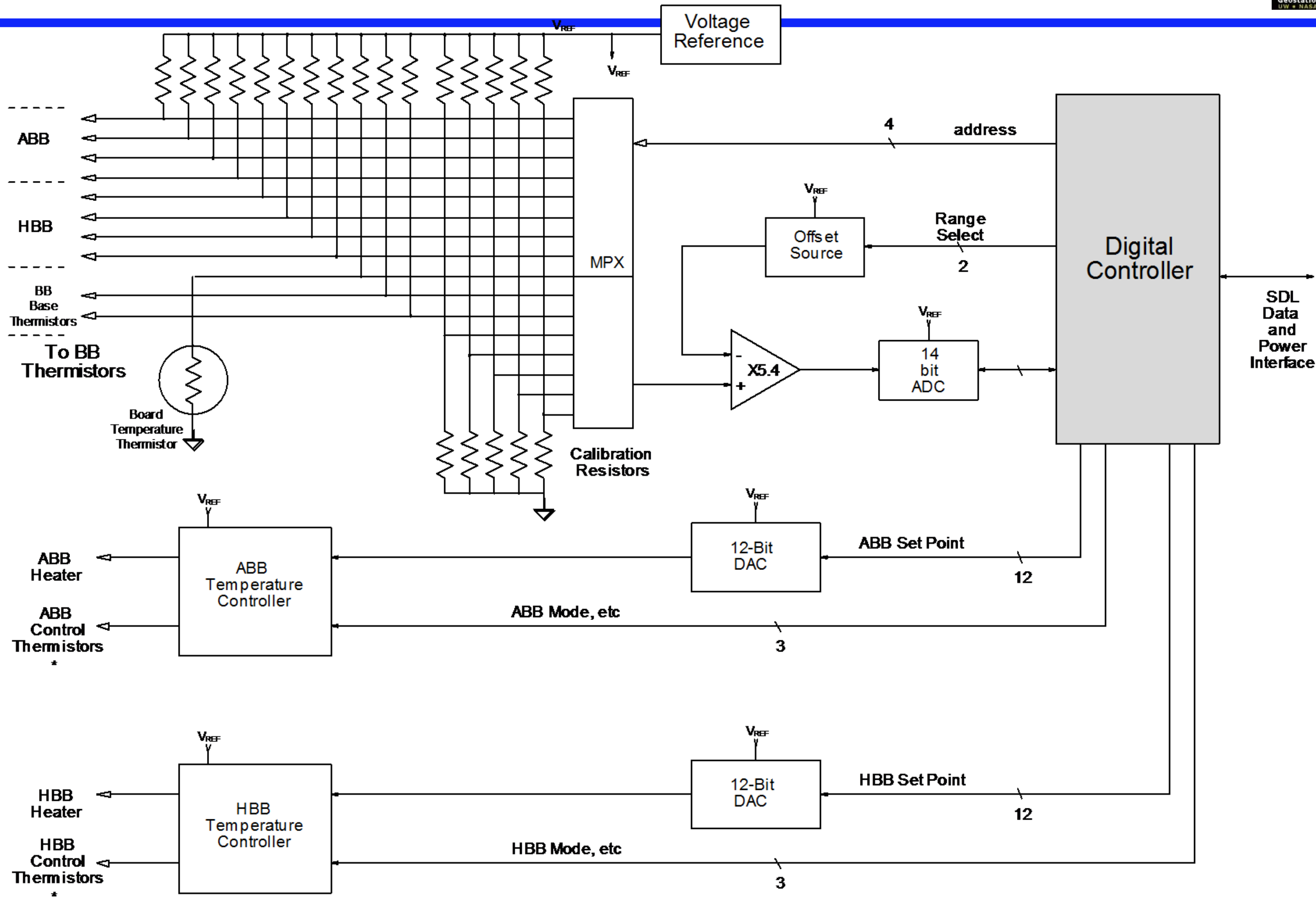
- Pass Control Parameters from C&DH to Analog Controller
  - Blackbody Set Point Information
  - Mode (Temp/Power)
  - Control Thermistor Selection (1of 2)
  - Offset Values (ABB, HBB, Spare1, Spare2, Spare 3)

- Data Collection
  - Control analog multiplexer (1 of 16 channels)
  - Control offset selection (auto/non-auto mode)
  - Wait for signal to settle
  - Control ADC
  - Average data (256 samples)

Changes Since PDR

- Control both Blackbodies
  - Redundant control thermistors for each blackbody
  - Delete redundant heaters.
- Primary over temperature protection for constant power mode.
- Add a reset input from the SDL bus.
- Low power reset mode added.
- Auto-ranging of temperature measurement offset voltages.
- Measurement rate change from 2 to 2.7 hertz.
- Registers added for three of the five calibration channels to allow for two calibration data values (offset high/low).

Blackbody Controller Functional Block Diagram



* HBB Control Thermistors are redundant. Redundant circuitry not shown.

Controller Logic Main Components

- SDL Bus Interface
- Interface to Analog Controller
- Data Collection

Digital Interface & Controller Logic Design Overview

SDL Bus Interface

- Address Decode logic
- Registers -- for passing information to/from BBC to C&DH
- Transceiver Direction Control logic

Interface to Analog Controller

- Outputs –
  * Set Point – D/A Output bits
  * Mode Select
  * Control Thermistor Select
  * Analog Multiplexor Address bits
  * Offset Multiplexor Address bits
- Inputs –
  * Over-temperature bits

Digital Interface & Controller Logic Design Overview

<u>Data Collection</u>

- Data Collection Control
- Data Averager
  * Interface to ADC – Initiate Conversion & Collect Data
  * Average Data Samples
- Offset Selector

Digital Interface & Controller Logic -- Register Summary

Read only

Status Information – bytes 0-3
- Two 16 bit registers

Set Point Information – bytes 4-7
- Two 16 bit register – 12 bit DAC

Mode/Auto Register – bytes 8,9
- Mode, Control Thermistor, Auto offset mode

Offset Register – bytes 10,11
- 3 bit offset values for HBB, ABB, Spare 1-3

Data Registers – bytes 12-49
- Averaged Data Samples from ADC – 19 registers

Frame Count – bytes 50,51
- 16 bit Counter Defines Data Set Number

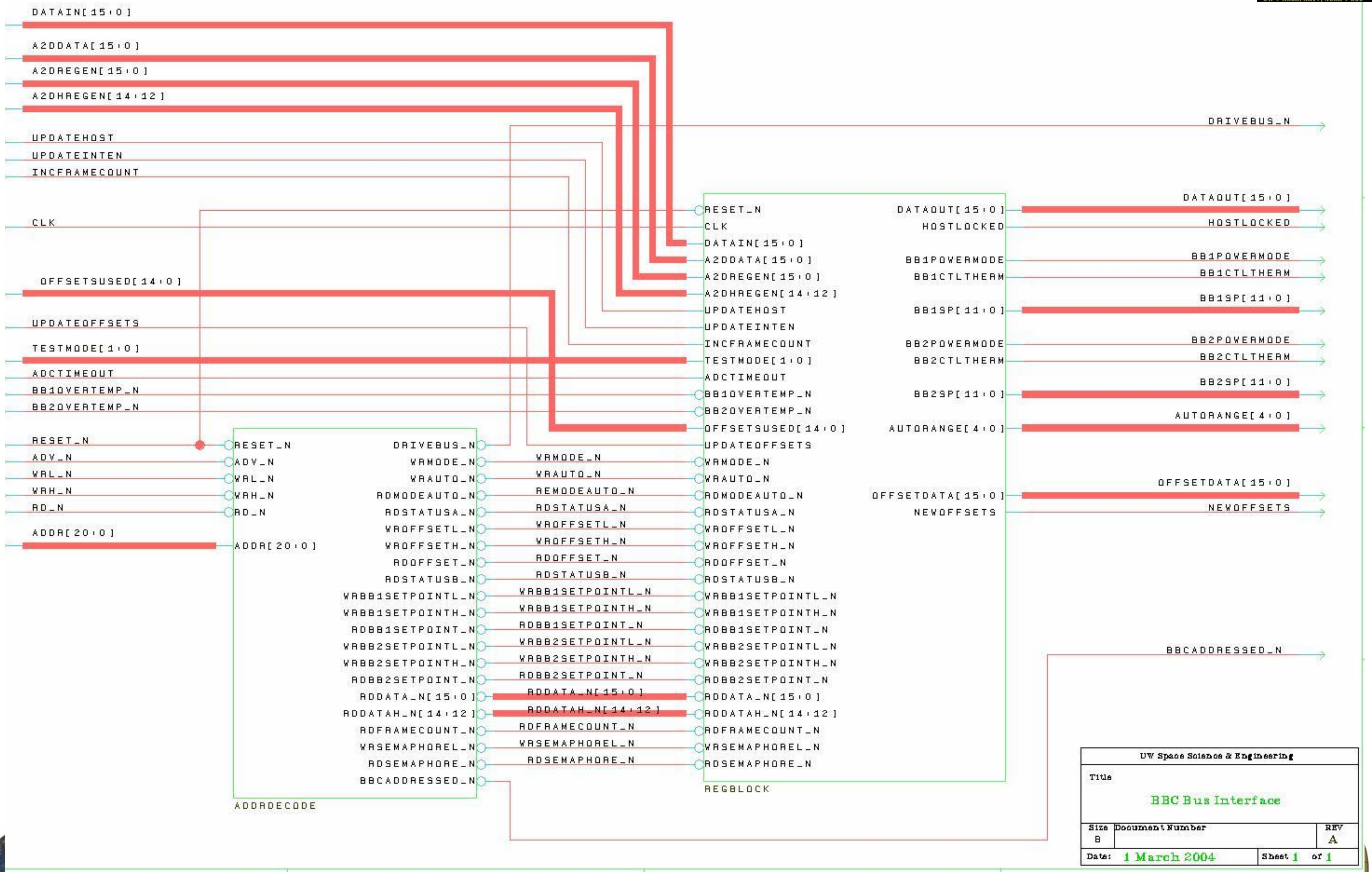
Semaphore Bit – bytes 52,53
- Controls internal access to bus access registers

Digital Interface & Controller Logic – Channel Data Order Definition

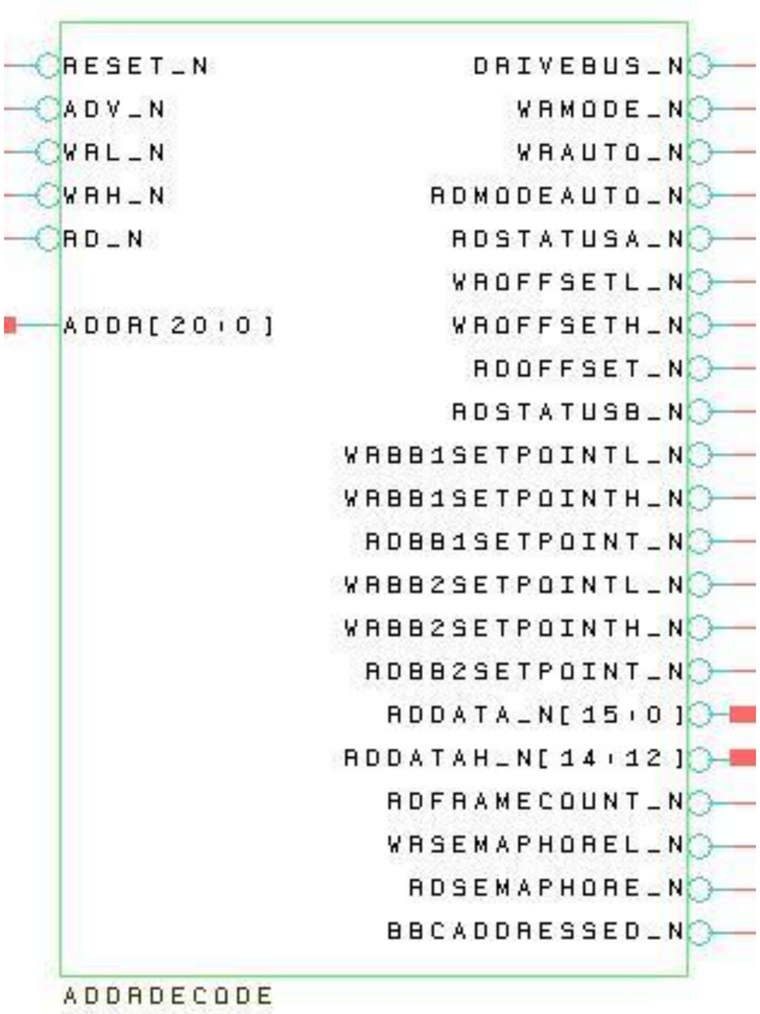
Channel	Analog Mux Address (Decimal)	Offset	Description	SDL Bus Byte Address Offset
ABB_A	0	ABB	ABB Thermistor A	12,13
ABB_B	1	ABB	ABB Thermistor B	14,15
ABB_C	2	ABB	ABB Thermistor C	16,17
ABB_D	3	ABB	ABB Thermistor D	18,19
HBB_A	4	HBB	HBB Thermistor A	20,21
HBB_B	5	HBB	HBB Thermistor B	22,23
HBB_C	6	HBB	HBB Thermistor C	24,25
HBB_D	7	HBB	HBB Thermistor D	26,27
ST1	8	ST1	Spare 1	28,29
ST2	9	ST2	Spare 2 (ABB Error)	30,31
ST3	10	ST3	Spare 3 (HBB Error)	32,33
CAL1	11	3	Calibration 1	34,35
CAL2	12	3	Calibration 2 Low	36,37
CAL3	13	2	Calibration 3 Low	38,39
CAL4	14	1	Calibration 4 Low	40,41
CAL5	15	0	Calibration 5	42,43
CAL2	12	2	Calibration 2 High	44,45
CAL3	13	1	Calibration 3 High	46,47
CAL4	14	0	Calibration 4 High	48,49

Digital Interface & Controller Logic – FPGA Top Level Block Diagram

Digital Interface & Controller Logic – Bus Interface Block Diagram



Digital Interface & Controller Logic – Address Decode



Key Points:

- Asynchronous decode
  Phase relationship of SDL Bus control signals to SysClk not well known
- Register specific write pulse
  Used by register block module to clock data into register
- Register specific read enable
  Used by register block module to enable data to data bus
- DriveBus_N
  Used to control transceiver direction
- BBC_Addressed
  Used to drive READY4#

Digital Interface & Controller Logic – Register Block

Key Points:

- Data Storage module
  * Internal registers
  * Bus access registers

- Receives control signals from
  * Address Decode module
  * Data Collector module

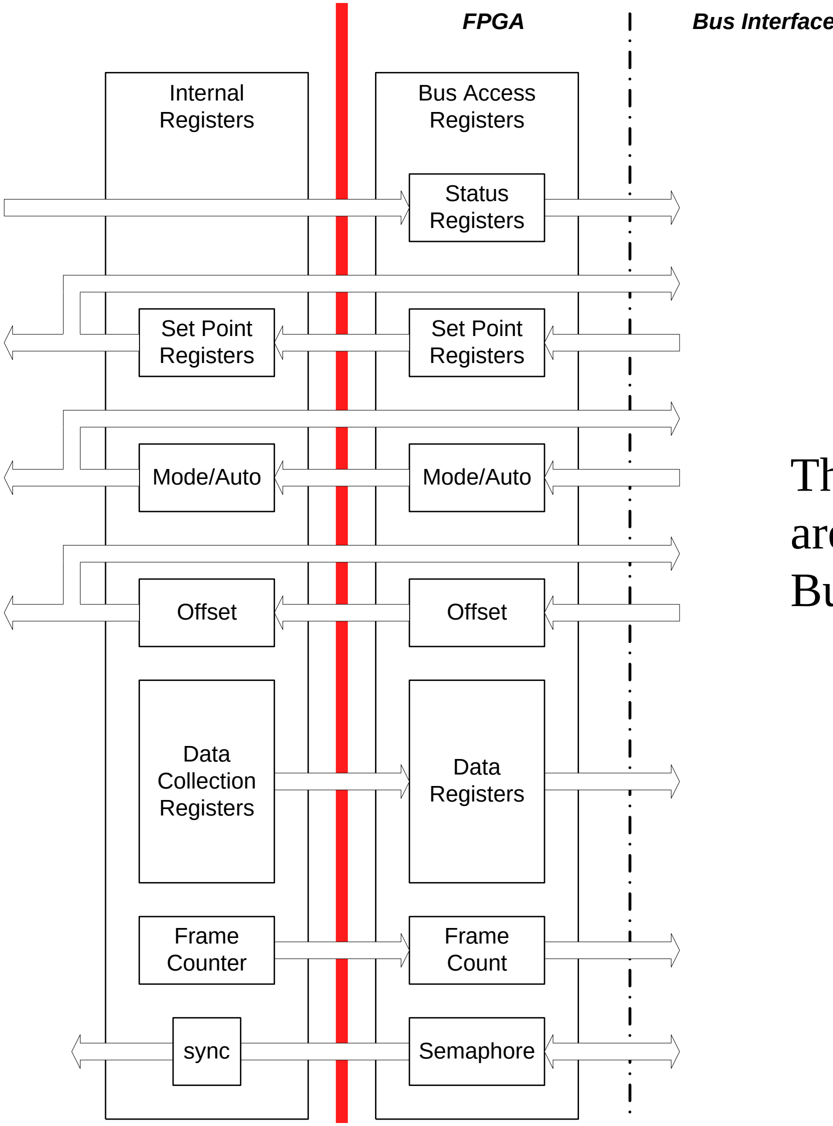
- Outputs internal register data to Data Collector module

- Outputs internal register bits to analog controller

- Stores data for the Lower Power Reset Mode

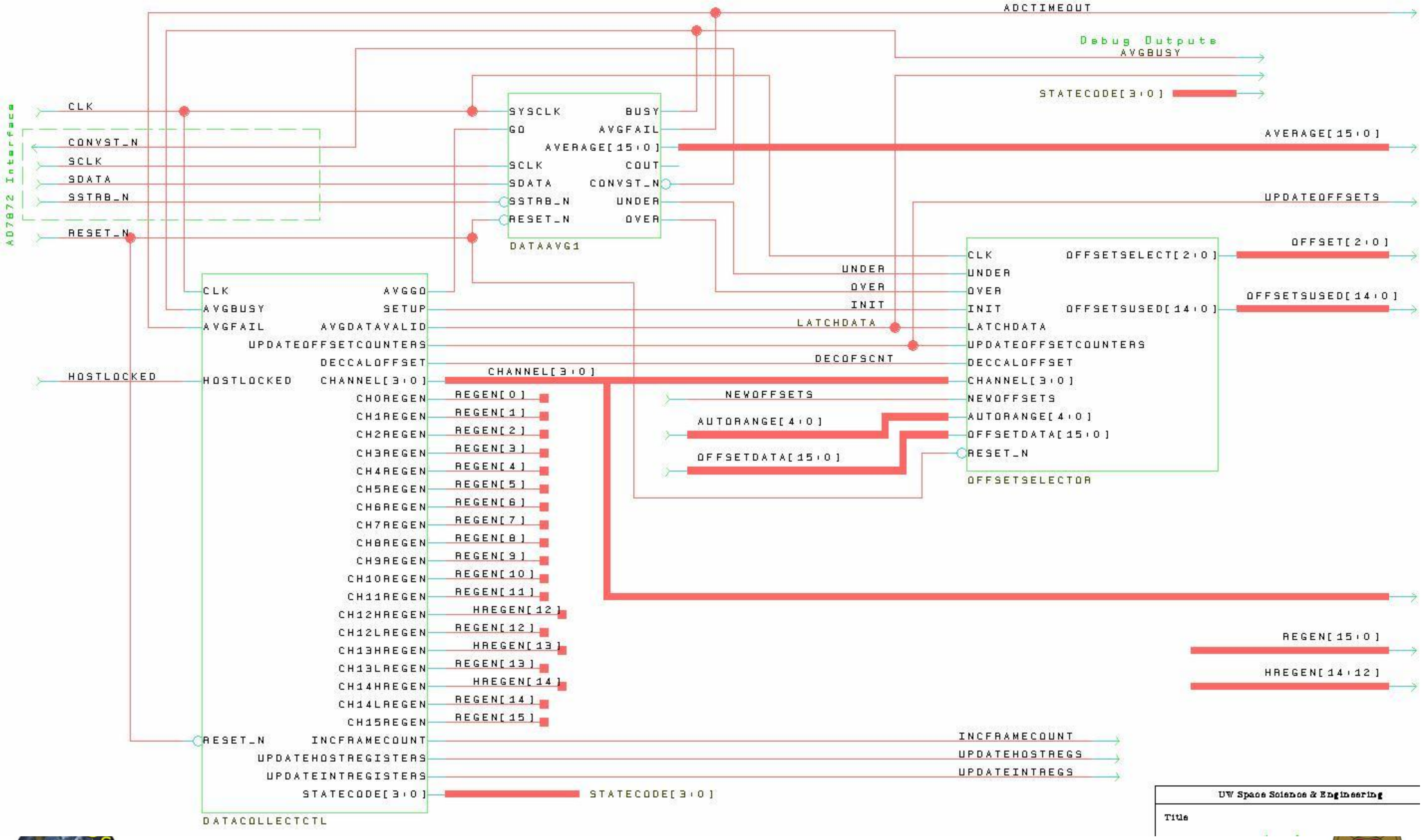
Digital Interface & Controller Logic – Register Type Definition

The registers on this side are accessed by the Data Collector module.

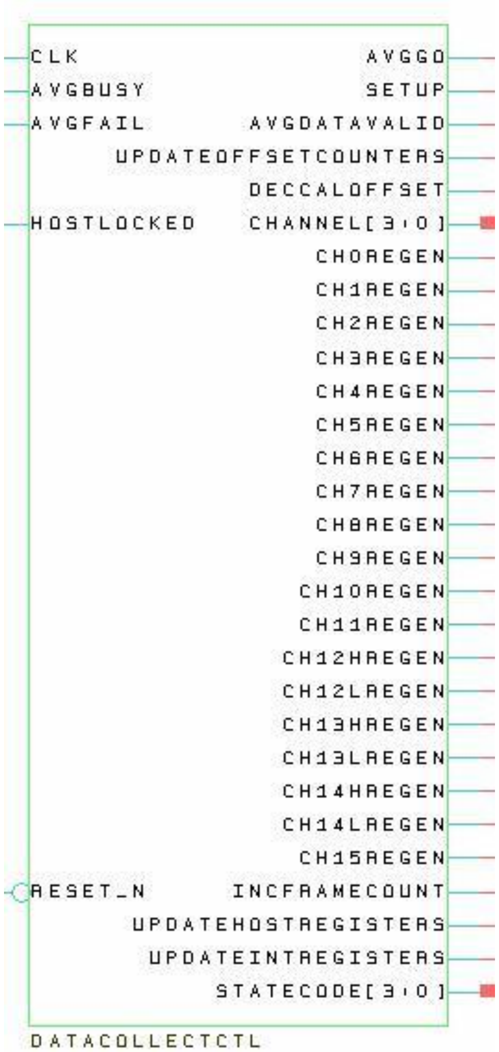


The registers on this side are accessed by the SDL Bus during a bus cycle.

Digital Interface & Controller Logic – Data Collector Top Level



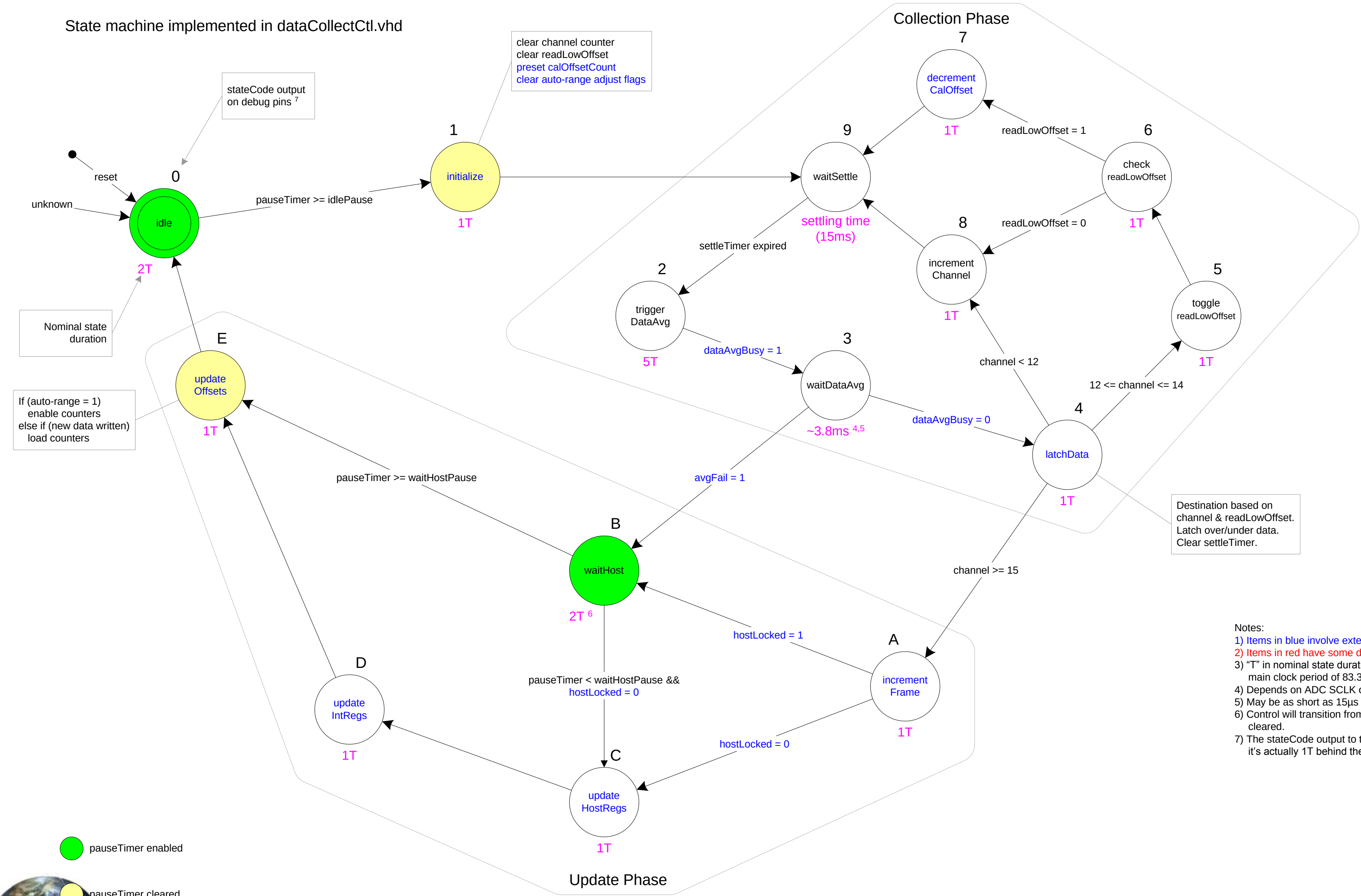
Digital Interface & Controller Logic – Data Collector Control



<u>Key Points:</u>

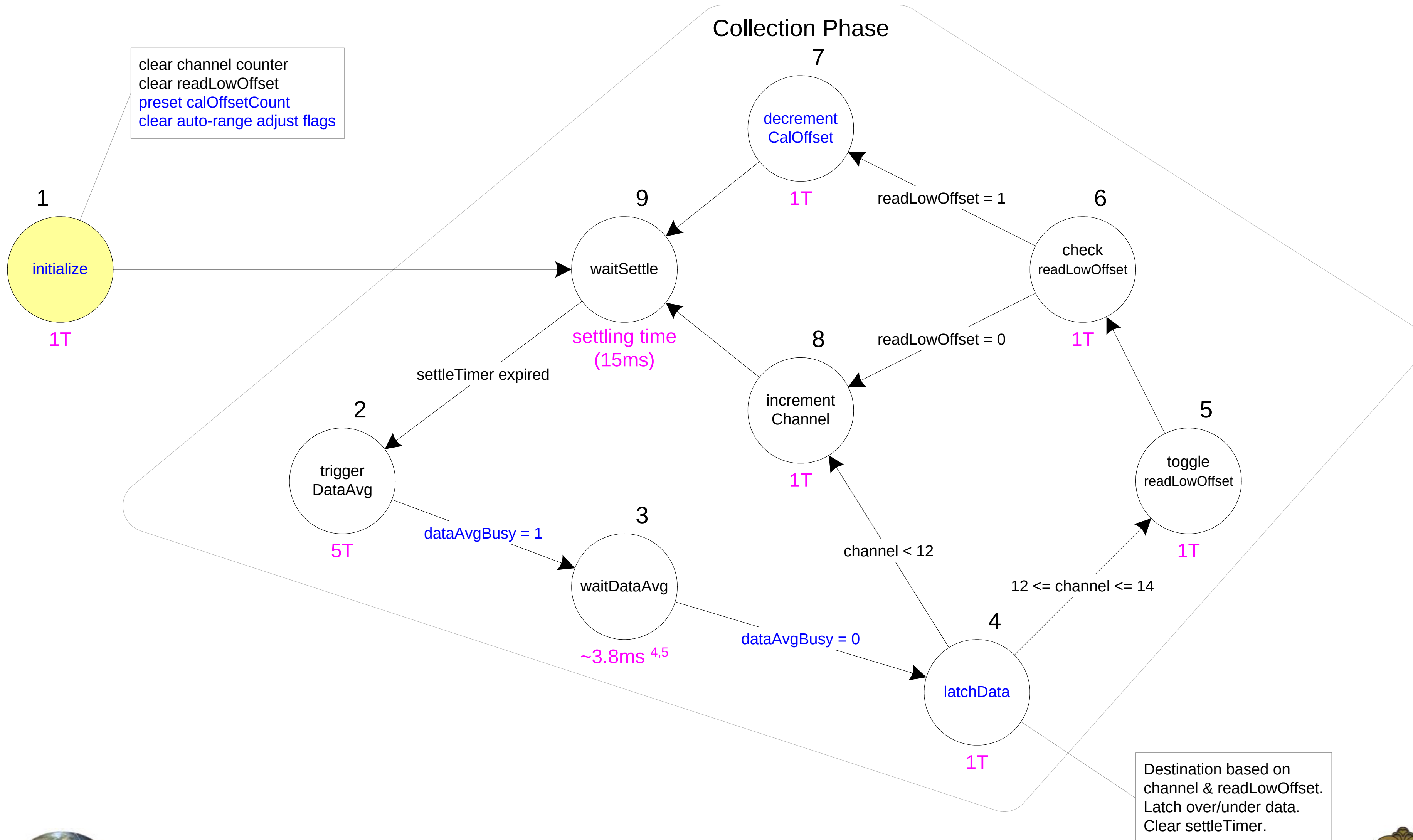
- Controls overall data collection timing
- Outputs control signals to Data Averager
- Receives status signals from Data Averager
- Outputs control signals for Register Block
  * Data Collection Registers write enables
  * Increment Frame Count Register
  * Update Bus Access (host) registers
  * Update Internal registers
- Outputs control signals for Offset Selector
- Outputs Analog Multiplexor address bits
- Synchronous Design

Digital Interface & Controller Logic
-- Data Collector Control - State Machine

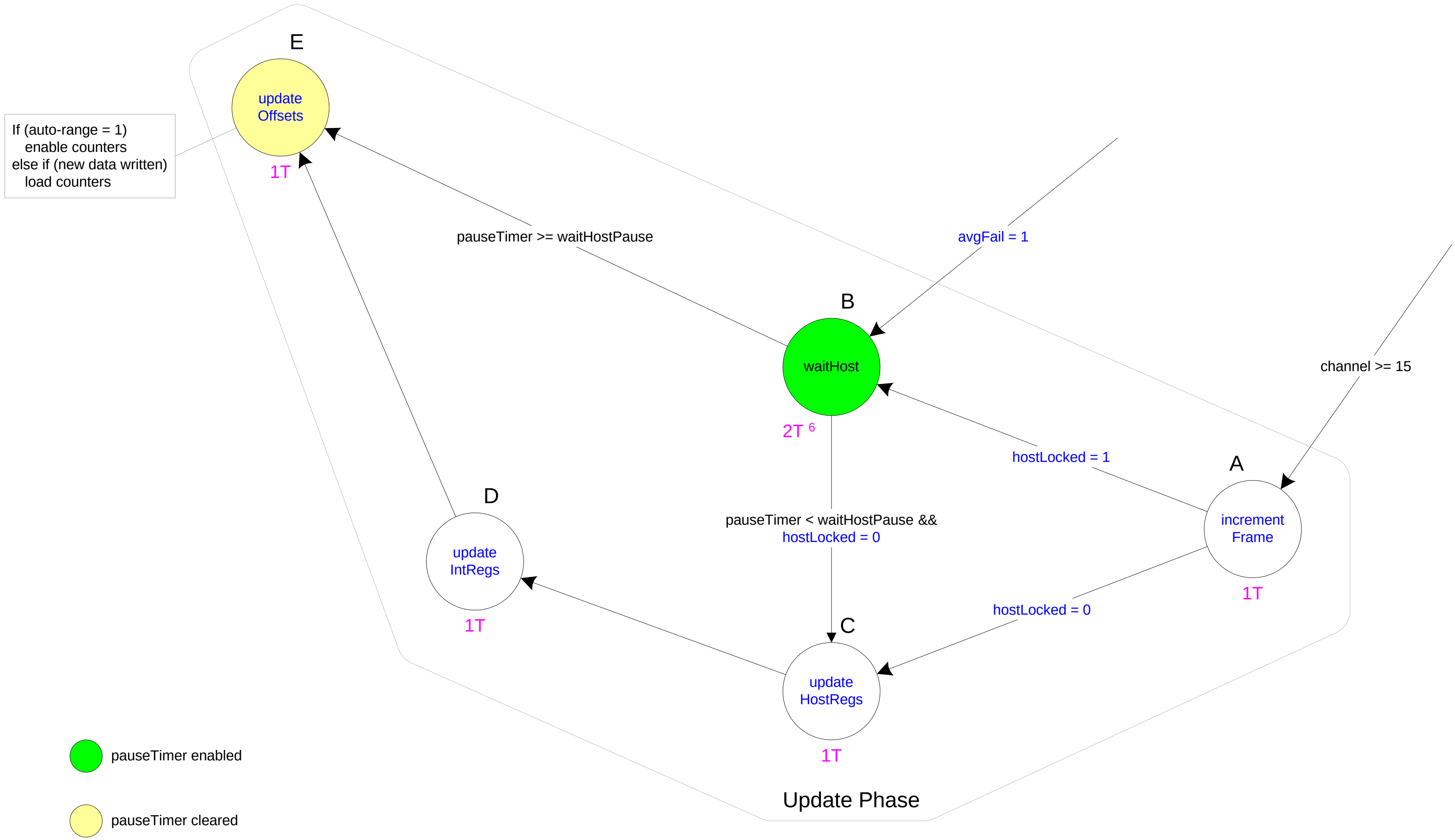


Notes:
1) Items in blue involve external signals.
2) Items in red have some details TBD.
3) "T" in nominal state duration expressions refers to the main clock period of 83.33ns.
4) Depends on ADC SCLK output period.
5) May be as short as 15µs in the event of an ADC failure.
6) Control will transition from this state after hostLocked is cleared.
7) The stateCode output to the debug pins is registerd, so it's actually 1T behind the internal state.

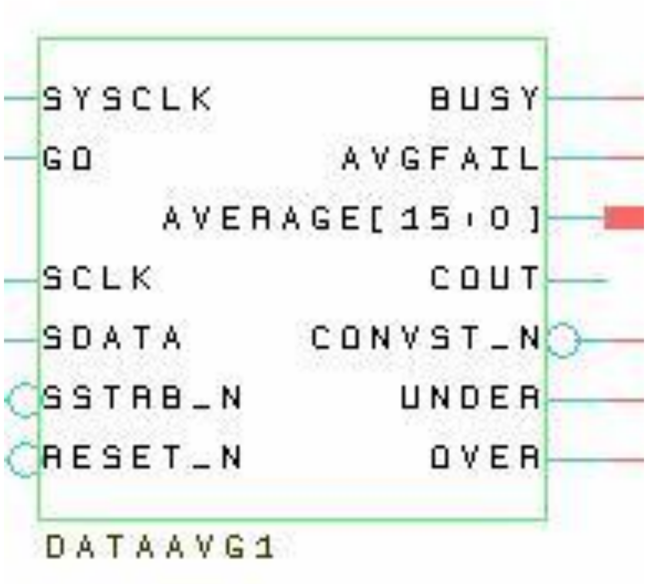
Digital Interface & Controller Logic
-- Data Collector Control - Collection Phase



Digital Interface & Controller Logic -- Data Collector Control - Update Phase



Digital Interface & Controller Logic – Data Collector Averager

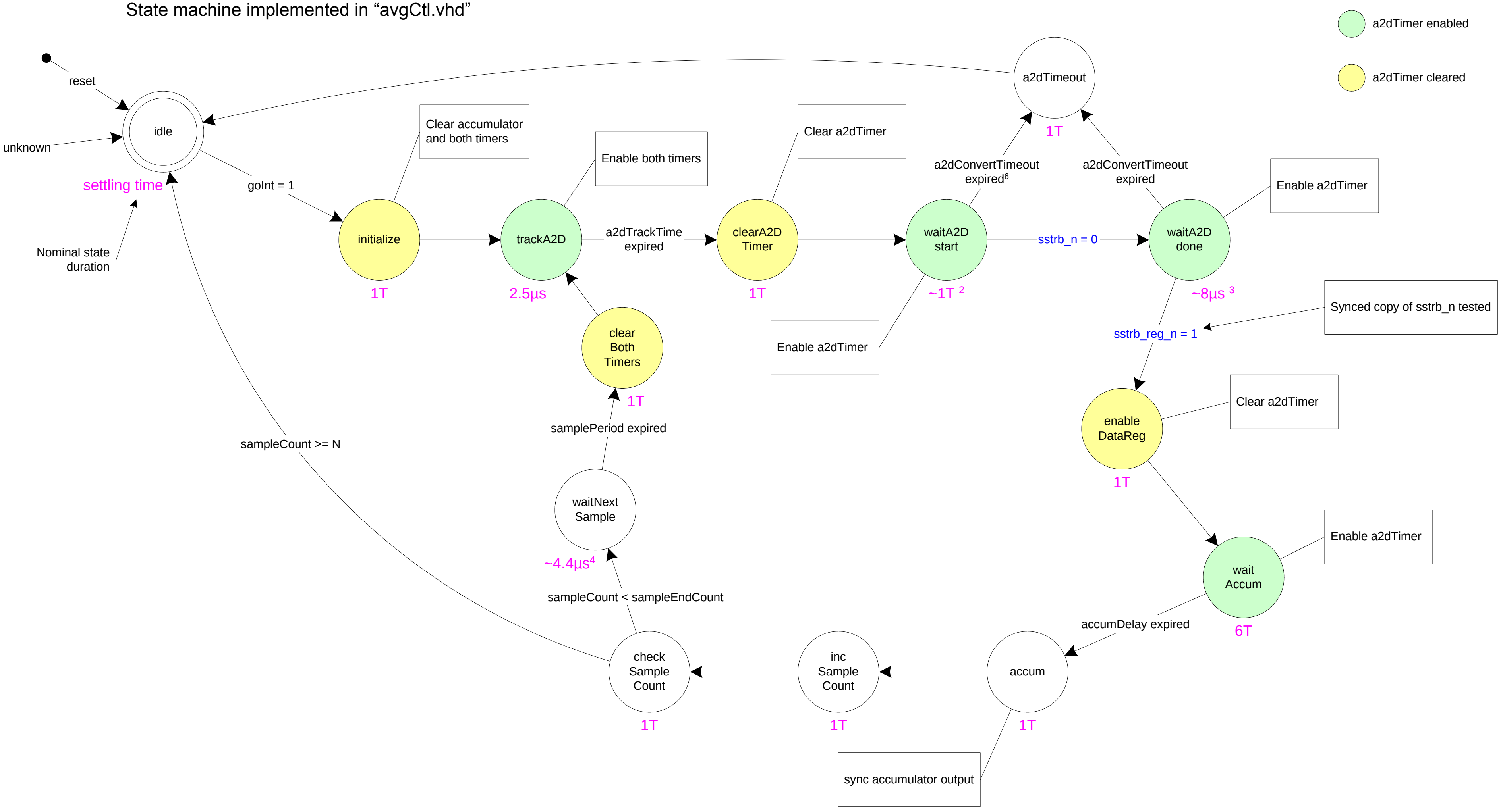


Key Points:

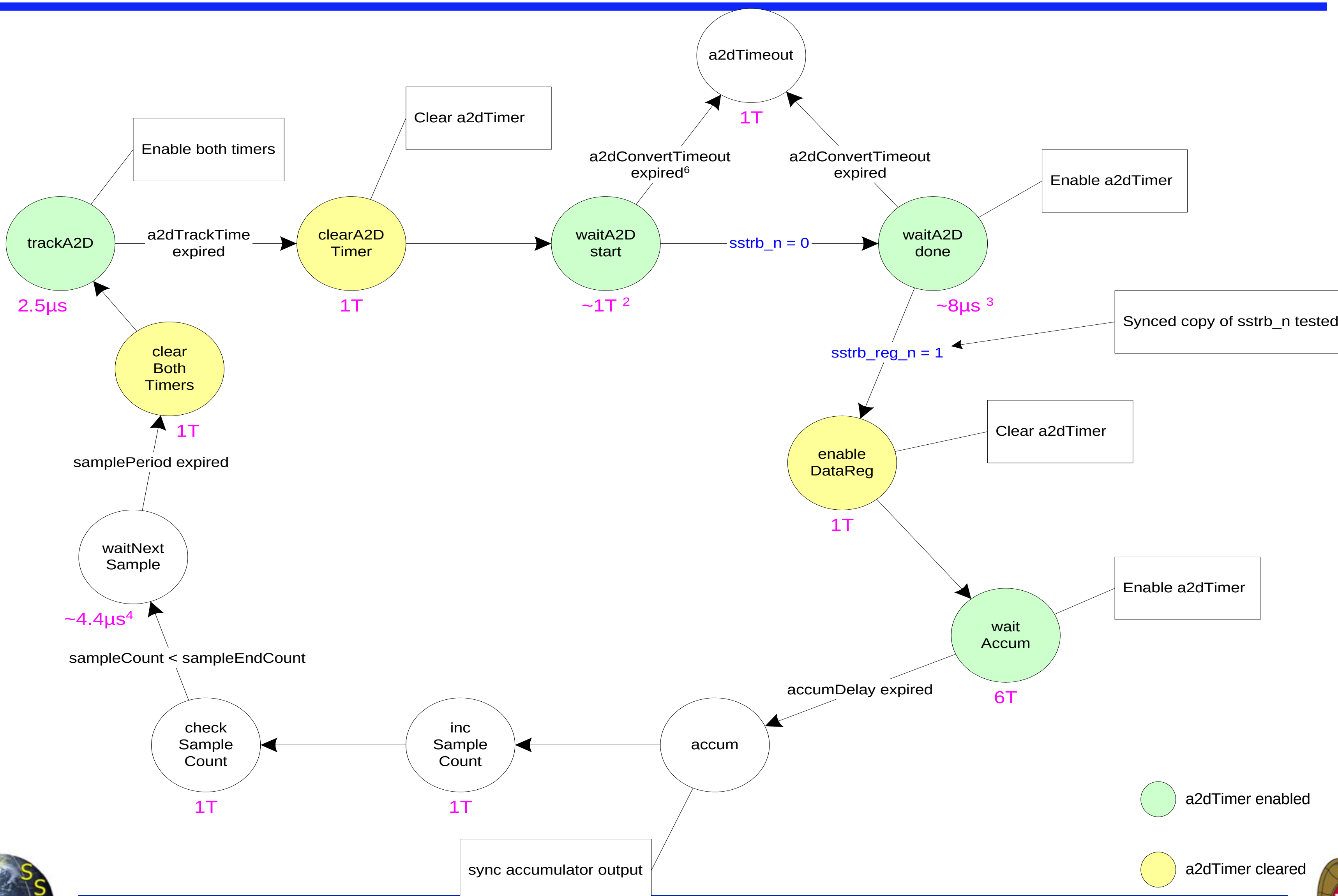
- Controls ADC interface
- Collects and averages 256 samples from ADC
- Synchronizes ADC data to SysClk
- Checks for proper ADC timeout
- Outputs status information to Data Collector Control module
- Compares averaged data to predefined thresholds
- Outputs control signals to Offset Selector
- Synchronous Design

Digital Interface & Controller Logic -- Data Collector Averager - State Machine

State machine implemented in "avgCtl.vhd"



Digital Interface & Controller Logic -- Data Collector Averager - State Machine

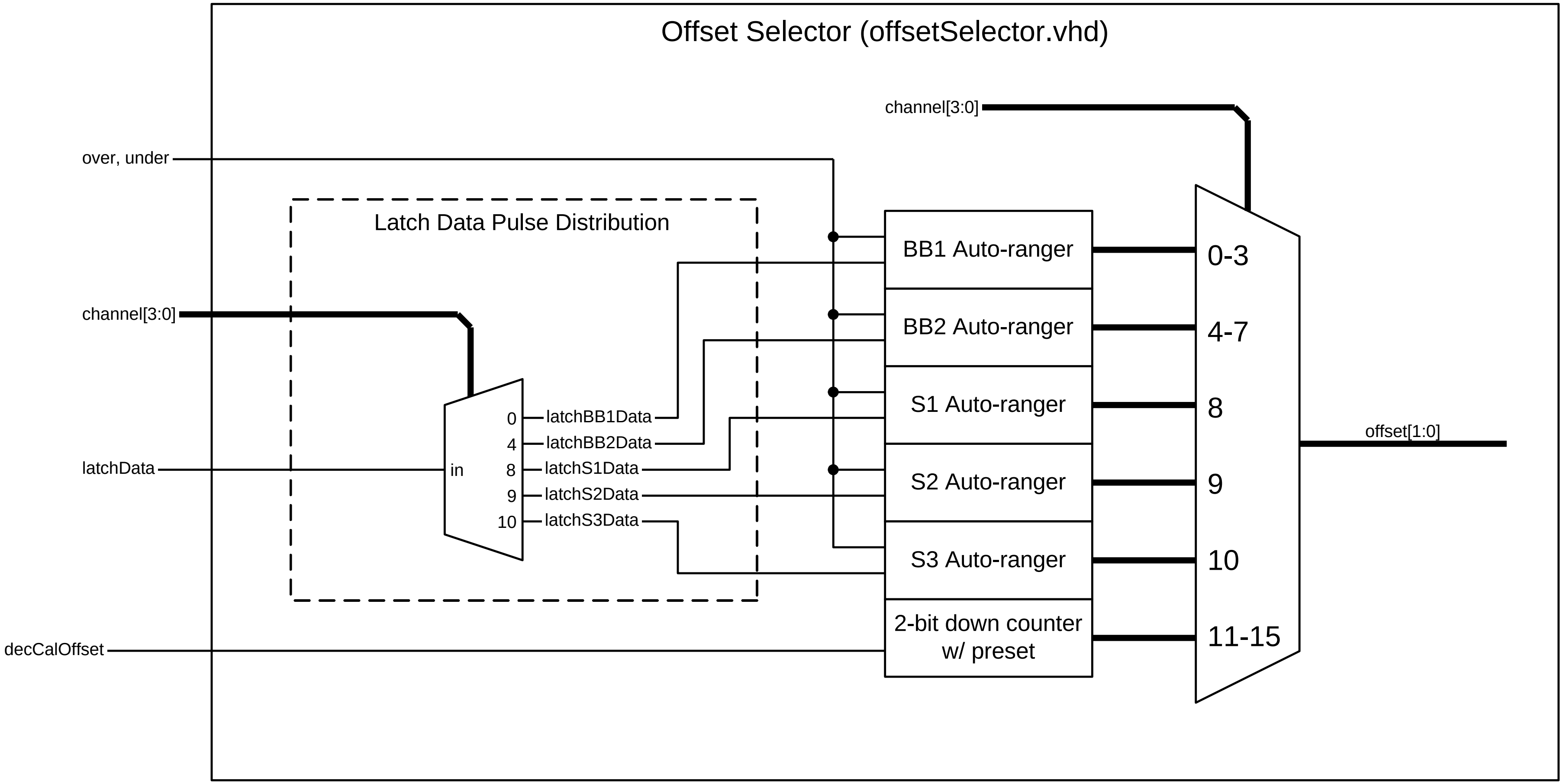


Digital Interface & Controller Logic -- Data Collector - Offset Selector

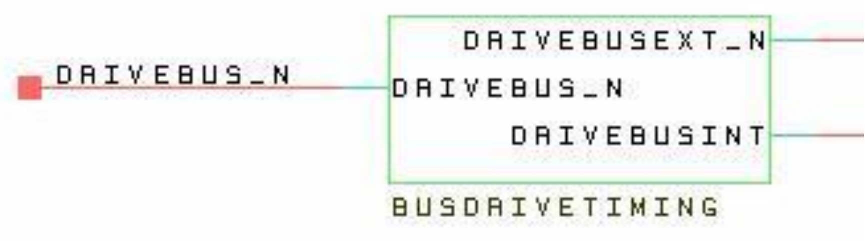
Key Points:

- Outputs Offset Multiplexer address bits
- Receives control signals from Data Collector Controller
- Receives control signals from Data Averager
- Uses 2 bit up/down counters for 2 LS bits of offset value
- Outputs Offset values used to Register Block for Status B register
- Synchronous Design

Digital Interface & Controller Logic -- Data Collector - Offset Selector



Digital Interface & Controller Logic – Drive Bus Timing



Key Points:

- Provides time delay to ensure no bus contention between FPGA transceivers and SDL bus transceivers
- Outputs Drive Bus External
- Outputs Drive Bus Internal
- Asynchronous Design

Digital Interface & Controller Logic – Supporting Analysis

General Requirements

- Data Collection Rate Requirement = 1 Hz — Actual = 2.7 Hz
- Interface to SDL Bus — Met

Digital Interface & Controller Logic – Supporting Analysis

- Verified data collection design meets BBC specification
  - Functionality
  - Timing
- Verified bus interface design meets SDL Bus requirements
  - Functionality
  - Timing
- Module design documentation
  - Requirements
  - Listing of input and outputs
  - Theory of operation
  - State machine implementation
    - * Method – Mealy and/or Moore
    - * Unused states
    - * Reset conditions
    - * State encoding
    - * Homing conditions

Digital Interface & Controller Logic – Supporting Analysis

- Module design documentation
  - Timing issues
    - * Synchronous or Asynchronous
    - * Clock skew worst case analysis
    - * Worst case timing analysis
    - * Timing diagrams
- Extensive Simulation using development tool (Libero)
  - Worst case simulations for ADC interface
    - * ADC published specifications
  - Worst case simulations for SDL bus transactions
    - * SDL bus specifications
    - * Response to SDL bus control signal glitches
- Worst Case power analysis for FPGA

Digital Interface & Controller Logic – Supporting Analysis

- Gate output loading analysis
- Interface voltage margins analysis
- Reset condition analysis
- Part safety analysis
  - Input voltage levels
  - Tri-state output overlap
  - Floating input analysis

EM1 Testing

- SDL Bus transactions
  - Writes and Reads of registers
  - Timing for bus write and read
  - Timing of Drive_Bus# signal
- Control Parameters to Analog Controller
  - Verified connections to all components
  - Verified register bits to outputs
  - Verified correct settings for Low Power Reset Mode
  - Verified correct settings for Lab Mode

EM1 Testing (continued)

- Data Collector Functions
  - Verified Data Collector State transitions
  - Verified Data Averager functionality
    - * Timing of ADC sampling
    - * Verify ADC data vs input voltage
    - * Number of ADC samples per channel
    - * Verify data averaging
    - * ADC timeout
  - Verified Offset Selector functionality
    - * Auto Mode
    - * Non-Auto Mode
- Verified Freeze Mode operation
- Verified Power up Reset timing
- Power supply current measurements for +2.5, +5V supplies

Digital Interface & Controller Logic – Verification Plans

- FPGA Design Verification

  Verify design on BBC EM2 with flight level FPGA

  - Use Actel Silicon Explorer tool to examine signals
    * Check signals not available on test outputs
    * Use logic analyzer function to:
      -- Verify test signal outputs
      -- Check ADC timing
  - Use digital storage scope to verify timing
    * SDL bus transactions
    * ADC timing

- System Verification

  Verify system operation at three operating temperatures using SDL Bus simulator

Actel Development Tools

- Libero V5.0.0.14
    * Viewdraw V7.7.0
    * Synplify V7.3
    * Waveformer Lite V 9.0
    * ModelSim V5.7b
    * Designer V5.0.0.14
        -- NetlistViewer
        -- Pin Editor
        -- Chip Editor
        -- Timer
- Silicon Explorer V5.0
- Silicon Sculptor V4.38

- Met Key Requirements – (see slide 2)
- Completed extensive analysis of design
- Completed extensive testing of design on EM1
- Plans to verify FPGA design in flight level FPGA on EM2

GIFTS
Blackbody Subsystem
Critical Design Review
Blackbody Mechanical Design

Doug Adler

9 March 2004

Requirements

- Envelope: 8 cm dia x 15.4 cm long
- Mass (2 BB's and Controllers): <2.4 kg
- Natural frequency >120 Hz
- Strength to withstand launch and vibration loading
  - 50 g design limit load, applied simultaneously in three directions
- Strength to withstand thermal stresses
  - Survival temp of 180 K
  - Operation with max HBB set point, minimum platform temp

Changes Since PDR

Requirements

- Vibration loading more severe
- Survival temperature defined as 180 K

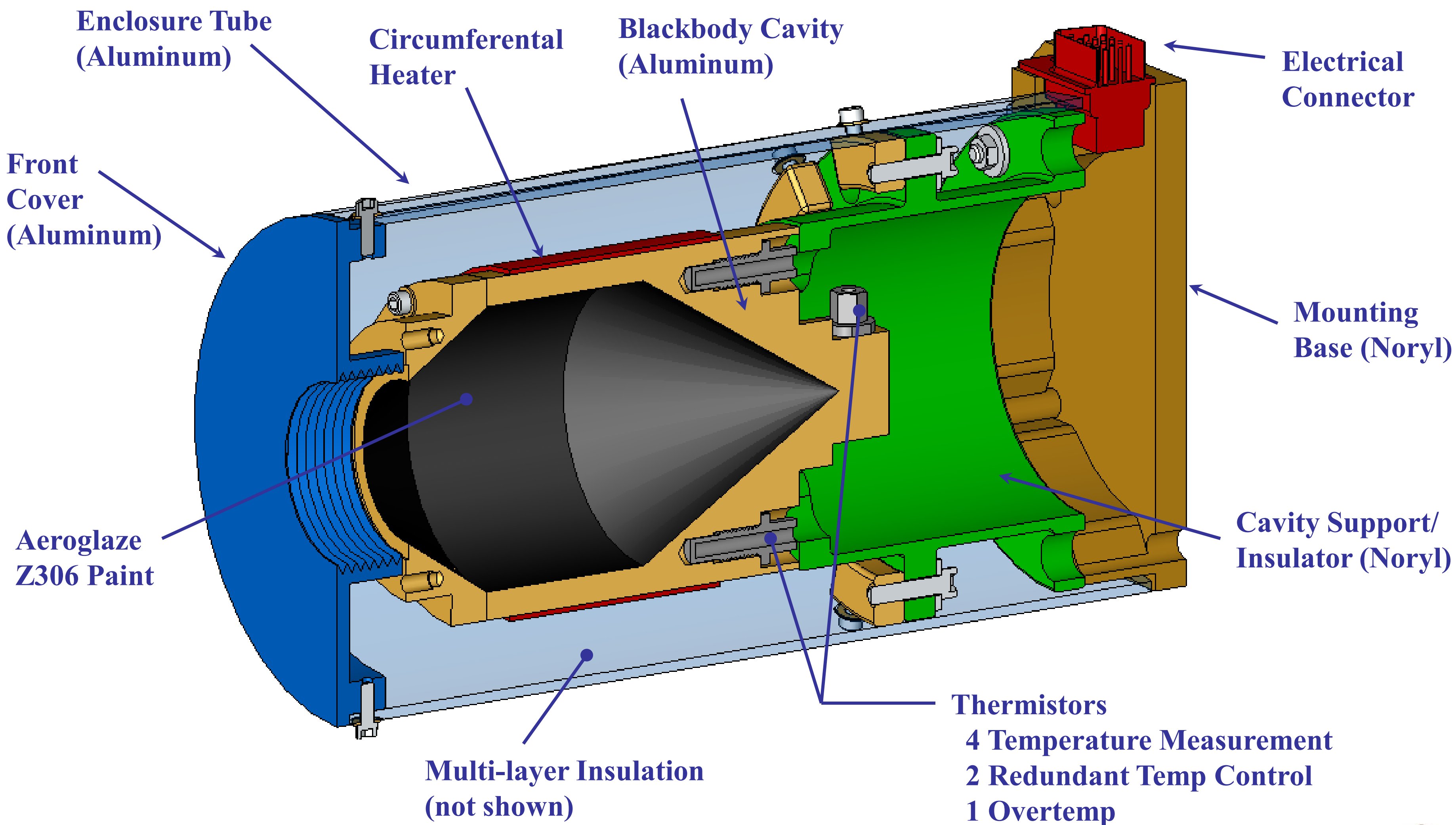
Design

- Cavity support/insulator changed from G-10 to Noryl
- Base changed from aluminum to Noryl to reduce heat loss
- Enclosure mounted to support tube to reduce heat loss
- Wire lengths increased to reduce heat loss
- Thermistors potted into threaded fittings

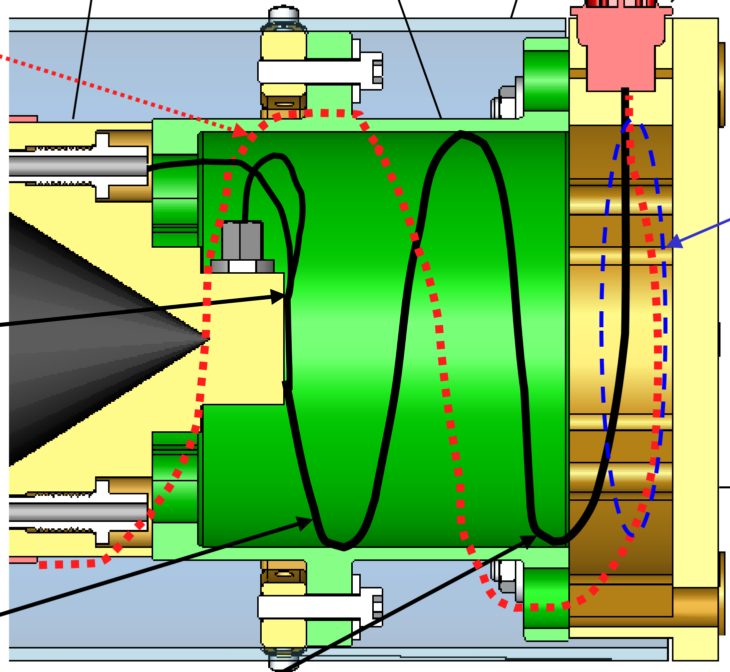
Top Level Blackbody Design

- Cavity Approach
  - Cavity shape provides high emissivity
  - Emissivity enhancement due to cavity is well characterized
  - Aluminum cavity walls minimize thermal gradients
  - Geometrically similar to AERI and S-HIS heritage designs
- Cavity insulator/support is 30% glass-filled Noryl
  - Enclosure mounts to support flange to reduce heat loss to base
- Aeroglaze Z-306 Paint
  - Provides high emissivity that is well characterized and stable
  - Straightforward to apply and provides a hardy surface
  - Extensively used in spaceflight environment
- Thermistor Temperature Sensors
  - Very stable at our temperature range
  - Not degraded by radiation environment
  - Easy to couple thermally to blackbody cavity
  - Reasonably rugged.

Blackbody Section View



Wire Routing



1. Heater wires wrapped around outside of support tube, through holes in flanges (epoxy staked) , into base to connector.

1. Thermistor wire twisted pairs are staked to tail of cavity, then bundled and shielded (wire & alum tape).

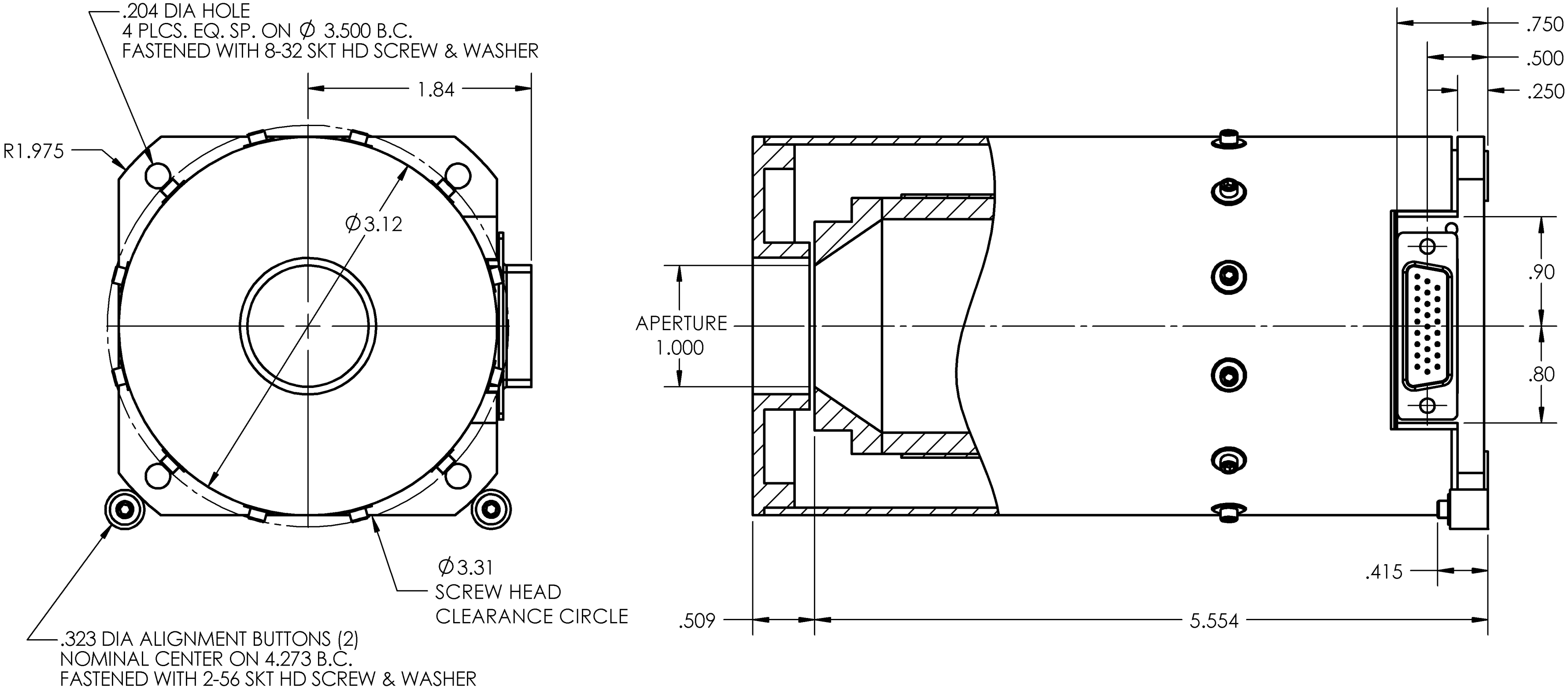
2. Bundle is spiralled out to support with about 3” wire length from cavity to support.

3. Bundle is then wrapped in a spiral along inside of support down to connector.

4. Retained with lacing through Noryl bosses epoxied to support tube as needed.

All wires in Hylar shield at base, flex loop allows connector to pull out 1” for access to enclosure screws.

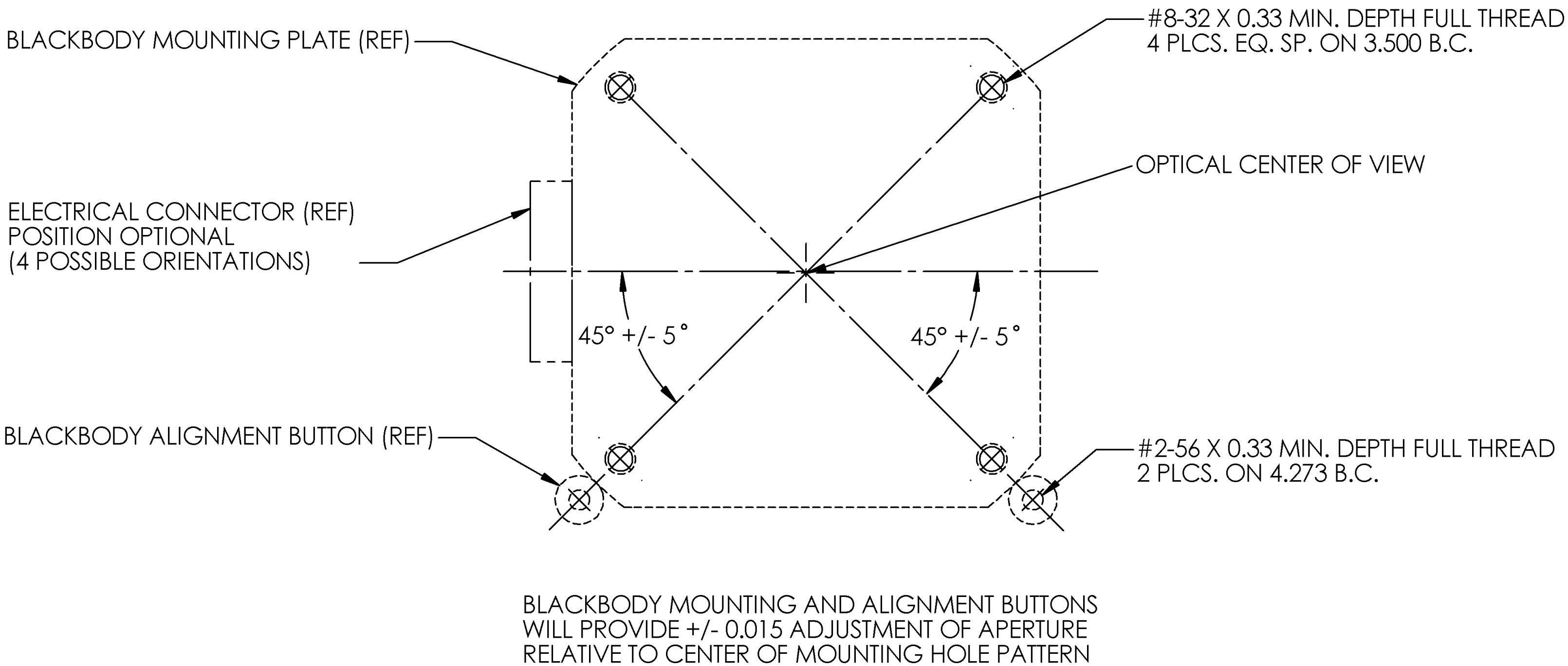
Mechanical Interface - Envelope



- Dimensions in inches

Mechanical Interface - Mounting

- Blackbodies will require 6 threaded holes as shown
- This mounting strategy provides +/- 0.015" adjustment for alignment with provisions for maintaining alignment if BB is removed/replaced



- Dimensions in inches

Blackbody Alignment Tool

- UW will provide SDL a Blackbody Alignment Tool to aid in the optical alignment of the blackbody to the SM Optics Bench.
- The tool closely represents key mechanical dimensions and the overall envelope of the flight blackbody assembly and can thus serve as both a surrogate for alignment and as a fit-check tool.
- The tool will have a translucent target at the position of the blackbody cavity entrance aperture (the perimeter of the aperture will be outlined on the target).
- Images from projections originating at the focal plane can be marked on the translucent target and the tool can be repositioned to center the images within the blackbody aperture outline.
- When the desired alignment has been obtained the alignment buttons that register the Blackbody base flange to the Optics Bench can be positioned and staked.
- The flight blackbodies and the alignment tools are interchangeable - when their base flanges are positioned by the alignment buttons, the aperture position of the tool is identical to the aperture position of the flight blackbody.

Blackbody Subsystem Mass

	Current Estimate	Contingency		Current+ Contingency	Allocation	Margin	
	[g]	[%]	[g]	[g]	[g]	[g]	[%]
ABB	659	15	99	758	1,000	242	24.2
HBB	659	15	99	758	1,000	242	24.2
Controller	500	10	50	550	400	-150	-37.5
	1,818		**248**	**2,066**	**2,400**	**334**	**13.9**

- Blackbody mass breakdown follows
- Controller mass breakdown in Controller section

GIFTS Blackbody Subsystem comfortably within mass allocation

Blackbody Mass Breakdown

Item#	Part Number	Item	Comment / Manufacturer	Material	Qty	Unit	Unit Mass (g)	Total Mass (g)	Actual
1	8300-0011	Cavity Barrel		Aluminum, 6061-T6	1	ea	178.0	178.0	x
2	8300-0012	Cavity Cap		Aluminum, 6061-T6	1	ea	35.7	35.7	x
3	8300-0014	Cavity Support Tube		Noryl GFN3	1	ea	51.3	51.3	x
4	8300-0018	Mounting Base		Noryl GFN3	1	ea	59.0	59.0	
5	8300-0016	Enclosure Cylinder		Aluminum, 6061-T6	1	ea	161.1	161.1	
6	8300-0017	Enclosure Front Cover		Aluminum, 6061-T6	1	ea	60.8	60.8	
7		Screw, Skt Hd #2-56x7/16	Blackbody Cap to Cavity	A286 CRES	6	ea	0.35	2.1	x
8		Washer, #2 x .188 OD	Blackbody Cap to Cavity	A286 CRES	6	ea			
9		Insert, Locking #2-56 x 2D	Blackbody Cap to Cavity	Phosphor Bronze	6	ea			
10		Screw, Skt Hd #4-40x1/2	Cavity to Support	A286 CRES	6	ea	0.73	4.4	x
11		Washer, #4 x .25 OD	Cavity to Support	A286 CRES	6	ea			
12		Insert, Locking #4-40 x 2D	Cavity to Support	Phosphor Bronze	6	ea		0.0	x
13		Screw, Skt Hd #4-40x1	Support to Base	A286 CRES	6	ea	0.95	5.7	x
11		Washer, #4 x .25 OD	Support to Base	A286 CRES	12	ea			
14		Nut, Locking Insert #4-40	Support to Base	A286 CRES, Nylon Insert	6	ea			
10		Screw, Skt Hd #4-40x1/2	Support to Mounting Tabs	A286 CRES	6	ea	0.53	3.2	x
11		Washer, #4 x .25 OD	Support to Mounting Tabs	A286 CRES	6	ea			
12		Insert, Locking #4-40 x 2D	Support to Mounting Tabs	Phosphor Bronze	6	ea			
15		Screw, Skt Hd #2-56x1/4	Enclosure Tube to Mounting Tabs	A286 CRES	6	ea	0.53	3.2	x
8		Washer, #2 x .188 OD	Enclosure Tube to Mounting Tabs	A286 CRES	6	ea			
9		Insert, Locking #2-56 x 2D	Enclosure Tube to Mounting Tabs	Phosphor Bronze	6	ea			
15		Screw, Skt Hd #2-56x1/4	Enclosure Tube to Front Cover	A286 CRES	6	ea	0.53	3.2	x
8		Washer, #2 x .188 OD	Enclosure Tube to Front Cover	A286 CRES	6	ea			
9		Insert, Locking #2-56 x 2D	Enclosure Tube to Front Cover	Phosphor Bronze	6	ea			
16		Screw, Skt Hd #8-32x1/2	Mounting Plate Attachment	A286 CRES	4	ea	1.90	7.6	x
17		Washer, #8 x .5 OD	Mounting Plate Attachment	A286 CRES	4	ea			
16		Screw, Skt Hd #8-32x1/2	Mounting Plate Alignment Bushings	A286 CRES	2	ea	1.90	3.8	x
17		Washer, #8 x .5 OD	Mounting Plate Alignment Bushings	A286 CRES	2	ea			

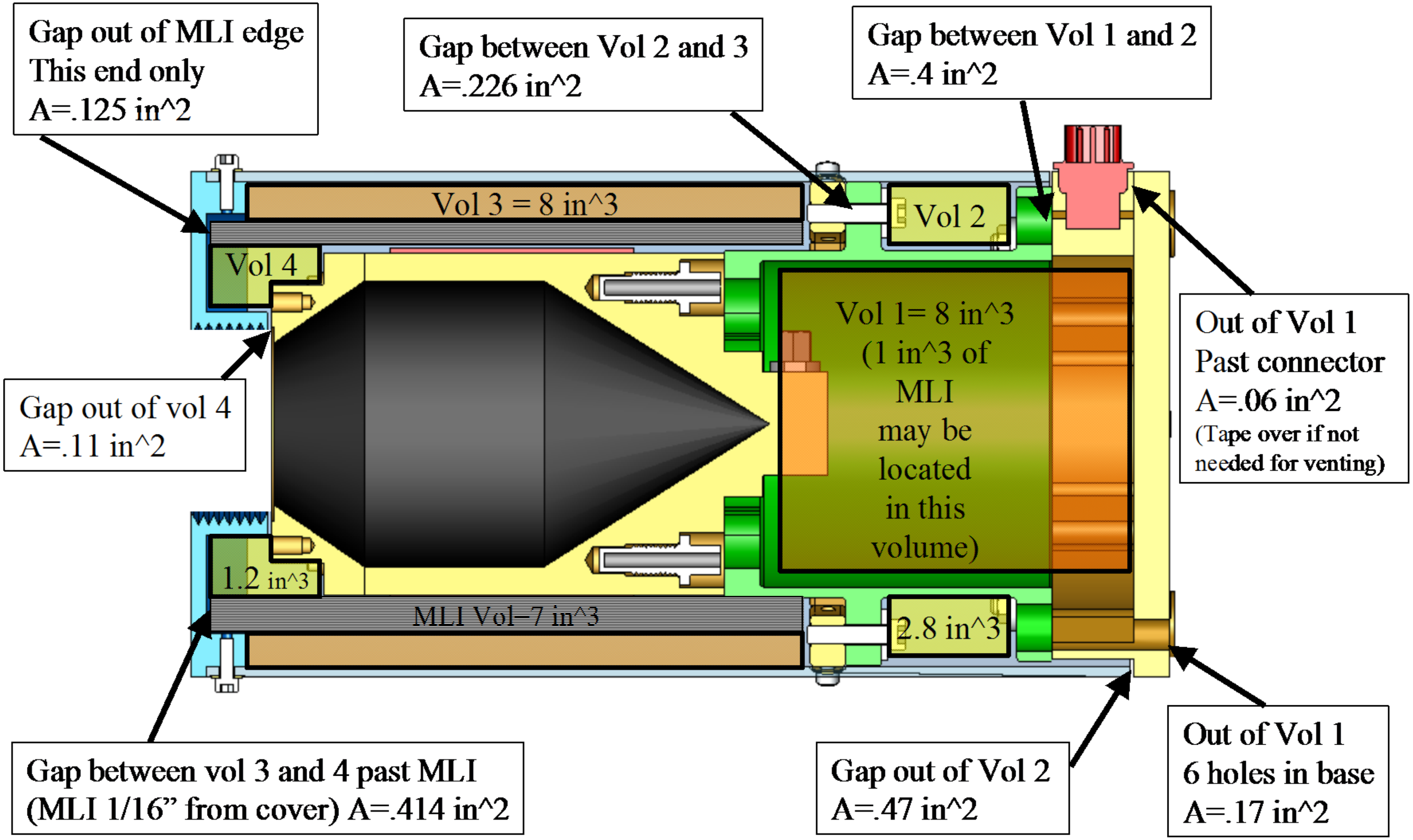
Blackbody Mass Breakdown

Item#	Part Number	Item	Comment / Manufacturer	Material	Qty	Unit	Unit Mass (g)	Total Mass (g)	Actual
18	HK24279	Heater	Minco HK24279	1.5 in x 6.5 in	1	ea	6.70	6.7	x
		Insulation Film	2 mil	Kapton Polyimide 2 mil	2	ea	0.45	(0.9)	
		Internal Adhesive	1 mil	FEP, 1 mil	2	ea	0.34	(0.7)	
		Mounting Adhesive	Minco #10 2 mil	PSA (3M 966 Acrylic transfer tape) 2 mil	1	ea	0.35	(0.4)	
		Foil		CuNi 70-30	1	ea	0.34	(0.3)	
		Heater lead wire insulation	AWG 26; 4 x 12 in	Teflon	1.22	m	1.10	(1.3)	
		Heater lead wire conductor	AWG 26; 4 x 12 in	Copper	1.22	m	1.38	(1.7)	
19	BM3	Heater Shrink Band	Minco BM3	Mylar Polyester	1	ea	1.00	1.0	x
20	AX-0310001-*	Thermistor, w/ pot, epoxy	Thermometrics		7	ea	1.00	7.0	
	8300-0022	Housing		Aluminum, 7075-T6	7	ea	0.74	(5.2)	
	SP60	Thermistor		Glass/dumet	7	ea			
		Silicone Coating	Emerson & Cuming, encaps. by 2850	E&C Stycast 4952 / CAT 25	7	ea			
		Potting Epoxy	Emerson & Cuming	E&C Stycast 2850 FT / CAT 24 LV	7	ea	0.20	(1.4)	
		Wires, thermistor & ground	AWG 28; 18 x 24 in	Teflon	11	m	0.96	10.6	
		Wires, thermistor & ground	AWG 28; 18 x 24 in	Copper	11	m	0.8	8.7	
21		Epoxy, thermistor wire stakes	Emerson & Cuming	E&C Stycast 2850 FT / CAT 24 LV	14	ea	0.5	7.0	
22		Lubricant, thermistor threads		Molybdenum Disulfide			A/R		
23		Insulation - MLI Blanket		Aluminized Mylar/polyester	1	ea	10.00	10.0	
24	SDD26FR4200G	Electrical Connector	Positronics SDD26FR4200G Male (High-density Sub-D Size 26) Specified by SDL	Copper/brass/gold and polyester	1	ea	8.0	8.0	
		Insulator	MIL-M-24519, RP-1124	Glass-filled polyester	1	ea	2.3	(2.3)	
		Pins		Copper alloy					
		Shell, screws, etc		Brass w/ gold over copper plate					
25		Wire Shielding	Chomerics	Aluminized tape, 1 mil PI, PSA				5.0	
26		Thermal Control Tape	Sheldahl	Aluminized tape, 1 mil PI, PSA				5.0	
27	Z306	Cavity paint	13.6 sq in x 3 mil	Chemglaze Z306, 9924 primer, 9951 thinn	0.669	cc	1.1	0.7	
28		Hardware Staking		3M Scotchweld 2216			A/R	10.0	

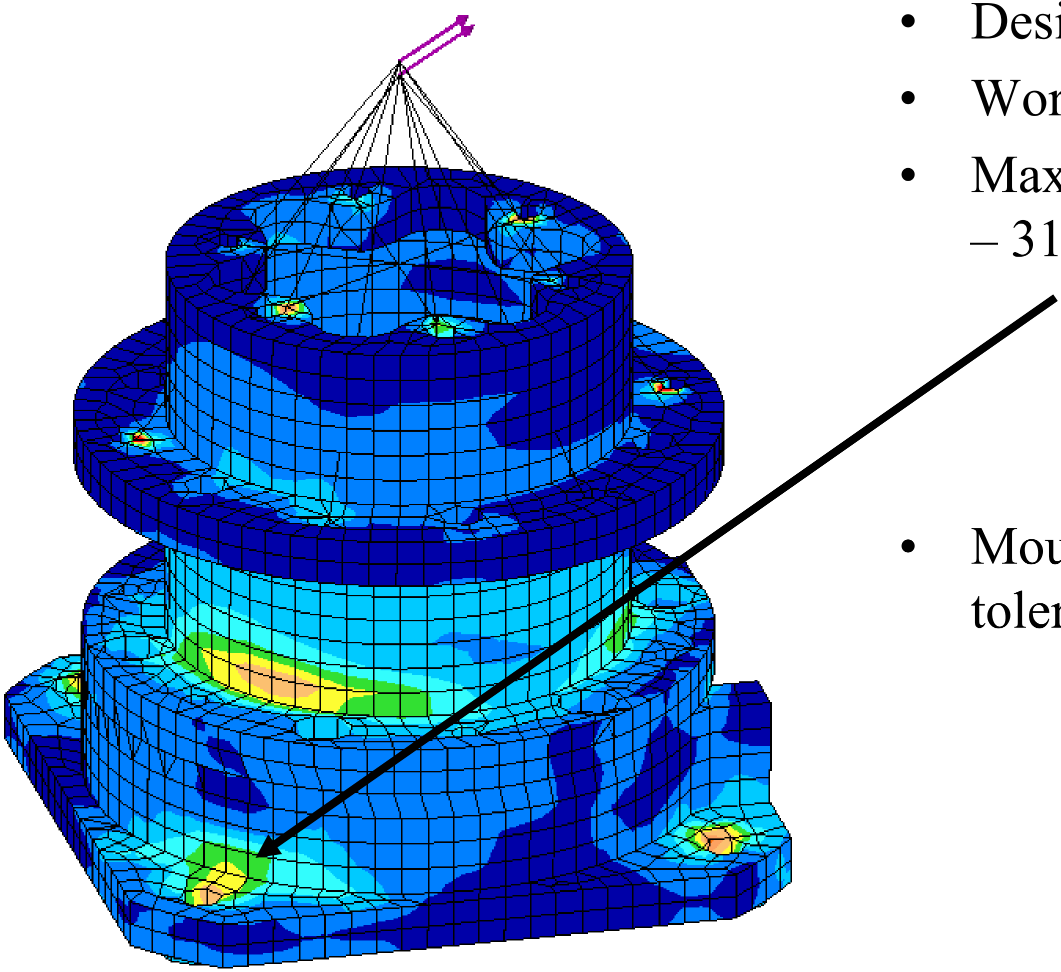
NOTE In total mass column values in parentheses are sub-component masses, not included in total.

Total Mass (g)	659	

Blackbody Venting



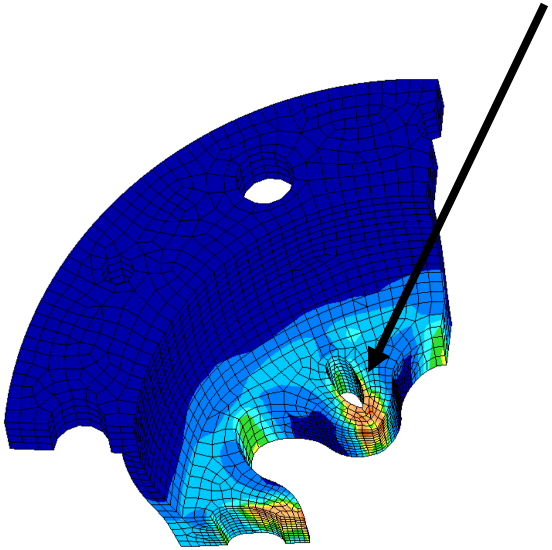
Blackbody G-loading

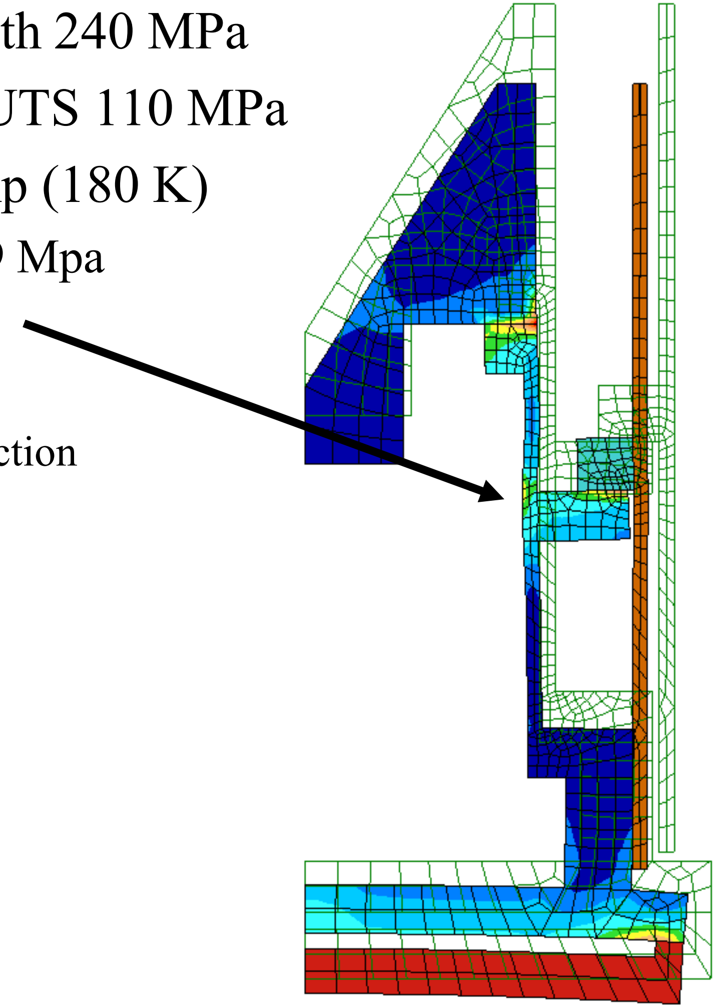


- Design limit load of 86.6 G
- Worst case is lateral direction
- Max stress in fillet near mount bolt
  – 31 Mpa (110 Mpa UTS)
- Mounting bolts are not two-fault tolerant and will be proof tested

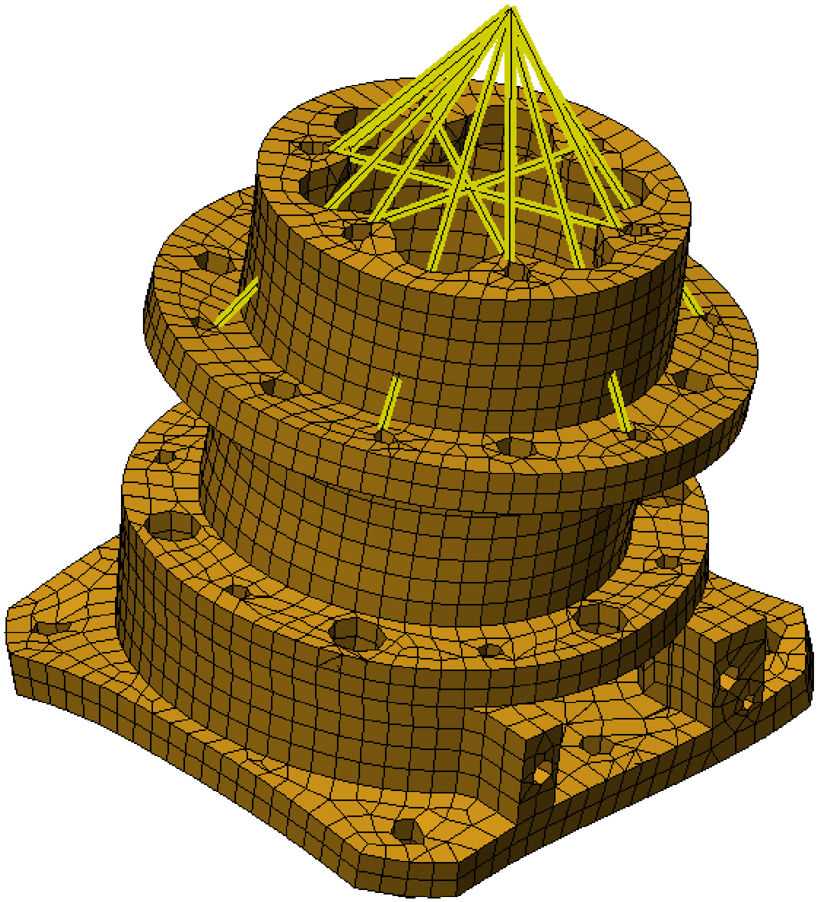
Blackbody Thermal Stress

- Aluminum CTE 23.6 E-6 /°C, Yield Strength 240 MPa
- Noryl CTE 25 E-6 /°C, assumed +/- 30%, UTS 110 MPa
- Max stresses occur in Noryl at survival temp (180 K)
  - In support tube due to enclosure loading – 9 Mpa
    - Assumes solid enclosure attachements
  - At cavity attachment – 14 Mpa
    - Assumes no give in bolt, concentrated deflection





Blackbody Natural Frequency



- Modeled with lumped masses at enclosure and cavity cg's
- Lumped mass trusses are point applied, so results are conservative (lower frequency)
- First mode is cantilever beam
- With fixed bolt holes, first mode at 190 Hz
- With pivot restraint, first mode at 145 Hz

PWB Analysis

- PWB board is 10 x 6 in, weight 1.213 lbf (assumed evenly distributed)
- Wedgelocks on short sides, bus connector one long side, 2-26 pin sub-D connectors on other long side
- Assumed short sides fixed or simply supported, long sides simply supported
- E_{eq}=3E6 psi (generic epoxy-glass with copper layers)
- Natural frequency
  - Assuming short sides fixed, long sides SS, natural frequency is 140 Hz
- Stress and displacement calculated using 86.6 G design limit load, same boundary conditions as above
  - Maximum stress in board is 4,000 psi (factor of ten below copper and epoxy-glass yield strengths)
  - Maximum displacement of board y=.066 in
    - General guideline is 0.01 inch per inch of board length (per SDL)
    - On short side this gives a max recommended deflection of 0.060 inches
    - Given conservative assumptions, we expect a more detailed analysis will show deflections are within guidelines

Verification Testing

- EM level BB assembly
  - Sine sweep for natural frequency identification
  - Design limit load of 86.6 G (50 G in 3 directions)
    - Quasi-static shaker or static applied at cg
  - Random vibration to acceptance level + 3 dB (8 G_{rms} + 3 dB)
  - Repeat sine sweep to verify no natural frequency shift
  - Thermal cycles 160 K – 343 K
- Flight level BB assembly acceptance testing
  - Sine sweep for natural frequency identification
  - Random vibration to acceptance level (8 G_{rms})
  - Repeat sine sweep to verify no natural frequency shift
  - Thermal cycles 170 K – 333 K (done as part of thermal balance and cycling test)

GIFTS
Blackbody Subsystem
Critical Design Review
Blackbody Thermal Design

Doug Adler

9 March 2004

Key Requirements

- Maximum total power 4W (2 BB)
- Nominal set points: HBB 290K, ABB 255K
- Max power to bench 0.5W (Total, HBB+ABB)
- BB must always be heated (can not be driven above set point by environment)
- Requirements must be met with environment temperatures specified in thermal interface
- Requirements must be met at BB nominal set points, not over entire BB ranges

Changes Since PDR

Requirements

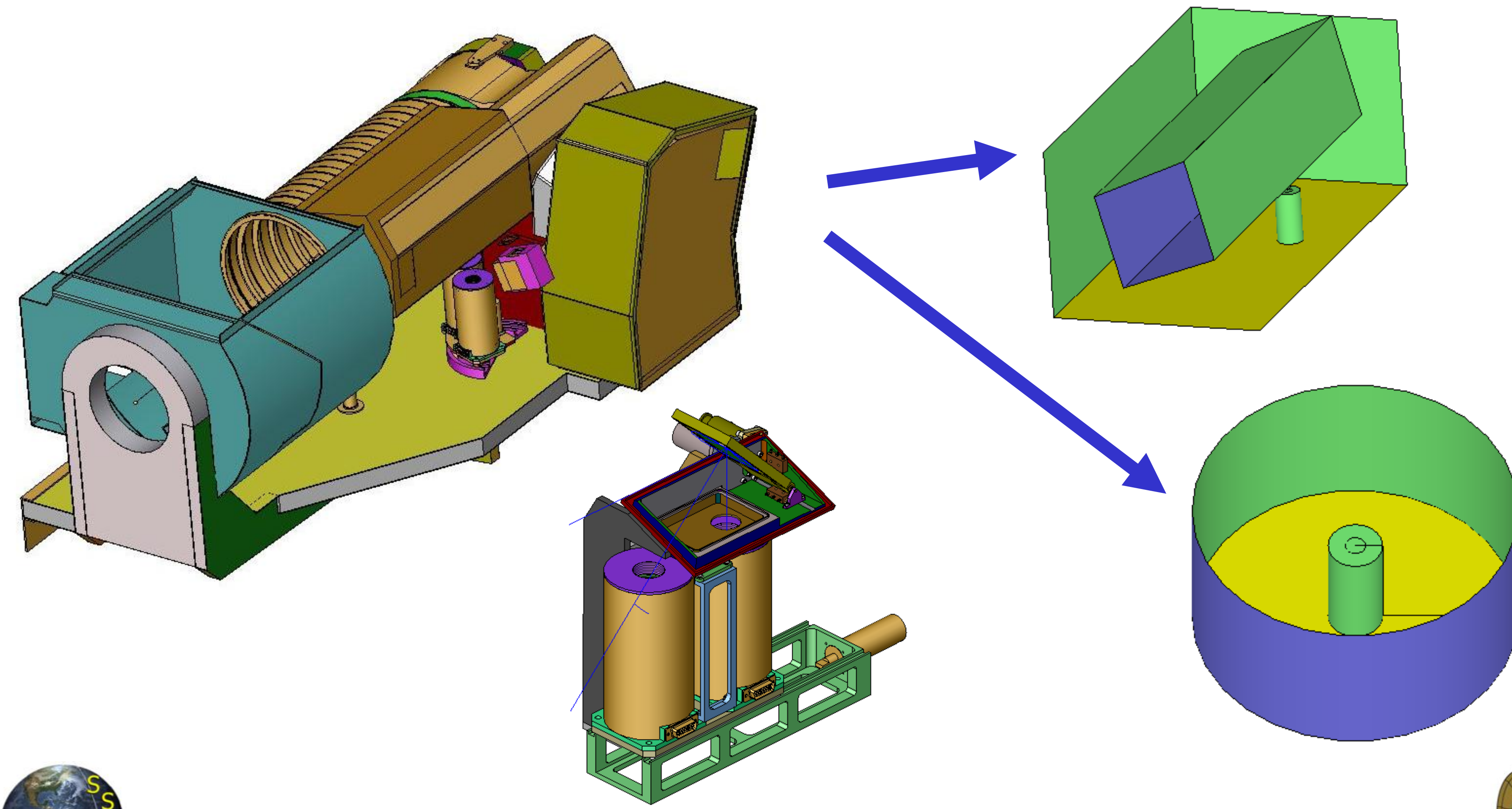
- Thermal interface is significantly more complex (was isothermal 265 K)
  - Mounted to platform/optics bench at 200 K, rising to 220 K end of mission
  - Baffle above blackbodies varies from 140-300 K
  - Mirror mount above blackbodies held at 250 K
  - Instrument survival temperature of 180 K
  - Heat loss through platform limited to 0.5 W total (ABB+HBB)
- Both blackbodies now heated, controlled to ‘ambient’ and hot temperatures of 255 K and 290 K respectively

Design

- Cavity support/insulator changed from G-10 to Noryl
- Enclosure mounted to support tube to reduce heat loss
- Internal wire length added to reduce heat loss
- Base modified to accommodate thermistor and flanges thickened for strength

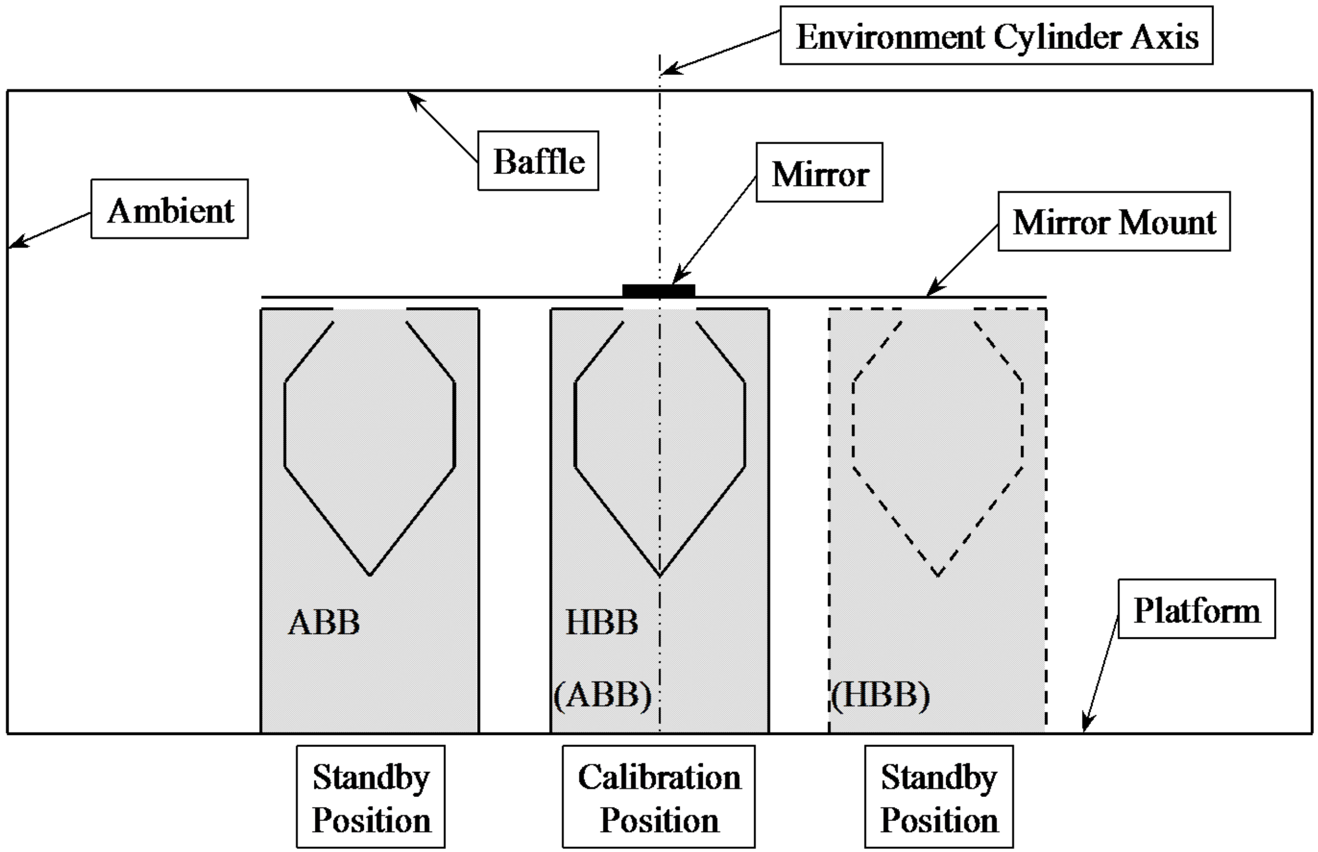
Thermal Environment

- Complex reflective surroundings difficult to model accurately
- Conservatively represented by non-reflective cylindrical surroundings



Thermal Interface

- Non-reflective (ε=1) cylinder represents baffle, ambient, and platform
- Blackbodies always covered by reflective mirror mount, slide on platform into center calibration position



Thermal Interface

- Baffle and ambient temps vary from hot to cold each orbit
- Platform and mirror mount temps are stable
- Major BB heat flow paths are radiation to environment and conduction to platform
- Environment temps in K are listed below:

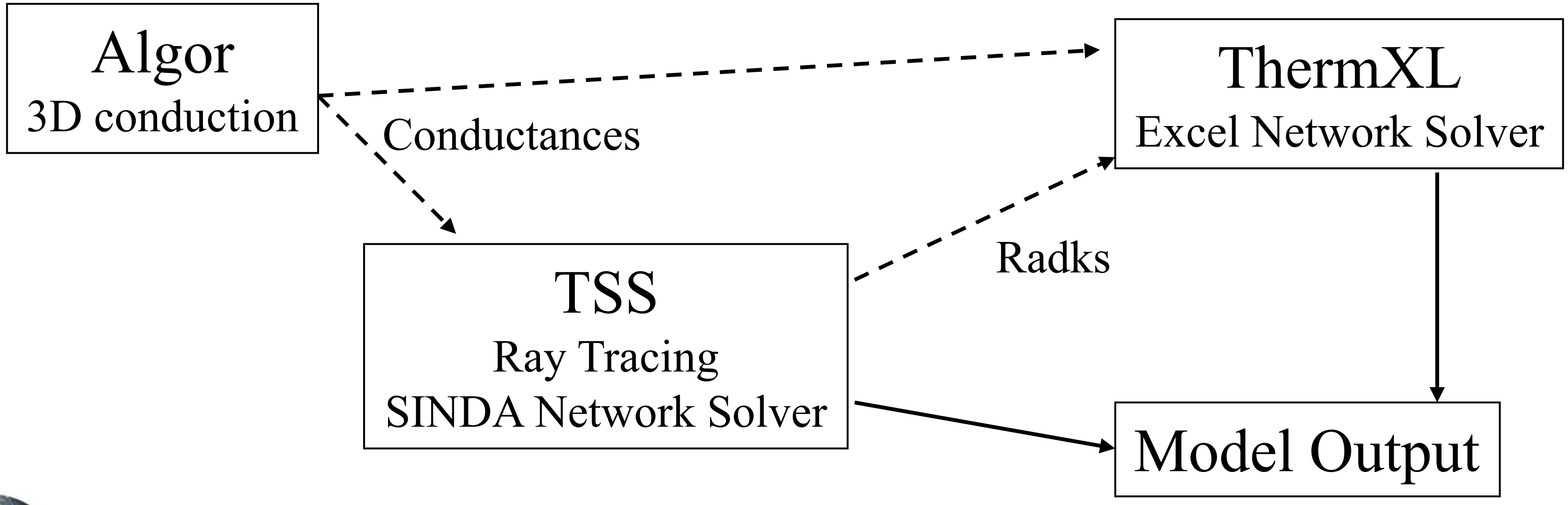
Instrument Mode	Normal – Mission Start		Normal – Mission End		Survival	
Baffle Condition	Hot	Cold	Hot	Cold	Hot	Cold
Baffle	300	140	300	140	300	140
Ambient	280	180	280	180	280	180
Platform	200	200	220	220	180	180
Mirror Mount	250	250	250	250	180	180
Electronics Box	250	240	280	270	223	223

Thermal Model Assumptions

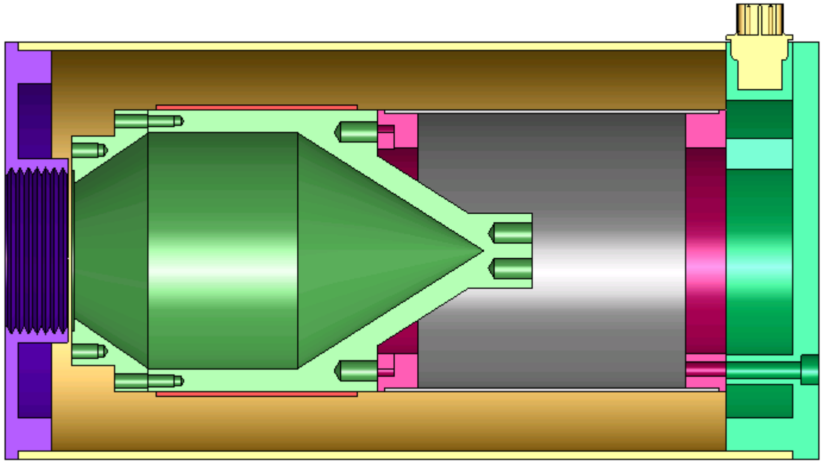
- MLI emissivity ε= 0.01-0.04, 0.04 used for worst case
- BB surfaces covered with low-ε tape (ε= 0.03-0.05) wherever possible, 0.05 used for worst case
- Wires well coupled to connector (worst case for power loss)
- During calibration flip-in mirror provides cavity aperture view to 60K
- Sliding platform is thermally coupled to optics bench, and can absorb .5W without significant temperature increase
- No heat flow in/out through external wiring harness to electronics box

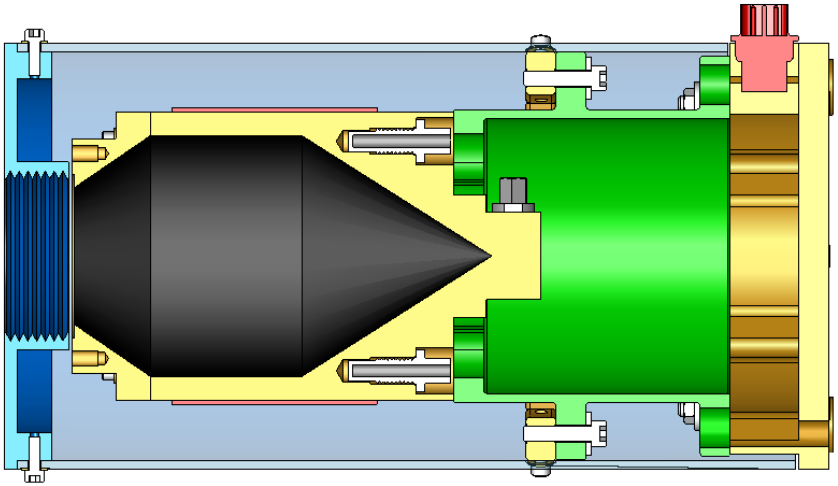
Thermal Models

- TSS model with Monte Carlo radk calculation and approximated conductances
- Network model in ThermXL with analytical view factors or TSS radks
  - Allows quick scenario changes
- Complex 3D conduction modeled with Algor FEA



Thermal Model Results





Old design

- Sensitive to Rep, inner MLI emissivity, material k
- Power to bench too high (.73W)

New design

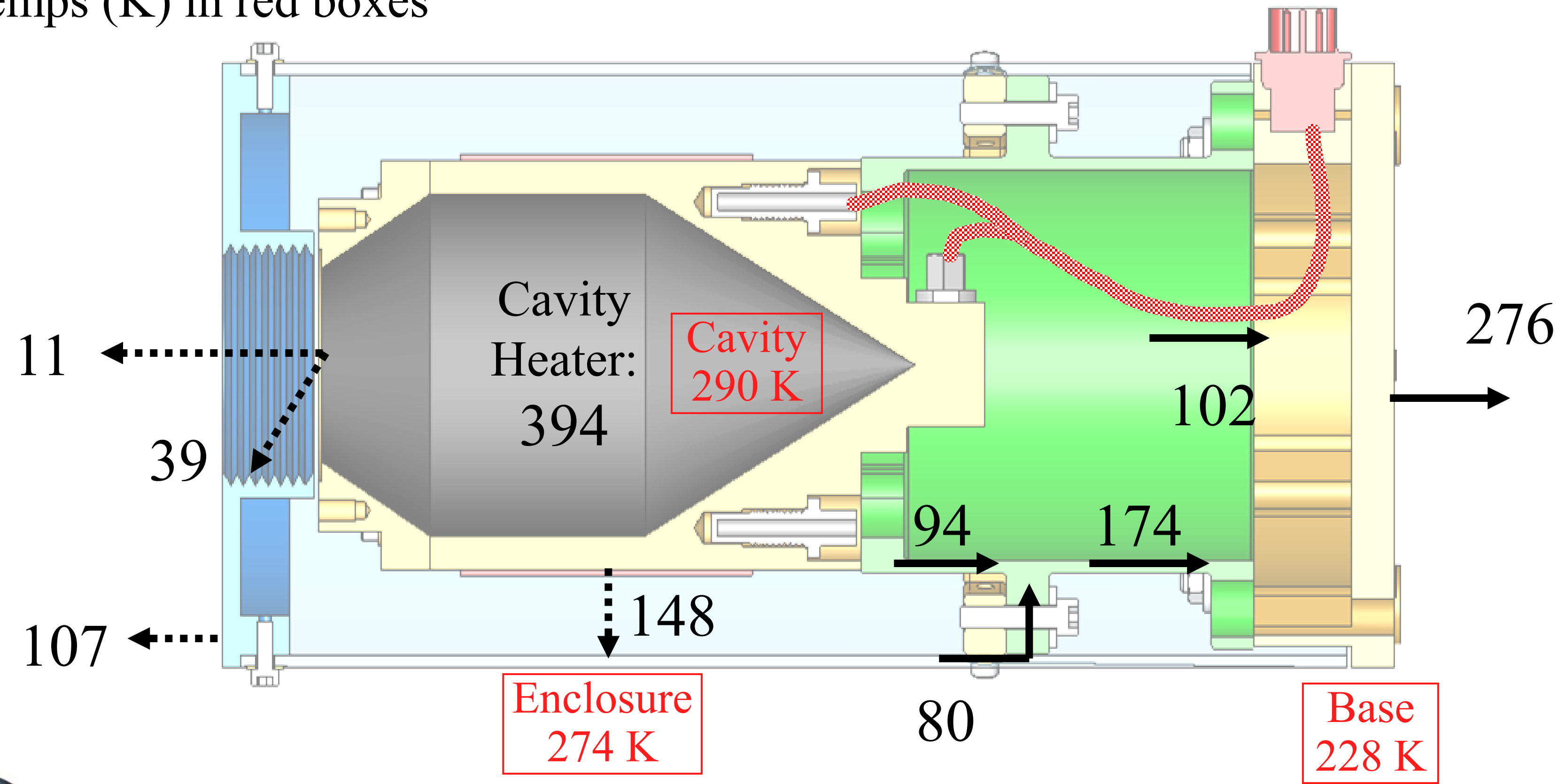
- Much less sensitive
- Power to bench meets target (.46W)

Thermal Model Results

Heat flows (in mW) for HBB, hot baffle, mission start

- Radiation (dashed arrows) out is to surrounds and cavity/enclosure
- Conduction represented by solid arrows

Temps (K) in red boxes



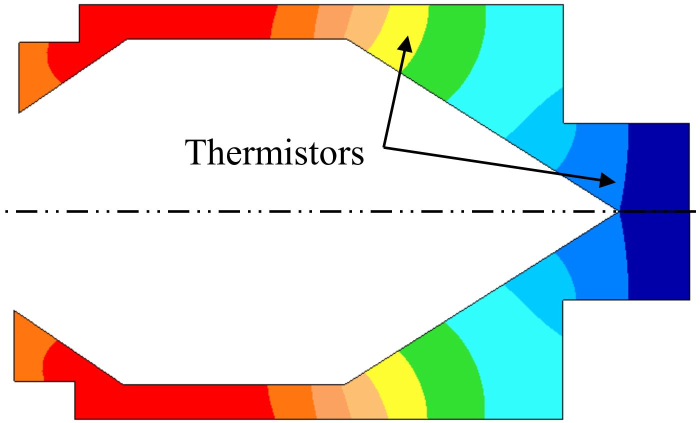
Thermal Model Results

- Worst case for heater power and power to bench is mission start (Platform at 200 K)

Condition	Blackbody	BB Heater Power (W)	Power to Bench (W)
Hot baffle, mission start	HBB (290 K)	.394	.276
	ABB (255 K)	.110	.183
	Total (HBB+ABB)	**.504**	**.459**
Cold baffle, mission start	HBB (290 K)	.626	.244
	ABB (255 K)	.346	.144
	Total (HBB+ABB)	**.972**	**.388**

Thermal Cavity Gradients

- Absolute gradients not an issue, only uncertainty in gradients
- Lateral gradients (across cavity)
  - Due to ABB and HBB proximity, estimate total gradient ~10 mK
  - Thermistors can be oriented to measure this gradient
  - Need to establish uncertainty and investigate effect of other surrounds
- Axial gradients (along cavity axis)
  - Due to radiation out front and conduction from rear
  - Results in difference between radiance view and thermistor temperatures
  - Estimate worst case 100 mK for gradient between thermistors



- Further analysis will refine the uncertainty in the error budget resulting from lateral and axial gradients

HBB Heating/Cooling Times

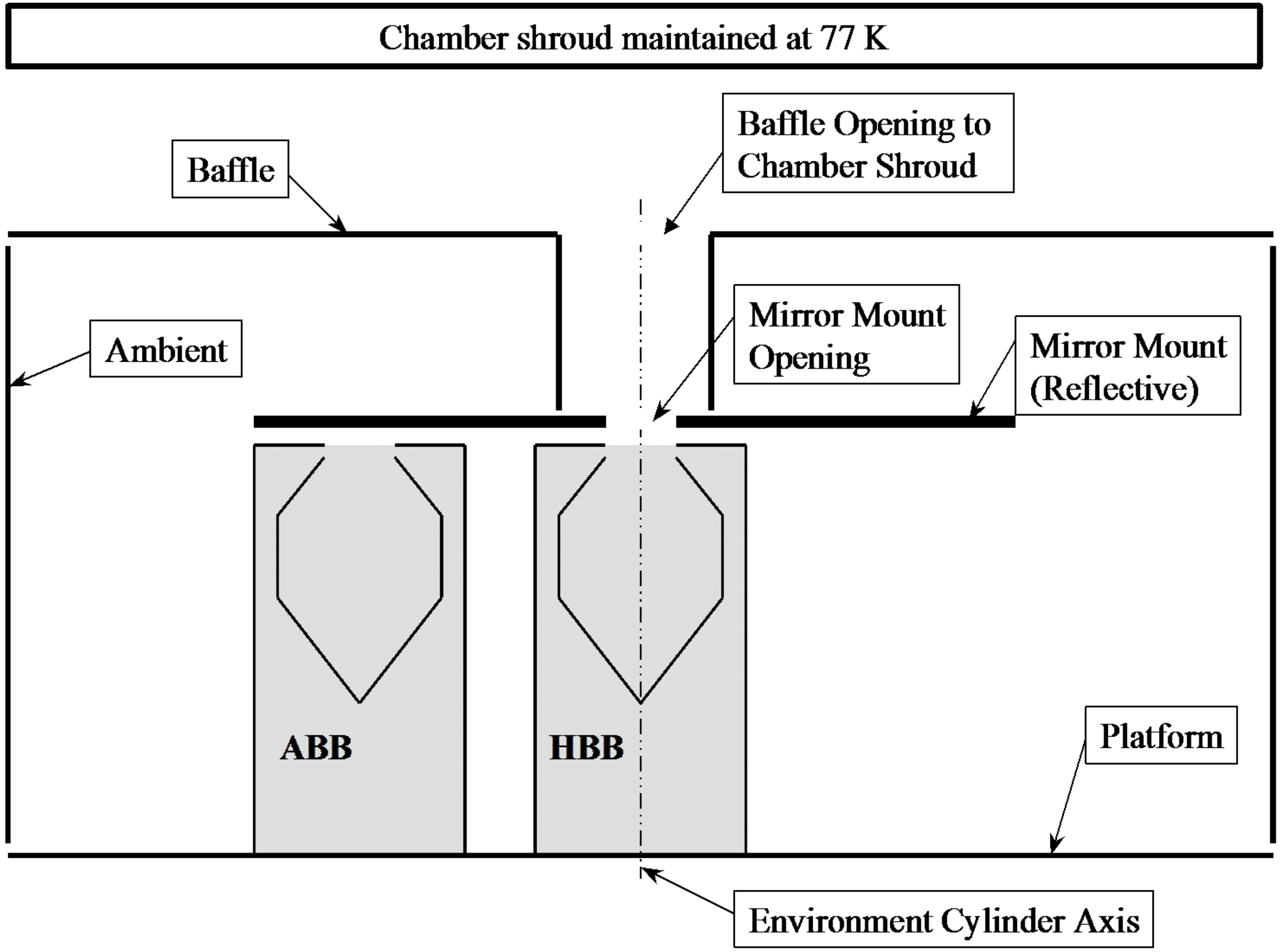
Estimate of cavity heating/cooling; neglects radiation and thermal mass of enclosure and support

- Thermal Resistance (to Platform at 200K), R = 373 K/W
- Thermal Capacitance (cavity only), C = 188 J/K
- Time Constant, $\tau = R*C$ = 19.5 h
- Time for BB to heat from 200 K to 290 K, assuming available power, P = 2 W :
- $t = -\tau * \ln[1-(Th-Ta)/(P*R)]$ = 2.5 h
- Heat-up time is 2.5 h

BB Thermal Testing

- No EM thermal tests are planned due to design robustness (not very sensitive to variations in emissivity, conductances)
- Flight acceptance test will be thermal vacuum with hot/cold balance and temperature cycling
  - Test is used to validate thermal models, which are then used to verify performance to requirements
- Bench power will be calculated based on validated thermal model, not directly measured
- Test fixture very similar to thermal interface environment, ABB and HBB tested simultaneously
  - HBB under mirror mount aperture with view to cold chamber shroud, ABB under mirror mount
  - Ambient, baffle, and platform temps independently controlled
  - All environment surfaces black except mirror mount
  - No provisions to position BBs during test or represent flip-in mirror transient

BB Thermal Verification Test



BB Thermal Verification Test

- Test Measurements:
  - BB thermistors and heater power
  - Thermocouples applied to BB enclosures and connectors
  - Monitor surroundings, fixture temperatures
- Test Procedure
  - Hot thermal balance
    - Hot baffle, end of life platform temp (220 K)
    - Worst case for ABB overheat
  - Cold thermal balance
    - Cold baffle, mission start platform temp (200 K)
    - Gives worst case heater powers
  - Temperature cycles – 12 cycles 170-333 K
  - Repeat hot & cold balance

Next Steps

- More detailed cavity modeling will be done to further refine the uncertainty budget
  - Flip-in transient
  - Cross-cavity gradient
  - Axial gradient

GIFTS
Blackbody Subsystem
Critical Design Review
Thermistors

Doug Adler

9 March 2004

Thermistor Selection

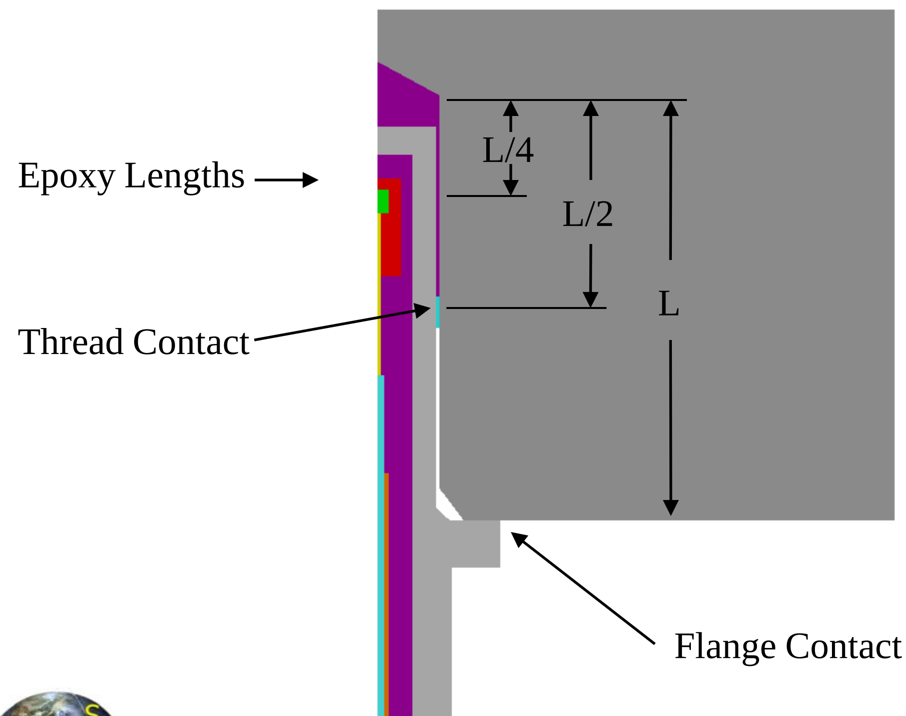
- Selected Thermometrics SP60 thermistors
  - SDL SABER mission heritage
  - Smaller size than YSI
  - Thermometrics measurement accuracy for stability testing
- Drift rated at 0.02% (of nominal 25°C resistance) per year, equates to 5 mK/year
  - Rated at 105°C, less drift at lower temperatures
  - SABER results showed up to 20 mK drift with initial 5 cycles to 77 K, < 1 mK drift with additional 5 cycles

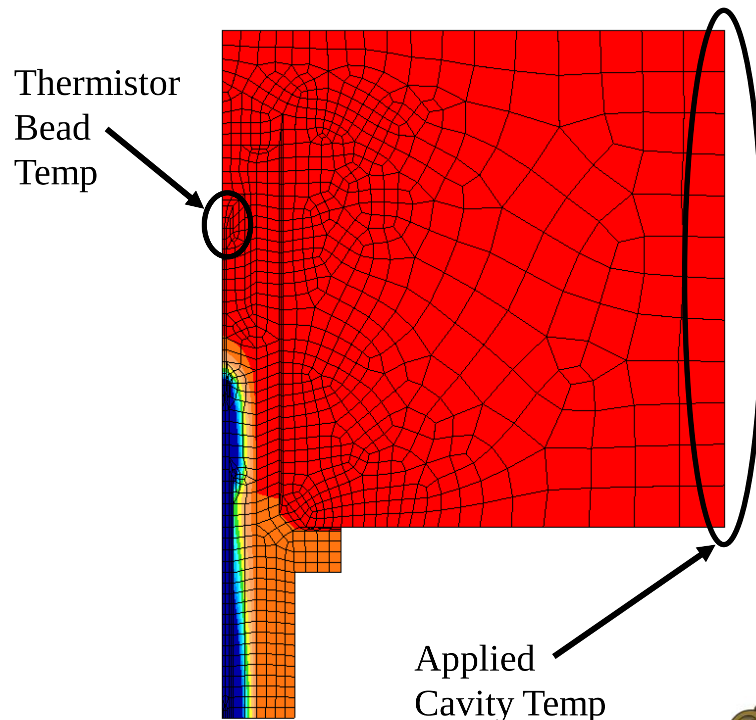
Thermistor Assembly Design

- Packaged into threaded aluminum housing
  - Similar mounting to SABER (potting, diameter, etc)
  - Allows stability testing in as-mounted condition
    - Aluminum housing ensures no additional stresses due to thermal cycling after installation in cavity
  - Lead wire joint encased in housing, eliminates risk of solder heat or handling damage affecting stability
  - Conductive epoxy used for thread lubrication, retention, and enhanced conduction to cavity
  - Dual thread-epoxy thermal path provides robustness and stability
  - 7075 chosen for reduced thread galling into 6061 cavity, and increased strength in the event of thermistor removal

Thermistor Heat Leak Bias

- FEA analysis to determine thermistor wire heat leak temperature bias
  - Heat out wire produces ΔT between the thermistor bead and surrounding material
- Considered bounding cases of contact between thermistor housing and cavity
  - Conductive epoxy length L/4, L/2, or L
  - Thread contact vs. none
  - Flange contact vs. 0.005” epoxy under flange





Thermistor Heat Leak Bias

- FEA results based on worst case heat flux out wires of 25 mW per thermistor
  - Assumes cavity at 313 K, baffle/ambient at 140 K, platform at 190 K
  - Assumes leads not staked to cavity (or ineffective stake), as long term stake performance is difficult to verify
  - Assumes wires wrapped in low-ε tape

Case	Thread Contact	Flange Contact	Epoxy Length	Temperature Error (mK)	
1	No	Yes	L/4	14	
2	No	Yes	L/2	8	Assumed for budget
3	No	Yes	L	4	
4	No	Epoxy	L	5	
5	Yes	Yes	None	4	
6	Yes	Yes	L	4	Design intent

- The cavity bores will be filled with conductive epoxy prior to thermistor housing installation, excess will exit through venting slot
- This will ensure performance of Case 2 at a minimum

Thermistor Heat Leak Bias

- FEA results were checked with a test on EM cavity and prototype thermistors
  - Thermistor housings installed with conductive paste
  - Cavity insulated, controlled to temp just above ambient
  - Leads from one thermistor dipped into ice bath
  - If thermistor had no gradient effect, predict 5-10 mK delta from ice dip lead to opposite side of cavity
  - Measured 10-15 mK delta to opposite side, which indicates 5 +/- 5 mK thermistor temperature gradient effect

Thermistor Test Plan

All flight and backup parts undergo this verification testing

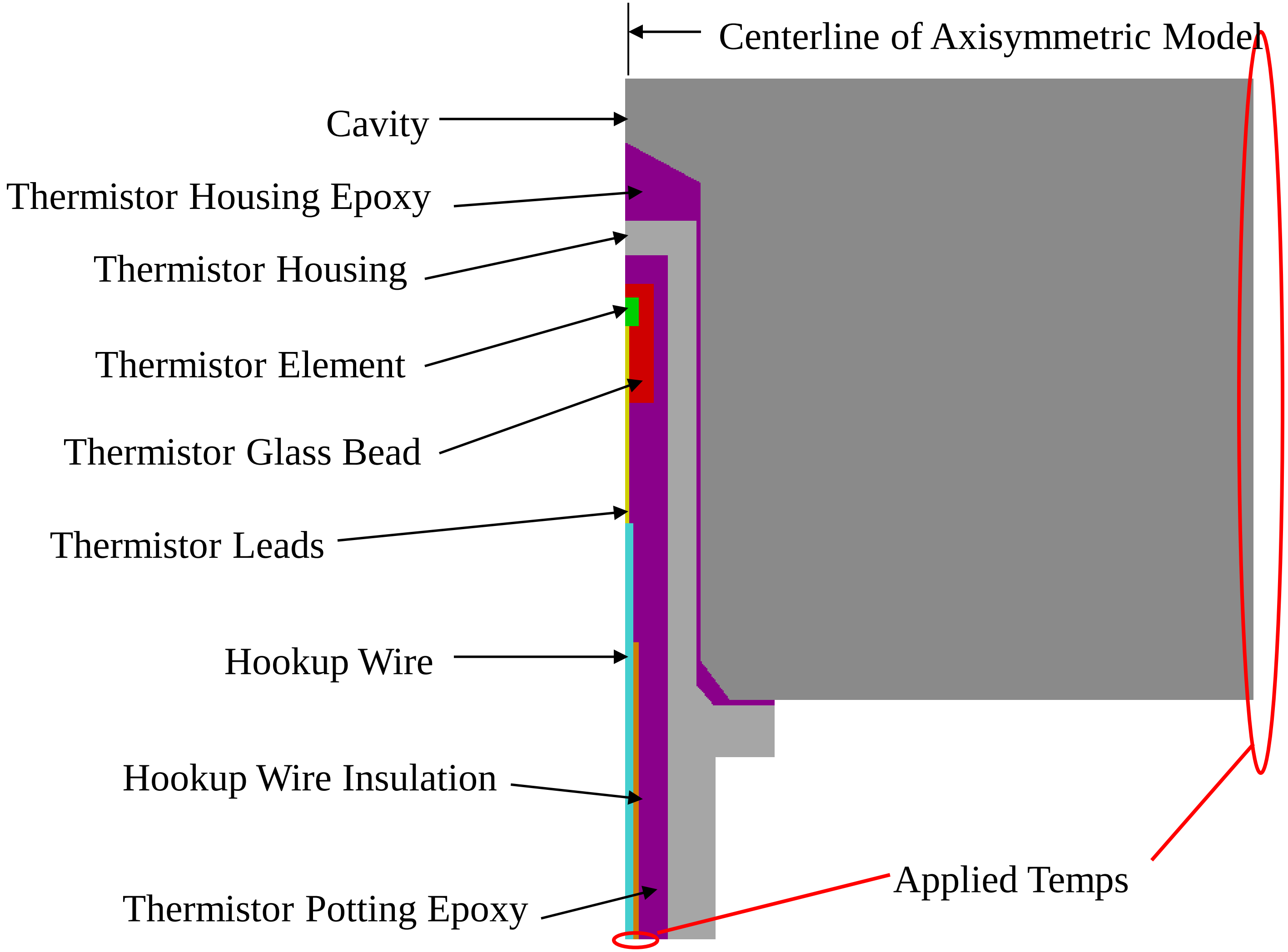
- Normal “ultrastable” thermistor stability screening performed by Thermometrics
- Lead wires attached and probes installed into housings
- Test procedure (based on SDL SABER testing)
  - Ro check
  - Vibration to 50g quasi-static, 8g +3dB random
  - Ro check
  - Thermal cycles – 5 cycles 170-333 K (-103 to +60 C)
  - Ro check
  - Thermal cycles – 5 cycles 170-333 K (-103 to +60 C)
  - Ro check and three point calibration (-40, 0, 40 C)
- Expect some thermistor drift during first set of thermal cycles based on SDL SABER results
- Second set of thermal cycles verifies no additional drifting

Backup parts will be maintained for long term drift testing

Backup Slides

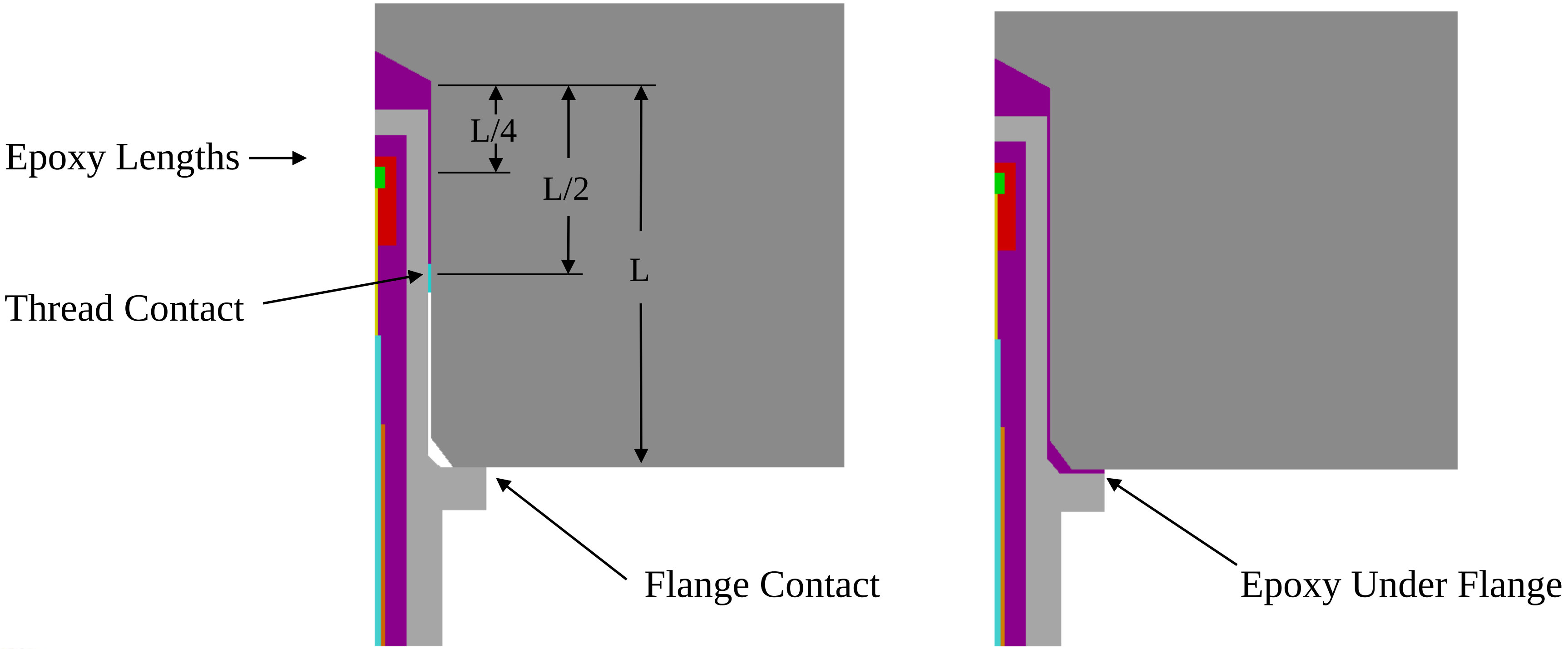
Thermistor Error Model

Thermal FEA Model

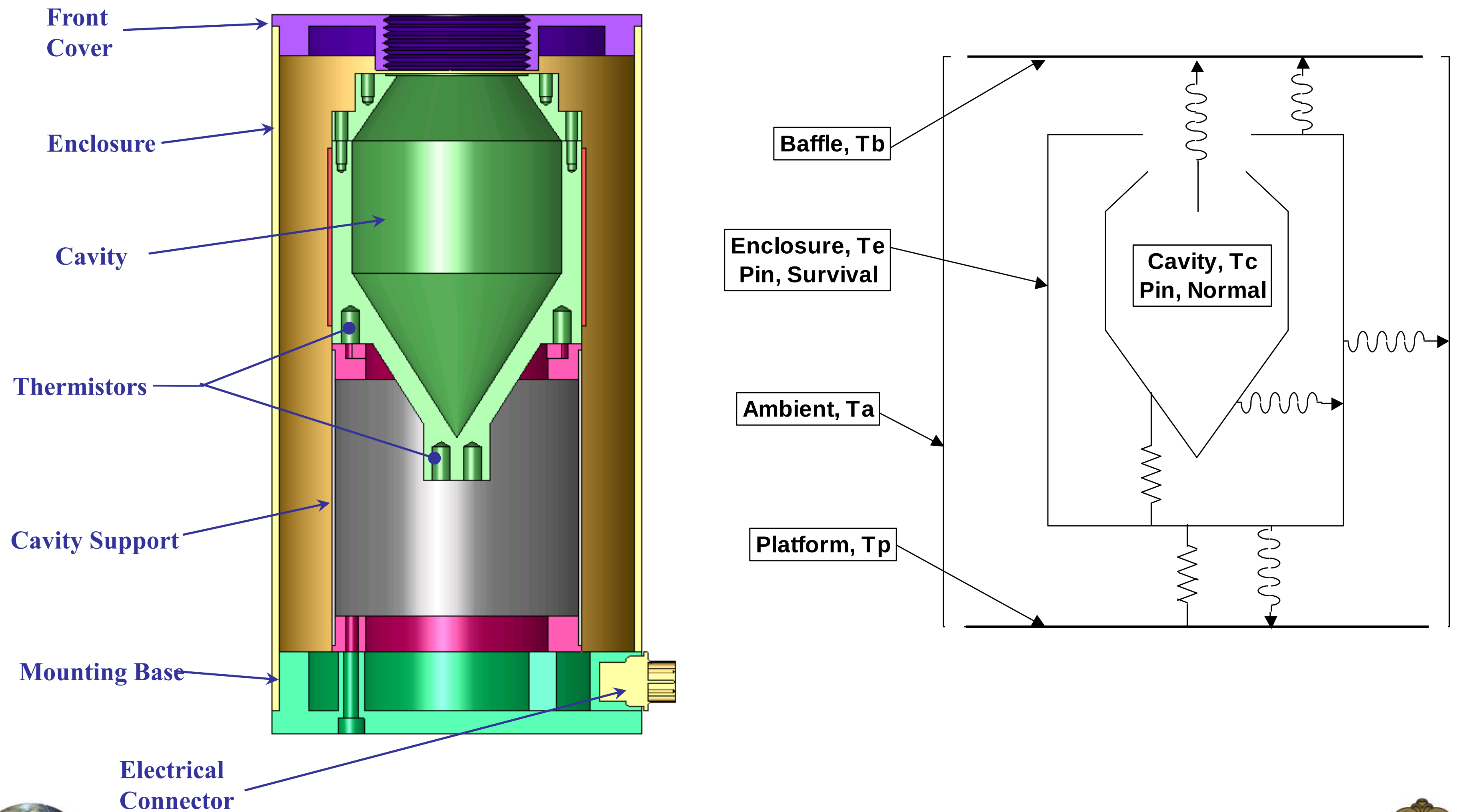


Thermistor Gradient

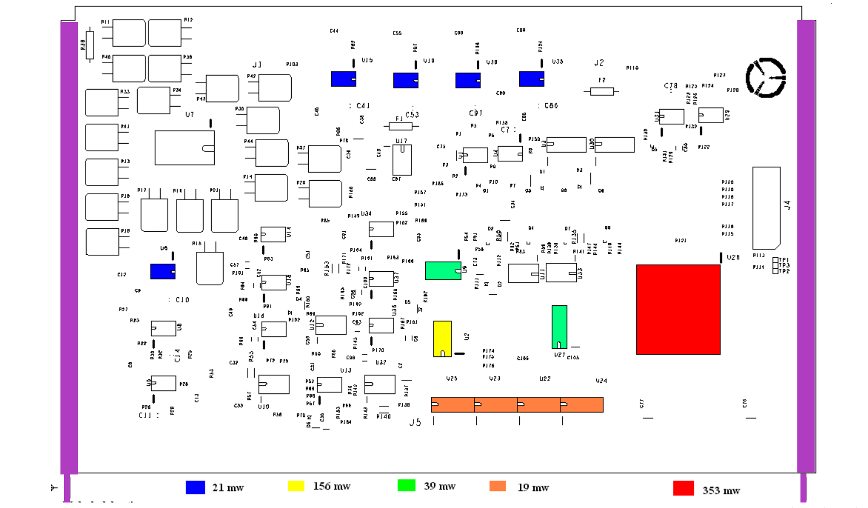
- FEA analysis to determine thermistor gradient due to heat loss out leads
- Considered bounding cases of contact between thermistor housing and cavity
  - Epoxy Length L/4, L/2, or L
  - Thread contact vs. none
  - Flange contact vs. 0.005" epoxy under flange



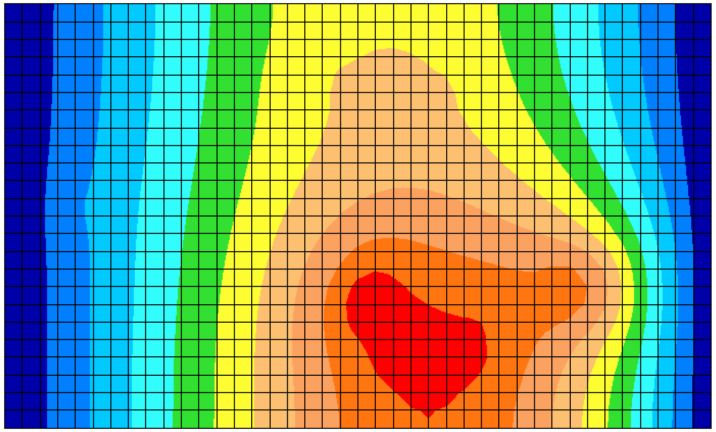
Blackbody Thermal Model



PWB Thermal Analysis



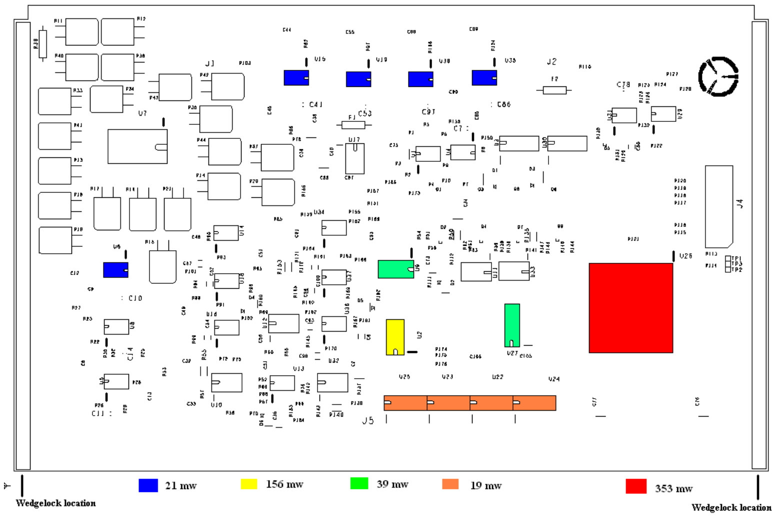
Board layout



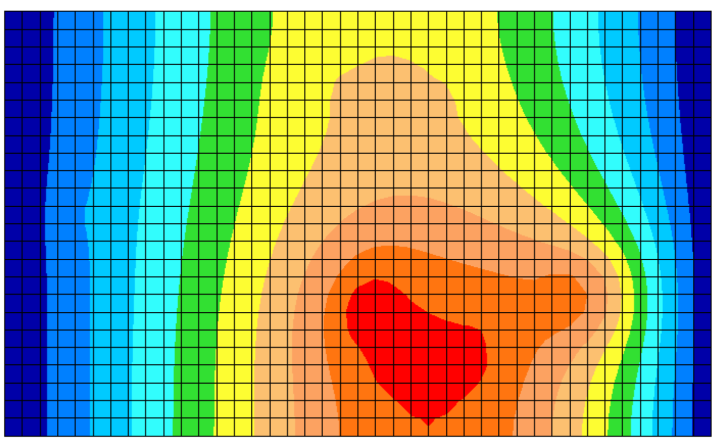
Temperature results

- Neglected radiation, conduction only to edges (wedgelocks) at 50°C
- Modeled board as single layer with equivalent lateral conductivity based on copper and polyimide layer thicknesses
- Heat flux into board assumed uniform over each component's area
- Components shown total .81W, remaining .39W evenly distributed over remaining board surface
- Results in max temp of 54°C at 1.2W power dissipation
- Heat to left edge is .43W, heat to right edge .77W

PWB Thermal Analysis



Board layout

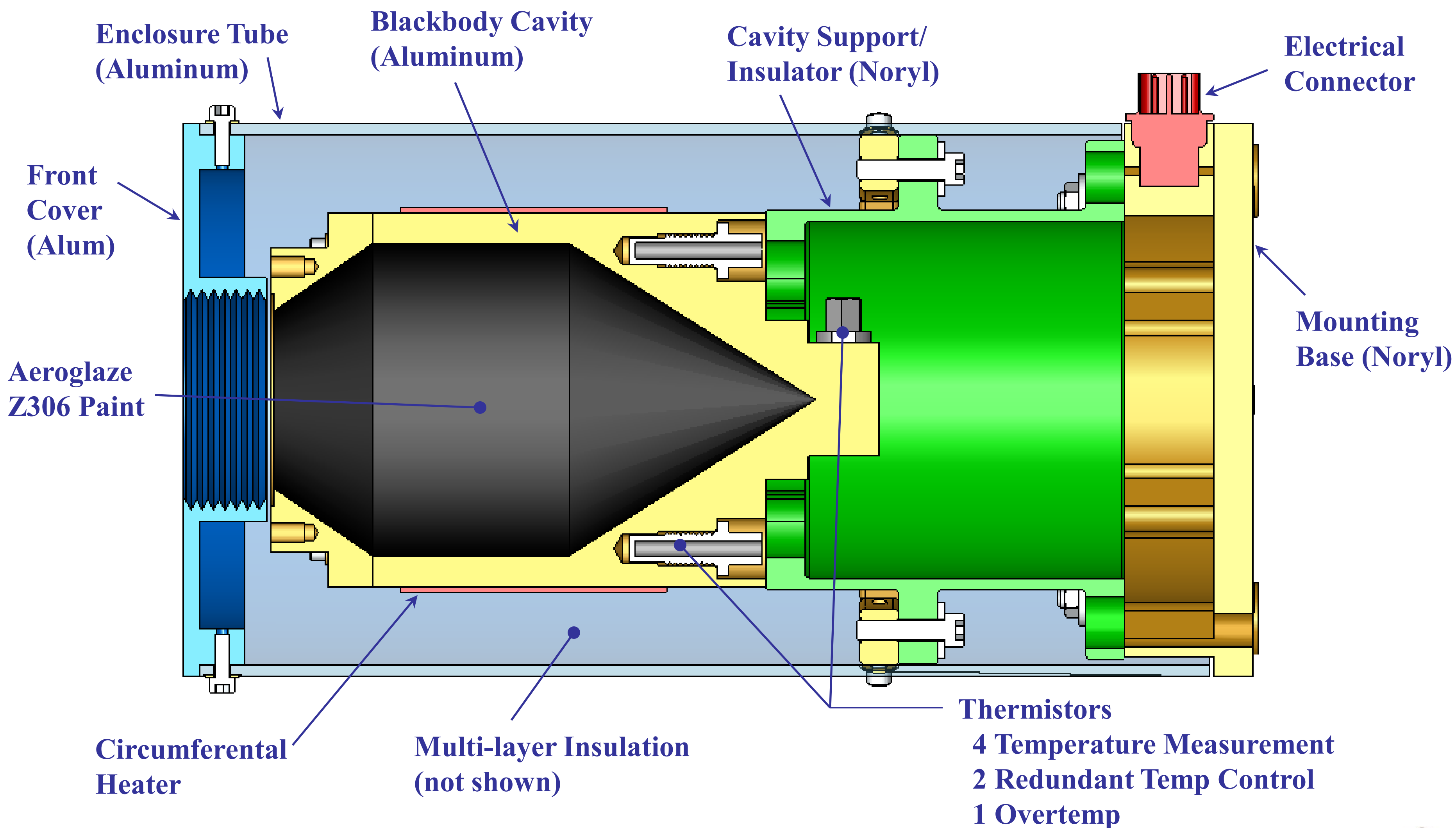


Temperature results

- Neglected radiation, assumed conduction only to edges at 50°C
- Modeled board as single layer with equivalent lateral conductivity based on copper and polyimide layer thicknesses
- Heat flux into board assumed uniform over each component's area
- Total power dissipation is 1.2W
- Components shown total 0.81W, remaining 0.39W evenly distributed over remaining board surface
- Heat to left edge is 0.43W, heat to right edge 0.77W

- **Maximum temperature is 54°C**

Blackbody Section – Side View



GIFTS
Blackbody Subsystem
Critical Design Review
Temperature Uncertainty Budget and Calibration

Fred Best

9 March 2004

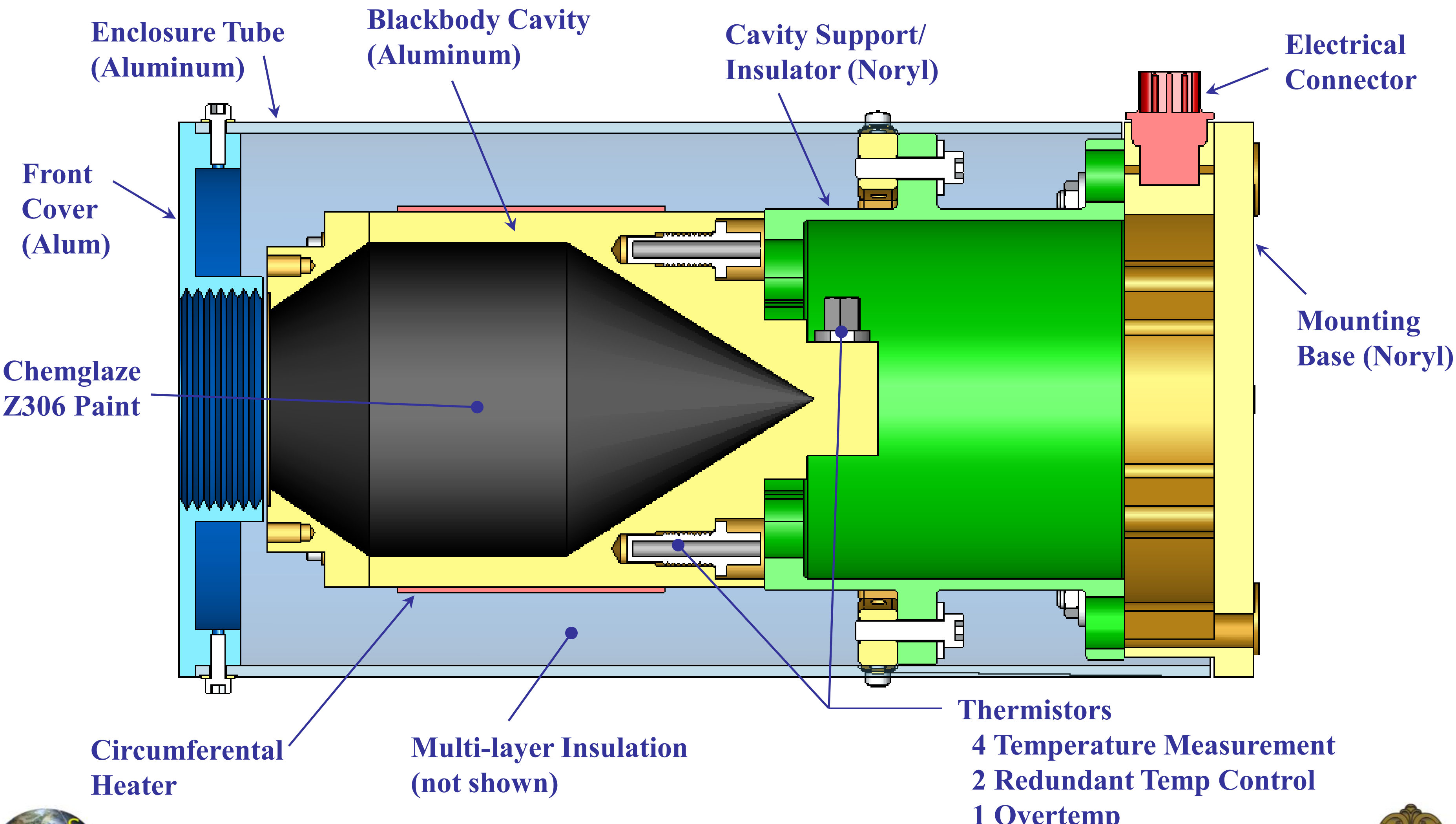
Temperature Error Budget

Temperature Uncertainty	3 sigma error [K]	RSS [K]
Temperature Calibration Standard* (Thermometrics SP60 Probe with Hart Scientific 2560 Thermistor Module)	0.005	
		0.005
Blackbody Readout Electronics Uncertainty		
Readout Electronics Uncertainty (at delivery*)	0.014	
		0.014
Blackbody Thermistor Temperature Transfer Uncertainty		
Gradient Between Temperature Standard and Cavity Thermistors**	0.020	
Calibration Fitting Equation Residual Error**	0.005	
		0.021
Cavity Temperature Uniformity Uncertainty		
Cavity to Thermistor Gradient Uncertainty *(1/3 of total max expected gradient)*	0.030	
Thermistor Wire Heat Leak Temperature Bias Uncertainty*	0.008	
Paint Gradient *(assumes nominal HBB Temp and conservative viewing geometry)*	0.018	
		0.036
Long-term Stability		
Blackbody Thermistor *(10 years of drift assuming 105 C)*	0.050	
Blackbody Controller Readout Electronics*	0.012	
		0.051
Effective Radiometric Temperature Weighting Factor Uncertainty		
Monte Carlo Ray Trace Model Uncertainty in Determining Teff *(1/3 of total max expected gradient)*	0.030	
		0.030
		0.074

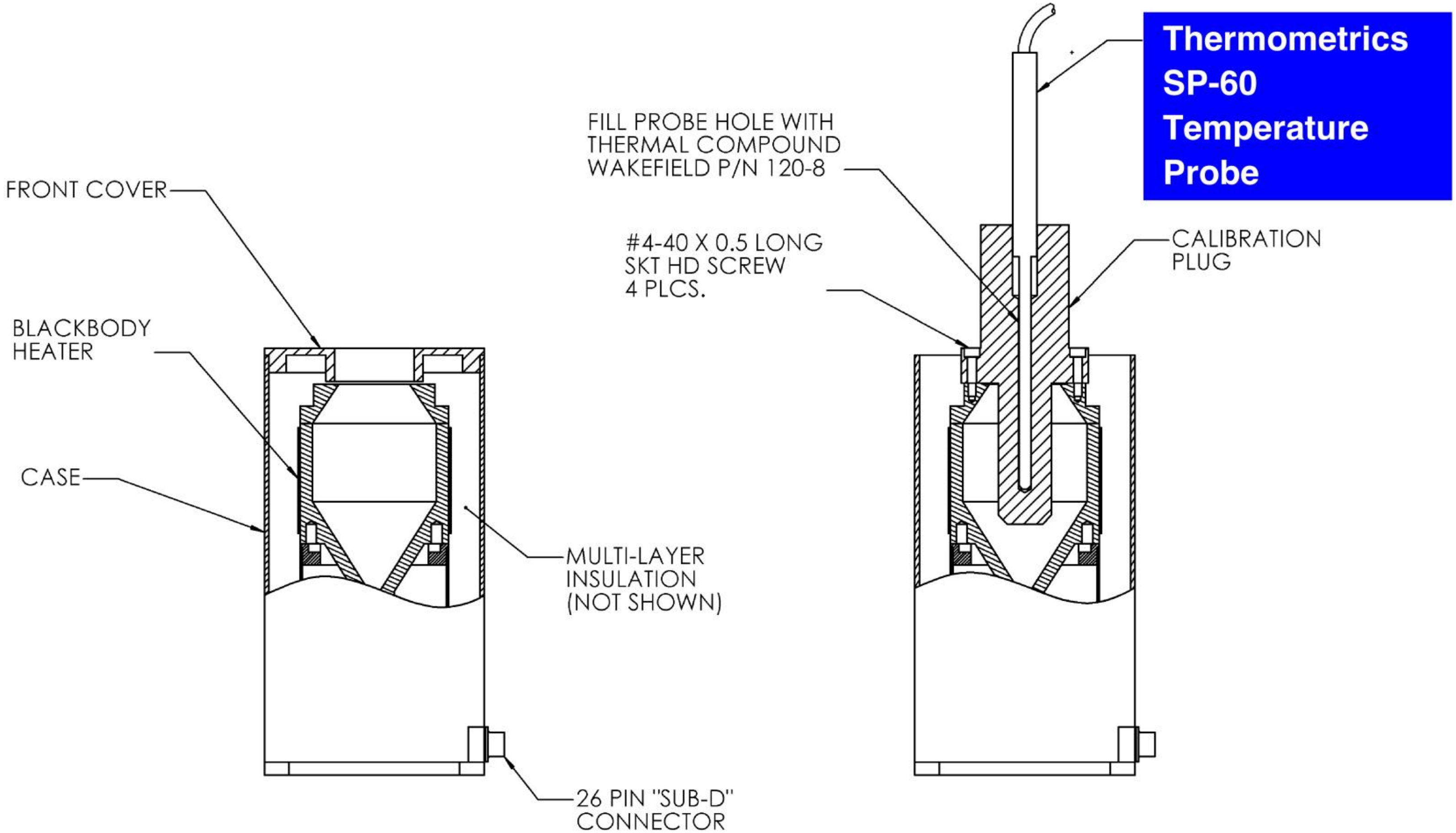
*Presented in earlier section

**Based on experience with UW AERI Blackbodies

Blackbody Section – Side View



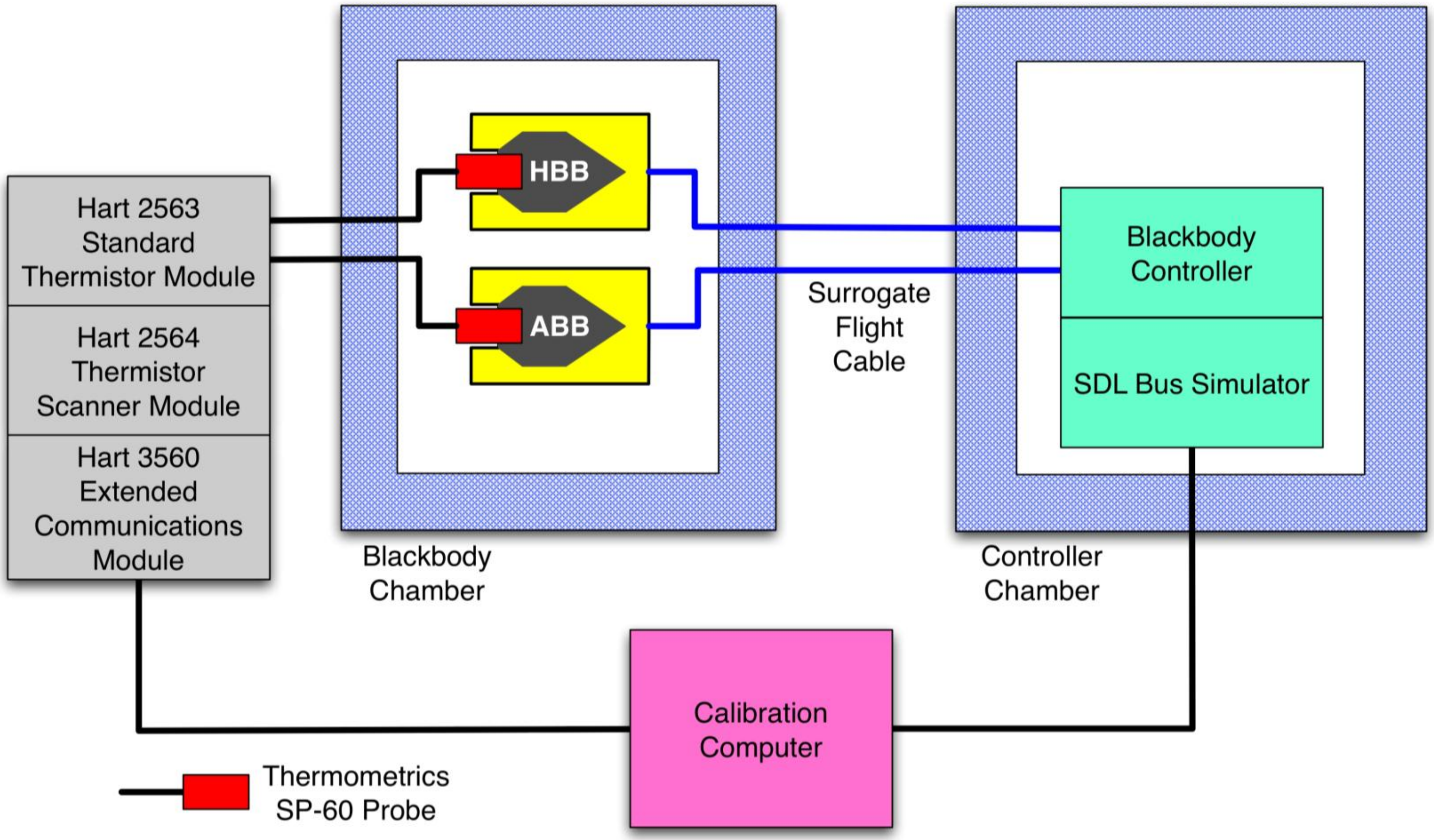
Blackbody Temperature Calibration Configuration



Standard Blackbody Configuration

Temperature Calibration Configuration

GIFTS BB Calibration Scheme



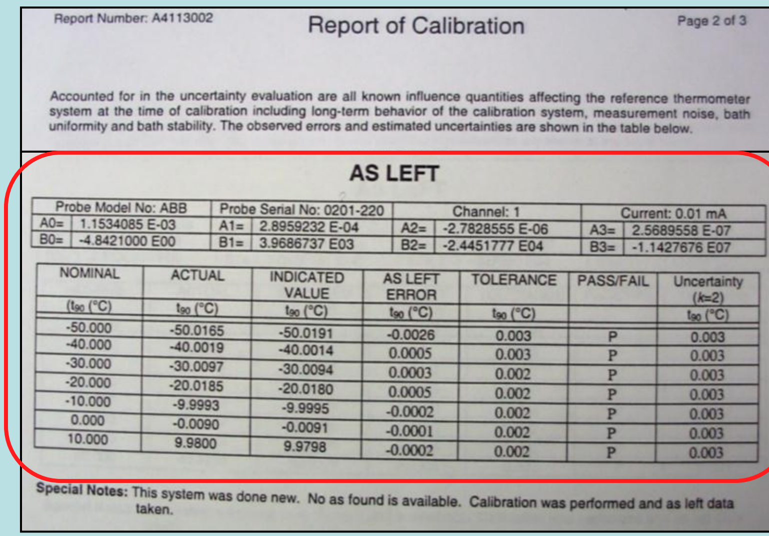
Blackbody Temperature Calibration

- The Blackbody and Controller will undergo end-to-end calibration.
- The temperature of the Blackbody and Controller can be independently controlled.
- Ambient Blackbody calibrated over the range from: -40 C to 0 C.
- Hot Blackbody calibrated over the range from: 0 C to +40 C.
- For calibration the Controller will be maintained at near 0 C. {The system will be calibrated at other Controller temperatures if a temperature dependence is discovered during EM-2 testing.

Temperature Calibration Standard

- **Hart 2563 Standard Thermistor Module**
- **Hart 2564 Thermistor Scanner Module**
- **Hart 3560 Extended Communications Module**
- **Calibration Computer**

Thermometrics SP-60 Probes (2)



Report Number: A4113002 | Report of Calibration | Page 2 of 3

Accounted for in the uncertainty evaluation are all known influence quantities affecting the reference thermometer system at the time of calibration including long-term behavior of the calibration system, measurement noise, bath uniformity and bath stability. The observed errors and estimated uncertainties are shown in the table below.

AS LEFT

Probe Model No: ABB		Probe Serial No: 0201-220		Channel: 1		Current: 0.01 mA	
A0=	1.1534085 E-03	A1=	2.8959232 E-04	A2=	-2.7828555 E-06	A3=	2.5689558 E-07
B0=	-4.8421000 E00	B1=	3.9686737 E03	B2=	-2.4451777 E04	B3=	-1.1427676 E07

NOMINAL	ACTUAL	INDICATED VALUE	AS LEFT ERROR	TOLERANCE	PASS/FAIL	Uncertainty (k=2)
(t_{90} (°C)	t_{90} (°C)	t_{90} (°C)	t_{90} (°C)	t_{90} (°C)		t_{90} (°C)
-50.000	-50.0165	-50.0191	-0.0026	0.003	P	0.003
-40.000	-40.0019	-40.0014	0.0005	0.003	P	0.003
-30.000	-30.0097	-30.0094	0.0003	0.002	P	0.003
-20.000	-20.0185	-20.0180	0.0005	0.002	P	0.003
-10.000	-9.9993	-9.9995	-0.0002	0.002	P	0.003
0.000	-0.0090	-0.0091	-0.0001	0.002	P	0.003
10.000	9.9800	9.9798	-0.0002	0.002	P	0.003

Special Notes: This system was done new. No as found is available. Calibration was performed and as left data taken.

Absolute Temperature Calibration of end-to-end System at Hart has Uncertainty Of +/- 0.003 K (k=2)

GIFTS
Blackbody Subsystem
Critical Design Review
Emissivity Modeling and Uncertainty Budget

09 March 2004

GIFTS BB Emissivity Topics

- Emissivity Requirements
- Radiance Model
- Cavity Geometry
- Cavity Paint Application & Emissivty
- Cavity Emissivity Calculations
- Emissivity Error Analysis
- CDR Status

GIFTS BB Emissivity Requirement

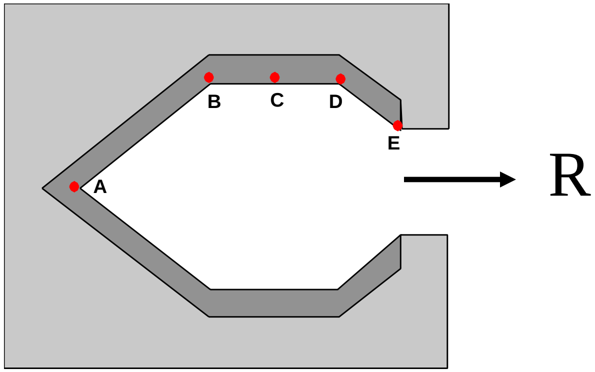
- Emissivity better than 0.996
- Emissivity knowledge: better than 0.002

• **A high absolute cavity emissivity (> 99.6%) reduces the accuracy needed to characterize the temperature of surfaces that are viewed by the blackbody through reflection.**

• **The requirement (< 0.2%) on the uncertainty in the knowledge of the cavity emissivity minimizes systematic errors in the on-orbit calibration.**

GIFTS BB Radiance Model

$$R(\lambda) = \varepsilon(\lambda) * B(T_{EFF}, \lambda) + (1 - \varepsilon(\lambda)) * B(T_{ENV}, \lambda)$$



where,

$B(T, \lambda)$ = Planck radiance at T and wavelength λ,

$\varepsilon(\lambda)$ = cavity isothermal emissivity,

$T_{EFF} = w_1 * T_A + w_2 * T_B$

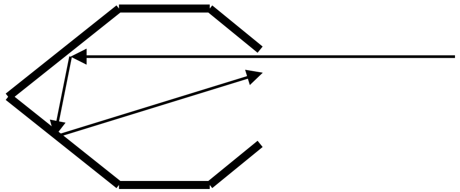
is the effective emitting temperature, and

T_{ENV} = environmental temperature.

ε, w_1, and w_2 are pre-computed using a numerical model while T_A, T_B, and T_{ENV} are measured in flight.

Isothermal Cavity Emissivity (Theory)

Following the theory outlined in Prokhorov (Metrologia, 1998), the effective emissivity of a cavity can be computed using the formula for a diffuse surface:

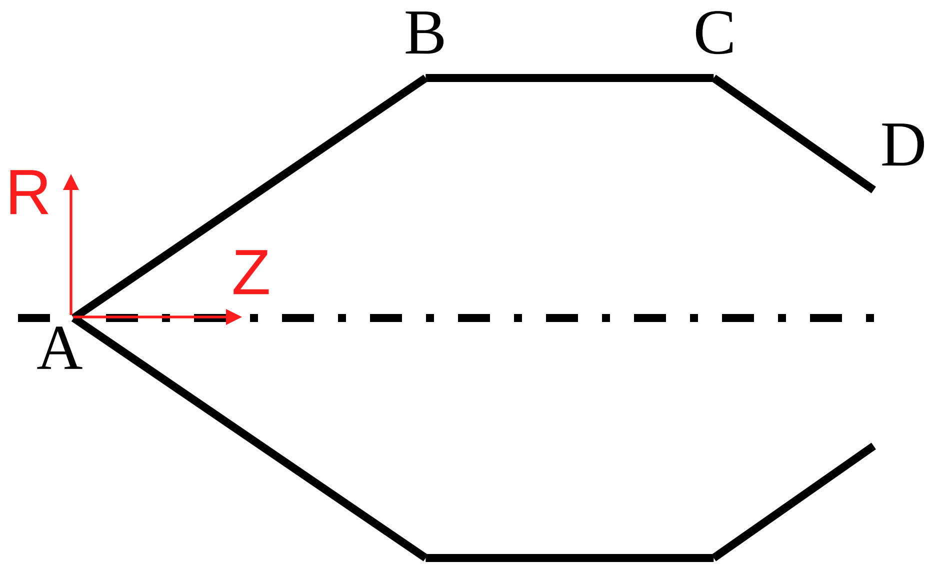


$$\varepsilon_{eff}(\tilde{\nu}, T_{ref}) = \frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{m_i}\varepsilon_j\,\rho^{j-1}$$

Where N represents the number of rays "shot" into the simulated cavity, m_i is the number of "bounces" within the cavity, and ε and ρ are the directional hemispheric emissivity and the directional hemispheric reflectivity, respectively.

A similar equation can be written for a specular reflector. The Prokhorov model implemented in the program STEEP3 allows for the use of diffusity factor (D=diffuse/total) as a function of incident angle.

GIFTS BB Geometry

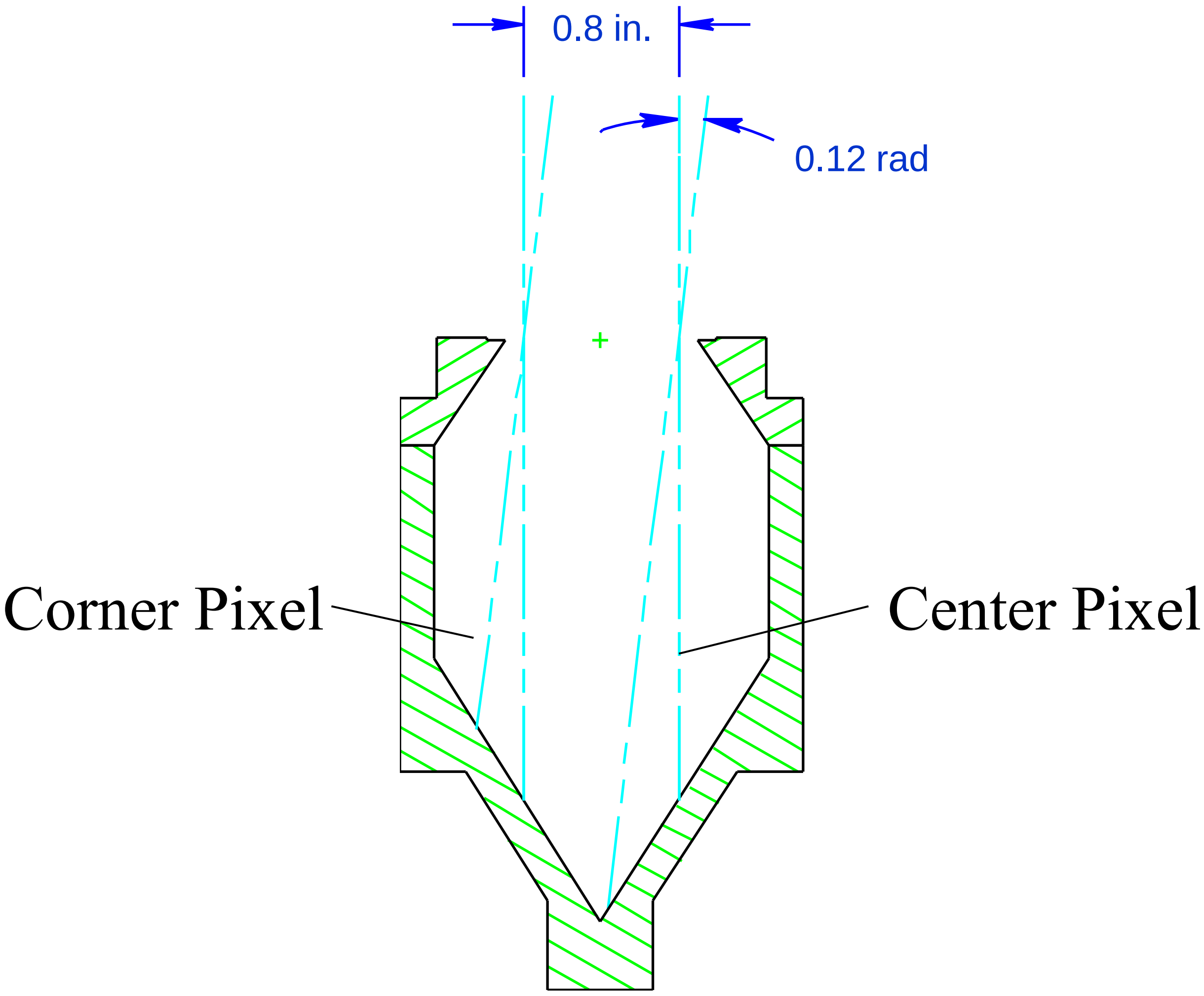


GIFTS blackbody internal cavity cross-section (dimensions in inches)

	Z	R
A	0	0.01
B	1.39	0.88
C	2.50	0.88
D	3.06	0.50

The GIFTS blackbody cavity is a relatively simple geometry with rotational symmetry about the central axis.

GIFTS BB Viewing Geometry



- The GIFTS aperture stop is located at the front face of the GIFTS BB with a nominal beam diameter of 0.8 inches. The beam divergence is only 1.3 mrad.
- The beam from the “corner pixel” enters at an angle of 6.9 degrees from the normal.

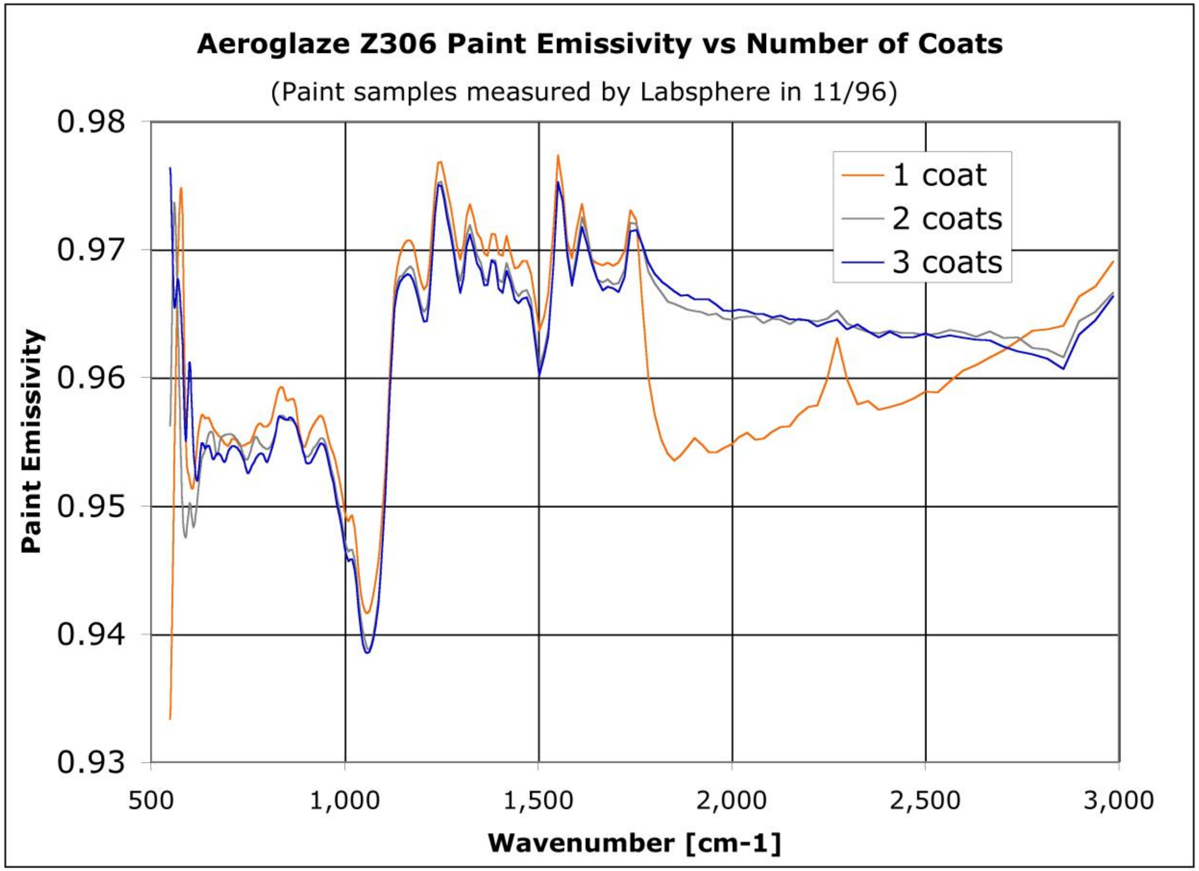
Blackbody Paint

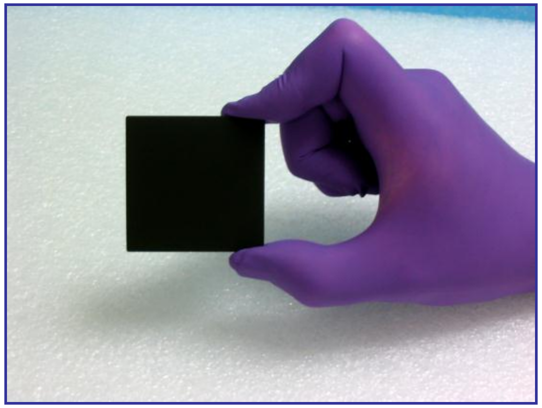
- The GIFTS Blackbody cavities are painted with Aeroglaze Z306 diffuse black paint (applied to a thickness of 0.003”).
- Witness samples will be painted at the same time as the cavities in fixtures that simulate the cavity geometry.
- Some of the witness samples will be checked after 24 hours to verify that the desired 3 mils of paint were applied - more paint will be applied if necessary.
- After a 7 day full cure at 77 °F and 50% humidity, the witness samples will undergo adhesion tests (tape pull test at edge).

Blackbody Paint

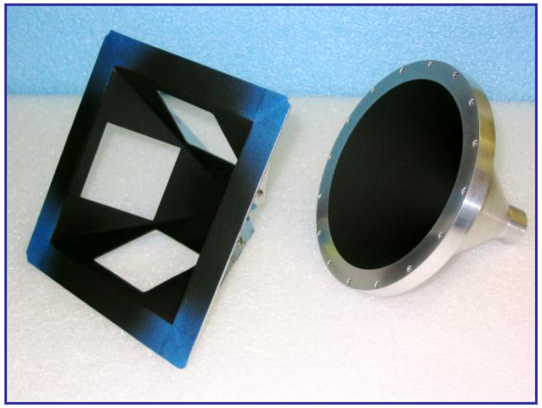
- The cavities and witness samples will then undergo a 3 day thermal vacuum bakeout at 90 C to drive off uncured polymers.
- The cavities will then proceed to mechanical and electrical assembly.
- The witness samples will be sent to NIST for reflectance testing:
  - Directional Hemispheric Reflectivity.
  - Diffusity at limited angles.

Paint Emissivity Measurement





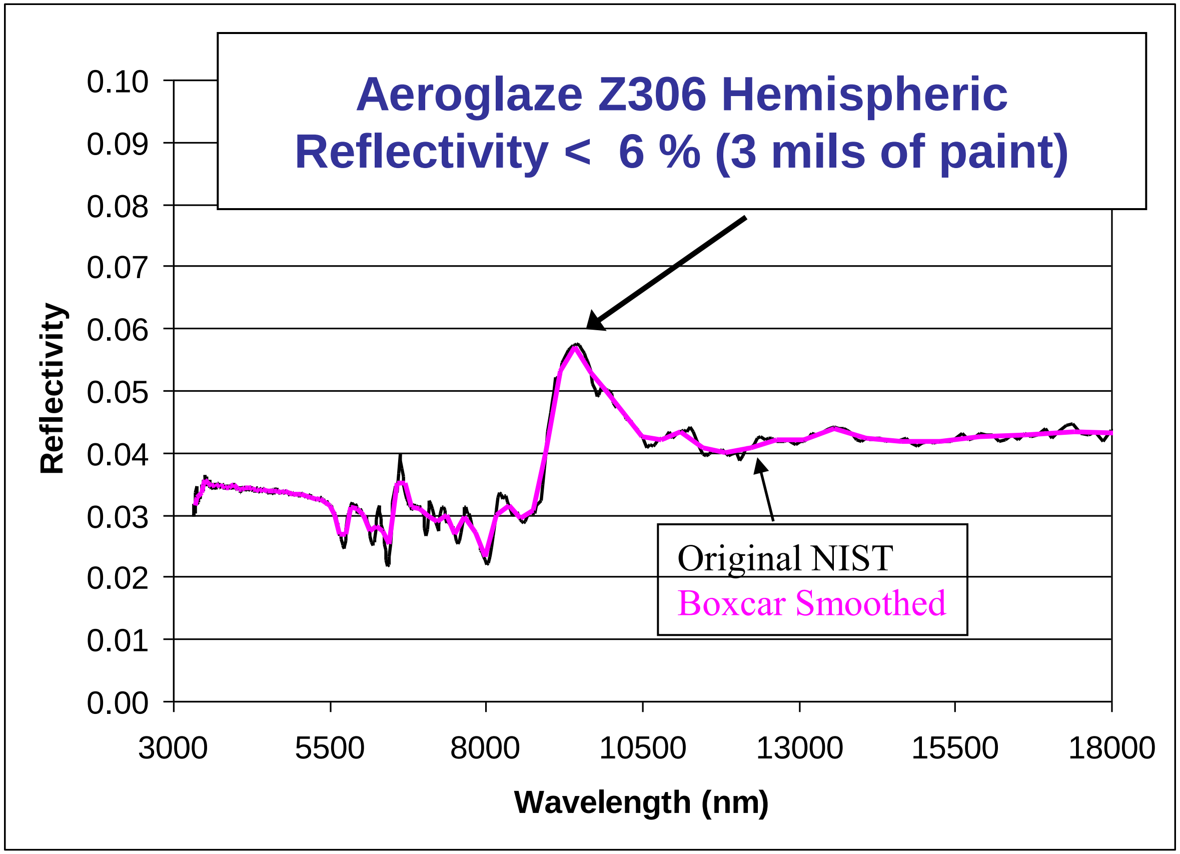
Blackbody Paint Witness Sample



Witness Sample Holder "Mimics" Blackbody Cone Geometry

Paint application variation is taken to be < 1% (3 sigma) of the paint emissivity.

NIST Measurement of Paint Reflectivity

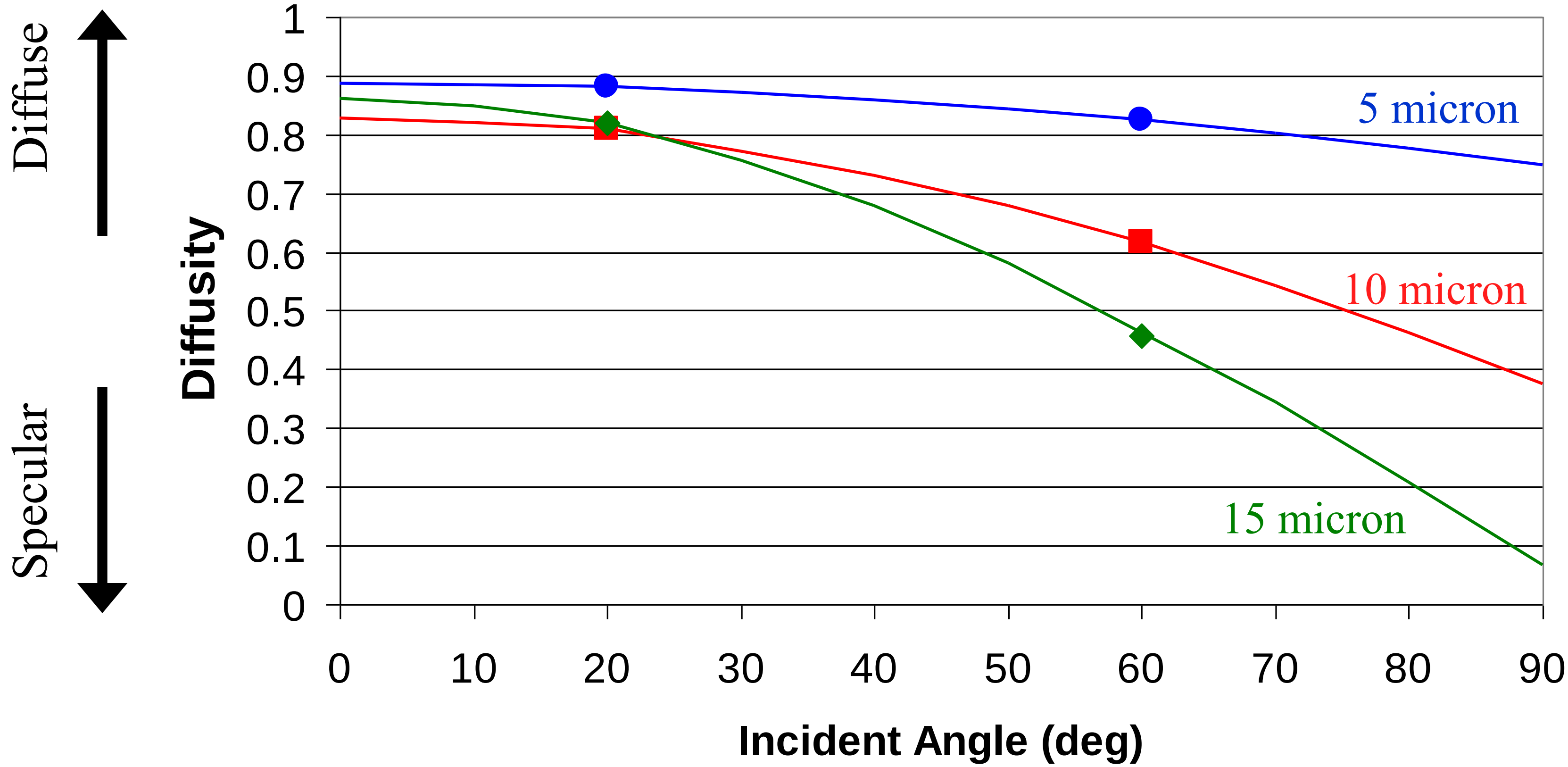


- NIST measurements of Z306 paint agree with historical Labsphere measurements of UW witness samples to within the NIST measurement accuracy.

- Z306 paint has a directional hemispheric emissivity greater than 0.94 over the GIFTS spectral range.

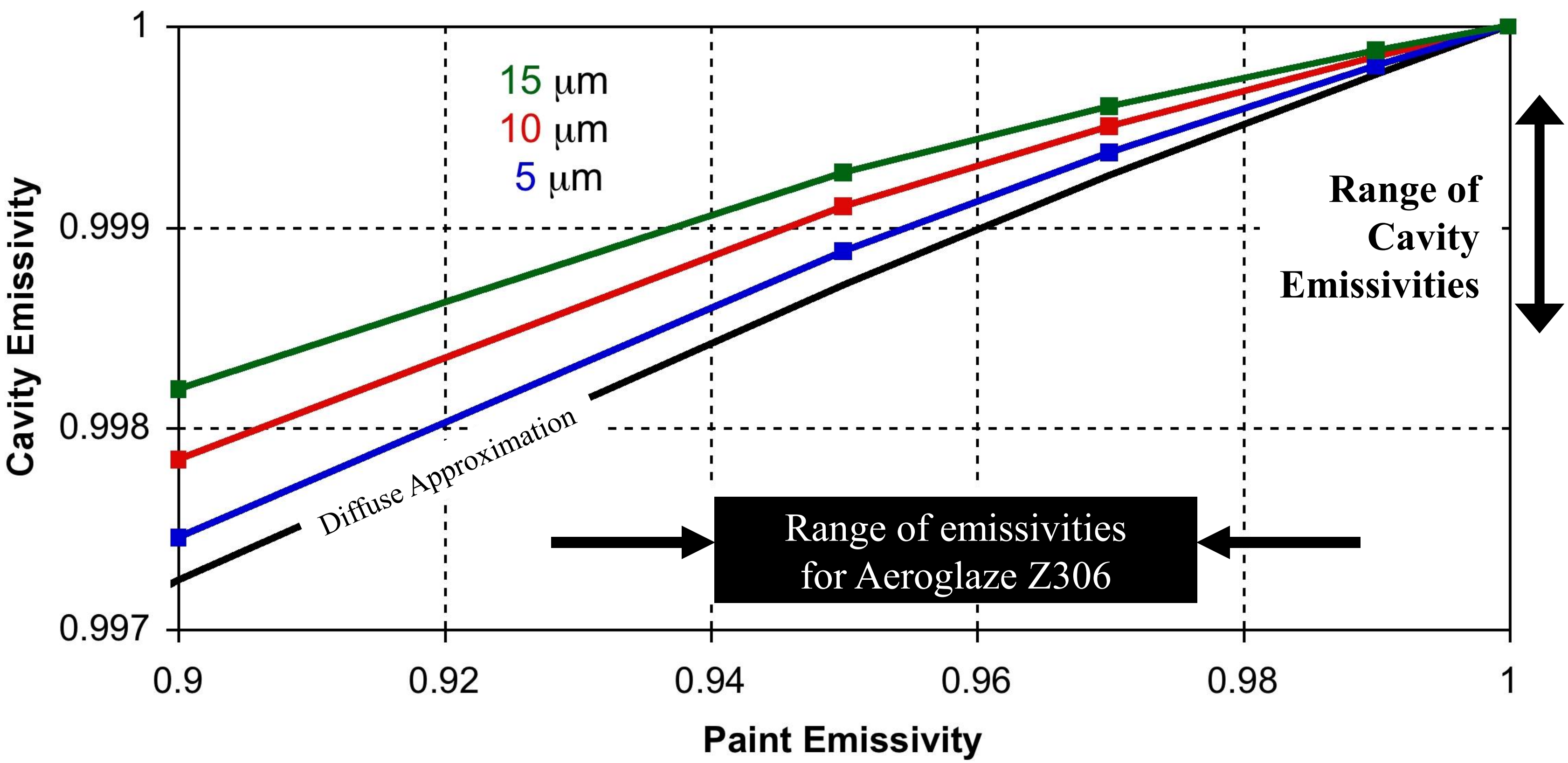
NIST stated uncertainty for the Z306 paint hemispheric emissivity measurement is < 0.4% (3 sigma)

Aeroglaze Z306 Diffusity vs. Angle



Paint diffusity for Aeroglaze Z306 estimated from published values (Persky, Rev. Sci. Instrum., 1999).

GIFTS BB Cavity Emissivity (Aeroglaze Z306)

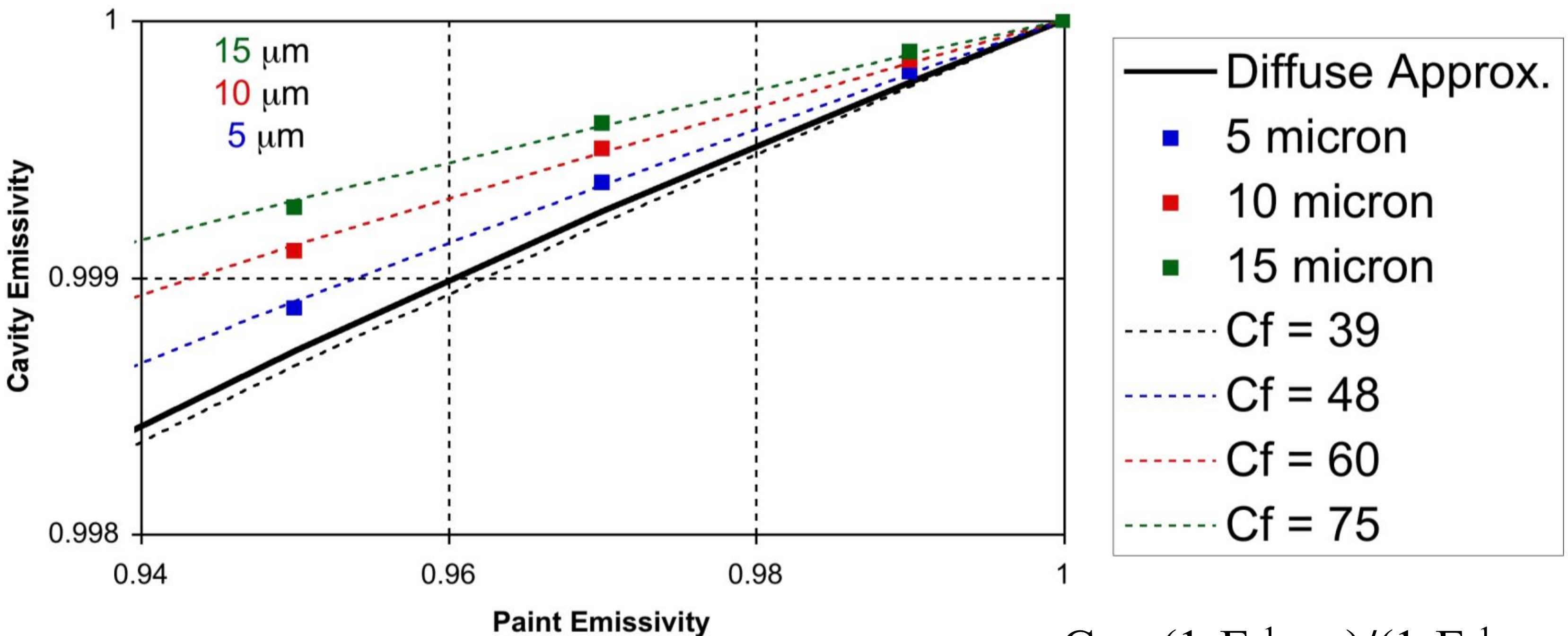


The numerical model STEEP3 was used to compute the average normal emissivity using diffusity versus incidence angle data from Persky (1999) at three wavelengths*.

Cavity shape leads to a BB emissivity > 0.998 for all wavelengths.

*tracing 1E6 shots per calculation

Isothermal Cavity Emissivity (Aeroglaze Z306)



$C_f = (1-E^{-1}_{paint})/(1-E^{-1}_{cavity})$

The Monte Carlo results can be summarized using a "cavity factor" which is a convenient parameterization of the relation between paint and cavity emissivity.

Calculations give a GIFTS BB cavity factor of > 39 for all wavelengths.

Emissivity Error Budget

	Uncertainty (3 sigma)	Note	for Ep=0.94 f=39	^{2}Ec	^{2}Ec (3 sigma)
Paint Witness Sample Measurement	**0.4% Ep**	**[1]**	**^{2}Ep=0.0038**	**(1/f)*^{2}Ep**	**0.00010**
Paint Application Variation	**1.0% Ep**	**[2]**	**^{2}Ep=0.0094**	**(1/f)*^{2}Ep**	**0.00024**
Long-term Paint Stability	**2.0% Ep**	**[3]**	**^{2}Ep=0.0188**	**(1/f)*^{2}Ep**	**0.00048**
Cavity Factor	**30% f**	**[4]**	**^{2}f=11.7**	**(1-Ep)/f^2*^{2}f**	**0.00046**
				RSS	**0.00072**

Notes:

[1] Factor of 1.5 times NIST* Stated Accuracy for 2 sigma
[2] Worst case difference between 1 and 3 coats
[3] 2 x above
[4] Accounts for Cavity Model Uncertainty

* NIST Stated accuracy is 4% of Reflectivity (2 sigma)

f=(1-Ep)/(1-Ec)

f=Cavity Factor
Ep=Emissivity of Paint
Ec=Emissivity of Cavity

Current Status

• GIFTS BB cavity emissivity best estimate is verified through Monte Carlo analysis to be higher than the 0.996 requirement. Engineering best estimate is > 0.998.

• GIFTS BB cavity emissivity knowledge uncertainty is verified through analysis to be within the 0.002 requirement. Current engineering best estimate is < 0.001.

• Further refinement of the blackbody emissivity characteristics will continue but under NOAA support of the ground data processing calibration algorithms.

GIFTS
Blackbody Subsystem
Critical Design Review
Development Plans, Logistics, and Facilities

Fred Best

9 March 2004

Topics

- Build Plan and Status
- Performance Verification Plan and Status
- Contamination Control
- Assembly, Integratin, and Test/Flow
- Facilities

Blackbody Subsystem Build Plan

	Breadboard	EM-1	EM-2	Flight	Flight Spare
Controller	¥ Commercial Parts (inexpensive) ¥ Verified design concept and critical circuits	¥ Commercial Parts (inexpensive) ¥ Used to verify electronics design ¥ Used to verify board layout	¥ Flight-type parts (not rad-hard or screaned) ¥ Risk reduction for Flight Board ¥ Will undergo Random Vibration	¥ Flight Controller	¥ Spare board will be fabricated ¥ Spare parts will be kitted
HBB & ABB	¥ Rough Mass and Thermal Simulator with feedback and measurement thermistor	¥ Closely Simulates Flight Configuration thermally and mechanically ¥ Flight-type thermisors and heater (without screaning and calibration) ¥ Used to verify crucial thermal resistances where necessary. ¥ Used also for fine-tuning key dynamic parameter		¥ Flight HBB Blackbody	¥ Flight Spare HBB will be fabriated ¥ Spare parts will be kitted

Verification Matrix

Specification	Typical	Minimum	Maximum	Units	Notes	Verification
HBB Temp. Measurement Range	--	0	+40	°C	2,*	Test
ABB Temp. Measurement Range	--	-40	0	°C	2,*	Test
Temp. Measurement Resolution	--	--	0.003	°C	2,^	Design/Analysis
Temp. Measurement Error (±)					2,3,7	
Electronics (at delivery)	--	--	0.02	¡C	*	Test
Thermistor (at delivery)	--	--	0.03	C	*	Test
On-orbit drift-electronics	--	--	0.01	C	^	Design/Analysis
On-orbit drift-thermistor	--	--	0.04	C	^	Design/Analysis
Total	--	--	0.10	C		
HBB Temp. Set Point	+17	0	+40	°C	*	Test
ABB Temp. Set Point	-18	-40	0	°C	*	Test
Temperature Set Point Resolution	--	--	0.2	°C	2,^	Design/Analysis
Heater PWM Frequency	10	8	12	Hz	*	Test
Sampling Rate	2.76	2.60	2.90	Hz	^	Design/Analysis
Data Readout Rate	--	--	3	Hz	^	Design/Analysis
Overtemperature Limit	--	+47	+60	°C	*	Test

Verification, Continued

Specification	Typical	Minimum	Maximum	Units	Notes	Verification
Power						
Heaters (Total)	0.7	0	4.0 ^	W	5,6	Design/Analysis
Electronics Dissipation	--	--	1.2 ^	W	4	Design/Analysis
Total	--	--	5.2 ^	W		Design/Analysis
Mass						
Hot Blackbody						
Ambient Blackbody						
Controller						
Total			2,400 *	g		Test
Cavity Aperture						
Diameter		2.54	2.57	Cm	*	Test
Field of View		10	14	Deg.	*	Test
Emissivity (680 cm^{-1} to 2,300 cm^{-1})						
Cavity Emissivity		0.996			^	Design/Test
Cavity Emissivity Uncertainty (3σ)		0.002			^	Design/Analysis

Notes

1. Unless otherwise noted, all specifications apply over the entire Controller and Blackbody temperature ranges.
2. With specified thermistors, over specified temperature measurement range.
3. After calibration with flight interconnecting cables, or equivalent.
4. Electronics dissipation at maximum heater power, but exclusive of heater power.
5. ÒTypicalÓ heater poweris the total for both blackbodies, calculated at the Orbital Average (average of the power to maintain the set point in the worst case cold and worst case hot parts of the orbit), with blackbodies at nominal set points, at the beginning of mission life.
6. Maximum heater power occurs during blackbody warm-up.
7. Guaranteed for Controller Temperature Range of -40 to +30¡C only.

Subsystem-level Test Plans

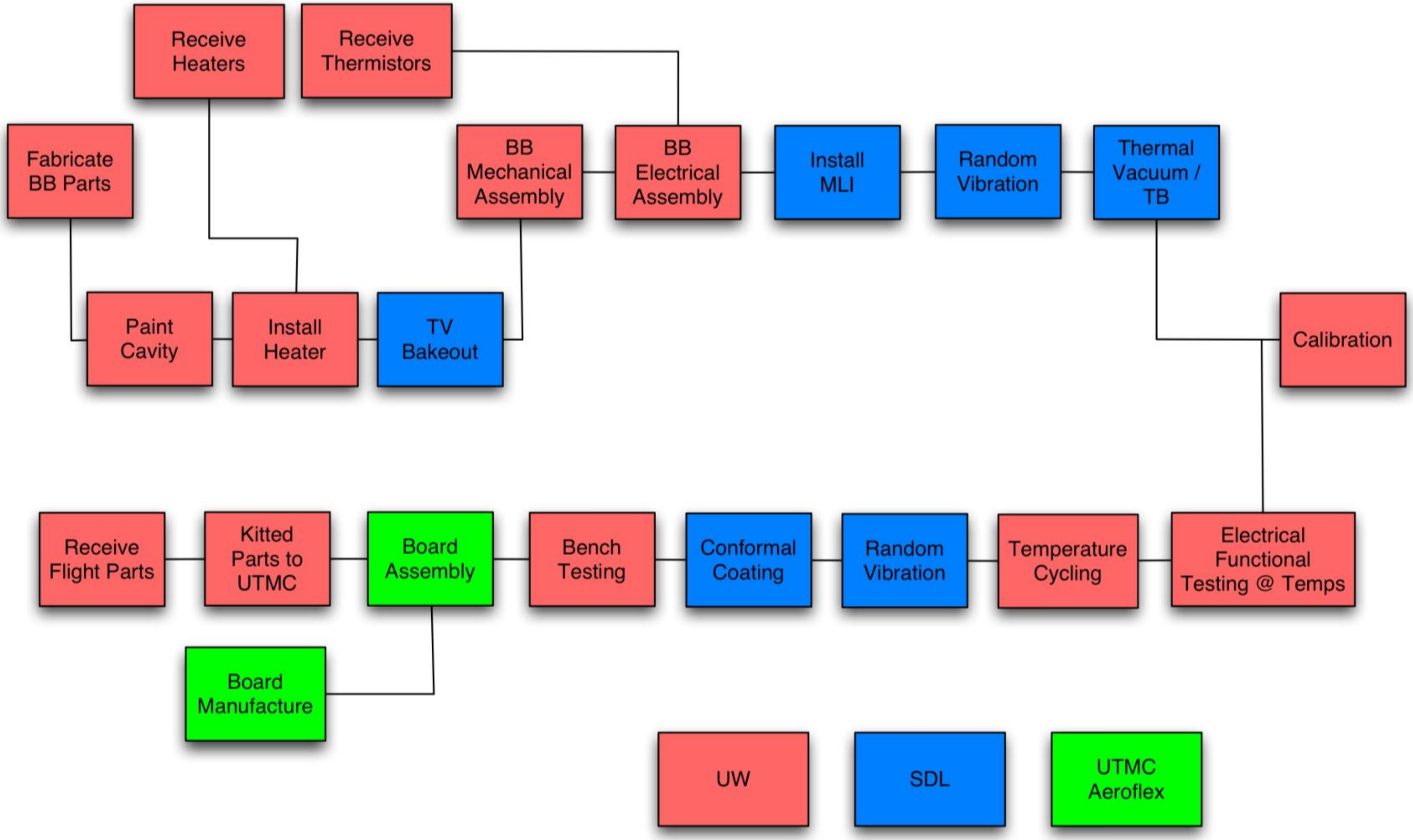
	Functional Test	Interface Verification	Mass Properties	Temperature	Frequency ID	Sine Burst	Random Vibration	Thermal Vacuum / TB	EMI/EMC	Calibration
Blackbody Controller										
Breadboard	■	■	■							
Engineering Model-1	■	■	■							
Engineering Model-2	■	■	■	■	■		■		SM Level	
Flight Unit	■	■	■	■	■		■	SM Level		■
Flight Spare										

	Functional Test	Interface Verification	Mass Properties	Temperature	Frequency ID	Sine Burst	Random Vibration	Thermal Vacuum / TB	EMI/EMC	Calibration
Blackbody (ABB & HBB)										
Brassboard	■	■								
Engineering Model	■	■	■	■	■	■	■		SM Level	
Flight Unit	■	■	■	■	■		■	■		■
Flight Spare										

Contamination Control

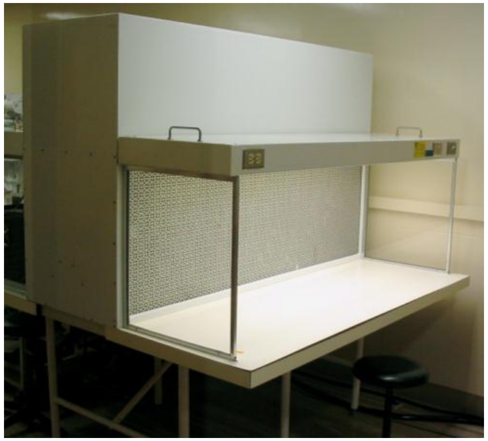
- All materials were selected to meet NASA low-ougassing requirements (1% TML, 0.1 CVCM).
- After Painting the BB will be baked out in a vacuum at SDL and returned to UW for completion of assembly and testing.
- Blackbody will be assembled on a Class 1000 laminar flow bench and will be double-bagged.
- Prior to installation of the internal MLI at SDL, the BB will be cleaned with a CO_2 Snow Cleaning process (except for the internal painted cavity surface).
- Following MLI Installation the BB double bagged and purged with dry N2 during any temperature testing.
- The Controller Board will be cleaned at SDL, prior to the Conformal Coating Process.
- After Conformal Coating at SDL, the Board will be stored in ESD bags. (during any temperature tests, it will be purged with dry N2)

Assembly, Integration, Test Flow



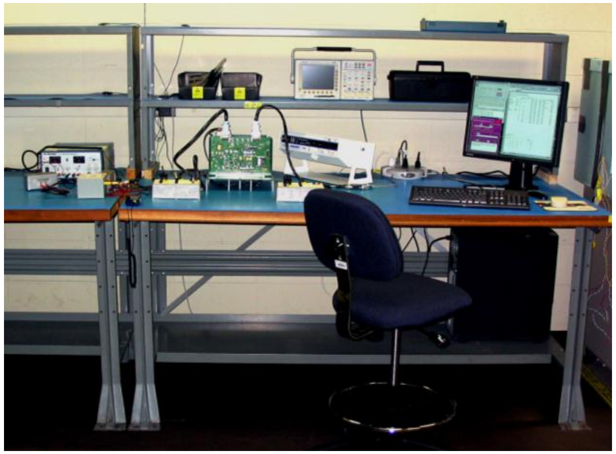
Facilities-Fabrication & Checkout

SSEC Machine Shop



Blackbody Assembly

Controller Bench-top Checkout



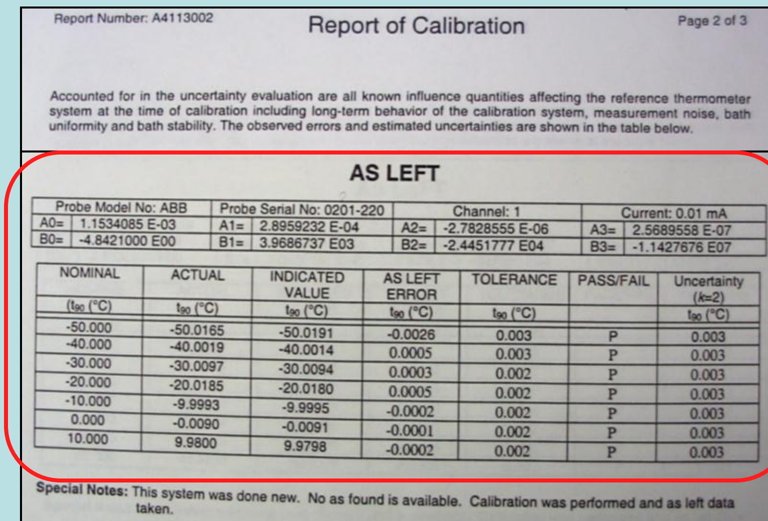
Temperature Test Facilities

Temperature Testing
(another identical chamber is available)

Temperature Calibration Standard

- **Hart 2563 Standard Thermistor Module**
- **Hart 2564 Thermistor Scanner Module**
- **Hart 3560 Extended Communications Module**
- **Calibration Computer**

Thermometrics SP-60 Probes (2)



Report Number: A4113002 | Report of Calibration | Page 2 of 3

Accounted for in the uncertainty evaluation are all known influence quantities affecting the reference thermometer system at the time of calibration including long-term behavior of the calibration system, measurement noise, bath uniformity and bath stability. The observed errors and estimated uncertainties are shown in the table below.

AS LEFT

Probe Model No: ABB		Probe Serial No: 0201-220		Channel: 1		Current: 0.01 mA	
A0=	1.1534085 E-03	A1=	2.8959232 E-04	A2=	-2.7828555 E-06	A3=	2.5689558 E-07
B0=	-4.8421000 E00	B1=	3.9686737 E03	B2=	-2.4451777 E04	B3=	-1.1427676 E07

NOMINAL (t_{90} (°C))	ACTUAL t_{90} (°C)	INDICATED VALUE t_{90} (°C)	AS LEFT ERROR t_{90} (°C)	TOLERANCE t_{90} (°C)	PASS/FAIL	Uncertainty (k=2) t_{90} (°C)
-50.000	-50.0165	-50.0191	-0.0026	0.003	P	0.003
-40.000	-40.0019	-40.0014	0.0005	0.003	P	0.003
-30.000	-30.0097	-30.0094	0.0003	0.002	P	0.003
-20.000	-20.0185	-20.0180	0.0005	0.002	P	0.003
-10.000	-9.9993	-9.9995	-0.0002	0.002	P	0.003
0.000	-0.0090	-0.0091	-0.0001	0.002	P	0.003
10.000	9.9800	9.9798	-0.0002	0.002	P	0.003

Special Notes: This system was done new. No as found is available. Calibration was performed and as left data taken.

Absolute Temperature Calibration of end-to-end System at Hart has Uncertainty Of +/- 0.003 K (k=2)

GIFTS
Blackbody Subsystem
Critical Design Review
Project Plan Status

Fred Best & Evan Richards

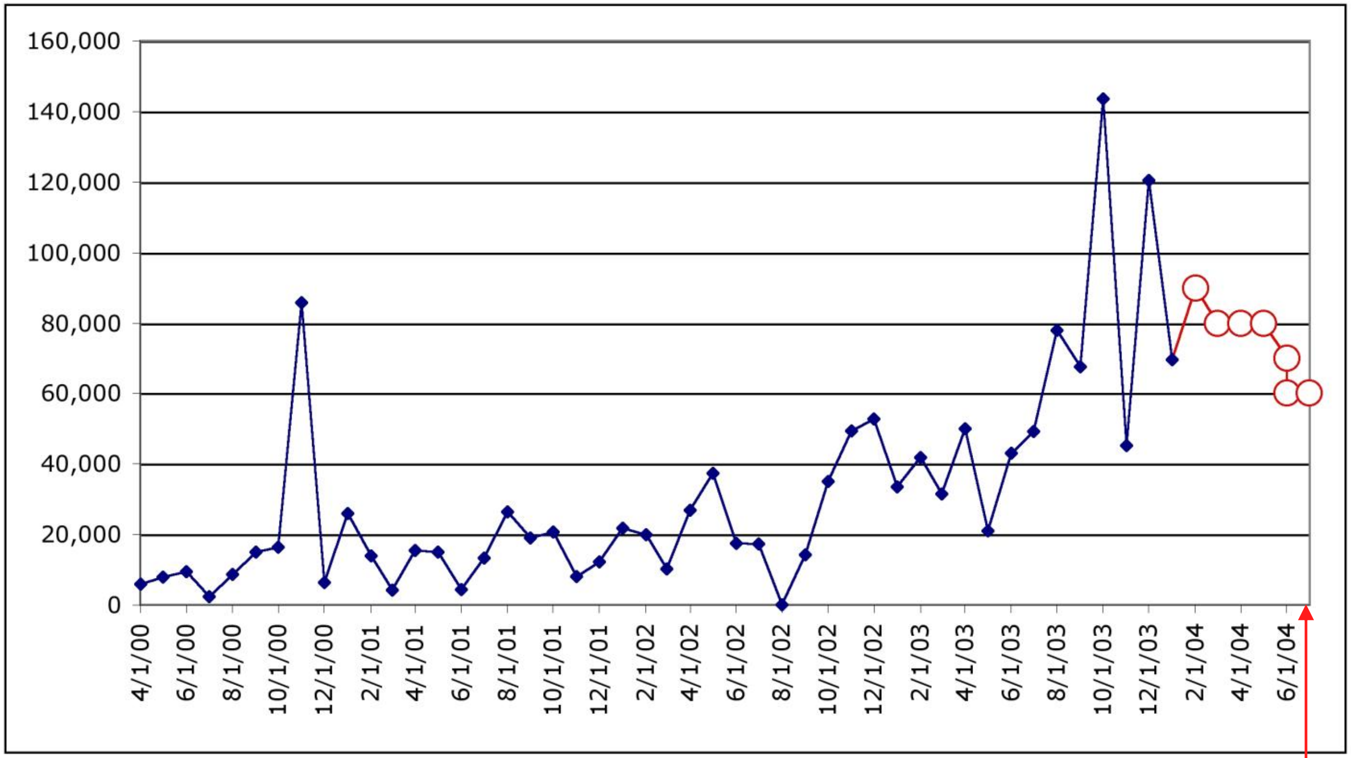
9 March 2004

Cost

• Total Spending through Jan 04:	$1,430,176
• Total of latest Request to SDL:	$1,954,515
• Balance to complete program	$ 524,338

Past and Projected Spending

Spending by Month on GIFTS BB Project



Time of Projected Delivery
Time Funding will be spent

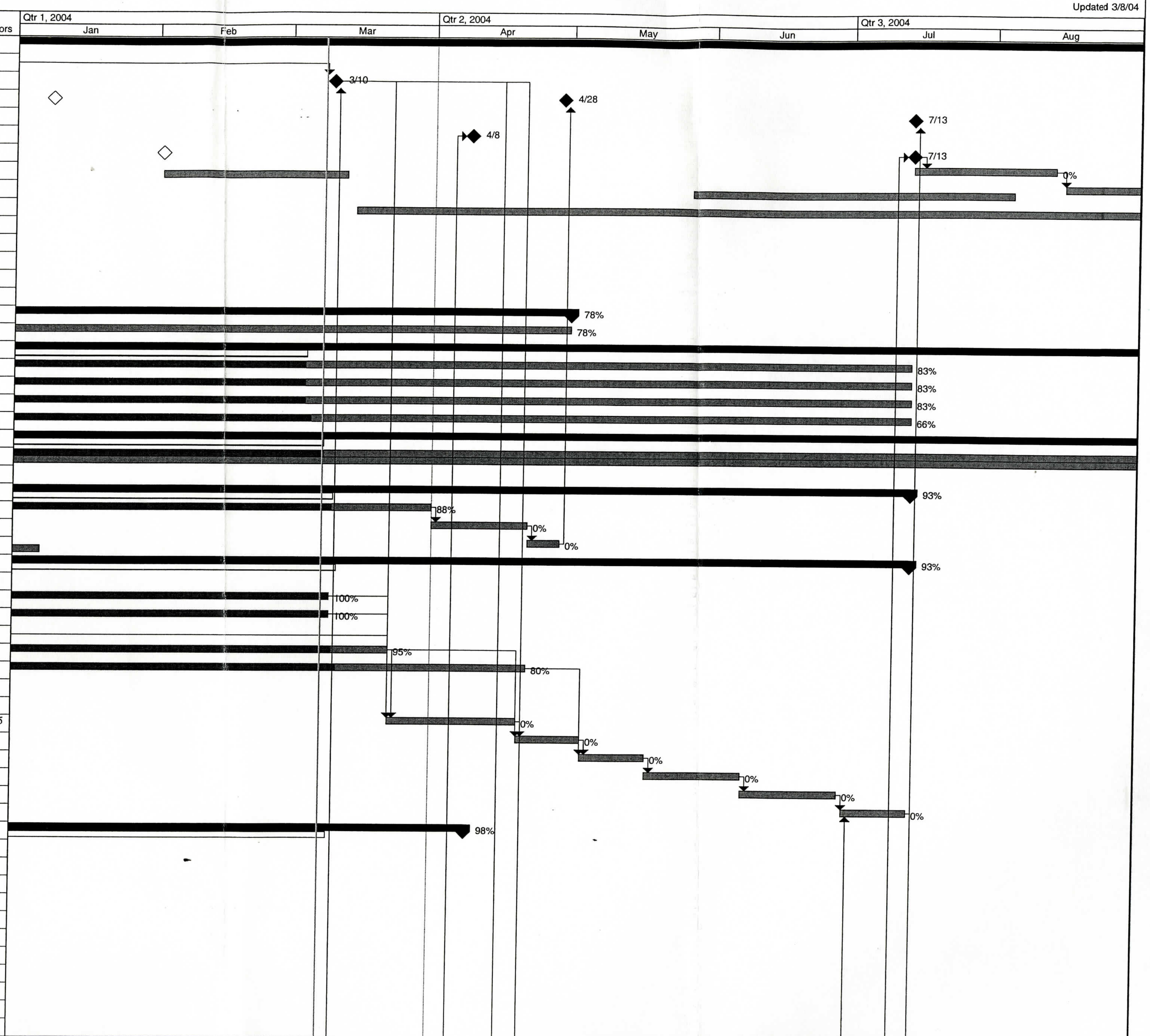
Schedule

- Updated project schedule shows the following key delivery dates:
  - Blackbody Alignment Tools: 4-28-04
  - Flight Blackbodies and Controller: 7-13-04
- Other key dates
  - Flight parts needed for board assembly: 4-1-04
  - Flight Surrogate Cable for calibration: 5-15-04

S_Schedule.mpp with baseline

Updated 3/8/04

ID	Indicators	Task Name	Duration	Start	Finish	Predecessors
1		**Key Program Events**	**810 days**	**Wed 12/11/02**	**Wed 1/18/06**	
2		Sources PDR	0 days	Wed 12/11/02	Wed 12/11/02	
3		**BBC CDR**	1 day	Wed 3/10/04	Wed 3/10/04	2,94
4		**Deliver Blackbody Alignment Simulators**	0 days	Wed 4/28/04	Wed 4/28/04	29
5		**Deliver Flight Blackbodies**	0 days	Tue 7/13/04	Tue 7/13/04	110,44
6		**BB Prototype Electronics for EMI/EMC**	0 days	Thu 4/8/04	Thu 4/8/04	92
7		**BB Flight Electronics Delivery**	0 days	Tue 7/13/04	Tue 7/13/04	111
8		Integration into SM	23 days	Wed 7/14/04	Fri 8/13/04	7
9		SM Performance Testing	50 days	Mon 8/16/04	Fri 10/22/04	8
10		SM Acceptance Test	54 days	Mon 10/25/04	Thu 1/6/05	9
11		GIFTS Engr. Calibration	55 days	Fri 1/7/05	Thu 3/24/05	10
12		SM Integration into CM & Test	115 days	Fri 3/25/05	Thu 9/1/05	11
13		GIFTS Calibration	70 days	Fri 9/2/05	Thu 12/8/05	12
14		Calibration Report Due	0 days	Fri 12/30/05	Fri 12/30/05	13
15		Launch	0 days	Wed 1/18/06	Wed 1/18/06	13
16		**FTS Design Support**	**500 days**	**Mon 6/3/02**	**Fri 4/30/04**	
17		Participate in Interferometer Design	500 days	Mon 6/3/02	Fri 4/30/04	
18		**GIFTS Characterization and Calibration Support**	**849 days**	**Mon 6/3/02**	**Thu 9/1/05**	
19		Develop & Maintain Calibration Model	552 days	Mon 6/3/02	Tue 7/13/04	
20		Develop and Maintain Radiometric Model	552 days	Mon 6/3/02	Tue 7/13/04	
21		Help Develop Characterization & Cal. Plan	552 days	Mon 6/3/02	Tue 7/13/04	
22		Participate in Char. & Cal. Proc. Development	271 days	Tue 7/1/03	Tue 7/13/04	
23		**Participate in Char. & Cal. Test & Analysis**	**459 days**	**Mon 12/1/03**	**Thu 9/1/05**	
24		Participate in GIFTS Engr. Calibration	371 days	Mon 12/1/03	Mon 5/2/05	
25		Participate in Char. & Cal. (SM/CM)	219 days	Mon 11/1/04	Thu 9/1/05	
26		**On-board Blackbody Calibration Subsystem**	**552 days**	**Mon 6/3/02**	**Tue 7/13/04**	
27		Design BB Alignment Simulators	133 days	Mon 9/29/03	Wed 3/31/04	
28		Fabricate BB Alignment Simulators	15 days	Thu 4/1/04	Wed 4/21/04	27
29		Verify BB Alignment Simulators	5 days	Thu 4/22/04	Wed 4/28/04	28
30		**Blackbody**	**552 days**	**Mon 6/3/02**	**Tue 7/13/04**	
31	✓	Update Design	65 days	Mon 6/3/02	Fri 8/30/02	
32	✓	Detailed Mechanical & Thermal Design	462 days	Mon 6/3/02	Tue 3/9/04	
33	✓	Mechanical & Thermal Modeling	462 days	Mon 6/3/02	Tue 3/9/04	
34	✓	Specify Thermistor Sensors & Materials	267 days	Thu 8/1/02	Fri 8/8/03	
35		Procure BB Materials	161 days	Mon 8/11/03	Mon 3/22/04	34
36		Procure Thermistor Sensors	146 days	Wed 10/1/03	Wed 4/21/04	31
37	✓	Fabricate Blackbody Simulators	30 days	Mon 9/2/02	Fri 10/11/02	31
38	✓	Blackbody Simulators complete	0 days	Fri 10/11/02	Fri 10/11/02	37
39		Fabricate Flight Blackbodies	20 days	Tue 3/23/04	Mon 4/19/04	32,33,3,34,35
40		Paint Flight Blackbodies	10 days	Tue 4/20/04	Mon 5/3/04	39,35
41		Assemble Flight Blackbodies	10 days	Tue 5/4/04	Mon 5/17/04	40,36
42		Functional & Characterization Testing	15 days	Tue 5/18/04	Mon 6/7/04	41
43		BB Calibration	15 days	Tue 6/8/04	Mon 6/28/04	42
44		Support Full System Calibration @ SSEC	10 days	Wed 6/30/04	Tue 7/13/04	43,109
45		**BB Controller (Thru EM2 testing)**	**471 days**	**Thu 6/20/02**	**Thu 4/8/04**	
46		**BB Controller Design**	**359 days**	**Thu 6/20/02**	**Tue 11/4/03**	
47	✓	Learn Actel Development Tool	100 days	Mon 9/9/02	Fri 1/24/03	
48	✓	Finalize design goals and constraints	140 days	Mon 9/23/02	Fri 4/4/03	
49	✓	Create design Ver1	109 days	Tue 10/1/02	Fri 2/28/03	
50	✓	Review design Ver1	1 day	Mon 3/3/03	Mon 3/3/03	49
51		**Initial Design Complete**	0 days	Mon 3/3/03	Mon 3/3/03	50
52	✓	Receive VHDL bus address decoder from SDL	1 day	Mon 3/17/03	Mon 3/17/03	51
53	✓	Review VHDL bus address decoder	1 day	Tue 3/18/03	Tue 3/18/03	52
54	✓	Simulate bus interface	5 days	Mon 5/5/03	Fri 5/9/03	
55	✓	FPLA Pin Definition	1 day	Mon 4/28/03	Mon 4/28/03	
56	✓	Continue Simulation & any design changes	135 days	Tue 4/29/03	Mon 11/3/03	55



Project: GIFTS Blackbody Controller						
Critical	Critical Progress	Split	Baseline	Baseline Milestone	Summary Progress	Project Summary	External Milestone
Critical Split	Task	Task Progress	Baseline Split	Milestone	Summary	External Tasks	Deadline

File = GIFTS_Schedule.mpp with baseline

Updated 3/8/04

ID	Indicators	Task Name	Duration	Start	Finish	Predecessors
57	✓	Program FPLA for EM model construction	1 day	Tue 11/4/03	Tue 11/4/03	56
58	✓	**FPLA Pins Defined for EM Board Layout**	0 days	Mon 7/14/03	Mon 7/14/03	
59	✓	Analog Design	283 days	Thu 6/20/02	Mon 7/21/03	
60	✓	Create analog bread board circuit(s)	30 days	Mon 9/23/02	Fri 11/1/02	
61	✓	Create analog test fixture(s)	7 days	Mon 10/28/02	Tue 11/5/02	
62	✓	Test analog test fixture	4 days	Wed 11/6/02	Mon 11/11/02	61
63	✓	Test bread board circuit(s)	84 days	Tue 10/1/02	Fri 1/24/03	
64	✓	Initial Analog Design Complete	0 days	Mon 7/21/03	Mon 7/21/03	63,59
65	✓	**EM1 Board Layout (UTMC)**	53 days	**Tue 7/22/03**	Thu 10/2/03	59,58
66	✓	EM Review Board Layout	2 days	Thu 10/2/03	Fri 10/3/03	65
67	✓	**EM1 Board Production**	**208 days**	**Fri 1/17/03**	**Tue 11/4/03**	
68	✓	Procure EM Parts	175 days	Fri 1/17/03	Thu 9/18/03	
69	✓	EM PWB Manufacture	5 days	Mon 10/6/03	Fri 10/10/03	66,68
70	✓	EM Board Fabrication	16 days	Mon 10/13/03	Mon 11/3/03	69,68
71	✓	Receive EM Board	1 day	Tue 11/4/03	Tue 11/4/03	70
72	✓	**EM1 Testing**	**20 days**	**Wed 11/5/03**	**Tue 12/2/03**	**71**
73	✓	Testing	20 days	Wed 11/5/03	Tue 12/2/03	71,80,57
74	✓	Test with Blackbody Simulators	8 days	Mon 11/17/03	Wed 11/26/03	38
75	✓	Complete EM1 Testing	0 days	Tue 12/2/03	Tue 12/2/03	73
76	✓	**Test Fixture for EM & Flight bds. Using SDL bus simulator**	**28 days**	**Wed 9/17/03**	**Fri 10/24/03**	
77	✓	Test Fixture Famliarization at SDL	2 days	Wed 9/17/03	Thu 9/18/03	
78	✓	Test Fixture Test Procedure Development	15 days	Fri 9/26/03	Thu 10/16/03	
79	✓	Test Fixture Software Coding	6 days	Fri 10/17/03	Fri 10/24/03	78
80	✓	Test Fixture Preparation Completed	0 days	Fri 10/24/03	Fri 10/24/03	79
81	✓	**Engineering Model 2**	**29 days**	**Tue 12/2/03**	**Fri 1/9/04**	
82	✓	Schematic Changes	4 days	Tue 12/2/03	Fri 12/5/03	75
83	✓	EM2 Board Layout	23 days	Mon 12/8/03	Wed 1/7/04	82
84	✓	Review EM2 Board Layout	2 days	Thu 1/8/04	Fri 1/9/04	83
85	✓	**EM2 Board Production**	**29 days**	**Wed 1/14/04**	**Mon 2/23/04**	
86	✓	EM2 PWB Manufacture	5 days	Wed 1/14/04	Tue 1/20/04	84
87	✓	EM2Board Fabrication	20 days	Mon 1/26/04	Fri 2/20/04	86
88	✓	Receive EM2 Board	1 day	Mon 2/23/04	Mon 2/23/04	87
89		**EM2 Testing**	**22 days**	**Wed 3/10/04**	**Thu 4/8/04**	
90		Testing	20 days	Wed 3/10/04	Tue 4/6/04	88,94
91		Review EM Tests	2 days	Wed 4/7/04	Thu 4/8/04	90
92		Complete EM2 Testing	0 days	Thu 4/8/04	Thu 4/8/04	91
93	✓	**CDR Preparation**	**15 days**	**Wed 2/18/04**	**Tue 3/9/04**	
94	✓	Prepare materials for CDR	15 days	Wed 2/18/04	Tue 3/9/04	
95		**BBC Flight Board (Flight)**	**552 days**	**Mon 6/3/02**	**Tue 7/13/04**	
96		Board Layout changes for flight board	5 days	Fri 4/9/04	Thu 4/15/04	92
97		Review Flight board layout	3 days	Fri 4/16/04	Tue 4/20/04	96
98		**Flight Parts**	**494 days**	**Mon 6/3/02**	**Thu 4/22/04**	
99	✓	Flight Parts Definition	295 days	Mon 6/3/02	Fri 7/18/03	
100		Flight Parts Procurement	191 days	Mon 7/21/03	Mon 4/12/04	99
101		Flight Parts to UTMC for kit audit	5 days	Fri 4/16/04	Thu 4/22/04	100,3,96
102		**Flight Board Procurement**	**25 days**	**Wed 4/21/04**	**Tue 5/25/04**	
103		Flight Board PWB Manufacture	5 days	Wed 4/21/04	Tue 4/27/04	97,3
104		Flight Board Fabrication	20 days	Wed 4/28/04	Tue 5/25/04	103,101
105		**Receive Flight Boards**	0 days	Tue 5/25/04	Tue 5/25/04	104
106		**Flight Board Testing**	**35 days**	**Wed 5/26/04**	**Tue 7/13/04**	
107		Initial Flight Boards Test	5 days	Wed 5/26/04	Tue 6/1/04	105
108		Functional Testing	10 days	Wed 6/2/04	Tue 6/15/04	107
109		Thermal Testing	10 days	Wed 6/16/04	Tue 6/29/04	108,107
110		Calibration w/ Flight BB	10 days	Wed 6/30/04	Tue 7/13/04	109
111		**Completion of Flight Bd. Testing**	0 days	Tue 7/13/04	Tue 7/13/04	110

Project: GIFTS Blackbody Controller

Critical	Critical Progress	Split	Baseline	Baseline Milestone	Summary Progress	Project Summary	External Milestone
Critical Split	Task	Task Progress	Baseline Split	Milestone	Summary	External Tasks	Deadline

Printed 4:20 PM Mon 3/8/04

Procurement Plan

- UTMC Aeroflex will get the Controller Board fabricated (Coretec) and will assemble using UW provided parts.
- Board fabrication vendor may be the same one used for EM-1 and EM-2, or we may go with the same vendor as SDL if it is different.
- Thermometrics is providing the S-60 thermistors in UW provided housings.
- Electronics Parts status provided on next page.

Flight Parts Status

Ref	Quant. (1)	Description	Flight Part Number	SMD/QPL	Flight Footprint	Part Mfg	Vendor	Notes	Purchase Responsibility
1	2	Rectifier	1N5811US	none	E-MELF	Micro-Semi	NA		SDL
2	1	MPX, 1X16	HS9-1840ARH-Q	5962F9563002VYC	CDFP3-F28	Intersil	NA		SDL
3	2	MPX, 3X2	HS9-303RH	5962R9581301VXC	CDFP3-F14	Intersil	NA		SDL
4	1	MPX, 1X8	HS9-508BRH-Q	5962F9674202VXC	CDFP4-F16	Intersil	Arrow		UW
5	5	Op Amp	RH108AW	none	GDFP1-F10	Lin. Tech	Arrow		UW
6	4	Small Signal Diode	1N6661US	none	A-MELF	Micro-Semi	NA		SDL
7	13	Dual Op Amp	RH1078MW	none	GDFP1-F10	Lin. Tech	NA		SDL
8	2	Quad Comparator	HS9-139RH-Q	5962F9861301VXC	CDFP3-F14	Intersil	Arrow		UW
9	2	D/A Converter	7545ARPFS	none	CDFP4-F20	Maxwell	NA		SDL
10	1	A/D Converter	7872RPFS	none	CDFP4-F16	Maxwell	Maxwell		UW
11	153	SMT Resistors	RM1005	MIL-PRF-55342/3	RM1005	State of the Art	State of the Art		UW
12	82	SMT Ceramic Capacitors	CDR05	MIL-PRF-55681E	CDR05	AVX	Spirit		UW
13	7	Tantalum Capacitors	CWR09 (G)	MIL-C-55365/4	CWR09 (G)	AVX	Spirit		UW
14	4	Power MOSFET	IRHNJ597034SCS	none	SMD-0.5	IR	ACI Electronics	60V, P channel, 100 K rads	UW
15	2	CWR06	CWR09 (C)	MIL-C-55365/4	CWR09 (C)	AVX	Spirit		UW
16	21	Precision Resistor	VH102K	none	VHK102K (4)	Vishay	Vishay		UW
17	1	Board Thermistor	tbd	none	RN55 (4)	tbd	tbd		UW
18	1	FPLA	RT54SX72S-1CQ208B	5962-0150802QYC	208 CQFP	Actel	Actel		SDL
19	7	8 Bit Transceiver	54ACTQ245WRQMLV	5962R9218701VSA	CDFP4-F20	National	Avnet Marshall		SDL
20	1	Bus Connector	WG208PR9SY-1	none	(2)	AirBorn	Airborn		SDL
21	1	3 test points	MTMM-103-07-G-S-255	none	(2)	Samtec	Samtec		UW
22	7	SMT Resistors	RM2208	none	RM2208	State of the Art	State of the Art		UW
23	5	PNP Transistor	SOC2907AHRB	MIL-PRF-19500/291	(SMT)	ST Micro	NA		SDL
24	2	Quad Nand Gate	HCS132KMSR	5962R9572601VXC	CDFP3-F14	Intersil	Arrow		UW
25	2	26-Pin Connector	SDD26F4R200G	none	(2)	Positronix	Positronics		UW
26	8	Zero Ohm Resistor	RM1005	none	RM1005	State of the Art	State of the Art		UW
27	1	16 Pin Connector	Not used for flight.	none	(2)	NA	NA		NA
28	2	Fuse	FM08A125V2A	none	(2)	Bussman Fuse	Fuses Ulimited		UW
29	9	CDR01	CDR01	MIL-PRF-55681E	CDR01	AVX	Spirit		UW
30	11	CDR03	CDR03	MIL-PRF-55681E	CDR03	AVX	Spirit		UW
31	6*	Blackbody Thermistor, ABB	AX-0310001-7	NA	NA	Thermometrics	Thermometrics		UW
32	6*	Blackbody Thermistor, HBB	AX-0310001-5	NA	NA	Thermometrics	Thermometrics		UW
33	4**	Heater for BB	HK25076(-)	NA	NA	Minco	Minco		UW

Notes:
(1) Quantity per board
(2) Through-hole component.
* Blackbody Thermistors are mounted in the Blackbodies (6 per blackbody)
** 2 heaters per Blackbody

All UW parts on hand except #17, #13 - expect in time for board assembly

Resources

- <u>Blackbody</u>
  - UW has all resources necessary to fabricate and assemble the blackbody.
  - SDL will provide Blackbody MLI.
  - Random Vibration can be done either at UW or SDL.
  - SDL facilities will be used for Thermal Vacuum Testing.
- <u>Controller</u>
  - UTMC Aeroflex will manufacture and assemble the board (to UW design, using UW provided parts)
  - UW has resources to perform temperature cycling and acceptance testing over required temperature range.
  - SDL will conformal coat board
  - SDL will perform Random Vibration in box fixture.

Resources

- <u>Blackbody/Controller</u>
  - UW has all the resources and facilities to perform the end-to-end calibration of the Blackbody subsystem.

Document Control

- Documents numbered
  - # format: 8300-0000 (8300 = GIFTS Project)
  - 8300-0001 is the Drawing List
  - Documents numbered in sequence (no "intelligent" number scheme)
- Major features
  - Drawing list is source of information about current revision of document
  - Pre-release: originator can update as needed and drawing list will have date of latest version

Document Control

- After release: changes only by ECN
- All ECNs result in Rev change (8300-xxxx Rev N is complete definition - no ECN as part of doc reference)

- Control
  - Source files stored in central FTP location
  - Drawing list searchable on-line
  - Current PDF available via web search/browse page

Configuration Management

- CIL basis of hardware CM
- Manufacturing records show all assembly & test steps
  - includes lower level assy & test records
  - part traceablility

Result: can answer questions about what is where, what was done, who did it, etc.

Product Assurance Requirements

- GIFTS Specific Product Assurance Requirements are derived from the Statement of Work and Product Assurance Plan.
- The GIFTS specific Quality Assurance Implementation Plan describes the methods and controls to be implemented by the University of Wisconsin.
- The requirements of GIFTS specific Product Assurance Implementation Plan are levied to subcontractors and suppliers.
- Personnel training and certification to NASA standards.
- Identification of risk and evaluation during all aspects of the work.
- Support design reviews, manufacturing readiness reviews, test readiness reviews, and pre-ship reviews.

Product Assurance Roles & Responsibilities

- The GIFTS Performance Assurance Manager (PAM) shall direct and monitor the activities to assure conformance, identify the need for preventive and/or corrective actions, and implement them when necessary.
- The PAM shall coordinate all Safety, Reliability, and Quality Assurance issues and will report progress to SDL.

Product Assurance Roles & Responsibilities

- Product Assurance activities include:
  - EEE Parts Engineering and Electronic Packaging
  - Radiation Effects Analysis
  - Reliability Engineering
  - Quality Assurance
  - Review and Inspection
  - Procurement Product Assurance
  - System Safety
  - Material and process control

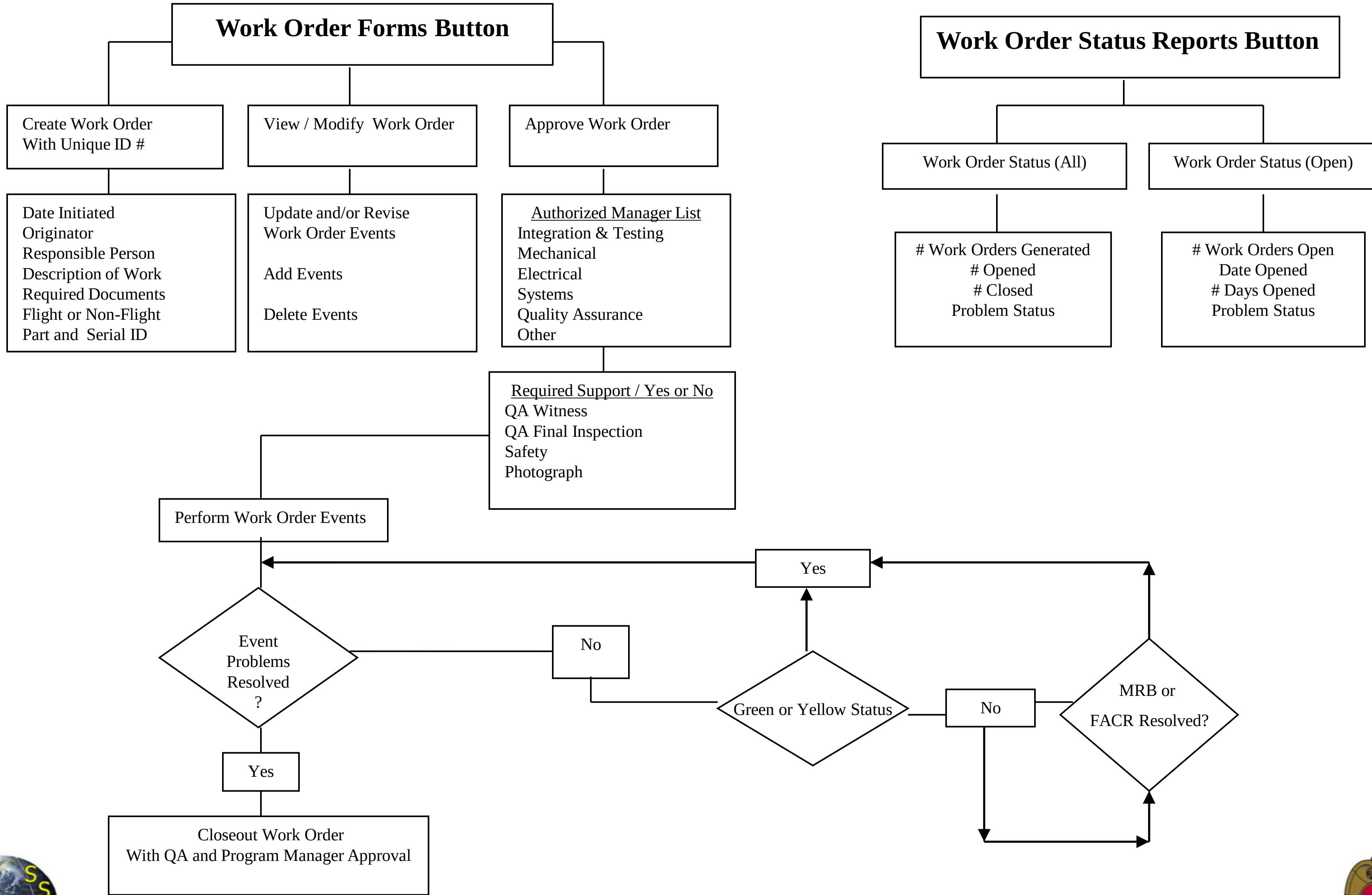
Product Assurance Roles & Responsibilities

- Product Assurance activities include cont'd:
  - Manufacturing and process control
  - Nonconformance Control & Reporting using close loop work order database (WOA)
    - Problem Report (PR)
    - Material Review Board (MRB),
    - Waiver,
    - Failure Analysis and Corrective Action report (FACR)
  - Ground Test Software Quality Assurance
  - Configuration Control

Product Assurance Roles & Responsibilities

- Verify workmanship standards.
- Train and certify personnel on ESD, contamination control, manufacturing processes and procedures.
- Inspect and witness testing of hardware.
- Verify test equipment calibration.
- Conduct surveys and perform audits of subcontractors and manufacturers.
- Provide test software quality assurance.
- Ensure contamination control requirements are met.
- Identify, review and approve special processes.
- Review, approve, and control work orders, problem reports, and failure reports.

Computer Controlled
Work Order and Problem Record Process Flow



Reliability and Quality Assurance Program

- **Questions answered – what can go wrong, what is likely, what are the consequences.**

Flow Down of Requirements of GIFTS Product Assurance Plan →

System Design →
- Design Margin Review
- Internal Peer Review
- Test

Parts Selection & Application →
- Level 2 parts as per GSFC 311-INST-001
- Part Derating to PPL-21
- GIDEP review of all parts
- Stress Analysis
- Parts review
- Testing where required

Understanding the Environment →
- Test

Reliability Verification FMEA when required →
- Mitigate risks

Flight Fabrication →
- Manufacturing readiness review.
- Approved procedure
- Close loop anomaly system with continuous risk management.

Workmanship & Testing →
- Inspection as per approved procedures
- Test readiness review.
- Inspections

Integration & Testing →
- Random Failures (ground equipment, etc.)
- Test
- Close loop anomaly system & continuous risk management

Shipping and Transport
- Approved procedures
- Controlled environments

- Requirements Summary
  - Parts screening and qualification per GSFC 311-INST-001, Level 2, requirements derived from the GIFTS-IOMI statement of Work.
  - SDL/LaRC review and approve EEE Part Lists.
  - Derate EEE Parts per PPL-21
  - Perform GIDEP Search
  - Parts Control Board (PCB) Approach, a partnership arrangement with NASA/LaRC parts engineer and SDL.

EEE Parts and Traceability Implementation Plan

- Part lists are reviewed and approved by the project team prior to flight procurements.
- Special considerations include:
  – Radiation evaluation of all active components
  – Radiation testing (TID and/or SEE) when necessary
  – No pure tin, cadmium, and zinc plating is allowed
  – Single lot (preferred), date code, traceability from part procurement, assembly, rework, and integration testing via parts identification and as build part lists

EEE Parts and Traceability Implementation Plan

- Special considerations include cont'd:
  - Mandatory surge current testing on all tantalum capacitors
  - Age control requirements. Lot Date Code (LDC) older than 9501 requires DPA and room temperature re-screen
  - Parts traceability from procurement to assembly of boards.
  - GIDEP Alerts & NASA Advisories review and disposition
  - Parts Identification list (PIL) includes LDC, MFR, Radiation information of the flight lot

No Hazards Identified for GIFTS BB Subsystem

SPACE DYNAMICS LABORATORY		
PAYLOAD HAZARD IDENTIFICATION MATRIX		
Origination Date: 2-19-04	**Revision:** 1.0	
PROGRAM: NASA/GIFTS		
SDL Project Manager: Lorin Zollinger		
Flight Category (Balloon, Rocket, Shuttle, ISS, etc.): Rocket		
Items shown with a "Y" in the table below are identified as hazard groups that will need further evaluation and possible mitigation/control.		
HAZARD GROUP	Anticipated? Yes or No	Notes
Acceleration/Impact	No	
Asphyxiation	No	
Ionizing Radiation	No	
Nonionizing Radiation	No	
Hazardous/Toxic Materials	No	
Purge Systems	No	
Pyro Systems	No	
Pressure Systems	No	
Confined Space	No	
Hydraulics	No	
Batteries	No	
Materials Handling	No	
Temperature	No	
Explosive Atmospheres	No	
Electrical	No	
Software	No	
Transportation	No	
Ground Operations	No	
Debris	No	

GIFTS
Blackbody Subsystem
Critical Design Review
Action Items From PDR

Fred Best

9 March 2004

Parts

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-1	SDL	UW and LaRC	UW requested input from SDL on the parts list. They need a source for an 80-krad op amp, and would like to use as many similar parts as SDL as possible. SDL will supply the complete UW parts list to LaRC for review. Add thermistors & heaters. Define date/time for discussion about flight part procurement.

CLOSED: UW and SDL have coordinated on parts selection and are using common part types, where possible. The UW Parts List has been submitted to LaRC through SDL. Thermistors and heaters have been added to the list. SDL and UW have coordinated on flight part delivery.

Electronics Error Budget

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-2	UW	SDL	UW will add all errors to the electronics error budget.

CLOSED: UW has broken-out and included all known error contributors (within reason) for the Electronics Error Budget.

EMI Requirements

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-3	SDL	UW & LaRC	SDL will provide UW with the EMI requirements, including limits. Will not send EV2 document.

CLOSED: SDL has provided UW the EMI document "GEO Weather EMC Requirements Specification and Control Plan."

ITAR Guidance

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-4	LaRC	SDL	Provide guidelines to SDL regarding providing sections of requirements documents to companies with potential ITAR issues.

OPEN: This action has not been closed.

Board Fabrication Standards

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-5	SDL	UW & LaRC	SDL will provide flight board fabrication quality standard definition to UW.

CLOSED: Flight Board Fabrication and Assembly quality specifications have been proved to UW by SDL. This information resides in the SDL SM Electronics Box ICD.

Board Fabrication Standards

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-6	LaRC	SDL	Determine what flight board fabrication quality standard is desired

CLOSED: Flight Board Fabrication and Assembly Standards have been provided to SDL.

MLI Venting

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-7	SDL	LaRC	SDL will determine if UW needs to perform a venting study on evacuating the blackbody in the MLI region, and whether a vent needs to be added to the blackbody design.

Closed: The Blackbody design was reviewed to ensure that all internal volumes have a sufficient vent path. While it was determined that there was sufficient venting, slight modifications were made to the design to preferentially improve the vent flow path to the rear of the blackbody (away from GIFTS optics).

Survival Temperature of BB

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-8	UW	SDL & LaRC	UW will define the survival temperature of the blackbody. Consider mechanical and thermistor issues.

CLOSED: UW has developed a mechanical design of the blackbody that will survive down to the required 180 K. We have also determined that the thermistors will survive temperatures down to this temperature. This is based on previous experience by the vendor (Thermometrics) and by the SABER program at SDL (using the same thermistors), where the required thermistor accuracy was demonstrated down to 77 K. For the GIFTS BB we have preserved the physical mounting techniques (to the extent possible) used by the SABER program.

BB Use of Survival Heater Power

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-9	SDL	LaRC	Define what survival heater power would be required to maintain blackbodies above survival temperature.

CLOSED: The idea of using survival heater power to maintain the blackbodies above survival temperature was rejected. The Survival Bus is on continuously, even during normal operation. Putting survival heaters on the cavity is an EMI concern because the bus is unfiltered which could lead to unwanted noise on the cavity thermistors. Putting survival heaters on the outside of the case (somewhat electrically shielded from the cavity thermistors) would cause thermal control problems (cavity heater fighting the case survival heater) which arise from a combination of thermal resistance between the cavity and the case and thermostat hysteresis.

Paint Emissivity Measurements

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-10	UW	SDL	Define if the paint emissivity measurements are normal or hemispherical. Decide which way witness samples should be measured.

CLOSED: To properly calculate the Blackbody cavity emissivity, directional hemispheric reflectance measurements of the intrinsic paint are required. These measurements are made using an integrating sphere configured for near normal illumination of the paint sample and then measuring total hemispheric reflectance. In the past, these measurements have been made for UW by Labsphere. For GIFTS they will be made at Labsphere and NIST.

Thermal Paste Outgassing

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-11	UW	SDL	UW will investigate outgassing characteristics of thermal paste (Thermalloy 250 Thermal Joint Compound) used with thermistors. Verify acceptance with SDL.

CLOSED: UW is using Thermometrics thermistors. These are potted in place using a NASA approved low outgassing thermally conductive epoxy (Stycast 2850 FT). The mounting technique and epoxy are the same as used for the SABER program.

BBC Address on SDL Bus

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-12	SDL	LaRC	Define base address of BBC on SDL bus.

CLOSED: SDL defined the BBC bus address space as 180400-1807FF Hex. UW is using only 180400-180435 Hex. (54 bytes, count 0-53 decimal).

SDL Bus Connector Weights

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR13	SDL	UW & LaRC	SDL will provide weight information on the SDL bus connectors.

CLOSED: UW obtained the Bus Connector weight.

26-pin Connector Weight

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-14	SDL	LaRC	Provide weight for 26-pin HD female board connector.

CLOSED: UW obtained the 26-pin HD female board connector weight.

SDL Bus Formating

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-15	SDL & UW	SDL	Robert Burt and Mark Werner will meet to decide how both the high and low calibration resistor measurements are included into the data coming down from the SM. (VHDL address decoder for SDL bus transactions.)

CLOSED: This meeting was held and a scheme was developed. UW added three permanent registers that will allow all the data for the calibration resistors to be available for every sample period.

End-to-End System Check

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-16	UW	SDL	Consider performing a final end-to-end check of thermistors and flight electronics. Perform test when blackbody is in isothermal temperature calibration chamber with reference PRT.

CLOSED: This calibration will be performed with the Flight Controller and Flight Blackbodies.

Use CMM to Measure Paint Thickness

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-17	UW	SDL	Consider using the CCM (coordinate measurement machine) at SDL (or other CMM) to help measure cavity paint thickness.

CLOSED: It is important to have a non-contacting method for directly measuring paint thickness on the blackbody cavity. CMM requires contact, so it is not suitable for direct cavity paint thickness measurements. Paint thickness measurements will be made on flat witness samples painted at the same time as the cavities in a fixture that simulates the cavity geometry. Thickness measurements will be made using a micrometer and by taking mass measurements (before and after painting).

Use Slot in G-10 Tube

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-18	UW	SDL	Consider using a slot in the circular end plates to mount the G-10 tube.

CLOSED: UW has gone away from using G-10 fiberglass epoxy. We now use a glass filled Noryl insulator that is better matched to the coefficient of expansion of the aluminum. There is a bolted connection between the Noryl and Aluminum (not epoxy as was planned when we were baselining G-10).

Qualified G-10 Vendors

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-19	SDL	UW	SDL will provide information on qualified G-10 vendors to UW. Provide previous experience and margin to use.

CLOSED: The UW Blackbody design no longer uses G-10 Figerglass.

Cal. BBs at Common Temp.

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-20	UW	SDL	Determine if both blackbodies can be at a common temperature for calibration tests.

CLOSED: The measurement range of the ABB is –40 to 0 C and for the HBB 0 to +40 C. Both blackbodies will be calibrated at an overlap temperature of 0 C.

Consider Controlling Both BBs

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-21	UW	SDL	Consider impacts of having capability to control both blackbodies

CLOSED: Due to the change in the thermal interface, both blackbodies will be controlled.

Ground Tests to Transfer Cal.

Action Item Number	ACTION TO	ACTION REQUESTED BY	DESCRIPTION OF ACTION
BB-PDR-22	SDL/UW	SDL	Define what tests are required during ground calibration to transfer calibration from ground calibration source to internal sources.

CLOSED: The external calibration source in thermal vacuum is viewed as a validation of the in-flight calibration procedures (provided by the internal sources combined with the required instrument characterization). Any unexpected differences will need to be resolved such that the fundamental calibration rests on the in-flight calibration.

REVISIONS

LTR.	ECN	DESCRIPTION	DATE	APPROVED
-	NA	Original release	3/8/04	

SHEET REVISION STATUS

SHEET	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
REVISION	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
SHEET	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
REVISION																		
SHEET	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
REVISION																		
SHEET	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
REVISION																		
SHEET	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
REVISION																		
SHEET	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108
REVISION																		

CONTROLLED	DIST. LIST
1	16
2	17
3	18
4	19
5	20
6	21
7	22
8	23
9	24
10	25
11	26
12	27
13	28
14	29
15	30

Space Science and Engineering Center

THE UNIVERSITY OF WISCONSIN - MADISON, WISCONSIN

TITLE

GIFTS

GIFTS Blackbody Subsystem Specification

ORIGINATOR	DATE	ENGINEER	DATE	ENGINEER	DATE
SDE		MW		DA	
		PRODUCT ASSURANCE NNC	DATE	PROJECT APPROVAL FAB	DATE

FILENAME	PROJECT NO.
GIFTS_BBC_Spec_8300-0004.doc	8300

DRAWING NO.	SCALE	SIZE	SHEET
8300-0004	NA	A	Page 1 of 27

1. Scope

This document provides the functional description, technical specifications, and external interface definition for the Blackbody Calibration Subsystem for the Geostationary Imaging Fourier Transform Spectrometer (GIFTS). The blackbody subsystem is located in the GIFTS SM and consists of two blackbodies (both located on the optics bench), a controller (located in the SM electronics box), and cabling that connects the blackbodies to the controller. The components of the Blackbody Calibration Subsystem are illustrated in Figure 1.0.

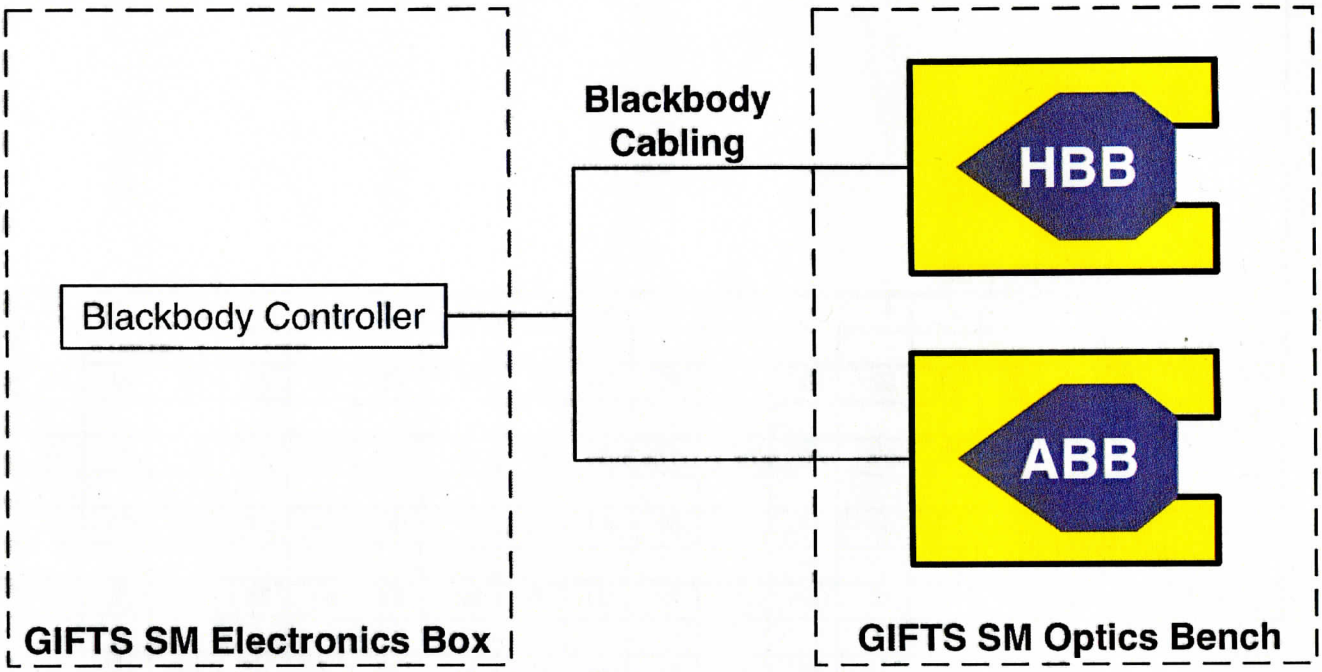


Figure 1.0

Designated specifications are guaranteed by test or guaranteed by design over the entire operating temperature range. All other specifications are for reference only.

2. Applicable Documents

The following documents are applicable to this specification:

- Statement of Work for SDL Contract to UW (C922185) (17 December 2003)
- GIFTS Instrument, Requirements Document 2.0
- GIFTS SM Main Electronics Box Circuit Card Interface Control Document (SDL/02-265)

The GIRD specifies the absolute calibration accuracy of the GIFTS instrument to be better than 1 K brightness temperature for Earth scenes brightness temperatures greater than 240 K (SW/MW channel) and > 190 K (LW channel) and shall be traceable to the National Institute of Standards and Technology. The reproducibility shall be ≤0.2K for the same conditions.

The GIFTS calibration model uses the calibration equation to determine the GIFTS instrument errors associated with uncertainties in various GIFTS instrument calibration parameters, including, blackbody emissivity uncertainty and blackbody temperature uncertainty. Emissivity and temperature uncertainties used in the calibration model are used in this specification for the on-board blackbody calibration subsystem.

3. Functional Description

This section provides the functional description of the Blackbody Calibration subsystem. A block diagram of the subsystem is shown in Figure 3.0.

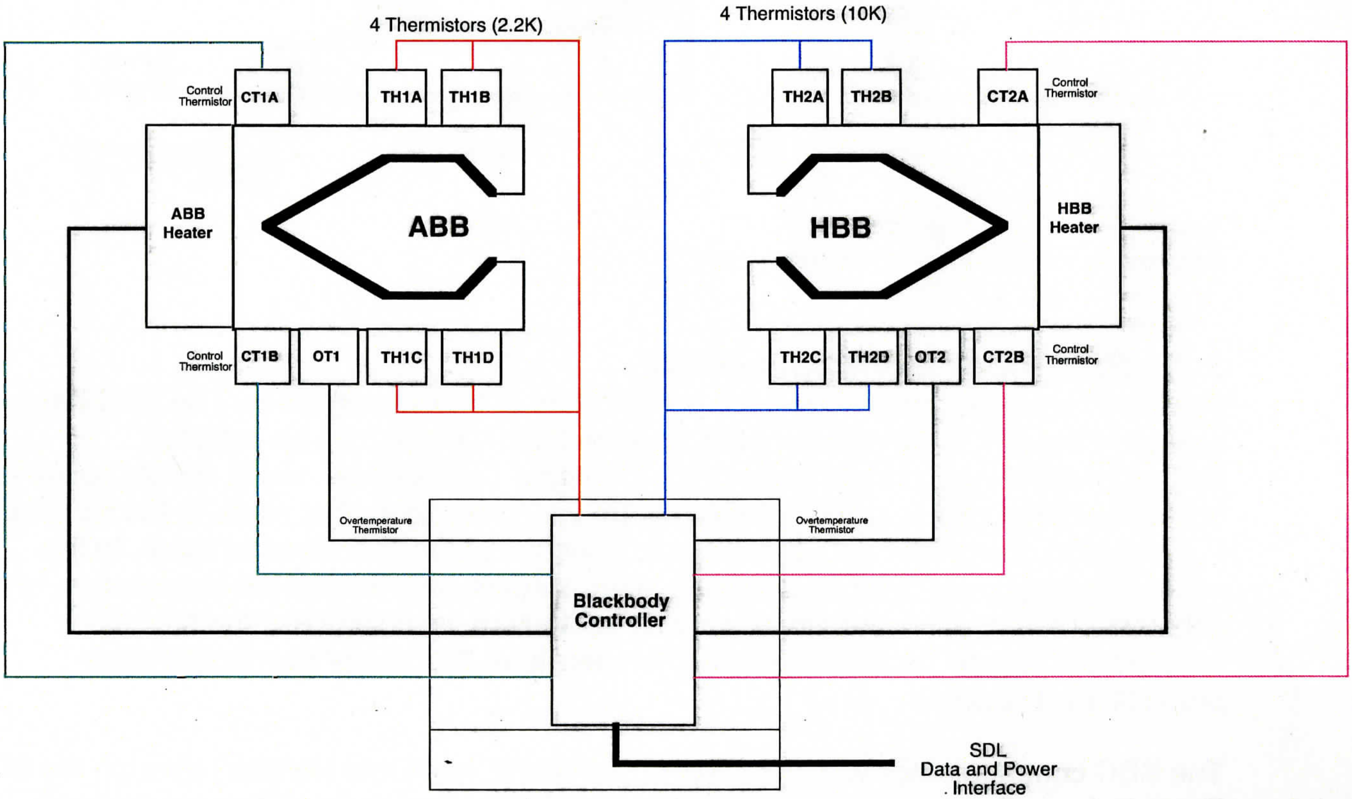


Figure 3.0. Blackbody Calibration Subsystem Block Diagram

3.1. Blackbodies

A section view of the Ambient Blackbody (ABB) is presented in Figure 3.1. The Hot Blackbody (HBB) is identical to the ABB except that the thermistors are of a different value. The inside of the cavity is painted black. The cavity is structurally supported and thermally isolated from the base of the blackbody case by the structural support. Multilayer insulation (MLI) (not shown in the figure) completely surrounds the cavity outer surface to minimize radiation heat transfer to the Blackbody Enclosure. There is MLI on the outside of the enclosure, as well. Thermistors, embedded into the cavity wall, are used for temperature measurement. Each blackbody has four temperature measurement thermistors, two temperature control thermistors, one overtemperature thermistor, and one heater.

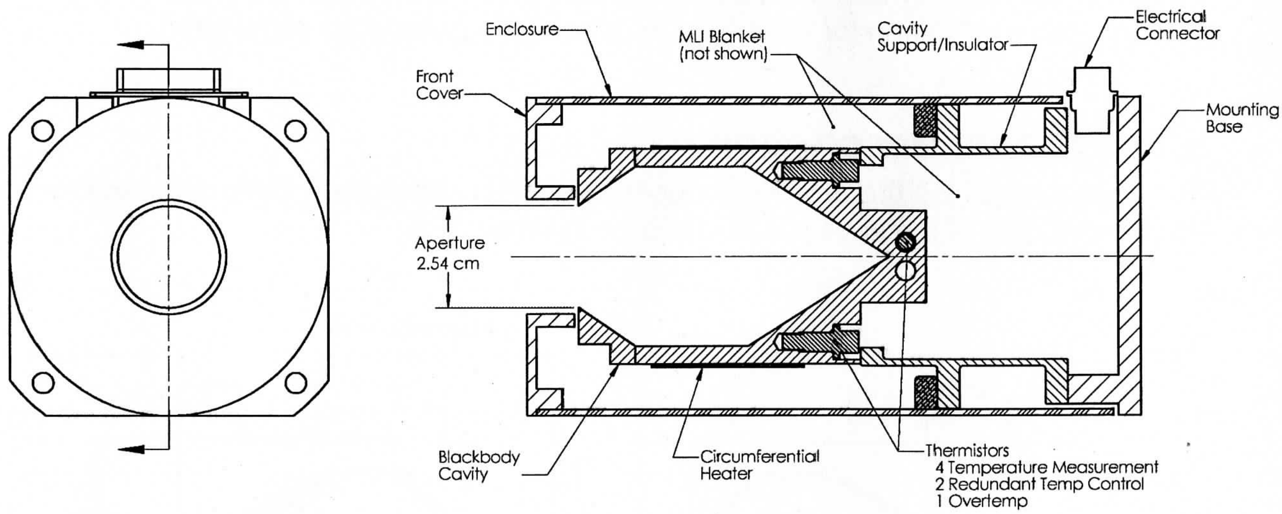


Figure 3.1 Section view of the Blackbody.

3.2. *Blackbody Controller (BBC)*

The BBC measures and controls the temperature of both blackbodies. The BBC has two modes: Constant Temperature and Constant Power. Mode may be selected independently for each blackbody. In the Constant Temperature mode, heater power is controlled to hold the blackbody temperature very close to the set point. In the Constant Power mode, the heater duty cycle is held constant at the commanded value. In this mode, the blackbody, after stabilization, approximately tracks ambient temperature with a constant difference. Heater power may be set to zero, in which case the blackbody temperature closely tracks the ambient temperature. Blackbody overtemperature protection is provided.

The BBC communicates with the C&DH (Command and Data Handler) through the SDL Bus interface. Commands may be sent to the BBC to change operating modes and parameters. Data is also sent to the C&DH through this interface. The available data includes resistance data as well as BBC operational data.

On power-up, the BBC automatically begins operating in it's default state. The default state causes the BBC to come up with both blackbodies in the constant temperature mode, with the set points at their normal values. Parameters of the default state can not be changed by command.

Thermistors are used to measure temperature. Each thermistor is continuously excited by a voltage source and a separate precision resistor in a half bridge configuration. The resulting voltage for each thermistor is measured at the sampling rate of once every 363 ms. The thermistors are sampled sequentially. Each sample consists of 256 consecutive 14-bit conversions, averaged to return a 16-bit value. Internal calibration resistors are measured during each sampling cycle to minimize measurement error. The BBC does not convert counts to actual temperature values; this conversion is performed elsewhere. Output data is updated at the sampling rate.

Dedicated redundant blackbody thermistors are used to control temperature. The temperature set point is set via the data interface. Analog controllers set the heater duty cycle to the appropriate value. Pulse width modulators (PWM) drive the blackbody heaters. The heater switches operates at approximately 10 Hz, with low output slew rates to minimize electromagnetic interference.

4. Top Level Specifications

Table 4.0

Specification	Typical	Minimum	Maximum	Units	Notes
HBB Temp. Measurement Range	--	0	+40	°C	2,*
ABB Temp. Measurement Range	--	-40	0	°C	2,*
Temp. Measurement Resolution	--	--	0.003	°C	2,^
Temp. Measurement Error (±)					2,3,7
Electronics (at delivery)	--	--	0.02	°C	*
Thermistor (at delivery)	--	--	0.03	C	*
On-orbit drift-electronics	--	--	0.01	C	^
On-orbit drift-thermistor	--	--	0.04	C	^
Total	--	--	0.10	C	
HBB Temp. Set Point	+17	0	+40	°C	*
ABB Temp. Set Point	-18	-40	0	°C	*
Temperature Set Point Resolution	--	--	0.2	°C	2,^
Temperature Set Point Stability			0.005	°C	8,^
Heater PWM Frequency	10	8	12	Hz	*
Sampling Rate	2.76	2.60	2.90	Hz	^
Data Readout Rate	--	--	3	Hz	^
Overtemperature Limit	--	+47	+60	°C	*
Power					
Heaters (Total)	0.7	0	4.0 ^	W	5,6
Electronics Dissipation	--	--	1.2 ^	W	4
Total	--	--	5.2 ^	W	
Mass					
Hot Blackbody			1,000 *	g	
Ambient Blackbody			1,000 *	g	
Controller			400 *	g	
Total			2,400 *	g	

* Guaranteed by Test
^ Guaranteed by Design

Specification	Typical	Minimum	Maximum	Units	Notes
Cavity Aperture Diameter Field of View		 2.54 10	 2.57 14	 Cm Deg.	 * *
Emissivity (680 cm^{-1} to 2,300 cm^{-1}) Cavity Emissivity Cavity Emissivity Uncertainty (3σ)		 0.996 0.002			 ^ ^

Notes

1. Unless otherwise noted, all specifications apply over the entire Controller and Blackbody temperature ranges.
2. With specified thermistors, over specified temperature measurement range.
3. After calibration with flight interconnecting cables, or equivalent.
4. Electronics dissipation at maximum heater power, but exclusive of heater power.
5. "Typical" heater power is the total for both blackbodies, calculated at the Orbital Average (average of the power to maintain the set point in the worst case cold and worst case hot parts of the orbit), with blackbodies at nominal set points, at the beginning of mission life.
6. Maximum heater power occurs during blackbody warm-up.
7. Guaranteed for Controller Temperature Range of -40 to +30°C only.
8. For a 1°C change in Controller board temperature.

4.1. Blackbody Operating Modes

There are two operating modes for the each blackbody, which may be selected independently.

Table 4.1

Mode	Description
Constant Temperature	Temperature is controlled at the commanded set point.
Constant Power	Heater duty cycle is maintained at the designated value. Duty cycle may be set to zero.

4.2. Blackbody Temperature Control

In the constant temperature mode, the blackbody temperature is maintained at a set point determined by the set point integer. Table 4.2.1 shows the relationships between set point integer, temperature, and thermistor voltage. More precise relationships may be determined by calibration.

* Guaranteed by Test
^ Guaranteed by Design

Table 4.2.1

Set Point Integer (decimal)	HBB Temperature, °C		ABB Temperature, °C		Nominal Voltage
	Minimum *	Maximum *	Minimum *	Maximum *	
4095	-5	0	-45	-40	0.827V
0	+40	+45	0	+5	0.328V

One of the two dedicated redundant control thermistors on each blackbody is used to control its temperature. The temperature set points are set via the SDL bus interface. Conversion from temperature to the set point integer is performed elsewhere. The difference between the thermistor resistance and the set point is processed by an analog Proportional-Integral-Derivative (PID) circuit to determine the required heater power. The output of the PID circuit sets the heater duty cycle. A pulse width modulator (PWM) drives the blackbody heater. The PWM frequency is asynchronous with respect to data collection. The heater switch operates at approximately 10 Hz, with low output slew rates to minimize EMI. PID parameters are determined by component values and are selected to match the characteristics of the blackbody. The PID circuit includes a single-pole lowpass function with a cutoff frequency of less than 5 Hz and limits the integral (I) component to ensure stability.

The control thermistors are redundant and selected by command from the C&DH. There is no automatic switching of control thermistor.

Table 4.2.2 lists the electrical parameters of each blackbody heater.

Table 4.2.2

Parameter	Minimum	Maximum	Units
Heater Voltage *	4.70	5.25	Volts
ABB Heater Resistance	14.4	14.7	Ohms
HBB Heater Resistance	14.4	14.7	Ohms
PWM Frequency *	8	12	Hz
Duty Cycle *	0	100	%
Heater Output Fuse	--	2	A

Table 4.2.3 lists blackbody characteristics related to the dynamic temperature response.

Table 4.2.3

Specification	Minimum	Maximum	Units
Cavity Thermal Mass	200	220	J/°C
Thermistor Time Constant	--	1	Second

4.3. Constant Power Mode Operation

In the Constant Power mode, the set point integer controls the heater duty cycle The relationship between the set point integer and duty cycle is given in table 4.3.1.

Table 4.3

Parameter	Minimum	Maximum
Set Point for zero duty cycle (decimal) *	10	200
Set Point for 100% duty cycle (decimal) *	3890	4090
Nonlinearity ^	--	1%
Duty Cycle Resolution ^	--	0.03%

4.4. Overtemperature Protection

Overtemperature protection systems ensure that overheating does not damage a blackbody. In the constant temperature mode, the BBC does not allow the set point to be commanded to a value outside the ranges specified in table 4.2.1. In the constant temperature mode, an overtemperature condition may occur only in case of a failure. In the constant power mode, however, an overtemperature condition may occur without a Blackbody Controller failure if excessive heater power is applied.

The overtemperature protection system is independent of the primary heater control system so that no single-point BBC or thermistor failure results in overheating of the blackbody. A dedicated blackbody temperature sensor on each blackbody senses its temperature and protection circuitry removes power from the heater if the temperature exceeds the overtemperature limit. The heater is automatically enabled when blackbody temperature drops below the limit. Hysteresis is at least 1°C. In the overtemperature protection mode, the blackbody temperature cycles about the limit as long as power is applied to the system. An indicator is set when an overtemperature condition is detected. The indicator is reset only when power is removed from the BBC, the BBC is reset, or new commands are received from the C&DH. Overtemperature protection systems for the two blackbodies operate independently, with separate indicators.

4.5. Temperature Measurement

Each thermistor and calibration resistor is connected to a precision resistor and voltage source in a half-bridge configuration. The fixed excitation voltage setting is common to all 16 channels. To improve resolution, the full range of the voltage across the thermistor is about four times the range of the A/D converter. Five values of offset voltage are available to bring the measured voltage within the A/D converter range. Four of these offset values are used for temperature measurement, while the fifth (zero offset) is used only for the temperature error and spare channels. All (4) ABB thermistors (Channels 0 - 3, see section 4.5.3) share the same offset value, as do the (4) HBB thermistors (Channels 4-7), though ABB and HBB offsets may be set independently. The offset for each of the three spare channels (8-10) may be set independently. Zero offset is available for all thermistor and spare channels, but is not useful for thermistor inputs.

Each thermistor and calibration resistor is sampled during each sampling interval. When a particular thermistor is to be measured, the offset value is set and a multiplexer connects the half-bridge to the A/D converter. A suitable delay then allows the input to

* Guaranteed by Test
^ Guaranteed by Design

the A/D converter to settle. After settling, 256 consecutive A/D conversions are rapidly performed and the data are averaged providing a 16 bit data value. After the results of the measurement have been stored, the next channel is measured in the same manner until all channels have been measured. The digital data from the A/D convert is in the 2's compliment binary format. The 16 bit data value at the negative full scale input voltage is 8000 H (-32,768 dec) and 7FFC H (32,764 dec) for a positive full scale input voltage.

Autoranging is available for all channels except the calibration channels. Autoranging can be enabled independently by group for ABB thermistors and HBB thermistors, and individually for each of the spare channels. Channel 0 is used for ABB autoranging, and Channel 4 for HBB autoranging. When an out of range value is detected, the offset is increased or decreased, as appropriate, for the next data collection. When autoranging is enabled, offset range count is increased if the averaged 16-bit ADC count is less than 4096 (dec) counts above the negative full scale value and decreased if the count is greater than the positive full scale value minus 4092 (dec) counts. Only offsets 00 through 03 are used in the autoranging mode. Offset is adjusted only once after each data collection; up to 3 data collections may be required before the correct offset is reached.

Offset values for the five calibration channels are fixed and selected automatically. The calibration channels corresponding to the ends of the highest and lowest ranges (Channels 11 and 15) are measured at one offset value. The remaining three calibration channels (Channels 12, 13, 14) are measured at two offset values, providing calibration points near the high and low ends of two ranges. Each set of data includes the data for both offset values for these channels. A total of 19 data registers are provided.

All spare channels may be configured to measure an external input voltage, with or without an internal half-bridge resistor. Spare channel 1 may also be configured to measure the voltage across an internal board temperature thermistor. The input voltage measurement ranges are given in Table 4.5.4.

Spare channels 2 and 3 may be configured to measure temperature error, which is the difference between the set point and actual blackbody temperature. Offset range 04 must be used in this configuration. Zero temperature error results in a value between -300 and +300 (decimal) counts. Full scale range is between ±11 °C and ±13 °C.

The spare channels are configured by selective installation of resistors, and cannot be changed after assembly and final testing.

Table 4.5.1 Blackbody Thermistors

Application	Part Number	Vendor	Notes
ABB Thermistor-measurement (4)	SP60AB103FAI	Thermometrics	10K at 25°C
ABB Thermistor-Control (2-redundant)	SP60AB103FAI	Thermometrics	10K at 25°C
ABB Overtemperature Thermistor (1)	SP60AB103FAI	Thermometrics	10K at 25°C
HBB Thermistor-measurement (4)	SP60AA222FAI	Thermometrics	2.20K at 25°C
HBB Thermistor-Control (2-redundant)	SP60AA222FAI	Thermometrics	2.20K at 25°C
HBB Overtemperature Thermistor (1)	SP60AA222FAI	Thermometrics	2.20K at 25°C

Table 4.5.2 Thermistor Input Parameters

All Channels	Minimum	Maximum	Units
Sampling Rate (all channels)	2.6	2.9	Hz
Voltage Range	0.247	0.726	Volts
External Shunt Capacitance	--	500	pF
Excitation Voltage *	0.95	1.05	Volts

Table 4.5.3 Measurement Channel Assignments

Channel	Analog Multiplexer Address (Decimal)	Offset	Description	SDL Bus Byte Address Offset
ABB_A	00	ABB	ABB Thermistor A	12,13
ABB_B	01	ABB	ABB Thermistor B	14,15
ABB_C	02	ABB	ABB Thermistor C	16,17
ABB_D	03	ABB	ABB Thermistor D	18,19
HBB_A	04	HBB	HBB Thermistor A	20,21
HBB_B	05	HBB	HBB Thermistor B	22,23
HBB_C	06	HBB	HBB Thermistor C	24,25
HBB_D	07	HBB	HBB Thermistor D	26,27
ST1	08	ST1	Spare 1	28,29
ST2	09	ST2	Spare 2 (ABB Error)	30,31
ST3	10	ST3	Spare 3 (HBB Error)	32,33
CAL1	11	03	Calibration 1	34,35
CAL2	12	03	Calibration 2 Low	36,37
CAL3	13	02	Calibration 3 Low	38,39
CAL4	14	01	Calibration 4 Low	40,41
CAL5	15	00	Calibration 5	42,43
CAL2	12	02	Calibration 2 High	44,45
CAL3	13	01	Calibration 3 High	46,47
CAL4	14	00	Calibration 4 High	48,49

Table 4.5.4 Measurement Offset Ranges

Offset (Decimal)	Input Voltage Range	ABB Temperature Range (°C)	HBB Temperature Range (°C)
00	+0.578 to +0.762	-14.1 to +4.9	25.5 to 47.1
01	+0.456 to +0.639	-24.7 to -8.6	14.6 to 28.2
02	+0.334 to +0.517	-33.6 to -19.2	4.3 to 19.8
03	+0.212 to +0.396	-43.4 to -28.4	-7.1 to +9.2
04	-0.092 to +0.092	N/A	N/A
05	-0.092 to +0.092	N/A	N/A
06	-0.092 to +0.092	N/A	N/A
07	-0.092 to +0.092	N/A	N/A

* Guaranteed by Test
^ Guaranteed by Design

4.6. *Default Operation*

When power is applied to the BBC and in the absence of commands from the C&DH and without reset applied, the BBC operates in the state indicated in table 4.6. A jumper (JMP1) may be installed on the board to change these defaults for laboratory operation.

Table 4.6

Parameter	State or Value *	
	JMP1 Out	JMP1 In
ABB Mode	Constant Temperature	Constant Temperature
ABB Set Point Temperature	-18°C ±1°C	0°C ±1°C
ABB Set Point Integer	1838	107
ABB Control Thermistor	A	A
ABB Offset	01	01
HBB Mode	Constant Temperature	Constant Temperature
HBB Control Thermistor	A	A
HBB Set Point Temperature	+17°C ±1°C	+40°C ±1°C
HBB Set Point Integer	2157	157
HBB Offset	01	01
ST1 Offset	01	01
ST2 Offset	01	01
ST3 Offset	01	01
Autoranging	Enabled	Enabled

4.7. *Reset Operation*

A reset input is also provided on the SDL interface. When the reset is applied, it causes the BBC to return to the default state. Reset occurs on the leading edge of this signal, however the BBC does not begin normal default operation and data collection until the trailing edge of the reset signal. Normal operation and data collection begins within 1 ms of the trailing edge of the reset signal.

While the reset is asserted, no data is collected, but both temperature controllers are enabled in the constant temperature mode. Temperature set point integer is 4095 (minimum temperature) while reset is asserted. This provides a minimum power mode while still keeping the blackbodies at a safe temperature.

4.8. *Freeze Mode Operation*

Freeze mode operation is used only for laboratory operation testing. When a jumper is applied (JMP2), the BBC collects data only from analog multiplexer channel 01. The data is stored in all (19) the measurement channel registers. Each register contains data from a separate set of averaged samples, as in normal operation, but each with the multiplexer set to channel 01. Timing is the same as in normal operation. The offset used in the freeze mode is the programmed ABB value. Autoranging is not available. The status registers for the offset values of all channels other than analog multiplexer channel 01 may be disregarded in this mode of operation.

5. Interfaces

This section defines the interfaces between the GIFTS S/M and the Blackbody Calibration Subsystem and between the Blackbody Controller and Blackbodies.

5.1. SDL Bus Interface

The BBC is allocated the address space 180400-1807FF. The BBC responds to the address space 180400-180735 hex on the SDL bus. The BBC does not require any wait states for SDL bus transactions. The BBC requires space for a total of 27 16-bit registers.

The SDL Bus is defined in the GIFTS SM Main Electronics Box Circuit Card Interface Control Document.

5.1.1. Command and Data Interface *

The BBC receives commands from the C&DH via write cycles on the SDL Bus. The BBC outputs data to the C&DH via read cycles on the SDL Bus. Commands are received by the BBC at any time. The BBC implements any commands at the end of a sampling interval. All command register are read/write. All data and status registers are read only. The data read from the command and data registers are valid if the C&DH sets the semaphore bit, see Section 5.1.3.

For the measurement channel assignments, see Table 4.5.3.

Table 5.1.1.1 lists the BBC commands and data.

Table 5.1.1.2 is a Command Summary.

Table 5.1.1.3 is a Data Summary.

Table 5.1.1.1 Commands and Data

Byte Address Offset	0	1	2	3
Description	Status 0 Low Byte	Status 0 High Byte	Status 1 Low Byte	Status 1 High Byte
Read/Write	R	R	R	R
Bit 0 (LSB)	Fail	ABB Offset Auto Range	ABB Offset Bit 0	Spare 1 Offset Bit 2
Bit 1	ADC Timeout	HBB Offset Auto Range	ABB Offset Bit 1	Spare 2 Offset Bit 0
Bit 2	ABB Temp/Power Mode	Spare 1 Offset Auto Range	ABB Offset Bit 2	Spare 2 Offset Bit 1

* Guaranteed by Test
^ Guaranteed by Design

Byte Address Offset	0	1	2	3
Bit 3	HBB Temp/Power Mode	Spare 2 Offset Auto Range	HBB Offset Bit 0	Spare 2 Offset Bit 2
Bit 4	ABB Control Thermistor Select	Spare 3 Offset Auto Range	HBB Offset Bit 1	Spare 3 Offset Bit 0
Bit 5	HBB Control Thermistor Select	0	HBB Offset Bit 2	Spare 3 Offset Bit 1
Bit 6	ABB Overtemperature	0	Spare 1 Offset Bit 0	Spare 3 Offset Bit 2
Bit 7 (MSB)	HBB Overtemperature	ADC Timout Sticky Bit	Spare 1 Offset Bit 1	0

Table 5.1.1.1 (continued)

Byte Address Offset	4	5	6	7	8	9
Description	ABB Set Point Low Byte	ABB Set Point High Byte	HBB Set Point Low Byte	HBB Set Point High Byte	Mode	Auto Range
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W
Bit 0 (LSB)	Bit 0 (lsb)	bit 8	bit 0 (lsb)	bit 8	RW Bit	ABB Offset Auto Range Sel.
Bit 1	Bit 1	bit 9	Bit 1	bit 9	RW Bit	HBB Offset Auto Range Sel.
Bit 2	Bit 2	bit 10	Bit 2	bit 10	ABB Temp/Power Mode	Spare 1 Offset Auto Range Sel.
Bit 3	Bit 3	bit 11	Bit 3	bit 11	HBB Temp/Power Mode	Spare 2 Offset Auto Range Sel.
Bit 4	Bit 4	Not Used	Bit 4	Not Used	ABB Control Thermistor Select	Spare 3 Offset Auto Range Sel.
Bit 5	Bit 5	Not Used	Bit 5	Not Used	HBB Control Thermistor Select	RW Bit
Bit 6	Bit 6	Not Used	Bit 6	Not Used	RW Bit	RW Bit
Bit 7 (MSB)	Bit 7	Not Used	Bit 7	Not Used	RW Bit	RW Bit

Table 5.1.1.1 (continued)

Byte Address Offset	10	11	12-48 even	13-49 odd	50	51
Description	Offset, Programmed Low Byte	Offset, Programmed High Byte	Data, Low Byte	Data, High Byte	Frame Count Low Byte	Frame Count High Byte
Read/Write	R/W	R/W	R	R	R	R
Bit 0 (LSB)	ABB Offset Bit 0	Spare 1 Offset Bit 2	Bit 00	Bit 08	bit 00	bit 08
Bit 1	ABB Offset Bit 1	Spare 2 Offset Bit 0	Bit 01	Bit 09	bit 01	bit 09
Bit 2	ABB Offset Bit 2	Spare 2 Offset Bit 1	Bit 02	Bit 10	bit 02	bit 10
Bit 3	HBB Offset Bit 0	Spare 2 Offset Bit 2	Bit 03	Bit 11	bit 03	bit 11
Bit 4	HBB Offset Bit 1	Spare 3 Offset Bit 0	Bit 04	Bit 12	bit 04	bit 12
Bit 5	HBB Offset Bit 2	Spare 3 Offset Bit 1	Bit 05	Bit 13	bit 05	bit 13
Bit 6	Spare 1 Offset Bit 0	Spare 3 Offset Bit 2	Bit 06	Bit 14	bit 06	bit 14
Bit 7 (MSB)	Spare 1 Offset Bit 1	RW Bit	Bit 07	Bit 15	bit 07	bit 15

Byte Address Offset	52	53
Description	Semaphore Low Byte	Semaphore High Byte
Read/Write	R/W	R/W
Bit 0 (LSB)	C&DH Access	Not used
Bit 1	Not used	Not used
Bit 2	Not used	Not used
Bit 3	Not used	Not used
Bit 4	Not used	Not used
Bit 5	Not used	Not used
Bit 6	Not used	Not used
Bit 7 (MSB)	Not used	Not used

Note: All "Not used" bits are read as 0.

Table 5.1.1.2 Command Summary (Read/Write)

Command	Bits
ABB Set Point	12
HBB Set Point	12
ABB Offset	3
HBB Offset	3
ABB Mode (Constant Power or Constant Temperature)	1
HBB Mode (Constant Power or Constant Temperature)	1
ABB Autorange Select	1
ABB Autorange Select	1
Spare Channel Offset Select	9
Spare Channel Autorange Select	3
ABB Control Thermistor A or B	1
HBB Control Thermistor A or B	1
C&DH Access	1
Not used	23
RW Bit	8
Total	80

Table 5.1.1.3 Data Summary (Read Only)

Data	Bits
Resistance Data (19 registers)	304
Frame Count	16
ABB Offset	3
ABB Offset Autorange	1
HBB Offset	3
HBB Offset Autorange	1
Spare Channel Offsets	9
Spare Channel Autorange	3
ABB Mode (Constant Power or Constant Temperature)	1
ABB Control Thermistor A or B	1
Status Register "zero" bits	3
HBB Mode (Constant Power or Constant Temperature)	1
HBB Control Thermistor A or B	1
ADC Timeout	1
ADC Timeout Sticky Bit	1
ABB Overtemperature	1
HBB Overtemperature	1
Failure Indicator	1
Total	352

5.1.2. Semaphore Register

The BBC register at the offset address of 34H contains the semaphore bit in location 0. To ensure that the data set read is from only one data collection cycle, the C&DH sets the semaphore bit to 1 before reading the BBC registers. The C&DH sets the semaphore bit back to 0 once it has read all the BBC data. Failure to set the semaphore bit back to 0 will cause the BCC to not update the data output registers.

The C&DH must also set the semaphore bit before writing any control parameters to the BBC and reset the semaphore bit after writing any control parameters. Any control parameters written to the BBC take effect at the end of the next sampling interval after the semaphore bit has been set to 0. This implies the C&DH wait for a minimum of 1.5 sampling intervals (0.544 sec) after writing a control parameter, before it executes a read to verify these written parameters.

Table 5.1.2 defines the semaphore register.

Table 5.1.2

Byte Address Offset	52	53
Description	Semaphore low	Semaphore high
Read/Write	R/W	R/W
Bit 0 (LSB)	C&DH Access	0
Bit 1	0	0
Bit 2	0	0
Bit 3	0	0
Bit 4	0	0
Bit 5	0	0
Bit 6	0	0
Bit 7 (MSB)	0	0

5.1.3. C&DH Interface Bus Timing ^

The Blackbody Controller meets the requirements of the GIFTS SM Main Electronics Box Circuit Card ICD.

5.1.4. Electrical Power Interface

Power requirements are given in table 5.1.4.

All supply voltages are turned on simultaneously. No more than 10 ms may elapse between the time the first supply voltage reaches 10% of its nominal value and the time at which the last reaches and remains within its specified range. Normal operation begins less than 3 seconds after all supply voltages reach and remain within their specified ranges.

Table 5.1.4

Nominal Voltage	Minimum Voltage *	Maximum Voltage *	Minimum Current	Maximum Current ^	Maximum Ripple and Noise 10 Hz to 1 MHz
2.5	2.3	2.7	0	120 mA	100 mV P-P
+5 V	4.75 V	5.25 V	0	805 mA	100 mV P-P
+12 V	+11.4 V	+12.6 V	0	18.0 mA	50 mV P-P
-12 V	-11.4 V	-12.6 V	0	21.0 mA	50 mV P-P

5.1.5. Bus Connector

Pin assignments for the Bus Connector are listed in Table 5.1.5. Pins not used by the Blackbody Controller are not shown.

Table 5.1.5

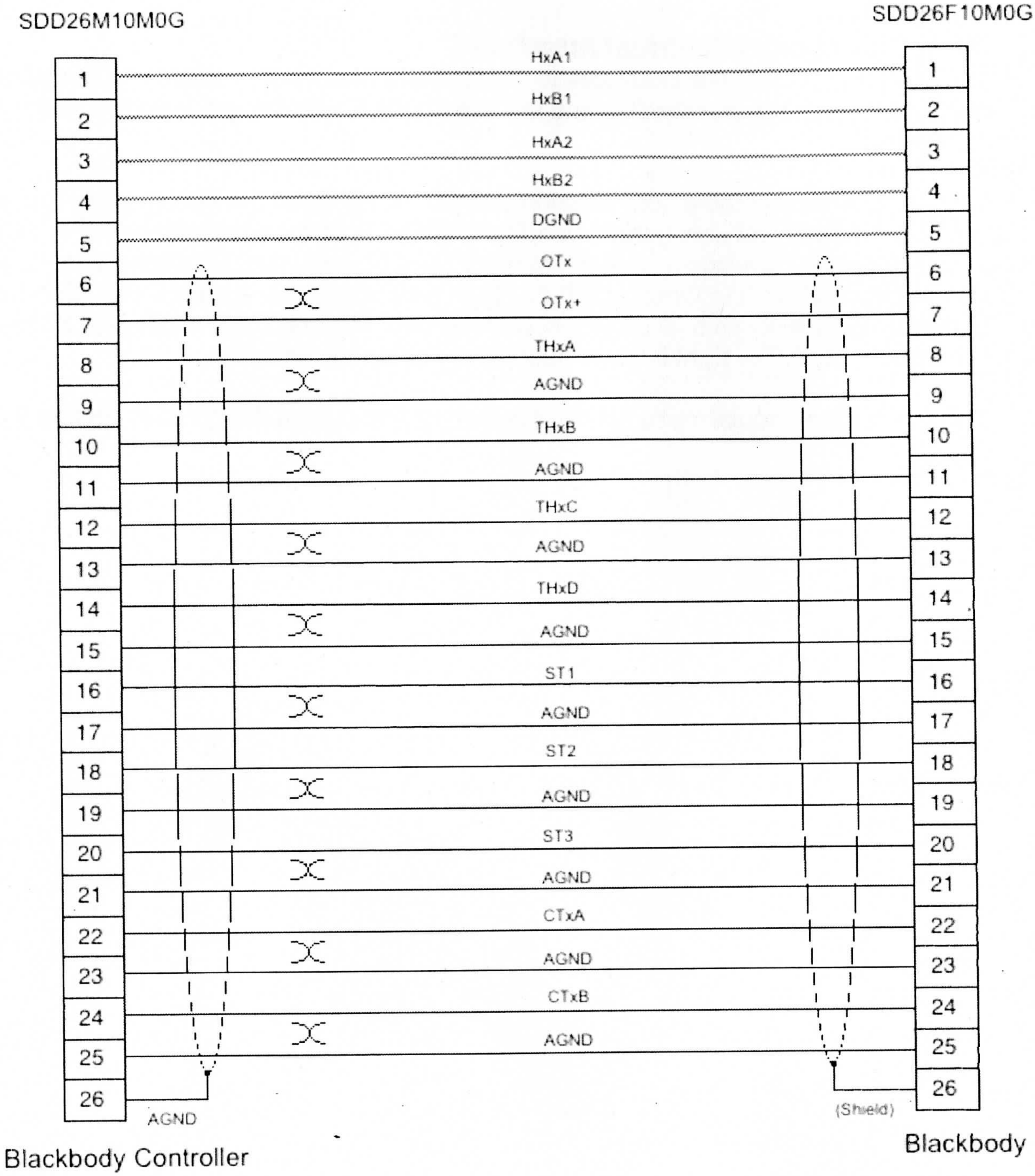
Signal	Pin	Signal	Pin	Signal	Pin
A0	166	DATA 15	22	GND	207
A1	28	WRL#	88	GND	208
A2	98	RESET4(BB)#	81	SHIELD	8
A3	167	ADV#	20	SHIELD	17
A4	29	READY4(BB)#	14	SHIELD	19
A5	168	RD#	157	SHIELD	37
A6	30	SYS_CLK	155	SHIELD	78
A7	100	+2.5V	3	SHIELD	87
A8	169	+2.5V	73	SHIELD	89
A9	31	+2.5V	141	SHIELD	94
A10	101	+3.3V	4	SHIELD	97
A11	170	+3.3V	74	SHIELD	99
A12	32	+3.3V	142	SHIELD	103
A13	102	+5V	5	SHIELD	146
A14	171	+5V	75	SHIELD	154
A15	33	+5V	143	SHIELD	156
A16	172	+12V	6	SHIELD	158
A17	34	+12V	76	SHIELD	174
A18	104	+12V	144	SHIELD	176
A19	173	-12V	7	SHIELD	188
A20	35	-12V	77	SHIELD	189
DATA 0	165	-12V	145	SHIELD	190
DATA 1	27	GND	1	SHIELD	191
DATA 2	96	GND	2	SHIELD	192
DATA 3	164	GND	8	SHIELD	193
DATA 4	26	GND	69	SHIELD	194
DATA 5	95	GND	70		
DATA 6	163	GND	71		
DATA 7	25	GND	72		
DATA 8	162	GND	137		
DATA 9	24	GND	138		
DATA 10	93	GND	139		
DATA 11	161	GND	140		
DATA 12	23				
DATA 13	92				
DATA 14	160				

5.2. *Blackbody Electrical Interface*

The Blackbody Controller interfaces to the Ambient Blackbody and the Hot Blackbody. All cabling between the blackbodies and the Blackbody Controller are provided by the SM contractor.

The interconnecting cable configuration and connector types are specified in Figure 5.2 and Table 5.2. Shield configuration and termination is precisely as shown in Figure 5.2 Ambient and Hot Blackbody cables are identical. The maximum DC resistance for each wire in the cable is 0.14 Ohm at 25° C. (Total wire resistance in series with each heater or thermistor is twice this value.) Final calibration of the Blackbody Controller Subsystem is performed with the flight interconnecting cables or equivalent.

The mechanical requirements for the interconnecting cables are given in section 5.3.1.



Notes:

⋊ Indicates twisted pair

Wires on pins 1-5 are **not** enclosed in shield

DC Resistance of each wire less than 0.14 Ohm at 25 degrees C

Two cables are required

Figure 5.2

Blackbody Cable Configuration

Table 5.2 Blackbody Cables and Connectors

Pin	Signal	Maximum Current	Signal Description
1	HxA1	0.5A	Heater 1 +
2	HxB1	0.5A	Heater 1 -
3	HxA2	0.5A	Heater 2 +
4	HxB2	0.5A	Heater 2 -
5	DGND	0.5A	Cavity Ground
6	OTx	--	Overtemperature Thermistor
7	OTx+	--	Overtemperature Thermistor Source
8	THxA	--	Thermistor A
9	AGND	--	Thermistor A Return
10	THxB	--	Thermistor B
11	AGND	--	Thermistor B Return
12	THxC	--	Thermistor C
13	AGND	--	Thermistor C Return
14	THxD	--	Thermistor D
15	AGND	--	Thermistor D Return
16	ST1	--	Spare Thermistor 1
17	AGND	--	Spare Thermistor 1 Return
18	ST2	--	Spare Thermistor 2
19	AGND	--	Spare Thermistor 2 Return
20	ST3	--	Spare Thermistor 3
21	AGND	--	Spare Thermistor 3 Return
22	CTxA	--	Control Thermistor A
23	AGND	--	Control Thermistor A Return
24	CTxB	--	Control Thermistor B
25	AGND	--	Control Thermistor B Return
26	Shield	--	Shield

(x=1 for ABB, 2 for HBB)

5.3. *Mechanical Interface*

5.3.1. Blackbody Mechanical Interface

The blackbody mounting interface is presented in Figure 5.3.1 and the Blackbody envelope is presented in Figure 5.3.2. The mechanical interfaces and envelopes for both the Ambient Blackbody and Hot Blackbody are identical.

All cabling between the blackbodies and the Blackbody Controller are provided by the SM contractor. The harness will accommodate blackbody platform translation, and will provide strain relief such that the resulting loads are not transmitted to the blackbody connectors. The blackbodies have no provisions for mounting the harness other than the electrical connectors with female jackscrews. The harness will have thermal resistance and insulation as noted in Section 5.4.1.

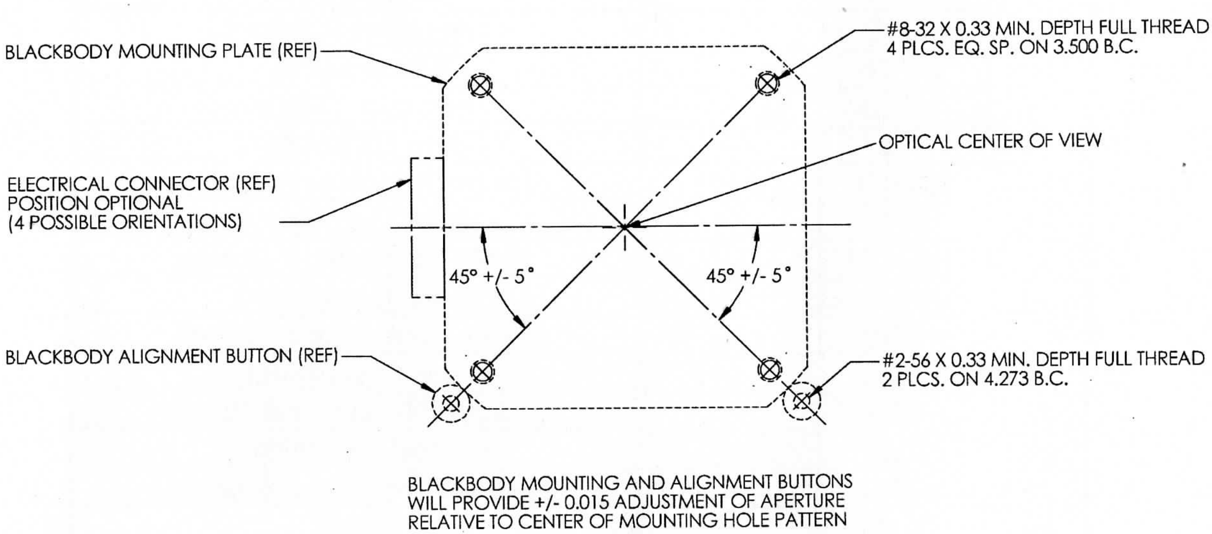


Figure 5.3.1. Mounting interface for the Blackbodies (dimensions in inches).

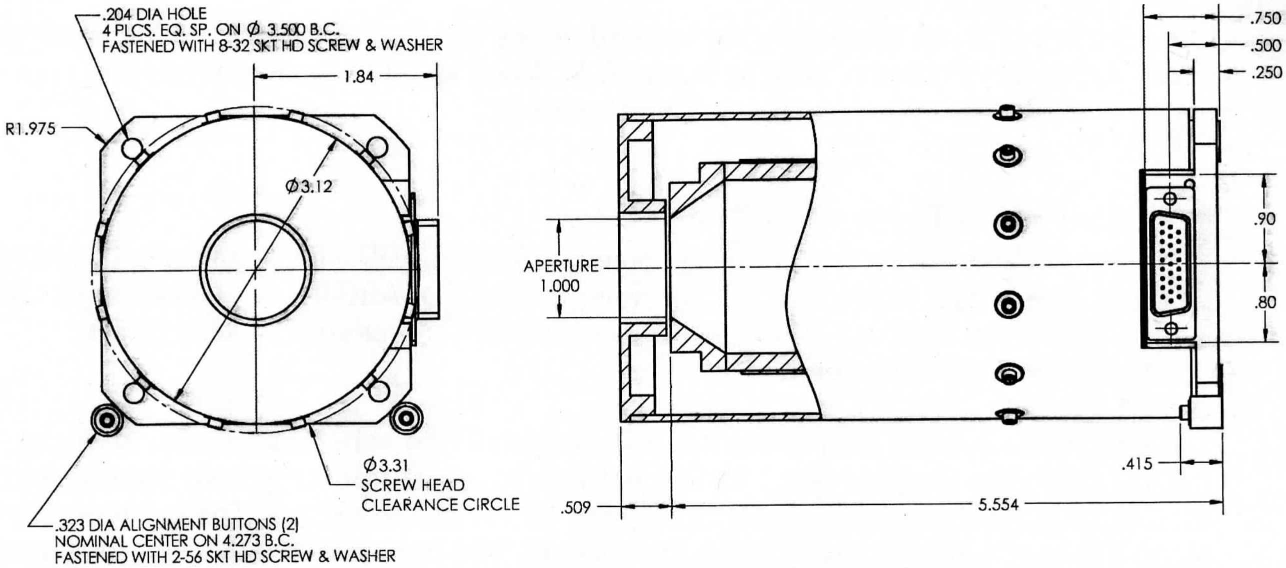


Figure 5.3.2. Envelope for the Blackbodies (dimensions in inches).

5.3.2. Blackbody Controller Mechanical Interface

The Blackbody Controller is contained on a single electronics board that is housed in the SM Electronics Box. The board outline is defined in the GIFTS SM Main Electronics Box Circuit Card Interface Control Document.

The Blackbody Controller has two connectors that are used to connect to the Blackbodies. The connector part number is (Positronix #) SDD26F4R200G. These are 26 pin socket high-density connectors with right angle (PWB mount) pins that connect to the circuit board. These connectors are listed in the GIFTS SM Main Electronics Box Circuit Card Interface Control Document. The maximum height of these connectors on the component side of the PWB is 0.485 inch. All other components meet the ICD limit of 0.419 inch.

The connector locations are defined in Appendix B of the GIFTS SM Main Electronics Box Circuit Card Interface Control Document and are listed below for reference only.

Board Location	Board Number	Board Name	Reference Designator	Connector Center Line	Dimension from top of board to first row of pins
3	28-0003	Blackbody Controller	J1	A	0.450"
3	28-0003	Blackbody Controller	J2	C	0.450"

5.4. Thermal Interface

The Ambient and Hot Blackbody are located on the SM Optics Bench and the Blackbody Controller is located in the SM Electronics Box. Each location (optics bench and electronics box) has a unique thermal environment.

5.4.1. Blackbody Thermal Interface

The Hot and Ambient calibration blackbodies (HBB and ABB) are mounted on a sliding platform. The sliding platform positions either the HBB or ABB in the calibration position. During calibration the back end of the Sensor Module is presented a view of the blackbody via a flip-in mirror.

The blackbody thermal environment is represented in the schematic shown in Figure 5.4.1. To simplify analysis of the interface, the complex surroundings are represented by equivalent surroundings defined by a cylinder 18" diameter x 9" tall. The cylinder axis lies along the central (calibration) blackbody position. The bottom of the cylinder (designated 'platform') lies in the plane of the blackbody mounting surface, and represents the blackbody sliding platform and optics bench. (The platform is mounted on and thermally linked to the optics bench.) The top of the cylinder (designated 'baffle') represents the fore optics primary and secondary baffles which lie above the blackbodies. The sides of the cylinder (designated 'ambient') represent the many components surrounding the blackbodies. The equivalent surrounding surfaces (baffle, ambient, and platform) are assumed to have uniform temperatures and emissivity ε=1. The sides of the two blackbodies are wrapped in a single MLI blanket with an emissivity ε=0.01-0.04.

The mirror mount is represented by a 3" x 10" rectangular surface that is 0.25" above the top of the blackbody enclosures. The mirror mount remains stationary while the blackbody platform slides to allow both blackbodies to be moved to the central (calibration) position. The mirror mount covers all three possible blackbody aperture positions, and has an emissivity ε=0.02-0.05. The mirror is represented by a 1.125" diameter circle in the mirror mount plane, aligned with the aperture of the blackbody in calibration position. During calibration, the mirror is assumed to be black (ε=1) at 0 K to represent the view to the SM cold optics. At all other times the mirror is assumed to have the same emissivity and temperature as the mirror mount.

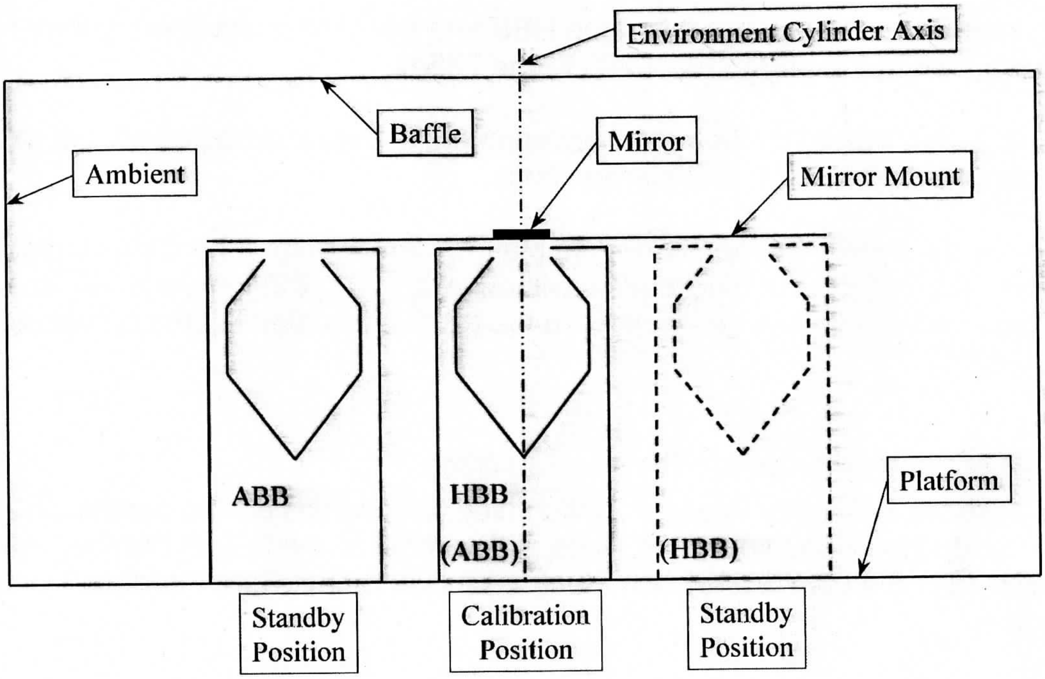


Figure 5.4.1 Blackbody Thermal Environment Schematic

The blackbody conductive paths are to the platform (optics bench), and through the wiring harness which routes from the blackbodies to the platform, along the optics bench to its termination in the electronics box. The harness will be insulated from the platform and optics bench and covered with MLI, and will have a thermal resistance from the blackbodies to the electronics box in the range of 500-2000 K/W.

The blackbodies exchange radiation with the mirror mount and the surroundings (baffle, platform, and ambient). The baffle is subjected to large temperature swings during orbit, which will drive the temperature of the ambient surroundings. The resulting ambient temperatures are slightly less extreme than the baffle temperatures. The optics bench and electronics box temperatures will increase from start to end of the mission. Table 5.4.1 lists the worst-case temperatures of the environment under various operating conditions.

Table 5.4.1 Environment Temperatures, K

Instrument Mode	Normal – Mission Start		Normal – Mission End		Survival	
Baffle Condition	Hot	Cold	Hot	Cold	Hot	Cold
Baffle	300	140	300	140	300	140
Ambient	280	180	280	180	280	180
Platform	200	200	220	220	180	180
Mirror Mount	250	250	250	250	180	180
Electronics Box	250	240	280	270	223	223

During normal instrument operation the HBB and ABB are maintained at their respective nominal set point temperatures of 290 K and 255 K.

The heat flux imparted by the actual environment to the blackbodies will not exceed the flux imparted by the equivalent surroundings.

During normal instrument operation, the platform will provide a heat sink capable of absorbing 0.5 W from the blackbodies without exceeding the temperatures in Table 5.4.1. The combined conductive heat flow from the two blackbodies to the platform will not exceed 0.5 W. *^

5.4.2. Blackbody Controller Thermal Interface

The Blackbody Controller heat dissipation (see "electronics power dissipation" in table 4.0) is conductively coupled to the sides of the board to the EG&G Birtcher wedge-locks as specified in the GIFTS SM Main Electronics Box Circuit Card Interface Control Document.

6. Environmental Specifications

The Blackbody Calibration Subsystem will be subject to the following environmental conditions:

Controller Operating Temperature (Full accuracy): -40 to +30 °C *
Controller Operating Temperature (Reduced accuracy): -55 to +50 °C *
(Measured at PWB rails.)

Controller Non-operating Temperature: -65 to +70 °C ^
(Measured at PWB rails.)

Pressure: Vacuum to 1.05 Atm ^

Total Radiation Dose: 100 K Rad (Si) (Includes 2:1 safety factor) ^

Radiation Single Event Effects: Non-destructive, automatic reset within 10 seconds. ^

Mechanical Loading

Quasi-static Design Limit Load: 50 G's in each direction simultaneously

* Guaranteed by Test
^ Guaranteed by Design

Launch Loads Exclusive of Random Vibrations (G)

	Loads due to Liftoff and Airloads			Loads due to MECO, pre-MECO, and Other		
	X	Y	Z	X	Y	Z
Blackbodies	Lateral 13.00		9.75	Lateral 10.40		10.40
Electronics (board in x-y plane)	5.20	7.80	7.80	5.30	8.01	10.40

Random Vibration Loads:

Blackbodies (X, Y, Z)
20 to 120 Hz + 6 dB/octave
120 to 500 Hz 0.080 G^2/Hz
500 to 2000 Hz - 6 dB/octave
Composite: 7.98 Grms

Controller (Y)	Controller (X, Z)
20 to 70 Hz +6 dB/octave	20 to 70 Hz +6 dB/octave
70 to 400 Hz 0.2 G2/Hz	70 to 600 Hz 0.1 G2/Hz
400 to 2000 Hz - 6 dB/octave	600 to 2000 Hz - 6 dB/octave
Composite: 11.6 Grms	Composite: 9.9 Grms

(Note controller is mounted in X-Y plane, long edge in X-direction.)

For analysis, the hardware must meet the design limit load. Alternatively, the launch and vibration loads are applied per the following:

Loads resulting from random vibration are combined with loads due to liftoff and airloads (does not include MECO, pre-MECO, and other) as follows:
Z-axis: Random loads (3σ) are linearly added to the launch loads.
X & Y axis: Random loads (3σ) are combined by RSS to the launch loads.
The resulting loads are applied simultaneously in all three directions. As a separate load case, the MECO, pre MECO, and Other loads are applied simultaneously in all three directions.