IMPACT Boom Thermal Balance Test And Thermal Analysis Report

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SUMMARY

This report contains the boom engineering model thermal balance (TB) test results versus analytical model predictions. In addition, a discussion of the analysis and updated flight predictions using the correlated thermal model are also included. The test was conducted at the SSL facility in Berkeley, CA per the test plan, Reference 2. Subsequently, the chamber configuration was modeled using the TSS program and a SINDA model of the boom and chamber was produced to predict test temperatures and correlate the analytical model. The test environment closely simulated the expected worst-case flight environments for the stowed boom mounted on the AHEAD (hot case) and BEHIND (cold case) spacecraft. Thermal balance results indicate that temperatures used for thermal vacuum qualification testing, which was conducted prior to thermal balance, meet the required 10ºC margin beyond expected extremes. After only minor changes to the boom analytical model, temperature predictions matched test results within 5ºC for most sensors. The primary issue resulting from the test was that the boom/spacecraft interface was found to be more conductive than expected and as specified in the ICD. The interface mechanical design was subsequently modified to provide increased thermal isolation of the mounting bolts.

Mass models of the boom instruments, SWEA and Magnetometer but not the STE, were included in the TB test to provide flight-like interfaces for the boom. However, these models were not thermally similar enough to the flight instruments to obtain meaningful data on the adequacy of instrument heaters or other aspects of their thermal design. A separate thermal balance test of the SWEA and STE instrument will be conducted in April 2004. The Magnetometer design has been verified on previous spacecraft programs but its thermal interface to the boom should be validated during spacecraft system level TV test. Potential future instrument design changes, if required, will have a negligible effect on the boom thermal design because the instruments have isolated designs. Thus, instrument thermal interfaces will be validated during instrument TB testing and/or during the integrated spacecraft thermal vacuum test.

The updated boom thermal model contains the correlated model of the stowed and deployed boom. In addition, the SWEA thermal model has been expanded to provide sufficient detail for TB test predictions and model correlation. Flight temperature predictions based on the correlated boom model are provided in the Updated Flight Predictions section. Conclusions and recommendations are also listed.

REFERENCES

1. ICD 7381-9012, INTERFACE CONTROL DOCUMENT (ICD) for the STEREO IMPACT INVESTIGATION, JHU Applied Physics Laboratory, dated March 7, 2002.
2. Document # XXXX, STERO/IMPACT BOOM THERMAL BALANCE TEST PLAN, SSL, UC, Berkeley, dated 29 August 2003.
3. STE ICD, SWEA ICD, and Magnetometer ICD.

FIGURES

TABLES

THERMAL BALANCE TEST VERSUS ANALYSIS RESULTS:

The boom thermal balance test was conducted from September 5 to September 13, 2003 at the SSL, Berkeley facility. Two equilibrium cases (worst-case cold and worst-case hot) provided results that were subsequently used to correlate the analytical model. A transient warm-up using the pinpuller heater was also run to verify the time constant, heater adequacy, and thermostat setpoints, but the data was not used in the correlation process.

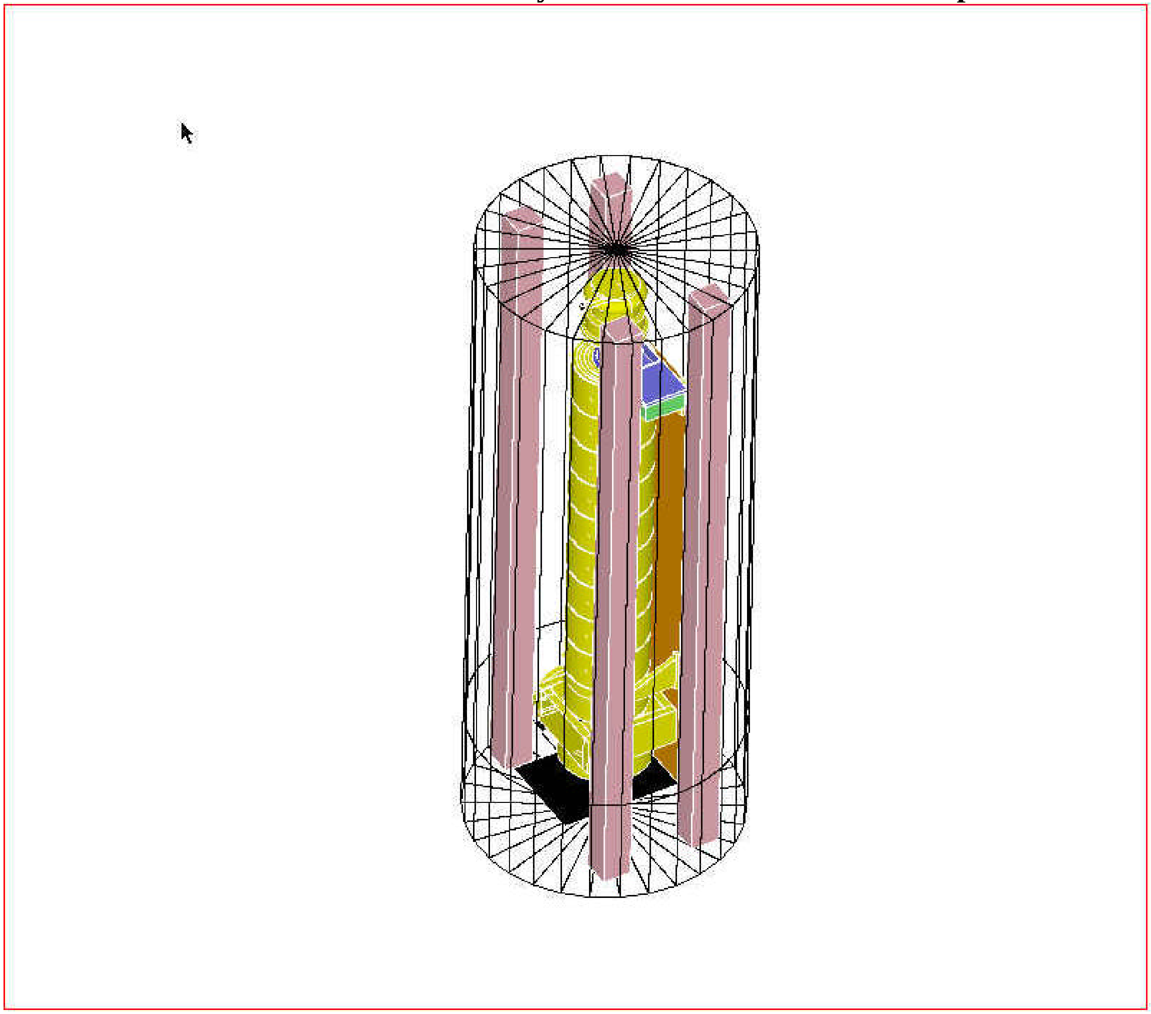
Chamber environment goals were attained for this test except for temperature control of the baseplate used to support the boom and simulate the spacecraft interface. The test plan called for interface temperatures of 0ºC (cold case) and 40ºC (hot case) but an uncontrollable gradient between the boom upper and lower mounting feet attachments occurred during each test run. This anomaly was undesirable but did not invalidate results because, (1) the boom has an isolated design that reduced the interface temperature gradient effect and (2) analytical correlation was attained by using the measured interface temperatures. Figure 1 shows the test configuration of the boom prior to insertion into the chamber. (Picture provided by SSL, Berkeley). Figure 2 depicts the TSS geometry model of the test configuration used for analytical model correlation.

<u>Model Changes to Achieve Correlation</u>

- Conduction couplings across bolted joints in the deployment housing were multiplied by a factor of 1.25. Conservative assumptions were originally made with regard to contact areas.
- Conduction within the boom graphite-epoxy tubes was increased by a factor of 1.5. The value used in the original computations (6 W/m-ºK) is apparently on the low end of the possible conductivity range for the material lay-up.
- Conduction couplings for the SWEA and Magnetometer mass model interfaces were multiplied by a factor of 2.5 to attain temperature and heater power correlation. However, these interfaces were not sufficiently flight-like to assume this factor for flight instrument thermal predictions.
- Conduction couplings across the boom mount interface were multiplied by a factor of 2.5. This reduced the overall thermal resistance from the specified 20ºC/W to 8ºC/W. Subsequent interface redesign has restored the boom thermal isolation to an acceptable value of 17ºC/W. This value is reflected in the updated model used for flight predictions.
- The MLI effective emittance (E*) was determined to be 0.01 for the Housing and 0.005 for the Tube area. Pre-test predictions were being run with E* = 0.01 for hot cases and 0.03 for cold cases.
- The highly effective blankets will bias the design toward the hot end of the predicted temperature range. Therefore, a lower a/e for the coating (tapes) on the Bobbin Cover (25 in2) window area should be considered. This issue will be addressed in the analysis section.

FIGURE 1: Picture showing Boom TB Test Configuration

FIGURE 2: TSS Geometry Model of Boom TB Test Setup



Summary of Results

Results show close correlation for most sensors after implementing the model changes listed in the previous section. Test temperatures versus thermal analytical model predictions are delineated in Appendix A, Table A-1 and Table A-2. A summary is provided in TABLE 1 below: (Test data was provided by SSL, Berkeley)

TABLE 1: Summary Comparison of Test vs. Analysis Results

Location	Cold Case (ºC)		Hot Case (ºC)	
	Test	Analysis	Test	Analysis
Bobbin Cover	7.4	7.6	35.5	34.1
Outer Bobbin	-5.8	-7.6	21.2	15.7
STE Pre-Amp MM	-12.1	-12.8	14.2	9.2
Pinpuller	-14.1	-11.2	9.9	11.3
Lower Mount Ring	-11.0	-13.0	15.0	9.3
Boom End	-25.3	-20.9	-1.7	-0.2

ANALYTICAL MODEL DEVELOPMENT

The current IMPACT Boom thermal model was developed at Orbital Sciences Corporation by upgrading the reduced model of the boom provided to APL at CDR by Swales Aerospace. Detailed models of the instruments had also been produced but these were not usable because the format was in a thermal program that could not be converted to TSS and SINDA. These are the programs used at Orbital and required by APL for compatibility with spacecraft models. The reduced model had been developed in the required format so no conversion was necessary. Upgrades included detailed modeling of the housing, deployment components, and graphite-epoxy tubes. Boom instrument models were maintained as reduced models. Analysis using the improved thermal model resulted in the following design changes:

- A small (25 sq. in.) solar-input window in the thermal blanket was added on the Bobbin Cover to maintain deployment component temperatures above –23ºC. Based on analysis results, the pre-test coatings for the window area were specified as follows:
    a) Boom on the AHEAD spacecraft – 18.75 in2 of Germanium Black Kapton tape and 6.25 in2 of Silver-Teflon tape.
    b) Boom on the BEHIND spacecraft – 25 in2 of Ger. Blk. Kapton tape.
- Allied with the above was a change to black anodize for several internal surfaces of the bobbin to enhance heat transfer from the cover to the Pinpuller.
- The pre-deployment warm-up heater location was finalized to be located on the pinpuller without the need to provide a proposed heat strap to the Outer Bobbin.
- The mounting of the STE-U Pre-Amp on the deployment housing was changed to a thermally coupled design rather than an isolated design to improve its thermal control.
- As a result of the above change, the STE-U sunshield, which is mounted on the Pre-Amp, was changed from a coupled to isolated design. In addition, MLI with Silver-Teflon outer surface was added on the top of the sunshield with the underside and bracket changed to black paint from VDA tape. The objective is for the sunshield to run as cold as possible to reduce thermal backload on the STE-U instrument.
- MLI specified at CDR for the sunside of the STE-U and STE-D instruments was deleted in favor of Silver-Teflon tape. The STE-U protrudes slightly beyond the Sunshade (projected area = 0.0642 in2) that results in an extremely small acceptable input. The STE-D does not receive direct sun during the operating mode.

ANALYSIS BASIS

<u>IMPACT Boom Thermal Interface Requirements</u>

Interface requirements are specified in Reference (1), ICD 7381-9012 (Section 5), as follows:

- The boom is required to have a thermally isolated mounting from the STEREO spacecraft. Interface thermal resistance was specified to be greater than 20ºC/W, but by a recent waiver has been reduced to 17ºC/W.
- The boom thermal design is required to meet the STEREO solar flux variation as follows:
  a) AHEAD S/C – 1308.3 W/m2 to 1653.8 W/m2 (0.844 to 1.067 W/in2)
  b) BEHIND S/C – 1152.3 W/m2 to 1414.2 W/m2 (0.743 to 0.912 W/in2)
- IMPACT mounting temperature limits are specified at –13ºC to +45ºC (operational) and –18ºC to +50ºC for survival. However, analysis by APL indicates operational limits are expected to be held to 0ºC to +40ºC for the boom interface.
- Additional Thermal Interface: A pinpuller warmup heater with 5 watts of input capability will be activated up to 30 minutes prior to boom deployment. The circuit is thermostat controlled to 0ºC (On)/10ºC (Off). The boom design should be capable of deployment without using this heater in case of heater or thermostat failure.

Boom and Instrument Temperature Requirements

Boom Pre-deployment: Housing and deployment components temperature range must not exceed –23ºC to +23ºC without use of the pinpuller warmup heater. Qualification testing was conducted from –33ºC to +40ºC.

Boom Post-deployment: Housing temperature range must not exceed STE-U pre-amp temperature limits because of the coupled design.

STE-U Pre-Amp: Operational and survival limits are –30ºC to +30ºC. Control is provided by the deployment housing temperature.

STE-U and STE-D: The requirement is for these instruments to be as cold as possible. Limits are –140ºC to +40ºC with detector temperatures maintained below –30ºC for proper performance.

Magnetometer: Operational and survival limits are –30ºC to +40ºC. A PWM controlled heater with one-watt maximum capability is incorporated in the design.

SWEA: Operational limits are –25ºC to +30ºC and survival limits are –30ºC to +50ºC. The design includes an operational heater with capability of 1.12 watts at 30.5 volts and a survival heater of 2.27 watts at 25 volts.

ANALYSIS ASSUMPTIONS

The IMPACT Boom TSS and SINDA models were developed based on the following assumptions:

1. All bolted joints are assumed to be dry. Conservative estimates were used in the computations based on bolt size and clamping pressure.
2. Thermal blanket effective emittance (E*) was originally assumed to be 0.01 for hot

cases and 0.03 for cold cases. The thermal balance test results indicated that the engineering model blankets performed extremely well; housing blanket E*= 0.01 and the graphite-epoxy tube blanket E*= 0.005. The flight blankets are expected to be virtually identical and should provide similar performance. The updated analysis assumes an E*=0.01 for all boom blankets (slightly conservative assumption). The boom flight blankets will be validated during spacecraft system level TV test.

3. The conductivity of the T300/RS36 graphite-epoxy tube material was assumed to be 6 W/m-ºK (0.1524 W/in-ºC) prior to the thermal balance test. Correlation of the test data indicated that the conductivity should be increased by 50% to 9 W/m-ºK. The thermal model was updated to use this value for flight predictions.
4. Conductivity (k) values used in the updated thermal analysis:

	Watts/in-ºC
• T300/RS36 graphite-epoxy tube material	0.228
• 6061-T6 Aluminum (housing, structural elements)	4.240
• Polyimide Epoxy-glass (isolator material)	0.007
• 303 Stainless Steel (mounting bolts)	0.413
• Copper drawn wire (electrical conductors)	7.3
• PEEK (material used for Magnetometer tray)	0.2339

5. Solar absorptance and thermal emittance values for the boom and instrument surfaces used in the TSS geometry model are per the GSFC optical property list for the STEREO program.
6. The thermal isolation design for the mounting interfaces of the STE-U and STE-D is unique and critical to proper performance. The total conductivity of the interface for both instruments as provided by SSL, Berkeley is k = 0.0048 W/ºK.

UPDATED FLIGHT PREDICTIONS

The analysis uses TSS to generate radiation exchange factors and solar flux inputs for boom surfaces, which are then included in the SINDA model runs. Figures 3, 4, and 5 show the Boom geometry models (Stowed and Deployed) for the AHEAD spacecraft. Figures 5, 6, and 7 show the same for the Boom on the BEHIND spacecraft. Model changes based on the correlated test data have been incorporated. In addition, the a/e ratio for the window area on the Bobbin Cover has been reduced. The solar input can be lowered because of the highly effective thermal blankets revealed during TB test. The revised coating arrangement reflected in the analysis is as follows:

- Boom on the AHEAD S/C: 12.75 in2 of Ger. Blk. Kapton tape and 12.25 in2 of Silver Teflon tape. (Total Area = 5 x 5 inches, Silver Teflon center = 3.5 x 3.5 inches)
- Boom on the BEHIND S/C: 16.0 in2 of Ger. Blk. Kapton tape and 9.0 in2 of Silver Teflon tape. (Total Area = 5 x 5 inches, Silver Teflon center = 3.0 x 3.0 inches)

The coatings key for the TSS geometry models is provided in Table 2. Temperature predictions are delineated in Tables 3 and 4.

TABLE 2: Coatings Key for TSS Geometry Models

Surface Type	Color	Location on Boom
Germ. Black Kapton tape	Orange	Bobbin Cover Window
Silver Teflon tape	Turquoise	Bobbin Cover Window
Silver Teflon tape	Turquoise	STE-U and STE-D; sunside surfaces
5-mil Silver Teflon MLI OL	Green	Bobbin Cover MLI
5-mil Silver Teflon MLI OL	Green	Magnetometer and STE-U Sunshield MLI
Germ. Blk. Kapton MLI OL	Orange	Housing, Fixed Tube and SWEA MLI
Black Paint- Z307	Black	STE-U and STE-D; Anti-sunside surfaces
Graphite-Epoxy material	Blue	Deployable Tubes
PEEK material	Blue	Magnetometer Tray
VDG coating	Gold	SWEA Grid

FIGURE 3: **TSS Model Showing External Surfaces for AHEAD Stowed Boom**
TSS geometry file: IB_Asto.tssgm
TSS RADK file: IB_Asto.rk
Heat Rates (cold case): IB_AstoBC.hr
Heat Rates (hot case): IB_AstoBH.hr

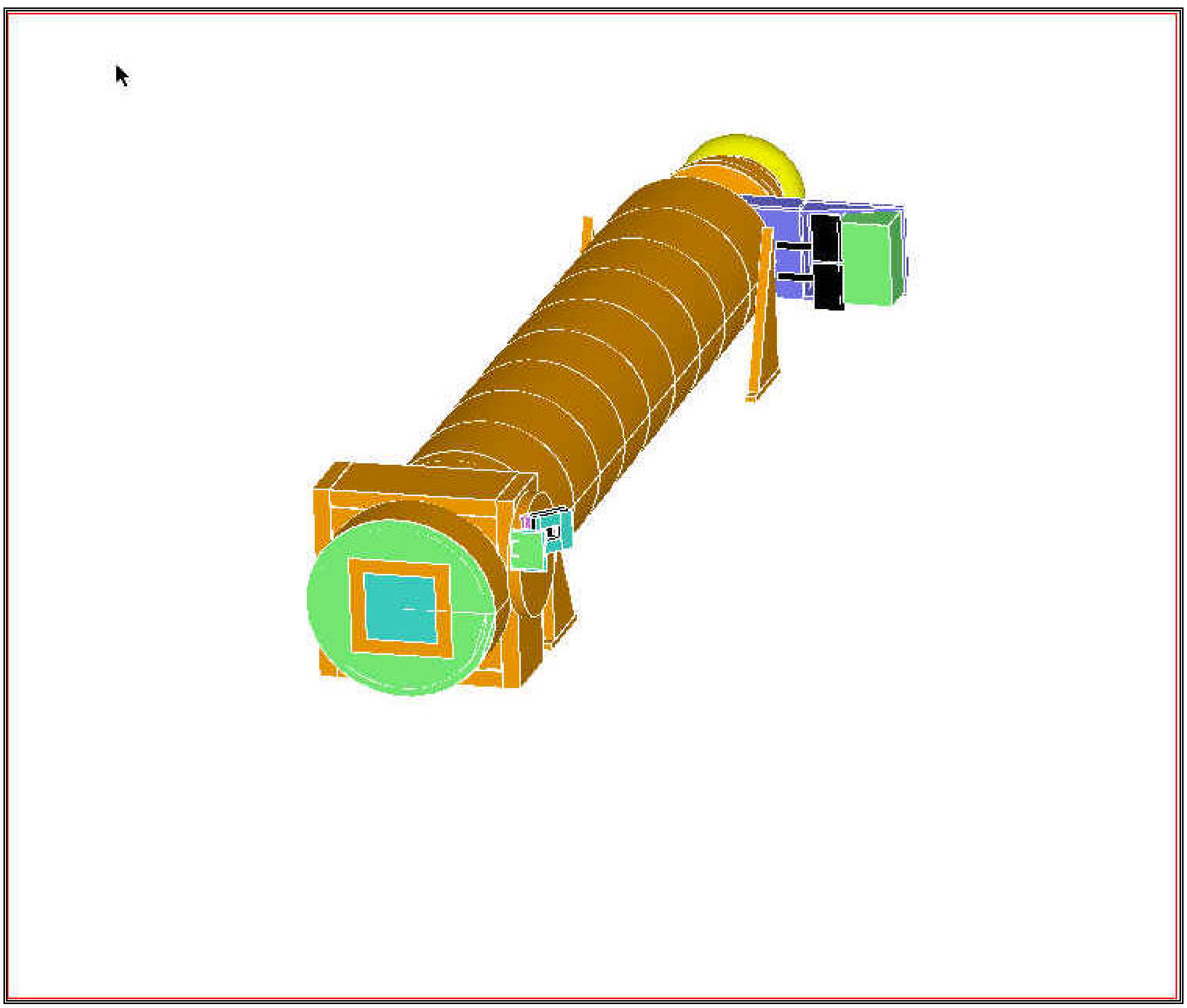


FIGURE 3: **TSS Model Showing External Surfaces for AHEAD Stowed Boom**
TSS geometry file: IB_Asto.tssgm
TSS RADK file: IB_Asto.rk
Heat Rates (cold case): IB_AstoBC.hr
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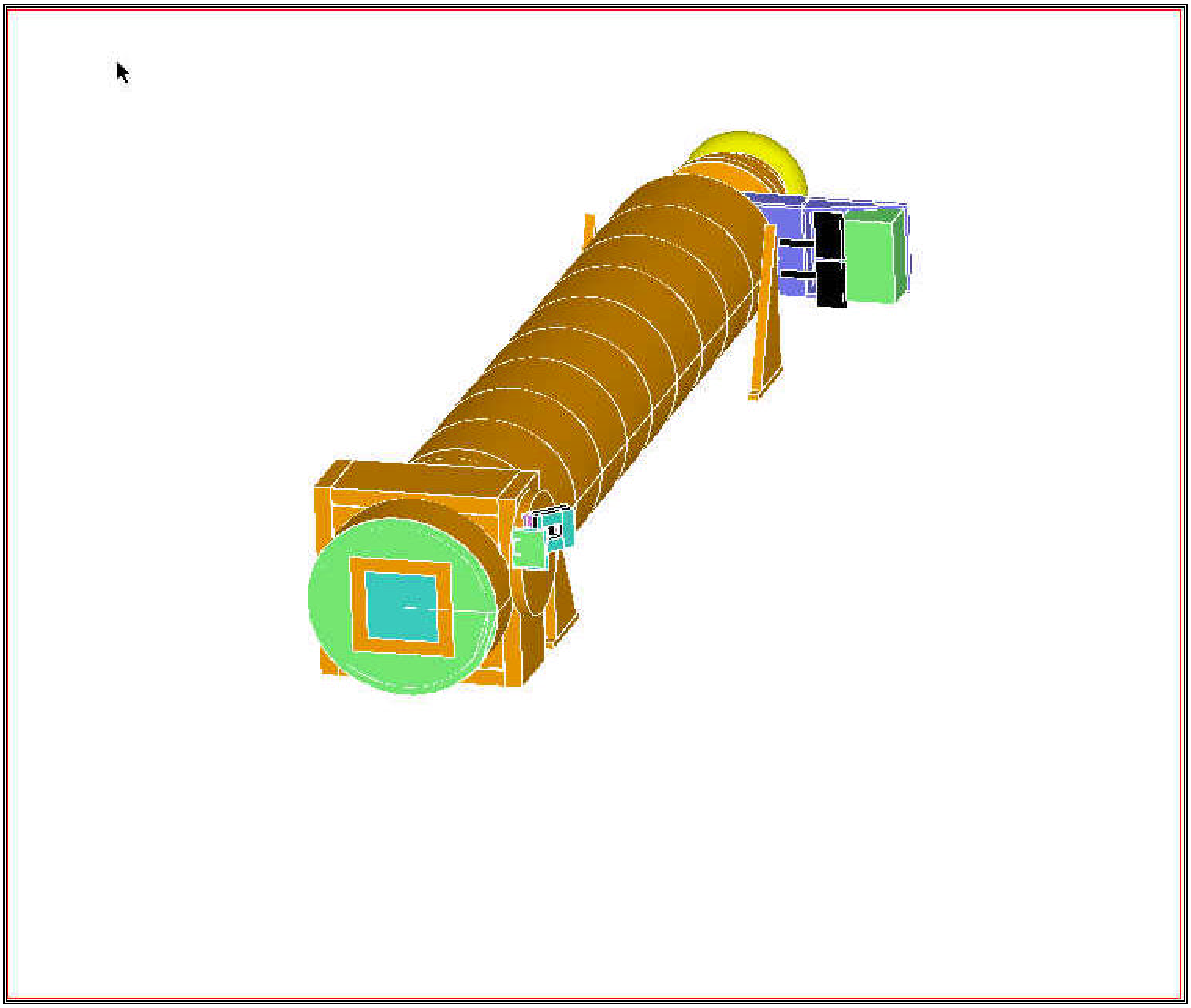

FIGURE 4: Anti-Sun View of TSS Model for AHEAD Stowed Boom

TSS geometry file: IB_Asto.tssgm
TSS RADK file: IB_Asto.rk
Heat Rates (cold case): IB_AstoBC.hr
Heat Rates (hot case): IB_AstoBH.hr

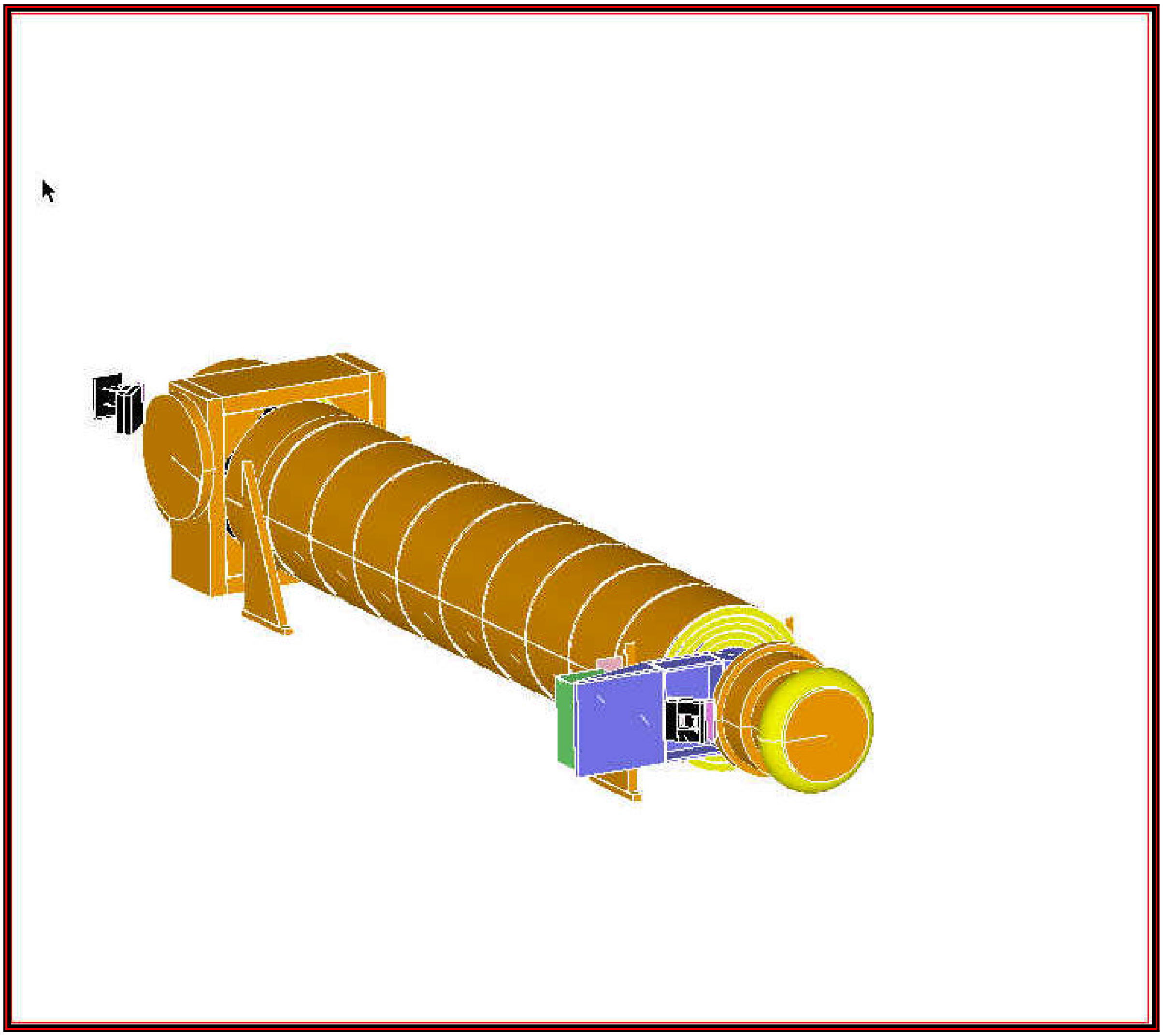

FIGURE 5: TSS Model Showing External Surfaces for AHEAD Deployed Boom
TSS geometry file: IB_Adpl.tssgm
TSS RADK files: IB_AdplB.rk (BOL) and IB_AdplE.rk (EOL)
Cold Case Heat Rates: IB_AdplBC.hr (BOL and Min. Sun)
Hot Case Heat Rates: IB_AdplBH.hr (EOL and Max Sun)

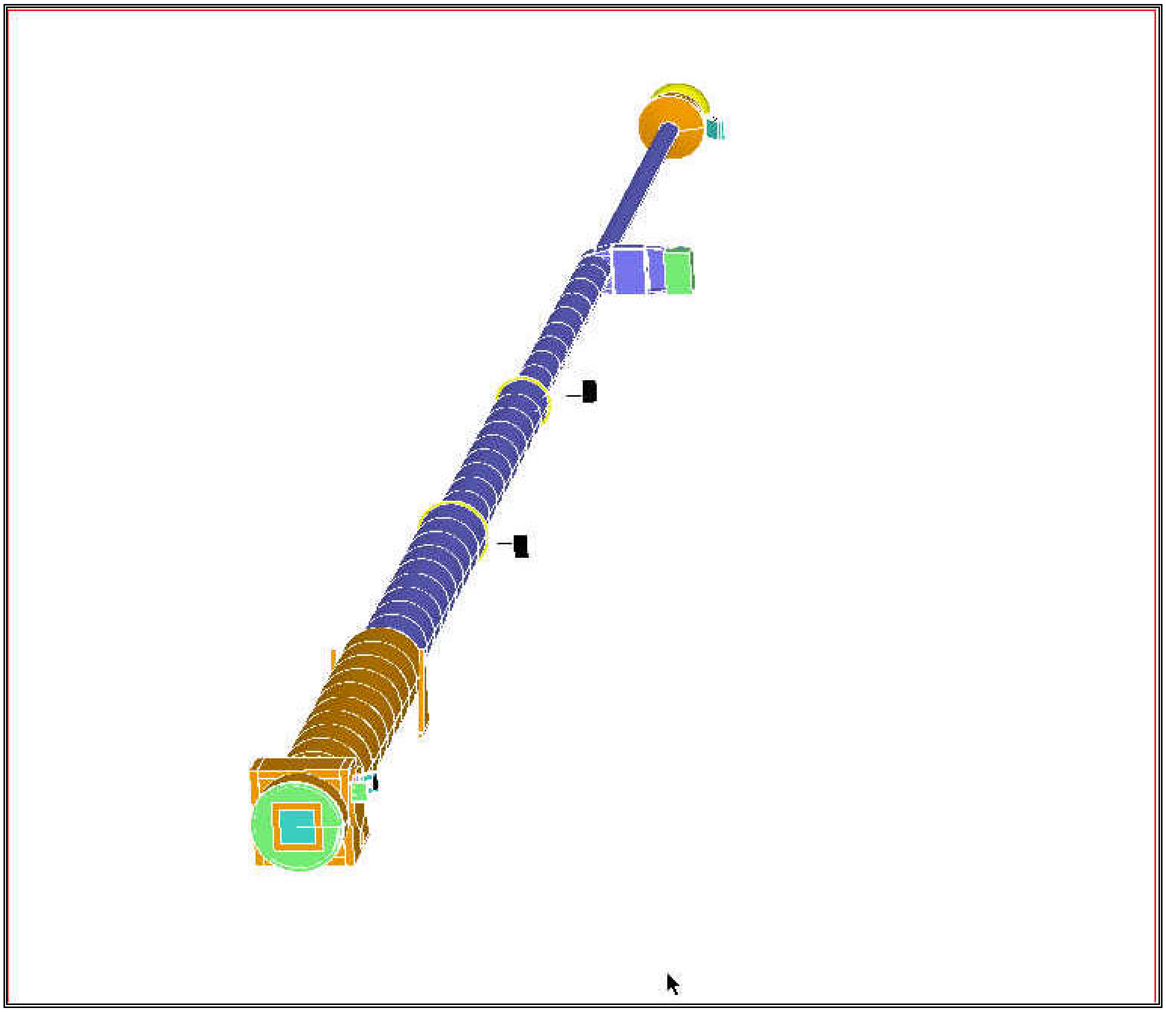

FIGURE 6: TSS Model Showing External Surfaces for BEHIND Stowed Boom

TSS geometry file: IB_Bsto.tssgm

TSS RADK file: IB_Bsto.rk

Heat Rates (cold case): IB_BstoBC.hr

Heat Rates (hot case): IB_BstoBH.hr

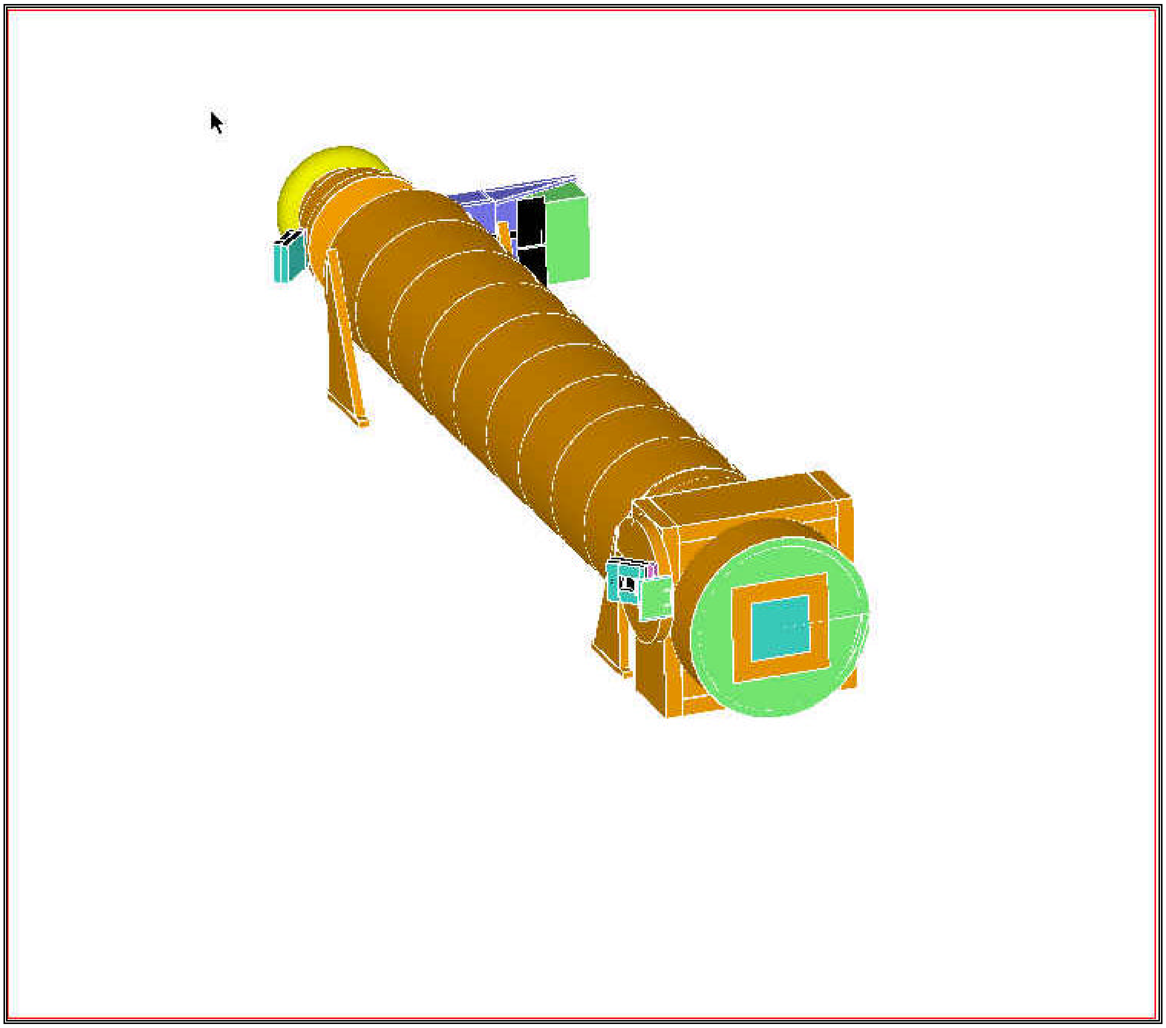

FIGURE 7: **Anti-Sun View of TSS Model for BEHIND Stowed Boom**
TSS geometry file: IB_Bsto.tssgm
TSS RADK file: IB_Bsto.rk
Heat Rates (cold case): IB_BstoBC.hr
Heat Rates (hot case): IB_BstoBH.hr

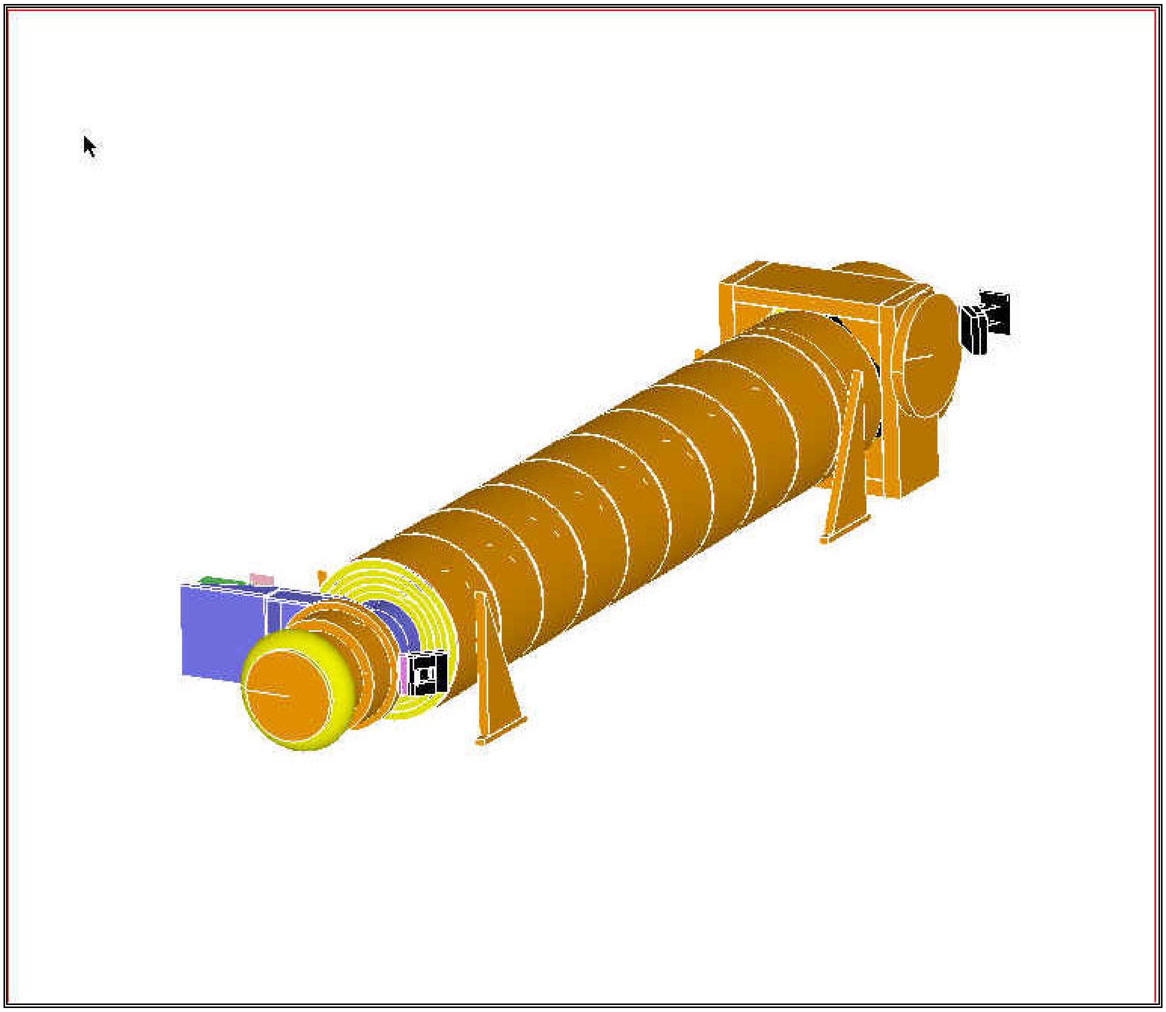

FIGURE 8: TSS Model Showing External Surfaces for BEHIND Deployed Boom

TSS geometry file: IB_Bdpl.tssgm
TSS RADK files: IB_BdplB.rk (BOL) and IB_BdplE.rk (EOL)
Cold Case Heat Rates: IB_BdplBC.hr (BOL and Min. Sun)
Hot Case Heat Rates: IB_BdplBH.hr (EOL and Max Sun)

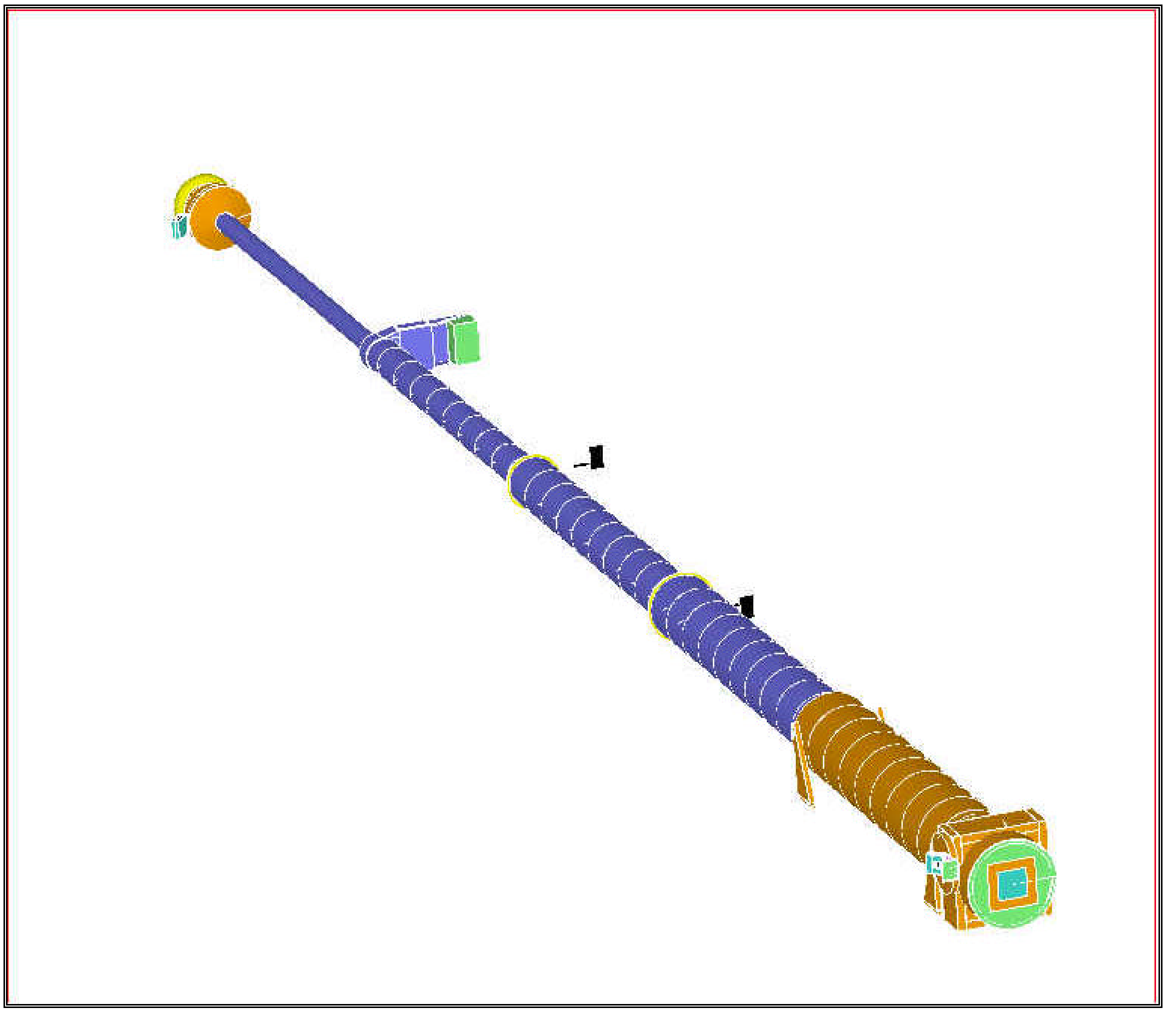

TABLE 3: IMPACT Boom Stowed Model Flight Predictions

Location	Worst Cold Cases (ºC)		Worst Hot Cases (ºC)	
	AHEAD	BEHIND	AHEAD	BEHIND
Bobbin Cover (10011)	-2.4	-3.9	17.6	14.7
Outer Bobbin (1031)	-12.1	-13.3	7.0	4.6
Pinpuller (1035)	-14.6	-15.7	4.3	2.1
L. Mt. Ring (1020)	-15.8	-16.8	3.0	1.0
Boom Center (1025)	-28.2	-28.5	-11.7	-12.9
Boom End (1030)	-13.2	-13.9	7.7	5.9
STE Pre-Amp (6302)	-15.9	-17.0	2.7	0.5
STE-U (6301)	-81.5	-82.1	-72.7	-74.0
Mag. Tray (6101)	-56.4	-53.0	-43.4	-40.5
Magnetometer (6102)	-18.5	-15.9	-7.1	-4.8
SWEA (6402)	-14.1	-15.7	-8.4	-10.5
STE-D (6201)	-79.4	-92.0	-73.2	-88.3
Spacecraft I/F	0.0	0.0	40.0	40.0

TABLE 4: IMPACT Boom Deployed Model Flight Predictions

Location	Cold BOL Cases (ºC)		Hot EOL Cases (ºC)	
	AHEAD	BEHIND	AHEAD	BEHIND
Bobbin Cover (10011)	-6.1	-8.5	40.9	29.2
Outer Bobbin (1031)	-16.4	-18.8	22.9	13.7
Pinpuller (1035)	-19.2	-21.4	18.2	9.5
L. Mt. Ring (1020)	-20.8	-22.8	15.5	7.3
Boom Center (1025)	-50.0	-51.6	-21.3	-26.4
Boom End (1030)	-68.5	-69.6	-48.5	-50.2
170 mm Tube (2005)	-178.5	-178.3	-171.4	-173.4
130 mm Tube (3005)	-187.7	-188.6	-184.2	-185.3
90 mm Tube (4005)	-187.2	-186.6	-184.1	-183.8
50 mm Tube (5000)	-144.3	-142.4	-141.6	-139.4
STE Pre-Amp (6302)	-20.3	-22.5	16.5	8.0
STE-U (6301)	-85.2	-85.0	-70.6	-72.2
Mag. Tray (6101)	-112.9	-101.4	-101.9	-91.8
Magnetometer (6102)	-26.9	-17.8	-14.4	-6.9
SWEA (6402)	-13.1	-12.6	-12.6	-11.9
STE-D (6201)	-96.9	-96.9	-95.5	-95.2
Spacecraft I/F	0.0	0.0	40.0	40.0

CONCLUSIONS AND RECOMMENDATIONS

1. Boom and Instrument temperatures are predicted to meet all requirements as specified for the STEREO mission.
2. The specified taping configuration for the Bobbin Cover window is predicted to provide acceptable deployment temperatures for the Boom mounted on the AHEAD and BEHIND spacecraft. In addition, results indicate that the Housing temperature controls the STE-U Pre-Amp at acceptable levels for BOL and EOL conditions.
3. The boom flight thermal blankets will be validated by inspection and during spacecraft thermal vacuum test. If they are determined to be significantly less efficient than the engineering model blankets (E*=0.01), the taping pattern on the Bobbin Cover window will be adjusted accordingly.
4. The Magnetometer heater adequacy and thermal coupling (0.005 W/ºC) to the Magnetometer Tray will be validated during spacecraft thermal vacuum test.
5. The SWEA and STE thermal interfaces will be verified during instrument thermal balance testing in April 04 and validated during spacecraft system level test. SWEA thermal blankets and heater power adequacy will also be verified. The following conductive interfaces will be determined by future tests:
   - SWEA Pedestal Base to 50 mm tube: Computed total coupling = 0.012 W/ºC.
   - STE–U to Pre-Amp via isolator: Computed total coupling = 0.0048 W/ºC.
   - STE–D to SWEA Pedestal Base via isolator: Computed coupling = 0.0048 W/ºC.

Appendix A – Detailed Test Temperatures vs. Analysis Results

TABLE A-1: Analysis vs. TB Cold Case Stabilized Temperatures at 9/11/03 03:00
(Thermistors conversion is best fit from online data.)

Sensor #	Location On Boom	TB Test Results (ºC)	TM Analysis Results (ºC)	Delta T (ºC)
TC4	Bobbin Cover (Window Area)	7.4+/-0.1	7.6	0.2
TM1	Bobbin Cover (Outer Edge)	6.9	3.99	2.9
TM3	Outer Bobbin (Between C/L & Edge)	-5.8	-7.6	1.8
TC5 & TM2	Pinpuller (Center)	-14.1 +/- 0.1 -7.9 (Bad data)	-11.2	2.9
TM4	Housing (STE-U Ahead S/C)	-8.5	(avg.) –11.6	3.1
TM5	Housing (STE-U Behind S/C)	-7.6	(avg.) –11.6	4.0
TM6	Housing Connector Area	-10.3		
TM8	Lower Mount Ring (Right Footpad)	-11.0	-13.0	2.0
TC6	Fixed Boom Center	-41.7 + 0/- 0.4	-34.2	7.5 *
TC7	Fixed Boom End	-25.3+/- 0.2	-20.9	4.4
TC11	Cable (10 in. from Housing)	-79.6 +/- 0.1		
TM7	STE-U Pre-Amp Mass Model	-12.1	-12.8	0.7
TM9	SWEA Mass Model	-21.2	-16.5	4.7
TC8	SWEA / Boom interface	-36.6 + 0/- 0.4		
TM10	Magnetometer Mass Model	-24	-26.7	2.7
TC9	Magnetometer / Boom interface	-138 +/-0.5		
TM11	Magnetometer Tray Mid-span	-71 (off chart)	(avg.) -78	7.0
TM12	Lower Right Foot-pad Mid-span	-11.8	11.7	0.1
TC10	End Cold Plate	-145 +/- 3	-145	-
Sensor #	Chamber and I/F Locations			
TC3	Boom Mounting Plate Control (–Z)	0.0 +/- 1	0.0	-
TC12	Boom Mounting Plate (+Z)	22 +/- 3	22.0	-
TC1	Chamber Shroud Control (Upper)	-144 +/- 3		
TC14	Chamber Shroud (Upper)	-165 +/- 3	Avg. = -160	-
TC15	Chamber Shroud (Upper)	-163 +/- 4		
TC2	Chamber Shroud Control (Lower)	-87 +/- 2	-87	-
TC13	Chamber Shroud (Lower)	Disconnect	Disconnect	

Test heaters measured inputs; used in correlation analysis run:
Bobbin Cover (Cold Case Simulated Sun) = 8.0 Watts
SWEA Heater = 4.29 Watts
Magnetometer Heater = 0.72 Watts

TABLE A-2: Analysis vs. TB Hot Case Stabilized Temperatures at 9/13/03 08:00
(Thermistors conversion is best fit from online data.)

Sensor #	**Location On Boom**	**TB Test Results (ºC)**	**TM Analysis Results (ºC)**	**Delta T (ºC)**
TC4	Bobbin Cover (Window Area)	35.5 +/- 0.2	34.1	1.4
TM1	Bobbin Cover (Outer Edge)	35.4	29.5	5.9
TM3	Outer Bobbin (Between C/L & Edge)	21.2	15.7	5.5
TC5 & TM2	Pinpuller (Center)	9.9 +/- 0.2 18.6 (Bad data)	11.3	1.4
TM4	Housing (STE-U Ahead S/C)	18.1	(avg.) 10.8	7.3*
TM5	Housing (STE-U Behind S/C)	18.8	(avg.) 10.8	8.0*
TM6	Housing Connector Area	16.0		
TM8	Lower Mount Ring (Right Footpad)	15.0	9.3	5.7
TC6	Fixed Boom Center	-11.8 +/- 0.2	-11.6	0.2
TC7	Fixed Boom End	-1.7 +/- 0.2	-0.2	1.5
TC11	Cable (10 in. from Housing)	-65 +/- 0.5		
TM7	STE-U Pre-Amp Mass Model	14.2	9.2	5.0
TM9	SWEA Mass Model	22.3	23.3	1.0
TC8	SWEA / Boom interface	-1.0 +/- 0.2		
TM10	Magnetometer Mass Model	22.6	18.9	3.7
TC9	Magnetometer / Boom interface	-133 +/- 0.5		
TM11	Magnetometer Tray Mid-span	-49	(avg.) -62.2	13.2*
TM12	Lower Right Foot-pad Mid-span	14.2	11.3	2.9
TC10	End Cold Plate	-136 +/- 3	-136	-
Sensor #	Chamber and I/F Locations			
TC3	Boom Mounting Plate Control (–Z)	30 +/- 1	30	-
TC12	Boom Mounting Plate (+Z)	57 +/- 2	57	-
TC1	Chamber Shroud Control (Upper)	-142 +/- 3		
TC14	Chamber Shroud (Upper)	-167 +/- 3	Avg. = -160	-
TC15	Chamber Shroud (Upper)	-167 +/- 4		
TC2	Chamber Shroud Control (Lower)	-84 +/- 3	-87	-
TC13	Chamber Shroud (Lower)	Disconnect	Disconnect	

Test heaters measured inputs; used in correlation analysis run:
Bobbin Cover (Hot Case Simulated Sun) = 11.0 Watts
SWEA Heater = 7.0 Watts
Magnetometer Heater = 1.25 Watts

APPENDIX B

TABLE B-1: Identification of Correlated IMPACT Boom SINDA Models and TSS Include Files (Located in Folders AL and AL_Corr)

Analysis Run Description	SINDA Input	Include RadK	Include Heat Rates
A stowed BOL / Min Solar	CB_AsBC1.inp	IB_AstoB.rk	IB_AstoBC.hr
B stowed BOL / Min Solar	CB_BsBC1.inp	IB_BstoB.rk	IB_BstoBC.hr
A stowed BOL / Max Solar	CB_AsBH1.inp	IB_AstoB.rk	IB_AstoBH.hr
B stowed BOL / Max Solar	CB_BsBH1.inp	IB_BstoB.rk	IB_BstoBH.hr
A deployed BOL / Min Solar	CB_AdBC1.inp	IB_AdplB.rk	IB_AdplBC.hr
B deployed BOL / Min Solar	CB_BdBC1.inp	IB_BdplB.rk	IB_BdplBC.hr
A deployed EOL / Max Solar	CB_AdEH1.inp	IB_AdplE.rk	IB_AdplEH.hr
B deployed EOL / Max Solar	CB_AdEH1.inp	IB_BdplE.rk	IB_BdplEH.hr

TSS Property Files: IB_BOL_Opt_Prop and IB_EOL_Opt_Prop
TSS geometry Files: Previously noted in Figures 3 through 8