STEREO/IMPACT BOOM THERMAL BALANCE

TEST PLAN

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Written By: _________________
A. Seivold OSC

Approved By: _____________________
J. McCauley UCB/SSL

Approved By: __________________
D. Curtis UCB/SSL

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1. TEST PURPOSE

To verify the thermal design of the IMPACT Boom pre-deployment configuration:

a) Determine the adequacy of the thermal blankets and measure the effective emittance.
b) Establish the adequacy of the Bobbin Cover MLI window surface property and predicted absorbed solar energy to maintain pre-deployment temperature levels.
c) Establish the adequacy of the thermal design to provide acceptable Instrument interface temperatures using dummy thermal/mass Instrument models.
d) Use the thermal balance data to verify and modify the Boom thermal math model.
e) Determine the adequacy of the pre-deployment heater to raise pinpuller and housing temperatures to specified temperature levels in the specified time period.

2. APPROACH

Establish the thermal balance of the Boom in a test chamber environment similar to the expected flight environment and use the resulting data to verify and modify the thermal math model as required:

a) Establish Boom equilibrium in at least one hot and one cold environmental condition.
   - Hot case is based on BOL properties with maximum solar heating after 60 days and reaching the AHEAD spacecraft heliocentric orbit when deployed.
   - Cold case is based on BOL properties with minimum solar heating after 90 days and reaching the BEHIND spacecraft heliocentric orbit when deployed.
   - Run transient case using the pinpuller warm-up heater.
b) Optional Case 1: Establish equilibrium for the nominal near Earth deployment case.
c) Optional Case 2: Break chamber vacuum and modify the Boom blanket by placing an MLI test blanket over the Bobbin Cover window area. Pump-down chamber and establish equilibrium to directly measure thermal blanket effective emittance.

3. TEST ARTICLE DESCRIPTION

a) The Protoflight Boom is utilized for this test with dummy instrument mass models.
b) The Boom MLI blanket is an engineering model version constructed to be similar to the final flight blanket but without the identical outer layer. External surface thermal emittance of the test blanket is similar to the specified flight surface properties. **NOTE:** Flight blanket adequacy will be validated during the spacecraft test program.
c) Boom interfaces will utilize flight or flight-like materials to provide proper heat flow and temperature boundary conditions.
d) Operational and test cables are wrapped with an MLI blanket to minimize these heat losses and include a temperature sensor at the expected coldest spot near the center of the cable.
e) The Bobbin Cover has a film heater or series of heaters with a 15-watt minimum capability covering at least 12 square inches of the 25 square inch exposed window area. This heater will simulate solar input to the window and will be mounted on the

inside surface of the cover. The flight cover will be replaced with an identical test cover for this test).

f) The Bobbin Cover external surface has a surface emittance property approximately equivalent to the flight thermal design which is specified as follows:
   - AHEAD S/C – Ger Blk Kapton Tape (18.75 in2) with e = 0.81 and a center area of Ag Teflon Tape (6.25 in2) with e = 0.77.
   - BEHIND S/C – Ger Blk Kapton Tape (25.0 in2) with e = 0.81. (Used for testing)

g) The flight 5-watt warm-up heater is mounted on the pinpuller and is controlled by a mechanical thermostat with set points of 0 C (closed) to 10 C (open).

h) The STE-U Pre-Amp is simulated with an aluminum plate of equivalent dimensions except for its thickness. No test heater is required for the Pre-Amp because the flight unit dissipation is only 0.1 watt and the Housing blanket encloses it.

i) The SWEA is simulated by an aluminum mass mockup that is totally insulated with an MLI blanket. A test heater with approximately a 5-watt maximum capability is mounted on the model to control it at predicted SWEA temperatures.

j) The Magnetometer is simulated by an aluminum mass mockup that is totally insulated with an MLI blanket. A test heater with approximately a 2-watt maximum capability is mounted on the model to control it at predicted Magnetometer temperatures.

4. THERMAL INSTRUMENTATION

The Impact Boom and Boom / Chamber interfaces are instrumented with thermocouples or thermistors to obtain temperature data throughout the test. Locations of thermal sensors are designated in Table 1. Thermocouples are secured to the surface to be measured with Aluminum tape. Thermistors will be secured with epoxy and covered with a low e tape after the epoxy has dried.

5. CHAMBER AND BOOM TEMPERATURE CONTROL

For thermal balance testing, the chamber shrouds are controlled with LN2 to provide a sink temperature that simulates deep space. Heaters are mounted on the shrouds for chamber warm-up. Designation of cooling loops and heater locations are provided in the chamber operating procedure. Heaters located on the Boom mounting plate and on the test article are specified in Table 2.

6. SUMMARY OF BOOM TEST CONFIGURATION

a) Bobbin Cover 25 in2 Window – Heaters cover at least 12 in2 with at least 15 watts capability. The window area is taped with Germanium Black Kapton tape or a material with an equivalent thermal emittance property (e ~ 0.8).

b) The MLI around the window area will be taped securely to the Cover (no gaps).

c) A minimum 5 layer MLI blanket is attached to the back of the STE-U Pre-amp mass model between the mass model and the Boom housing.

d) The standoffs between the Boom housing and STE-U Pre-amp mass model are made of a conductive material such as Aluminum.

e) The Boom MLI blanket will totally cover the fixed Boom except for a keep-out edge area at the opening for the deployable sections. Overlaps will be taped.

f) The Boom mounting brackets and thermal isolators will be totally insulated and taped to the Boom blanket. All gaps will be closed and securely taped in position.
g) The Instrument mass models (Magnetometer and SWEA) are equipped with heaters and temperature sensors and fully enclosed in an MLI blanket.
h) Mass model attachments to the Boom are similar to the flight configuration.
i) A cable harness guard heater may be utilized for this test but this is optional. The heat loss at this interface can be determined if the harness temperature is measured, the entire cable is insulated, and conductive characteristics (# of wires, material, and wire diameters) are provided for the post-test analysis.
j) The test cable harness will be fully insulated with at least 20 layers of MLI and taped to housing blanket flaps. All gaps will be closed and overlaps taped in position.

7. TEST PREPS; SETUP AND CHECKOUT SEQUENCE

a) Install and checkout heaters.
b) Install and checkout temperature sensors.
c) Tape the STE-U Pre-amp model thermal blanket on the side facing the Boom and attach the model to the Boom as designated for the flight configuration.
d) Install solar window area tape that provides an equivalent emittance to the designated flight configuration for the BEHIND Boom (Germanium Black Kapton and Silver Teflon tape).
e) Install Boom thermal blankets verifying that all overlaps are taped and gaps are closed. Use single or double adhesive backed Kapton tape as required.
f) Install SWEA and Magnetometer thermal blankets.
g) Install Boom in the chamber and attach to the chamber mounting plate.
h) Wrap cable harness with MLI and tape to the connector blanket boot.
i) Verify mounting plate and other chamber hardware MLI are properly positioned.
j) Close chamber and prepare for pumpdown.

8. TEST PROCEDURE

Boom thermal balance test conditions are specified Table 3. Equilibrium criteria for this test shall be defined as less than 0.25°C temperature change per hour for a 3-hour period.

a) Pumpdown chamber per chamber operating procedure.
b) Start LN^2 to chamber shrouds and establish at hard vacuum conditions.
c) Allow chamber temperatures, Boom baseplate, and the Boom to cool to predicted cold case temperature levels.
d) Enable Baseplate and control at 0.0°C ± 2 °C as specified in Table 3 for TB Case 1.
e) Enable Instrument mass model heaters and maintain Boom boundary conditions as specified in Table 3 for TB Case 1.
f) Set Bobbin Cover window heater at the predicted solar simulation input of 8.0 watts as specified for TB Case 1.
g) Allow Pinpuller to stabilize without enabling the Pinpuller warm-up heater.
h) Allow temperatures to stabilize and reach equilibrium as defined in the criteria above.
i) When equilibrium for TB Case 1 is attained, record all temperature and heater data.

j) Turn-On Pinpuller warm-up heater and monitor transition to TB Case 2. Maintain Boom boundary conditions as specified in Table 3.
k) Allow temperatures to stabilize and reach equilibrium as defined in the criteria above.
l) When equilibrium for TB Case 2 is attained, record all temperature and heater data.
m) Raise Baseplate temperature and control at 40.0°C ± 2 °C as specified in Table 3 for TB Case 3.
n) Reset Instrument mass model heaters and maintain Boom boundary conditions as specified in Table 3 for TB Case 3.
o) Set Bobbin Cover window heater at the predicted solar simulation input of 11.0 watts as specified for TB Case 3.
p) Turn-Off Pinpuller warm-up heater and allow to stabilize without heater enabled.
q) Allow temperatures to stabilize and reach equilibrium as defined in the criteria above.
r) When equilibrium for TB Case 3 is attained, record all temperature and heater data.
s) Review all balance test data and verify that no additional test cases are required to establish Boom thermal balance parameters including the blanket effective emittance property.
t) Return Boom and chamber temperatures to ambient conditions
u) When safe temperature levels are attained, re-pressurize chamber according to the chamber operating procedure.

9. POST-TEST ANALYSIS AND REPORT

A post-test thermal analysis of the Boom shall be performed using test data to specify the measured effective emittance of the thermal blankets and correct thermal couplings as required. Model predictions for the test conditions run should match recorded data within 5 °C. After establishing that the math model of the Boom predicts temperatures and heat flow accurately, re-run flight predictions for nominal and worst-case deployments. Also, rerun the corrected deployed Boom models for the Ahead and Behind spacecraft.

Write and publish a test report. Include the modified thermal model predictions and any established flight Boom hardware thermal changes required as a result of the thermal balance test.

TABLES AND FIGURES

TABLE 1: Description of Temperature Sensors (Thermocouples and Thermistors)

Sensor #	Location On Boom	Expected Test Extremes (C)	TB CASE ___ Temp (C)
TC1 & TM1	Bobbin Cover (Window Area)	-10 / +35	
TM2	Bobbin Cover (Outer Edge)	-10 / +30	
TM3	Outer Bobbin (Between C/L & Edge)	-15 / +20	
TC2 & TM4	Pinpuller (Center)	-20 / +15	
TM5	Housing (Right Side toward –Z)	-25 / +15	
TM6	Housing (Left Side +Z Pre-amp I/F)	-25 / +15	
TM7	Connector Panel Area	-25 / +15	
TM8	Lower Mount Ring	-25 / +12	
TC3	Fixed Boom Center	-50 / +12	
TC4	Fixed Boom End	-30 / +12	
TC5	Cable (10 in. from Housing)	-80 / +20	
TM9	STE-U Pre-Amp Mass Model	-30 / +15	
TM10	SWEA Mass Model	-30 / +20	
TC6	SWEA / Boom interface	-100 / +20	
TM11	Magnetometer Mass Model	-30 / +20	
TC7	Magnetometer / Boom interface	-100 / +20	
TC8	Cable (1” from Housing)	-30 / +20	
Sensor #	**Chamber and I/F Locations**	**Expected Test Extremes (C)**	
TC9	Boom Mounting Plate (–Z)	-10 / +50	
TC10	Boom Mounting Plate (+Z)	-10 / +50	
TC11	Chamber Shroud (Upper)	-180 / +30	
TC12	Chamber Shroud (Upper)	-180 / +30	
TC13	Chamber Shroud (Upper)	-180 / +30	
TC14	Chamber Shroud (Lower)	-180 / +30	
TC15	Chamber Shroud (Lower)	-180 / +30	
TC16	Chamber Shroud (Lower)	-180 / +30	

TABLE 2: Description of Test Heaters

Heater #	Location	Capability (watts)	Control Limits (C)
1	Bobbin Cover	15	+35 / 0.0
2	Pinpuller	5	+20 / -30*
3	SWEA Mass Model	5	+20 / -30
4	Magnetometer Mass Model	2	+20 / -30
5	Mounting Plate	TBD	+40 / 0.0

* The pinpuller heater is thermostatically controlled when enabled to approx. 0.0 / +10 C.

Insert Excel Spreadsheet

Table 3 – BOOM TB

FIGURE 1: External Thermal Surfaces and Coatings for Ahead Stowed IMPACT Boom

- Bobbin Cover Window (18.75 in2) - Germanium Black Kapton tape (Orange)
- Bobbin Cover Window (6.25 in2) - Silver Teflon tape (Turquoise)
- Bobbin Cover MLI - 5-mil Silver Teflon OL (Green)
- Housing and Fixed Boom MLI - Germanium Black Kapton OL (Orange)
- STE-U Sunshade MLI – Silver Teflon OL (Green)
- Instruments (STE-U, STE-D, Magnetometer, and SWEA) are replaced for this test by mass models enclosed with MLI blankets.
- Outer layer MLI and Tapes used for this test need not be identical to the specified design materials but must have nearly identical surface emittance properties.

FIGURE 2: External Thermal Surfaces and Coatings for Behind Stowed IMPACT Boom

- Bobbin Cover Window (25.0 in2) - Germanium Black Kapton tape (Orange)
- Bobbin Cover MLI - 5-mil Silver Teflon OL (Green)
- Housing and Fixed Boom MLI - Germanium Black Kapton OL (Orange)
- STE-U Sunshade MLI – Silver Teflon OL (Green)
- Instruments (STE-U, STE-D, Magnetometer, and SWEA) are replaced for this test by mass models enclosed with MLI blankets.
- Outer layer MLI and Tapes used for this test need not be identical to the specified design materials but must have nearly identical surface emittance properties.