STEREO IMPACT

PROBLEM REPORT
PR-1030
FM1 SWEA Too Cold
2004-12-28

PR Numbers: 1xxx=UCB, 2xxx=Caltech/JPL, 3xxx=UMd, 4xxx=GSFC/SEP, 5xxx=GSFC/Mag, 6xxx=CESR, 7xxx=Keil, 8xxx=ESTEC, 9xxx=MPAe

Assembly : SWEA/STE-D	**SubAssembly :**
Component/Part Number:	**Serial Number:** FM1
Originator: David Curtis	**Organization:** U.C. Berkeley
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Failure Occurred During (Check one √)

☐ Functional test √ Qualification test ☐ S/C Integration ☐ Launch operations

Environment when failure occurred:

☐ Ambient ☐ Vibration ☐ Shock ☐ Acoustic
☐ Thermal ☐ Vacuum √ Thermal-Vacuum ☐ EMI/EMC

Problem Description

During SWEA FM1 Thermal Balance SWEA was found to be significantly colder than predicted. The survival heater was inadequate to maintain survival temperatures even in the chamber, with shrouds at –150C – it will be worse in space. Operational tests were limited because of the cold start-up problem (PFR1028). At no time did the instrument go below –28C, so no unexpected thermal stresses occurred.

Analyses Performed to Determine Cause

An experiment was run with a blanket on the boom segment that SWEA is attached to see if that was the major heat loss (greater than expected conductivity). During cool-down the instrument was turned on before it got too cold to get an operational case. The instrument was warmer but still below predict. Visual comparison of the instrument and its blanketing with the model by the thermal analyst (Al Seivold) revealed some differences, but they were also inadequate to cause the problem. A spare part that was gold-plated with the rest of the parts in the aperture was obtained and passed off to GSFC for analysis (worse thermal properties for that plating could help explain the problem). The analyst worked the updated model to see what additional changes were needed to match the data, and found that the thermal blanket characteristics and unblanketed areas on the pedestal base seem to be the most likely cause. The blanket does not cover the entire pedestal base because of deployment interference concerns. Discussions with APL confirm that blankets are more likely to be close to the value the analyst used to match the data than the previous, more efficient value he had used. They thought it unlikely they could improve the situation significantly, but agreed to make some changes.

Corrective Action/ Resolution

√ Rework ☐ Repair ☐ Use As Is ☐ Scrap

1. Improve blankets – APL to adjust test blanket and implement new design on flight blankets.
2. Improve isolation between instrument and boom – UCB to add a thermal insulator between the pedestal and base.
3. The operational and survival heaters will be re-sized, adding ~1.2W at 24V. (still within instrument margin, waiver not needed)

Thermal balance was repeated after these changes were implemented. See attached SWEA/STE-D Thermal Balance Test Report, dated February 8, 2005.

Date Action Taken:__2005-1-6______________ **Retest Results**:____Success_______________

Corrective Action Required/Performed on other Units √ Serial Number(s): ___FM2_____

Closure Approvals

Subsystem Lead: __________________________ Date:____________
IMPACT Project Manager: __________________________ Date ____________
IMPACT QA: __________________________ Date:____________
NASA IMPACT Instrument Manager: __________________________ Date:____________

SWEA/STE-D Thermal Balance Test Report
IMPACT Boom Instruments

Report No. 05-ALS-7352

Prepared By:

Al Seivold

February 8, 2005

Orbital Sciences Corporation
Technical Services Division
Greenbelt, Maryland 20770

Distribution List

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SUMMARY

This report contains the SWEA and STE-D thermal balance (TB) test results and correlation with analytical model predictions. The first attempt at TB was run on 12/9/04 to 12/10/04. The SWEA ran too cold in this test which indicated the need to modify the thermal design. A subsequent test was run on 12/13/04 to 12/14/04 to evaluate heat flows from the instrument via conduction to the boom and radiation losses from surface areas not covered by the thermal blanket. These areas are near the boom deployment interface and also surrounding the detector grid where the GSE protective cover is clamped. These tests indicated the need to add thermal isolation, improve the MLI blanket and incorporate additional heater power. The test of the revised design was conducted on 1/13/05 to 1/14/05 at the SSL facility in Berkeley, CA per the test plan, Reference 2. Two test conditions were run that simulated the coldest operational case and a hot operational case using heater power only. There was no environment change from the cold to hot case. The test setup was analytically modeled using the TSS program. A corresponding SINDA model was developed to predict test temperatures and correlate the SWEA and STE-D analytical models. After minor adjustments to the SWEA internal couplings, temperature predictions matched test results for all internal sensors within 5ºC. Externally taped thermocouples match within 6ºC except for the pedestal base thermocouple and the thermocouple mounted on the 50-mm tube 1-inch from the base. Both of these sensors were reading much colder than expected based on heat flow calculations and are therefore considered erroneous.

The flight analytical models of the SWEA, STE-D and 50 mm boom were updated based on the correlated test results. Temperature predictions for the cold orbital environment were then run using several SWEA heater settings. Results indicate that for an instrument dissipation of 3.67 watts (per the test condition), an additional 0.5 watts of heater power is needed to maintain the instrument above –20 C, using the SWEA pedestal PRT as control. The cold qualification test will be run at –30 C.

REFERENCES

1. ICD 7381-9012, INTERFACE CONTROL DOCUMENT (ICD) for the STEREO IMPACT INVESTIGATION, JHU Applied Physics Laboratory, dated 3/7, 2002.
2. Document, IMPACT SWEA/STE-D TB and TV Qualification Test Plan, SSL, UC, Berkeley, dated 12/6/2004.
3. STE ICD, SWEA ICD, and Magnetometer ICD.

TABLES and FIGURES

THERMAL BALANCE TEST CONFIGURATION

Figure 1 is a CAD drawing of the SWEA/STE-D revised thermal/mechanical design. It shows the isolators that were incorporated to restrict heat flow from the instrument to the boom mount. Figure 2 is a photograph of the SWEA and STE-D test article configuration showing the MLI blanket design and lack of total coverage. Figure 3 is a CAD drawing of the test setup in the SSL chamber. (These figures were provided by SSL, Berkeley)

TB TEST CONDUCT

The SWEA ran colder than predicted in the initial test conducted in December. After a subsequent test with the boom insulated to evaluate heat flows, the following hardware changes were incorporated: a) Thermal isolators were added between the instrument pedestal and base. b) A new improved thermal blanket was constructed at APL that covered more of the pedestal base. c) Additional heater capacity was added to provide thermal design margin. d) A thermal blanket was added inside the 50-mm tube to provide additional thermal isolation.

The final thermal balance test was conducted with the hardware improvements indicated above on January 13 and 14, 2005 at the SSL, Berkeley facility. Chamber environment goals as specified in the SWEA/STE-D test plan, Reference 2, were attained. Two equilibrium cases were conducted. The cold case was run with operational power measured at 3.67 watts and no heater power. The hot case utilized the same chamber environment but with the operational heater On at 70% duty cycle. This provided a total of 3.67 watts operational power plus 2.01 watts of heater power (total = 5.68 watts). Test results from these two equilibrium cases provided sufficient data to correlate the analytical model.

The TB test also included verification of the survival heater operation. The survival heater dissipates 3.5 watts at 25 volts. The heater and mechanical thermostat operation were verified by allowing cooldown to the thermostat turn-on point (-30 C) and subsequent heater turn-off (-20 C). Three on/off cycles were conducted.

TEST VERSUS ANALYSIS RESULTS

Figure 4 depicts the TSS geometry model of the test configuration used for analytical model correlation.

Design and Modeling Considerations

The primary SWEA heat loss paths from the pedestal and detector are as follows:

- Conduction from the pedestal to the pedestal base which is conductively coupled tightly to the T300 Graphite-Epoxy 50-mm tube.
- Radiation from the pedestal and detector to space via the thermal blanket determined

by the blanket effective emittance (E*).

- Radiation from the MLI uncovered area of the base near the deployment interface to space. Radiation determined by black Peek interface blocks, an alodine area, and VDA-Kapton tape covered area.
- Conduction and radiation to the inside of the 50-mm tube by the SWEA/STE-D cable harness. The harness is wrapped with MLI from the pedestal base up the tube for several feet.
- Conduction and radiation to space via the magnetometer cable harness. The cable is contained inside a Tin-plated Copper braid (Flight = 0.0025 sq. in. cross section, ETU used in TB = 0.0037 sq. in). The braid enclosed mag. harness for flight will run in an aluminum track attached to the outside of the 50-mm tube. This track was not included in the TB test.
- Radiation from the detector housing not covered by MLI, which is determined by the exposed surface area and gold plating emissivity.
- Radiation from the detector via the grid, which is determined by the surface area and gold plating emissivity.

Model Assumptions

These assumptions are based on the revised thermal/mechanical configuration tested in the final TB test.

- T300 Graphite Epoxy conductivity = 9 W/m/K (see next section below).
- SWEA thermal blanket E* = 0.03 (see next section below).
- Six G-10 Pedestal/Base isolators conductance = 0.12 W/C.
- Base Hub area (Peek blocks, alodine, VDA Kapton tape) emissivity = 0.5
- Gold plating emissivity = 0.05.
- The magnetometer harness guide that was not included in the test is also not included in the flight model predictions. It is attached to the cold 50-mm tube in four places. The effect of the harness guide on heat loss is assumed to be negligible.
- Conduction coupling through the STE-D isolator is assumed to be 0.0072 Watts/ºK. This value was also derived from the STE-U TB test correlation.

Model Changes to Achieve Correlation

- Data was provided that indicated that T300 Gr/E can vary between 6 W/m/K and 9 W/m/K. Because the conductivity of the SWEA lay-up was not tested, the value in the model was varied until the analysis results came close to the measured results. It appeared that the correct value to use was 9 W/m/K.
- The thermal blanket effective emittance was assumed to be between E* = 0.02 and 0.05. After several iterations, the temperatures and heat flows matched quite well using an E* = 0.03.
- Internal SWEA thermal gradients between circuit boards and from the circuit boards to the aluminum housing were greater than predicted. A few internal couplings in the analytical model were changed to yield similar gradients. This is permissible without violating the integrity of the analysis because of the variability of bolted joint conductance values.

Summary of Results

SWEA and STE-D test temperatures versus thermal analytical model predictions are provided in Table 1 for the two equilibrium cases. Results show close correlation after implementing the model changes listed above. All internal (flight) sensors match predictions within 5ºC for both test cases. All externally mounted thermocouples are reading colder than model predictions. It is surmised that these taped thermocouples may not have maintained intimate surface contact introducing an error in the readout. However, all TCs still match predictions within 10ºC except for the Pedestal Base TC and one of the TCs on the 50-mm tube near the base. These two sensors were reading significantly colder than considered possible based on their location and heat flow calculations. Updated flight predictions using the correlated model are provided in Table 2 for several heater power settings. A plot of these predictions is provided in Figure 5.

TABLE 1: Summary Comparison of Test vs. Analysis Results

Location (Node #)	**Cold Case (ºC)**		**Hot Case (ºC)**	
	Test	**Analysis**	**Test**	**Analysis**
STE-D PRT (6202)	– 82.0	– 78.8	– 66.0	– 65.0
SWEA Det.TC (6402)	– 32.0	– 27.1	+ 1.0	+ 6.7
MCP Bd. Ther.(64021)	– 20.0	– 21.2	+26.0	+ 21.9
DAC Bd.Ther. (64032)	– 19.0	– 21.9	+14.0	+ 11.9
SWEA Ped. PRT (6403)	– 24.0	– 26.0	+ 12.0	+ 7.8
SWEA Ped. TC (6404)	– 29.0	– 27.0	+ 2.0	+ 6.8
SWEA Base TC (6405)	– 68.0 *	– 40.0	– 48.0 *	– 12.5
Tube 1” TC (5021/5022)	– 77.0 *	– 60.0	– 60.0 *	– 39.5
G/R Tube 9.5”TC (5017)	– 142	– 133.9	– 140	– 130
G/R Tube 19” TC (5012)	– 147	– 145.9	– 146	– 144.7
Upper Shroud TC (9995)	– 149	– 150	– 150	– 150
Lower Shroud TC (9994)	– 149	– 150	– 149	– 150
Baseplate TC (888)	– 97	– 97	– 98	– 97
Cryo Plate TC (998)	– 147	– 147	– 148	– 147
Baseplt Op. H. TC (998)	– 85	– 85	– 86	– 85
Boom Mt. Ft TC (NA)	– 108	–	– 109	–

***** Thermocouples appear to be reading erroneously based on heat flow calculations.

TABLE 2: SWEA and STE-D Correlated Model Flight Predictions

	SWEA Power Dissipation (3.67 watts + Heater)			
Location (Node #)	**3.67 w.**	**4.5 w.**	**5.0 w.**	**5.68 w.**
STE-D PRT (6202)	– 86.6	– 79.4	– 75.6	– 71.2
SWEA Det. Hous. (6402)	– 30.7	– 14.0	– 4.6	+ 6.8
MCP Bd. Ther.(64021)	– 21.9	+ 0.6	+13.4	+ 29.5
DAC Bd. Ther. (64032)	– 12.9	– 6.2	+ 3.2	+ 14.6
SWEA Ped. PRT (6403)	– 29.1	– 12.3	– 3.0	+ 8.4
SWEA Ped Hous. (6404)	-30.5	– 13.8	– 4.4	+ 7.0
Pre-amp Bd. (64034)	– 22.9	– 4.6	+ 4.8	+ 16.2
Shaper Board (64033)	– 21.9	– 5.1	+ 4.2	+ 15.6
LVPS Board (64031)	– 26.3	– 9.6	– 0.2	+ 11.1
Instru. Bd. Stk. (64022)	– 17.1	+ 5.4	+ 18.2	+ 34.3
SWEA Base (6405)	– 49.6	– 36.6	– 29.4	– 20.9
Tube 1 " (5021/5022)	– 70	– 62	– 56	– 50
G/R Tube 9.5"TC (5017)	– 163	– 160	– 159	– 157
G/R Tube 19" TC (5012)	– 185	– 184	– 183	– 183

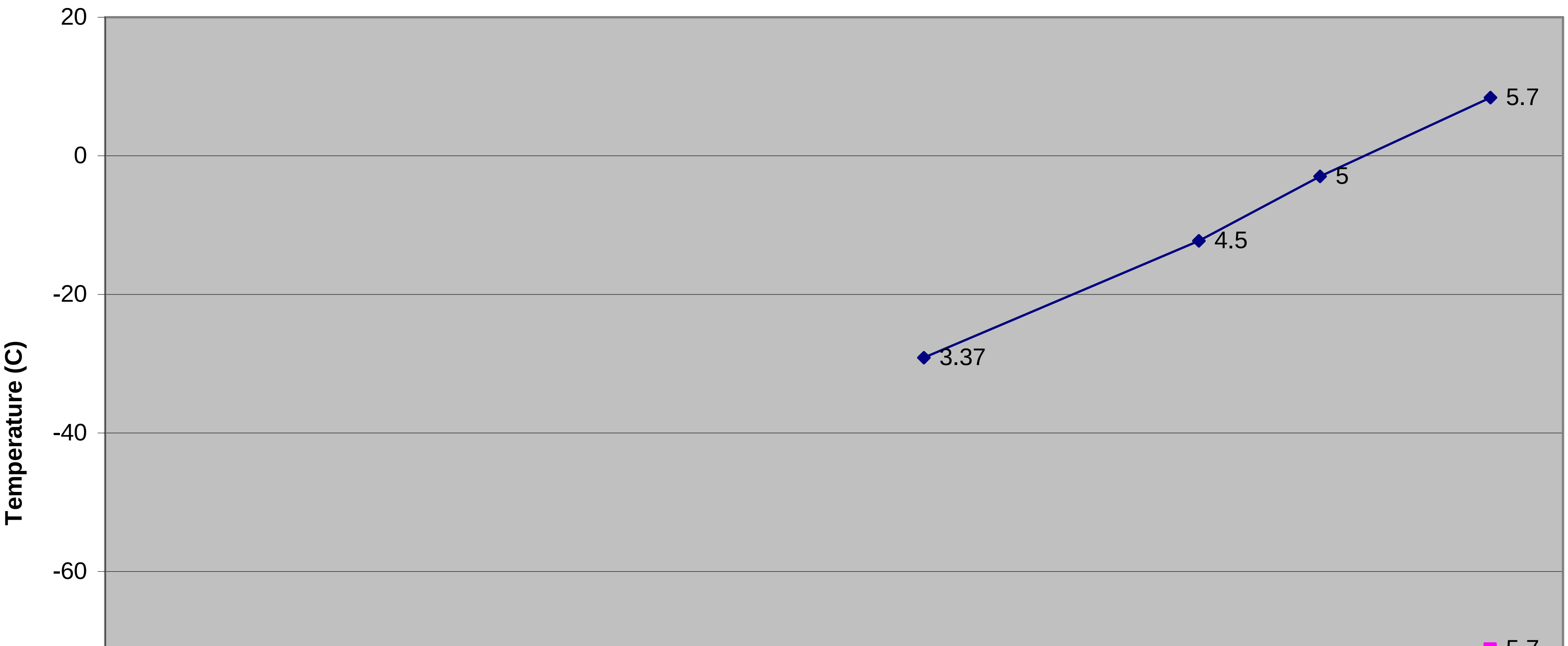
CONCLUSIONS AND RECOMMENDATIONS

- The thermal balance test correlation successfully verified the SWEA and STE-D thermal designs and the analytical models.
- MLI coverage of the Pedestal Base and the Detector Housing near the Grid must be equal to or greater than the TB test blanket.
- The flight SWEA thermal blanket must yield an effective emittance E* = 0.03 or better.
- Thermal coatings chosen for the STE-D are adequate for maintaining STE-D in an acceptable temperature range.
- Using the SWEA PRT located on the Pedestal Chassis as control, the model predicts that the SWEA will need operational power of 3.67 watts plus 0.5 watts of heater power to maintain the SWEA above –20ºC. If the operational heater were to fail, the temperature of the Pedestal Chassis is predicted to reach the –29ºC level.
- The qualification test for the SWEA is specified to be conducted at the following temperatures: Non-Op = –40ºC to +40ºC, Operational = –30ºC to +35ºC.
- The qualification test for the STE-D is specified to be conducted at the following temperatures: Non-Op = –95ºC to +40ºC, Operational = –95ºC to –35ºC.

SWEA/STE-D THERMAL BALANCE TEST

FIGURES

Figure 1: SWEA and STE-D Correlated Model Flight Predictions



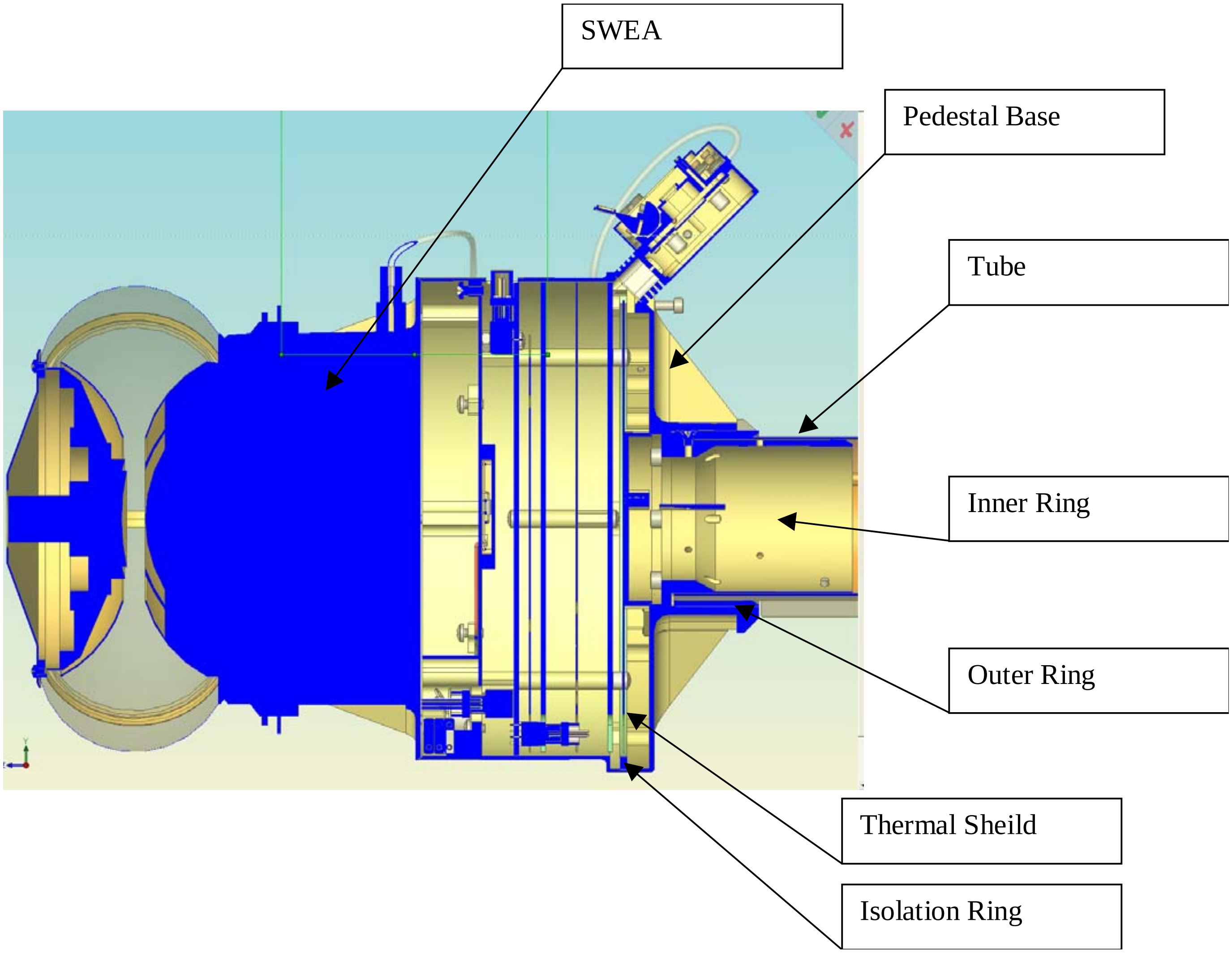


FIGURE 2: CAD Drawing of SWEA/STE-D Revised Design

FIGURE 3: Picture of SWEA/STE-D TB Test Configuration

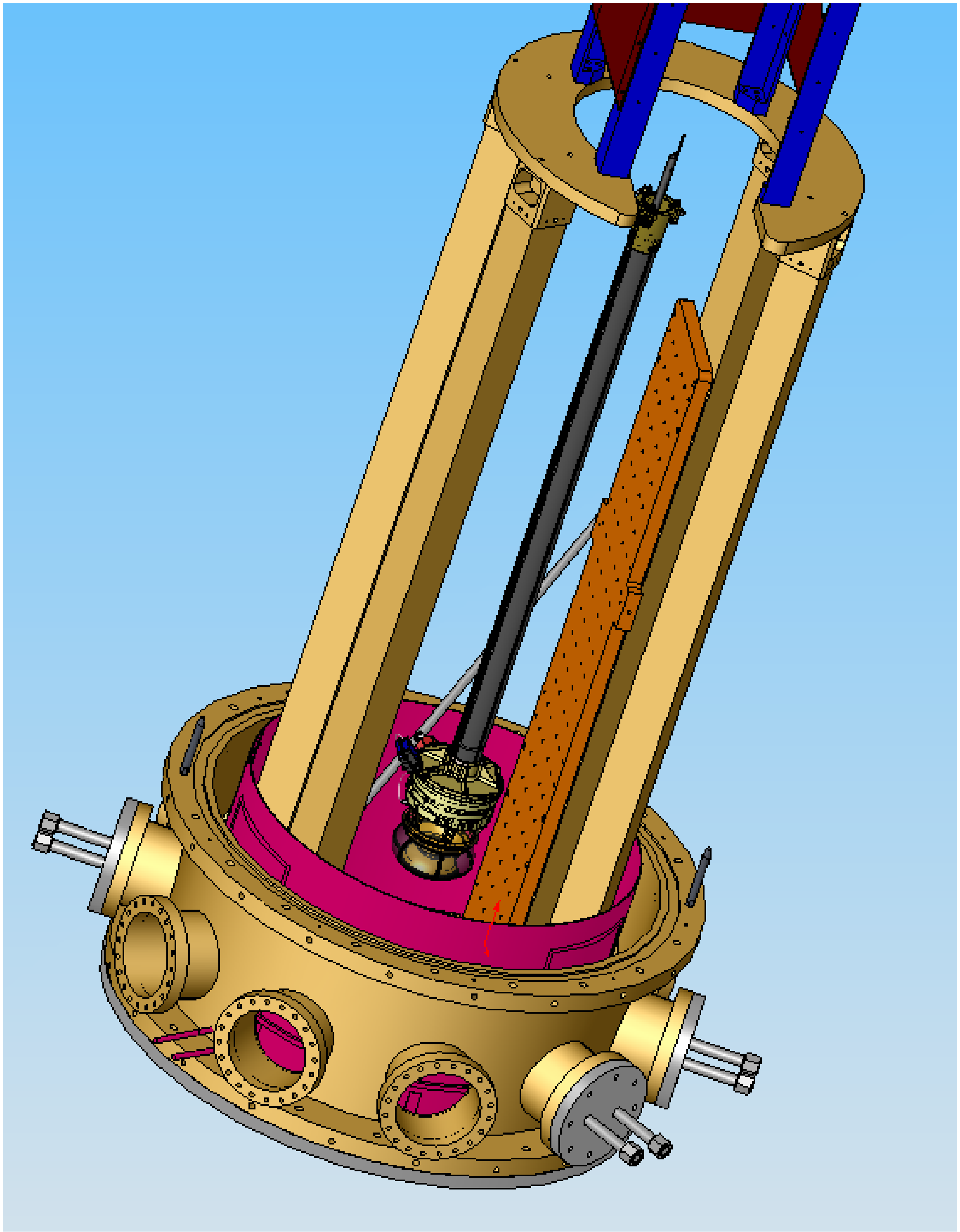


FIGURE 4: CAD Drawing showing SWEA/STE-D TB Test Setup

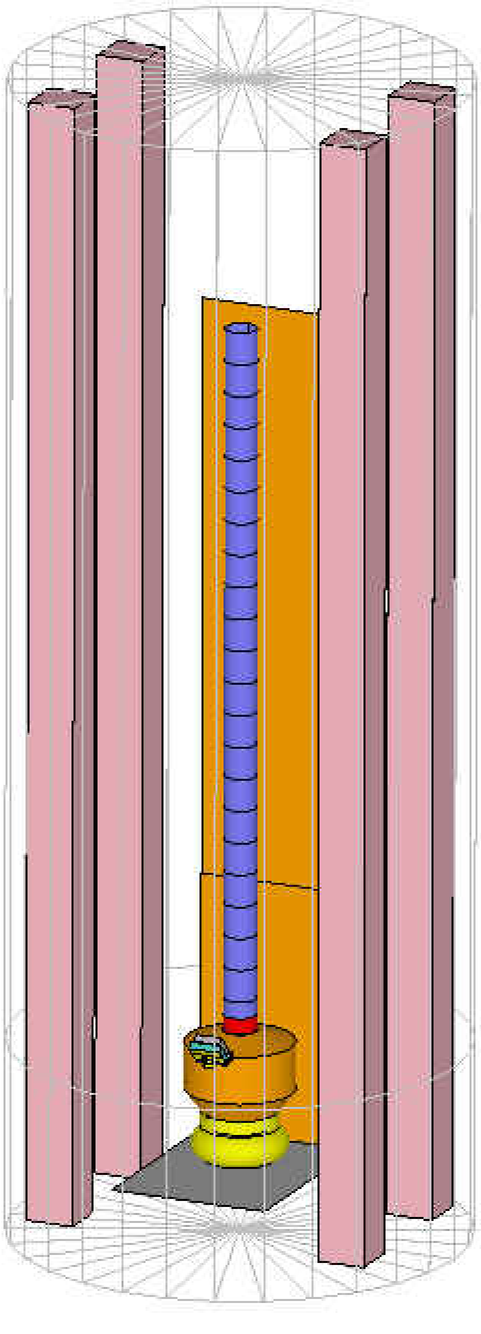


FIGURE 5: SWEA/STE-D TB Test TSS Model Geometry

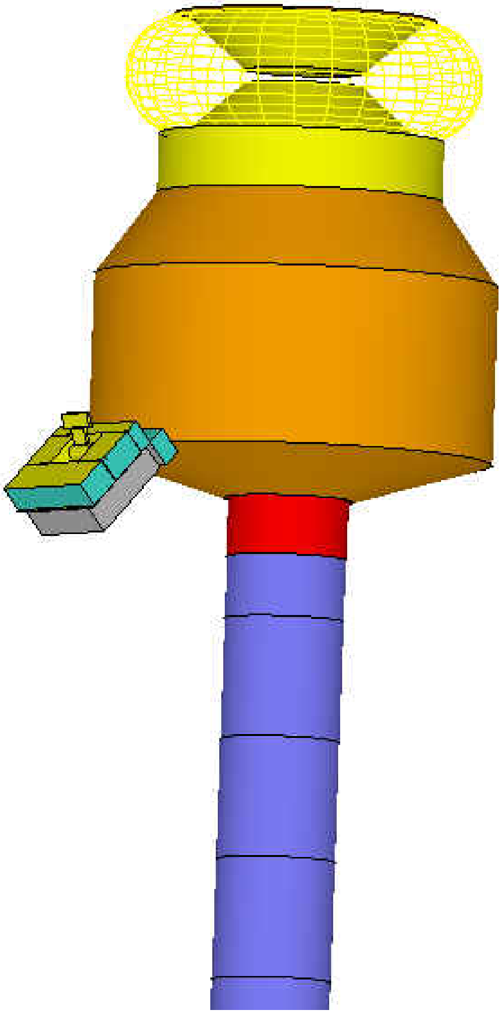


FIGURE 6: SWEA/STE-D Correlated TSS Model Geometry