STEREO Impact Boom Vibration Report

Document # IMP-448-DOC
Revision: A

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Approved By: Paul Turin
Date: August 18, 2003

1. OVERVIEW

The STEREO Boom vibration tests for the proto-flight boom were conducted July 21 through 23, 2003 at Wyle Laboratories in El Segundo, California. Paul Turin and Jeremy McCauley were in attendance for instrument handling, verification and test support. David Pankow attended to provide added support for the force limited vibration tests. Wyle Laboratories provided Test Engineer Matt Klicka.

Tests were conducted in the X-, Z-, and Y-axis, where the X-axis is defined as along the boom deployment axis, the Z-axis is along the magnetometer mount, and the Y-axis is perpendicular to the mounting plane (See Figure 1). Test objectives, procedures and levels are defined and explained in IMP-562-DOC, STEREO BOOM Vibration Test Procedure (Attached). The only exception of note was the use of an expander provided by Wyle Laboratories for the vertical orientation of the shake table rather than the configuration shown on Sheet 14 for the Y-axis tests.

All vibration runs were completed and no further testing is required. No degradation to the boom mechanically, structurally, or functionally was shown by post-test deployment of the boom or by subsequent stiffness testing. First fundamental frequencies of the stowed boom in the X-, Y-, and Z-axis were found to be 114, 92, and 75, respectively.

A change was seen in the pre- and post-sine sweeps in the Y-axis. A mechanical shift had occurred between the magnetometer mount and the alignment combs. This problem has been remedied for flight models through the use of dowel pins to set the location of the alignment blocks.

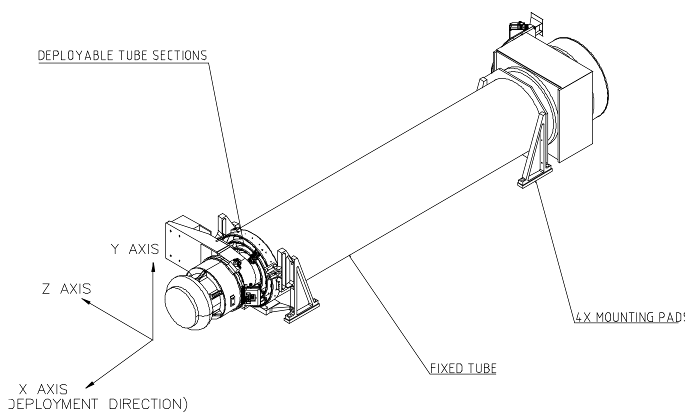

Figure 1: Definition of Shake Axes

2. REFERENCE DOCUMENTS (Attached):

APL Document APL 7381-9003 Rev A – STEREO Environment Definition, Observatory and Instrument Test Requirements Document (Not attached)
Wyle Laboratories Report Number 48856 – Report on Sinusoidal and Random Vibration Tests of one STEREO BOOM ASSY Part Number IMP-001 Serial Number 001 (Selected)
UCB Document IMP-562-DOC – STEREO BOOM Vibration Test Procedure
Report on Finite Element Modal Analysis of STEREO IMPACT Boom, Prepared by Robert Besuner
FEMCI Book – Creating a Random Vibration Component Test Specification

3. PASS/FAIL CRITERIA

Post-vibration deployment of the boom assembly verified functionality was not lost in testing. Full deployment with actuation was completed July 31, 2003, prior to thermal vacuum testing. Post deployment inspections found no notable degradation mechanically or structurally.

One set screw was found in the square housing around the actuator mechanism. Inspection found it came loose from one of the preload wedges for the 50 mm tube. Though the wedge had been allowed to loosen, the part is not necessary once the boom is fully stowed and did not produce any loss in structural rigidity. This part is merely a stop point when stowing the boom. Once the pinpuller is inserted, the stacer tip piece provides the required structure. The screw was likely not tightened to the specified torque before vibration testing. This part will be staked before flight and therefore is not a design issue.

Change in the pre- and post-sine sweep signatures is addressed above (Section 1.) and in Section 7. No degradation was found in the functionality of the boom due to this change.

4. DYNAMIC TEST REQUIREMENTS FOR BOOM MOUNTED COMPONENTS

Accelerometers were attached in each position of an instrument that attaches to the STEREO BOOM and envelopes were created from the test data recorded.

4.1. SWEA AND STE-D

Table 1: Random Vibration Levels X-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 80	+6.5 dB/oct
80 to 300	0.2 g^2/Hz
300 to 400	-16.8 dB/oct
400 to 500	0.04 g^2/Hz
500 to 2000	-3.0 dB/oct
2000	0.01 g^2/Hz

Overall Amplitude = 9.50 g rms
Duration = 60 seconds

Table 2: Random Vibration Levels Y-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 50	+12.9 dB/oct
50 to 60	0.5 g^2/Hz
60 to 100	-14.9 dB/oct
100 to 500	0.04 g^2/Hz
500 to 600	+3.7 dB/oct
600 to 700	0.05 g^2/Hz
700 to 2000	-4.6 dB/oct
2000	0.01 g^2/Hz

Overall Amplitude = 8.36 g rms
Duration = 60 seconds

Table 3: Random Vibration Levels Z-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 50	+11.2 dB/oct
50 to 80	0.2 g^2/Hz
80 to 110	-19.1 dB/oct
110 to 500	0.04 g^2/Hz
500 to 2000	-3.0 dB/oct
2000	0.01 g^2/Hz

Overall Amplitude = 7.69 g rms
Duration = 60 seconds

4.2. MAGNETOMETER

Table 4: Random Vibration Levels X-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 80	+8.5 dB/oct
80 to 150	0.5 g^2/Hz
150 to 200	-24.1 dB/oct
200 to 240	0.05 g^2/Hz
240 to 400	+10.6 dB/oct
400 to 450	0.3 g^2/Hz
450 to 700	-15.7 dB/oct
700 to 2000	-3.2 dB/oct
2000	0.02 g^2/Hz

Overall Amplitude = 12.4 g rms
Duration = 60 seconds

Table 5: Random Vibration Levels Y-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 50	+14.0 dB/oct
50 to 60	0.7 g^2/Hz
60 to 120	-12.4 dB/oct
120 to 300	0.04 g^2/Hz
300 to 400	+9.6 dB/oct
400 to 500	0.1 g^2/Hz
500 to 2000	-5.0 dB/oct
2000	0.01 g^2/Hz

Overall Amplitude = 9.71 g rms
Duration = 60 seconds

Table 6: Random Vibration Levels Z-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 50	+11.2 dB/oct
50 to 70	0.3 g^2/Hz
70 to 100	-17.0 dB/oct
100 to 500	0.04 g^2/Hz
500 to 2000	-3.0 dB/oct
2000	0.01 g^2/Hz

Overall Amplitude = 7.52 g rms
Duration = 60 seconds

4.3. STE-U

Table 7: Random Vibration Levels X-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 70	+5.3 dB/oct
70 to 170	0.09 g^2/Hz
170 to 200	+22.3 dB/oct
200 to 800	0.3 g^2/Hz
800 to 2000	-11.2 dB/oct
2000	0.01 g^2/Hz

Overall Amplitude = 16.6 g rms
Duration = 60 seconds

Table 8: Random Vibration Levels Y-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 120	+6.2 dB/oct
120 to 160	0.4 g^2/Hz
160 to 200	-23.5 dB/oct
200 to 300	0.07 g^2/Hz
300 to 600	+10.6 dB/oct
600 to 900	0.8 g^2/Hz
900 to 2000	-16.5 dB/oct
2000	0.01 g^2/Hz

Overall Amplitude = 23.3 g rms
Duration = 60 seconds

Note: These values are uncomfortably high. Therefore, vibration of the STE-U instruments is recommended to be done on the flight booms after the standoffs which support the instruments have been redesigned. (See Section 7.)

Table 9: Random Vibration Levels Z-axis

Frequency (Hz)	PSD Level
20	0.01 g^2/Hz
20 to 80	+8.9 dB/oct
80 to 100	0.6 g^2/Hz
100 to 150	-20.1 dB/oct
150 to 500	0.04 g^2/Hz
500 to 2000	-3.0 dB/oct
2000	0.01 g^2/Hz

Overall Amplitude = 8.68 g rms
Duration = 60 seconds

5. FUNDAMENTAL FREQUENCY

First fundamental frequencies as seen in the response data are as shown in Table 10. The values for the Y- and Z-axis are reasonably close to the higher values predicted by the Finite Element Modal Analysis for the first three natural frequencies at 60.2, 81.8 and 83.4 Hz. However, Besuner notes that the frequencies are likely to be conservatively low since they lack the resisting force of the pins springs to center the tubes. The X-axis is not specifically modeled in the analysis.

Table 10: STEREO Boom Fundamental Frequencies

Excitation Axis	Frequency (Hz)
X	114
Y	92
Z	75

6. ACCELEROMETER PLACEMENT

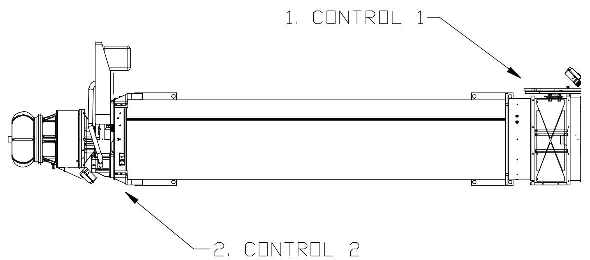

Figure 2: Control Accelerometer Placement

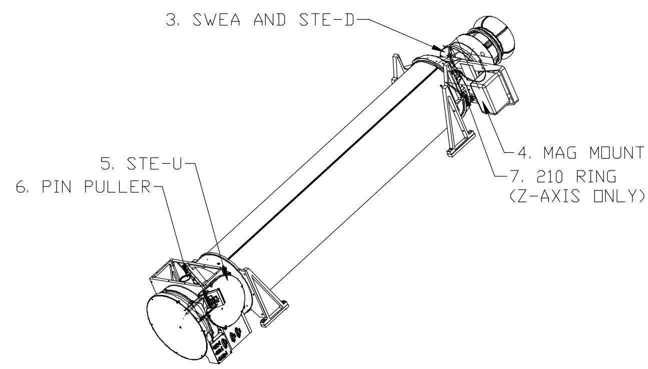

Figure 3: Accelerometer Placement

7. PRELIMINARY RESULTS SUMMARY (as provided via email by Paul Turin, July 25, 2003)

Here's a summary of the IMPACT boom vibration testing and my preliminary conclusions.

For the most part, it went well. It took three days to get all the testing done, which is longer than I expected, but with the additional work required for force limiting, was reasonable (21 sets of data = ~550 plots to look thru and evaluate between tests). I feel it was well worth the trip to LA to get force limiting, as it allowed us to significantly reduce the loads imposed by the random tests. Thanks to Dave P for lending his invaluable expertise.

The X and Z tests went off without a hitch, but we had a minor problem with the Y axis sine test. This test imparts a moment on the 90mm tube due to the offset mass of the mag and mag tray. A superposition of the pre- and post-vibe sine signatures showed a noticeable frequency shift of several peaks, indicating a change in something mechanically. Inspection revealed that something had loosened slightly and the mag tray could now be moved up and down a few millimeters with the application of 10lbs or so, rotating the 90mm tube a bit. The apparent cause was slippage of the combs mounted to the mag tray. There are two of these mounted to the mag tray and two to ears on the 90mm tube on the opposite side. These are there to coaxially locate all of the tubes at the SWEA end and to carry the lateral vibration loads. They are currently bolted in place, so that we are counting on friction to resist the shear loads, and it appears that the two on the mag tray slipped slightly during the Y axis sine strength test, adding some play on that side and allowing the tray and 90mm tube to rotate a small amount, pivoting about the combs on the other side. The simple solution is to add dowel pins to the combs to carry the shear loads while eliminating the possibility of play, and this can easily be implemented after environmental testing by drilling a pair of holes.

After evaluating the amount of motion possible and the likely effects on the boom, we decided to continue with the tests anticipating that there was at best only a small chance of damage, although higher levels at the SWEA and MAG might result. An additional possibility was that the combs might loosen more.

We checked the mag play after the Y-axis random test and it appeared to be the same, so I think it is limited to the play between the bolts and their holes. A comparison of pre- and post-vibe sine signatures showed no change, further evidence that the problem didn't get worse during the test. A check of the levels at the instrument locations showed low levels at the SWEA (5.6grms max for an input of 10.4grms), and reasonable levels at the mag (11.2grms) given its mounting on a cantilever. I also checked the compression of the spring that set the axial preload on the boom, and it had relaxed about 1mm, which corresponds to a reduction of the preload force from 375 lbs to 314, which was more than enough to maintain contact given the built-in margins.

The levels seen at STE-U were uncomfortably high throughout the testing (as high as 18.8grms). I am confident that this is due to the rather narrow and tall thermal standoffs used to mount the STE-U to the boom. Now that we are no longer thermally isolating the STE-U from the boom, I can change the mounting to a much stockier scheme that will greatly reduce the amplification. Since one of the goals of this test was to measure the inputs to the instruments and to use these instead of the higher levels required by the APL environmental spec for boom mounted instruments tested separately, changing the feet will invalidate the measured levels for STE-U. This leaves us with three choices: use the APL levels (14.7grms), rerun the boom test to get better levels with a revised STE-U model, or vibrate the STE-U's on the flight booms. I propose we do the latter, as we don't have time for a boom retest, and I'm sure we will end up with an easier ride for the STE with it mounted more rigidly.

A larger question is whether the mag slippage is a significant enough problem to require a retest before continuing with the qualification testing. My opinion is that it should not because 1) it's cause is well understood and easily fixed with high confidence that it will not reoccur, 2) it did not cause banging and subsequent high levels at the SWEA and MAG (the levels seen before the slippage on the other transverse axis were slightly higher), 3) we did not see any change in the pre- and post-vibe signatures for the random test which would indicate a worsening problem, 4) the preload remained adequate to hold the boom tightly closed, 5) there is no evidence that any damage was done to the hardware. I propose that we continue as it appears that the boom survived what was definitely a worst case test and I except it will deploy without problems. If the powers that be are uncomfortable with this, another option would be to add an additional deployment between vibe and thermal vac, which would allow closer inspection of the hardware and prove it deploys, at the cost of ~1-2 days. We did not plan to deploy between vibe and TV, following the test-as-you-fly philosophy, but we could add another deployment. This decision would need to be made quickly.

8. RELEVANT DATA

Selected data is included to depict the pre- and post-test signatures (overlays of "SUM LOAD CELL"), the random vibration test levels with force limiting enabled ("Random Control", "Avg. of C1&C2"), and the testing envelopes created for the boom mounted instruments ("Random Limit Channel", R3 (SWEA and STE-D), R4 (Magnetometer), and R5 (STE-U).

Full data is available for review upon request.