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SPIRE Test Report
On
BDA Pathfinder Unit

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DOCUMENT CHANGE LOG

CHANGE LETTER	CHANGE DATE	PAGES AFFECTED	CHANGES/ NOTES	GENERAL COMMENTS
A	8/25/2002	All	Initial Release	

1 Introduction

1.1 Objective

To subject the BDA pathfinder unit to the following environmental tests (in that order):

1) Warm Vibration Test (Room temperature)
2) Two Thermal cycles (to 90 K)
3) Cold Vibration Test (90 K)

1.2 Approach

The BDA Pathfinder unit consisted a BDA suspension system without a detector assembly. Instead, a mass simulator was installed in its place. During the vibration tests, there was a tri-axial accelerometer installed on the mass simulator to measure the BDA response.

During the warm vibration test, three force transducers are used. The force transducers are used to evaluate dynamic response but are not used to control the test. Part of the purpose of this test is to measure the modal frequencies and damping of the BDA unit. And to correlate this data between the on-board accelerometer and the force transducers, since during the cold vibe only the on-board accelerometer is used.

For the thermal cycle tests, the BDA unit is mounted inside the thermal cycle dewar (Cryomech ST405, Pulse Tube cooler) with a thermal strap to the cold plate.

During the cold vibration test, the on-board accelerometer gives the response of the BDA. The BDA is mounted inside the cold vibe fixture. The cold vibration fixture is then evacuated and backfilled with Nitrogen gas. In addition a thermal strap was used with the BDA to connect it to the cold plate.

Metrology measurements were performed on the unit before and after each test.

1.3 Applicable Documents

1. Herschel SPIRE Detector Subsystem Specification Document, SPIRE-JPL-PRJ-000456
2. Environmental Requirements Document (ERD) document for Herschel/Planck, JPL D-19155
3. SPIRE BDA Warm Vibration Test Plan, JPL D-22969 rev. C
4. SPIRE BDA Cold Vibration Test Plan, JPL D-24013 Rev. A

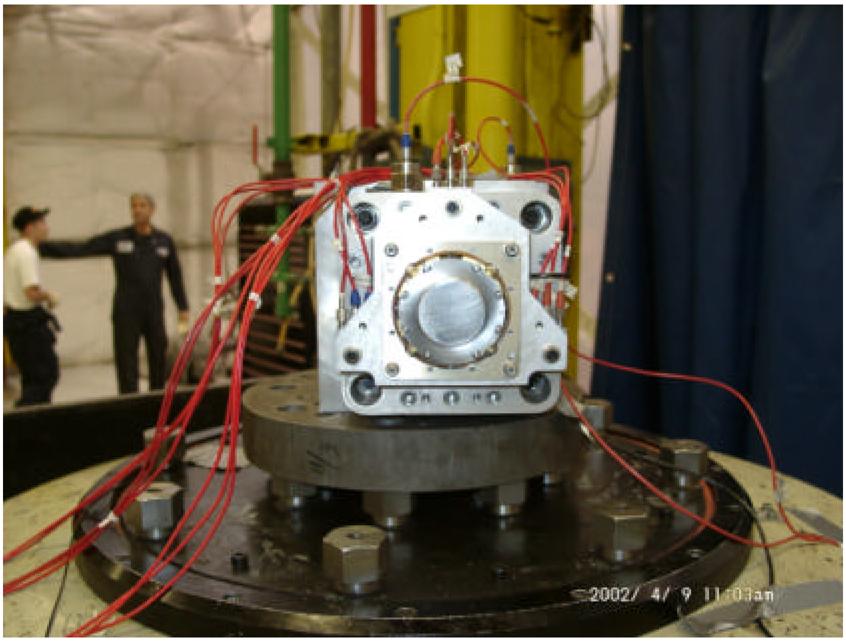
1.4 Hardware Description

The BDA Pathfinder unit consisted a BDA suspension system without a detector assembly. Instead, a mass simulator was installed in its place. During the vibration tests, there was a tri-axial accelerometer installed on the mass simulator to measure the BDA response.

2 Warm Vibration Test

2.1 Test set-up

The BDA was mounted on a 3/8 inch thick plate and the plate mounted on a vibration fixture using #10 bolts passing through force transducers. The vibration fixture can be mounted to a small cube vibration fixture, which facilitates testing for all three axes as shown in Figure 2.1.1



2.2 Test Levels

The Proto Flight level (or Qualification level) random vibration test spectrum used during the test is defined in Table 2.2.1. A 0.25 g sine sweep was performed on the hardware before and after the random vibration test.

Vibration Spectrum	
Frequency 20 Hz to 100 Hz	Test Level +6dB/Octave
100 Hz to 170 Hz	0.8 g2/Hz
170 Hz to 210 Hz	-40 dB/Octave
210 Hz to 500 Hz	0.05 g2/Hz
500 Hz to 540 Hz	+40 dB/Octave
540 Hz to 200 Hz	-6dB/Octave

Table 2.2.1

As can be seen from the above vibration spectrum, the spectrum is notched between 210 Hz and 500 Hz effectively notching out the resonance modes of the BDA. The resonance modes of the BDA were determined by the 0.25 g sine sweep at room temperature.

2.3 Test Procedure

The unit was subjected to the test levels in all three directions.

2.4 Test Data and Metrology

The lowest modal frequency of resonance was determined to be about 235 Hz.

The metrology measurements showed that the BDA had passed the test within specification as per the SPIRE Sub-System Specification document.

3 Thermal Cycle Test

3.1 Test set-up

The BDA was mounted in the thermal cycle dewar with a thermal strap and cooled down to 90 K twice.

3.2 Test Data and Metrology

The metrology measurements showed that the BDA had passed the test within specification as per the SPIRE Sub-System Specification document.

4 Cold Vibration Test

4.1 Test set-up

The BDA was mounted the vibration test fixture (same as the warm vibration fixture) which in turn was bolted onto the cold vibration fixture as shown in Fig. 4.1. The thermal strap used was made up of nine 1 mm diameter 5N Copper wires.

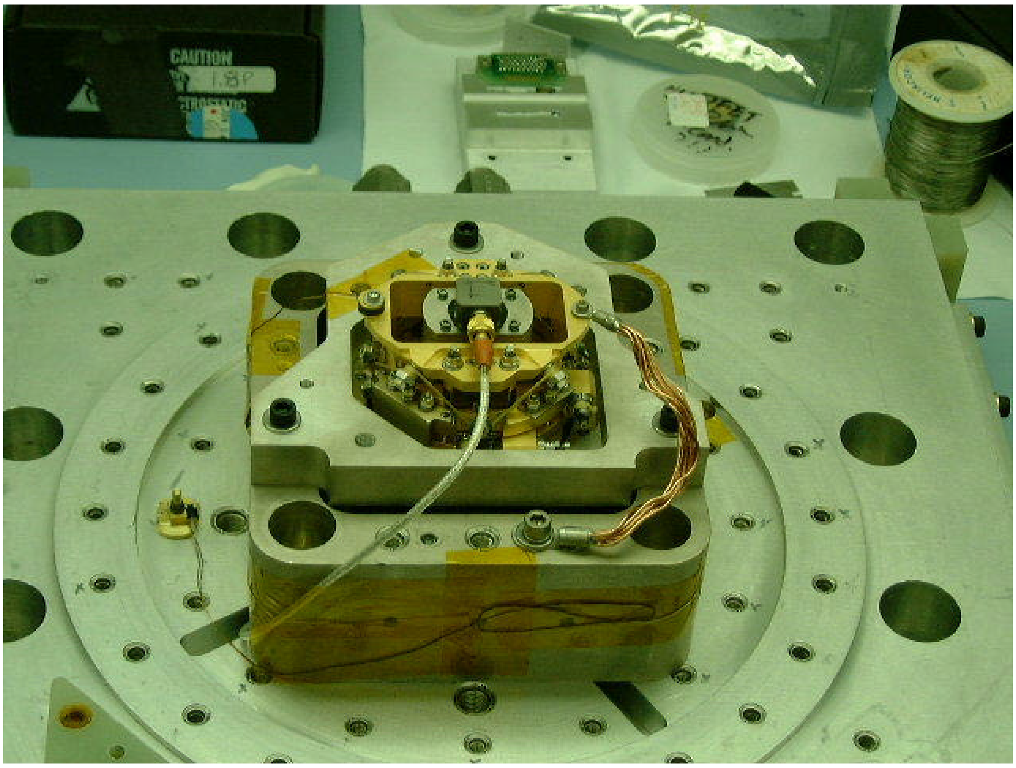


Figure 4.1.1

4.2 Test Levels

The Proto Flight level (or Qualification level) random vibration test spectrum used during the test is defined in Table 2.2.1. A 0.25 g sine sweep was performed on the hardware before and after the random vibration test.

Vibration Spectrum	
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Table 2.2.1

As can be seen from the above vibration spectrum, the spectrum is notched between 210 Hz and 500 Hz effectively notching out the resonance modes of the BDA. The resonance modes of the BDA were determined by the 0.25 g sine sweep at room temperature.

4.3 Test Procedure

The following sequence of tests was performed on the unit.

1. Pre random vibe, 0.25 g sine sweep at room temperature in the z-axis
2. 0.25 g sine sweep at 90 K in the z-axis
3. Random Vibration (as per spectrum given in table 2.2.1) at 90 K in the z-axis
4. Warm up
5. Post random vibe, 0.25 g sine sweep at room temperature in the z-axis
6. 0.25 g sine sweep at room temperature in the x axis
7. 0.25 g sine sweep at 90 K in the x axis
8. Random Vibration (as per spectrum given in table 2.2.1) at 90 K in the z-axis
9. Warm up

4.4 Test Data and Metrology

The lowest modal frequency of resonance was determined to be about 245 Hz at room temperature in the z-axis. The other modes were at 265 Hz, 365 Hz, 450 Hz, and 514 Hz. The sine sweep data taken at 90 K in the z-axis shows that the lowest mode frequency shifted to lower frequency of 202 Hz. The other modes too shifted lower by about 30 Hz. The post-random vibration sine sweep showed that the lowest mode was 247 Hz.

The lowest modal frequency of resonance was determined to be 235 Hz at room temperature in the x-axis. The sine sweep data taken at 90 K in the z-axis shows that the lowest mode frequency had moved down to 208 Hz. The higher frequency resonance modes had also moved lower by roughly 30 Hz.

4.4.1 BDA failure under cold vibration test

The metrology measurements done after the cold vibration test showed that the BDA had moved outside the maximum motion specification (as per the SPIRE Sub-System Specification document) in the X and Y directions indicating a BDA failure.

5 Failure Analysis

5.1 Motion After the Cold Vibration Test

The motion of the BDA is shown below in Figure 5.1.1. The Yellow arrows show direction of motion. (Not to scale.)

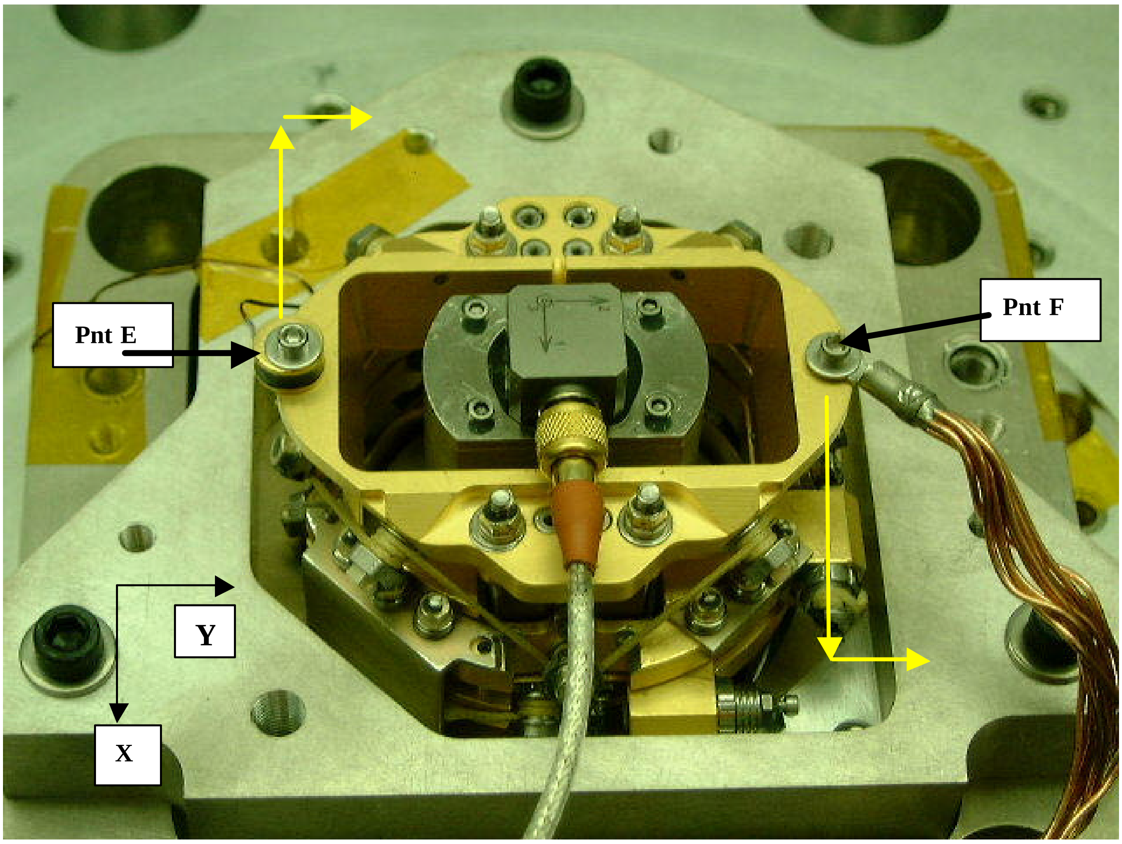

Figure 5.1.1

As can be seen from the figure the BDA moved in a twist form and also shows some translational movement. The twist effect is more in magnitude than the translation effect.

5.2 Metrology data through the entire test flow.

Figure 5.2.1 shows the motion of the BDA at each point in its testing sequence. The figure shows the position of point E and point F marked in Figure 5.1.1.

The data was taken before and after each test as explained below:
Point 0 : Before initial bakeout
Point 1 and 2 : Before warm vibe with 1 and ¼ wraps. Kevlar broke during warm vibe.

BDA restrung. So for this BDA actually point 3, is the baseline.

Point 3 : Before warm vibe of this BDA unit
Point 4 : After warm vibe
Point 5: After 1st thermal cycle
Point 6: After 2nd thermal cycle
Point 7: After aborted cold vibe at –12 dB and –9 dB. During this we saw evidence of something knocking during vibe.
Point 8: After Cold vibe to full qual level in z-axis and x-axis

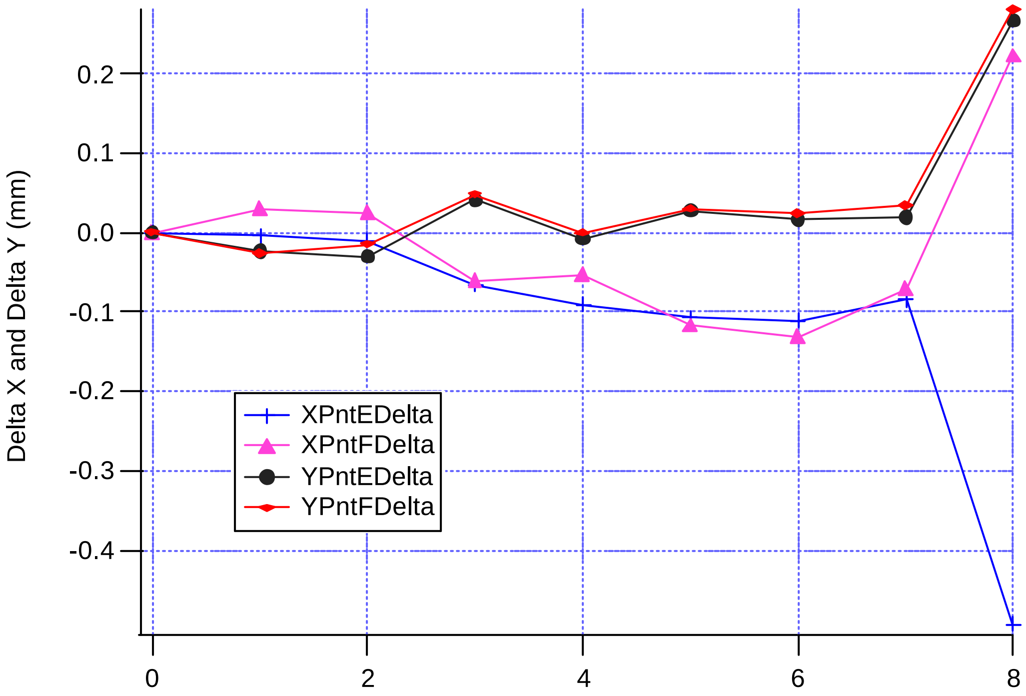

Figure 5.1.1

5.3 Metrology on the flexures

Further inspection of the flexures showed that two of the three flexures on the BDA had bent by as much as 0.3 degrees from the vertical. This bending explains the motion in the point E and F of the BDA.

5.4 Effect of thermal strap

In order to eliminate the possibility that the thermal strap used during the cold vibe was affecting the BDA, warm vibration test (sine sweep) was repeated for the unit. A 0.25 g sine sweep test was performed on the BDA under three configurations, namely a)With non-flight like thermal strap (as used in the cold vibe) b) With flight like thermal strap (consisting of one 1 mm diameter 5N copper wire) and c) no thermal strap.

The sine sweep response data showed that the resonance modes of the BDA are essentially independent of the thermal strap configuration.

5.5 Effect of Residual Stress in the flexure

A sample flexure part was put through a stress relief process (325 C for two hours) and was measured before and after to determine if there was any residual stress in the metal that could have been the cause for the BDA failure during cold vibration test. A comparison of the metrology data on the flexure part showed that the motion due to the stress relief process was minimal and could not have given rise to the motion seen in the BDA failure.

6 Conclusion

The BDA failed during the cold vibration test as shown by the metrology data from the BDA after the test. The following points are worth noting:

1. The BDA failure cannot be attributed to the thermal strap.
2. The BDA failure cannot be attributed to any residual stress that may be present in the flexure part.
3. The resonance modes of the BDA moved to a lower frequency by about 30 Hz. This shift in the BDA modes is still under investigation.

The shift in the resonance modes to a lower frequency resulted in moving the modes up against the edge of the notch in the vibration spectrum. That possibly resulted in the BDA being subjected to a much higher level than the notch-bottom level, namely 0.05 g^2/Hz. That is the most reasonable explanation of the BDA failure.

The lower edge of the notch cannot be moved any lower (since that would mean putting it closer to an instrument resonance mode). Moreover, the test program incorporates cold vibration testing for only one flavor of the BDA and the resonance shifts at cold temperature might be different for the various BDA flavors. The BDA units are at risk of failure due to the high vibration level requirement that necessitated the notched vibration spectrum. Eliminating the notch in the vibration spectrum by testing the BDA to a flat spectrum at 0.05 g^2/Hz would mitigate the above risk.