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Kennedy Space Center, FL 32899

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INFICON Transpector MPH Mass Spectrometer Random Vibration Test Report

Regolith and Environment Science & Oxygen and Lunar Volatile Extraction (RESOLVE)
INFICON Transpector MPH Mass Spectrometer Random Vibration Test Report

Signature Page

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Contents

1. Scope

The purpose of this test report is to summarize results from the vibration testing of the INFICON Transpector MPH100M model Mass Spectrometer. It also identifies requirements satisfied, and procedures used in the test.

2. Objectives

As a payload of Resource Prospector, it is necessary to determine the survivability of the mass spectrometer to proto-qualification level random vibration. Changes in sensitivity of the mass spectrometer can be interpreted as a change in alignment of the instrument. The results of this test will be used to determine any necessary design changes as the team moves forward with flight design.

3. Definitions and Acronyms

The following terms, abbreviations, and acronyms are used in this document:

Hz	Hertz
RESOLVE	Regolith and Environment Science and Oxygen and Lunar Volatile Extraction
LAVA	Lunar Advanced Volatile Analysis
KSC	Kennedy Space Center

4. References and Applicable Documents

Document Number	Document Title
APR 8070.2	Class D Spacecraft Design and Environmental Test
GSFC-STD-7000	General Environmental Verification Standard
NASA-STD-7001A	Payload Vibroacoustic Test Criteria
K0000284282-PLN	INFICON Transpector MPH Mass Spectrometer Random Vibration Test Plan

5. Test Hardware

5.1 Test Articles

The INFICON Transpector MPH100M model Mass Spectrometer was vibration tested at proto-qualification amplitudes for a one-minute duration on each axis. The mass spectrometer was not powered during the vibration tests, as it is powered off during launch. There were two types of ion sources for the mass spectrometer to be tested, and two almost-identical electronics boxes. Vibration on three axes (X, Y, Z) was done using the following hardware combinations:

- Cross-beam ion source with vacuum chamber-tested electronics
- Open Ion with the SBIR electronics

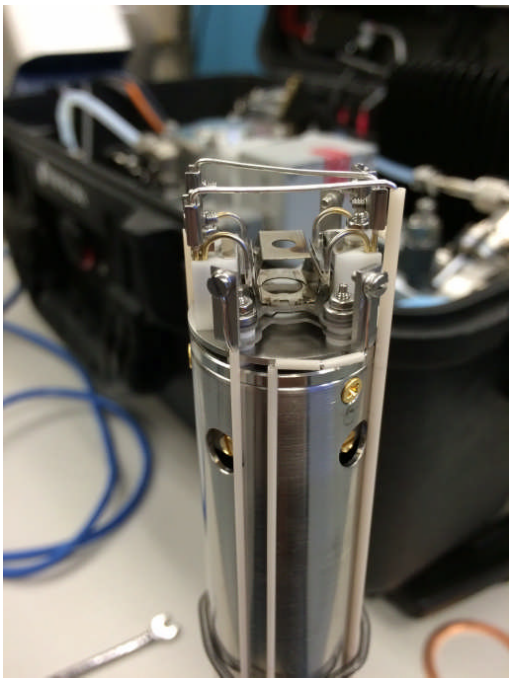


Figure 1. Crossbeam Ion Source.

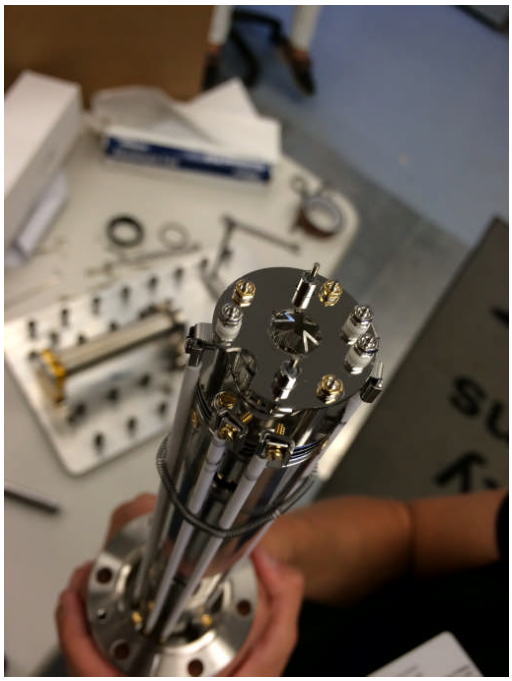


Figure 2. Open Ion Source.

The difference between the two electronics boxes is that the vacuum chamber-tested electronics has more thermal gap pad material.

More info on INFICON Transpector MPH100M can be found in:
http://products.inficon.com/GetAttachment.axd?attaName=Brochure+-+Transpector+MPH+Residual+Gas+Analyzer

5.2 Test Fixture

The Medium/22k Shaker Table and its associated instrumentation, also called the Unholtz-Dickie Model 2XSAI240-T-1000-32LH/ST Electrodynamic Shaker System, are located in the Vibration Laboratory in Building M7-0557 at Kennedy Space Center.

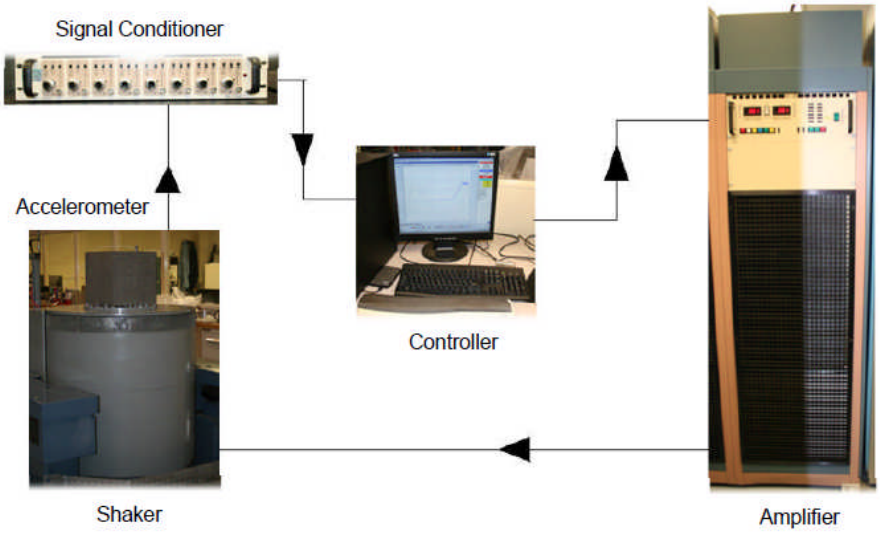


Figure 3. Medium/22k Shaker system.

5.2.1 Specifications

- Generated force, continuous rating 22,000 lbs peak for Sine tests; 20,000 lbf RMS for Random tests (based on flat spectrum 20-2,000 Hz with 1,000 lb payload)
- 480 kVA Amplifier
- 200g max free table acceleration
- 70 inches/sec maximum velocity
- 2 in peak-to-peak shaker stroke
- 100 lb. 17.5” Diameter armature
- Natural frequency Fn = 2,320 Hz
- 48”x48” slip table with 140,000 in-lbs. of pitch moment
- 48”x48” expander head
- 16-channel controller

5.2.2 Sine/Random Vibration Performance Curve

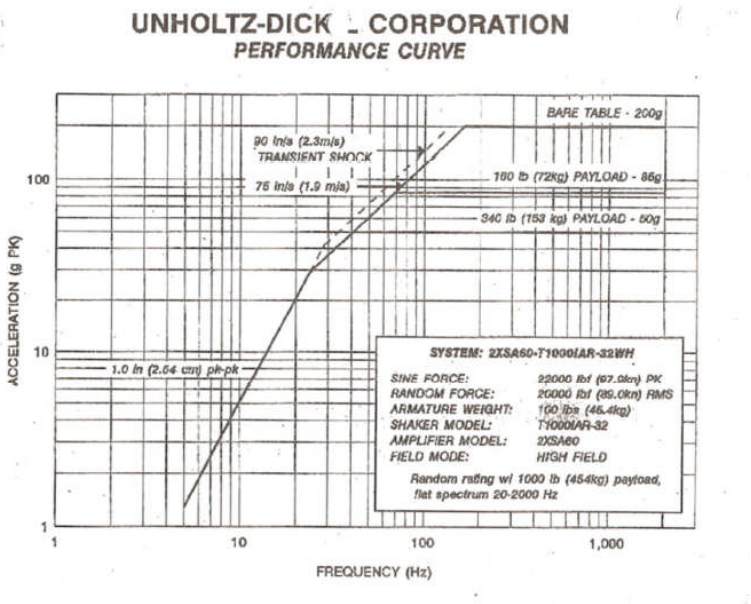


Figure 4. Sine/Random Vibration Performance Curve

5.2.3 Instrumentation

There were two accelerometers used to control vibration levels. The control accelerometers were be placed in locations selected by the vibration test engineer. Monitoring/response/test accelerometers were not used since the ion source and electronics components of interest are too small for accelerometer attachment.

5.3 Test Support Equipment

The portable vacuum system and supporting laptop provided by INFICON was used to establish sensitivity of each MPH with room air sample before and after vibration testing. Optionally, it was used after the Z-axis vibration test.

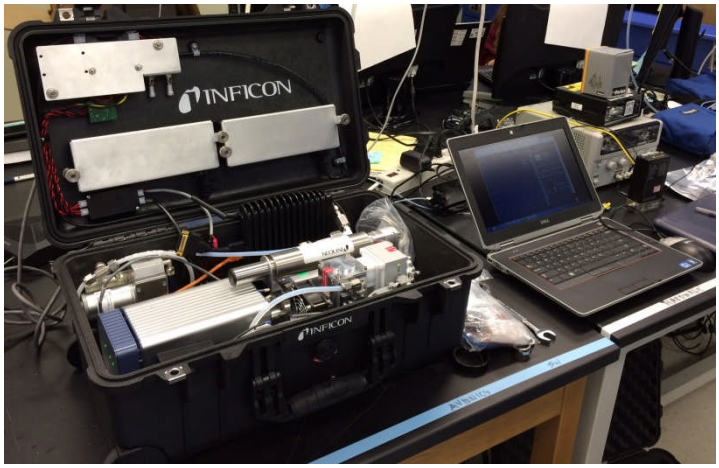


Figure 5. Portable Vacuum System and Supporting Laptop.

5.4 Test Configuration

Mounting hardware was provided by INFICON. Holding the electronics to the plate was a bracket and threaded rod. The sensor extension flange had welded mounting brackets that were secured by M8 x 1.25" serrated cap screw and locking nut onto the mounting plate, as shown below in Figure 6.

The mounting plate was designed and fabricated by the Prototype Laboratory at KSC. It was fabricated from ½" thick aluminum with counterbore on the backside for the head of the serrated cap screw. The test article (either Crossbeam MPH or Open Ion MPH) and the mounting plate and hardware constitute the test assembly.

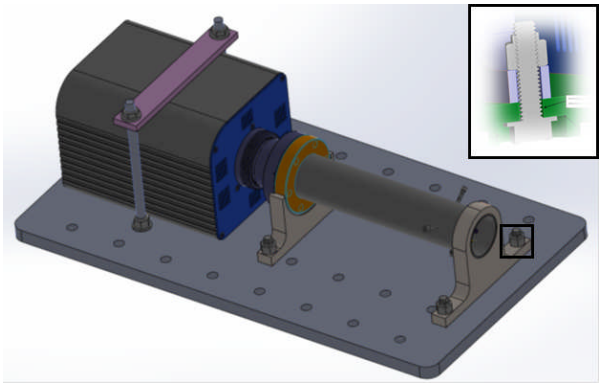
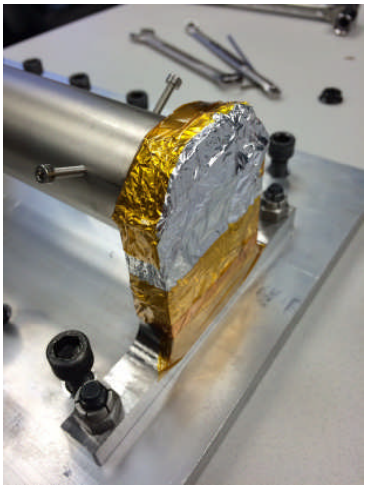


Figure 6. Model of INFICON Transpector MPH with mounting plate and mounting hardware.

The Ion Source was always covered with foil and Kapton tape during the vibration tests in case small components broke off, such that debris did not become projectile.



For the Z-axis, the test assembly was mounted on the Medium/22k shaker table using a secondary attachment fixture called the 32” expander head, as shown in Figure 7. The test assembly mounting screws were torqued down to 300 inch lbs.

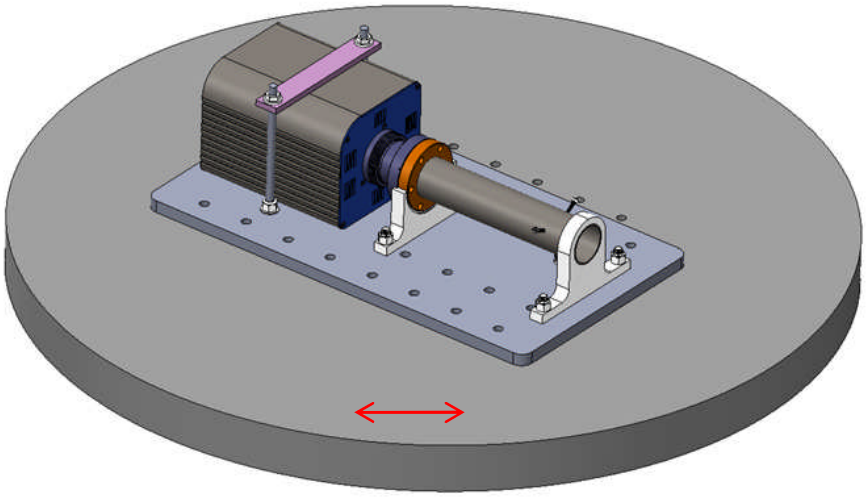


Figure 7. Z-axis configuration using the 32" expander head.

The horizontal plane is shown by the arrows on Figure 7, Figure 8 and Figure 9

For the X and Y axes, the test assembly was mounted directly on the slip table as shown in Figure 8 and Figure 9, with screws torqued down to 300 inch lbs.

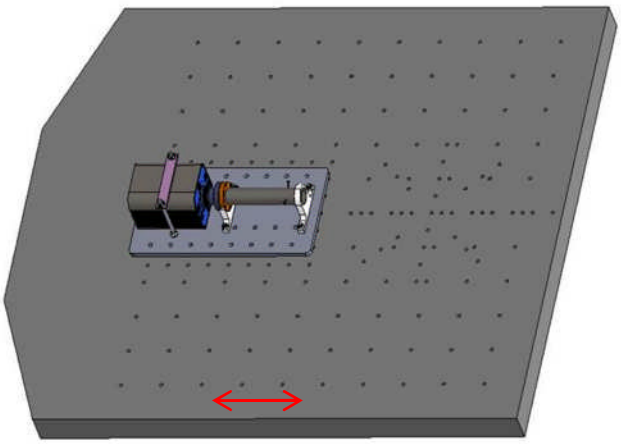


Figure 8. X-axis mounting configuration.

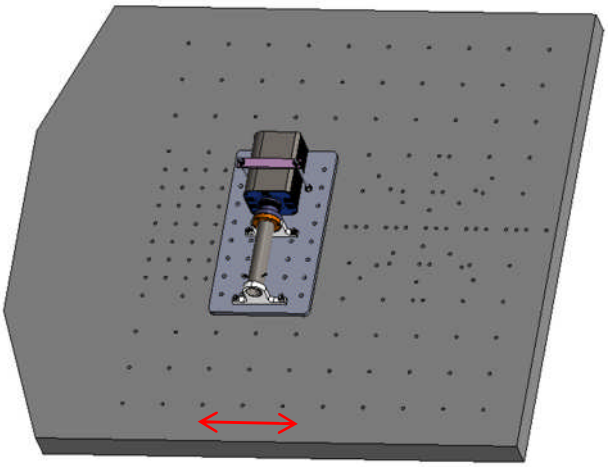


Figure 9. Y-axis mounting configuration.

6. Test Procedure

Since there were no locations of interest on the test article that had large enough surfaces to mount an accelerometer, vibration levels were conducted directly at full level (not stepped up from -12dB to -6dB to -3dB to full level/0dB), and low-level random vibration signature surveys were not conducted before and after testing each axis.

Test Levels, Durations and Tolerances are listed in in Appendix A. The MPH units were both in the unpowered/OFF state during vibration tests.

The tests were performed in the sequence shown in Table 1.

Table 1. Summary of Test Sequence.

Run #	Description	Configuration	Vib Lab Reference Number
-	Pre-Vibration Functional Test	Open Ion MPH	-
-		Crossbeam MPH	-
1	Z-Axis Vibration Test	Open Ion MPH*	K0000284282-PLN-1
2		Crossbeam MPH*	K0000284282-PLN-2
-	Post-Z-axis Functional test	Open Ion MPH	-
-		Crossbeam MPH	-
3	Y-Axis Vibration Test	Open Ion MPH*	K0000284282-PLN-3
4	X-Axis Vibration Test	Open Ion MPH*	K0000284282-PLN-4
5	Y-Axis Vibration Test	Crossbeam MPH*	K0000284282-PLN-5
6	X-Axis Vibration Test	Crossbeam MPH*	K0000284282-PLN-6
-	Post-Y and X-Axes Functional Test	Open Ion MPH	-
-		Crossbeam MPH	-

* Note that the Open Ion MPH was always paired with the SBIR electronics, while the Crossbeam MPH was always paired with the Vacuum-tested electronics during vibration tests.

6.1 Pre-Vibration Functional Test

A Pre-Vibration Functional test was performed on both Crossbeam and Open Ion MPH using the portable vacuum system provided by INFICON to establish pre-vibration sensitivity of the test articles.

Note that the Pre-Vibration Functional tests were conducted one day prior to the vibration tests and in a different location at Kennedy Space Center, such that the room air properties (ex. Temperature) were different. The Pre-Vibration Functional tests were done at O&C Lab 1292, while the vibration tests were done in the Vibration Laboratory.

Following its Pre-vibration Functional Test, the Open Ion MPH was installed in the mounting bracket as shown in Figure 6.

6.2 Z-Axis Vibration Test of Open Ion and Crossbeam MPH

To reduce setup time, vibration testing started with the Z-axis, which was the existing position of the test fixture. The Open Ion MPH was tested first on its Z-axis (Run 1), then uninstalled from the mounting plate. The Crossbeam MPH was installed on the mounting plate, then tested on its Z-axis (Run 2).

Both test assemblies were tested on the Z-axis before reconfiguring the test fixture for Y-axis, then X-axis testing.

6.3 Post-Z-Axis Functional Test

Post-Z-Axis vibration Inspection and functional Tests were conducted on both the Crossbeam and Open Ion MPH units. The inspection was done to examine the test articles for debris and failed components. The functional test was used to determine whether the Z-axis vibration altered the instruments' sensitivities adversely.

6.4 Y and X-Axes Vibration Test of Open Ion MPH

The Open Ion MPH was installed on the mounting plate, tested on its Y-axis (Run 3) then its X-axis (Run 4), then uninstalled from the mounting plate.

6.5 Y and X-Axes Vibration Test of Crossbeam MPH

The Crossbeam MPH was installed on the mounting plate, tested on its Y-axis (Run 5), tested on its X-axis (Run 6), the uninstalled from the mounting plate.

6.6 Post-Y and X-Axes Functional Test

Post-Y and X-axes vibration inspection and functional test were conducted on both the Crossbeam and Open Ion MPH units. Again, the inspection was done to examine the test articles for debris and failed components. The functional test was used to determine whether the Y- and X-axes vibration altered the instruments' sensitivities adversely.

7. Test Results

Table 2 shows a summary of observations from the tests.

Table 2. Summary of Test Observations.

Run #	Description	Configuration	Date & Time	Observations
-	Pre-Vibration Functional Test	Open Ion MPH	8/5/15, PM	
-		Crossbeam MPH	8/5/15, PM	
1	Z-Axis Vibration Test	Open Ion MPH*	8/6/15, 09:52	
2		Crossbeam MPH*	8/6/15, 11:24	
-	Post-Z-axis Functional test	Open Ion MPH	-	Ion Source OK; Failed RF board
-		Crossbeam MPH	-	Ion Source and Electronics OK; External set screw fell off
3	Y-Axis Vibration Test	Open Ion MPH*	8/6/15, 12:21	
4	X-Axis Vibration Test	Open Ion MPH*	8/6/15, 12:37	
5	Y-Axis Vibration Test	Crossbeam MPH*	8/6/15, 13:09	
6	X-Axis Vibration Test	Crossbeam MPH*	8/6/15, 13:21	
-	Post-Y and X-Axes Functional Test	Open Ion MPH	-	Ion Source functional in EM mode; EM detector damaged but low intensity peaks still observed.
-		Crossbeam MPH	-	Lost a quad screw on RF shunt (no lock washer) - Functional with replaced screw; One ceramic sheath broke

* Note that the Open Ion MPH was always paired with the SBIR electronics, while the Crossbeam MPH was always paired with the Vacuum-tested electronics during vibration tests.

7.1 Open Ion MPH

7.1.1 Open Ion MPH Pre-Vibration Functional Test

Raw data is in Appendix D: MPH Functional Test Data.

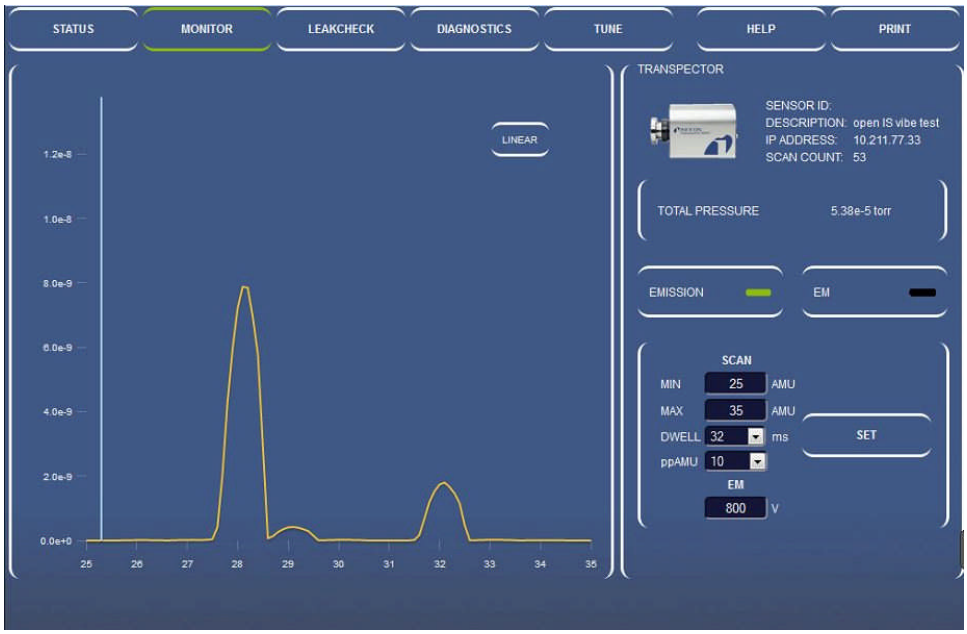
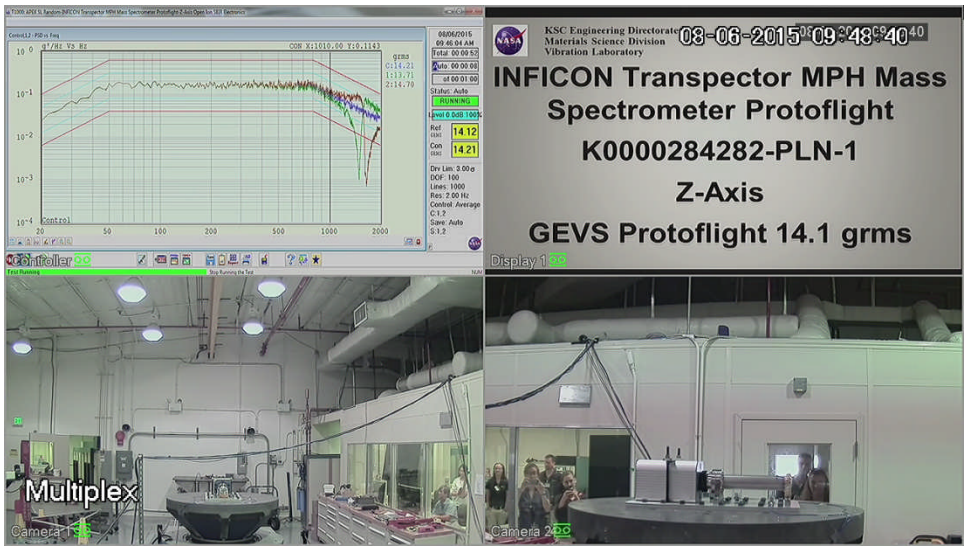


Figure 10. Open Ion MPH Pre-Vibration Functional Test with Room Air.

7.1.2 Open Ion MPH Z-Axis Vibration Test

Vibration video is in B.1 INFICON Transpector MPH Mass Spectrometer Protoflight Z-Axis Open Ion SBIR Electronics.



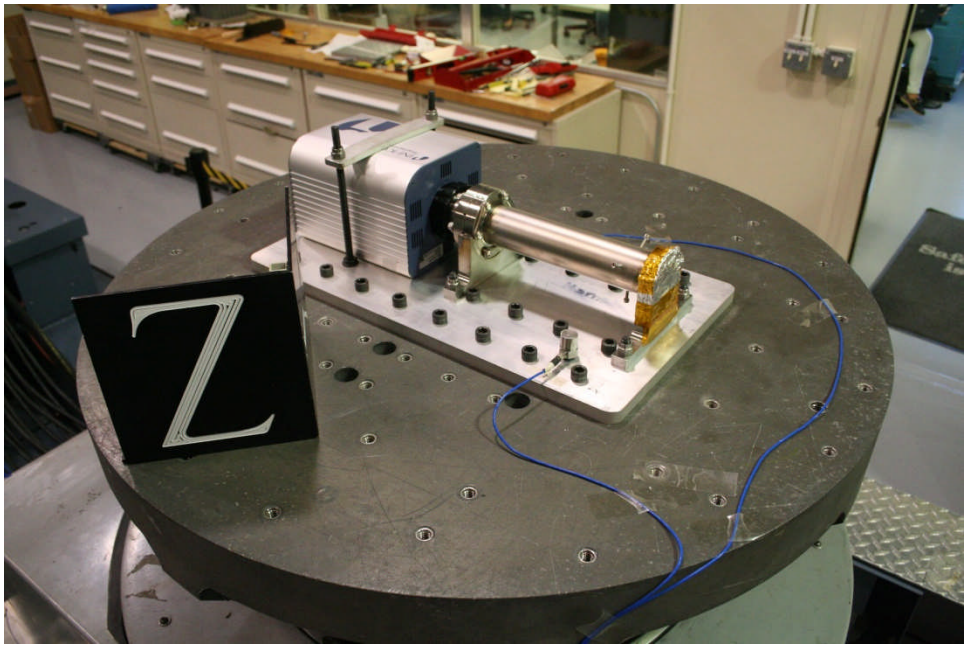


Figure 11. Open Ion MPH Z-Axis Vibration Test Screenshot and Photo.

7.1.3 Open Ion MPH Post-Z-Axis Functional Test

The SBIR electronics failed during Z-axis Vibration Testing. The damage was narrowed down to the RF board by swapping a known working RF board temporarily with the SBIR electronics' RF board and testing the electronics. Upon closer inspection, a nut was found to have shaken loose, allowing the coil to move and be damaged during vibration testing.

The Open Ion source was tested with vacuum-tested electronics and determined to be healthy. For the remaining Y- and X-axes, the SBIR electronics was again paired with the SBIR electronics, including the damaged RF board.

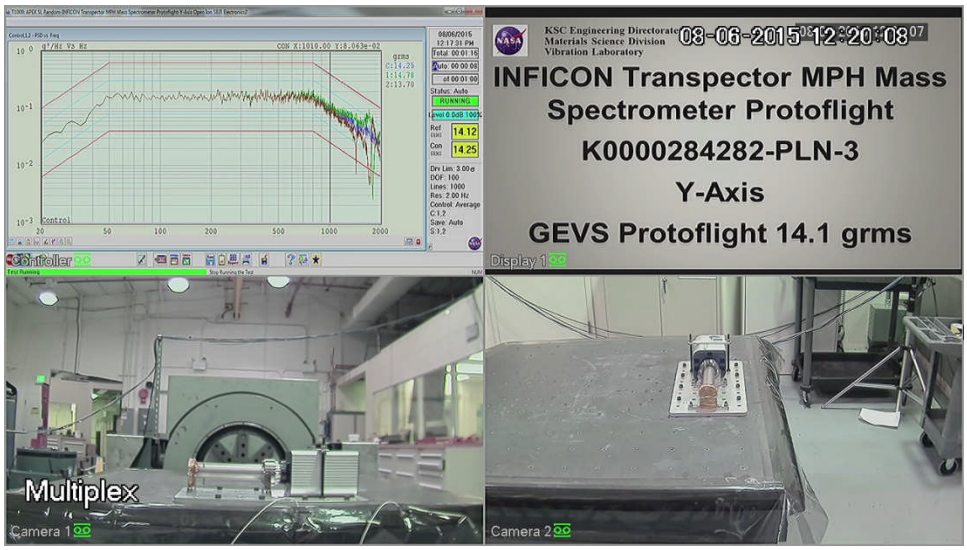
Raw data is in Appendix D: MPH Functional Test Data.

Figure 12. Open Ion Source Post-Z-Axes Functional Test with Room Air.

Figure 13. RF board inside the SBIR electronics enclosure (top) and disassembled for inspection (bottom).

7.1.4 Open Ion MPH Y-Axis Vibration Test

Vibration video is in B.2 INFICON Transpector MPH Mass Spectrometer Protoflight Y-Axis Open Ion SBIR Electronics.



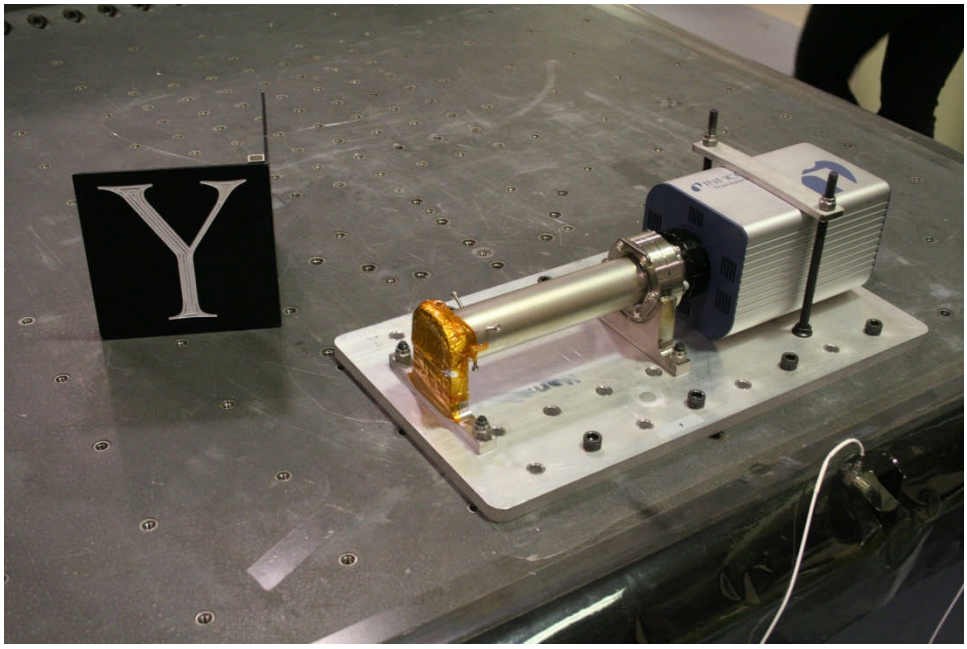


Figure 14. Open Ion MPH Y-Axis Vibration Test Screenshot and Photo.

7.1.5 Open Ion MPH X-Axis Vibration Test

Vibration video is in B.3 INFICON Transpector MPH Mass Spectrometer Protoflight X-Axis Open Ion SBIR Electronics.

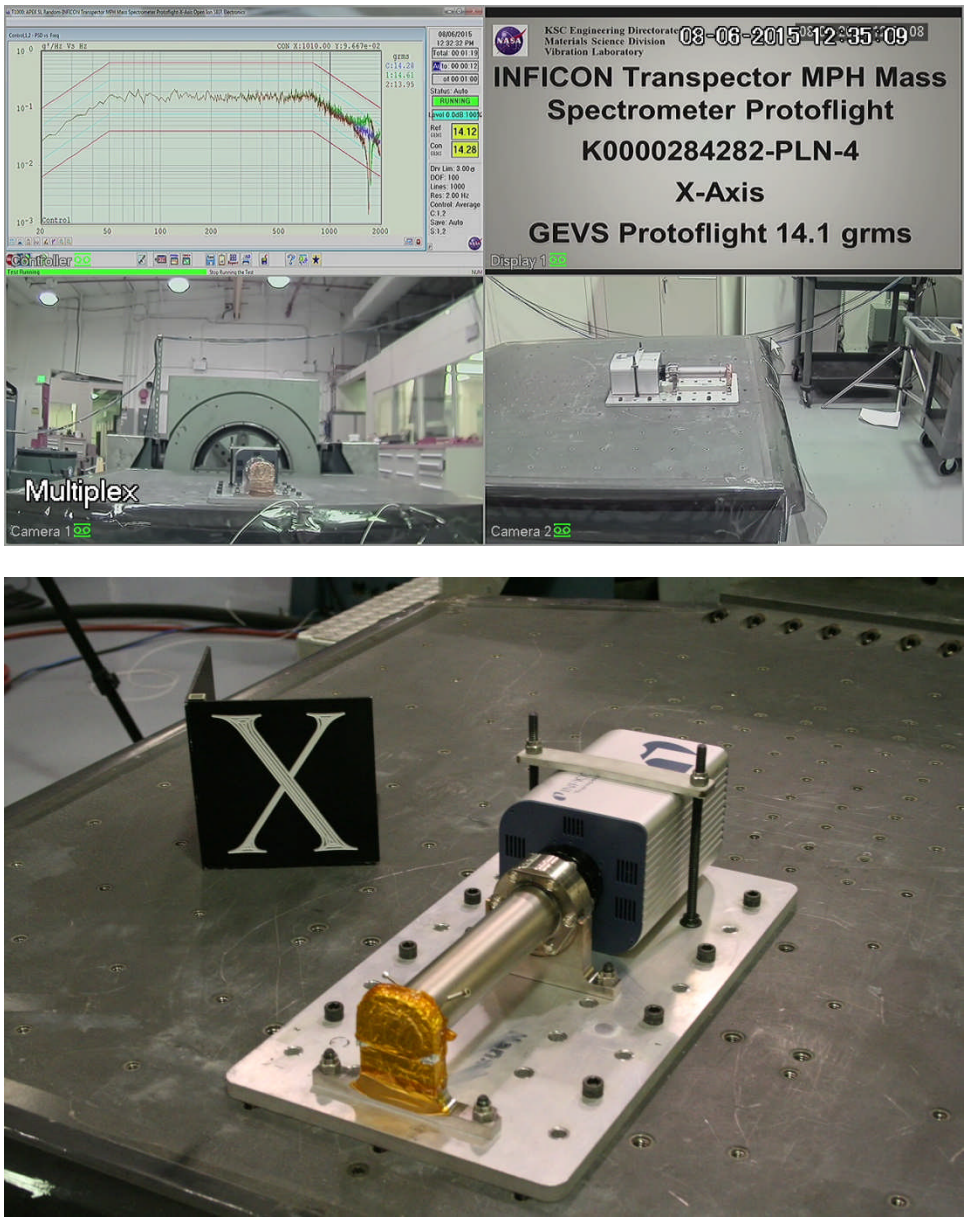


Figure 15. Open Ion MPH X-Axis Vibration Test Screenshot and Photo.

7.1.6 Open Ion MPH Post-Y and X-Axes Functional Test

Since the SBIR electronics' RF Board Failed during Z-axis Vibration Testing, the Open Ion source was tested with vacuum-tested electronics.

The Open Ion source did not perform as expected with EM OFF. All other testing was done with EM OFF. Low intensity peaks were observed when the test was performed in emission mode (EM ON). Emission mode has a higher sensitivity that was able to pick up signal despite the damage. Note the unusal shape of the water peak in Figure 16.

Raw data is in Appendix D: MPH Functional Test Data.

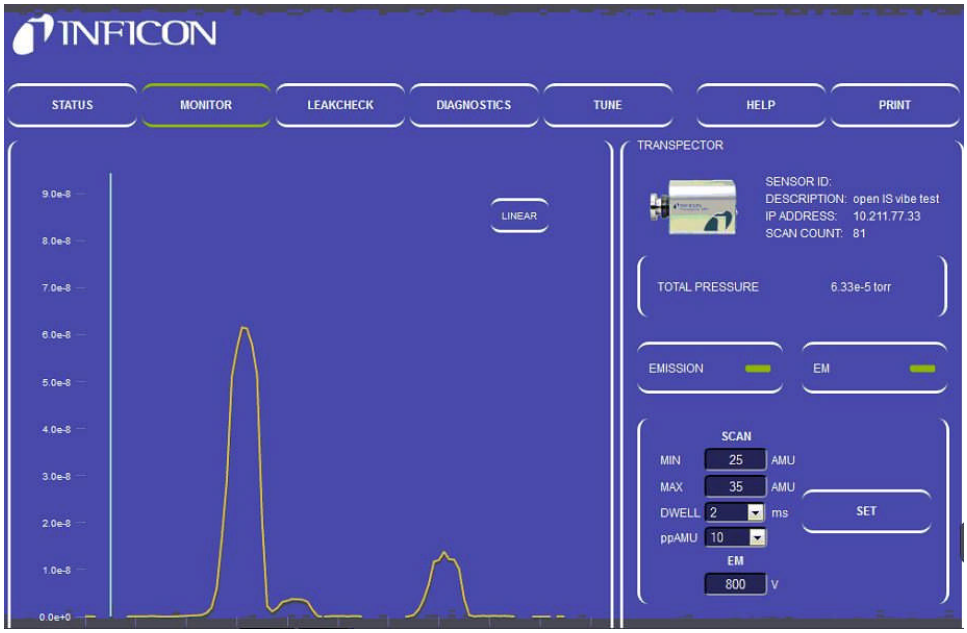


Figure 16. Open Ion Source Post-Y and X-Axes Functioanl Test with Room Air.

Upon disassembly and inspection, it was discovered that the detector was damaged in an area where it was spot welded.

Figure 17. Damaged detector.

7.2 Crossbeam MPH

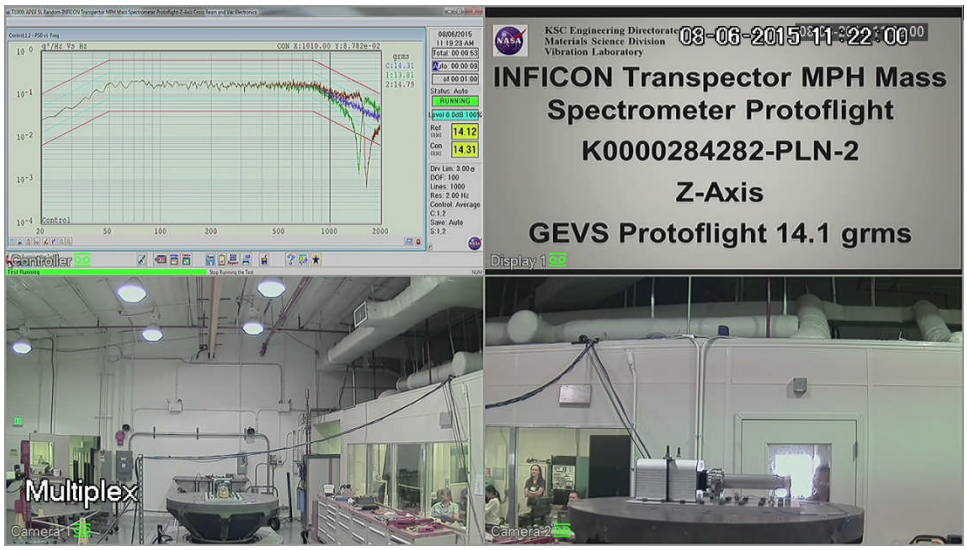
7.2.1 Crossbeam MPH Pre-Vibration Functional Test

Raw data is in Appendix D: MPH Functional Test Data.

Figure 18. Crossbeam MPH Pre-Vibration Functional Test with Room Air.

7.2.2 Crossbeam MPH Z-Axis Vibration Test

Vibration video is inC.1 INFICON Transpector MPH Mass Spectrometer Protoflight Z-Axis Crossbeam and Vac Electronics.



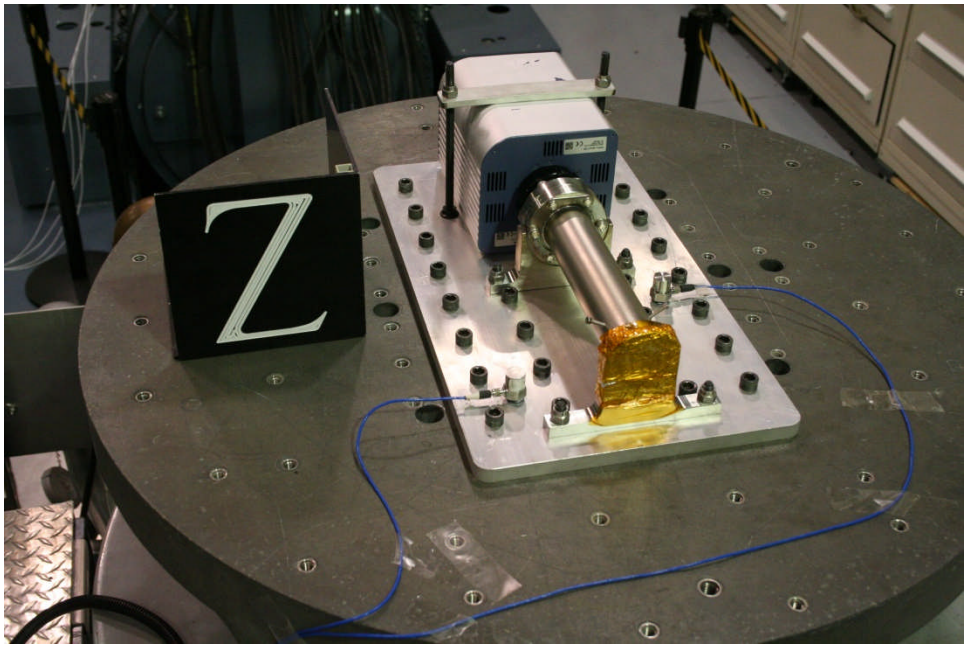


Figure 19. Crossbeam MPH Z-Axis Vibration Test Screenshot and Photo.

One external set screw fell off during the test. That screw is one of three that secure the detector inside the sensor extension flange.

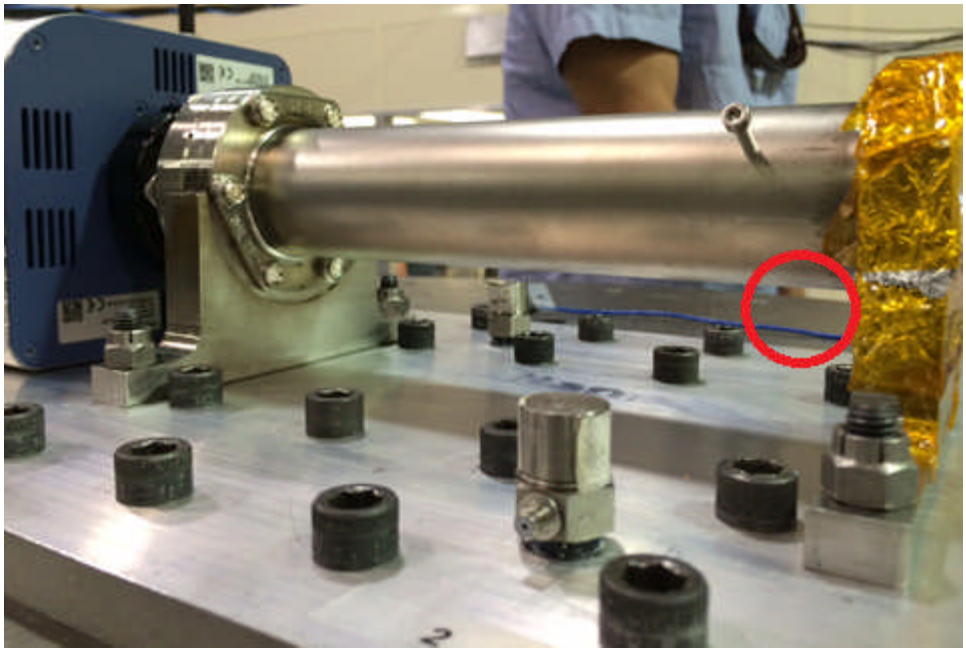


Figure 20. Missing external set screw location depicted in red.

7.2.3 Crossbeam MPH Post-Z-Axis Functional Test

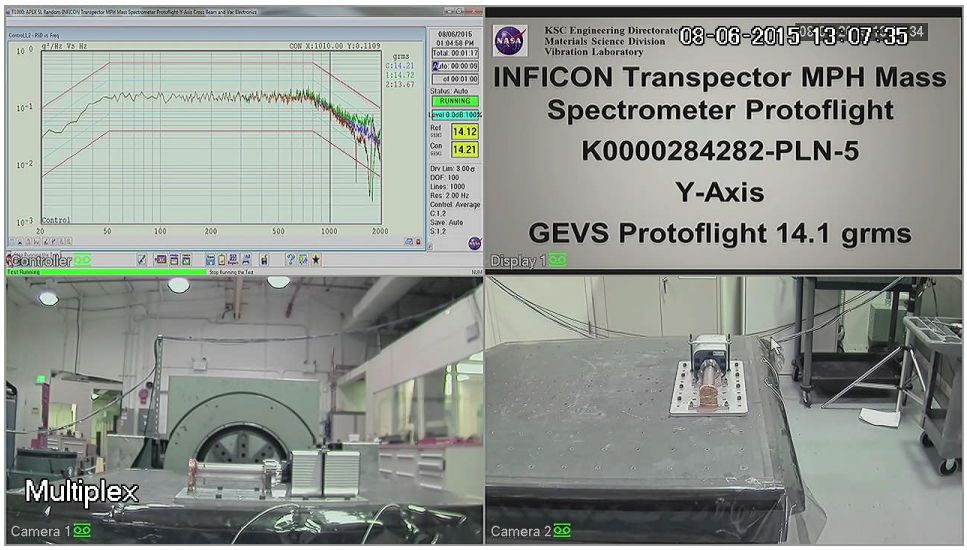
The external screw that fell off did not affect the functionality of the test article.

Raw data is in Appendix D: MPH Functional Test Data.

Figure 21. Crossbeam MPH Post-Z-Axis Functional Test with Room Air.

7.2.4 Crossbeam MPH Y-Axis Vibration Test

Vibration video is inC.2 INFICON Transpector MPH Mass Spectrometer Protoflight X-Axis Crossbeam and Vac Electronics.



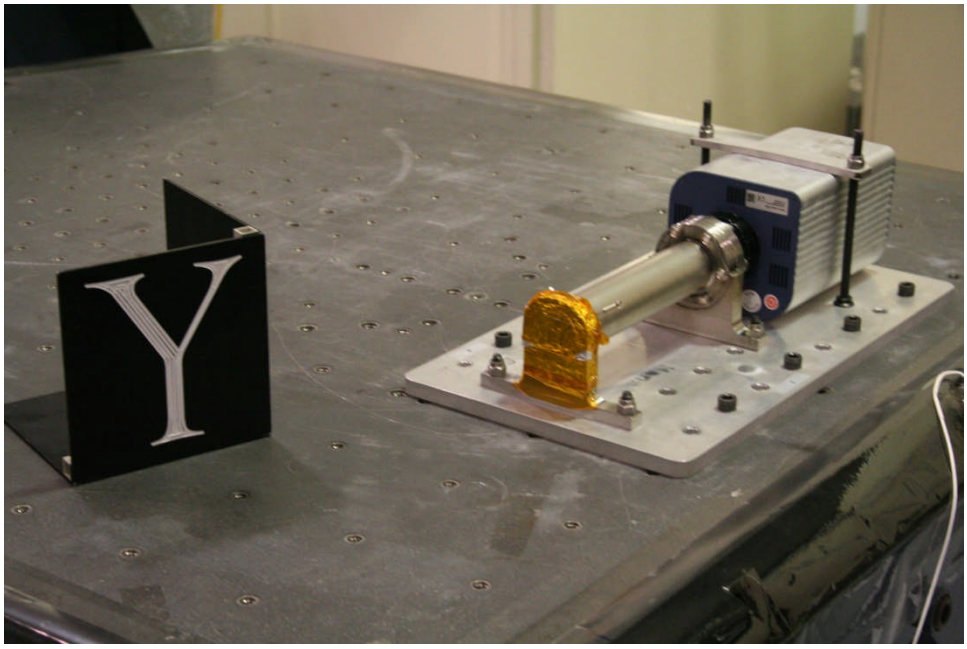
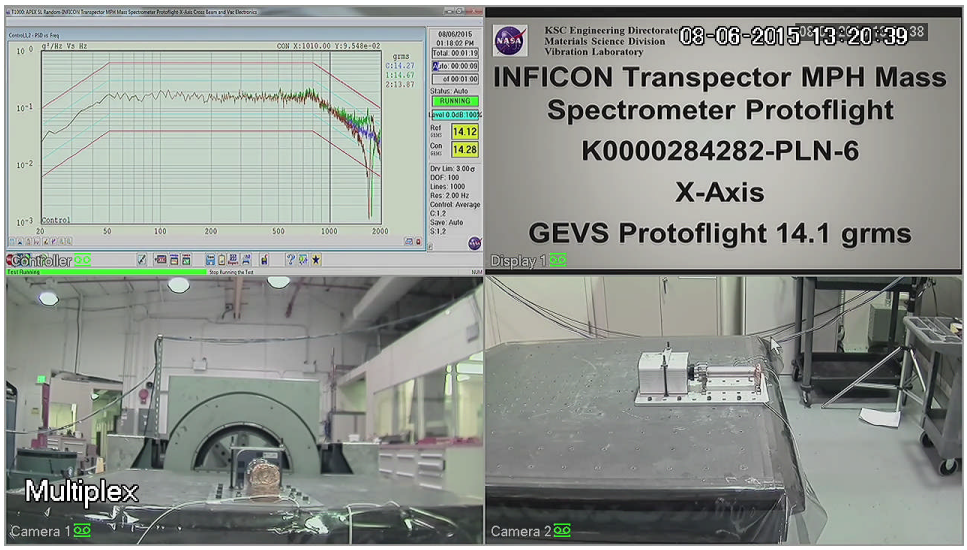


Figure 22. Crossbeam MPH Y-Axis Vibration Test Screenshot and Photo.

7.2.5 Crossbeam MPH X-Axis Vibration Test

Vibration video is in C.3 INFICON Transpector MPH Mass Spectrometer Protoflight Y-Axis Crossbeam and Vac Electronics.



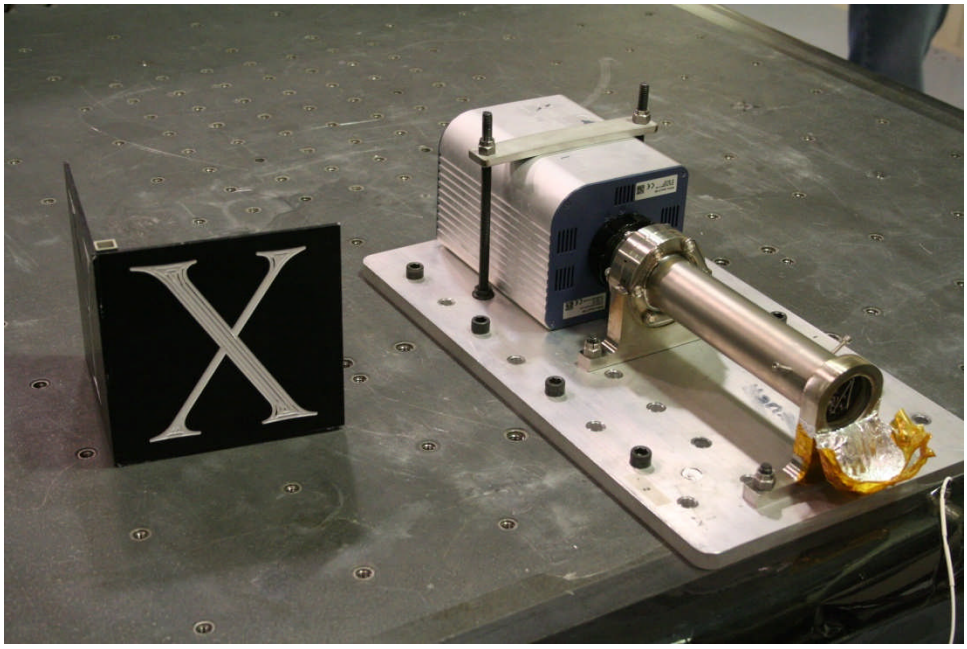


Figure 23. Crossbeam MPH Y-Axis Vibration Test Screenshot and Photo.

7.2.6 Crossbeam MPH Post-Y and X-Axes Functional Test

One set screw, out of four holding the RF shunt together, came off. The screw was replaced before being functionally tested. The test article responded nominally. There was also a ceramic sheath that was damaged, but did not seem to affect functionality.

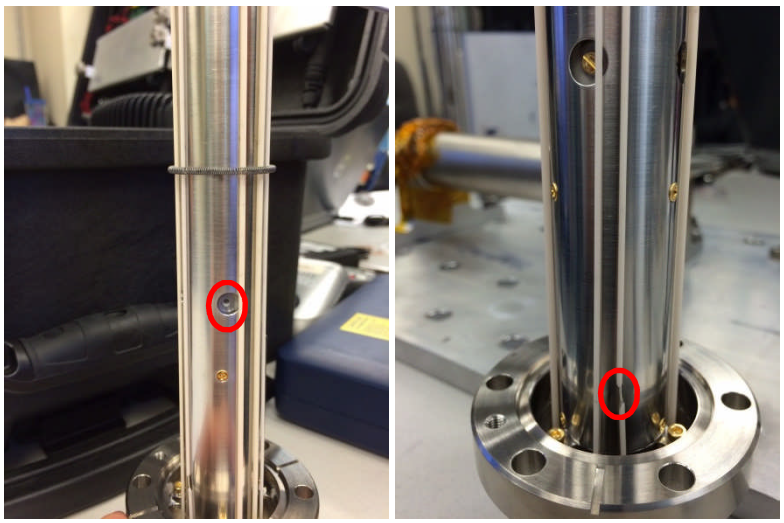


Figure 24. RF shunt showing a missing screw (left) and broken ceramic sheath (right).

Raw data is in Appendix D: MPH Functional Test Data.

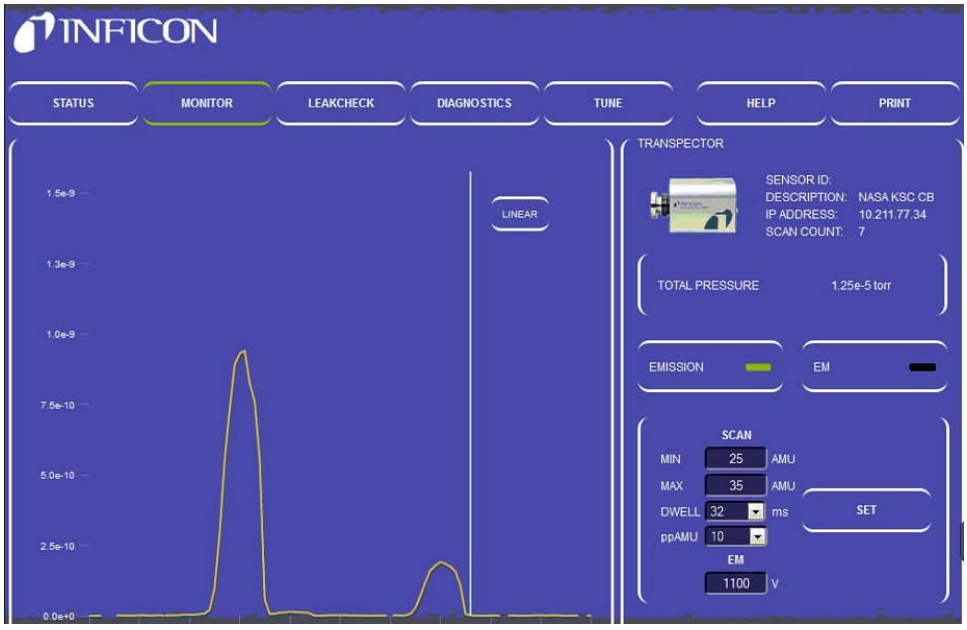


Figure 25. Crossbeam MPH Post-Y and X-Axis Functional Test with Room Air.

Appendix A: Test Levels, Durations and Tolerances

• Generalized Random Vibration Test Levels

From GSFC-STD-7000, Table 2.4-3. This table is similar to APR 8070.2 Table 4.3.2.1-1 but the APR document has the levels for the Qualification and Acceptance Test levels reversed. Per APR 8070.2 and NASA –STD-7001A the protoflight test levels are the same as the qualification test levels.

Frequency (Hz)	Protoflight Level
20	0.026 g^2/Hz
20-50	+6 dB/Oct
50-800	0.16 g^2/Hz
800-2000	-6 dB/Oct
2000	0.026 g^2/Hz
Overall	14.1 g_{rms}

• Test Durations

From APR 8070.2 Table 4.3.1-1 Test Factors & Durations

Test	**Protoflight**
Random Vibration Level Duration	1 minute/axis

• Test Control Tolerances

From APR 8070.2 Table 4.2.2.1-1 Testing Tolerances and NASA-STD-7001A Section 4.3.4.1

Composite RMS Acceleration	**Acceleration Spectral Density (25 Hz or less frequency resolution)**	**Frequency**	**Test Duration**
+/- 10%	+/- 3dB	+/- 5%	+10%, -0%

Appendix B: Open Ion MPH Vibration Video

B.1 INFICON Transpector MPH Mass Spectrometer Protoflight Z-Axis Open Ion SBIR Electronics

B.2 INFICON Transpector MPH Mass Spectrometer Protoflight Y-Axis Open Ion SBIR Electronics

B.3 INFICON Transpector MPH Mass Spectrometer Protoflight X-Axis Open Ion SBIR Electronics

Appendix C: Crossbeam MPH Vibration Video

C.1 INFICON Transpector MPH Mass Spectrometer Protoflight Z-Axis Crossbeam and Vac Electronics

INFICON-201508061
12151[8]_2_A_M.avi

C.2 INFICON Transpector MPH Mass Spectrometer Protoflight X-Axis Crossbeam and Vac Electronics

INFICON-201508061
30725[8]_5_A_M.avi

C.3 INFICON Transpector MPH Mass Spectrometer Protoflight Y-Axis Crossbeam and Vac Electronics

INFICON-201508061
32029[8]_6_A_M.avi

Appendix D: MPH Functional Test Data

VIBE MS DATA.xlsx