DynaQual Test Labs

Where being stressed is a good thing

ISO/IEC 17025:2017 ACCREDITED

Test Report
Sine Sweep and Random Vibration

TR-120423-1   December 04, 2023

COMPANY: NanoRacks, LLC
503 Forge River Road
Webster, TX 77598

COMPANY REP: Maximilian Brummel, Joel Murch-Shafer

DYNAQUAL TEST TECH: Ken Dimick

PRODUCT TESTED: Big Red SAT 1

The undersigned have produced and reviewed the data collected and presented in the following report. By signing below, DynaQual Test Labs technical staff verifies that the data is accurate and obtained from functioning and calibrated equipment. Also, the undersigned determine that all data collection techniques are authentic, and the observations and conclusions are true results of the tests performed on the dates indicated above. This report shall not be reproduced except in full without approval of the laboratory. Lastly, the report's results apply only to the sample(s) received for this test.

APPROVAL SIGNATURE SECTION:

Testing Performed By:

Ken Dimick

Ken Dimick, Lab Technician

Approved By:

Bill Burt

Bill Burt, Sr. Technical Writer

12/06/2023
Date

PROJECT SCOPE

NanoRacks, LLC requested the services of DynaQual Test Labs to perform vibration testing on one of their Soft Stow Big Red SAT assemblies. The testing consisted of sine sweep and random vibration testing.

The following test report covers the test program and describes the tests performed, with any associated input/output profiles. The testing was performed at DynaQual's vibration lab. All equipment and sensor measurements were performed with calibrated equipment and trained, qualified personnel.

Definitions

UUT – Unit Under Test

UUT Identification

The UUT and dates the unit was subjected to testing is shown in Table 1.

Table 1 – Product Identifiers

UUT	Description	S/N	Date Tested
1	Big Red SAT 1	001	12/04/2023

VIBRATION TESTING PARAMETERS/SETUP

Table 2 – Description of Test Equipment

Description	Manufacturer	Model	S/N	Cal Due
Vibration System	ETS-714 Shaker	MPA714	SH1204115	N/A
Vibration Controller	Vibration Research	VR9500	9511B7F2	06/20/2024
Vibration Controller	Vibration Research	VR9500	950E43A0	06/20/2024
Control accelerometer	Dytran Instruments	3055B1T	16147	06/22/2024

Vibration System: ETS MPA714 15,400 lbf shaker was used to perform the testing. (Figure 1)

Figure 1: ETS-714, 15,400 lbf Shaker with 2'x5' slip table

Testing Program – Vibration

The UUT was subjected to testing per the following:

1. Sine sweep, 5-2000Hz, $0.5G_{peak}$, 2 octaves per minute, in the Z, X, and Y axes, performed both pre and post random vibration.
2. Random vibration, 20-2000Hz, $5.757G_{rms}$, for 1 minute, in the Z, X, and Y axes.
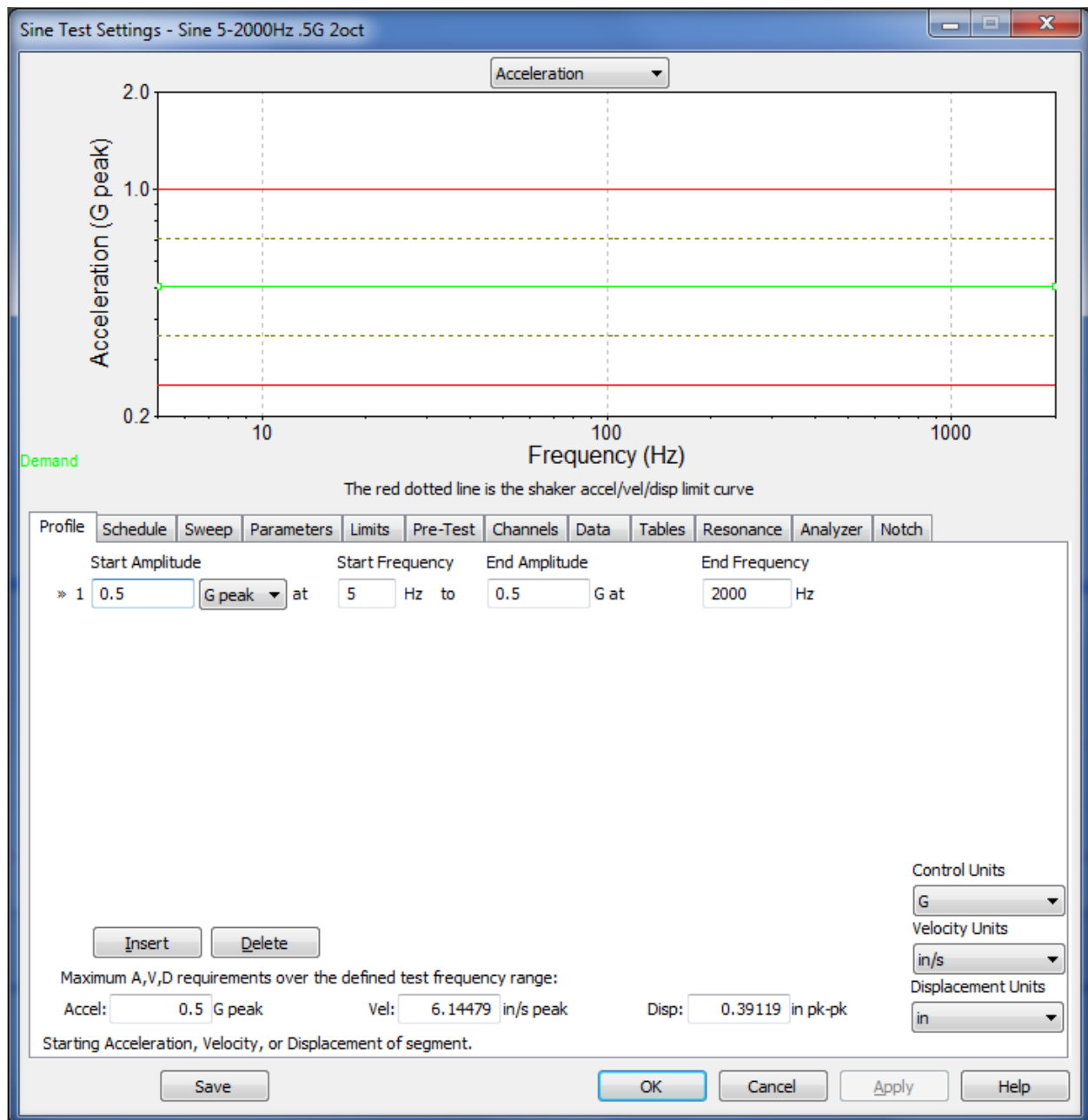
The vibration profiles are shown below in Figures 2–7.

Sine Test Settings - Sine 5-2000Hz .5G 2oct

Acceleration ▼

The red dotted line is the shaker accel/vel/disp limit curve

| Profile | Schedule | Sweep | Parameters | Limits | Pre-Test | Channels | Data | Tables | Resonance | Analyzer | Notch |

Start Amplitude   Start Frequency   End Amplitude   End Frequency

» 1 `0.5` `G peak ▼` at `5` Hz to `0.5` G at   `2000` Hz

Control Units
`G ▼`

Velocity Units
`in/s ▼`

Displacement Units
`in ▼`

[Insert] [Delete]

Maximum A,V,D requirements over the defined test frequency range:

Accel: `0.5` G peak   Vel: `6.14479` in/s peak   Disp: `0.39119` in pk-pk

Starting Acceleration, Velocity, or Displacement of segment.

[Save]   [OK] [Cancel] [Apply] [Help]

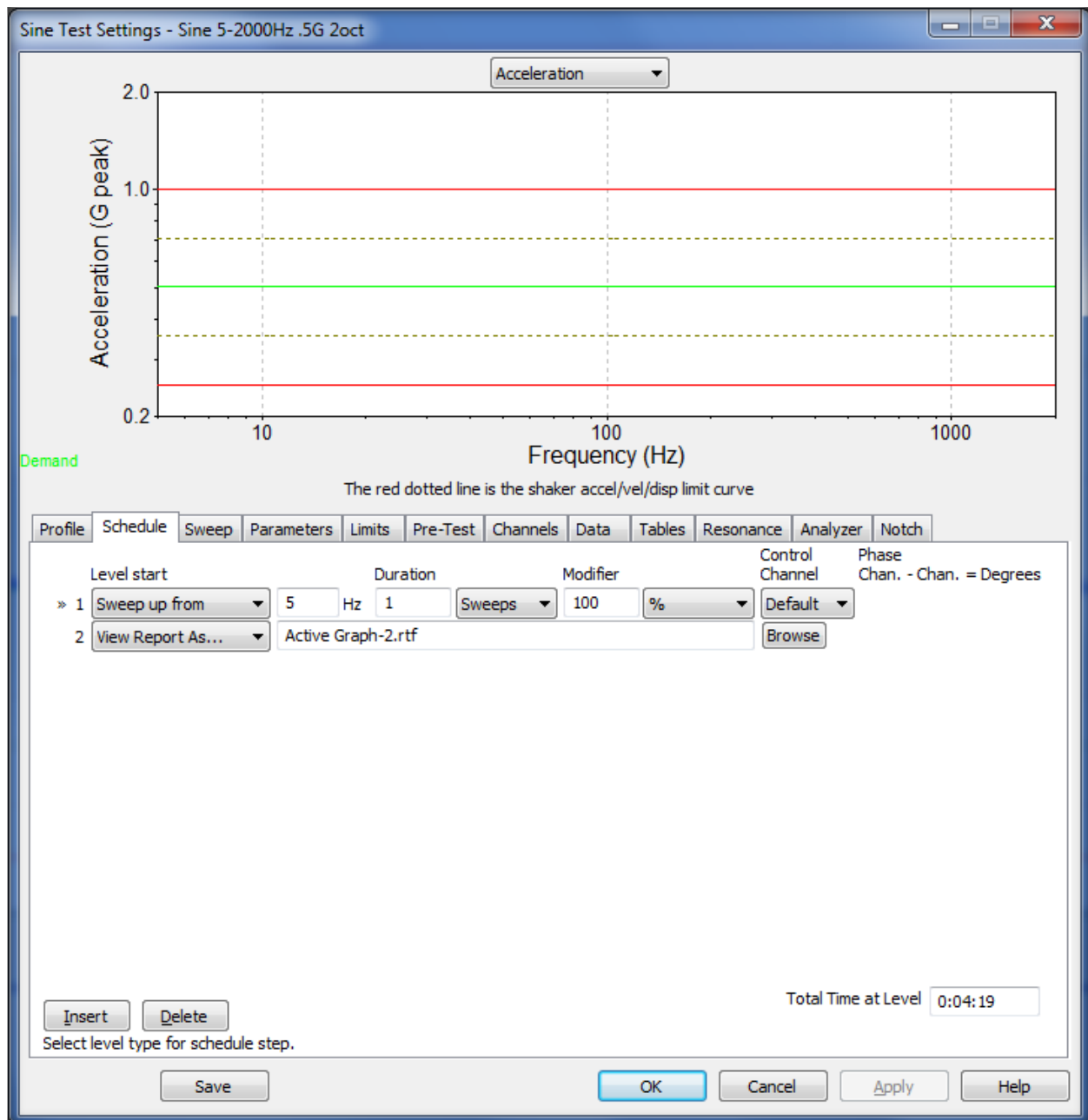**Figure 2: Pre and Post Random Sine, 5-2000Hz, 0.5G$_{peak}$, 2 Octaves per Minute – Profile**

Figure 3: Pre and Post Random Sine, 5-2000Hz, 0.5G_peak, 2 Octaves per Minute – Schedule
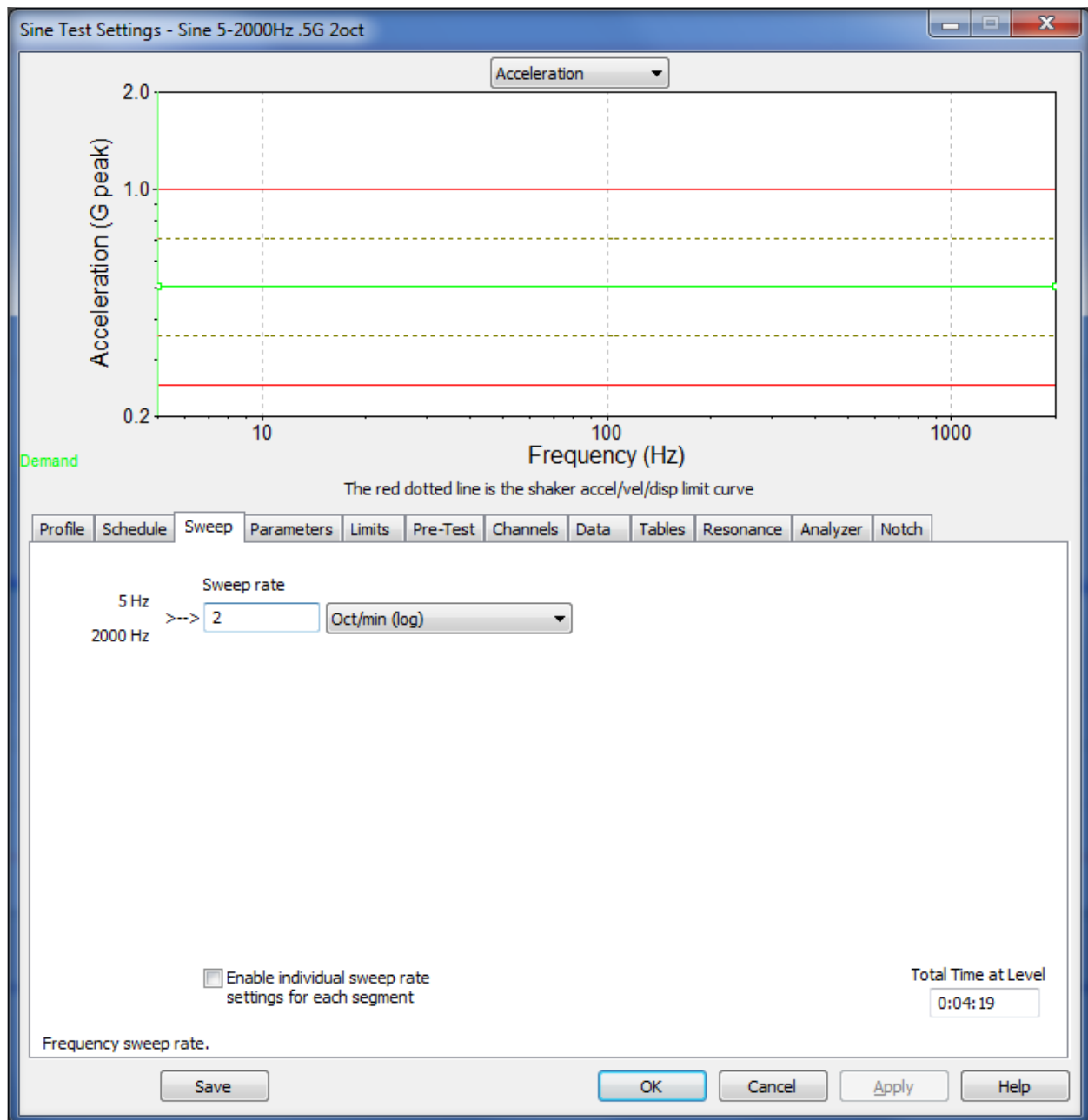
Figure 4: Pre and Post Random Sine, 5-2000Hz, 0.5G$_{peak}$, 2 Octaves per Minute – Sweep
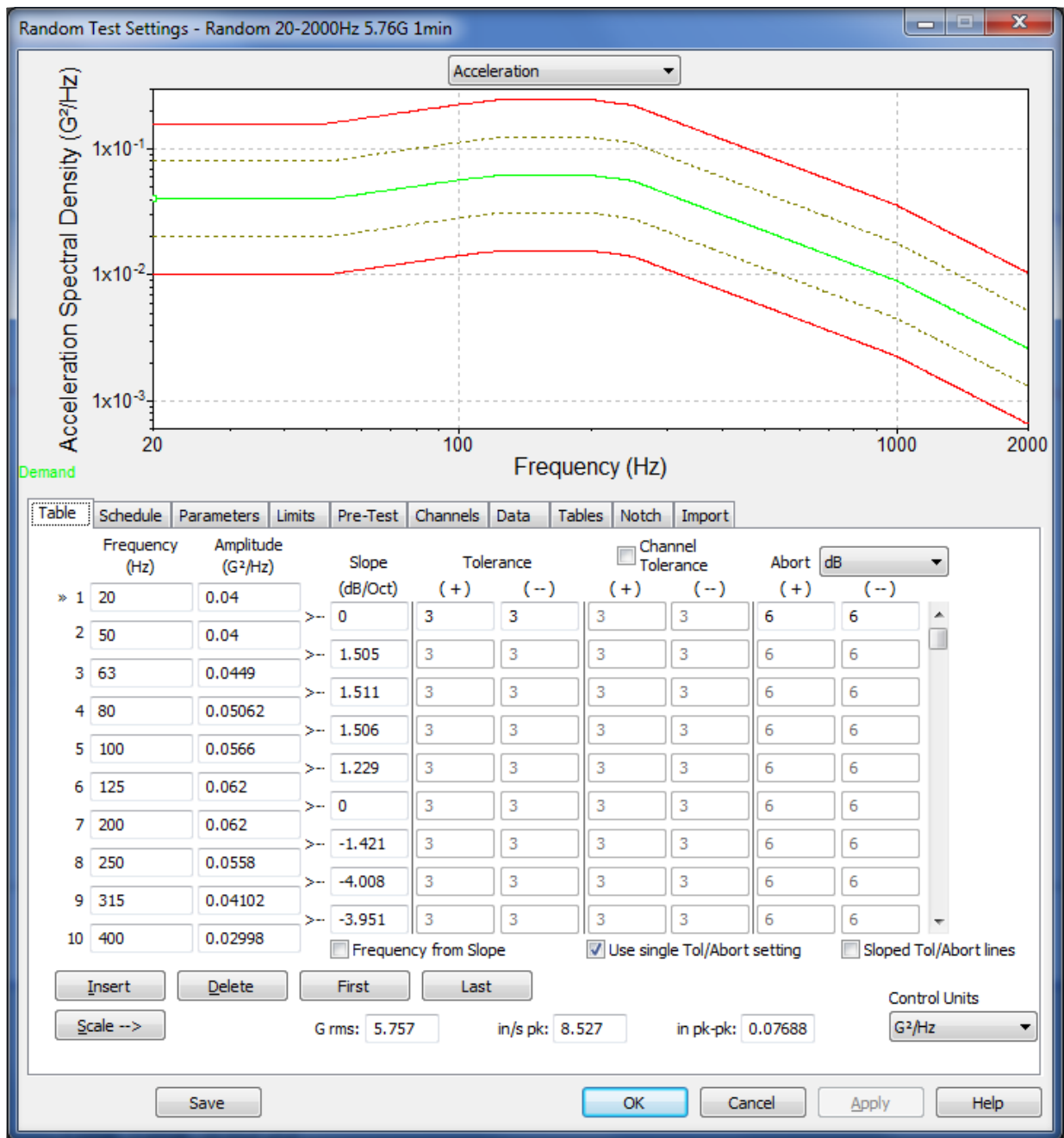
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Random Test Settings - Random 20-2000Hz 5.76G 1min

Acceleration

#	Frequency (Hz)	Amplitude (G²/Hz)	Slope (dB/Oct)	Tolerance (+)	Tolerance (--)	Channel Tolerance (+)	Channel Tolerance (--)	Abort dB (+)	Abort dB (--)
» 1	20	0.04	0	3	3	3	3	6	6
2	50	0.04	1.505	3	3	3	3	6	6
3	63	0.0449	1.511	3	3	3	3	6	6
4	80	0.05062	1.506	3	3	3	3	6	6
5	100	0.0566	1.229	3	3	3	3	6	6
6	125	0.062	0	3	3	3	3	6	6
7	200	0.062	-1.421	3	3	3	3	6	6
8	250	0.0558	-4.008	3	3	3	3	6	6
9	315	0.04102	-3.951	3	3	3	3	6	6
10	400	0.02998							

☐ Frequency from Slope   ☑ Use single Tol/Abort setting   ☐ Sloped Tol/Abort lines

Insert   Delete   First   Last

Scale -->

G rms: 5.757   in/s pk: 8.527   in pk-pk: 0.07688

Control Units: G²/Hz

Save   OK   Cancel   Apply   Help

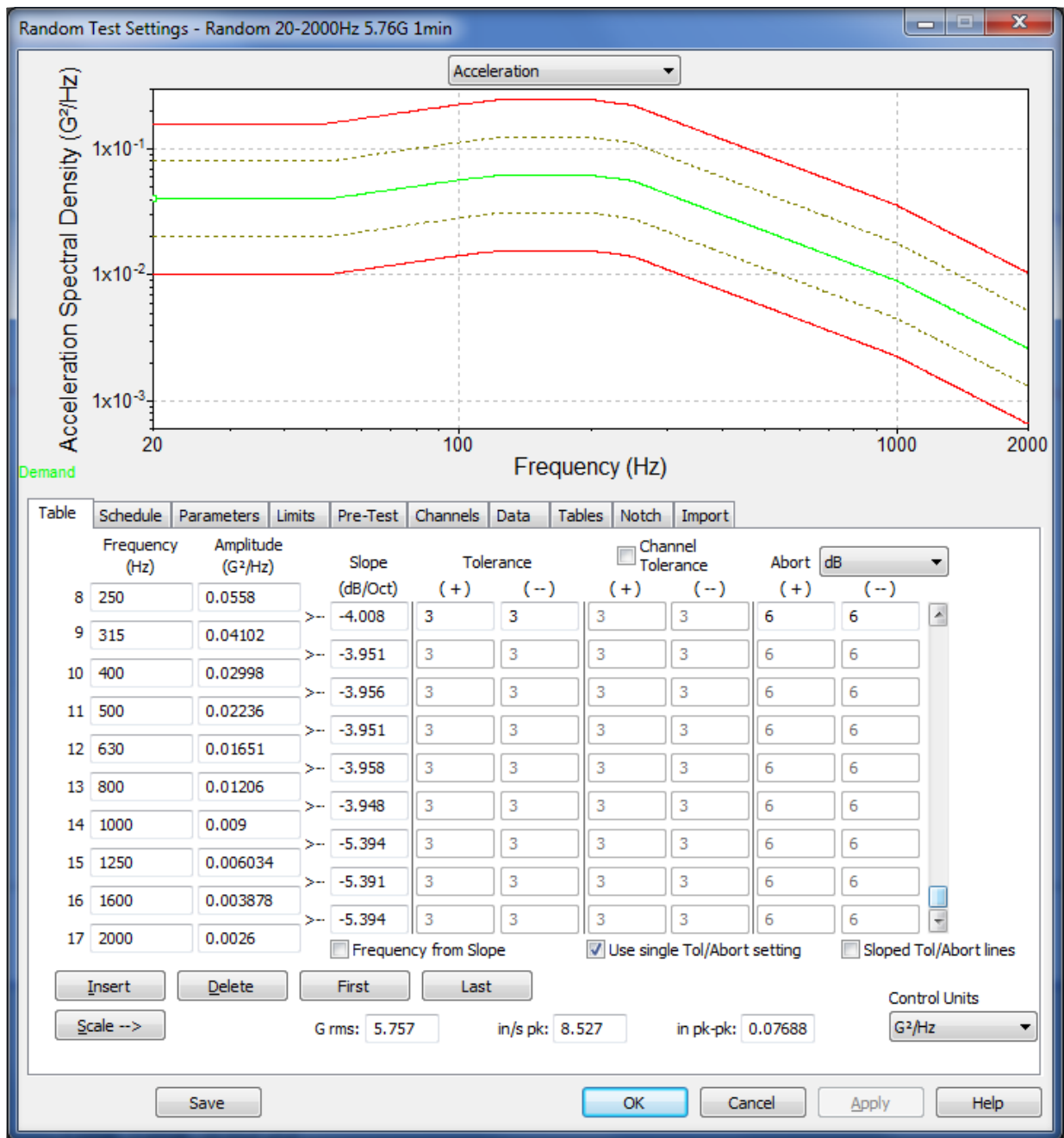**Figure 5: Random, 5.757 G$_{rms}$, 20-2000Hz, 1 Minute – Table 1 of 2**

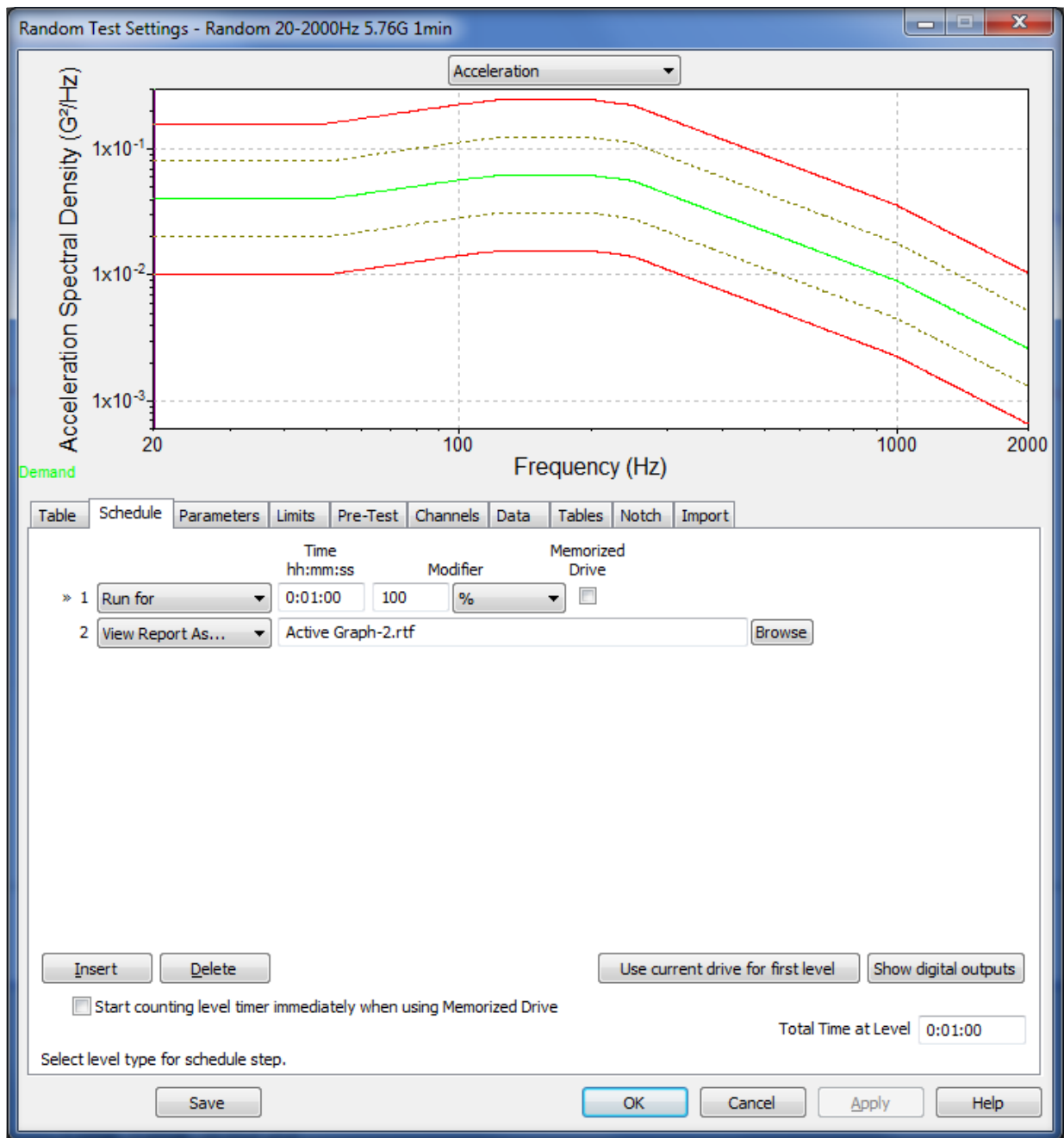**Figure 6: Random, 5.757 G$_{rms}$, 20-2000Hz, 1 Minute – Table 2 of 2**

Random Test Settings - Random 20-2000Hz 5.76G 1min

Acceleration

#	Frequency (Hz)	Amplitude (G²/Hz)		Slope (dB/Oct)	Tolerance (+)	Tolerance (--)	Channel Tolerance (+)	Channel Tolerance (--)	Abort (+)	Abort (--)
8	250	0.0558								
			>--	-4.008	3	3	3	3	6	6
9	315	0.04102								
			>--	-3.951	3	3	3	3	6	6
10	400	0.02998								
			>--	-3.956	3	3	3	3	6	6
11	500	0.02236								
			>--	-3.951	3	3	3	3	6	6
12	630	0.01651								
			>--	-3.958	3	3	3	3	6	6
13	800	0.01206								
			>--	-3.948	3	3	3	3	6	6
14	1000	0.009								
			>--	-5.394	3	3	3	3	6	6
15	1250	0.006034								
			>--	-5.391	3	3	3	3	6	6
16	1600	0.003878								
			>--	-5.394	3	3	3	3	6	6
17	2000	0.0026								

Tabs: Table | Schedule | Parameters | Limits | Pre-Test | Channels | Data | Tables | Notch | Import

☐ Frequency from Slope ☑ Use single Tol/Abort setting ☐ Sloped Tol/Abort lines

[Insert] [Delete] [First] [Last]

[Scale -->] G rms: 5.757 in/s pk: 8.527 in pk-pk: 0.07688

Control Units: G²/Hz

[Save] [OK] [Cancel] [Apply] [Help]

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Figure 7: Random, 5.757 G$_{rms}$, 20-2000Hz, 1 Minute – Schedule

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Fixture

The UUT was secured to an aluminum extender plate. The plate and the UUT were secured to the slip table using 3 sets of 3/8-16 swivel hoist rings and straps. Testing started in the Z axis. To differentiate between the Z and X axes testing, the extender plate was rotated 90° on the slip table. For the Y axis testing, the UUT was rotated 90° horizontally on the extender plate. See Figures 8-13 below for illustrations of the UUT fixtured for testing, along with views of the control accelerometer location.
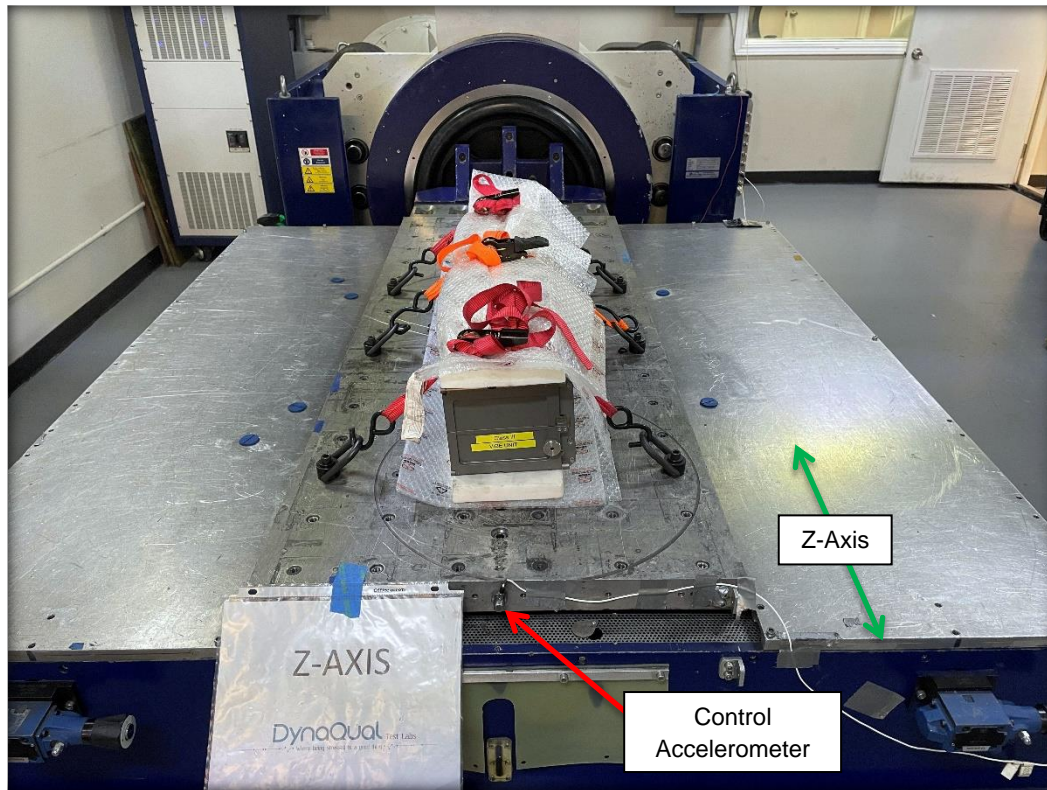
Figure 8: UUT shown fixtured for Z axis testing

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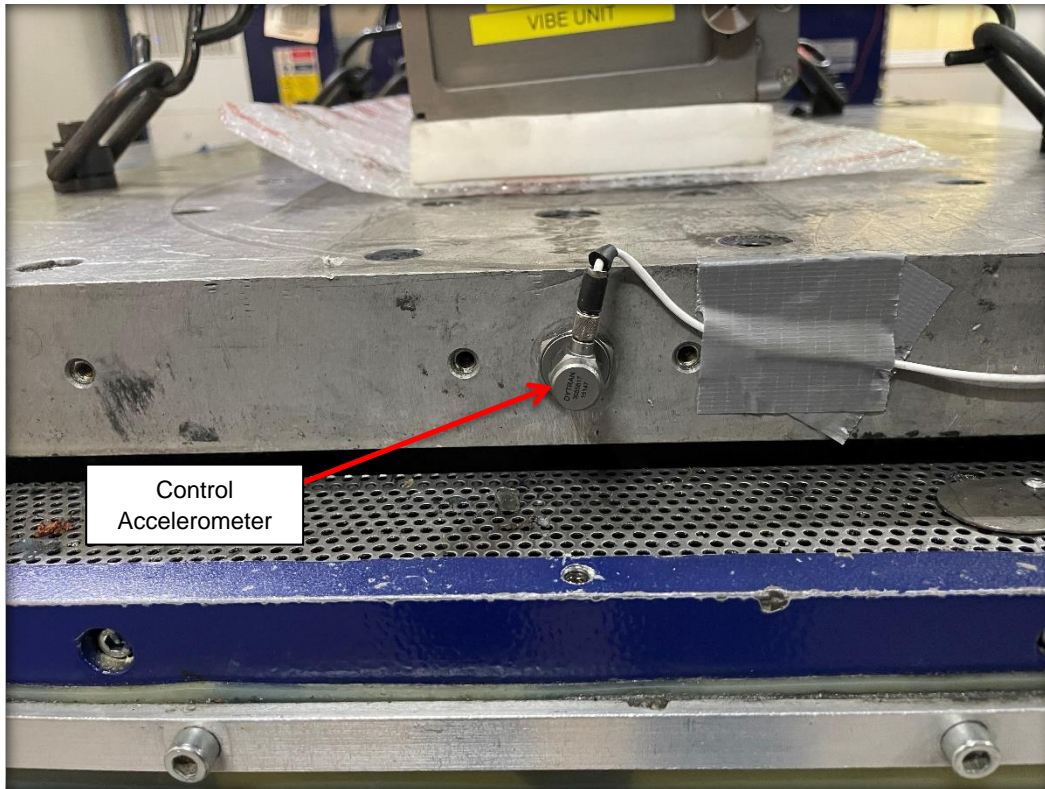
Figure 9: Detailed view of the control accelerometer for all axes testing
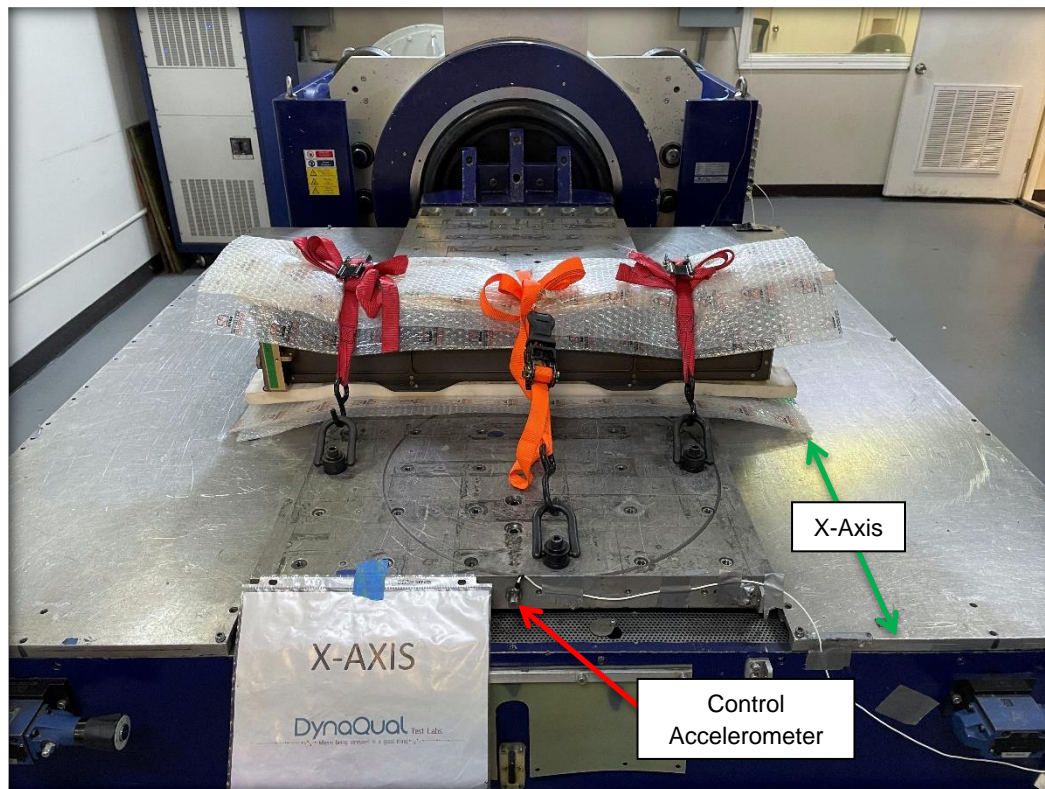
Figure 10: UUT shown fixtured for X axis testing

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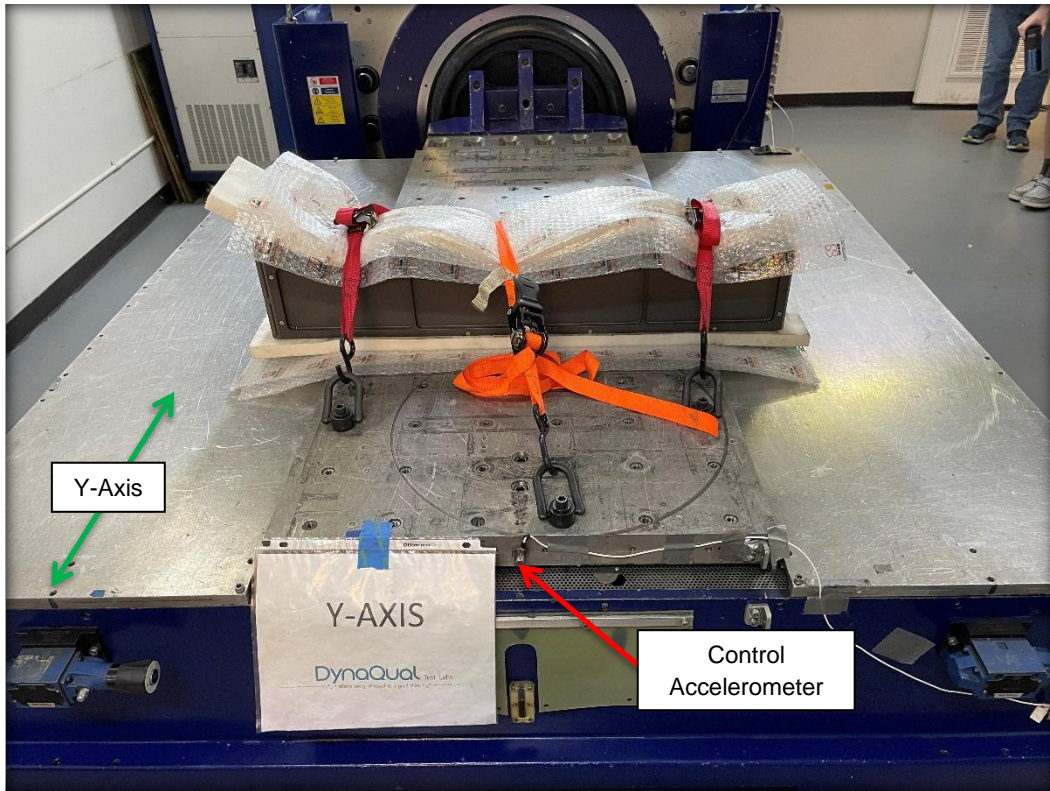
Figure 11: UUT shown fixtured for Y axis testing
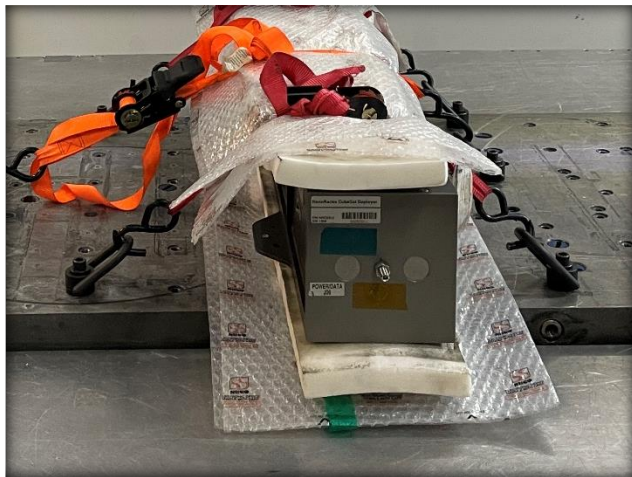
Figure 12: Side view of UUT shown in X axis

Figure 13 Side view of UUT shown in Y axis

Product Functional Testing

The UUT was not powered or tested functionally during the vibration testing. The UUT was to be inspected by NanoRacks personnel at their facility upon completion of the vibration testing at DynaQual.

Vibration Testing Program

Table 3 summarizes the vibration test steps for the UUT, showing the type of test, with input parameters, any associated notes referencing the data collected, and observations or changes noted. Software generated reports for each test performed are shown below Table 3 and are also provided in the customer data file, made available after the conclusion of testing.

Table 3 – Vibration Testing Program

Test #	Axis	Test Type	Frequency	Amplitude	Duration/Rate	Notes
1	Z	Pre Sine	5-2000Hz	0.5 G_{peak}	2 Oct/Min	
2	Z	Random	20-2000Hz	5.757 G_{rms}	1 Minute	
3	Z	Post Sine	5-2000Hz	0.5 G_{peak}	2 Oct/Min	
4	X	Pre Sine	5-2000Hz	0.5 G_{peak}	2 Oct/Min	
5	X	Random	20-2000Hz	5.757 G_{rms}	1 Minute	
6	X	Post Sine	5-2000Hz	0.5 G_{peak}	2 Oct/Min	
7	Y	Pre Sine	5-2000Hz	0.5 G_{peak}	2 Oct/Min	
8	Y	Random	20-2000Hz	5.757 G_{rms}	1 Minute	
9	Y	Post Sine	5-2000Hz	0.5 G_{peak}	2 Oct/Min	1

Notes:

1. Testing was completed with no physical failures of the UUT observed or reported. The UUT will be inspected and functionally tested at the customer's facility.
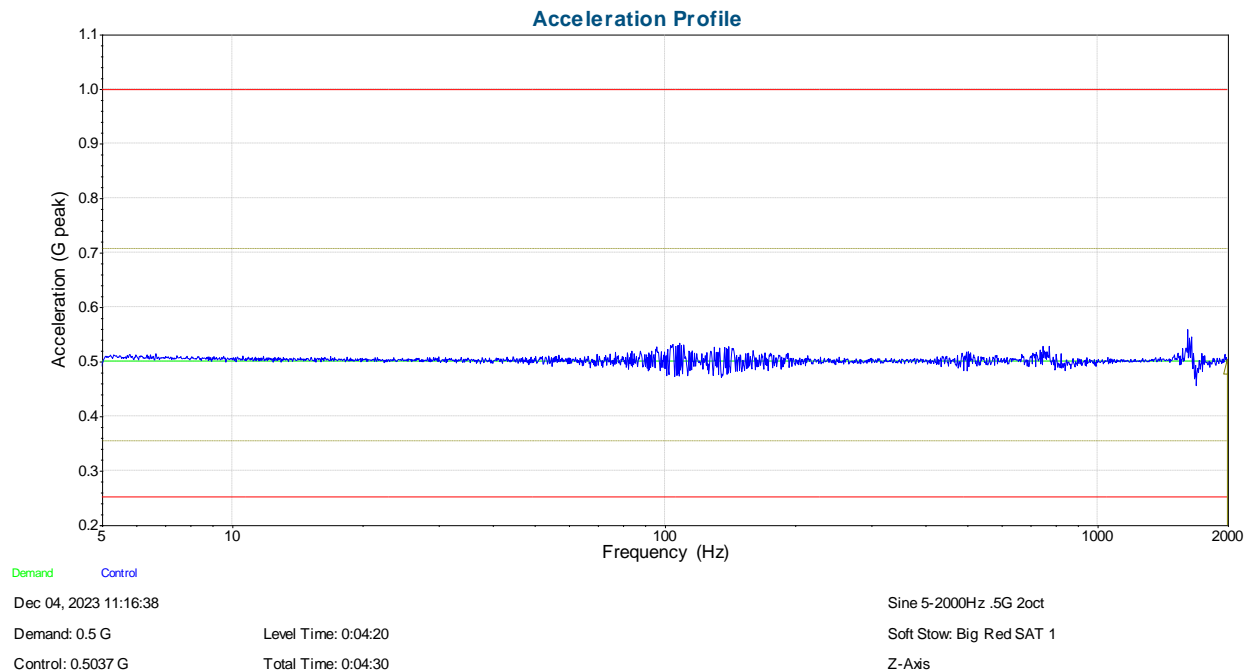
<u>Test 1: Z Axis</u>
Test Mode: Sine (Pre-Random)
Frequency: 5-2000Hz
Rate: 2 Octaves per Minute
Amplitude: 0.5 G_{peak}

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1112-0001.vsd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Sine 5-2000Hz .5G 2oct.vsp
Data stored on Dec 04, 2023 11:16:38

Dec 04, 2023 11:16:38		Sine 5-2000Hz .5G 2oct
Demand: 0.5 G	Level Time: 0:04:20	Soft Stow: Big Red SAT 1
Control: 0.5037 G	Total Time: 0:04:30	Z-Axis

Test level schedule:

	Duration	**Level**
1)	1 sweeps	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 11:12:09, running for 0:04:30
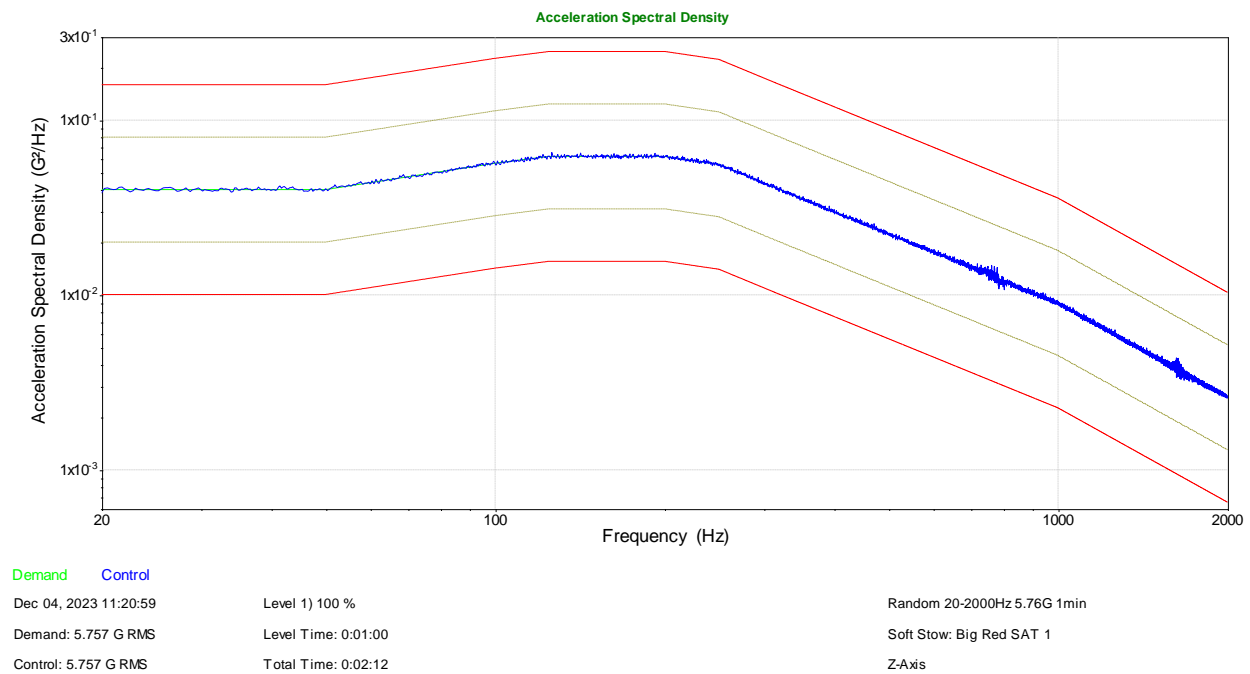** Current level: 1, running at 100 % for 0:04:20 of 1 sweeps

<u>Test 2: Z Axis</u>
Test Mode: Random
Frequency: 20-2000Hz
Duration: 1 Minute
Amplitude: 5.757 G$_{rms}$

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1118-0001.vrd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Random 20-2000Hz 5.76G
1min.vrp
Data stored on Dec 04, 2023 11:20:59

Acceleration Spectral Density

Demand	Control		
Dec 04, 2023 11:20:59	Level 1) 100 %		Random 20-2000Hz 5.76G 1min
Demand: 5.757 G RMS	Level Time: 0:01:00		Soft Stow: Big Red SAT 1
Control: 5.757 G RMS	Total Time: 0:02:12		Z-Axis

Test level schedule:

	Duration	**Level**
1)	0:01:00	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 11:18:47, running for 0:02:12
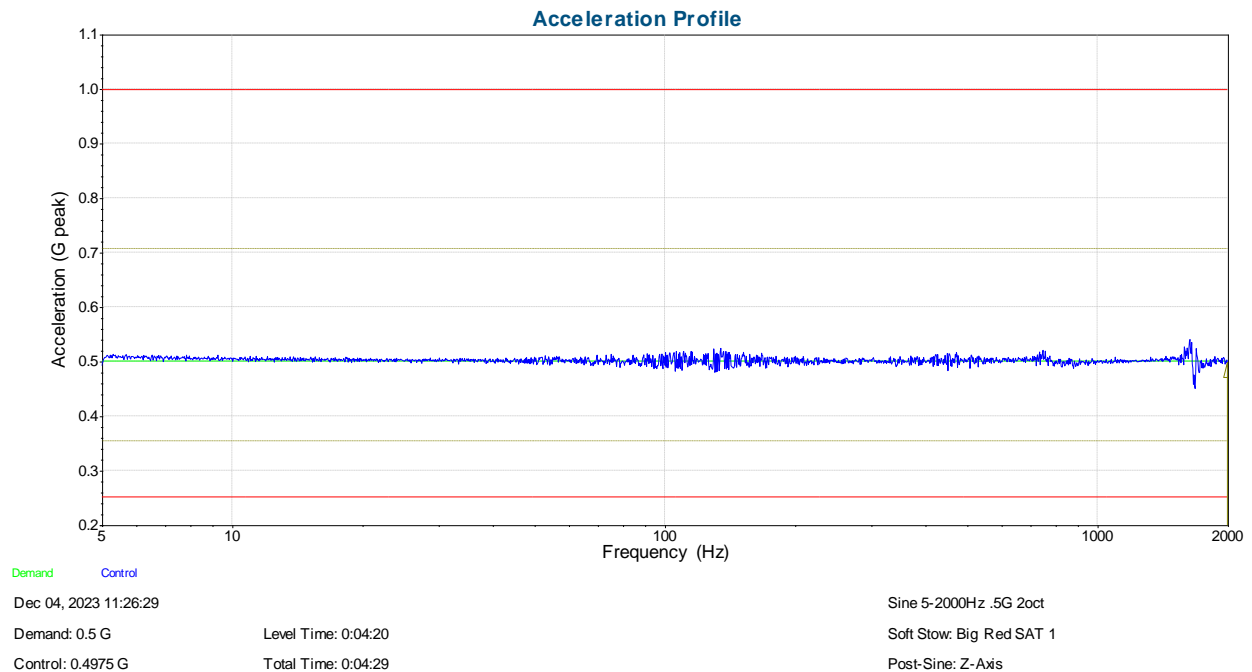** Current level: 1, running at 100 % for 0:01:00 of 0:01:00

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<u>Test 3: Z Axis</u>
Test Mode: **Sine (Post-Random)**
Frequency: **5-2000Hz**
Rate: **2 Octaves per Minute**
Amplitude: **0.5 G$_{peak}$**

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1122-0001.vsd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Sine 5-2000Hz .5G 2oct.vsp
Data stored on Dec 04, 2023 11:26:29

Acceleration Profile

Dec 04, 2023 11:26:29		Sine 5-2000Hz .5G 2oct
Demand: 0.5 G	Level Time: 0:04:20	Soft Stow: Big Red SAT 1
Control: 0.4975 G	Total Time: 0:04:29	Post-Sine: Z-Axis

Test level schedule:

	Duration	**Level**
1)	1 sweeps	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 11:22:00, running for 0:04:29
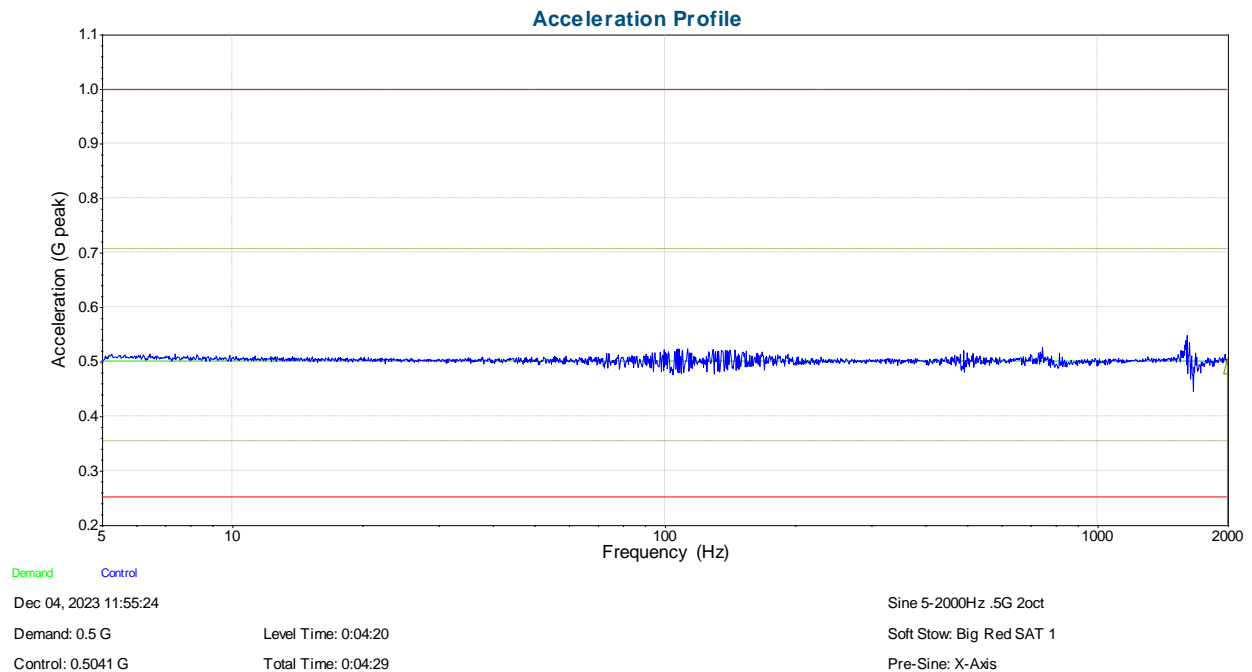** Current level: 1, running at 100 % for 0:04:20 of 1 sweeps

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Test 4: X Axis
Test Mode: **Sine (Pre-Random)**
Frequency: **5-2000Hz**
Rate: **2 Octaves per Minute**
Amplitude: **0.5 G$_{peak}$**

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1150-0001.vsd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Sine 5-2000Hz .5G 2oct.vsp
Data stored on Dec 04, 2023 11:55:24

Demand   Control

Dec 04, 2023 11:55:24		Sine 5-2000Hz .5G 2oct
Demand: 0.5 G	Level Time: 0:04:20	Soft Stow: Big Red SAT 1
Control: 0.5041 G	Total Time: 0:04:29	Pre-Sine: X-Axis

Test level schedule:

	Duration	**Level**
1)	1 sweeps	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 11:50:55, running for 0:04:29
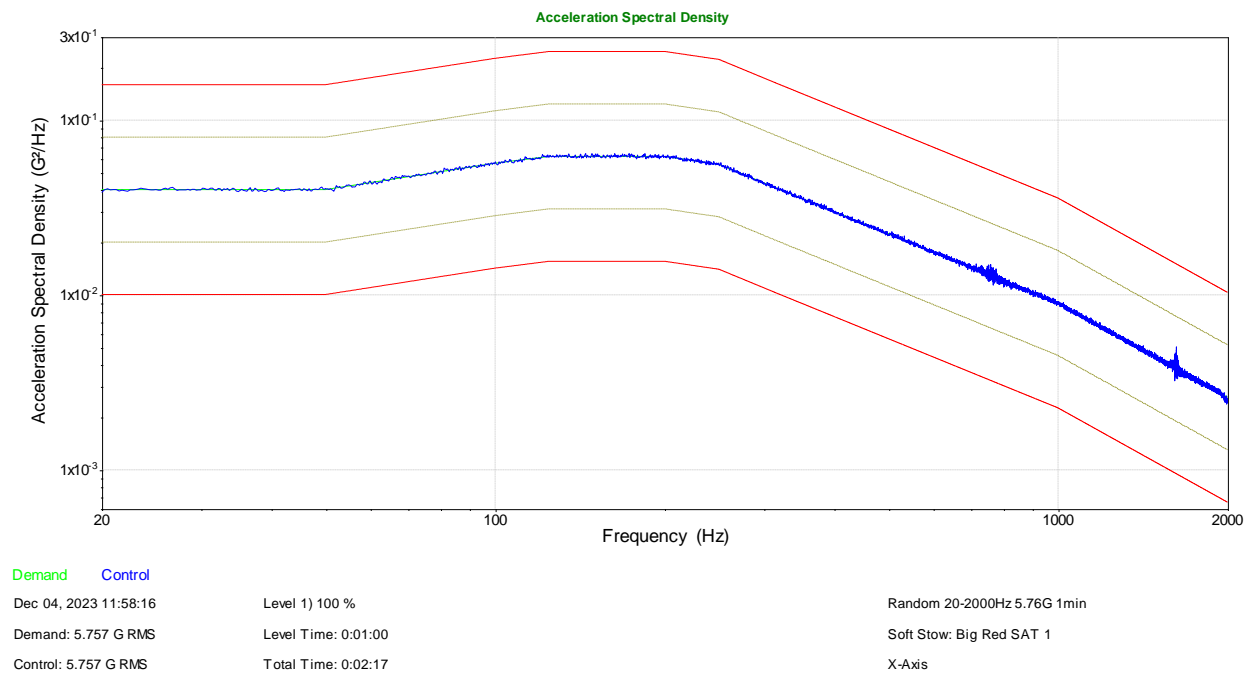** Current level: 1, running at 100 % for 0:04:20 of 1 sweeps

Test 5: X Axis
Test Mode: **Random**
Frequency: **20-2000Hz**
Duration: **1 Minute**
Amplitude: **5.757 G$_{rms}$**

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1156-0001.vrd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Random 20-2000Hz 5.76G 1min.vrp
Data stored on Dec 04, 2023 11:58:16

Demand	Control			
Dec 04, 2023 11:58:16	Level 1) 100 %		Random 20-2000Hz 5.76G 1min	
Demand: 5.757 G RMS	Level Time: 0:01:00		Soft Stow: Big Red SAT 1	
Control: 5.757 G RMS	Total Time: 0:02:17		X-Axis	

Test level schedule:

	Duration	**Level**
1)	0:01:00	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 11:56:00, running for 0:02:17
** Current level: 1, running at 100 % for 0:01:00 of 0:01:00
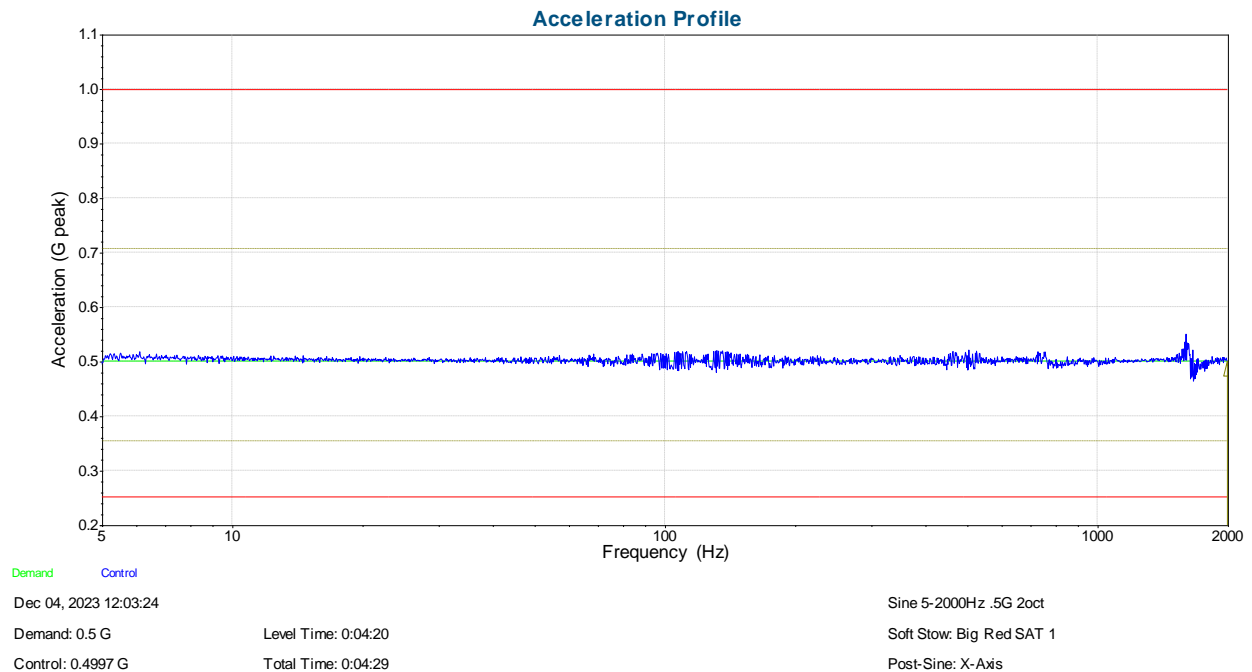
Test 6: X Axis
Test Mode: **Sine (Post-Random)**
Frequency: **5-2000Hz**
Rate: **2 Octaves per Minute**
Amplitude: **0.5 G$_{peak}$**

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1158-0001.vsd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Sine 5-2000Hz .5G 2oct.vsp
Data stored on Dec 04, 2023 12:03:24

Acceleration Profile

Demand   Control

Dec 04, 2023 12:03:24		Sine 5-2000Hz .5G 2oct
Demand: 0.5 G	Level Time: 0:04:20	Soft Stow: Big Red SAT 1
Control: 0.4997 G	Total Time: 0:04:29	Post-Sine: X-Axis

Test level schedule:

	Duration	**Level**
1)	1 sweeps	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 11:58:55, running for 0:04:29
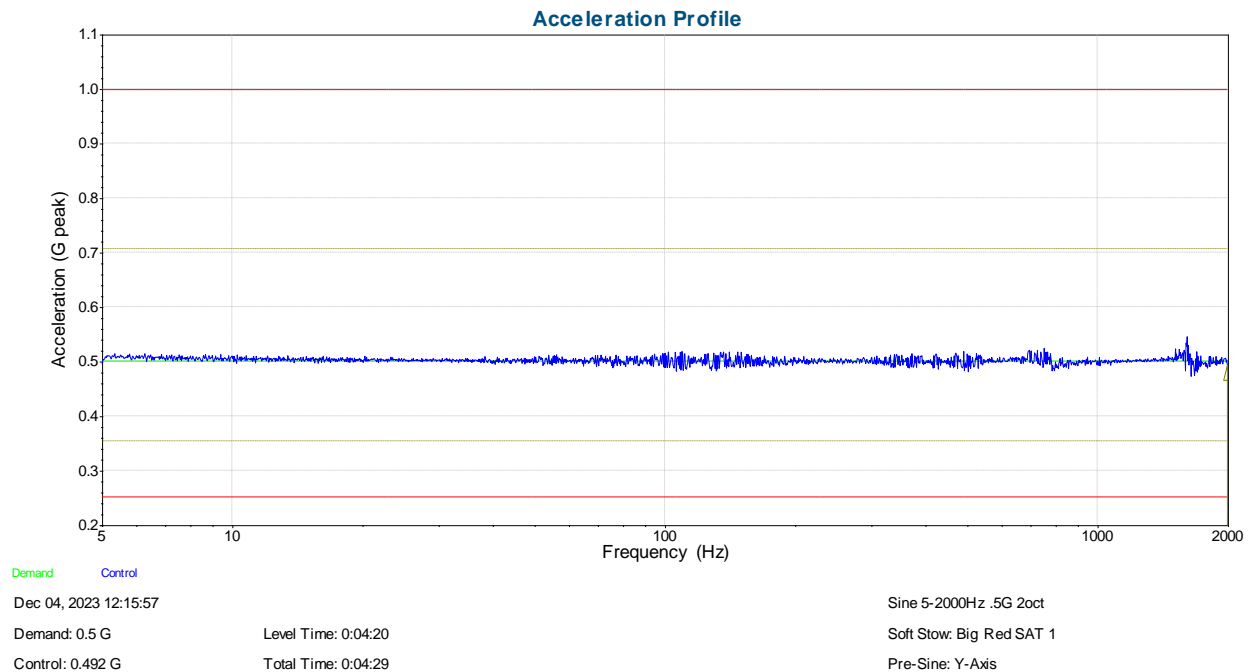** Current level: 1, running at 100 % for 0:04:20 of 1 sweeps

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Test 7: Y Axis
Test Mode: **Sine (Pre-Random)**
Frequency: **5-2000Hz**
Rate: **2 Octaves per Minute**
Amplitude: **0.5 G$_{peak}$**

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1211-0001.vsd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Sine 5-2000Hz .5G 2oct.vsp
Data stored on Dec 04, 2023 12:15:57

Dec 04, 2023 12:15:57		Sine 5-2000Hz .5G 2oct
Demand: 0.5 G	Level Time: 0:04:20	Soft Stow: Big Red SAT 1
Control: 0.492 G	Total Time: 0:04:29	Pre-Sine: Y-Axis

Test level schedule:

	Duration	Level
1)	1 sweeps	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 12:11:28, running for 0:04:29
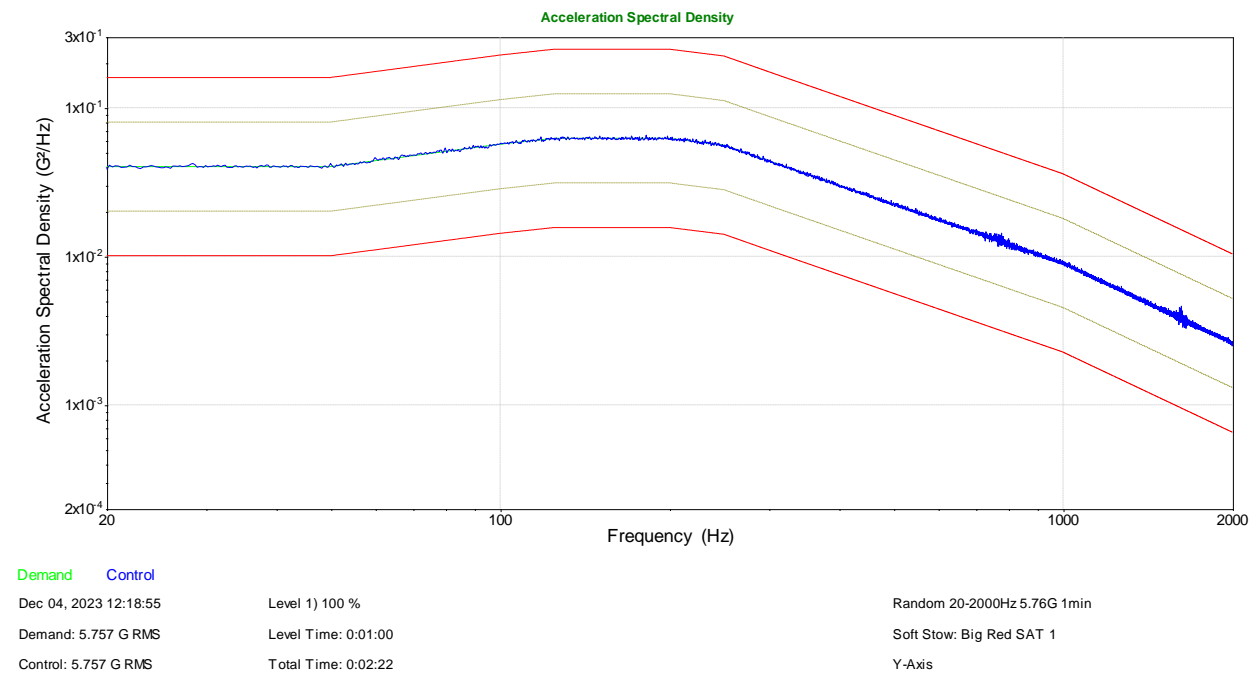** Current level: 1, running at 100 % for 0:04:20 of 1 sweeps

<u>Test 8: Y Axis</u>
Test Mode: Random
Frequency: 20-2000Hz
Duration: 1 Minute
Amplitude: 5.757 G$_{rms}$

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1216-0001.vrd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Random 20-2000Hz 5.76G 1min.vrp
Data stored on Dec 04, 2023 12:18:55

Demand	Control		
Dec 04, 2023 12:18:55	Level 1) 100 %		Random 20-2000Hz 5.76G 1min
Demand: 5.757 G RMS	Level Time: 0:01:00		Soft Stow: Big Red SAT 1
Control: 5.757 G RMS	Total Time: 0:02:22		Y-Axis

Test level schedule:

	Duration	**Level**
1)	0:01:00	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 12:16:33, running for 0:02:22
** Current level: 1, running at 100 % for 0:01:00 of 0:01:00

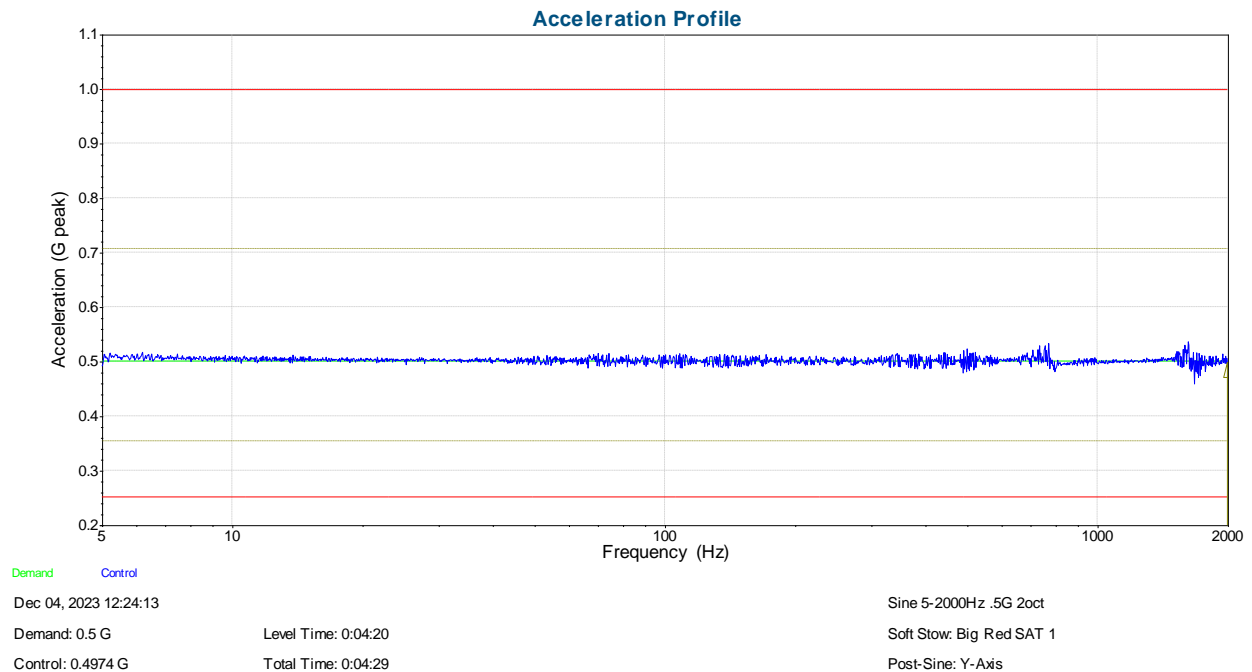DynaQual.com / 301 Wells Fargo Dr., Houston, TX 77090

Test 9: Y Axis
Test Mode: **Sine (Post-Random)**
Frequency: **5-2000Hz**
Rate: **2 Octaves per Minute**
Amplitude: **0.5 G$_{peak}$**

Data: C:\VibrationVIEW\Data\2023-12\2023Dec04-1219-0001.vsd
Test: C:\VibrationVIEW\Profiles\Customers Profiles\Customer Profiles\NanoRacks\Sine 5-2000Hz .5G 2oct.vsp
Data stored on Dec 04, 2023 12:24:13

Acceleration Profile

Demand   Control

Dec 04, 2023 12:24:13		Sine 5-2000Hz .5G 2oct
Demand: 0.5 G	Level Time: 0:04:20	Soft Stow: Big Red SAT 1
Control: 0.4974 G	Total Time: 0:04:29	Post-Sine: Y-Axis

Test level schedule:

	Duration	**Level**
1)	1 sweeps	100 %
2)	View Report (prompt)	

** Test started Dec 04, 2023 12:19:44, running for 0:04:29
** Current level: 1, running at 100 % for 0:04:20 of 1 sweeps

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TESTING SUMMARY/CONCLUSIONS

The following summarizes the vibration testing performed for NanoRacks, LLC on one Soft Stow Big Red SAT 1 assembly, on December 4, 2023.

1. DynaQual test labs performed vibration one Big Red SAT assembly for NanoRacks on 12/04/2023.

2. Pre, and Post Random Sine Sweeps were performed at 0.5 G_{peak}, from 5-2000Hz, at a rate of 2 octaves per minute, in the Z, X, and Y axes.

3. Random Vibration was done between the frequencies of 20-2000Hz, at a level of 5.757 G_{rms}, for a period of 1 minute in the Z, X and Y axes.

4. The UUT was not powered during testing but was returned to NanoRacks LLC for inspection and functional testing after the vibration testing concluded.

5. No visible or mechanical failures were observed or reported by NanoRacks personnel during the testing.

6. The testing provided quality data for further analysis by NanoRacks, LLC personnel back at their facility.

Data File Provided to Customer
(Profile Screen Shots, Graphs, Test Data, Pictures of set up)

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