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01	32-261	Initial Release	M. Smith		12-6-07

**Flight Unit S/N 001**  
**Environmental Vibration Test Report**

**Dwg. No. 32-06050.0101**

Revision 01  
 December 8, 2007

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# 1 Introduction

## 1.1 Activity Description

This report summarizes the results for the Environmental Vibration testing of the CRaTER Instrument, S/N 001 as performed per The Flight Unit Vibration Test Procedure, 32-06004.03.

## 1.2 Test Item Description

The Unit Under Test (UUT) is CRaTER Flight Unit, 32-10000, S/N 001. The Thermal Blanket was not installed for this test.

The overall weight of the UUT is 11.5 lbs (excludes the weight of the Thermal Blanket System.).

## 1.3 Support Documents

### 1.3.1 Applicable Documents

431-SPEC-000012	Lunar Reconnaissance Orbiter Mechanical System Specification, Rev D.
32-06003.01	Crater Long Form Functional Test Procedure.
32-06003.02	Crater Short Form Functional Test Procedure
32-06004.03	Flight Unit Vibration Test Procedure

## 2 Requirements.

CRaTER shall demonstrate the ability to “survive” the ground, launch, and operational environments. The survival criteria are listed below.

### 2.1 Acceptance criteria, applicable to CRaTER

- Complete testing to limit levels with the appropriate test factor.
- No structural degradation after test.
- No unexplained frequency shifts more than 5% between pre and post test.
- No visible damage that is a result of the test environment.
- Pass all functional performance testing performed during and upon completion of the test.

### 2.2 Vibration Testing Levels

All applicable vibration tests were preceded by low level -20 db test then ramped up to the desired levels to ensure no anomalies are evident.

#### 2.2.1 Low-Level Resonance Search (Sine Sweep)

This test determined the baseline for verifying that no significant changes occur during each vibration test. Low-Level resonance search was performed at 1/2g at a rate is 2 Octaves per minute.

#### 2.2.2 Sine Vibration Environment

The CRaTER instrument Sine vibration environments are shown below. The input is defined in the LRO coordinate system. Duration was 4 Oct/Min/Axis.

**Table 2-1. CRaTER Instrument X-Axis Sine Vibration Environment**

Protoflight/Qualification	
Frequency (Hz)	Level
5 – 9.9	1.27 cm D.A.
9.9 - 50	2.5 g’s

**Table 2-2. CRaTER Instrument Y-Axis Sine Vibration Environment**

Protoflight/Qualification	
Frequency (Hz)	Level
5 - 15.6	1.27 cm D.A.
15.6 - 25	6.25 g’s
25 - 50	3.125 g’s

**Table 2-3. CRaTER Instrument Z-Axis Sine Vibration Environment**

Protoflight/Qualification	
Frequency (Hz)	Level
5 - 17.1	1.27 cm D.A.
17.1 - 25	7.5 g’s
25 - 50	3.125 g’s

### 2.2.3 Random Vibration

Crater was subjected to the following Random Vibration levels in each axis. Rate was 1 minute per axis.

**Table 2-4. Random Vibration Protoflight Levels**

Frequency (Hz)	Level
20	0.026 g <sup>2</sup> /Hz
20-50	+6dB/Octave
50-800	0.160 g <sup>2</sup> /Hz
800-2000	-6dB/Octave
2000	0.026 g <sup>2</sup> /Hz
Overall	14.1 grms

### 2.2.4 Post Low-Level Resonance Search (Sine Sweep)

Low-Level resonance search was tested at 1/2g at a rate of 2 Octaves per minute. This test was used to verify that the natural frequencies of the assembly did not change more than 5% from the pre-shake 1/2g sine sweep.

### 2.3 Order of Testing.

The Z axis was tested first, followed by the Y Axis then the X Axis.

### 2.4 Electrical Testing

Before vibration testing started, the UUT was electrically tested per the CRaTER Long Form Functional Test Procedure.

After each axis tested the UUT was electrically tested per the CRaTER Short Form Functional Test Procedure.

After the last axis vibration test the unit was electrically tested per the CRaTER Long Form Functional Test Procedure, while the unit was inside the Thermal Vacuum chamber.

### 3 Facilities and Configuration

#### 3.1 Facility

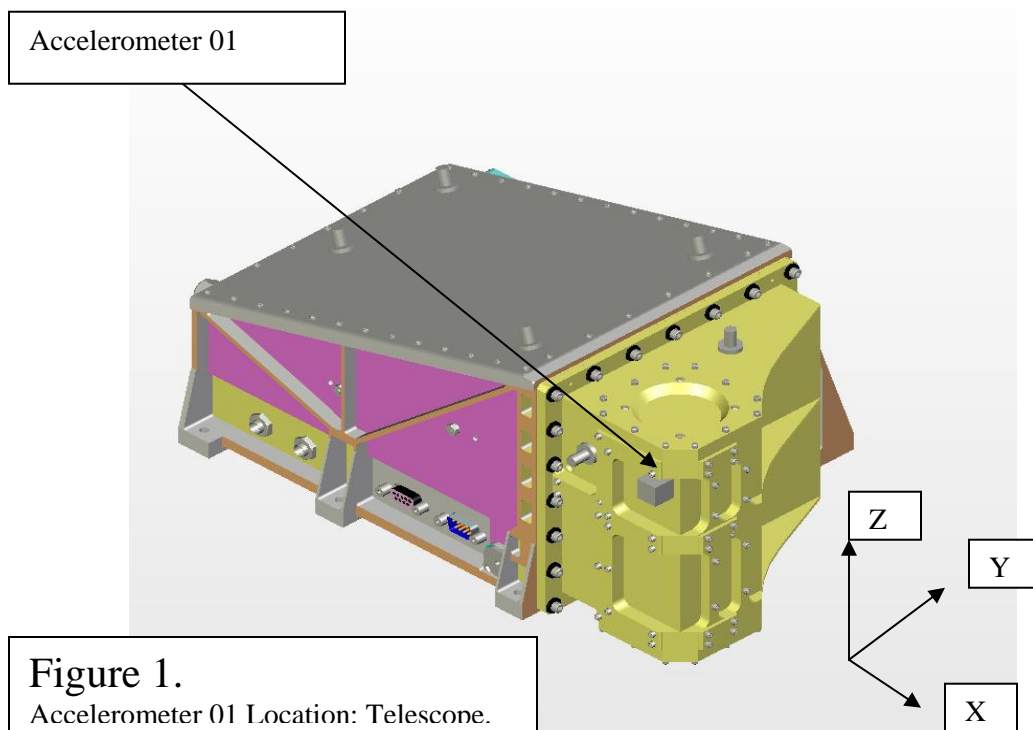
The facility and shaker used for this test is provided by Charles Stark Draper Labs, Cambridge MA.

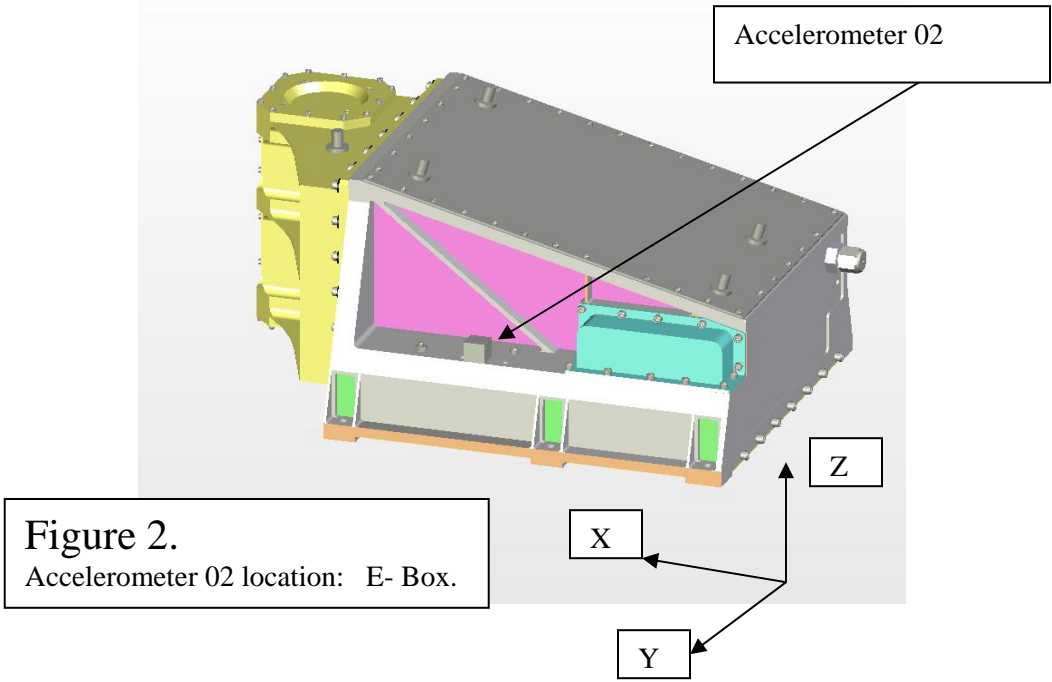
#### 3.2 Test Configuration

The CRaTER Assembly is attached to the vibration test fixture at the mounting flange by a total of five (5), #10-32UNC x 1" SHCS, High Strength, and one (1) #10-32UNC x 3/4" SHCS, high strength, and six (6) washers.

#### 3.3 Accelerometers

Two triax accelerometers were located per Figures 1 and 2. These were adhered by first placing Kapton tape on the instrument surface and then the accelerometers were bonded to the Kapton tape with a fast drying adhesive.







### 3.4 Coordinate System

The Axis for vibration testing as defined by the LRO coordinate system. The LRO Coordinate system is shown in Figure 3.

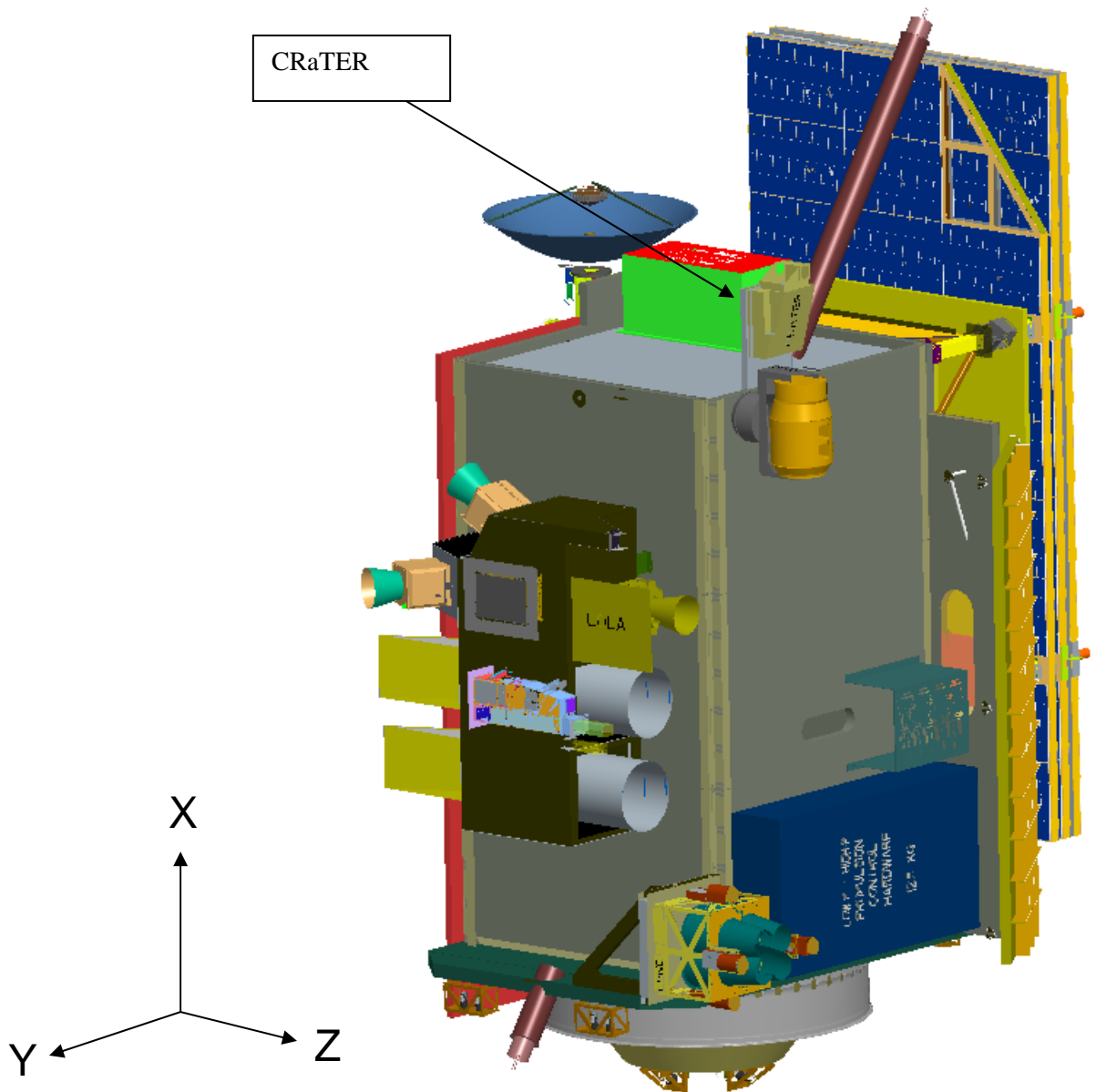


Figure 3. LRO Coordinate System.

## 4 Preparation

### 4.1 Identification

#### 4.1.1 Equipment

Accelerometer model and serial numbers are listed below.

Description	Acc Model number
Telescope @1	40900
E-Box @ 2	40899
Control #1	Not recorded
Control #2	Not recorded

#### 4.1.2 Installation

The shaker plate was attached to the shaker head. The bolts were torque to 45 ft lbs.

Two control accelerometers at opposing ends of the plate during the Z direction and only one was used for the lateral direction. A sine sweep was run on the interface plate to verify no loose connections and to see the profile of the shaker plate.

The Crater assembly was mounted to the shaker table using five(5) high strength SHCS, #10-32 x 1" with Heavy Duty Flat washers. And one (1) high strength SHCS, #10-32x ¾"L also with a Heavy Duty Flat washer. The #10-32 screws were torque to 35-40 in-lbs.

A piece of Kapton tape was placed at the locations where the accelerometers were to be placed on the unit. The accelerometers were then mounted to the Kapton tape with Loctite 454. After testing was completed the tape was removed and any residue was cleaned.

## 4.2 Test Results

All plots can be viewed in the Appendices.

### 4.2.1 X-Axis

#### 4.2.1.1 Low-level Resonance Search, Pre-Vibe, X-Axis.

Performed a Low-Level Resonance sine sweep at 1/2g for a minimum of 2 Oct/min. The peak frequencies and responses are listed below.

Axis	Frequency	Response
X	973	3.8
	1273	2.3
	1337	1.3
	717	1.2
	974	15.4
	1085	1.4
	1271	3.2
	1331	3.2
	1415	3.6
	974	20.9
	1273	9.7

The Low-Level Resonance ½ g sine sweep, pre-vibe, test results can be viewed in Appendix A.

#### 4.2.1.2 Sine Vibration, X-Axis.

Performed Sine Vibration Test per Table 2.1, X- Axis.

The Sine Vibration Test results can be viewed in Appendix B.

#### 4.2.1.3 Random Vibration, X-Axis.

Performed Random Vibration per Table 2.4, X-Axis.

The Random Vibration Test results can be viewed in Appendix C.

**4.2.1.4 Low-Level Resonance Search, Post-Vibe, X-Axis.**

Performed post vibe Low-Level Resonance Sine Sweep at ½ g for a minimum of 2 Oct/min. The peak results are listed below.

Axis	Frequency	Response
X	969	3.7
	1269	2.4
	718	1.2
	971	15.4
	1086	1.4
	1267	3.2
	1331	3.3
	1414	3.6
	973	20.5
	1269	10.3

Low-Level Resonance ½ g Sine Sweep, post-vibe, test results can be viewed in Appendix D.

**4.2.1.5 Resonance Comparison, X-Axis.**

Comparing the results of the pre and post Low-level Resonance Sine Sweep searches for differences in recorded resonances shows that no frequencies shifted more than 1% between pre and post vibration in the X axis.

Freq. Pre Shake (Hz)	Freq. Post Shake (Hz)	Difference (Hz)ABS	Difference (%)
973	969	4	<1%
1273	1269	4	<1%
717	718	2	<1%
974	971	3	<1%
1085	1086	1	<1%
1271	1267	4	<1%
1331	1331	0	<1%
1415	1414	1	<1%
974	973	1	<1%
1273	1269	4	<1%

## 4.2.2 Y-Axis

### 4.2.2.1 Low-Level Resonance Search, Pre-Vibe, Y-Axis.

Performed Low-Level Resonance vibration sine sweep at 1/2g for a minimum of 2 Oct/min. The peak frequencies and responses are listed below.

Y-Axis	Frequency	Response
Telescope	936	7.8
	973	7.8
	1301	5.3
	1399	10.9
E-box	934	1.8
	971	1.0
	1301	2.7
	1338	2.4
	1394	4.9
	1548	1.9
	1643	2.0
	1708	2.6

The Low-Level Resonance ½ g sine sweep, pre-vibe, test results can be viewed Appendix E.

### 4.2.2.2 Sine Vibration, Y-Axis,

Performed Sine Vibration per Table2-2, Y-Axis.

Sine Vibration Test results can be viewed in Appendix F.

### 4.2.2.3 Random Vibration, Y-Axis.

Performed Y-Axis Random Vibration per Table 2-4

For Random Vibration Test results see Appendix G.

**4.2.2.4 Low-Level Resonance Search, Post Vibe, Y-Axis.**

Performed post vibe Low-Level Resonance vibration sine sweep at 1/2g for a minimum of 2 Oct/min. The peak frequencies and responses are listed below.

Axis	Frequency	Response
Telescope	905	13.9
	1080	3.8
	1299	11.4
	1388	10.5
E-Box	904	2.4
	1074	1.1
	1296	4.1
	1379	4.0
	1516	2.3
	1639	2.3
	1701	2.5

For the Y-Axis post vibe Low Level Resonance 1/2 g sine sweep test results see Appendix H.

**4.2.2.5 Resonance Comparison, Y-Axis.**

Comparing the results of the pre and post Low-Level resonance searches for differences in recorded resonances shows some changes in frequencies greater than 5%. See section 4.2.2.6. for discussion of these shifts in frequency.

	Freq. Pre Shake (Hz)	Freq. Post Shake (Hz)	Difference (Hz)	Difference (%)
Telescope	936	905	31	<5%
	973	1080	107	>10%*
	1301	1299	2	<5%
	1399	1388	11	<5%
E-Box	934	904	30	<5%
	971	1074	103	>10%*
	1301	1296	5	<5%
	1394	1378	16	<5%
	1548	1516	32	<5%
	1643	1639	4	<5%
	1708	1701	7	<5%

#### 4.2.2.6 Discussion for Y Axis.\*

There was an anomaly between the pre and post 1/2g sine sweeps. The Pre-Vibe sine sweep showed an in-line resonance at 936 Hz and 969 Hz while the post sine sweep at 905 Hz and 1080 Hz. It is evident that something had shifted during the test to have this discrepancy. Comparing the S/N 002 pre and post sine sweep showed that their frequencies were similar to the post sine sweep of S/N 001. The anomaly seemed to be in the Pre-Vibe sine sweep of S/N 001.

After taking a closer look it appears that the frequency of the shake table (without CRaTER attached) has a frequency at 1080Hz which also shows up in our vibration test. During the Pre-Vibe sine sweep of S/N001 this peak was at 969Hz and then shifted to its natural frequency of 1080 Hz after the random vibration.

This is believed to be caused by the mounting hardware securing CRaTER to the table. After closer investigation to the hardware used, the washers used had a countersink in them that is about the diameter of the socket head screw used to mount the instrument to the vibration plate. This results in a very small amount of bearing surface that supports the head. During other vibration tests these washer were installed with the countersink upside down so that the head of the screws had a larger bearing surface on them. The screws more than likely shifted during vibration testing and cause the anomaly.

### 4.2.3 Z-Axis

#### 4.2.3.1 Low-Level Resonance Search, Pre Vibe, Z-Axis.

Performed Low-Level Resonance sine sweep at 1/2g for a minimum of 2 Oct/min. The peak frequencies and responses are listed below.

Axis	Frequency	Response
Z	728	1.7
	941	4.4
	1219	3.9
	1301	1.9
	1565	1.4
	950	2.3
	1402	1.8

The Pre-Vibe Low-Level Resonance sine sweep Test results can be viewed in Appendix I.

#### 4.2.3.2 Sine Vibration, Z-Axis,

Performed Sine Vibration per Table2-3, Z-Axis.

Sine Vibration Test results can be viewed in Appendix J.

**4.2.3.3 Random Vibration, Z-Axis.**

Perform Random Vibration per Table 2-4, Z-Axis

Random Vibration Test results can be viewed in Appendix K.

**4.2.3.4 Low-Level Resonance Search, Post Shake, Z-Axis.**

Performed post vibrate Low-Level Resonance sine sweep at 1/2g for a minimum of 2 Oct/min. The peak frequencies and responses are listed below.

Axis	Frequency	Response
Z	720	1.6
	948	5.1
	960	5.5
	1246	2.7
	1738	1.4
	1920	1.4
	1929	1.2

Low-Level Resonance vibration Test results can be viewed in Appendix L.

**4.2.3.5 Resonance Comparison, Z-Axis.**

Comparing the results of the 2 Low-Level Resonance sine sweep tests for differences in recorded resonances shows no change in frequency greater than 2%.

Freq. Pre Shake (Hz)	Freq. Post Shake (Hz)	Difference (Hz)	Difference (%)
725	720	5	<1%
965	960	5	<1%
1247	1246	1	<1%
1743	1738	5	<1%
1938	1920	18	<1%
1955	1929	26	<2%



#### **4.2.3.6 Discussion for Z-Axis**

There was an anomaly at 160 Hz in the cross axis between pre and post shake. After closer review and testing it was concluded that the anomaly was associated with the accelerometers and the shake table and not the CRaTER instrument.

#### **4.3 Inspections**

The UUT was inspected after each axis of vibration testing for loose hardware and visible signs of damage. No signs of damage or loose external hardware were observed. The UUT was also gently rotated and shook to listen for loose items inside the unit and no sounds were noted.

## 5 Summary

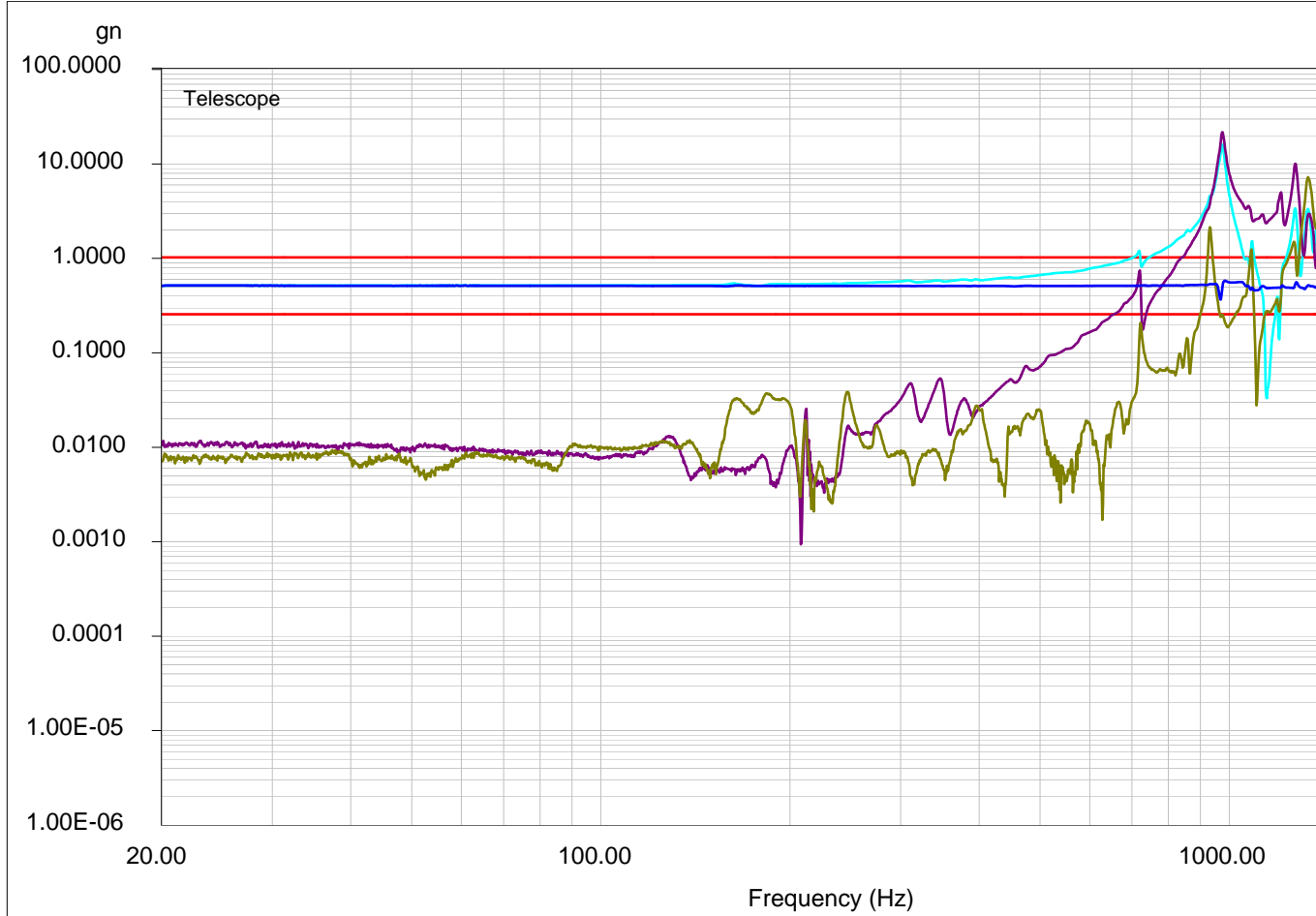
The UUT, CRaTER S/N 001 meets all the acceptance criteria as specified in summary below:

- Complete testing to limit levels with the appropriate test factor.
- No structural degradation after test.
- No unexplained frequency shifts more than 5% between pre and post test.
- No visible damage that is a result of the test environment.
- Pass all functional performance testing performed during and upon completion of the test.

# Appendix A

## CRaTER X-axis Low Level Sine sweep Pre Vibe

s/n 001



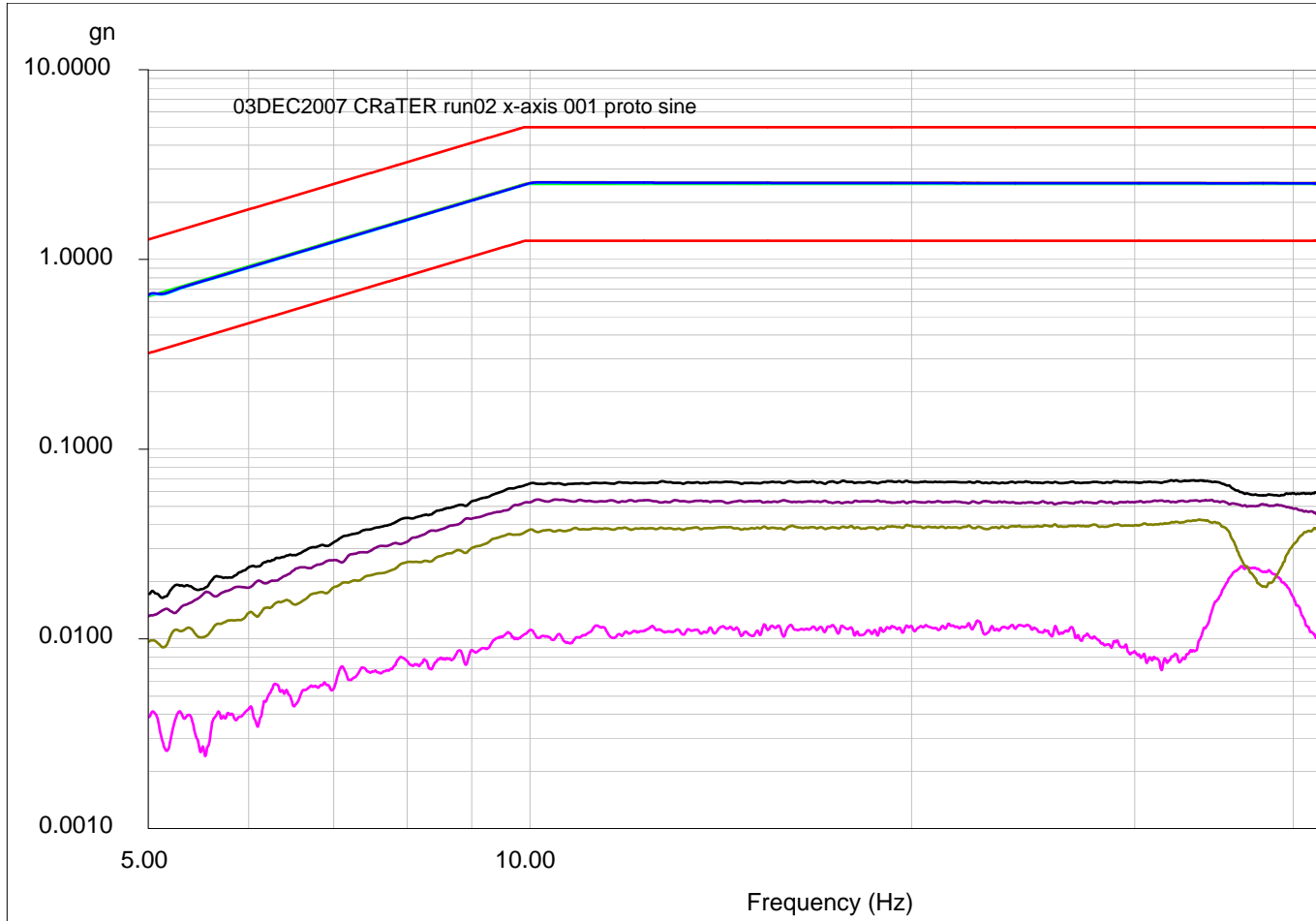
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Frequency:	1997.569702 Hz	Demand Peak:	0.500000 gn	Time Remaining:	00:00:00	Sweep Ra

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Report created at Report created at 11:31:45 AM, M

# Appendix B CRaTER X-axis, Sine Vibe

S/N 001



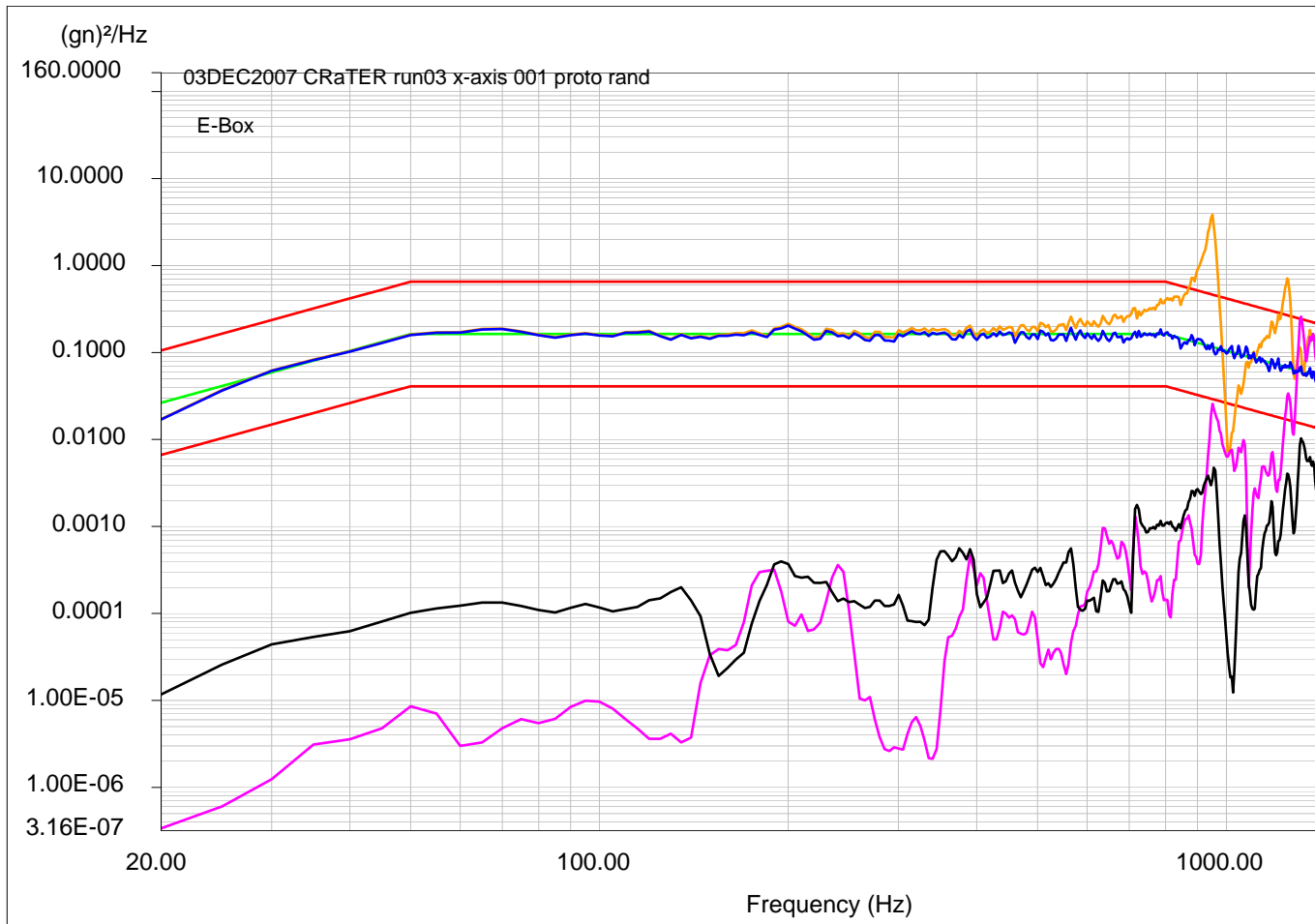
Level:	100 %	Control Peak:	2.519759 gn	Full Level Time:	00:00:50	Sweep Ty
Frequency:	49.833302 Hz	Demand Peak:	2.500000 gn	Time Remaining:	00:00:00	Sweep Ra

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Report created at Report created at 11:47:02 AM, Mo

# Appendix C. CRaTER X-axis, Random Vibe

S/N 001

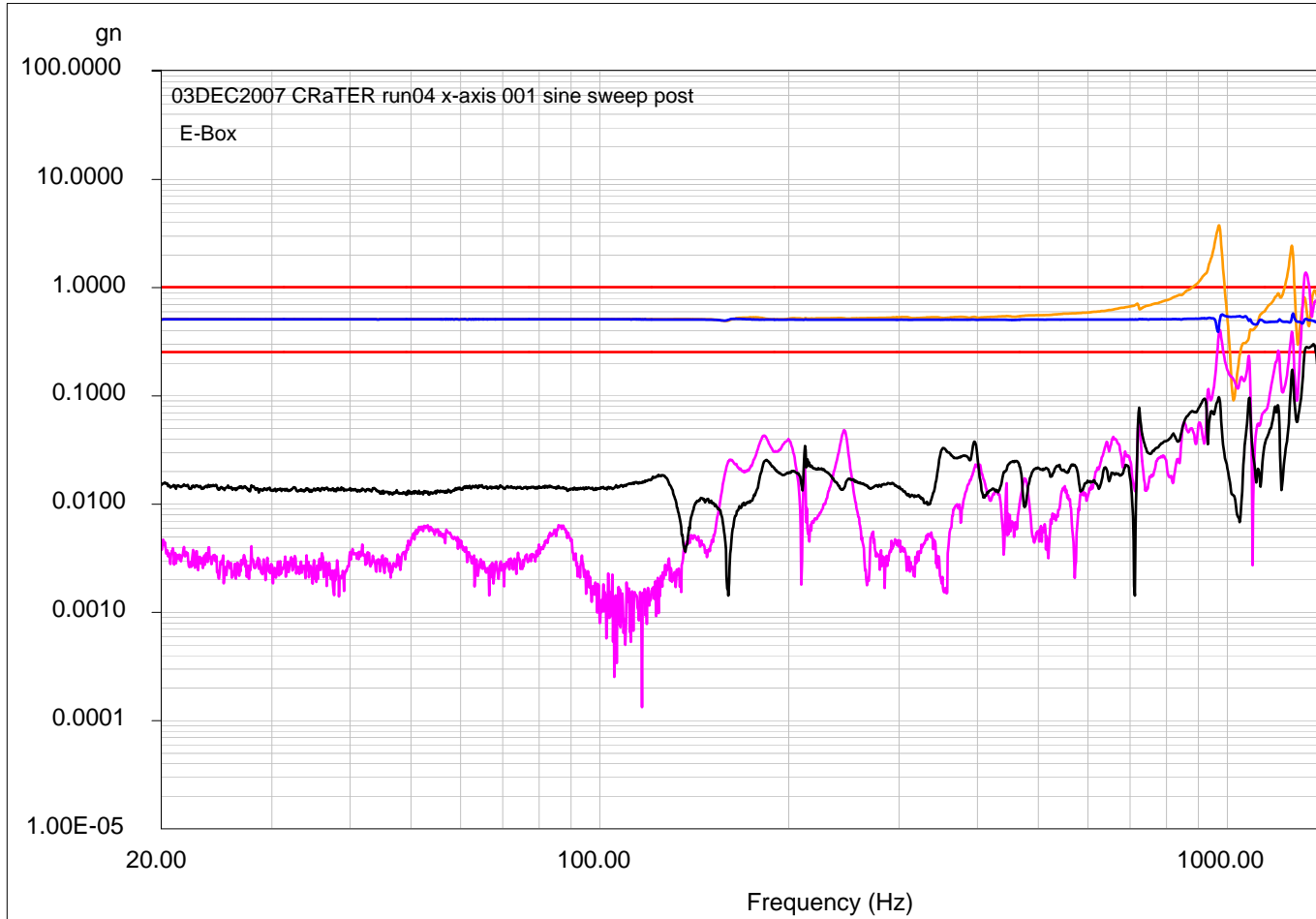


Level: 0 dB  
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 Demand RMS: 14.138149 gn    Remaining Time: 00:00:00    DOF: 100    dF: 5.000000

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## Appendix D. CRaTER X-axis, Post Vibe 1/2g Sine Sweep

s/n 001



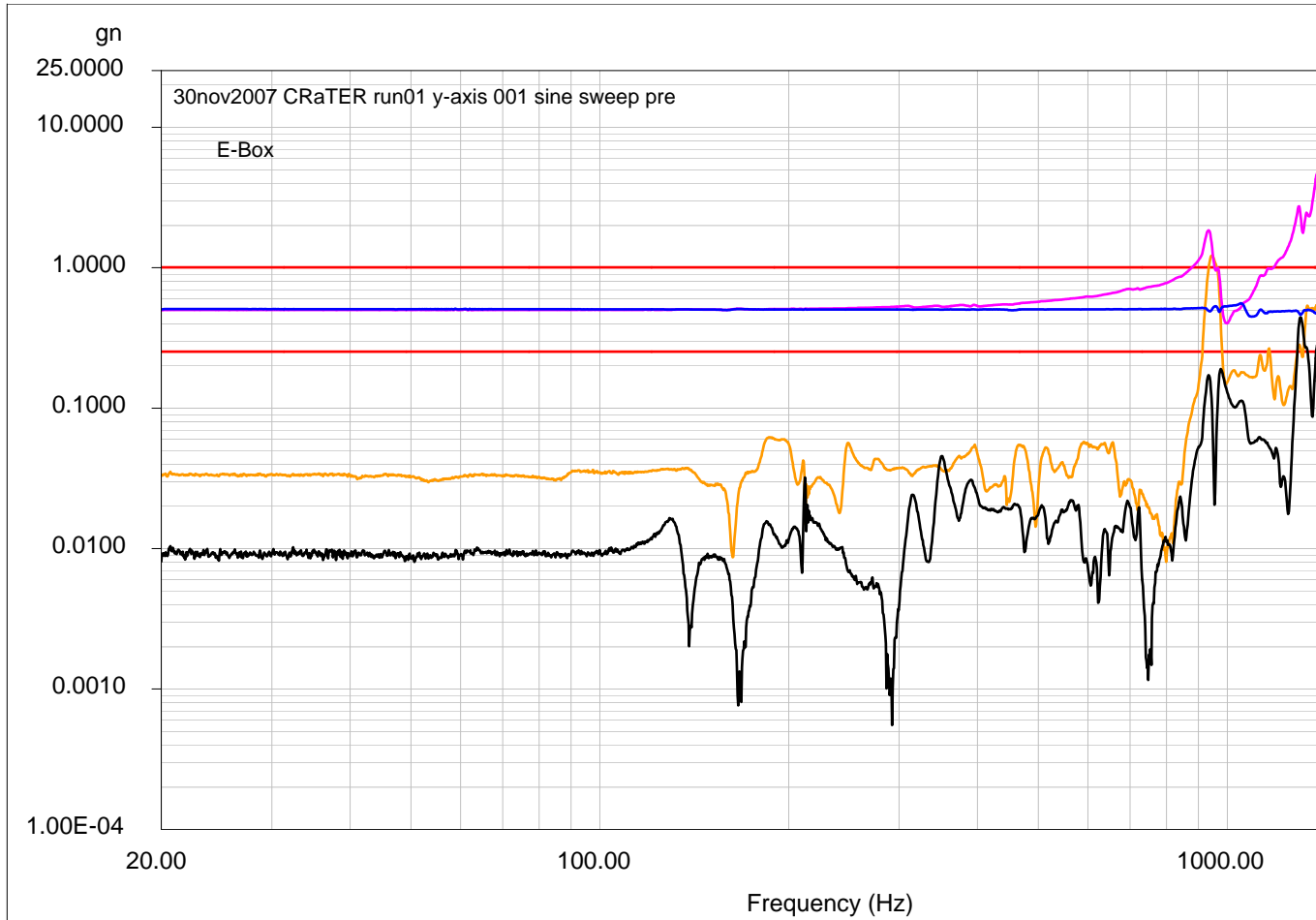
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Frequency:	1996.093872 Hz	Demand Peak:	0.500000 gn	Time Remaining:	00:00:00	Sweep Ra

Data saved at 12:05:38 PM, Monday, December 03, 2007

Report created at Report created at 12:05:39 PM, Mo

## Appendix E. CRaTER Y-axis, Pre Vibe 1/2g Sine Sweep

s/n 001



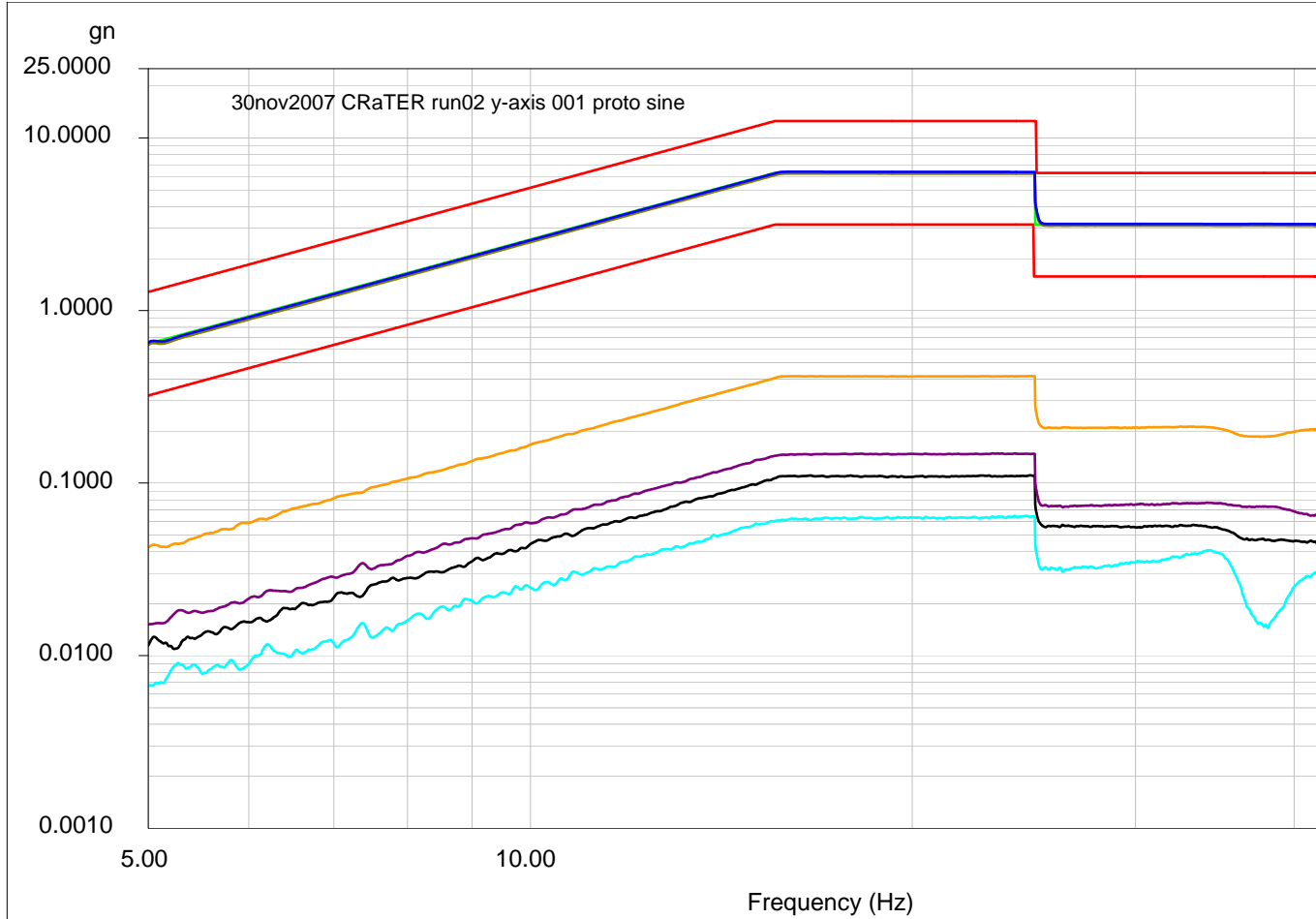
Level:	100 %	Control Peak:	0.482648 gn	Full Level Time:	00:03:19	Sweep Ty
Frequency:	1999.046631 Hz	Demand Peak:	0.500000 gn	Time Remaining:	00:00:00	Sweep Ra

Data saved at 10:08:54 AM, Friday, November 30, 2007

Report created at Report created at 10:08:58 AM, Fri

# Appendix F. CRaTER Y-axis, Sine Vibe

S/n 001



Level:	100 %	Control Peak:	3.150644 gn	Full Level Time:	00:00:50	Sweep Ty
Frequency:	49.857864 Hz	Demand Peak:	3.125000 gn	Time Remaining:	00:00:00	Sweep Ra

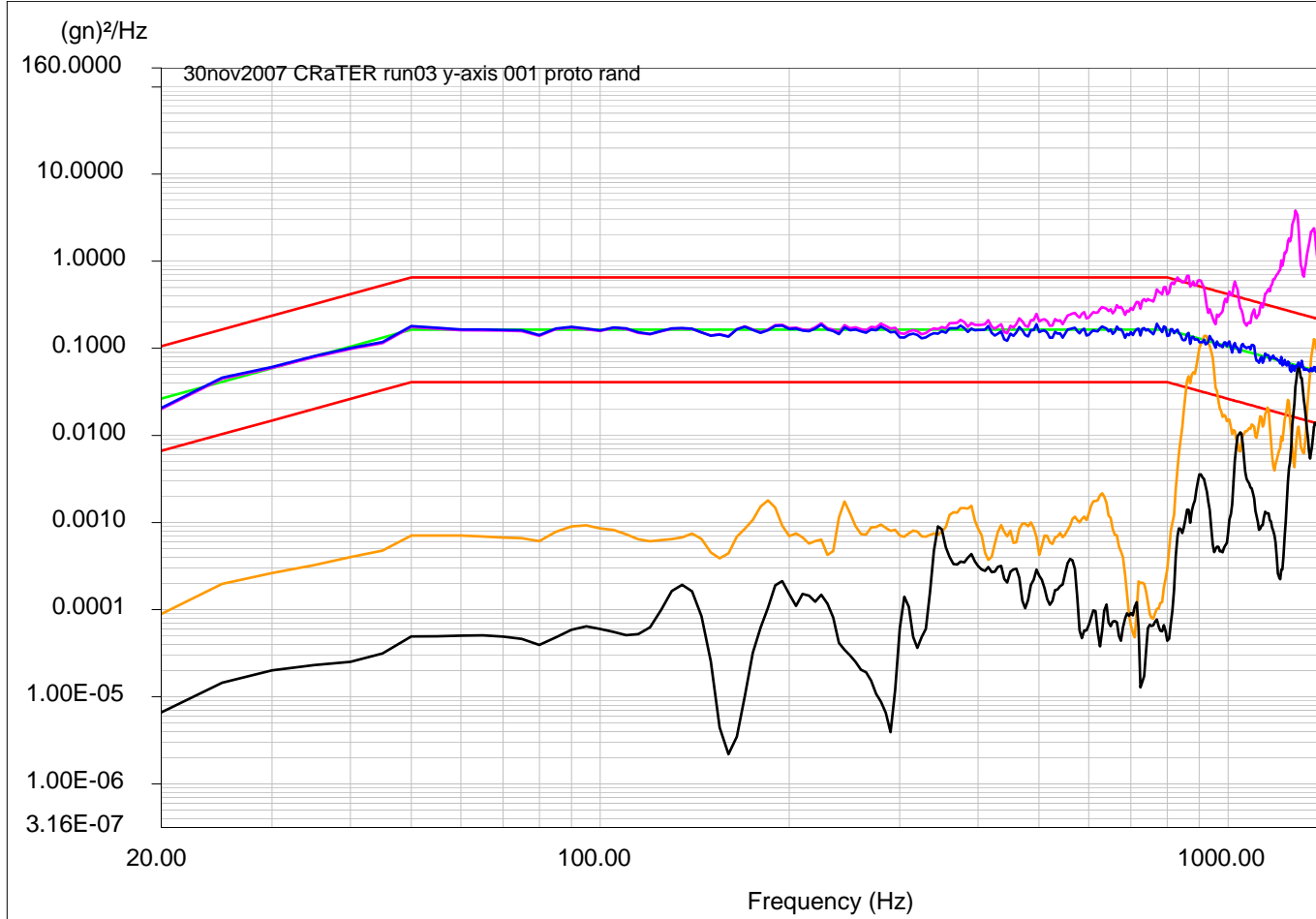
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Report created at Report created at 10:26:32 AM, Fri



# Appendix G. CRaTER Y-Axis, Random Vibe

S/N 001



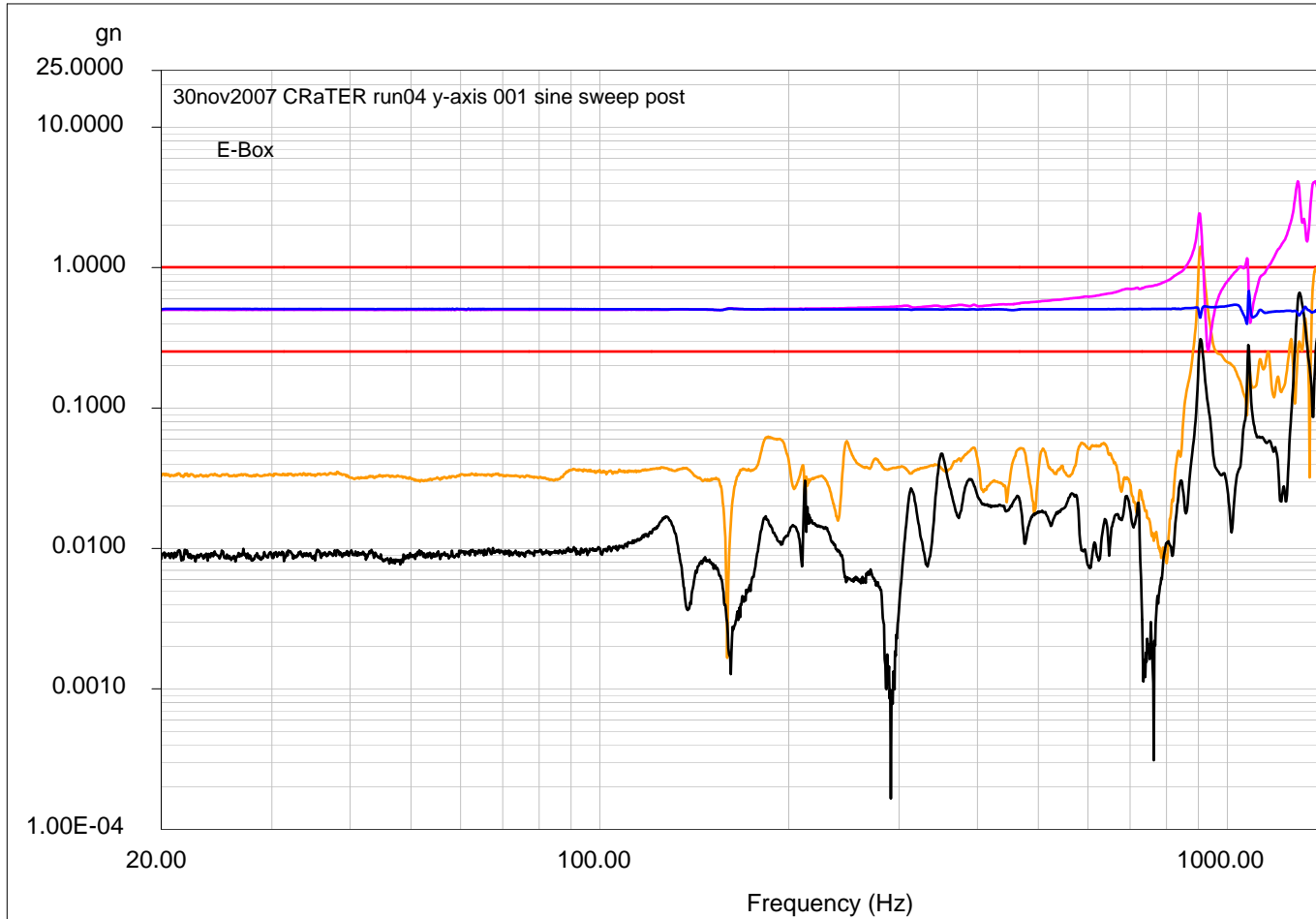
Level:	0 dB						
Control RMS:	13.975968 gn	Full Level Elapsed Time:	00:01:00	Lines:	400	Frame Time:	0.200000
Demand RMS:	14.138149 gn	Remaining Time:	00:00:00	DOF:	100	dF:	5.000000

Data saved at 01:12:35 PM, Friday, November 30, 2007

Report created at 01:12:36 PM, Friday, November 30, 2007

# Appendix H. CRaTER Y-axis, Post Vibe 1/2g Sine Sweep

s/n 001



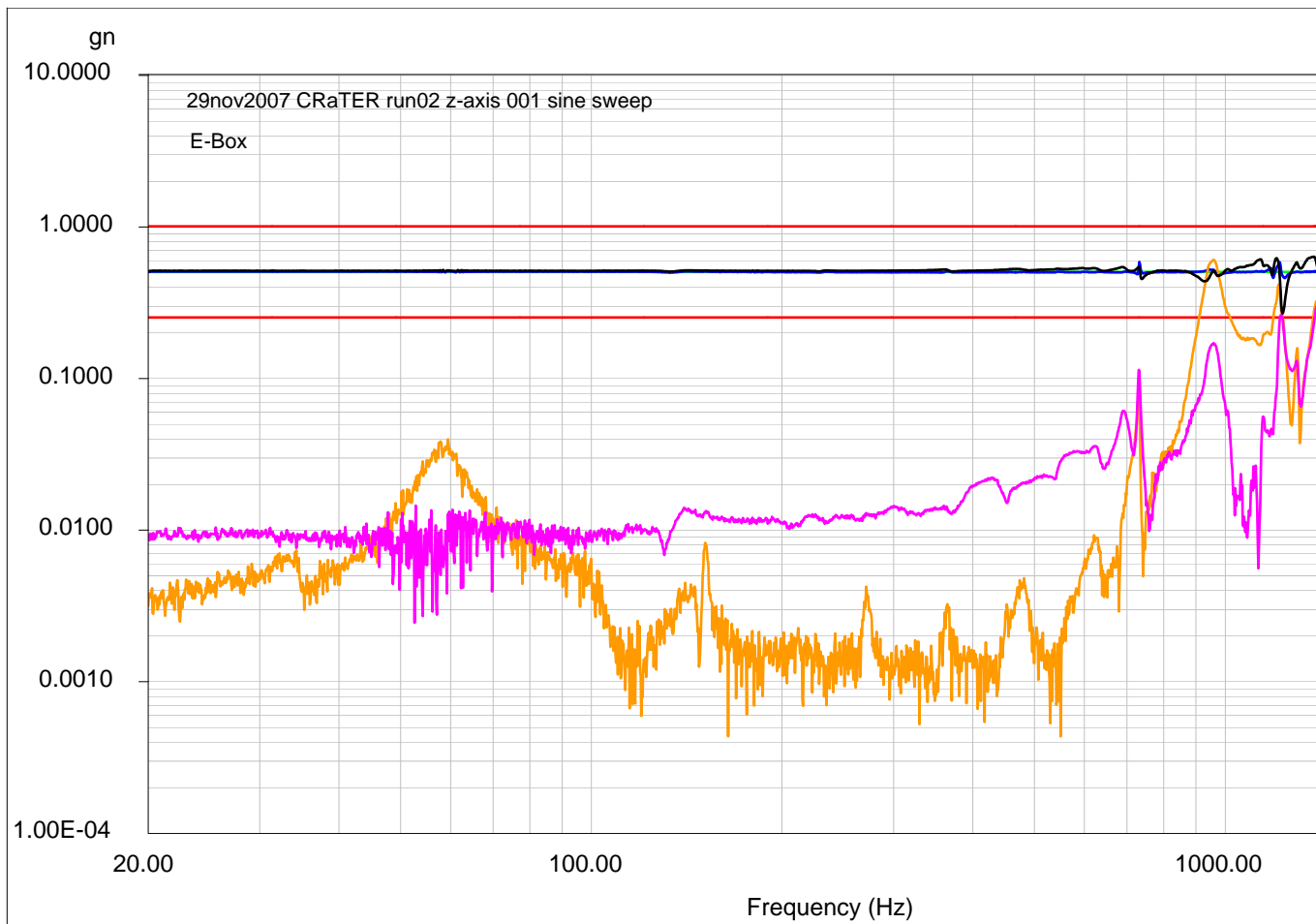
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Frequency:	1998.061890 Hz	Demand Peak:	0.500000 gn	Time Remaining:	00:00:00	Sweep Ra

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Report created at Report created at 01:32:40 PM, Frid

## Appendix I. CRaTER Z-axis, Pre Vibe 1/2g Sine Sweep

S/N 001



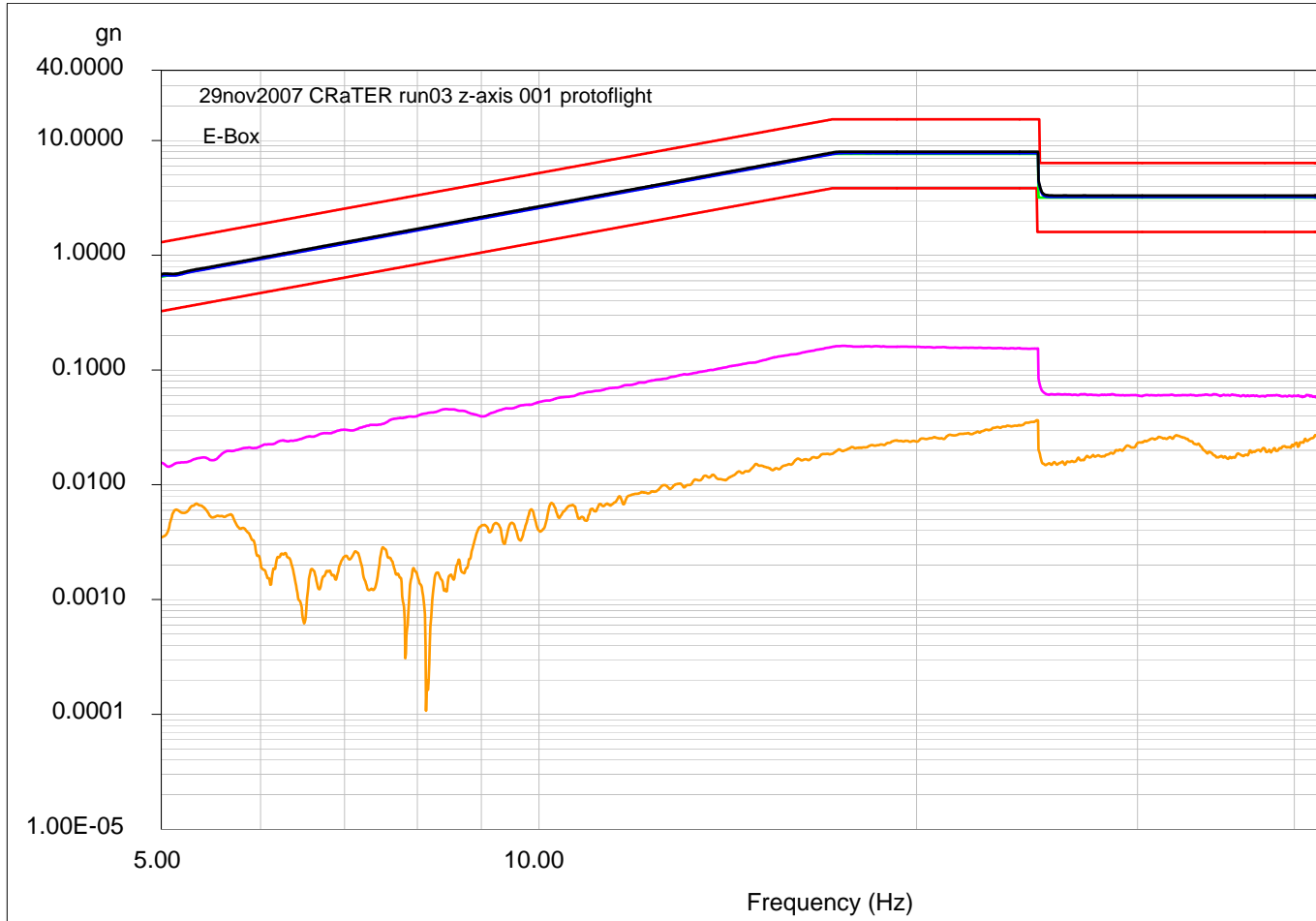
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Frequency:	1998.554199 Hz	Demand Peak:	0.500000 gn	Time Remaining:	00:00:00	Sweep Ra

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Report created at Report created at 12:46:38 PM, Thu

# Appendix J. CRaTER Z-axis, Sine Vibe

S/N 001



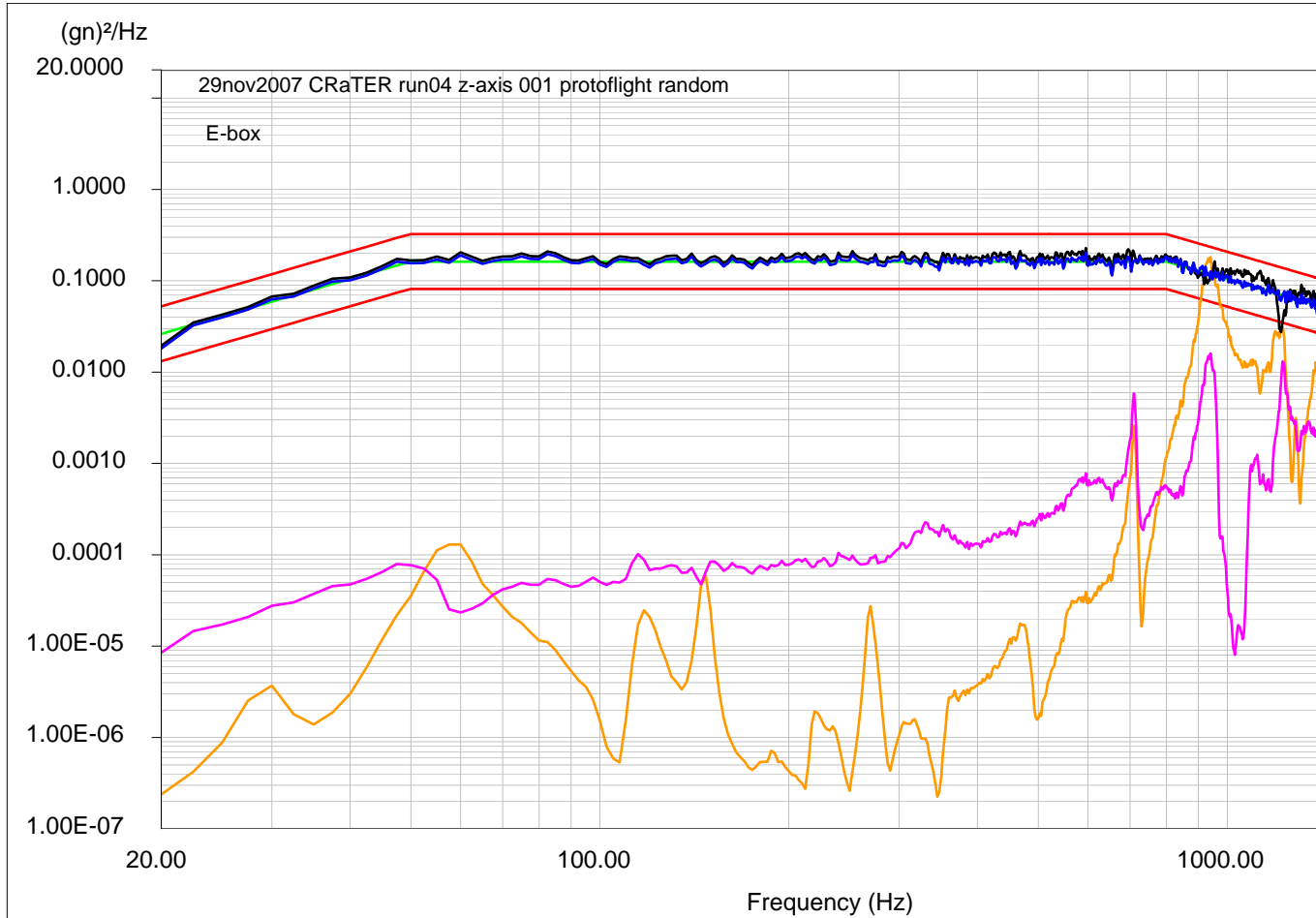
Level:	100 %	Control Peak:	3.150810 gn	Full Level Time:	00:00:50	Sweep Ty
Frequency:	49.808750 Hz	Demand Peak:	3.125000 gn	Time Remaining:	00:00:00	Sweep Ra

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Report created at 01:14:24 PM, Thu

## Appendix K. CRaTER Z-axis, Random Vibe

S/N 001



Level: 100 %

Control RMS: 14.190080 gn

Full Level Elapsed Time: 00:01:00

Lines: 800

Frame Time: 0.400000

Demand RMS: 14.126707 gn

Remaining Time: 00:00:00

DOF: 200

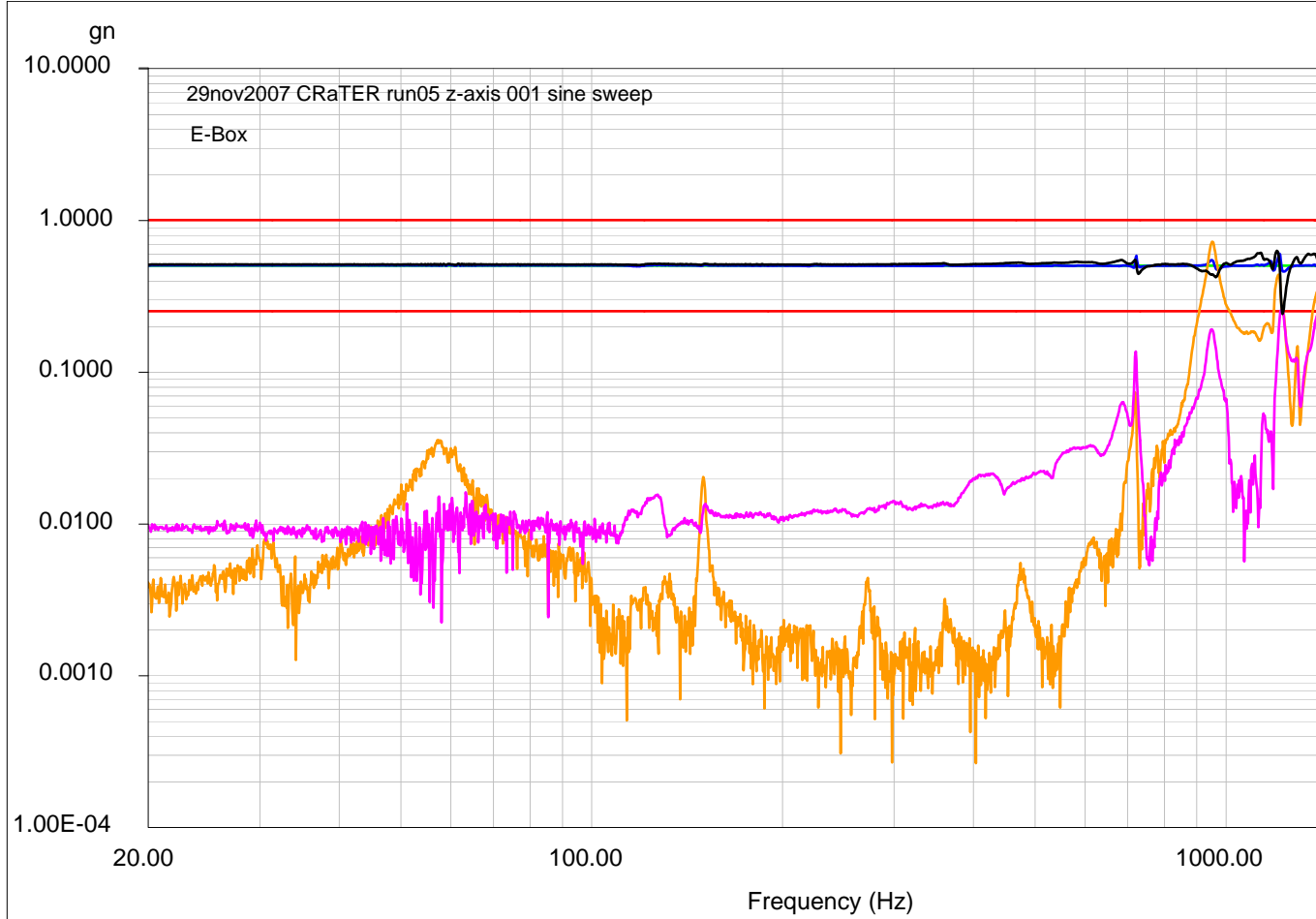
dF: 2.500000

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Report created at Report created at 01:32:33 PM, Thu

# Appendix L. CRaTER Z-axis, Post Vibe 1/2g Sine Sweep

s/n 001



Level:	100 %	Control Peak:	0.478241 gn	Full Level Time:	00:03:19	Sweep Ty
Frequency:	1995.602173 Hz	Demand Peak:	0.500000 gn	Time Remaining:	00:00:00	Sweep Ra

Data saved at 01:40:50 PM, Thursday, November 29, 2007

Report created at Report created at 01:40:52 PM, Thu