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# Modal Analysis and Vibration Test of NASA MSFC Shaker Table

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Modal Analysis and Vibration Test of Shaker Table

**Brian Mincks** 

Marshall Space Flight Center

July 13, 2018

**Reviewed by NASA Mentor Ron Burwell** ET40

Que Mentor Signature Here

National Aeronautics and Space Administration George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812



July 13, 2018

To:ET40 Vibrations TeamFrom:Brian MincksSubject:Modal Analysis and Vibration of UD T4000-H Shaker

The Unholtz-Dickie T4000A horizontal shaker (UD T4000A-H) was subject to both a modal tap test and a subsequent vibration test. The modal test was completed on July 2, 2018 and the vibration test was completed on July 9, 2018. The FRF's from the modal test and the acceleration profiles and duration schedules from the vibration test are shown in the attached tests and procedures.

Please direct any questions or comments to Brian Mincks at (740) 348-6826, brian.mincks@nasa.gov, or b.d.mincks@wustl.edu.

Buan Munde

Brian Mincks Structural Dynamics Intern NASA MSFC ET40



UD T4000A-H 07/2/2018-7/9/2018

# Unholtz-Dickie T4000A Modal Analysis & Vibration Test

#### Abstract

A shaker can be used to simulate launch vibrations and check responses of structures forced at different frequencies. When vibrating at certain frequencies during tests, structural modes of the shaker table itself can cause the test to abort by accelerating too much or by pushing too much electrical gain through the system. Furthermore, structural modes can produce misleading data at these modal frequencies and cause the test article to be under-tested or over-tested. A modal roving hammer test of the horizontal shaker table is conducted to characterize these modes of the shaker table. Two cases were tested in an attempt to simulate the boundary condition of the table on the shaker: free-free and free-fixed. The free-free case revealed a stretching mode at 1334.2Hz while free-fixed showed two stretching modes at 576.7Hz and 1372.3Hz. A subsequent vibration test revealed controlling 20in from the shaker attachment point best controls these modes without drastically over-testing or under-testing. **Introduction** 

The goal of this experiment is to characterize the structural modes of the UD T4000A horizontal shaker in an effort to better understand how to control it at these resonances. A control accelerometer is attached to the shake table and relays how many g's the test article is feeling to the control system. The control system adjusts power to the shaker in an attempt to shake the control accelerometer at a specified level. Due to the continuity in the shaker table structure and the finite location at which a control accelerometer can sense, the control accelerometer can be subject to more or less g's relative to the rest of the structure depending on where it is in the mode shape. If the control accelerometer at the specified level and the rest of the mode shape will feel less g's (under testing). Conversely, if the control accelerometer is in a node, the control system will push the shaker harder than necessary. This causes the rest of the mode shape to feel more g's (over testing). Furthermore, the control system may be forced to abort the test in this case because it puts too much gain through the amps in an attempt to push the control accelerometer to the specified levels.

Damage and test abort problems usually occur in the axis of vibration so the in-axis component of the modes is all that is considered in this report. The plate stretching mode responds completely in axis and usually causes the most problems. The stretching modal frequency in Hz of any structure is calculated as in Eq. 1 [1].

$$f = \frac{V}{AL} \tag{1}$$

Here, *V* is the speed of sound of the material defined as  $V = \sqrt{\frac{E}{\rho}}$  where *E* is the elastic modulus of the material and  $\rho$  is the density. *L* is the length of the structure in the axis of stretching. *A* is a constant dependent on the boundary condition and is defined in Eq. 2.

$$A = \begin{cases} 2, & Free - Free \\ 4, & Free - Fixed \end{cases}$$
(2)

A modal roving hammer test is performed to reveal the stretching modes that Eq. 1-2 predict. The table has a free-forced boundary condition on the table itself. A forced boundary condition cannot be simulated in the modal tap test so the plate will be simulated as both free-free and free-fixed to reveal all frequencies around which the stretching mode might appear. A subsequent vibration test is performed to sweep through the modal frequencies discovered in the modal tests. The swept sine test will be repeated, but controlled at various locations along the length of plate. This should reveal how much vibration gain or attenuation is being felt around the plate

#### **Apparatus & Procedures**

#### Part 1: Modal Analysis

The experiment starts with the free-free modal test. The equipment list for the modal tests is seen below in Table 1.

	ltem	NEMS/SN	Cal Date	Cal Due
R1	Accelerometer	LW147719	9/20/14	9/20/15
R2	Accelerometer	LW147963	2/28/15	2/28/16
	Hammer/Load Cell	LW40109	N/A	N/A
	20g hammer mass	N/A	N/A	N/A
	Plastic hammer tip	N/A	N/A	N/A
	Data Acquisition Front End	45034708	N/A	N/A
	Dell M6400 Computer	TL13A	N/A	N/A
	Free Shaker Table	N/A	N/A	N/A
	Fixed Shaker Table	N/A	N/A	N/A

Table 1 Equipment List

Accompanying, relevant calibration documents are available in Appendix A.1. A schematic showing the equipment setup is seen below in Figure 1.





To simulate the free-free boundary condition, the shaker is setup on foam blocks. Simple, checkout tests revealed the first structural mode was more than ten times that of the first rigid body mode signifying the free-free simulation is valid [1]. Figure 2 shows this setup of the shaker table on foam.



Figure 2 Free-Free test setup

To simulate a free-fixed boundary condition, the table is left on the shaker. Lubricating oil that flows during shaker operation is pumped in between the table and its support structure to create the free boundary condition. The shaker is left locked to fix the other end. Figure 3 shows the free-fixed configuration.



Figure 3 Free-fixed test setup

The tap test utilized two response accelerometers and six tap locations. The plate geometry, accelerometer locations, and hammer tap locations are seen below in Figure 4.



Figure 4 Geometry and tap locations on shaker table (dimensions in inches)

Here P1 – P6 signify the tap locations of the hammer and R1 and R2 are the accelerometer locations. The accelerometers are glued onto the table using Cyanoacrylate. The test excites frequencies over 1000Hz so glue must be used to ensure good energy transfer. Taps on point P1-P3 happen along the thickness of the plate in the +Z direction while taps on points P4-P6 happen in the -Z direction.

All of the data is taken using LMS Impact Testing 13A software. Table 2 shows all of the test setup parameters. The impact scope parameters are all codependent. Once two are defined, the other two are calculated. Bandwidth is set to 1600Hz because tests usually abort around what is suspected to be the stretching mode at 700Hz. In order to prevent leakage in the data, 1600Hz is chosen to ensure at least twice the frequency of interest is measured [1]. Acquisition time was set next at 5.12s. The plate rang for approximately three seconds in the free-free case when struck with the hammer. In order to observe the entire impact with a margin of safety, 5.12s is chosen. Once the Impact scope parameters are chosen, the tip and hammer masses has to be addressed. A 10 - 20 dB drop in impact energy is desired across the bandwidth of interests. This prevents the introduction of leakage through non negligible energy being input at a frequency that's not being measured [1]. This can be accomplished with many different hammer mass and tip configurations. For this experiment, a hard plastic tip and two 20g masses were used. All the trigger settings were chosen from what the software suggests. A few test taps will yield suggested values similar to those seen below in Table 2. The data is slightly windowed to ensure the entire impact is observed without having lengthy acquisition time. If excluded from the table below, use the default settings.

	Software		
Software Section	Subsection	Field	Value
		Bandwidth	1600Hz
Impact Scope	N/A	Spectral Lines	8192
		Resolution	0.1953125Hz
		Acquisition Time	5.12s
		Input Range	10V
	Trigger	Trigger level	0.0916
Impact Setup		Pretrigger	0.0028s
	Windowing	Input	Force-Exponential (0.1403%)
		Response	Uniform (100%)
Measure	N/A	Averages	5

Table 2 LN	IS parameters
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## Part 2: Vibration Test

Once the modes have been found and characterized, a vibration test is conducted to sweep across the modal frequencies. The test uses 4 accelerometers at varying lengths from the shaker attachment point. The same test will be run 4 times with the exception of changing the control accelerometer. This should reveal what the rest of the structure is feeling compared to what the control accelerometer feels. The test equipment list is seen below in Table3.

	Item	NEMS/SN	Cal Date	Cal Due
P1	Accelerometer	LW129160	2/26/18	1/26/2019
P1	Charge Amp	M667358	7/1/17	7/1/18
P2	Accelerometer	LW189436	11/13/17	11/13/18
P2	Charge Amp	M666781	7/1/17	7/1/18
Р3	Accelerometer	LW189425	11/13/17	11/13/18
Р3	Charge Amp	M654005	11/16/17	11/16/18
P4	Accelerometer	LW189432	11/13/17	11/13/18
Ρ4	Charge Amp	M665526	10/23/17	9/23/18
	Shaker	UD T4000A-H	N/A	N/A
	Control System Ch 1-4	VR9500 M671477	N/A	N/A
	Control System Ch 5-8	VR9500 M671481	N/A	N/A
	Control System Ch 9-12	VR9500 M671484	N/A	N/A

## Table 3 Vibration test equipment

Accompanying, relevant calibration documents are available in Appendix A.2. A schematic of the test setup is seen in Figure 5.



Figure 5 Vibration test setup schematic

Figures 6 shows a detailed drawing of the accelerometer locations on the table.



Figure 6 Accelerometer locations for vibration test (dimensions in inches)

Figure 7 shows a picture of the actual test setup.



Figure 7 Vibration test setup

The test is controlled and recorded with the VibrationVIEW software. The test sweeps from 40Hz – 2000Hz at 0.5g. The test sweeps through the frequencies at 5 octaves/min with an abort range of  $\pm 50$ dB. All of the other settings are default. The first test controls with an accelerometer at P1, the second test controls with an accelerometer at P2, etc. All the other accelerometers in these tests simply record the response.

## Results

## Part 1: Modal Analysis

The frequency response functions (FRF's) at each tap location of the free-free tap test are seen below in Figure 8. The free-fixed FRF's are seen in Figure 9. Both Figures 8 and 9 are obtained directly from LMS.



Figure 8 FRF's of free-free modal tap test



Figure 9 FRF's of free-fixed modal tap test

The quality of the data appears to be good. There is some noise in the data but it's all relatively small compared to the modal peaks.

All the peaks in all the test configurations correspond to a stretching mode. LMS directly animates the mode shapes that it is recording. The free-free stretching mode at 1334.2 Hz is seen below in Figure 10. The first and second modes of the free-fixed case at 576.7 Hz and 1360.6 Hz are seen in Figures 11 and 12, respectively.



Figure 10 Free-free stretching mode at 1334.2 Hz, 0.02% damping



Figure 11 Free-fixed stretching mode at 576.7 Hz, 0.67% damping



Figure 12 Free-fixed stretching mode at 1360.6 Hz, 1.19% damping

## Part 2: Vibration Test

Figure 13 shows the vibration profile controlling at P1. Figure 14 shows the vibration profile controlling at P2. Figure 15 shows the acceleration profile controlling at P3. Figure 16 shows the vibration profile controlling at P4. All of the acceleration profiles are exported directly from VibrationView



Figure 13 Vibration profile controlling at P1



Figure 14 Vibration profile controlling at P2



Figure 15 Vibration profile controlling at P3



Figure 16 Vibration profile controlling at P4

The data looks good in quality. There doesn't appear to be any outliers that signify something went wrong in the tests.

### Discussion

## Part 1: Modal Analysis

The FRF peaks denote the modal stretching frequencies and align well with the predicted analytical first stretching mode frequencies as seen in Table 3.

Test Configuration	Measured Frequency [Hz]	Analytical Frequency [Hz]	Percent Error
Free-Free	1334.2	1446.9	7.78
Free-Fixed	576.7	723.5	20.3

### Table 4 Experimental-analytical comparison of modal frequencies

The discrepancies in the data can be accredited to the irregular plate geometry. Equations 1 and 2 model a fixed-length uniform plate. The plate is not of fixed length and is riddled with mounting and bearing holes which both directly contradict the assumptions that are necessary to use Equations 1 and 2 accurately. The exaggerated error in the free-fixed case is due to an imperfect fixed boundary condition. While the plate is locked in the shaker, the whole shaker/plate system can still move because the shaker sits on airbags.

## Part 2: Vibration Test

Point 1 appears to be a node. Figure 13 shows the acceleration profile controlling at point 1. While it stays on its 0.5g line through the frequency, all the other points have vibration gains over 20 at the first stretching mode. The control system has to push the shaker hard to get this node up to a 0.5g while the others are resonating. Point 2 appears to be approaching a resonance. Figure 14 shows the control system doesn't have to push the shaker too hard to get Point 2 up to the specified acceleration. It's also seen that the Point 1 node is barely moving and Points 3 and 4 are resonating a little harder at the first stretching mode. Figures 15 and 16 show similar trends with points 3 and 4. It appears that point 4 resonates the hardest followed by point 3 and then point 2. This was analyzed by exporting all the vibration view data to Excel. At each control location, the acceleration gains were analyzed by comparing the responses to the control. Table 5 shows these trends.

<b>Control Point</b>	Vibration Gain				
	P1	P2	P3	P4	
P1	1	34.59554	45.88156	60.12159	
P2	0.009636	1	1.573561	1.753507	
Р3	0.010218	0.628204	1	1.10232	
P4	0.010724	0.559686	0.878997	1	

**Table 5** Vibration gains across table at varying control points

This makes sense from the results from the modal test. The animations in Figures 11 and 12 show both ends moving like an accordion. However, that is for a free fixed boundary condition. Since the 'fixed' end is actually forced in the actual vibration test, a Galilean transformation must be applied to the frame of reference so that the free-fixed mode shapes can be applied. In this transformed reference frame, the mode shape is viewed from the perspective of the shaker head and the end (P4) will be resonating the most while the attachment point (P1) will be fixed.

#### Conclusion

Stretching modes exist in the shaker table. The free-free configuration has a stretching mode at 1334.2 Hz and the free-fixed configuration has two modes at 576.7 Hz and 1360.6 Hz. The free-free test aligns quite well with the analytical solution while the free-fixed case test setup could be improved to make a more fixed end. These results can be used to help control the shaker through the stretching modal frequencies. A Galilean transformation of the reference frame is conducted to the accordion-like mode shape from the free-fixed test so it is viewed from the perspective of the shaker. In this reference frame the accordion mode will be stationary at the attachment point to the shaker and be resonating at the full length. Table 5 concisely depicts how this length dependent resonance affects the vibration gain in the structure. To best control the shaker table and to provide an accurate, safe, abort free test through the stretching modes, control around 20 inches from the attachment head. The vibration gains felt throughout the rest of the structure only get as big as 1.75. This should prevent the test from aborting and ensure the test article is not being damagingly over-tested.

## References

1. Rost, Robert, Allemong, Randal. (2018, May 15-17). *Practical Data Acquisition and Experimental Modal Analysis Theory and Applications*.

# Appendix A.1 Modal Test accelerometer calibration information

Ch2/ Free side

AS FOUND CALIBRATION         Calibration Performed By:         Calibration Performed For:           MSC METROLOGY & CALIBRATION LABORATORY         Department:         FTADE           BLDG 46505 DODD ROAD         Requested By:         STEVE RODGERS           MARSHALL SPACE FLIGHT CENTER, AL 35812         User Location:         4619RM 151           ECN (ID):         M667029         Calibration Interval Adjustment Method:         EOPR           Manufacturer:         POED PIEZONTRONICS         Effective EOPR:         100%         Cale In Tolerance           Model Number:         LW147719         Minimum EOPR Target:         89 %         Total Cale           Bescription:         ACCELEROMETER         CLAM Comments:         25 %         Secal Category:         2         Interval Suggested:         12 Months           Current Calibration Information         Work Order Number:         201400940002         Condition Resceived:         A IN TOLERANCE           Priority:         3 - LOW         Action Target:         89 %         Secal Category:         2         Calibration Information           Work Order Number:         201400940002         Condition Resceived:         A IN TOLERANCE         Pointry:         3 - LOW         Action Target:         89 %         Secal Category:         2         Calibration Information         Ca				Calibratio	on Certificate		
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Model Number:       36821       Previous EOPR:       0%       Total Cals         Description:       ACCELEROMETER       CIAM Comments:       CIAM Comments:         Serial Number:       LW147719       Minimum EOPR Target:       98 %         Sange(ff applicable):       500GPK       Maximum EOPR Target:       95 %         Recall Category:       2       Interval Suggestack:       12 Months         Verk Order Number:       20140904002       Condition Received:       A IN TOLERANCE         Priority:       3 - LOW       Action Taken:       C CALIBRANCE         Jalibration Interval:       12 MONTHS       Found/Left       FOUND/LEFT         Calibration Date:       09/20/14       Calibration Result:       PASS         Calibration Date:       09/20/15       Quality Requirement:       ANSIMCSL Z540-1-1994(20         Performed By:       THOMAS MAGRUDER       Ratio Descr. / Ratio:       TAR / 3.16         Performed By:       Thomas.umagnuder@nasa.gov       Lab Temperature/Relative Humidity:       24C /         Imitations (if applicable):       **** Unless admode indexed.dee and/of them models in date in the and/of them models in date	Manufactu	rer: P	CB PIEZONTRONICS		Effective EOPR: 100 %	Cals In To	erance: 1
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Berial Number:         LW147719         Minimum EOPR Target:         89 %           Sange(If applicable):         500GPK         Maximum EOPR Target:         95 %           Recall Category:         2         Interval Suggested:         12 Months           Mork Order Number:         20140904002         Condition Received::         A IN TOLERANCE           Priority:         3 - LOW         Action Taken:         C CALIBRATED           Zalibration Interval:         09/20/14         Calibration Result:         PASS           Zalibration Interval:         12 MONTHS         FoundLeft         FOUNDLEFT           Zalibration Interval:         12 MONTHS         Curality Requirement:         ANSINCSL Z540-1-1994(20           Performed By:         THOMAS MAGRUDER         Ratio Descr / Ratio:         TAR / 3.16           Performed By:         ThoMAS MAGRUDER         Ratio Descr / Ratio:         TAR / 24.C /           Imitations (if applicable):         *Nex Unless clamate indexts due and/of the area result         Standards Used During Calibration           Science         Manufacturer         Model         Description         Calibration           Science         Manufacturer         Model         Description         Calibration           Science         301/114         Edid Traceable Standards Use	Description	n: A	CCELEROMETER		CIAM Comments:		
Range (if applicable):         500 GPK         Maximum EOPR Target:         95 %           Recall Category:         2         Interval Suggested:         12 Months           Current Calibration Information         Current Calibration Information         More Condition Reserved:         A IN TOLERANCE           Priority:         3 - LOW         Action Taken:         C CALIBRATED         Calibration Result:         PASS           Calibration Date:         09/20/14         Calibration Result:         PASS         Calibration Result:         PASS           Calibration Due Date:         09/20/15         Quality Requirement:         ANSINCSL Z540-11994(20           Performed By:         THOMAS MAGRUDER         Ratio Descr / Ratio:         TAR / 3.16           Performed By Email:         thomas.v.magn.der@mass.gov         Lab Temperature/Relative Humidity:         24C /           imitations (if applicable):         The Unities otherwise indente: Mee and allore a whold was motion and and and and the amee allore a whold was motion and and and and and the amee allore a motion and and and and and the amee allore a whold and and and and and the amee allore a whold and and and and and and the amee allore a motion and and and and and the amee allore a motion and and and and and and the amee allore a motion and and and and and and and and and an	Serial Num	ber:	LW147719		Minimum EOPR Target	89 %	
Recall Category:         2         Interval Suggested:         12 Months           Mork Order Number:         20140904002         Condition Information         A IN TOLERANCE           Average State         20140904002         Condition Received:         A IN TOLERANCE           Order Number:         20140904002         Condition Received:         A IN TOLERANCE           Calibration Date:         09/20/14         Calibration Result:         PASS           Calibration Interval:         12 MONTHS         Found/Left*         FOUND/LEFT           Calibration Due Date:         09/20/15         Quality Requirement:         ANSI/NCSL Z540-1-1994(20           Performed By:         THOMAS MAGRUDER         Ratio Descr. (Ratio:         TAR /         3.16           Performed By:         THOMAS MAGRUDER         Ratio Descr. (Ratio:         TAR /         3.16           Performed By:         Thomas.v.magnuder@nasa.gov         Lab Temperature/Relative Humidity:         24 C /           Imitations (if applicable):         Yote: Unless oftendee indeted; the condition of the fem was aff in the same adue as whoid a was required.           Statistication         Statistication         Cal Date         07/25/14           AdSedso         DR PrivalAurCes         301115         ACCELEROMETER         09/71/14           AdSedso </td <td>Range(if an</td> <td>oplicable)</td> <td>500GPK</td> <td></td> <td>Maximum EOPR Target</td> <td>05 %</td> <td></td>	Range(if an	oplicable)	500GPK		Maximum EOPR Target	05 %	
Traceable Standards Used During Calibration           Sch         Manufacturer         Model         Description           Calibration Notes (if applicable):         ************************************	Recall Cate	eqory:	2		Interval Suggested:	12 Months	
Nork Order Number:         20140904002         Condition Received:         A IN TOLERANCE           Priority:         3 - LOW         Action Result:         PASS           Calibration Date:         09/20/14         Calibration Result:         PASS           Calibration Interval:         12 MONTHS         Found/Leff*         FOUND/LEFT           Calibration Due Date:         09/20/15         Quality Requirement:         ANSI/NCSL Z540-1-1994(20           Performed By:         THOMAS MAGRUDER         Ratio Descr / Ratio:         TAR /         3.16           Performed By:         THOMAS MAGRUDER         Ratio Descr / Ratio:         TAR /         3.16           Performed By:         Thomas.v.magruder@nase.gov         Lab Temperature/Relative Humidity:         24C /           imitations (if applicable):         "Wore Unless otherwhere indonted, the condition of the tem wes left in the same state as which it was moaved.           Selection Notes (if applicable):         "Wore Unless otherwhere indonted, the condition of the tem wes left in the same state as which it was moaved.           Selection Notes (if applicable):         "Wore Unless otherwhere indonted.ge condition of the tem wes left in the same state as which it was moaved.           Selection Notes (if applicable):         "Wore Unless otherwhere indonted.ge condition of the tem wes left in the same state as which it was moaved.           Selection Notes (if appl				Current Calibra	tion Information	12 WORTS	
Priority:       3 - LOW       Action Taken:       C ACUBRATED         Calibration Date:       09/20/14       Calibration Result:       PASS         Calibration Interval:       12 MONTHS       Found/Leff*       C CALIBRATED         Calibration Due Date:       09/20/15       Quality Requirement:       ANNCSL Z540-1-1994(20         Calibration Due Date:       09/20/15       Quality Requirement:       ANNCSL Z540-1-1994(20         Performed By Email:       fnomas.vmaqruder@mass.gov       Lab Temperature/Relative Humidity:       24 C /         Imitations (if applicable):       were under@mass.gov       Lab Temperature/Relative Humidity:       24 C /         Zalibration Notes (if applicable):       were under@mass.gov       Lab Temperature/Relative Humidity:       24 C /         Zalibration Notes (if applicable):       were under@mass.gov       Lab Temperature/Relative Humidity:       24 C /         Zalibration Notes (if applicable):       were under@mass.gov       Lab Temperature/Relative Humidity:       24 C /         Zalibration Notes (if applicable):       were under@mass.gov       Lab Temperature/Relative Humidity:       24 C /         Zalibration Notes (if applicable):       were under@mass.gov       Lab Temperature/Relative Humidity:       24 C /         School MB DYNAMICS       406L       Desconption       Calibate <t< td=""><td>Nork Orde</td><td>r Number</td><td>20140904002</td><td></td><td>Condition Received:</td><td></td><td></td></t<>	Nork Orde	r Number	20140904002		Condition Received:		
Calibration Date:       09/20/14       Calibration Result:       PASS         Calibration Interval:       12 MONTHS       Found/Left*       FOUND/LEFT         Calibration Due Date:       09/20/15       Quality Requirement:       ANSI/ACSL 2540-1-1994(20         Calibration Due Date:       09/20/15       Quality Requirement:       ANSI/ACSL 2540-1-1994(20         Performed By:       THOMAS MAGRUDER       Ratio Descr / Ratio:       TAR       /       3.16         Performed By:       thomas.v.magnuder@nass.gov       Lab Temperature/Relative Humidity:       24C       /         Imitations (if applicable):       "were Unless onewnee indented, the condition of the tem wee bit in the same state as which it was monited."         Scin       Manufacturer       Model       Description       Cal Date         195390       MB DYNAMICS       405L       SiGNAL.CONDITIONER       07/25/14         4056450       PCB PIEZOTRONICS       301M15       ACCELEROMETER       06/17/14         4656450       PCB PIEZOTRONICS       301M15       ACCELEROMETER       06/17/14         4656450       PCB PIEZOTRONICS       301M15       ACCELEROMETER       06/17/14         4656450       PCB PIEZOTRONICS       301M15       ACCELEROMETER       06/17/24/14         End of Tracesable Stan	Priority:		3 - LOW		Action Taken: C	CALIBRATED	
Calibration Interval:       12 MONTHS       Found/Left*       FOUND/LEFT         Calibration Due Date:       09/20/15       Quality Requirement:       ANSI/NCSL Z540-1-1994(20         Performed By:       THOMAS MAGRUDER       Ratio Descr / Ratio:       TAR       /       3.16         Performed By:       ihomas.v.magruder@nasa.gov       Lab Temperature/Relative Humidity:       24 C       /         Jimitations (if applicable):       Traceable Standards Used During Calibration       Calibration       Calibration         Conserver       Model       Description       Calibration       Calibration         Scin       Manufacturer       Model       Description       Calibration         Conserver       Model       SiGNAL CONDITIONER       07/25/14         M656450       PCB PiezoTRONICS       301M15       ACCELEROMETER       06/17/14         A656502       NATIONAL INSTRUMENTS       Procedures Used in This Event       Procedures Used in This Event       07/24/14         Frocedure By       Procedure Number       Description       Revision       Revision         SFC       2-0142       ACCELEROMETER AND VIBRATION PICKUPS       3       0         Nis instrument was calibrated to leboratory standards which are traceable through an unbroken chain of comparisons to the Net stitute of Standards. Th	Calibration	Date:	09/20/14		Calibration Result: P	ASS	
Calibration Due Date:         09/20/15         Quality Requirement:         ANSINCSL Z540-1-1994(20           Performed By:         THOMAS MAGRUDER         Ratio Descr / Ratio:         TAR / 3.16           Performed By Email:         thomas.v.magnuder(2)nasa.gov         Lab Temperature/Relative Humidity:         24 C /           Imitations (if applicable):         ************************************	Calibration	Interval:	12 MONTHS		Found/Left* Fi	OUND/LEFT	
Performed By:       THOMAS MAGRUDER       Ratio Descr / Ratio:       TAR       /       3.16         Performed By Email:       thomas.v.magnuder@nase.gov       Lab Temperature/Relative Humidity:       24C       /         Imitations (if applicable):       Imitations (if applicable):       Value: Unless otherwise indexted, the condition of the flum was bit in the same state as which it was received.         Calibration Notes (if applicable):       Work: Unless otherwise indexted, the condition of the flum was bit in the same state as which it was received.         ECN       Manufacturer       Model       Description       Cal Date         2105300       MB DYNAMICS       405L       SIGMAL CONDITIONER       07/25/14.         4656450       PCB PIEZOTRONICS       301M15       ACCELEROMETER       06/17/14         Frocedure By       Procedures Values       Of Traceable Standards       BORNETER       07/22/14         Frocedure By       Procedures Used In This Event       Procedures Used In This Event       Revision       Revision         Procedure By       Procedures Number       Description       Revision       Revision       Revision       Revision         NSFC       2-0142       ACCELEROMETERS AND VIBRATION PICKUPS       3       0         Inis instrument was calibrated to laboratory standards which are traceable through an unbroken chai	Calibration	Due Date	e: 09/20/15		Quality Requirement: Al	NSI/NCSI 7540-1-1	994/2002)
Conserts       Initiations (if applicable):       24C /         Initiations (if applicable):       Note: Unless oftennike indicated, the condition of the item was left in the same left is an which it was received.         Selibration Notes (if applicable):       Note: Unless oftennike indicated, the condition of the item was left in the same left is an which it was received.         Selibration Notes (if applicable):       Note: Unless oftennike indicated, the condition of the item was left in the same left as which it was received.         Selibration Notes (if applicable):       Note: Unless oftennike indicated, the condition of the item was left in the same left as which it was received.         Selibration Notes (if applicable):       Note: Unless oftennike indicated, the condition of the item was left in the same left as which it was received.         Selibration Notes (if applicable):       Note: Unless oftennike indicated, the condition of the item was left in the same left as which it was received.         Selibration Notes (if applicable):       Note: Unless oftennike indicated, the condition of the item second item item item of the same left as which it was received.         Selibration Notes (if applicable):       Note: Unless oftennike indicated.         Selibration Notes (if applicable):       Note: Unless oftennike indicated.         Selibration Notes (if applicable):       Selibration of the same left in	Performed	By:	THOMAS MAGE	UDER	Ratio Descr / Ratio:	TAR /	3 16.1
Imitations (if applicable):       Traceable Standards Used During Calibration         Calibration Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Traceable Standards Used During Calibration         Construction Notes (if applicable):       Nodel       Description         Construction Notes (if applicable):       301M15       Accelleroometer         Procedure Number       Procedure Standards       07/24/14         End of Traceable Standards       Traceable Standards         Procedure Number       Description       Revision         Test Of Traceable Standards and Technology (NIST), laboratories recognized by the same, inthinsic standards, fundamental constants of utual consent standards. This report may not be rep	Performed	By Email	thomas.v.magruc	ler@nasa.gov	Lab Temperature/Relative	Humidity: 24	C / 41 0/
Traceable Standards Used During Calibration           Salibration Notes (if applicable):           Vole: Unless otherwise indicated, the condition of the item was left in the same state as which it was received.           Salibration Notes (if applicable):           Vole: Unless otherwise indicated, the condition of the item was left in the same state as which it was received.           Salibration Notes (if applicable):           Vole: Unless otherwise indicated, the condition of the item was left in the same state as which it was received.           Salibration Notes (if applicable):           Vole: Unless otherwise indicated, the condition of the item was left in the same state as which it was received.           Salibration Notes (if applicable):           Vole: Unless otherwise indicated, the condition of the item same state as which it was received.           Salibration Notes (if applicable):           Vole: Unless otherwise indicated, the condition of the item same state as which it was received.           Salibration Notes (if applicable):           Vole: Unless otherwise indicated, the condition of the item same state and received.           Procedures Used In This Event           Procedures Used In This Event           Procedure Number         Description         Revision	imitatione	(if applic	able);			riannany. Li	
Traceable Standards Used During Calibration           SCN         Manufacturer         Model         Description         Cal Date           2195390         MB DYNAMICS         405L         SIGNAL CONDITIONER         07/25/14           2656450         PCB PIEZOTRONICS         301M15         ACCELEROMETER         06/17/14           2656502         NATIONAL INSTRUMENTS         PCI-MIO-16E-1         DAC BOARD         07/24/14           Procedures Used in This Event           Procedure Number         Description         Revision         Revision           ISFC         2-0142         ACCELEROMETERS AND VIBRATION PICKUPS         3         0						N.	
SCN         Manufacturer         Model         Description         Cal Date           195390         MB DYNAMICS         405L         SIGNAL CONDITIONER         07/25/14           1656450         PCB PIEZOTRONICS         301M15         ACCELEROMETER         06/17/14           1656502         NATIONAL INSTRUMENTS         PCI-MIO-16E-1         DAC BOARD         07/24/14           Ind of Traceable Standards           Procedure Number         Description         Revision         Rev           Ind of Traceable Standards           Procedure Number         Description         Revision         Rev           Information of Comparisons to the Nation Stitute of Standards and Technology (NIST), laboratories recognized by the same, intrinsic standards, fundamental constants of utual consent standards. This report may not be reproduced, except in full, without written permission from the organization issupport. The results of this calibration apply only to the item identified above, at the time of test, and under the conditions reaonfed				Traceable Standards	Used During Calibration		
INSDUCT         MIS DYNAMICS         405L         SIGNAL CONDITIONER         07/25/14           A656450         PCB PIEZOTRONICS         301M15         ACCELEROMETER         06/17/14           A656502         NATIONAL INSTRUMENTS         PCI-MIO-16E-1         DAC BOARD         07/24/14           End of Traceable Standards         Procedure Used In This Event         07/24/14         End of Traceable Standards           Procedure By         Procedure Number         Description         Revision         Revision           ISFC         2-0142         ACCELEROMETERS AND VIBRATION PICKUPS         3         0	CN	Manuf	acturer	Model	Description	Cal	Date Due Da
Instrument         Was calibrated to laboratory standards which are traceable through an unbroken chain of comparisons to the Nation under standards. This report may not be reproduced, except in full, without written permission from the organization issue port. The results of this calibration apply only to the item identified above, at the time of test, and under the conditions reported         Object         Object <th< td=""><td>195390</td><td>MB DY</td><td>NAMICS</td><td>4051_</td><td>SIGNAL CONDITIONE</td><td>R 07/</td><td>25/14 07/25/</td></th<>	195390	MB DY	NAMICS	4051_	SIGNAL CONDITIONE	R 07/	25/14 07/25/
International and the second sec	1656502	NATIO	NAL INSTRUMENTS	PCI_MIO_16E_4	ACCELEROMETER	06/	17/14 06/17/1
Procedures Used In This Event           Procedure By         Procedure Number         Description         Revision		1101101		End of Traceabl	e Standards	07/	24/14 07/24/1
rocedure By         Procedure Number         Description         Revision         Revisio				Procedures Use	d In This Event		
his instrument was calibrated to laboratory standards which are traceable through an unbroken chain of comparisons to the Nativi stitute of Standards and Technology (NIST), laboratories recognized by the same, intrinsic standards, fundamental constants of utual consent standards. This report may not be reproduced, except in full, without written permission from the organization issu port. The results of this calibration apply only to the item identified above, at the time of test, and under the conditions renorded	TOCEDUTE E	sy .	2-0142	Description	AND MODATION COMMENT	Revision	Revision Dat
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y	his instrume stitute of S outual conse aport. The n	ent was ca tandards a ent standa	alibrated to laboratory sta and Technology (NIST), it rds. This report may not	ndards which are tracea aboratories recognized b be reproduced, except is	ble through an unbroken chair by the same, intrinsic standard	n of comparisons to t s, fundamental consi	he National
eneration Date: 09/20/14 Page 1 of 1 MISFC CERT REV 2 (08	ports tine It	esults of t	his calibration apply only	to the item identified abo	ove, at the time of test, and un	der the conditions re	ion issuing this ported.

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MSFC METI BLDG 46503 MARSHALL (256) 544-49	Calib ROLOGY &		me i ekin	IN CALICINATION				01600
MSFC METH BLDG 46503 MARSHALL (256) 544-49	ROLOGY &	ration Performed	Bv:	Ca	libration Pe	rformed F	or:	
BLDG 46503 MARSHALL (256) 544-49		CALIBRATION LAP	BORATORY	Department:	ET40-E			
MARSHALL (256) 544-49	S DODD RC	DAD		Requested By:	STEVE F	RODGERS	5	
(256) 544-49	SPACE FL	IGHT CENTER, AL	35812	Owner:	STEVE F	RODGERS	6	
	900			User Location:	4619RM1	151		
most (in)			Equipme	nt Information				
ECN (ID):	M66/	6/1 DIFTONTRONICO		Calibration Interval /	Adjustment M	lethod:	EOPR	and the f
Manutacture	PCBI	PIEZONTRONICS		Effective EOPR:	100 %	winnmum	EOPR IS	arget: a
Model Numb	Der. Jood	LEDOMETED		Interval Suggested:	12 MON.	Maximum	EOPK 18	arget: S
Description:	ACCE	ELEROMETER		CIAW Comments:	r∠ monun inte database wit	erval per Eu h this	OPR OF OD	ners in
Serial Numb	per;	LW147963		Calibrations Found I	n Tolerance:		1	
Range(if app	olicable):	500G		Calibrations Found I	noperative/Of	ther:	0	
Recall Categ	gory:	2		Total Calibrations:			1	
			Current Calib	ration Information				
Work Order	Number:	20150212065		Condition Received:	A INTO	LERANCE	E	
Priority:		3 - LOW		Action Taken:	C CALI	BRATED		
Calibration D	Date:	02/28/15		Calibration Result:	PASS			
Calibration In	nterval:	12 MONTHS		Found/Left*	FOUND/	LEFT		
Calibration D	Due Date:	02/28/16		Quality Requiremen	t: ANSI/NC	SL Z540-1	-1994(20)	02)
	2.4	THOMAS MAGE	UDER	Ratio Descr / Ratio:	TAR	1	3.16:	1
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Performed B Performed B _imitations (i Calibration N	sy: By Email: (if applicable Notes (if app	thomas.v.magnuc ): licable):	Ier@nasa.gov *Note: Unless otherwise Indice	Lab Temperature/Re	elative Humidi e seme state es which.	ity: 2	23C /	44 %
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ECN 2195390 M656450	Manufacti Manufacti MB DYNAM PCB PIEZC	thomas.v.magruc ): licable): urer (ICS TRONICS	Traceable Standard Model 405L 301M15	Lab Temperature/Re ted, the condition of the Item was left in the des Used During Calibration Description SIGNAL CONDI ACCELEROME	elative Humidi e same state as which e same state as which n n n TIONER TER	ity: 2 R was received.	al Date 77/25/14 18/17/14	<b>Due Da</b> 07/25/ 06/17/
ECN 2195390 M656502	Manufacti Manufacti MB DYNAM PCB PIEZC NATIONAL	thomas.v.magruc ): licable): licable): licable instruments	Traceable Standard Model 405L 301M15 PCI-MI0-16E- End of Trace	Lab Temperature/Re ted, the condition of the Item was left in the des Used During Calibration Description SIGNAL CONDI ACCELEROME 1 DAC BOARD able Standards	elative Humidi e same state as which e same state as which n n n n n n n n n n	ity: 2 R was received.	Cal Date 23 C / 27/25/14 36/17/14 37/24/14	<b>Due Da</b> 07/25/ 06/17/ 07/24/
ECN 2195390 M656502	Manufacti Manufacti MB DYNAM PCB PIEZC	thomas.v.magruc ): licable): urer fiCS DTRONICS INSTRUMENTS	Traceable Standard Mode: Unless otherwise indice Model 405L 301M15 PCI-MI05-16E- End of Trace	Lab Temperature/Re ted, the condition of the Item was left in the ted in the ted ted ted ted ted ted ted ted ted te	elative Humidi e same state as which e same state as which n n n n n n n n n n	ity: 2 R was received.	Cal Date 23 C / 23 C / 23 C / 24/14	<b>Due Da</b> 07/25/ 06/17/ 07/24/
ECN 2195390 M656502 Procedure B	Manufacti     Manufacti     MB DYNAM     PCB PIEZC     NATIONAL	thomas.v.magruc ): licable): urer fiCS DTRONICS INSTRUMENTS rocedure Number	Traceable Standard Model 405L 301M15 PCI-MIO-16E- End of Trace Procedures L Description	Lab Temperature/Re ted, the condition of the Item was left in the ted, the condition of tem was left in the tem	elative Hurnidi e same state as which e same state as which n n TIONER TER	ity: 2 R was received.	Cal Date 07/25/14 06/17/14 07/24/14	44%
ECN 2195390 M656450 M656502	Manufacti Manufacti MB DYNAM PCB PIEZC	thomas.v.magruc ): licable): urer IICS DTRONICS INSTRUMENTS	Traceable Standard Model 405L 301M15 PCI-MIO-16E- End 0-Trace Procedures L	Lab Temperature/Re ted, the condition of the item was left in the ted, the condition of the item was left in the ted, the condition of the item was left in the ted, the condition of the item was left in the ted in The Second ted in This Event	elative Humidi e same state es which es anne state es which on TIONER FER	ity: 2	Cal Date 77/25/14 76/17/14 77/24/14	Due D 07/25 06/17/ 07/24

# Appendix A.2 Vibration Test accelerometer calibration information

		Calibratio	n Certificate				
Marshall Space Flight Center					Certificate #:		
		AS FOUND	CALIBRATION			554787	
C	Calibration Performed B	v:	Calib	ration Perfor	med For:		
MSFC METROLO	GY & CALIBRATION LAE	ORATORY	Department:	ET40-E			
BLDG 4650S DOD	D ROAD		Requested By:	STEVE ROD	DGERS		
MARSHALL SPAC	E FLIGHT CENTER, AL	35812	Owner:	STEVE ROD	DGERS		
(256) 544-4900			User Location:	4619RM 151	1		
	1000500	Equipment	Information			<b>`</b>	
EGN (ID):			Calibration Interval Ad	Justment Metr	100: EOPF	1 2 Targot: 0	0.0/
Manufacturer: F			Effective EOPR: 10			Target. 0	9 /0
Model Number: 3			CIAM Commenter	2 MON. Maxi		R Target: 9	5 %
Description: F	ACCELEROMETER		CIAM Comments:				
Serial Number:	LW189425		Calibrations Found In	Tolerance:	3		—
Range(if applicable	e): 500G PK		Calibrations Found Inc	operative/Othe	er: 0		_
Recall Category:	2		Total Calibrations:		3		
	-	Current Calibrat	ion Information		-		
Work Order Numb	er: 20171109183	ourient oanbrat	Condition Received:		BANCE		_
Priority:	1 - HIGH		Action Taken:	C CALIBR	ATED		
Calibration Date:	11/13/17		Calibration Result:	PASS			
Calibration Interval	: 12 MONTHS		Found/Left*	AS FOUND			
Calibration Due Da	ate: 11/13/18		Quality Requirement:	NPD 8730.1	С		
Performed By:	NATE GONZALE	S	Ratio Descr / Ratio:	TUR	/ 2	2.94:1	
Performed By Ema	il: nathaniel.s.gonza	les@nasa.gov	Lab Temperature/Rela	ative Humidity	: 20.7 C	/ 45.3%	_
Limitations (if appli	cable).	<u> </u>		,			_
Calibration Notes (	if applicable): *Note: Unles	s otherwise indicated the cor	adition of the item was left in the s	amo stato as which	it was received		
		Traceable Standards	Used During Calibration				
ECN Man	ufacturer	Model	Description		Cal Da	te Due Dat	ie
M666865 PCB		443B101	DUAL MODE SIGN		NE 12/12/1	16 12/12/17	
M666867 PCB	PIEZOTRONICS	442A102	SHAKER REFERE		RC 12/07/	16 12/07/17	,
M667153 NATIO	ONAL INSTRUMENTS	NI PC-4461	24 BIT DATA ACQ	UISITION MOD	DU 12/05/1	16 12/05/17	
		End of Traceabl	le Standards			1	
		Procedures Use	ed In This Event				
Procedure By	Procedure Number	Description			Revision	Revision Da	ate
This instrument was Institute of Standard mutual consent star	calibrated to laboratory sta s and Technology (NIST), it dards. This report may not	ndards which are trace aboratories recognized be reproduced, except	able through an unbroker by the same, intrinsic sta in full. without written peri	n chain of comp. ndards, fundam mission from the	arisons to the nental consta e organizatio	e National nts of nature, n issuing this	or
report. The results of Generation Date: 11	of this calibration apply only	to the item identified at	bove, at the time of test, a	nd under the co	onditions repo	orted.	()
						- 100 00 2014	/

Calibration Certificate						
		Marshall Spac	e Flight Center		C	ertificate #:
		AS FOUND C	ALIBRATION			583623
	Calibration Performed B	y:	Calibratio	on Performe	ed For:	
MSFC METRO	OLOGY & CALIBRATION LA	BORATORY	Department: ET	40-E		
BLDG 4650S	DODD ROAD		Requested By: ST	EVE RODG	ERS	
MARSHALL S	SPACE FLIGHT CENTER, AL	35812	Owner: ST	EVE RODGI	ERS	
(256) 544-490	00	E audia au a da la	Jser Location: 46	19RM151		
	Mccooco	Equipment in	Tormation	mont Mothed		
EGN (ID):			Jalibration Interval Adjustr	Minimu		Target: 80 %
Manufacturer:			Effective EOPR: 75%			Target. 05 %
				Jii. Maximu		Target: 95 %
Description:		ETER V	JIAM Comments:			
Serial Number	r: LW129160		Calibrations Found In Tole	rance:	3	
Range(if appli	cable): 500G PK		Calibrations Found Inoperation	ative/Other:	0	
Recall Catego	pry: 2	-	Total Calibrations:		4	
		Current Calibratio	on Information			
Work Order N	umber: 20180220007		Condition Received: A	IN TOLERA	NCE	
Priority:	3 - LOW		Action Taken: C	CALIBRATI	ED	
Calibration Da	ate: 02/26/18		Calibration Result: PA	SS		
Calibration Int	erval: 11 MONTHS		Found/Left* AS	FOUND		
Calibration Du	ie Date: 01/26/19		Quality Requirement: NF	PD 8730.1C		
Performed By	: NATE GONZALE	S	Ratio Descr / Ratio:	TUR /	2.9	94:1
Performed By	Email: nathaniel.s.gonza	ales@nasa.gov	Lab Temperature/Relative	Humidity:	21.8 C /	50.7 %
Limitations (if	applicable):					
Calibration No	otes (if applicable): *Note: Unles	s otherwise indicated the cond	tion of the item was left in the same s	tate as which it w	as received	
See data.						
		Traceable Standards U	sed During Calibration			
ECN	Manufacturer	Model	Description		Cal Date	Due Date
M666866		080A200			12/13/17	12/13/18
M667153	NATIONAL INSTRUMENTS	NI PC-4461			12/13/17	12/15/18
PCB-539	PCB PIEZOTRONICS	443B101	DUAL MODE SIGNAL	CONDITIONE	11/17/17	11/17/18
		End of Traceable	Standards			
		Procedures Used	In This Event			
Procedure By	Procedure Number			Re		Aevision Date
10131 0	2-0142	ACCELENCIALIENS	IND VIBRATION FICKUPS		5	02/07/2011
This instrumon	t was calibrated to laboratory sta	indards which are traces	hle through an unbroken cho	in of comparis	sons to the	National
Institute of Sta	ndards and Technology (NIST), I	aboratories recognized b	y the same, intrinsic standard	ds, fundamen	tal constant	s of nature, or
mutual consen	t standards. This report may not	be reproduced, except ir	full, without written permissi	on from the o	rganization	issuing this
report. The res	suits of this calibration apply only	to the item identified abo	eve, at the time of test, and ui	naer the cond	nions report	ea.
Generation Dat	e: 02/26/18	Page 1 of	1	MSFC	CERT REV 2	(08-06-2014)

			Calibratio	n Certificate			
			Marshall Spa	ice Flight Center		C	ertificate #:
			AS FOUND	CALIBRATION			554775
	Cal	ibration Performed B	y:	Calibra	ation Perform	ed For:	
MSFC METR	OLOGY	<b>' &amp; CALIBRATION LAE</b>	BORATORY	Department: E	ET40-E		
BLDG 4650S	DODD	ROAD		Requested By:	STEVE RODG	ERS	
MARSHALLS	SPACE	FLIGHT CENTER, AL	35812	Owner: S	STEVE RODG	ERS	
(256) 544-490	00		<b>F</b>	User Location: 2	4619RM 151		
	MG	COE 40	Equipment	Information	atmost Mathe		
EGN (ID):				Effective FORD			Targot: 80 %
Manufacturer	: PC			Interval Suggested: 12	Mon Maxim		Target. 05 %
	31: 350				MON. Maxim		Target: 95 %
Description:	AC	GELEROMETER		CIAM Comments:			
Serial Numbe	er:	LW189432		Calibrations Found In To	olerance:	3	
Range(if appl	icable):	500G PK		Calibrations Found Inop	erative/Other:	0	
Recall Catego	ory:	2		Total Calibrations:		3	
			Current Calibrat	ion Information			
Work Order N	lumber:	20171109178		Condition Received:	A IN TOLERA	ANCE	
Priority:		1 - HIGH		Action Taken:	C CALIBRAT	ED	
Calibration Da	ate:	11/13/17		Calibration Result:	PASS		
Calibration In	terval:	12 MONTHS		Found/Left*	AS FOUND		
Calibration Du	ue Date	: 11/13/18		Quality Requirement:	NPD 8730.1C		
Performed By	/:	NATE GONZALE	S	Ratio Descr / Ratio:	TUR /	2.9	94:1
Performed By	/ Email:	nathaniel.s.gonza	ales@nasa.gov	Lab Temperature/Relativ	ve Humidity:	20.7 C /	45.2 %
Limitations (if	applica	ble):					
Calibration No	otes (if a	applicable): *Note: Unles	s otherwise indicated. the co	ndition of the item was left in the sam	ne state as which it w	vas received.	
See data.		,					
			Traceable Standards	Used During Calibration			
ECN	Manufa		Model	Description		Cal Date	Due Date
A989990V	PCB PIE		0804200			12/12/16	12/12/17
M666867	PCB PIF	ZOTRONICS	442A102	SENSOR SIGNAL C	ONDITIONER	12/07/16	12/07/17
M667153	NATION	IAL INSTRUMENTS	NI PC-4461	24 BIT DATA ACQUI	ISITION MODU	12/05/16	12/05/17
			End of Traceab	le Standards			
Dreedure Dr		Dressdure Number	Procedures Use	ed In This Event		ovicion I	Paviaian Data
MSEC		2-0142	ACCELEBOMETERS	AND VIBRATION PICKLIPS	S	3	02/07/2011
		2 0112	//OOLLEHOME FERG			Ū	02/07/2011
This instrumer	nt was ca	alibrated to laboratorv sta	ndards which are trace	able through an unbroken c	hain of comparis	sons to the I	Vational
Institute of Sta	andards a	and Technology (NIST), I	aboratories recognized	by the same, intrinsic stand	lards, fundamen	ntal constant	s of nature, or
mutual conser	nt standa	ards. This report may not	be reproduced, except	in full, without written permis	ssion from the o	organization	ssuing this
Generation De	to: 14/45		Done 1	4 1			(08.06.0014)
Generation Dat	<i>ie:</i> 11/13	0/17	Page 1 c	11	MSFC	CERT REV 2	(08-06-2014)

	С	alibration	Certificate			
		Marshall Space	e Flight Center			Certificate #:
		AS FOUND C	ALIBRATION			555120
Calibration I	Performed By:		Calib	ration Perfor	med For:	
MSFC METROLOGY & CALIB	RATION LABOR	RATORY	Department:	ET40-E		
BLDG 4650S DODD ROAD		F	Requested By:	STEVE ROD	DGERS	
MARSHALL SPACE FLIGHT (	CENTER, AL 358	812 0	Owner:	STEVE ROL	DGERS	
(256) 544-4900		E audio ant la		4619RM 151		
		Equipment in	formation			
EGN (ID): M668549	DONICO		Calibration Interval Ad	justment Metr	100: EOPR	Target: 90 %
Manufacturer: PCB PIEZOI	RUNICS		TIECTIVE EOPR: 1			Target: 09 %
	45750		nierval Suggested.	2 Mon. Max		Target: 95 %
Description: ACCELEROI	VIETER	(	JAM Comments:			
Serial Number: LW189	436	(	Calibrations Found In	Tolerance:	3	
Range(if applicable): 500G P	ΥK	(	Calibrations Found Ind	operative/Othe	er: 0	
Recall Category: 2		-	Fotal Calibrations:	•	3	
		Current Calibratio	n Information			
Work Order Number: 2017	71109180	<u>eunent eunstatie</u>	Condition Received		BANCE	
Priority: 1 - H	ligh		Action Taken:	C CALIBR	ATED	
Calibration Date: 11/1	3/17		Calibration Result:	PASS		
Calibration Interval: 12	MONTHS		Found/Left*	AS FOUND		
Calibration Due Date: 11/1	3/18		Quality Requirement:	NPD 8730 1	C	
Performed By: NAT	E GONZALES		Batio Descr / Batio	TUR	/ 2	94.1
Performed By Email: nath	aniel s gonzales	@nasa gov	ab Temperature/Rel:	ative Humidity	· 2120	/ 44.4 %
Limitations (if applicable):	amono.gonzaioo	e naba.gov			. 21.20	/ 11.1 /0
Oplibration Nata (if applicable).	\					
	Trac	ceable Standards Us	sed During Calibration			
ECN Manufacturer		Model	Description		Cal Date	e Due Date
M666865 PCB PIEZOTRON	CS	443B101	DUAL MODE SIG	VAL CONDITIO	NE 12/12/1	6 12/12/17
M666866 PCB PIEZOTRONI	CS	080A200	SHAKER REFERE	NCE ACCELEI	RC 12/07/1	6 12/07/17
M666867 PCB PIEZOTRON		442A102	SENSOR SIGNAL	CONDITIONE		6 12/07/17
MATIONAL INSTR	UMENTS	End of Traceable	Standards		0 12/05/1	0 12/05/17
		Procedures Used	In This Event			
Procedure By Procedu	re Number De	escription			Revision	Revision Date
MSFC 2-0142	AC	CELEROMETERS A	ND VIBRATION PICKU	PS	3	02/07/2011
This instrument was calibrated to Institute of Standards and Techno mutual consent standards. This re report. The results of this calibrat	laboratory standa plogy (NIST), labo eport may not be r ion apply only to tl	rds which are traceal ratories recognized b eproduced, except in he item identified abo	ble through an unbroker y the same, intrinsic sta full, without written per ve, at the time of test, a	n chain of comp ndards, fundar mission from the nd under the co	arisons to the pental constar organization pnditions repo	National hts of nature, or hissuing this rted.
Generation Date: 11/14/17		Page 1 of	1	MSI	FC CERT REV	2 (08-06-2014)