DAMPING VALUES IN AEROSPACE STRUCTURES AND COMPONENTS
Revision D

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Table 1. Typical Q values for Structures and Components

System	fn (Hz)	Damping Ratio	Q	Appendix
Pegasus XL Launch Vehicle Body-Bending during Drop Transient	9.9	1.0%	50	A
Fairing Ring Frequency	897	3.7%	13.5	B
Battery Cells inside Foam-lined Box	80	15.2%	3.3	C
Avionics Circuit Boards, Hardmounted Boxes	220 to 650	1.7% to 5.6%	9 to 29	D
Component Mounting Brackets	70 to 2000	2% to 50%	1 to 25	E
Avionics Boxes Mounted via Lord Isolators	27 to 31	8.3%	6	F
Flexible Confined Detonating Cord (FCDC)	8 to 107	6%	8.3	G
Space Integrated GPS/INS (SIGI) Inertial Sensor Assembly (ISA) Isolators	55	13.5%	3.7	H

Table 1. Typical Q values for Structures and Components (continued)

System	fn (Hz)	Damping Ratio	Q	Appendix
Circular Bulkhead, Homogeneous	57	6.5%	7.7	I
Circular Bulkhead, Honeycomb Sandwich	40	5.9%	8.5	J

Excerpt from NASA SP-8050, Structural Vibration Prediction.

Type of Structure	Percent of Critical Viscous Damping	Remarks
Homogeneous-element configurations (machined brackets, solid beams, welded construction)	1 to 2	Damping factor depends on stress levels induced during vibration
Riveted or bolted structures	3 to 10	Damping cause by friction at joints significantly reduces the vibration amplification
Laminated plastics	4 to 10	Phenolic laminate
Honeycomb-core panels	3 to 6	Damping factor depends on method of fabrication (brazed versus adhesive bond) and on acoustic radiation
Vibration-isolated components	10 to 20	Damping factor depends on the isolator design
Nonviscous fluids	0.5 1.0 1.5	Frequency < 5 Hz 5 Hz $\le$ Frequency $\le$ 15 Hz Frequency > 15 Hz

Excerpt from NASA SP-8079, Structural Interaction with Control Systems

Vehicle	Vibration Mode	Frequency (Hz)	Damping Ratio
Saturn V/Apollo	First	1.0	0.005
	Second	1.7	0.007
	Third	2.3	0.006
	Fourth	3.0	0.010

The damping values were measured during a modal test.

APPENDIX A

Pegasus Launch Vehicle Body-Bending during Drop Transient

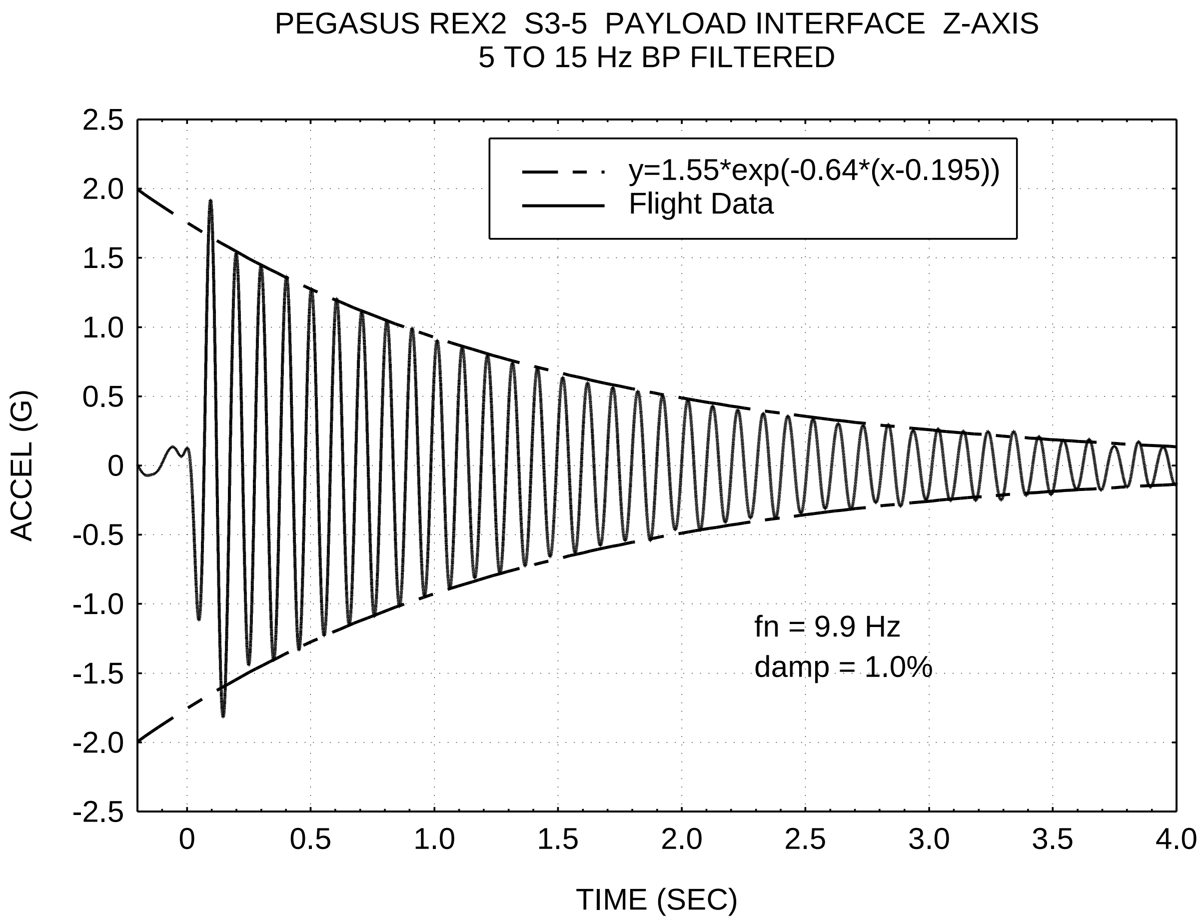

Figure A-1.

APPENDIX B

Fairing Ring Frequency

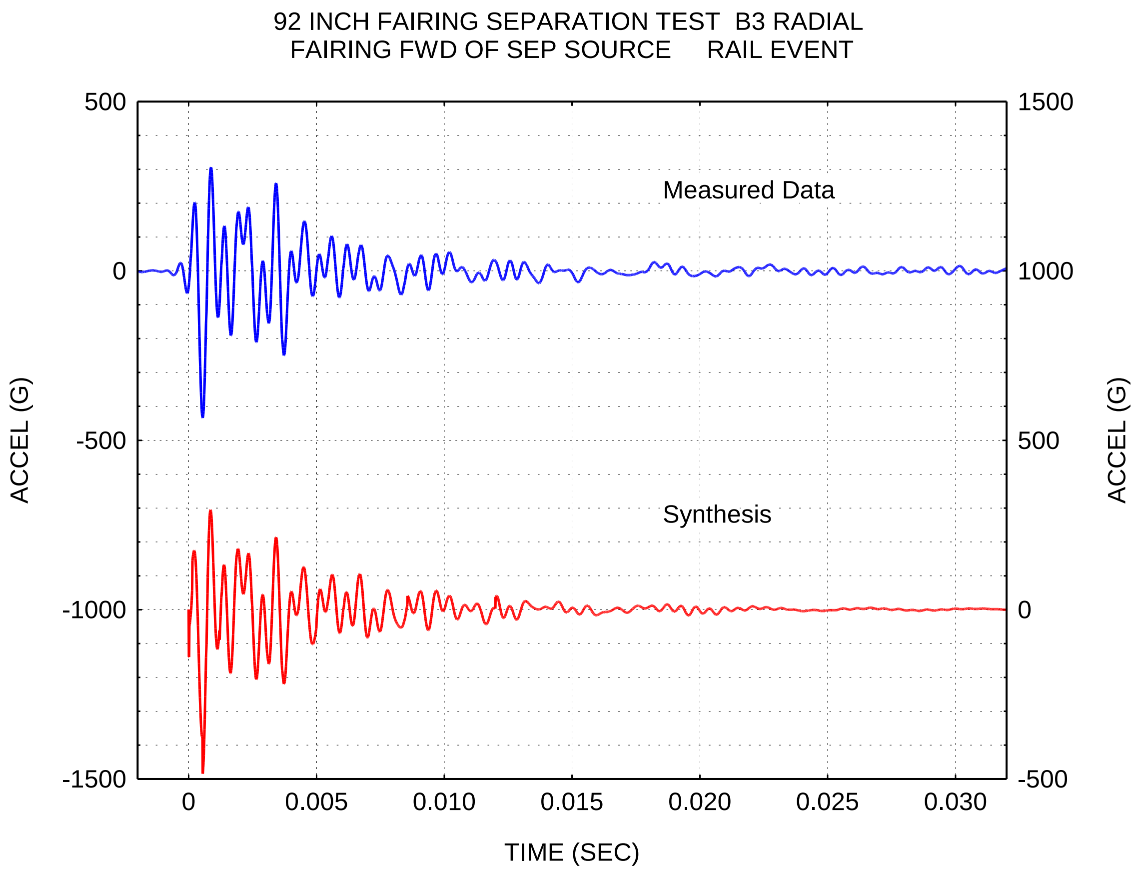

Figure B-1.

The source device was a frangible joint rail. The data was measured during a ground test.

The fairing consists of graphite-epoxy skins over an aluminum honeycomb core.

Note that the data is bandpass filtered from 20 to 2000 Hz.

The fairing's ring frequency is

$$fn = \frac{C_L}{\pi d} \tag{B-1}$$

C_L	=	257,976 in/sec	Longitudinal wave speed in the composite skin material
d	=	92 in	Diameter

$$fn = \frac{257{,}976\,\text{in/sec}}{\pi(92\text{ in})} = 893\text{ Hz}$$

The synthesis consists of ten components. The first three are given in Table 2.

Table B-1. Synthesis Results					
N	Amp (G)	Freq (Hz)	Phase (rad)	Damping	Delay (sec)
1	186.2	1888.895	1.682	0.017	0.000
2	172.7	897.063	3.609	0.037	0.000
3	112.6	1573.298	1.648	0.026	0.001

The second component represents the ring frequency.

APPENDIX C

Battery Cells inside Foam-lined Box

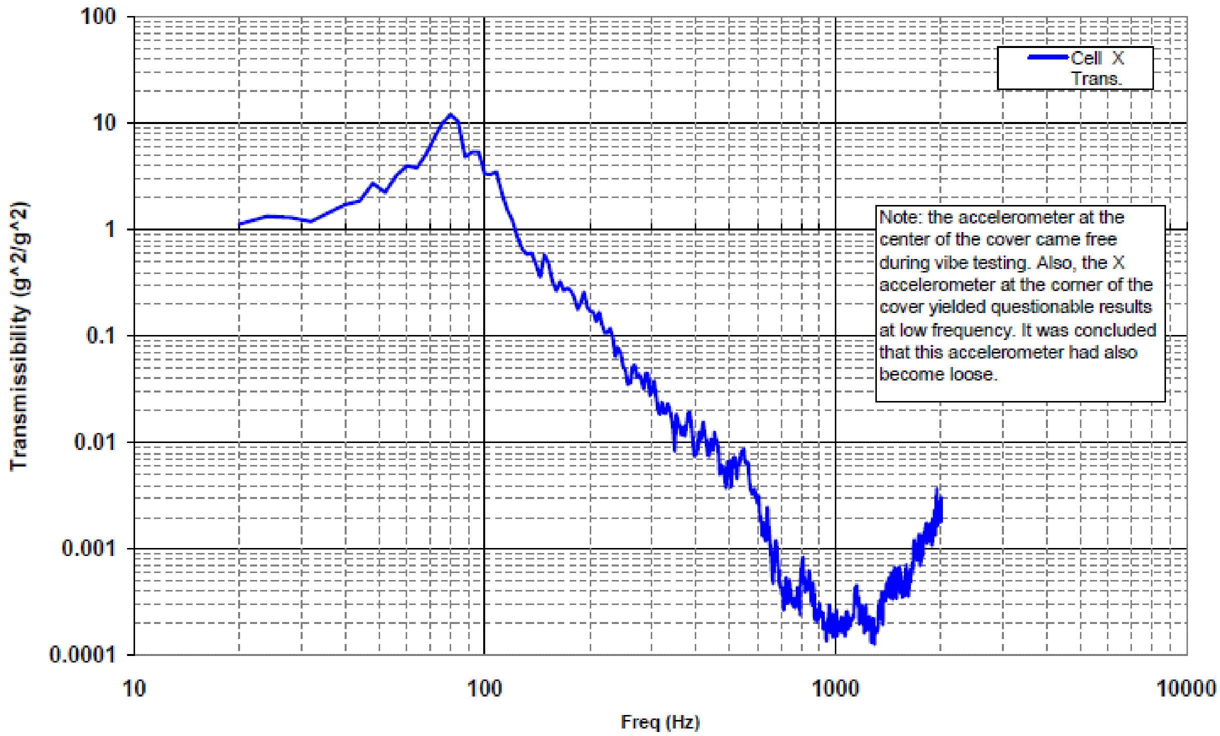

Figure 19: X Axis Transmissibility to Cells

Figure C-1.

The X-axis is vertical.

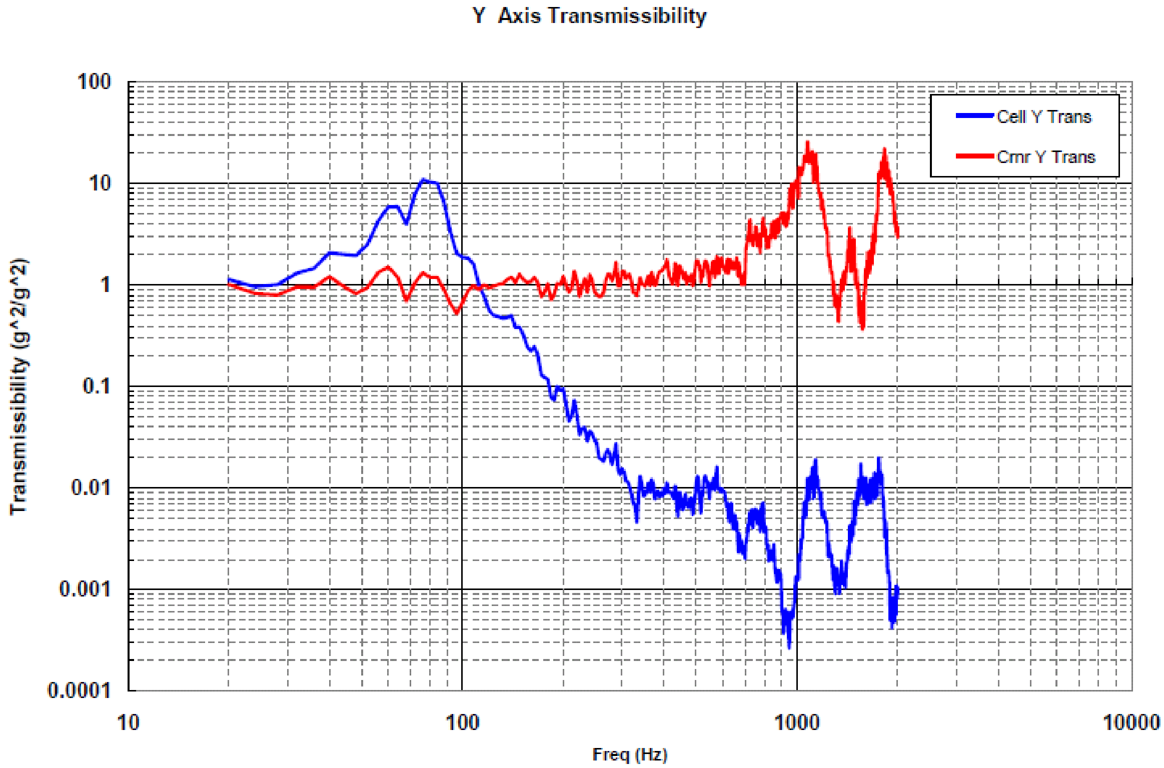

Figure 23: Y Axis Transmissibilities

Figure C-2.

The Y-axis is a lateral axis.

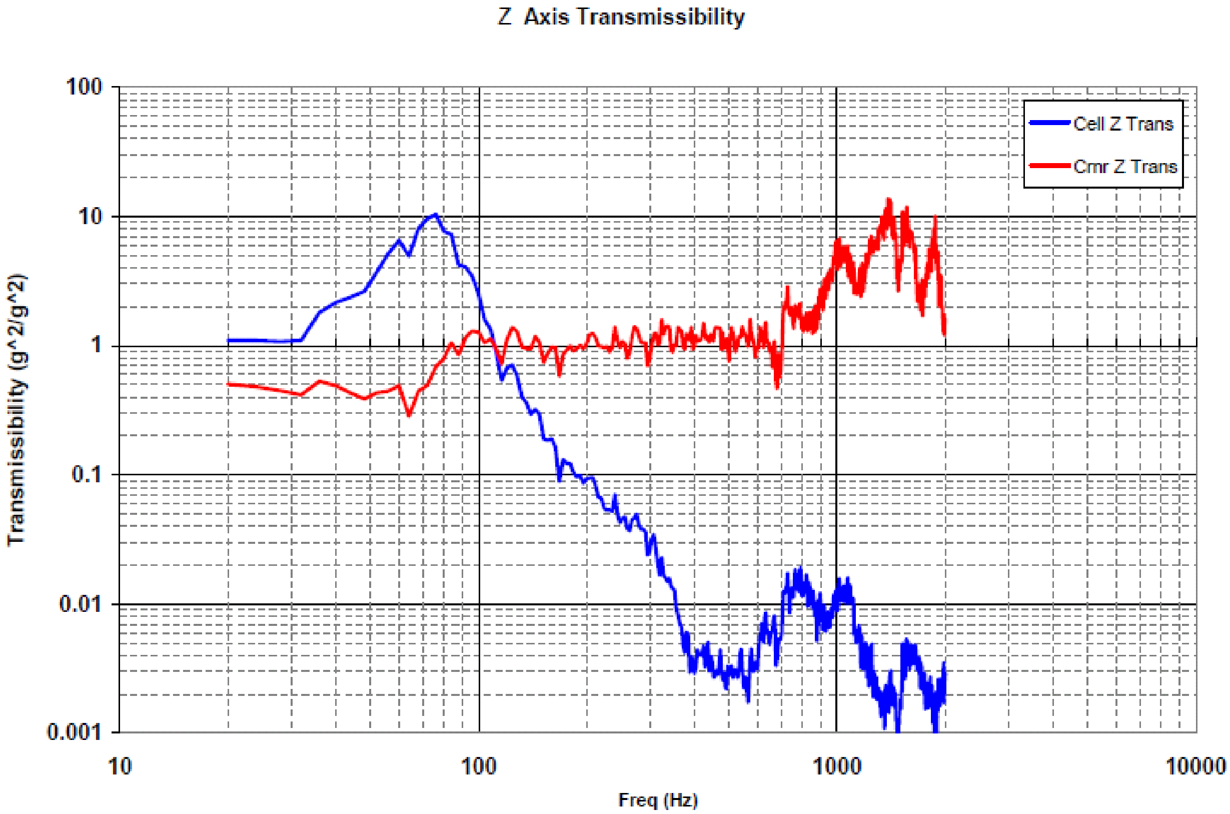

Figure 27: Z Axis Transmissibilities

Figure C-3.

The Z-axis is a lateral axis.

Reference:

ME File:T042-040, Random and Sine Vibe Test, 2nd ACME Evaluation Battery, 2008.

APPENDIX D

Avionics Circuit Board

The 3 dB Bandwidth method is used to determine the Q value for the following avionics boxes.

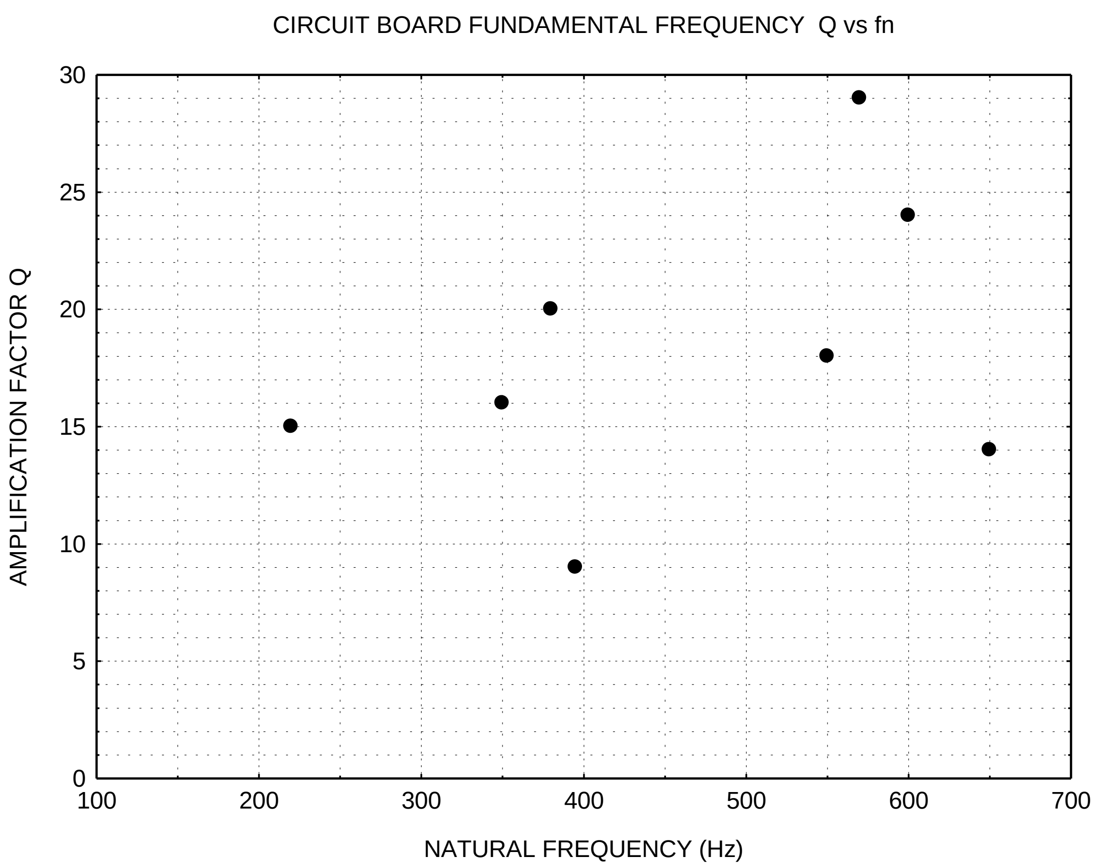

Figure D-1.

Table D-1. Q at Fundamental Frequency			
n	fn (Hz)	-3 dB Bandwidth (Hz)	Q
1	380	20	19
2	220	15	15
3	395	45	9
4	550	30	18
5	600	25	24
6	570	20	29
7	350	22	16
8	650	45	14

The range is 9 to 29. The average is 18.1 with a standard deviation of 6.2.

Transmissibility Data wrt the AVG CNTRL for All Boards, IBUSs, and I/Fs

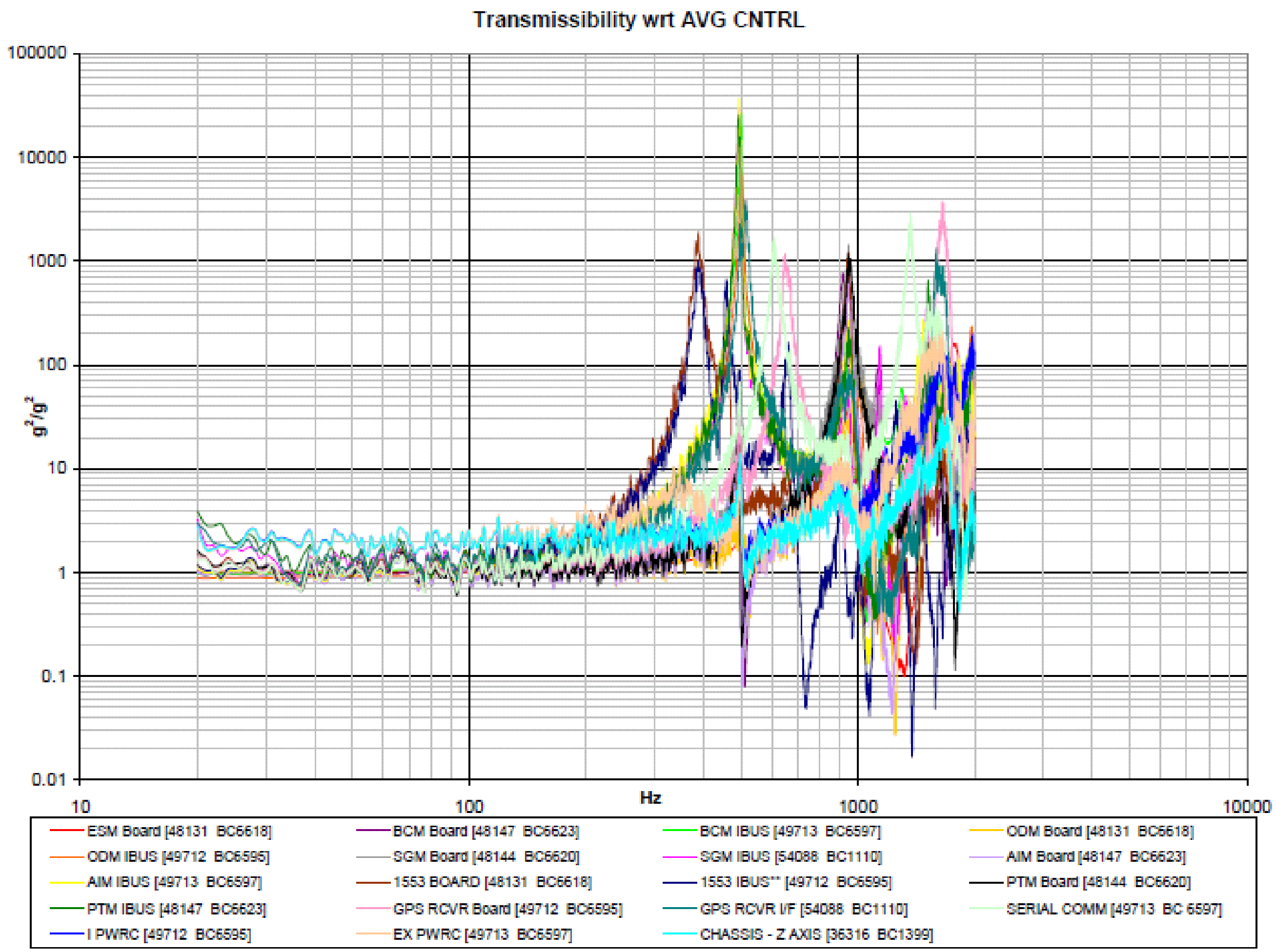

Figure D-1. Avionics Box 1

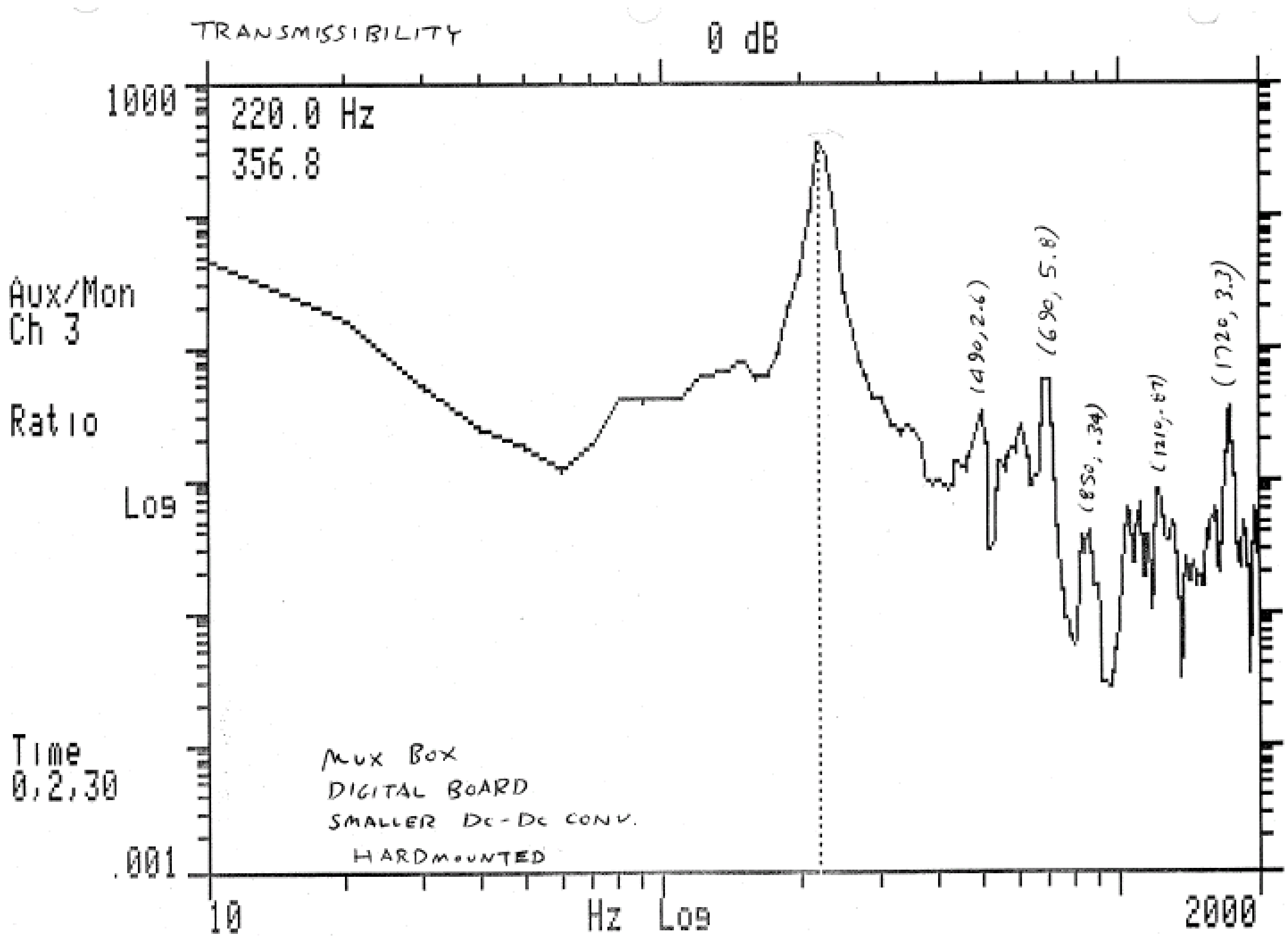

Figure D-2. Avionics Box 2

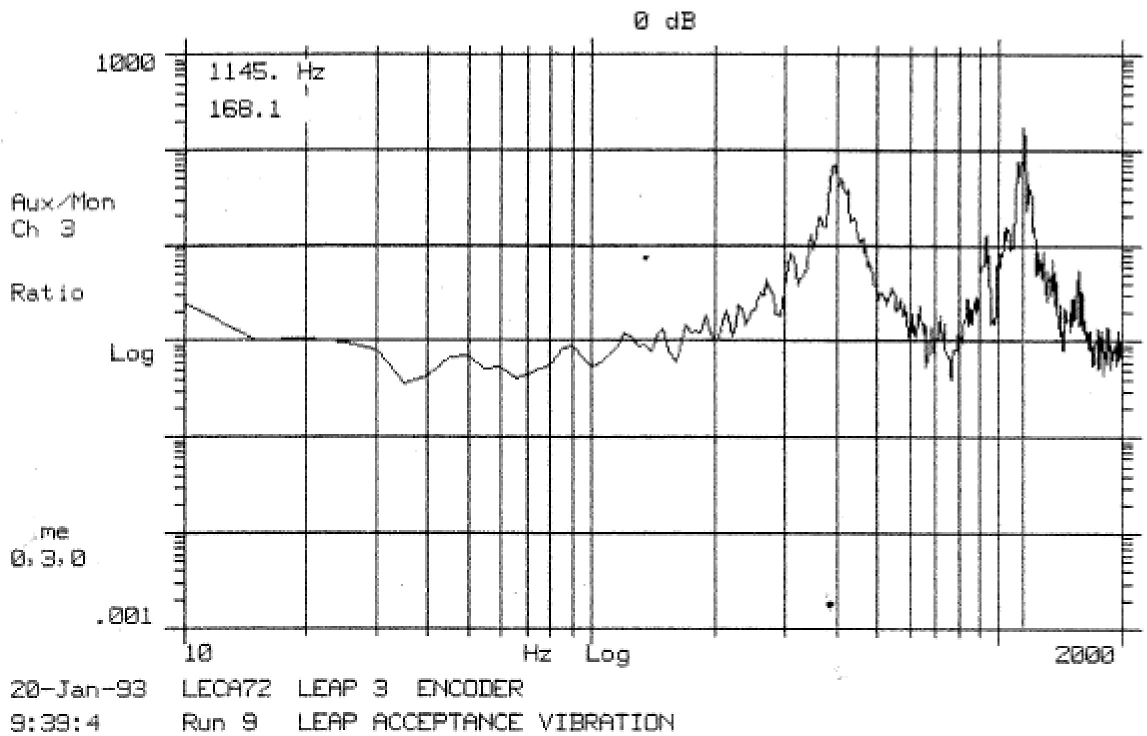

Figure D-3. Avionics Box 3

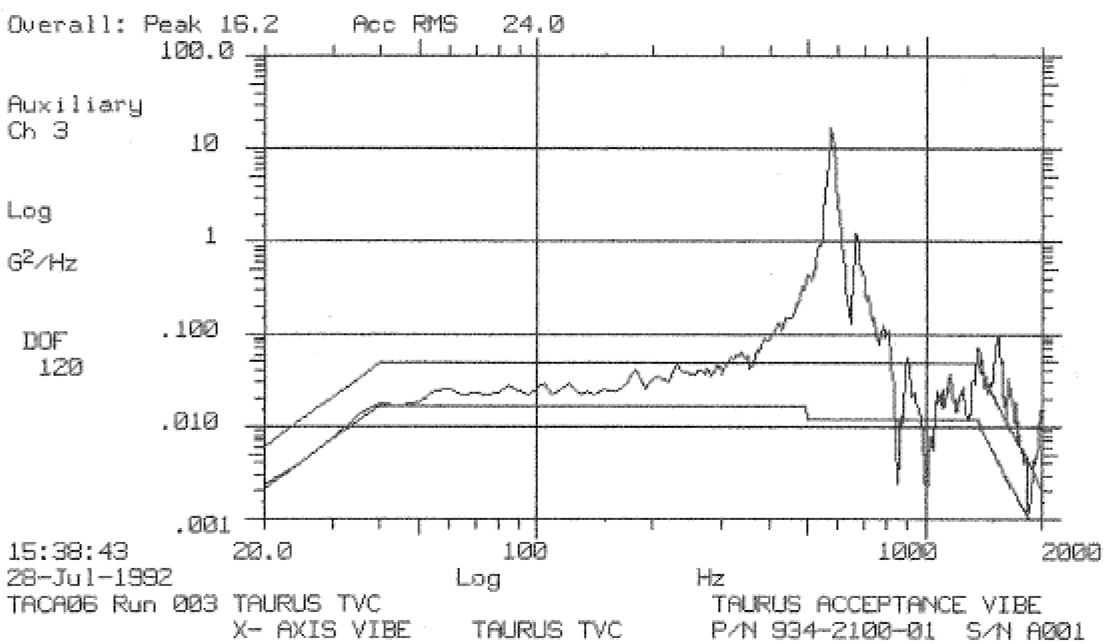

Figure D-4. Avionics Box 4

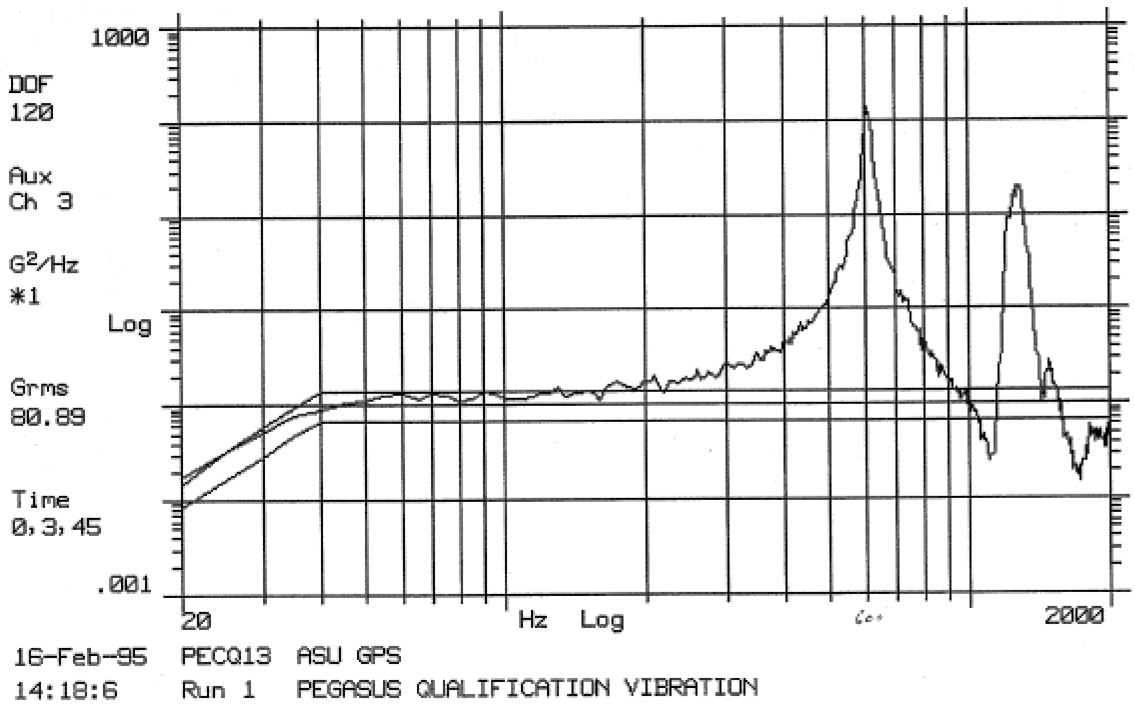

Figure D-5. Avionics Box 5

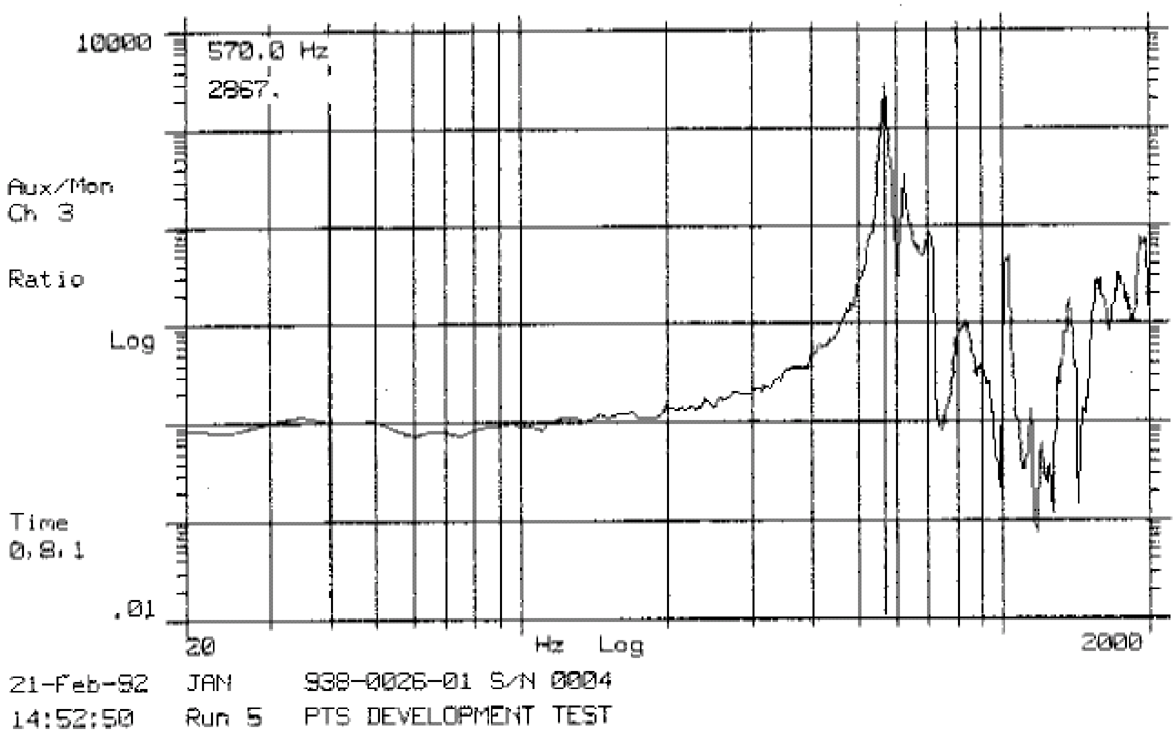

Figure D-6. Avionics Box 6

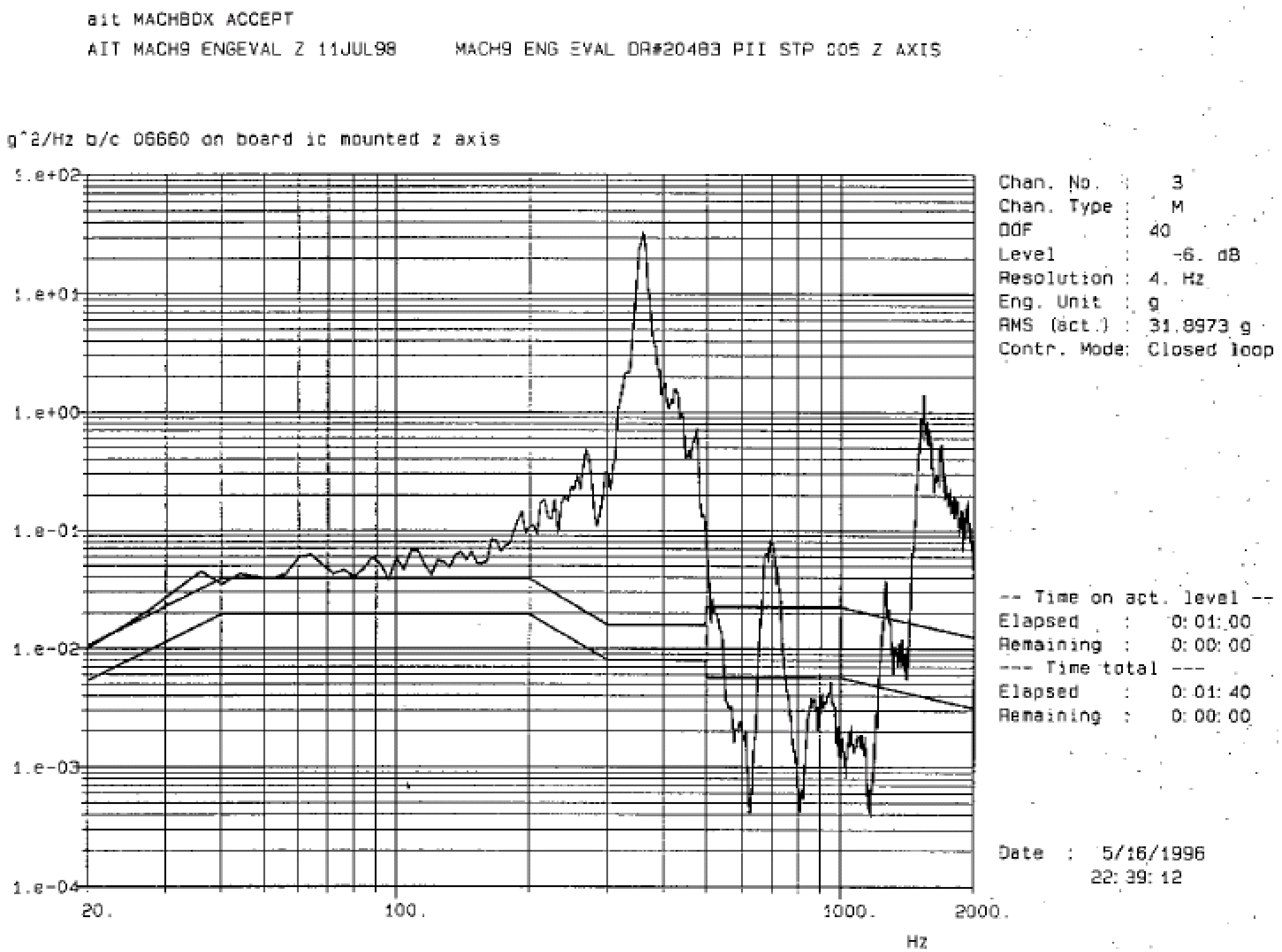

Figure D-7. Avionics Box 7

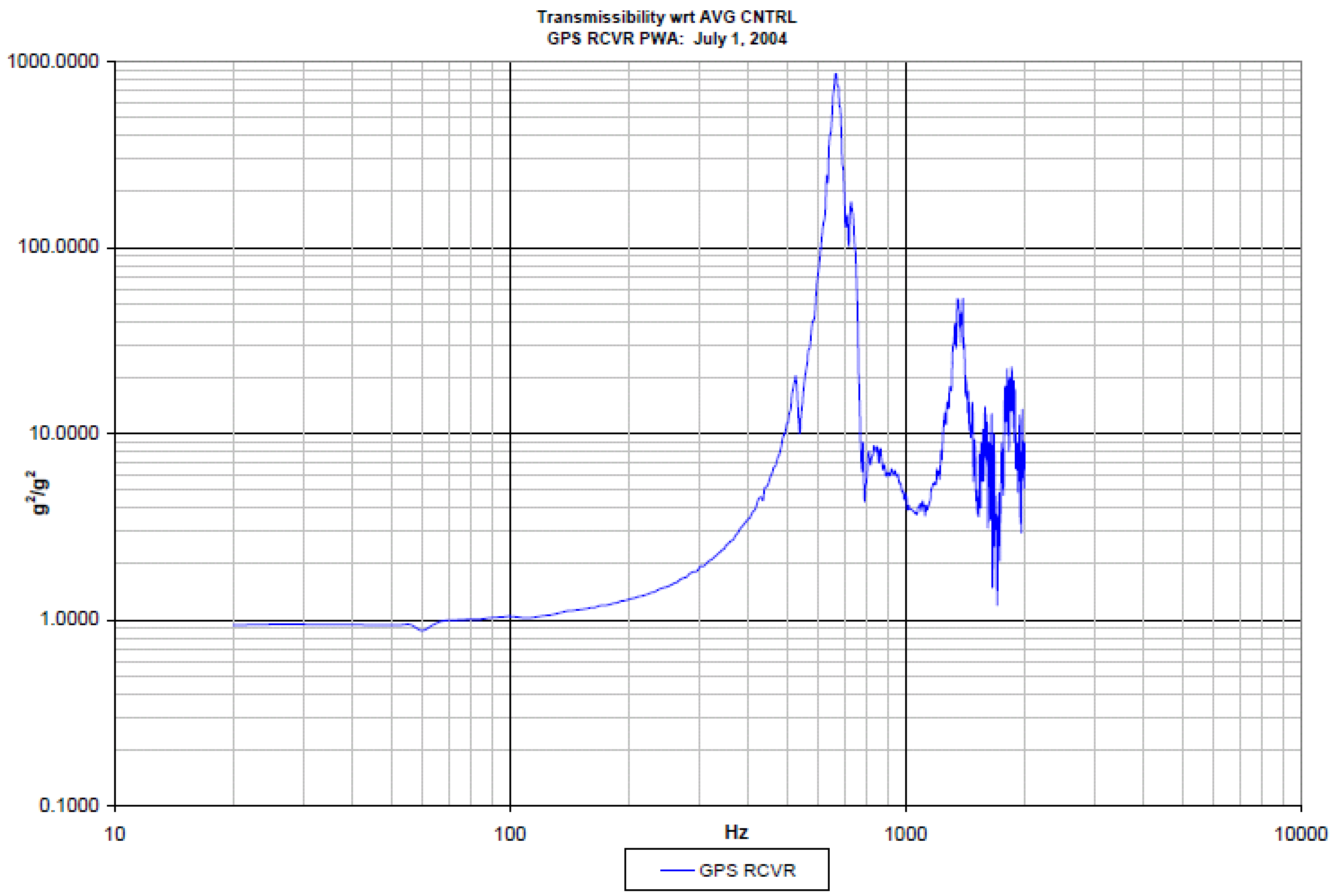

Figure D-8. Avionics Box 8

APPENDIX E

Component Mounting Brackets

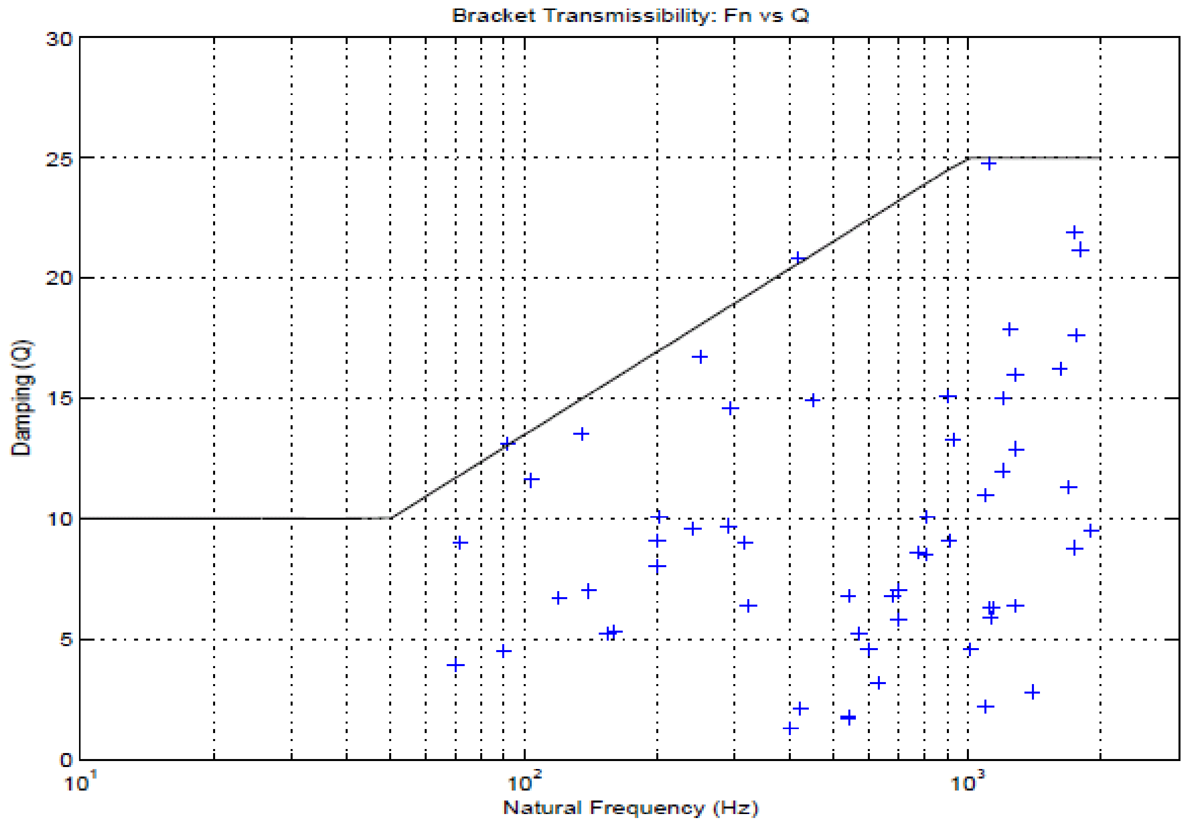

Figure 1: Bracket Mode Natural Frequency (Fn) vs. Damping (Q)

Equation 1:

$Q = 10$	fn<=100Hz
$Q = 11.53 * \log_{10}(fn) - 9.588$	100Hz<fn<1000Hz
$Q = 25$	fn>=1000Hz

Figure E-1.

<u>Reference</u>

ME File: 030-356, Bracket Transmissibility Data Review, 2008.

APPENDIX F

Avionics Boxes Mounted via Lord Isolators

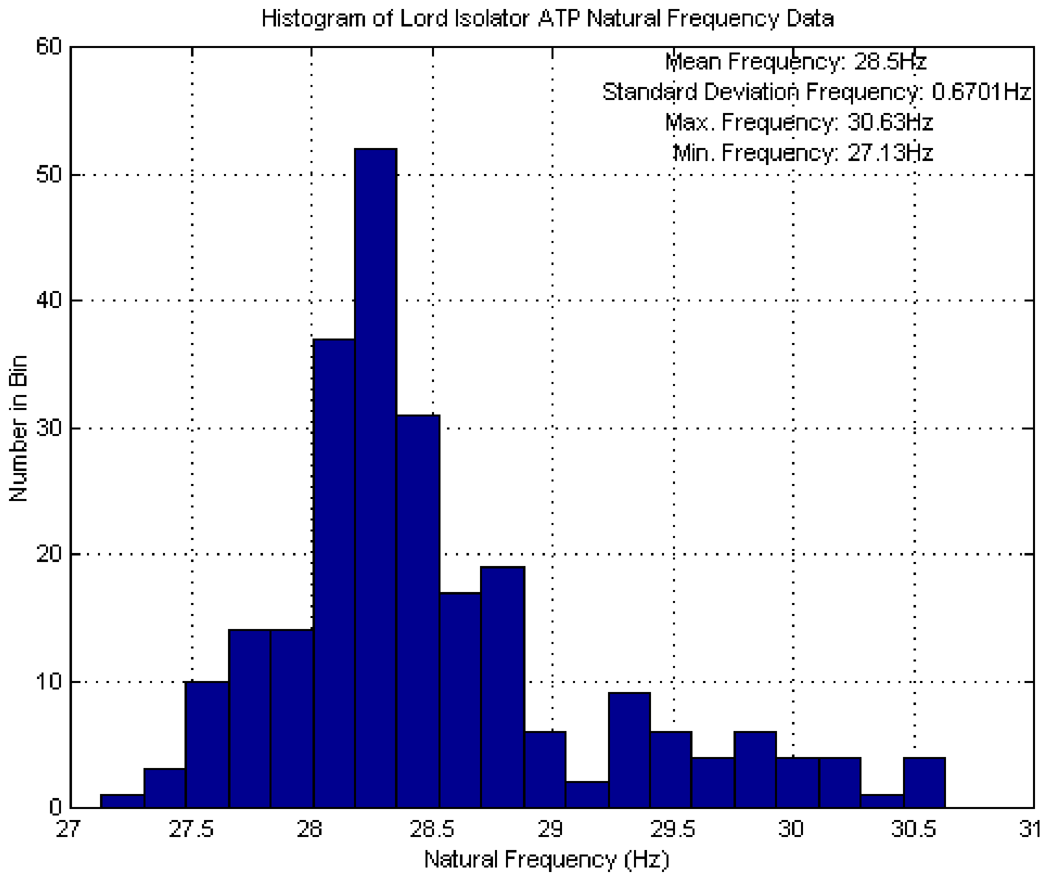

Figure F-1.

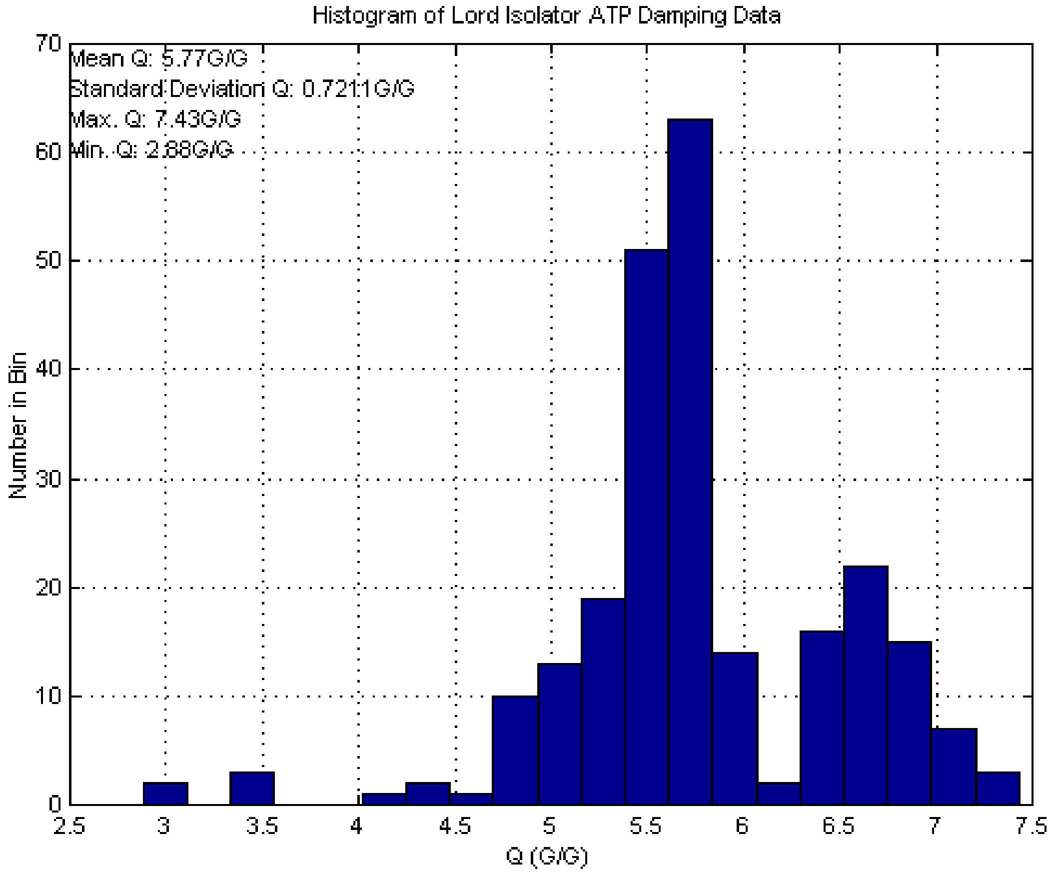

Figure F-2.

Reference:

ME File: 030-227A, Lord Isolator (156APLQ-8) General Random Vibration Transmissibility, 2002.

APPENDIX G

Flexible Confined Detonating Cord (FCDC)

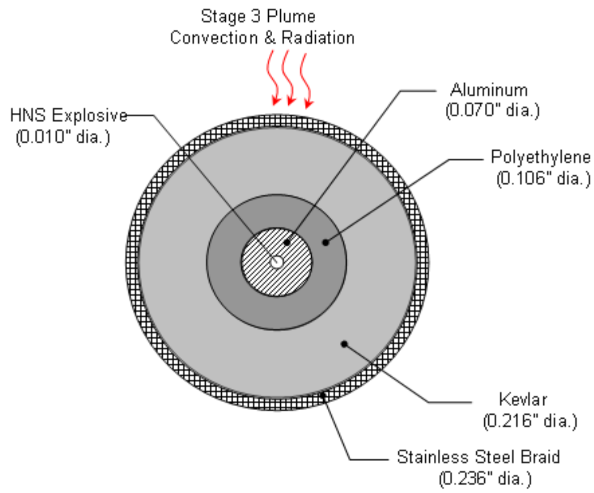

Figure G-1.

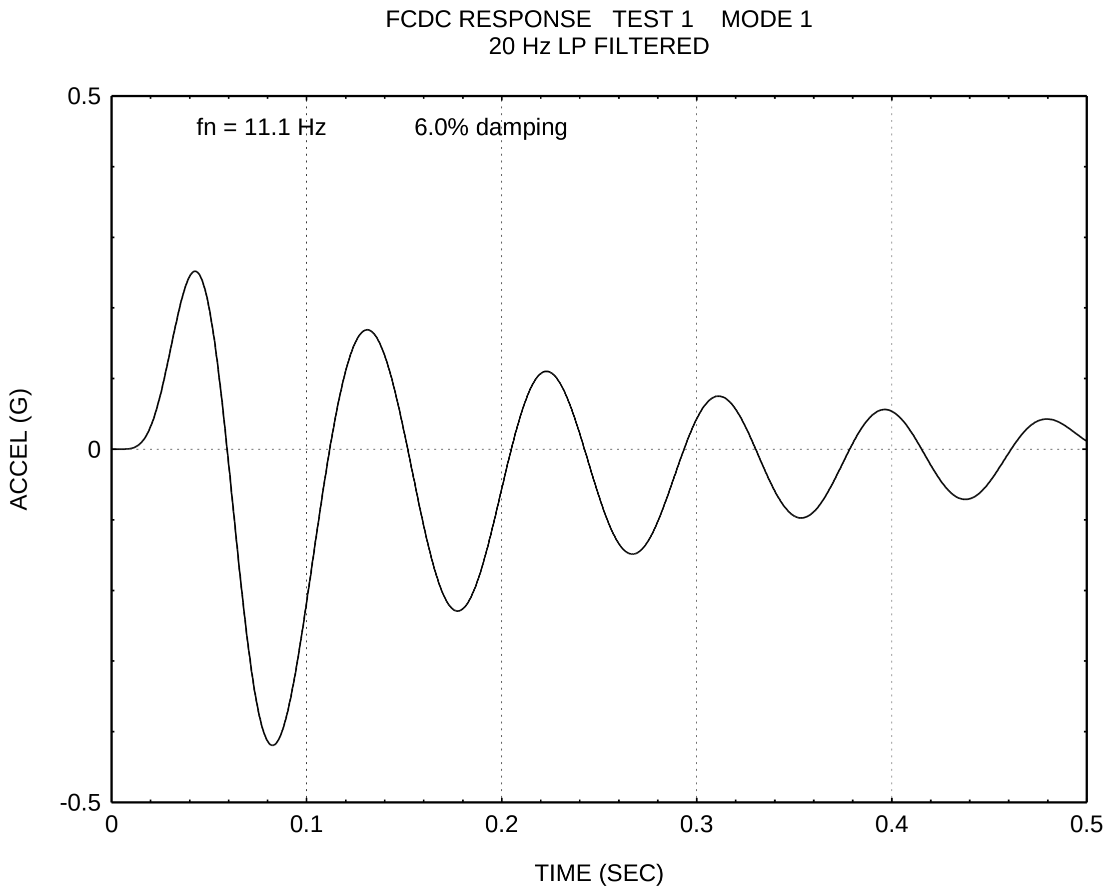

Figure G-2.

This was a test case for a particular configuration.

Other configurations were analyzed via FEA models in:

ME File: MISC 030-259, FCDC Vibration Frequency Analysis, 2003.

APPENDIX H

Figure H-1.

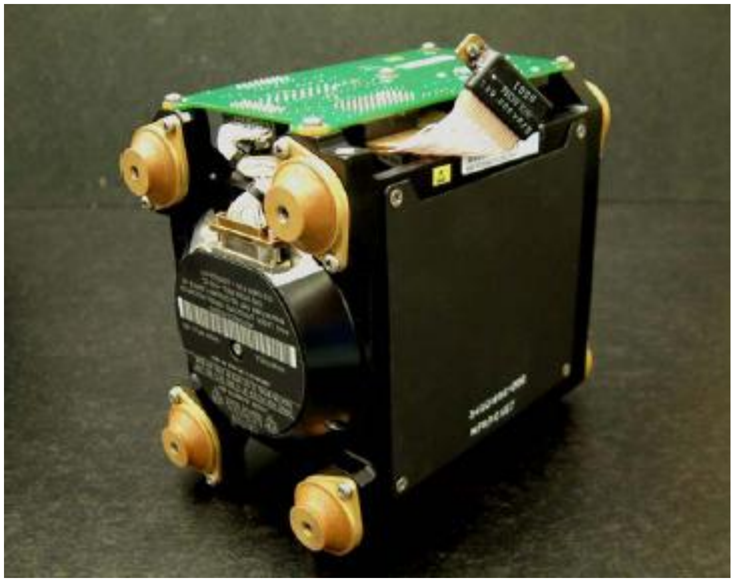

Figure H-2.

References:

ME File: 070-211A
ME File: 043-063

APPENDIX I

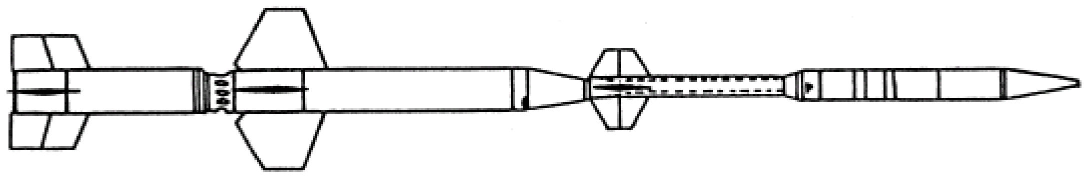

Figure I-1. HAVE Jeep VII F & G Talos-Sergeant-Hydac Vehicle

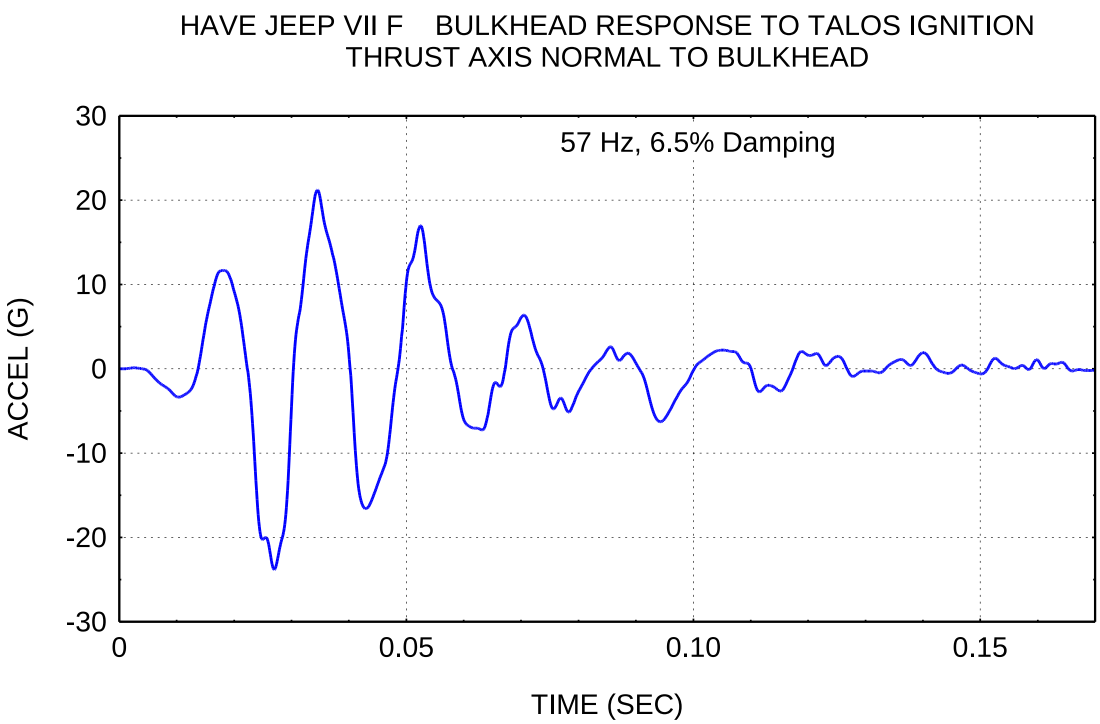

Figure I-2.

The bulkhead was circular, made from aluminum, homogeneous, with an 18 inch diameter. The data is from a flight in 1991.

The natural frequency and damping ratio were determined using a damped sine curve-fit.

APPENDIX J

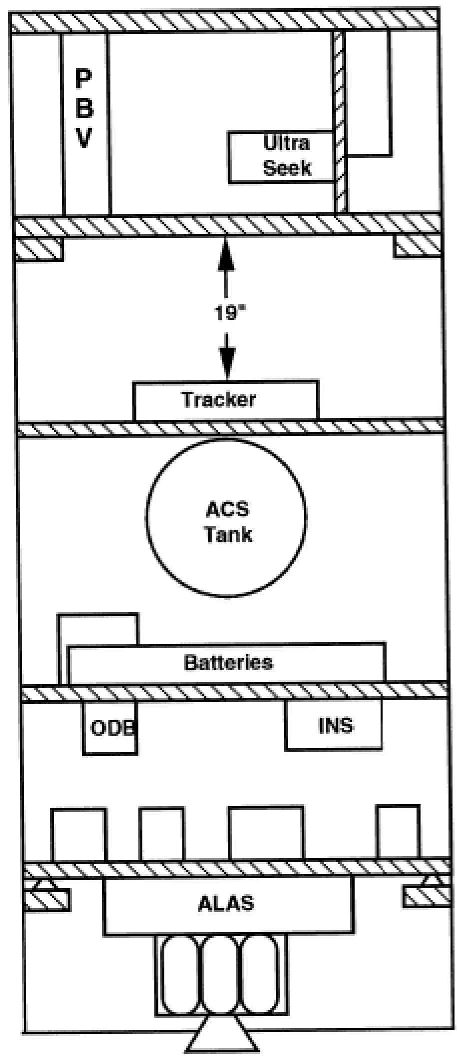

Figure J-1. Avionics Module with ALAS Bulkhead

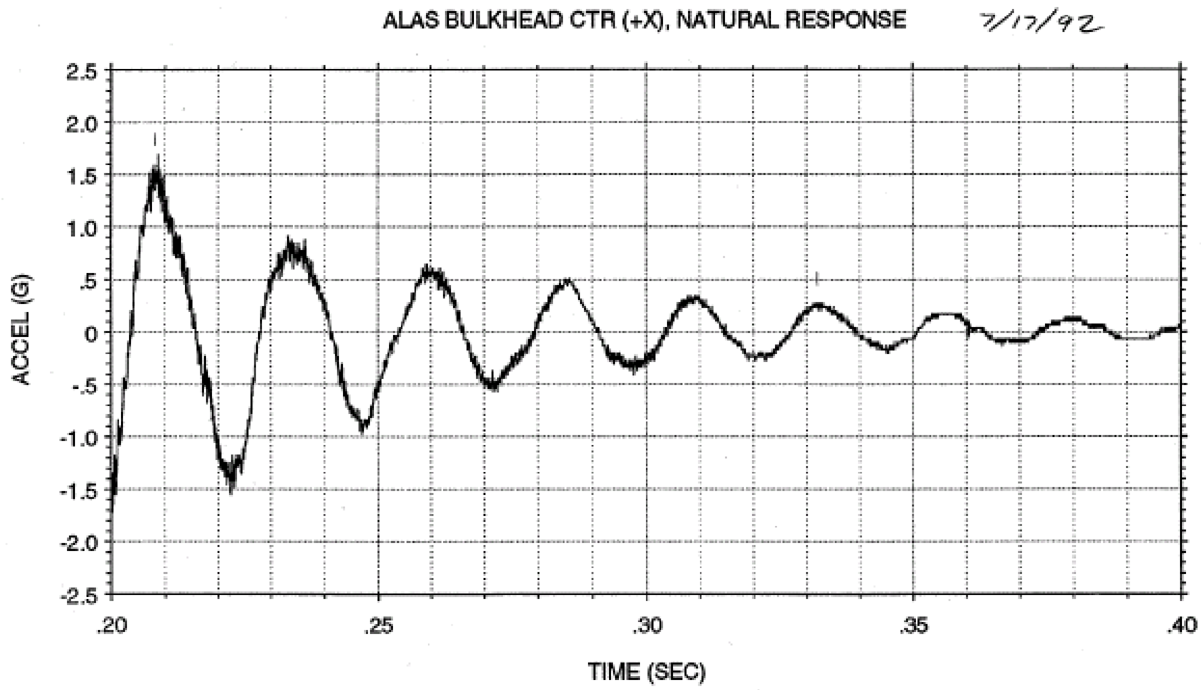

Figure J-2.

The bulkhead was circular, made from aluminum skins with a honeycomb core, and with a 38 inch diameter. It was mounted in a cylindrical avionics module. The module was then mounted to a shaker table. The shock pulse was applied in the axis normal to the bulkhead plane.

The data is from a shaker table shock test in 1992. The time segment shown represents the natural response immediately after the end of the input pulse. It is due to out-of-plane bending.

The natural frequency and damping ratio were determined using a damped sine curve-fit. The natural frequency is 40.0 Hz with 5.9% damping.