NASA-TP-2315 19840015608

NASA
Technical
Paper
2315

May 1984

Shock Response Spectra Variational Analysis for Pyrotechnic Qualification Testing of Flight Hardware

James Lee Smith

NASA
Technical
Paper
2315

1984

Shock Response Spectra Variational Analysis for Pyrotechnic Qualification Testing of Flight Hardware

James Lee Smith

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama

National Aeronautics
and Space Administration

Scientific and Technical
Information Branch

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

NASA TECHNICAL PAPER

SHOCK RESPONSE SPECTRA VARIATIONAL ANALYSIS FOR PYROTECHNIC QUALIFICATION TESTING OF FLIGHT HARDWARE

I. INTRODUCTION

Many problems have arisen in the aerospace industry as a result of the large variations in shock response spectra (SRS) produced by the firing of pyrotechnic charges. High shock levels may break solder joints, crack electronic crystals, trigger g-sensing switches, etc. Most pyrotechnic manufacturers state a variation of ±3 dB, or about 50 percent, in the SRS produced by pyrotechnic devices such as linear shaped charges (LSC). An understanding of the causes of these variations would allow a better interpretation of pyrotechnic shock environments for use in design and qualification testing of electronic and mechanical components.

Before pursuing a large scale research project on pyrotechnic charge SRS variations, a "crude" analysis of existing pyrotechnic data was conducted. Data from the "Eighteen Mission Pyrotechnic Shock Certification Test of the SRB Integrated Receiver Decoder (IRD)" was chosen for the following reasons: (1) the test was conducted recently on state-of-the-art equipment, (2) 18 firings were made, yielding 18 SRSs in each axis, and (3) the same type of explosive devices were used in each firing.

II. TEST PLAN

A. Test Setup

Dupont E-1A (8) blasting caps were used to excite a 96 x 48 x 1/2-in. mild steel plate upon which the IRD was mounted. The steel plate is secured to the floor and ceiling by steel cables and bungee cord as shown in Figure 1. Figure 2 shows the locations of the IRD, blasting caps, and accelerometers. The two blasting caps were taped along the bottom edge of the plate approximately 27 in. from the corner. For each firing (single mission test), accelerometer data was recorded and analyzed by 1/3 octave SRS analysis. Table 1 lists the instrumentation used.

B. Test Procedure

The charges were fired by applying a 1.5 A, 28 Vdc current. The average firing time was 5.7 msec. A SRS was calcualted from a 20 msec time history window utilizing a 5 percent damping factor.

C. Test Criteria

The following test criteria was empirically derived for the pyroshock test:

50 Hz @ 12 g's peak
50 - 100 Hz @ +12 dB/oct] a displacement line
100 Hz @ 47 g's peak
100 - 4,000 Hz @ +6 dB/oct] a velocity line
4000 - 10,000 Hz @ 1875 g's peak] an acceleration line

Figure 3 is a graphic representation of the test criteria.

TABLE 1. TEST INSTRUMENTATION

Item	Quantity	Manufacturer	Model
1. Accelerometers	3	Endevco	2225, 2225M5A, 2291
2. Calibration System	1	Endevco	28350f
3. Accelerometer Standard	1	Endevco	2270
4. Oscilloscope	1	Hewlett Packard	181A
5. Shock Amplifiers	3	Endevco	2740A, 2740B
6. Tape Recorder	1	CEC	VR3600
7. Multimeter	1	Fluke	8800A
8. Analyzer System	1	Hewlett Packard	5425A
9. Hardcopy Unit	1	Tektronix	4631
10. Terminal-Display	1	Tektronix	4014-1

III. SHOCK RESPONSE SPECTRAL DATA

Figures 4, 5, and 6 illustrate the 18 SRS for each axis. Notice the SRS variations.

IV. SHOCK DATA ENVELOPES AND MEAN VALUES

SRS envelopes were formulated by taking the maximum G/Hz values for the upper envelope and the minimum G/Hz values for the lower envelope. Therefore, no one SRS will vary as much as the envelopes. The envelopes are "worst-case" boundary values.

SRS mean values were calculated by averaging the G values at each frequency. Figures 7, 8, and 9 illustrate the envelopes, means, and test criteria for each axis. The upper and lower curves are the envelopes. The darker curves between the envelopes are the means. The three-segmented line is the derived test criteria.

V. SHOCK DATA VARIATION ANALYSIS

A. Values for Particular Frequencies

The variation between the envelopes and means are measured for various frequencies on each axis. Decibel (dB) variation is calculated as follows:

$$\text{Upper Envelope:} \quad +dB = 20 \log (EG/MG) \tag{1}$$

$$\text{Lower Envelope:} \quad -dB = 20 \log (MG/EG) \tag{2}$$

where

EG = envelope G value

MG = mean G value

Figure 10 lists dB values for the frequencies in each axis.

B. Mean Values for all Frequencies

A mean dB variation value was calculated for each envelope by the following two formulas:

$$\text{Upper Envelope:} \quad +dB = 20 \log \left(\sum_{N=50}^{10000} (EG_N/MG_N) \right) /M \tag{3}$$

$$\text{Lower Envelope:} \quad -dB = 20 \log \left(\sum_{N=50}^{10000} (MG_N/EG_N) \right) /M \tag{4}$$

where:

M = number of ratios summed

N = frequency from 50 to 10,000 HZ

The values calculated are as follows:

Axis	Variation (dB), Upper Envelope	Variation (dB), Lower Envelope
X	5.04	-15.69
Y	4.65	-10.03
Z	2.72	- 6.21

A triaxial average was calculated for positive and negative envelopes using equations (3) and (4), but summing over all three axes. The positive envelope (XYZ+) value was 4.20 dB. The negative envelope (XYZ–) value was -11.52 dB.

Finally, the G ratios (EG/MG and MG/EG) were averaged for both envelopes in all three axes to yield a general variation value. The shock variation (XYZ±) is ±8.61 dB. That is a 169 percent variation.

VI. SUMMARY

SRS data from flight certification tests were analyzed to determine envelope variation with respect to mean values in each axis. Composite variations for all positive envelopes, all negative envelopes, and for all envelopes (positive and negative) were determined. An overall variation of ±8.61 dB or 169 percent exists for the data.

VII. CONCLUSIONS

The large variation noted in this investigation may be attributed to one or more of the following potential causes:

1) Instrumentation problems may exist. Notice the five spectra on the lower part of Figure 4. Why don't these data follow the rest of the SRS? Instrumentation accuracy needs to be investigated.

2) Since two charges were used, a very minute delay may have occurred between firings. A variation in delay time between charges will produce different SRS's.

3) Variations may occur between charges of the same type and from the same lot. These variations, if not predicted, are sufficient to damage electronics and trigger switches prematurely.

A research project needs to be conducted under extremely controlled conditions with as few variables as possible to investigate variations in SRS as a function of variations in pyrotechnic charges.

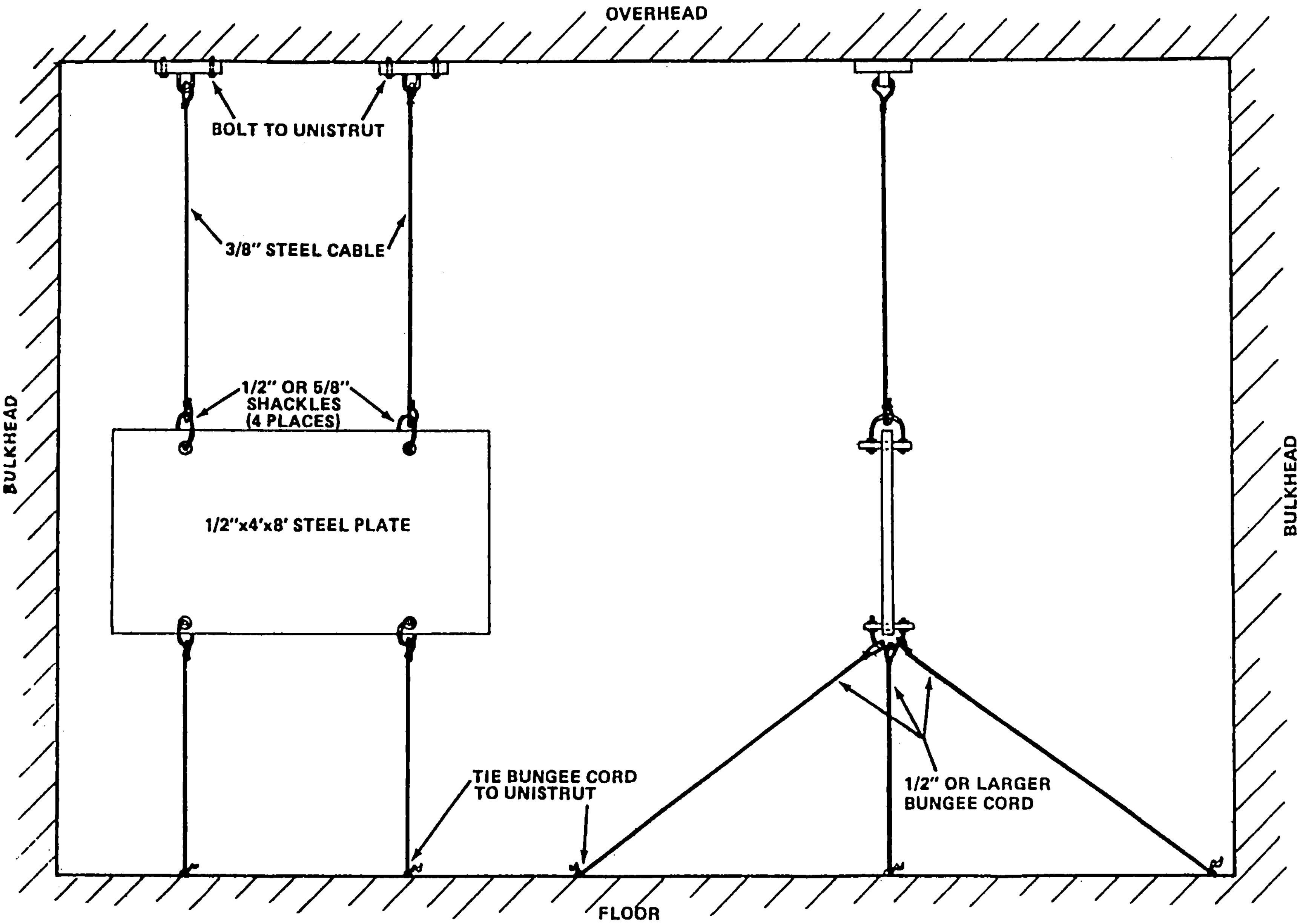

Figure 1. Test cell internal configuration.

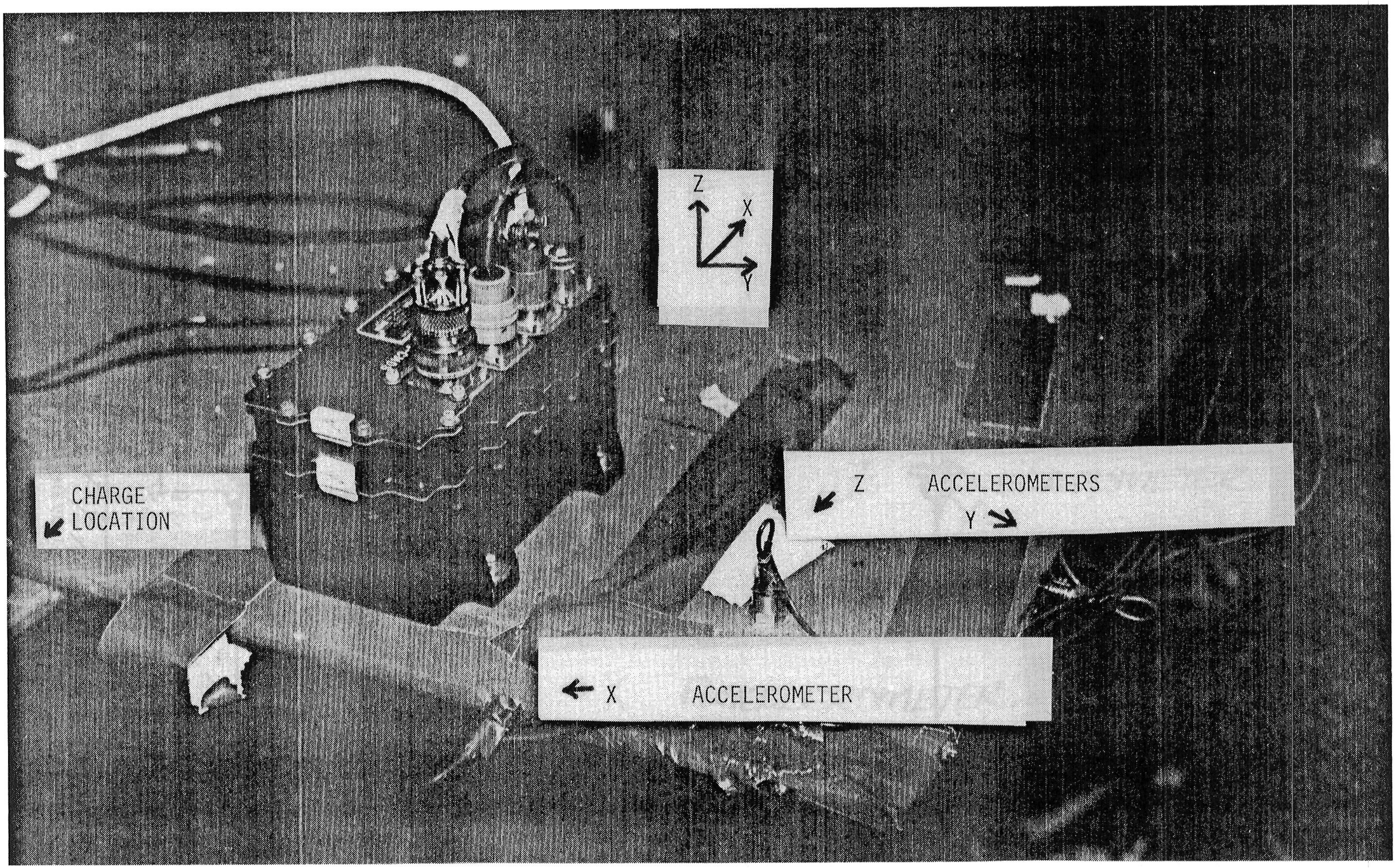

Figure 2. Test setup.

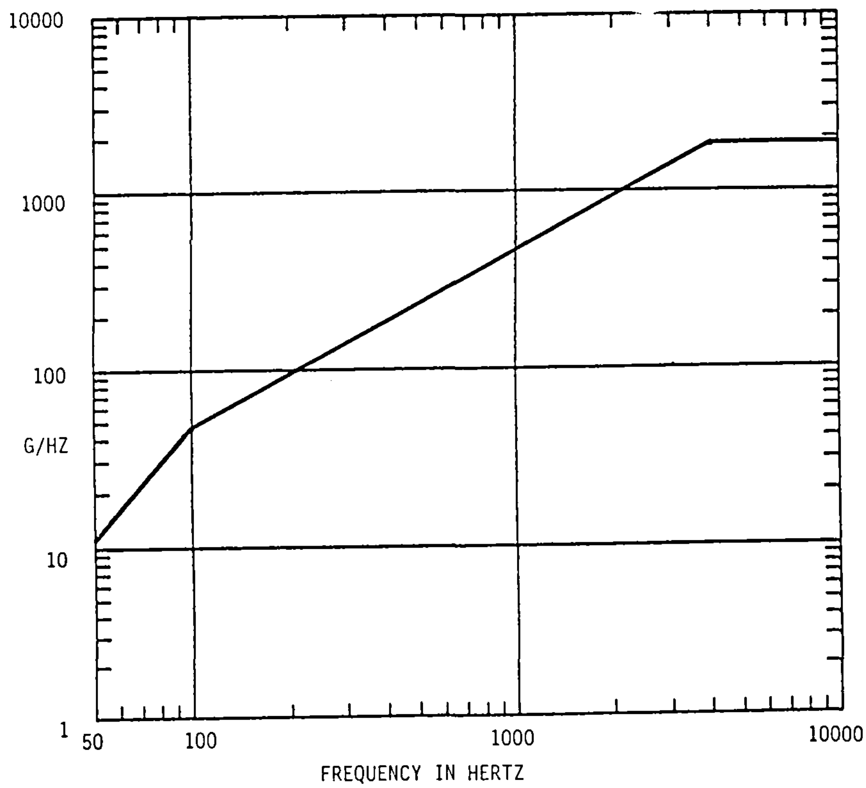

Figure 3. Test criteria.

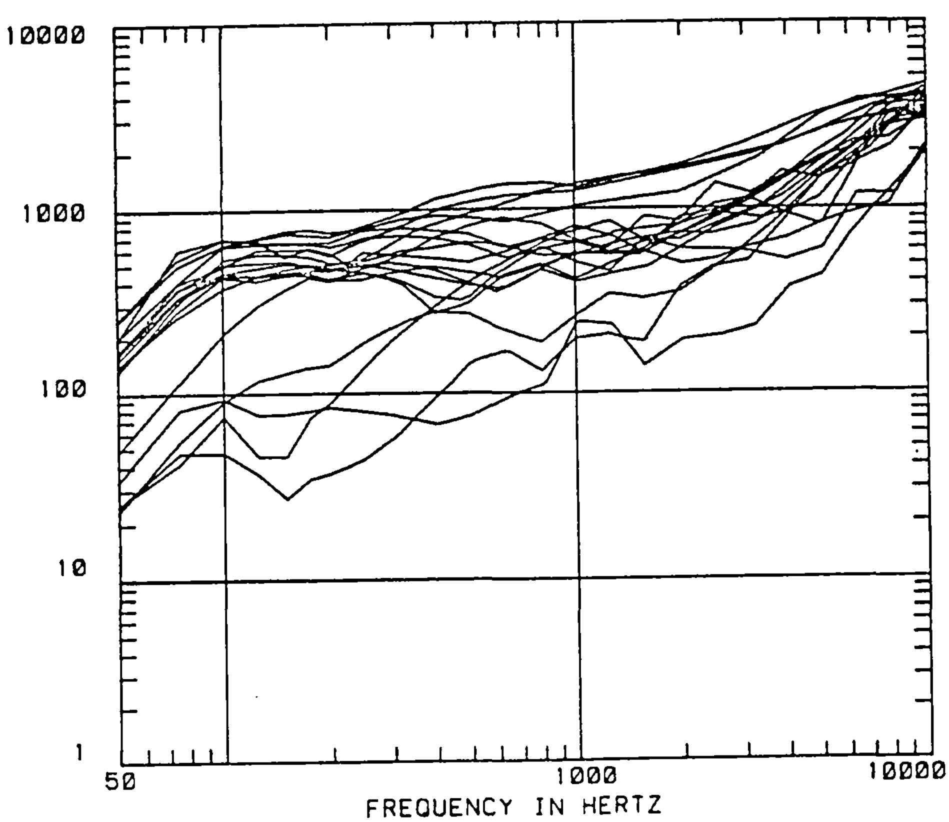

Figure 4. X axis – SRS 18 firings.

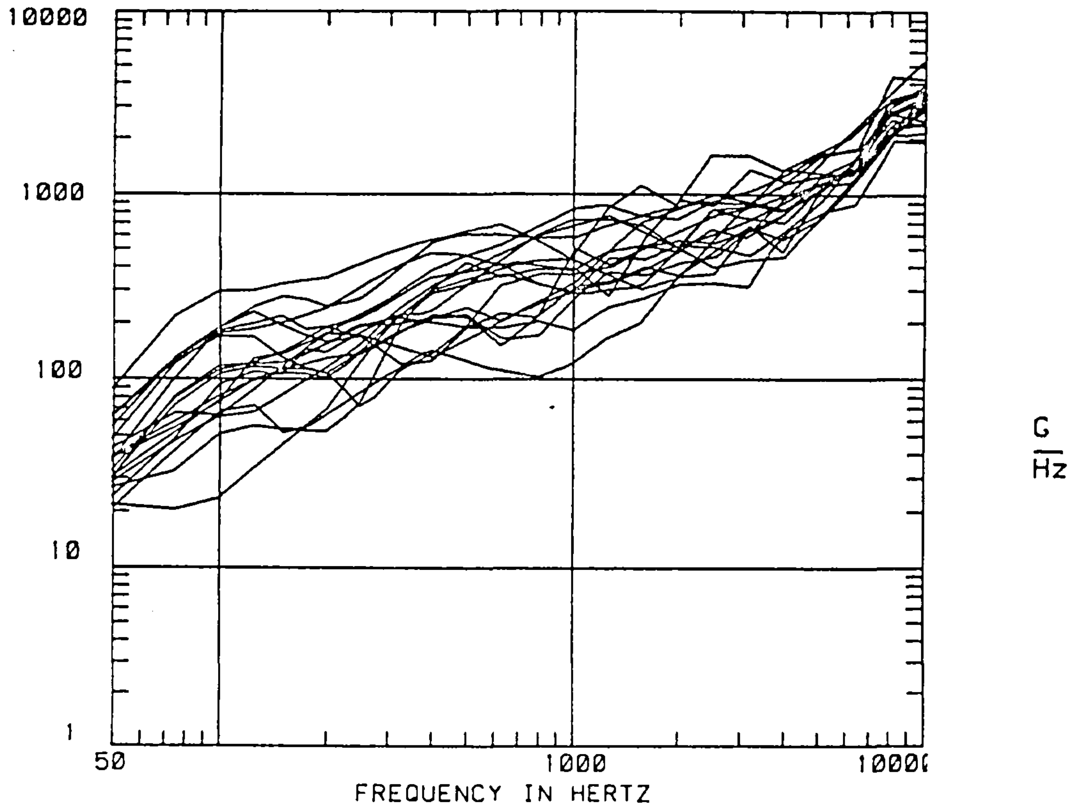

Figure 5. Y axis – SRS 18 firings.

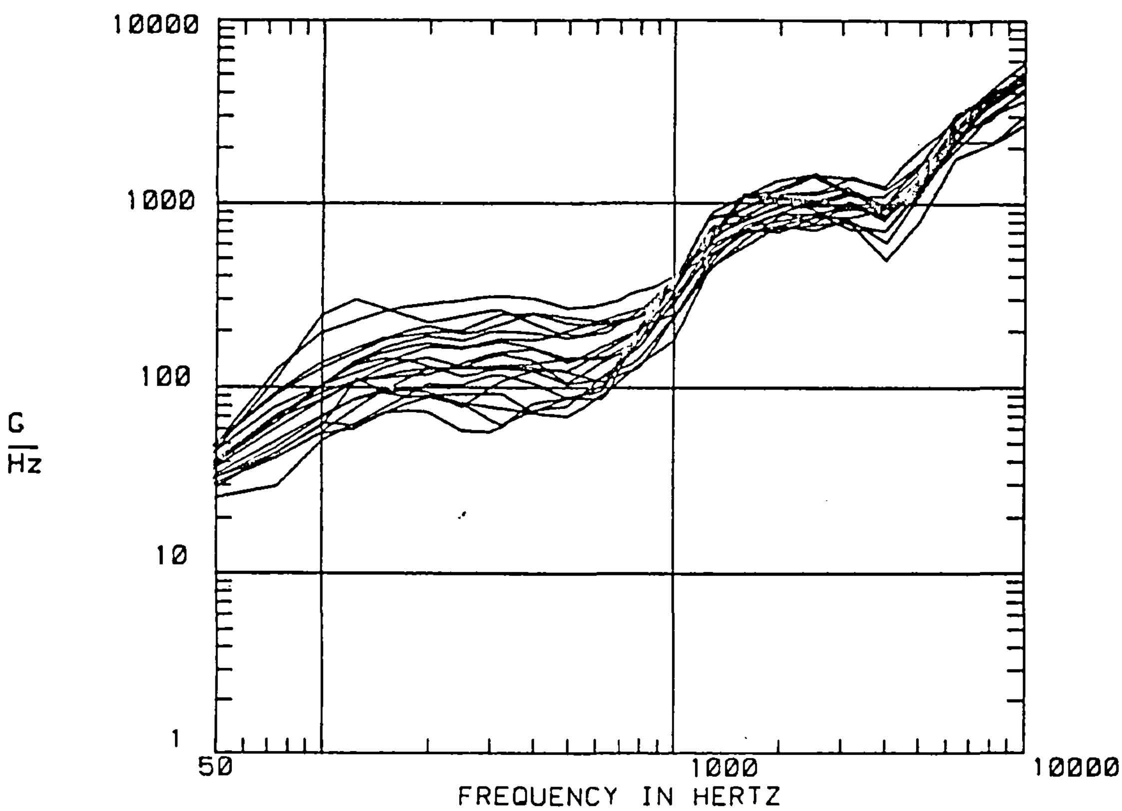

Figure 6. Z axis – SRS 18 firings.

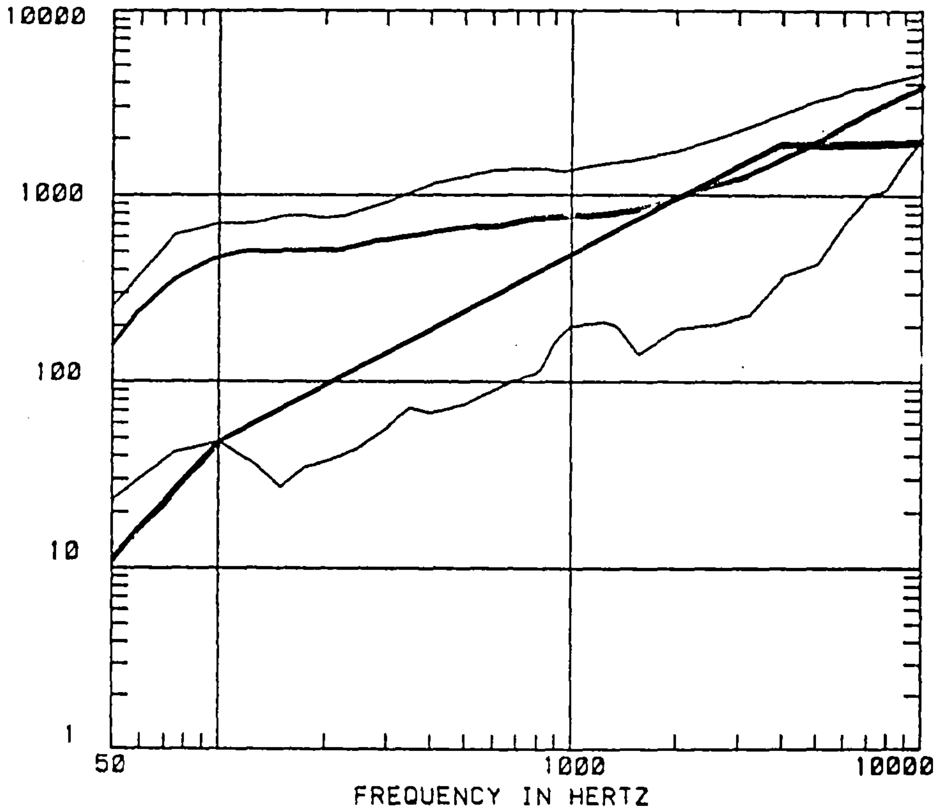

Figure 7. X axis – SRS envelopes, mean, and test criteria.

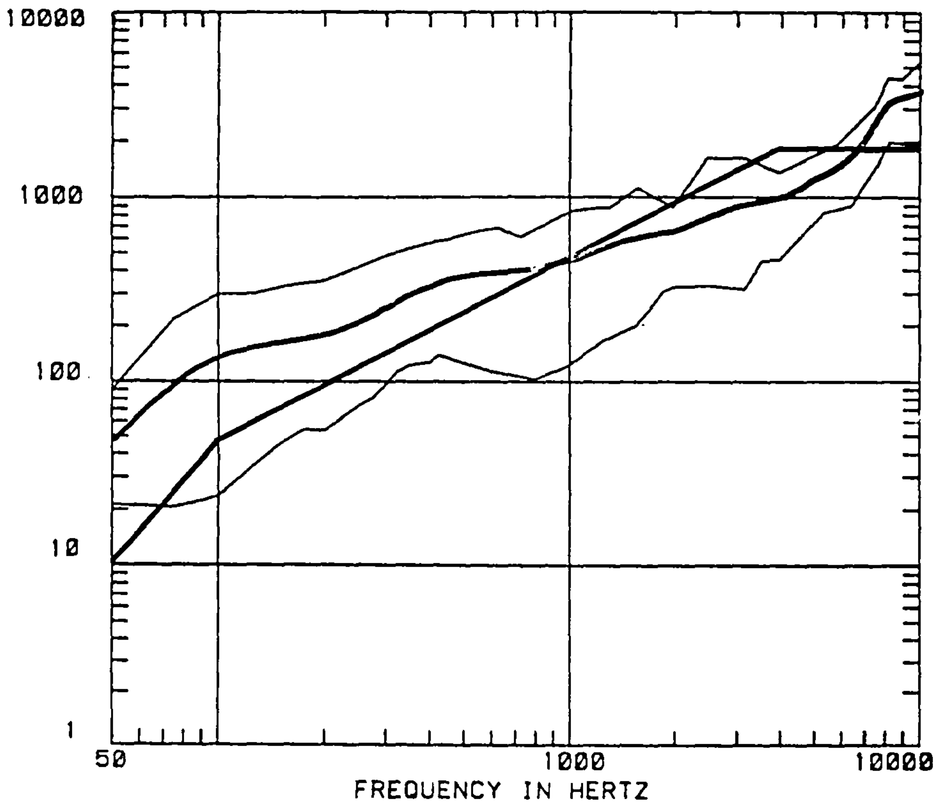

Figure 8. Y axis – SRS envelopes, mean, and test criteria.

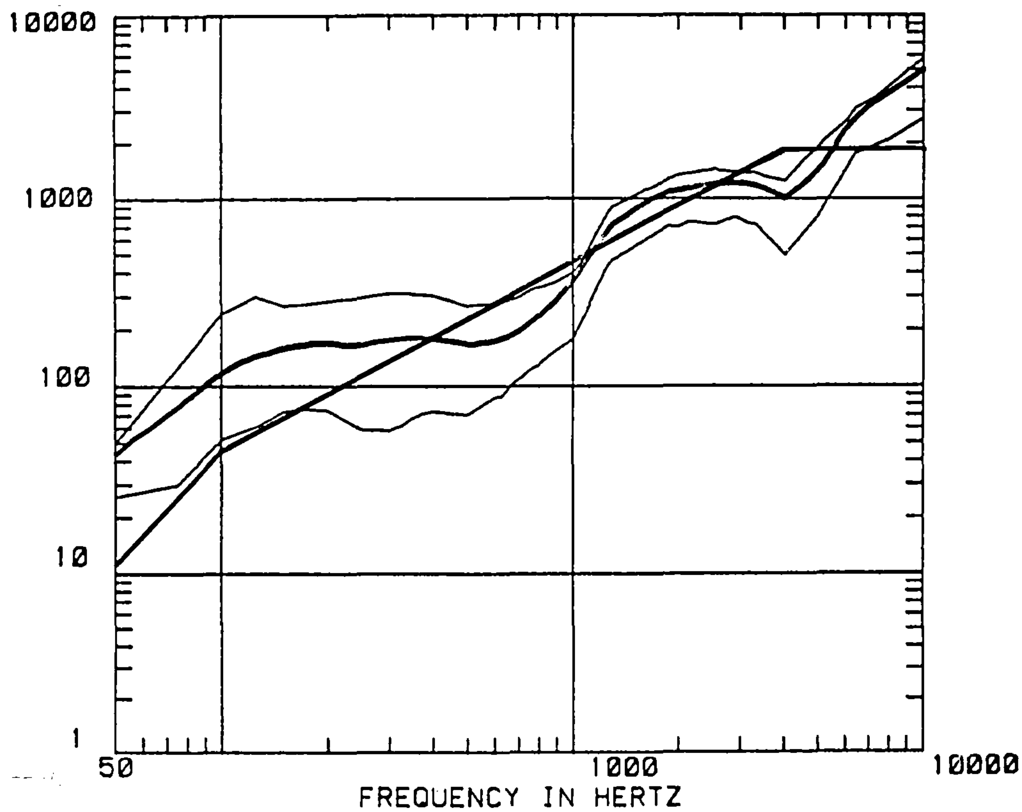

Figure 9. Z axis – SRS envelopes, mean, and test criteria.

VARIATION (dB)

f (Hz)	Upper Envelope X	Upper Envelope Y	Upper Envelope Z	Lower Envelope X	Lower Envelope Y	Lower Envelope Z
50	7.71	5.48	0.91	-9.31	-7.20	-4.45
60	6.61	7.68	2.54	-13.39	-9.40	-6.32
70	8.03	7.42	4.08	-15.19	-12.57	-7.96
80	4.56	7.12	5.01	-19.36	-14.39	-7.71
90	4.24	6.65	4.86	-19.61	-15.83	-7.96
100	3.86	5.71	5.67	-19.81	-16.28	-7.46
200	4.08	5.53	4.14	-22.61	-10.76	-7.96
300	4.30	5.67	4.71	-20.31	-8.30	-9.54
400	5.67	5.20	3.97	-19.87	-8.10	-8.06
500	6.02	4.51	3.86	-19.08	-9.66	-8.20
600	6.73	5.06	3.35	-17.89	-10.24	-7.00
700	6.61	3.69	3.11	-16.90	-11.22	-4.86
800	6.02	4.56	2.61	-15.92	-12.36	-4.76
900	5.15	5.01	1.94	-12.95	-11.48	-4.66
1000	5.48	4.76	1.14	-12.04	-11.53	-5.53
2000	5.53	3.23	1.58	-13.53	-6.40	-5.06
3000	3.52	5.30	1.58	-16.28	-9.46	-3.86
4000	4.91	1.94	2.08	-12.53	-7.60	-6.85
5000	4.81	2.08	1.14	-12.51	-5.48	-5.76
6000	4.35	1.94	0.83	-9.74	-6.02	-3.86
7000	3.11	1.29	0.00	-8.94	-5.67	-1.29
8000	2.48	2.54	0.26	-7.60	-4.08	-4.96
9000	2.21	2.21	1.14	-5.76	-4.86	-4.91
10,000	1.44	2.48	1.14	-5.56	-5.48	-5.34

Figure 10. Upper and lower envelope variations for particular frequencies.

1. REPORT NO. NASA TP-2315	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE Shock Response Spectra Variational Analysis for Pyrotechnic Qualification Testing of Flight Hardware		5. REPORT DATE May 1984
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) James Lee Smith		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812		10. WORK UNIT NO. M-446
		11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546		13. TYPE OF REPORT & PERIOD COVERED Technical Paper
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Systems Dynamics Laboratory, Science and Engineering.

16. ABSTRACT

Shock response spectra data from flight certification tests were analyzed to determine envelope variation with respect to mean values in each axis. An overall variation of ±8.61 dB or 169 percent exists for the data. This large variation may be attributed to one or more of the following:

1) Instrumentation problems may exist.

2) Variations in the source charge (blasting caps) such as shape or explosive load may exist.

3) Two blasting caps were used to excite the pyrotechnic plate tester. Delay time between charge firings may have varied.

The cause or causes of the variations need to be identified and researched to prevent future pyroshock problems.

17. KEY WORDS Pyrotechnics Shock Response Spectrum (SRS) Linear Shaped Charges (LSC) Pyrotechnic Plate Tests Pyrotechnic Charge Source Variation	18. DISTRIBUTION STATEMENT STAR Category: 18 Unclassified – Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	13	A02

For sale by National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1984

National Aeronautics and
Space Administration

Washington, D.C.
20546

Official Business
Penalty for Private Use, $300

THIRD-CLASS BULK RATE

Postag
Nation
Space
NASA-451

U.S.MAIL

NASA

POSTMASTER: If Undeliverable (Section 158 Postal Manual) Do Not Return