55

BOEING

RECEIVED
NASA STI FACILITY
INPUT BRANCH
AUG 1970

[redacted]

[redacted]

[redacted]

[redacted]

APOLLO TIE
WASHINGTON, D. C.

FACILITY FORM 602

N70-34190
(ACCESSION NUMBER)
(THRU)
348
(PAGES)
1
(CODE)
CR-109902
(NASA CR OR TMX OR AD NUMBER)
31
(CATEGORY)

DOCUMENT NO. D2-120001-2

TITLE SUMMARY OF VIBRATION AND ACOUSTIC TESTS ON FOUR SPACECRAFT PROGRAMS

MODEL NO. -

CONTRACT NO. NASw-1650
TECH L DIRECTION
SERIAL NO. 3, ITEM 3

ORIGINAL RELEASE - June 28, 1968

D. B. JACOBS
APOLLO TIE CHIEF ENGINEER

[redacted]

ISSUE NO.

ISSUED TO

[redacted]

THE BOEING COMPANY SPACE DIVISION LAUNCH SYSTEMS BRANCH

REVISIONS

REV. SYM	DESCRIPTION	DATE	APPROVED

ABSTRACT

This document summarizes the vibration and acoustic test programs for four spacecraft: Mariner, Lunar Orbiter, Gemini and Surveyor. Information is presented on laboratory test programs and results, flight results, derivation of test levels, identification of test factors, and spacecraft contractor conclusions and recommendations.

KEY WORDS

Acceptance test
Acoustics
Development Test
Gemini
Lunar Orbiter
Mariner
Qualification test
Spacecraft
Surveyor
Vibration

CONTENTS

PARAGRAPH		PAGE
	REVISIONS	ii
	ABSTRACT AND LIST OF KEY WORDS	iii
	CONTENTS	iv
	ILLUSTRATIONS AND TABLES	vi
	REFERENCES	ix
	PREFACE	x
	DEFINITIONS	xi
	SECTION 1 - INTRODUCTION	
1.0	PURPOSE	1-1
1.1	SCOPE	1-1
	SECTION 2 - SUMMARY	
	SECTION 3 - MARINER MARS 64	
3.0	GENERAL	3-1
3.1	LABORATORY TEST PROGRAM	3-1
3.2	LABORATORY TEST FAILURES	3-9
3.3	FLIGHT FAILURES	3-13
3.4	DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS	3-14
3.5	COMPARISON OF TEST LEVELS AND FLIGHT DATA	3-16
3.6	CONCLUSIONS AND RECOMMENDATIONS BY JPL	3-17
	SECTION 4 - MARINER VENUS 67	
4.0	GENERAL	4-1
4.1	LABORATORY TEST PROGRAM	4-1
4.2	LABORATORY TEST FAILURES	4-9
4.3	FLIGHT FAILURES	4-14
4.4	DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS	4-14
4.5	COMPARISON OF TEST LEVELS AND FLIGHT DATA	4-14
4.6	CONCLUSIONS AND RECOMMENDATIONS BY JPL	4-14
	SECTION 5 - LUNAR ORBITER	
5.0	GENERAL	5-1
5.1	LABORATORY TEST PROGRAM	5-1
5.2	LABORATORY TEST FAILURES	5-8
5.3	FLIGHT FAILURES	5-9
5.4	DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS	5-9
5.5	COMPARISON OF TEST LEVELS AND FLIGHT DATA	5-11
5.6	CONCLUSIONS AND RECOMMENDATIONS BY BOEING	5-11

CONTENTS (CONTINUED)

		PAGE
	SECTION 6 - GEMINI	
6.0	GENERAL	6-1
6.1	LABORATORY TEST PROGRAM	6-1
6.2	LABORATORY TEST FAILURES	6-9
6.3	FLIGHT FAILURES	6-13
6.4	DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS	6-13
6.5	COMPARISON OF TEST LEVELS AND FLIGHT DATA	6-18
6.6	CONCLUSIONS AND RECOMMENDATIONS BY MCDONNELL-DOUGLAS	6-18
	SECTION 7 - SURVEYOR	
7.0	GENERAL	7-1
7.1	LABORATORY TEST PROGRAM	7-1
7.2	LABORATORY TEST FAILURES	7-7
7.3	FLIGHT FAILURES	7-10
7.4	DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS	7-10
7.5	COMPARISON OF TEST LEVELS AND FLIGHT DATA	7-13
7.6	CONCLUSIONS AND RECOMMENDATIONS BY JPL	7-16
	APPENDIX A - MARINER 64 DETAILED FAILURE INFORMATION	
	APPENDIX B - MCDONNELL-DOUGLAS INPUT TO SPACECRAFT SURVEY	
	APPENDIX C - STATEMENT OF WORK	
	APPENDIX D - PRESENTATION OF SURVEY RESULTS TO THE APOLLO PROGRAM OFFICE	

ILLUSTRATIONS

FIGURE		PAGE
3-1	Mariner 64 Configuration	3-21
3-2	Mariner 64 Test Program Documentation	3-22
3-3	Subsystem Qualification Test, Low Frequency Sine Sweep	3-23
3-4	Subsystem Qualification Test, Random Vibration	3-24
3-5	Subsystem Qualification Test, Combined Random and Sine Sweep	3-25
3-6	Subsystem Acceptance Test, Random Vibration	3-26
3-7	Subsystem Acceptance Test, Combined Random Vibration and Sine Sweep	3-27
3-8	Mariner 64 Launch Configuration	3-28
3-9	System Qualification Test, Sinusoidal Sweep Vibration	3-29
3-10	System Qualification Test, Random Vibration	3-30
3-11	System Qualification Test, Acoustic Noise	3-31
3-12	System Acceptance Test, Sinusoidal Sweep Vibration	3-32
3-13	System Acceptance Test, Random Vibration	3-33
3-14	Derivation of System Vibration Levels	3-34
3-15	Derivation of System Test Durations	3-35
3-16	Comparison of System and Subsystem Qualification Levels, Random Vibration	3-36
3-17	Comparison of System and Subsystem Qualification Levels, Sine Sweep Vibration	3-37
3-18	Comparison of Flight Vibration Time Histories	3-38
3-19	Comparison of Flight Vibration Data and System Test Levels, Liftoff	3-39
3-20	Comparison of Flight Vibration Data and System Test Levels, Transonic Flight	3-40
3-21	Comparison of Laboratory Test Vibration Response to Measured Flight Response on Spacecraft Adapter	3-41
4-1	Mariner 67 Configuration	4-18
5-1	Lunar Orbiter Configuration	5-13
5-2	Lunar Orbiter Test Program Outline	5-14
5-3	Heat Shield Development Test, Acoustic Noise in 1/3 Octave Bands	5-15
5-4	Component Qualification, Sine Sweep	5-16
5-5	Component and System Qualification Test, Random Vibration	5-17
5-6	Component Acceptance Test, Sine Sweep	5-18
5-7	Component and System Acceptance Tests, Random Vibration	5-19
5-8	System Qualification Test, Sinusoidal Vibration, Longitudinal Axis	5-20
5-9	System Qualification Test, Sinusoidal Vibration, Lateral Axes	5-21
5-10	System Acceptance Test, Sinusoidal Vibration, Longitudinal Axis	5-22
5-11	System Acceptance Test, Sinusoidal Vibration, Lateral Axes	5-23
5-12	Comparison of Acceptance Test Levels with Measured Flight Response Levels, Random Vibration	5-24

ILLUSTRATIONS (CONTINUED)

FIGURE		PAGE
5-13	Comparison of Acceptance Test Levels with Measured Flight Response Levels, Random Vibration	5-25
5-14	Comparison of Laboratory Test Vibration Response to Measured Flight Response, Longitudinal Direction	5-26
5-15	Comparison of Laboratory Test Vibration Response to Measured Flight Response, Lateral Direction	5-27
6-1	Gemini Spacecraft	6-20
6-2	Laboratory Vibration and Acoustic Test Program Relationships	6-21
6-3	Envelope of Component Qualification Test Levels, Sinusoidal Vibration	6-22
6-4	Envelope of Component Qualification Test Levels, Random Vibration	6-23
6-5	Envelope of Component Qualification Test Levels, One-Third Octave Acoustics	6-24
6-6	Envelope of Component Acceptance Test Levels, Sinusoidal Vibration	6-25
6-7	Envelope of Component Acceptance Test Levels, Random Vibration	6-26
6-8	Gemini Subsystem Vibration Qualification Test Levels	6-27
6-9	Component Qualification Test, Sinusoidal Sweep Vibration	6-28
6-10	Component Qualification Test, Random Vibration	6-29
6-11	Derivation of Original Qualification Test Levels, Random Vibration	6-30
6-12	Derivation of Revised Re-Entry Vehicle Test Levels, Random Vibration	6-31
6-13	Derivation of Adapter Blast Shield Test Levels, Random Vibration	6-32
6-14	Comparison of Time Histories of Adjusted Mercury Launch Vibration with Original Gemini Qualification Test Times	6-33
6-15	Derivation of Original External Acoustic Test Spectra	6-34
6-16	Derivation of Original Cabin Acoustic Test Spectra	6-35
6-17	Mercury Cabin Acoustic Time History	6-36
6-18	Gemini Spacecraft No. 1 Vibration Pickup Locations	6-37
6-19	Gemini Spacecraft No. 2 Vibration Pickup Locations	6-38
6-20	Comparison of Time History of GT-1 Measured Re-Entry Vehicle Vibration with Qualification and Acceptance Test Durations	6-39
6-21	Comparison of Measured Flight Levels to Test Levels	6-40
6-22	Comparison of GT-1 Acoustic Time History with Qualification Test Duration	6-41
6-23	Comparison of Peak GT-1 Cabin Acoustic Measurement with Qualification Test Levels	6-42
7-1	Surveyor 1 Spacecraft Configuration	7-17

ILLUSTRATIONS (CONTINUED)

FIGURE		PAGE
7-2	Envelope of Subsystem Qualification Test Levels, Sinusoidal Vibration	7-18
7-3	Envelope of Subsystem Acceptance Test Levels, Sinusoidal Vibration	7-19
7-4	Subsystem Random Vibration Acceptance Test Levels	7-20
7-5	S-2 Structural Test Vehicle Vibration Test Levels	7-21
7-6	S-2A Structural Test Vehicle Vibration Test Levels	7-22
7-7	S-9 Torsional Vibration Test Levels	7-23
7-8	S-9 Structural Test Vehicle Vibration Test Levels	7-24
7-9	System Qualification Test Levels, Sinusoidal Vibration	7-25
7-10	System Acceptance Test Levels, Sinusoidal Vibration	7-26
7-11	Comparison of Flight Environment to Test Levels, Random Vibration	7-27
7-12	Comparison of Flight Environment to Test Levels, Sinusoidal Vibration	7-28
7-13	Comparison of Flight Environment to Test Levels, Sinusoidal Vibration	7-29
7-14	Comparison of Flight Environment to Test Levels, Torsional Sinusoidal Vibration	7-30

TABLES

TABLE		
3-I	Systems Qualification Test Torsional Vibration Levels	3-8
3-II	Subsystem Qualification Test Failure Summary	3-9
3-III	Subsystem Acceptance Test Failure Summary	3-10
3-IV	System Qualification Test Failures	3-10
3-V	System Acceptance Test Failures	3-11
4-I	Subsystem Qualification Test Failures	4-11
4-II	Subsystem Acceptance Test Failures	4-12
4-III	Summary of System Qualification Test Failures	4-15
4-IV	Summary of System Acceptance Test Failures	4-16
5-I	Systems Qualification Test Torsional Vibration Levels	5-6
5-II	System Acceptance Test Failures	5-10
6-I	Gemini Component Vibration/Acoustic Qualification Test Summary	6-4
6-II	Gemini Component Vibration Acceptance Test Summary	6-6
6-III	Gemini Subsystem Vibration Qualification Test Summary	6-8
6-IV	Gemini System Vibration/Acoustic Acceptance Test Summary	6-10
6-V	Component Vibration/Acoustic Qualification Test Failure Summary	6-11
6-VI	Component Vibration Acceptance Test Failure Summary	6-12
6-VII	System Vibration Acceptance Test Failure Summary	6-14
7-I	Relationship Between Systems Vibration Test Levels	7-14

REFERENCES

1. D2-120001-1, "Survey of Vibration and Acoustic Tests Conducted on Spacecraft/Launch Vehicles," The Boeing Company, Huntsville, Alabama, December 21, 1967.

2. ED-268, "Mariner Mars 1964 Spacecraft Environmental Test Results," Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, June 15, 1965.

3. Shipley, W. S. and Maclay, J. E., "Mariner 4 Environmental Testing," Astronautics and Aeronautics, August 1965.

4. Schiffer, R. A. and Hyde, J. R., "Mariner Mars 1964 Acoustically Induced Vibration Environment," The Shock and Vibration Bulletin, Bulletin 35, Part 7, April 1966.

5. JPL Technical Report 32-740, "Mariner Mars 1964 Project Report: Mission and Spacecraft Development," Volume I, Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, March 1, 1965.

6. JPL Technical Report 32-1249, "Mariner Venus 67 Spacecraft Environmental Test Results," Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, To Be Released.

7. DLRM 68-1, "A Review of Lunar Orbiter Acoustic and Vibration Testing," The Boeing Company, Seattle, Washington, April 15, 1968.

8. JPL Technical Report 32-1265, "Surveyor Project Final Report, Part One: Project Description and Performance," Jet Propulsion Laboratory, California Institute of Technology, To Be Released.

PREFACE

This document was prepared for the National Aeronautics and Space Administration, Washington, D.C., by The Boeing Company in partial fulfillment of the requirement of Contract NASw 1650, Technical Direction Serial No. 3, Item 3.

The following personnel are chiefly responsible for the document preparation.

C. J. Beck
D. W. Caba
W. H. Lawler

ABBREVIATIONS

Hz	Hertz, a unit of frequency in cycles per second
G	Acceleration in gravitational units
Grms	Root mean squared acceleration
PSD	Power spectral density
MAX q	Maximum dynamic pressure

DEFINITIONS

ACCEPTANCE TEST - A test to detect workmanship deficiencies in a component, subsystem or system which is destined for use in service. The test environment may or may not simulate the expected service environment, but the test level is generally less than the qualification test level.

COMPONENT - An integral package such as a camera, a valve, a battery or a transmitter.

DEVELOPMENT TEST - A test to evaluate the performance of a component, subsystem or system under environmental conditions and to determine its ability to withstand such conditions. The test environment may or may not simulate the expected service environment, but the test level is generally equal to or greater than the qualification level. The test is usually run early in a program to seek out design weaknesses and correct or improve them prior to qualification testing.

QUALIFICATION TEST - A test on a component, subsystem or system to demonstrate design capability to withstand a critical service environment. The test environment is usually a conservative simulation of the expected service environment.

SUBSYSTEM - A group of components which is part of a larger system. An example of a subsystem is the Gemini fuel cell module consisting of two fuel cell sections, a hydrogen tank, an oxygen tank, pressure regulators, valves and associated tubing and wiring.

SYSTEM - A complete or major portion of a spacecraft.

SECTION 1

INTRODUCTION

1.0 PURPOSE

The purpose of this document is to present the results of a detailed vibration and acoustic test survey performed on four spacecraft programs, Mariner, Gemini, Lunar Orbiter and Surveyor. This is a more detailed continuation of the vibration and acoustic survey conducted by the Boeing Company in 1967 and documented in Reference 1. These data are intended to support Apollo flight worthiness decisions and aid the evaluation of flight acceptance testing philosophy.

1.1 SCOPE

During the survey data was collected on laboratory test programs and results, flight results, derivation of test levels, identification of test factors, and spacecraft contractor conclusions and recommendations. The ground rules and specific information desired on this survey are included in Appendix C.

The information presented in this document is the condensation of many volumes of data and was accumulated for this survey in a very short period of time. Therefore, the text of this document is by necessity a series of concise statements relevant to the Appendix C statement of work instead of a complete discussion of each subject. Wherever possible, the spacecraft contractors (JPL, McDonnell-Douglas, Boeing) are quoted directly from available document, memos, telecons, etc., to eliminate interpretation errors by the authors of this document. Care was exercised to avoid injecting opinions or conclusions since the purpose of this document is to report the data as is, rather than to evaluate or make judgements.

SECTION 2

SUMMARY

The vibration and acoustic test programs are detailed for four spacecraft, Mariner, Gemini, Lunar Orbiter and Surveyor. Since the Mariner program has separate and distinct missions for different spacecraft, the Mariner Mars 64 and Mariner Venus 67 projects are included in separate sections.

The Mariner Mars 64 survey results are presented in Section 3. This information was obtained from JPL documentation and from both oral and written correspondence with JPL engineers.

Section 4 presents the Mariner Venus 67 spacecraft survey results. Since the Mariner Venus 67 spacecraft consisted of essentially the same hardware as did Mariner Mars 64, Section 4 is directed toward detailing the program differences and changes. One of the more significant things about the Mariner Venus 67 project was the retest philosophy developed to utilize leftover Mariner 64 hardware.

Section 5 details the Lunar Orbiter spacecraft survey results. This information was collected by Boeing-Seattle vibration and acoustics engineers from available Lunar Orbiter data for inclusion in this document.

Section 6 presents the Gemini spacecraft survey results. This information was collected by McDonnell-Douglas Gemini project engineers for this survey. The Gemini spacecraft was the only manned vehicle considered in this survey.

The Surveyor spacecraft survey results are presented in Section 7. This section is incomplete due to the lack of time available to gather information. The data shown are taken from partially completed JPL documentation and conversations with JPL engineers.

Appendix A presents detailed laboratory test failure data for the Mariner Mars 64 spacecraft program. Subsystem test failure data are presented for both qualification and acceptance tests.

Appendix B presents detailed laboratory and flight test data for the Gemini spacecraft program as received from McDonnell-Douglas.

Appendix C contains the original task descriptions that were used to conduct this survey. The information desired and ground rules used in conducting this survey are found in Appendix C.

Appendix D consists of the presentation made to the Apollo Program Office summarizing the findings of this vibration and acoustics survey.

SECTION 3

MARINER MARS 64

3.0 GENERAL INFORMATION

Project Management - Jet Propulsion Laboratory

Launch Vehicle - Atlas/Agena D

Spacecraft

Mariner I	Launched 1962	Destroyed during boost
Mariner II	Launched 8/27/62	Successful Venus fly by
Mariner III	Launched 11/5/64	Shroud failed to jettison
Mariner IV	Launched 11/28/64	Successful Mars fly by
Mariner V	Launched 1967	Spare to Mariner IV, became Mariner 67

Mariner III and IV are the Mariner Mars 1964 spacecraft and are the subject of this section.

Mariner 64 physical characteristics, see Figure 3-1.

Weight - 575 lbs.
Diameter - 5 ft. with solar panels folded
17 ft. with solar panels extended
Length - 9 ft.

The information presented in this section were obtained from References 2, 3, 4 and 5.

3.1 LABORATORY TEST PROGRAM

3.1.1 Test Program Rationale

3.1.1.1 General

Environmental testing is a controlled series of interrelated and integrated events which permit a quality judgment to be made of equipment design and flight acceptability. The formal testing constituting the program--i.e., qualification and acceptance tests at the subsystem level, and at the system level--are implicitly related.

Specifically, the inspection and successful performance of a subsystem or system during and following qualification testing offers implicit evidence that the flight subsystem or system will not be degraded by less severe environmental exposures during acceptance testing. Further, the qualification test establishes confidence in the existence of acceptable design margins in the equipment.

The Mariner 64 test program was geared to the qualification test.

3.1.1.2 Objectives

Special development tests are intended to prove the feasibility and adequacy of spacecraft mechanical hardware.

Qualification tests are intended to verify designs.

Acceptance tests are intended to certify readiness for flight.

The spacecraft systems test provides the only true mechanical, thermal and electrical environments and environmental interactions for the various spacecraft subsystems and components.

3.1.1.3 Requirements

One set of each subsystem was qualification tested except for waivers granted by the spacecraft system manager.

All proof test model (PTM) and flight-spacecraft subsystems were acceptance tested.

Systems level qualification testing was performed on the PTM spacecraft.

Systems level acceptance testing was performed on each flight spacecraft.

Special development tests were performed only on a few items (flight hardware not used) usually using qualification test hardware.

Equipment subject to qualification level tests was not flown.

All PTM, flight and spare spacecraft equipment was required to pass the tests before considered acceptable for flight.

3.1.1.4 Environmental Test Program Outline

Figure 3-2 shows relationships between environmental tests and governing documentation.

3.1.2 Component Vibration and Acoustic Tests

The Mariner program used the terminology assembly, subassembly and subsystem. This terminology included test articles which are defined as components and subsystems in this document (see Definitions). Therefore, the component and subsystem level tests are discussed in the paragraphs describing subsystems since no distinction between the two was made in JPL documentation.

3.1.3 Subsystem Development Tests

3.1.3.1 Objectives

Subsystem development tests were conducted to confirm analyses, verify problem solutions and gather critical information essential to project success.

Prototype and test hardware were used for these tests.

3.1.3.2 Test Levels and Durations

Test levels and durations for special development tests were not uniform. In general, test levels were at least as severe as qualification levels. Durations are unknown for these tests.

3.1.3.3 Test Descriptions and Results

(1) Damped structure feasibility tests

Solar panel damper design verified by 10 g peak sinusoidal test swept through all panel resonances up to 200 hz.

Low gain antenna damper system tests revealed that the damper reduced the structure motion by a factor of more than twenty.

(2) Electronic packaging development tests

Electronic assembly chasses were subjected to 3 g sine sweep levels from 20-1500 hz in three axes. All exhibited similar resonances.

Prototype chassis and lightened chassis were subjected to 1-g sine sweep from 20-1500 hz. As a result lightened chassis were selected for flight, wt. savings = 6 lbs.

(3) High gain antenna tests

A combined heat-vibration test was performed to verify that aerodynamic heating would not degrade the antenna structure.

(4) Solar panel structural development tests

Weight limitations required radical departure from previous panel design.

Preliminary acoustic tests showed the critical sensitivity of spot welding construction to acoustic energy. Spot welding abandoned and all bonded substrate construction adopted.

3.1.3.3 (Continued)

Final developmental vibration tests were used to determine the ability of the panel to survive the vibration environment. After successful test completion, a test to failure was performed wherein the panel failed at 112% "ultimate" vibratory load. The test to failure vividly illustrated the lack of excessive (unnecessary) margins of safety.

3.1.4 Subsystem Qualification Tests

3.1.4.1 Objectives

Environmental qualification tests were intended to verify designs.

The tests were intentionally severe in order to compensate for material and fabrication differences in flight hardware.

3.1.4.2 Test Levels and Durations

Low frequency (1-15 hz) sinusoidal sweep vibration in each of three orthogonal axes (see Figure 3-3).

Complex wave tests (15-2000 hz) in each of three orthogonal axes consisting of:

Random vibration (see Figure 3-4),

Combined random vibration and swept sinusoidal vibration (see Figure 3-5).

No acoustic test was required.

3.1.4.3 Subsystems Tested

There were 154 complex wave vibration tests performed on 54 subsystems (tests waived for one subsystem).

There were 90 low frequency vibration tests performed on 51 subsystems (tests waived for four subsystems).

3.1.4.4 Operational Requirements

Subsystems which did not operate during booster operation were not required to function within tolerance during the tests, only to survive.

Each subsystem was required to operate in accordance with its test specification without repair or adjustment following the test.

3.1.5 Subsystem Acceptance Tests

3.1.5.1 Objectives

Demonstrate the ability of the subsystems to perform satisfactorily in the selected environments at levels at least as severe as flight levels.

Certify subsystem flight worthiness.

3.1.5.2 Test Levels and Durations

Complex wave tests consisting of:

Random vibration (see Figure 3-6),

Combined random vibration and swept sinusoidal vibration (see Figure 3-7).

No acoustic test was required.

3.1.5.3 Subsystems Tested

There were 538 vibration acceptance tests performed on 49 subsystems.

3.1.5.4 Operational Requirements

Subsystems which did not operate during booster operation were not required to function within tolerance during the tests, only to survive.

Each subsystem was required to operate in accordance with its test specification without repair or adjustment following the test.

3.1.6 System Development Tests

3.1.6.1 General

Systems level tests are required early in project development for the following reasons:

(1) To demonstrate hardware feasibility,

(2) To evaluate interactions of the spacecraft and the vibration and acoustic environments,

(3) To verify subsystem level test requirements,

(4) To confirm analyses,

(5) To verify problem solutions and gather critical information essential to project success.

3.1.6.2 Test Configurations

Two test space frames were subjected to vibration and acoustic development tests:

Development test model (DTM) was composed of mass mockups of all structurally critical spacecraft items.

Structural test model (STM) was composed of mass and structural simulations of all spacecraft components.

3.1.6.3 Objectives

DTM vibration tests were performed to demonstrate structural integrity of the shroud and interface hardware and to measure interface clearances (see Figure 3-8).

DTM acoustic tests were performed to determine the vibration response at selected spacecraft locations when subjected to a high level acoustic field and to measure the shroud acoustic transmission loss.

STM vibration tests were performed to verify the feasibility and adequacy of the basic structural design.

STM acoustic tests were performed to subject the STM spacecraft to the proof test model type acoustic test in preparation for the PTM qualification test and to measure the acoustic transmission loss of the flight shroud.

3.1.6.4 Test Descriptions and Results

DTM vibration tests consisted of a series of sinusoidal excitations. From these tests it was concluded that the Mariner shroud-spacecraft system was qualified to withstand maximum flight dynamic loads and all clearances were deemed adequate.

DTM acoustic tests consisted of a 142 db shaped acoustic reverberant field. Some structure degradation occurred, however the shroud acoustic transmission characteristics were recorded.

STM vibration tests consisted of sinusoidal and random excitation in three axes plus torsional vibration about the roll axis. Significant results included strong nonlinear behavior of several elements of the spacecraft, i.e., solar panel dampers, PIPS bladder fuel sloshing and scan platform bearing backlash.

STM acoustic tests consisted of a 142 db shaped reverberant field. DTM acoustic test results were corroborated by the STM test results.

3.1.7 Systems Qualification Tests

3.1.7.1 Objectives

Demonstrate the integrity of the spacecraft design for the deleterious effects of the launch environment.

Qualify the design and demonstrate with a margin a specific level of equipment capability.

Locate faults and inadequacies by subjecting the spacecraft to test levels more severe than flight levels.

3.1.7.2 Test Levels and Durations

Vibration tests consisting of:

Sinusoidal sweep in three lateral axes and roll axis (see Figure 3-9),

Random vibration in three lateral axes and roll axis (see Figure 3-10),

Torsional sine test (see Table 3-1).

Acoustic tests were performed in a reverberation room (see Figure 3-11).

3.1.7.3 Test Configuration

Proof test model (PTM) spacecraft was used for all systems qualification tests.

The PTM spacecraft was composed of 85% actual flight hardware.

Control for all PTM vibration tests was obtained from six accelerometers on the Agena/Mariner adaptor.

3.1.8 Systems Acceptance Tests

3.1.8.1 Objectives

Certify flight worthiness and demonstrate capability of each spacecraft to survive the launch environment.

Detect spacecraft assembly errors and subsystem early life failures.

3.1.8.2 Test Levels and Durations

Systems vibration acceptance consisted of:

Sinusoidal sweep test in three orthogonal axes (see Figure 3-12),

Random vibration in three orthogonal axes (see Figure 3-13).

No acoustic tests were performed.

TABLE 3-I. SYSTEMS QUALIFICATION TEST TORSIONAL VIBRATION LEVELS

FREQUENCY (CPS)	FREQUENCY SWEEP TIME	ANGULAR* ACCELERATION (RAD/SEC^2)	REMARKS
69	0.14 sec.	205	Amplitude modulated tone.
20-150-20	3.0 min.	12.86	Torsional sweep.
50-150	5.5 sec.	154	Rolled off spectrum - 6 db/octave
150-50	5.5 sec.	154	Rolled off spectrum - 6 db/octave
69	0.14 sec.	205	Amplitude modulated tone

*Torsion about the roll axis.

3.1.8.3 Test Configuration

Each spacecraft tested was fully flight equipped except for the post injection propulsion subsystem (PIPS). Acceptance testing of the PIPS flight assembly is conducted independent of flight spacecraft tests to avoid hazardous test conditions. Control for all vibration tests was obtained from six accelerometers on the Agena/Mariner adapter.

3.1.8.4 Operational Requirements

A system verification test was performed before and after each axis of vibration. System verification test data was thoroughly evaluated after each vibration axis to insure proper vehicle condition.

3.2 LABORATORY TEST FAILURES

3.2.1 Component Vibration and Acoustic Test Failures

Component testing was not distinguished from subsystem testing (see 3.1.2).

3.2.2 Subsystem Development Test Failures

Information pertaining to subsystem development test failures could not be made available in the limited time allotted for this survey.

3.2.3 Subsystem Qualification Test Failures

Subsystem vibration test failures are summarized in Table 3-2. Detailed failure information is presented in Table A-1 of Appendix A.

TABLE 3-II. SUBSYSTEM QUALIFICATION TEST FAILURE SUMMARY

No. of Subsystems	Total Items Tested	Failed	Failure Rate
54	244	30	12.3%

Failure Category	Number
Design Deficiency	23
Part Failure	7
*Workmanship	7
*Operator Error	5
*Operational Support Equipment (OSE) Failure	2
*Misc.	2
Total vibration test problems	46
Total vibration test failures	30

*Not considered test failures by JPL

3.2.4 Subsystem Acceptance Test Failures

Subsystem acceptance test failures are summarized in Table 3-3. Detailed failure information is presented in Table A-2 of Appendix A.

TABLE 3-III. SUBSYSTEM ACCEPTANCE TEST FAILURE SUMMARY

No. of Subsystems	Total Items Tested	Failed	Failure Rate
49	538(1)	26	4.8%

Category	Number
Design Deficiency	5(2)
Part Failures	11
Workmanship	5
*Operator Error	1
Operational Support Equipment (OSE)	4
Misc. Procedure	1
Total vibration test problems	27
Total vibration test failures	26

*Not considered as test failure by JPL

(1) Over 1/2 the subsystems acceptance tested were later subjected to system level tests.

(2) The 5 subsystems which failed due to design deficiencies had not been previously subjected to qualification tests.

3.2.5 System Development Test Failures

Information pertaining to system development test failures could not be made available in the limited time allotted for this survey.

3.2.6 System Qualification Test Failures

System qualification test failures are presented in Table 3-4.

TABLE 3-IV. SYSTEM QUALIFICATION TEST FAILURES

Environment	Anomaly Type	Item	Resolution
Acoustic	Failure	CC&S fuse	Transformer redesign
Vibration	Failure	Science scan cover	Redesign
Vibration	Failure	Torsional vibration fixture	Reworked fixture
Vibration	Failure	Canopus tracker	Redesign image dissector tube
Vibration	Problem	Cosmic ray telescope	Change calibrate reset
Vibration	Problem	Cosmic duct detector	Incorporated change order

3.2.7 System Acceptance Test Failures

System acceptance test failures are presented in Table 3-5.

TABLE 3-V. SYSTEMS ACCEPTANCE TEST FAILURES

FLIGHT* VEHICLE	ANOMALY TYPE	ITEM	RESOLUTION
MC-3	Failure	Ring harness trough ass'y	Structural beef-up
MC-2,3 & 4	Problem	Microphone	Changed out for high frequency accelerometer
MC-2	Problem	Low frequency accelerometer	Improper grounding for test set up, no change for flight vehicles
MC-3	Problem	Microphone and charge amplifier connector	Changed out for high frequency accelerometer
MC-4	Problem	Charge amplifier connector	No action
MC-4	Problem	Low-frequency accelerometer connector	Safety wired all connectors
MC-4	Problem	Separation rate monitor bolt	Safety-wired all fasteners

*MC-2 was Mariner III Flight Vehicle
MC-3 was Mariner IV Flight Vehicle
MC-4 was Spare Flight Vehicle

3.2.8 Special Problems, P-List Items

During project development significant problems arose of such scope and magnitude as to jeopardize the success of the mission and were therefore subjected to a thorough study under a maximum effort. These problems were designated as "P-List Items".

Three of the "P-List Items" were caused by inability of certain hardware to survive the laboratory vibration environments. The three items are listed below and will be discussed in the following paragraphs.

Canopus Tracker
Vidicon Camera
LMSC Instrumentation System

3.2.8.1 Canopus Tracker

Mariner STM vibration tests indicated that the tracker would experience relatively high inputs in certain frequency ranges due to mounting method and location in the spacecraft. The tracker employed in the STM tests was only a mass mock-up; therefore, no functional problems were apparent.

A flight like tracker was tested on the PTM and was found to be inoperable after test. A failure of an anode wire in photo-multiplier tube had occurred. It was later established that a similar failure had occurred in subsystem qualification.

A new subsystem qualification test was run with the tracker hardmounted to a shaker. The photo-multiplier tube failed. Tests were then run with and without washers. The results of these tests showed that hardmounting the tracker increased vibration response in the critical frequency range.

A tracker with an improved tube design was then tested on the PTM with a bushing and washers installed at the S/C-Tracker interface. The PTM test qualified the tracker at the PTM level and provided data for new subsystem acceptance and qualification levels.

The tracker with an improved tube satisfactorily passed subsystem level testing.

The tracker with the improved tube design was used on Mariner IV.

3.2.8.2 Vidicon Camera

Unlike the Canopus Tracker the Vidicon Camera passed the PTM qualification test. The first indication of a significant problem was when the camera failed during subsystem qualification. The failure occurred in weld joints and conductor leads.

Sine and random tests were then run on hardmounted vidicon tubes to determine critical frequencies and response variations between tubes.

3.2.8.2 (Continued)

The tube was then tested on a structural mockup of the camera chassis using hard and soft tube mount configurations. These tests indicated that a soft tube mount afforded the maximum tube protection. Extensive tests were run using different test techniques in an attempt to preserve the original hardmount design.

The soft tube mount passed qualification tests and was adopted for the flight configuration.

Attempts at modifying the normal subsystem qualification test and test techniques were made to solve both the Canopus Tracker and Vidicon Camera problems. The actual solutions were obtained by design modifications. In the case of the Canopus Tracker, the tube was modified by internal structural stiffening. The vidicon solution was obtained by vibration isolation. This points toward the realization that the best approach to environmental type problem areas is that of design improvement and not test technique and/or specification modifications.

3.2.8.3 Lockheed (LSMC) Instrumentation

Microphone for measuring flight acoustic environment displayed unacceptable behavior during system acceptance test on MC-3 and MC-2.

Microphone mounting bracket was highly resonant and microphone was sensitive to local pressure fluctuations from the laboratory air conditioner.

Modifications to the microphone system on MC-4 spacecraft tests did not solve the problems. The microphone was removed and a vibration transducer was added at the adapter/Agena interface in lieu of the microphone.

3.3 FLIGHT FAILURES

Shroud failed to jettison on Mariner III. The possibility was suggested of a shroud structural failure due to skin separation from the fiberglass honeycomb core. Immediate action was taken to subject a test shroud to a combined thermal-vacuum test. The shroud skin delaminated and further evaluation indicated that the flight failure mode probably was similar. There was no evidence of a vibration-induced problem.

The failure (skin separation from the core) was of such a nature that it could have been detected only by tests under combined environments (temperature, vacuum, and time). Such tests were not performed on the shroud system until after the failure of the Mariner III shroud.

3.4 DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS

3.4.1 Component Test Levels and Durations

Component testing was not distinguished from subsystem testing (see 3.1.2).

3.4.2 Subsystem Test Levels and Durations

3.4.2.1 Vibration Levels

Information available on the method of derivation indicates that the subsystem vibration levels were determined by applying transfer functions to the system test levels.

3.4.2.2 Vibration Duration

Same as system test durations, see 3.4.3.

3.4.3 Systems Test Levels and Durations

3.4.3.1 Random Vibration Levels

Acceptance test spectra were established by generously enveloping the 95th percentile level (50 hz bands) Ranger data (see Figure 3-14). The levels were intended to be mild enough to avoid fatigue or reduced life expectancy, but severe enough to indicate workmanship defects and subsystem early life failures.

Qualification test levels were established by increasing the acceptance test spectra 4.5 db (factor of 2.9 on PSD and 1.7 on RMS), as shown in Figure 3-14. The qualification levels were felt to be in excess of Ranger 99th percentile levels.

These levels were never changed during the course of the program even though the initial levels were continuously reviewed to insure validity.

3.4.3.2 Random Vibration Durations

Acceptance and qualification test durations were rather arbitrarily set at 1 minute/axis and 3 minutes/axis, respectively.

These durations (based on Ranger data) were intended to adequately cover the period of time during flight that the vibration level would be within 10 db (factor of 3.2 on RMS) of the maximum level,(see Figure 3-15.)

3.4.3.3 Sinusoidal Vibration Levels and Durations

No information available on derivation methods.

3.4.3.4 Torsional Vibration Levels and Durations

No information available on derivation methods, except that the test is to account for vibration phenomena peculair to the Atlas/Agena launch vehicle.

3.4.3.5 Acoustic Levels and Durations

The acoustic qualification test level was established using Mercury launch pad measurements.

Method for derivation of the test duration (1.5 minutes) is unknown.

3.4.4 Source of Data

3.4.4.1 Vibration Data

Ranger spacecraft was considered to be of sufficiently similar general configuration to extrapolate its data to Mariner with confidence.

Vibration data from the Ranger 1-5 flights were analyzed and the 95th percentile levels used as the predicted flight environemtns.

Staging torsional transients from the Atlas/Agena vehicle were used to establish torsional test levels.

3.4.4.2 Acoustic Data

Estimates for the liftoff acoustic environment were based on Atlas/Mercury launch pad measurements.

3.4.5 Identification of Test Factors

3.4.5.1 System Random Vibration Tests

The following tabulation indicates level and duration test factors for the various system random vibration tests:

Ratio	PSD Level	RMS Level	Duration
Qualification to Acceptance	2.9	1.7	3

3.4.5.2 Subsystem Random Vibration Tests

Test factors were in general the same as systems factors. However, this was not a requirement.

3.4.5.3 Comparison of System and Subsystem Tests

Figure 3-16 shows a comparison of system and subsystem qualification random vibration test levels and durations.

Figure 3-17 shows a comparison of system and subsystem qualification sine sweep vibration test levels and durations.

3.5 COMPARISON OF TEST LEVELS AND FLIGHT DATA

3.5.1 Flight Vibration Data

Mariners III & IV carried an identical complement of instrumentation for measurement of inflight vibration data.

Data shown here are from two accelerometers mounted at the Agena/spacecraft adaptor interface, sensitive in the longitudinal axis. Both accelerometers were on high frequency channels and attached to rigid structure to avoid resonant mounting characteristics.

A time history of spacecraft adapter acceleration is shown in Figure 3-18.

The liftoff PSD plot was taken from a 2.5 second time sample (see Figure 3-19).

The transonic PSD plot represents a 4 second time sample (see Figure 3-20).

The ratio between flight acceptance test vibration response and flight vibration response at the spacecraft adapter illustrates the conservatism in the imposed requirements, (see Figure 3-21).

There was one radial and two tangential low frequency measurements on the adapter oriented to obtain torsional as well as lateral oscillations. This data was not available.

3.5.2 Flight Acoustic Data

Acoustic data were acquired by two microphones on the umbilical tower and two microphones on a ground lamppost during Mariner III launch.

3.5.3 Significant Comments

The wideband transonic vibration build-up and duration observed on Mariner (Figure 3-18) were unlike that experienced during any Ranger flight (Figure 3-15). The implication is that the validity of extrapolating these data to "similar" vehicles should be questioned.

Comparing flight and laboratory data it appears that the nature of vibrational response to acoustic excitation may require a degree of simulation unobtainable, except under a flight condition.

3.6 CONCLUSIONS AND RECOMMENDATIONS BY JPL

3.6.1 Conclusions

The Mariners Mars 64 spacecraft equipment was subjected to an orderly and conservative environmental test program. Clearly defined general testing requirements enabled attention to be focused on potentially damaging problems and contributed to the timely accomplishment of the test program. Satisfactory completion of the testing activity permitted the project management to approach the launch with confidence in the environmental integrity of the spacecraft.

The spacecraft acceptance tests, established by enveloping the Ranger 95th percentile probability level, were never exceeded in flight.

The qualification levels, accomplished by scaling in such a way that the ratio to the acceptance tests were approximately 1.69, appear to have developed sufficient conservatism for vehicle qualification.

Of the 55 subsystem acceptance test failures,* 14 resulted in redesign. Ten of these 14 tests had not been preceded by the qualification test. The remaining 4 failures were identical failures on each of the 4 flight units of one subsystem. The nature of the failure was very subtle, and it is felt that the same anomaly should have been seen during the qualification test. Discounting these 4 acceptance failures then, all 10 of the 10 acceptance environmental test failures which resulted in redesign had one thing in common - qualification testing had not yet occurred.

The 10 workmanship errors detected during subsystem qualification environmental* testing indicate the need for a pre-qualification test.

Although not covered in the survey, the shock test resulted in 3 failures; all 3 were latching relay malfunctions. There were no relay malfunctions during vibration). Although this represents a small failure rate, there is an indication of fragility of latching relays in a shock environment.

*Not all of these failures were due to vibration.

3.6.1 (Continued)

Analysis of problem/failure reports generated during the environmental testing program indicated a number of parts and processes which were vulnerable to the launch and space environment. Some of the more outstanding cases indicating trends of failure are enumerated for the benefit of future projects:

1) Ceramic capacitors should not be used for low level amplification in a vibration environment because of the initiation of piezoelectric action.

2) Sigma relays are non-operational when exposed to shock environment in excess of 100 g.

3) Glass (vacuum) tubes constitute a potential major design problem and should be ruggedized and/or soft mounted. Every vacuum tube application should be viewed from the very outset as a vibration problem, but amendable to solution.

From the feasibility studies of damped structures, early in the program, it was determined that their utilization for the Mariner spacecraft would result in large savings of structural weight. Continued investigation in this area appears to be equally attractive for application to future programs.

3.6.2 JPL Recommendations for Future Programs

Many of the qualification environmental tests caused no failures. This provides a strong implication that if a unit passes certain key environmental tests, it will pass all tests. Complex wave vibration and vacuum/temperature would be the key tests. A cautionary word - simply dropping all tests but thermal vacuum and vibration is not advocated, rather, it is suggested that by purposefully structuring certain key tests and acknowledging certain operational constraints, it appears reasonable to drop less productive tests.

The importance of completing qualification environmental testing early in a project cannot be overemphasized. Accomplishing required design revisions and the deletion of unsatisfactory subsystems and components, prior to acceptance testing, saves expensive retrofit and retesting, with the attendant increased environmental exposure of flight hardware. Design changes originating as a result of acceptance test problems sometimes paralled identical problems arising in a concurrent qualification test program. Therefore, it is recommended that an attempt be made to complete qualification testing at the earliest possible data.

3.6.2 (Continued)

The failures detected during system level environmental testing illustrate certain unavoidable deficiencies in the subsystem level testing: some units (such as spacecraft cabling) are not amendable to assembly level tests; subsystem environmental interactions cannot be simulated nor controlled; and degradation can occur between subsystem level acceptance and incorporation into a spacecraft. Systems level testing is the only solution for such problems.

Because of the present state-of-the-art in estimating vibration environments, and since future programs will be faced with the "same old problem" of prescribing qualification testing levels at early dates with little available information, it appears highly desirable to strive toward a failure test of the prototype vehicle at an early date in the program. This test would show just what design margin actually exists. It would be invaluable to know just how much inherent but untested margin there is in a typical design when the need for trade-offs arises late in the program. A demonstration of margin, by a test to failure, appears to be a highly desirable engineering tool.

The laboratory results, observed during the high gain antenna combined heating and vibration tests, produced only moderate agreement between the antenna structural response to the swept sine and the decaying sine transient. The technique presently employed for structural integrity demonstration utilizes swept sinusoids and generally results in overly conservative testing. This is due largely to the fact that:

1) Safety factors are used to establish the swept sinusoid equivalent for a transient impulse, and

2) Detailed knowledge of the dynamic response characteristics of a particular structure are not fully known at the time when the test specifications are established.

As a result, spacecraft structures appear to be considerably heavier than the boost environment necessitates and it would appear that large savings could be achieved on future programs by developing the transient testing technique. The corollary to this problem is, of course, the development of the tools and techniques necessary to design and analyze for transient loads.

Although the overall RMS value of the observed launch vehicle inflight vibration has been quite similar from flight to flight, the spectrum is known to be variable. A large effort should be expended in order to obtain inflight vibration measurements both inside the spacecraft and on the launch vehicle. Work in areas such as wind tunnel analysis, acoustical testing of the spacecraft, etc., should be emphasized in order to better understand the manner in which the mechanism of vibration is affected and how it is transmitted into and throughout the spacecraft. Specific emphasis should be placed on obtaining estimates of the response and transfer characteristics for complex electronic systems due to acoustical excitation.

3.6.2 (Continued)

Testing of the vehicle on the ground is grossly affected by the fixture transfer characteristics which modify the input spectrum. To compensate for fixture problems, such techniques as multiple shaker systems, flexible fixtures, etc., should be studied in order to increase the dimensions in which the vibration testing technique can be controlled.

Improved reporting of environmental testing would permit more rapid dissemination of information to the project and the cognizant personnel. All acceptance and qualification tests must be reported on a test result summary since the total history of an item under test is just as important as the fact that it passed.

Dynamic modeling of spacecraft - while this area was not of particular significance to a program such as Mariner, largely because of the vehicle's relatively small size and weight, the anticipated size of future spacecraft would indicate that some work needs to be initiated at this time in order to study the scaling effects on very large/complex structures and the testing techniques to be employed.

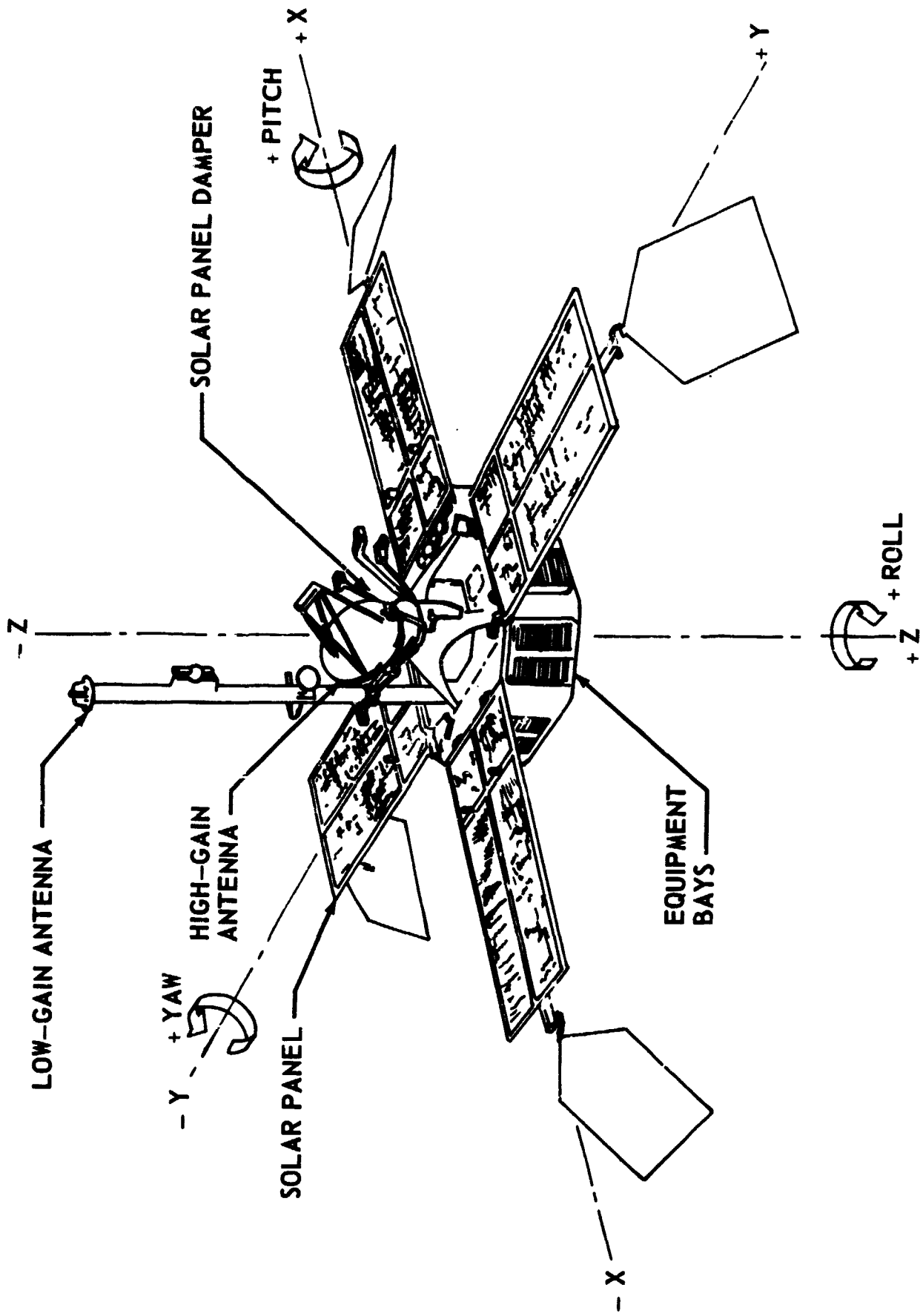


Figure 3-1: MARINER 64 CONFIGURATION

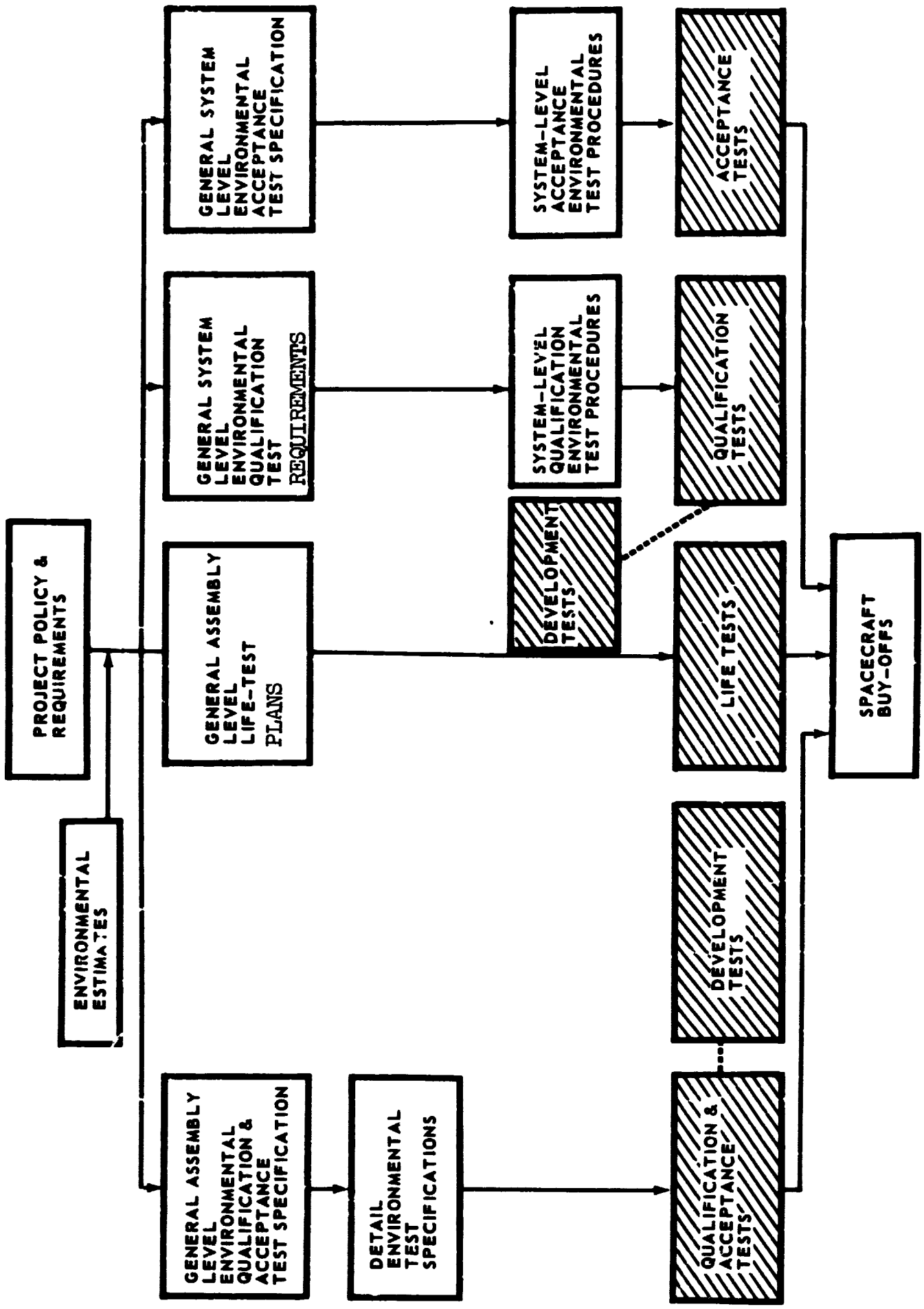


Figure 3-2: MARINER 64 TEST PROGRAM DOCUMENTATION

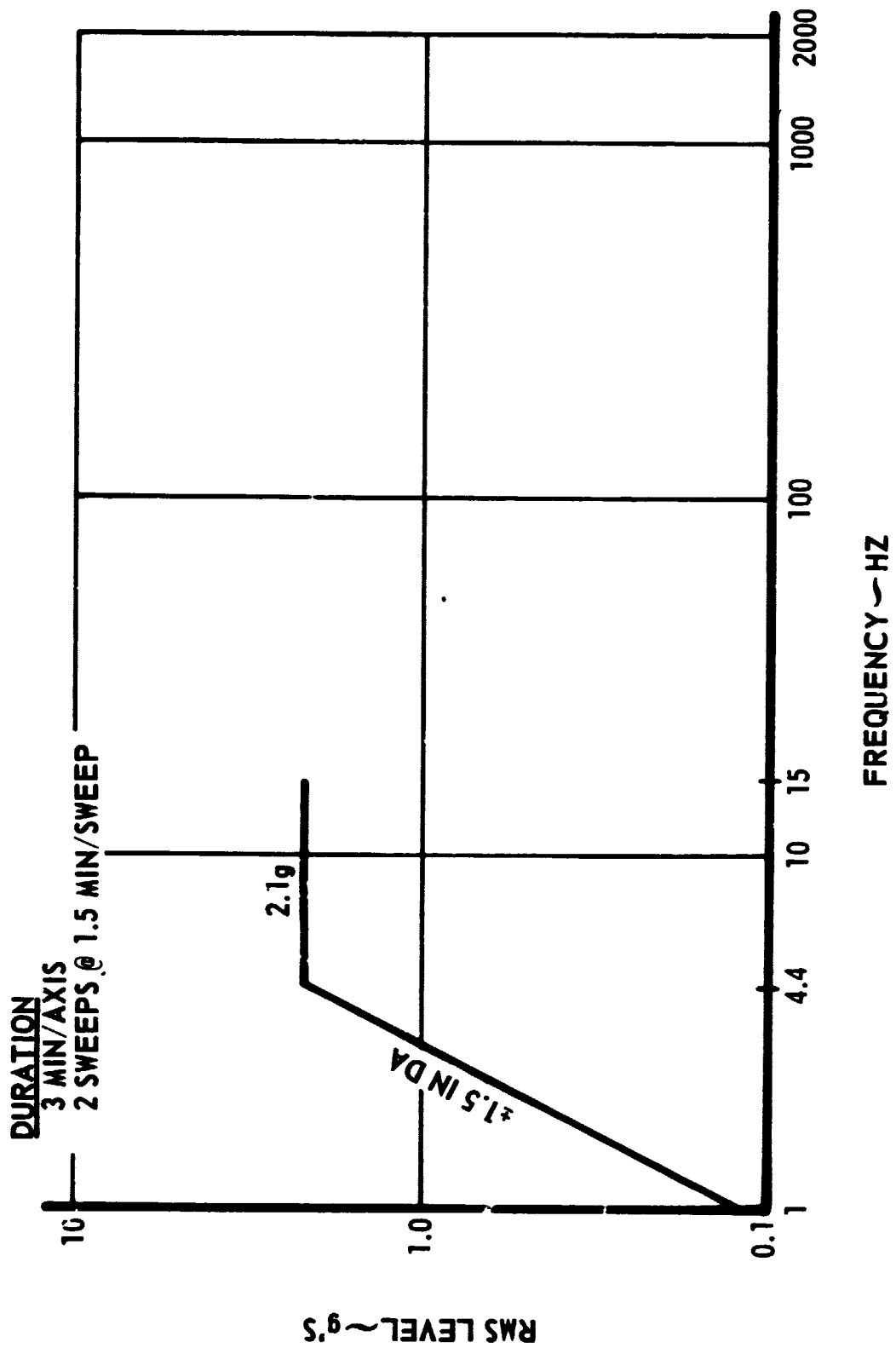


Figure 3-3: SUBSYSTEM QUALIFICATION TEST LOW FREQUENCY SINE SWEEP

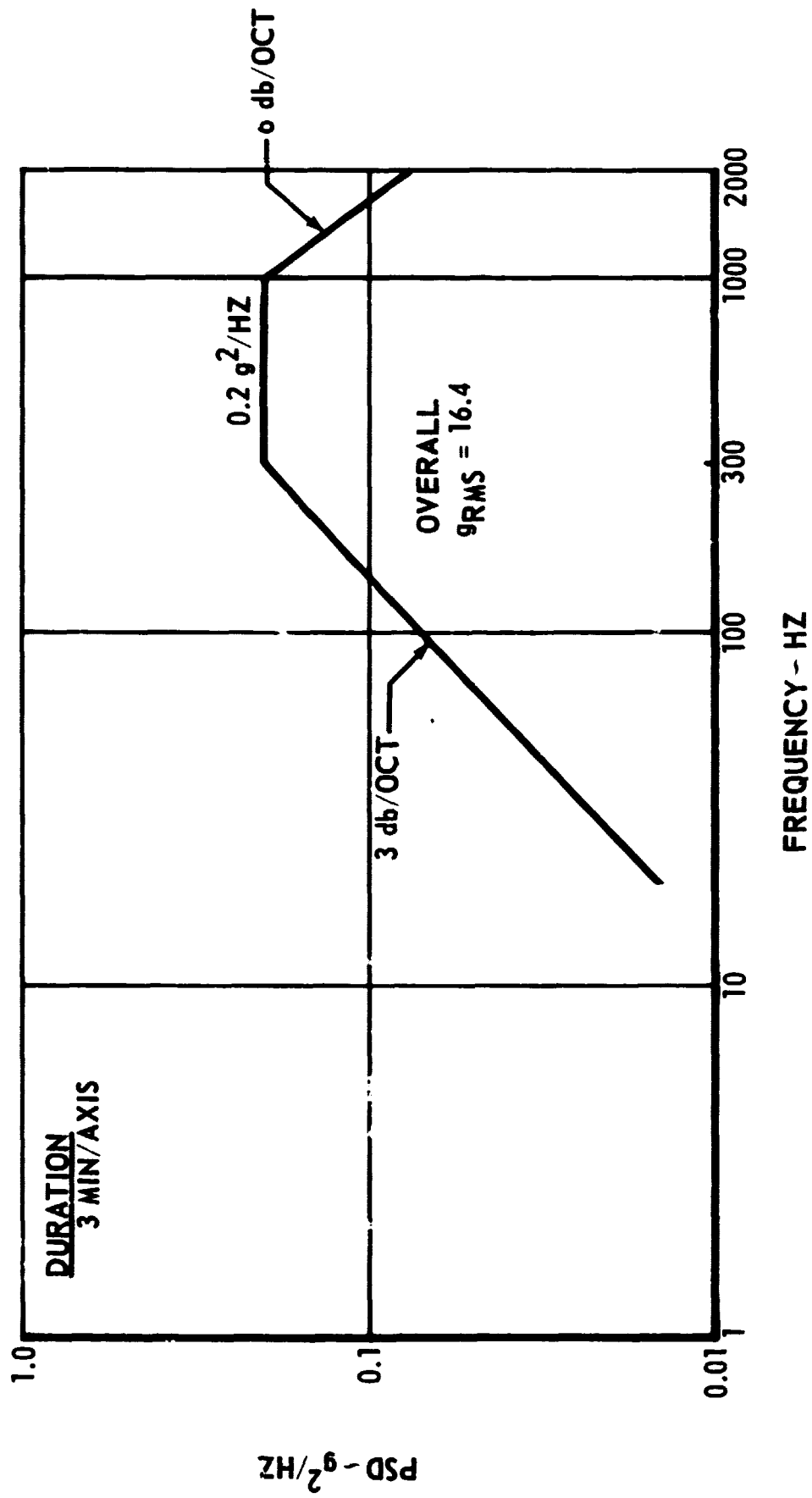


Figure 3-4: SUBSYSTEM QUALIFICATION TEST RANDOM VIBRATION

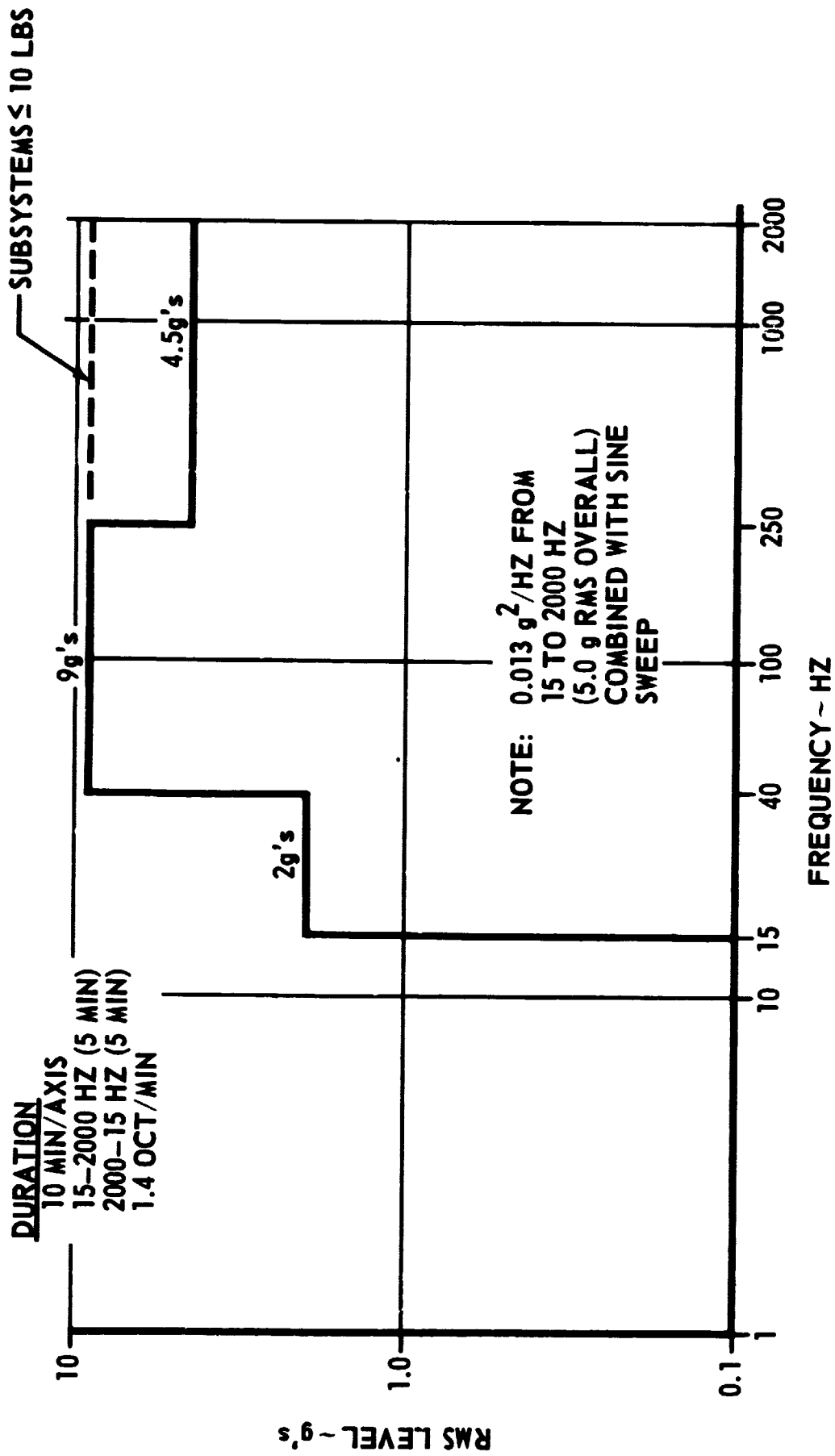


Figure 3-5: SUBSYSTEM QUALIFICATION TEST COMBINED RANDOM VIBRATION AND SINE SWEEP

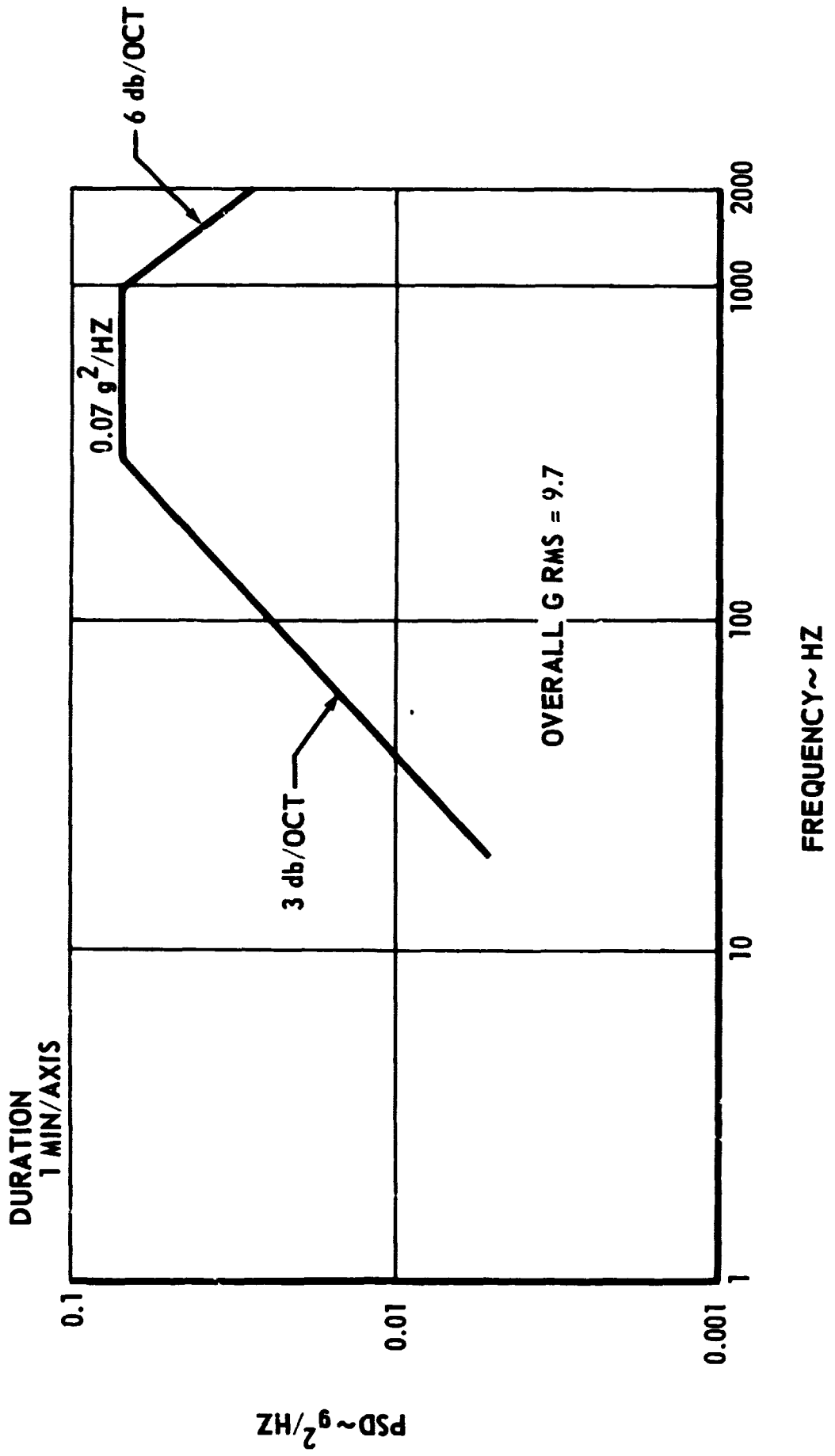


Figure 3-6: SUBSYSTEM ACCEPTANCE TEST RANDOM VIBRATION

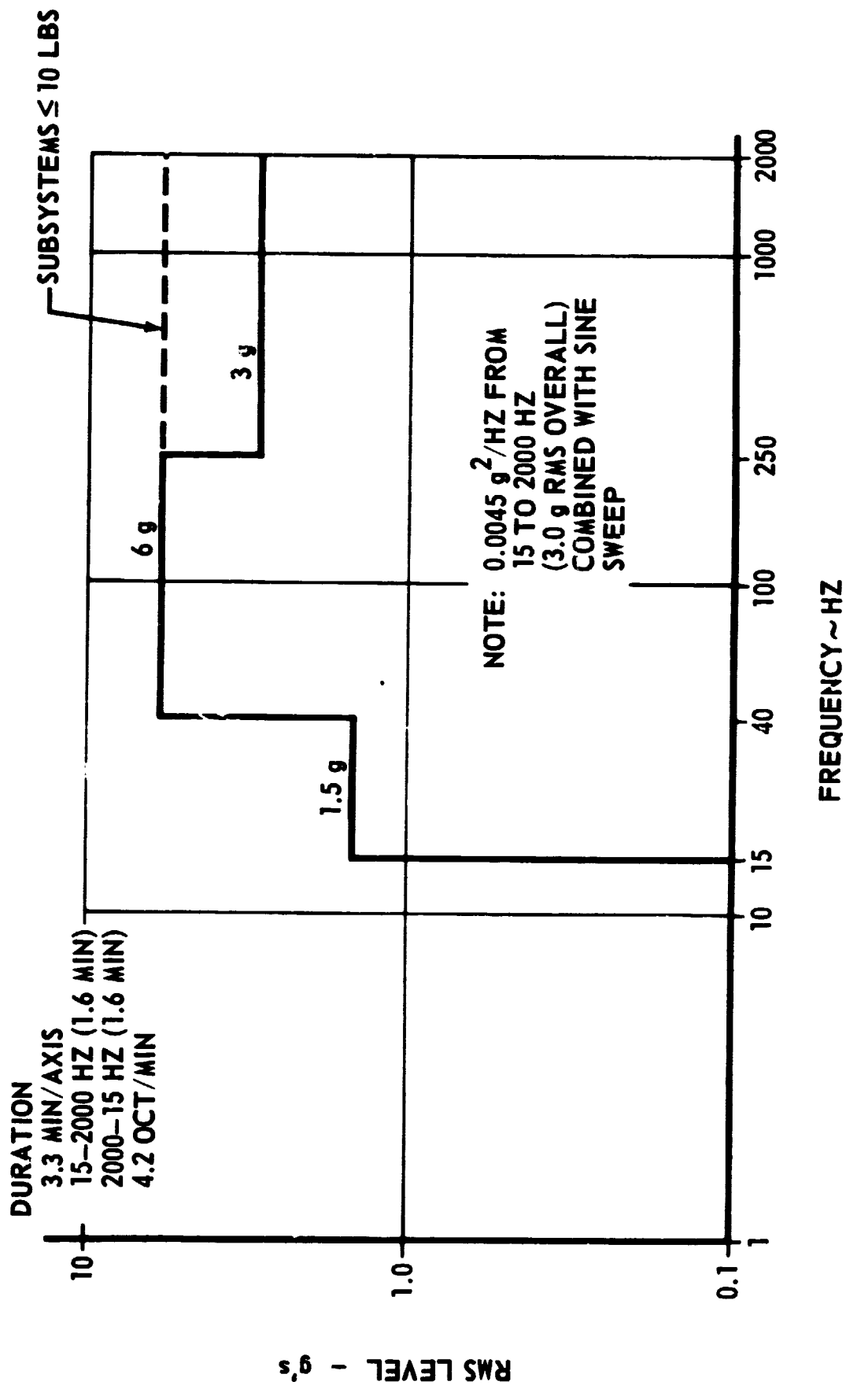


Figure 3-7: SUBSYSTEM ACCEPTANCE TEST COMBINED RANDOM VIBRATION AND SINE SWEEP

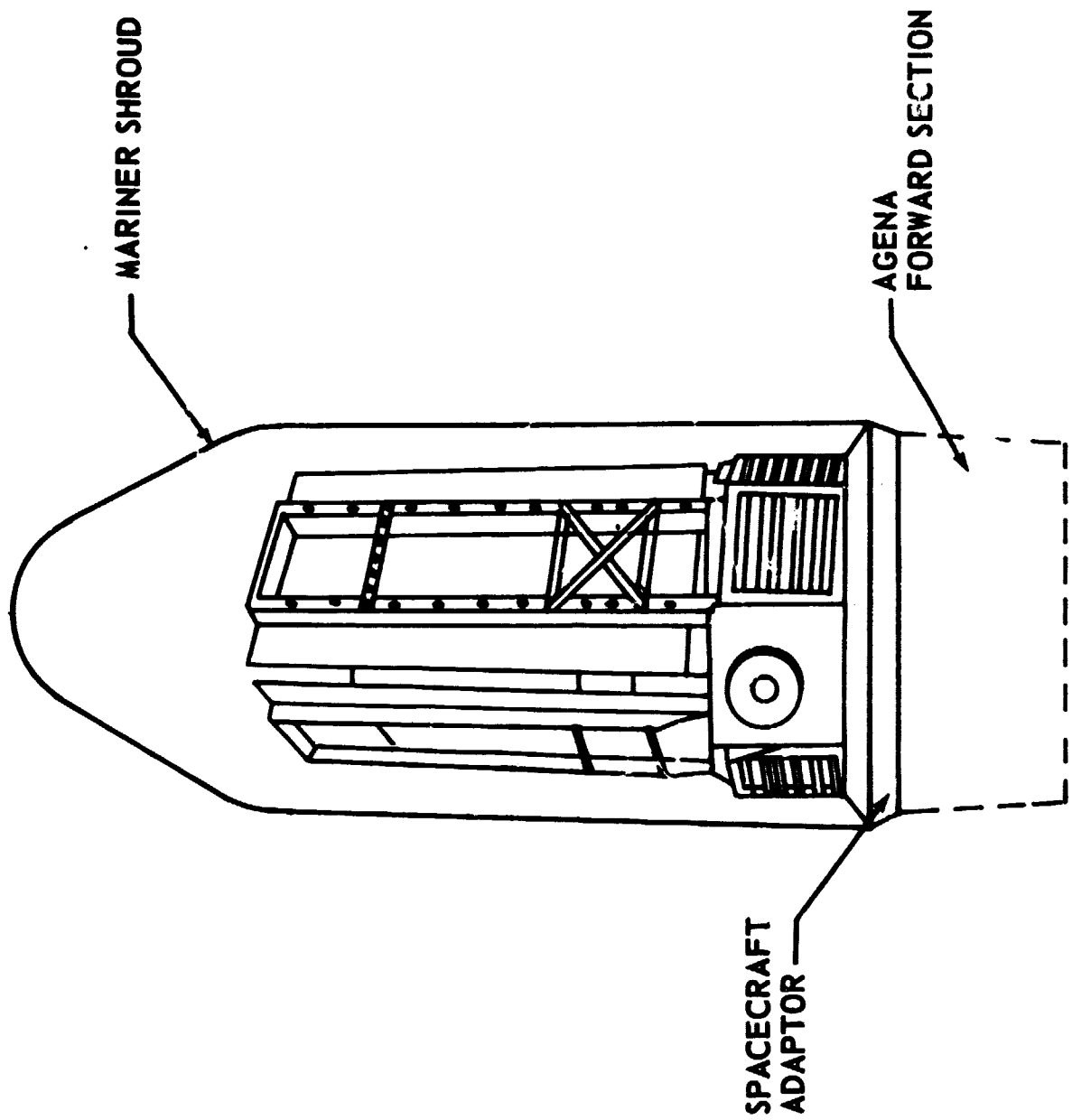


Figure 3-8: MARINER 64 LAUNCH CONFIGURATION

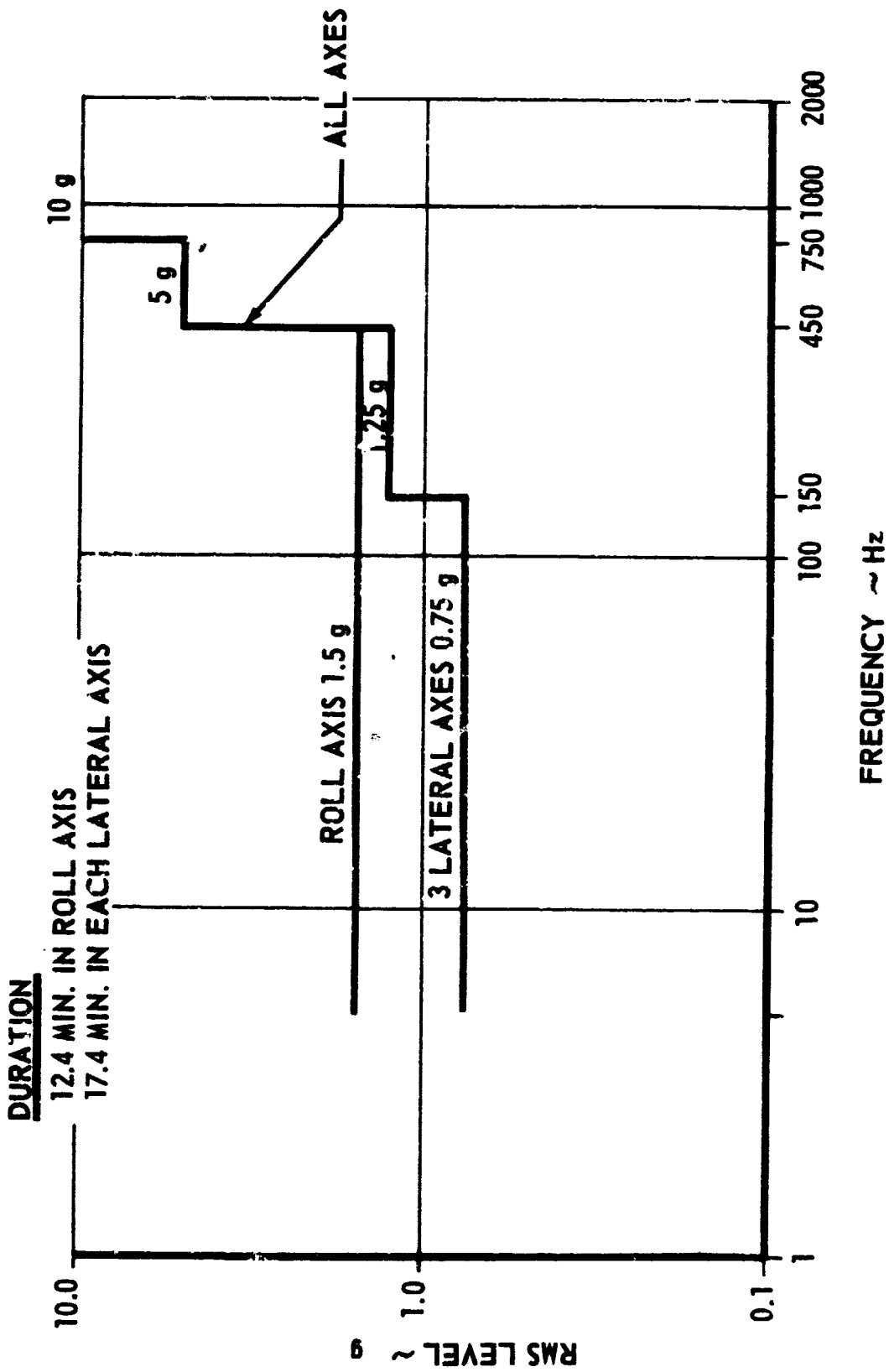


Figure 3-9: SYSTEM QUALIFICATION TEST SINUSOIDAL SWEEP VIBRATION

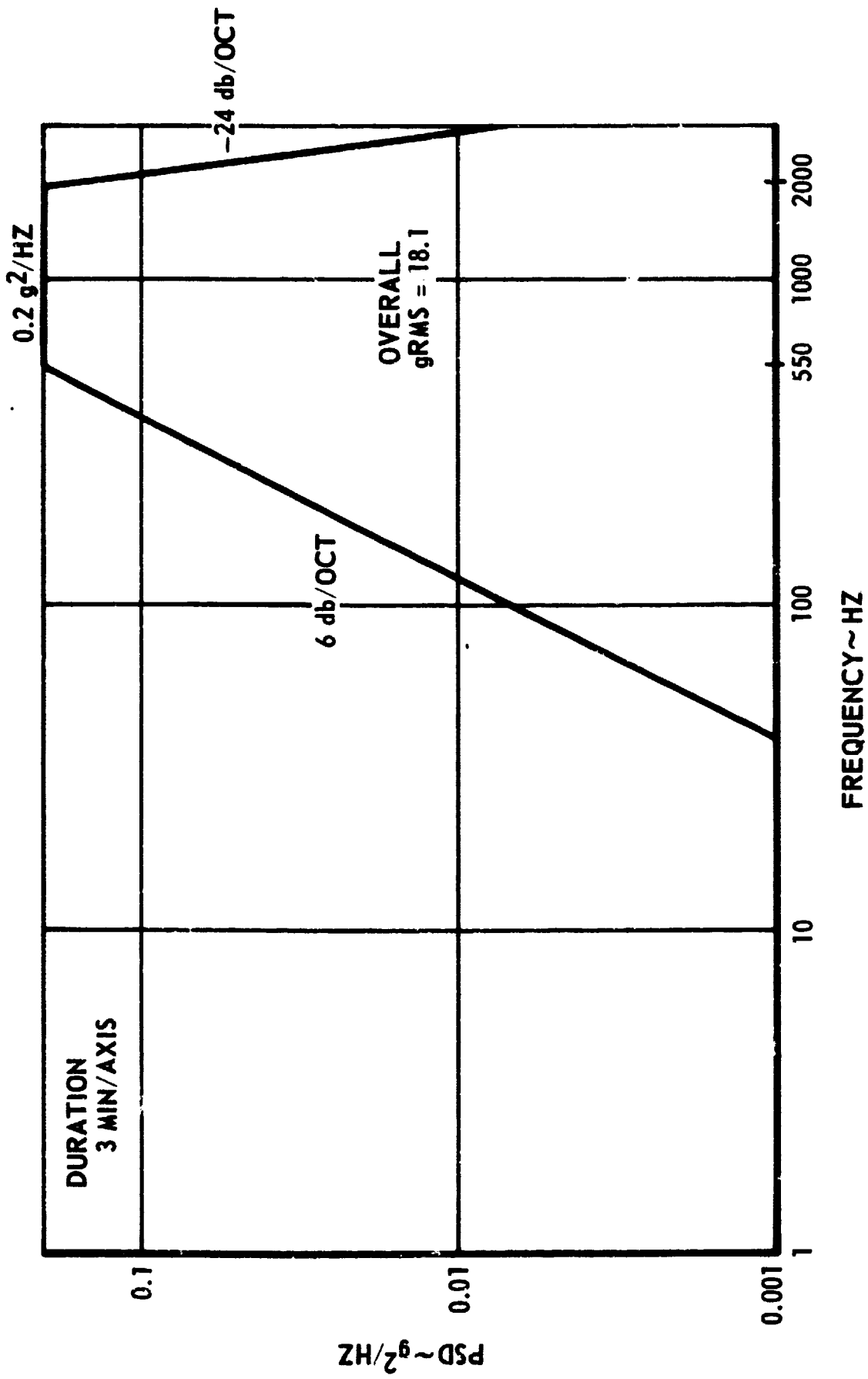


Figure 3-10: SYSTEMS QUALIFICATION TEST RANDOM VIBRATION

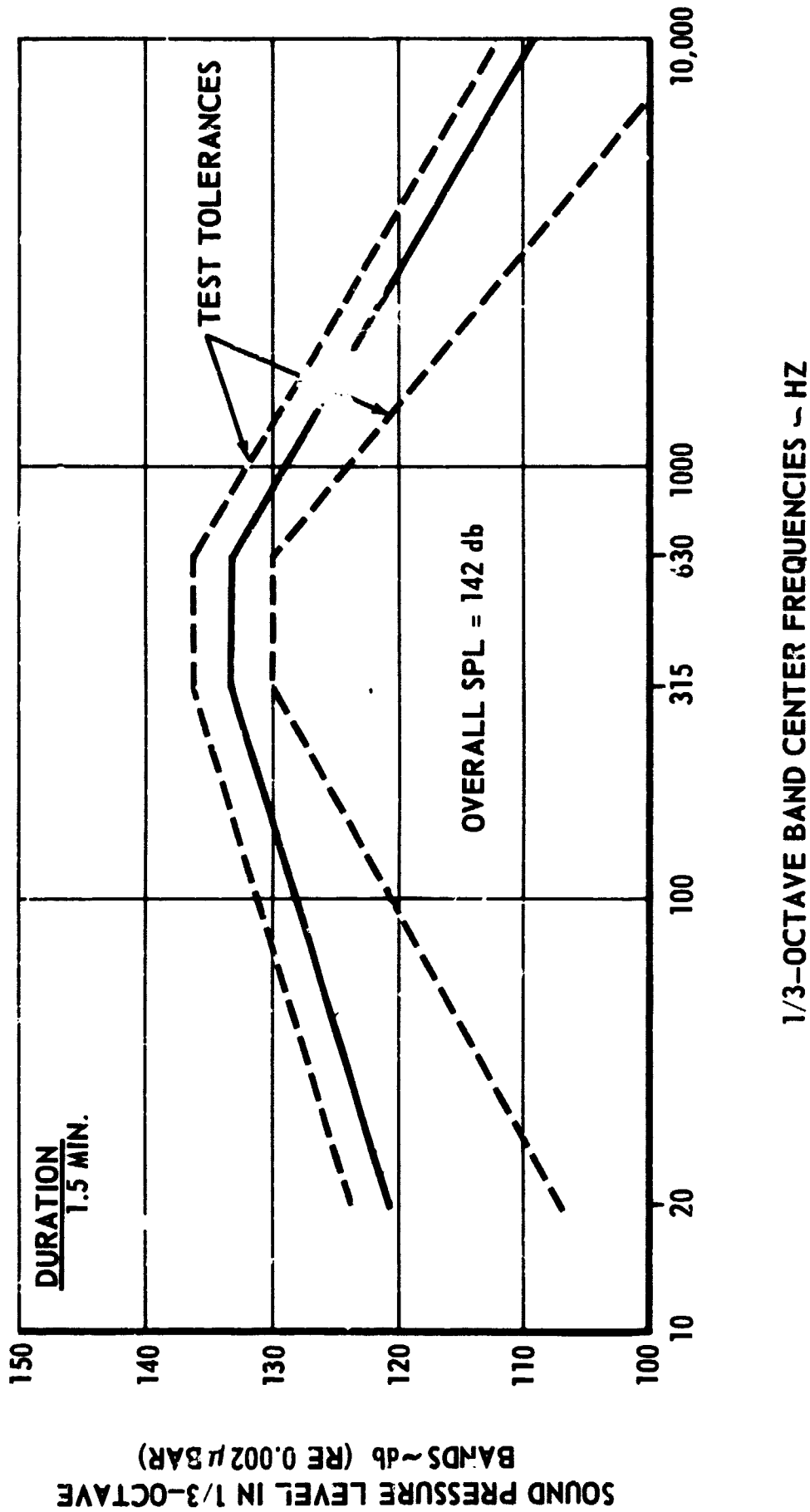


Figure 3-11: SYSTEMS QUALIFICATION TEST ACOUSTIC NOISE

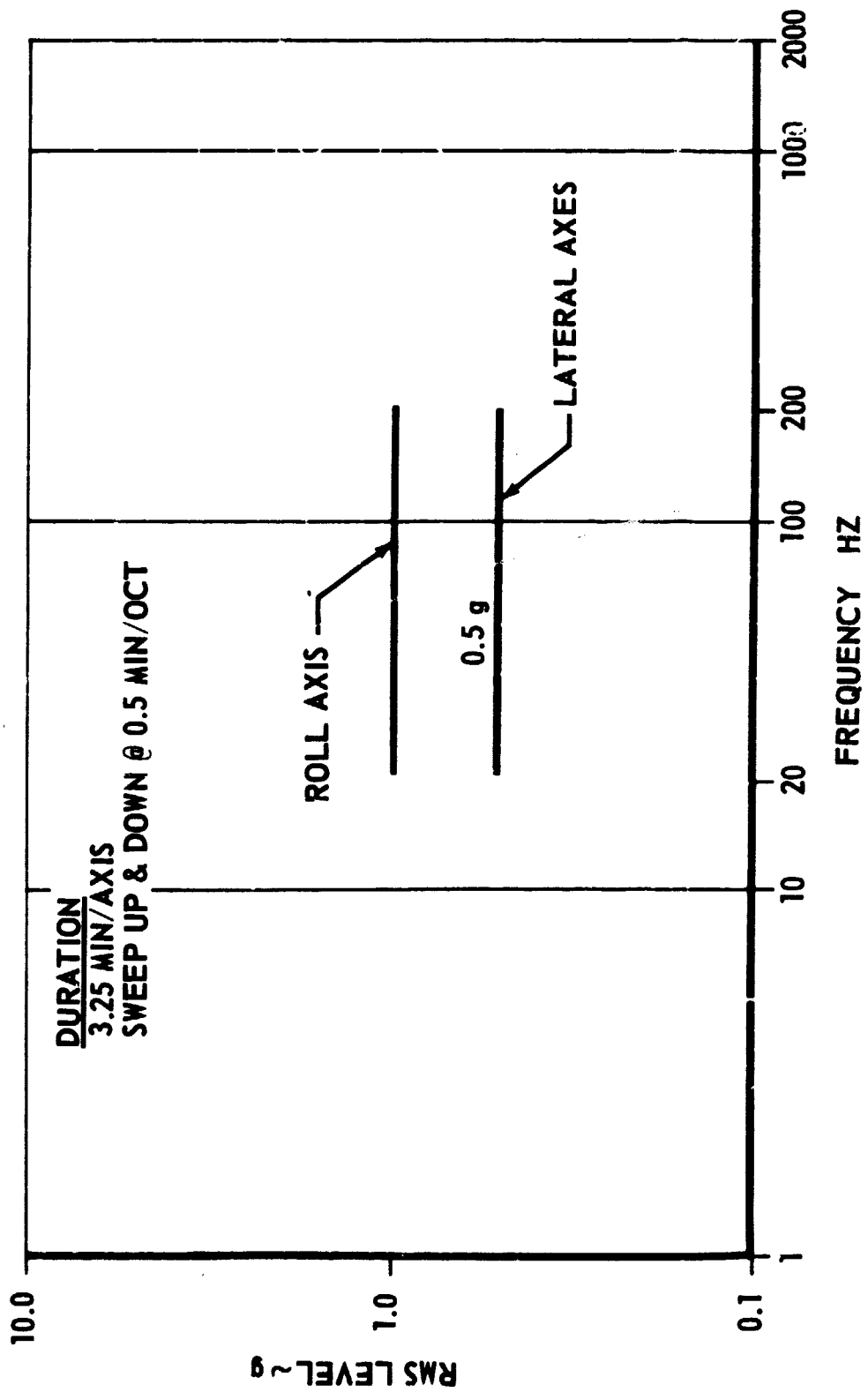


Figure 3-12: SYSTEM ACCEPTANCE TEST SINUSOIDAL SWEEP VIBRATION

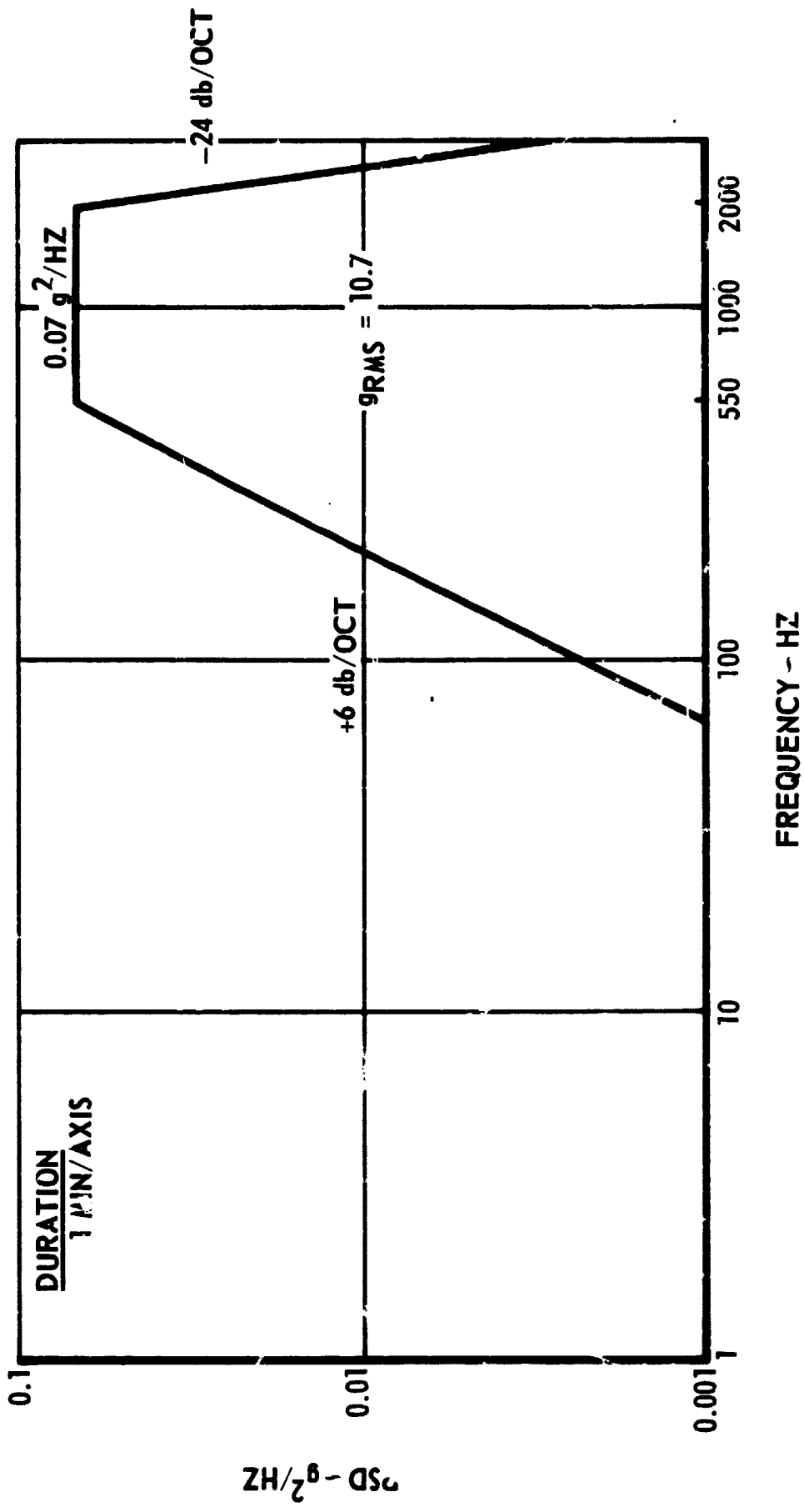


Figure 3-13: SYSTEMS ACCEPTANCE TEST RANDOM VIBRATION

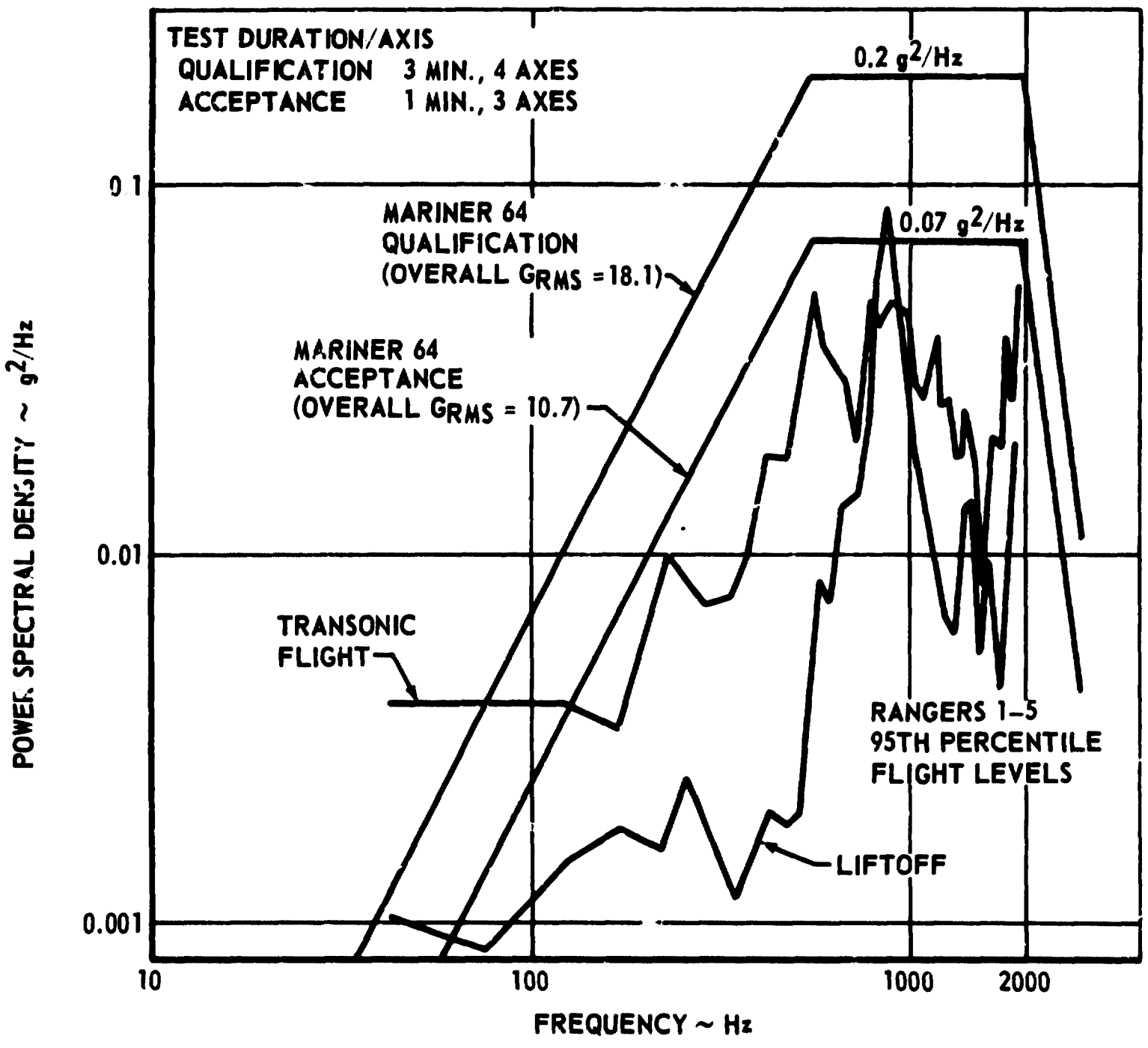


FIGURE 3-14 DERIVATION OF SYSTEM VIBRATION LEVELS

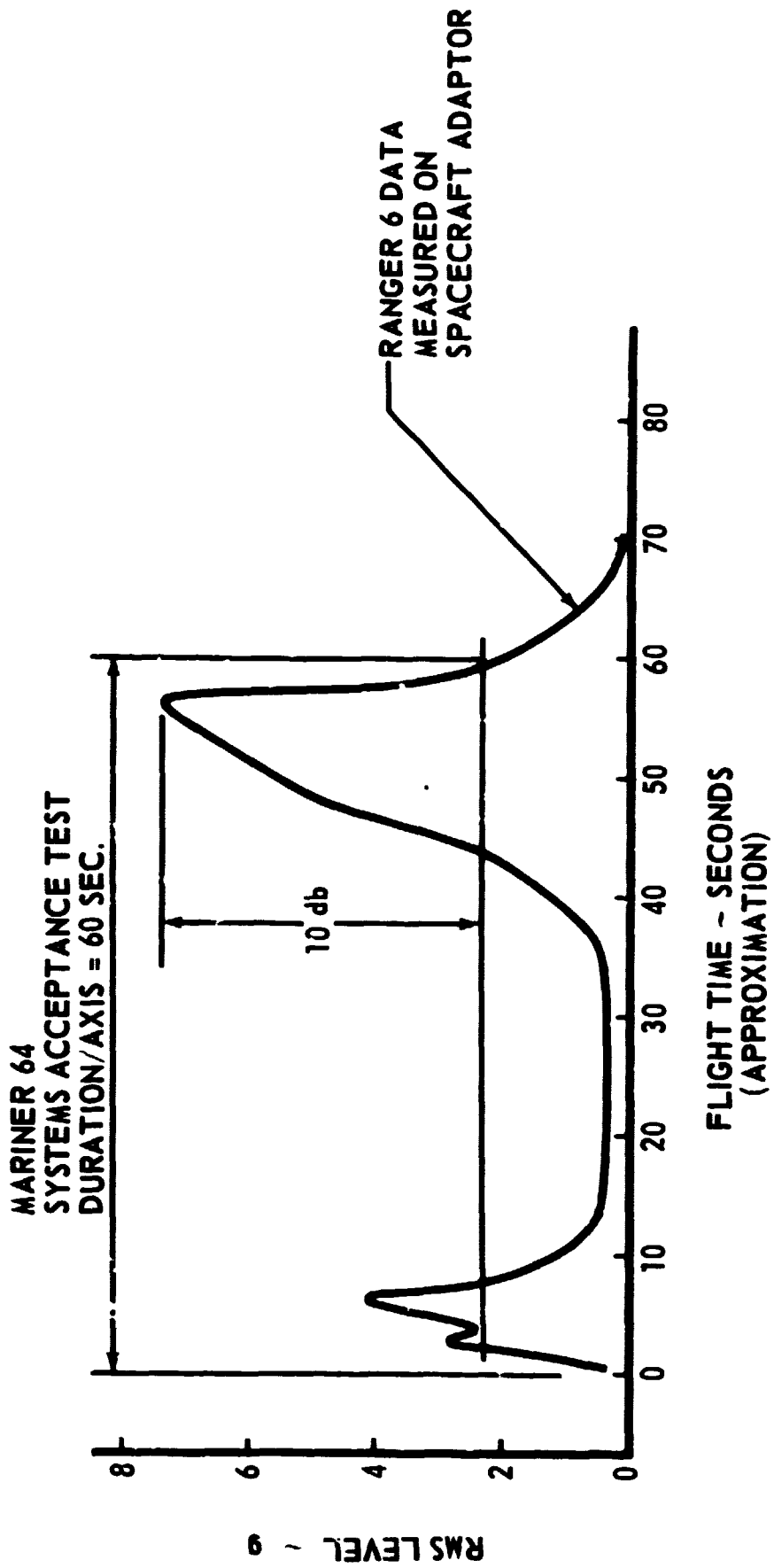


Figure 3-15: DERIVATION OF SYSTEM TEST DURATIONS

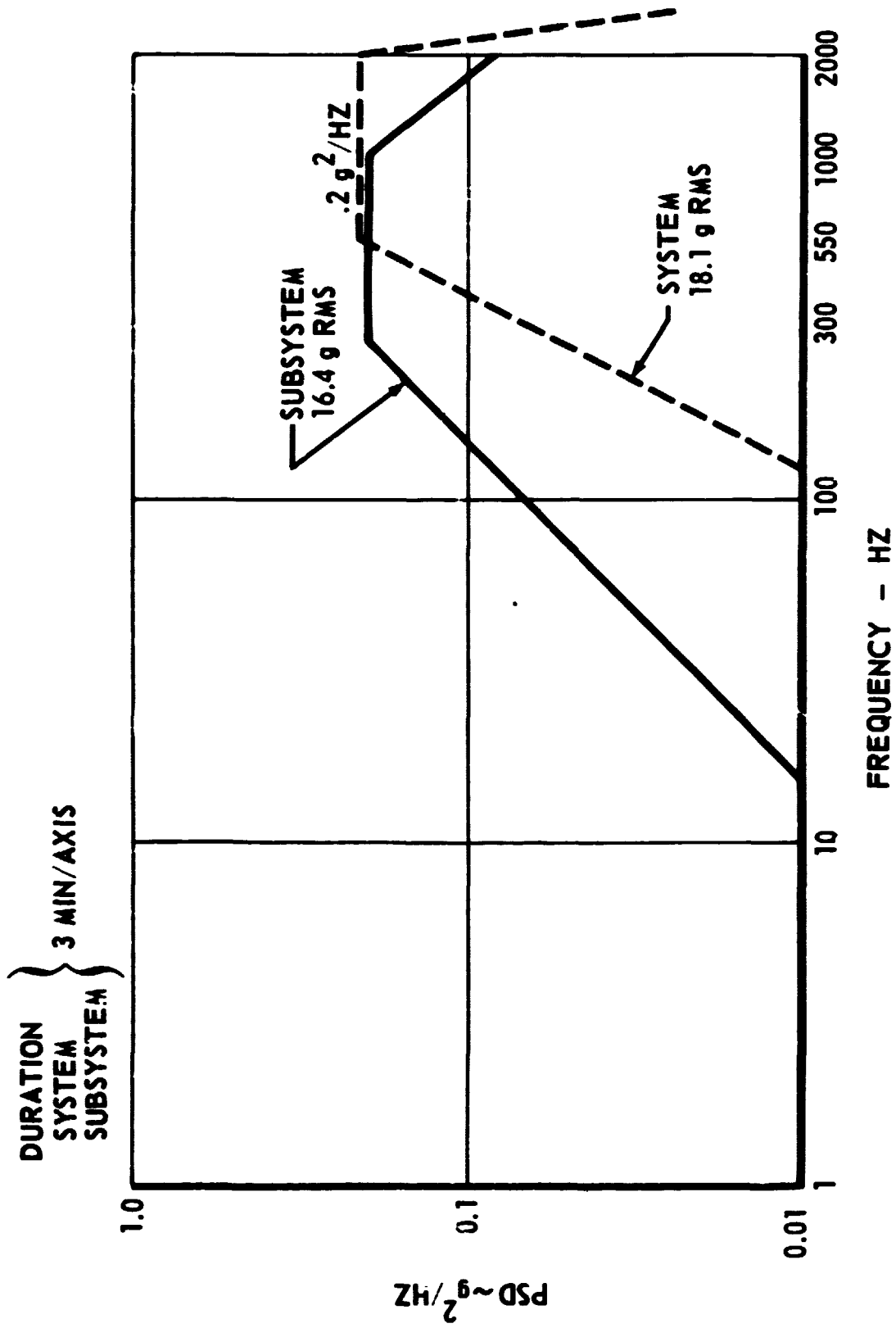


Figure 3-16: COMPARISON OF SYSTEM AND SUBSYSTEM QUALIFICATION LEVELS - RANDOM VIBRATION

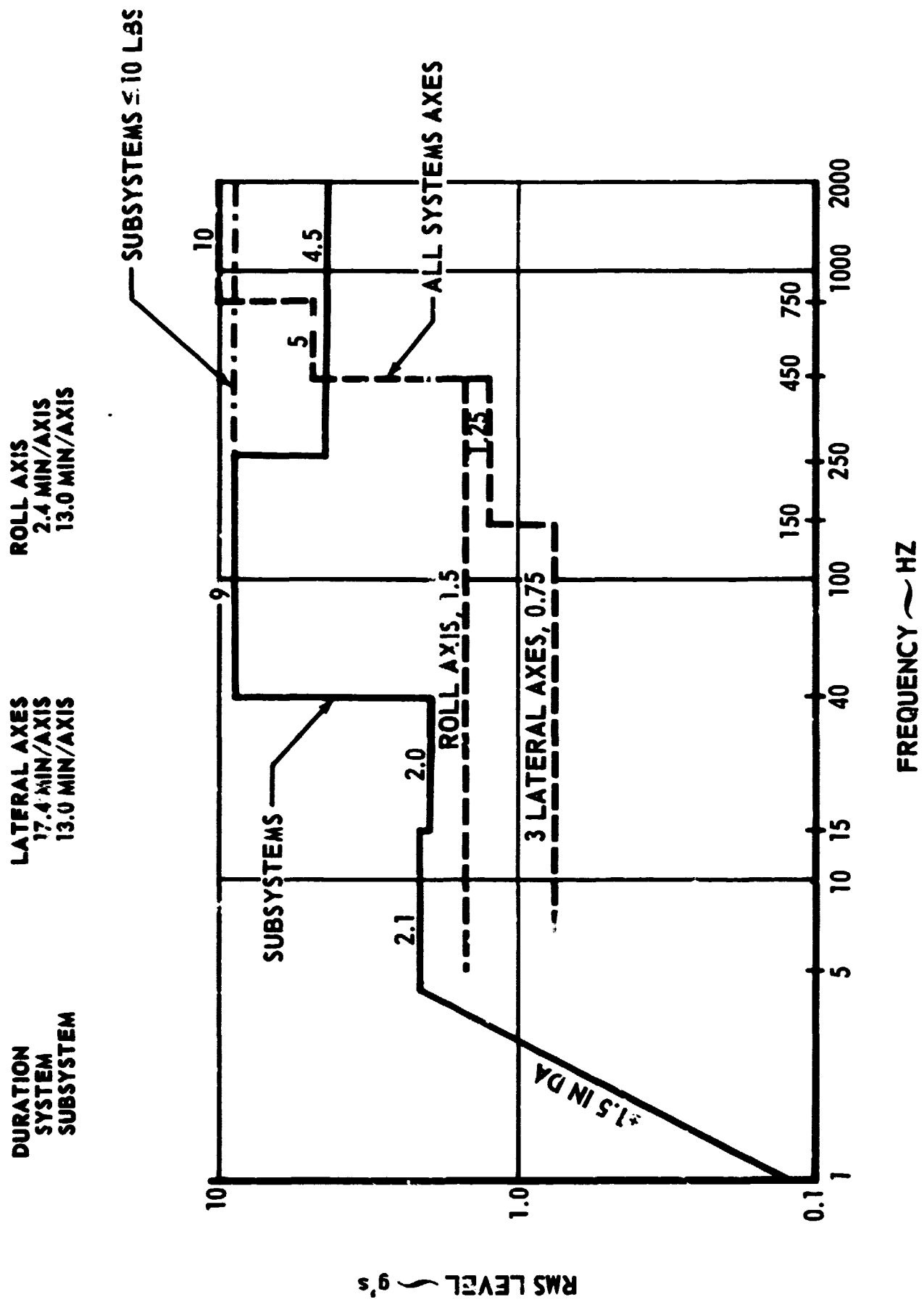


Figure 3-17: COMPARISON OF SYSTEM AND SUBSYSTEM QUALIFICATION LEVELS - SINE SWEEP VIBRATION

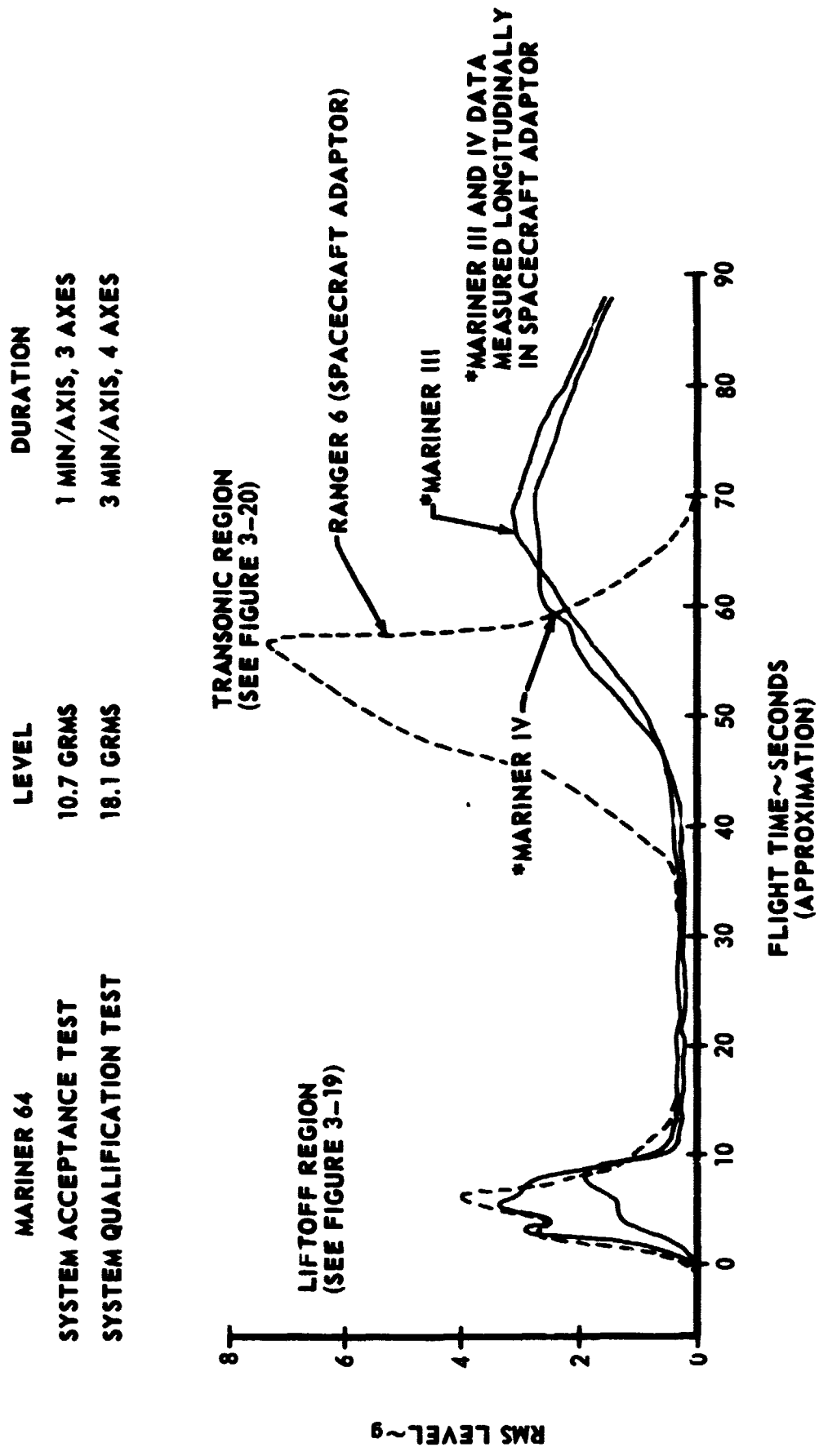


Figure 3-18: COMPARISON OF FLIGHT VIBRATION TIME HISTORIES

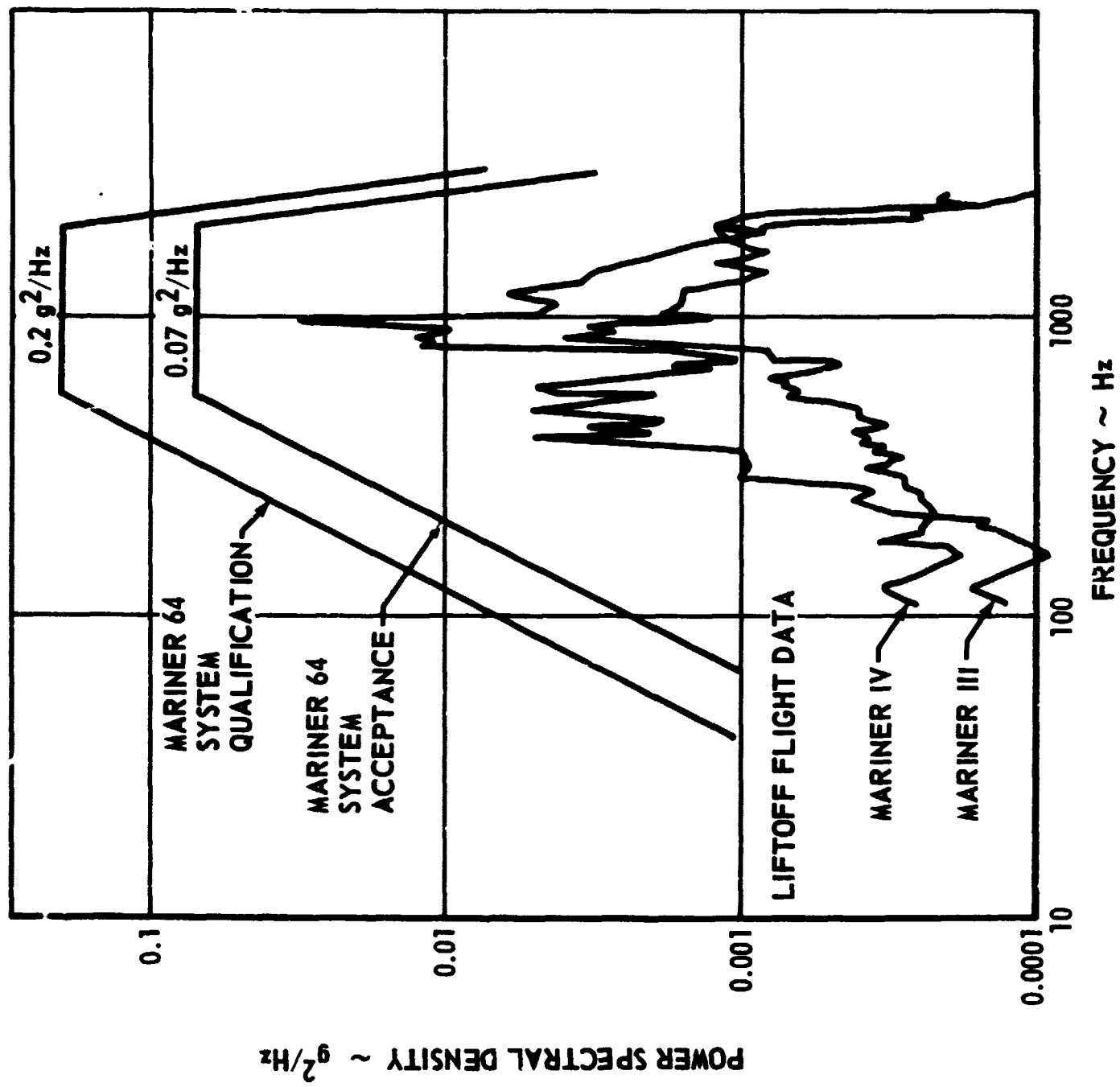


Figure 3-19: COMPARISON OF FLIGHT VIBRATION DATA AND SYSTEM TEST LEVELS - LIFTOFF

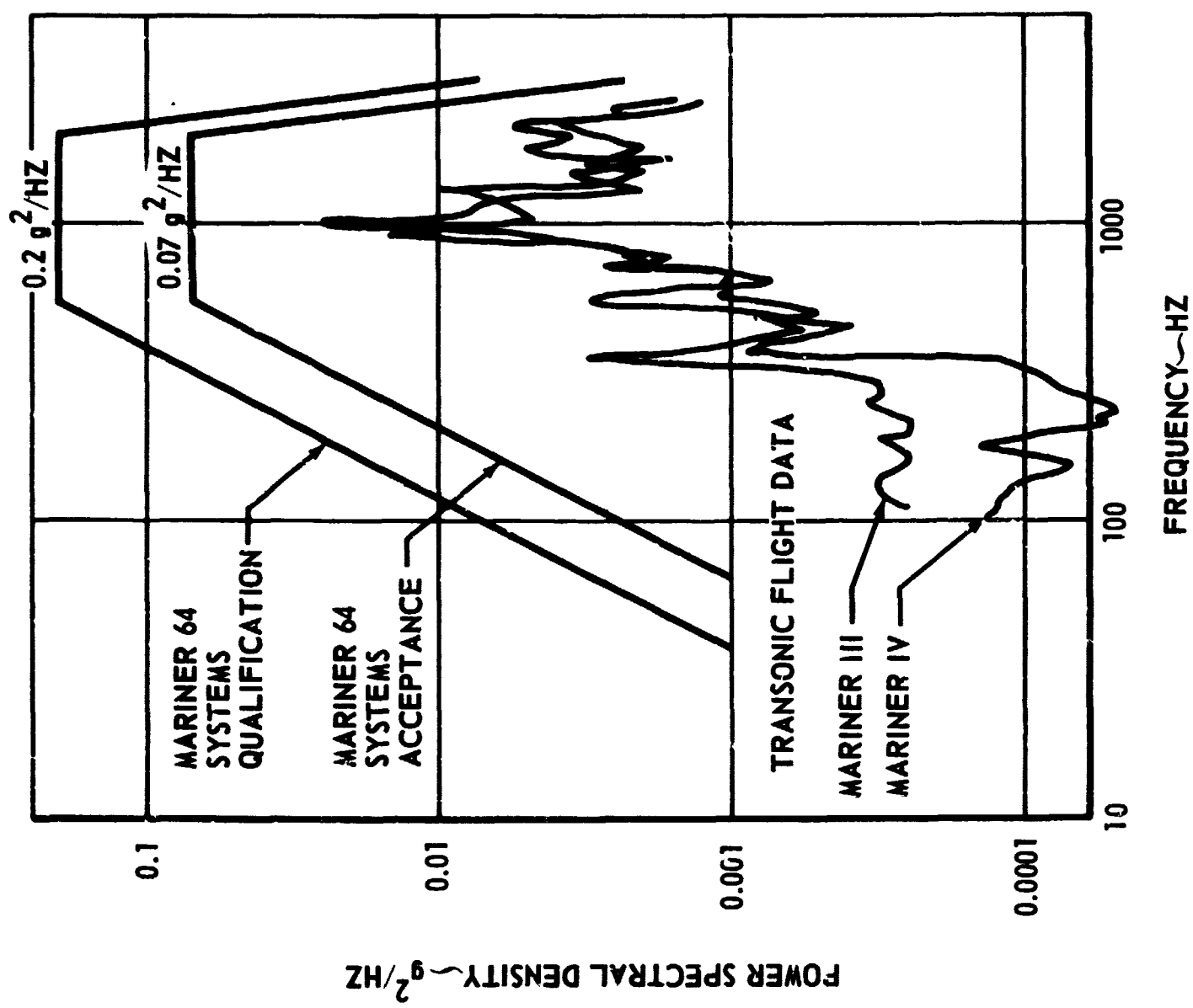


Figure 3-20: COMPARISON OF FLIGHT VIBRATION DATA AND SYSTEM TEST LEVELS - TRANSONIC FLIGHT

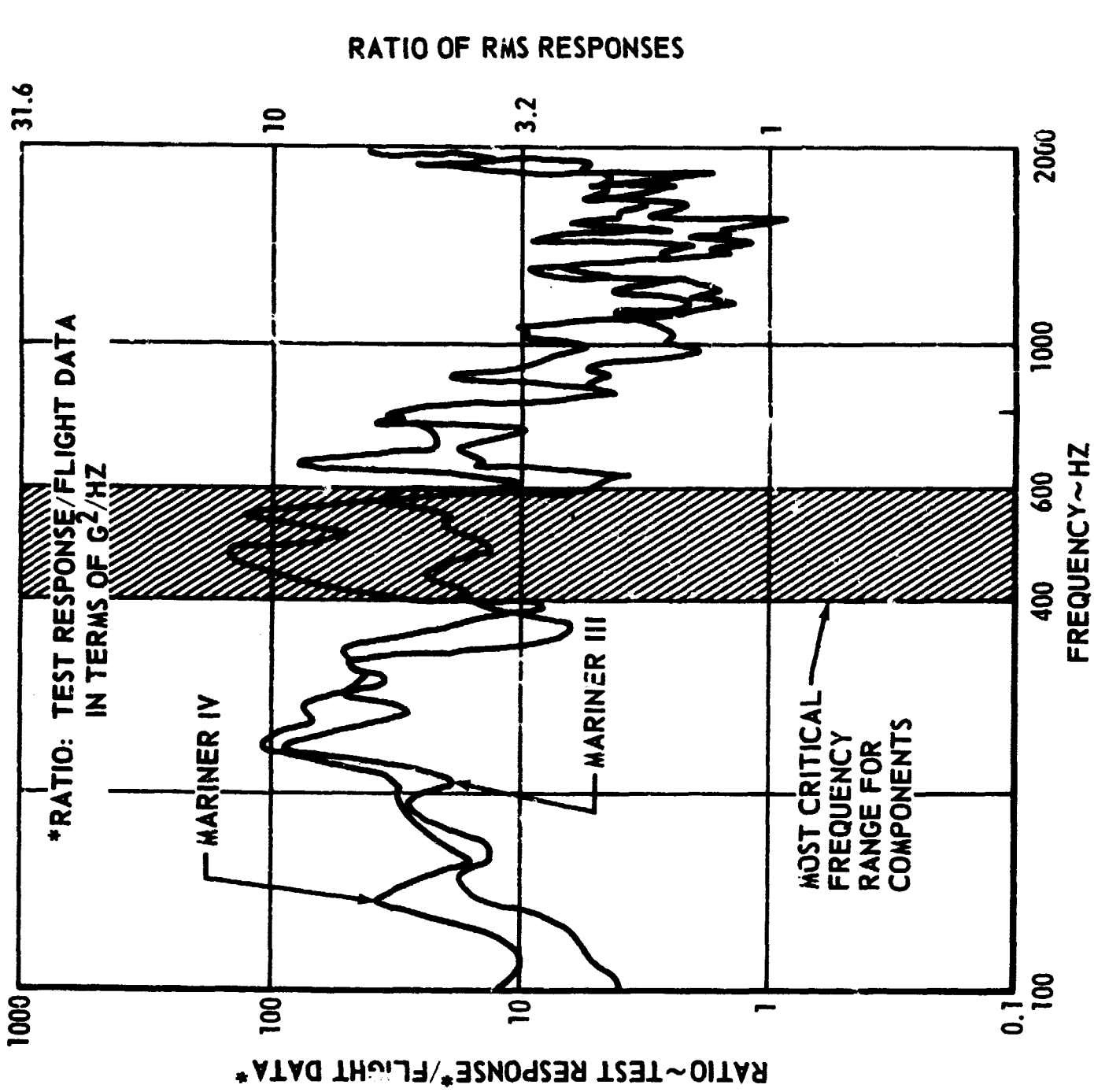


Figure 3-21: COMPARISON OF LAB TEST VIBRATION RESPONSE TO MEASURED FLIGHT RESPONSE ON SPACECRAFT ADAPTER

SECTION 4

MARINER VENUS 67

4.0 GENERAL INFORMATION - MARINER VENUS 1967

Project Management - Jet Propulsion Laboratory

Launch Vehicle - Atlas/Agena D

Spacecraft

M67-1 - Never Flown. M67-1 was a flight spare made up of the following:

1. Frame was the Mariner 64 proof test model (PTM).
2. Best remaining subsystems from the Mariner 64 flight spare (Mariner V).
3. Some subsystems from the Mariner 64 (PTM).
4. Some subsystems used for qualification tests.

M67-2 - Flown in 1967. M67-2 was made up of the following:

1. Frame was the Mariner 64 flight spare (Mariner V).
2. New subsystems used if available.
3. Some subsystems came from the Mariner 64 critical flight spares.
4. Some subsystems came from the Mariner 64 flight spare spacecraft (Mariner V).

Mariner 67 Physical Characteristics (See Figure 4-1).

Weight - 575 lbs.

Diameter - 5 ft. with solar panels folded
17 ft. with solar panels extended

Length - 9 ft.

The information presented in this section was obtained from Reference 6.

4.1 LABORATORY TEST PROGRAM

4.1.1 Test Program Rationale

4.1.1.1 General

The philosophy of the Mariner Venus project was to provide a Venus fly-by mission using the basic Mariner Mars 1964 spacecraft design and hardware.

The general approach to the environmental test program was to consider the Mariner Venus 67 design a derivation of the adequately qualified Mariner Mars 64 design.

4.1.1.2 Objectives

The goal of the environmental test program was to ensure that policies were realized - obtaining maximum results without a system qualification test article.

4.1.1.3 Requirements

A flight spacecraft (M67-2) and a flight spare spacecraft (M67-1) were required to be acceptance tested at both the subsystem and system level.

Qualification tests were conducted on the Mariner Venus 67 subsystems as required to verify the design.

The system qualification test (Proof Test Model) was eliminated from the Mariner Venus 67 program.

Mariner Mars 64 had the requirements that equipment subject to qualification tests would not be flown. However, the Mariner Venus 67 flight spare spacecraft (M67-1) utilized the system qualification test structure (PTM) of Mariner Mars 64 plus some Mariner Mars 64 subsystems which had been subjected to qualification testing.

4.1.2 Component Vibration and Acoustic Tests

The Mariner program used the terminology assembly, subassembly and subsystem. This terminology included test articles which are defined as components and subsystems in this document (see Definitions). Therefore, the component and subsystem level tests are discussed in the paragraphs describing subsystems since no distinction between the two was made in JPL documentation.

4.1.3 Subsystem Vibration and Acoustic Tests

4.1.3.1 General

The Mariner Mars 1964 program was critically reviewed to determine what parts of the spacecraft were invalidated by design and mission changes.

The review indicated qualification and acceptance test levels for Mariner Mars 64 were generally adequate for Mariner Venus 67.

Following the review, requalification testing was performed at the subsystem level if necessary.

Since there was no PTM, subsystems whose environments were either partially or wholly influenced by the spacecraft were qualified aboard the structural test model (STM).

Many special developmental and investigative tests were conducted on Mariner Venus 67 to prove the feasibility and adequacy of the spacecraft hardware.

4.1.3.1 (Continued)

Acceptance tests were conducted on subsystems for each spacecraft.

4.1.4 Subsystem Development Tests

4.1.4.1 General

Development tests were not formal project requirements but were usually performed by organizations who felt additional information was needed prior to formal testing.

Development tests were generally run for one or more of the following reasons:

(1) To evaluate expected environment.
(2) To evaluate anticipated problems.
(3) To determine compatibility between subsystems.
(4) As a result of other systems development problems.

4.1.4.2 Objectives

Tests were conducted to prove the feasibility and adequacy of the spacecraft hardware.

4.1.4.3 Test Levels and Durations

Test levels and durations were not available for this survey.

4.1.4.4 Test Description and Results

(1) Solar Panel Deployment Tests

A modal test was conducted to verify dynamic analyses (mode shapes, frequencies and damping). The tests verified the panel properties predicted by analysis.

Modified Mariner Mars 64 panels were tested to verify suitability of tip latching scheme. The test demonstrated the soundness of tip latching and damping approach and verified the suitability of solar panel analysis.

(2) High Gain Antenna and Superstructure Tests

The Mariner Venus 67 high gain antenna subsystem was a new design. A test was run to determine the dynamic response of the new design for comparison with theoretical analyses. Test data indicated the theoretical analysis amplitudes were conservative by 20% to 30%.

(3) Dual-Frequency-Receiver Test

A vibration test was conducted to determine the response characteristics of the 432-Hz test specimen. Test levels were derived from STM vibration tests. The results from the development test verified the structural adequacy of the design.

4.1.4.4 (Continued)

(4) Temperature-Control-Reference (TCR) Tests

Vibration tests were conducted to determine the dynamic response characteristics and structural integrity of TCR design. Four tests were run over the frequency range of 20 to 400 hz at acceleration levels from 1 to 12 grms. The tests indicated that the structural integrity of TCR was more than sufficient, and resonant frequencies were not expected to couple with solar panels.

(5) Data Automation System (DAS) Subchassis Test

A large subchassis was required for the new DAS design. Tests were required in order that the subchassis would meet the 400 hz minimum resonance requirement. The tests resulted in modification to the standard subchassis (addition of screws and increased material thickness).

(6) Radio Relay Tests

A relay failure occurred just prior to launch of M67-2. The relay was replaced but a different mounting bracket was used. Two relays were tested at JPL using the same relay that was onboard M67-2. Qualification random and sine sweep tests were run with relays energized and circuitry monitored for chatter. The relays passed the test.

4.1.5 Subsystem Qualification Tests

4.1.5.1 General

To provide assurance of locating design inadequacies qualification tests are more severe than operational conditions, but not so severe that reasonable safety limits are exceeded or that unrealistical failure modes are excited.

Qualification tests are not intended to be destructuve tests.

4.1.5.2 Objectives

Subsystem qualification tests were conducted to requalify Mariner Mars 64 subsystems invalidated by Mariner Venus 67 design and mission changes.

They were also intended to validate the acceptance test techniques.

4.1.5.2 (Continued)

The STM tests yielded environmental data to confirm subsystem test requirements.

4.1.5.3 Test Levels and Durations

Same as Mariner Mars 1964 (see Section 3).

4.1.5.4 Subsystems Tested

Of the 38 subsystems that were qualified on Mariner Mars 64, it was decided that 25 should be subjected again to some degree of qualification testing for the following reasons:

(1) 10 because of new design.
(2) 12 because of design change between Mariner Mars 64 and Mariner Venus 67.
(3) 3 because of new environment (not necessarily new vibration or acoustic environment).

The degree of qualification retesting was determined by the cognizant subsystem engineer and spacecraft environmental requirements engineer.

Because of no PTM the following were either wholly or partially qualified for vibration aboard the STM:

(1) solar panels
(2) solar panel tip dampers
(3) dual frequency receiver (DFR) antennas
(4) temperature-control references
(5) high-gain antenna deployment assembly
(6) thermal-control shields and blankets

4.1.5.5 Special Subsystem Tests

Special testing of the solar panel system was conducted because most of the qualification testing of Mariner Mars 64 was voided since Mariner Venus 67 mission changes affected many of the spacecraft appendages. The testing sequence was:

(1) Vibration qualification test on the STM. Selected modes for single panel qualification test ($\pm$4.2 g's @ 74 hz and $\pm$9.9 g's @ 111 hz). No physical damage. No electrical degradation during or after test.

(2) Vibration development test on a single panel. The test was originally intended to be formal qualification but changed to development test because of panel damage due to thermal-vacuum test. Input acceptance test levels were established during this test ($\pm$1.2 g's from 67 to 83 hz, $\pm$2 g's from 105 to 120 hz).

4.1.5.5 (Continued)

(3) Single panel acoustic test in a reverberation room at acceptance and qualification levels. All appendages were not on panel. Exposed to acceptance level for 20 seconds, followed by qualification levels for 60 seconds. Cell covers broken mostly during acceptance test. Broken cells probably due to damage during thermal vacuum test.

(4) Single panel acoustic test in a reverberation room at qualification levels. The panel was mounted on the STM with all appendages in place. Test had to be run twice to obtain proper acoustic level at all frequencies. No damage to panel or appendages.

4.1.6 Subsystem Acceptance Tests

4.1.6.1 General

Acceptance test levels were intended to equal or exceed flight levels.

4.1.6.2 Objectives

Subsystem acceptance tests were conducted to uncover major problems prior to system level testing.

4.1.6.3 Test Levels and Duration

Same as Mariner Mars 64 (see Section 3).

4.1.6.4 Subsystems Tested

35 of the 38 subsystems for each spacecraft were subjected to a subsystem acceptance test prior to spacecraft assembly. Mariner Mars 64 tests were still valid on three subsystems.

4.1.6.5 Special Subsystem Tests

Special vibration acceptance testing was conducted on 3 solar flight panels. The panels were tested separately. Difficulties in controlling the vibration response levels established during qualification tests resulted in a decision to include the panels as part of the systems level test.

4.1.6.6 Subsystem Retest

Five M67-1 subsystems underwent limited subsystem acceptance retests because of rework following system level acceptance tests. They were:

(1) Data automation subsystem,
(2) Rapid subsystem,
(3) Tape recorder subsystem,
(4) Power Subsystem,
(5) Dual frequency receiver.

4.1.6.7 Operational Requirement

Subsystems were required to operate during acceptance tests as required during the spacecraft mission.

4.1.7 System Development Tests

4.1.7.1 General

See paragraph 4.1.4 for a discussion of development testing.

4.1.7.2 Test Description

System developmental tests were conducted as part of the system qualification test, see paragraph 4.1.8.

4.1.8 Systems Qualification Tests

4.1.8.1 General

Since Mariner Venus 67 was considered to be a derivative of the adequately qualified Mariner Mars 64 the project management decided early in the program to eliminate the PTM (system qualification test vehicle) in order to save both time and money. In some cases, however, the Mariner Venus 67 STM was used as a substitute for the PTM to qualify subsystems whose vibration environment is strongly influenced by the spacecraft system. System level test objectives could not always be satisfied on the STM which sometimes led to an unusual system test on the spare spacecraft (M67-1), or in rare cases an unavoidable deficiency in the test program.

4.1.8.2 Objectives

Systems qualification tests were conducted to:

Validate the environmental techniques for use in acceptance testing.

Verify the spacecraft's ability to structurally withstand the boost environment.

Obtain supplemental dynamic response data required by late design changes.

Provide data for confirming subsystem test requirements.

4.1.8.3 Test Levels and Durations

The Mariner Mars 64 system level acoustic test was considered valid for Mariner Venus 67 except for the solar panel tests, see Paragraph 4.1.5.

4.1.8.3 (Continued)

The spare spacecraft (M67-1) was subjected to limited qualification test levels. The levels were higher than M67-2 vibration acceptance levels below 800 Hz, but less than Mariner Mars 64 PTM levels. These levels did not invalidate M67-1 flight worthiness.

4.1.8.4 Test Configuration

The structural test model (STM) was composed of flight structural items and structural simulation of all spacecraft components.

4.1.8.5 Test Description and Results

The initial vibration tests on STM were low frequency structural development and design ultimate load tests were run for torsional, lateral and roll axes with four uncelled solar panels. Low frequency and complex wave vibration tests were run for the roll axis and two lateral axes to qualify the one celled solar panel. Low level tests were run in the roll axis to determine dynamic response of the PIPS. The STM withstood design ultimate-load and structural-qualification dynamic-load tests. Total vibration time was 208 minutes.

Final vibration tests on STM were conducted on a modified version of the initial Mariner Venus 67 STM.

The tests were run to supplement dynamic response data required by late design changes and to qualify structure not included in initial tests. The test also verified complex vibration test procedures to be used on flight spacecraft. Low frequency structural development and qualification dynamic load tests were run for the roll axis and two lateral axes. The STM withstood the qualification dynamic load test. Total vibration time was 60 minutes.

4.1.9 System Acceptance Tests

4.1.9.1 General

Acceptance levels were intended to either equal or exceed flight levels.

Both spacecraft were acceptance tested to conservative levels for vibration.

4.1.9.2 Objectives

System acceptance tests were conducted to give assurance that the flight hardware is a representative sample of the design subjected to the qualification test and to identify any manufacturing defects that may be present in the flight hardware.

4.1.9.3 Test Levels and Durations

System acceptance test levels were the same as Mariner Mars 64 (see Section 3).

4.1.9.4 Test Configurations

The M67-1 spare spacecraft was acceptance tested and consisted of flight hardware with the exception of the post-injection propulsion system (PIPS), pyrotechnic actuators, and 2 solar panels.

The M67-2 flight spacecraft was acceptance tested and consisted of flight hardware except for the PIPS and pyrotechnic actuators.

4.1.9.5 Subsystem Retest

Five M67-1 subsystems had to undergo limited subsystem acceptance retesting because of rework necessary following the M67-1 system test, see Paragraph 4.1.6.

4.1.9.6 Operational Requirements

All systems are required to operate during acceptance tests as required during corresponding periods of the spacecraft mission.

4.2 LABORATORY TEST FAILURES

4.2.1 Component Vibration and Acoustic Test Failures

Included in subsystem data (see Paragraph 4.1.2).

4.2.2 Subsystem Development Test Failures

No failures noted.

4.2.3 Subsystem Qualification Test Failures

4.2.3.1 Vibration Test Summary

TOTAL ITEMS TESTED	FAILED	FAILURE RATE
21	5	23.8%

A failure is considered to be one unique problem, i.e., if several units failed due to the same problem, it was considered as one failure.

4.2.3.2 Failure Categories (see Table 4-1 for Details)

CATEGORY	NUMBER
Design Deficiency and Age	1
Unrealistic Test Condition	1
Design Deficiency and Faulty Workmanship	1
Age	1
Unknown	1

4.2.4 Subsystem Acceptance Test Failures

4.2.4.1 Vibration Test Summary

TOTAL ITEMS TESTED	FAILED	FAILURE RATE
117	7	6.0%

All subsystem acceptance failures were followed by a successful rerun of the acceptance test. A failure is considered to be one unique problem, i.e., if several units failed due to the same problem, it was considered as one failure.

4.2.4.2 Failure Categories (see Table 4-2 for Details)

CATEGORY	NUMBER
Design Deficiency	3
Faulty Workmanship	3
Faulty Procedure	1

TABLE 4-I. SUBSYSTEM QUALIFICATION TEST FAILURES

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
1. Transponder Radio, S/N 2	Loose connector and gain loss due to design problem with capacitors (design deficiency and age)	There was no concern over this problem as to mission success because RF portions of the radio experienced no difficulty during Mariner Venus 67 testing, and the receiver passed qualification testing on Mariner C. Problems not surprising considering age of units.
2. Battery, S/N's 27, 28 & 29	Header wires broke in battery (unrealistic test condition)	At very low frequencies (approx. 2 Hz) the battery plates go through a slosh mode which broke some of the header wires inside the battery. The same condition existed on Mariner C units. If a similar failure were to occur in flight the batteries had sufficient capability to still function.
3. Dual Frequency Receiver (DFR)	During vibration, a spot bond on a lead broke loose and allowed motion of the wire to break the solder terminal. (Design deficiency and faulty workmanship)	No concern over this failure. Since the qualification unit was satisfactoril reshaken, no flight unit exhibited this problem, and the flight units were verified as being better quality bonding.
4. Plasma Probe	Plasma probe failed to sequence properly. (Age)	This module had previously passed qualification vibration. The test was repeated to check the integrity of the diode board added as a result of PFR. The failure was in old circuitry which had been successfully qualification tested twice before, so did not affect the validity of this test.

TABLE 4-II. SUBSYSTEM ACCEPTANCE TEST FAILURES

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
1. Transponder Radio, S/N's 2, 7, 8	An L-Shaped tuning cavity was not supported at its ends. The overhanding end contacted the chassis under vibration and caused an adjacent crystal to fluctuate in frequency. This design condition existed on all radios but was not as noticeable on others as on the SN 2, 7 & 8 radios. (Design Deficiency)	A fillet of bonding was put around the perimeter of the cavity and verified that it cured the problem. There was no concern over the tuning cavity PFR; in fact, at one time, a decision had been reached to launch without correcting the problem, which was known to occur only under certain levels of vibration and always return to its original condition at the end of vibration. Since the design remedy was simple, however, it was instituted on all units.
2. Transponder Radio, S/N 7	Crystal and capacitor failed on SN 7. (Design Deficiency)	A piece-part failure was responsible for crystal and capacitor failure. Part replaced.
3. Dual Frequency Receiver, VHF Antennas S/N 3 & 4	Following vibration, a crack between a phenolic fitting and the aluminum mast was noted. It was determined that differences in expansion coefficients between the fittings and the mast caused separation during curing, and a fiberglas dowel pin was added to the design to retail the fitting on the mast. (Design Deficiency)	Since qualification tests had occurred prior to acceptance, this failure should have been noted at that time. It was not; but after the acceptance failures, when the qualification was reexamined, a crack was found that had not previously been noted. An antenna test model that had experienced no environmental testing was examined, and it also exhibited the same crack. The addition of the dowel pin was felt to be an adequate correction and no concern remained over this failure. Failure occurred on SN 3 & 4; however, units SN 3 through 6 were reworked.

TABLE 4-2. SUBSYSTEM ACCEPTANCE TEST FAILURES (Continued)

	SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
4.	Thrust Vector Control Assembly	The potentiometer brush block came loose on the shaft during vibration. (Faulty Workmanship)	Although the unit successfully passed the test following retightening of the locking screw, enough concern remained to institute null position checks during Pasadena and Afetr operations.
5.	Thrust Vector Control Assembly	Following vibration it was noted that all 4 actuators in the vane assembly had experienced a loss of torque. This problem was utlimately traced to a procedural error in magnetizing the torquer magnets in the actuators. (Faulty Procedure)	The new magnetizing procedure gave superior results to the procedure used on Mariner Mars 1964. This new procedure resulted in adequate gain under all conditions.
6.	Separation Initiated Timer	A dimensional problem on a bracket allowed switch contacts to chatter in vibration. The bracket was replaced and the unit successfully retested. (Faulty Workmanship)	No concern.
7.	Pyroarming Switch S/N C110, C111	During vibration, contact chatter was observed. This was traced to improper adjustment of spring load on switch levels. Both units experienced the same problem. (Faulty Workmanship)	Discrepancy was corrected and the unit satisfactorily retested.

4.2.5 System Development Test Failures

System development tests were conducted as part of the system qualification test, see Paragraph 4.2.6.

4.2.6 System Qualification Test Failures

None of the subsystem test failures recurred during system level tests. System qualification test failures are summarized in Table 4-3.

4.2.7 Systems Acceptance Test Failures

There were no failures reported on the M67-2 flight spacecraft. Systems acceptance test failures on the flight spare vehicle are shown in Table 4-4.

4.3 FLIGHT FAILURES

No failures were reported by JPL.

4.4 DERIVATIONS OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS

An examination of the general qualification and acceptance test levels for Mariner Mars 64 revealed that they were appropriate for Mariner Venus 67. Certain procedure changes which had negligible effects on test level were made to facilitate testing.

4.5 COMPARISON OF TEST LEVELS AND FLIGHT DATA

No comparisons were available for Mariner Venus 67. The comparisons for Mariner Mars 64 should be applicable (see Section 3).

4.6 CONCLUSIONS AND RECOMMENDATIONS BY JPL

4.6.1 Conclusions by JPL

All the goals regarding the Mariner Venus 67 test program were realized in many cases more satisfactorily than those for the Mariner II and Mariner IV test programs. A greater depth of penetration was possible on the Mariner 67 program, because of the fact that the spacecraft hardware and gross design had been previously qualified, permitting emphasis to be placed on specific hardware items for which either the hardware or the environment had changed.

The current success of Mariner Venus 1967 could not have been achieved without a highly successful environmental test program designed with the capability to identify potentially dangerous problems.

TABLE 4-III. SUMMARY OF SYSTEM QUALIFICATION TEST FAILURES

ENVIRONMENT	ANOMALY TYPE	ITEM	RESOLUTION
Vibration	Test hardware unacceptable	Solar panel tip dampers	Changed size of sealing O rings and changed viscosity of damping fluid.
Vibration	Large dynamic excursion at 8 Hz caused contact of piston and housing	Solar panel tip dampers	Dampers removed and mechanically adjusted to prevent contact.
Vibration	Spot welds failed	Attitude control jet Sunshade support bracket	Repaired welds.
Vibration	Tube fitting cracked	Hi gain antenna feed Support structure	Crack repaired.

TABLE 4-IV. SUMMARY OF SYSTEMS ACCEPTANCE TEST FAILURES

VEHICLE	ANOMALY TYPE	ITEM	RESOLUTION
M67-1	Intermittent signal during vibration	Data automation system (DAS)	Problem only occurred once. indications were that problem was not due to vibration.
M67-1	Operator error caused low test level during sine	Spacecraft vibration response	Correction made to procedure and sweep rerun
M67-1	Audible transient at 35 Hz during sine sweep	Spacecraft Bay II	Spacecraft dismantled in vicinity of Bay II for inspection. No damage found. Thought to be instrumentation problem.

4.6.1 (Continued)

The qualification failure rate was higher for both vibration and thermal vacuum on the Mariner 67 project. This fact most likely reflects the use of old hardware on the Mariner Venus 67 project, which was left from the Mariner Mars 64 project, since the test levels were essentially the same for both projects. Another reason for the higher qualification failure rate was due to a lack of developmental testing.

Since there was no PTM (system qualification article) for Mariner Venus 67, the spare spacecraft, M67-1, often served as a PTM but was subjected to levels lower than the Mariner Mars 64 PTM. A deficiency in the test program was that the Mariner Venus 67 flight spare spacecraft system (Mariner Venus 67-1) was not tested to full PTM levels. This would have rendered the spare spacecraft unflightworthy.

The sweeping sine vibration test exists in present test programs largely because of precedent and its use as a diagnostic tool; however, no sine or sweeping sine vibration occurs in an actual launch environment.

4.6.2 Recommendations for Future Programs

The retest philosophy that evolved from the Mariner Mars 1964 and the Mariner Venus 67 testing programs is recommended for future programs.

If a subsystem has a failure, it is certainly necessary to requalify that portion of the subsystem that has had to be reworked. If the subsystem is a qualification unit, it is recommended that the reworked portion of the subsystem be required to pass a qualification test and, also, multiple acceptance tests if time permits. If the subsystem is an acceptance unit, then the reworked portion of the unit should be required to pass an acceptance test.

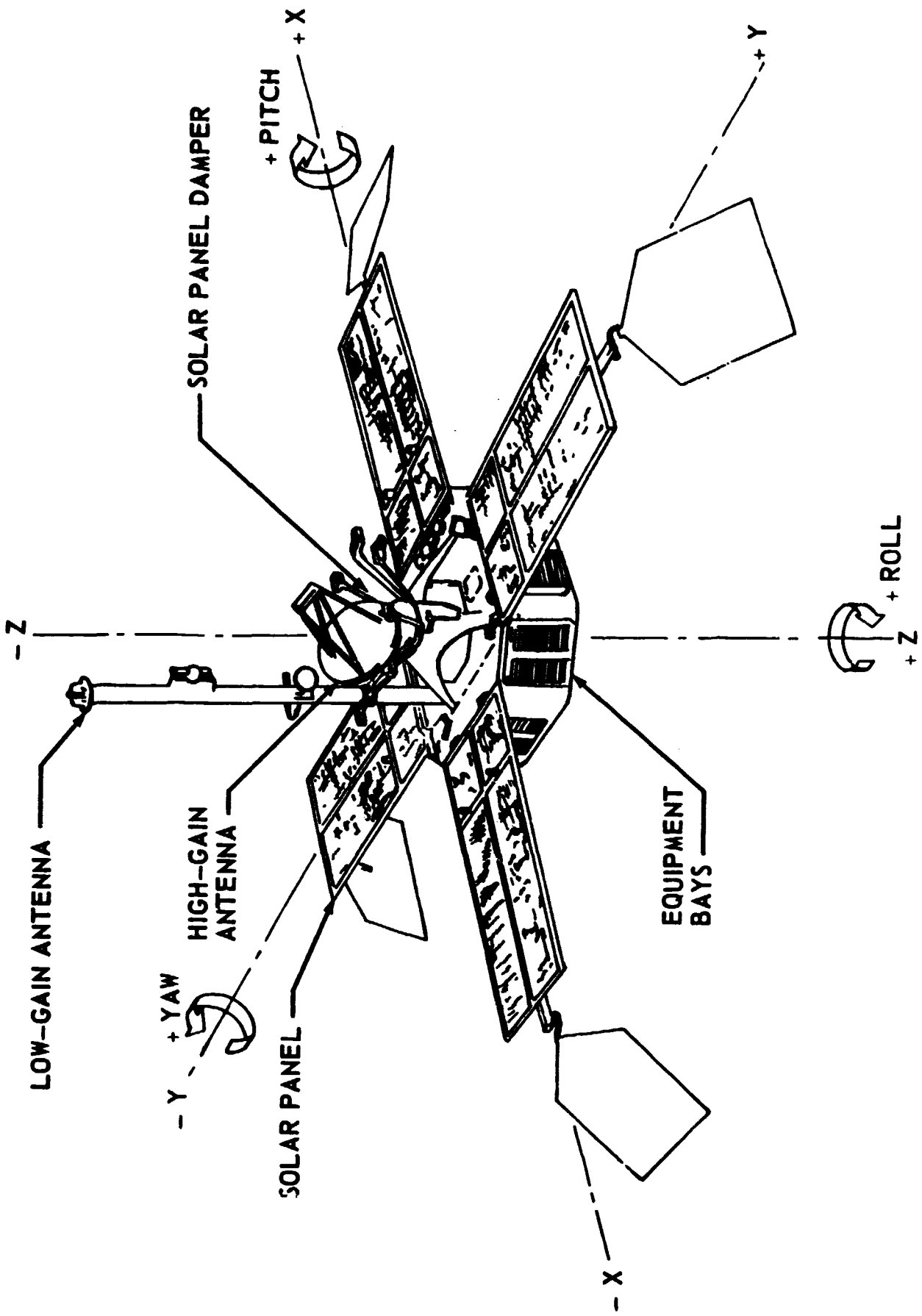


FIGURE 4-1. MARINER 67 CONFIGURATION

SECTION 5

LUNAR ORBITER

5.0 GENERAL INFORMATION

Spacecraft Development and Manufacturer - The Boeing Company

Program Management - NASA/Langley Research Center

Launch Vehicle - Atlas/Agena

Spacecraft-Lunar Orbiter

Ground Test Spacecraft #1 (Qualification Test Model)
Ground Test Spacecraft #2 (Acceptance and Mission Simulation Test Model)

Spacecraft #4	Mission I	Launched 8/10/66
Spacecraft #5	Mission II	Launched 11/6/66
Spacecraft #6	Mission III	Launched 2/5/67
Spacecraft #7	Mission IV	Launched 5/4/67
Spacecraft #3	Mission V	Launched 8/1/67

Lunar Orbiter physical characteristics (see Figure 5-1)

Weight - 853 lbs.
Diameter - 17.5 ft. from tip of high-gain antenna to tip of low-gain antenna
5.0 ft. with antennas and solar panels folded
Height - 7 ft.

The information presented in this section was obtained from Reference 7.

5.1 LABORATORY TEST PROGRAM

5.1.1 Test Program Rationale

5.1.1.1 General

The test program in general was based on three major test phases: (1) development testing, (2) component testing, (3) system testing.

Specific allocation of program hardware was defined early in program to meet test and flight program requirements.

All tests leading up to the acceptance testing of final configuration assemblies may be considered to be part of the development and qualification test program.

5.1.1.2 Objectives

Developmental tests were conducted to generate engineering data, to resolve technical problems to verify or improve design concepts.

Qualification tests were conducted to determine that design and fabrication procedures were adequate to allow for expected variations in individual articles and environments.

Acceptance tests consisted of functional tests to assure compliance with performance specification and flight level environmental tests to demonstrate the adequacy of hardware items for flight use.

Mission simulation tests were performed to verify spacecraft operation under a realistic flight environment; demonstrate performance and susceptibility to mission environments; demonstrate reliability and life cycle capability.

Major portions of the spacecraft were subjected to spacecraft test levels with the prime objective of qualification and/or acceptance of components or subsystems.

5.1.1.3 Requirements

Systems qualification vibration and acoustic tests were performed on ground test spacecraft #1.

Acceptance and mission simulation tests were performed on ground test spacecraft assembly #2.

Acceptance tests were required on all flight spacecraft.

Components were acceptance tested before being qualification tested.

Development tests were conducted on the Dynamic Development Models I thru III.

Equipment subjected to a qualification test was not flown.

5.1.1.4 Environmental Test Program Outline

Figure 5-2 shows the relationships between environmental tests. In practice, the various test types were interspersed with parallel development and concurrent testing at all levels.

5.1.2 Component Development Test

Component vibration development testing was performed using Dynamic Development Models (DDM) as test beds. More information on these tests including test levels was not available for this survey.

At least one component acoustic development test was performed. The rocket engine heat shield was tested in a reverberation chamber at the levels and durations shown in Figure 5-3.

5.1.3 Component Qualification Tests

5.1.3.1 General

A general test requirement was set for components; however, the general requirement was modified as required to provide a more realistic test. Two methods were used to modify the requirements:

(1) Define requirements based on measurements taken during system level tests.

(2) Qualify component during system level test.

Certain component tests were waived if the tests were not relevant.

5.1.3.2 Objectives

Component qualification tests were intended to determine that design and fabrication techniques were adequate to allow for expected variations in individual articles and environments.

5.1.3.3 Test Levels and Durations

Vibration tests consisted of:

Sinusoidal sweep in each of three orthogonal axes (see Figure 5-4).

Random vibration in each of three orthogonal axes (see Figure 5-5).

Random vibration levels are the same for component and system level testing.

No acoustic test was required.

5.1.3.4 Operational Requirements

Following completion of the qualification tests, components were considered not flightworthy.

Components were required to operate within tolerances before and after the test.

The components must have successfully completed acceptance tests before qualification testing.

5.1.4 Component Acceptance Tests

5.1.4.1 General

A general test requirement was set for components; however, the general requirement was modified as required to provide a more realistic test. Two methods were used to modify the requirements:

(1) Define requirements based on measurements taken during system level tests.

(2) Acceptance test component during system level test.

Certain component tests were waived if tests were not relevant.

5.1.4.2 Objectives

Acceptance tests were conducted to demonstrate the adequacy of components for flight use.

5.1.4.3 Test Levels and Durations

Vibration tests consisted of:

Sinusoidal sweep in each of three orthogonal axes (see Figure 5-6).

Random vibration in each of three orthogonal axes (see Figure 5-7).

Random vibration levels are the same for component and system level testing.

No acoustic test was required.

5.1.4.4 Operational Requirements

Components were required to operate within tolerances before and after the test.

The components must have successfully completed acceptance tests before qualification testing.

5.1.5 Subsystem Vibration and Acoustic Tests

Extensive dynamic testing at the subsystem level in distinct contrast to either component or system level tests was not conducted on the Lunar Orbiter. The photographic subsystem was independently tested by the subsystem vendor; however, qualification and acceptance testing of the photographic subsystem was performed with the camera package installed on the Boeing-furnished spacecraft assembly designated as a Dynamic Test Fixture (DTF), with test level inputs based on the system test criteria. Similar system tests were conducted with particular attention to other components or subsystem elements.

5.1.6 System Development Tests

There were no systems acoustics development tests performed on the Lunar Orbiter. Systems vibration development tests were performed using the DDM hardware, but detailed information was not available for this survey.

5.1.7 Systems Qualification Tests

5.1.7.1 Objectives

System qualification tests were performed to determine that design and fabrication procedures were adequate to allow for expected variations in individual articles and environments.

5.1.7.2 Test Levels and Durations

Vibration tests consisted of:

Sinusoidal sweep, lateral axis (see Figure 5-8).

Sinusoidal sweep, longitudinal axis (see Figure 5-9).

Random vibration, three axes (see Figure 5-5).

Torsional sine test (see Table 5-1).

Random testing at four input levels is unique to the Lunar Orbiter program.

A significant feature of the system level sine test is the provision for notching to reduce input amplitudes at major spacecraft resonances.

Acoustic tests were conducted in a reverberation room (see Figure 5-3).

TABLE 5-I. SYSTEMS QUALIFICATION TEST TORSIONAL VIBRATION LEVELS

One sinusoidal sweep at 4 octaves/minute as follows:

Frequency	Level
20-60 Hz	± 8.6 radians/sec^2
60-150 Hz	± 17.2 radians/sec^2

Following the above sweep, a 0.4 second tone burst of angular vibration shall be applied as follows: If a torsional resonance of the spacecraft structure is noted in the 60-75 cps band during the foregoing sweep, this resonance frequency shall be used as the frequency of the burst. If no such resonance is noted 68 cps shall be used. The tone burst shall be amplitude-modulated by a half-cycle of 2.5 cps sinusoidal modulation with an amplitude of 96.6 radians/sec^2.

This tone burst shall be repeated in the same manner, except that, if the frequency of the major resonance varies with amplitude, the second tone burst shall be applied at the frequency which will produce the greatest response.

5.1.7.3 Test Procedure

Testing in each axis was generally conducted in the following sequence:

(1) Preliminary diagnostic surveys with sinusoidal test inputs at 1/2 the prescribed acceptance input level.
(2) Sinusoidal sweep testing at the full qualification test input level (spacecraft #1 only)
(3) Random vibration testing progressing from the lowest to the highest of four input levels dictated by qualification test input criteria (spacecraft #1 only).

5.1.7.4 Test Configuration

Vibration and acoustic qualification tests were conducted on ground test spacecraft #1 (qualification test model).

All assemblies were fully representative of the flight configuration spacecraft assembly with the following exceptions:

(1) Propellant masses were simulated with substitute inert fluids.
(2) A Dynamic Simulation Model (DSM) of the photographic subsystem was incorporated on all vibration test models. Flight configuration was used for spacecraft #1 acoustic test.
(3) The Lunar Orbiter shroud and thermal barrier were incorporated for selected tests and test conditions only.

All dynamic tests were conducted with major appendages of the spacecraft in stowed position.

5.1.7.4 (Continued)

Vibration tests were conducted with the spacecraft mated to the Agena adapter. The input accelerometer was at the base of the Agena adapter.

5.1.7.5 Operational Requirements

Functional performance of operational components and subsystem elements was monitored during the test.

Functional discrepancies noted during or after tests were documented and investigated.

The resolution of a discrepancy was verified by retest.

5.1.8 Systems Acceptance Tests

5.1.8.1 Test Levels and Durations

Sinusoidal sweep test levels and durations are shown in Figure 5-10 for the longitudinal axis.

Sinusoidal sweep test levels and durations are shown in Figure 5-11 for the lateral axis.

Random vibration levels and durations are shown in Figure 5-7 for all axes.

5.1.8.2 Test Configuration

All tests were conducted with the spacecraft mated to an Agena Adapter installed on the vibration test fixture.

All assemblies for the spacecraft acceptance test program were fully representative of flight configuration spacecraft with the following exceptions:

(1) propellant masses were simulated with substitute inert fluids.

(2) a Dynamic Simulation Model (DSM) of the photographic subsystem was incorporated on all vibration test models.

(3) the Lunar Orbiter shroud and thermal barrier were incorporated for selected tests and test conditions only.

5.1.8.3 Requirements

Preliminary diagnostic surveys were required with sinusoidal test inputs at 1/2 the prescribed acceptance input levels followed by sinusoidal sweep testing at the full acceptance test input level.

5.1.8.3 (Continued)

Random vibration tests were required to progress from the lowest to the highest of four input levels as dictated by the acceptance level criteria.

5.2 LABORATORY TEST FAILURES

5.2.1 Component Vibration and Acoustic Test Failures

Component failure information was not documented at the time of this survey.

5.2.2 Subsystem Vibration and Acoustic Test Failures

There were no formal subsystem tests conducted.

5.2.3 System Development Test Failures

No information was available.

5.2.4 System Qualification Test Failures

A broken weld was discovered during reinstallation of the high-gain antenna on the spacecraft following the qualification thermal-vacuum test. This defect was not detected during or immediately following the vibration test phase. Attribution of the broken weld to the vibration test is therefore tentative and subject to conjecture. However the following summary is included for information.

ENVIRONMENT		CATEGORY OF FAILURE	RESOLUTION
Vibration	High-Gain Antenna, Broken Weld	Design	X-ray inspection of this weld on all antennas showed only two were adequate. An aluminum collar was epoxied over weld on all flight units. The repair was qualified at the component and system level.

Two flight spacecraft had been delivered when the broken weld was discovered. Flight acceptance testing did not disclose the existing weld defects. Notwithstanding consideration that the defect should have been disclosed at the component test or inspection level, it must be noted that qualification/flight acceptance test conduct and the associated post-test inspection functions did not incorporate adequate provisions for detection of this defect.

5.2.5 System Acceptance Test Failures

Table 5-2 lists the system acceptance test failures.

5.3 FLIGHT FAILURES

No flight failure or anomaly was severe enough to cause mission failure. The number of identified flight failures and anomalies are tabulated below:

MISSION	FAILURES	ANOMALIES
I	10	-
II	8	7
III	4	15
IV	5	8
V	2	4
	TOTAL 29	34

Only two out of the sixty-three problems were related to the vibration environment. These are:

MISSION	PROBLEM DESCRIPTION	CAUSE	RESOLUTION
I	Transponder Telemetry Power Variation	Temperature and/or vibration effects on the signal sampler position	None, not considered a problem.
IV	Transponder power variation	Vibration varied ground RF probe resistance	None, problem did not warrant design or operational change.

5.4 DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS

5.4.1 Derivation of Levels and Durations

Lunar Orbiter test criteria was based on flight response data measured at the base of the spacecraft/booster adapter in previous missions employing the same (Atlas/Agena) booster configuration.

TABLE 5-II. SYSTEMS ACCEPTANCE TEST FAILURES

VEHICLE	CATEGORY OF FAILURE	ITEM	RESOLUTION
#2*	Workmanship	Screw came loose on in-flight disconnect plug, stripped thread.	Replaced with nut and bolt.
#2*	Workmanship	Nuts not lock-wired on solar panel release mechanism.	Nuts lock-wired per drawing.
#2*	-	Rocket engine heat shield assembly tie wire broken.	None, one of 40 tie wires, loss of one negligible.
#4	Workmanship	Support brace on high gain antenna dish not torqued properly.	retorqued
#5	Workmanship	Mounting bolts and nuts missing on low gain antenna.	Epoxy added to retaining nuts.
#7	Workmanship	Retaining nut and bolt on microswitch actuator vibrated loose.	Epoxy added to retaining nuts

*Vehicle #2 was the ground test vehicle.

5.4.1 (Continued)

The test criteria was also an "evolution" resulting from discussions and negotiations between NASA/Langley and Boeing. Negotiations were conducted from the time of initial specification of test criteria, through development, the early part of spacecraft qualification and acceptance testing.

5.5 COMPARISON OF TEST LEVELS AND FLIGHT DATA

Mission V flight measurements of random vibration response to lift-off and transonic acoustic environments are shown in Figures 5-12 and 5-13. The prescribed test levels defining inputs to the base of the spacecraft for random vibration acceptance tests are also shown. The comparisons of flight and test data shown in Figures 5-12 and 5-13 for Spacecraft #3 are representative of corresponding data for other flight spacecraft. These comparisons generally reveal that flight responses were substantially lower in level than the responses induced by the acceptance test environments.

The ratios of flight levels to acceptance test levels at corresponding locations for the Mission V spacecraft are shown for comparison in Figures 5-14 and 5-15.

5.6 CONCLUSIONS AND RECOMMENDATIONS BY BOEING-LUNAR ORBITER

5.6.1 Conclusions

Successful performance of the Lunar Orbiter spacecraft in mission applications is attributed to the stringent implementation of test, review, and control functions comprising a comprehensive overall program to assure spacecraft reliability.

Specific provisions of dynamic testing, representing a single function of the overall program, cannot be shown to be essential to subsequent mission success, since flight failures attributable to inadequate dynamic testing did not exist.

There is no suggestion in the flight history that any problems arose from the launch and boost vibro/acoustic environment nor does the flight history suggest that the spacecraft were overtested.

The vibration test history also discloses that there was no significant failure that occurred or was detected during or immediately after the vibration test.

5.6.1 (Continued)

One is forced to the conclusions that the spacecraft acceptance vibration tests had little significance to the success of the Lunar Orbiter except as they afforded an additional step in the inspection procedure.

The Lunar Orbiter, during flight, did not experience steady-state sinusoidal vibrations. Therefore, only the random tests simulated the environment.

The modifications of test levels during Lunar Orbiter program were downward. Measured flight vibrations were lower than test levels; therefore, the test criteria must be considered more than adequate as far as levels are concerned.

5.6.2 Recommendations for Future Programs

Test plans and testing techniques should be adapted so that high level test responses are similar to those which are expected in flight. That is, random vibration tests should be used for random environments, pulse-like testing for pulse-like events, and steady-state testing only when sinusoidal vibrations are expected to occur on the vehicle.

More attention should also be paid to the comparison of the test results with theoretical predictions. Comparisons of prediction and experiment can then be made during the tests, and detection of anomalous responses could aid in failure detection.

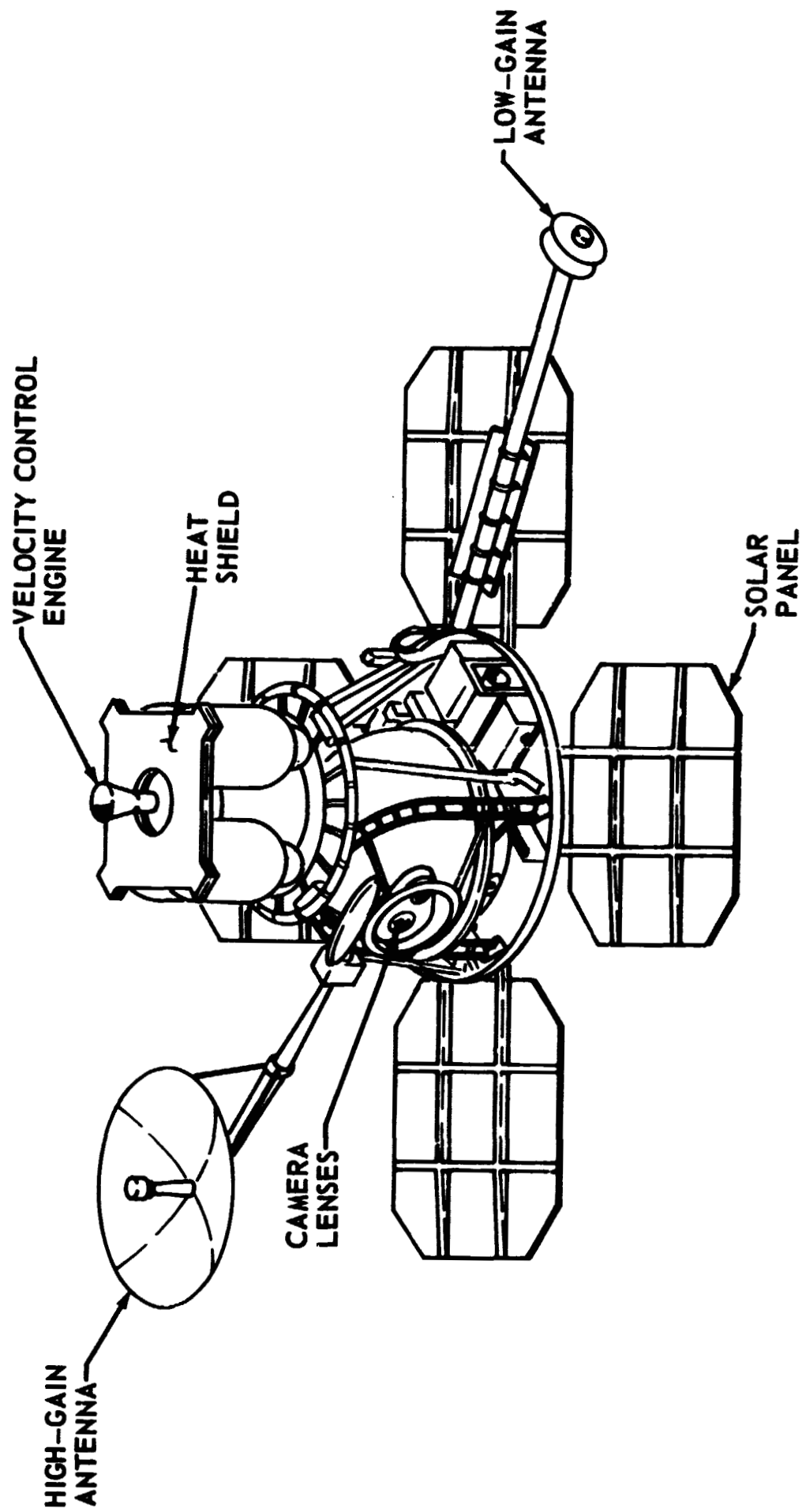


FIGURE 5-1. LUNAR ORBITER CONFIGURATION (THERMAL BARRIER REMOVED)

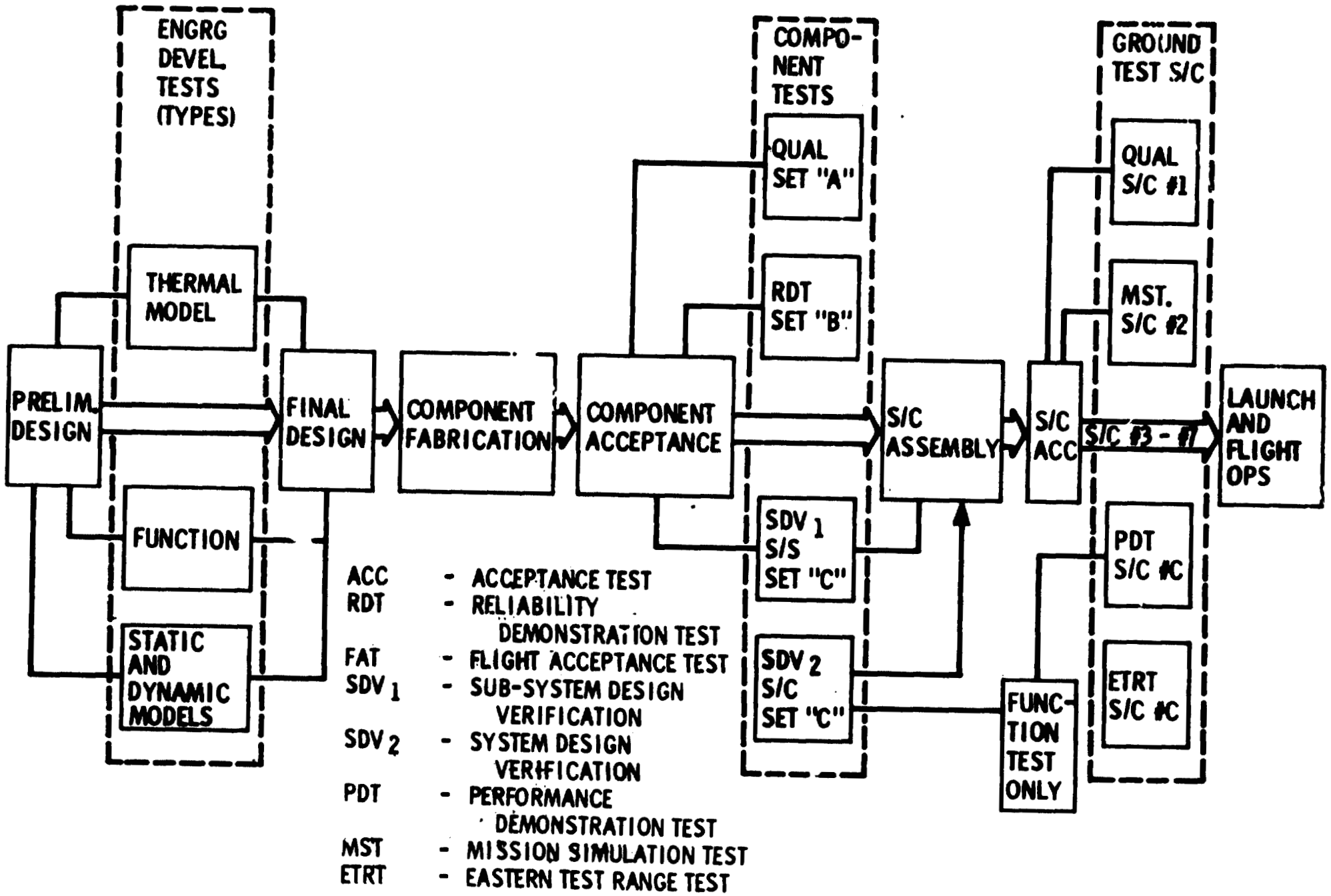


FIGURE 5-2. LUNAR ORBITER TEST PROGRAM OUTLINE

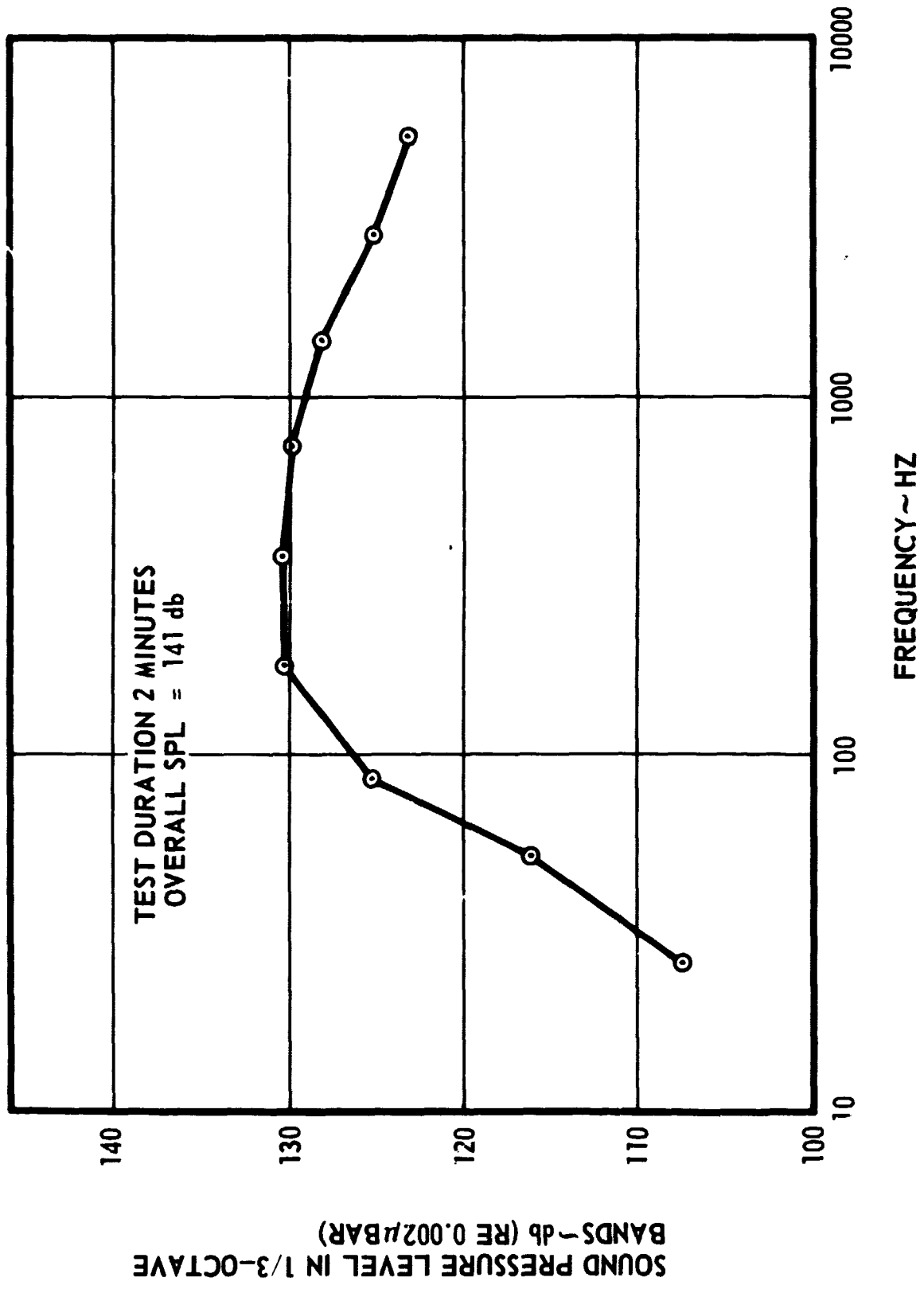


Figure 5-3. HEAT SHIELD DEVELOPMENT TEST ACOUSTIC NOISE, 1/3 OCTAVE BAND

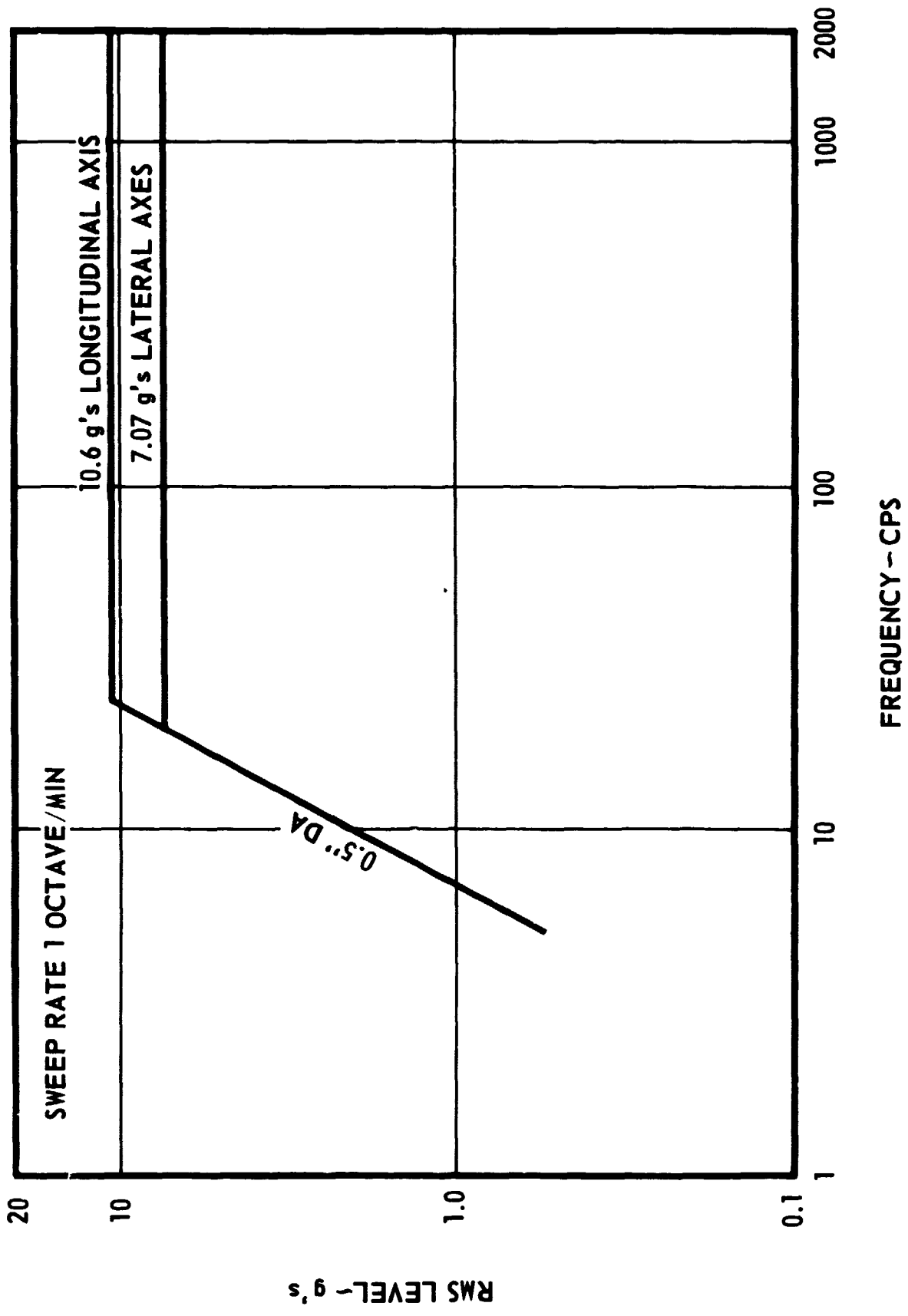


Figure 5-4. COMPONENT QUALIFICATION SINE SWEEP

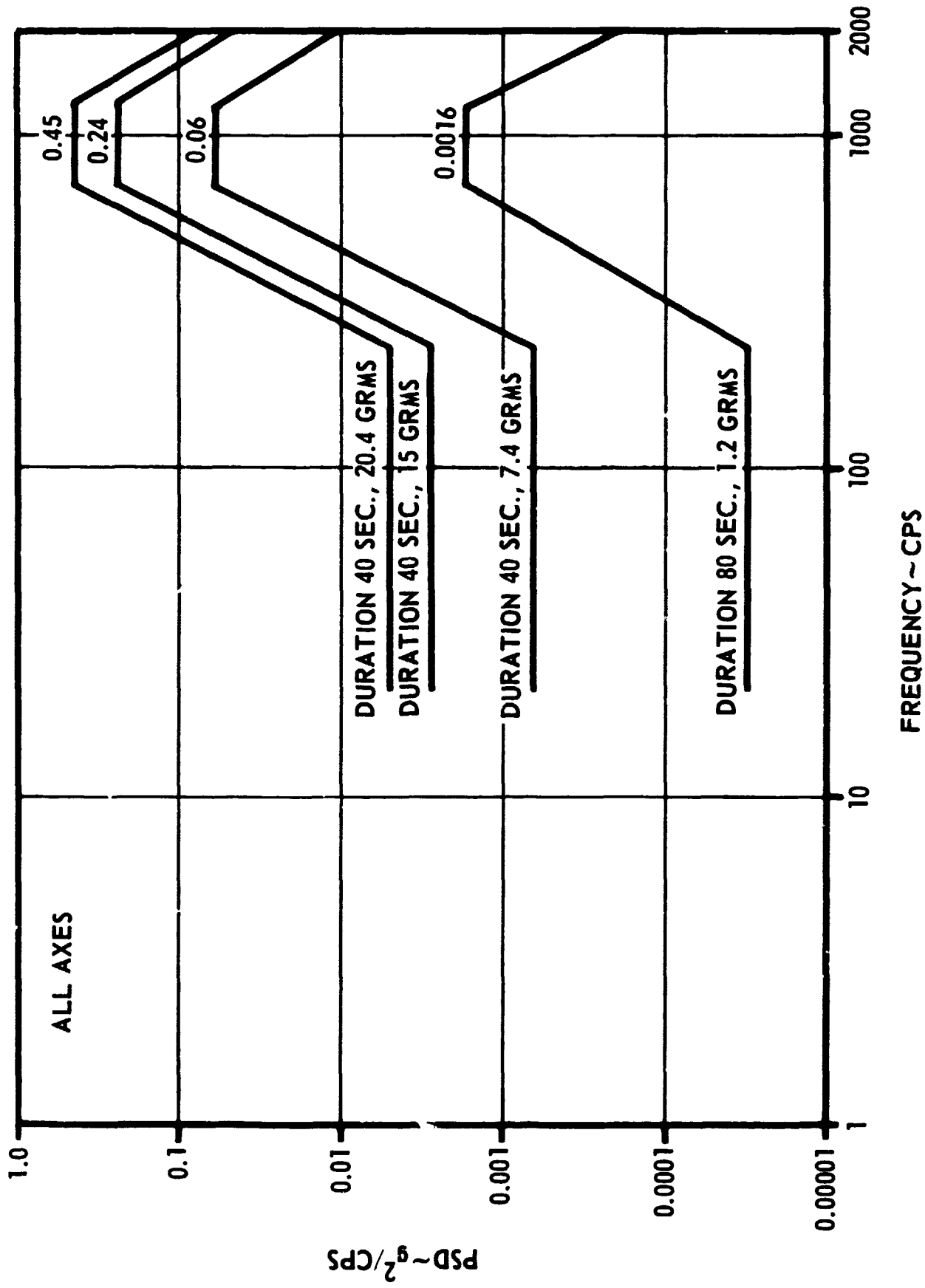


Figure 5-5. COMPONENT AND SYSTEM QUALIFICATION TEST RANDOM VIBRATION

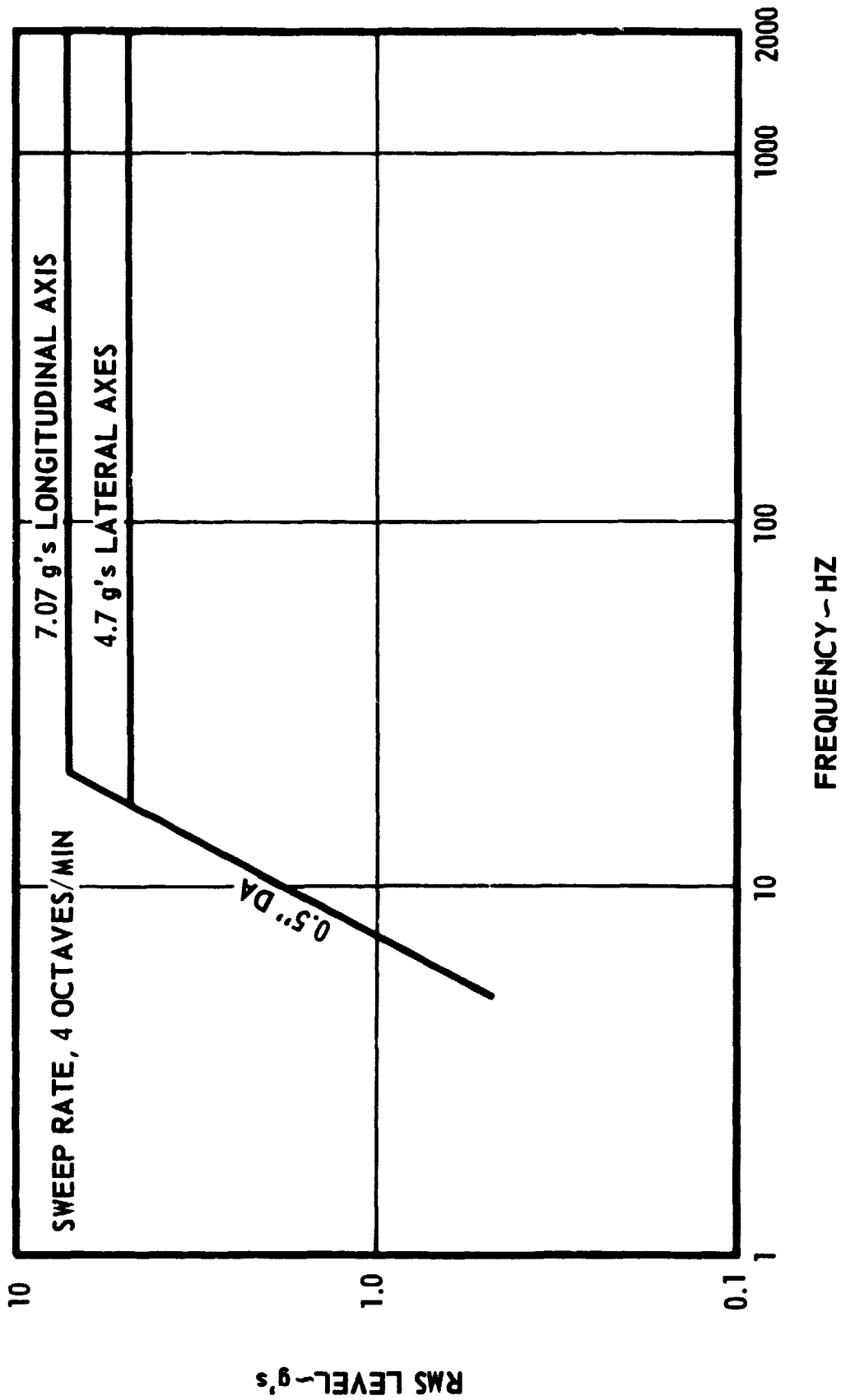


Figure 5-6. COMPONENT ACCEPTANCE TEST SINE SWEEP

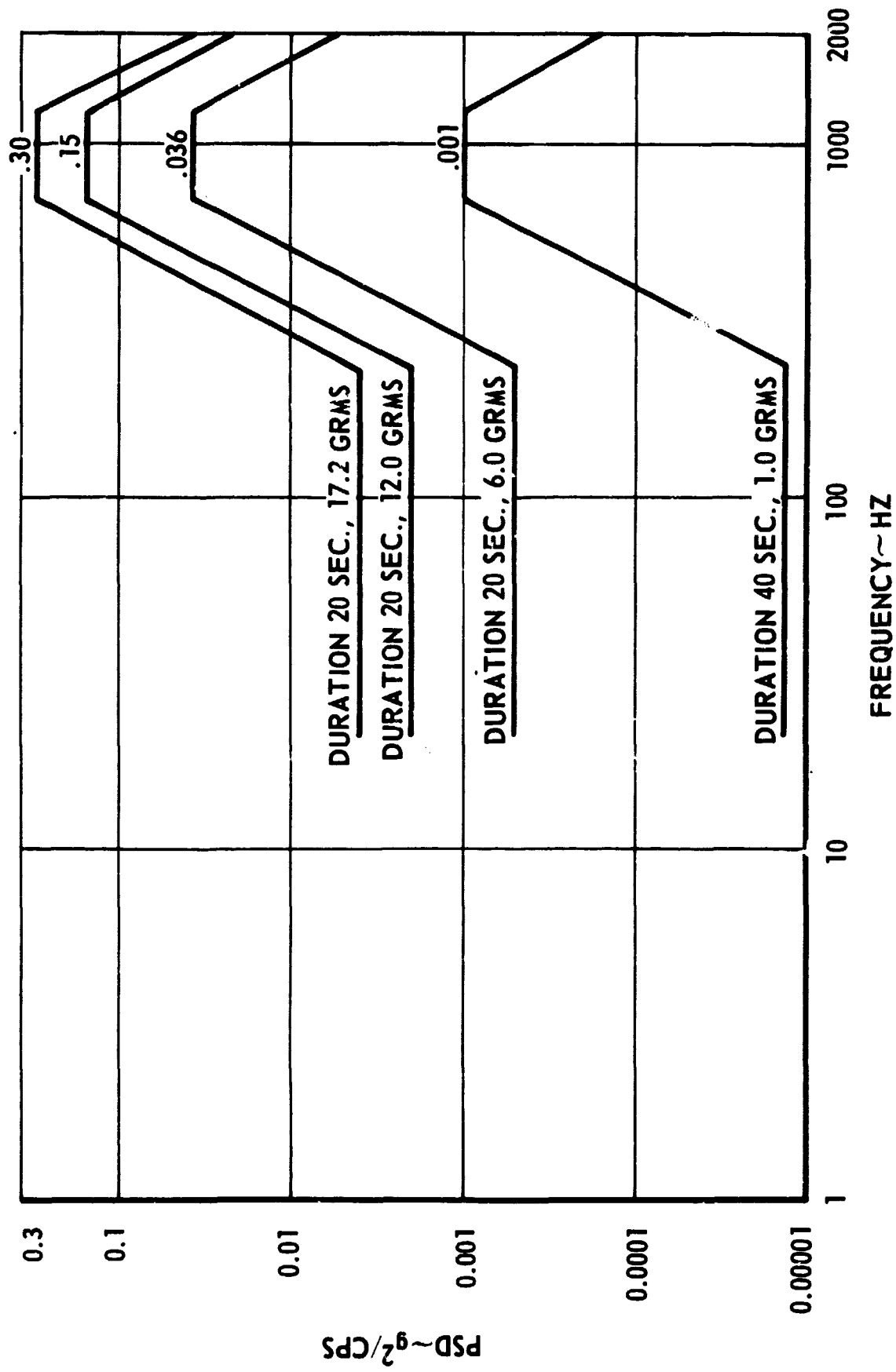


FIGURE 5-7. COMPONENT ACCEPTANCE TEST RANDOM VIBRATION

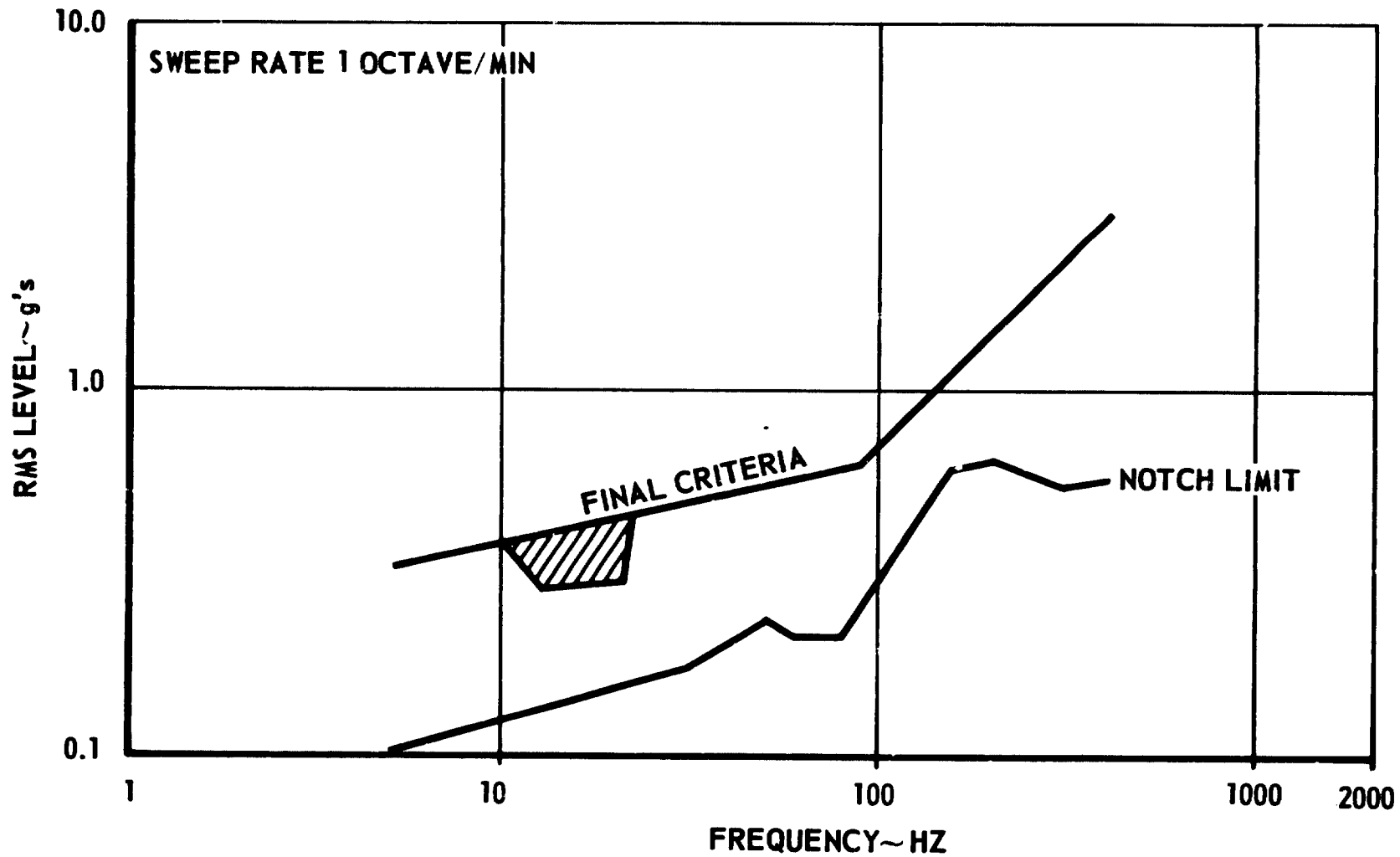


Figure 5-8. SYSTEM QUALIFICATION TESTS
SINUSOIDAL VIBRATION, LATERAL AXIS

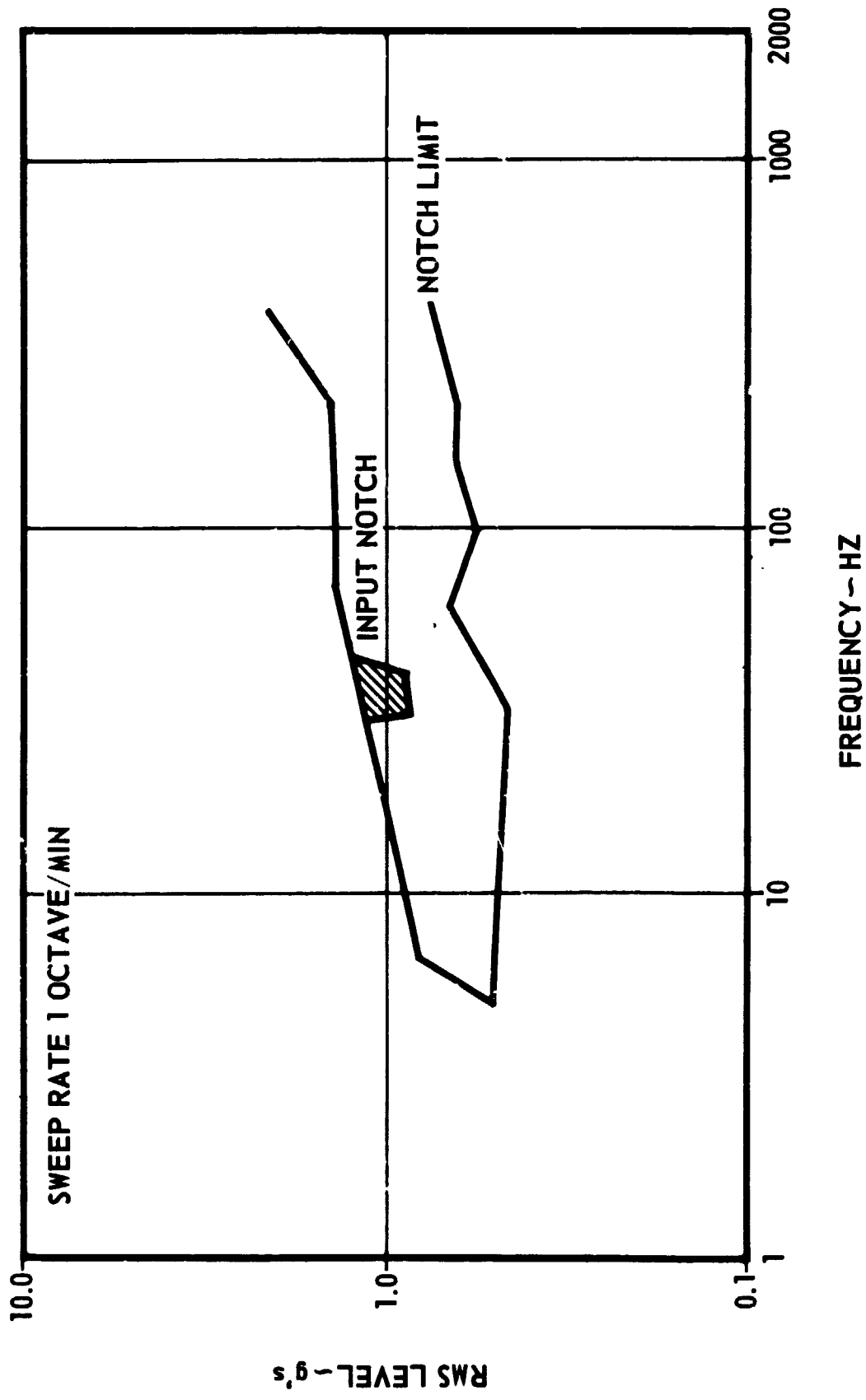


Figure 5-9. SYSTEM QUALIFICATION TESTS
SINUSOIDAL VIBRATION, LONGITUDINAL AXIS

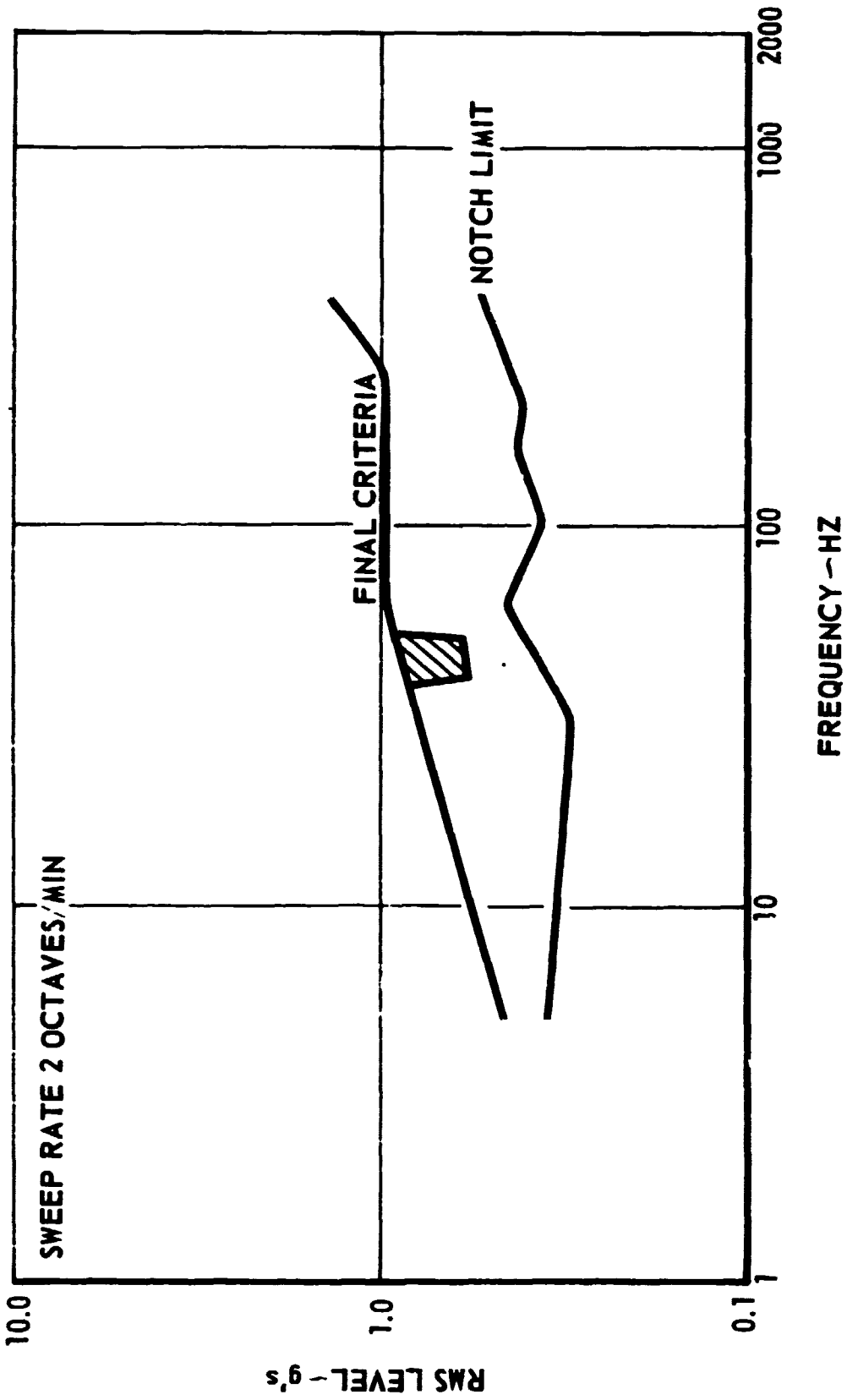


Figure 5-10. SYSTEM ACCEPTANCE TEST
SINUSOIDAL VIBRATION, LONGITUDINAL AXIS

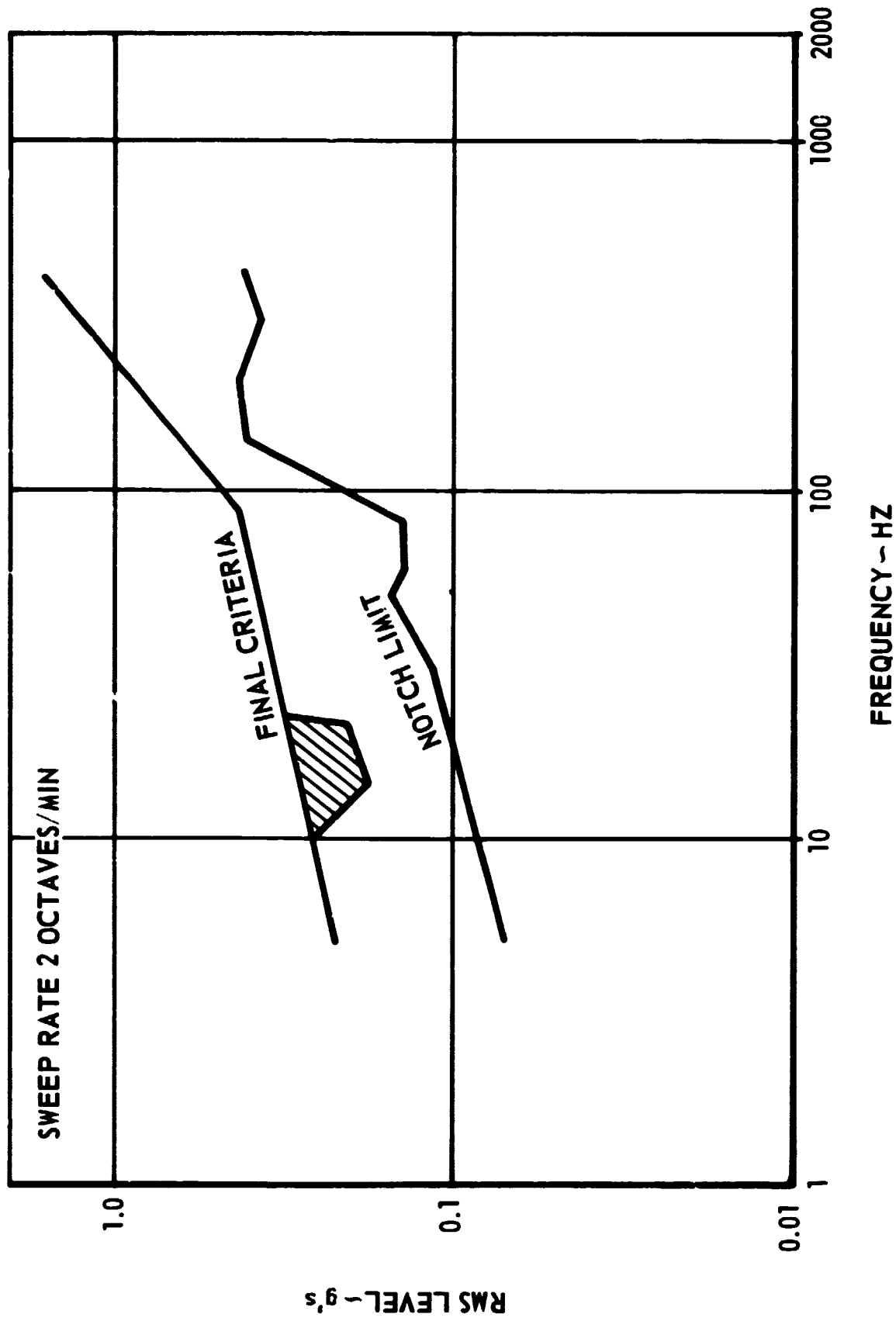


Figure 5-11. SYSTEM ACCEPTANCE TEST
SINUSOIDAL VIBRATION, LATERAL AXIS

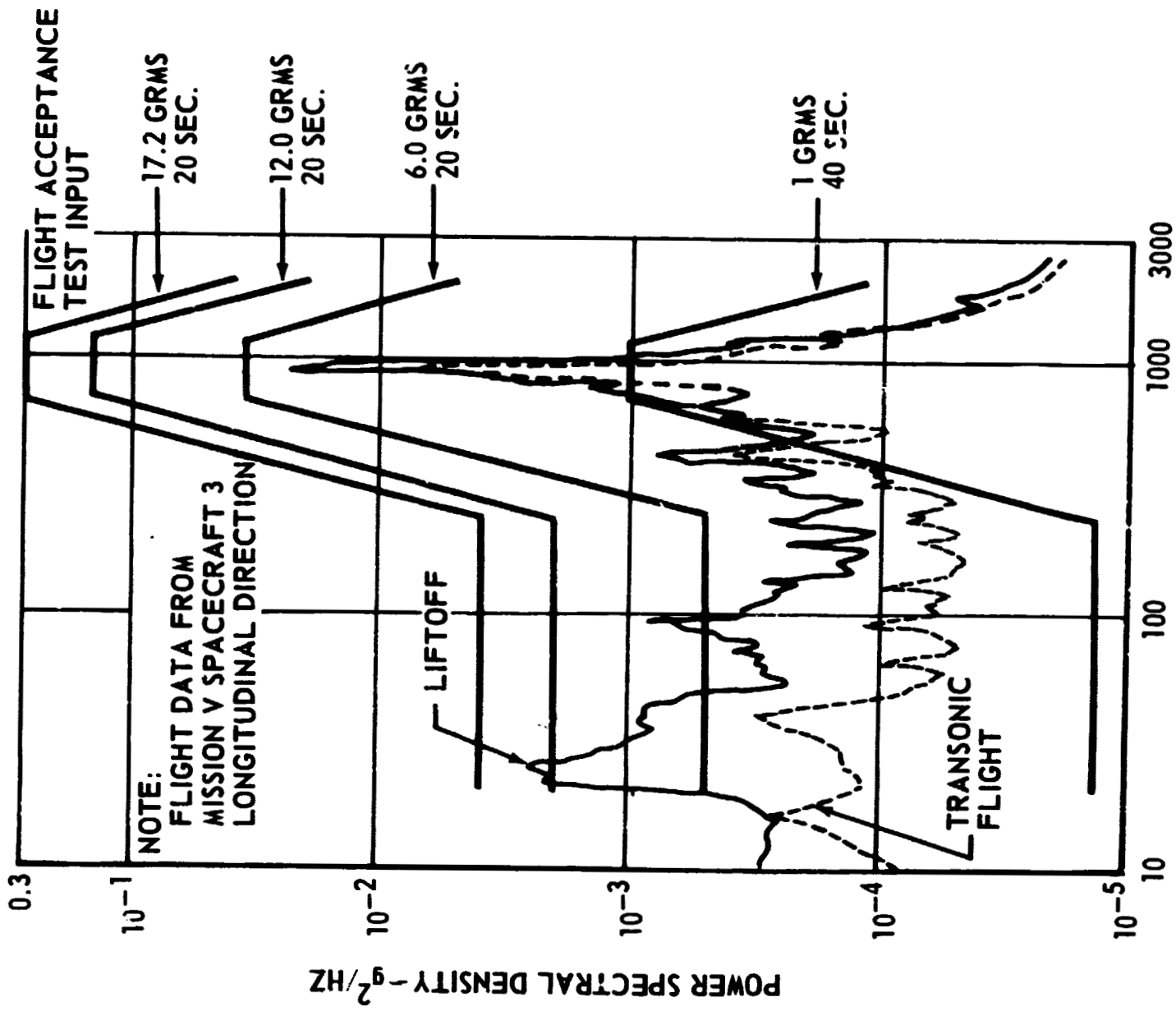


Figure 5-12. COMPARISON OF ACCEPTANCE TEST LEVELS WITH MEASURED FLIGHT RESPONSE LEVELS, RANDOM VIBRATION, LUNAR ORBITER

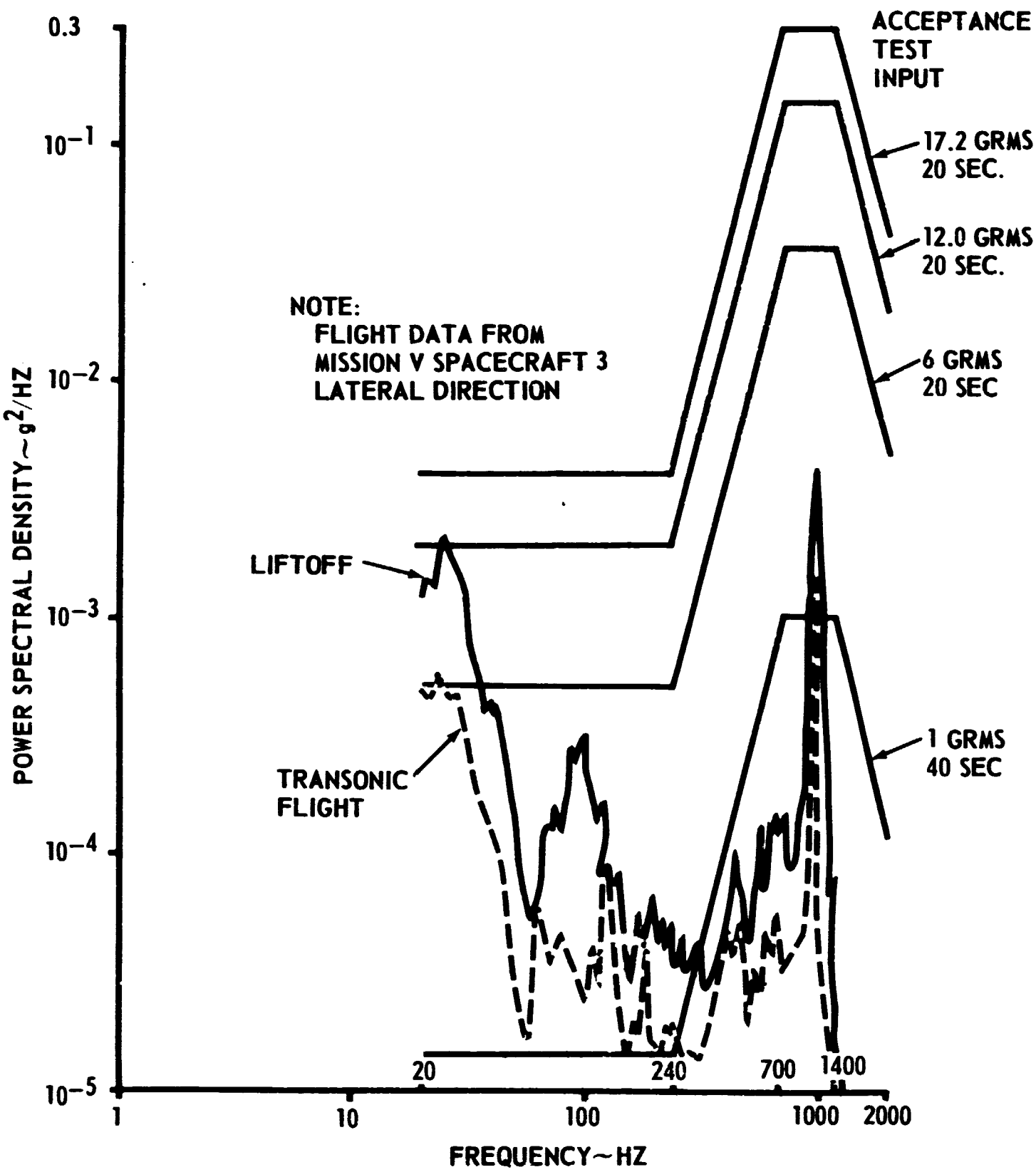


Figure 5-13. COMPARISON OF ACCEPTANCE TEST LEVELS WITH MEASURED FLIGHT RESPONSE LEVELS, RANDOM VIBRATION

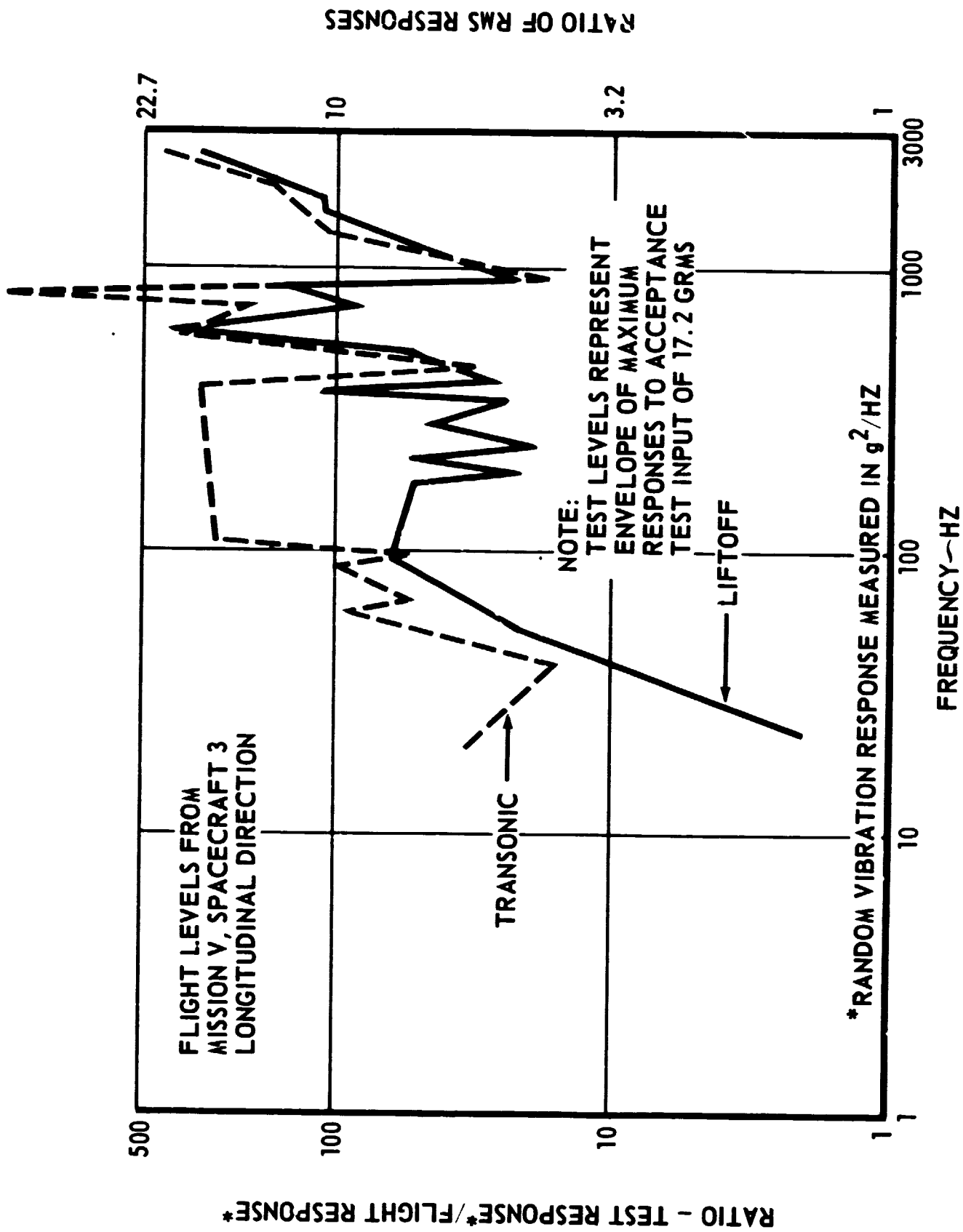


Figure 5-14. COMPARISON OF LAB TEST VIBRATION TESPONSE TO MEASURED FLIGHT RESPONSE IN LONGITUDINAL DIRECTION

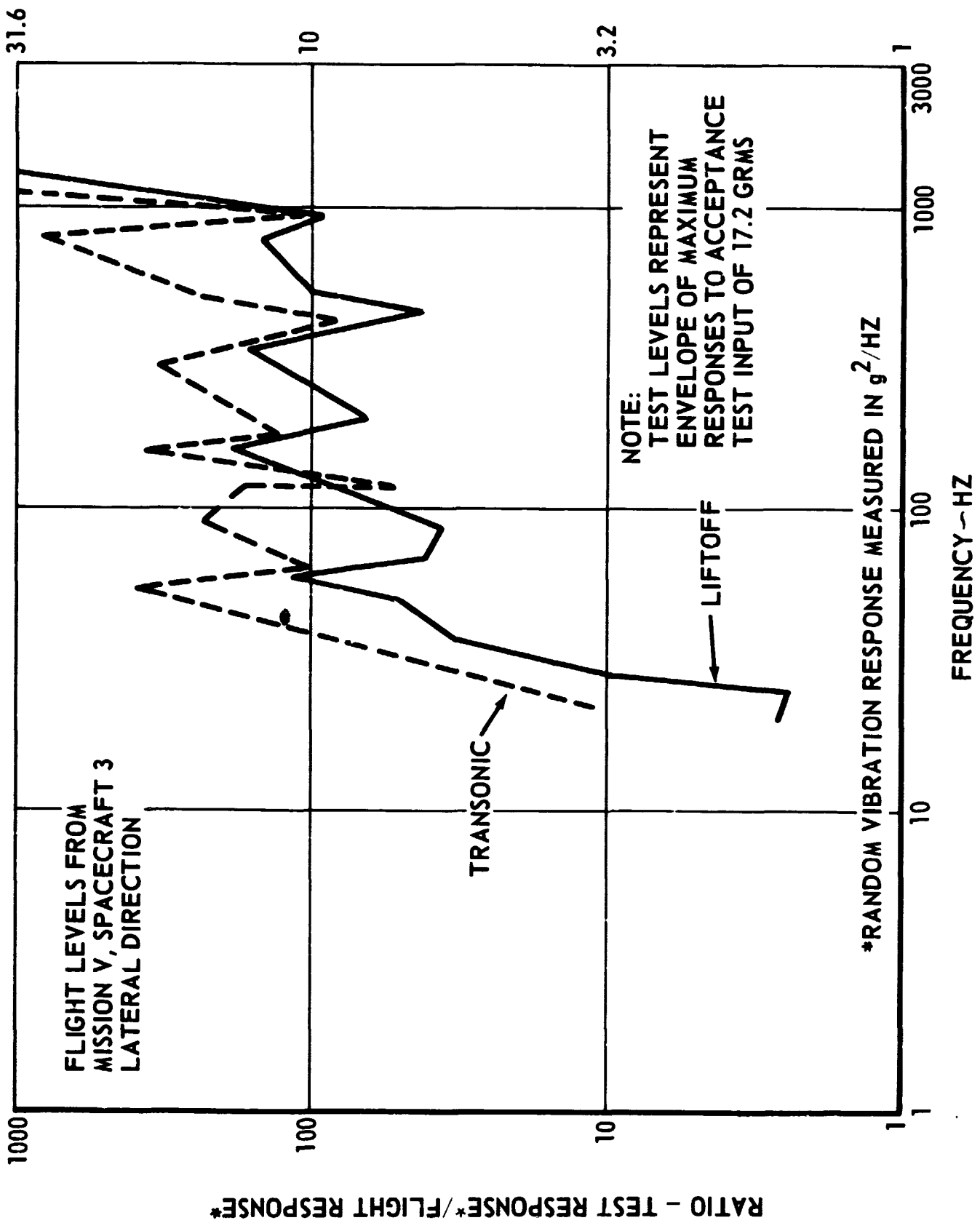


Figure 5-15. COMPARISON OF LAB TEST VIBRATION RESPONSE TO MEASURED FLIGHT RESPONSE IN LATERAL DIRECTION

SECTION 6

GEMINI

6.0 GENERAL INFORMATION - GEMINI

Spacecraft Development and Manufacturer - McDonnell-Douglas, St. Louis, Mo.

Project Management - NASA Manned Spacecraft Center

Launch Vehicle - Modified Titan II, Two Stages

Spacecraft	Launch Date	Remarks
Gemini I	4/8/64	Unmanned
Gemini II	1/19/65	Unmanned
Gemini III	3/23/65	Manned
Gemini IV	6/3/65	Manned
Gemini V	8/21/65	Manned
Gemini VI	12/15/65	Manned
Gemini VII	12/4/65	Manned
Gemini VIII	3/16/66	Manned
Gemini IX	6/3/66	Manned
Gemini X	7/18/66	Manned
Gemini XI	9/12/66	Manned
Gemini XII	11/11/66	Manned

Gemini physical characteristics (see Figure 6-1).

Weight - 7000 lbs.
Diameter - 10 ft.
Length - 19 ft.

The information presented in this section was obtained from the data shown in Appendix B.

6.1 LABORATORY TEST PROGRAM

6.1.1 Test Program Rationale

6.1.1.1 Objectives

Provide a method to uncover design or workmanship deficiencies that could have been sources of problems with equipment in operational vehicles.

6.1.1.2 Requirements

The test programs had to be financially compatible with the overall program and provide satisfactory results at reasonable cost.

Cost effectiveness approach resulted in carry-over of test procedures from Mercury, qualification by similarity, elimination of testing for non-sensitive items and omission of formal development testing.

6.1.1.3 Tests Conducted

Multiple level testing was used for qualification and acceptance to provide the most realistic tests at the earliest possible times. A list of the tests conducted is given below.

	Development	Qualification	Acceptance
Component	None*	Vibration and Acoustic	Vibration
Subsystem	None	Vibration	None
System	None	None	Vibration

*Some development tests were conducted by McDonnell subcontractors but are not reported here.

6.1.1.4 Vibration and Acoustic Test Program Outline

The laboratory vibration and acoustic test program relationships are shown in Figure 6-2.

No feedback loops are shown in Figure 6-2. But if a failure or undesirable condition were detected during an acceptance vibration test, changes would be made in manufacturing and/or design to correct the condition.

6.1.2 Component Vibration/Acoustic Tests

Gemini component tests drew heavily on Mercury experience. Procedures were similar for sine vibration and acoustic tests with some changes in sine test levels and reduction of resonance dwell times. Major difference was the incorporation of random vibration tests for Gemini.

Components which were complex were vibration tested to only the random vibration requirements.

Simple components were subjected to only sinusoidal vibration.

Tests were not conducted on Gemini hardware if the components were qualified to equivalent levels for some other program.

Many designs were qualification tested before the acceptance tests were incorporated and were not subjected to acceptance tests. Therefore, a failure in a qualification test required a review of the acceptance test history of the test article.

Tests were eliminated on items considered insensitive to the environment.

6.1.3 Component Development Test

There was no requirement for component development testing. Some development tests were conducted by McDonnell subcontractors but are not reported here.

6.1.4 Component Qualification Tests

6.1.4.1 Objectives

To provide a method to uncover design or workmanship deficiencies that could have been sources of problems with equipment in operational vehicles.

6.1.4.2 Test Levels and Durations

The range of levels and durations for sinusoidal vibration qualification tests are shown in Figure 6-3. Sinusoidal levels varied to account for launch, orbit and re-entry conditions, see paragraph 6.4.1.

The range of levels and durations for random vibration qualification tests are shown in Figure 6-4. Random vibration varied to account for launch, orbit and re-entry conditons, see paragraph 6.4.1.

The range of levels and durations for acoustic qualification tests are shown in Figure 6-5.

6.1.4.3 Components Tested

A summary of component qualification tests is shown in Table 6-1.

6.1.4.4 Test Configuration

Components were generally hardmounted using flight fasteners for vibration tests. If the item was vibration isolated, isolators were included.

Components were suspended as softly as practicable for acoustic tests.

6.1.4.5 Operational Requirements

Satisfactory component operation was required before and after the tests.

Operation was required during the test only if the component was required to function during the corresponding flight phase.

A component might be tested non-operating to a survival environment and then re-tested operating at a lesser environment to demonstrate functional capability.

TABLE 6-I. GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

COMPONENT TYPE	TOTAL NO. OF COMPONENTS	TOTAL NO. TESTED VIBRATION SINE	TOTAL NO. TESTED VIBRATION RANDOM	TOTAL NO. TESTED ACOUSTIC
Electrical	108	53	48	9
Electronic	43	7	37	30
Mechanical	126	77	35	7
Electro-Mechanical	33	7	21	5
Structural	66	28	13	1
Instrumentation Sensors	97	21	3	10
Other	21	13	5	2
TOTAL	494	206	162	64

6.1.5 Component Acceptance Tests

6.1.6.1 General

Acceptance tests were generally initiated by vendors of electronic devices. Environments bore little relation to qualification or expected environments but most acceptance environments were revised during program. Revised levels and durations were selected so that the test would be significantly less severe than the qualification requirement. One exception was the spacecraft digital computer. The vendor recommended testing at qualification levels. This was done, but it resulted in the elimination of re-use capability of the flight equipment.

Decision not to acceptance test based on relation of cost to expected results and/or because the life of the item might be severely reduced by the test.

6.1.5.2 Test Levels and Durations

The levels and durations used for the tests were selected so that in all cases the test would be significantly less severe than the qualification requirement for the component.

The extreme levels and the durations for sinusoidal vibration tests are shown in Figure 6-6.

The extreme levels and the durations for random vibration tests are shown in Figure 6-7.

No acoustic acceptance tests were conducted.

6.1.5.3 Components Tested

A summary of component acceptance tests is shown in Table 6-2.

6.1.5.4 Test Configuration

Components were hardmounted for acceptance vibration.

6.1.5.5 Operational Requirements

Operation was usually required during the acceptance tests.

If the component was not required to operate during the period of severe flight vibration, then no operation was required during acceptance tests.

TABLE 6-II. GEMINI COMPONENT VIBRATION ACCEPTANCE TEST SUMMARY

COMPONENT TYPE	TOTAL NO. OF COMPONENTS	TOTAL NO. TESTED VIBRATION SINE	TOTAL NO. TESTED VIBRATION RANDOM
Electrical	108	3	18
Electronic	43	2	33
Mechanical	126	2	0
Electro-mechanical	33	1	20
Structural	66	0	1
Instrumentation	97	89	0
Other	21	0	0
TOTAL	494		72

6.1.6 Subsystem Vibration Tests

Only vibration qualification tests were conducted on Gemini subsystems.

6.1.6.1 Objective

Demonstrate the capability of the components to withstand the environment as a subsystem.

Assure satisfactory installation of the components.

6.1.6.2 Test Levels and Durations

Test levels and durations are shown in Figure 6-8.

6.1.6.3 Subsystems Tested

A single subsystem of each type was tested.

A summary of the subsystems tests is shown in Table 6-3.

6.1.6.4 Test Configurations

Test configurations are described in Table 6-3.

Transducers to control the test levels were as near the place of excitation as possible.

6.1.6.5 Operational Requirements

The tests simulated launch conditions and therefore only the fuel cell module was fully operational.

Satisfactory operation before and after the tests were demonstrated.

6.1.7 System Vibration Tests

6.1.7.1 General

Only acceptance vibration tests were conducted at the system level on Gemini. The first 3 flight spacecraft were tested. Decision to eliminate tests after spacecraft 3 based on estimated cost effectiveness. Although a test on spacecraft 4 might have required 1/3 less effort, cost was deemed excessive in view of expected returns.

System acceptance tests most effective on early vehicles before learning curve improvement takes place.

TABLE 6-III. GEMINI SUBSYSTEM VIBRATION QUALIFICATION TEST SUMMARY

SUBSYSTEM DESCRIPTION	RANDOM VIBRATION		SINE VIBRATION	
	RMS LEVEL	DURATION	LEVEL	DURATION
Fuel cell module (Note 1)	7.0 g	8 min. each of 3 axes	Low level surveys	
Orbit attitude maneuvering system module (14 day) (Note 2)	7.0 g	8 min. each of 2 axes	Low level surveys	
Orbit attitude maneuvering system module (2 day) (Note 3)	7.0 g	8 min.	Low level surveys	
Re-entry control system module (Note 4)	8.8 g	15 min. each of 3 axes	Low level surveys	
Rendezvous evaluation pod (Note 5)	7.0 g	1 min. each of 3 aces	Low level surveys	

Notes:

1. The fuel cell module consisted of two fuel cell sections, a hydrogen tank, an oxygen tank, pressure regulators, valves, and associated tubing and wiring installed in a production structure adapter.

2. The 14-day orbit attitude maneuvering system module (OAMS) consisted of a pressurant tank, a fuel tank, an oxidizer tank, regulators, valves, and tubing and wiring installed on production structure.

3. The 2-day OAMS was identical to the 14-day OAMS preceding except that it included an additional pressurant tank, fuel tank and oxidizer tank.

4. The re-entry control system (RCS) test included production structure with a pressurant tank, a fuel tank, an oxidizer tank, regulators, valves, thrust chamber assemblies, and tubing and wiring. Flight vehicles included a second redundant system but it was not included in the test.

5. The rendezvous evaluation pod (REP) was a Gemini radar transponder package to which was added 2 spiral and 1 dipole antennas, 2 flashing lights and 2 batteries to supply power. A sunshade and the deployment mechanisms for the sunshade and for the REP were included in the test.

6.1.7.2 Objectives

System acceptance tests were conducted to demonstrate satisfactory operation of the flight systems during a simulated launch.

6.1.7.3 Test Levels and Durations

Test levels and durations are shown in Figure 6-9.

6.1.7.4 Systems Tested

A summary of the systems level tests is shown in Table 6-4.

6.1.7.5 Test Configurations

Production hardware was used for all systems except for pyrotechnic elements.

Tests levels were controlled by an accelerometer mounted on the fixture as near the attachment of the vehicle as practicable.

6.1.7.6 Operational Requirements

All systems normally operating during the launch phase were operational and monitored during the tests.

Satisfactory system operation was established before and after each test phase.

6.2 LABORATORY TEST FAILURES

The failures reported in this section were taken from a review of Gemini malfunction summary reports and test reports of Gemini equipment. In some cases the level at failure was determined by reviewing the failure report and the equipment test requirements and the probable level inserted.

6.2.1 Component Vibration/Acoustic Test Failures

A summary of failures during component qualification tests is presented in Table 6-5 and for component acceptance tests in Table 6-6. Detailed failure information is presented in Appendix

Failures are not included where the fault was either test procedure or test error since these do not have any bearing on the flight capability of the equipment. The letter D or A is included on the appendix tabulations to indicate whether the failure was detected during or after the test.

TABLE 6-IV. GEMINI SYSTEM VIBRATION/ACOUSTIC ACCEPTANCE TEST SUMMARY

SYSTEM DESCRIPTION	RANDOM VIBRATION		SINE VIBRATION	
	RMS LEVEL	DURATION	LEVEL	DURATION
Spacecraft 1	8.4 g	3 min. in long. axis	Low level surveys plus ± .6 g at 11 cps for 20 sec. (POGO simulation)	
Spacecraft 2	6.2 g	1 min. each of 2 axes (long. and lateral)	Low level surveys plus ± .3 g at 17 cps for 10 sec. (POGO simulation)	
Spacecraft 3	6.2 g	1 min. long. axis, 1.5 min. lateral axis	Low level surveys plus ± .3 g at 17 cps for 10 sec. (POGO simulation)	

TABLE 6-V. COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST FAILURE SUMMARY

FAILURE CATEGORY	COMPONENT TYPE			
	ELECTRICAL	ELECTRONIC	ELECTRO-MECH.	MECHANICAL
Design deficiency	2	29	4	4
Part failure	-	12	-	-
Workmanship	-	14	-	-
Fabrication procedure	-	15	1	-
Unknown	-	4	1	1
TOTALS	6	74	6	5

TABLE 6-VI. COMPONENT VIBRATION ACCEPTANCE TEST FAILURE SUMMARY

FAILURE CATEGORY	COMPONENT TYPE ELECTRICAL	ELECTRONIC	ELECTRO-MECH.	MECHANICAL
Design deficiency	2	10	5	-
Part failure	1	20	8	-
Workmanship	2	20	8	1
Fabrication procedure	1	14	5	-
Excessive rework	-	-	2	-
Unknown	-	6	1	-
Inspection error	-	-	2	1
Test procedure	-	1	-	-
TOTAL	6	71	31	2

6.2.2 Subsystem Vibration Test Failures

No table is included since the only failure reported was a structural problem during the 14 day orbital altitude maneuvering system (OAMS) module qualification tests. The test was random vibration at 7.0 g's rms and a fault in design was detected when a crack occurred at a weld on the bracket holding the pressurant tanks. The structure was modified by a beef-up which was also incorporated in the 2 day OAMS. The failure was not detected during component testing since it was structure which supported several components and so was first tested at the subsystem level.

6.2.3 System Vibration Test Failures

Table 6-7 presents a summary of the failures reported for the system acceptance vibration tests performed on Gemini. Detailed failure information is presented in Appendix B.

6.3 FLIGHT FAILURES

The in-flight problems which could be connected with vibrations or acoustics are listed in Appendix B. For some of these failures the chances that they are associated with vibration is very small, yet the possibility remains and so they are included. For items possibly more closely associated with vibration a note is included to indicate where it was thought that the failure might have only been displayed due to inflight vibration.

One thing not included in the tables, which also cannot be assessed, is the fact that a failure might have been caused by some event which might occur after the vibration tests and therefore could not be eliminated by the ground tests. This, of course, is a major problem since all vehicles will be moved and worked on after all tests are completed.

The total number of spacecraft problems detected immediately prior to flight, during flight, or during post-flight tests was 228. Not all of the flight problems can be classified as failures but the distinction is not clear-out. The McDonnell estimate of the number of those properly classified as failures is 127.

6.4 DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS

6.4.1 Component Test Levels and Durations

6.4.1.1 General

Test levels were derived for three flight conditions, launch, orbit and re-entry, see Figure 6-9 and 6-10.

TABLE 6-VII. SYSTEMS VIBRATION ACCEPTANCE TEST FAILURE SUMMARY

FAILURE CATEGORY	NUMBER OF FAILURES
Design	1
Part failure	3
Workmanship	1
Fabrication	4
Handling	1
Unknown	9
TOTAL	19

6.4.1.2 Random Vibration Levels - Launch Environment

The original random spectrum for launch was based on a statistical analysis of Mercury measured data (20-1200 hz) considering the vibration to be linearly correlated with dynamic pressure.

The mean plus 2σ (95% confidence level) was the original qualification requirements. (See Figure 6-11)

The shape of the random spectrum was changed based on data from the first Gemini flight (GT-1). The change was based on comparable data between Gemini and Mercury (see Figure 6-12).

Blast shield measurements from GT-1 indicated lower levels than did the GT-1 re-entry vehicle measurements resulting in the creation of a separate spectrum for this region (see Figure 6-13).

In addition, special spectra were derived for specific items during the program.

6.4.1.3 Random Vibration Levels - Orbit Environment

Orbit vibration was estimated as simply low level band-limited white noise since there were no significant sources of environmental vibration on the vehicle, see Figure 6-10.

6.4.1.4 Random Vibration Levels - Re-entry Environment

Re-entry random vibration levels were originally estimated from the relationship of g's versus dynamic pressure derived for launch, see Figure 6-10.

Although GT-1 provided no re-entry data the random vibration spectrum for re-entry was modified to be identical with the frequency distribution of the launch curve.

6.4.1.5 Random Vibration Durations

Qualification test durations encompassed two flight capability.

Qualification test duration normally 15 minutes per axis to account for the following:

5 minutes for vibration tests on flight hardware.

5 minutes (3 minutes for launch and 2 minutes for re-entry) for each of 2 flights.

Items which did not re-enter or were not reused were tested to appropriately shorter times.

6.4.1.5 (Continued)

Acceptance tests durations were conducted for 1 minute per axis.

Mercury flight time histories used for derivation of Gemini durations are shown in Figure 6-14.

6.4.1.6 Sinusoidal Vibration Levels

The sinusoidal qualification levels used for the Mercury spacecraft at launch were used for Gemini with a reduction incorporated in the high frequency range to account for lower dynamic pressure levels.

Orbit and re-entry sinusoidal levels were estimated to be lower than launch consistent with the random spectra, see Figure 6-10.

6.4.1.7 Sinusoidal Vibration Durations

Sinusoidal qualification test durations included two 15 minute sinusoidal sweeps per axis and 10 minute dwells at significant resonances. Durations were reduced for items which did not re-enter or were not reused.

Sinusoidal acceptance tests, consisting of sweep tests only, were conducted for 5 minutes per axis.

6.4.1.8 Acoustic Levels and Durations

Acoustic spectra were based on Mercury in-flight measurement, considering transmission losses due to structure, see Figure 6-15.

Transmission losses were estimated as 10 db for the adapter area, 20 db for the equipment bay areas and 30 db for inside the cabin, see Figure 6-16.

Acoustic noise qualification test durations were 30 minutes. If the facility provided a progressive wave, reorientation of the test article was required at 10 minute intervals. Mercury time histories are shown in Figure 6-17.

6.4.2 Sources of the Data

6.4.2.1 Vibration Data

Inflight vibration measurements from three Mercury vehicles, MA-2, MA-3 and MA-4 were used to establish Gemini test spectra.

The data used were taken from radial accelerometers located on a primary structural ring, see Figures 6-18 and 6-19.

6.4.2.1 (Continued)

The sinusoidal test procedures of the Mercury qualification requirements were a source of data.

Inflight data from the Gemini GT-1 were used to revise qualification requirements (only the measurements showing the highest levels were used in the derivations).

6.4.2.2 Acoustic Data

Mercury vehicle acoustic noise data were used to establish Gemini requirements. These data were measured under a shingle on MA-1 and inside the cabin on MA-2 and MA-4.

6.4.3 Identification of Test Factors

6.4.3.1 Random Vibration Levels

The ratio of power spectral densities of the qualification tests to the corresponding acceptance tests was 2 to 1.

This ratio provided qualification tests at a level in excess of the mean plus 2σ and acceptance test levels near the mean plus 1σ.

Subsequent to GT-1 flight the acceptance test procedures of the vendors were standardized. For items that had been qualified in random vibration the acceptance power spectral density was set at 1/2 of qualification level. This results in the rms level being 0.7 of qualification level.

6.4.3.2 Random Vibration Duration

The test durations for qualification included a 5 minute test period intended to demonstrate the capability of the design to withstand expected flight vibration plus ground test vibrations, including re-tests if necessary. The time relation is not simple since the levels are not one-to-one for the time period.

6.4.3.3 Sinusoidal Levels and Durations

[illegible]mple relation exists for sine tests since sine qualification levels were a carry over from Mercury.

Sine acceptance levels were made less than qualification levels by one or more of the following techniques:

(1) Eliminating resonant dwells,
(2) Fewer sweeps,
(3) Faster sweeps,
(4) One axis test.

6.5 COMPARISON OF TEST LEVELS AND FLIGHT DATA

6.5.1 Flight Vibration Data

GT-1 and GT-2 instrumentation locations are shown in Figures 6-18 and 6-19.

GT-1 and GT-2 vibration time histories are shown in Figure 6-20 and comparisons are made with Mercury data and laboratory test durations.

Comparison plots of GT-1 and GT-2 re-entry vehicle vibration measurements during launch and test requirements are shown in Figure 6-21.

6.5.2 Flight Acoustic Data

GT-1 sound pressure level time history is compared with laboratory test duration in Figure 6-22.

GT-1 acoustic spectrum is compared with test requirements in Figure 6-23.

6.6 CONCLUSIONS AND RECOMMENDATIONS BY MCDONNELL-DOUGLAS

6.6.1 Conclusions

The significance of the vibration and acoustic tests which were performed during the Gemini program should be evaluated in these ways: The flight problems which they avoided, the confidence which they provided and the cost compared to their value.

The vibration tests of components and subsystems resulted in many failures. Although many of these might not have occurred in flight even had they not been corrected, the procedures for these tests were realistic so that many of these failures could have occurred in flight. The costs of these tests are high, but a great deal of confidence is placed in equipment when a vibration test is successfully completed.

The Gemini system tests revealed some problem areas, but not many in comparison to testing at other levels. The system level test was not fully effective in that vibration levels were not transmitted throughout the vehicle. Therefore, even though some subsystems successfully completed the test only a limited amount of confidence would result.

6.6.2 Recommendations for Future Programs

If the environment is considered to be random in amplitude, and the vehicle is of similar size and complexity to Gemini, then all tests would be conducted with a random forcing function.

All test times should be comparable to the expected flight durations, but "scaling" test times should be avoided if at all possible.

The use of qualification and acceptance vibration tests for components should be incorporated.

6.6.2 (Continued)

Development tests to qualification levels can be eliminated with very little effect on the outcome of qualification tests. The savings of development test costs should offset the additional qualification testing that would become necessary.

Acoustic noise tests should be eliminated from all non-sensitive equipment, especially if the level is 135 db or less.

Perhaps the biggest change that we would recommend for future programs compared to the Gemini procedures is the thorough evaluation of acoustic excitation for vehicle acceptance and qualification tests. The use of acoustic noise for these tests would provide a step closer toward simulation of the expected dynamic forcing function, as compared to vibration testing. System acoustic tests might require the use of development tests, but it would be serving to develop the test techniques for the vehicle rather than to develop the vehicle or its components.

The need for improved techniques was demonstrated for Gemini when it was found that the test levels were not transmitted satisfactorily throughout the structure. Regions close to the shaker attach points were subjected to the desired levels, but elsewhere the levels were down considerably.

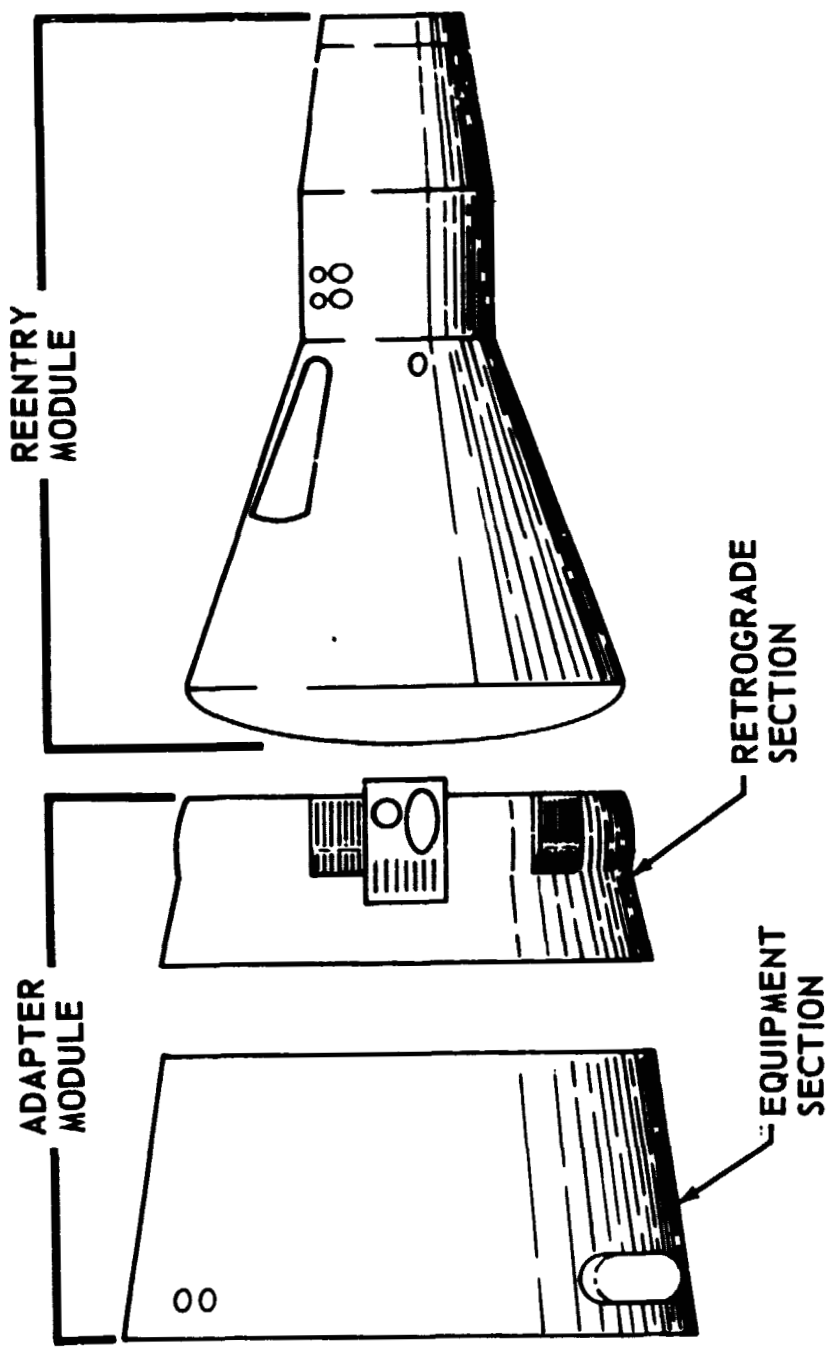


Figure 6-1: GEMINI SPACECRAFT

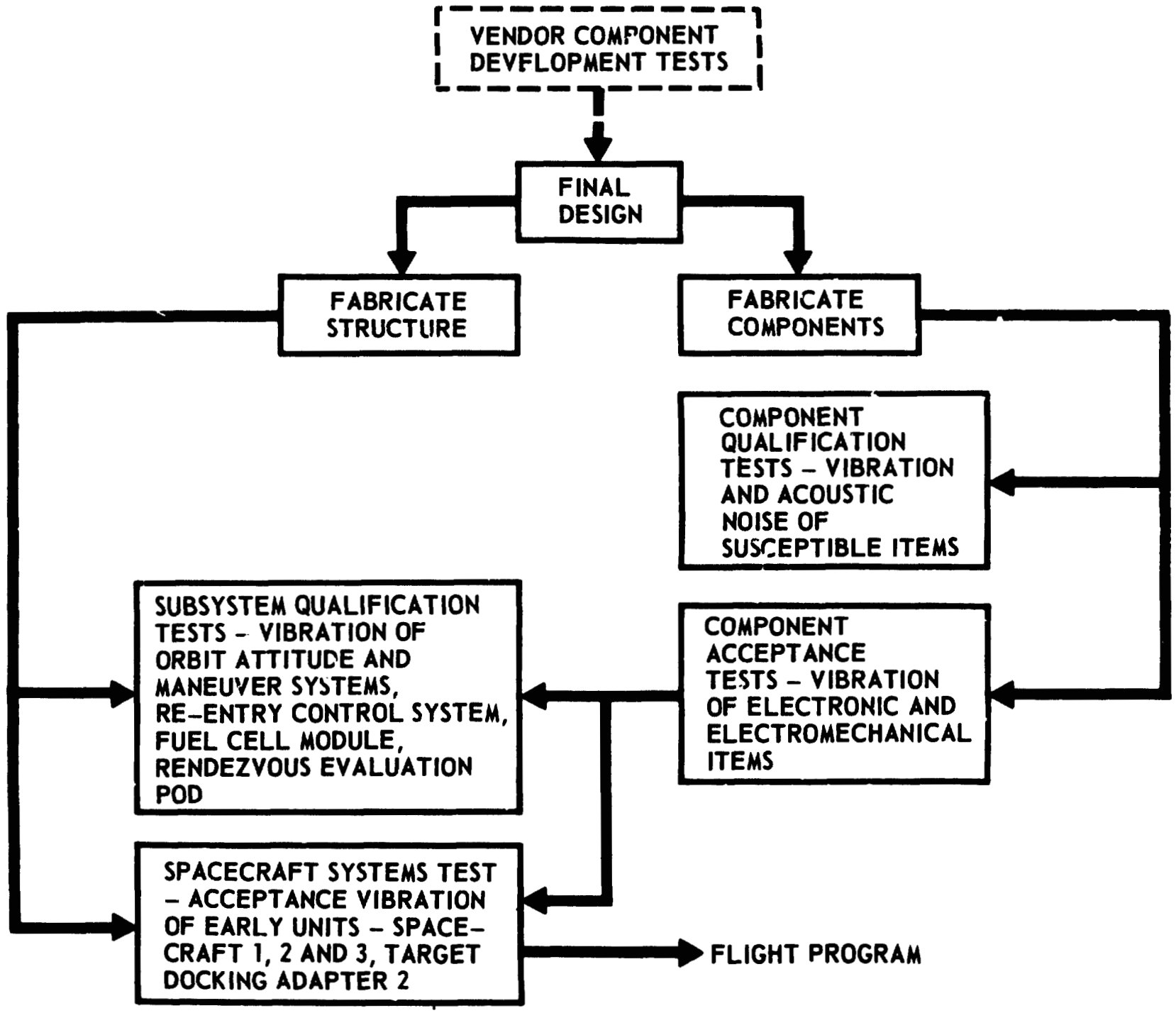


Figure 6-2: LABORATORY VIBRATION AND ACOUSTIC TEST PROGRAM RELATIONSHIPS

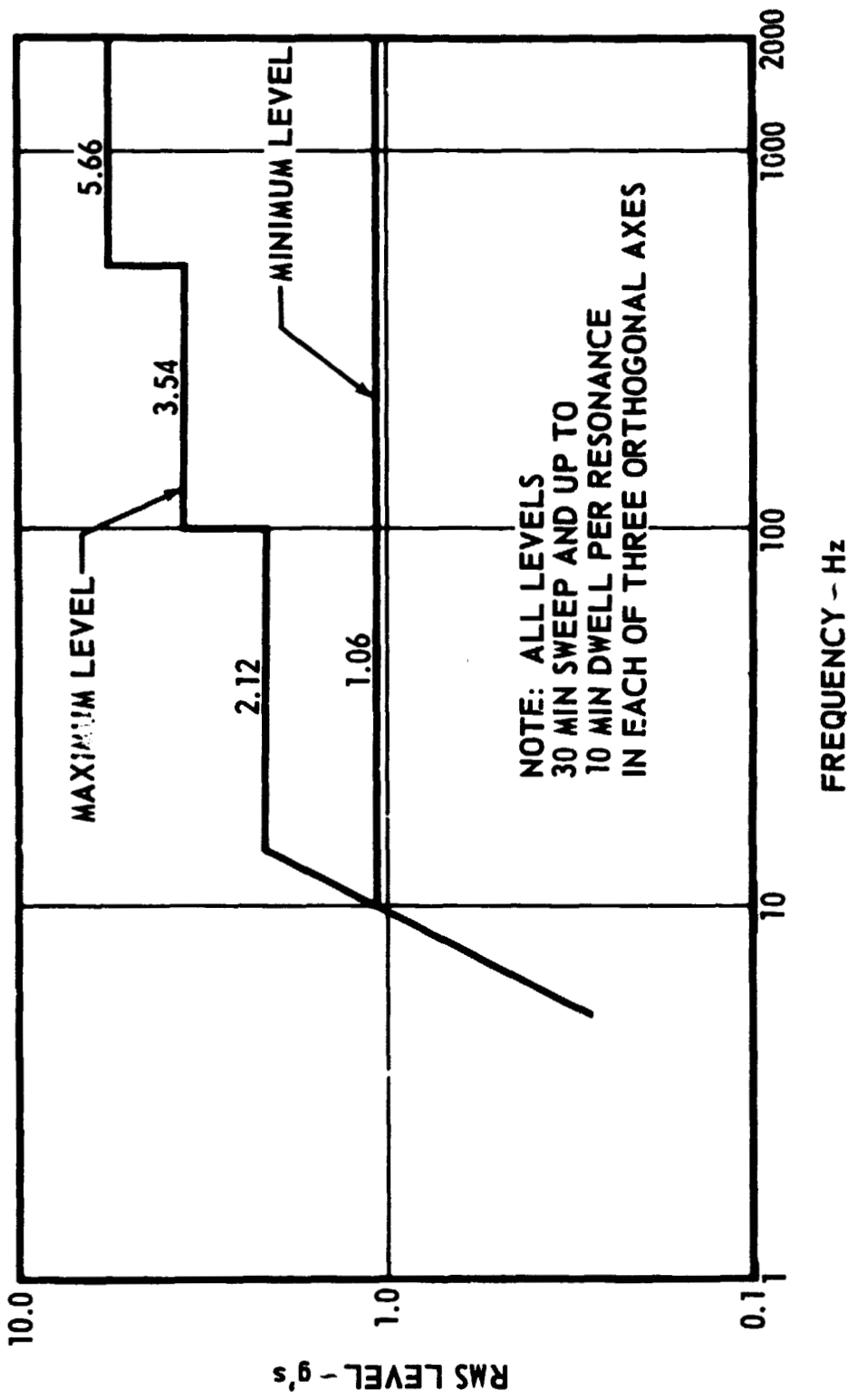


Figure 6-3: ENVELOPE OF COMPONENT QUALIFICATION TEST LEVELS, SINUSOIDAL VIBRATION

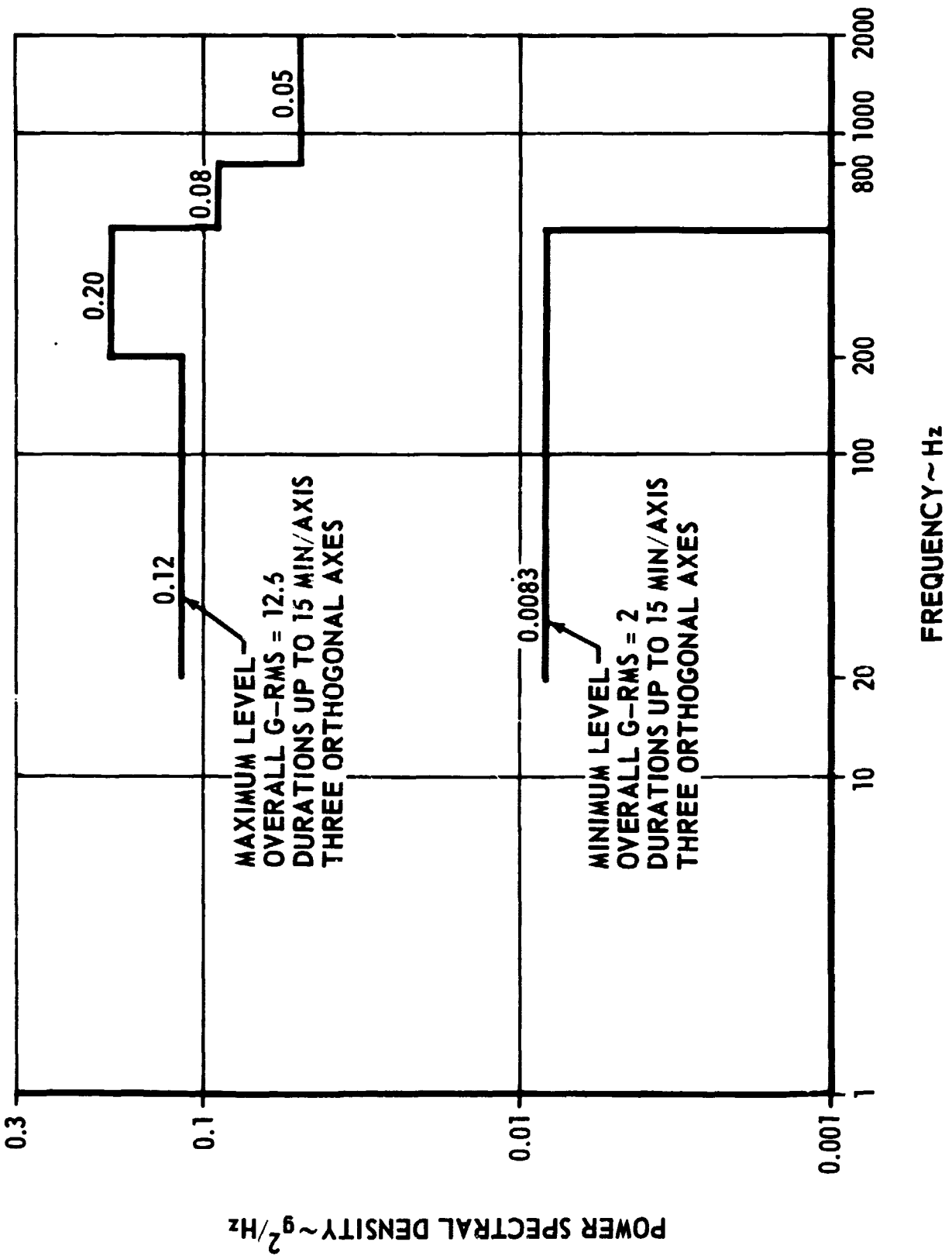


Figure 6-4: ENVELOPE OF COMPONENT QUALIFICATION TEST LEVELS, RANDOM VIBRATION

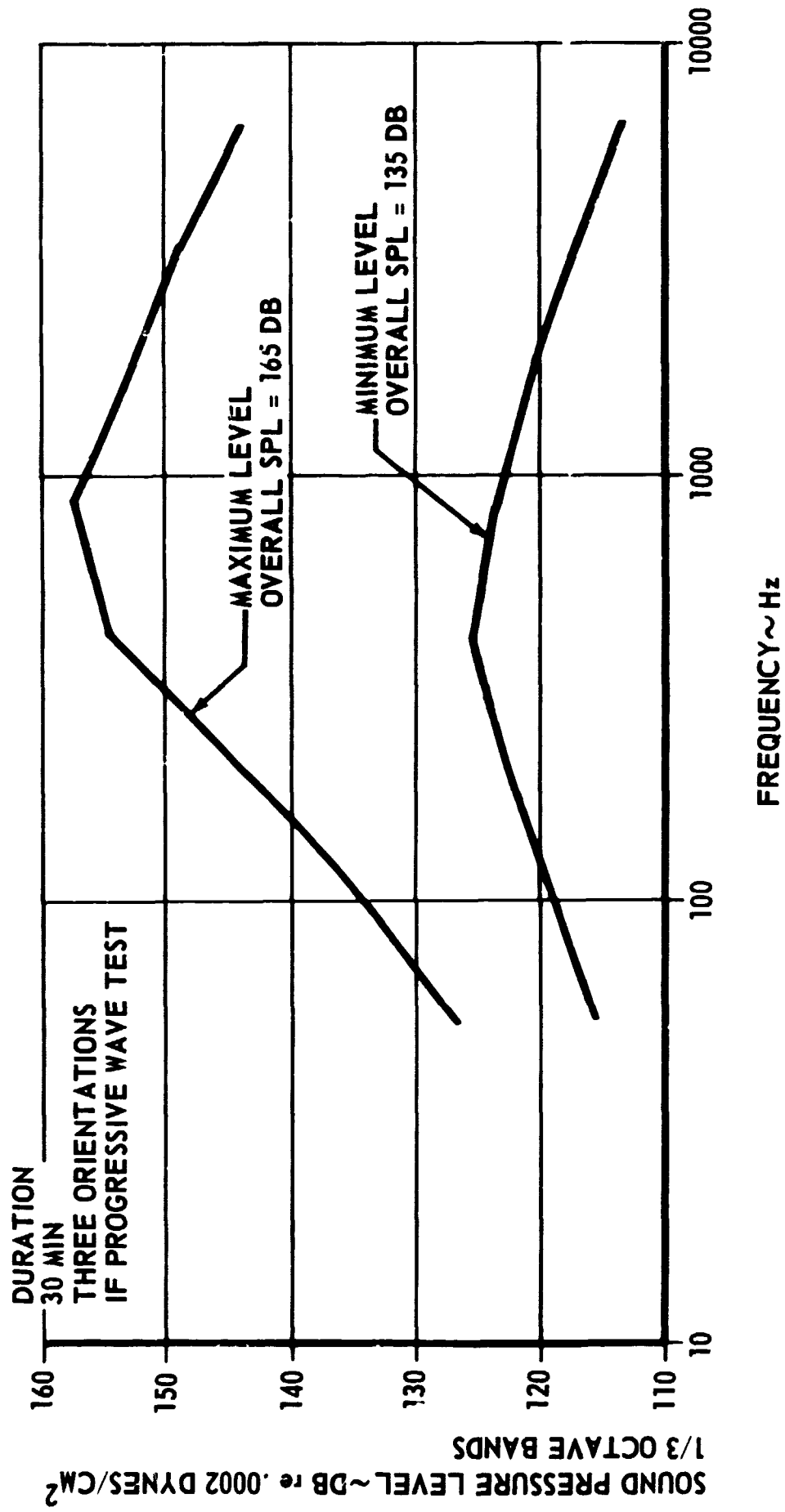


Figure 6-5: ENVELOPE OF COMPONENT QUALIFICATION TEST LEVELS, ONE-THIRD OCTAVE ACOUSTICS

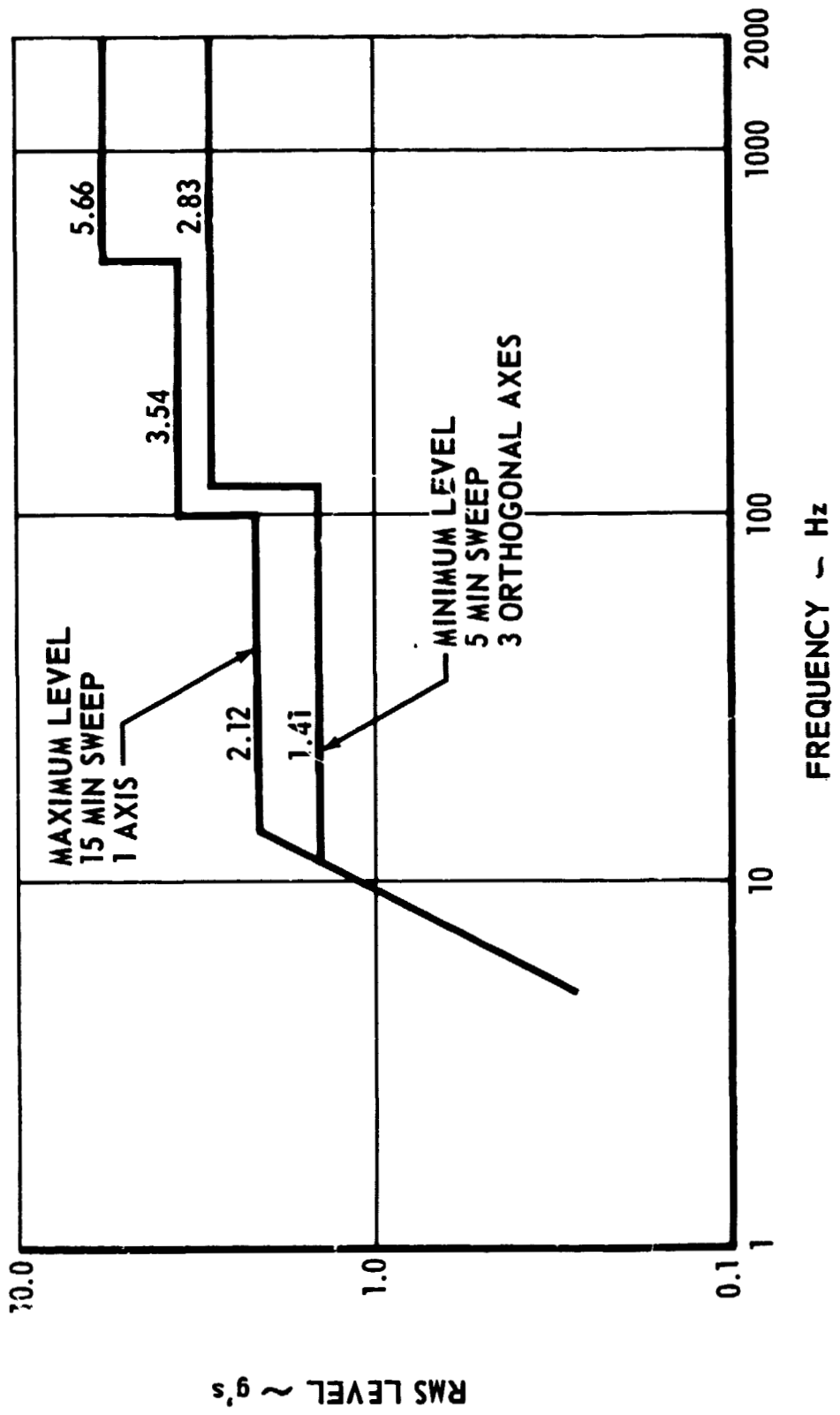


Figure 6-6: ENVELOPE OF COMPONENT ACCEPTANCE TEST LEVELS, SINUSOIDAL VIBRATION

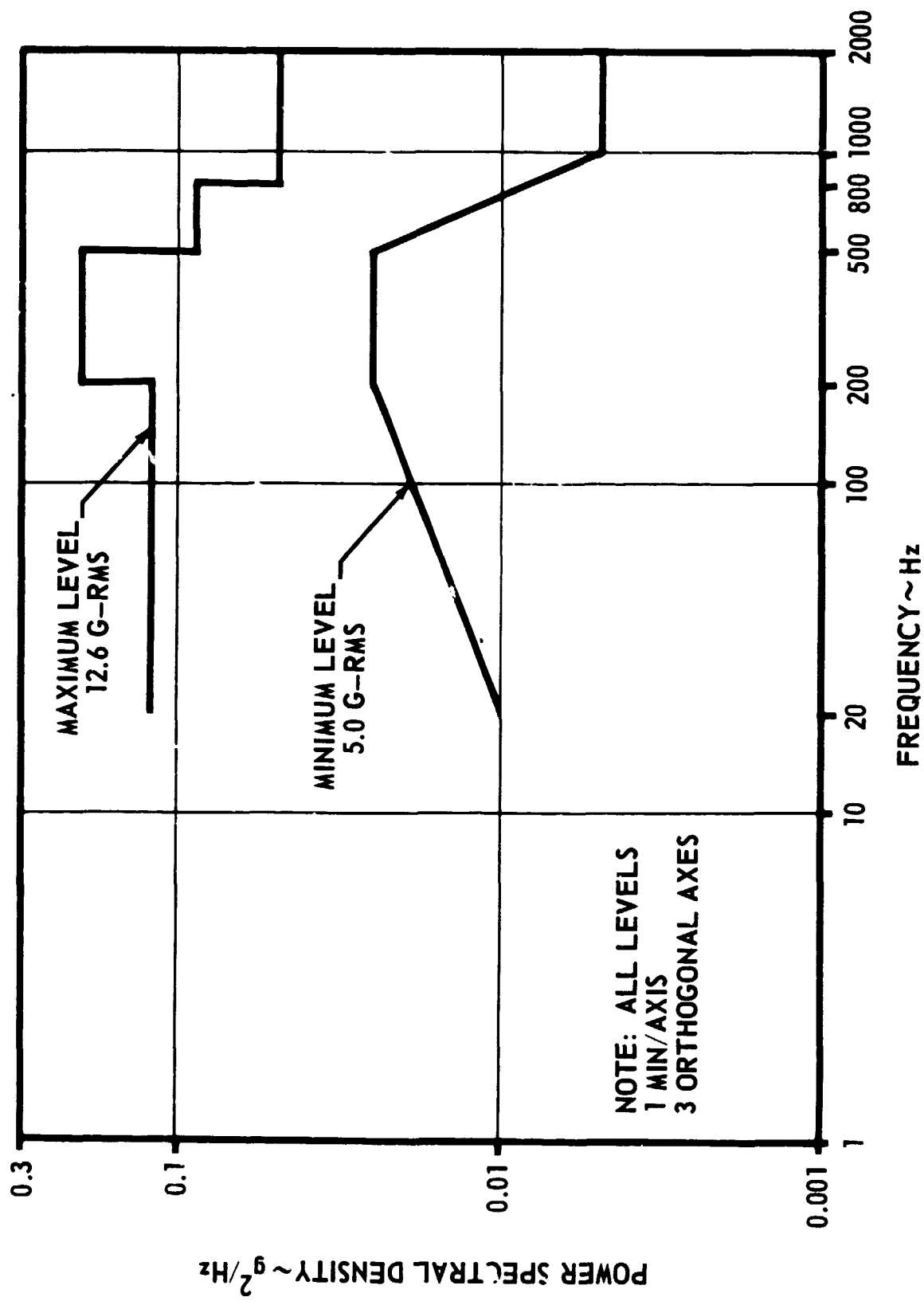


Figure 6-7: ENVELOPE OF COMPONENT ACCEPTANCE TEST LEVELS, RANDOM VIBRATION

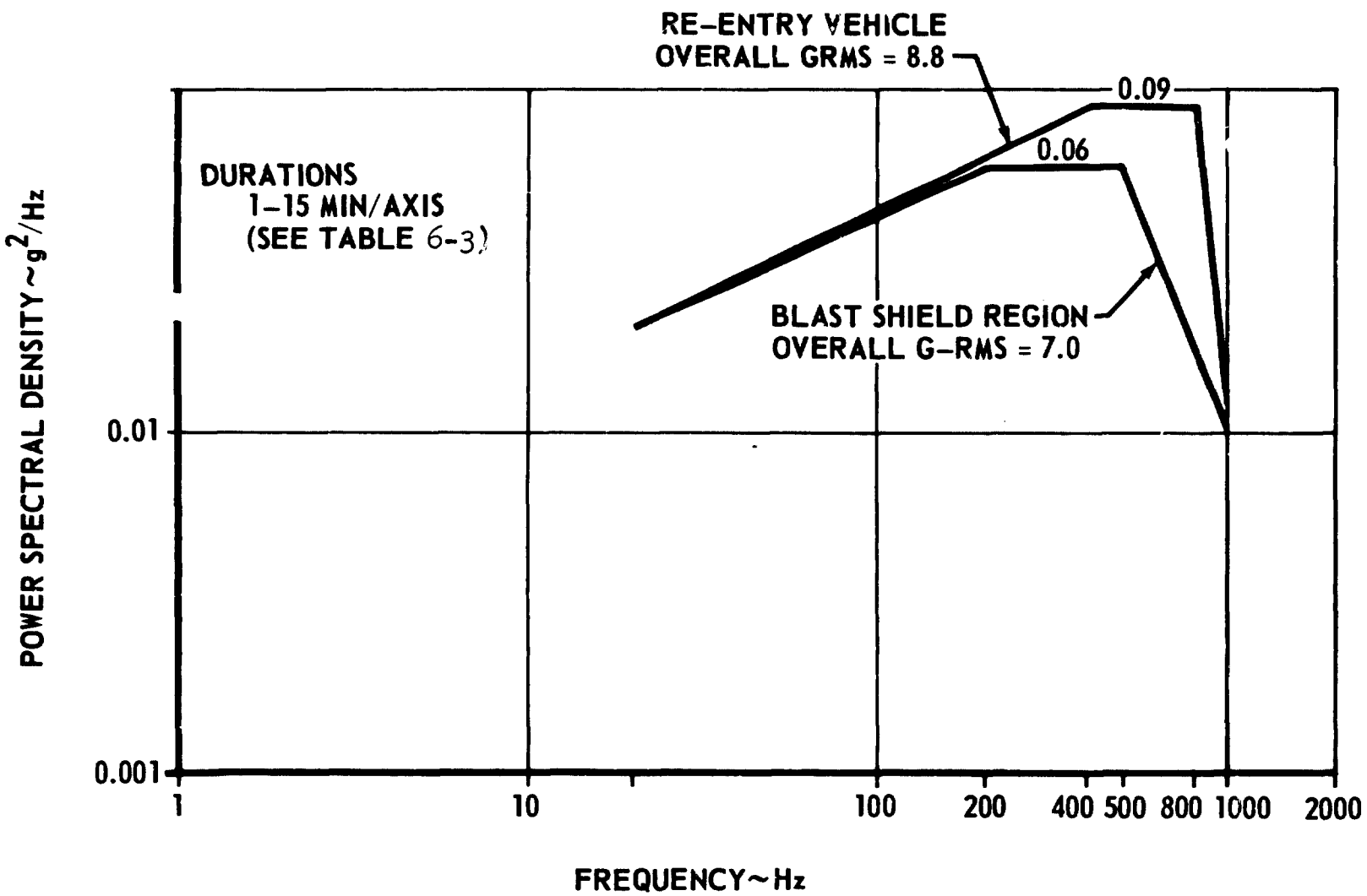


Figure 6-8: GEMINI SUBSYSTEMS VIBRATION QUALIFICATION TEST LEVELS

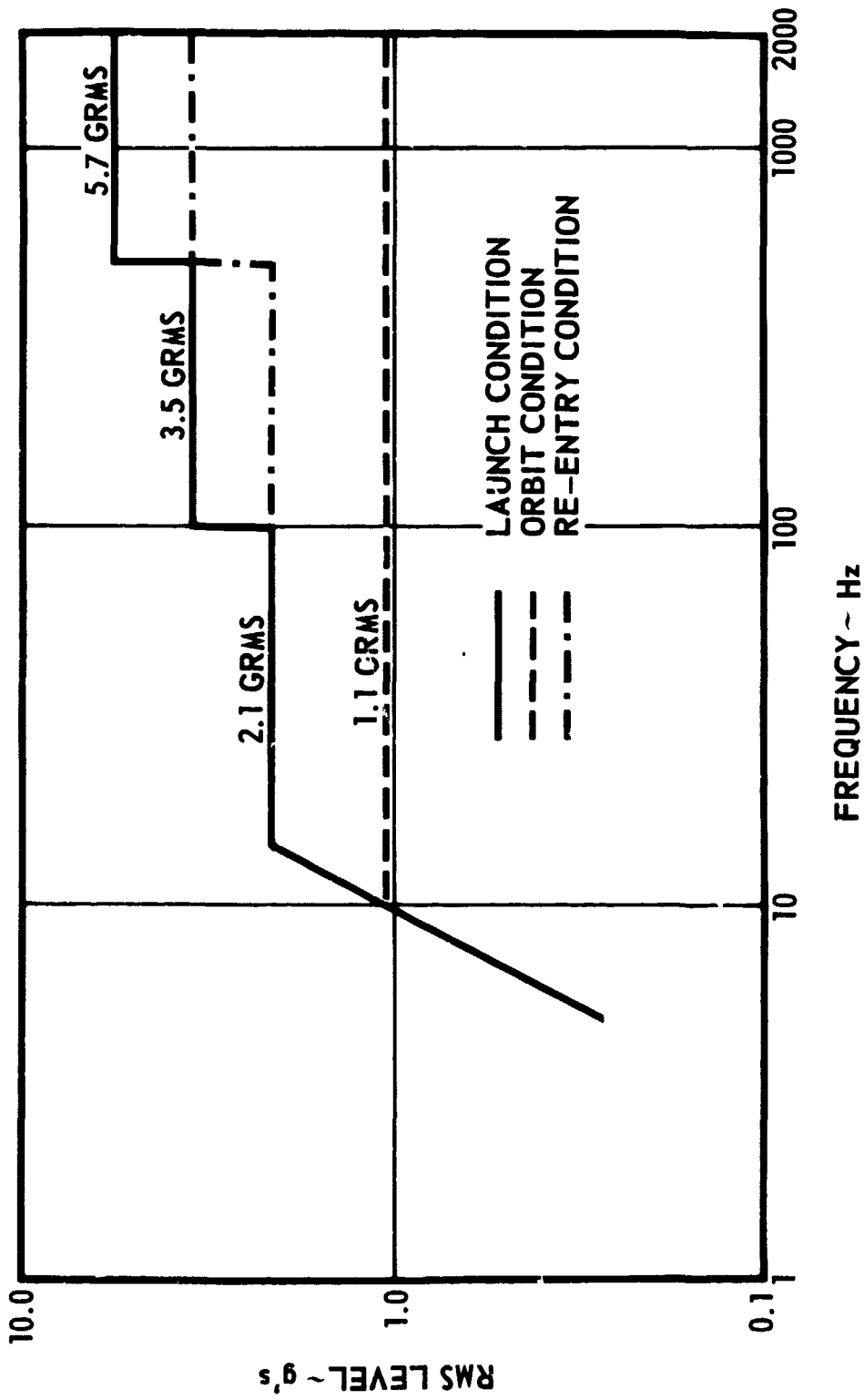


Figure 6-9: COMPONENT QUALIFICATION TEST, SINUSOIDAL SWEEP VIBRATION

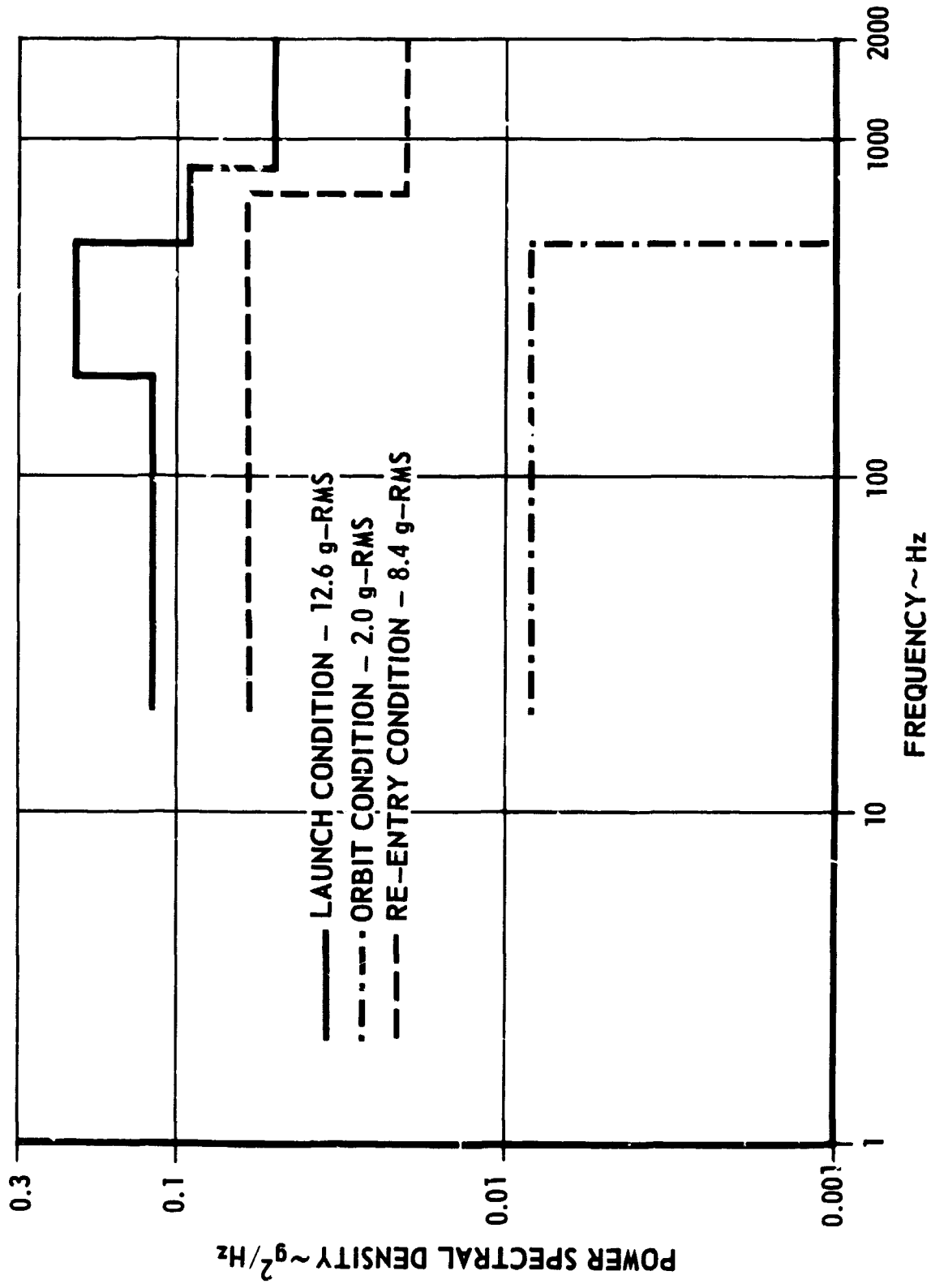


Figure 6-10: COMPONENT QUALIFICATION TEST, RANDOM VIBRATION

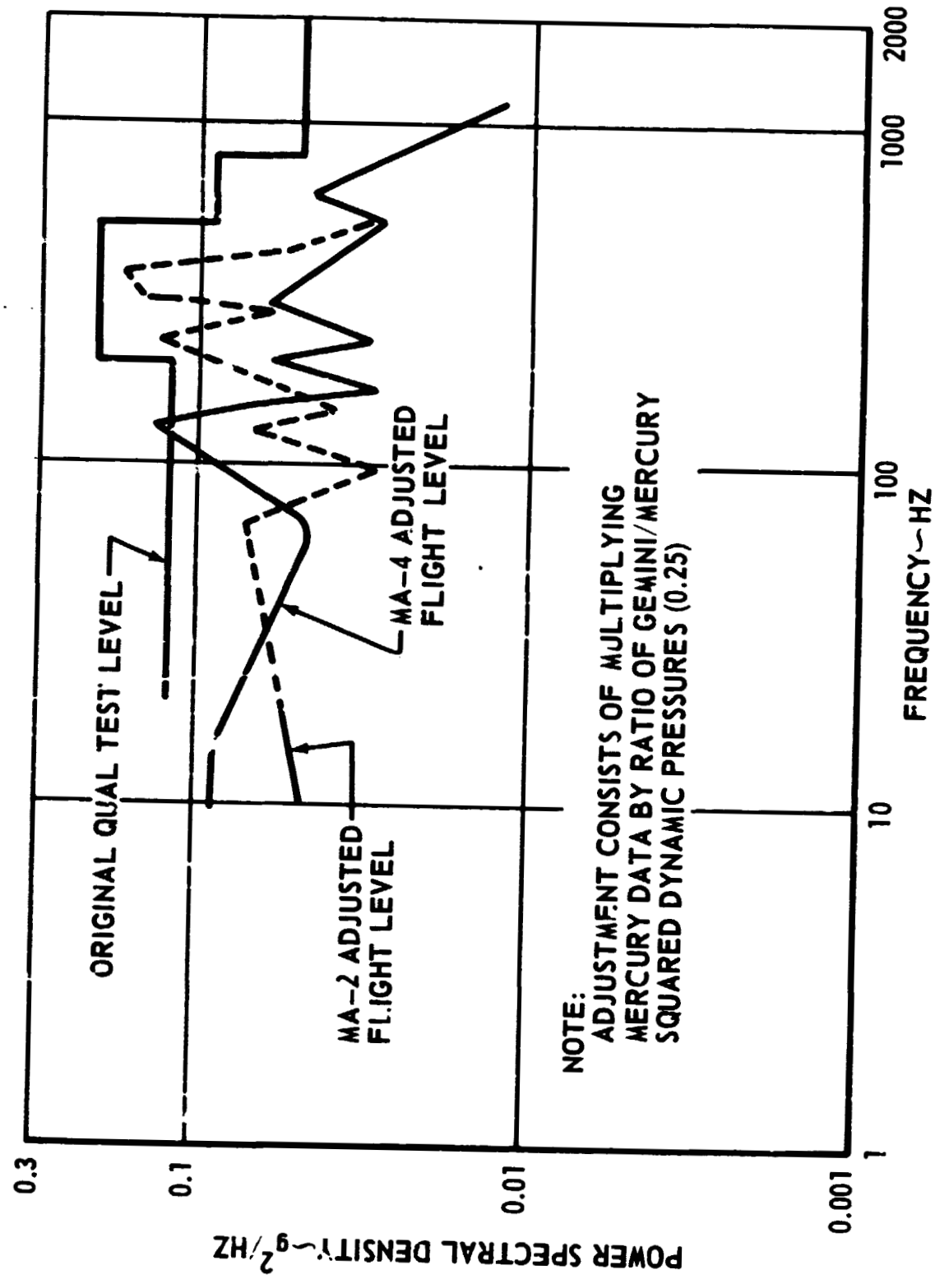


Figure 6-11: DERIVATION OF ORIGINAL QUALIFICATION TEST LEVELS, RANDOM VIBRATION

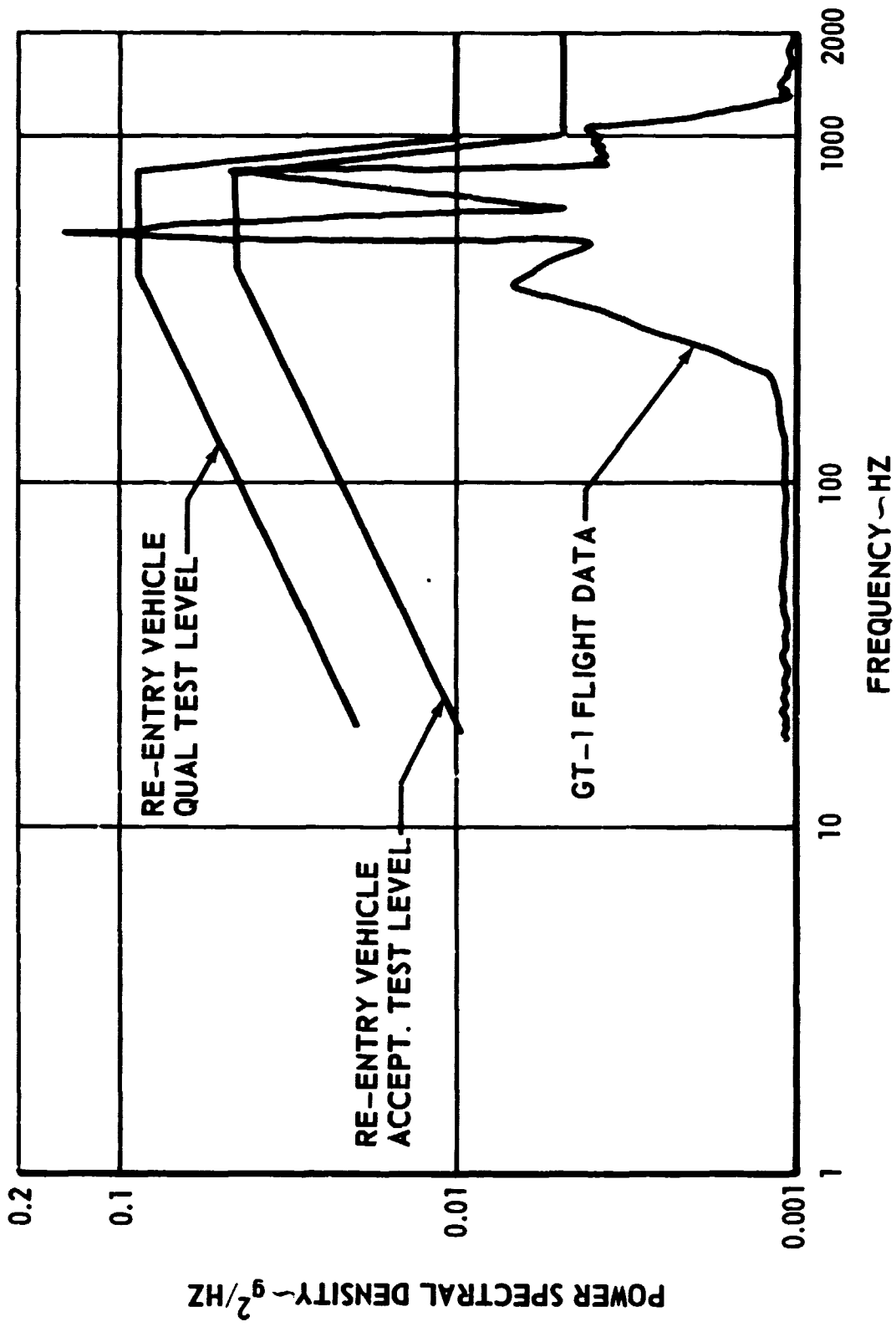


Figure 6-12: DERIVATION OF REVISED RE-ENTRY VEHICLE TEST LEVELS, RANDOM VIBRATION

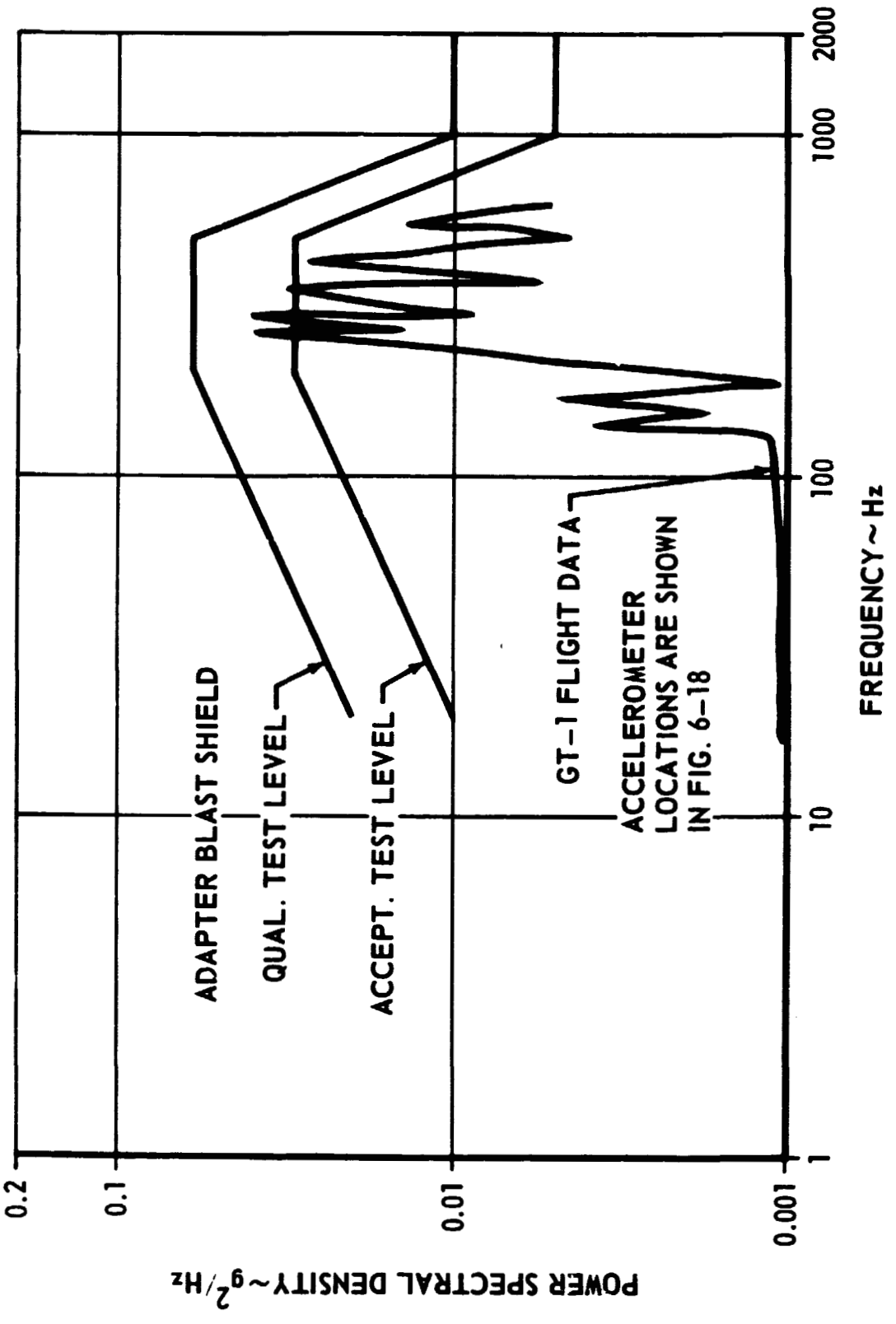


Figure 6-13: DERIVATION OF ADAPTER BLAST SHIELD TEST LEVELS, RANDOM VIBRATION

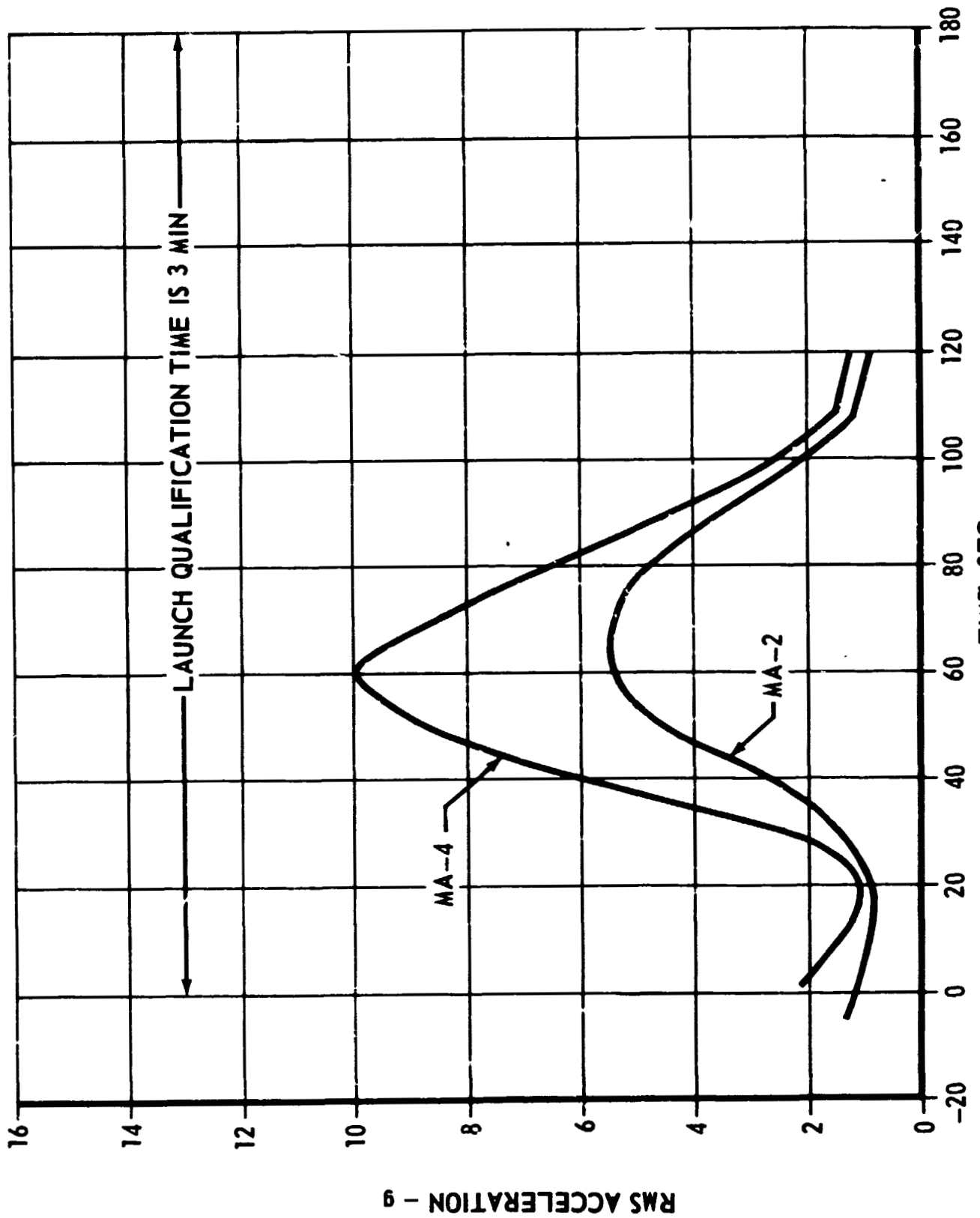


Figure 6-14: COMPARISON OF TIME HISTORIES OF ADJUSTED MERCURY LAUNCH VIBRATION WITH ORIGINAL GEMINI QUALIFICATION TEST TIMES

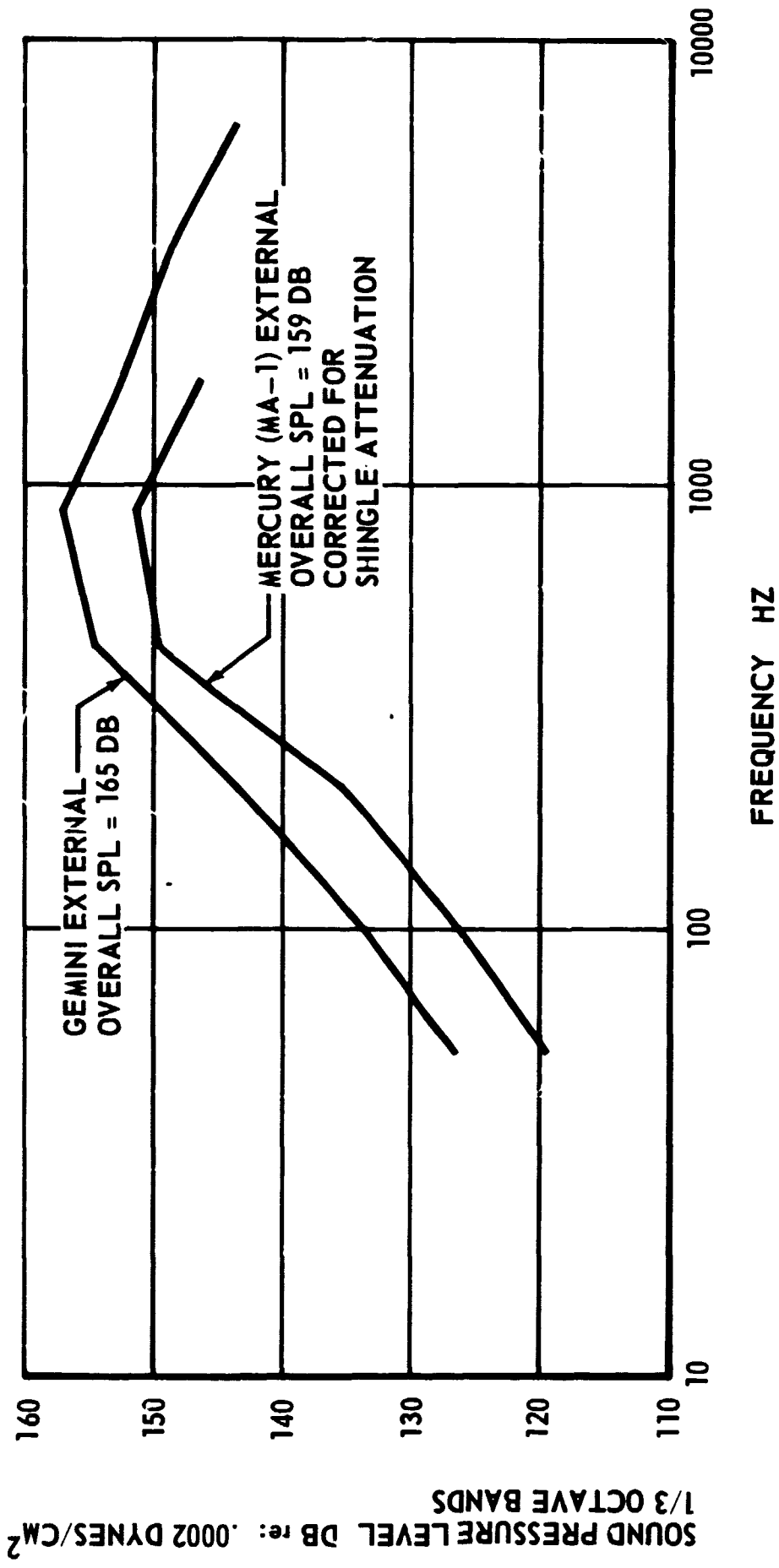


Figure 6-15: DERIVATION OF ORIGINAL EXTERNAL ACOUSTIC TEST SPECTRA.

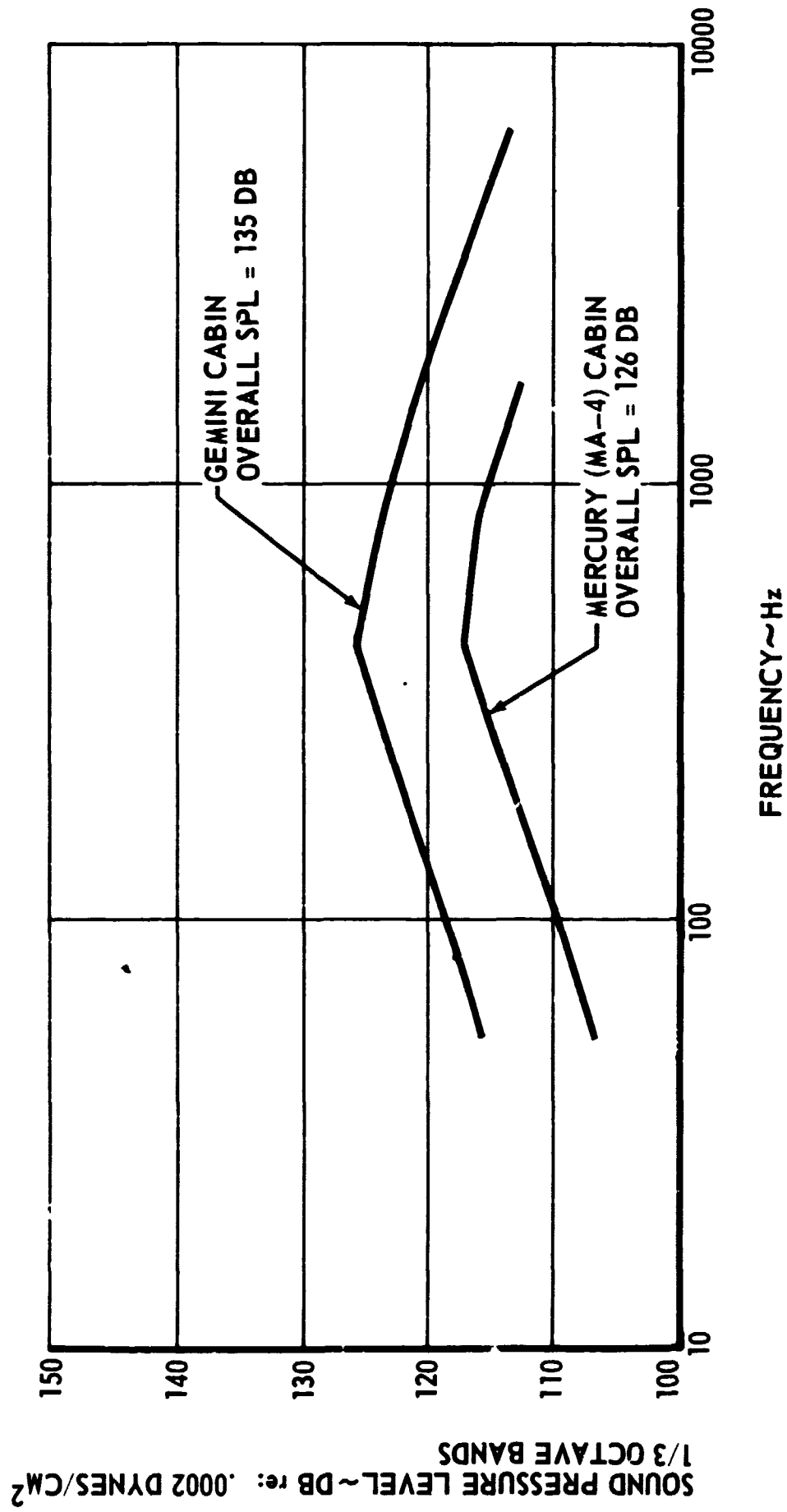


Figure 6-16: DERIVATION OF ORIGINAL CABIN ACOUSTIC TEST SPECTRA

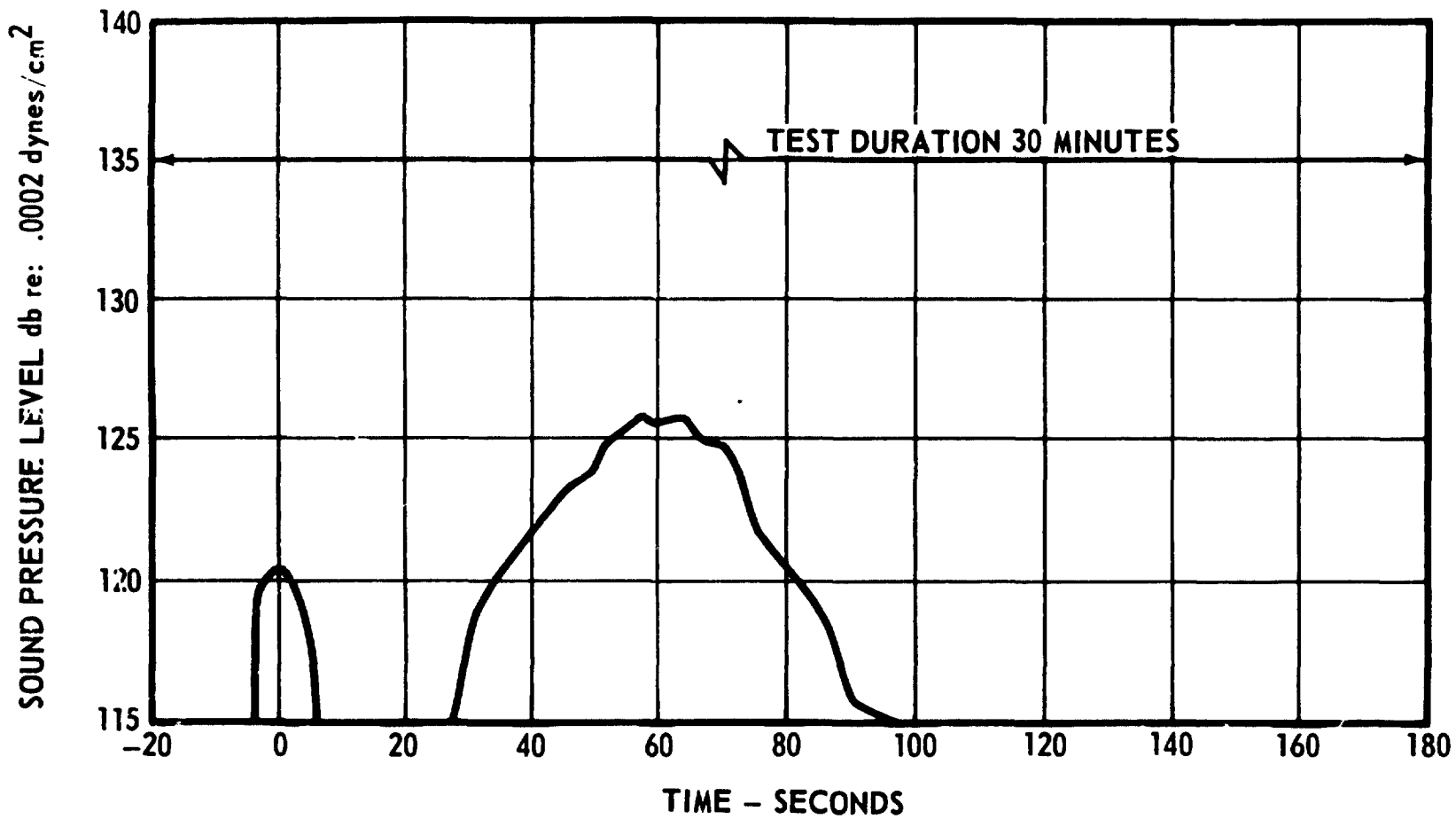


Figure 6-17: MERCURY CABIN ACOUSTIC TIME HISTORY

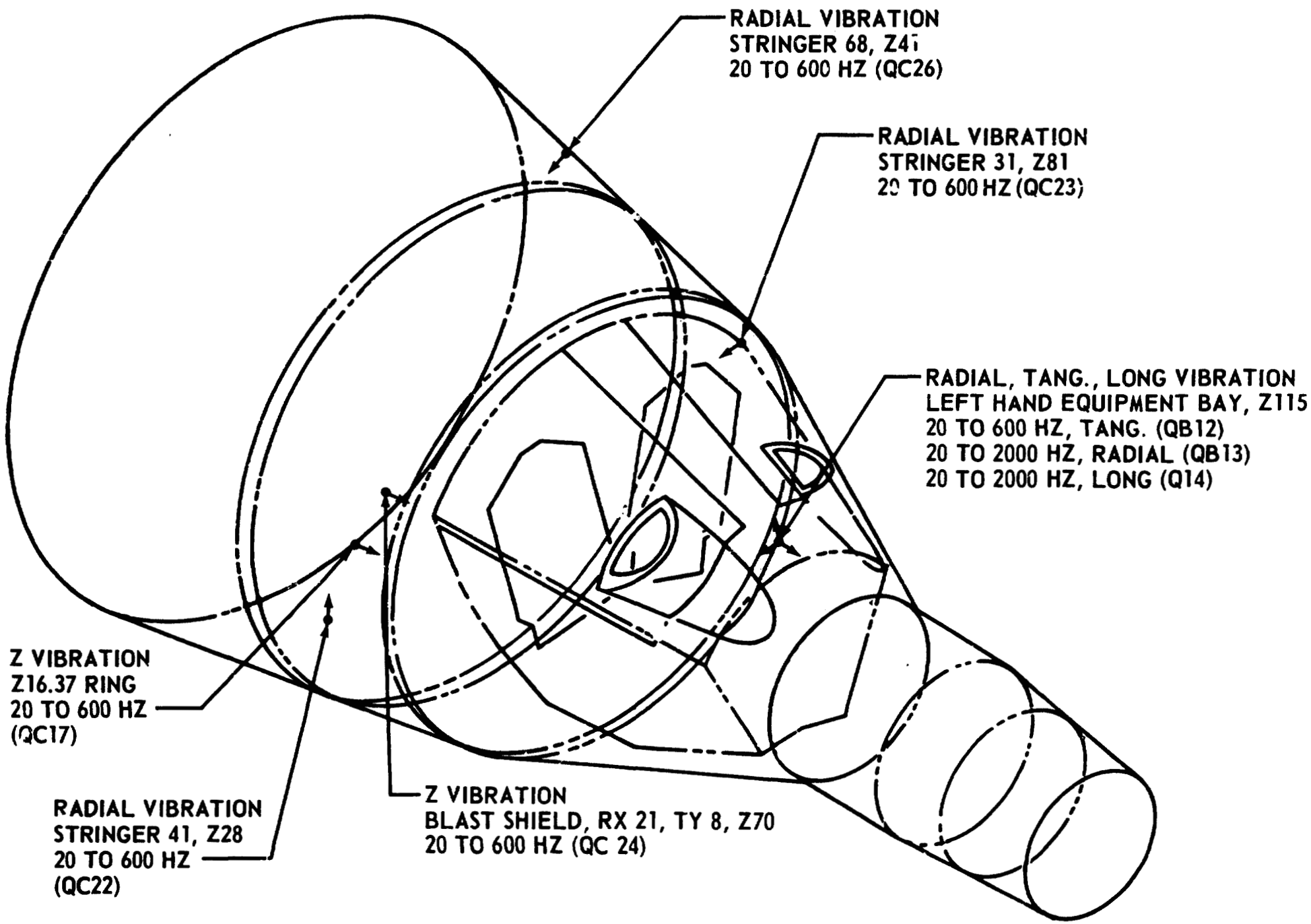


Figure 6-18: GEMINI SPACECRAFT NO. 1 VIBRATION PICKUP LOCATIONS

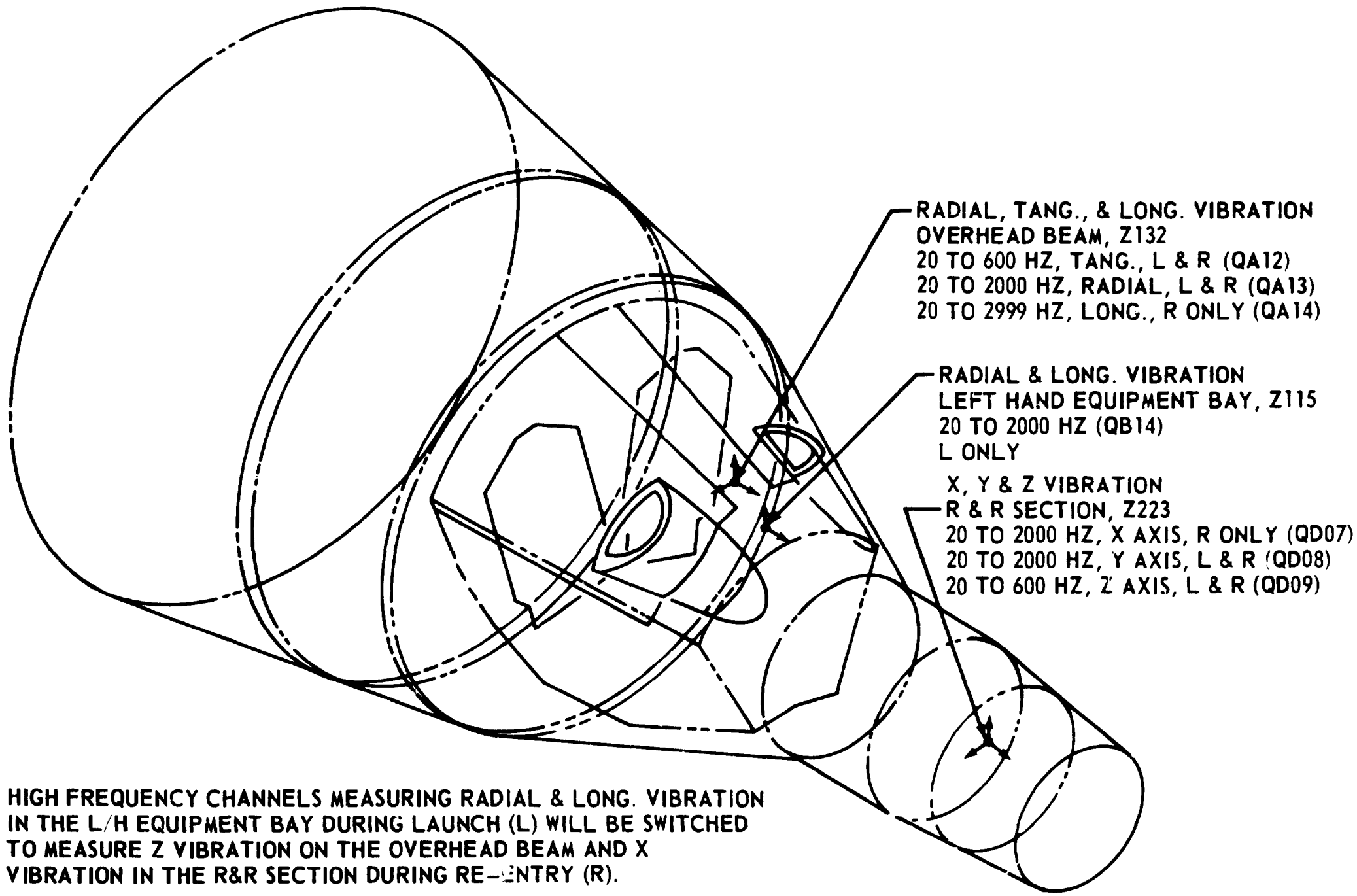


Figure 6-19: GEMINI SPACECRAFT NO. 2 VIBRATION PICKUP LOCATIONS

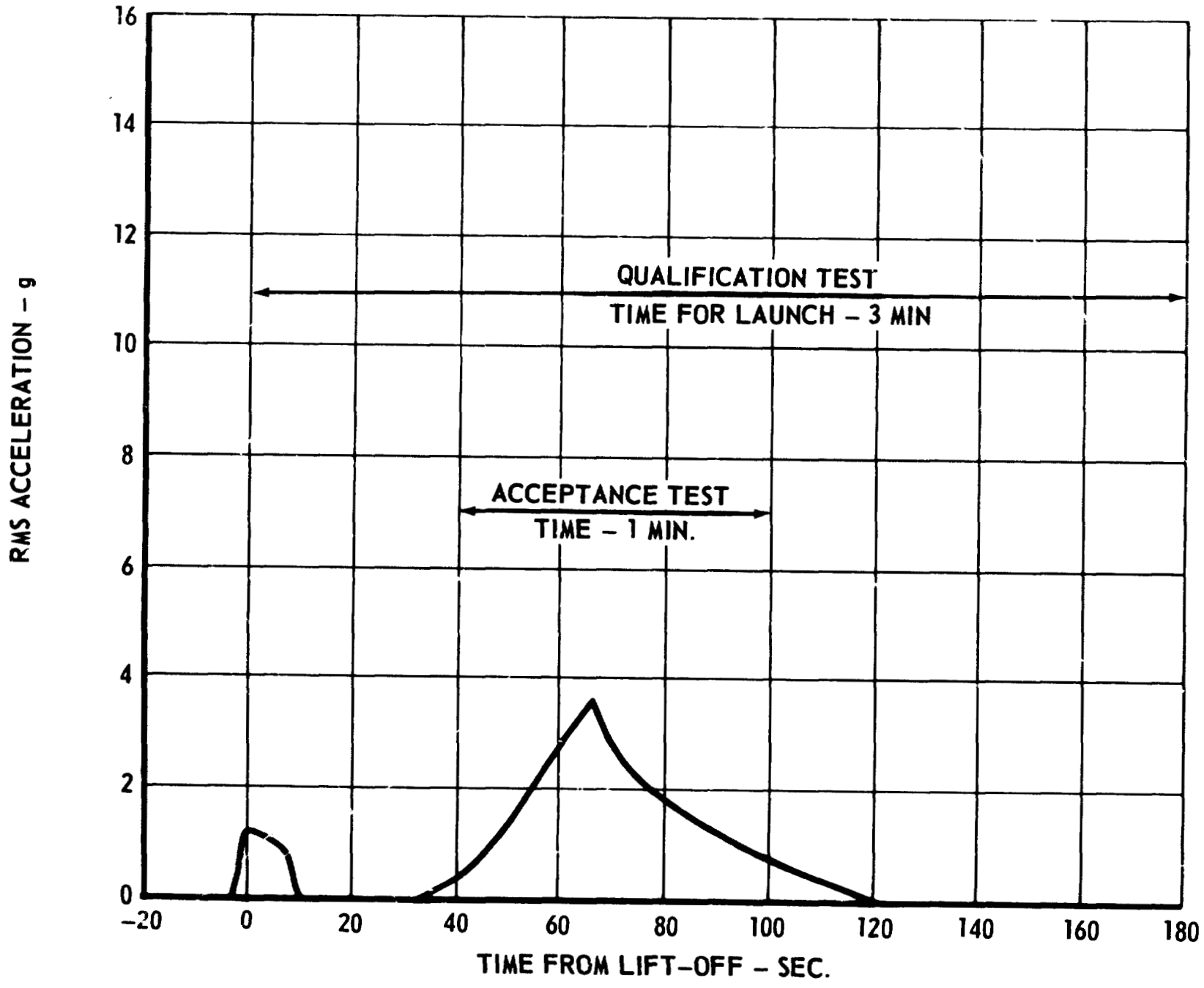


Figure 6-20: COMPARISON OF TIME HISTORY OF GT-1 MEASURED RE-ENTRY VEHICLE VIBRATION WITH QUALIFICATION AND ACCEPTANCE TEST DURATIONS

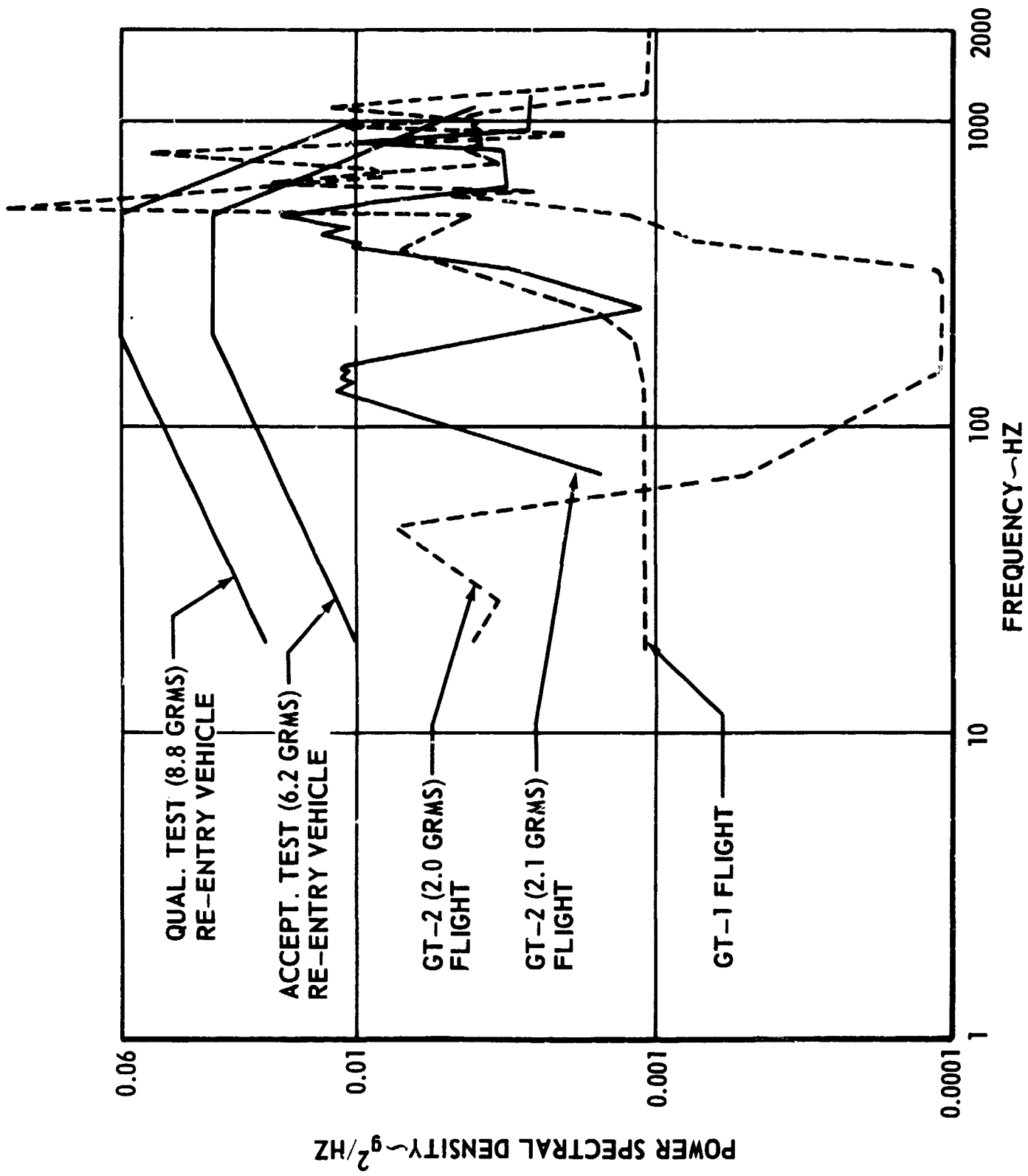


Figure 6-21: COMPARISON OF MEASURED FLIGHT LEVELS TO TEST LEVELS

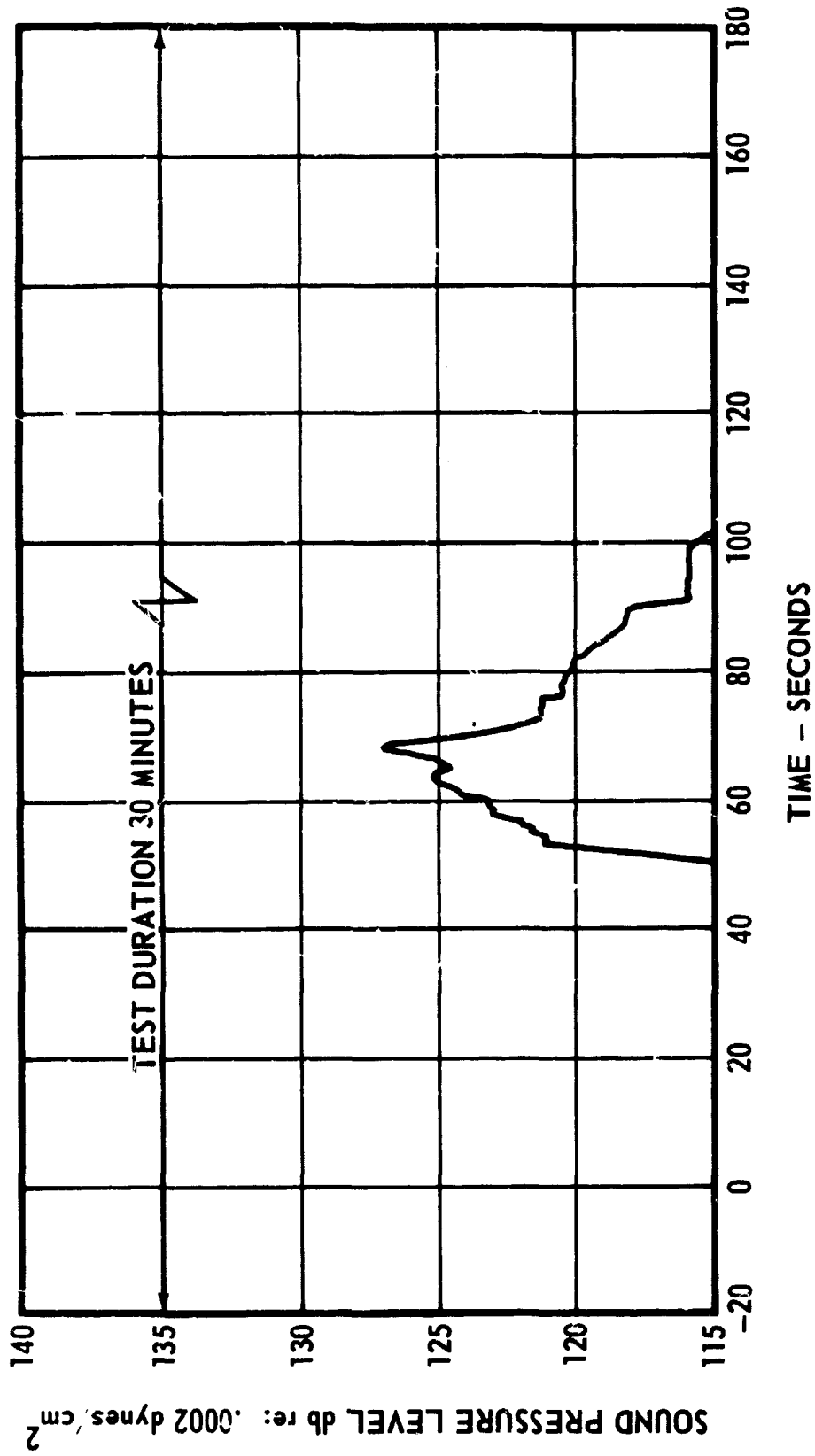


Figure 6-22: COMPARISON OF GT-1 ACOUSTIC TIME HISTORY WITH QUALIFICATION TEST DURATION

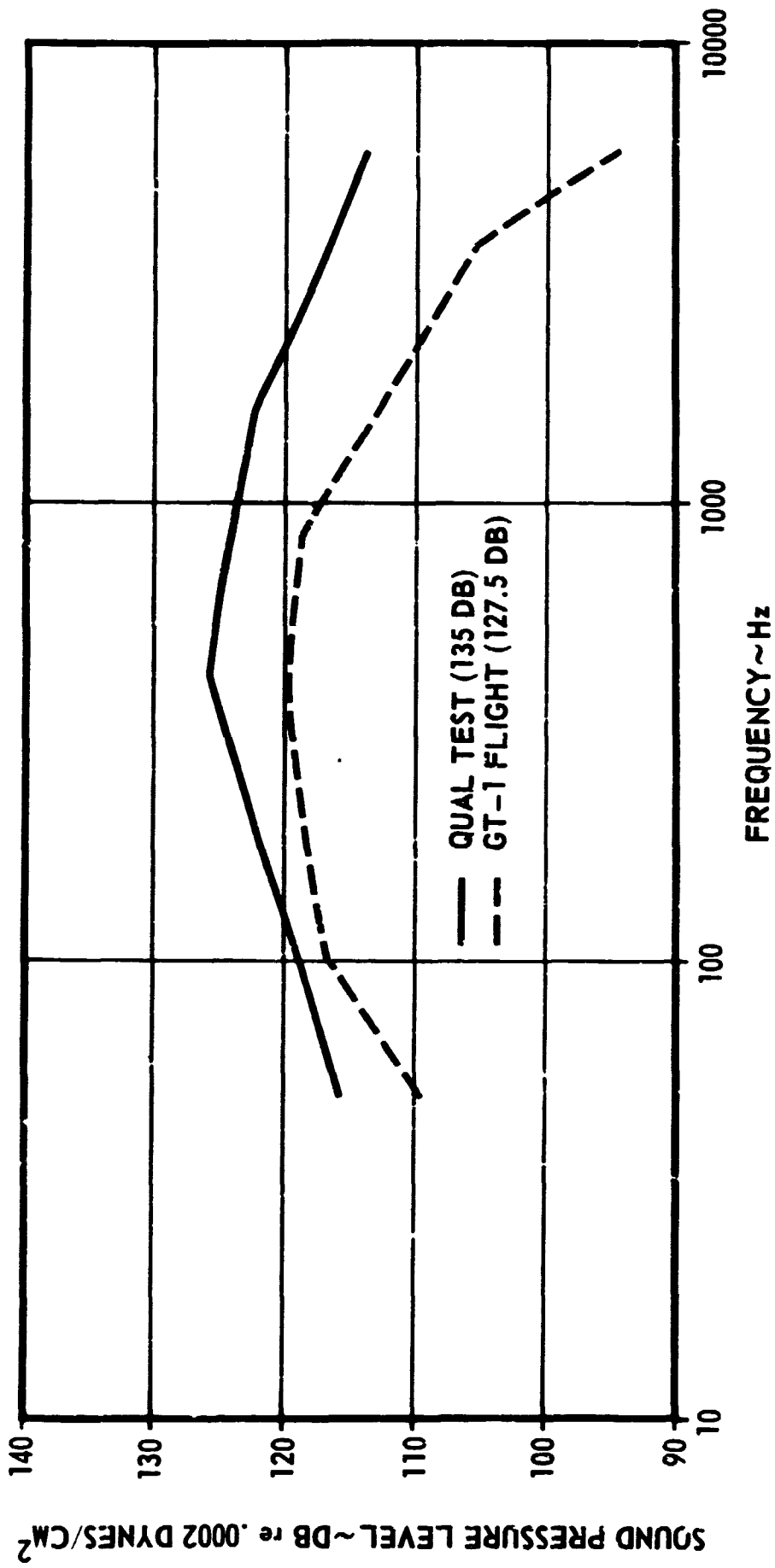


Figure 6-23: COMPARISON OF PEAK GT-1 CABIN ACOUSTIC MEASUREMENT WITH QUALIFICATION TEST LEVELS

SECTION 7

SURVEYOR

7.0 GENERAL INFORMATION - SURVEYOR SPACECRAFT

Project Management - JPL (Prime) - Hughes (Secondary)

Launch Vehicle - Atlas/Centaur

Spacecraft

SD-1
SD-2
SC-1
SC-2
SC-3
SC-4
SC-5
SC-6
SC-7

Surveyor physical characteristics (configuration shown in Figure 7-1).

Weight - 220 lbs.
Diameter - 14 ft. (landing configuration)
Length - 10 ft.

The information presented in this section was obtained from Reference 8.

7.1 LABORATORY TEST PROGRAM

7.1.1 Test Program Rationale

Subsystems used as qualification test hardware were classified 4T upon test completion. This prohibited their use as flight equipment. No other information available on Surveyor test rationale.

7.1.2 Component Vibration and Acoustic Tests

Surveyor documentation uses the term 'control item' to describe the level of tests. Discussions with JPL personnel indicate this designation covers both components and subsystems as defined in this survey. Since no distinction was made between components and subsystems all 'control item' tests are discussed in the subsystem section for convenience.

7.1.3 Subsystem Vibration and Acoustic Tests

Environmental testing at the subsystem level was performed to qualify the subsystem and to establish their flight acceptability before the subsystems were integrated into a spacecraft system.

7.1.3 (Continued)

This minimized the impact of subsystem failures or deficiencies on the spacecraft system integrity, program schedules and cost control.

Each subsystem to be qualification tested was first acceptance tested to establish its workmanship and components as being adequate.

All subsystems to be flown or used as flight spares were acceptance tested before being classified as flight acceptable.

Acceptance test levels for some subsystems were greater than the qualification levels. The main battery, main battery switch, planar array antenna and shock absorbers were examples of "negative" qualification/acceptance margins.

7.1.4 Subsystem Development Tests

No information available.

7.1.5 Subsystem Qualification Tests

7.1.5.1 Objectives

Qualify the subsystem design as functionally and/or structurally adequate. Meet the specification requirements while exposed to specific environmental conditions.

7.1.5.2 Test Levels and Durations

Most subsystem sine sweep vibration tests covered the frequency range of 40 to 1500 hz. In each of three orthogonal axes an envelope of sine levels is shown in Figure 7-2. The figure enveloped 29 spectra.

Random vibration was superimposed on the sinusoidal input between 100-1500 hz at a constant PSD level in each axis of test. The random vibration levels varied from 2.0 to 6.75 grms.

Total time duration in each axis was 12 minutes for all subsystems with a few exceptions. Sweep durations were 6 minutes, 5 minutes or 2 minutes. Sweep rates varied from 1.1 oct/min to 4.1 oct/min.

Acoustic testing was not performed.

7.1.5.3 Subsystems Tested

Vibration qualification tests were performed on 55 subsystems out of a total of approximately 70 subsystems.

7.1.5.4 Operational Requirements

Subsystems required to operate during the descent phase of the mission were given a special functional vibration test. During this vibration testing (random and sine) the units were required to function in the operational mode they would be in during the descent phase of the flight mission.

7.1.6 Subsystem Acceptance Tests

7.1.6.1 Objectives

Verify integrity of workmanship and ability of the units to function as required in the expected flight environments.

Establish workmanship and components on qualification test subsystems as being adequate.

7.1.6.2 Test Levels and Durations

Sinusoidal vibration testing of all flight units in each of three orthogonal axes. Figure 7-3 shows the envelope of test levels.

Total time duration per axis of sinusoidal vibration was 6 minutes.

Generally, sine sweep rate was about 2.6 oct/min.

Random vibration testing was performed on three subsystems (see Figure 7-4).

Random test durations were at least two minutes.

7.1.6.3 Subsystems Tested

All units to be flown or used as flight spares were acceptance tested.

7.1.7 Systems Development Tests

7.1.7.1 General

Early in the Surveyor program, the need for special structural test vehicles was established which resulted in the S-1, S-2, S-2A and S-9 series of vehicles.

These vehicles evolved both in response to need for test vehicles and to changes in design configuration.

These vehicles were comprised of representative structural members and had ballast, dummy or qualification subsystems installed which simulated c.g., mass, inertia and function.

7.1.7.2 Test Configurations

Four test vehicles were used for vibration development tests:

The S-1 structural test vehicle represented an early Surveyor configuration and was used for initial sinusoidal vibration testing.

The S-2 structural test vehicle represented the A-21 spacecraft configuration and was used for sinusoidal vibration testing.

The S-2A structural test vehicle was a modification of the S-2 vehicle in which spacecraft design changes were incorporated and component simulation improved. This vehicle was subjected to both sinusoidal and random vibration.

The initial S-9 structural test vehicle configuration represented the final A-21 configuration and was subjected to a torsional vibration test. After the S-9 configuration was upgraded to the A-21E configuration, it was subjected to both sine and random vibration levels.

7.1.7.3 Objectives

S-1 vibration tests were performed to simulate the specification vibration input and to show flexibility effects of the adaptor.

S-2 vibration tests were performed to qualify the Surveyor space frame and subsystem integrating structures for dynamic loads experienced during launch.

S-2A vibration tests were performed to verify structural integrity of the space frame under development test levels.

S-9 vibration tests (A-21 configuration) were intended to:

Demonstrate that a vehicle with an A-21 flight space frame and substructure and an engineering payload could withstand the specified torsional environment.

Measure the dynamic responses of the thermal compartments and antenna/solar panel positioner for comparison to design loads.

S-9 vibration tests (A-21E configuration) were performed to:

Verify the functional operation of the antenna/solar panel positioner after exposure to simulated launch vibrations;

Verify the structural integrity of SC-5 type hardware.

Demonstrate adequate dynamic clearance between the Centaur shroud and the antenna/solar panel during launch.

7.1.7.4 Test Description and Results

S-1 vibration test consisted of a lateral sinusoidal vibration level of 0.25 grms input at the separation plane in the frequency range from 5 to 200 hz.

Three configurations were tested:

Mounted rigidly to the vibration table,
Mounted on the Centaur payload adapter,
Mounted on the Centaur payload adapter with damping tape applied to the adapter.

S-2 vibration tests consisted of a longitudinal axis test and a series of lateral axis tests with the S-2 mounted rigidly to a fixture at the separation plane. Input vibration levels are shown in Figure 7-5.

S-2A vibration tests were conducted in three orthogonal axes with the S-2A rigidly mounted to a test fixture at the spacecraft/adaptor attach points. The input vibration levels are shown in Figure 7-6.

S-9 torsional vibration tests were performed with the vehicle in the stowed position and attached to the Centaur payload adaptor which was rigidly attached to a test fixture. The torsional environment was applied about the vehicle's roll axis and controlled at the spacecraft/adapter attach points. The levels are shown in Figure 7-7.

S-9 vibration tests were conducted with the vehicle rigidly mounted to the test fixture at the spacecraft/adaptor attach points. The vibration inputs are shown in Figure 7-8.

7.1.8 Systems Qualification Tests

7.1.8.1 General

Qualification tests were performed to qualify the complete spacecraft system.

This was the first test phase to qualify the electronic subsystems integrated into the spacecraft system.

7.1.8.2 Objectives

Verify functional operation and structural integrity during and after vibration.

7.1.8.2 (Continued)

Establish test criteria level and standards for use in system acceptance testing.

Verify adequacy of clearance between spacecraft and centaur shroud during launch.

Qualify Surveyor spacecraft design for establishment of test methods, techniques and procedures used in system acceptance tests.

7.1.8.2 Test Levels and Durations

Swept sinusoidal vibration tests were performed in three axes from 5-100 hz (see Figure 7-9).

Complex wave vibration tests consisting of combined sinusoidal and random vibration from 100-1500 hz, were performed in three axes (see Figure 7-9).

7.1.8.3 Test Configuration

T-21 spacecraft vehicle was used for all systems qualification tests.

The T-21 configuration represented the flight spacecraft design electrically and mechanically.

All functional requirements of the flight spacecraft were imposed on the T-21.

Control for sine tests was obtained from three fixture-mounted accelerometer sensitive in the direction of shake.

Control for random tests obtained from a single fixture-mounted accelerometers sensitive in the direction of shake.

7.1.8.4 Test Results

No major failure occurred during the systems qualification test program which would have demonstrated inherent design weaknesses.

There were, however, a considerable number of minor problems which developed during the test program and were cleared up prior to the first spacecraft flight.

7.1.9 Systems Acceptance Tests

7.1.9.1 Objectives

Verify functional operation during and following simulated launch.

Serve as a quality control check on fabrication and spacecraft assembly.

7.1.9.1 (Continued)

Verify that spacecraft subsystems alignments were not degraded by exposure to vibration.

7.1.9.2 Test Levels and Durations

Vibration inputs to the spacecraft in each of three orthogonal directions (one longitudinal and two lateral) consisted of:

Low frequency (5-100 hz) sine tests (see Figure 7-10).

High frequency (100-1500 hz) combined sine-random tests (see Figure 7-10).

Control was obtained from fixture-mounted accelerometers sensitive in the direction of shake.

7.2 LABORATORY TEST FAILURES

7.2.1 Component Vibration and Acoustic Test Failures

Components not distinguished from subsystems by Surveyor documentation (see paragraph 7.1.2).

7.2.2 Subsystem Development Test Failures

No information available.

7.2.3 Subsystem Qualification Test Failures

Detailed failure information is not available for the Surveyor subsystem test program. The following comments were made relative to the subsystem qualification test results.

Documentation for SC-7 indicates that all subsystems except four have passed all required qualification tests. These four units had been reviewed, and were cleared for the flight spacecraft. The SC-1 documentation indicated five subsystems had not successfully passed or had not been exposed to all required qualification tests.

Approximately 35 SC-1 subsystem test specifications had discrete requirement differences from the general test specification. There were also indications the qualification tests were not always performed exactly to subsystem specification requirements.

In some instances the acceptance tests of flight equipment were completed before the qualification of the equipment design was accomplished. These early acceptance tests contributed to the evaluation of design adequacies.

7.2.3 (Continued)

Design configurations of the flight equipment were modified as necessary during the course of the surveyor program. Qualification tests were required by the cognizant engineers as deemed necessary to requalify the unit. Many design changes were not requalified.

Some configuration changes were qualified with a partial re-qualification test. An example of a partial qualification test is a vibration test performed on an electrical chassis to qualify revised welding techniques.

Examples of complete requalification testing are the ASPP, TV camera, boost regulator, battery charge regulator, transmitter, helium tank, solar panel and the altitude marking radar. These units were redesigned for the SC-5 through SC-7 spacecraft. (JPL qualified the new solar panel).

7.2.4 Subsystems Acceptance Test Failures

Detailed failure data were not available for the Surveyor subsystem acceptance test program. The following comments relate to the acceptance test results.

The acceptance test history of many subsystems consists of a very significant number of retests. The retests were required primarily by repairs and rework following failures. In some cases the units were upgraded and retested. Hughes Aircraft Company placed no limitations on the number of environmental tests that could be performed on any unit unless fatigue analyses limited the number of test cycles. The retest decisions were dictated by the failure and resulting repairs.

The qualification and acceptance test configurations of environmental tests conducted by the contractor were not always consistent. Examples of these differences are shown below.

VIBRATION TEST CONFIGURATION DIFFERENCES

Subsystem	Qualification Configuration	Acceptance Configuration
Ant/Solar Panel Positioner	Installed on S/C Structure	Installed on Shake Fixture
Secondary Sun Sensor	Installed on Solar Panel Substrate	Installed on Shake Fixture
Attitude Control Gas Supply Plumbing	Tested at Tank Level with Mass Mockups	Tested as Assembly with Valves and Regulators

7.2.5 System Development Test Failures

No information available.

7.2.6 System Qualification Test Failures

No major failures occurred during the system vibration qualification test program which would have demonstrated inherent design weaknesses.

Considerable amount of minor problems occurred which were cleared up by ECR (Engineering Change Request) prior to the first flight spacecraft test.

7.2.7 System Acceptance Test Failures

7.2.7.1 General

On several occasions during more than two years of flight spacecraft testing, minor anomalies in either test procedure, test control or data analysis occurred.

Only one anomaly was of sufficient proportion to require major spacecraft rework and retest. This was a transient input to the SC-2 spacecraft.

7.2.7.2 SC-2 Shaker Transient Input

A transient was introduced to the SC-2 spacecraft through the shaker system during systems acceptance vibration testing.

The transient input in the direction of shake resulted in levels greater than 30 g's peak, and lasted approximately 110 milliseconds.

The response of the retro motor in longitudinal, perpendicular to shake, and axis of shake direction was greater than 30 g's, 9 g's and 9'g respectively.

Based on retro design constraints, the maximum acceleration level permitted for the retro during test was 15 g's. These transient levels then yielded serious damage potential and accounted for retro motor support system failure at leg 1.

Major effects on spacecraft were:

(1) Retro motor support system at leg 1 failed.
(2) Bathtub fittings at legs 1 and 2 failed.
(3) Column base fittings inspection indicated holes for attachment to adapter out of alignment .0005-0015 inches.
(4) One solar panel support brace disengaged from the solar panel during the transient and the threads were found to be elongated.

7.2.7.2 (Continued)

"Further, compartments A and B support tubes were visually inspected and X-rayed and no failures were noted. Torque on all accessible bolts were within specs the ASPP was stepped and functioned properly; all other accessible support structures were visually inspected. Additional low frequency vibration tests (one at low level, the other at full level) were performed and the agreement in response between the same test before and after the transient appeared to demonstrate that structural integrity of the spacecraft had not been compromised."

7.2.7.3 Spacecraft Retests

During the course of the Surveyor system level acceptance vibration program, four spacecraft underwent retesting.

SC-1--complete one axis test performed to subject redesigned flight hardware to z axis vibration. Special tests and troubleshooting sequences were performed to qualify reworked and upgraded equipment for flight readiness.

SC-2--to demonstrate confidence in the integrity of the spacecraft and to further investigate a possibility of failure following the transient input, two low frequency tests in a lateral axis were run. They consisted of 2 octave per minute sine sweeps from 5-100 hz at 0.25 g o-pk and 1.33 g o-pk respectively. Agreement between these runs and the one prior to the transient helped to insure flight worthiness.

SC-3--a short in ground equipment during initial spacecraft mechanical operations at AFETR resulted in failure of the flight control sensor group and suspected electrical overstressing of other units, necessitating considerable rework; bladders on two oxidizer tanks were inadvertently collapsed also during this period. A decision was made to re-verify spacecraft integrity with a complete roll axis vibration test.

SC-6--low frequency test between 5-100 hz in the lateral axis to verify that the pins on the pinpullers on the ASPP did not exceed their motion tolerance and back out.

7.3 FLIGHT FAILURES

"There were no flight failures attributed to the vibration environment."

7.4 DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS

7.4.1 Component Test Levels

No distinction made between components and subsystems (see Paragraph 7.1.2).

7.4.2 Subsystem Test Levels and Durations

7.4.2.1 Vibration Levels

Structural test models were vibrated with a sinusoidal input to determine the response of individual subsystems.

Using these responses and the environmental predictions made early in the Surveyor program for systems level tests, the response levels for each subsystem were extrapolated.

The envelope of these response levels were used to derive test requirements for individual subsystems.

7.4.2.2 Test Durations

No information available on derivations at subsystem level.

However, the duration per axis of test (12 min) is the same as is the systems qualification tests.

7.4.3 Systems Test Levels and Durations

7.4.3.1 Random Vibration Levels

Random vibration acceptance test level represents the mean of the Ranger spacecraft random vibration flight data.

Mean level specified for two reasons:

Surveyor less subject than Ranger to acoustic excitation because of Surveyor being further away from acoustic source on the Centaur vehicle.

Shroud protecting Surveyor was assumed to provide more attenuation of acoustic energy.

7.4.3.2 Sinusoidal Vibration Levels

Original sinusoidal environment was based on Ranger data.

Original estimate higher than Ranger data in the lower frequencies because it was felt that Surveyor/Centaur would have a higher modal density in the lower frequencies than the Ranger/Agena.

Original estimate corresponded to the maximum from the Ranger data in the higher frequencies.

Original estimates were lowered because:

The original assumptions were questionable,

7.4.3.2 (Continued)

Dynamic data from Atlas/Centaur AC-2 flight indicated that the vibration levels might be lower than anticipated.

7.4.3.3 Torsional Vibration Levels

The torsional pulses resulted from a JPL study of torsional motion of the Atlas launch vehicle.

No other information available.

7.4.3.4 Vibration Test Durations

Sweep rates for the sine portion of the various tests, qualification, development, acceptance, also determined the duration of the random vibration.

"Acceptance test sweep rate was derived by first determining the duration of the Atlas/Centaur AC-2 wideband acoustic time history at a level whose ratio to the total level represents the ratio of the response of a single degree of freedom oscillator when excited by the random portion of the specified test levels to the response of the combined sine and random portions."

This duration was then equated to the duration spent in bandwidth of a swept sine to compute the sweep rate.

The sweep rate provided a duration of excitation in a resonance band simulating the service use duration.

7.4.4 Source of Data

7.4.4.1 Vibration Levels

Original test levels were obtained from Ranger spacecraft data using Atlas/Agena launch vehicles.

The accelerometers supplying this data were located in the adapter connecting the Ranger to the Agena booster.

7.4.4.2 Test Durations

Durations for all vibration tests were derived from Atlas/Centaur launch vehicle data, primarily from the AC-2 flight.

7.4.5 Identification of Test Factors

7.4.5.1 Systems Level Tests

Ratio between qualification and acceptance test levels generally follows the ratios established for Ranger and Mariner except in the 1-15 hz range for the lateral axes. The ratio was lower in this range because of critical resonances of the spaceframe.

The ratio of development to qualification test levels was set at 1.15 for 1-50 hz and 1.0 above 50 hz for all axes, which compares with 1.33 for Ranger and Mariner.

The ratio of 1.0 for development to qualification was chosen for the higher frequencies since it was felt that the high frequency vibration was not critical for structural loads. Table 7-1 summarizes the systems test factors.

7.4.5.2 Subsystems Level Tests

Generally, the ratio of qualification levels to acceptance levels was 1.5 to 1. There were exceptions as noted in 7.1.3.

7.5 COMPARISON OF TEST LEVELS AND FLIGHT DATA

7.5.1 Flight Vibration Levels

The SD-1, SD-2 and SC-1 through SC-4 Atlas/Centaur--Surveyor flights provided a data base upon which to characterize the 95% vibration environment at the spacecraft/adapter separation plane.

On SD-1 and SD-2 there were three longitudinal accelerometers (one at each column base), one tangential accelerometer and one radial accelerometer.

On SC-1 through SC-4 there were three longitudinal accelerometers (one at each column base).

Because of the small sample size, the 95% sinusoidal flight environment was obtained by adding 6 db to the steady state sine equivalent of the maximum envelope of the shock spectra of the measured flight transients for 5% of critical damping.

Figure 7-11 compares the 95% flight random vibration environment at the spacecraft/adaptor separation plane and the systems acceptance test level. The measured environment is less than that predicted, especially above 400 hz. In specifying a test level based on the measured data, the levels would be increased at least 1.5 db as a test tolerance, making the comparison much closer. Considering the basis of the original estimate, the agreement between the two environments is quite good and, as is desirable, test conservatism was obtained in the original estimate.

TABLE 7-I. RELATIONSHIP BETWEEN SYSTEMS VIBRATION TEST LEVELS

FREQUENCY, HZ	RELATIVE LEVEL ACCEPTANCE	QUALIFICATION	DEVELOPMENT
	Longitudinal (Roll) Axis		
5 - 50	1.0	1.5	1.73
50 - 1500	1.0	1.5	1.5
	Lateral Axes		
1 - 15	1.0	1.25	1.44
15 - 50	1.0	1.50	1.73
50 - 1500	1.0	1.50	1.50

7.5.1 (Continued)

Figure 7-12 compares the 95% flight longitudinal axis equivalent sinusoidal vibration environment at the spacecraft/adaptor separation plane and the systems acceptance test level. The dip in the 30240 separation plane environment in the 10 to 50 hz range represents the attenuation of the separation plane vibration levels during spacecraft testing when the retro motor acceleration levels reach those specified for the separation plane and control the vibration input. The data for this portion of the plot were taken from the SC-1 vibration test. The original estimate is seen to be conservative except in the ranges of 23 to 40 hz and above 150 hz. The high level equivalent sinusoid in the high frequencies is due to the transient flight events termed insulation panel jettison and Atlas/Centaur separation. These are both pyrotechnic events which generally are characterized by high level, high frequency response throughout the structure. Main structural members are generally not adversely affected by high frequency vibration because they are designed for the high stress levels of low frequency, large amplitude response. Spacecraft functional equipment, both mechanical and electrical, are subject to high frequency vibration failures because the components that make up this equipment have many resonances in the high frequency region comprised of many different modal configurations. Although the spacecraft was not subjected to any ground vibration testing to ensure its ability to withstand the magnitude of the high level, high frequency flight vibration environment or the environment in the region of 23 to 40 hz, no failures during flight were attributable to the vibration environment. Also, the multiple axis ground vibration tests, both qualification and acceptance, at the unit and system level, demonstrated a margin for fatigue failures that would not have been exceeded during one flight of a spacecraft even with the inclusion of the high level transients and the 23 to 40 hz environment.

Figure 7-13 compares the 95% flight lateral axis equivalent sinusoidal vibration environment at the spacecraft separation plane and the systems acceptance test level. The dip in the 30240 separation plane environment in the 7 to 25 hz range is the attenuation of the separation plane vibration levels during lateral axis spacecraft testing due to retro motor control. Here again, the original estimate shows various degrees of conservatism up to 150 hz and an unconservatism from 17 to 25 hz and from 150 hz to 1000 hz. The comments and discussion included in the comparison of the longitudinal axis measured and estimated 95% environment apply here also.

Figure 7-14 compares the 95% flight torsional equivalent sinusoidal vibration environment and the torsional vibration environment specified for the S-9 structural test vehicle torsional test. The agreement is particularly good above 20 hz. Below 20 hz, the original estimate is conservative. Since three accelerometers were also used to determine the flight torsional environment, accuracy above 100 hz is questionable. The environment was extended to 300 hz to be consistent with the S-9 levels, but above 100 hz the torsional environment was made from one tangential accelerometer. Because this accelerometer would be indicating either torsional or lateral vibration, the environment given for above 100 hz is not considered reliable.

7.5.1 (Continued)

During flight, the random vibration and the transient events upon which the equivalent sinusoids are based occur separately except for the Atlas/Centaur launcher release transient. The average duration of the random vibration during flight for acceleration greater than 10 db down from the peak level is 40 seconds. This compares with a test duration of 3.9 minutes for the random vibration when combined with a swept sine. The sweep rate for the equivalent sinusoid, based on the combined flight transient durations, is 2 octaves/minutes for an up and down sweep, which is the same as that used for surveyor testing. The sweep rate computed from the combined durations of the transient events is based on a model that provides excitation in a resonance band equal to the service use duration.

7.6 CONCLUSIONS AND RECOMMENDATIONS BY JPL

No information available.

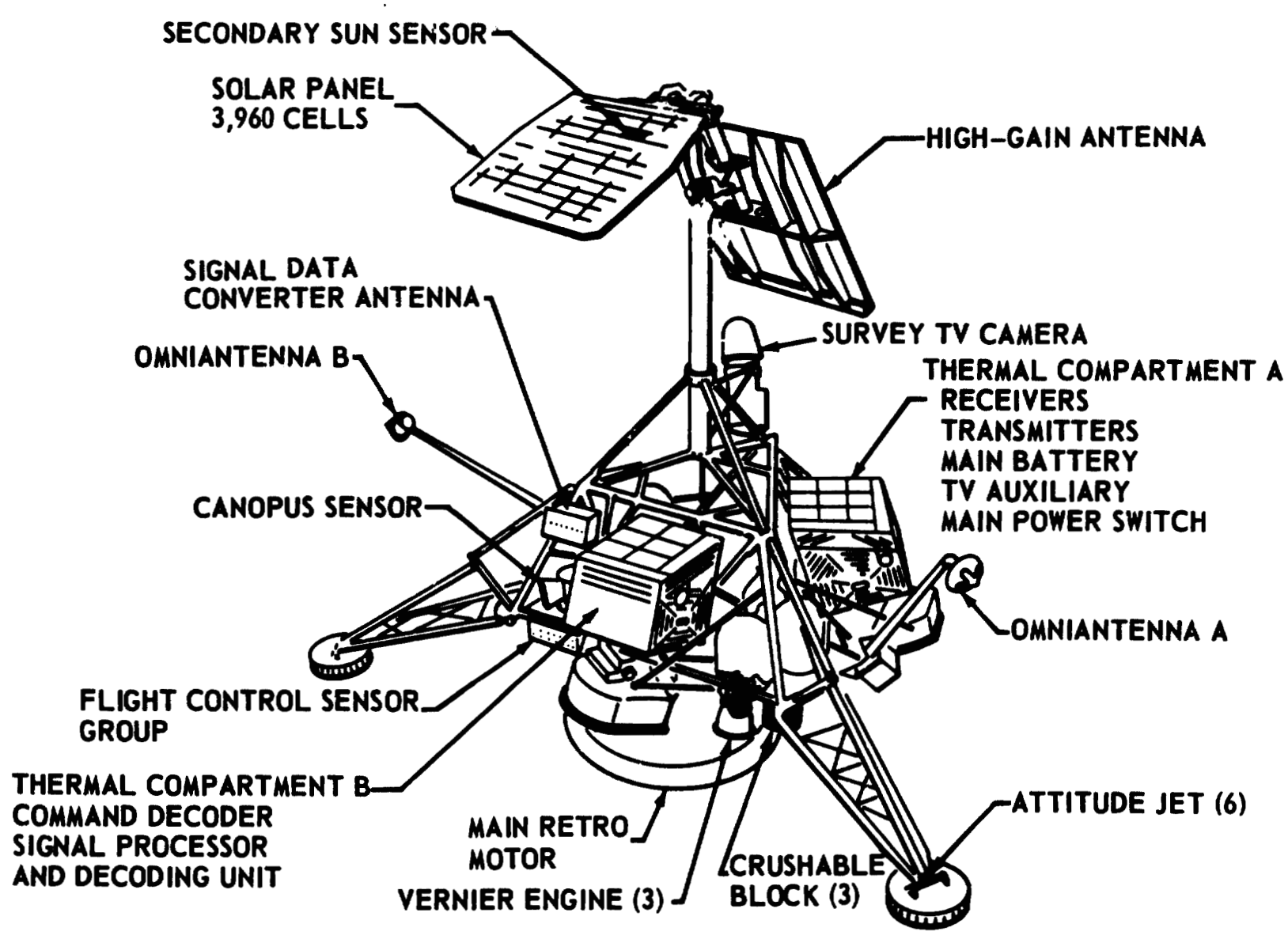


Figure 7-1: SURVEYOR 1 SPACECRAFT CONFIGURATION

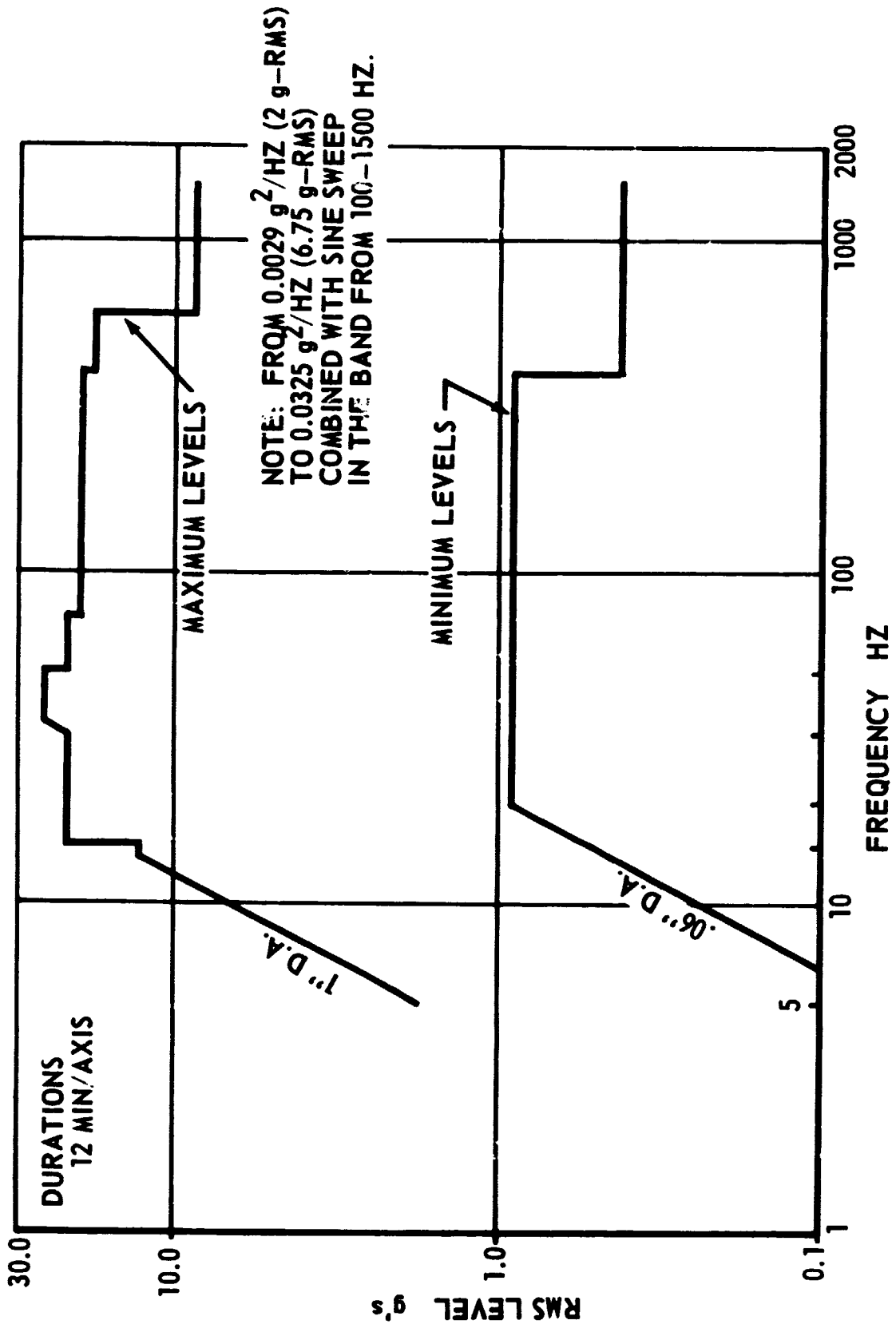


Figure 7-2: ENVELOPE OF SUBSYSTEM QUALIFICATION TEST LEVELS, SINUSOIDAL VIBRATION

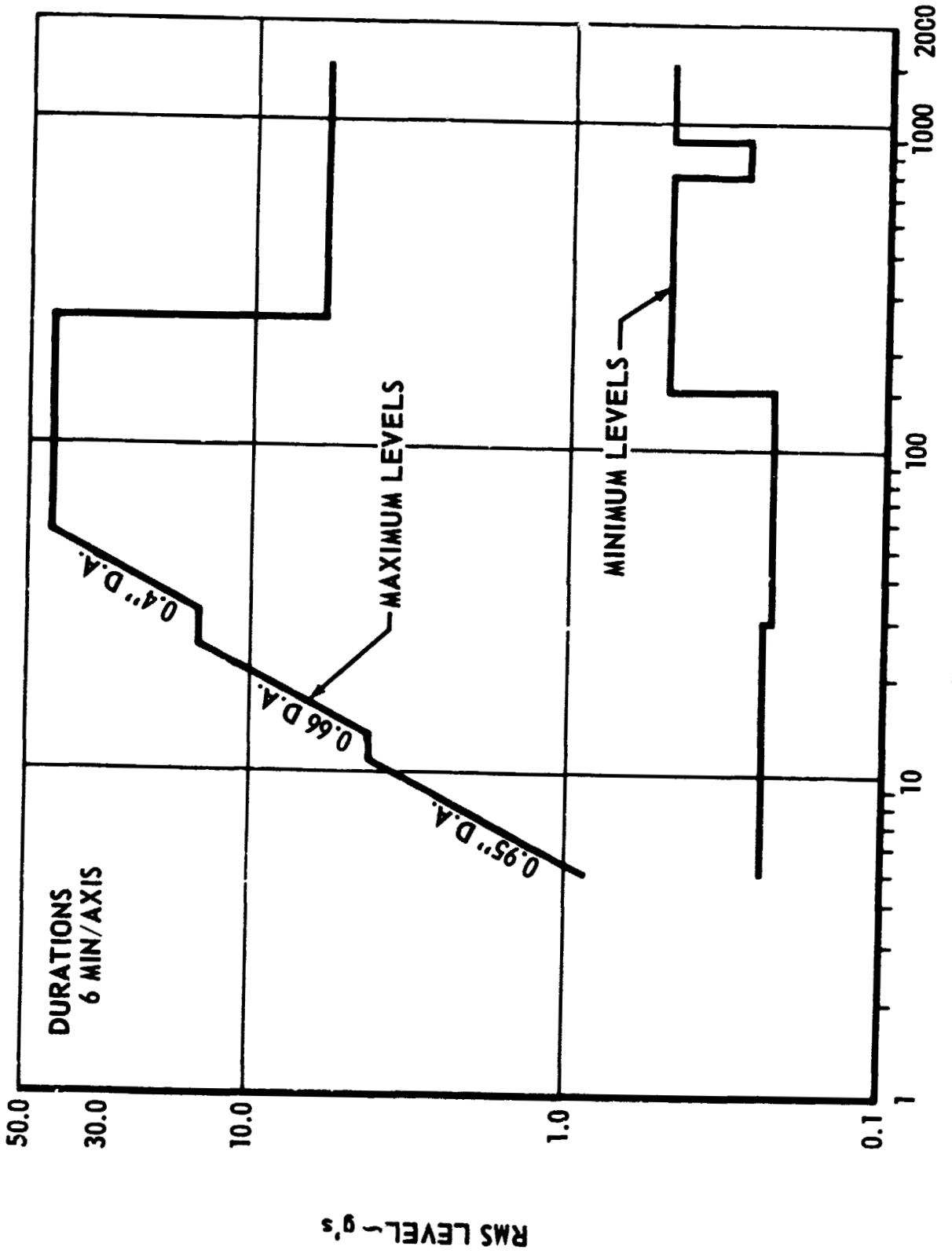


Figure 7-3: ENVELOPE OF SUBSYSTEM ACCEPTANCE TEST LEVELS, SINUSOIDAL VIBRATION

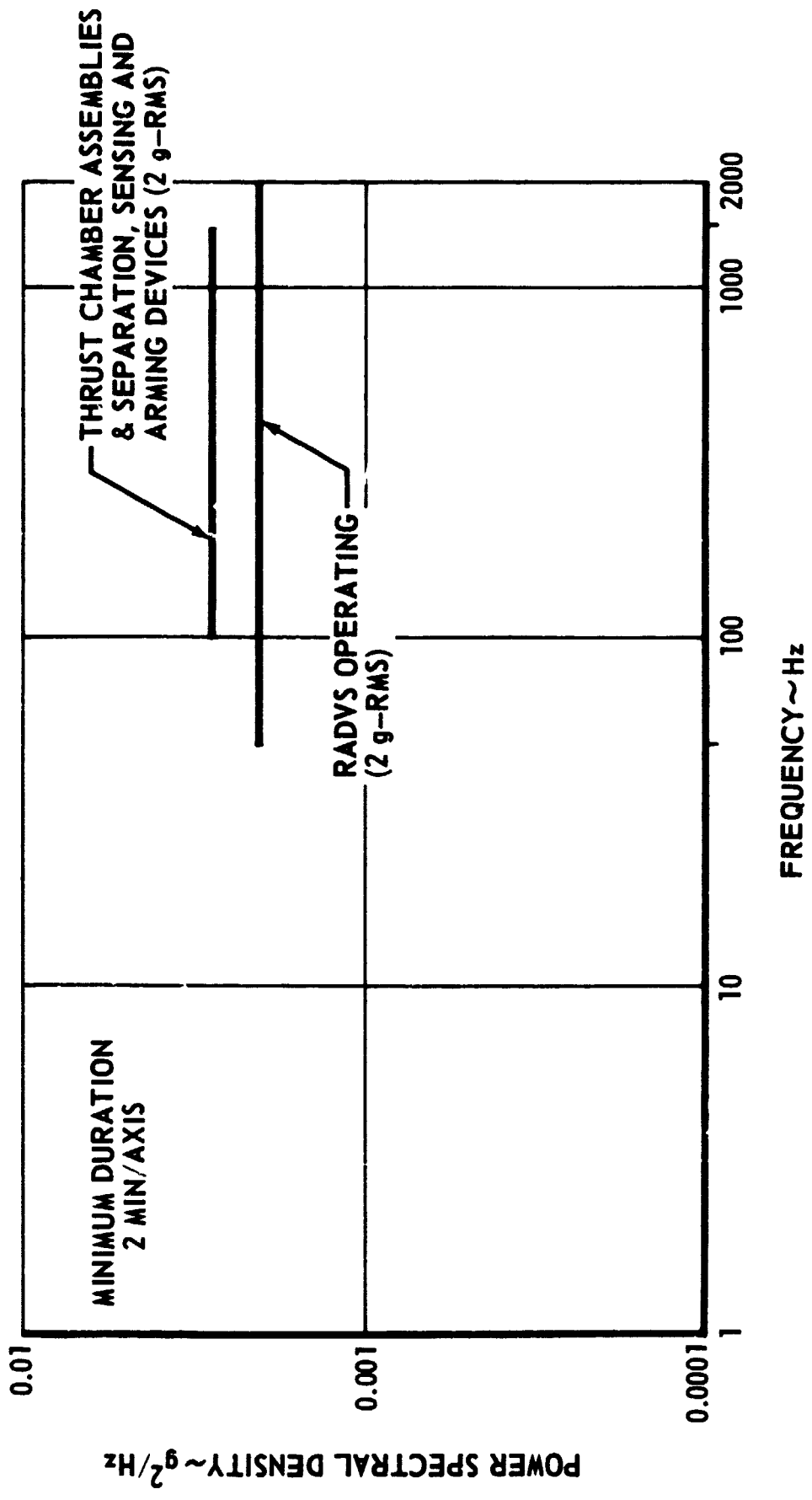


Figure 7-4: SUBSYSTEM RANDOM VIBRATION ACCEPTANCE TEST LEVELS

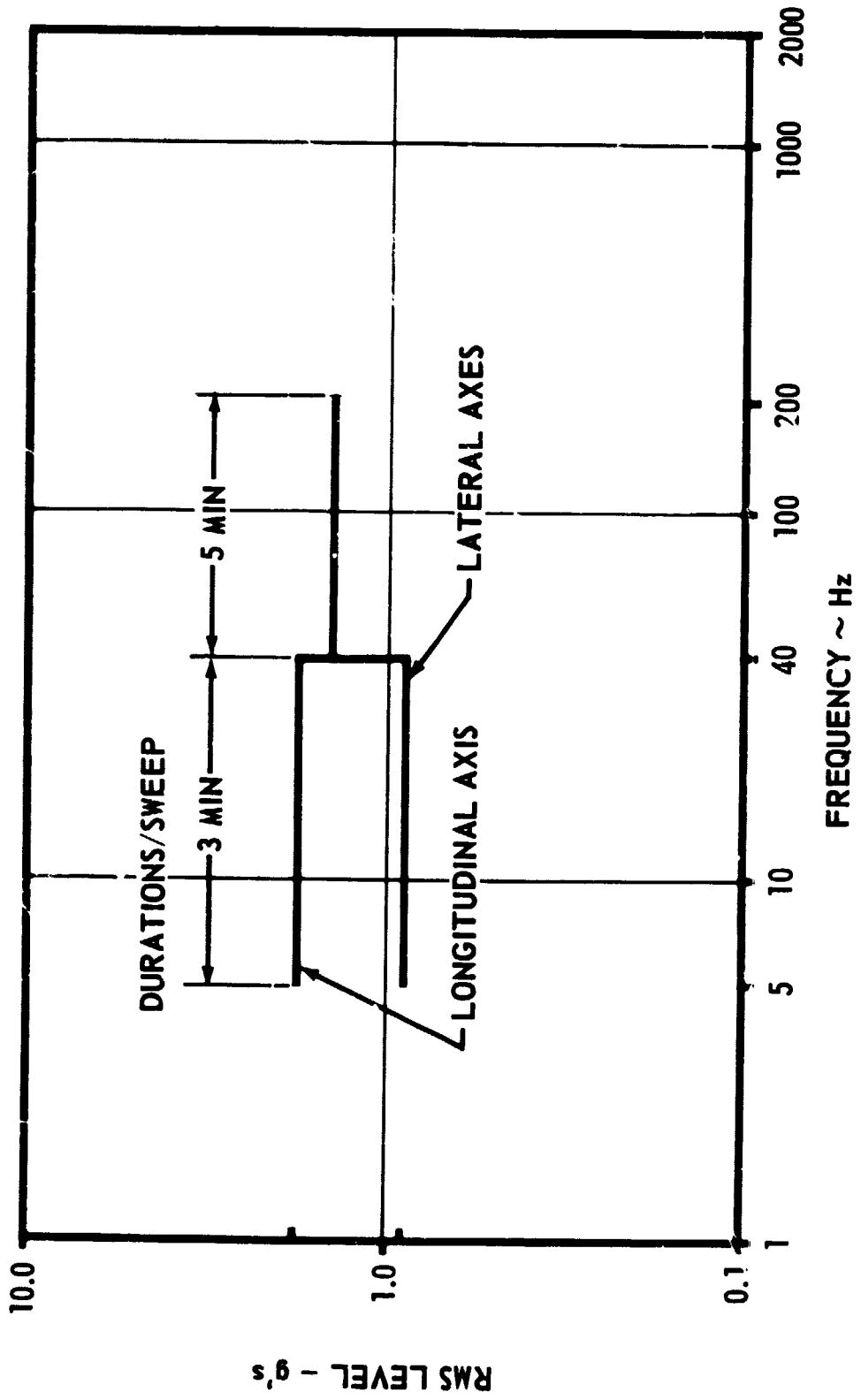


Figure 7-5: S-2 STRUCTURAL TEST VEHICLE VIBRATION TEST LEVELS

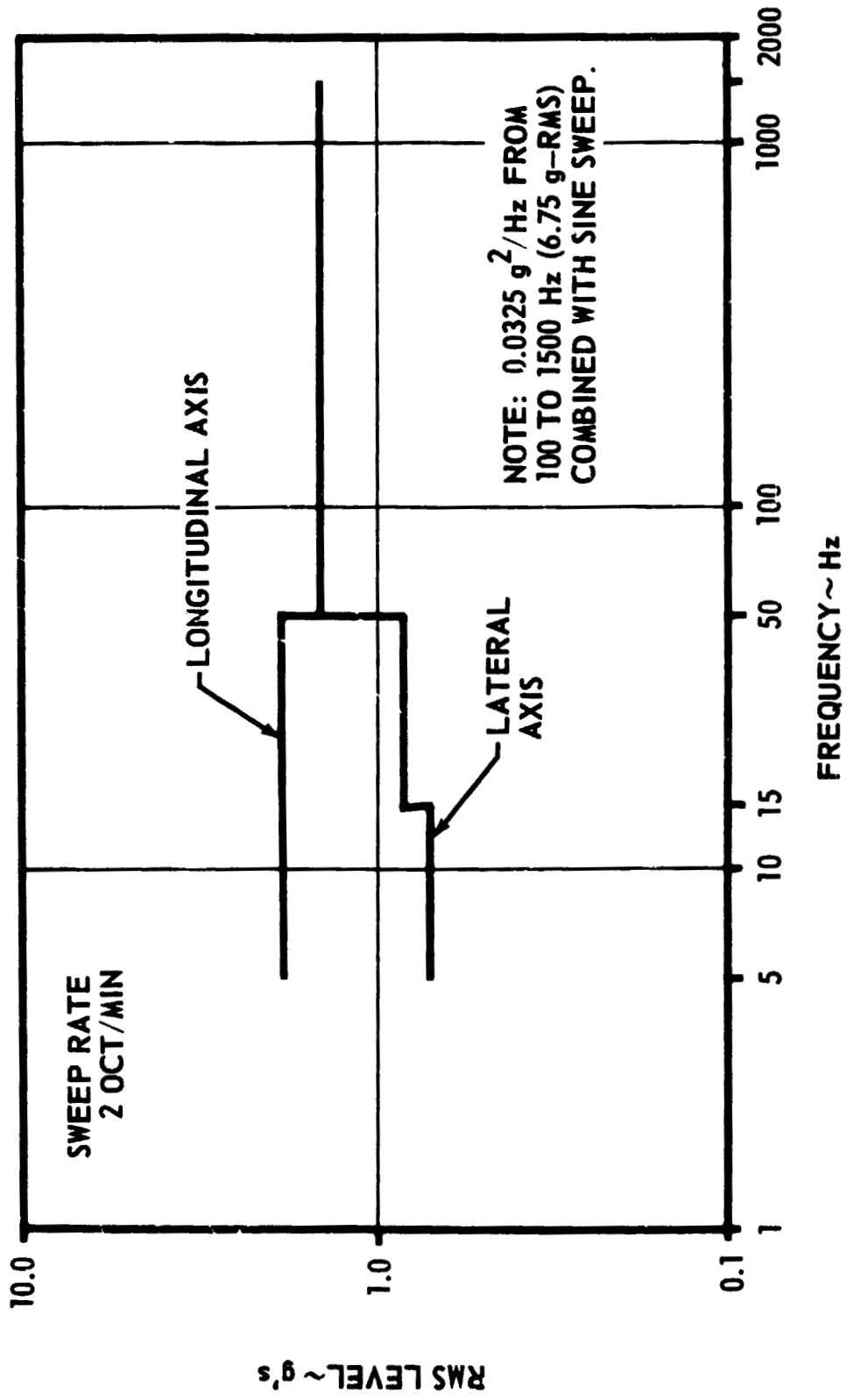


Figure 7-6: S-2A STRUCTURAL TEST VEHICLE VIBRATION TEST LEVELS

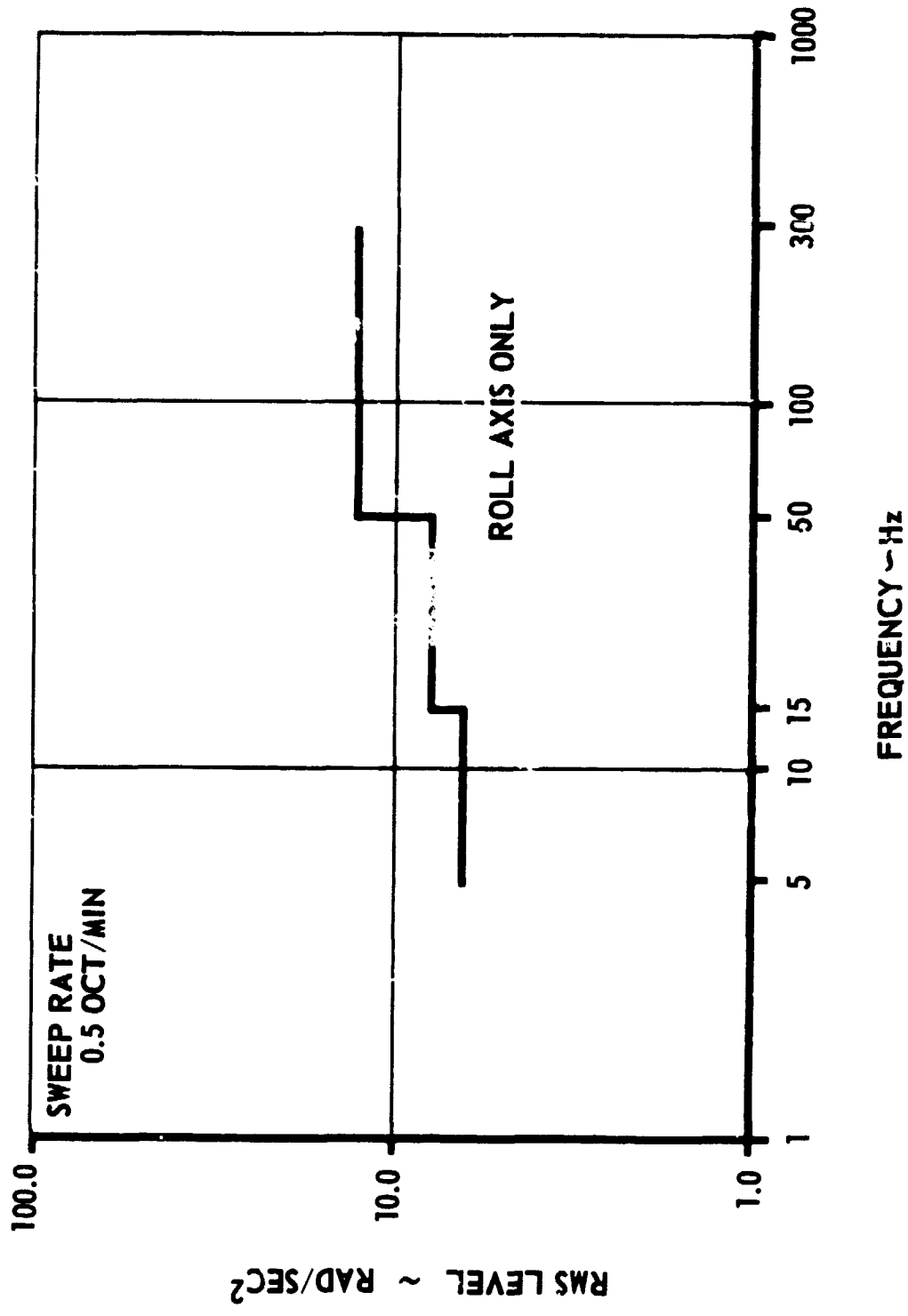


Figure 7-7: S-9 TORSIONAL VIBRATION TEST LEVELS

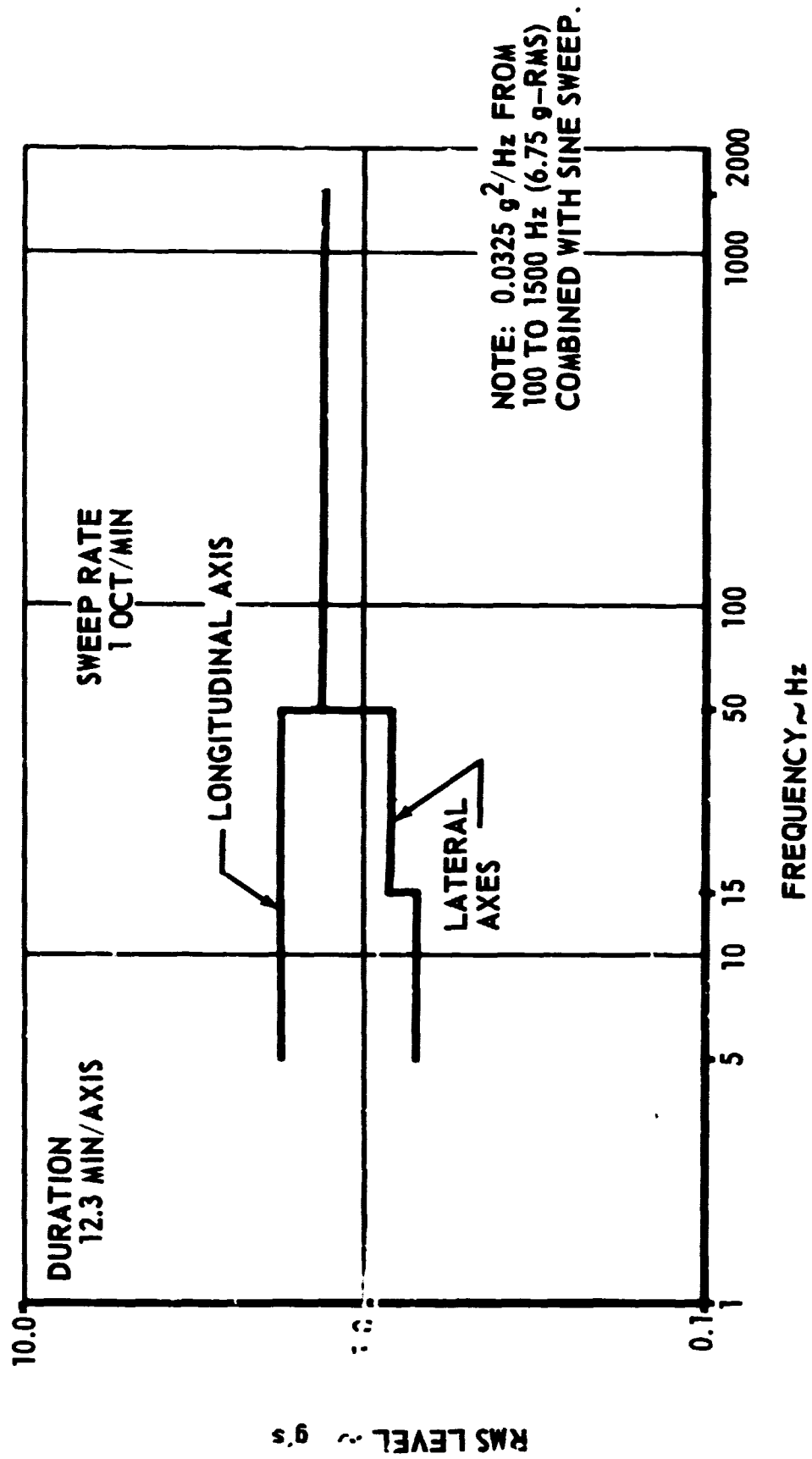


Figure 7-8: S-9 STRUCTURAL TEST VEHICLE VIBRATION TEST LEVELS

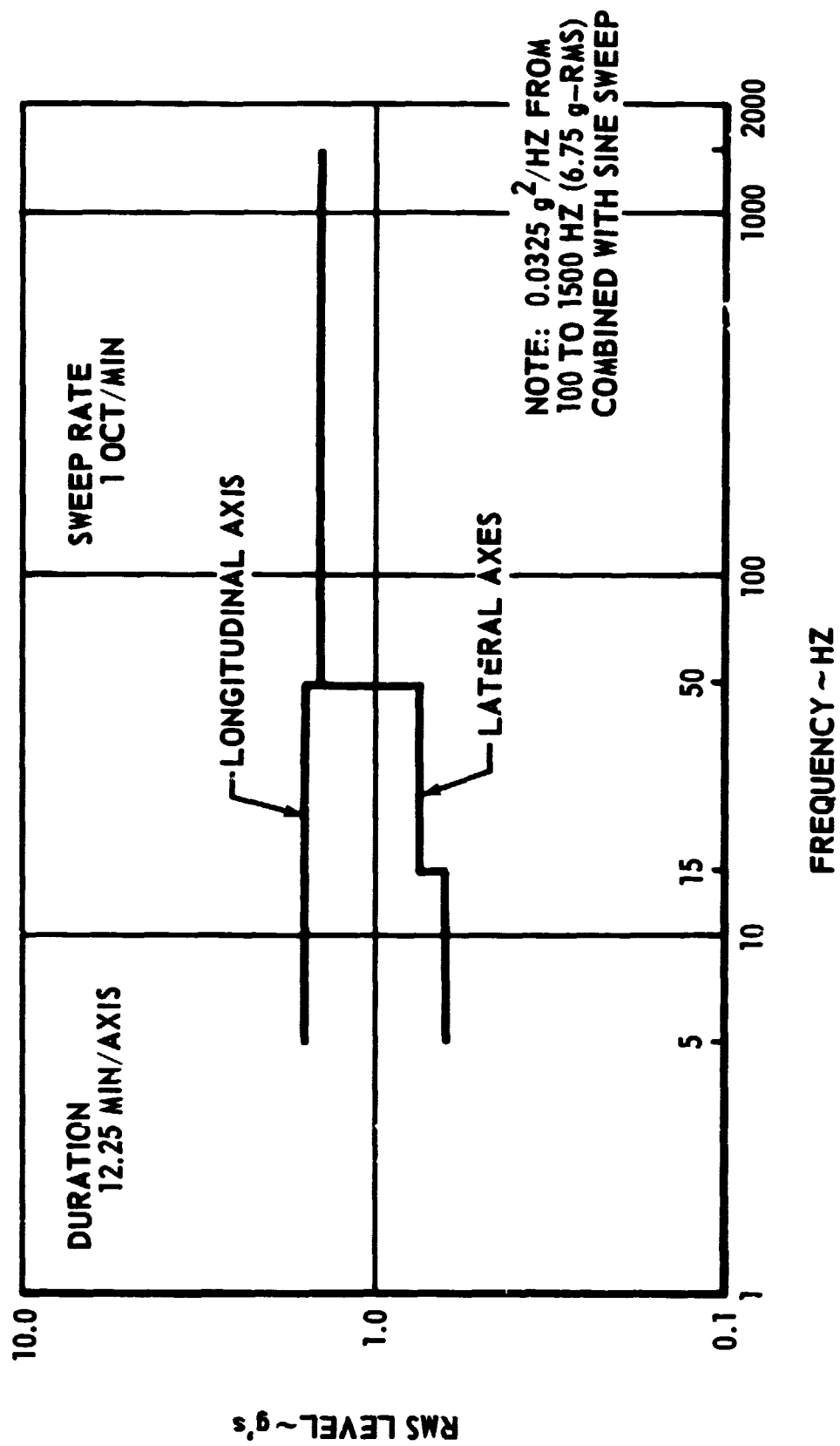


Figure 7-9: SYSTEMS QUALIFICATION TEST LEVELS SINUSOIDAL VIBRATION

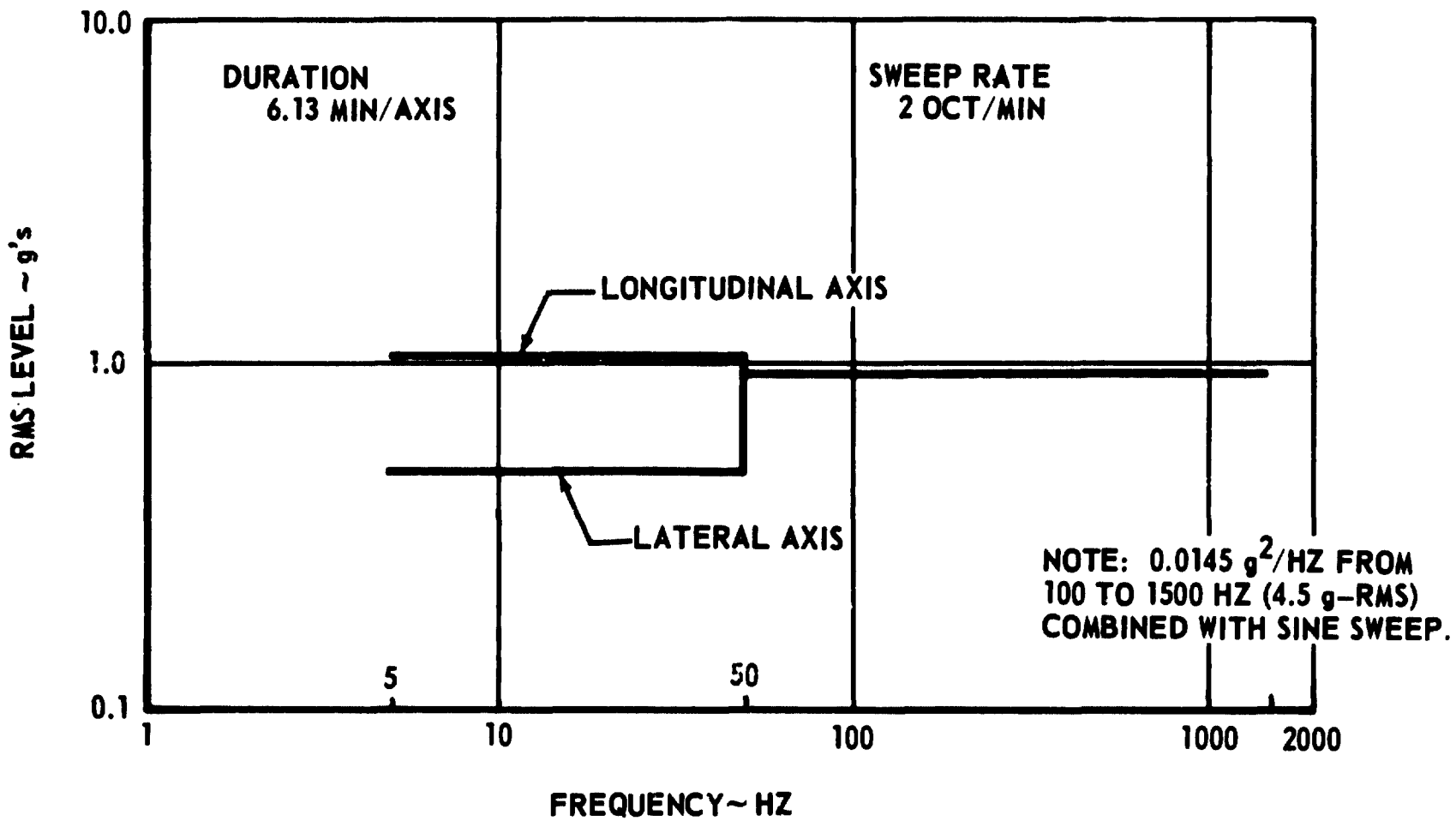


Figure 7-10: SYSTEMS ACCEPTANCE TEST LEVELS SINUSOIDAL VIBRATION

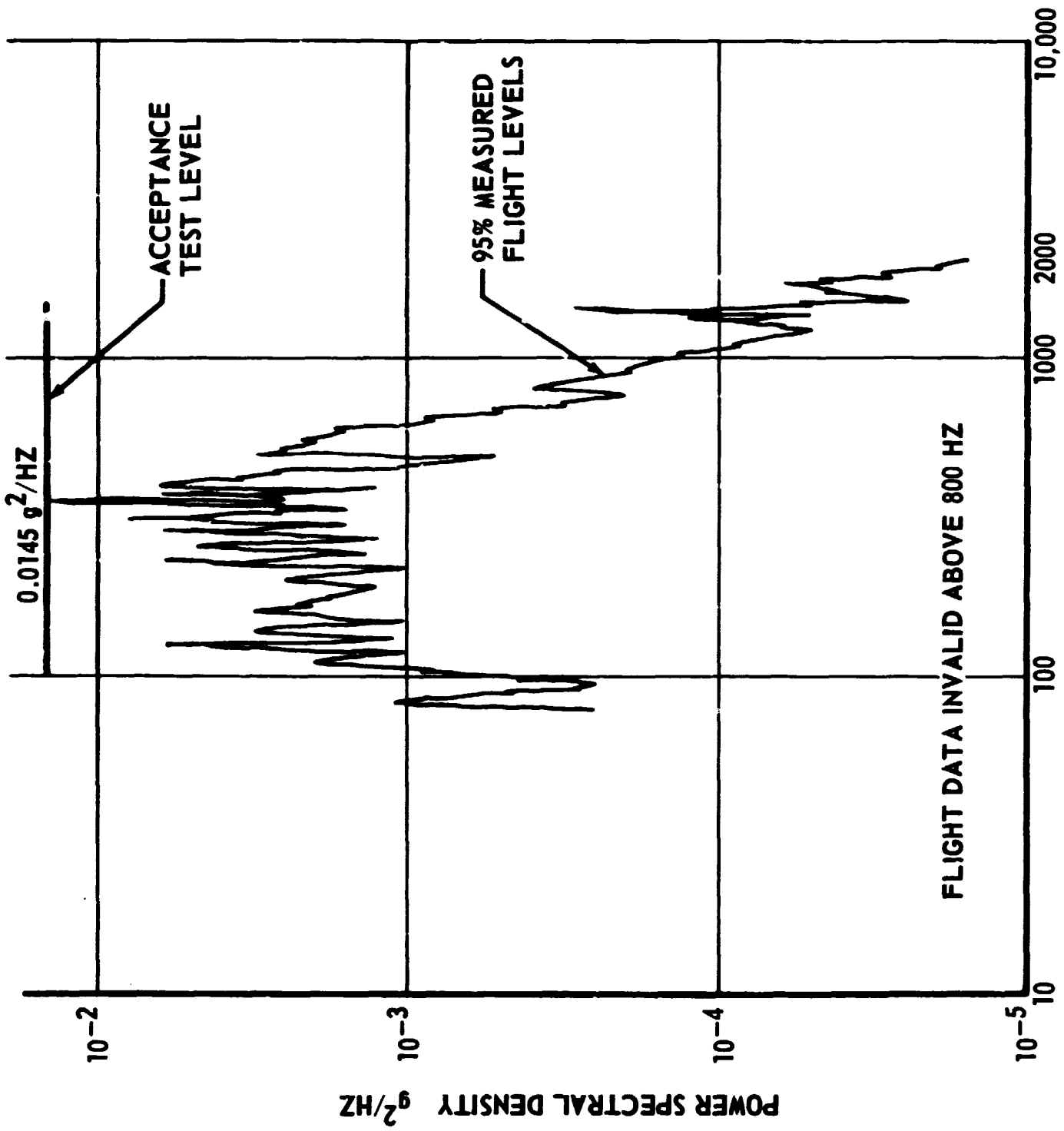


Figure 7-11: COMPARISON OF FLIGHT ENVIRONMENT TO TEST LEVELS, RANDOM VIBRATION

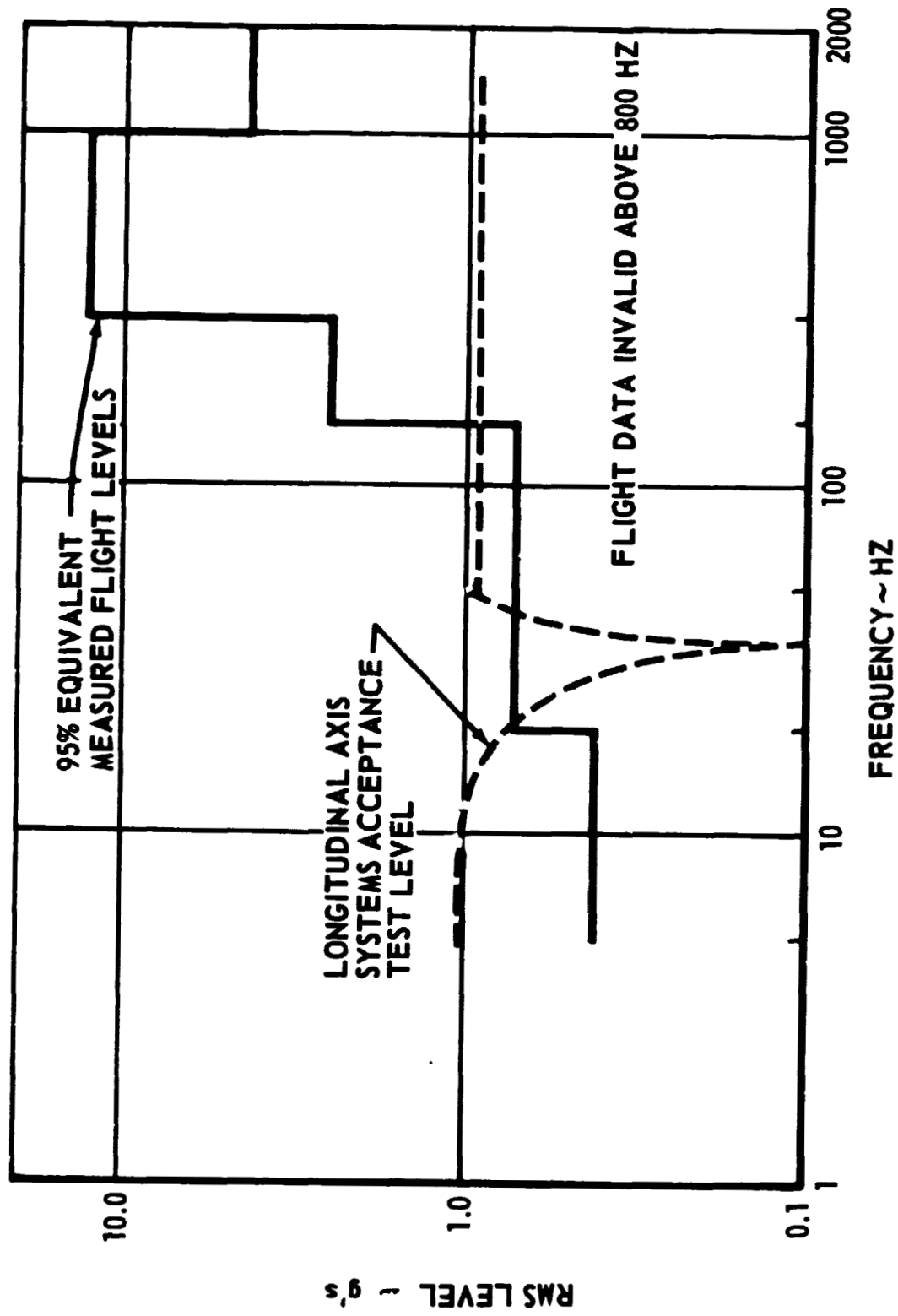


Figure 7-12: COMPARISON OF FLIGHT ENVIRONMENT TO TEST LEVELS, SINUSOIDAL VIBRATION

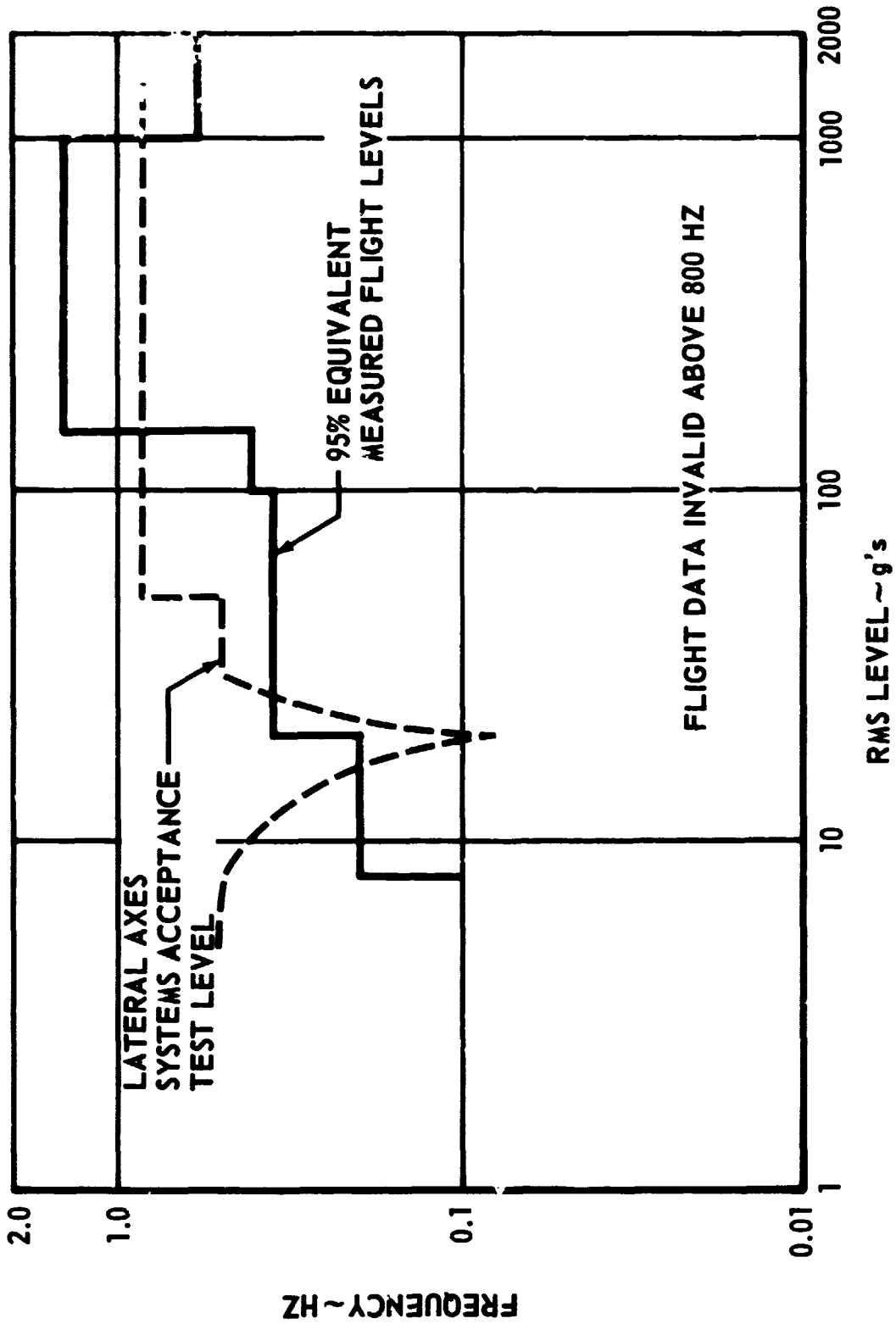


Figure 7-13: COMPARISON OF FLIGHT ENVIRONMENT TO TEST LEVELS, SINUSOIDAL VIBRATION

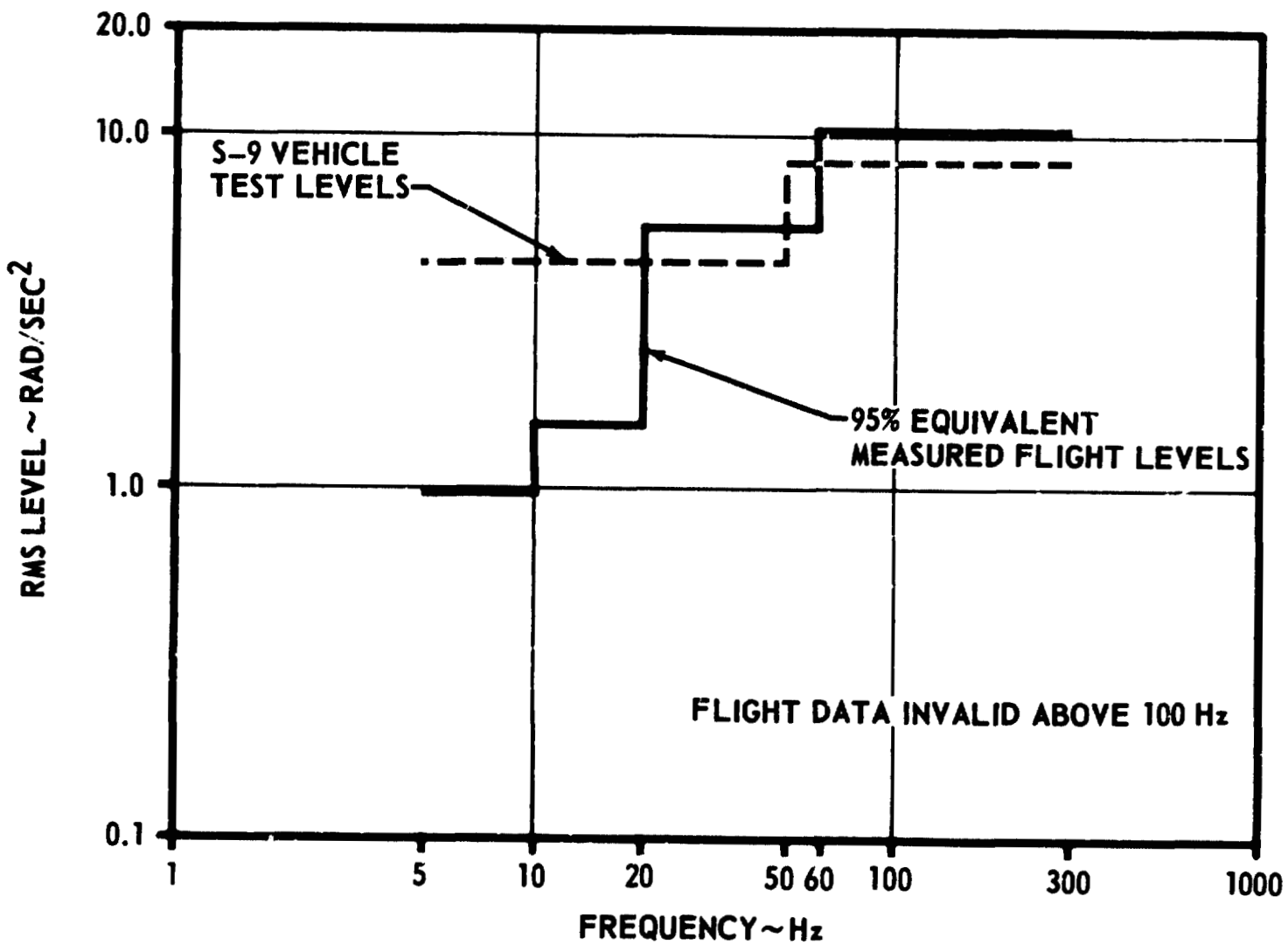


Figure 7-14: COMPARISON OF FLIGHT ENVIRONMENT TO TEST LEVELS, TORSIONAL SINUSOIDAL VIBRATION

APPENDIX A. MARINER 64 DETAILED FAILURE INFORMATION

TABLE A-1. SUBSYSTEM VIBRATION QUALIFICATION TEST FAILURE

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
Cosmic ray telescope	Shielded cable broke (Design)	Shortened cable and deleted potting
Cosmic Dust Detector	Noise film on sensor (Design)	Modify sensor
TV - Optics	Vidicon tube failed (Design)	Ruggedized tube and soft mount
TV - Optics	Aluminum strip cracked (Design)	Change material - berylium copper
Data Encoder	Current oscillator (Design)	Circuit modified
Data Encoder	Resonance phenomena due to piezoelectric current developed during vibration (Design)	None, but avoid ceramic capacitors in this application for future designs.
Video Storage	Insulator screws loosened (Design)	Add safety wire

TABLE A-1. SUBSYSTEM VIBRATION QUALIFICATION TEST FAILURE (Continued)

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
Sun Shutter (Canopus)	Blade damaged (Probable mishandling and design)	Blade redesigned for longer service life
A/C - Gas System	Leakage at flex tube hinge (Design)	Revise piping
Power - Regulator	Switch case fractured (Design)	Redesign
Solar Vane Actuator	Damper inadequate (Design)	Redesign
Solar Panel Structure	Cracked corrugations - undersize (Design)	Maintain gauge and apply doubler cap
Solar Vane	Strap failed (Design)	Change material
L.G. Antenna Support	Cracked (Design)	Add doublers
L.G. Antenna Support	Cracked (Design)	Add strong stiffener
Rod End Bearing	Axial looseness (Design)	Change bearing design

TABLE A-1. SUBSYSTEM VIBRATION QUALIFICATION TEST FAILURE (Continued)

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
Rod End Bearing	Loosened after 1 hour (Design)	Change material and tolerances
Trough Assembly	Failed at attachment (Design)	Redesign
Trough Assembly	Failed at attachment (Design)	Redesign
Strap Assembly - Latch	Strap failed (Design)	Change material
Hi Gain Antenna	Skin buckled (Design)	Add doubler
Damper - L.G. Antenna	Tube failed (Design)	Redesign for safety margin
Science Cover	Structural failure (Design)	Rebuilt stiffeners added
Cosmic Ray Telescope	Noise readout (Part Failure)	Replaced and bonded loose capacitor
RF - Receiver	Intermittent signal at low frequency vibration (Part Failure)	Replaced resistor

TABLE A-1. SUBSYSTEM VIBRATION QUALIFICATION TEST FAILURE (Continued)

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
RF-TWT	Power fluctuation (Part Failure)	Replaced faulty connector.
Ion Chamber Temperature Transducer	Intermittent failure (Part)	Defective weld-unit replaced
Ion Chamber Temp. Transducer	Intermittent failure (Part)	Defective weld-unit replaced
Canopus tracker	No output (Part Failure)	Replace image dissector tube vendor to develop ruggedized tube
Canopus Tracker	Failure to acquire (Part)	Replace image dissector tube
DAS	*Broken wires in harness (Workmanship)	Harness reworked and bonded properly
Planetary Scan	*Retaining ring loosened (Workmanship)	Lens assembly reworked by vendor

*NOT INCLUDED IN FAILURE RATE CALCULATIONS.

TABLE A-1. SUBSYSTEM VIBRATION QUALIFICATION TEST FAILURE (Continued)

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
RF - Power Amplifier	*Lost plate and filament voltage (Workmanship)	Replaced power supply (failed unit was prototype intended for elec. test only)
A/C - Gyro	*Lost signal - broken leads (Workmanship)	Reworked
Sol. Pen. Boost Damper	*Bond failure - poor surface preparation (Workmanship)	Reworked - aluminum surface etched
Hi Gain Antenna	*Creases in elliptical dish (Workmanship)	Vendor notified
A/C Installation	*Screw loosened - wrong type (Workmanship)	Replaced with proper screw
Cosmic Ray Telescope	*Screws loose in case (Operator Errors)	Proper torquing of screws
Data Encoder	*Acceptance test level tape was run - one plane (Operator Error)	Cognizant engineer supply applicable test spec.

*NOT INCLUDED IN FAILURE RATE CALCULATIONS.

TABLE A-1. SUBSYSTEM VIBRATION QUALIFICATION TEST FAILURE (Continued)

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
Trough Assembly	*Flange damaged (Operator Error)	Operators cautioned as photos indicated damage occurred prior to shake
Solar Panels	*Bolts loosened-wrong length (Operator Error)	Replaced with correct bolts
Solar Panel Ass'y	*Low frequency vibration level too high - damaged panel, accelerometer conn. loose (Operator Error)	ETL operators will inspect all accelerometer connections
Cosmic Ray Telescope	*Would not leave calibrate mode (OSE)**	Revamp OSE to send correct pulse
Solar Vane Actuator	*Coupler (Torque Ass'y) delaminated (OSE)	Modify shake fixture to support ass'y
Solar Vane Actuator	*Screws loosened (Misc.)	None, unit had been thru prior qual. shake
Case EA3	*Screws failed, damaged shake fixture (Misc.)	Use flight screws

*NOT INCLUDED IN FAILURE RATE CALCULATIONS
**OPERATIONAL SUPPORT EQUIPMENT

TABLE A-2. SUBSYSTEM VIBRATION ACCEPTANCE TEST FAILURES

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
Cosmic Dust Detector	PHA limits changing (Design)	Delete calibrate crystal
RF-Exciter B	No power output (Design)	Redesigned
RF-EA6	Capacitor failure (Design)	Change all capacitors
Power-Case 1	Delay in tape turn-on (Design)	Redesign - add filter circuits
Science Cover	Structural collapse (Design)	Redesign and quality control
Ion Chamber	GM tube failed (Part Failure)	Replace tube
Data Encoder	Loss of synchronization (Part Failure)	Replace sequence modules
RF-TWT & Power Supply	Power output lost (Part Failure)	Rework amplifier and rework power supply

TABLE A-2. SUBSYSTEM VIBRATION ACCEPTANCE TEST FAILURES (Continued)

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
RF-TWT	Power output lost (Part Failure)	Replace
RF-TWT	Power output lost (Part Failure)	Repaired input connector
RF-TWT	Power fluctuation (Part Failure)	Repaired connector
RF-TWT	Power fluctuation (Part Failure)	Repaired connector
RF-Aux. Osc.	Phase jitter (Part Failure)	Replaced crystal
RF-Receiver	Phase spike and error (Part Failure)	Replaced transistor and crystal
Earth Detector	Short in photocell (Part Failure)	Replaced cell

TABLE A-2. SUBSYSTEM VIBRATION ACCEPTANCE TEST FAILURES (Continued)

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
A/C - Gas Regulator	Lock-up pressure out of spec. (Part Failure)	Returned to vendor for rework
Ion Chamber	Detector failure (Workmanship)	Reworked by vendor with proper welding
Video Storage	Recorder motor stopped (Workmanship)	Remove metal particle from connector
RF - Mixer Amplifier	Cap screw fell out (Workmanship)	Reinstalled and staked
S.I.T.	Switch chatter (Workmanship)	Correct adjustment
Pyro Control	Non-uniform current decay time (Workmanship)	Correct wiring error
A/C - Jet Valve	*Valve could not open-filter reversed (Operator Error)	Install filter correctly
RF - Exciter	15° pk phase spike (OSE)	Increase blower output to reduce heating in TWT acceptance test set #1

*NOT INCLUDED IN FAILURE RATE CALCULATIONS

TABLE A-2. SUBSYSTEM VIBRATION ACCEPTANCE TEST FAILURES (Continued)

SUBSYSTEM	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
Power - Case 1	Subjected to 21 g (OSE)	Replace defective shake fixture
CC&S	Erroneous events from magnetic shield shorting (OSE)	Rework test magnetic shield
Pyro Control	Ignored inhibit command (OSE)	Pulse duration short-installed new unit in OSE.
VSS - Tape Transport	No function - circ. chg. (Procedures)	Institute new procedure for setting pressure pad spring

APPENDIX B

MCDONNELL-DOUGLAS INPUT TO SPACECRAFT SURVEY

1.0 LABORATORY TEST PROGRAM

1.1 TEST PROGRAM RATIONALE

The purpose of the laboratory vibration and acoustic test programs was to provide a method to uncover design or workmanship deficiencies that could have been sources of problems with equipment in operational vehicles. To accomplish this the test programs had to be financially compatible with the overall program and provide satisfactory results at resonable cost. The elimination of tests that were not considered cost-effective was an area of effort throughout the Gemini program. This was reflected in the use of test procedures which were carried over from the Mercury program, the heavy reliance on qualification by similarity whenever possible, the elimination of environmental tests for non-sensitive items, especially in acoustics, and in the omission of formal development tests for most items.

The omission of development tests was not complete because some vendors did conduct tests of this type. McDonnell did not specify or control these tests and therefore cannot report on them as part of the overall program tests.

Multiple level testing was used for qualification and acceptance during the Gemini program. That is, items were tested at the component level as early as possible and then many were also tested at a module or subsystem level, or at the spacecraft level. This was done to provide the most realistic tests at the earliest times possible. A list of the tests which were conducted is given below.

	Development	Qualification	Acceptance
Component	None*	Vibration and Acoustic	Vibration
Subsystem	None	Vibration	None
System	None	Vibration	Vibration

* Some development tests were conducted by McDonnell subcontractors but are not reported here.

The laboratory vibration and acoustic test program relationships are shown in Figure 1-1. The sequence of the tests are shown by the arrows. The vendor component development tests are shown in a dashed box since they were made by only some of the Gemini subcontractors and are not reported here. No feedback loops are shown in the figure, although there were for specific items. If a failure or undesirable condition were detected during an acceptance vibration test, changes would be made in manufacturing and/or design to correct the condition. Similar loops would exist for all of the tests.

1.2 COMPONENT VIBRATION/ACOUSTIC TESTS

The Gemini component test program drew heavily on experience and results of the Mercury program. Thus, the procedures for sinusoidal tests and acoustic noise tests were essentially the same. Changes in the test levels and reduction of some resonance dwell times were the only differences in the sinusoidal tests. A major difference was the incorporation of random vibration requirements for Gemini. Items which were complex were vibration tested to only the random vibration requirements, while only the sinusoidal requirements were imposed on simple items. Tests were not conducted on the Gemini hardware if the items were qualified for some other program to requirements which were equivalent or more severe than the appropriate Gemini requirements. In addition, minor changes in a design would not be requalified by test if the changes were judged to have no effect on the dynamic capability of the item.

Tests were also eliminated on those items which were considered insensitive to the environment. Thus, acoustic noise tests were not conducted on mechanical hardware of heavy mass and small volume. Nor were many acoustic tests conducted on cabin area equipment where the environment was expected to be very low.

Tables 1-1 through 1-10 summarize the Gemini component qualification tests by the spacecraft system in which they were used. This format is compatible with the qualification status reports furnished the NASA during the program. Table 1-21 totals all of the spacecraft systems with the exception of target docking adapter which, of course, was not part of the spacecraft itself.

Acoustic noise levels and procedures for qualification were not changed during the course of the Gemini program. Different levels were specified based on the location of the item in the spacecraft as described in Paragraph 4. Figure 1-2 shows the extreme levels and the durations used for the tests.

Random vibration qualification tests were conducted to spectra which were revised during the course of the program. The details of the various requirements are given under Paragraph 4, but the extreme levels and the durations are given in Figure 1-3. The extreme levels and durations for sinusoidal vibration qualification tests of spacecraft equipment are given in Figure 1-4.

The mounting of components for vibration tests was generally to a rigid fixture using the fasteners intended for the flight installation since most components were mounted directly to primary structure. If the item was to be vibration isolated, the isolators would be included. There were, of course, exceptions to the hardmounted procedure. These were most predominant if the test article itself were a structural item, or a mechanical item related to structure. For acoustic tests the items were suspended as softly as practicable.

Satisfactory component operation was required before and after the tests. It was also required during the test if a similar requirement existed for the actual flight phase represented by the particular test. Sometimes this would result in multiple tests of a component - it might be tested non-operating to an environment to demonstrate survival only, then be tested operating to a lesser environment to demonstrate functional capability.

The component acceptance test program was generally initiated by vendors of electronic devices who recommended them as part of a burn-in program for their

components. These generally bore little relation to the qualification or expected environments but most were revised during the course of the program to be compatible with the other phases. The initial vendor-originated procedures which were not actually related to the program usage are not included in the summary descriptions of this report. They included such tests as circular motion, common years ago in airplane specifications, and excitation by a source of complex sine waves whose amplitudes were never measured.

No acoustic acceptance tests were conducted, and the type of vibration test was the same as that which had been used for qualification. Generally only electronic and electromechanical devices were tested as shown in Tables 1-11 through 1-20. These tables are arranged identically to the qualification tables and a table listing totals for everything but the target docking adapter is given in Table 1-22. The decision not to test items was generally based on a decision that the cost could not be justified by the expected results, and because the item itself might be a life-limited device whose life might be severely reduced by the test. An example of the latter is the omission of acceptance vibration of propellant tank assemblies whose bladders would be abraded during vibration exposure.

Component acceptance vibration tests were not deleted from production runs once they were incorporated. Many initial units were not vibrated since the incorporation of a unified acceptance program started later in the Gemini program.

Many designs were qualification tested before the incorporation of acceptance vibration procedures, therefore, these qualification test units were not subjected to acceptance vibration. No general procedure for this was established during the program. The result was, of course, that a failure in a qualification test required a review of the acceptance test history of the test article. The results of that review would then have to be included in the evaluation of the failure.

The levels and durations used for the tests were selected so that in all cases the test would be significantly less severe than the qualification requirement for the item. The details for their selection are reported in Paragraph 4. One exception was the spacecraft digital computer which the vendor recommended be tested at the qualification levels. This was done, but it resulted in the elimination of re-use capability of the flight equipment. The extreme levels and the durations for the random vibration are given in Figure 1-5, and for sinusoidal vibration in Figure 1-6.

Components were hardmounted for acceptance vibration and operation was usually required during the test. In some instances operation during the vibration test was not typical of the condition of the unit in service during the periods of severe vibration. Since no similar condition would have been qualification tested the system would not be operated during the acceptance tests.

1.3 SUBSYSTEM VIBRATION/ACOUSTIC TESTS

Only vibration qualification tests were conducted on Gemini subsystems. A listing of the tests which were run is given in Table 1-23. Transducers to

control the test levels were as near the place of excitation as possible for all tests except that of the fuel cell module. For this test the excitation was at the base of production adapter structure and the control transducers were located at the blast shield/adapter interface. The tests simulated launch conditions, and therefore only the fuel cell module was fully operational during the tests. Satisfactory operation before and after the tests was demonstrated.

The objectives of the test were to demonstrate the capability of the components to withstand the environment as a system, and to assure satisfactory installation of the components. A single subsystem of each type was tested.

1.4 SYSTEM VIBRATION/ACOUSTIC TESTS

Acceptance vibration tests were conducted at the system level on Gemini. These included tests on the first three flight spacecraft and on the first flight target docking adapter. A photograph showing Gemini Spacecraft 1 is presented as Figure 1-7. The first flight target docking adapter, TDA 2, is shown in the photograph of Figure 1-8. These vehicles contained production hardware for all systems with the exception of pyrotechnic elements which for safety reasons were not installed until after delivery of the vehicles.

Table 1-24 presents a summary of the tests which were conducted. The test levels were controlled by an accelerometer mounted on the fixture as near the attachment of the vehicle as practicable. Although several transducers were installed on the fixture around the circumference of the vehicle only one of them was actually used to control the test.

All systems normally operating during the launch phase were operational and monitored during the tests. In addition, satisfactory system operation was established before and after each phase. The objectives of the tests were to demonstrate satisfactory operation of the flight systems during a simulated launch.

The decision to eliminate the test after early production spacecraft was based on the estimated cost-effectiveness of the tests for future vehicles which were similar to the vehicles on which the testing had been completed. The testing of Spacecraft 3, the first manned vehicle, represented about 20,000 manhours. Although a test of Spacecraft 4 might have required up to 1/3 less effort because of the experience gained from the earlier testing, the cost of such a test was deemed excessive in view of the diminishing returns expected. System acceptance tests are considered most effective on early vehicles before normal learning-curve improvement takes place.

The first flight TDA represented a new system which was significantly different than the previously tested units. Since the TDA was passive during launch and was not complex compared to the Gemini, the cost of the test was perhaps only 5% that for Gemini. The tests were discontinued after the initial article, however, because it was again judged that results of tests on future similar vehicles would not justify their costs.

TABLE 1-1

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Electrical

Component Type	Total No. of Components	Total No. Tested		
		Vibration Sine	Vibration Random	Acoustic
Electrical	64	30	30	0
Mechanical	15	15	3	0
Structural	5	5	0	0
Electro-Mechanical	4	0	1	0
Instrumentation Sensors	2	2	0	0
Totals	90	52	34	0

TABLE 1-2

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Guidance and Control

Component Type	Total No. of Components	Total No. Tested		
		Vibration Sine	Vibration Random	Acoustic
Electronic	16	0	16	11
Electrical	9	4	2	2
Structural	9	2	7	1
Mechanical	11	2	7	1
Electro-Mechanical	10	0	9	4
Other	4	0	4	0
Totals	59	8	45	19

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION
TEST SUMMARY

TABLE 1-3

SPACECRAFT SYSTEM: Communications and Signaling				
		Total No. Tested		
Component Type	Total No. of Components	Vibration Sine	Vibration Random	Acoustic
Electronics	21	7	15	13
Electrical	10	7	3	2
Mechanical	2	1	1	0
Electro-Mechanical	1	1	0	0
Totals	34	16	19	15

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION
TEST SUMMARY

TABLE 1-4

SPACECRAFT SYSTEM: Instrumentation and Recording				
		Total No. Tested		
Component Type	Total No. of Components	Vibration Sine	Vibration Random	Acoustic
Electronic	6	0	6	6
Electrical	11	2	9	4
Instrumentation Sensors	95	19	3	10
Totals	112	21	18	20

TABLE 1-5 GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Crew Station

Component Type	Total No. of Components	Total No. Tested		
		Vibration Sine	Vibration Random	Acoustic
Electrical	12	8	4	1
Electro-Mechanical	10	1	9	1
Mechanical	1	0	1	0
Structural	7	3	3	0
Total	30	12	17	2

TABLE 1-6 GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Environmental Control System

Component Type	Total No. of Components	Total No. Tested		
		Vibration Sine	Vibration Random	Acoustic
Mechanical	63	44	2	0
Structural	41	18	3	0
Electro-Mechanical	7	5	1	0
Electrical	2	2	0	0
Other	9	6	0	0
Total	122	75	6	0

TABLE 1-7

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Landing and Escape

Component Type	Total No. of Components	Total No. Tested		
		Vibration Sine	Vibration Random	Acoustic
Structural	1	0	0	0
Mechanical	9	4	5	0
Electro-Mechanical	1	0	1	0
Others	1	1	0	0
Totals	12	5	6	0

TABLE 1-8

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Sequentials/Pyrotechnics

Component Type	Total No. of Components	Total No. Tested		
		Vibration Sine	Vibration Random	Acoustic
Mechanical	25	11	13	3
Others	7	6	1	2
Totals	32	17	14	5

TABLE 1-9

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Structures				
		Total No. Tested		
Component Type	Total No. of Components	Vibration Sine	Vibration Random	Acoustic
Structural	3	0	3	3
Totals	3	0	3	3

TABLE 1-10

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Target Docking Adapter				
		Total No. Tested		
Component Type	Total No. of Components	Vibration Sine	Vibration Random	Acoustic
Electrical	18	7	8	1
Mechanical	6	2	4	0
Electronic	4	0	4	4
Electro-Mechanical	2	0	2	1
Total	34	9	18	6

TABLE 1-11 TEST SUMMARY

SPACECRAFT SYSTEM: Electrical				
Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Electrical	64	0	0	0
Mechanical	15	0	0	0
Structural	5	0	0	0
Electro-Mechanical	4	0	4	0
Instrumentation Sensors	2	0	0	0
Total	90	0	4	0

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE

TABLE 1-12 TEST SUMMARY

SPACECRAFT SYSTEM: Guidance and Control				
Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Electronic	16	2	14	0
Electrical	9	0	2	0
Structural	9	0	1	0
Mechanical	11	0	0	0
Electro-Mechanical	10	0	9	0
Other	4	0	0	0
Total	59	2	26	0

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE TEST SUMMARY

TABLE 1-13

SPACECRAFT SYSTEM: Communications and Signaling				
Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Electronics	21	1	14	0
Electrical	10	0	8	0
Mechanical	2	2	0	0
Electro-Mechanical	1	1	0	0
Total	34	4	22	0

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE TEST SUMMARY

TABLE 1-14

SPACECRAFT SYSTEM: Instrumentation and Recording				
Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Electronic	6	0	5	0
Electrical	11	3	6	0
Instrumentation Sensors	95	87	0	0
Totals	112	90	11	0

TABLE 1-15

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE TEST SUMMARY

SPACECRAFT SYSTEM: Crew Station				
Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Electrical	12	0	2	0
Electro-Mechanical	10	0	6	0
Mechanical	1	0	0	0
Structural	7	0	0	0
Totals	30	0	8	0

TABLE 1-16

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE TEST SUMMARY

SPACECRAFT SYSTEM: Environmental Control System				
Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Mechanical	63	0	0	0
Structural	41	0	0	0
Electro-Mechanical	7	0	1	0
Electrical	2	0	0	0
Other	9	0	0	0
Totals	122	0	1	0

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE
TEST SUMMARY

TABLE 1-17

SPACECRAFT SYSTEM: Landing and Escape

Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Structural	1	0	0	0
Mechanical	9	0	0	0
Electro-Mechanical	1	0	0	0
Other	1	0	0	0
Totals	12	0	0	0

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE
TEST SUMMARY

TABLE 1-18

SPACECRAFT SYSTEM: Sequentials/Pyrotechnics

Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Mechanical	25	0	0	0
Other	7	0	0	0
Totals	32	0	0	0

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE
TEST SUMMARY

TABLE 1-19

SPACECRAFT SYSTEM: Structures				
Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Structural	3	0	0	0
Totals	3	0	0	0

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE
TEST SUMMARY

TABLE 1-20

SPACECRAFT SYSTEM: Target Docking Adapter				
Component	Total No. of Components per Spacecraft	Total Components Tested		
		Vibration Sine	Vibration Random	Acoustic
Electrical	18	0	3	0
Mechanical	6	1	0	0
Electronic	4	0	1	0
Electro-Mechanical	2	0	2	0
Totals	34	1	6	0

TABLE 1-21

GEMINI COMPONENT VIBRATION/ACOUSTIC QUALIFICATION TEST SUMMARY

SPACECRAFT SYSTEM: Gemini Vehicle

Component Type	Total No. of Components	Total No. Tested		
		Vibration Sine	Vibration Random	Acoustic
Electrical	108	53	48	9
Electronic	43	7	37	30
Mechanical	126	77	35	7
Electro-Mechanical	33	7	21	5
Structural	66	28	13	1
Instrumentation Sensors	97	21	3	10
Other	21	13	5	2
Total	494	206	162	64

TABLE 1-22

GEMINI COMPONENT VIBRATION/ACOUSTIC ACCEPTANCE TEST SUMMARY

SPACECRAFT SYSTEM: Gemini Vehicle

Component Type	Total No. of Components	Total No. Tested		
		Vibration Sine	Vibration Random	Acoustic
Electrical	108	3	18	0
Electronic	43	2	33	0
Mechanical	126	2	0	0
Electro-Mechanical	33	1	20	0
Structural	66	0	1	0
Instrumentation Sensors	97	89	0	0
Other	21	0	0	0
Total	494	97	72	0

GEMINI SUBSYSTEM VIBRATION/ACOUSTIC QUALIFICATION
TEST SUMMARY

TABLE 1-23

Subsystem Description	Random Vibration		Sine Vibration		Acoustic	
	RMS Level	Duration	Level	Duration	Level	Duration
Fuel Cell Module (Note 1)	7.0g	8 min. each of 3 axes	low level surveys		-	-
Orbit Attitude Maneuvering System Module (14 Day) (Note 2)	7.0g	8 min. each of 2 axes	low level surveys		-	-
Orbit Attitude Maneuvering System Module (2 Day) (Note 3)	7.0g	8 min. each of 2 axes	low level surveys		-	-
Re-Entry Control System Module (Note 4)	8.8g	15 min. each of 3 axes	low level surveys		-	-
Rendezvous Evaluation Pod (Note 5)	7.0g	1 min. each of 3 axes	low level surveys		-	-

NOTES:

1. The fuel cell module consisted of two fuel cell sections, a hydrogen tank, an oxygen tank, pressure regulators, valves, and associated tubing and wiring installed in a production structure adapter.

2. The 14-day orbit attitude maneuvering system module (OAMS) consisted of a pressurant tank, a fuel tank, an oxidizer tank, regulators, valves, and tubing and wiring installed on production structure.

3. The 2-day OAMS was identical to the 14-day OAMS preceding except that it included an additional pressurant tank, fuel tank and oxidizer tank.

4. The Re-entry Control System (RCS) test included production structure with a pressurant tank, a fuel tank, an oxidizer tank, regulators, valves, thrust chamber assemblies, and tubing and wiring. Flight vehicles included a second redundant system but it was not included in the test.

5. The rendezvous evaluation pod (REP) was a Gemini radar transponder package to which was added 2 spiral and 1 dipole antennas, 2 flashing lights and 2 batteries to supply power. A sunshade and the deployment mechanisms for the sunshade and for the REP were included in the test.

TABLE 1-24 GEMINI SYSTEM VIBRATION/ACOUSTIC ACCEPTANCE TEST SUMMARY

System Description	Random Vibration		Sine Vibration		Acoustic	
	RMS Level	Duration	Level	Duration	Level	Duration
Spacecraft 1	8.4g	3 min. Longit. axis	low level surveys plus ±.6g at 11cps	20 sec. (POGO simulation)	-	-
Spacecraft 2	6.2g	1 min. each of 2 axis	low level surveys plus ±.3g at 17cps	10 sec. (POGO simulation)	-	-
Spacecraft 3	6.2g	1 min. Longit. axis 1.5 min lateral axis	low level surveys plus ±.3g at 17cps	10 sec. (POGO simulation)	-	-
Target Docking Adapter 2	7.5g	3 min. Longit. axis	low level surveys		-	-

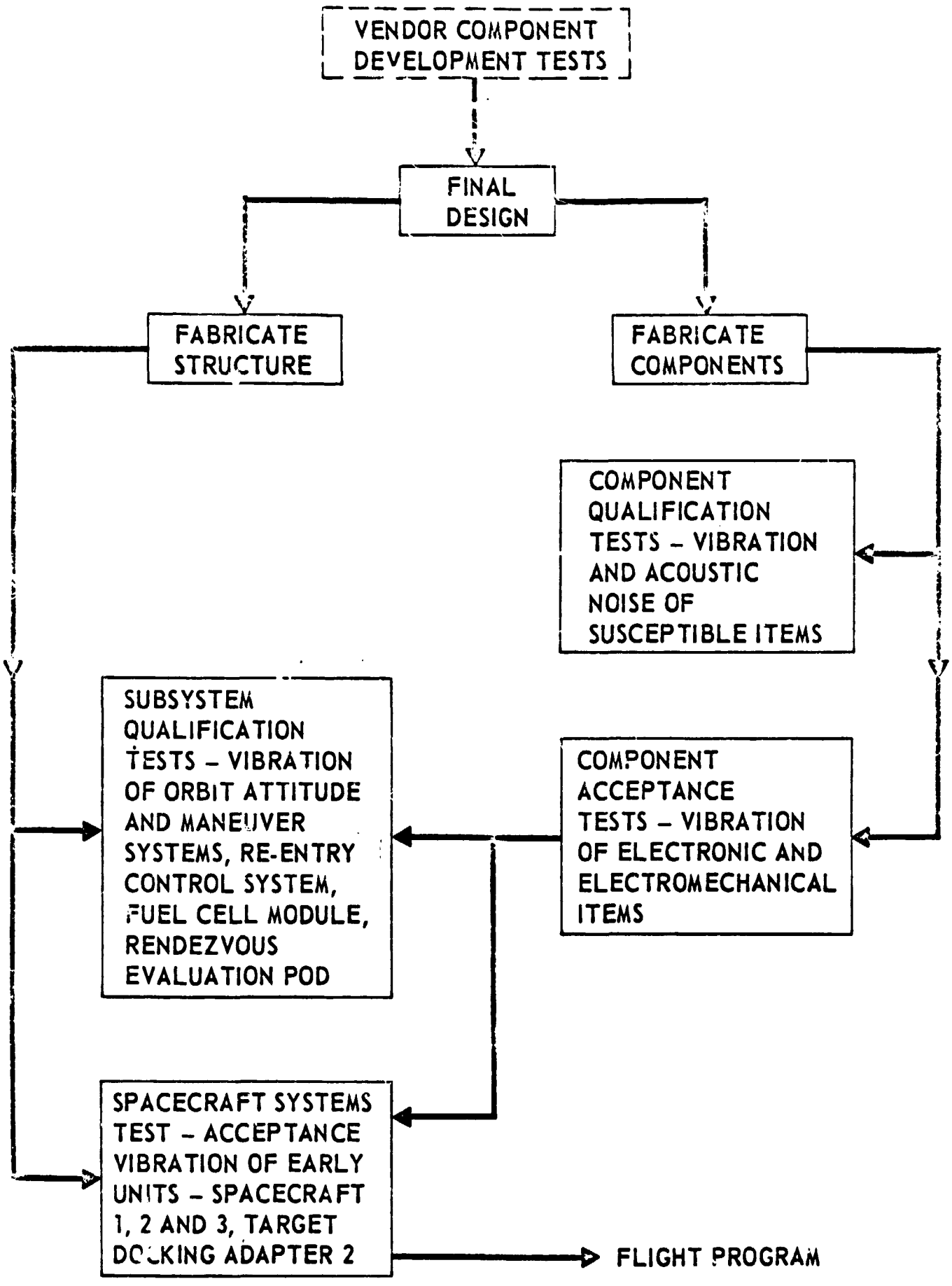


FIGURE 1-1 LABORATORY VIBRATION AND ACOUSTIC TEST PROGRAM RELATIONSHIPS

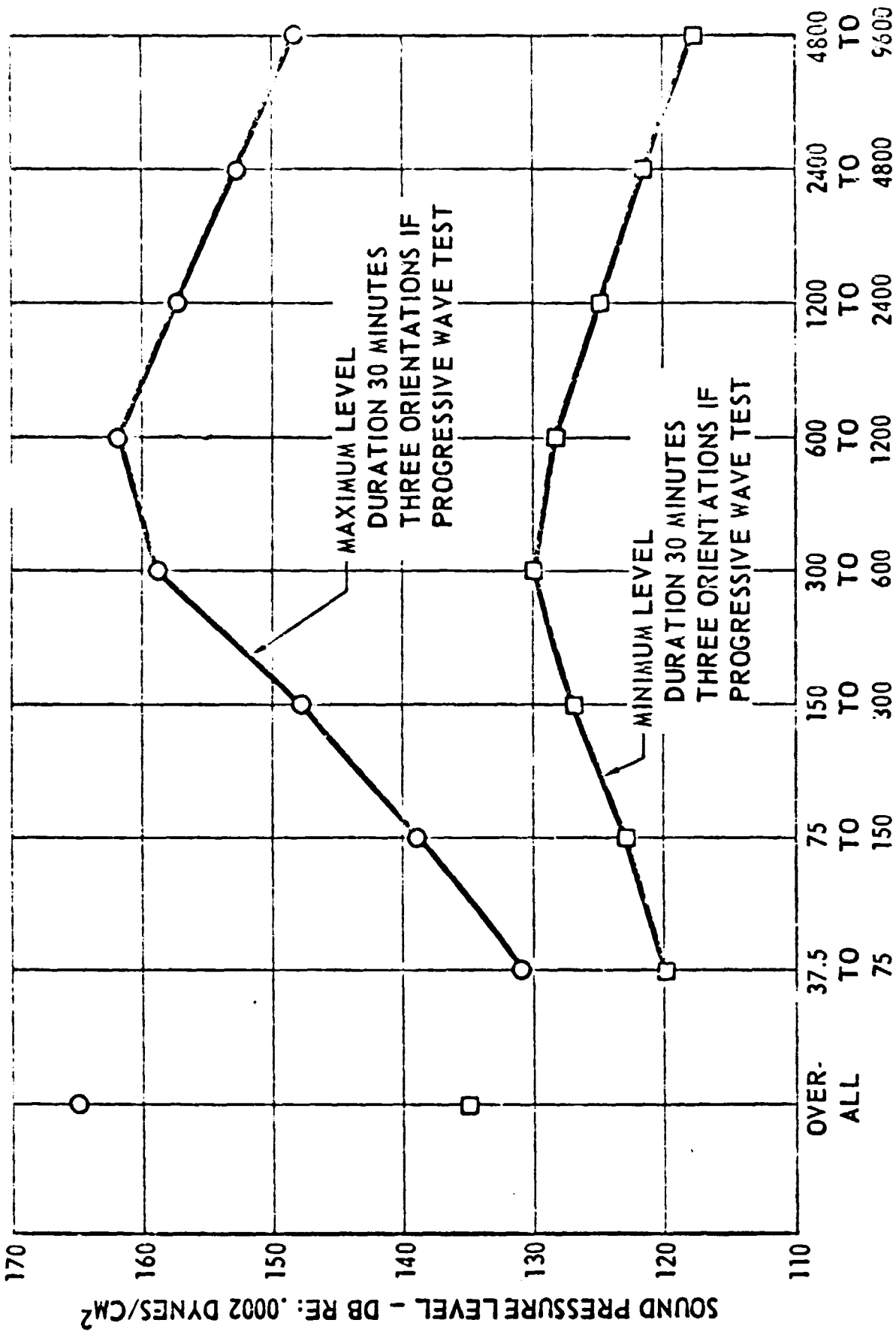


FIGURE 1-2 ENVELOPE OF ACOUSTIC QUALIFICATION TEST LEVELS.

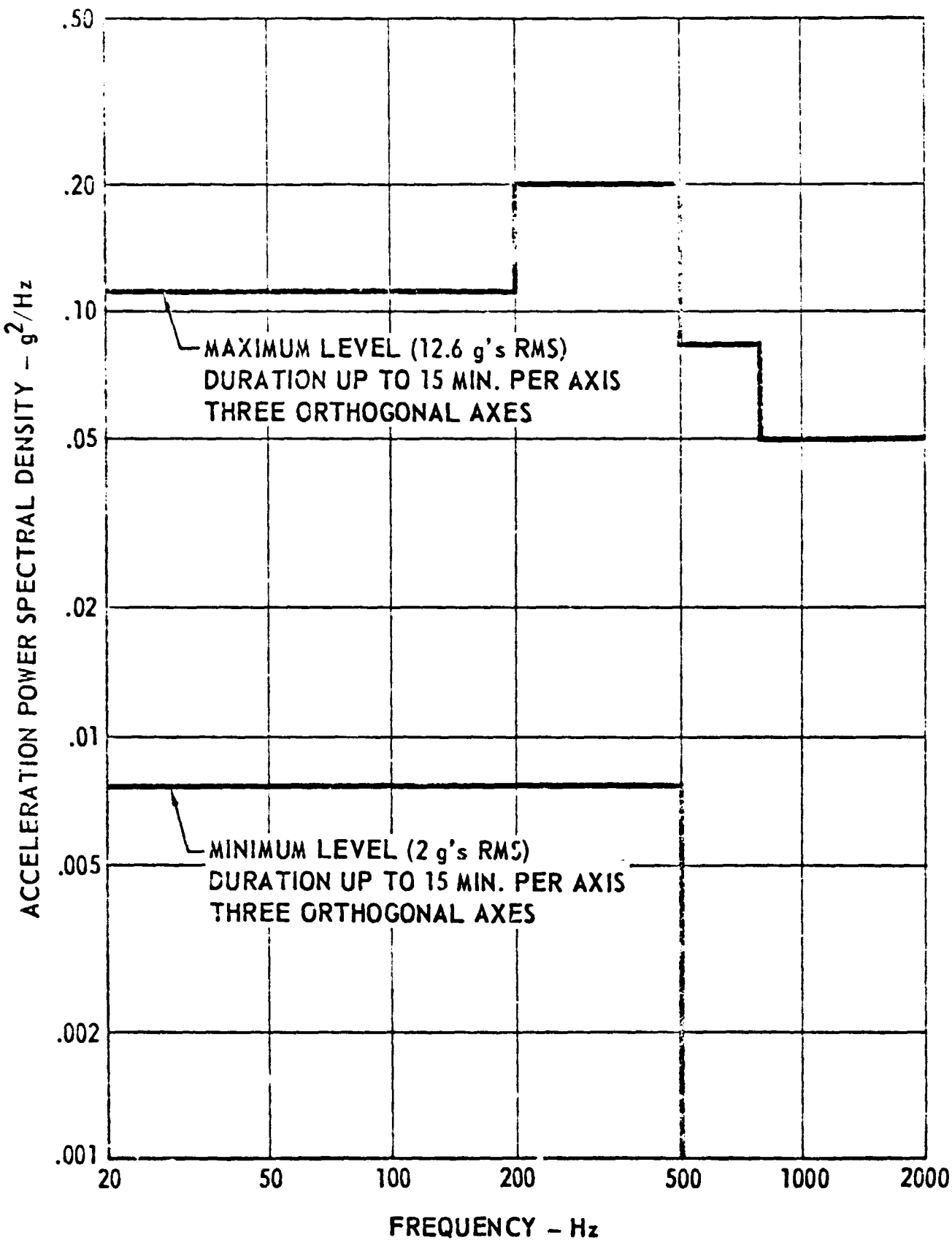


FIGURE 1—3 ENVELOPE OF RANDOM VIBRATION QUALIFICATION TEST LEVELS

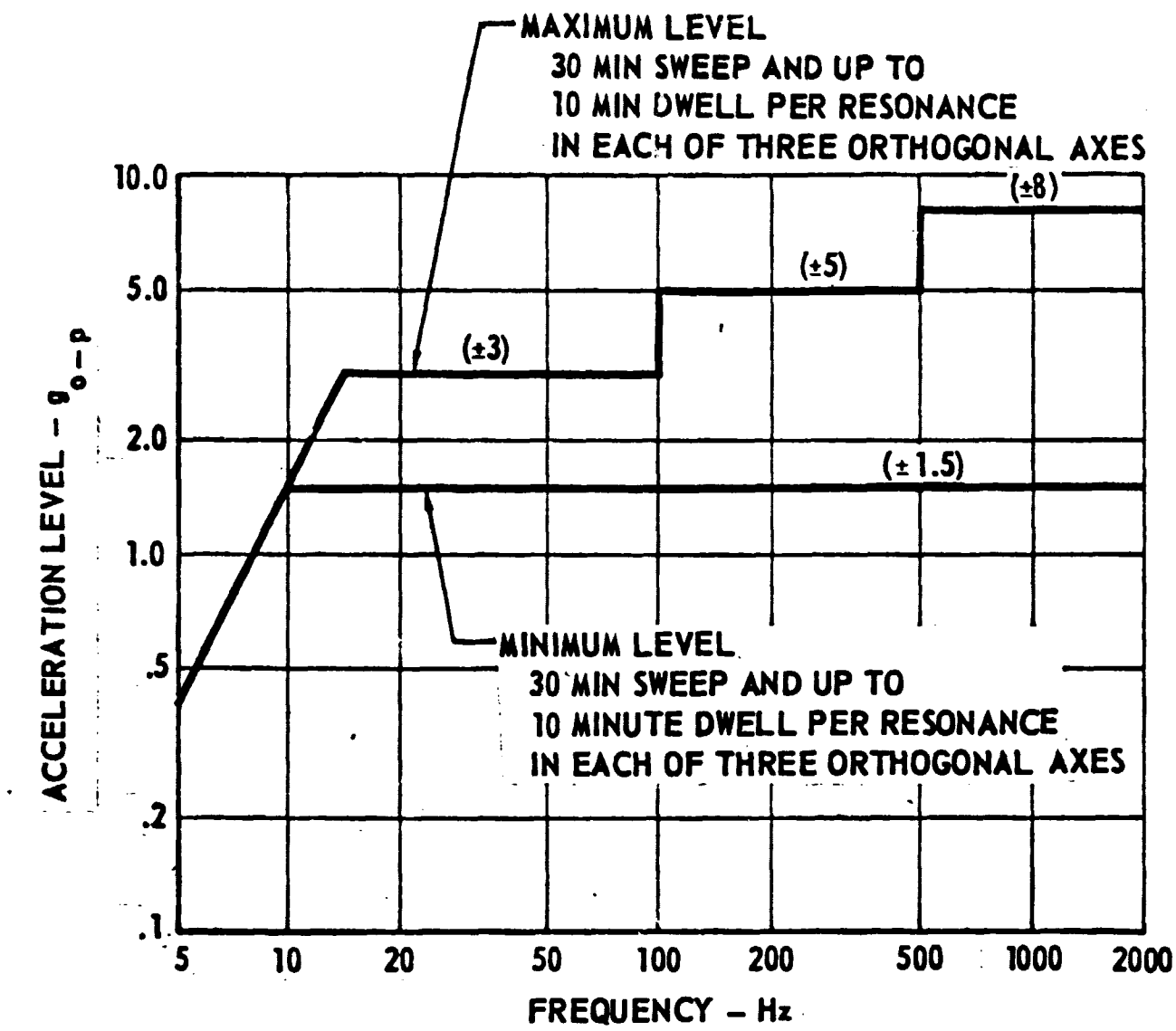


FIGURE 1-4 ENVELOPE OF SPACECRAFT SINUSOIDAL VIBRATION QUALIFICATION TEST LEVELS

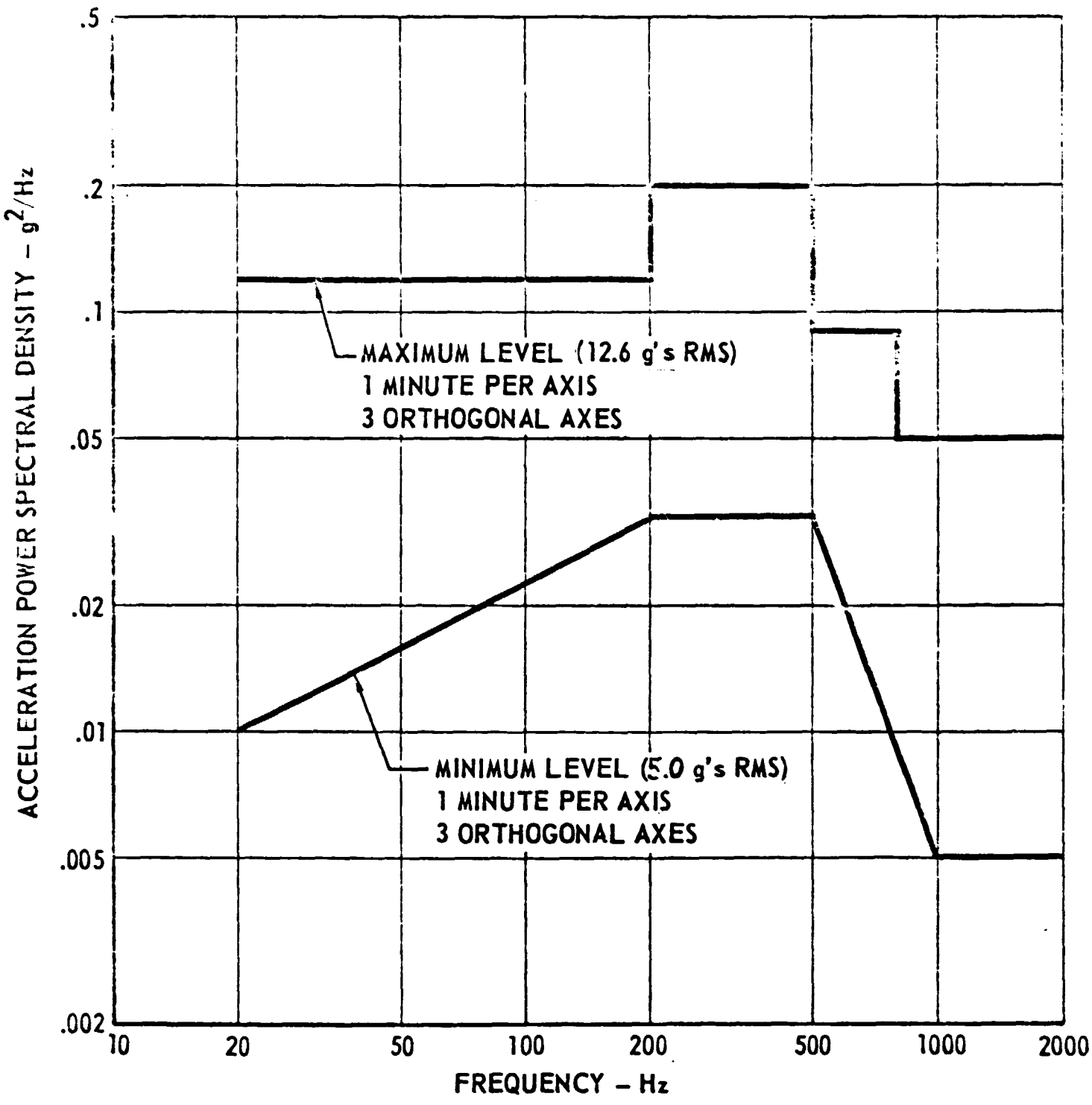


FIGURE 1—5 ENVELOPE OF RANDOM VIBRATION ACCEPTANCE TEST LEVELS

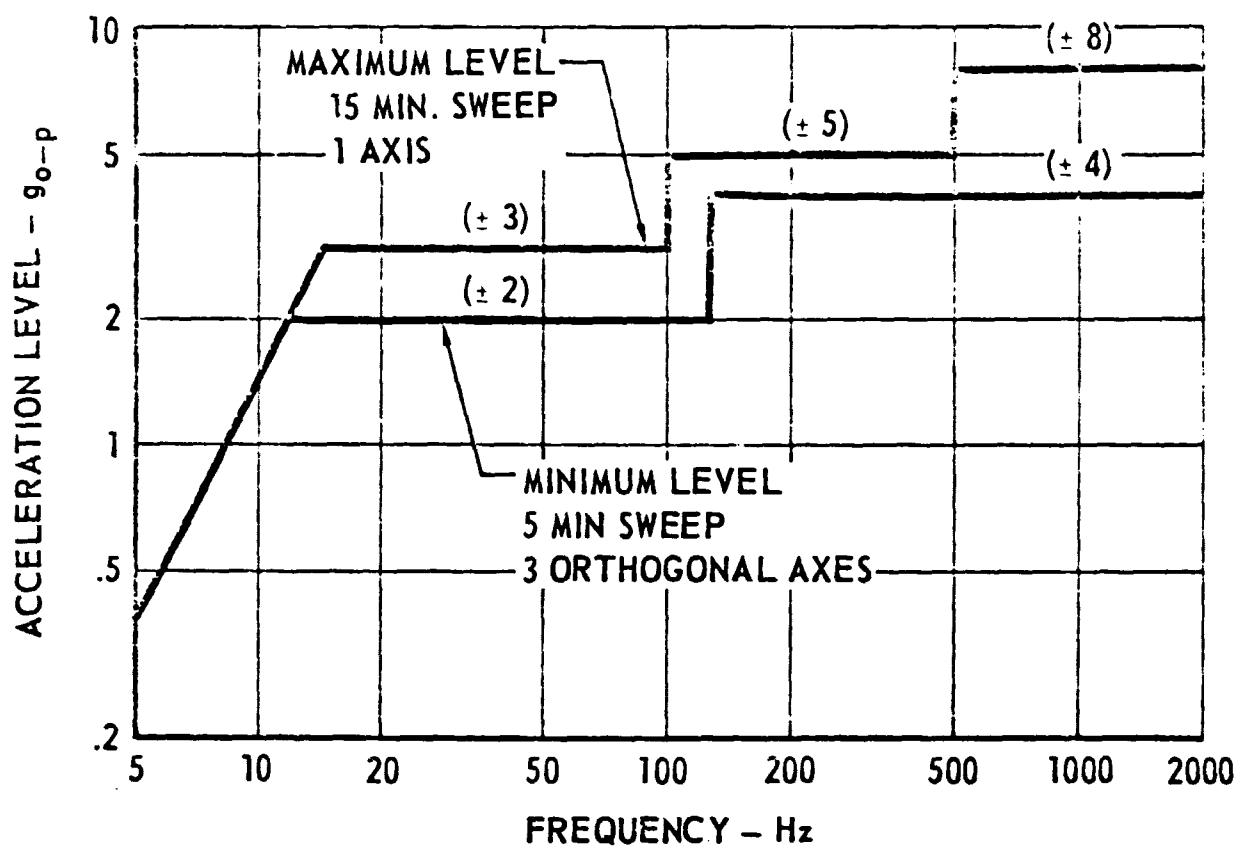


FIGURE 1–6 ENVELOPE OF SINUSOIDAL VIBRATION ACCEPTANCE TEST LEVELS

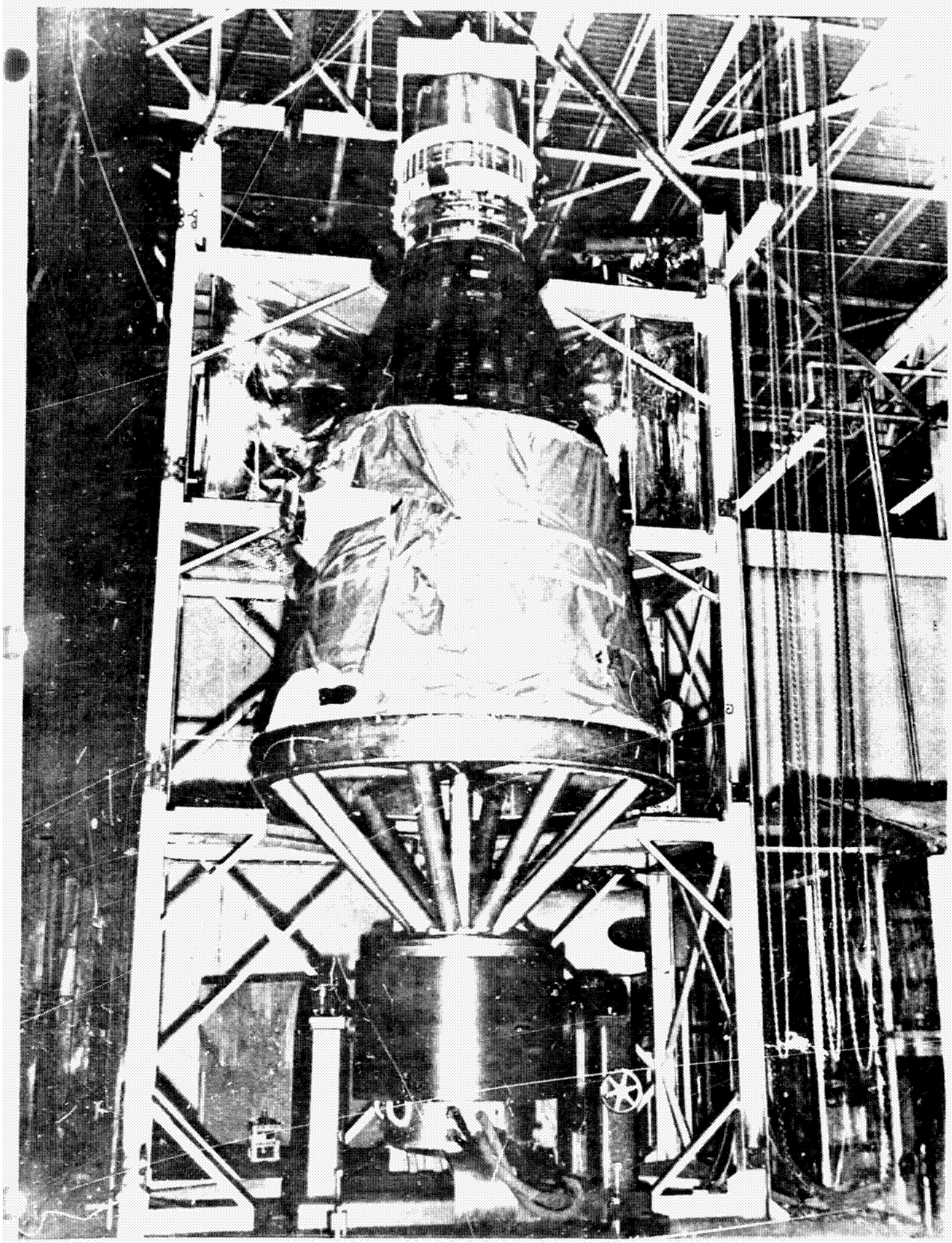


FIGURE 1-7 VIBRATION TEST OF SPACECRAFT 1

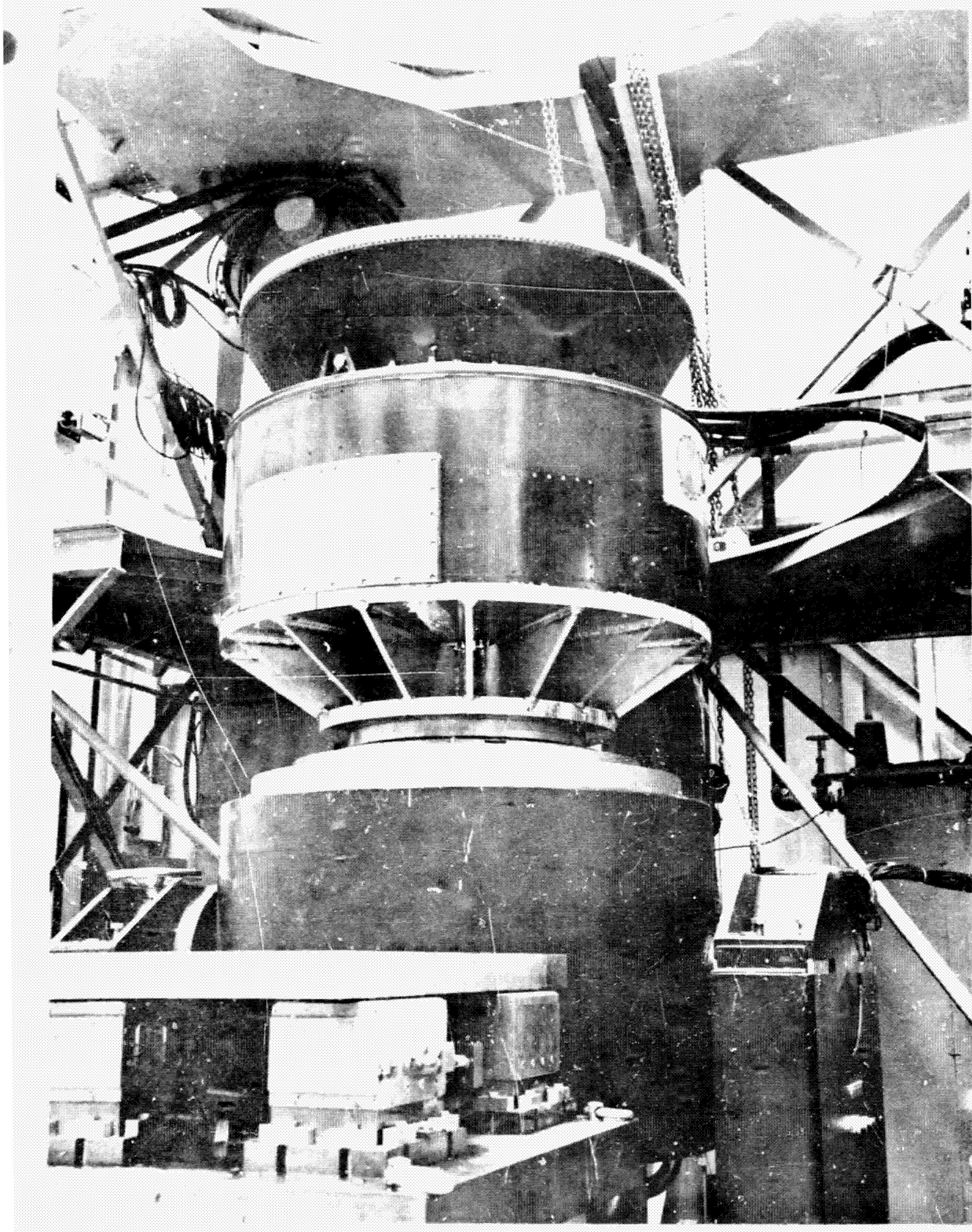


FIGURE 1-8 VIBRATION TEST OF THE FIRST FLIGHT TARGET DOCKING ADAPTER.

2.0 LABORATORY TEST FAILURES

The failures reported in this section were taken from a review of Gemini malfunction summary reports and test reports of Gemini equipment. In some instances the documents did not report full details of the level of the test conducted. In those cases the level was determined by reviewing the failure report and the equipment test requirements and the probable level inserted. The sources for this uncertainty arise since the random vibration qualification levels were changed during the program, since different levels were used to simulate different phases of flight, and in the case of acceptance tests the procedures were not closely controlled early in the program.

2.1 COMPONENT VIBRATION/ACOUSTIC TEST FAILURES

The failure lists for component qualification tests are given in Table 2.1 and for component acceptance are given in Table 2.2. The components are listed by name and are also categorized as to type. Failures are not included where the fault was either test procedure or test error since these do not have any bearing on the flight capability of the equipment. The number of such problems which were actually reported was 33 during qualification tests and 24 during acceptance tests. All acoustic tests were random, as described in Paragraph 4.0, and so only the level is given for the failures shown in the lists. The vibration tests are indicated as to whether they were sine or random, and only an abbreviated description of the levels is given. In the case of random vibration the level is given by the RMS acceleration in units of g's. The appropriate power spectral densities can be found in Paragraph 4.0 if desired. For sinusoidal tests the zero to peak acceleration levels are given which correspond to the g versus frequency spectrum of Paragraph 4.0 which has the same acceleration levels. The letter D or A is included on the table to indicate whether the failure was detected during or after the test.

2.2 SUBSYSTEM VIBRATION/ACOUSTIC TEST FAILURES

No table is included since the only failure reported was a structural problem during the 14 day Orbit Attitude and Maneuvering System (OAMS) module qualification tests. The test was random vibration at 7.0 g's RMS and a fault in design was detected when a crack occurred at a weld on the bracket holding the pressurant tanks. The structure was modified by a beef-up which was also incorporated in the 2 day OAMS. The failure was not detected during component testing since it was structure which supported several components and so was first tested at the subsystem level.

2.3 SYSTEM VIBRATION/ACOUSTIC TEST FAILURES

Table 2.3 presents the failures reported for the systems acceptance vibration tests performed on Gemini. No failures were reported for the Target Docking Adapter, and so the table is divided by spacecraft number. Detection during or after the test is noted under comments and the categories of the failed item and of the type of failure are given in that order after the description of the failure. If it was known why the failure was not detected in earlier testing the reason is included under comments.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Photo Light Assy. (Electrical)	6 of 6 lamp filaments opened. (Part failure)	Random Vibration (D)	12.6 g	Assy. modified to use 14 V bulbs and shock mount added.
Photo Light Assy. (Electrical)	4 of 6 14 V lamp filaments opened due to loose fit in socket. (Part failure)	Random Vibration (D)	12.6 g	Bulb type and mounting changed.
Photo Light Assy. (Electrical)	Lamp filaments opened due to loosening of RTV around bulb base. (Design)	Random Vibration (D)	12.6 g	Bulb type changed and rigid mount incorporated.
HF Voice T/R (Electronic)	Relay flutter due to cold solder joint at relay pin (design/workmanship)	Random Vibration (D)	12.6 g	Adjacent component relocated to allow visual and mechanical access.
Voice CNTL Center (Electronic)	Broken spring in switch actuation mechanism (part failure)	Random Vibration (A)	12.6 g	Visually examine all springs at 40 X magnification prior to installation.
S-Band Radar Beacon (Electronic)	Loose locking set screw in transmitter body (design)	Random Vibration (D)	12.6 g	Screw changed from 2-56 to 3-48.
VHF Diplexer (Electronic)	Trimmer capacitor lead fatigued (part failure)	Random Vibration (A)	8.8 g	Capacitor vendor changed and mounting changed to reduce flexure during vibration.
Horizon Sensor (Electro-mechanical)	Bolometer cap assembly pin was loose on bolometer pin causing intermittent loss of bolometer output (fabrication procedure)	Random Vibration (D)	8.8 g	Each pin socket in bolometer cap assembly now checked with a pin gage to insure proper fit on bolometer pins

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Power Inverter (Electronic)	Frequency of output signal increased for 10 sec. Cause not determined. (Unknown)	Random Vibration (D)	8.8 g	Sealing process changed to reduce chance of solder contamination during case sealing.
H.F. Antenna (Electro-mechanical	Rubber extension sleeve tore loose from its root attachment when boom extended. (Design)	Sine Vibration (A)	3, 5, 8 g	Design modified.
TM Transmitter (Electronic)	Capacitor lead broken due to excessive vibration amplification of PC board (design).	Random Vibration (D)	12.6 g	Design change incorporated thicker cover, stiffeners, and selective potting of components.
TM Transmitter (Electronic)	Internal lead of transistor separated from chip (part failure).	Random Vibration (D)	12.6 g	Transistor type changed.
TM Transmitter (Electronic)	Transformer leads broken at ground terminal (fabrication procedure).	Random Vibration (D)	12.6	Transformer leads changed from three strand to seven strand wire.
TM Transmitter (Electronic)	Plates of variable capacitor shorted by unidentified material. Attributed to excessive vibration amplification of PC board. (Design).	Random Vibration (D)	12.6 g	Design change incorporated thicker cover, stiffeners, and selective potting of components.
Low Level Multiplexer (Electronic)	Connector hold down nuts vibrated loose (Design)	Random Vibration (A)	8.8 g	Star washers/nut replaced with elastic stop nut.
Tape Recorder (Electronic)	Tape reel screws hit cover and capstan face plate hit epoxy strap. This resulted in deposition of particles on tape causing excessive data drop out. (Design)	Sine Vibration (A)	3, 5, 8 g	Strap relocated and screws replaced with button head type to increase clearance.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Inst. Pkg. (Electronic)	Package positive pressure lost due to insufficient margin between package pressure and relief valve cracking pressure (design).	Random Vibration (D)	12.6 g	Relief valve changed to one with 5 psid cracking pressure.
Inst. Pkg. (Electronic)	Relief valve opened causing loss of package positive pressure. (Part failure).	Acoustic Noise (D)	155 db	None
Phase Sensitive Demod. (Electronic)	Cause of out of tolerance performance could not be verified. Attributed to wiring external to unit. (Design).	Random. Vibration (D)	8.8 g	Wire bundle clamps added for external wiring.
D.C. Voltage Monitor (Electronic)	Cause of out of tolerance performance could not be verified. Attributed to wiring external to unit. (Design).	Random Vibration (D)	8.8 g	Wire bundle clamps added for external wiring.
D.C. Voltage Monitor (Electronic)	Loose particles in zener diode caused erratic performance. (Part failure).	Random Vibration (D)	8.8 g	Diode vendor changed.
D.C. Voltage Monitor (Electronic)	Poor bond between resistor terminal end and resistance film caused out of spec. performance. (Part failure).	Random Vibration (D)	8.8 g	Existing stocks were x-rayed for voids. Resistor vendor changed for new procurement.
CO_2 Sensor (Electronic)	Contamination shook into sensing chamber causing erratic output. (Workmanship error).	Random Vibration (D)	12.6 g	Change to lint-free lens tissue for cleaning chamber and add microscopic inspection prior to final assembly.
Temp. Sensor (Instrumentation Sensor)	Open sensor element. (Workmanship error).	Sine Vibration (A)	3, 5, 8 g	In process inspection of all brazing operations added.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Temp. Sensor (Instrumentation Sensor)	Broken sensor element resulting from cantilever mounting of ceramic sensor body in stainless steel tube. (Design)	Sine Vibration (A)	3, 5, 8 g	Design changed to support ceramic body in silicon rubber throughout length of stainless steel tube.
Temp. Sensor (Instrumentation Sensor)	Sensor element coils shook apart (increased separation) causing calibration change. (Fabrication procedure)	Sine Vibration (A)	3, 5, 8 g	Element selection initiated followed by 20 temp. cycles prior to sensor calibration.
Flashing Recovery Lt. (Electronic)	Power supply battery mounting screws backed out. (Workmanship).	Random Vibration (A)	12.6 g	Tighter quality control imposed.
Hardline Amplifier (Electronic)	Amplifier oscillated with no input signal. (Design).	Random Vibration (D)	12.6 g	Bypass capacitor added.
V.C.O. Chassis (Electronic)	Noise on output. (Design)	Random Vibration (D)	12.6 g	Design changed.
Accelerometer (Electronic/Mechanical)	Attachment screws backed out. (Design).	Random Vibration (A)	12.6 g	All units repaired and re-inspected.
Inertial Platform (Electro-Mech)	Loose and noisy synchro. (Design/fabrication procedure).	Random Vibration (L)	6.2 g	Screw type and bonding process revised, and board wire rerouted.
Inertial Platform (Electro-mech)	Excessive Gimbal 1 drift rates were recorded (subsequent vibration tests revealed that drift was not due to pitch gyro) (Unknown).	Random Vibration (D)	8.8 g	None - reason for discrepancy was not determined.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Digital Computer (Electronic)	Broken wire (design).	Random Vibration (D)	8.8 g	The 7 strand wire was replaced by 19 strand wire.
Digital Computer (Electronic)	Cold relay solder connection (poor workmanship).	Random Vibration (D)	8.8 g	Responsible operator was re-certified in a 40-hour soldering course.
Rendezvous Radar (Electronic)	Broken lead on outter perimeter of radar package (could have been broken during removal or replacement of the radome). (Unknown).	Acoustic Noise (A)	145 db	None.
Rendezvous Radar (Electronic)	Azimuth servo became stuck (suspect cause was that during assembly the start torque may not have been measured throughout the entire range of rotation) (Fabrication procedure).	Acoustic Noise (A)	145 db	Process spec. rewritten in greater detail with more emphasis applied to starting torque measurement after assembly.
Rendezvous Radar (Electronic)	Two connector were found disconnected due to burrs in the locking devices. (Fabrication procedure/poor workmanship)	Random Vibration (A)	8.8 g	Connectors were deburred and replaced eliminating the problem. In addition, inspection procedure changed.
Radar Transponder (Electronic)	Transistor lead which is soldered to a PC board broke due to added mass of a heat sink connected to the transistor case. (Design).	Random Vibration (D)	11.2 g	The heat sink is now secured to the PC board.
Radar Transponder (Electronic)	Visual inspection, after vibration and during post acoustic noise test checkout, revealed a cracked diode due to insufficient support to meet vibration requirements. (Design).	Random Vibration (A)	11.2 g	All diodes and resistors now cemented to the chasis.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Radar Transponder (Electronic)	Overstressed lockwire due to improper torque applied to lock screw. (Fabrication procedure).	Random Vibration (A)	11.2 g	Torque requirement has been applied to the locking screw and the lockwire replaced with cement.
Radar Transponder (Electronic)	Loose screws; the split lock washers used lost their effectiveness due to build up of paint, metal washers, and plastic washers. (Fabrication procedure)	Random Vibration (A)	11.2 g	Loctite now applied to screw threads.
Radar Transponder (Electronic)	Collector lead of transistor Q402 came loose from the solder which was holding it to a PC board. (Design/fabrication procedure).	Random Vibration (A)	11.2 g	Replaced the single sided board with a double sided board, and incorporated an improved mechanical holding technique in the form of a silastic.
Radar Transponder (Electronic)	Two screws were missing and the head of a third one was sheared off (condition was not detected by inspection prior to testing). (Poor workmanship/inspection procedure).	Random Vibration (A)	11.2 g	Present procedures call for recording all disassembly operations. Reinspection is required prior to beginning another environmental test.
Radar Transponder (Electronic)	A resistor exhibited a broken lead due to cross axis amplification.	Random Vibration (A)	11.2 g	Vibration amplification reduced by side panel material change.
Radar Transponder (Electronic)	Outputs out-of-spec; a cable appeared to have an intermittent open, however, during further analysis the cable was destroyed. (Unknown).	Random Vibration (A)	11.2 g	No action taken since faulty condition was not located.
Radar Transponder (Electronic)	Isolation resistor failed open due to excessive power; cause of excessive power could not be found. (Part failure).	Random Vibration (A)	11.2 g	Design change incorporated which vents this isolation resistor.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Radar Transponder (Electronic)	Broken wire at terminal of a PC board. (Design).	Random Vibration (A)	11.2 g	Vibration amplification reduced by side panel material change.
Radar Transponder (Electronic)	Lead of transistor broken at header (Design).	Random Vibration (A)	11.2 g	Vibration amplification reduced by side panel material change.
Radar Transponder	Connector found disconnected. (Design).	Random Vibration (A)	11.2 g	Vibration amplification reduced by side panel material change.
Radar Transponder (Electronic)	Frequency shifts due to defective isolator. (Part failure).	Random Vibration (D)	11.2 g	Isolator was replaced.
Radar Transponder (Electronic)	Broken resistor lead caused by motion between the heat sink and PC board during vibration. (Design).	Random Vibration (D)	11.2 g	Design change incorporated to add a rivet in the area of the resistor to reduce the motion between the heat sink and the PC board.
Radar Transponder (Electronic)	Broken lead at plus terminal of capacitor ; due to excessive amount of vibration on the unit. (Design).	Random Vibration (D)	11.2 g	Design was reviewed to insure the service loop is sufficient and that the wire is adequately supported.
Radar Transponder (Electronic)	Defective isolator; analysis revealed that the garnets internal to the isolator had shifted in position due to inadequate surface preparation for the adhesive bonds between brass spacer-stripline and garnet discs. (Part failure).	Random Vibration (A)	11.2 g	No action necessary, failure considered an isolated case.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Radar Transponder (Electronic)	Defective R-F coaxial cable and an intermittent ground connection observed on a connector. (Poor workmanship).	Random Vibration (D)	2 g	Both the coax adapter and the connector were replaced.
Radar Transponder (Electronic)	Extra transmitted pulses observed; during assembly of coax cable and connector the outside glass braid had not been trimmed far enough back allowing it to get between ground connections. (Fabrication procedure).	Random Vibration (D)	2 g	Cable assembly removed from shop area to clean room for better process control, detailed instructions issued for assembly, manufacturing and inspectioned tightened, and requirements for hi-pot test added to process.
Transponder Antenna Boom (Mechanical)	An end plug sleeve fractured at the tread undercut on the small diameter due to inadequate transponder antenna dummy load support, incorrect material, and undercut notched deeper than specified. (Design).	Random Vibration (D)	11.2 g	Sleeve end plugs to be manufactured from a different alloy and to be carefully inspected for freedom from notches and undercuts larger than specified. An additional support provided for the dummy transponder antenna.
Receiver Decoder (Electronic)	Adhesive on the board and two pins on the input side of the audio transformer were broken due to inadequate adhesive application. (Fabrication procedure).	Random Vibration (D)	12.6 g	Board assembly modified requiring adhesive bead application around transformer edge and change order issued to insure proper adhesive application.
Receiver Decoder (Electronic)	Broken transformer mounting tab caused by flexing of tab during retork to provide proper tab strength. (Fabrication procedure).	Random Vibration (D)	12.6 g	Transformers now purchased with proper tab length, and proper assembly procedures established to prevent tab damage.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Receiver Decoder (Electronic)	Transformer exhibited an open primary and secondary winding; the rubber washer between the shell and core had lost its resiliency due to being exposed to excessive temperature during curing. (Part failure).	Random Vibration (D)	12.6 g	Transformer construction was changed bonding the terminal board, spacer, cup core, core, and shell together with an epoxy adhesive, eliminating the dependency of a washer.
Receiver Decoder (Electronic)	Broken capacitor lead; lead damage of the type imposed by long nose pliers (capacitor was transferred from one board to another during manufacture). (Poor workmanship/production procedure).	Random Vibration (D)	12.6 g	Nylon block staked to lead board for added strength. Tighter inspection and limits on part reusage and transfer established.
Receiver Decoder (Electronic)	Sandwich mounting frame exhibit cracks; machining tool marks were observed at point were fracture originated.	Random Vibration (D)	12.6 g	All frames to be reworked to remove all tool marks and to provide a polished surface, and mounting fit tolerances also controlled to eliminate static overstress.
Receiver Decoder (Electronic)	Broken connector lead at the solder cup; fatigue considered to be failure cause. (Fabrication procedure).	Random Vibration (D)	12.6 g	Connector leads potted to add support and preclude fatigue type failures.
Receiver Decoder (Electronic)	Broken connector lead; 6 of 19 strands of wire were broken prior to solder operations (poor workmanship/fabrication procedure).	Random Vibration (A)	12.6 g	Connector leads now supported by potting material.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Receiver Decoder (Electronic)	Defective solder joint at the input filter; module had been transferred from one board to another with improper cleaning of pins during transfer (poor workmanship).	Random Vibration (D)	12.6 g	Procedures established for pins to be cleaned, tinned, and microscopic inspection of solder joints following rework.
Receiver Decoder (Electronic)	Resonance excitation of solder joint. (Design).	Random Vibration (D)	12.6 g	Supports added which reduce vibration levels.
Receiver Decoder (Electronic)	One broken and several loose screws were found. (Poor workmanship/fabrication procedure).	Random Vibration (A)	12.6 g	Established a torque requirement for all mounting screws, and the use of loctite on all mounting screws.
Electronic Timer (Electronic)	A relay failed to close; cause and point of failure could not be determined. (Unknown).	Random Vibration (A)	12.6 g	All production units now subjected to a limited random vibration test prior to delivery.
Electronic Timer (Electronic)	Crystal oscillator broke loose from the cement bond to Module #1, and the wire to Pin #2 of the oscillator was broken off. (Poor workmanship/fabrication procedure).	Random Vibration (D)	12.6 g	A bonding procedure has been added to the assembly drawings.
Electronic Timer (Electronic)	(1) No crystal oscillator output due to two defective internal solder connections (poor workmanship).	Random Vibration (D)	12.6 g	(1) Redesigned packaging to change from printed circuit construction to terminal construction, and change resistors.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Electronic Timer (Electronic) (Continued)	(2) Two heat sinks sheared off at the bend radius; aluminum alloy used in making the heat sinks had been structurally degraded during the dip brazing operation (fabrication procedure/design).	Random Vibration (D)	12.6 g	(2) A new base plate assembly is now being used and the heat sinks are now riveted on after completion of the dip brazing operation.
Electronic Timer (Electronic)	Timer stopped due to a wire bundle not being properly tied down. (Poor Workmanship/inspection procedure).	Random Vibration (D)	12.6 g	A paragraph covering spot ties and lacing of bundles has been incorporated in the inspection procedures.
Mechanical Clock (Mechanical)	The minute hand slipped due to insufficient tension of U-shaped friction minute recorder spring. (Design).	Random Vibration (D)		Clock spec changed requiring a 2.5 gram minimum slipping force.
Mechanical Clock (Mechanical)	The normal minute hand and elapsed time minute hand separated by 19 minutes; the friction minute recorder spring slips excessively on the center wheel shafts. (Design).	Random Vibration (D)	12.6 g	None
Mechanical Clock (Mechanical)	Clock slowed down during vibration testing but returned to normal operation during subsequent testing at room ambient conditions. (Unknown).	Random Vibration (A)	8.8 g	None since cause of discrepancy was undetermined.
Rate Gyro Package (Electro-Mech)	Broken lead wire due to inadequate strain relief. (Design).	Random Vibration (A)	12.6 g	Two cable tie-downs were added as well as one cable clamp to prevent movement of wires.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Attitude Control Electronics (Electronic)	Five of the six mounting screw assemblies were loose due to yielding of the mounting bracket material (resulted in multiple mechanical failures). (Design/fabrication procedure).	Random Vibration (A)	12.6 g	Mounting bolt assemblies changed to a new configuration, and brackets added to the interior of the unit to stiffen the cards.
Mechanical Clock (Mechanical)	The normal minute hand separated from the elapsed time minute hand; this is a problem where the clock cannot be designed to meet spec requirements. (Design.)	Random Vibration (D)	8.8 g	None.
Attitude Control Electronics (Electronic)	Various broken wires, pins, and leads were found between modules and boards (design).	Random Vibration (A)	12.6 g	Additional leadwires on the module were provided for support. Additional tie points added.
Attitude Control Electronics (Electronic)	Two broken wires due to incorrect installation of diodes. (Fabrication procedure).	Random Vibration (D)	12.6 g	Diodes re-installed correctly and cement applied to wires to provide support.
Attitude Control Electronics (Electronic)	Several capacitors broken loose from cement bond. (Fabrication procedure).	Random Vibration (A)	12.6 g	Capacitors replaced and new cement now used.
Attitude Control Electronics (Electronic)	Broken wire on terminal of a PC board. (Fabrication procedure).	Random (A)	12.6 g	Note added to production drawing calling out the use of gelatinous cement to secure leadwires to board.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Attitude Control Electronics (Electronic)	Relay failed due to a solder particle stuck on the inside surface of the relay can. (Poor workmanship).	Random Vibration (D)	8.4 g	Relays now receive x-ray inspection prior to use in assemblies.
Attitude Control Electronics (Electronic)	Erroneous jet firing signals due to oscillation caused by capacitor and transformer in the minimum pulse generator (design).	Random Vibration (D)	8.4 g	The minimum pulse generator was redesigned.
Attitude Control Electronics (Electronic)	Broken wires due to wire bundle not being adequately tied down (design).	Random Vibration (D)	12.6 g	Change initiated modifying the chasis to the wire bundle in two additional places.
Orbit Attitude and Maneuver Electronics (Electronic)	Jets failed to fire due to a failed relay. (Part failure).	Random Vibration (A)	12.6 g	Relay vendor changed.
Orbit Attitude and Maneuver Electronics (Electronic)	Four captive screws broke loose from mounting bracket due to excessive bearing load and yielding of bracket mounting material. (Design/fabrication procedure).	Random Vibration (D)	12.6 g	The captive fasteners and mounting bracket redesigned.
Orbit Attitude and Maneuver Electronics (Electronic)	Wires on two relay terminals found broken. (Design).	Random Vibration (D)	12.6 g	An aluminum spacer has been added between the relay and relay mounting board, and new fasteners now being used.
Orbit Attitude and Maneuver Electronics (Electronic)	Two relays were found to have a broken wire. (Fabrication procedure).	Random Vibration (A)	12.6 g	Strain relief loop cemented to relay board.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Orbit Attitude and Maneuver Electronics (Electronic)	Relay was not switching properly. (Part failure).	Acoustic Noise (A)	155 db	Relay vendor changed.
Attitude Control and Maneuver Electronics (Electronic)	Multiple pulsing was exhibited due to coupling of transients from the collapsing field on the jet solenoid currents circulating in the suppression networks. (Design).	Random Vibration (A)	8.8 g	Suppression networks were removed.
Attitude Control and Maneuver Electronics (Electronic)	The paraglider input resistor leads susceptible to noise pickup (design).	Random Vibration (A)	8.8 g	Removed input resistors and associated board wiring (mode of operation was not needed).
Indicator (Electro-Mechanical)	Solder seam leaked at housing/electrical connector joint (Workmanship Error).	Random Vibration (D)	8.8 g	Added leak check.
Pressure Regulator (Mechanical)	Lubricant prevented Locktite from locking bellows adjustment (Design).	Sine Vibration (A)	3, 5, 8 g	Redesigned to add positive locking of bellows adjustment.
Temperature Sensor (Instrumentation Sensor)	Coil element broke due to fatigue (Workmanship error).	Sine Vibration (D)	3, 5, 8 g	Add microscopic inspection of coil attachment.
Thrust Chamber Assembly (Mechanical)	Excessive external leakage at weld joint (Design).	Sine Vibration (A)	3, 5, 8 g	Test requirements revised to use random vibration in lieu of sine.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Relay Panel (Electrical)	Contact chatter (Design).	Random Vibration (D)	8.8 g	Additional testing indicated unit acceptable.
Relay Panel (Electrical)	Contact chatter (Design).	Random Vibration (D)	8.8 g	None.
Relay Panel (Electrical)	Contact chatter (Design).	Random Vibration (D)	8.8 g	Unit accepted.
Docking Bar Assembly (Mechanical)	Radial crack around gas port when fired (Design).	Random Vibration (A)	8.8 g	Redesign strengthened area around gas port.
Fuel Tank (Mechanical)	Leakage due to torn, deformed, blistered bladder (Design).	Random Vibration (A)	7.0 g	Reduced required test duration.
Control Relay (Electrical)	Excessive contact voltage drop due to contacts arcing when vibrated (Design).	Sine Vibration (D)	3, 5, 8 g	Increased allowable voltage drop.
Fuel Tank Assembly (Mechanical)	Leaking at housing interface flange Teflon seal (Design).	Random Vibration (A)	7.0 g	Flange redesigned adding Teflon shims and improved fasteners.
Pressure-Temperature Indicator (Electro-Mechanical)	Leak at crack in solder joint (Design).	Random Vibration (A)	8.8 g	Solder joints in case changed to weldments.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Horizon Sensor (Electro-Mechanical)	Positor springs fractured near soldered ends due to reduced spring strength caused by overheating during soldering (Workmanship).	Random Vibration (D)	8.8 g	Soldering procedure changed and personnel trained.
Thrust Chamber Assembly (Mechanical)	Fuel solenoid valve had seat leakage due to contamination (Fabrication Procedure).	Random Vibration (A)	8.8 g	Improved cleaning procedures.
Supercritical Oxygen Container (Electro-Mechanical)	Electrical lead from quantity sensor broke (Fabrication Procedure).	Sine Vibration (D)	3, 5, 8 g	Brazing technique for attaching lead revised to avoid local embrittling.
Cabin Fan Power Supply (Electrical)	Incomplete epoxy encapsulation resulted in fatigue failure of inductor lead (Workmanship Error).	Sine Vibration (D)	3, 5,	Inspection step added to insure complete encapsulation.
Guillotine Cutter (Mechanical)	Shear pins fell off (Workmanship).	Sine Vibration (D)	3, 5, 8 g	Additional inspection incorporated.
Cartridge (Mechanical)	Bridgewires broken (Fabrication Procedure).	Sine Vibration (A)	3, 5, 8 g	Revised procedures to prevent embrittlement.
Horizon Scanner Release Assembly (Mechanical	Piston broke off (Design).	Sine Vibration (D)	3, 5, 8 g	Piston material changed from Aluminum to steel.
Firing Bar Assembly (Mechanical)	Gas port ruptured when fired (Design).	Random Vibration (A)	8.8 g	Redesign strengthened area around gas port.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Breech, Pilot Mortar (Mechanical)	Breech material yielded resulting in a bulge (Fabrication Material).	Sine Vibration (A)	3, 5, 8 g	Replace aluminum breeches with steel breeches.
Cartridge, Inversion Bridle (Mechanical)	Leakage current fluctuated during dielectric check (Fabrication Procedure)	Sine Vibration (A)	3, 5, 8 g	Purchase order terminated - new procurement source established.
Pyrogen Initiator (Mechanical)	Ignition cartridge did not ignite pellets (Design).	Sine Vibration (A)	3, 5, 8 g	Redesign internal components and cartridge.
Cabin Heat Exchanger (Mechanical)	Fatigue failure of mounting bracket (Design).	Sine Vibration (D)	3, 5, 8 g	Bracket redesigned.
Coolant Shutoff Valve (Mechanical)	Extrusion of o-ring and backup ring during combined pressure - temperature - vibration testing (Workmanship Error).	Sine Vibration (D)	3, 5, 8 g	Increased inspection to assure that threads and o-ring seat meet drawing requirements.
Optical Sight (Mechanical)	Glass-to-frame epoxy bond separated (Design).	Random Vibration (A)	8.8 g	Frame redesigned to increase rigidity and adhesive changed.
Optical Sight (Mechanical)	Resonance broke reticle illumination filaments (Design).	Random Vibration (A)	8.8 g	Silicone foam damping tape added to sight base and lamp clamped in socket.
Range Rate Indicator (Electro-Mechanical)	Pivot wear induced balance error (Design).	Random Vibration (A)	8.8 g	Specification relaxed for qual. test units.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Flight Director Controller (Electrical)	Absence of tie-down strap resulted in broken wire (Workmanship Error).	Random Vibration (D)	12.6 g	Inspection procedures revised to verify presence of strap.
Flight Director Controller (Electrical)	Fatigue failure resulted from flexing of excessive length of unsupported wire. (Fabrication Procedure).	Random Vibration (D)	12.6 g	Tie points added to secure cable. Limit to length of unsupported wire added.
Incremental Velocity Indicator (Electro-Mechanical)	Poor bond between glass shell and end electrodes resulted in an intermittantly open diode (Fabrication Procedure)	Random Vibration (D)	8.8 g	Bonding progress improved.
Suit Circuit ECS (Mechanical)	Seal which retains lithium hydroxide and charcoal was found loose (Design).	Sine Vibration (A)	3, 5, 8 g	Seal redesigned.
Power Supply (Electrical)	Voids and pits in cover-to-base plate solder seal resulted in leakage (Design)	Sine Vibration (A)	3, 5, 8 g	All solder joints coated with epoxy.
Pressure Switch (Electro-Mechanical)	Contacts burnt from contact chatter (Design).	Sine Vibration (D)	3, 5, 8 g	100% trigger spring inspection added.
Hydrogen Subassembly (Electro-Mechanical)	Gaging system operation was erratic (Design).	Sine Vibration (D)	3, 5, 8 g	Subassembly redesigned.
Pressure Switch (Electro-Mechanical)	Trigger assembly actuating pad was misaligned (Design).	Sine Vibration (D)	3, 5, 8 g	Pressure switch was redesigned.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Secondary Oxygen Supply (Electro-Mechanical)	Brazed joint between regulator tubing and manifold cracked (Design).	Sine Vibration (D)	3, 5, 8 g	Bracket redesigned to increase rigidity.
Press Oxygen Regulator (Mechanical)	Silver seat damaged resulting in leakage (Design).	Sine Vibration (D)	3, 5, 8 g	Seat material changed to silicone.
Suit Fan Check Valve (Mechanical)	Fatigue failure of semi-rigid spring allowed flapper to remain open (Design).	Sine Vibration (A)	3, 5, 8 g	Spring design changed to more flexible "looped" design.
Lithium Hydroxide Cartridge (Mechanical)	Buckled filters allowed particles of lithium hydroxide and charcoal to pass into the suit loop (Design).	Sine Vibration (A)	3, 5, 8 g	Cartridge redesigned to increase rigidity of filter. Lithium hydroxide now bagged.
MDF Interconnect (Mechanical)	Separation at solder joint (Fabrication Procedure).	Random Vibration (A)	8.8 g	Fabrication procedure revised; pressure test added.
MDF Interconnect (Mechanical)	Separation at solder joint (Fabrication Procedure).	Random Vibration (A)	8.8 g	Soldering procedure revised; cleaning methods revised; load test added.
Sabot (Mechanical)	Sabot fractured when break bolt didn't break (Design).	Sine Vibration (A)	3, 5, 8 g	Designed weaker break bolt.

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

REPRODUCIBILITY OF THE ORIGINAL PAGE IS POOR

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
[illegible]ridge [illegible]nical)	Dielectric breakdown (Design).	Sine Vibration (A)	3, 5, 8 g	Cup changed from anodized aluminum to mykroy glass bonded mica cermoplastic insulator cup.
[illegible] Mortar [illegible]hanical)	Breech bulged when fired (Design).	Sine Vibration (A)	3, 5, 8 g	Breech material changed from aluminum to steel.
[illegible]ridge [illegible]nical)	Broken leadwires (Design).	Sine Vibration (D)	3, 5, 8 g	Incorporated centrally located anchor pin to prevent relative motion between initiator and body.
[illegible]tion Test [illegible]n Assembly [illegible]nical)	Broken bridgewire ([illegible]ication Procedure).	Sine Vibration (A)	3, 5, 8 g	Tightened inspection and test procedures for welded bridgewire joints.
[illegible] Sensor [illegible]nics Package [illegible]tronic)	Shorted wire due to wear through of insulati[illegible] cause by oscillations of wire during vibration (Design).	Random Vibration (D)	8.8 g	Design change incorporated to allow more clearance and prevent abrasion.
[illegible]gment [illegible] C [illegible]nical)	Crack in tube-to-housing weld joint due to undercut condition (Workmanship).	Sine Vibration (A)	3, 5, 8 g	Additional inspection point added.
[illegible] Tank [illegible]ly (Mechani-[illegible])	Leakage at housing interface flange Teflon seal (Design).	Random Vibration (A)	8.8 g	Redesign flange with added Teflon shims and improved fasteners.
[illegible]tal Velo-[illegible] Indicator [illegible]nical	During accuracy check the "Y" channel dropped one bit three times (Unknown).	Random Vibration (A)	8.8 g	None. Unit was dropped and failure could not be repeated.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Maneuvering Control (Electro-Mechanical)	Over stressed caliper spring failed (Design).	Sine Vibration (D)	3, 5, 8 g	Centering mechanism was redesigned.
Oxygen Quantity and Pressure Indicator (Electro-Mechanical)	Leakage resulted from voids in the potting between the case and the glass face (Fabrication Procedure).	Random Vibration (A)	8.8 g	Increased care used to mix and apply potting material and added leak check during acceptance tests.
Fuse (Electrical)	Fuse wire broken due to excessive power application (Design).	Random Vibration (D)	8.8 g	Fuse changed to different design incorporating silicon fill for improved vibrational and thermal characteristics
Fuse (Electrical)	Fuse wire melted and separated due to excessive heat. Over heating caused by absence of heat convection when unsealed fuse was exposed to vacuum (Design).	Random Vibration (A)	8.8 g	Fuse design changed to incorporate hermetical sealed unit.
Circuit Breaker (Electrical)	Leaked at soldered seal due to loads induced from test set-up and improper solder procedure (Fabrication).	Sine Vibration (A)	3, 5, 8 g	Assembly procedures and test set-up revised.
Circuit Breaker (Electrical)	Leaked from glass bead around terminal due to sleeve type terminal requiring two soldering operation. Heating from second operation caused crack (Design).	Sine Vibration (A)	3, 5, 8 g	Terminal changed to eliminate necessity for two separate soldering operations.
Circuit Breaker (Electrical)	Unit leaked at solder joint due to improper assembly (Workmanship).	Sine Vibration (A)	3, 5, 8 g	Manufacturing personnel cautioned.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Circuit Breaker (Electrical)	Unit failed to open at required current input due to incorrect counter balance position and distorted armature adjustment (Fabrication Procedure).	Sine Vibration (A)	3, 5, 8 g	Improved inspection, adjustment and cleaning procedures.
Relay Panel (Electrical)	Intermittent discontinuities (Design).	Random Vibration (D)	7.0 g	Panel modified with a bridge circuit and retested.
Relay Panel (Electrical)	Contact chatter (Design).	Random Vibration (D)	8.8 g	Thickness of panel chasis material increased.
Relay Panel (Electrical)	Contact chatter (Design).	Random Vibration (D)	7.0 g	None; panel considered acceptable.
Relay Panel (Electrical)	Contact chatter (Design).	Random Vibration (D)	8.8 g	Panel redesigned to incorporate increased chasis thickness and supporting ribs.
Relay Panel (Electrical)	Panel Mounting spacers cracked; contact chatter (Design).	Random Vibration (D)	8.8 g	Unit repaired; unit considered flight-worthy with existing contact anomalies.
Relay Panel (Electrical)	Contact chatter (Design).	Random Vibration (D)	8.8 g	None; unit considered acceptable for use on S/C 2.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
I.G.S. Static Power Supply (Electronic)	DC section overload circuitry actuated due to diode CR35 failure; diode exhibited a hairline crack thru chip with evidence of metal migration (Part Failure)	Random Vibration (D)	6.2g	Unit identified as unacceptable for flight
Gimbal Control Electronics (Electronic)	Shorted diode due to loc solder ball inside the device (Part Failure)	Random Vibration (D)	6.2g	All diodes of this type in stock were radiographic inspected; diodes with foreign matter greater than 1 milli-inch diameter rejected
Horizon Sensor Electronics Pkg. (Electronic)	Primary winding of power transformer open. (Fabrication Procedure)	Random Vibration (A)	6.2g	Transformers now soldered and inspected per process spec 1, then potting accomplished in two steps.
Horizon Sensor (Electro-Mech)	Coil wire found separated at the junction of coil wire and lead out wire. (Fabrication Procedure and Design)	Random Vibration (D)	6.2g	Coil wire increased in length for heat sinking purposes. Oper. Sheets revised to include flux removal from solder joints before potting.
Horizon Sensor (Electro-Mech)	Azimuth Drive Ring Assy. contacted the Azimuth Drive Coils due to improper seating at time of attachment. (Febrication)	Random Vibration (D)	6.2g	Operation sheets modified to reflect seating techniques and QA checks added. Manufacturing and QA Personnell instructed in seating methods and checks.
Horizon Sensor (Electro-Mech)	Rotor shaft broken and insulator broken loose from conductor. Adhesive bond failure resulted from excessive vibration combined with excessive positor rotor shaft rework. (Excessive Rework)	Random Vibration (A)	6.2g	Positor Drawings, procedure, and geration sheets revised to prevent more than one rework on any positor without replacing it.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Horizon Sensor (Electro-Mech)	One assembly in scale factor loop moved during vibration resulting in a pitch output reading 50 mv out-of-spec. (Part Failure)	Random Vibration (A)	6.2g	Pitch null potentiometer readjusted.
Horizon Sensor (Electro-Mech)	Piece of wire found between coasting and yoke caused yoke to fail to azimuth in Y Axis vibration. (Workmanship Error)	Random Vibration (D)	6.2g	All cut wires will be accounted for prior to continuing the operation severed end of wire cut to be held with special cutters.
Horizon Sensor (Elec-Mech)	Null shift -Bolometer flake centering lost when bolometer worked loose during vibration. (Workmanship error)	Random Vibration (A)	6.2g	Since Loc-Tite was not applied to screw threads, QC operation and inspection sheets have been revised to insure operation is accomplished.
Horizon Sensor (Electro-Mech)	One of the two mechanical stop assemblies on positor assembly worked loose and backed out of its threaded hole during vibration testing. (Workmanship error)	Random Vibration (D)	6.2g	Since Loc-Tite had not been applied to the screw threads, QC operation and inspection sheets have been revised to insure operation is accomplished
Rendezvous Radar (Electronic)	Out of spec readings on sensitivity, angle and readout. (Design)	Random Vibration (A)	6.2g	Unit accepted as is.
Rendezvous Radar (Electronic)	Transistor base lead open due to vibration and intermittently shorting with variations in temperature. (Part Failure)	Random Vibration (A)	6.2g	No corrective action. Failure considered unlikely to reoccur.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Rendezvous Radar (Electronic)	Range and Range Rate Voltage out-of-spec. (Design)	Random Vibration (D)	6.2g	Unit accepted as is.
Rendezvous Radar (Electronic)	Valve threads stripped due to excessive torque during installation. (Fabrication Procedure)	Random Vibration (A)	6.2g	Test Spec. clarified for proper directional operation and proper torque requirement of 50 ± 5 in.-lbs. Open end adapter also provided for torque wrench for improved operation.
Rendezvous Radar Transponder (Electronic)	Excessive local oscillator output power. Extra pulses displayed on video during vibration. (Part Failure)	Random Vibration (A)	6.2g	Local oscillator replaced and test rerun.
Dipole Antenna (Electronic)	Antenna gain out-of-spec. (Design)	Random Vibration (A)	7.9g	Unit accepted as is.
Dipole Antenna (Electronic)	Antenna gain out-of-spec. (Design)	Random Vibration (A)	7.9g	Unit accepted as is.
Radar Transponder (Electronic)	Pulse width out-of-spec during vibration. (Unknown)	Random Vibration (D)	7.9g	Condition accepted, identified not acceptable for flight.
Manual Data Readout Unit. (Elec-Mech)	While in non-operating mode, wheel indicator drove to 7, 0, and 5 alternately and vibrated up and down. (Part Failure)	Random Vibration (D)	8.4g	Condition attributed to out-of-balance drum and/or excessive bearing clearance. Unit life tested then scrapped.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Manual Data Readout Unit. (Elec-Mech)	During non-operational vibration, wheel indicator digits began to oscillate. (Part Failure)	Random Vibration (D)	6.2g	Indicator assembly replaced and unit subjected to complete re-acceptance test.
Manual Data Readout Unit. (Elec-Mech)	MDIU indicator lights went out. MDIU Tester -12V power supply failed. (Part Failure)	Random Vibration (A)	6.2g	Replaced -12V power supply in MDIU Tester, recalibrated and resumed testing.
Manual Data Readout Unit. (Elec-Mech)	During operational and non-operational vibration, wheel indicator digits began to oscillate. (Part Failure)	Random Vibration (D)	6.2g	Indicator assembly replaced and unit subjected to reacceptance test.
Manual Data Readout Unit. (Elec-Mech)	"Clear" switch had low contact pressure which caused it to open during vibration. (Part Failure)	Random Vibration (D)	6.2g	Switch replaced.
Elapsed Time Digital Clock. (Elec-Mech)	Digital readout display stopped as a result of transitor base to collector short. (Part Failure)	Random Vibration (D)	6.2g	Monitored vibration test established for 100% screening of transistors prior to assembly.
Mechanical Clock (Mechanical)	Elapsed time hand advanced .2 minutes due to friction spring decreased contact area. (Inspection Error)	Random Vibration (D)	6.2g	Vibration screening to be accomplished per Design Instructions.
Mechanical Clock (Mechanical)	Elapsed time hand advanced 9 minutes under 1 minute vibration due to misadjustment of end play between shaft and bearing surfaces. (Workmanship Error)	Random Vibration (D)	6.2g	Vibration screening to be accomplished per design instructions.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Attitude Control Electronics (Electronic)	Secondary jets did not fire due to breakage of two wires from terminations. (Design)	Random Vibration (D)	8.4g	Wire bundle had no tie down clamps for six inch span. Change incorporated to tie down wire in two places.
Attitude Control Electronics (Electronics)	24 volt supply fuse blows because diode installed backwards. (Workmanship Error)	Random Vibration (D)	6.2g	Testing adequate to detect this type of failure.
Tape Recorder (Electronic)	Coil tuning screw backed out. (Fabrication Procedure)	Random Vibration (A)	8.4g	Lock-Tite added to all components with screw adjustments.
Telemetry Transmitter (Electronic)	Glass case of crystal was cracked. (Workmanship)	Random Vibration (D)	6.2g	Assembly and inspection personnel cautioned to exercise care in handling and assembly.
Telemetry Transmitter (Electronic)	Microscopic particles in transistor caused loss of transmitter output. (Part Failure)	Random Vibration (D)	8.4g	Transistor type changed. New unit to undergo vibration screening.
Telemetry Transmitter (Electronic)	Coil lead broke. (Part Failure)	Random Vibration (D)	8.4g	Lead wire changed from 3 strand to 7 strand wire.
Telemetry Transmitter (Electronic)	Transistor shorted due to metal balls resulting from case welding process.	Random Vibration (D)	8.4g	New weld head and new weld process instituted.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
PCM Programmer (Electronic)	Broken lead on multilayer P.C. Board.	Random Vibration (A)	6.2g	Multilayer P.C. Board Vendor changed.
PCM Programmer (Electronic)	Metal contaminant in teflon insulating tape caused short. (Workmanship)	Random Vibration (A)	6.2g	Tape thickness increased and special pre-assy. test incorporated.
Low Level Multiplexer (Electronic)	Broken lead on multilayer P.C. Board at plated thru hole. (Part Failure)	Random Vibration (A)	6.2g	Added inspection including micro-sectioning of sample boards instituted.
High Level Multiplexer (Electronic)	Open Resistor. (Part Failure)	Random Vibration (A)	6.2g	Replaced defective module.
Tape Recorder (Electronic)	Reel screws interfering with lid. (Design)	Random Vibration (A)	6.2g	Cap screws replaced with button head screws and reel snubbers added.
DC-DC Converter (Electronic)	Out of spec performance due to undetermined cause. (Unknown)	Random Vibration (A)	6.2g	None
BIO-MED. DC-DC Converter (Electronic)	Open resistor due to cracked glass base (Part Failure)	Random Vibration (A)	6.2g	Resistor venor changed.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
BIO-MED. Power Supply (Electronic)	Variation in element spacing of wire-sound potentiometer caused ripple. (Part Failure)	Random Vibration (D)	6.2g	Potentiometer replaced.
DC-DC Converter (Electronic)	Shorted transistor due to external solder ball. Loose nuts on mounting studs of two Diodes and two transistors. (Workmanship)	Random Vibration (A)	6.2g	Manufacturing personnel cautioned. Nuts to be epoxy bonded.
DC-DC Converter (Electronic)	Screw backed out due to broken lock-washer. (Part Failure)	Random Vibration (D)	6.2g RMS	None. As test considered adequate screen.
Synchro. Repeater (Electrical)	Lead wire and capacitor lead broken due to flexing of connector harness. (Fabrication Procedure)	Random Vibration (D)	8.9g RMS	Tie point added to harness.
Synchro. Repeater (Electrical)	Cover amplified G level to internal components causing potentiometers to not track input. (Design)	Sine Vibration (D)	2,4g	None. Resonance not predictable due to cover being welded to the assembly.
Temperature Sensor (Instrument. Sensor)	Element unwound during vibration, causing an increase in resistance. (Part Failure) NOTE: This same failure mode occurred on 13 separate components.	Sine Vibration (A)	3,5,8g	All sensor elements were subjected to a vibration screening test prior to element calibration.
Temperature Sensor (Inst. Sensor)	Leads broke away from attachment in element ceramic. (Design)	Sine Vibration (A)	3,5,8g	Redesign added metal case housing for added lead support.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Temperature Sensor (Inst. Sensor)	Fractured braze joint at tip of element. (Workmanchip)	Sine Vibration (A)	3,5,8g	Production personnel cautioned. Additional inspection incorporated.
Temperature Sensor (Inst. Sensor)	Open element at temp. test following vibration. Element had been improperly installed. (Workmanship)	Sine Vibration (A)	3,5,8g	Temp. shock of elements prior to use.
RCVR - Decoder (Electronic)	Crystal lead separated causing intermittent contact. This damage due to crystal being moved after installation (Workmanship)	Random Vibration (D)	8.4g	Caution note added to mfg. process sheet.
RCVR - Decoder (Electronic)	Four mounting screws backed out because during prior rework assy. personnel failed to remove old lock-tite before re-assembly. (Workmanship)	Random Vibration (D)	8.4g	Process specification issued to require removal of old lock-tite from screws during rework.
RCVR - Decoder (Electronic)	Noise caused by floating connectors vibrating against mounting frame. (Design)	Random Vibration (D)	8.4g	None as performance and life of unit not compromised.
RCVR - Decoder (Electronic)	Cracked solder joint resulted in erroneous pulse. (Workmanship)	Random Vibration (D)	8.4g RMS	None as then current test and design considered adequate.
Power Inverter (Electronic)	Transistor shorted collector-emitter causing loss of regulation. Failure attributed to pre-potting handling damage. (Workmanship)	Random Vibration (D)	8.4g	Inspection and production personnel cautioned by refresher training session.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
UHF Voice T/R (Electronic)	Tuning coils detuned due to vibration. (Design)	Random Vibration (D)	6.2g	Epoxy applied to coil slugs after final tuning.
UHF Voice T/R (Electronic)	Contaminant on tube grid caused power fluctuation. (part Failure)	Random Vibration (D)	6.2g	All tubes in stock inspected for contamination.
HF Voice T/R (Electronic)	Power output decreased due to undetermined cause. (Unknown)	Sine Vibration (D)	3g	None as cause of failure was undetermined.
HF Voice T/R (Electronic)	Zener diode shorted. (Part Failure)	Random Vibration (D)	6.2g	Replaced diode. No design change.
Voice Control Center (Electronic)	Volume control knob changed position during vibration. (Design)	Random Vibration (D)	6.2g	Detent added to potentiometer drive gear to preclude position change.
Voice Control Center (Electronic)	Secondary of output transformer was intermittently open. (Part Failure)	Sine Vibration (D)	3g	Transformer screening tests initiated.
Voice Control Center (Electronic)	Motion of input transformer due to poor adhesion of foam potting - caused noise. (Workmanship)	Random Vibration (D)	6.2g	Unit cleaned and repotted.
Voice Control Center (Electronic)	Shorted diode (Part Failure)	Random Vibration (D)	6.2g	Replaced diode

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
C-Band Beacon (Electronic)	Two nuts fell off during vibration. (Workmanship)	Random Vibration (D)	6.2g	Inspection and production personnel cautioned.
C-Band Beacon (Electronic)	Transistor die cracked during vibration causing junction shorts. (Part Failure)	Random Vibration (D)	6.2g	Beacon level vibration test considered sufficient to detect defective transistors.
C-Band Beacon (Electronic)	Coax cable connector came loose. (Workmanship)	Random Vibration (D)	6.2g	None as Beacon level vibration considered sufficient to detect problem.
C-Band Beacon (Electronic)	Diode solder lug shorted to cover. Improper location caused lug to be adjacent to cover. (Fabrication Procedure)	Random Vibration (D)	6.2g	Solder lug relocated and production routing sheets revised.
C-Band Beacon (Electronic)	Ground lead to capacitor broken due to capacitor moving. (Fabrication Procedure)	Random Vibration (D)	6.2g	Production personnel alerted of necessity to provide sufficient staking compound on capacitor.
C-Band Beacon (Electronic)	SCR had low forward breakdown due to moisture leakage into case. (Part Failure)	Random Vibration (D)	6.2g	Leak test added for all SCR;s.
C-Band Beacon (Electronic)	Excessive count-up on output. Cause undetermined. (Unknown)	Random Vibration (D)	6.2g	All beacons vibrated in three planes during acceptance test.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
C-Band Beacon (Electronic)	Diode case shorting to capacitor lead. (Fabrication Procedure)	Random Vibration (D)	6.2g	Capacitor lead dressed away from diode and shrink tubing sleeve put over diode case.
C-Band Beacon (Electronic)	Open capacitor due to insufficient electrolyte. (Part Failure)	Sine Vibration (A)	2,4g	Epoxy seal and special fill procedures added to capacitor.
C-Band Beacon (Electronic)	Crack in coax cable due to flattened surface on inner radius at 90 degree bend. (Workmanship)	Sine Vibration (D)	2,4g	Production personnel cautioned
C-Band Beacon (Electronic)	Defective solder connection on L.O. input. (Workmanship)	Sine Vibration (D)	2,4g	Production personnel cautioned. Inspection of all connections with 5x glass instituted.
C-Band Beacon (Electronic)	Loose coax cable connector. (Workmanship)	Sine Vibration (D)	2,4g	Additional production and inspection procedures instituted to assure proper tightening of connectors.
C-Band Beacon (Electronic)	Diode Shorted. Diode manufacturer changed construction without notice to user resulting in PIV being exceeded. (Part Failure)	Random Vibration (A)	6.2g	Additional diode inserted in series to compensate for reduced PIV of changed (original) diode.
C-Band Beacon (Electronic)	Loose coax connector had been improperly safety wired. (Workmanship)	Random Vibration (D)	6.2g	Inspection personnel cautioned.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
H.F. Antenna (Electro-Mech)	Mislocated shim washer shorted out retraction motor lead. (Workmanship)	Sine Vibration (A)	2,4g	Sine vibration and tighter inspection added.
H.F. Antenna (Electro-Mech)	Rubber extension sleeve tore loose from its root. (Design)	Sine Vibration (A)	2,4g	Spacer added to preclude sleeve from adhering to compression disk.
Dipole Angenna Boom (Electro-Mech)	Element failed to extend due to vibration caused shape change of element. (Fabrication Procedure)	Random Vibration (A)	7.9g	Slotted holes added at tip end of element to improve assy. alignment.
Inertial Platform (Electro-Mech)	The bearing of two synchro resolvers became unloaded, allowing axial play, due to inadequate application of locking cement on retaining ring threads. (Fabrication Procedure)	Random Vibration (D)	8.3g	Threads now covered 50% to 75% with locking cement and checked to a breakaway friction of 14 to 16 inch pounds minimum.
Inertial Platform (Electro-Mech)	Noisy gimbal 1 and gimbal 3 synchro signals resulting from low impedance shorts to ground, caused by cold flow through teflon insulation; cold flow problems existed where a number of wires had been routed between terminal posts. (Poor Workmanship)	Random Vibration (D)	1g	Production workers cautioned to route as few wires between terminals as possible, and a mockup of wire routing was made as a guide for production and inspection personnel.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Inertial Platform (Electro-Mech)	Z gyro temperature control amplifier output fluctuated erratically. During trouble-shooting and rework multiple failures were found: 1. Contaminated slip rings (Design/ Test Procedure) 2. Two synchro rotor stiffners were loose due to poor epoxy bonding (Fabrication Procedure/Workmanship) 3. Terminal board broken loose (Design) 4. Shorted brush block in slip ring assembly (Design)	Random Vibration (D & A)	3g	1. Period wiping of slip ring contact surfaces incorporated in all phases of testing. 2. Use of lens tissue to replace nylon wipers, finger cots now used to handle clean parts, tightened time limits on epoxy handling and storage, and epoxy now put in sealed tubes. 3. Redesign terminal board. 4. Brush blocks now temperature cycled with resistance measurements taken at elevated temperatures, and internal lead wire insulation revised.
Inertial Platform (Electro-Mech)	Broken synchro bearing shaft (examination revealed that bearing shaft consisted of two distinct pieces instead of one integral part; shaft had undergone rework) (Rework Problem)	Random Vibration (D)	8.4g	All flight platforms, units and housings built to be used in future platforms were checked and cleared. Subcontractor took necessary action to prevent recurrence for future rework.
Inertial Platform (Electro-Mech)	A leadwire, one of a two-conductor shielded pair, broke at the solder cup due to wire flexing (Design)	Random Vibration (D)	6.2g	Single shielded conductors for all shielded conductor applications now used, connectors now potted in a more rigid compound, and increased conductor size from #30 to #26.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Inertial Platform (Electro-Mech)	A synchro rotor stiffner was loose due to two missing screws. Four wire shield screws were too long and bottomed out on the rotor housing; resulted in separation of epoxy bond at stiffner and rotor housing joint) (Poor Workmanship/Design)	Random Vibraton (A)	6.2g	Production layout revised to change the length of the wire shield screws and to protect the epoxy bond.
Inertial Platform (Electro-Mech)	Broken terminal board wire (Design)	Random Vibration (D)	8.4g	Wire routing revised.
Inertial Platform (Electro-Mech)	Rotor lead to synchro was shorted to synchro case due to improper routing of wire. (Poor Workmanship)	Random Vibration (D)	1g	Since this was a workmanship problem, rather than lack of proper instruction, no corrective action was deemed necessary other than cautioning production and inspection personnel.
Inertial Platform (Electro-Mech)	Z gyro temperature control was erratic (the discrepancy was isolated to one of the slip rings, however, the inherent cause of the problem could not be found after subsequent tests) (Unknown)	Random Vibration (D)	6.2g	No positive corrective action taken since cause of discrepancy was unknown.
Inertial Platform (Electro-Mech)	1. Broken wire due to large stress loop. (Design) 2. The screws holding the synchro rotor to the rotor housing were loose (4 screw had no evidence of loctite and 3 screws had zero torque (poor workmanship)	Random Vibration (D)	6.2g	1. Smaller stress loop now used. 2. Production layout revised, inspectors now apply Glyptol (ZV903 purple) in place of loctite and torque the screws themselves.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Inertial Platform (Electro-Mech)	Loss of pre-amp output due to a transistor emitter to nickle ribbon weld being open (neither the weld nor the ribbon had been indented in the weld process) (Inspection Procedure)	Random Vibtation (D)	6.2g	Inspection procedure revised to cover resistance welding.
Inertial Platform (Electro-Mech)	Gimbal 4 exhibited excessive drift rate due to a synchro rotor to rotor housing mechanical shift of .060 inches. (Part Failure)	Random Vibration (D)	5g	Present test procedures will remove any similar discrepant device.
Inertial Platform (Electro-Mech)	Excessive gyro drift due to synchronous vibration torques induced in the gyro (Part Failure)	Random Vibration (D & A)	6.2g	Gyro was replaced. Present system and platform level testing considered adequate for detection of synchronous vibration torque problem.
Inertial Platform (Electro-Mech)	Broken wire; visual examination revealed the end was bent and kinked indicating the wire broke due to mechanical stress. (Inspection problem)	Random Vibration (D)	6.2g	Inspection personnel cautioned about the discrepency.
IMU System Electronics (Electronic)	Transistor body shorted to adjacent mounting plug due to the mounting hold not being deburred (Poor Workmanship)	Random Vibration (D)	6.2g	None.
Digital Computer (Electronic)	Loose screw cap due to lack of Locktite application during build cycle (Fabrication Procedure)	Random Vibration (D)	8.9g	Production procedure released covering application and usage of Locktite

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Digital Computer (Electronic)	Defective solder joint (Fabrication Procedure)	Random Vibration (D)	12.6g	Use higher wattage soldering irons to improve solder flow and all power distribution lug-solder joints to receive X-ray inspection.
Digital Computer (Electronic)	Defective PC board solder joint (Fabrication Procedure/Design)	Random Vibration (D)	10g	Use higher wattage soldering irons to improve solder flow, and design change for adding lands on opposite side of edge connectors.
Digital Computer (Electronic)	Elapsed time indicator (a) stopped operating due to inadvertent reversal of indicator leads, and (b) contaminated with paint and metal chips due to loose screw (Production Error/Fabrication Procedure)	Random Vibration (A)	12.6g	Manufacturing personnel advised to exercise caution when installing subassemblies in computer and production procedure released requiring Locktite application on all screws.
Digital Computer (Electronic)	Loose and stipped screw/helicoil combination (abnormal number of removals (Fabrication Procedure)	Random Vibration (A)	12.6g	Instructive documentation issued for the installation and inspection of helicoils
Digital Computer (Electronic)	Wire shorted to chasis (Test Procedure)	Random Vibration (D)	12.6g	Harness taped with teflon wrap prior to test operations.
Digital Computer (Electronic)	Broken wire on the base connection of transistor (Fabrication Procedure)	Random Vibration (D)	12.6g	Baselead tied to base pole with lacing tape.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Digital Computer (Electronic)	Loose metal sleeve between face plate and case of Elapsed Time Indicator Resulting in radial end play (design)	Random Vibration (D)	12.6g	New sleeve now being used with a larger O.D. which is press fitted into the case eliminating radial end play within the unit.
Digital Computer (Electronic)	Broken output ground wire due to bending and flexing of the lead during handling and vibration (Fabrication Procedures)	Random Vibration (D)	12,6g	None - PDA vibration testing provides a screen against this type of failure
Digital Computer (Electronic)	Computer failed to sequence on properly (Unknown)	Random Vibration (A)	12.6g	None accomplished due to unknown cause.
Digital Computer (Electronic)	Fractured solder connector between electrical planes 1 and 3 of a multi layer interconnection board (Poor Workmanship)	Random Vibration (D)	12.6g	Inspection and soldering techniques reviewed and considered adequate
Digital Computer (Electronic)	Relay failed to close when the coil was energized (metal particles wedged between armature and coil have prevented armature rotation) (Poor Workmanship)	Random Vibration (A)	12.6g	Relay manufacturer clean room facilities were improved.
Digital Computer (Electronic)	Open solder connection due to insufficient solder (Poor Workmanship)	Random Vibration (D)	12.6g	Responsible personnel alerted to condition and cautioned to exercise care during all soldering operations.
Digital Computer (Electronic)	Severed tail lead pin (Poor Workmanship)	Random Vibration (D)	12.6g	No action taken other than continued vibration testing which is considered an effective and adequate screen.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Low Level Commutator (Electronic)	Open diode due to cracked chip (Part Failure)	Random (A)	8.4g	Replaced diode.
Indicator, Agena Fuel Time (Electro-Mechanical)	Unit stopped during burn-in due to inadequate armature clearance and improper alignment (Design and Fabrication Procedures).	Random Vibration (A)	7.9g	Armature relocated and assembly procedures corrected.
Monitor, Pow. System (Electro-Mechanical)	Meter exhibited hang-up at one scale point due to damaged and broken pivots caused by improper adjustment (Workmanship and Assembly Procedures).	Random Vibration (A)	8.4g	Verification of proper adjustment techniques and assignment of experienced technicians to adjustment operation.
Altimeter (Electro-Mechanical	Pointer sticky due to bearing inner race erosion of aluminum shaft; aluminum particles got into bearings (Design).	Random Vibration (A)	6.2g	Loc-Tite adhesive used to tighten fit between bearing retainer and shaft.
Altimeter (Electro-Mechanical)	Erroneous pointer shift due to disengagement of pointer gears from pointer shaft (Design)	Random Vibration (D)	6.2g	Loc-Tite adhesive used to prevent movement of bearing retainer.
Incremental Velocity Indicator (Electro-Mechanical	Wire strands separated at sharp bend incurred during assembly (Workmanship Error).	Random Vibration (D)	6.2g	Assembly personnel cautioned and inspection added.
Incremental Velocity Indicator (Electro-Mechanical	Transistor shorted due to insufficient clearance between posts and cap (Fabrication Procedure).	Random Vibration (D)	8.4g	Adequate clearance to be verified by special shock test and x-ray films.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Incremental Velocity Indicator (Electro-Mechanical)	Sharp edged solder joint punctured Teflon cable and caused shorting (Workmanship Error).	Random Vibration (D)	8.4g	Special inspection step added.
Incremental Velocity Indicator (Electro-Mechanical)	Incorrectly attached buss wire lead shorted against printed circuit ribbon (Workmanship Error)	Random Vibration (D)	8.4g	Assembly personnel cautioned and inspection intensified.
Incremental Velocity Indicator (Electro-Mechanical)	Binding between gear and pinion resulted in inaccuracies in hundreds dial (Manufacturing Procedure).	Random Vibration (D)	8.4g	Gears to be inspected for humps.
Incremental Velocity Indicator (Electro-Mechanical)	Diode was weakened during assembly process and opened during this test (Workmanship Error).	Random Vibration (D)	8.4g	Increased care during assembly.
Incremental Velocity Indicator (Electro-Mechanical)	Wide detent zone and low torque of stepper motor, and high friction of register, resulted in loss of several bits (Design).	Random Vibration (D)	8.4g	Stepper motor was redesigned to reduce detent zone and increase torque.
Incremental Velocity Indicator (Electro-Mechanical)	Resistor lead broken and module loose from mounting board (Fabrication Procedure).	Random Vibration (D)	8.4g	Assembly and inspection procedures revised to show proper use of rubber base adhesive pictorially.
Incremental Velocity Indicator (Electro-Mechanical)	Defective glass-to-slug diode seal resulted in faulty operation (Design).	Random Vibration (D)	8.4g	Vendor trying to improve seal and conducting shock test to detect defective seals.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Incremental Velocity Indicator (Electro-Mechanical)	Stresses induced by hysol potting compound damaged transistor leads. Potting failed to hold internal components in position (Design).	Random Vibration (D)	8.4g	Potting compound changed to epoxy and subject terminal board relocated.
Incremental Velocity Indicator (Electro-Mechanical)	Register mounting screw threads were stripped allowing screw to loosen (Design).	Random Vibration (D)	8.4g	Longer screw used with lock washer and vulcabond applied over screw head.
Incremental Velocity Indicator (Electro-Mechanical)	Terminals on logic board were shorting on clamping bracket (Design).	Random Vibration (D)	8.4g	Shorter pins used on logic board and cut-out made in clamping bracket to increase clearance.
Incremental Velocity Indicator (Electro-Mechanical)	Diode shorted by loose screw, spacer, lock washer, and clamp (Workmanship Error).	Random Vibration (D)	8.4g	Assembly operators instructed to avoid reusing lock washers.
Attitude Indicator (Electro-Mechanical)	Pivot damaged during assembly, and end play improperly set (Workmanship Error). NOTE: Similar failures were detected on 9 other units.	Random Vibration (D)	4.4g	Assembly personnel cautioned.
Incremental Velocity Indicator (Electro-Mechanical)	Adhesive applied in wrong area rubbed against units dial (Workmanship Error).	Random Vibration (D)	8.4g	Assembly personnel cautioned and inspection added.
Flight Director Controller (Electro-Mechanical)	Dielectric breakdown due to pinching of ground lead between terminal board and mounting stud on chassis (Workmanship).	Random Vibration (A)	8.4g	Inspection procedure changed to show pictorially the proper routing of wires near mounting stud.

VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL COMPONENT TEST ACTIVITY ACCEPTANCE

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
Flight Director Controller (Electro-Mechanical)	Roll channel output current was intermittent due to wire lead fracture at solder joint on terminal board (Fabrication Procedure).	Random Vibration (D)	8.4g	Assembly process changed to provide easier method of wiring and inspection spot check incorporated.
Flight Director Controller (Electro-Mechanical)	Output voltage from all channels dropped to zero due to break in printed circuit element (Unknown).	Random Vibration (D)	6.2g	Six additional modules tested - no problems. Remaining units to receive environmental stresses of ATP.
Indicator, Attitude (Electro-Mechanical	Yaw transmitter dial reading excessive due to loose clamp on output shaft of yaw servo, no Locktite (Workmanship).	Random Vibration (D)	4.4g	Assembly and inspection personnel cautioned to exercise care and assure that Locktite is used in assembly.

TABLE 2.3 **VIBRATION/ACOUSTIC FAILURE SUMMARY**

TEST LEVEL System **TEST ACTIVITY** Acceptance

S/C	FAILURE (CATEGORY)	TEST	RESULTING ACTION	COMMENTS
1	Accelerometer oversensitive due to backing out of seismic system mounting screws (Instrumentation Sensor/ Fabrication Procedure)	8.4 g	Epoxy cement placed on all screws and nuts in the seismic system. Retrofitted into other units.	Detected after the test.
1	ECS O_2 bottle separated from the blast shield because honeycomb insert was not the specified part (Structural/Workmanship)		Insert changed to specified unit.	Detected during the test. Structure not previously tested.
1	Data signal for an in-flight vibration measuring channel was noisy due to out-of-spec zener diode voltage in amplifier (Instrumentation Sensor/ Part Aging)		Selection process for zener diode altered to prevent recurrence of problem.	Detected during the test.
1	In-flight vibration measuring channel was inoperative due to a broken lead (Instrumentation Sensor/Handling)	8.4 g	Lead repaired.	Detected during the test. Problem caused by other work on spacecraft.
2	Leaks were detected in the O_2 system (Mechanical/Fabrication Procedure)	6.2 g	Leakage areas were repaired.	Detected after the test. Problem caused by workmanship on vehicle.
2	Low level multiplexer 6 counts high. Trouble shooting showed unit to be faulty (Electronic/Part Failure)		Unit was replaced.	Detected during the test.
2	Momentary loss of 1 T/M parameter. Anomaly could not be repeated (Instrumentation Sensor/Unknown)	6.2 g	None - condition acceptable for S/C 2.	Detected during the test.

TABLE 2.3 (Cont.) VIBRATION/ACOUSTIC FAILURE SUMMARY

TEST LEVEL System TEST ACTIVITY Acceptance

S/C	FAILURE (CATEGORY)	TEST	RESULTING ACTION	COMMENTS
2	Wire bundle had outer insulation on chromel wire broken at the end of the SCL over the floating shield (Electrical/Unknown)	6.2 g	Removed SCL and reinstalled to completely cover broken insulation as well as portion of wire previously covered.	Detected after the test.
3	Two in-flight acceleration measuring channels had noise spikes due to seismic mount, top pivot and bearing assembly not being securely fastened. (Instrumentation Sensor/Fabrication Procedure)	6.2 g	Accelerometer replaced. Defective unit readjusted by vendor.	Detected during the test.
3	PCM data on tape recorder was irrecoverable due to loss of synchronization. Loss was due to insufficient light incident upon motion monitor photocell (Electronic/Design)		Light source redesigned to use lower voltage bulb and power circuit for bulb changed from AC to DC.	Detected after the test on data recorded during the test.
3	On two occasions the light indicating no coolant flow remained on although the coolant pump was turned on (Electrical/Unknown)	6.2 g	No action.	Detected after the test.

TABLE 2.3 (cont.) **VIBRATION/ACOUSTIC FAILURE SUMMARY**

TEST LEVEL System **TEST ACTIVITY** Acceptance

S/C	FAILURE (CATEGORY)	TEST	RESULTING ACTION	COMMENTS
2	Commutator segment read open (Electric/Unknown)	6.2 g	None - accepted for S/C 2.	Detected during the test.
2	Yaw rate gyro scale factor intermittent (Electro-mechanical/Unknown)		None - accepted for S/C 2.	Detected during the test.
2	Potting did not adhere to connector or wire (Electrical/Fabrication Procedure)		Repaired with RTV-60.	Detected after the test.
2	Low level commutator read underscale (Electric/Unknown)		Unit replaced.	Detected during the test.
2	Camera produced a double image on film (Electro-mechanical/Unknown)		Unit replaced.	Detected after the test.
2	Two fairings developed cracks at a weld bead (Structural/Part Failures)		Trimout cracks and dye check - repair.	Detected after the test. Structure not previously tested.
2	Torque stripes not aligned on collar fastener bolts of thrust chamber assembly nor on two nuts attaching coolant lines (Mechanical/Unknown)		Verify torque requirement and repaint torque stripes.	Detected after the test.
2	Wire bundle connector shell stuck - will not travel 90° (Mechanical/Unknown)		Connector replaced.	Detected after the test.
2	Switch was loose on the mounting (Electrical/Unknown)	6.2 g	Switch remounted.	Detected after the test.

3.0 FLIGHT FAILURES

The in-flight problems which could be connected with in-flight vibrations or acoustics are listed in Table 3.1. For some of these failures the chances that they are associated with vibration is very small, yet the possibility remains and so they are included. For items possibly more closely associated with vibration a note is included to indicate where it was thought that the failure might have been caused by vibration or where it was thought that the failure might have only been displayed due to in-flight vibration. The latter condition would be true in the case of an open circuit which was faulty because of a break caused by a workman which would not be detected until vibration permitted the pieces to separate. Included in the tables are notes telling if the failure was considered a fault of design, and a note indicating if the failure might have been detected by qualification or acceptance tests, and whether this might be at the component, subsystem, or system level. One thing not included in the tables, which also cannot be assessed, is the fact that a failure might have been caused by some event which might occur after the vibration tests and therefore could not be eliminated by the ground tests. This, of course, is a major problem since all vehicles will be moved and worked on after all vibration tests are completed.

The total number of spacecraft problems detected immediately prior to flight, during flight, or during post-flight tests was 228. Not all of the flight problems can be classified as failures but the distinction is not clear-cut. Our estimate of the number of those properly classified as failures is 127.

VIBRATION/ACOUSTIC SUMMARY - IN-FLIGHT PROBLEMS

S/C No.	Problem	Cause or Remarks	Resolution
2	Outer skin temperature measurement erratic during flight.	Unknown	Not resolved - no effect on mission.
2	GLV Stage II fuel-pressure meter in the spacecraft failed 1 second after lift-off.	Short circuit of movable coil. Failure may have been revealed by vibration.	Isolated case of poor quality. Manufacturer notified. Component-Acceptance.
3	Primary dc-dc converter failed.	Improper use of lockwasher allowed nut to back off and cause short. Failure may have been caused by vibration.	Design - use of epoxy to bond all lock nuts on dc-dc converters and biomedical power supplies. Component/System-Qualification/Acceptance
4	High roll rate on reentry.	TCA 5B was inoperative due to a broken wire in a connector between the ACME and the TCA solenoid. Failure may have been revealed by vibration.	Modification of procedures for handling of spacecraft wiring during installation and inspection. System-Acceptance
5	Malfunction detection system Stage II fuel pressure indicator failed.	Apparently an open circuit in wiring. Failure may have been revealed by vibration.	Pilot used redundant indicator. System-Acceptance
5	Noisy telemetry during launch, orbit maneuvers, and reentry.	Loose terminal connection between programmer and input power lines. Failure may have been revealed by vibration.	All terminal connections are to be torqued and coated with torque paint. Component/System-Acceptance
5	Rapid decay in RSS O_2 pressure.	Supply-tank heater failure.	Cross-over to be installed from O_2 tank to RSS O_2 tank to permit restoration of pressure.

VIBRATION/ACOUSTIC SUMMARY - IN-FLIGHT PROBLEMS

S/C No.	Problem	Cause or Remarks	Resolution
5	Thrusters 7 and 8 malfunctioned beginning at approximately 75 hours	Unknown - possible heater failure.	Redundant heaters added to OAMS solenoid valves.
6	At 24 minutes 53.4 seconds g.e.t. a group of five PCM parameters in the reentry vehicle low level multiplexer were lost. The parameters returned to normal operation after retrofire.	Lab vibration, low and high temperature test at vendor subsequent to mission could not cause failure to repeat.	No possible action, no effect on mission.
7	Bright setting of optical sight intermittent.	Intermittent connector in one filament of dual filament lamp for reticle. Failure may have been revealed by vibration.	During mission - tapping of light caused proper operation. Subsequent flights - use of redundant circuit. Component/System-Acceptance
8	Uncontrolled firing of TCA No. 8.	Probably caused by a short circuit to ground occurring between the positive side of solenoid coils in the thrust chamber valves and common contact of the relay that selects the primary or secondary valve drivers in attitude control electronics. Equipment jettisoned with spacecraft adapter. Failure may have been revealed by vibration.	Inspection and assembly procedures changed. Flight procedures changed. System-Acceptance
8	Non-illumination of the amber indicator retro attitude light at T-256 seconds was reported by the crew.	Unknown. The cause for this discrepancy could not be duplicated by post-flight laboratory analysis.	Changes resulting from the analysis include diode product improvement replacement and diode coating with RTV rubber.

IBRATION/ACOUSTIC SUMMARY - IN-FLIGHT PROBL

S/C No.	Problem	Cause or Remarks	Resolution
8	Cyro mass quantity readout was erratic.	Postflight testing conducted on the reentry vehicle circuitry did not reveal source of the problem.	No action conside ed necessary.
8	Orbital Attitude and Maneuver System regulated helium pressure indicated zero.	The instrumentation pressure transducer or its associated wiring failed. Satisfactory regulator performance was verified by other instrumentation. (This sensor is located in the adapter section and was jettisoned before reentry).	No action considered necessary.
9	One general illumination light in adapter failed to illuminate.	Possible causes - pyrotechnic induced shock or vibration.	Addition of shock mounts for lights. System-Acceptance
9	Measurement of RSS hydrogen cryogenic mass-quantity (parameter CA09) failed at approximately 26 hours 58 minutes	Failure in transducer or adapter wiring (not recovered).	None required, no effect on mission.
9	Measurement of left-hand suit inlet air temperature (parameter CC03) failed at approximately 69 hours 13 minutes	No cause could be found.	None known; however, not essential to flight and past performance has been good.
9	One pyrotechnic cartridge on hoist-loop door release did not fire.	Postflight testing of pyros and electrical system did not reveal cause of failure. End-to-end circuit test not possible due to previous disconnects in circuitry for other spacecraft testing.	None - redundant pyro fired and hoist-loop door released.

VIBRATION/ACOUSTIC SUMMARY - IN-FLIGHT PROBLEMS

S/C No.	Problem	Cause or Remarks	Resolution
9	One utility electrical cord failed open.	Broken wire in cord at power end.	Change in design to provide permanent potting - replacement of solder type connectors with crimp type pin connectors.
9	Resistance of 1000 ohms from main bus to spacecraft ground after recovery.	Potting seal on one relay of relay panel broken resulting in low resistance due to water exposure after touchdown.	All relays are to be inspected after potting.
12	Pilot reported the microphone on right side of helmet was inoperative.	Postflight tests revealed a broken wire at the connector external to the helmet and suit harness.	None required - no follow-on Gemini missions.

4.0 DERIVATION OF TEST LEVELS AND IDENTIFICATION OF TEST FACTORS

4.1 TEST LEVELS

The original Gemini vibration spectra included both random and sinusoidal vibration qualification curves shown in Figures 4-1 and 4-2. To be qualified an item was tested to either the random or to the sinusoidal vibration as required by the detailed specification. The curves applied to both components and to subsystems. The derivation of the random spectrum for launch was based on a statistical analysis of Mercury measured data (20 to 1200 Hz) considering the vibration to be linearly correlated with dynamic pressure. The mean plus 2σ level was carried as the qualification requirement. Spectrum shape was based on the shape of the power spectral density analyses of the measured data, with the levels held constant from 1000 Hz to 2000 Hz. Plots showing the measured vibration during Mercury-Atlas (MA) launches as well as details of the statistical analysis are included in Reference (1). Figure 4-3 is an adjusted plot of the MA-2 and MA-4 right hand trunnion radial vibration which was used in the prediction. This adjustment consists of multiplying the power spectral densities by the ratio of the squares of the peak dynamic pressures for Gemini and for Mercury. The corrected plot can thus be considered a typical "expected" vibration spectra for Gemini based on Mercury experience. The original launch random vibration spectrum is also shown on Figure 4-3.

Re-entry random vibration was estimated from the relationship of g's versus dynamic pressure derived for launch. Orbit vibration was estimated as simply low level band-limited white noise since there were no significant sources of environmental vibration on the vehicle. The curves for orbit and re-entry random vibration are also shown in Figure 4-1.

The sinusoidal qualification spectrum used for Mercury launch was retained for Gemini except that a reduction was incorporated in the high frequency range to reflect the effect of lower maximum dynamic pressures. Orbit and re-entry sinusoidal levels were estimated to be lower than launch consistent with the random spectra. The Gemini curves are shown in Figure 4-2.

Acoustic spectra were taken as 165 db externally during launch, then reduced 10 db for the adapter area, 20 db for the equipment bay areas and 30 db for inside the cabin. The curves were based on Mercury in-flight measurements, considering transmission losses due to structure. Figure 4-4 shows the estimated Mercury external levels compared to the Gemini prediction. Figure 4-5 shows the measured Mercury cabin levels compared to the requirement for Gemini. Figures 4-6 and 4-7 show the spectra for the equipment bay areas and for the Gemini adapter area, respectively.

The first Gemini vehicle had production structure but only ballast simulating equipment items. Measurements were taken on this vehicle which were used to modify the random vibration spectra. The method of incorporating the data used only the comparable radial measurement in the re-entry vehicle, QB13, as another statistical sample with the Mercury data. The analysis indicated the GT-1 measurements at maximum dynamic pressure were slightly below the statistical mean for the three flights. A new shape of the frequency spectrum was

selected on the basis of the GT-1 measurement. Because of the existence of narrow band peaks in the power spectral density analyses of the flight measurement the qualification spectrum which was negotiated with the NASA was slightly higher than the 3σ level. Levels at frequencies above 1000 Hz were again held constant. The resulting spectrum is shown in Figure 4-8 as is the PSD of the Gemini re-entry vehicle measurement, QB13. The curved portions of the spectrum corresponds to constant db per octave roll-offs.

Although GT-1 provided no re-entry data the random vibration spectrum for this was modified to be consistent with the frequency distribution of the launch curve. In fact, the re-entry curve was taken to be identical with the launch curve which resulted in the increase of the RMS level from 8.4 g's to 8.8 g's.

Because measurement QC24 on the blast shield, which holds most adapter equipment, indicated levels which were lower than on the re-entry vehicle, a separate spectrum was generated for this region. The shape was based on the blast shield measurement. Since the statistical analysis of the re-entry vehicle data indicated the GT-1 measurement was less than the mean to be expected on Gemini flights, the amplitude was obtained by increasing the RMS level by the same factor which the re-entry vehicle measurement had been increased to derive the spectrum for that region. The PSD of the blast shield measurement is shown in Figure 4-9 as is the resulting spectrum. Again the curved portions of the spectrum correspond to constant db per octave roll-offs.

Separate vibration requirements were established for the target docking adapter which was launched by an Agena. The random vibration level was taken from the g's versus dynamic pressure curve derived for the spacecraft. With the higher peak q, the shape was selected to have higher levels in the frequency range of expected resonances. The resulting spectrum is shown in Figure 4-10. A sinusoidal spectrum was established for the adapter using information supplied by the booster manufacturer and is shown in Figure 4-11. Acoustic requirements were taken to be the same as the Gemini adapter externally, 165 db, and internally, 155 db, Figures 4-4 and 4-7, respectively. These spectra were not revised during the program.

In addition to the preceding, special spectra were derived for specific items during the course of the program. These include the inertial platform which required extensive test data, analysis, and modification to structure to produce a spectrum which had reduced input in the region of a significant system resonance. Other examples are adapter skin mounted items, many of which were customer furnished.

While the qualification spectra were being revised after GT-1 the acceptance vibration test programs initiated by many vendors were reviewed because of the disparity between the many procedures and the expected flight environments. In many cases the vendor tests on flight equipment were entirely unrelated to the end use of the items and unrelated to the qualification requirements. To standardize acceptance tests so that the procedures would result in tests that could be compared to the flight levels and to the qualification requirements, the following procedure was used. For items that had been qualified to random vibration the acceptance power spectral density levels should be 50% of the qualification requirement. This results in the RMS level being 70% of the qualification requirement and at a value nearly equal to the mean plus 1σ level predicted by the statistical analysis. The appropriate curves are included in Figures 4-8 and 4-9.

No acoustic acceptance tests were conducted, but some sinusoidal vibration tests were. The sinusoidal spectrum is shown in Figure 4-12, although some tests were conducted at the qualification levels.

4.2 TEST DURATION

Qualification tests were intended to demonstrate two flight capability for most items. For random vibration the duration was normally 15 minutes which was to allow 5 minutes for vibration tests to be conducted on the flight hardware, then 5 minutes for each of two flights. In addition, the 5 minutes representing a single flight was considered to be 3 minutes for launch and two minutes for re-entry. Items which did not re-enter or would not be reused were tested to the appropriate time determined by subtracting the flight times which were not applicable. Typical time histories of the launch vibrations with the appropriate qualification and acceptance test durations are shown in Figures 4-13, 4-14 and 4-15.

The sinusoidal qualification test duration which was used for qualification included two 15 minute sinusoidal sweeps and 10 minute dwells at significant resonances. The procedures incorporated reductions in time similar to the random vibration procedures.

Acoustic noise qualification tests were conducted for 30 minutes. If the facility provided a progressive wave then reorientation of the article was required at 10 minute intervals. A time history of the cabin level with the test durations noted is shown in Figure 4-16.

No acoustic noise acceptance tests were conducted on Gemini. Random vibration acceptance tests were conducted for 1 minute per major axis. Sinusoidal acceptance tests, consisting of sweep tests only, were conducted for 5 minutes per axis.

4.3 SOURCES OF THE DATA

In-flight vibration measurements were taken on three Mercury vehicles, MA-2, MA-3 and MA-4. MA-3 was aborted before reaching maximum dynamic pressure, and therefore was not so useful as MA-2 and MA-4. Accelerometers were located on a primary ring. Only the radial measurements on the structural ring were used to predict the Gemini environment. Because of the similarity in wind tunnel data and the similarity in structural design, the data was assumed to be directly applicable to Gemini with only the differences in maximum dynamic pressures having importance.

Acoustic noise data was measured under a shingle on MA-1 and inside the cabin on MA-2 and MA-4. These measurements were used along with estimated transmission losses to establish the Gemini environments.

In addition, the sinusoidal test procedures of the Mercury qualification requirements should be considered a data source. At the time the Gemini environment predictions were being made, all Mercury items had been qualified to sinusoidal test procedures. Since the Gemini was an advanced version of the Mercury, many equipment items and test procedures were carried over to the new vehicle. In the case of the vibration environment, this resulted in the

use of sinusoidal vibration simulating an environment which was predicted to be random. The sinusoidal qualification procedures have since been dropped from the Gemini B vehicle which is, of course, an advanced version of the Gemini.

In-flight dynamic measurements were taken on Gemini flights GT-1 and GT-2, the only un-manned flights. Plots showing approximate locations of the measurements are shown in Figures 4-17 and 4-18. Only the data from GT-1 was used to establish qualification requirements. Again, only the measurements with the highest levels of all applicable measurements were used in the derivations. This resulted in the use of data from the parameter QB13, equipment bay radial vibration, for the re-entry vehicle requirement. Measurement QC24 was the only parameter applicable to equipment supporting structure, and therefore was the only measurement used for the adapter spectrum derivations.

4.4 IDENTIFICATION OF TEST FACTORS

The ratio of power spectral densities of the qualification tests to those of the corresponding acceptance test was two to one. The ratio resulted as a convenient specification of levels which would provide qualification tests in excess of the predicted mean plus 2σ vibration levels and acceptance tests near the mean plus 1σ vibration levels. The test durations for qualification included a 5 minute test period which was intended to demonstrate the capability of the design to withstand expected flight vibrations plus ground test vibrations, including re-tests if necessary. The time relation is really not so simple since the levels are not one-to-one for the time period, but more detailed comparison was not made.

No simple general relations exist for the sinusoidal tests. This is because sinusoidal qualification tests were a carry-over of procedures from the Mercury program. Sinusoidal acceptance tests were specified only when it was expected that a component had a simple failure mode which could be detected under many conditions of vibration. It was always intended that the acceptance test be significantly less severe than qualification. This was done by specifying sinusoidal acceptance tests without resonance dwells, with fewer and faster sweeps and sometimes at lower levels or only along a single test axis.

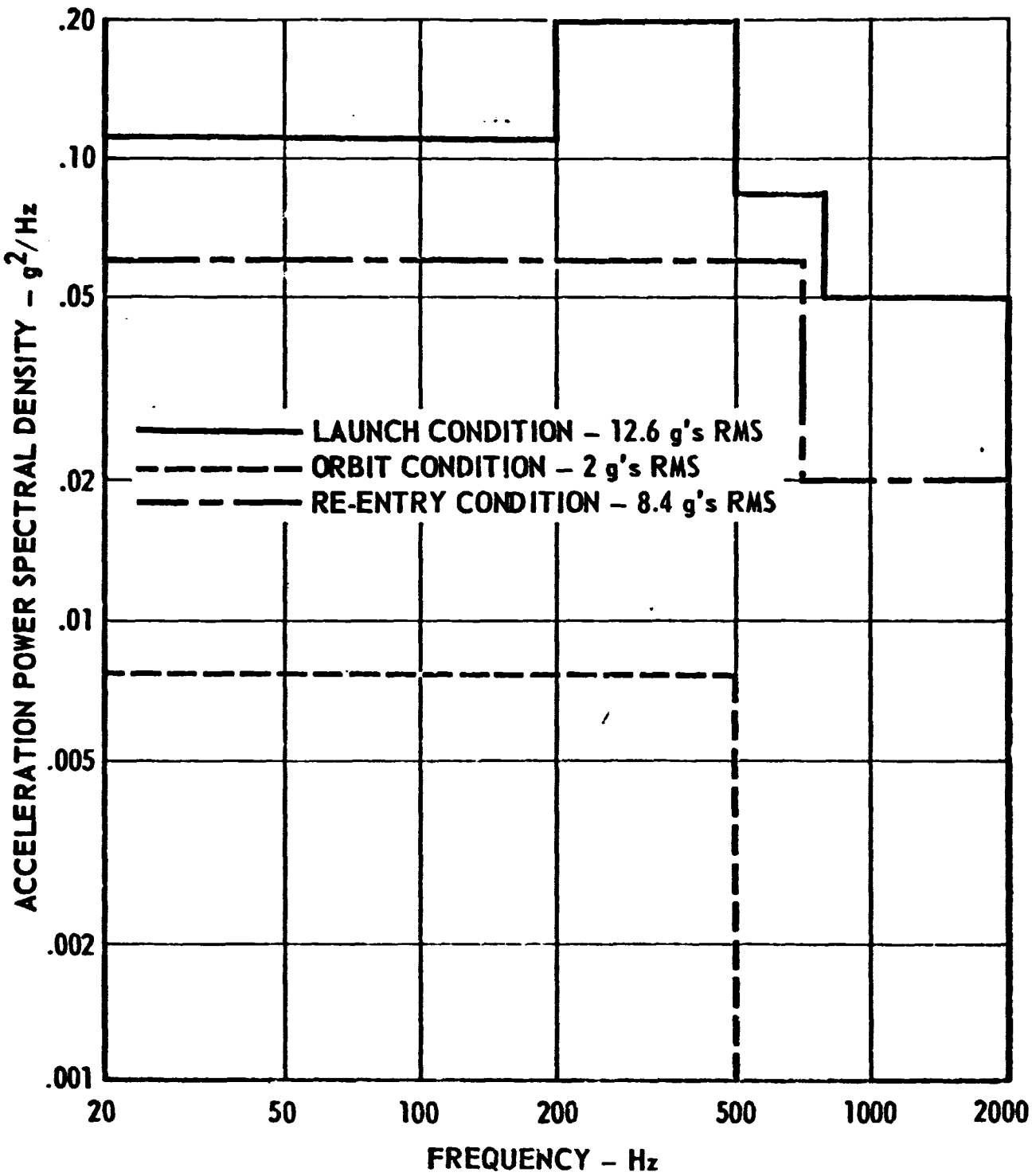


FIGURE 4-1 GEMINI SPACECRAFT
RANDOM VIBRATION QUALIFICATION SPECTRA -
ORIGINAL REQUIREMENTS

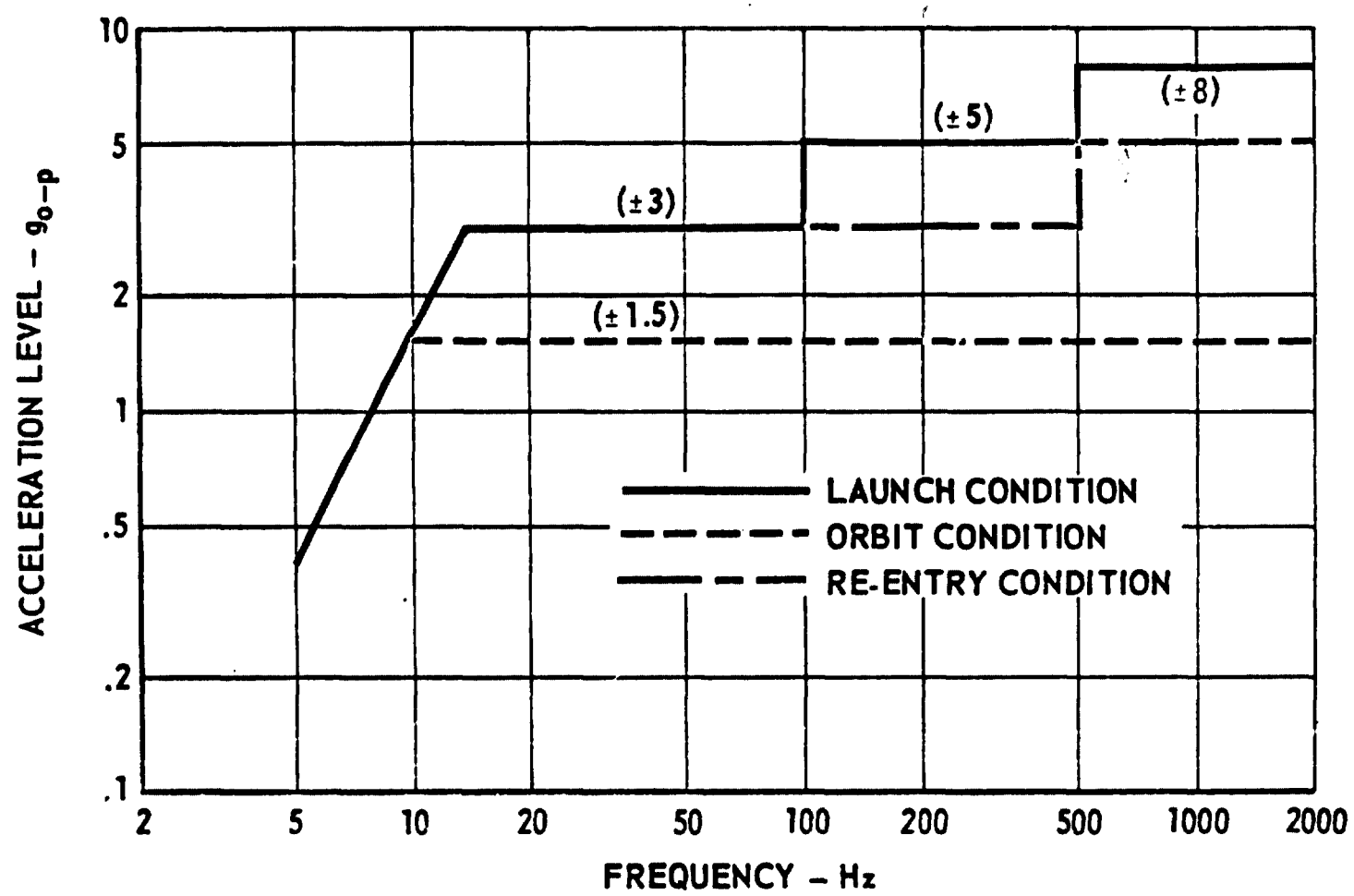


FIGURE 4-2 GEMINI SPACECRAFT SINUSOIDAL VIBRATION QUALIFICATION SPECTRA

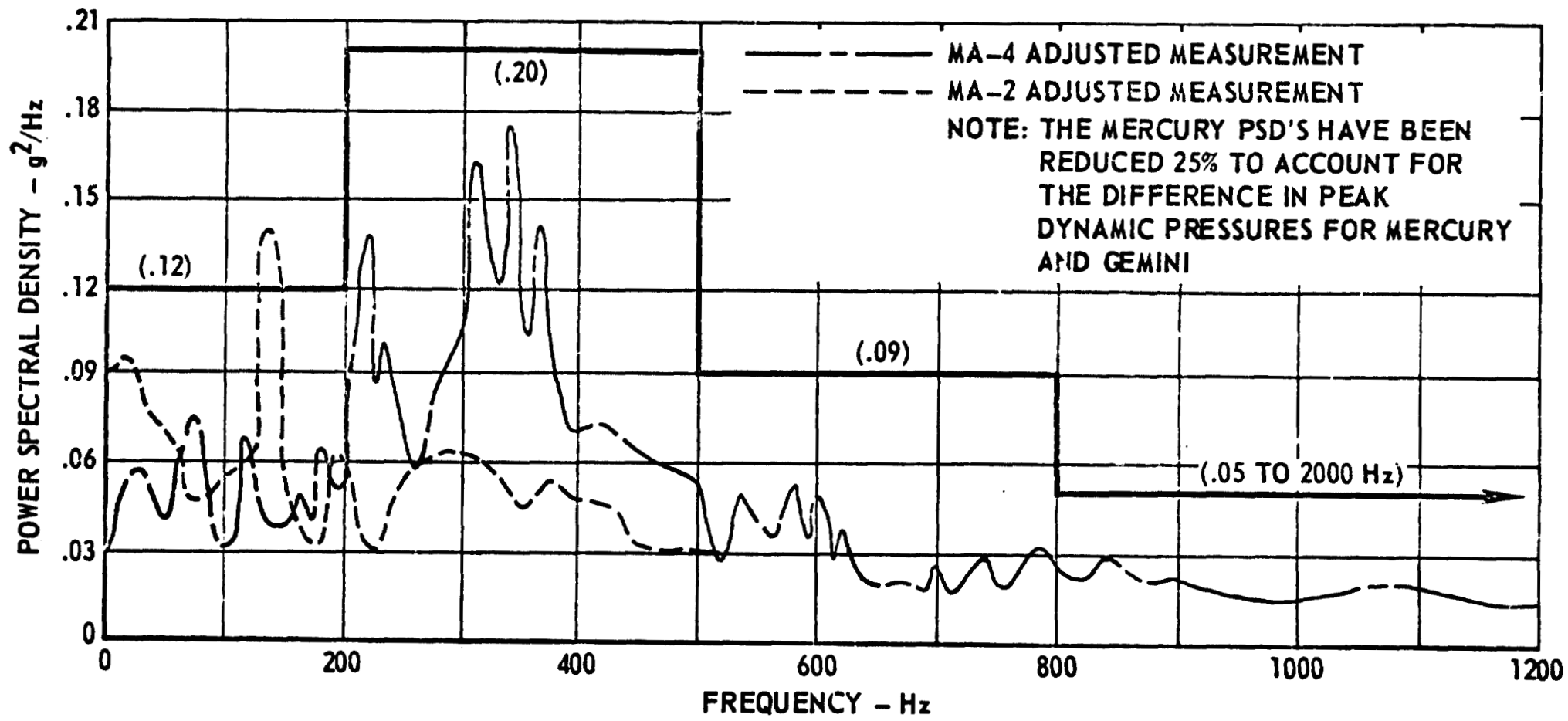


FIGURE 4-3 COMPARISON OF SPECIFIED TEST LEVEL WITH ADJUSTED MERCURY DATA

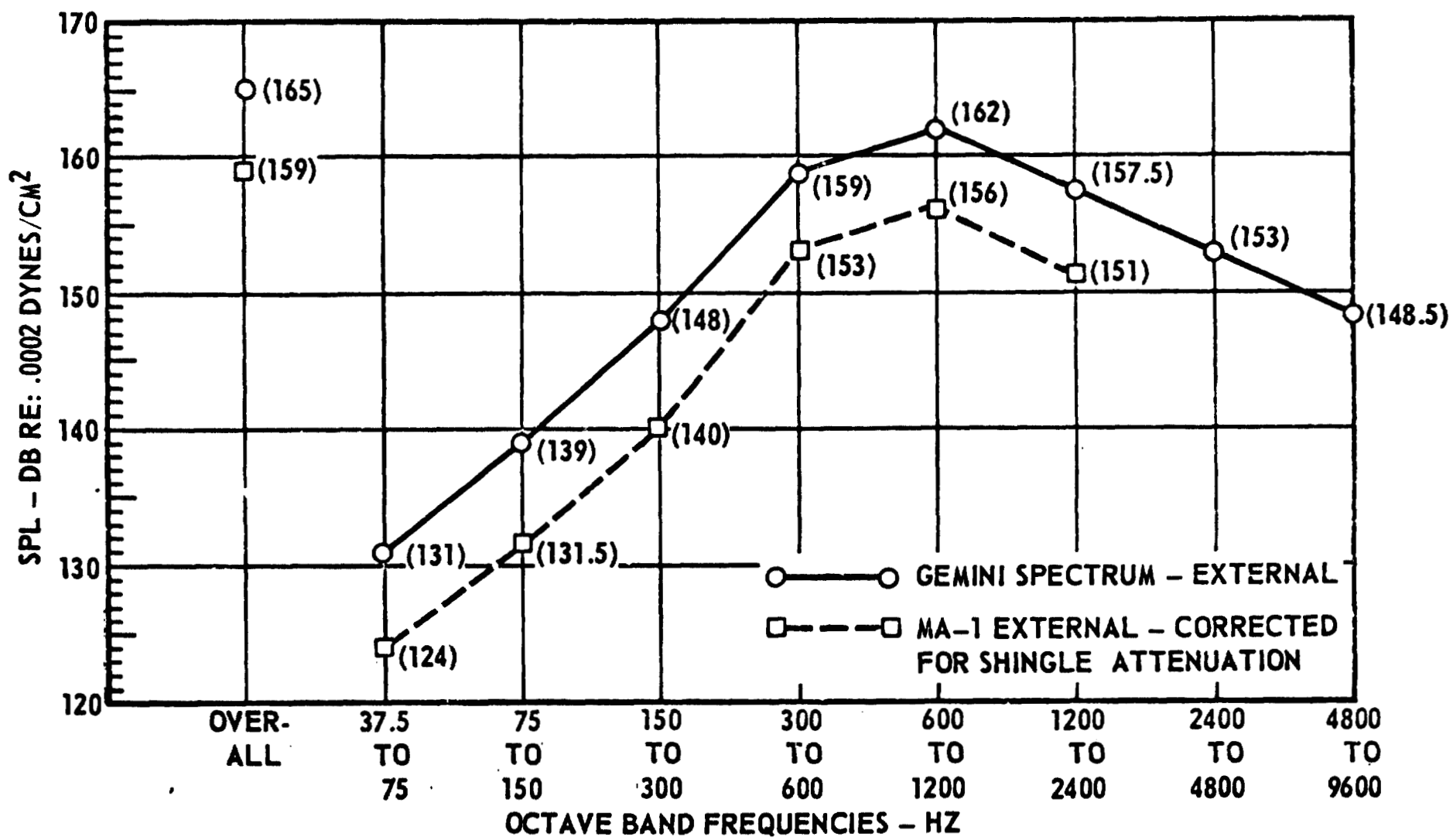


FIGURE 4-4 GEMINI EXTERNAL ACOUSTIC SPECTRA

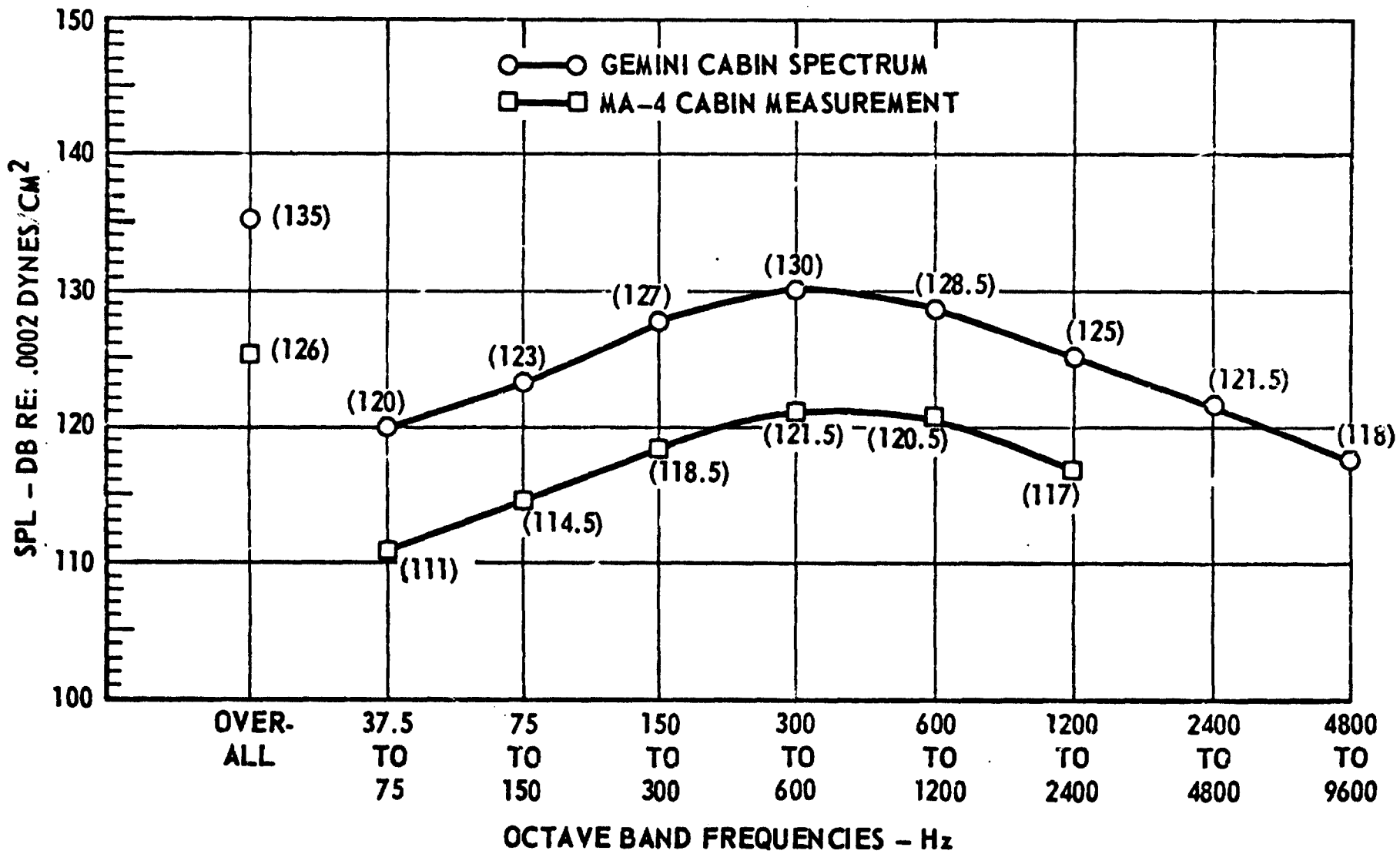


FIGURE 4-5 ACOUSTIC SPECTRA FOR GEMINI CABIN AREA

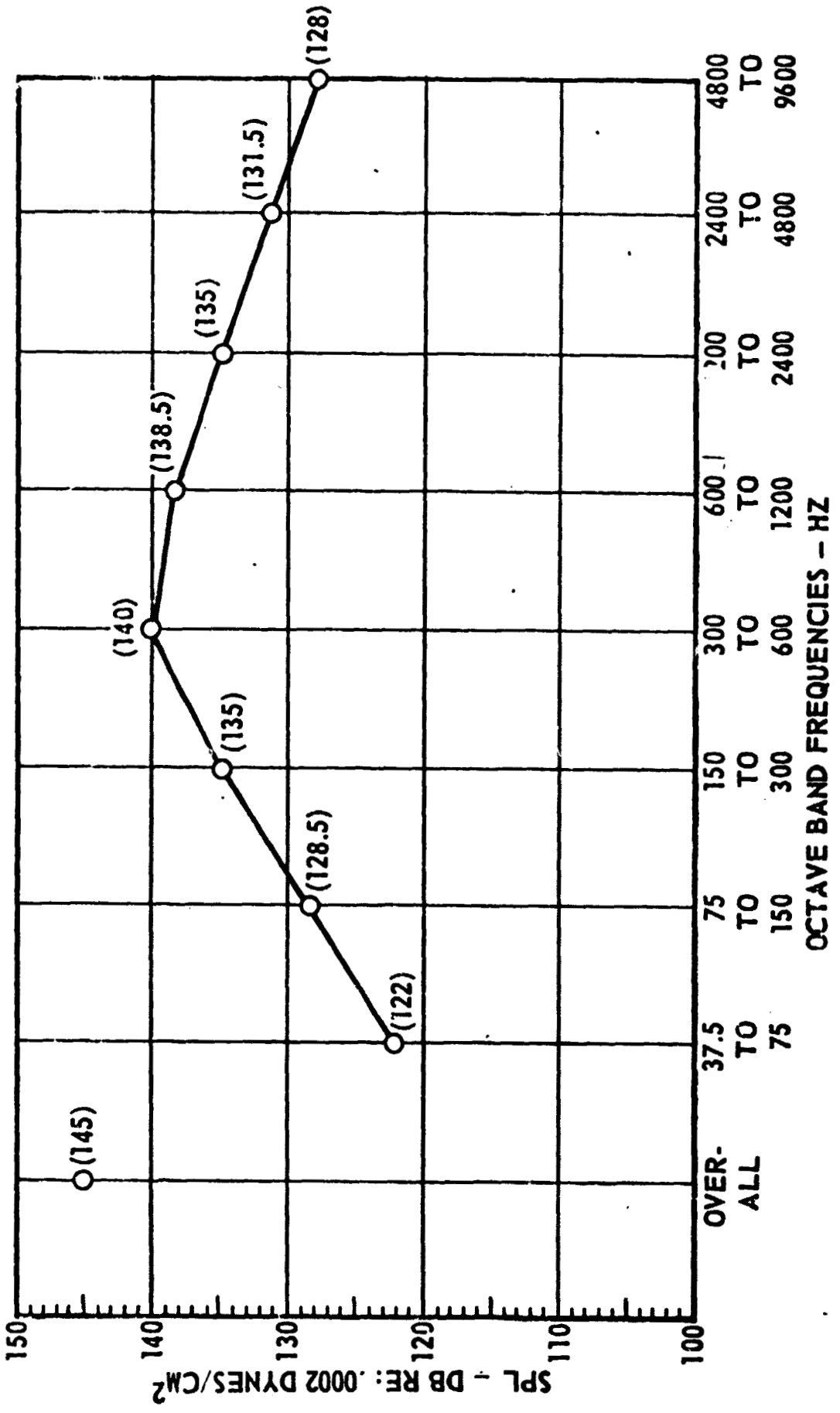


FIGURE 4-6 ACOUSTIC SPECTRA FOR GEMINI EQUIPMENT BAY AREAS

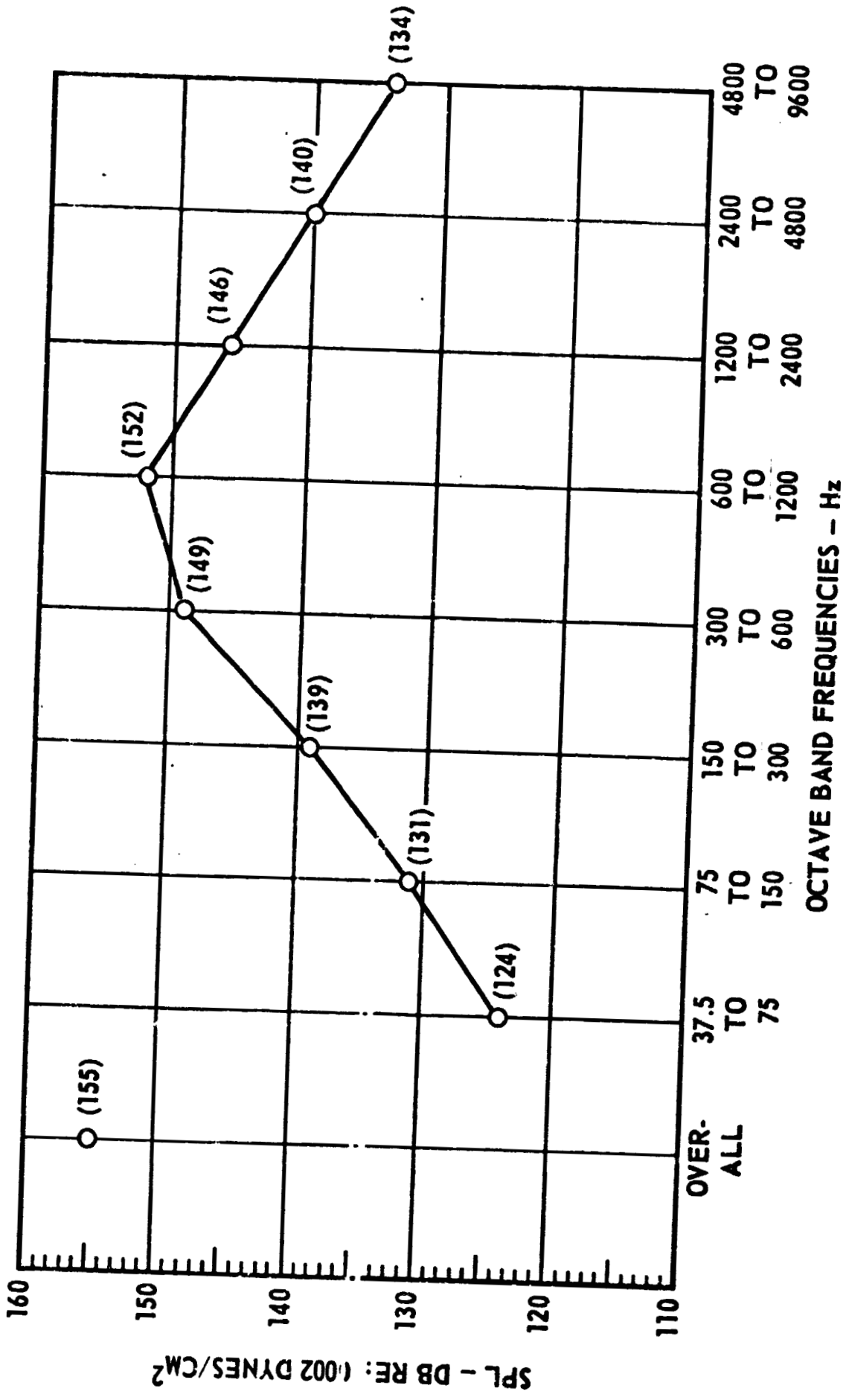


FIGURE 4-7 ACOUSTIC SPECTRA FOR GEMINI ADAPTER AREA

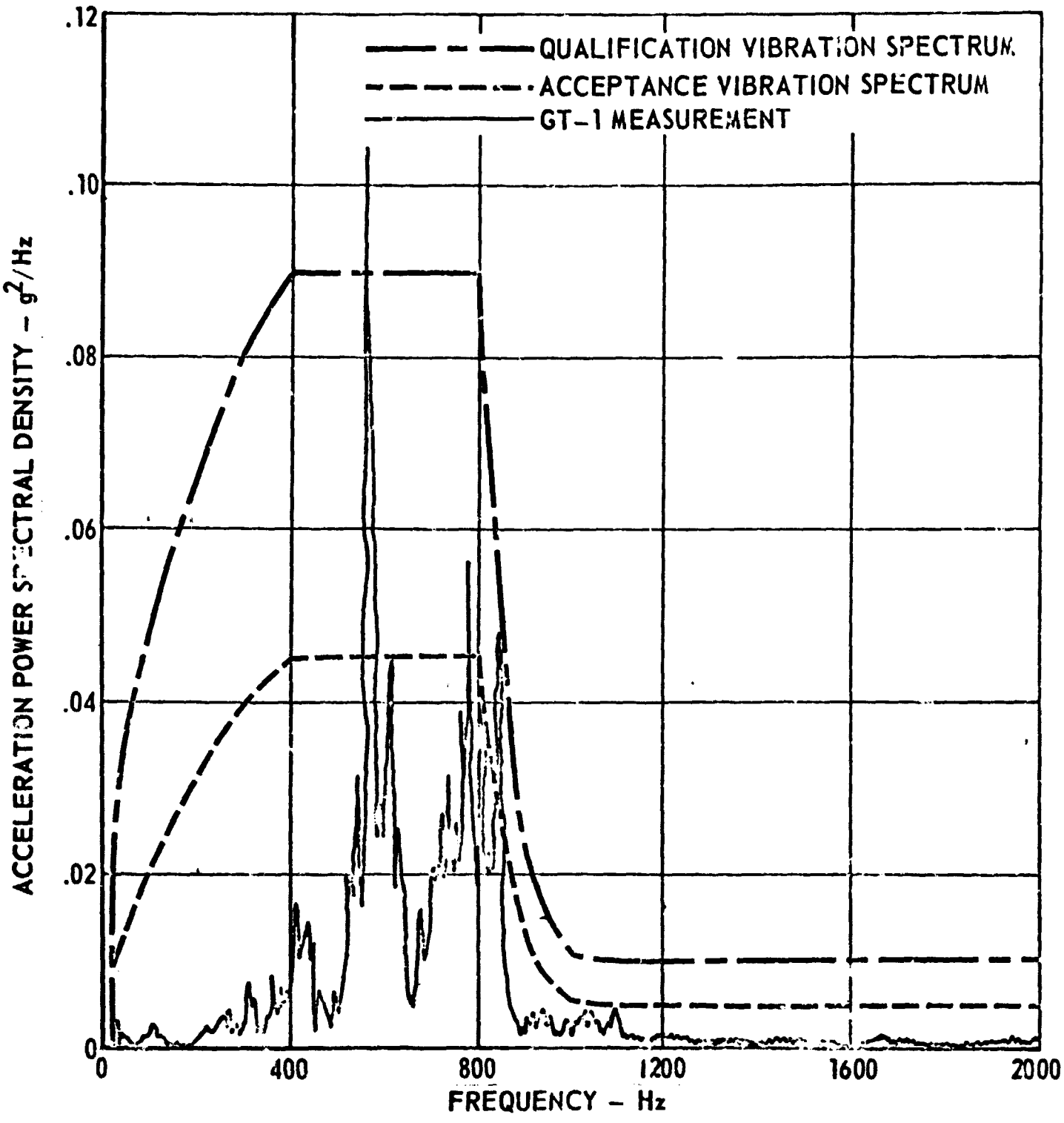


FIGURE 4-8 GT-1 EQUIPMENT BAY VIBRATION MEASUREMENT COMPARED WITH QUALIFICATION AND ACCEPTANCE VIBRATION SPECTRA

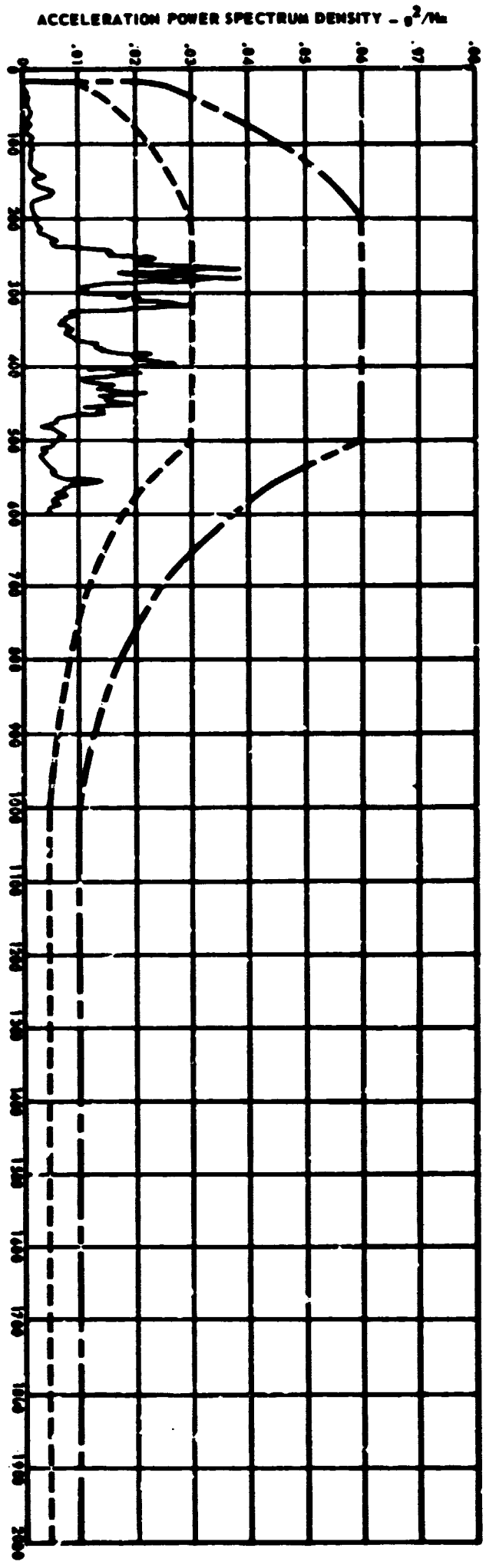


FIGURE 4-9 GT-1 ADAPTER BLAST SHIELD VIBRATION MEASUREMENT COMPARED WITH QUALIFICATION AND ACCEPTANCE VIBRATION SPECTRA

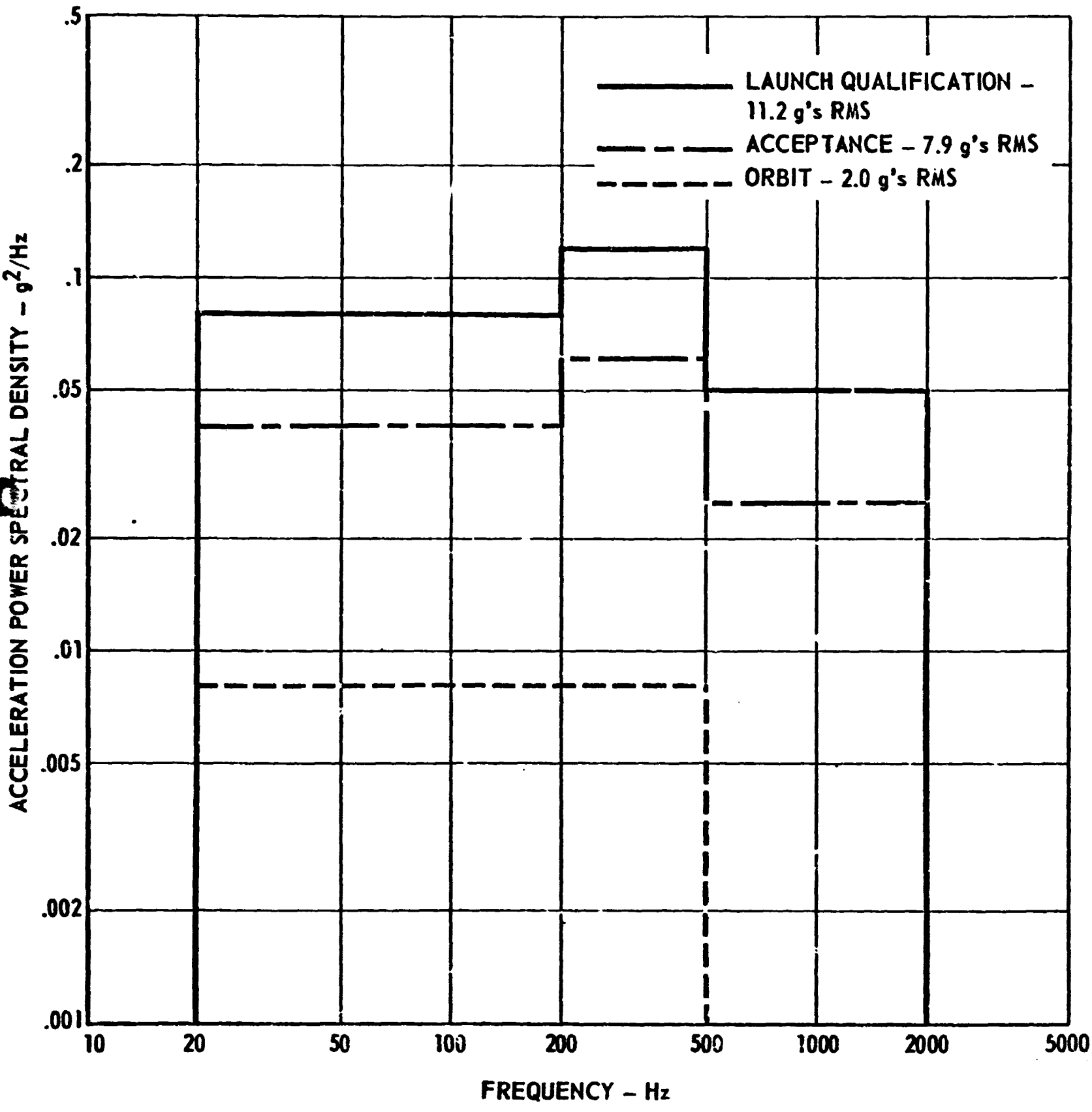


FIGURE 4-10 GEMINI TARGET DOCKING ADAPTER RANDOM VIBRATION SPECTRA

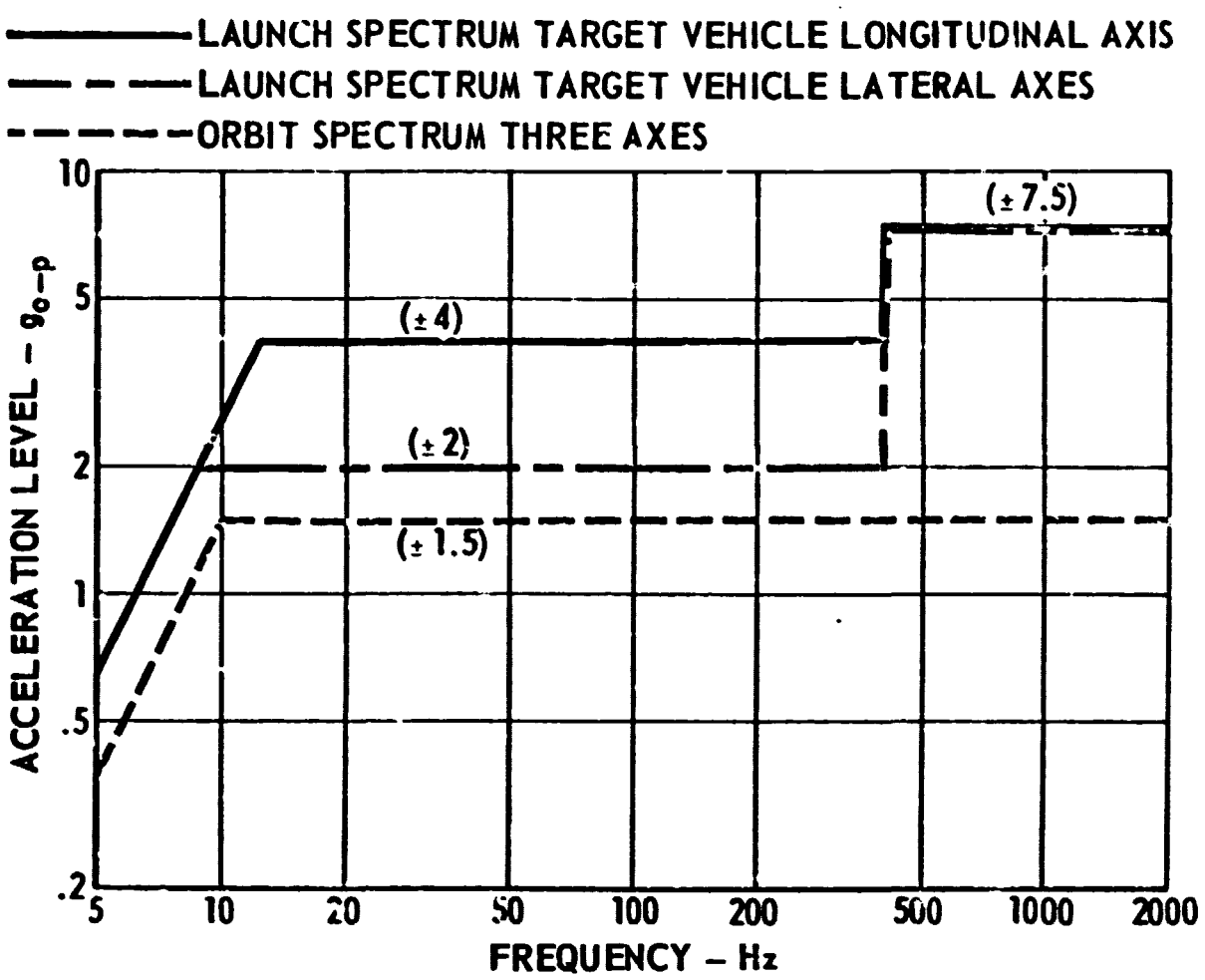


FIGURE 4-11 GEMINI TARGET DOCKING ADAPTER SINUSOIDAL VIBRATION QUALIFICATION SPECTRA

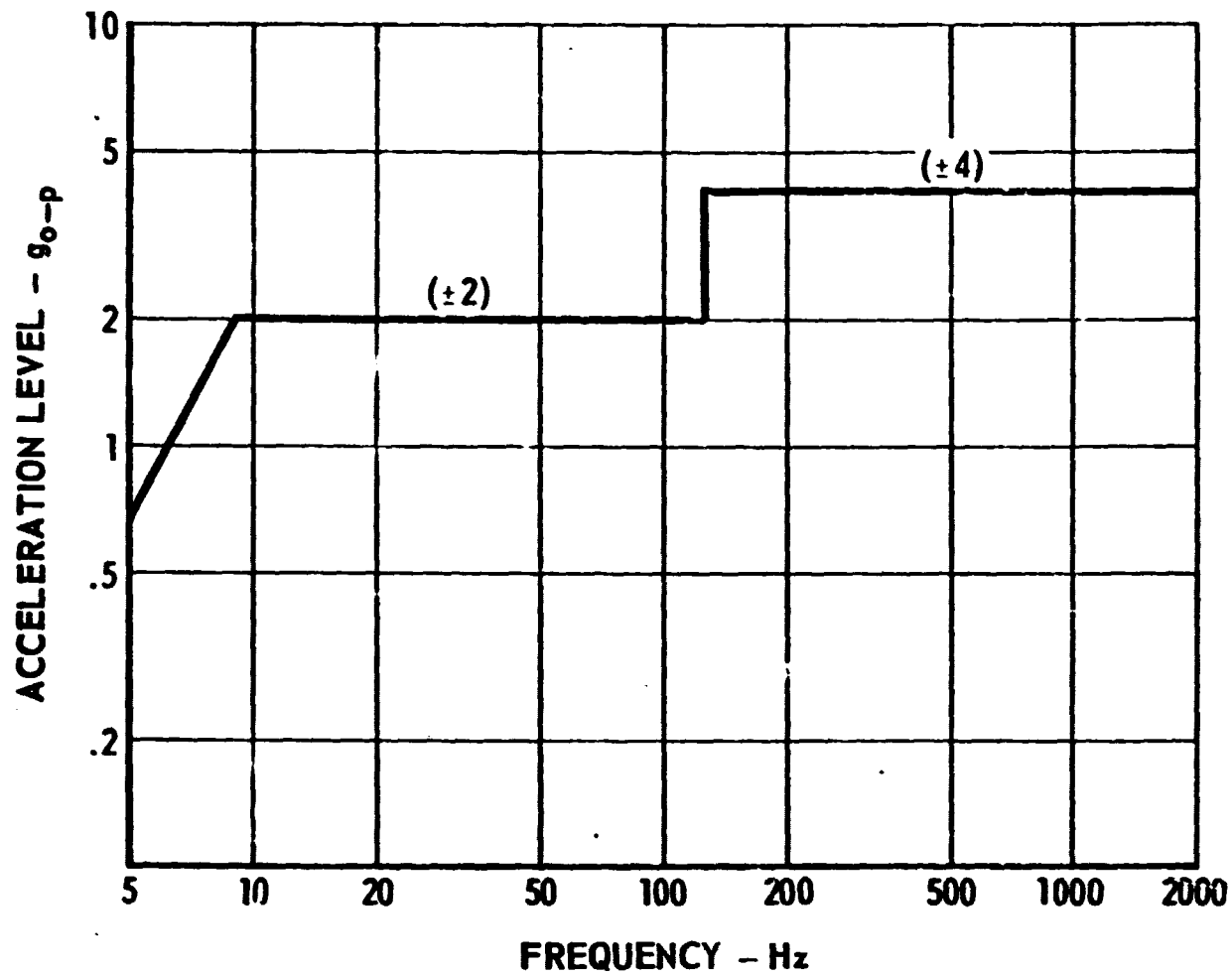


FIGURE 4-12 GEMINI SPACECRAFT SINUSOIDAL VIBRATION ACCEPTANCE SPECTRUM

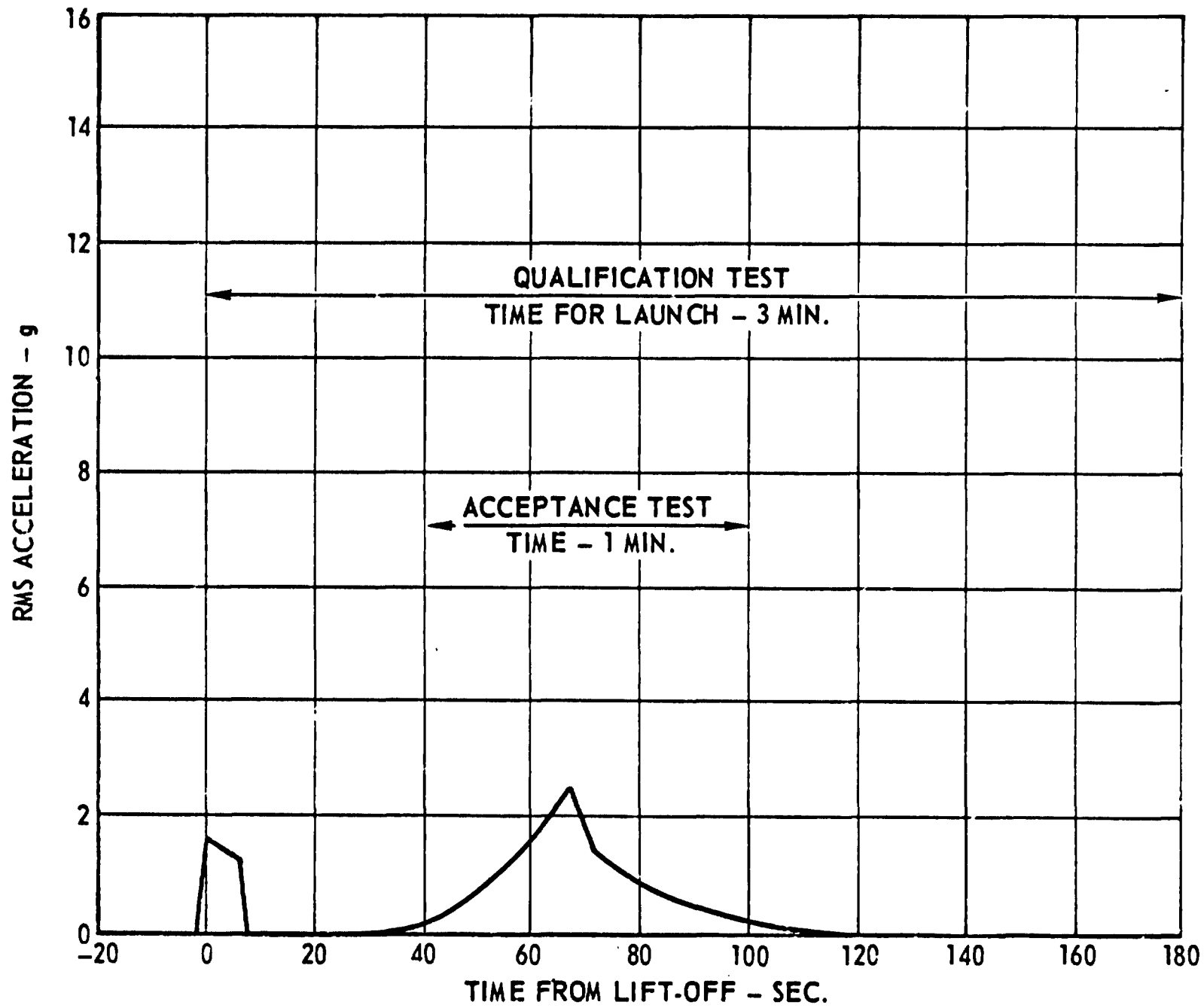


FIGURE 4-15 COMPARISON OF TIME HISTORY OF GT-1 MEASURED ADAPTER BLAST SHIELD VIBRATION WITH QUALIFICATION AND ACCEPTANCE TEST DURATIONS

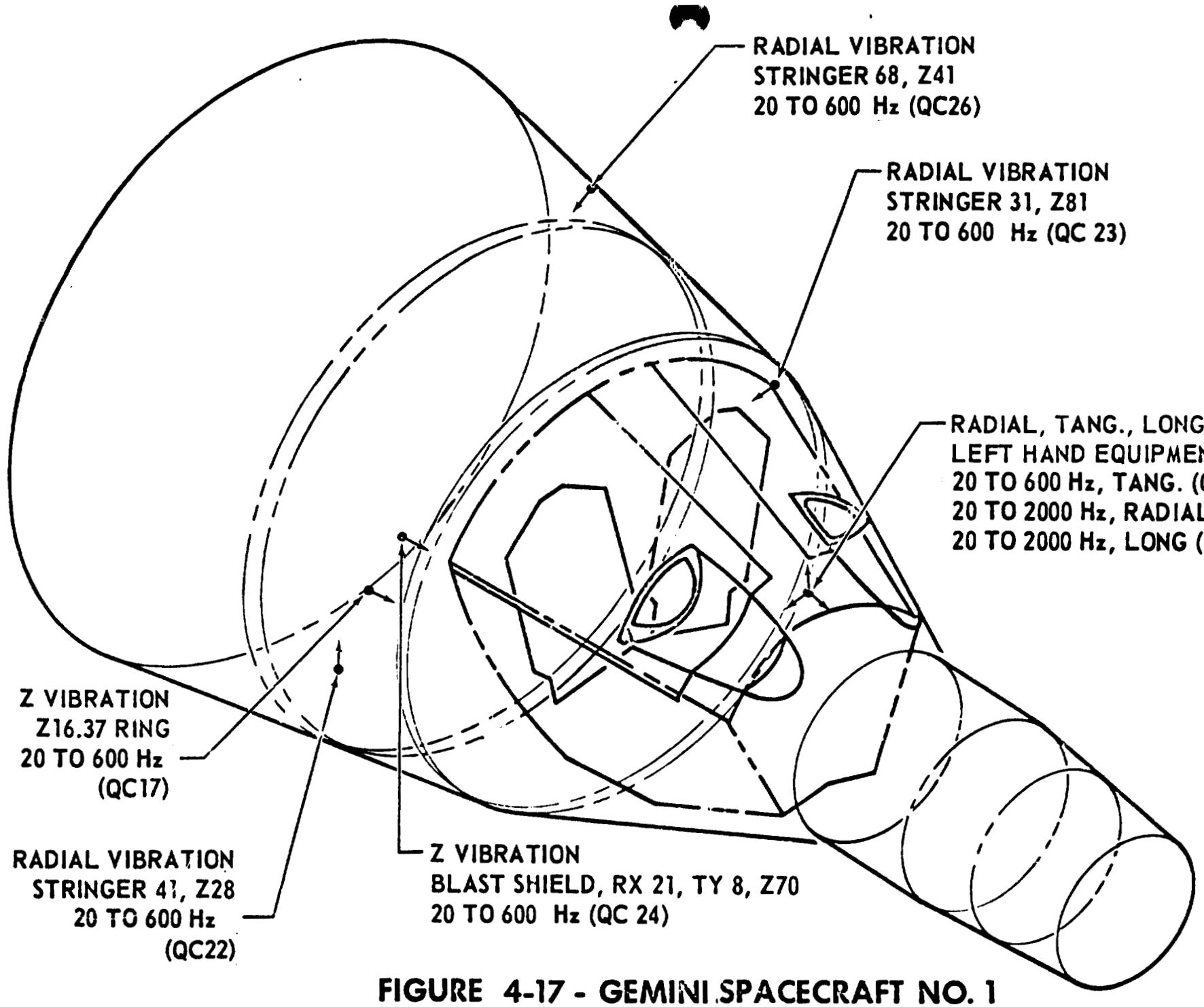
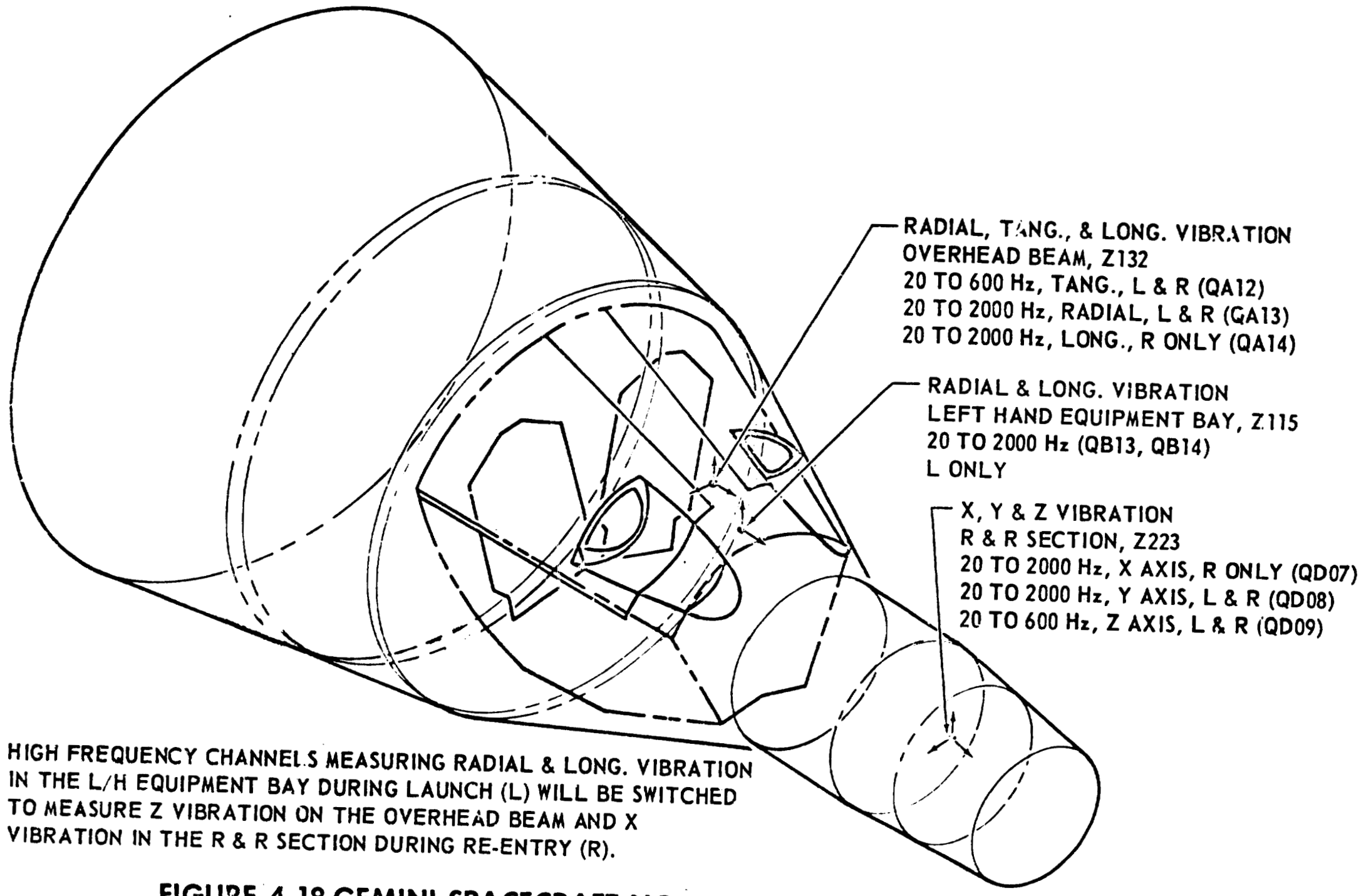


FIGURE 4-17 - GEMINI SPACECRAFT NO. 1 (VIBRATION PICKUP LOCATIONS)



HIGH FREQUENCY CHANNELS MEASURING RADIAL & LONG. VIBRATION IN THE L/H EQUIPMENT BAY DURING LAUNCH (L) WILL BE SWITCHED TO MEASURE Z VIBRATION ON THE OVERHEAD BEAM AND X VIBRATION IN THE R & R SECTION DURING RE-ENTRY (R).

FIGURE 4-18 GEMINI SPACECRAFT NO. 2 VIBRATION PICKUP LOCATIONS

5.0 COMPARISON OF TEST LEVELS AND FLIGHT DATA

As mentioned in paragraph 4.0, GT-1 flight data were used in the derivation of test requirements. A sketch showing instrument locations for the GT-1 spacecraft is shown in Figure 5-1. Plots of GT-1 re-entry vehicle vibration data are included as Figures 5-2 and 5-3, showing the comparisons of level versus frequency and level versus time, respectively. Figures 5-4 and 5-5 are the comparable plots for the adapter measurement. A single cabin acoustic measurement was also taken, and the comparison plots are shown in Figures 5-6 and 5-7. Figures 5-1 through 5-5 are identical to figures given in paragraph 4.0 but are repeated for convenience.

Flight measurements were taken on GT-2 during launch and re-entry. The spacecraft instrument locations are shown in Figure 5-8. The comparison plots of frequency distribution of the re-entry vehicle radial vibration measurements during launch and test requirements are shown in Figure 5-9. RMS levels versus time for the measurements are shown and the duration of the test requirements are shown in Figure 5-10. The measured re-entry data are not presented because they were extremely low compared to full scale of the instrumentation.

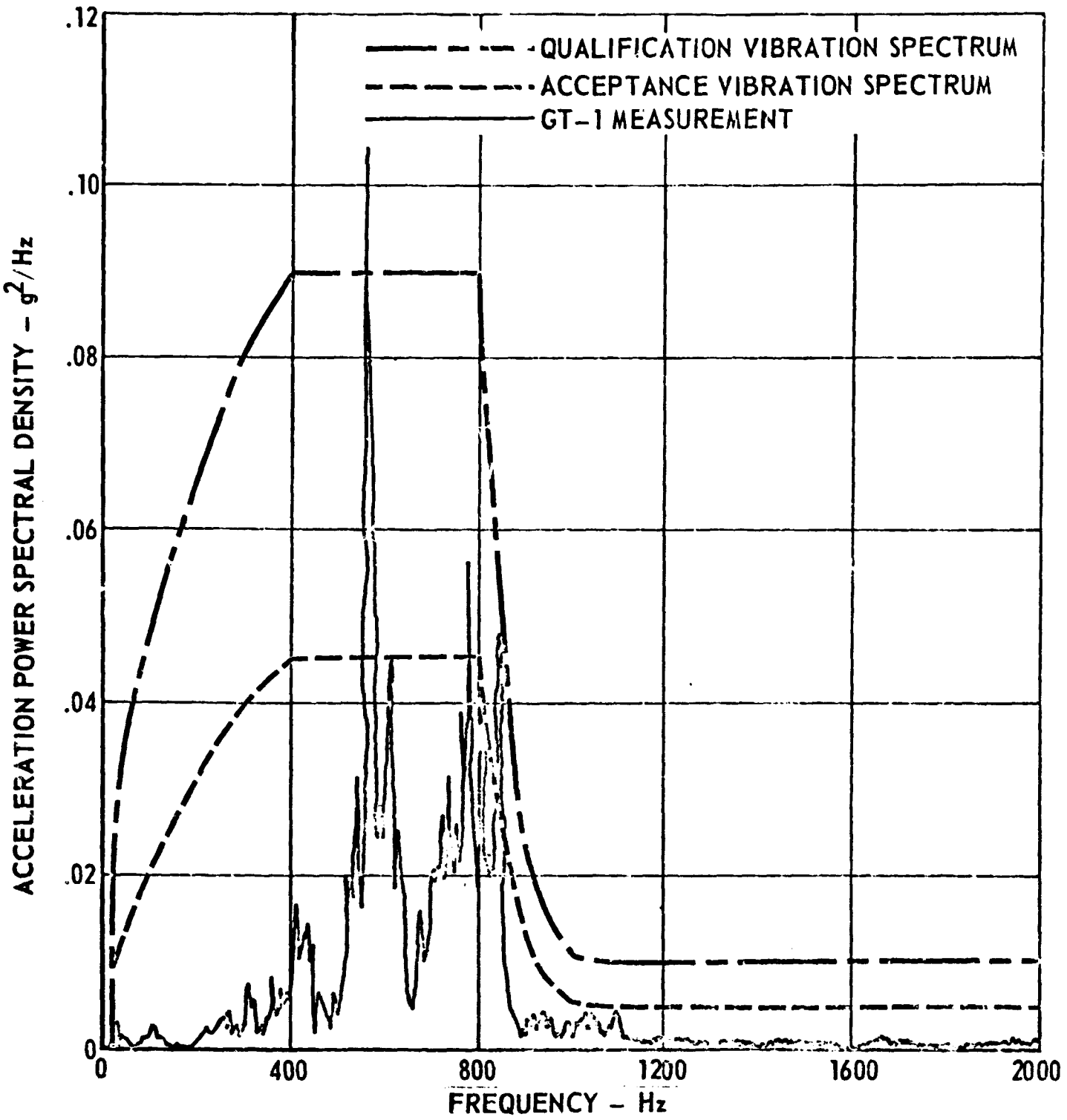


FIGURE 5-2 GT-1 EQUIPMENT BAY VIBRATION MEASUREMENT COMPARED WITH QUALIFICATION AND ACCEPTANCE VIBRATION SPECTRA

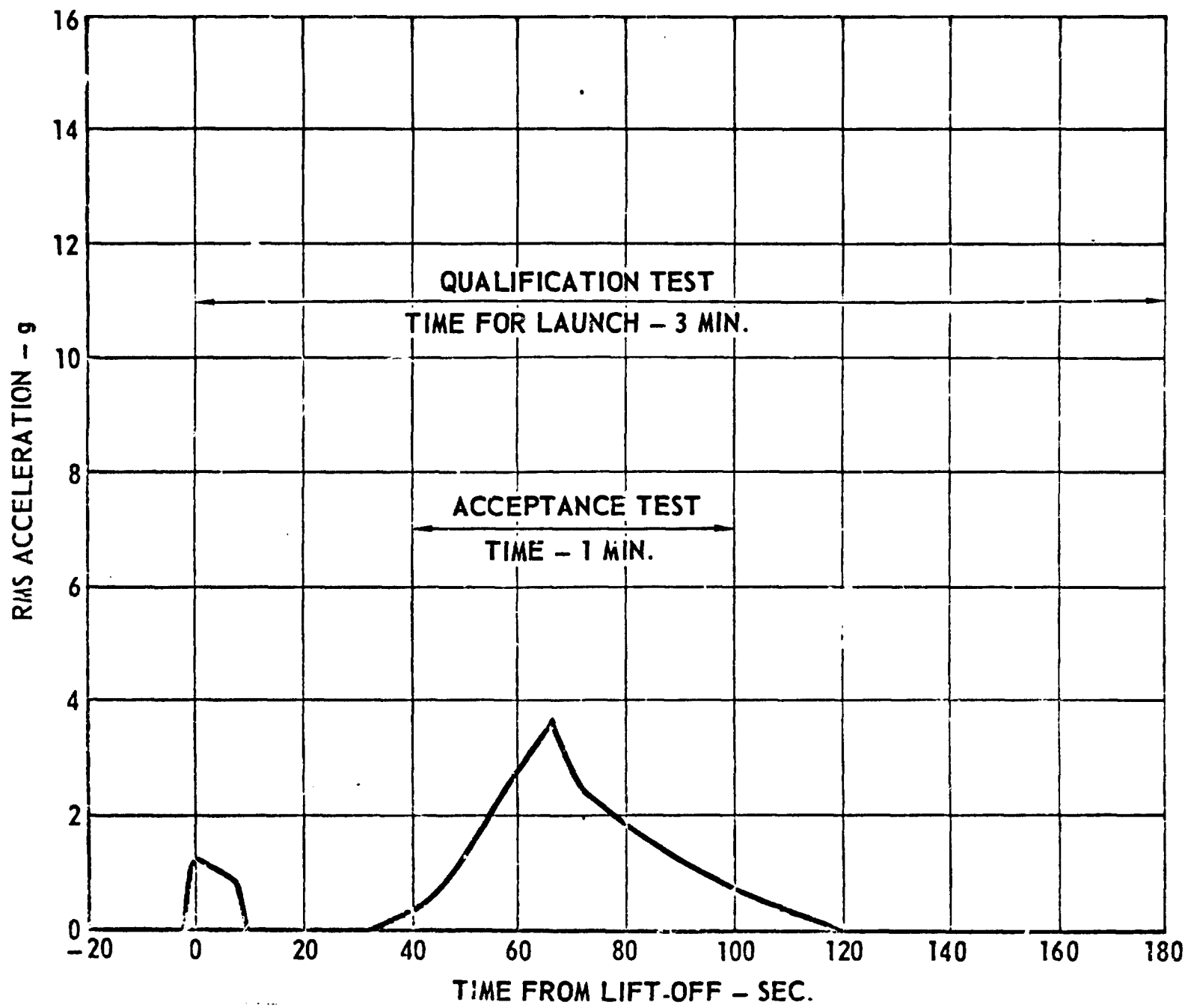


FIGURE 5-3 COMPARISON OF TIME HISTORY OF GT-1 MEASURED RE-ENTRY VEHICLE VIBRATION WITH QUALIFICATION AND ACCEPTANCE TEST DURATIONS

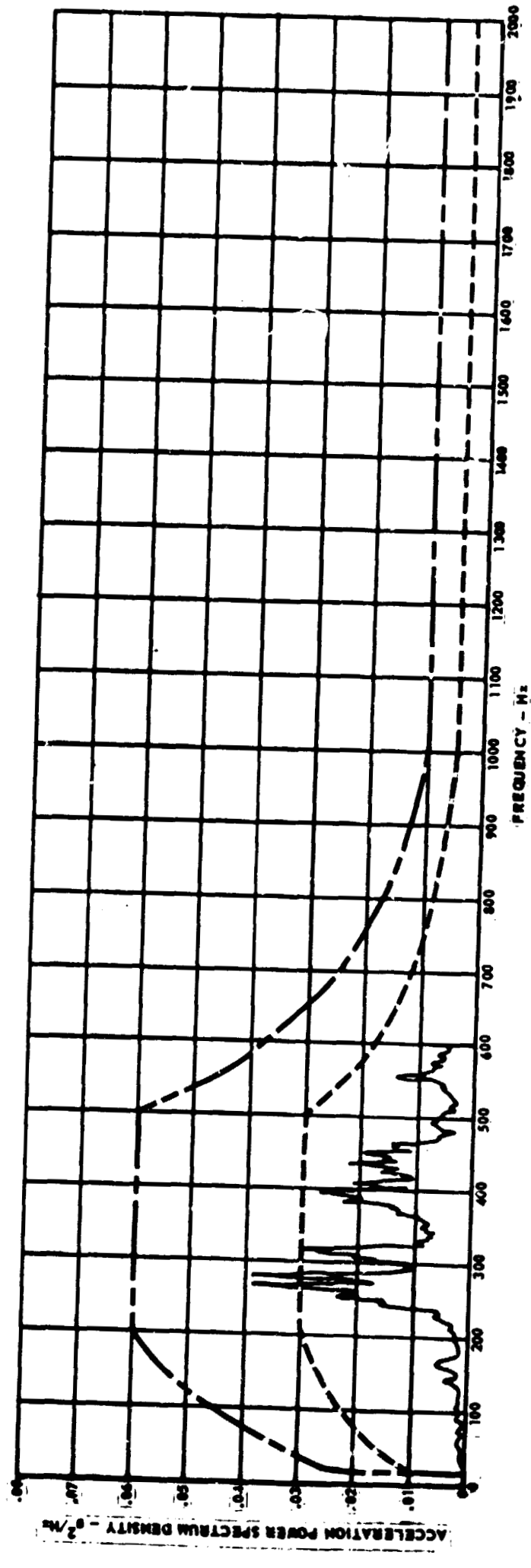


FIGURE 5-4 GT-1 ADAPTER BLAST SHIELD VIBRATION MEASUREMENT COMPARED WITH QUALIFICATION AND ACCEPTANCE VIBRATION SPECTRA

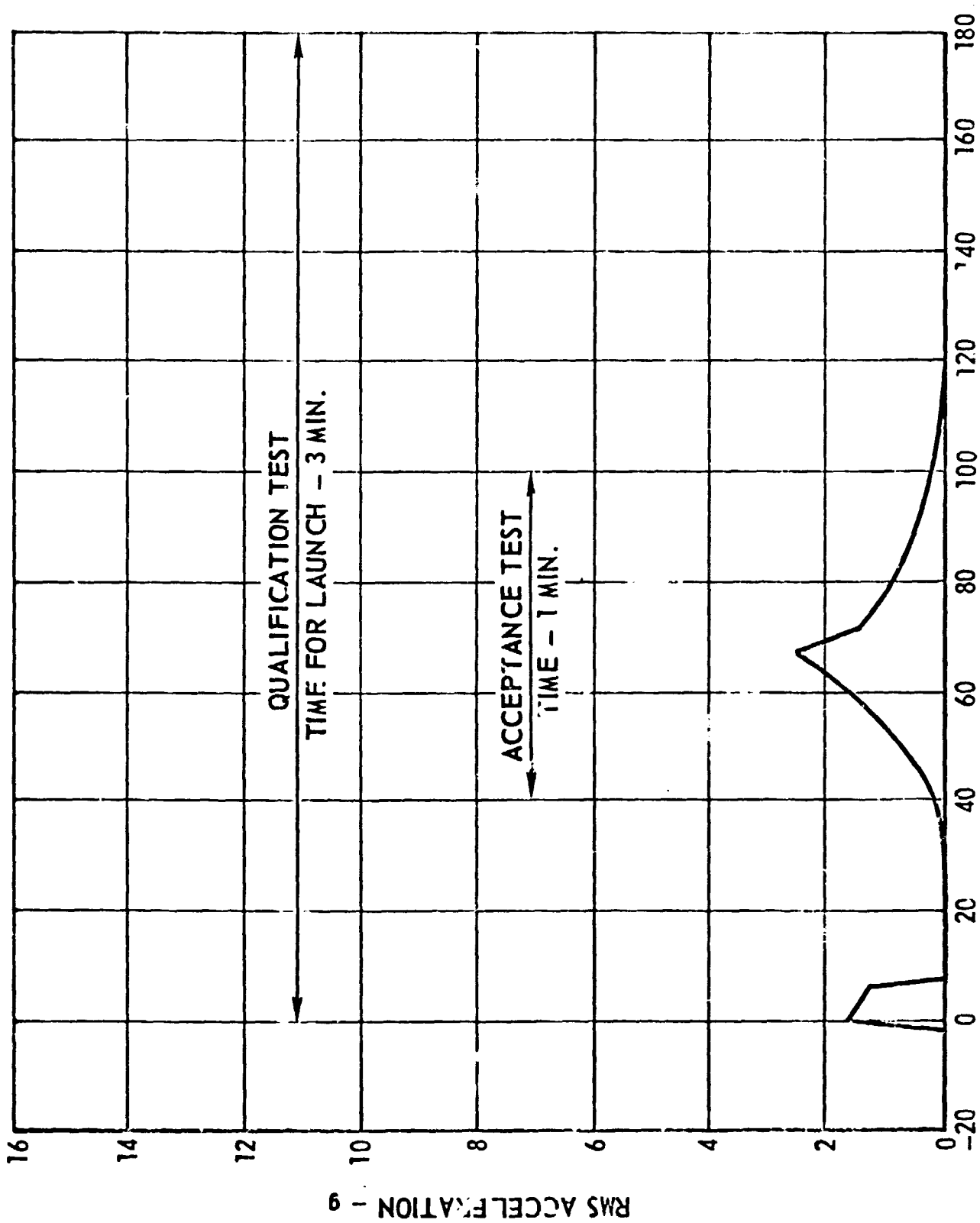


FIGURE 5-5 COMPARISON OF TIME HISTORY OF GT-1 MEASURED ADAPTER BLAST SHIELD VIBRATIONS WITH QUALIFICATION AND ACCEPTANCE TEST DURATIONS

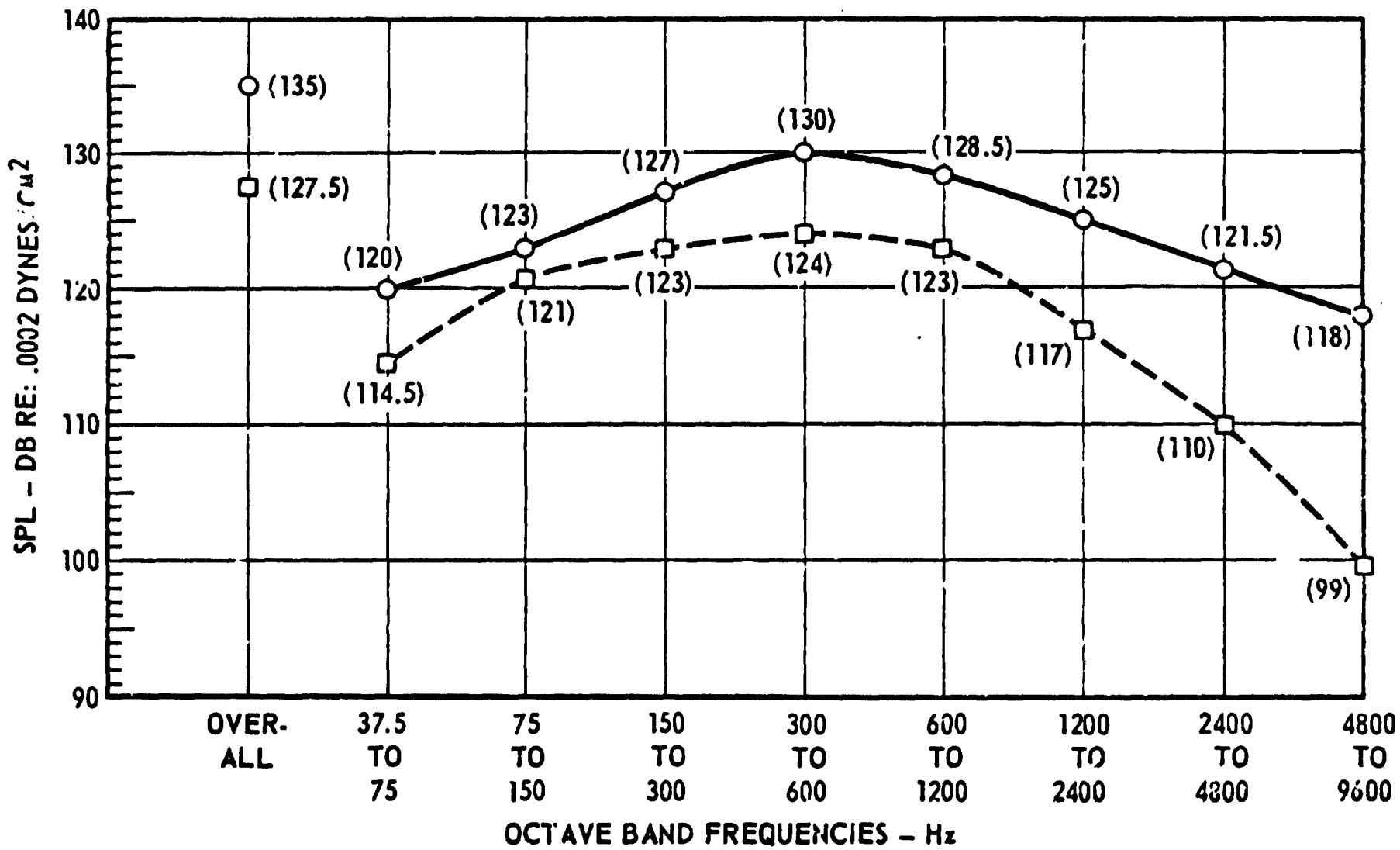


FIGURE 5-6 COMPARISON OF PEAK GT-1 CABIN ACOUSTIC MEASUREMENT WITH QUALIFICATION LEVELS

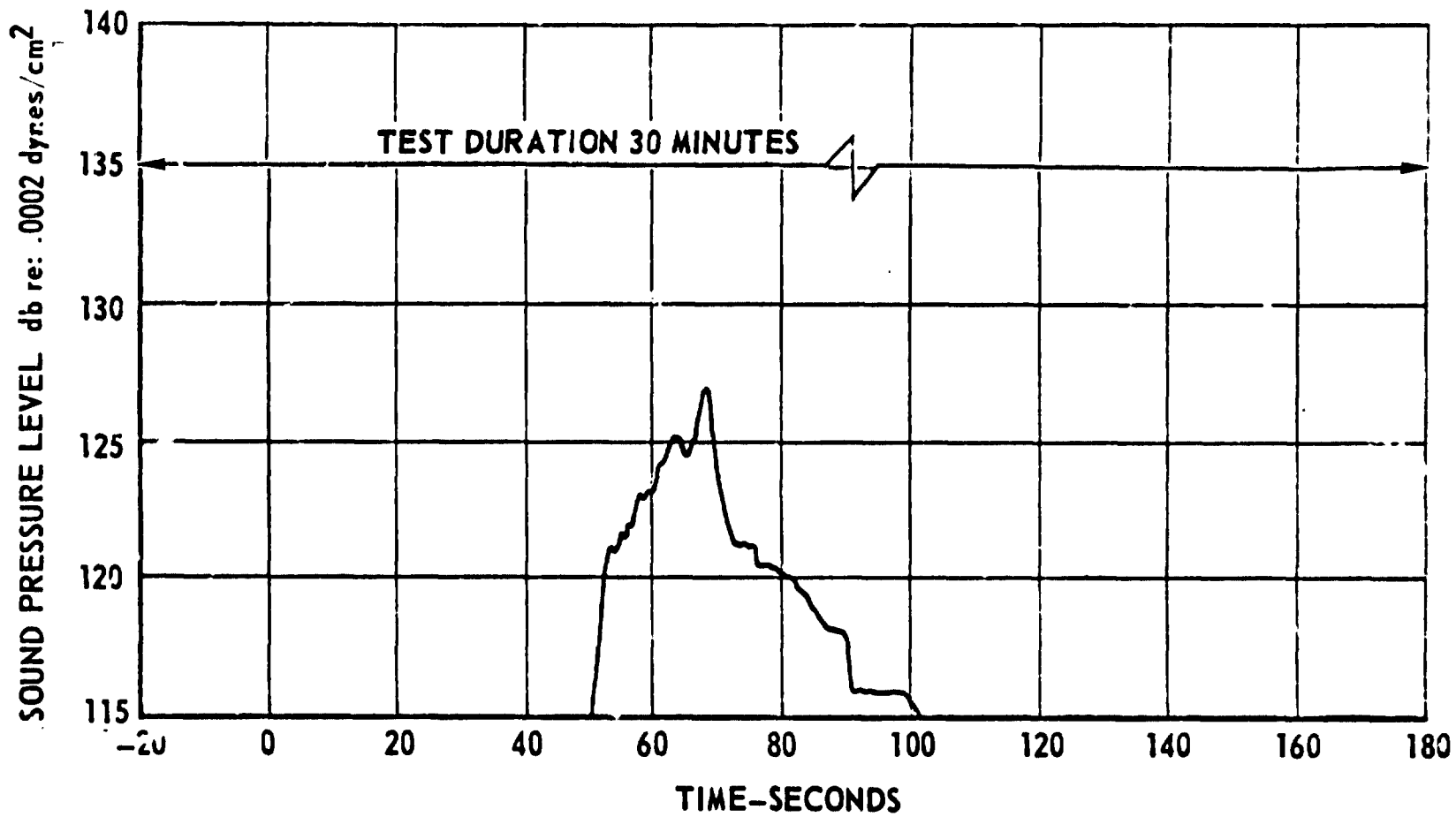


FIGURE 5-7 COMPARISON OF GT-1 ACOUSTIC TIME HISTORY WITH QUALIFICATION TEST DURATION

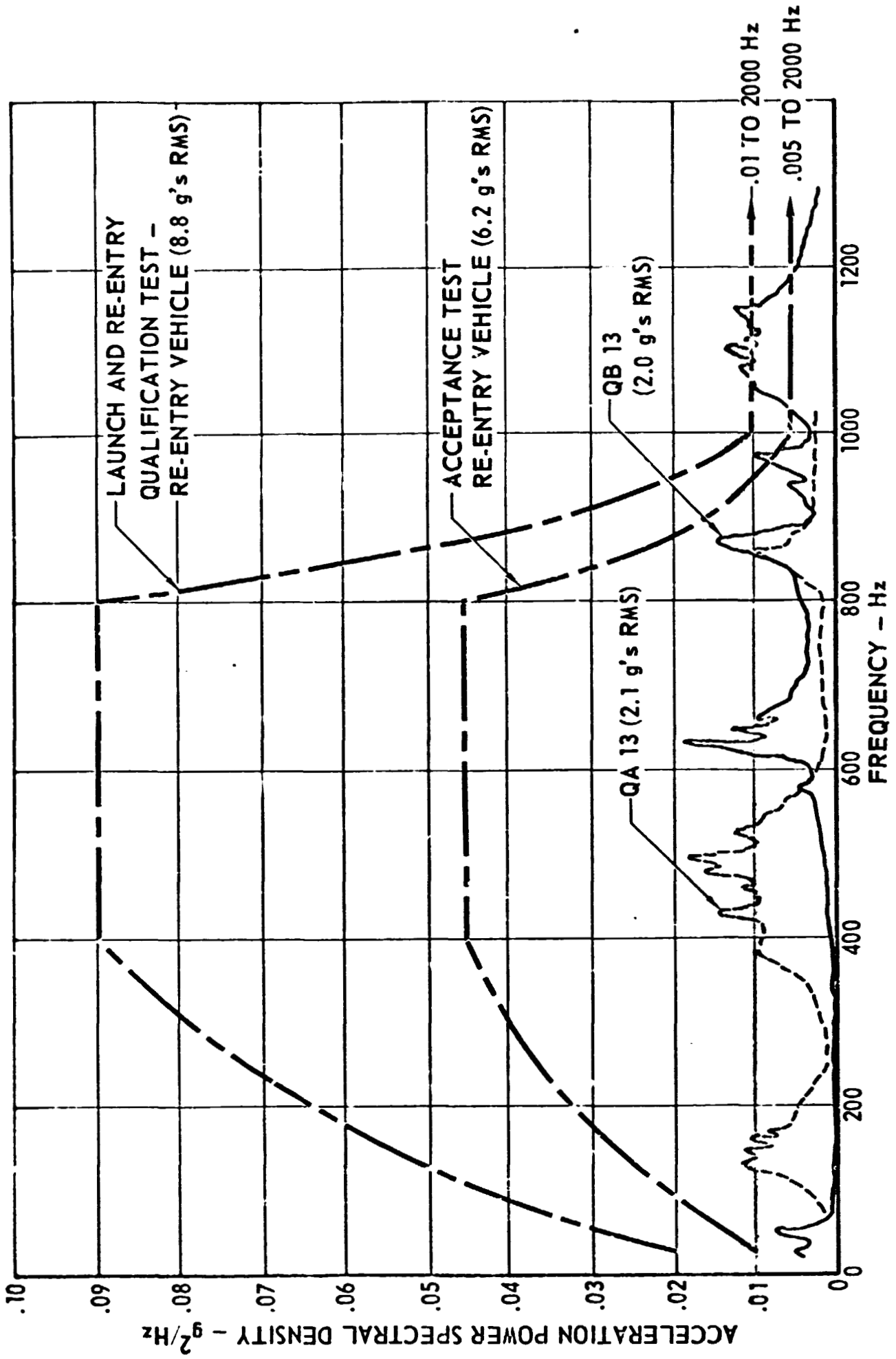


FIGURE 5-9 GT-2 LAUNCH MEASURED VIBRATION PSD'S COMPARED TO QUALIFICATION AND ACCEPTANCE SPECTRA

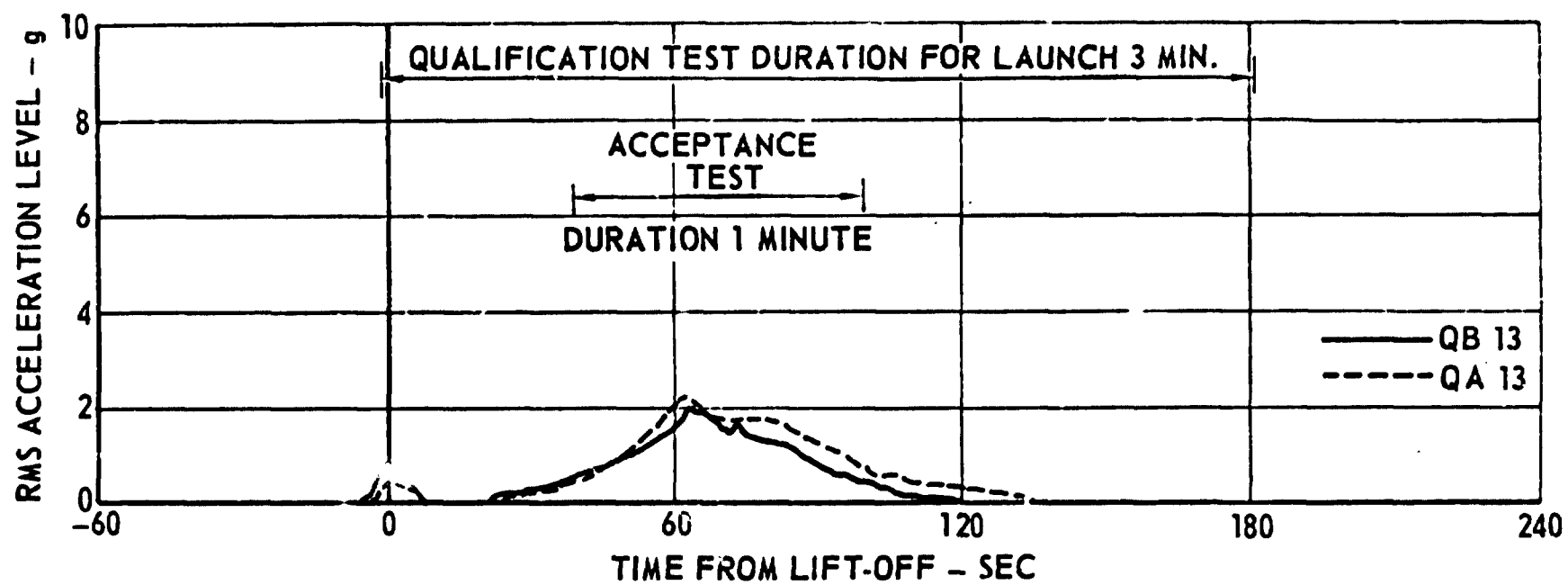


FIGURE 5-10 COMPARISON OF GT-2 MEASURED VIBRATION RMS LEVELS WITH QUALIFICATION AND ACCEPTANCE TEST DURATIONS

6.0 CONCLUSIONS AND RECOMMENDATIONS

The significance of the vibration and acoustic testing which were performed during the Gemini program should be evaluated in these ways: the flight problems which they avoided, the confidence which they provided and the cost compared to their value. Acoustic tests were not generally conducted on Gemini and in those conducted only four test failures resulted. The elimination of the tests was based on previous experience that only the most sensitive items might fail when acoustic levels are less than 135 db, and that some items are not sensitive to even higher levels. Those tests which were retained did result in additional confidence in the flight capability of the design.

The vibration tests of components and subsystems resulted in many failures. Although many of these might not have occurred in flight even had they not been corrected, the procedures for these tests were realistic so that many of these failures could have occurred in flight. The costs of these tests are high, but a great deal of confidence is placed in equipment when a vibration test is successfully completed. The Gemini system tests revealed some problem areas, but not many in comparison to testing at other levels. The system level test was not fully effective in that vibration levels were not transmitted throughout the vehicle. Therefore, even though some subsystems successfully completed the test only a limited amount of confidence would result. This will be discussed further as part of our recommendations for future programs.

The test level derivations were hampered by the lack of samples to use in the original predictions. Significant advantage was gained by having the first structural vehicle flown used to gather inflight data. In the case of Gemini the data was made available in time for many items to be qualified at the lower level - in some cases after they had failed under the original requirements. One of the problems in test level derivation is the disparity among individuals in the interpretation of the values assigned to tests. This problem is not considered to be unique to the Gemini, not even unique compared to the environments which are simulated by ground tests.

Another major consideration consists of recommendations for future programs, assuming the vehicle to be of similar size and complexity to Gemini. If the environment is considered to be random in amplitude, then all tests would be conducted with a random forcing function. The use of sinusoidal excitation is not warranted for a new vehicle since current test equipment permits random tests to be performed very easily, and commercial test facilities are readily available for vendors. All test times should be comparable to the expected flight durations. Changing the test time may be required if the expected environment cannot be obtained, or if the flight hardware is to be reflown, but "scaling" test time should be avoided if at all possible. The use of qualification and acceptance vibration tests for components should be incorporated. Development tests to qualification levels can be eliminated with very little effect on the outcome of qualification tests. The savings of development test costs should offset the additional qualification testing that would become necessary. Acoustic noise tests should be eliminated from all non-sensitive equipment, especially if the level is 135 db or less.

Perhaps the biggest change that we would recommend for future programs compared to the Gemini procedures is the thorough evaluation of acoustic excitation for vehicle acceptance and qualification tests. The use of acoustic noise for these tests would provide a step closer toward simulation of the expected dynamic forcing function, as compared to vibration testing. The need for improved techniques was demonstrated for Gemini when it was found that the test levels were not transmitted satisfactorily throughout the structure - regions close to the shaker attach points were subjected to the desired levels, but elsewhere the levels were down considerably. The use of an additional exciter reduced the problem some, but to simulate the expected environment by shakers seems to have severe limitations for vehicles designed for distributed loadings. System acoustic tests might require the use of development tests, but it would be serving to develop the test techniques for the vehicle rather than to develop the vehicle of its components.

The derivation of test levels for a new vehicle could be made from the data obtained in-flight on Mercury and on GT-1 and GT-2 with corrections for differences indicated by wind tunnel fluctuating pressure tests or expected trajectories if the structural construction is similar. The use of different construction would require some vibration testing to estimate the applicability of the Mercury-Gemini data.

APPENDIX C

STATEMENT OF WORK

A. BACKGROUND

The statement of work presented herein has been prepared in response to a request by the NASA Apollo Project Office. The work represents a continuation of the vibration and acoustic survey conducted by the Boeing Company in 1967 in which your organization participated. The survey results are presented in Boeing Document D2-120001-1. The purpose of this work statement is to provide requirements for more detailed information than was obtained in the original survey.

B. SCOPE

The contractor shall provide the technical data relative to vibration and acoustic testing associated with the _____ program. These data are required in the specific areas of Laboratory Test Programs and Results, Flight Test Results, Environment Derivations and Verifications, Spacecraft Agency Conclusions and Recommendations as described in the following tasks.

TASK 1 - LABORATORY TEST PROGRAM

a. Discuss the role of laboratory vibration and acoustic testing in the overall spacecraft program and the rationale of this approach. Utilize charts or diagrams to depict the interrelationships between laboratory vibration or acoustic tests and other aspects of the spacecraft program. The following types of vibration or acoustic tests should be included in the discussion and charts.

	Development	Qualification	Acceptance
Component	X	X	X
Subsystem	X	X	X
System	X	X	X

b. Provide the following information relative to <u>component qualification and component acceptance tests</u>.

   1) Number of components tested and type of test (random vibration, sine vibration or acoustic).
   2) The specified test levels and durations of the tests. If different levels and durations were used for different components, indicate the extremes and provide a general explanation of the reasons for these variations.

c. Provide the following information relative to <u>subsystem development tests</u>, <u>subsystem qualification tests</u> and <u>subsystem acceptance tests</u>.

1) Descriptive nomenclature for each subsystem tested.
2) The objectives of the test.
3) The type of tests performed (random vibration, sine vibration, acoustic) on each subsystem and associated test levels and durations.

d. Provide the following information relative to system development tests, system qualification tests and system acceptance tests.

1) Descriptive nomenclature for each system tested. Provide a schematic or photograph of the system tested.
2) Objectives of each test.
3) The type of tests performed (random vibration, sine vibration, acoustic) on each system and associated test levels and durations.
4) Describe the test configuration and indicate percentage of production components installed during each test.

TASK 2 - LABORATORY TEST FAILURES

a. Provide the following information relative to failures during component qualification tests, and component acceptance tests.

1) Identify the type of component which failed and provide a brief indication of the failure or malfunction.
2) Indicate the type of test which caused the failure (random vibration, sine vibration, etc.) and the associated test level.
3) Briefly describe action taken as the result of the failure, i.e., retest, redesign, change inspection procedure, test requirements revised, etc.

b. Provide the following information relative to failures during subsystem development tests, subsystem qualification tests and subsystem acceptance tests.

1) Describe the failure or malfunctions.
2) Indicate the type of test which caused the failure (random vibration, sine vibration, etc.) and the associated test level.
3) Briefly describe action taken as the result of the failure, i.e., retest, redesign, change inspection procedure, test requirements revised, etc.
4) Comment on why the failure was not uncovered during component level tests.

c. Provide the following information relative to failures during system development tests, system qualification tests and system acceptance tests.

1) Describe the failure or malfunction.
2) Indicate the type of test which caused the failure (random vibration, sine vibration, etc.) and the associated test level.
3) Briefly describe action taken as the result of the failure, i.e., retests, redesign, change inspection procedure, test requirements revised, etc.
4) Comment on why the failure was not uncovered during component level tests or subsystem level tests.

TASK 3 - FLIGHT FAILURES

a. Describe each failure or malfunction occurring during flight.

b. Identify the cause of the failure or probable cause of the failure and if the failure could be attributed to the vibration environment.

c. Describe the effect of the failure on the vehicle mission.

d. If the failure is suspected or known to be the result of the vibration environment, identify the type of test(s) where the failure should have been detected (component qualification, system acceptance, etc.).

e. Describe action taken to correct failure.

TASK 4 - DERIVATION OF TEST LEVEL AND IDENTIFICATION OF TEST FACTORS

a. Provide a description of the method or methods used to derive vibration and acoustic tests levels and durations for the following types of tests:

	Development	Qualification	Acceptance
Component	-	X	X
Subsystem	X	X	X
System	X	X	X

b. Provide at least one comparative graph for each type of test showing the different between the specified test level and duration and the measured, predicted or extrapolated data used to derive the test level and duration.

c. Identify the source of the data used to derive the test level and duration. Provide comments on the reasons for using subject data to derive the test levels and durations.

d. Identify the relationships between development, qualification and acceptance test levels and durations. Provide the reasoning used to arrive at these relationships.

TASK 5 - COMPARISON OF TEST LEVELS AND FLIGHT DATA

The contractor shall provide graphs showing the relationship between measured flight vibration or acoustic data and specified test levels. These graphs shall depict the full range of vibration or acoustic data measured in flight.

TASK 6 - CONTRACTOR CONCLUSIONS AND RECOMMENDATIONS

The contractor shall provide conclusions and recommendations relative to the information provided in Tasks 1 thru 5. The conclusions and recommendations should include but not be limited to the following:

a. The significance of vibration and acoustic testing to the subject spacecraft program.

b. Relative significance and value of the various types of tests conducted.

c. Adequacy and/or inadequacies of the test level derivation methods.

d. Inadequacies in the vibration and acoustic test program for the subject spacecraft program.

e. Recommendations relative to vibration and acoustic test programs for future programs.

f. Recommendations regarding test level derivation and test procedures for future programs.

C. PERIOD OF PERFORMANCE

The information described in the Statement of Work is required on or before April 1, 1968.

D. DEFINITIONS

COMPONENT - An integral package such as a camera, a valve, a battery or a transmitter.

SUBSYSTEM - A group of components which is part of a larger system. An example of a subsystem is the Gemini fuel cell module consisting of two fuel cell sections, a hydrogen tank, an oxygen tank, pressure regulators, valves and associated tubing and wiring.

SYSTEM - A complete or major portion of a spacecraft.

DEVELOPMENT TEST - A test to evaluate the performance of a component, subsystem or system under environemental conditions and to determine its ability to withstand such conditions. The test is usually run early in a program to seek out design weaknesses and correct or improve them prior to qualification testing.

QUALIFICATION TEST - A test on a component, subsystem or system to demonstrate design capability to withstand a critical service environment.

ACCEPTANCE TEST - A test to detect workmanship deficiencies in a component, subsystem or system which is destined for use in service.

APPENDIX D

PRESENTATION OF SURVEY RESULTS TO THE APOLLO PROGRAM OFFICE

The information contained in this appendix was presented to the Chief of Apollo Test, C. C. Gay, Jr. on May 1, 1968.

A SUMMARY OF SPACECRAFT VIBRATION AND ACOUSTIC TESTING

THE BOEING COMPANY
MAY 1, 1968

HISTORY

July '67	Conversation between C. C. Gay and Boeing regarding survey.
Sept. '67	Work started on survey.
Oct. - Nov. '67	Survey of 10 spacecraft agencies and review of CSM 105 test requirements with Boeing-Houston.
Dec. '67	Survey results and comments on CSM-105 test presented to NASA APO.
Dec. '67	Request for more detailed information by NASA APO.
Jan. - Feb. '68	Prepared statement of work for detailed survey and presented to NASA APO.
Mar. - Apr. '68	Conduct survey - JPL provided available documentation, Boeing-Seattle prepared a document under IDWA, McDonnell prepared document under Boeing contract.
1 May '68	Present survey results to NASA APO.

INTRODUCTION

This summary contains information on 5 spacecraft programs.

(1) Mariner Mars 1964

(2) Mariner Venus 1967

(3) Surveyor (Very Incomplete)

(4) Lunar Orbiter

(5) Gemini

Information on the following topics will be presented for each program.

Test program rationale
Relationships between environmental tests
*Types of vibration and acoustic tests
*Test levels and durations
*Laboratory test failures
*Failures in flight
Derivation of laboratory test requirements
Comparison of flight data and lab test requirements
Spacecraft agency conclusions
*Spacecraft agency recommendations

*Information requested via letter from C. C. Gay to D. B. Jacobs, dated 11 January 1968.

TEST PROGRAM RATIONALE

MARINER MARS 1964	MARINER VENUS 1967
(1) Qualification test offers evidence that test article will not be degraded by acceptance test.	
(2) Qualification assures design margin in equipment.	
(3) System test provides environmental interactions.	
(4) Equipment subject to qualification tests not flown.	(4) MV67 design a derivation of the adequately qualified MM 64.
	(5) MV67 flight spare S/C made up of some MM64 qualification hardware.

TEST PROGRAM RATIONALE

LUNAR ORBITER

(1) Program consisted of 3 phases:

Development test
Component Test
System Test

(2) Hardware allocated early in program for lab & flight tests.

(3) Components acceptance tested prior to qualification test.

(4) Equipment subject to qualification tests not flown.

GEMINI

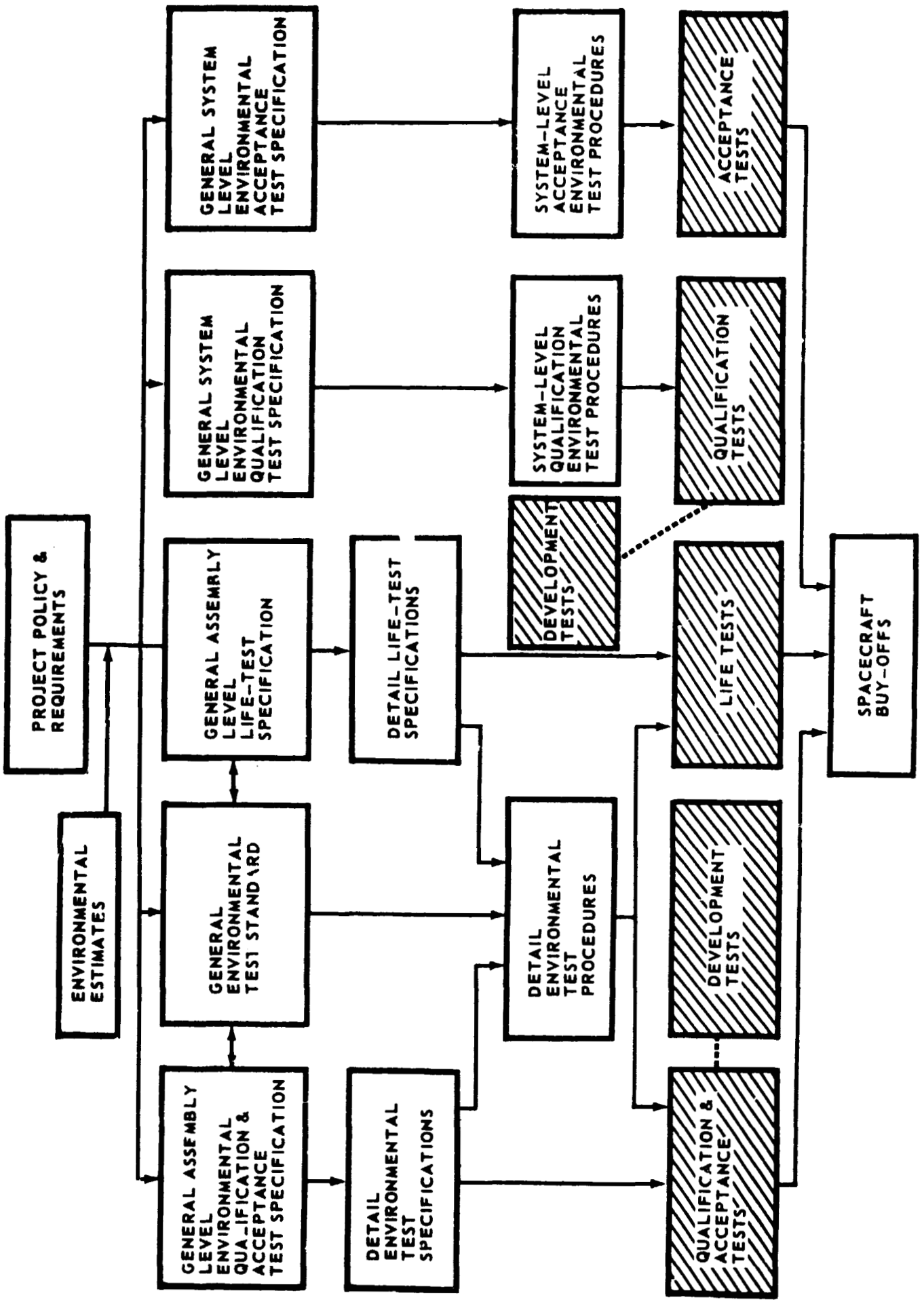
(1) Environmental test uncover design or workmanship deficiencies.

(2) Cost effective approach resulted in:

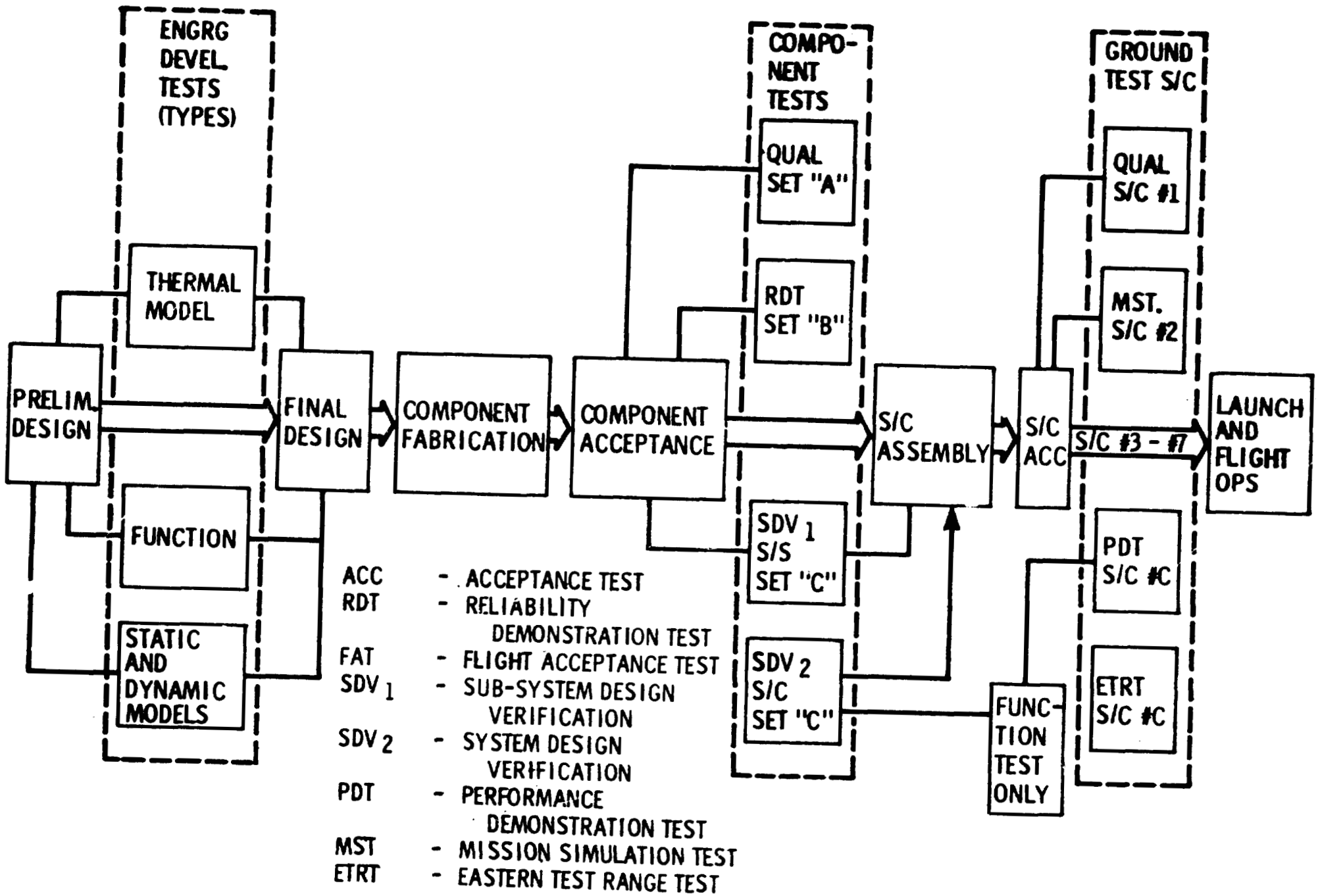
Use of Mercury procedures
Qualification by similarity
Non-sensitive items not tested
Omit formal development tests

(3) Eliminated system acceptance test after S/C 3.

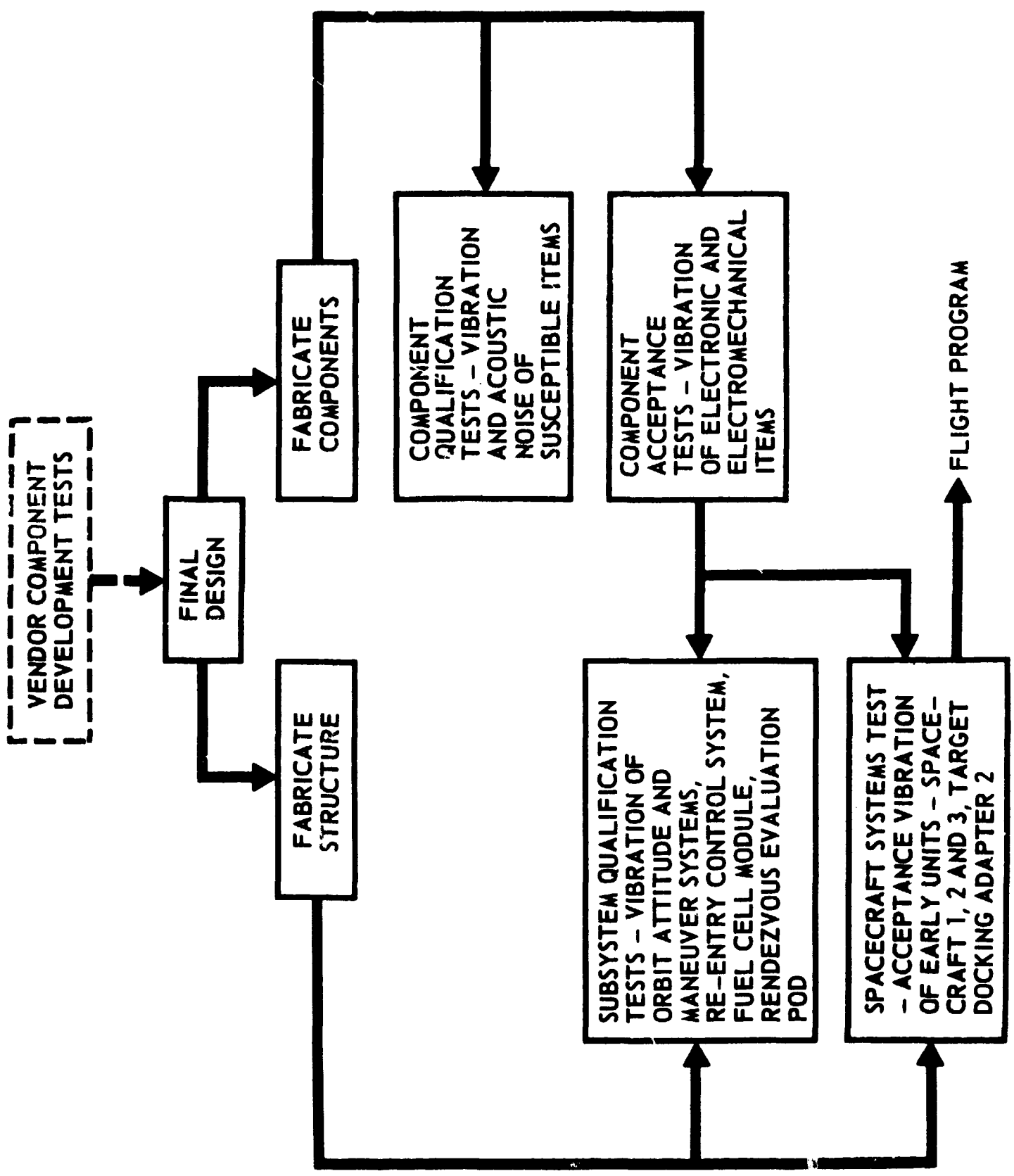
(4) Multiple level tests provided realistic tests at an early date.



MARINER 64 TEST PROGRAM DOCUMENTATION



LUNAR ORBITER TEST PROGRAM OUTLINE



LABORATORY VIBRATION AND ACOUSTIC TEST PROGRAM RELATIONSHIPS -GEMINI

TYPES OF TESTS CONDUCTED

		MM 64	MM 67	LUNAR ORBITER	GEMINI	SURVEYOR
COMPONENT	DEVEL	V	V	V	*	
	QUAL	V	V	V	V/A	V
	ACCEPT	V	V	V	V	V
SUBSYSTEM	DEVEL	V	V			
	QUAL	V	V		V	V
	ACCEPT	V	V			V
SYSTEM	DEVEL	V/A	V			V
	QUAL	V/A	V	V/A		V
	ACCEPT	V	V	V	V	V

NOTES

V = VIBRATION TEST
A = ACOUSTIC TEST
* = CONDUCTED BY VENDOR

COMMENT ON WDC 9

The Mariner and Surveyor programs used the terminology assembly, subsystem and control item. This terminology included test articles which we defined as components and subsystems. Therefore both component and subsystems test have been indicated for these agencies.

We found from the survey that two test categories are readily identifiable, they are: (1) system level and (2) tests below the system level. Below the system level there is a great variety of nomenclature and definitions used to describe a test article.

COMPONENT AND SUBSYSTEM VIBRATION TEST LEVELS AND DURATIONS

SPACECRAFT	SINUSOIDAL QUALIFICATION	SINUSOIDAL ACCEPTANCE	RANDOM QUALIFICATION	RANDOM ACCEPTANCE
MARINER - MM 64 AND MV 67	9g/10 MIN.	6g/3.3 MIN.	16.4g/3 MIN.	9.7g/1 MIN.
LUNAR ORBITER	10.6g/8.6 MIN.	7.07/2.2 MIN.	20.4g/0.7 MIN.	17.2g/0.3 MIN.
GEMINI	5.7g/30 MIN. 1	5.7g/15 MIN. 1	12.6g/15 MIN. 2	12.6g/1 MIN.
SURVEYOR	11.1g/12 MIN. 3	8.3g/6 MIN. 4	6.75g/12 MIN.	2g/2 MIN. 5

NOTES

- RANDOM LEVELS ARE MAXIMUM OVERALL LEVEL SPECIFIED.
- SINE LEVELS ARE THE MAXIMUM LEVEL IN THE TEST FREQUENCY RANGE.
- g VALUES ARE RMS.
- DURATIONS ARE FOR EACH AXIS. SINE DURATIONS ARE SWEEP TIME FOR AN AXIS.

1 IN ADDITION TO SINE SWEEP DURATION THERE WERE 10 MINUTE SINE DWELLS FOR MAJOR RESONANCES.

2 THE 15 MINUTE DURATION INCLUDED A 10 MINUTE PERIOD TO DEMONSTRATE A 2 FLIGHT CAPABILITY.

3 AVERAGE OF MAXIMUM LEVELS FROM 32 ENVELOPES.

4 AVERAGE OF MAXIMUM LEVELS FROM 23 ENVELOPES.

5 RUN ON 4 ITEMS ONLY.

SYSTEM VIBRATION TEST LEVELS AND DURATIONS

SPACECRAFT	SINUSOIDAL QUALIFICATION	SINUSOIDAL ACCEPTANCE	RANDOM QUALIFICATION	RANDOM ACCEPTANCE
MARINER - MM 64 AND MV 67	10g/17.4 MIN.	0.5/3.2 MIN.	18.1g/3 MIN.	10.7g/1 MIN.
LUNAR ORBITER	2.1g/6.3 MIN.	1.4g/3.2 MIN.	24.4g/0.7 MIN.	17.2g/0.3 MIN.
GEMINI	NONE	±6g @ 11 cps/ 0.3 MIN. [1]	NONE	8.4g/3 MIN.
SURVEYOR	1.6g/12.3 MIN.	1.1g/6.1 MIN.	6.8g/12.3 MIN.	4.5g/6.1 MIN.

NOTES

- RANDOM LEVELS ARE MAXIMUM OVERALL LEVEL SPECIFIED
- SINE LEVELS ARE THE MAXIMUM LEVEL IN THE TEST FREQUENCY RANGE.
- g VALUES ARE RMS.
- DURATIONS ARE FOR EACH AXIS. SINE DURATIONS ARE SWEEP TIME FOR AN AXIS.

[1] POGO SIMULATION

SYSTEMS ACOUSTIC TEST LEVELS AND DURATIONS

SPACECRAFT	QUALIFICATION	ACCEPTANCE
MARINER - MM 64	142 DB/1.5 MIN.	NONE
MARINER - MV 67	NONE*	NONE
LUNAR ORBITER	141.5 DB/2 MIN.	NONE
GEMINI	NONE	NONE
SURVEYOR	NONE	NONE

NOTES

*TESTS ON MM 64 CONSIDERED APPLICABLE TO MV 67.
•LEVELS ARE OVERALL SOUND PRESSURE LEVELS.

COMMENT ON WDC 13 & 14

GEMINI failure data changed due to receipt of additional information from McDonnell on 5/6/68.

COMPONENT AND SUBSYSTEM QUALIFICATION TEST FAILURES

CATEGORY	MARINER MM 64	MARINER MV 67	LUNAR ORBITER	GEMINI	SURVEYOR
DESIGN	23	2	*	81	*
PART FAILURE	7			15	
WORKMANSHIP	7			24	
TEST ERROR	5	1			
OPERATIONAL SUPPORT EQUIPMENT	2				
FABRICATION				27	
MISCELLANEOUS	2	2		9	
TOTAL	46	5		156	
TOTAL ITEMS TESTED	244	21		432**	
FAILURE RATE	19%	24%		36%	

*INFORMATION NOT DOCUMENTED IN TIME FOR THIS SUMMARY.
**APPROXIMATE

EXAMPLES OF FAILURE CATEGORIES - GEMINI

TEST LEVEL Component TEST ACTIVITY Qualification

COMPONENT (TYPE)	FAILURE (CATEGORY)	TEST FAILED	TEST LEVEL	RESULTING ACTION
TM Transmitter (Electronic)	Capacitor lead broken due to excessive vibration amplification of PC board (Design).	Random Vibration (D)	12.6 G	Design change incorporated thicker cover, stiffeners, and selective potting of components.
TM Transmitter (Electronic)	Internal lead of transistor separated from chip (Part Failure)	Random Vibration (D)	12.6 G	Transistor type changed.
TM Transmitter (Electronic)	Transformer leads broken at ground terminal (Fabrication procedure).	Random Vibration (D)	12.6 G	Transformer leads changed from three strand to seven strand wire.
Flashing Recovery LT, (Electronic)	Power supply battery mounting screws backed out (Workmanship).	Random Vibration (A)	12.6 G	Tighter quality control imposed.
Inertial Platform (Electro-Mech)	Excessive gimbal 1 drift rates were recorded (subsequent vibration tests revealed that drift was not due to pitch gyro) (Unknown).	Random Vibration	8.8 G	None - Reason for discrepancy was not determined.

EXAMPLES OF COMPONENT FAILURE CATEGORIES - MARINER

COMPONENT	VIBRATION FAILURE (CATEGORY)	RESULTING ACTION
COSMIC RAY TELESCOPE	SHIELDED CABLE BROKE (DESIGN)	SHORTENED CABLE AND DELETED POTTING
RF - RECEIVER	INTERMITTENT SIGNAL AT LOW FREQUENCY VIBRATION (PART FAILURE)	REPLACED RESISTOR
PLANETARY SCAN	RETAINING RING LOOSENED (WORKMANSHIP)	LENS ASSEMBLY REWORKED BY VENDOR
DATA ENCODER	ACCEPTANCE TEST LEVEL TAPE WAS RUN - ONE PLAN (TEST ERROR)	COGNIZANT ENGINEER SUPPLY APPLICABLE TEST SPEC.
COSMIC RAY TELESCOPE	WOULD NOT LEAVE CALIBRATE MODE (OPERATIONAL SUPPORT EQUIPMENT)	REVAMP OPERATIONAL SUPPORT EQUIPMENT TO SEND CORRECT PULSE
SOLAR VANE ACTUATOR	SCREWS LOOSENED (MISCELLANEOUS)	NONE, UNIT HAD BEEN THRU PRIOR QUAL. SHAKE

COMPONENT AND SUBSYSTEM ACCEPTANCE TEST FAILURES

CATEGORY	MARINER MM 64	MARINER MV 67	LUNAR ORBITER	GEMINI	SURVEYOR
DESIGN	5	3	*	25	*
PART FAILURE	11			30	
WORKMANSHIP	5	3		41	
TEST ERROR	1	1		1	
OPERATIONAL SUPPORT EQUIPMENT	4				
FABRICATION				24	
MISCELLANEOUS	1			13	
TOTAL	27	7		134	
TOTAL ITEMS TESTED	538	117		2029**	
FAILURE RATE	5%	6%		7%	

*INFORMATI DOCUMENTED IN TIME FOR THIS SUMMARY.
**APPROXIMATE

SYSTEM QUALIFICATION TEST FAILURES

CATEGORY	MARINER MM 64	MARINER MV 67	LUNAR ORBITER	GEMINI*	SURVEYOR**
DESIGN	4	1	1		
PART FAILURE		1			
WORKMANSHIP		1			
FABRICATION		1			
PROCEDURE	2				
TOTAL	6	4	1		

* NO SYSTEMS QUALIFICATION

** NO INFORMATION AVAILABLE

2.3.2 SYSTEM QUALIFICATION TEST FAILURES -MARINER 64

SUMMARY

ENVIRONMENT	ANOMALY TYPE	ITEM	RESOLUTION
Acoustic	Failure	CC&S fuse	Transformer redesign
Vibration	Failure	Science scan cover	Redesign
Vibration	Failure	Torsional vibration fixture	Reworked fixture
Vibration	Failure	Canopus tracker	Redesign image dissector tube
Vibration	Problem	Cosmic ray telescope	Change calibrate reset
Vibration	Problem	Cosmic dust detector	Incorporated change order

2.3.2 SYSTEM QUALIFICATION TEST FAILURES -MARINER 67

SUMMARY

ENVIRONMENT	ANOMALY TYPE	ITEM	RESOLUTION
VIBRATION	TEST HARDWARE UNACCEPTABLE	SOLAR PANEL TIP DAMPERS	CHANGED SIZE OF SEALING O RINGS AND CHANGED VISCOSITY OF DAMPING FLUID.
VIBRATION	LARGE DYNAMIC EXCURSION AT 8 HZ CAUSED CONTACT OF PISTON & HOUSING.	SOLAR PANEL TIP DAMPERS	DAMPERS REMOVED AND MECHANICALLY ADJUSTED TO PREVENT CONTACT.
VIBRATION	SPOT WELDS FAILED	ATTITUDE CONTROL JET SUNSHADE SUPPORT BRACKET	REPAIRED WELDS.
VIBRATION	TUBE FITTING CRACKED	HI GAIN ANTENNA FEED SUPPORT STRUCTURE	CRACK REPAIRED.

2.3 SYSTEMS VIBRATION AND ACOUSTIC TEST FAILURES -LUNAR ORBITER

2.3.1 SYSTEM DEVELOPMENT TEST FAILURES

NO INFORMATION AVAILABLE

2.3.2 SYSTEM QUALIFICATION TEST FAILURES

ENVIRONMENT	ITEM	CATEGORY OF FAILURE	RESOLUTION
VIBRATION	*HIGH-GAIN ANTENNA, BROKEN WELD	DESIGN	X-RAY INSPECTION OF THIS WELD ON ALL ANTENNAS SHOWED ONLY TWO WERE ADEQUATE. AN ALUMINUM COLLAR WAS EPOXIED OVER WELD ON ALL FLIGHT UNITS. THE REPAIR WAS QUALIFIED AT THE COMPONENT AND SYSTEM LEVEL.

* INITIAL DISCOVERY OF THE BROKEN WELD OCCURRED DURING REINSTALLATION OF THE HIGH-GAIN ANTENNA ON THE SPACECRAFT FOLLOWING THE QUALIFICATION THERMAL-VACUUM TEST. THIS DEFECT WAS NOT DETECTED DURING OR IMMEDIATELY FOLLOWING THE VIBRATION TEST PHASE. ATTRIBUTION OF THE BROKEN WELD TO THE VIBRATION TEST IS THEREFORE TENTATIVE AND SUBJECT TO CONJECTURE.

TWO FLIGHT S/C HAD BEEN DELIVERED WHEN THE BROKEN WELD WAS DISCOVERED. FLIGHT ACCEPTANCE TESTING DID NOT DISCLOSE THE EXISTING WELD DEFECTS. NOTWITHSTANDING CONSIDERATION THAT THE DEFECT SHOULD HAVE BEEN DISCLOSED AT THE COMPONENT TEST OR INSPECTION LEVEL, IT MUST BE NOTED THAT QUALIFICATION/FLIGHT ACCEPTANCE TEST CONDUCT AND THE ASSOCIATED POST-TEST INSPECTION FUNCTIONS DID NOT INCORPORATE ADEQUATE PROVISIONS FOR DETECTION OF THIS DEFECT.

WOC-16

SYSTEM ACCEPTANCE TEST FAILURE

CATEGORY	MARINER MM 64	MARINER MV 67	LUNAR ORBITER	GEMINI	SURVEYOR*
DESIGN	3			1	
PART FAILURE			1	3	
WORKMANSHIP			5	1	
FABRICATION	2			4	
HANDLING				1	
UNKNOWN	1	2		9	
PROCEDURE	1	4			
TOTAL	7	6	6	19	

* NO INFORMATION AVAILABLE

2.3.3 SYSTEMS ACCEPTANCE TEST FAILURES -MARINER 64

SUMMARY

FLIGHT[1] VEHICLE	ANOMALY TYPE	ITEM	RESOLUTION
MC-3	Failure	Ring harness trough ass'y	Structural beef-up
MC-2, 3 & 4	Problem	Microphone	Changed out for high frequency accelerometer
MC-2	Problem	Low frequency accelerometer	Improper grounding for test set up, no change for flight vehicles
MC-3	Problem	Microphone and charge amplifier connector	Changed out for high frequency accelerometer
MC-4	Problem	Charge amplifier connector	No action
MC-4	Problem	Low-frequency accelerometer connector	Safety wired all connectors
MC-4	Problem	Separation rate monitor bolt	Safety-wired all fasteners.

1 MC-2 was Mariner III Flight Vehicle
MC-3 was Mariner IV Flight Vehicle
MC-4 was Spare Flight Vehicle

2.3.3 SYSTEMS ACCEPTANCE TEST FAILURES -MARINER 67

SUMMARY

FLIGHT* VEHICLE	ANOMALY TYPE	ITEM	RESOLUTION
M67-1	Intermittent signal during vibration	Data automation system (DAS)	Problem only occurred once. indications were that problem was not due to vibration.
M67-1	Operator error caused low test level during sine sweep	Spacecraft vibration response	Correction made to procedure and sweep rerun
M67-1	Audible transient at 35 Hz during sine sweep	Spacecraft Bay II	Spacecraft dismantled in vicinity of Bay II for inspection. No damage found. Thought to be instrumentation problem.

*M67-1 - Spare flight spacecraft

2.3.3 SYSTEMS ACCEPTANCE TEST FAILURES -LUNAR ORBITER

VEHICLE	CATEGORY OF FAILURE	ITEM	RESOLUTION
#2 *	WORKMANSHIP	SCREW CAME LOOSE ON IN-FLIGHT DISCONNECT PLUG, STRIPPED THREAD.	REPLACED WITH NUT AND BOLT.
#2 *	WORKMANSHIP	NUTS NOT LOCK-WIRED ON SOLAR PANEL RELEASE MECHANISM.	NUTS LOCK-WIRED PER DRAWING.
#2 *	-	ROCKET ENGINE HEAT SHIELD ASSEMBLY TIE WIRE BROKEN.	NONE, ONE OF 40 TIE WIRES, LOSS OF ONE NEGLIGIBLE.
#4	WORKMANSHIP	SUPPORT BRACE ON HIGH GAIN ANTENNA DISH NOT TORQUED PROPERLY.	RETORQUED
#5	WORKMANSHIP	MOUNTING BOLTS AND NUTS MISSING ON LOW GAIN ANTENNA.	EPOXY ADDED TO RETAINING NUTS.
#7	WORKMANSHIP	RETAINING NUT AND BOLT ON MICROSWITCH ACTUATOR VIBRATED LOOSE.	EPOXY ADDED TO RETAINING NUTS

* VEHICLE #2 WAS THE GROUND TEST VEHICLE.

TABLE 2.3 VIBRATION/ACOUSTIC FAILURE SUMMARY -GEMINI

TEST LEVEL System TEST ACTIVITY Acceptance

S/C	FAILURE (CATEGORY)	TEST	RESULTING ACTION	COMMENTS
1	Accelerometer oversensitive due to backing out of seismic system mounting screws (Instrumentation Sensor/ Fabrication Procedure)	8.4 g	Epoxy cement placed on all screws and nuts in the seismic system. Retrofitted into other units.	Detected after the test.
1	ECS O_2 bottle separated from the blast shield because honeycomb insert was not the specified part (Structural/Workmanship)		Insert changed to specified unit.	Detected during the test. Structure not previously tested.
1	Data signal for an in-flight vibration measuring channel was noisy due to out-of-spec zener diode voltage in amplifier (Instrumentation Sensor/ Part Aging)		Selection process for zener diode altered to prevent recurrence of problem.	Detected during the test.
1	In-flight vibration measuring channel was inoperative due to a broken lead (Instrumentation Sensor/Handling)	8.4 g	Lead repaired.	Detected during the test. Problem caused by other work on spacecraft
2	Leaks were detected in the O_2 system (Mechanical/Fabrication Procedure)	6.2 g	Leakage areas were repaired.	Detected after the test. Problem caused by workmanship on vehicle.
2	Low level multiplexer 6 counts high. Trouble shooting showed unit to be faulty (Electronic/Part Failure)		Unit was replaced.	Detected during the test.
2	Momentary loss of 1 T/M parameter. Anomaly could not be repeated (Instrumentation Sensor/Unknown)	6.2 g	None - condition acceptable for S/C 2.	Detected during the test.

TABLE 2.3 (Cont.) VIBRATION/ACOUSTIC FAILURE SUMMARY -GEMINI

TEST LEVEL System TEST ACTIVITY Acceptance

S/C	FAILURE (CATEGORY)	TEST	RESULTING ACTION	COMMENTS
2	Wire bundle had outer insulation on chromel wire broken at the end of the SCL over the floating shield (Electrical/Unknown)	6.2 g	Removed SCL and reinstalled to completely cover broken insulation as well as portion of wire previously covered.	Detected after the test.
3	Two in-flight acceleration measuring channels had noise spikes due to seismic mount, top pivot and bearing assembly not being securely fastened. (Instrumentation Sensor/Fabrication Procedure)	6.2 g	Accelerometer replaced. Defective unit readjusted by vendor.	Detected during the test.
3	PCM data on tape recorder was irrecoverable due to loss of synchronization. Loss was due to insufficient light incident upon motion monitor photocell (Electronic/Design)		Light source redesigned to use lower voltage bulb and power circuit for bulb changed from AC to DC.	Detected after the test on data recorded during the test.
3	On two occasions the light indicating no coolant flow remained on although the coolant pump was turned on (Electrical/Unknown)	6.2 g	No action.	Detected after the test.

TABLE 2.3 (cont.) VIBRATION/ACCUSTIC FAILURE SUMMARY -GEMINI

TEST LEVEL System TEST ACTIVITY Acceptance

S/C	FAILURE (CATEGORY)	TEST	RESULTING ACTION	COMMENTS
2	Commutator segment read open (Electric/Unknown)	6.2 g	None - accepted for S/C 2.	Detected during the test.
2	Yaw rate gyro scale factor intermittent (Electro-mechanical/Unknown)		None - accepted for S/C 2.	Detected during the test.
2	Potting did not adhere to connector or wire (Electrical/Fabrication Procedure)		Repaired with RTV-60.	Detected after the test.
2	Low level commutator read underscale (Electric/Unknown)		Unit replaced.	Detected during the test.
2	Camera produced a double image on film (Electro-mechanical/Unknown)		Unit replaced.	Detected after the test.
2	Two fairings developed cracks at a weld bead (Structural/Part Failures)		Trimout cracks and dye check - repair.	Detected after the test. Structure not previously tested.
2	Torque stripes not aligned on collar fastener bolts of thrust chamber assembly nor on two nuts attaching coolant lines (Mechanical/Unknown)		Verify torque requirement and repaint torque stripes.	Detected after the test.
2	Wire bundle connector shell stuck - will not travel 90° (Mechanical/Unknown)		Connector replaced.	Detected after the test.
2	Switch was loose on the mounting (Electrical/Unknown)	6.2 g	Switch remounted.	Detected after the test.

FLIGHT FAILURES

MARINER MARS 1964

Shroud failed to jettison on Mariner III. Probable cause - skin separation from fiberglass honeycomb core.

MARINER VENUS 1967

None listed in available documents.

SURVEYOR

"There were no flight failures attributed to the vibration environment".

LUNAR ORBITER

63 problems out of 5 flights.

2 of 63 related to vibration.

GEMINI

228 problems out of 12 flights.

127 out of 228 classified as failures.

21 failures could have been due to vibration.

DERIVATION OF TEST LEVELS

MARINER 64 AND 67

(1) Systems random vibration levels based on Ranger data.

(2) Qualification levels obtained by increasing acceptance levels by 1.7 (RMS).

(3) Subsystem levels determined from acoustic test on Mariner S/C.

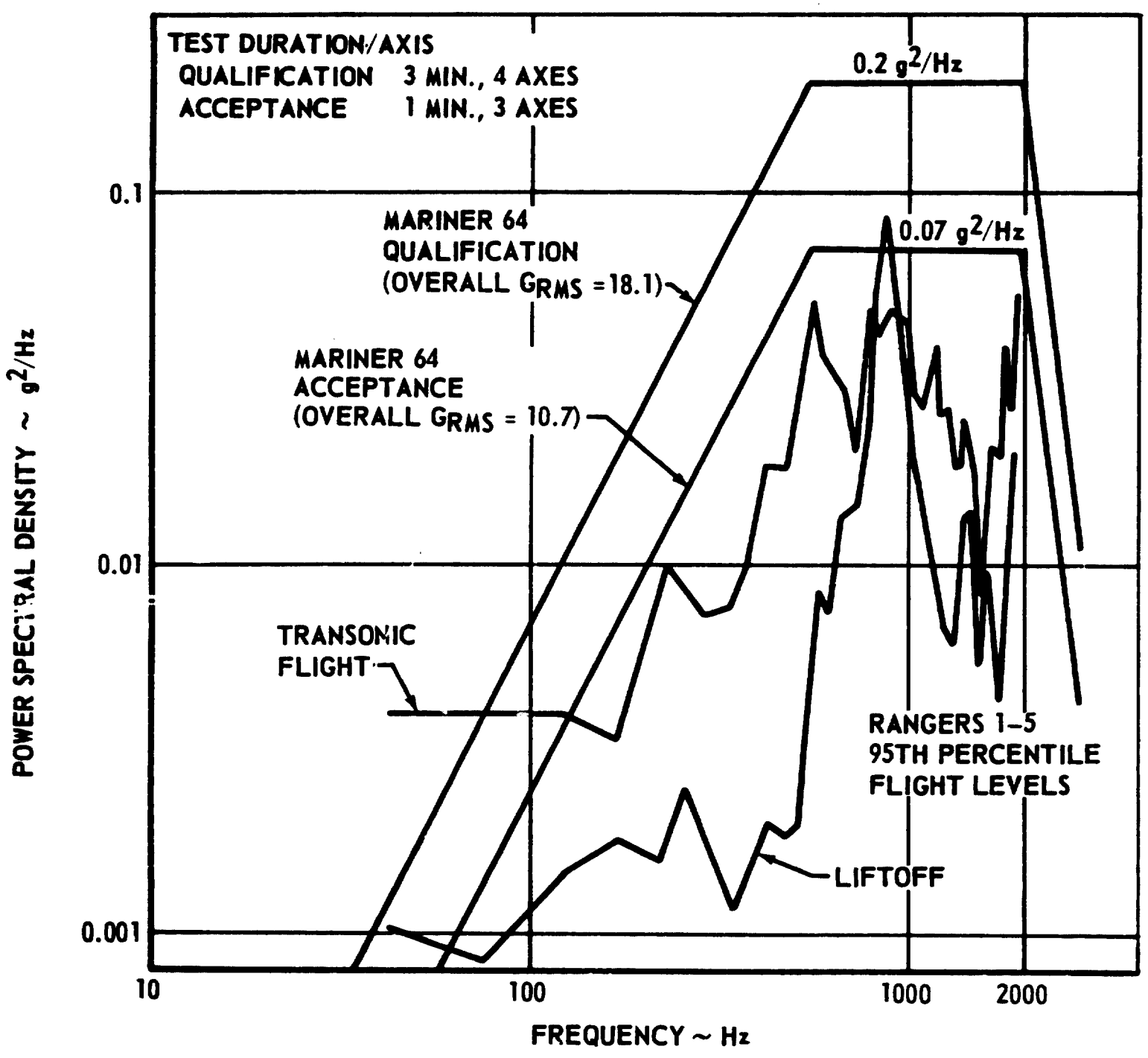
(4) Vibration test durations based on Ranger data.

(5) Qualification durations obtained by increasing acceptance duration by factor of 3.

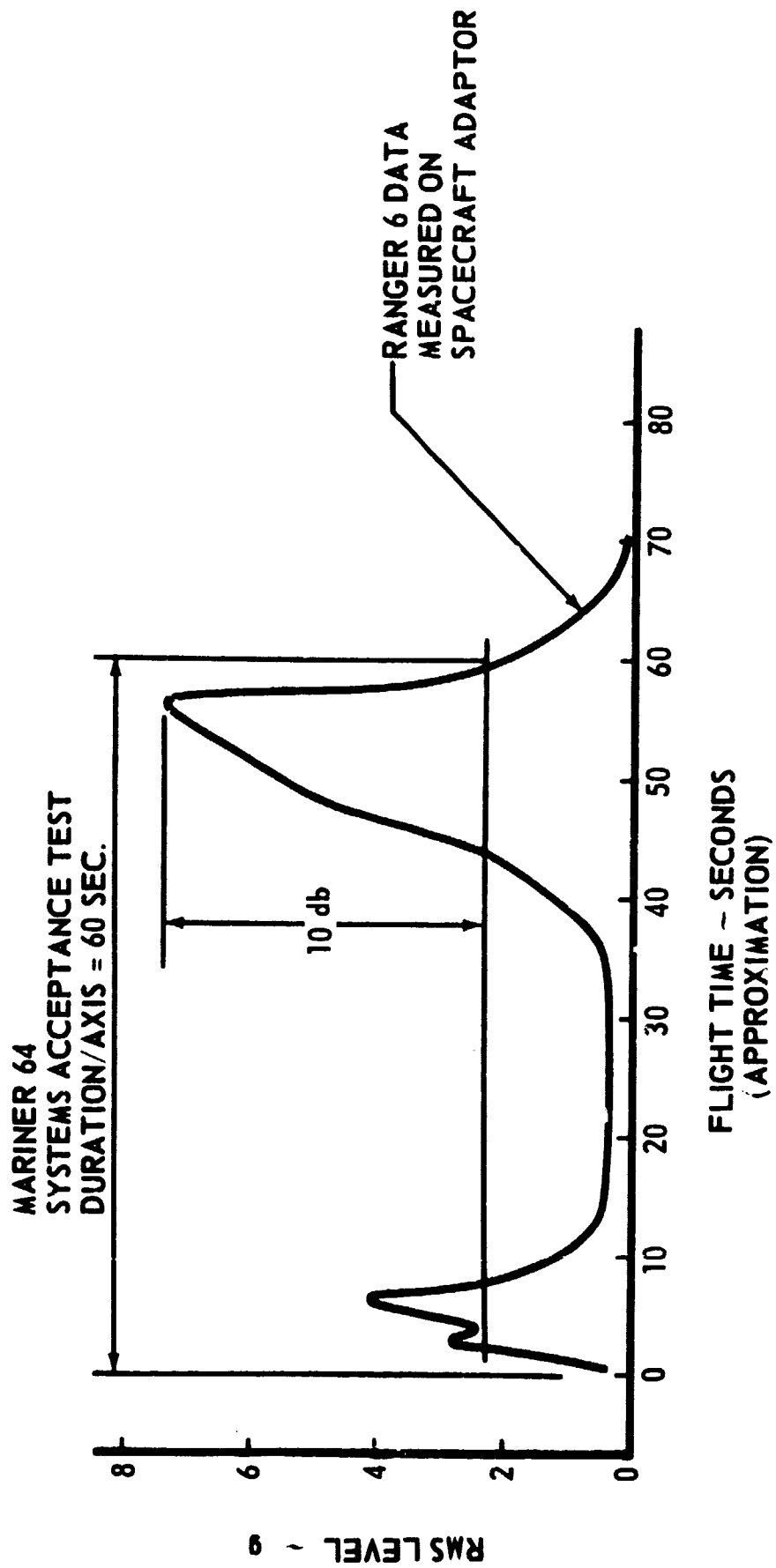
(6) Acoustic qualification levels based on measurements from Mercury/Atlas launch.

LUNAR ORBITER

(1) Based on data from Atlas/Agena flights.



DERIVATION OF SYSTEM VIBRATION LEVELS



DERIVATION OF SYSTEM TEST DURATIONS

DERIVATION OF TEST LEVELS

GEMINI

(1) Random vibration levels based on Mercury data corrected for difference in dynamic pressure.

(2) Gemini GT-1 data used to revise levels.

(3) Acoustic levels based on Mercury data.

(4) Sine qualification levels based on Mercury test requirements with dynamic pressure corrections.

(5) Gemini test durations based on Mercury flight time histories.

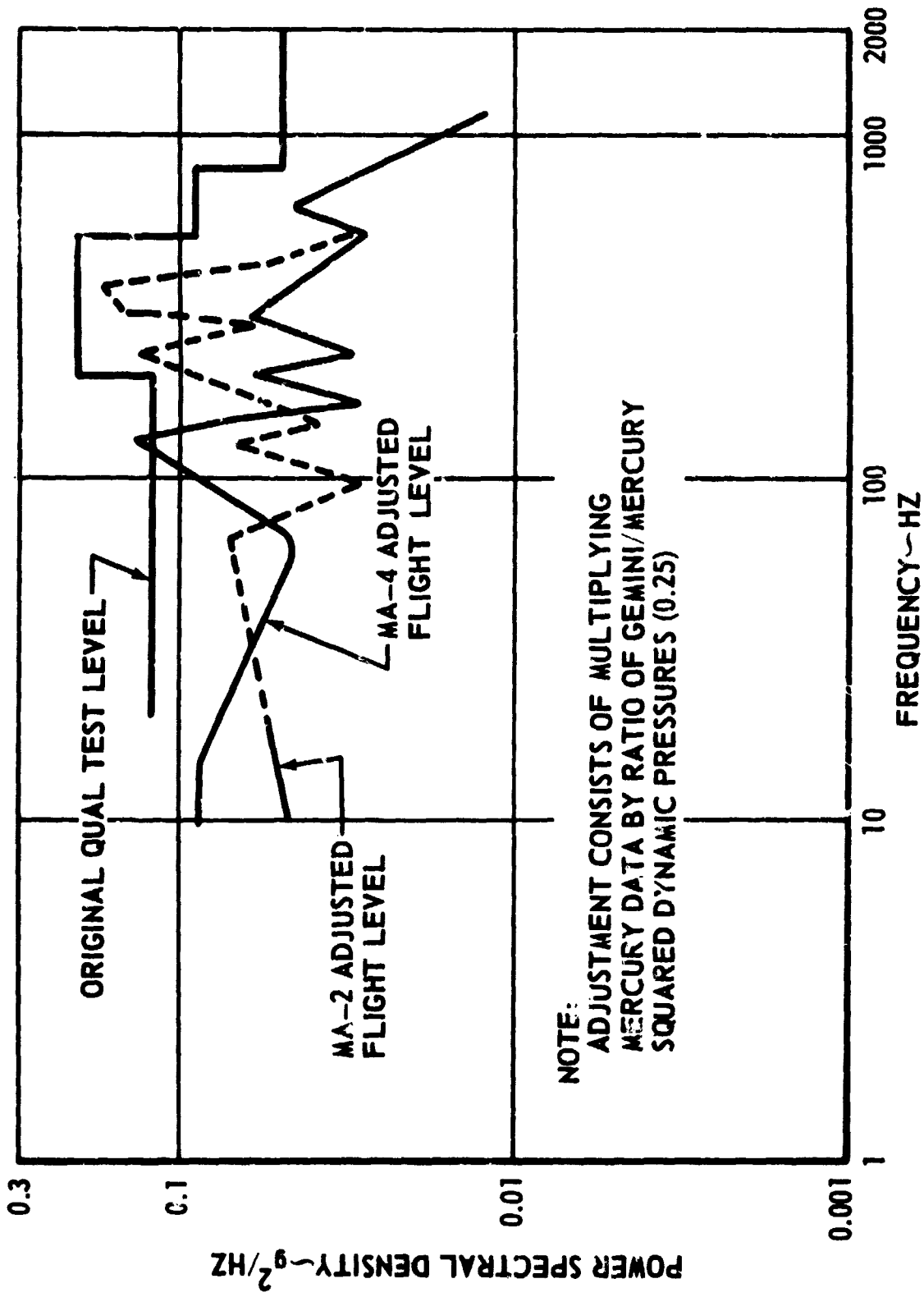
SURVEYOR

(1) System vibration acceptance test levels based on Ranger data.

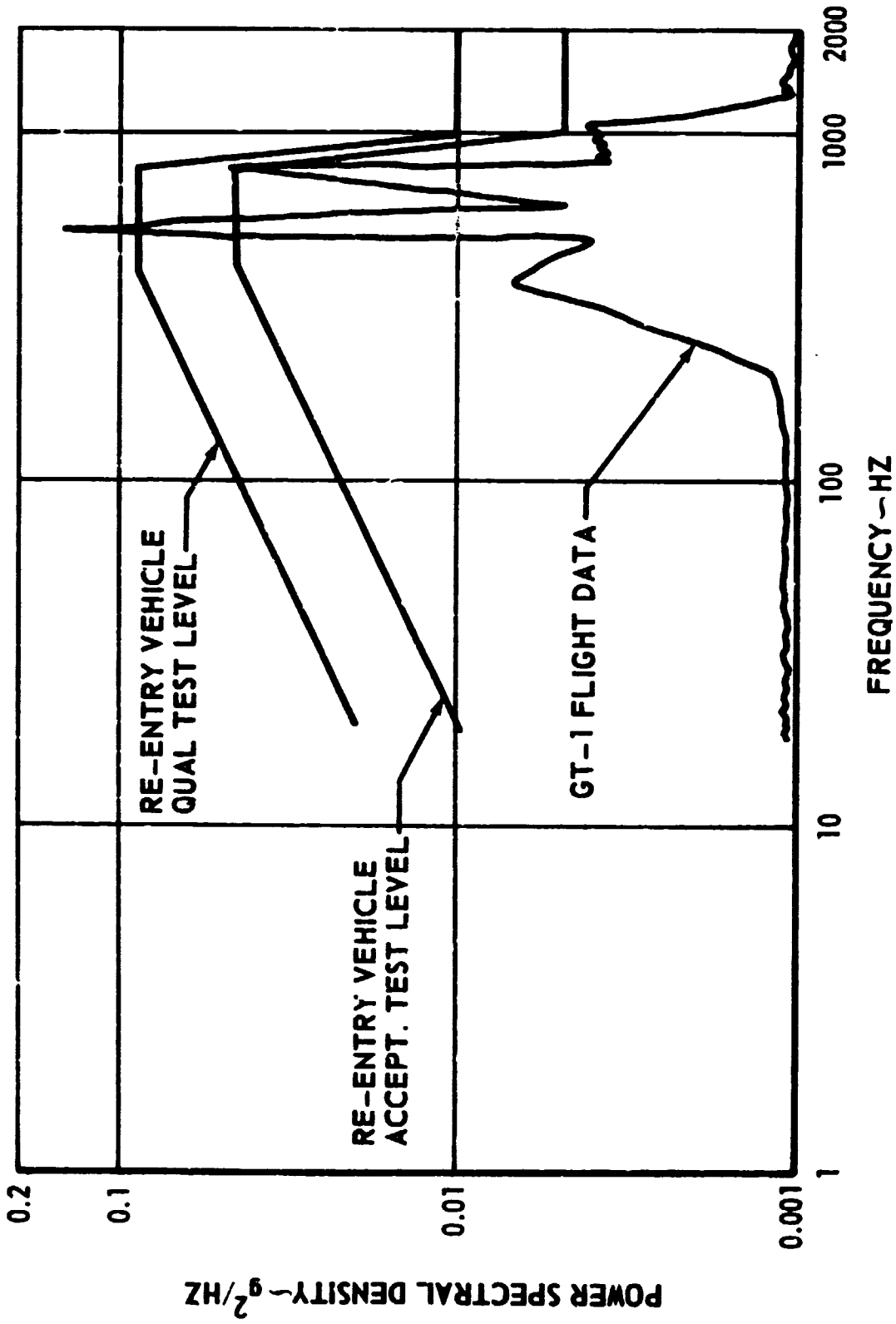
(2) System sine levels based on Ranger data and modified by Atlas/Centaur data.

(3) Subsystem levels derived from a sine test on Surveyor S/C.

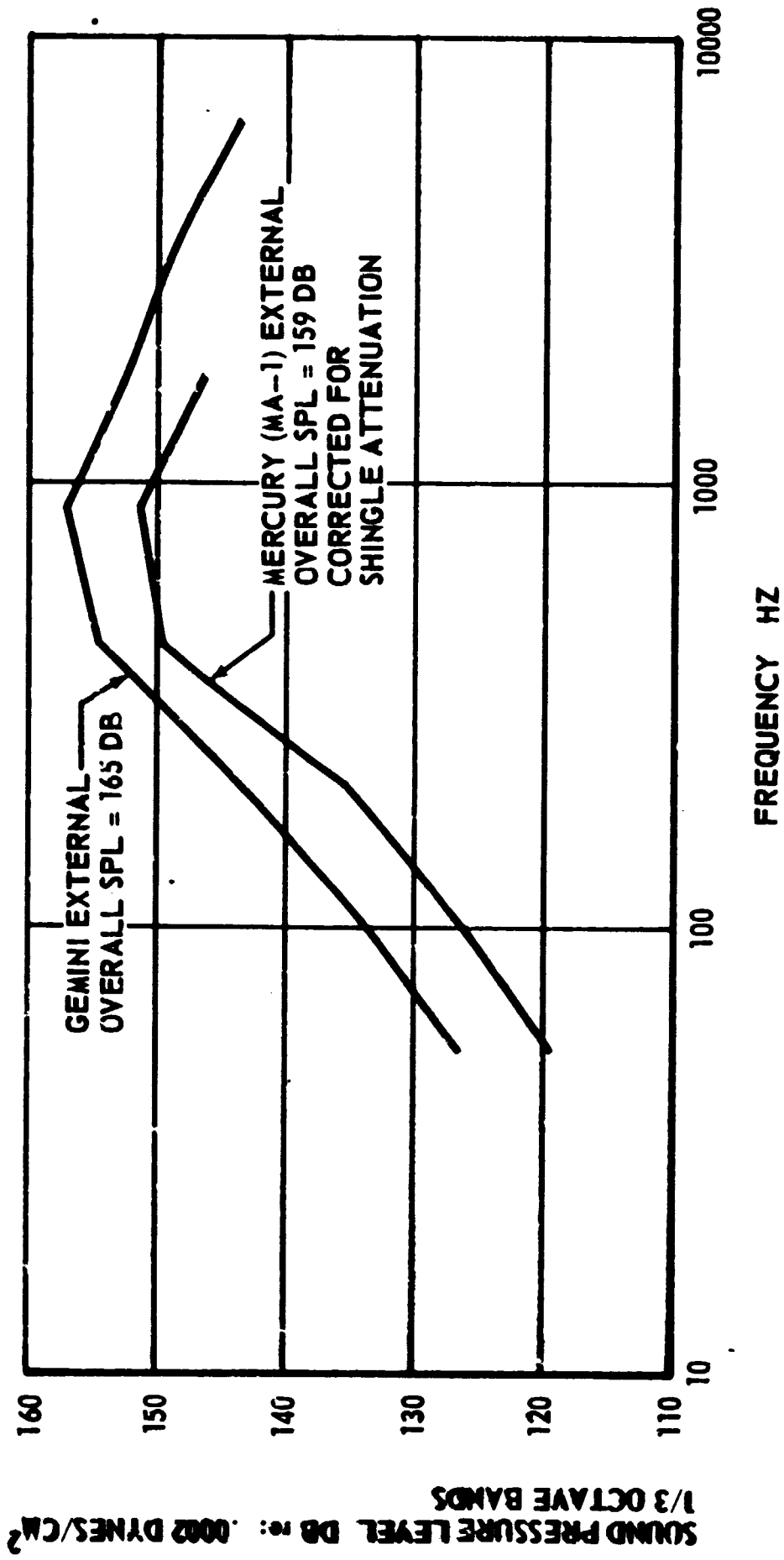
(4) Surveyor test durations based on Atlas/Centaur flight time histories.



DERIVATION OF ORIGINAL QUALIFICATION TEST LEVELS, RANDOM VIBRATION -GEMINI



DERIVATION OF REVISED RE-ENTRY VEHICLE TEST LEVELS,
RANDOM VIBRATION -GEMINI



DERIVATION OF ORIGINAL EXTERNAL ACOUSTIC TEST SPECTRA -GEMINI

IDENTIFICATION OF TEST FACTORS

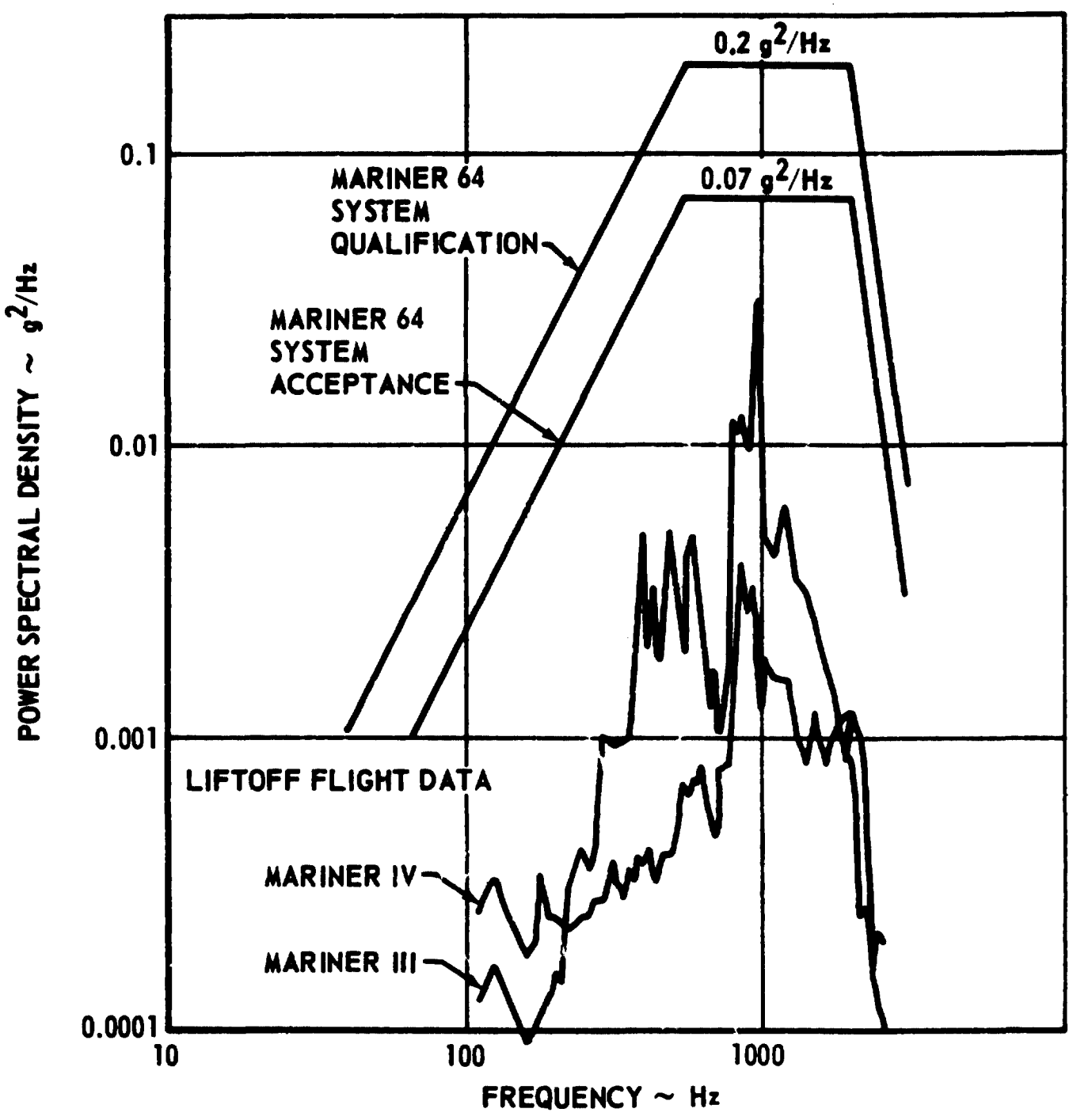
RATIO	MARINER	LUNAR ORBITER	GEMINI	SURVEYOR
QUALIFICATION TEST RMS / ACCEPTANCE TEST RMS	1.7	1.2 TO 1.5	1.4	1.3 TO 1.5
DEVELOPMENT TEST RMS / ACCEPTANCE TEST RMS	-	-	-	1.4 TO 1.7
QUALIFICATION TEST DURATION / ACCEPTANCE TEST DURATION	3.0	2.0	2.0 TO 15.0 [1]	2.0
ACCEPTANCE TEST RMS [2]	1.8	-	2.8	-
ACCEPTANCE TEST RMS [3]	5.1	0.7 TO 12.3	2.7	3.8

NOTES

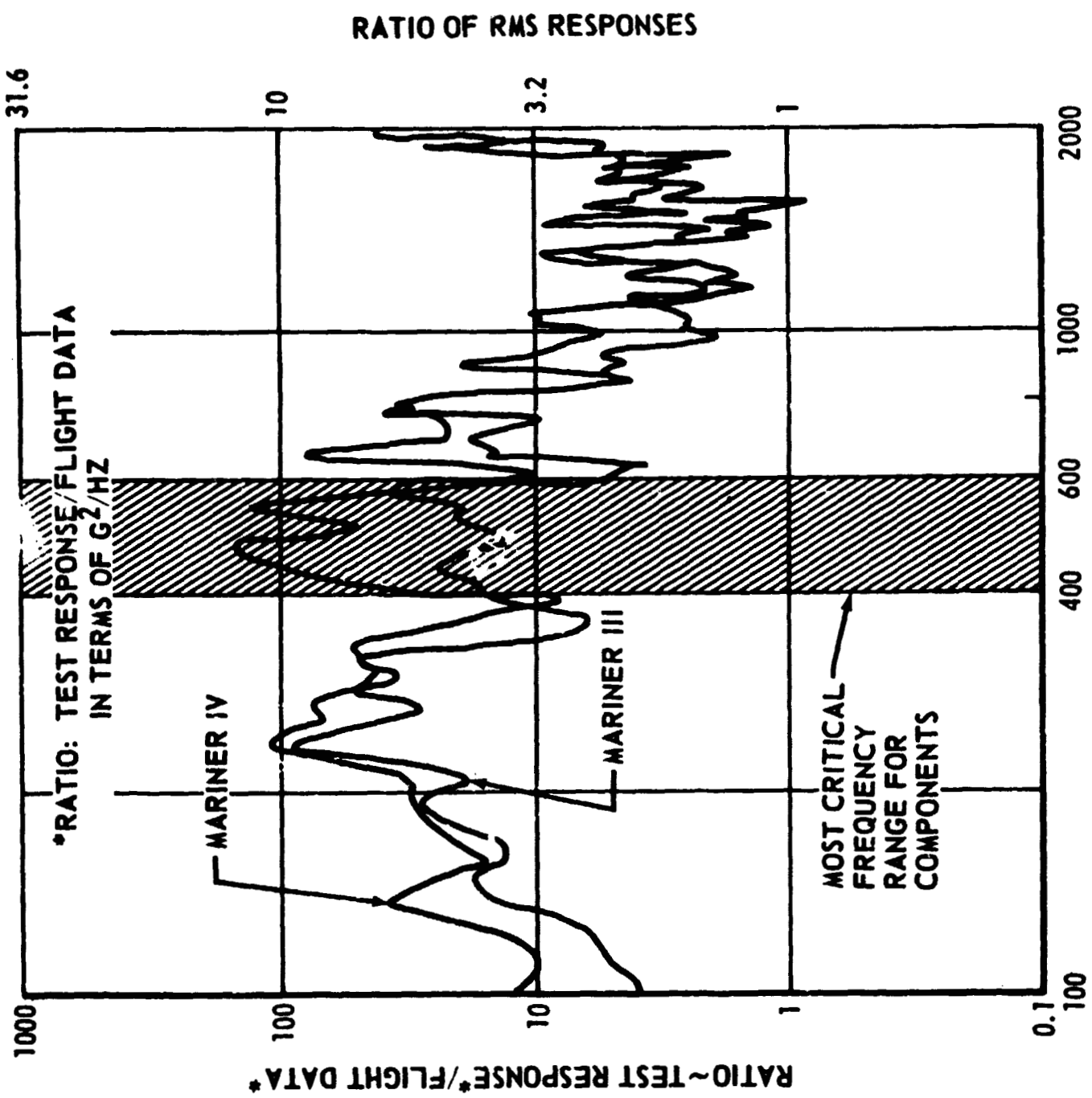
[1] THE RATIO OF 15 RESULTS FROM GEMINI QUALIFICATION DURATIONS WHICH DEMONSTRATED A 2 FLIGHT CAPABILITY.
[2] VIBRATION LEVELS USED TO DERIVE TEST LEVELS
[3] VIBRATION LEVELS MEASURED DURING SPACECRAFT FLIGHT.

COMPARISON OF FLIGHT DATA AND TEST REQUIREMENTS

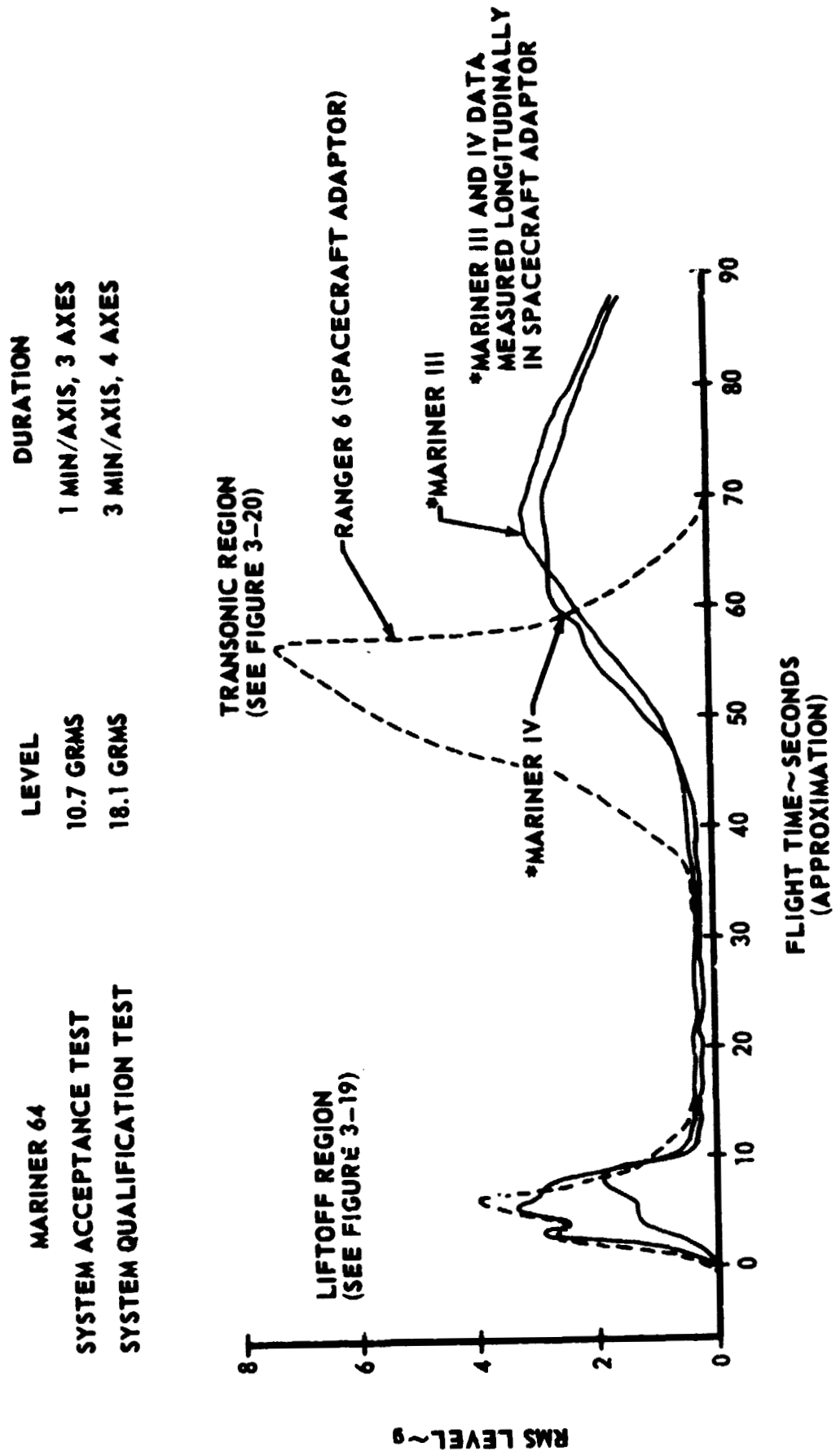
The following charts compare flight data from the various S/C with lab test requirements.



COMPARISON OF FLIGHT VIBRATION DATA AND SYSTEM TEST LEVELS - LIFTOFF

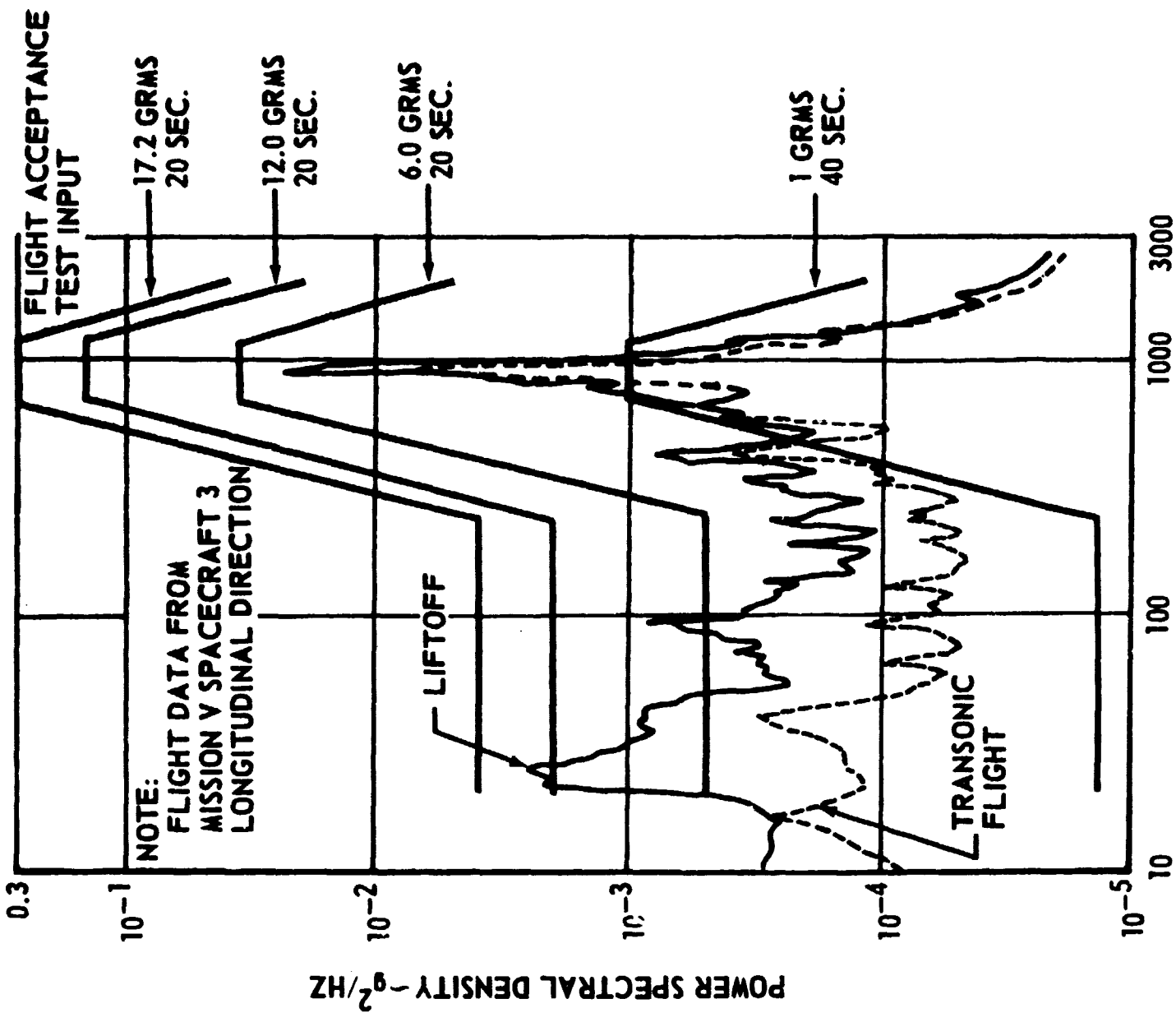


COMPARISON OF LAB TEST VIBRATION RESPONSE TO MEASURED FLIGHT RESPONSE ON SPACECRAFT ADAPTER

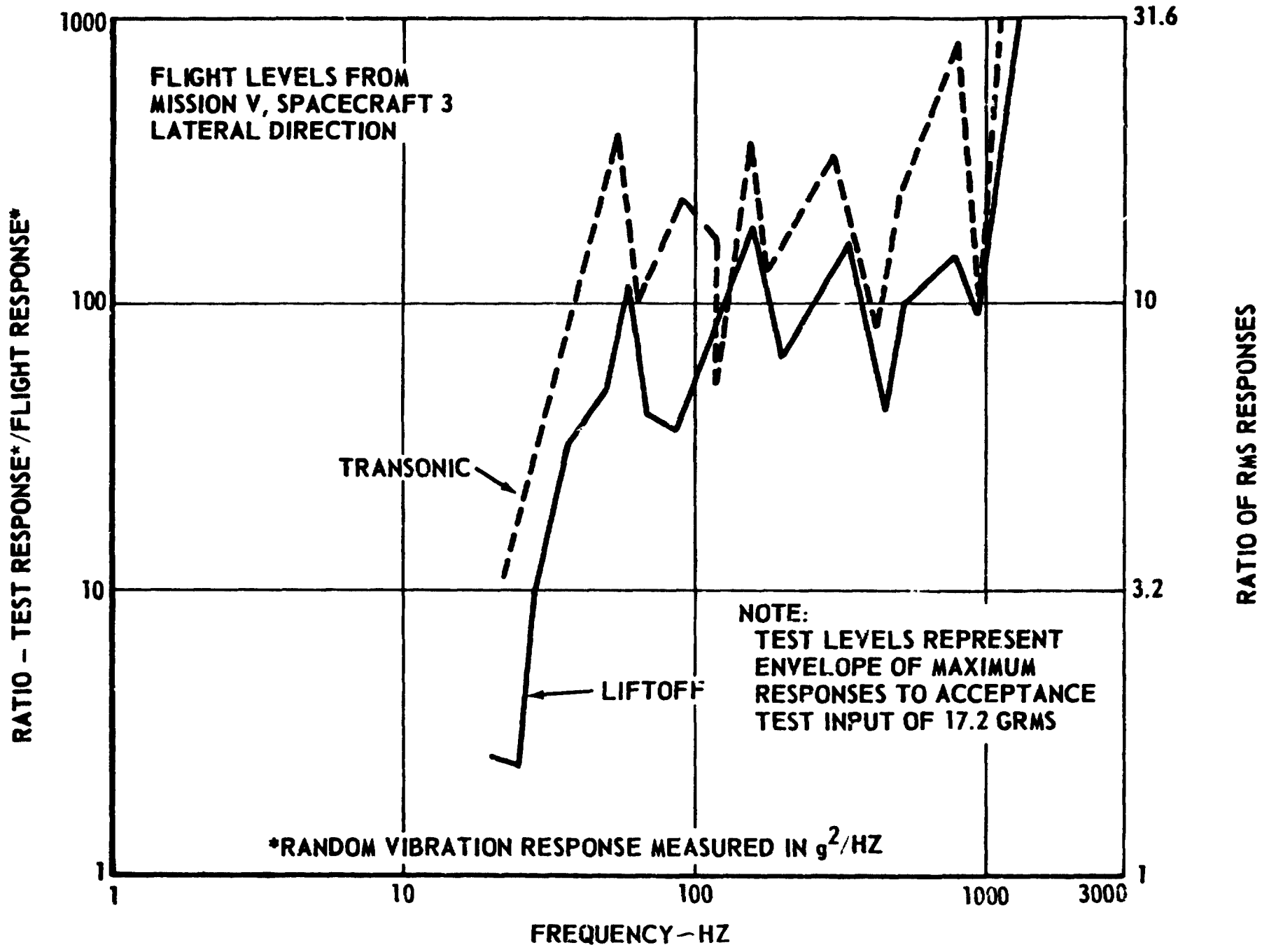


COMPARISON OF FLIGHT VIBRATION TIME HISTORIES

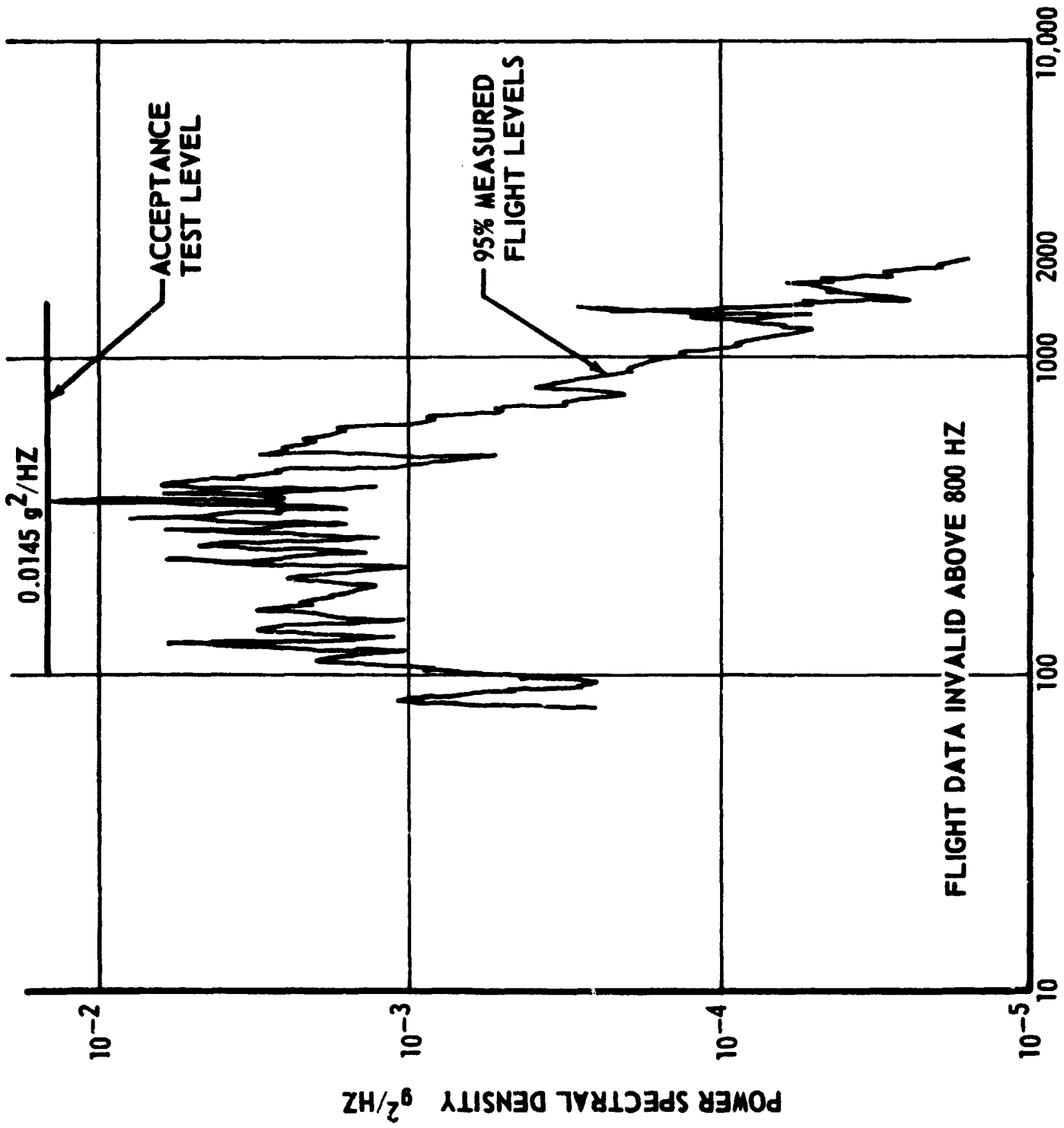
WDC-30



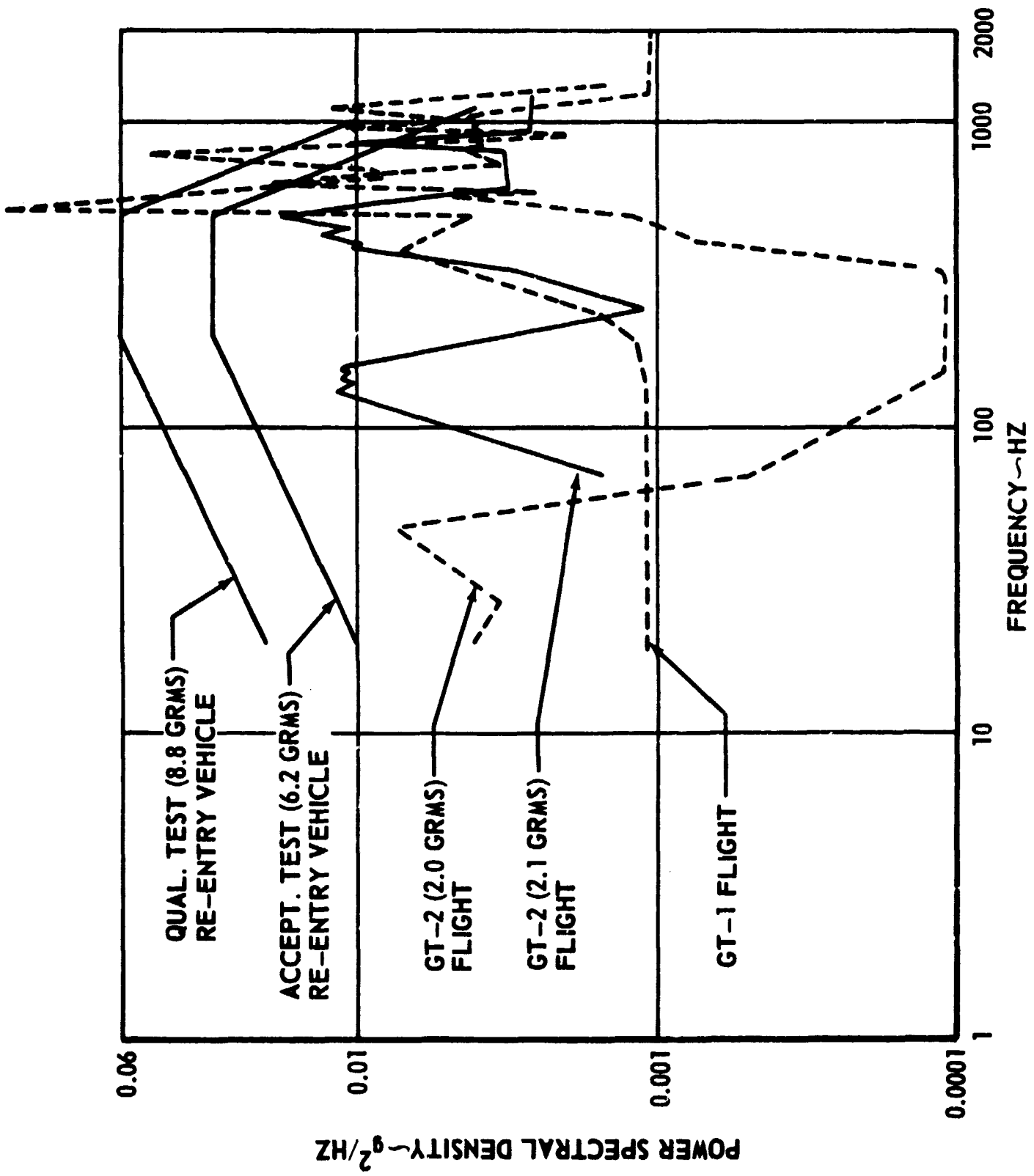
COMPARISON OF ACCEPTANCE TEST LEVELS WITH MEASURED FLIGHT RESPONSE LEVELS, RANDOM VIBRATION, LUNAR ORBITER



COMPARISON OF LAB TEST VIBRATION RESPONSE TO MEASURED FLIGHT RESPONSE IN LATERAL DIRECTION -LUNAR ORBITER



COMPARISON OF FLIGHT ENVIRONMENT TO TEST LEVELS,
RANDOM VIBRATION -SURVEYOR



COMPARISON OF MEASURED FLIGHT LEVELS TO TEST LEVELS -GEMINI

CONCLUSIONS BY S/C AGENCIES

MARINER MARS 64

(1) Clearly defined requirements contributed to timely program accomplishment.

(2) Satisfactory test completion gives confidence in design.

(3) Qualification levels develop conservative design.

(4) Significant failures occur when acceptance precedes qualification.

(5) Pre-qualification test needed to eliminate workmanship problems.

MARINER VENUS 1967

(1) MM64 tests allowed emphasis to be placed on certain MV67 tests.

(2) Success of MV67 not possible without environmental test program.

(3) MV67 failure rates higher than MM64 due to use of old hardware and lack of development tests.

(4) Sine tests good for diagnosis but sines do not exist in flight.

CONCLUSIONS BY S/C AGENCIES

LUNAR ORBITER

(1) Success due to test, review and control.

(2) Success not explicity attributable to dynamic tests.

(3) No steady state sine during flight.

(4) Test levels were adequate.

GEMINI

(1) Significance of vibration and acoustic tests:

Avoid flight problems.

Provide confidence even though costs are high.

(2) System vibration test not fully effective.

RECOMMENDATIONS BY S/C AGENCIES

MARINER MARS 64

(1) Perform qualification test early in program.

(2) System level tests are mandatory.

(3) Test prototype to failure.

(4) Document total test history of each item.

(5) Obtain in-flight measurements.

(6) Perform studies to better understand transmission of vibration.

MARINER VENUS 67

(1) Re-test reworked units.

(2) Consider response control of test level.

RECOMMENDATIONS BY S/C AGENCIES

LUNAR ORBITER

(1) Adapt test environment more closely to flight environment.

(2) Compare test levels to theoretical predictions.

(3) Environmental test of entire S/C to test mission functions where necessary.

GEMINI

(1) Eliminate development tests to qualification levels.

(2) No acoustic tests on non-sensitive equipment.

(3) Acoustic excitation for vehicle acceptance and qualification tests.

(4) Perform calibration tests for (3).

(5) Consider all random forcing function.

(6) Avoid "Scaling" test times.

(7) Perform component level qualification and acceptance tests.