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Viking Mars Lander 1975 Dynamic Test Model/Orbiter Developmental Test Model Forced Vibration Test

Summary Report

J. Fortenberry
G. R. Brownlee

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JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA

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16. Abstract

The Viking Mars Lander 1975 dynamic test model and Orbiter developmental test model were subjected to forced vibration sine tests in November-December 1973, at JPL's dynamic test facility. Flight acceptance (FA) and type approval (TA) test levels were applied to the spacecraft structure in a longitudinal test configuration using a 133,440-N (30,000-lb) force shaker. Testing in the two lateral axes (X, Y) was performed at lower levels using four 667-N (150-lb) force shakers.

Forced vibration qualification (TA) test levels were successfully imposed on the spacecraft at frequencies down to 10 Hz. JPL test equipment and methods have been adequately checked out for use on the proof test Orbiter.

Measured responses showed the same character as analytical predictions, and correlation was reasonably good. Because of control system test tolerances, Orbiter primary structure generally did not reach the design load limits attained in earlier static testing.

A post-test examination of critical Orbiter structure disclosed no apparent damage to the structure as a result of the test environment.

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PREFACE

The work described in this report was performed by the Applied Mechanics Division of the Jet Propulsion Laboratory.

The Jet Propulsion Laboratory is responsible for the Viking Orbiter System, which is part of the overall Viking Project managed by the Viking Project Office at Langley Research Center for NASA.

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CONTENTS

APPENDIXES

TABLES

FIGURES

ABSTRACT

The Viking Mars Lander 1975 dynamic test model and Orbiter developmental test model were subjected to forced vibration sine tests in November – December 1973, at JPL's dynamic test facility. Flight acceptance (FA) and type approval (TA) test levels were applied to the spacecraft structure in a longitudinal test configuration using a 133,440-N (30,000-lb) force shaker. Testing in the two lateral axes (X, Y) was performed at lower levels using four 667-N (150-lb) force shakers.

Forced vibration qualification (TA) test levels were successfully imposed on the spacecraft at frequencies down to 10 Hz. JPL test equipment and methods have been adequately checked out for use on the proof test Orbiter.

Measured responses showed the same character as analytical predictions, and correlation was reasonably good. Because of control system test tolerances, Orbiter primary structure generally did not reach the design load limits attained in earlier static testing.

A post-test examination of critical Orbiter structure disclosed no apparent damage to the structure as a result of the test environment.

I. INTRODUCTION

The objectives of the stack test series (Ref. 1) were to

(1) Evaluate the effect of Lander/Orbiter interaction on response at subsystem/component locations.

(2) Evaluate the adequacy of the Viking Mars Lander 1975 dynamic test model (LDTM)/Orbiter developmental test model (ODTM) secondary structure.

(3) Serve as a precursor to the proof test Orbiter (PTO) forced vibration test, and evaluate PTO test levels.

(4) Evaluate component sinusoidal test levels.

(5) Obtain data for comparison to analytical results.

The primary interest in the stack tests was centered in the mid- to low-frequency regions (200 to 8 Hz), where component responses reach their largest amplitudes. Forced vibration testing in the longitudinal axis was initiated on November 5, 1973, and concluded November 29, 1973 Lateral axis excitation started December 7, 1973, and finished December 10, 1973.

II. TEST PROGRAM

A. TEST SPECIMEN

The test article consisted of the following major hardware assemblies:

(1) LDTM.

(2) ODTM.

(3) Viking transition adapter (VTA).

Major assemblies of the LDTM/ODTM were of flight-configured hardware wherever possible. Mass mockups or simulators had inertial properties similar to the components being replaced. Thermal control hardware such as louvers and blankets was not used on the ODTM.

Pressurized systems on the LDTM consisted of the bioshield and propellant tanks. The bioshield was pressurized to 249 ±224 N/m^2 (1.0 ±0.9 in. of water)* during testing. The lander propellant tanks were filled with reference fluids and pressurized to 137,900 N/m^2 (20 psig) with gaseous nitrogen. This pressurization was maintained throughout the entire test series.

The only active pressurized subsystems on the ODTM was the propulsion module (PM), which was configured as shown in Table 1.

B. IMPLEMENTATION

1. Longitudinal Test Setup

The test specimen setup for longitudinal axis testing proceeded according to the following sequence (Ref. 2):

(1) VTA mounted on longitudinal test fixture.

(2) Viking spacecraft adapter (V-S/C-A) mounted on VTA.

(3) ODTM bus mated to loaded, unpressurized PM.

(4) Bus/PM combination mounted on V-S/C-A.

(5) Viking Lander capsule adapter (VLCA) preassembled on handling equipment.

(6) LDTM mated to VLCA.

(7) LDTM/VLCA combination mated to ODTM bus.

The final longitudinal test configuration is shown in Figs. 1 and 2. Excitation was provided by a Ling 249 133,440-N (30,000-lb) force shaker. The interface between the shaker and the VTA was provided by the test fixture. The test fixture, a welded magnesium structure, was stabilized by a restraining system consisting of three steel piers on which hydrostatic bearings were mounted (Fig. 3). The bearings allowed vertical movement only, while the piers provided the reaction points for the spacecraft overturning moment predicted by response analysis (Appendix A).

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*Customary U.S. units were used for primary measurements and calculations.

The combined weights of the LDTM/ODTM and the test fixture (4,536 kg = 10,000 lb) would have caused excessive deflection of the shaker armature, preventing normal operation. Pneumatic springs with a resonant frequency of approximately 2 Hz (Barry Serva-Levels, Fig. 4) were mounted on the shaker body at 120-deg intervals. A position control servo regulated the springs, air volume and positioned the shaker armature at the center of its stroke under static conditions.

Experimentation with the shaker indicated a trunnion resonance of approximately 12 Hz when the shaker was suspended on its isolation pads. Blocking the shaker or lifting the trunnions off the isolation pads increased this frequency to 35 Hz. More experimentation demonstrated the potential danger of sweeping through the trunnion resonance. This position was blocked for all tests below 25 Hz by inserting shims between the shaker body and steel posts hard-mounted to the seismic mass (Fig. 5). For testing above 25 Hz, the shims were removed.

2. Lateral Test Setup

Following longitudinal testing, the LDTM/VLCA combination was demated from the ODTM bus and set aside. The remainder of the test specimen, which included the ODTM bus/PM, V-S/C-A, and VTA was then lifted as a unit and placed in the modal test tower, and the LDTM/VLCA was mated to the test assembly. The test setups for lateral excitation in the X- and Y axes are illustrated in Figs. 6 - 9.

Excitation of the LDTM/ODTM in each axis was accomplished with four Unholtz-Dickie electrodynamic shakers, each rated at 667-N (150-lb) force. The shakers were pendulously supported from crane hooks and chain and attached to the ODTM bus main longerons through adjustable "stingers" and mechanical fuzes (flexures), as illustrated in Fig. 7.

3. Test Levels

Precursor or low-level test runs were made prior to full-level (flight acceptance (FA), type approval (TA)) testing. From these precursor runs, the responses of critical structural elements or components were evaluated by analysis of 0-graph plots, X-Y tracking filter plots, and an analog computer program that generated ODTM member loads. Comparison of these data with response analysis predictions provided confidence in the test structure to withstand full-level loading.

The vibration inputs as originally defined in Ref. 3 were modified and applied to the LDTM/ODTM, as noted in Tables 2 and 3.

4. Vibration Control

Control of the longitudinal vibration input to the LDTM/ODTM was accomplished with a 36-channel peak select system. The peak select control system continuously monitored the output signals of 12 input control accelerometers located on the ODTM bus structure main longerons (Fig. 10) plus a 24-channel mix of strain-gage/accelerometer response transducers. Bolted attachment was mandatory for the input control accelerometers (Refs. 2 and 4).

The acceleration input to the test structure was controlled on the one transducer whose output signal matched its peak select setting. A functional diagram of the control system is shown in Fig. 11.

A 59-channel peak limit system was used. This safety circuit terminated the output of the vibration exciter without transient if the instantaneous peak magnitude of any of the 59-peak limit settings exceeded a preset value. Because of test philosophy/hardware differences, the peak limited signals assigned to the LDTM were passed through a 200-Hz filter prior to reaching the protection module. Those channels used for ODTM peak limiting were conditioned with 800-Hz filters.

The control of the lateral axis testing, in which four separate shakers were used, was accomplished in a manner similar to the longitudinal test. The four Unholtz-Dickie Model 4 667-N (150-lb) shakers and associated power supply were married to the peak select control system. Because the individual shakers were carefully matched with their transformers, it was decided to control the force input on all four shakers by connecting them together in series and using the armature current output signal from just one of the four shakers. This technique proved very successful.

5. Data Recording, Reduction

Control and response amplitude of the LDTM/ODTM were measured with strain gages and accelerometers. The allocation of dynamic recording channels is shown in Table 4. The overall instrumentation flow is presented in Fig. 12.

The 274 output signals noted in Table 4 were recorded on electromagnetic tape for all test runs. In addition, approximately 48 channels of control and housekeeping data were recorded in real-time display on oscillographs for each test run. Following each test run, quick-look data reduction was accomplished according to the sequence shown in Fig. 13. More formal data reduction consisted primarily of X-Y plots of all component responses for the FA and TA test runs.

A large number of static measurements were made on the ODTM during buildup and always following each test run. These strain measurements (approximately 140 to 175) were in printed paper tape format. Monitoring of dc offsets in this manner contributed greatly to test confidence where the integrity of ODTM structure was concerned.

Detailed measurement assignment sheets and patch assignments are contained in Appendix C.

6. Test Run Summary

Test sequencing and run parameters are shown in Table 5. A total of 44 separate test runs were made on the LDTM/ODTM during the period of November 5 through December 10, 1973 — a span of 24 days. Actual test runs were short — a matter of several minutes. Test preparation, control console setup, and trouble-shooting made the largest demands on the time budget.

III. DISCUSSION OF TEST RESULTS

A. DATA REDUCTION

The response characteristics of the test structure were derived from analysis of recorded test data. As originally planned, the bulk of ODTM test data on electromagnetic tape was to be reduced from analog to digitized format, manipulated by program, and output in a tab run form. These tab runs were to furnish the following information for each test run:

(1) Identification of control or response limiting channel at each 0.1 Hz of selected bandwidths of interest.

(2) Display of maximum amplitudes of response channels and frequencies of maximum response.

(3) Manipulated data from maximum response channels (loads, moments, cumulative damage ratios).

From examination of these tab runs, selected X-Y plots of amplitude versus frequency were to be selected for comparison with response analysis plots. Manual reduction of on-line (real-time) oscillographs was to be accomplished on a quick-look basis to assess the adequacy of a test run.

During the initial test runs, it became apparent that the format specified in steps (1), (2), and (3) could not be achieved because of equipment limitations. Existing capability did not include the possibility of identifying the controlling channel or maximum response in a digitized, tab run format. Since confidence was lacking in these basic data, attempts to perform step (3) were abandoned in favor of an analog computer.

Another major change that became apparent as testing progressed was that the original plan for processing and evaluating LDTM data was inadequate. The initial scheme was to rely on real-time oscillograph records for test evaluation and accomplish final data reduction following completion of all testing. Since this level of effort could not support the LDTM, the entire concept of data reduction was redirected and typically accomplished in the manner shown in Fig. 14.

Following a typical test run, the test team would gather in the data acquisition facility to review the 48 channels of on-line oscillograph records.

Anomalous or suspicious channels would then be patched in to an oscilloscope for further examination. This phase of the data reduction process generally required 1 or 2 h.

Once the test appeared acceptable, the tapes from recorders 1, 2, and 3 and the 140MX were secured and forwarded to the data analysis facility. First priority was to obtain X-Y plots of amplitude versus frequency for all control channels. TR2 was then returned to the data acquisition facility to join the 78MX for oscillograph playback of all LDTM channels. Because of equipment problems, the control channel X-Y plots required 1 to 3 days for processing. Playback of all LDTM channels was normally accomplished in one or two shifts.

The ODTM strain gage channels* were run through an analog computer for derivation of member loads. These loads were averaged over several cycles to lessen transient effects and digitized to yield peak values at particular frequencies. To determine maximum stress, the axial loads and moments were added, assuming the worst combination of loading and phasing. Assessment of peak select levels and cumulative damage estimates were based on this process.

While the foregoing was being accomplished, the on-line oscillograph records were manually reduced. Control channels, peak amplitudes, and overshoot were determined and summarized for presentation to the test operations board.

Following completion of the testing, X-Y plots were made for all LDTM/ODTM channels for FA and TA levels. This effort took over 2 months to complete and was complicated by calibration misunderstandings or errors and equipment breakdown.

B. TEST LEVEL/LOADS CONTROL

Because of control system and load limitations combined with the response characteristics of the LDTM/ODTM (narrow bands with high amplitudes), the servo control was unable to maintain a constant input acceleration

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*Only a limited number of ODTM strain channels were recorded on TR3,4, and the 140MX during the later phases of testing. During the initial low-level runs, a large portion of LDTM strain recording capability (78MX) was made available to the ODTM.

at any one of the twelve control accelerometers. This was not unexpected since similar behavior had been observed in earlier spacecraft testing. In addition, studies conducted at the dynamic test facility using instrumented cantilevered beams and the proposed control hardware disclosed that control might be difficult at frequencies below 17 Hz. That is, during the switching from one control channel to another, overshoot errors could occur resulting in a possible overtest. Overshoot is defined as maximum observed test amplitudes greater than the peak desired select control level.

Two basic sources contribute to overshoot: RC time constant of ac to dc conversion, and deadband. The time constant is simply the time required to convert the ac signal from the transducer into a dc voltage. This is done in two places: in the ACS-6 (peak selector) and in the servo. The time constant is a function of frequency and is longer at low frequency than high. Deadband may be defined as the amount that one signal must exceed another in order to cause a switch of the ACS-6 output from the latter to the former. Of the above two overshoot sources, the RC time constant was the more significant.

Although a definitive model of the control system capability is not available, the overshoot appeared to be dependent on the following parameters:

(1) Resonant frequency.

(2) Slope or Q of the resonance.

(3) Sweep rate.

(4) Direction of sweep (up or down).

Significant overshoots were observed during the test runs. Low-level (precursor) test runs were made and the peak select control levels carefully monitored to evaluate this phenomenon. Examination of on-line oscillograph records of response control strain gages disclosed initial amplitudes of 1.00 to 1.52 times the peak select level established for these transducers. The stress values from these low-level test runs were used to derive internal loads in the ODTM structural members. The peak limit and peak select load values were established based on these low-level runs and applied to full FA and TA test levels. The formulation shown in Fig. 15 was used to derive these control levels.

C. RESPONSE MEASUREMENTS

All forced vibration test runs on the LDTM/ODTM were controlled by ODTM bus input accelerometers or by various strain-gage/accelerometer response measurements. The characteristics of this 36-channel peak select control system were not included in the response analysis. In addition, the type approval control values selected for load limiting were approximately two-thirds of the limit values used in the analysis. Therefore, extremely close correlation between test and analysis cannot be expected. Nevertheless, some typical accelerometer and strain-gage response measurements have been compared with analytical predictions and are presented in Tables 6 and 7. In general, the correlation appears reasonably good (Ref. 5).

The response analysis of the coupled LDTM/ODTM math models was very helpful in estimating potential response control channels. Examination of Table 8 gives an approximate indication of the actual versus predicted control channels. At first glance, it would appear that the correlation is not good. However, the agreement between analysis and test is better than casual observation indicates for the following reasons:

(1) These frequencies marked (1) represent conditions where the terminal descent (TD) tank peak select levels were set substantially lower than the values used in the analysis. Consequently, the TD tanks were biased to attain greater control during actual testing. The sensitivity of the control system to lower TD tank control levels is demonstrated by comparison of the FA and TA runs in the table. DE-079 used in the FA tests was replaced by DE-082, with a peak select setting approximately 80% of its initial TA level. This channel assumed control so effectively that no other Lander controls appeared in the TA switching sequence.

(2) The (2) notation in FA testing represents Lander payload adapter strains that were never included in the response analysis.

(3) Precision in determining exactly when a control accelerometer will take over (other than for rigid-body modes) is beyond the capability of present analysis. This is particularly true when the actual control system constraints are considered (i.e., overshoots, time constants, etc.).

(4) The upper plane truss 134-S was shown by analysis to be at 80% of its limit.

Some typical measured load values have been compared with their analytical counter parts (Table 6). Based on that sample, 50% of the measured frequencies were higher than predicted and 50% lower. Approximately two thirds of the measured loads were somewhat lower than predicted values. This was not unexpected because of the tolerances used in establishing peak limit/select values; i.e., the analysis limits did not include test tolerances.

Examination of typical response accelerations (Table 7) reveals that measured frequencies were usually higher than those predicted by analysis. Amplitudes were generally lower than predicted by approximately that amount established by test tolerances.

IV. CONCLUSION

The following remarks may be made based on the stack testing experience and review of the test data:

(1) Test implementation went better than anticipated. This was due, in large part, to the careful preparation leading up to the test and the long hours of overtime donated by the test team.

(2) Forced vibration qualification levels were successfully imposed on the LDTM/ODTM Orbiter primary structure. Load levels generally did not reach design load limits attained in static testing because of the control system test tolerances.

(3) Test predictions based on the Viking mathematical model correlated reasonably well with the test data. In general, test frequencies were slightly higher than analytical predictions and

amplitudes lower. This further demonstrates that the coupled Viking spacecraft mathematical model has no major errors.

(4) JPL test equipment and methods have been checked out for use on the proof test Orbiter. The test was controllable down to 10 Hz at TA levels.

REFERENCES

1. Snyder, R. E., Summary of LDTM/ODTM Stack Test Results for Viking Management Council. Langley Research Center, Hampton, Va., Feb. 1974.
2. Morgan, N., and Fortenberry, J., Viking 75 ODTM/RL and LDTM/ODTM Forced Vibration Test Plan and Procedures, Project Document 611-51. Jet Propulsion Laboratory, Pasadena, Calif., Dec. 1973 (Internal document.)
3. Rader, W. P., Test Specification for LDTM/ODTM Sinusoidal Vibration Test, Document No. 837J2000141. Martin Marietta Corporation, Denver, Colo., Oct. 1973.
4. Milder, G. J., Structures and Dynamics Section Viking 1975 ODTM/LDTM Forced Vibration Test Procedure Longitudinal Axis (Z), Test Procedure 507000. Jet Propulsion Laboratory, Pasadena, Calif., Oct. 1973. (Internal document.)
5. Vigil, R. A., LDTM/ODTM Forced Vibration Test Analytical and Test Data Comparison, Document No. 0433/74-044. Martin Marietta Corporation, Denver, Colo., Feb. 1974.
6. Milder, G. J., and Valtier, H., Viking 1975 ODTM/RL and Viking 1975 ODTM/LDTM Forced Vibration Test, October 26 – December 10, 1973. Test Report VO75-35-100. Jet Propulsion Laboratory, Pasadena, Calif., Jan. 1974. (Internal document.)
7. Valtier, H., Accelerometer Cable Test, Interoffice Memorandum 354/HV/2-74. Jet Propulsion Laboratory, Pasadena, Calif., Jan. 1974. (Internal document.)

Table 1. ODTM propulsion module mass configuration, 294 K (70° F)

Tank	Referee fluid	Fluid, weight, kg (lb)	Ullage, %	Pressure, N/m^2 (psia)[a]
Oxidizer	Freon TF	935.6 (2,063)	16.8	723,950 (105)
Fuel	Isopropyl alcohol	504.3 (1,112)	10.1	723,950 (105)
Pressurant	—	—	—	Atmospheric

[a] ODTM propellant tank pressures were closely monitored during the stack test series (Appendix C).

Table 2. Forced vibration test levels, longitudinal (Z) axis

Level	Amplitude, g peak					
	25-7 Hz	22-8 Hz	22-10 Hz	200-20-200 Hz	128-20-128 Hz	200-128-200 Hz
Precursor	0.5	—	—	0.5	—	—
Flight acceptance	—	1.0	—	—	1.0	0.00003 m (0.0012 in.) double amplitude
Type approval	—	—	1.5	—	1.5	0.00046 m (0.0018 in.) double amplitude

Table 3. Forced vibration test levels, lateral (X, Y) axes

Level	Test axis	Amplitude – g peak	
		200-5-200 Hz	200-8-200 Hz
Precursor	Y	1.5 (311/70)[a]	–
Full	Y X	–	1.5 (556/125)

[a] Numbers in parentheses indicate force level (N/lb) of each of the four Unholtz-Dickie Shakers.

Table 4. Recording channel capability, tape recorder allocation

Data User	Peak select		Peak limit	Component response	Timing, reference	Housekeeping Miscellaneous	Total
	Input control	Response control					
LDTM/ MMA		12 (TR2)	11	65 (78MX)	4 (TR2, 78MX)		92
ODTM/ JPL	12 (TR1)[a]	12 (TR3)	12	129 (140)	6 (TR1, 3, 140)		171
Test facility/ JPL					2 (TR4)	9 (TR4)	11
Total	12	24	23	194	12	9	274

[a] Parentheses indicate tape recorder assignment.

Table 5. Summary of LDTM/ODTM forced vibration test runs

Run No.	Date of run, 1973	Axis of excitation	Frequency range, Hz	Sweep rate, oct. /min	Control accel. level, g peak	Remarks
108	11/5	Z	25-7	2	0.5	Overhead sling attached to LDTM showed large motion. Replaced.
109	11/5	Z	200-20-200	2	0.5	Acceptable test.
110	11/5	Z	200-20-200	4	0.5	Acceptable test.
111	11/8	Z	25	2	0.5	Abort on control accel. 4 peak limit at test start.
111-1	11/8	Z	25-19	2	0.5	Abort on control accel. 9 peak limit.
111-2	11/8	Z	25-7	2	0.5	Acceptable test.
112	11/8	Z	200-23	2	0.5	Abort by SD 123 overtest circuit, hereafter called the "WOW"[a] anomaly.
112-1	11/9	Z	200-20-25	2	0.5	Abort on control accel. peak limit at location 4 (4 and 7 switched for this run).
113	11/16	Z	128-48	4	1.0	Abort on LDTM peak limit DE-080.
113-1	11/16	Z	53-47	4	1.0	Abort on LDTM peak limit DE-082.

[a] WOW refers to the nature of the sound output of the Ling 249 shaker/structure combination. See Refs. 6 and 7 for further clarification.

Table 5 (contd)

Run No.	Date of run, 1973	Axis of excitation	Frequency range, Hz	Sweep rate, oct. /min	Control accel. level, g peak	Remarks
113-2	11/16	Z	53-36	4	1.0	Abort on LDTM peak limit DE-083.
113-3	11/16	Z	53-21	4	1.0	Abort on LDTM peak limit DE-306.
113-4	11/16	Z	53-21	4	1.0	Abort on LDTM peak limit DE-303.
113-5	11/19	Z	128-30	4	1.0	Incorrect control setting caused abort on LDTM peak limit DS-332.
113-6	11/19	Z	128-23	4	1.0	Arithmetic error resulted in wrong peak limit voltage setting at control console, causing abort on LDTM peak limit DS-331.
113-7	11/19	Z	128-20-24	4	1.0	Abort on ODTM peak limit 128-S (upper plane truss 726). Acceptable test.
113-8	11/19	Z	22-128	4	1.0	Acceptable test.
114	11/20	Z	20-128-200	4	0.00003 m (0.0012 in.) double amplitude DA	Acceptable test.

Table 5 (contd)

Run No.	Date of run, 1973	Axis of excitation	Frequency range, Hz	Sweep rate, oct./min	Control accel. level, g peak	Remarks
115	11/20	Z	22-10	2	1.0	Abort on ODTM peak limit 313-S (PM bipod P36). Acceptable test.
115-1	11/20	Z	15-8	2	1.0	Acceptable test.
116	11/27	Z	22	2	1.5	Abort on LDTM peak limit DE-082 at start of test.
116-1	11/27	Z	22	2	1.5	Incorrect console setting caused abort on LDTM peak limit DE-082 at test start.
116-2	11/27	Z	22-21	2	1.5	Abort on LDTM peak limit DE-306.
116-3	11/28	Z	22-20	2	1.5	Abort on LDTM peak limit DE-306.
116-4	11/28	Z	22-10	2	1.5	Abort on ODTM peak limit 8-S (VLCA 752) due to 200-Hz filter in ODTM circuit. Acceptable test.
117	11/28	Z	128-87	2	1.5	Abort by test conductor due to WOW anomaly.
117-1	11/29	Z	128-85	2	1.5	Abort by test conductor due to WOW anomaly.

Table 5 (contd)

Run No.	Date of run, 1973	Axis of excitation	Frequency range, Hz	Sweep rate, oct./min	Control accel. level, g peak	Remarks
117-2	11/29	Z	128-84	2	1.5	Exploratory run with control accel. 4 removed from peak select. Same channel peak limit aborted test.
117-3	11/29	Z	128-70	2	1.5	Exploratory run with new equipment for control accel. 4.
117-4	11/29	Z	128-20-21	2	1.5	Large irregular signal on control accel. 5 caused overshoot abort on LDTM peak limits DS-330, DS-333. Acceptable test.
117-5	11/29	Z	23-20-128	2	1.5	Acceptable test.
118	11/29	Z	200	2	0.000046 m (0.0018 in.) DA	Abort on power amplifier input (too low) at test start
118-1	11/29	Z	200-128-200	2	0.000046 m (0.0018 in.) DA	Acceptable test.
200	12/7	Y	200	2	1.5 (311 N/70 lb)[a]	Abort on control accel. 8 peak limit at test start.

[a] Numbers in parentheses indicate force level (N/lb) of each of the four Unholtz-Dickie shakers.

Table 5 (contd)

Run No.	Date of run, 1973	Axis of excitation	Frequency range, Hz	Sweep rate, oct. /min	Control accel. level, g peak	Remarks
200-1	12/7	Y	200-6	2	1.5 (311 N/70 lb)	Abort on ODTM peak limit 336-S (PM lower connector P-43).
200-2	12/10	Y	200	2	1.5 (311 N/70 lb)	Abort by facility engineer; control level backup reading from data recording center incorrect.
200-3	12/10	Y	200-5-200	2	1.5 (311 N/70 lb)	Acceptable test.
201	12/10	Y	200-175	2	1.5 (623 N/140 lb)	Abort on power amplifier input. Peak limit of 140 lb equals peak select setting of 140 lb.
201-1	12/10	Y	200-110	2	1.5 (623 N/140 lb)	Abort by ODTM structural engineer. Fracture of mechanical fuze on shaker 12. Possible broken load cell.
201-2	12/10	Y	200-170	2	1.5 (623 N/140 lb)	Abort on modal console amplifier dump. Overshoot results in excessive power demand at 140-lb level.

Table 5 (contd)

Run No.	Date of run, 1973	Axis of excitation	Frequency range, Hz	Sweep rate, oct. /min	Control accel. level, g peak	Remarks
201-3	12/10	Y	200	2	1.5 (556 N/125 lb)	Abort by facility engineer. Could not get control level backup reading from data recording center.
201-4	12/10	Y	200-8-200	2	1.5 (556 N/125 lb)	Acceptable test. Load cell at shaker 13 damaged. Readout error on shaker 11 armature current. Force correct.
301	12/10	X	200-8-200	2	1.5 (556 N/125 lb)	Partially acceptable test. Tape recorder 4 out of tape on upsweep.
301-1	12/10	X	8-200	2	1.5 (556 N/125 lb)	Acceptable test.

Table 6. Typical ODTM loads derived from strain-gage measurements, TA input, Z-axis, 10–40 Hz

Member	Comparison set 1				Comparison set 2			
	Frequency, Hz		Load, N (lb)		Frequency, Hz		Load, N (lb)	
	Analysis	Measured	Analysis	Measured	Analysis	Measured	Analysis	Measured
VLCA								
750	20.8	19.8	7780 (1750)	8100 (1820)	32.4	27.0	5560 (1250)	4090 (920)
752	17.0	17.2	7340 (1650)	6490 (1460)	21.2	23.0	9560 (2150)	8980 (2020)
Upper plane truss								
726	19.3	22.0	6230 (1400)	3670 (825)	29.7	30.0	2780 (625)	4400 (990)
727	19.3	24.0	5600 (1260)	4140 (930)	22.4	25.5	6340 (1425)	4230 (950)
730	22.4	23.5	5830 (1310)	4270 (960)	29.7	38.0	2890 (650)	4560 (1025)
Main longerons								
808	17.0	17.0	6050 (1360)	5870 (1320)	21.0	21.0	8450 (1900)	7870 (1770)
818	10.7	10.5	6360 (1430)	9210 (2070)	21.5	21.0	8580 (1930)	8450 (1900)
828	10.7	11.0	5070 (1140)	8410 (1890)	20.8	19.8	10,810 (2430)	7250 (1630)
837	17.0	16.8	5290 (1190)	6270 (1410)	20.8	19.7	9650 (2170)	7470 (1680)
He tank support								
P28	17.0	16.5	1020 (230)	1070 (240)	31.6	31.0	1780 (400)	930 (210)
P82	17.9	17.0	1310 (294)	1330 (300)	31.4	32.0	(1530) 345	890 (200)

Table 7. Typical ODTM response acceleration levels compared to analytical predictions, TA input, Z-axis, 10-40 Hz

Channel[a]	Sensitivity axis[b]	Comparison set 1				Comparison set 2			
		Frequency, Hz		g, 0-peak		Frequency, Hz		g, 0-peak	
		Analysis	Measured	Analysis	Measured	Analysis	Measured	Analysis	Measured
Scan platform input									
IRTM	O	26	28	3.0	1.10	31.3	33	1.75	1.13
IRTM	Z	26	30	3.07	1.49	29.2	35	3.60	1.46
MAWD	O	18	17	2.18	0.81	26	28	2.47	1.27
MAWD	Z	20.7	19	6.30	1.70	22.4	27	5.75	3.18
VIS	O	18-19	17-18	2.03	0.74	26	28	2.62	1.49
VIS	Z	20.7	19	4.40	1.27	22.4	27	3.80	2.05
Bus									
Bay 4/5 bottom	R	17	17	1.32	0.77	21	22	1.31	0.60
Bay 4/5 bottom	T	18.5	19	1.13	1.00	27.5	30	1.13	1.10
Bay 4/5 bottom	Z	20.7	20	6.00	1.70	22.4	23	5.38	2.83
Bay 14/15 bottom	R	16.9	17	1.25	0.93	26	30	1.18	0.40
Bay 14/15 bottom	T	19.3	18	1.27	0.50	26	26	1.52	0.44
Bay 14/15 bottom	Z	19.7	19	2.80	0.88	26	25	2.57	1.18
Outriggers									
Bay 1	R	19.3	19	1.26	0.82	27.5	28	0.64	0.52
Bay 1	T	15.3	17	1.58	0.43	26	29	1.35	1.16
Bay 1	Z	20.7	20	4.2	0.95	22.4	28	4.10	2.34
Bay 5	R	17	17	1.03	2.12	27.5	28	2.05	1.49
Bay 5	T	15.3	17	1.90	0.95	29.7	29	1.20	0.79
Bay 5	Z	20.7	20	10.3	2.54	22.4	27	9.70	3.82
Propulsion module									
REA	X	17.8	17	2.56	2.05	22.4	27	1.20	0.20
REA	Y	18.5	20	1.13	0.71	26	30	1.68	1.20
REA	Z	10.8	11	2.43	0.64	19	19	1.82	2.12
Fuel tank tab	X	12	11	0.47	0.08	21	19	0.49	0.30
Fuel tank tab	Y	17	17	1.30	0.89	21	21	1.12	0.74
Fuel tank tab	Z	10.8	11	2.05	1.49	18.6	18	3.05	2.20
PCA regulator	X	11.8	11	0.47	0.71	17	19	1.38	1.03
PCA regulator	Y	15.4	17	0.65	0.57	27	28	0.61	0.60
PCA regulator	Z	10.8	11	2.29	1.46	18.7	18	2.82	1.59

[a] IRTM = infrared thermal mapper; MAWD = Mars atmospheric water detector; VIS = visual imaging system; REA = rocket engine assembly; PCA = pressure control assembly.

[b] O = optical, Z = longitudinal; R = radial; T = tangential.

Table 8. LDTM/ODTM forced vibration test comparison of control channels for longitudinal axis testing

Approximate f, Hz	FA testing (40-8 Hz)				TA testing (40-10 Hz)			
	Control	Predicted by analysis		Others	Control	Predicted by analysis		Others
		Yes	No			Yes	No	
40	140-S, upper plane truss		X		140-S, upper plane truss		X	
39	140-S, upper plane truss		X		140-S, upper plane truss		X	
38	DE-079 TD tank			(1)	DE-082 TD tank			(1)
37	DE-079 TD tank			(1)	DE-082 TD tank			(1)
36	DE-079 TD tank			(1)	DE-082 TD tank			(1)
35	DE-079 TD tank			(1)	DE-082 TD tank			(1)
34	128-S, upper plane truss		X		DE-082 TD tank			(1)
33	128-S, upper plane truss		X		128-S, upper plane truss		X	
32	128-S, upper plane truss		X		128-S, upper plane truss		X	
31	128-S, upper plane truss		X		128-S, upper plane truss		X	
30	Control No. 5			(3)	128-S, upper plane truss		X	
29	134-S, upper plane truss			(4)	Control No. 2	X		
28	134-S, upper plane truss			(4)	Control No. 2	X		
27	128-S, upper plane truss		X		128-S, upper plane truss		X	
26	DE-052, equipment plate		X		128-S, upper plane truss		X	
25	DS-330, payload adapter			(2)	DE-082 TD tank	X		

Table 8 (contd)

Approximate f, Hz	FA testing (40-8 Hz)				TA testing (40-10 Hz)			
	Control	Predicted by analysis		Others	Control	Predicted by analysis		Others
		Yes	No			Yes	No	
24	DS-333, payload adapter			(2)	DE-082 TD tank	X		
23	289-S, bedframe		X		Control No. 2	X		
22	DS-330 adapter			(2)	289-S, bedframe		X	
21	DS-330 adapter		X		DE-082 TD tank	X		
20	DS-333 payload adapter			(2)	Control No. 4			(3)
19	288-S bedframe	X			289-S bedframe	X		
18	289-S bedframe	X			289-S bedframe	X		
17	289-S bedframe		X		Control No. 4	X		
16	295-S bedframe	X			295-S bedframe	X		
15	295-S bedframe	X			295-S bedframe	X		
14	295-S bedframe		X		295-S bedframe		X	
13	295-S bedframe		X		295-S bedframe		X	
12	295-S bedframe		X		295-S bedframe	X		
11	Control No. 4	X			Control No. 2	X		
10	Control No. 4	X			Control No. 2	X		
9	8-S, VLCA	X						
8	Control No. 1	X						
	Total	8	14	11		14	11	6

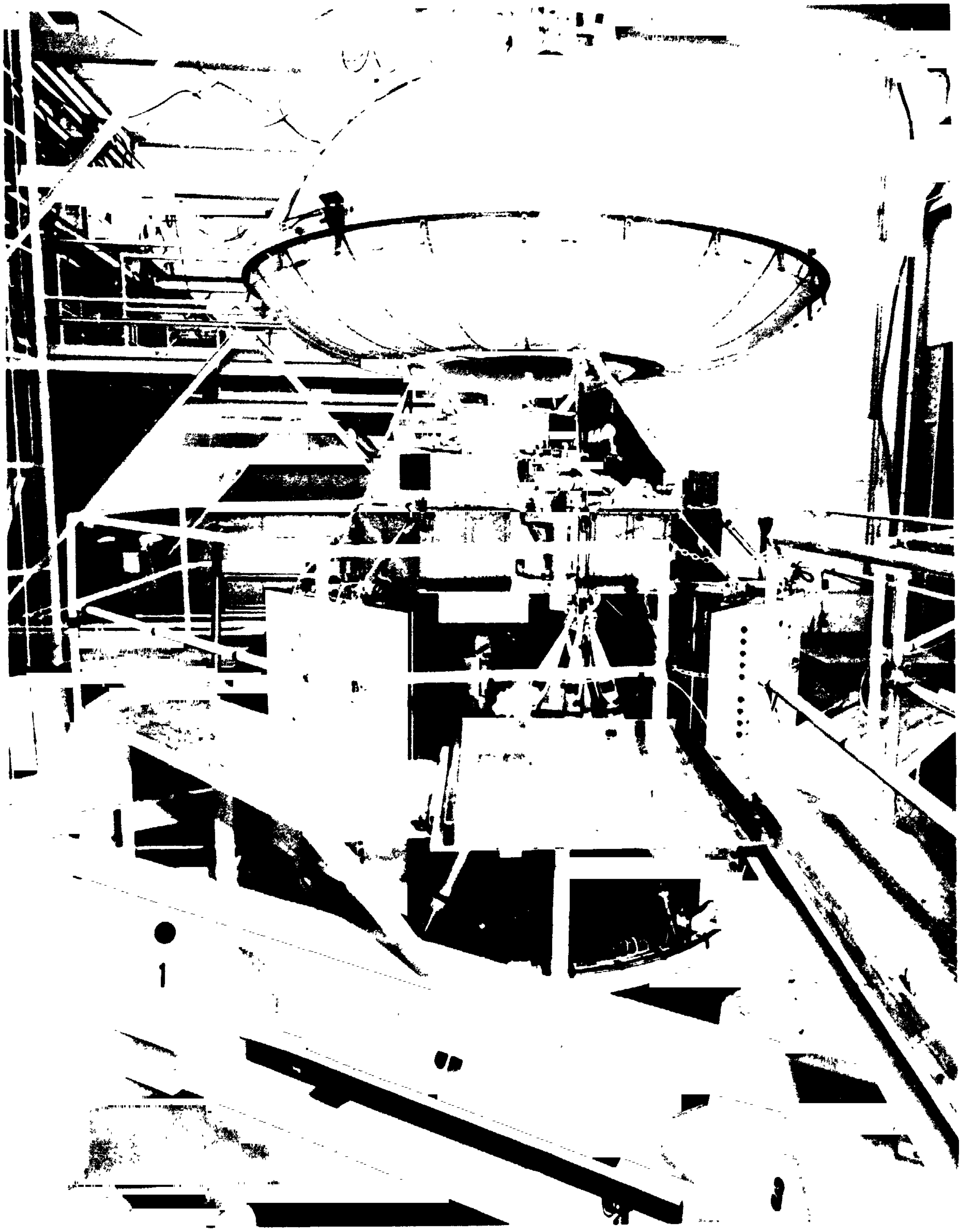


Fig. 1. View from balcony of LDTM/ODTM longitudinal (Z) axis test setup

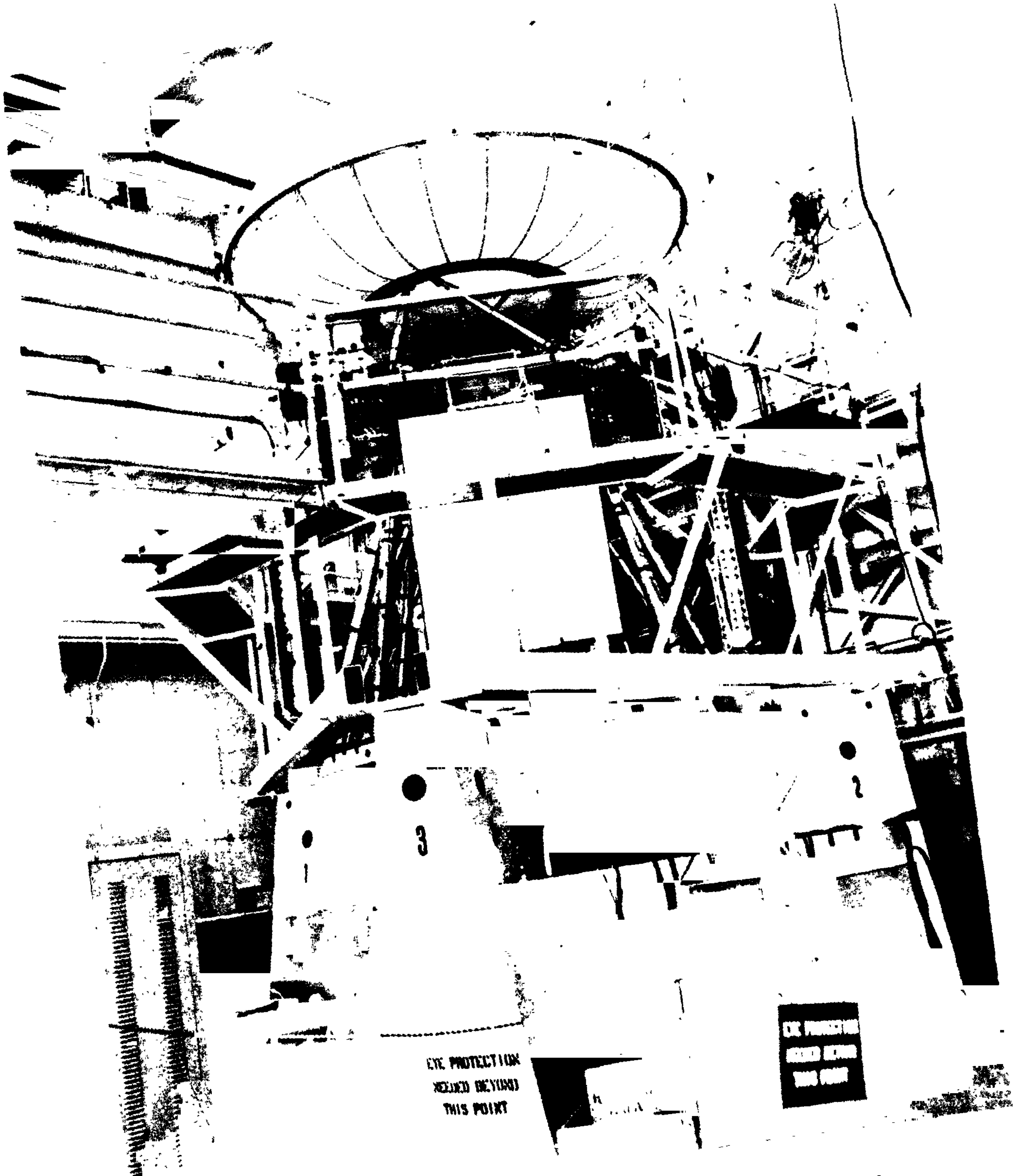


Fig. 2. View from floor of LDTM/ODTM longitudinal (Z) axis test setup

Fig. 3. Typical hydrostatic bearing installation

Fig. 4. Pneumatic spring support system

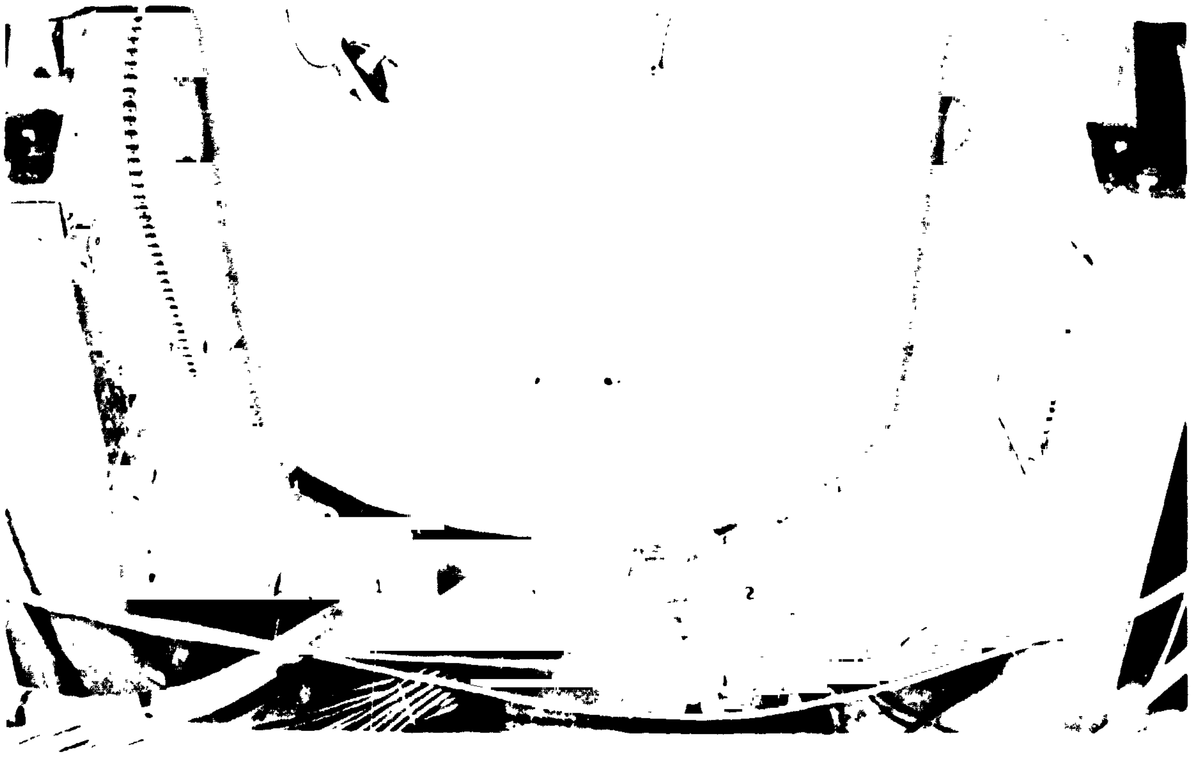


Fig. 5. Shaker body blocking system

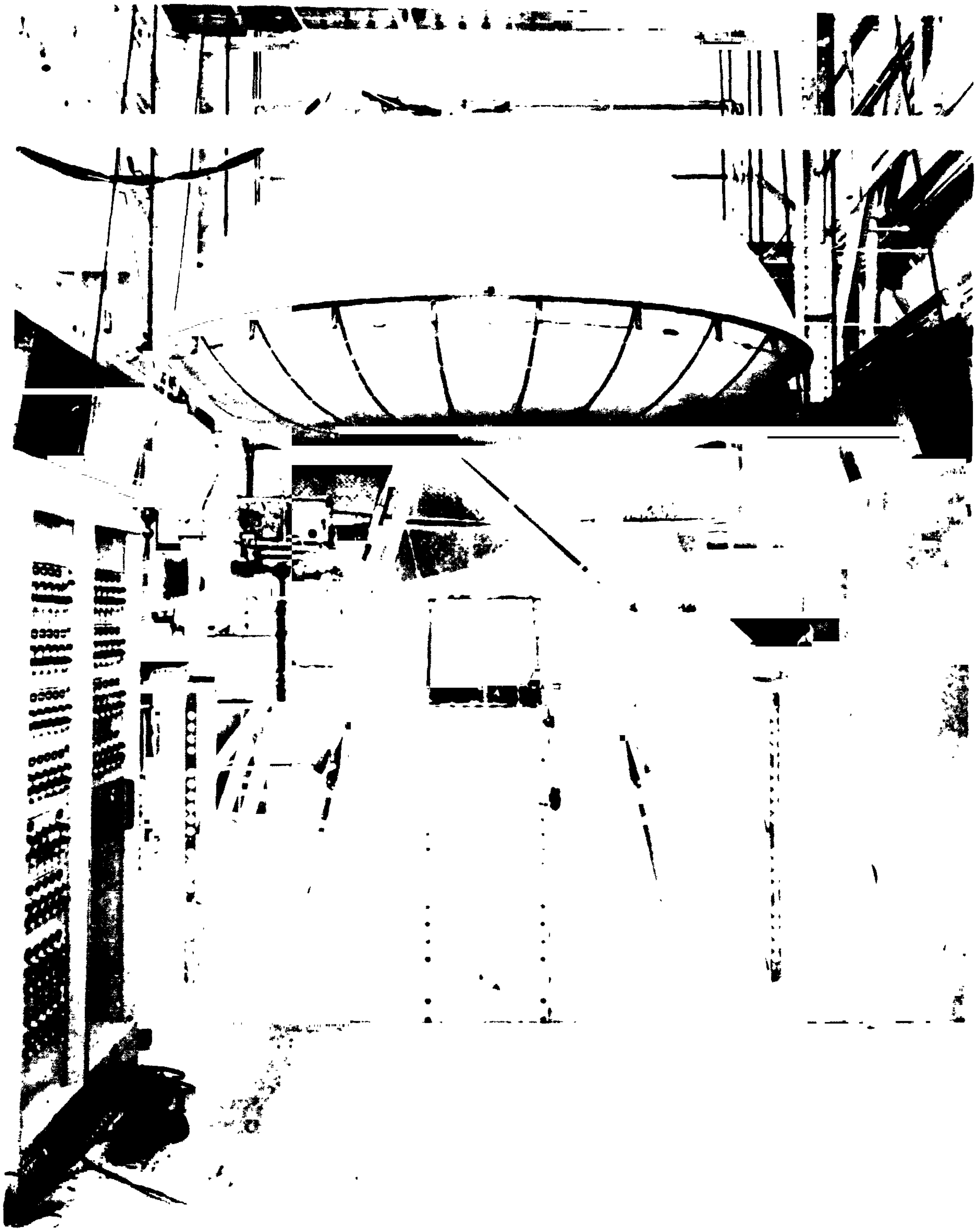


Fig. 6. Overall view of LDTM/ODTM lateral (Y) axis test setup

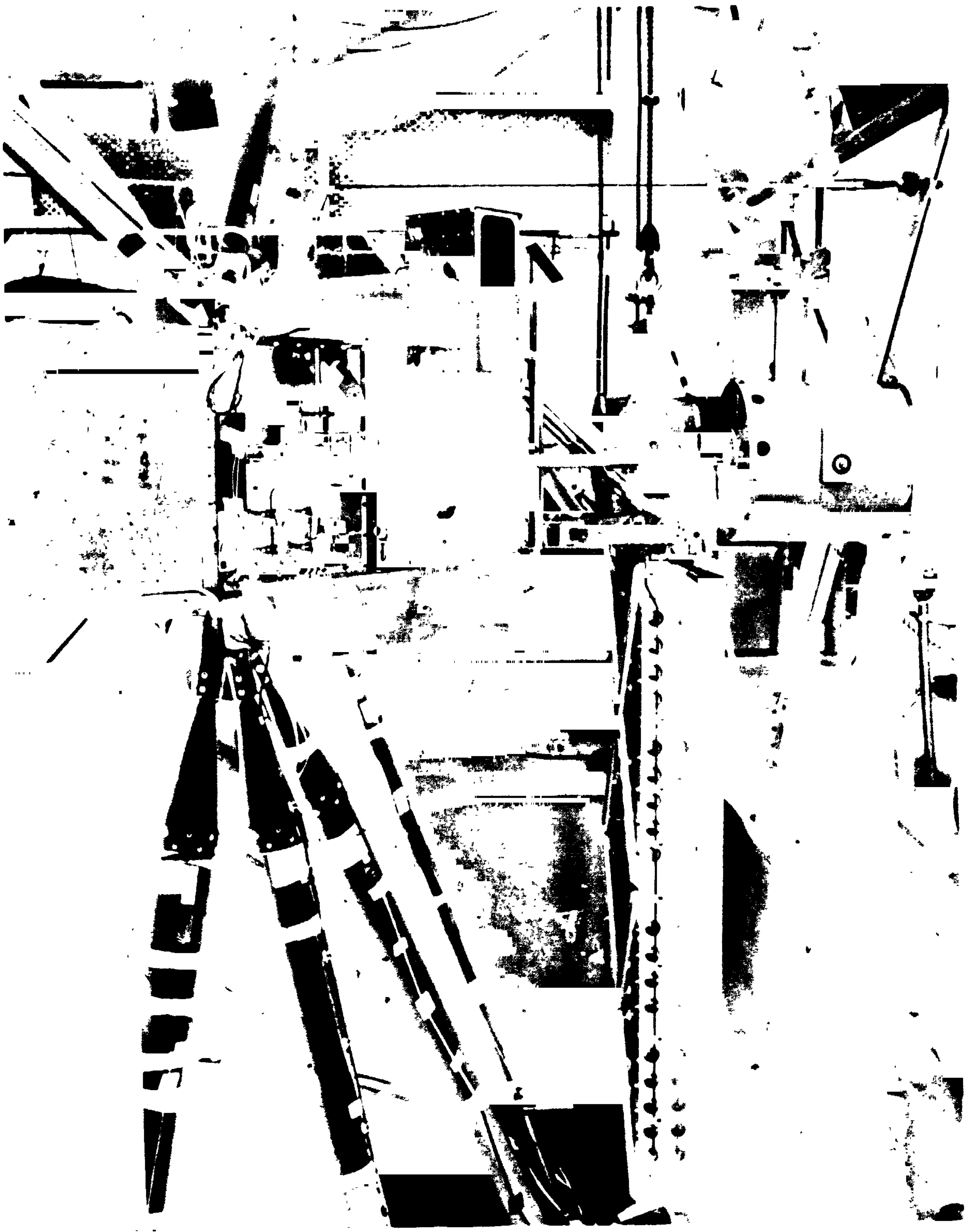


Fig. 7 Shaker 12, stinger, mechanical fuze, and ODTM bus longeron attachment (Y-axis)

Fig. 8. Closeup view of mechanical fuze and ODTM bus longeron attachment (Y-axis)

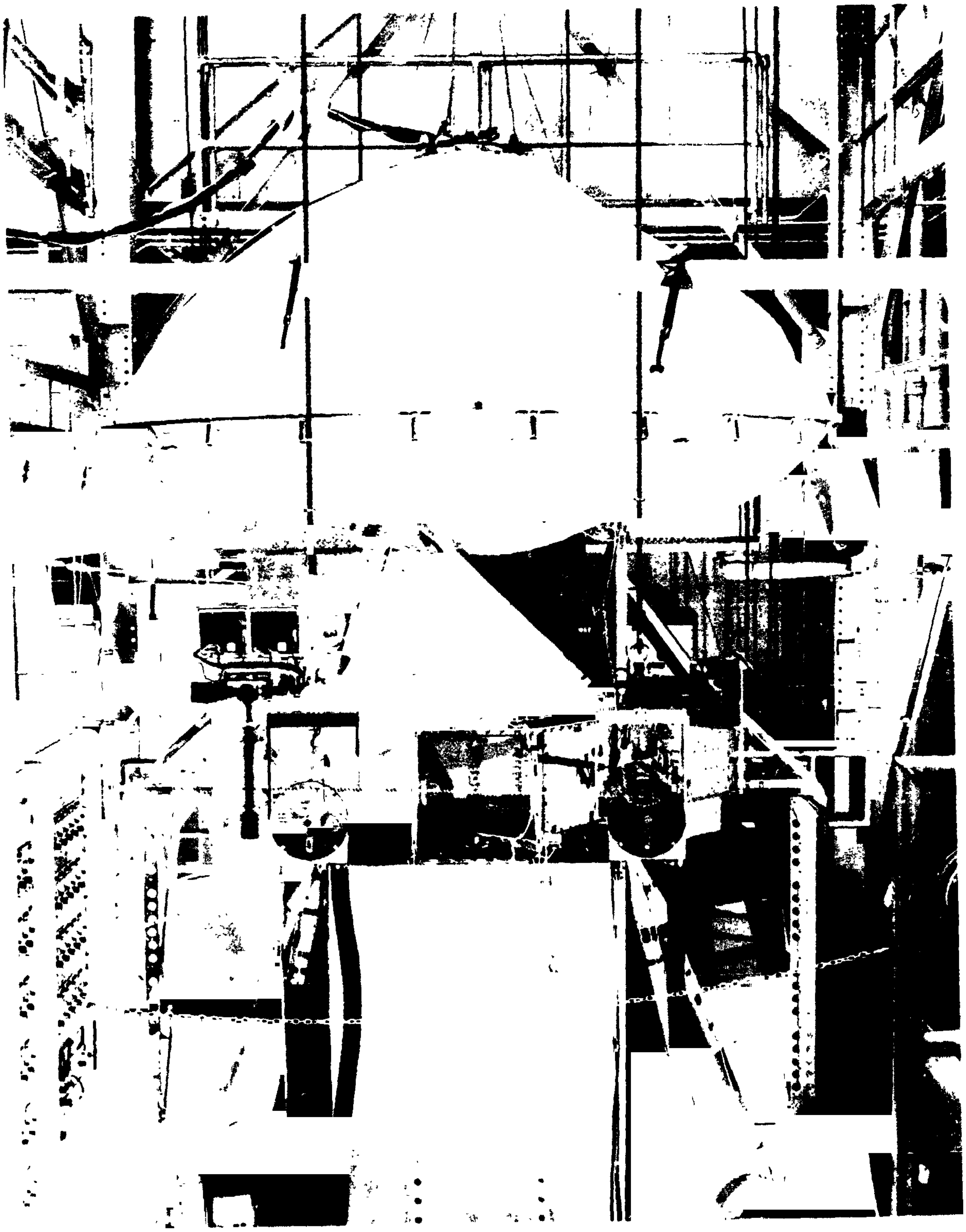
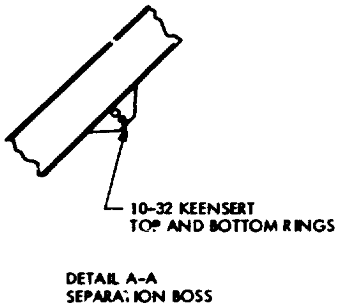


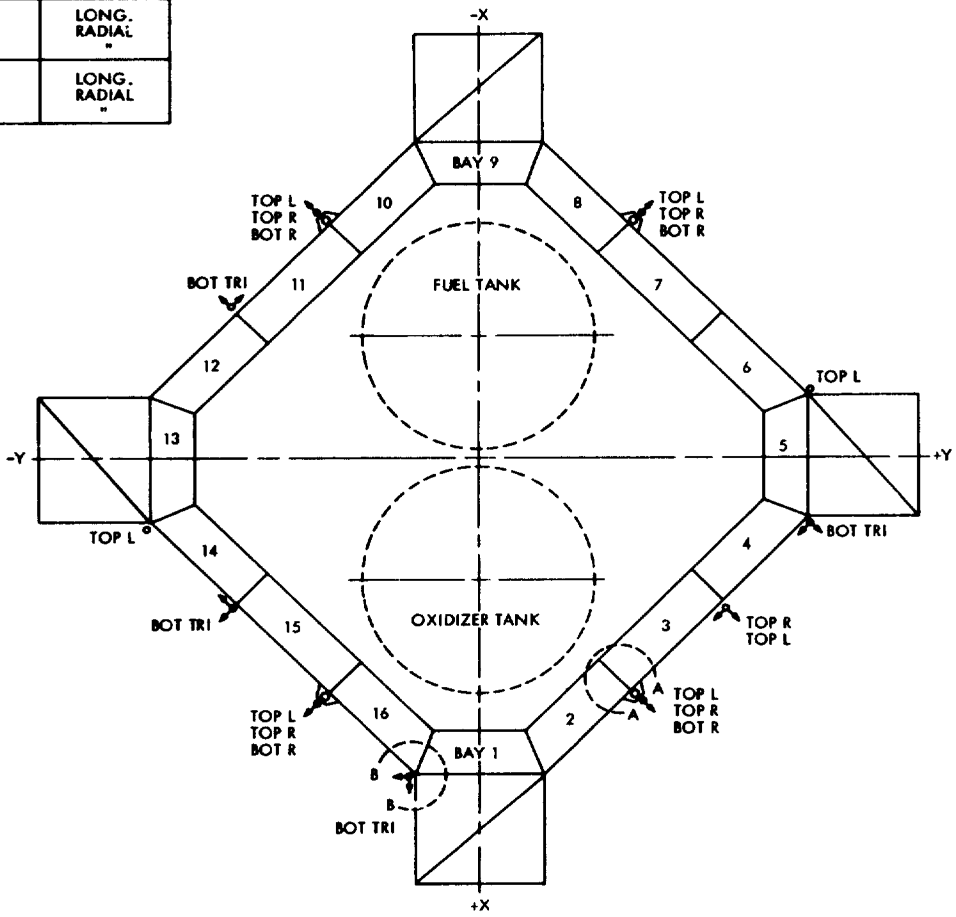
Fig. 9. Overall view of LDTM/ODTM lateral (X) axis test setup

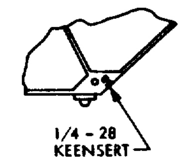
CONTROL ACCELEROMETERS MOUNTED ON MAIN LONGERONS			
ACC. I.D.	UPPER RING	LOWER RING	DIRECTION
2-3 TOP L	✓		LONG.
2-3 TOP R	✓		RADIAL
2-3 BOT R		✓	"
7-8 TOP L	✓		LONG.
7-8 TOP R	✓		RADIAL
7-8 BOT R		✓	"
10-11 TOP L	✓		LONG.
10-11 TOP R	✓		RADIAL
10-11 BOT R		✓	"
15-16 TOP L	✓		LONG.
15-16 TOP R	✓		RADIAL
15-16 BOT R		✓	"

ADDITIONAL POSITIONS			
ACC. I.D.	UPPER RING	LOWER RING	REMARKS
4-5 BOT TRI		✓	ACCEL. TO BE MOUNTED ON BLOCKS ATTACHED TO CHASSIS FACE BY No. 8 SHEAR-PLATE FASTENERS
15-15 BOT TRI		✓	
1-16 BOT TRI		✓	



DETAIL A-A
SEPARATION BOSS





DETAIL B-B
UPPER AND LOWER RING
(CORNERS)

NOTES:
(1) TOP - UPPER RING
(2) BOT - LOWER RING
(3) L - LONGITUDE
(4) R - RADIAL
(5) TRI - TRIAXIAL

Fig. 10. LDTM/ODTM forced vibration test bus accelerometer location

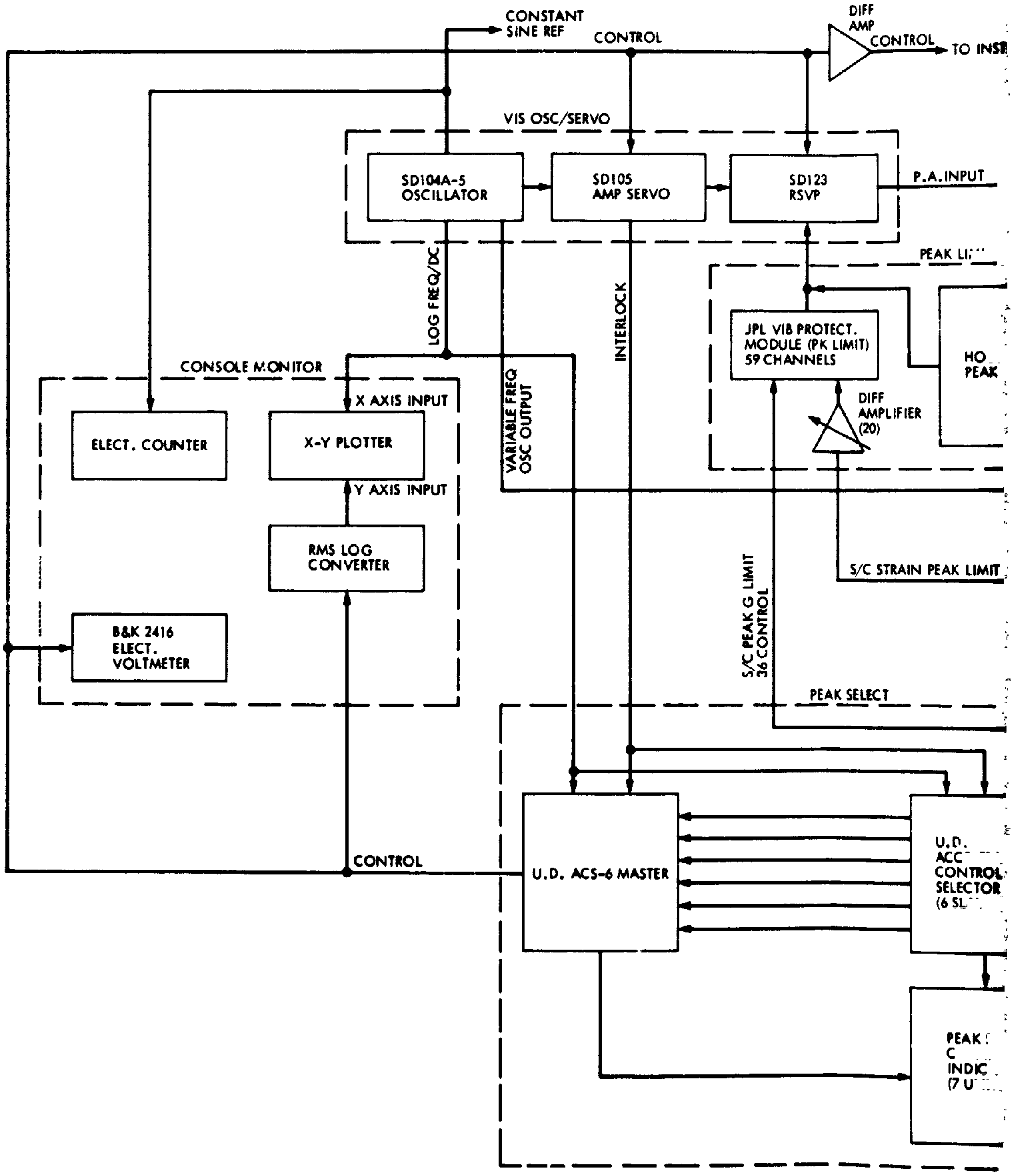
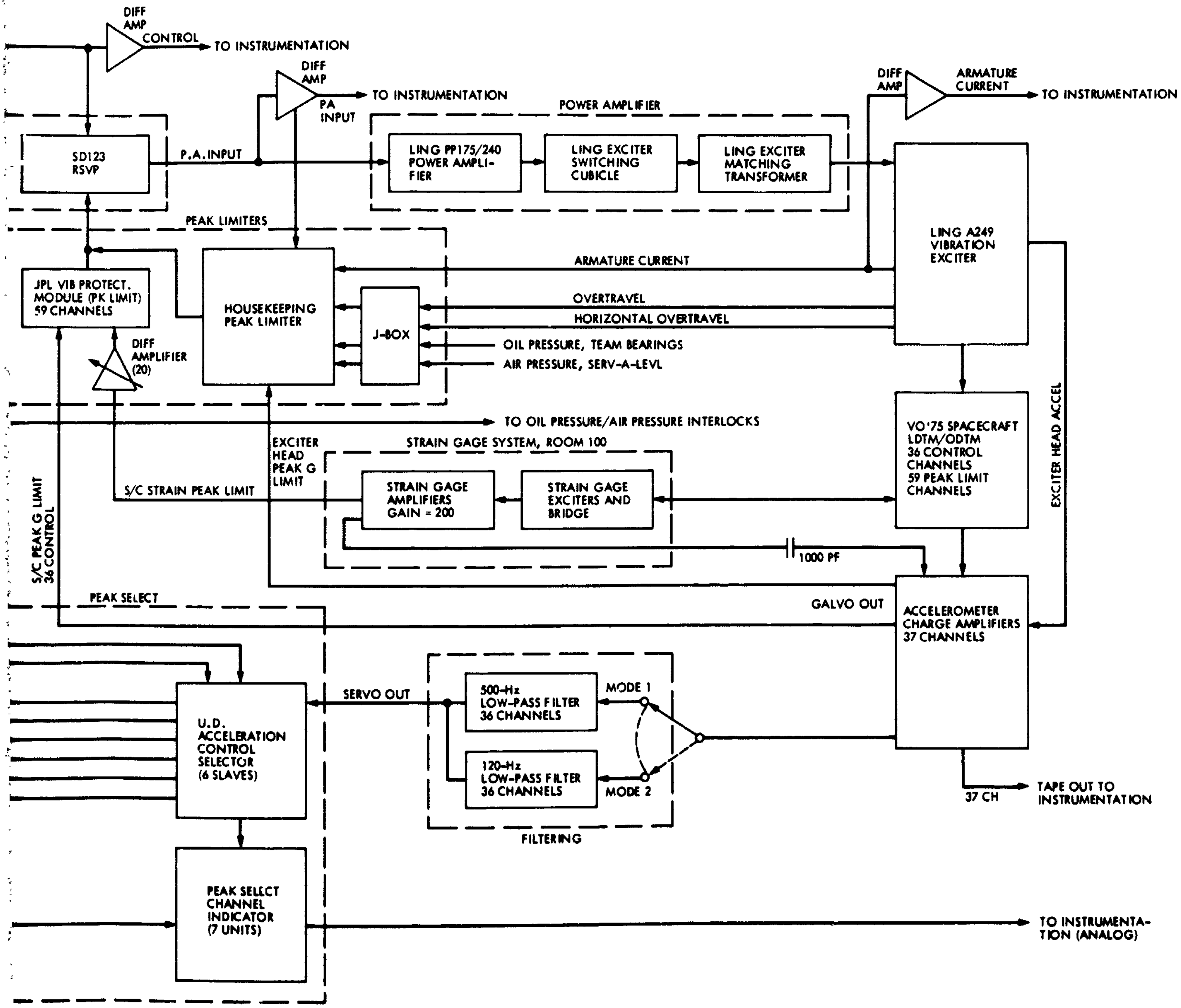


Fig. 11. LDTM/OD

FOLDOUT FRAME

FOLDOUT



ig. 11. LDTM/ODTM longitudinal (Z) axis vibration test control circuit, functional block diagram

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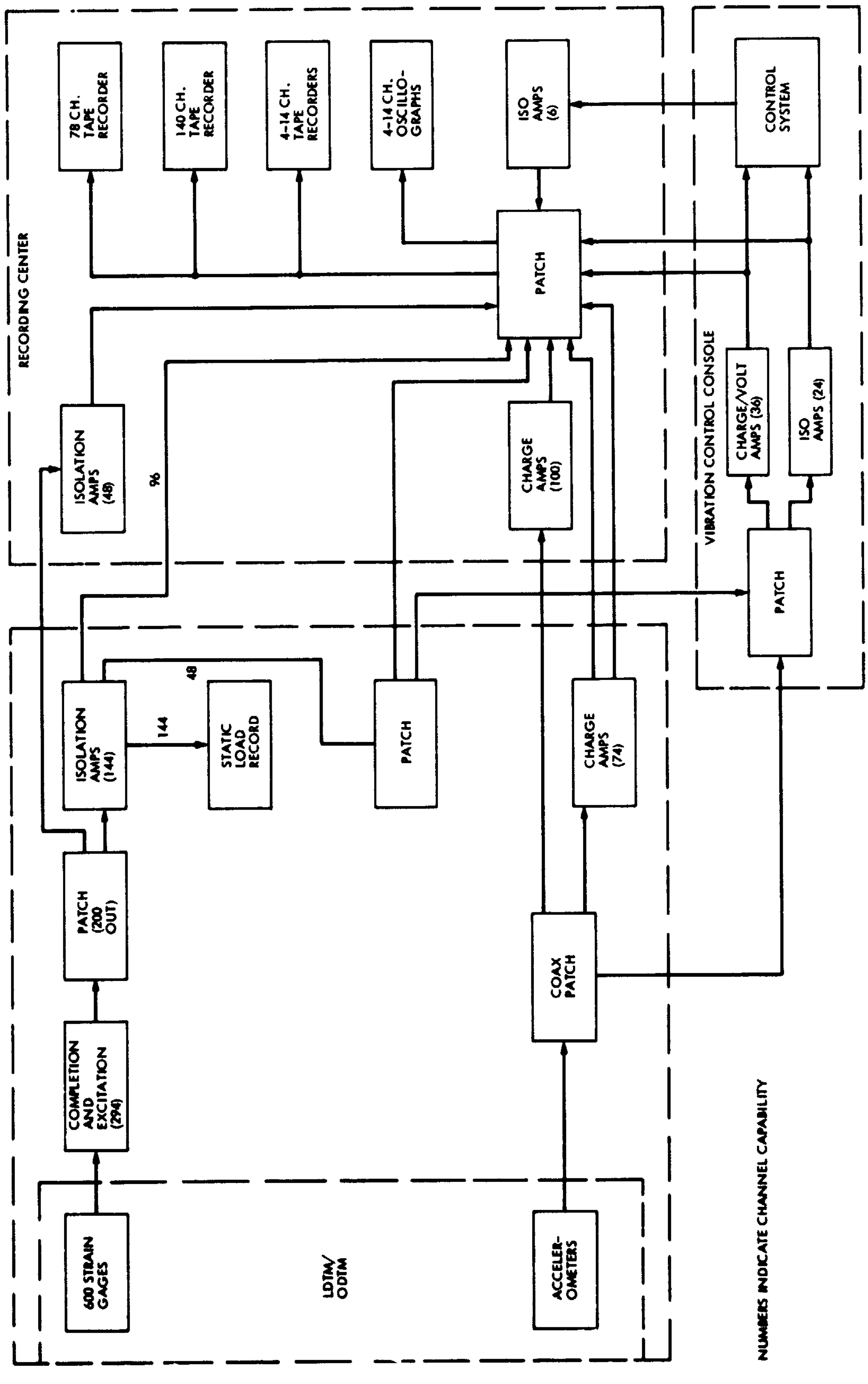

Fig. 12. Data acquisition system

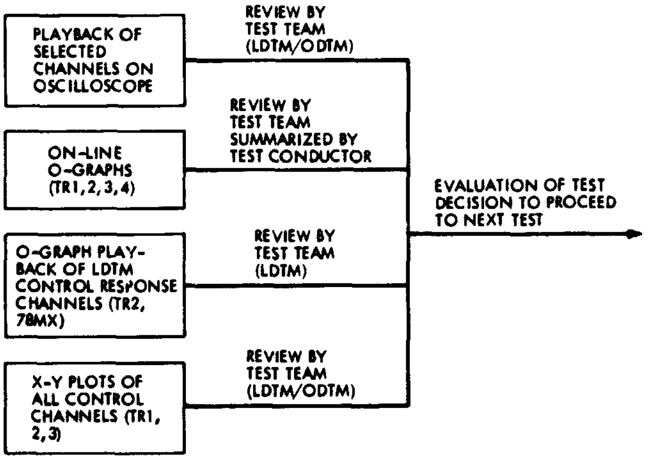

Fig. 13. Sequence of quick-look data reduction for test run evaluation

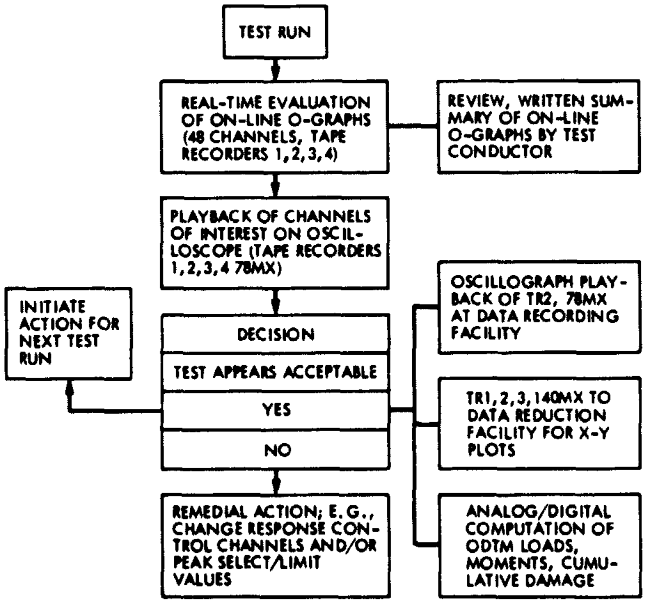

Fig. 14. Typical data reduction sequence

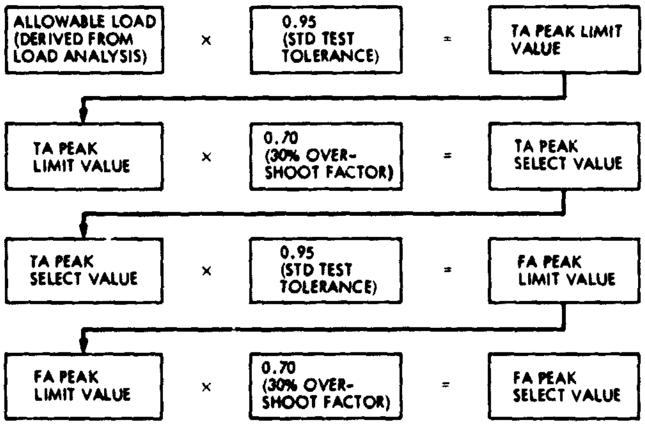

Fig. 15. Flow plan for establishing peak limit/select values

APPENDIX A

SUPPORTING ANALYSES

The complexity, scope, and tight schedule of the stack test left no time for surprises or emergencies. As a result, significant effort was devoted to pretest analysis. The analyses were divided into four categories: test fixture, overturning moment, response or test simulation, and fatigue damage.

I. TEST FIXTURE ANALYSIS

The predesign of the magnesium Z-axis test fixture was evaluated as a first step in the analysis of the stack test setup. The objective of this analysis was to determine characteristics of the basic fixture and to ascertain the level of fixture representation required for the response analysis.

The analytical configuration consisted of a simplified 12-degree-of-freedom (DOF) model of the spacecraft (6 DOF each for Lander and Orbiter), combined with a dynamic model of the test fixture. The VLCA and V-S/C-A were elastically modeled. The fixture was considered fixed at the base of its core.

Two types of analyses were performed: static and modal. Static loads applied to the combined system yielded only a qualitative estimate of the fixture strength since boundary conditions were not represented in this analysis. Modal analysis was performed on the combined fixture/spacecraft model and also on the spacecraft model cantilevered from the base of the V-S/C-A. The comparison of combined system modes with cantilevered spacecraft modes gave an indication of fixture rigidity.

The first fixture mode (torsional) occurred at 36 Hz, with five additional modes between 100 and 200 Hz. Since a design goal was to keep fixture resonances close to 200 Hz, considerable changes were made to the proposed test setup. These modifications included a pair of V-type hydrostatic bearings at one location around the fixture. A further refinement of the analysis disclosed that the addition of torsional restraint flexures did not contribute enough stiffness to be cost-effective. The results are summarized in Table A-1.

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II. OVERTURNING MOMENT

Early in the program, it became apparent that the longitudinal test buildup, its stack height coupled with the spacecraft CG offset, would be subject to large overturning moments. Estimates of these moments ranged from 56,000 to 113,000 Nm (500,000 to 1,000,000 lb-in.) applied to the VTA/test fixture interface.

For this analysis, the Orbiter elastic model was coupled to a rigid lander. This combination, in turn, was mated to a rigid longitudinal fixture model restrained at three locations by hydrostatic bearings of known stiffness. The results of the analysis offered the first positive indication that the stack test could be implemented. Angular deflection limits of the shaker armature, a source of concern, were shown to be no problem.

In addition, reaction forces on the hydrostatic bearings and the forces applied to the fixture were computed and used to perform a stress/fatigue analysis of the fixture and check the bearing adequacy. These same moment reaction forces were applied to the piers supporting the bearings to check their stability.

III. TEST SIMULATION, RESPONSE ANALYSIS

Response analysis of the test setup was required for the following reasons:

(1) To obtain an estimate of the test environment, i.e., identify member loads and locate accelerometers at critical response points.

(2) To evaluate shaker force requirements and control levels.

(3) To provide reaction forces for fixture design.

(4) To provide an estimate of the spacecraft fatigue capability.

The analysis followed an evolutionary pattern and was accomplished in phases since both LDTM and ODTM elastic models were being revised and upgraded. A comparison of the characteristics of each phase is shown in Table A-2 for longitudinal excitation.

Simulation of lateral axis excitation was noteworthy because of a change in test philosophy. Preliminary analysis had indicated excessive coupling of the lateral and torsional modes of the spacecraft. This was due to the combination of spacecraft CG offset and the application of unrestrained driving forces at the bus main longerons. As a result, an intermediate analysis using restrained or guided input forces was performed; it appeared to solve the coupling problem at all but the lowest frequencies (5-10 Hz). In this bandwidth, analysis indicated that the driving forces required were so small that control might be difficult to achieve.

Finally, at the Test Readiness Review meeting, members of the Engineering Steering Group objected to the restraint of spacecraft torsional motion due to the massive lateral test fixture connected to a Ling 249 shaker. The fixture was to be constrained by hydrostatic bearings to move only in one direction. As a result, the test team was directed to seek a lateral driving scheme with minimum restraint. The final choice (and analysis) consisted of using the four 667-N (150-lb) shakers discussed in Section II-B-2.

IV. ESTIMATE OF FATIGUE DAMAGE

The objective of the fatigue analysis was to monitor and enable prediction of possible fatigue damage so that vibration test levels could be controlled to prevent cracks from forming in the ODTM primary structure.

The cumulative damage ratio (CDR) used to determine fatigue damage can be stated as

$$\mathrm{CDR} \leq \sum_{i=1}^{J} \frac{n_i}{N_i} \leq 0.20$$

where n_i = number of cycles experienced at a particular stress level σ_i and N_i = allowable number of cycles at that same stress level. The number of cycles n in any frequency bandwidth is given by the expression

$$n = \frac{60\,\Delta f}{\lambda \ln 2}$$

where Δf = bandwidth (Hz) and λ = sweep rate (oct/min).

The CDR of 0.20 (failure is assumed at 1.00) was felt to be conservative yet generally consistent with prevailing practice in industry at present. Since the ODTM was scheduled for ultimate static testing following the vibration test, every effort had to be made to assure a healthy test structure. The analysis, performed in two phases, consisted of the following basic steps:

(1) Identification of critical primary structure.

(2) Survey of parts for material, notch-sensitive areas.

(3) Compilation of S/N curves, derivation of curve fitting equations.

(4) Obtaining loading spectrum (predicted or test).

(5) Computation of CDRs.

Phase I of the analysis, FA I, was designed to take computer-generated (response analysis) loads combined with geometric and material properties and compute the CDR. FA II did the same but was designed to accept data in digitized format. In addition, FA II would print out the contribution of each frequency interval to the total CDR for the member.

FA I performed its function as intended. FA II fell prey to the limitation noted in Subsection III-A, Data Reduction. Namely, manipulated load data was to be provided in digitized format. The effort of converting the analog signals on the tapes to digital form was finally abandoned in favor of the analog setup shown in Fig. A-1.

The net result of the fatigue analysis was that the ODTM possessed substantial margin to withstand a moderate number of FA and TA level vibration sweeps without exceeding the CDR of 0.20. This provided considerable confidence in the conduct of the test since earlier approximate hand analyses had indicated potential problems in the VLCA and bus main longerons. This confidence was borne out when a rigorous post-test dye-penetrant examination disclosed no apparent fatigue cracks.

Table A-1. Test fixture modes as a function of design iteration

Fixture mode	Frequency, Hz		
	Initial design	V-bearing plus lower ring	Torsional restraint flexures
First torsion	36	109	130
Lateral translation	102	122	122
Second torsion	147	177	183
Longitudinal translation	199	209	209

Table A-2. Comparison of two phases of response analysis (longitudinal)

Analysis component	Phase I	Phase II
Lander	Rigid	Elastic model
Fixture, shaker	Not included, spacecraft cantilevered at base of V-S/C-A	Shaker modeled, fixture assumed rigid (5-40 Hz), hydrostatic bearings included
Propellant .ks	Flight mass simulation	Test mass simulation (referee fluids)
Orbiter	Elastic model 7, no VTA, solar panel dampers	Elastic model 8, no VTA, solar panel dampers

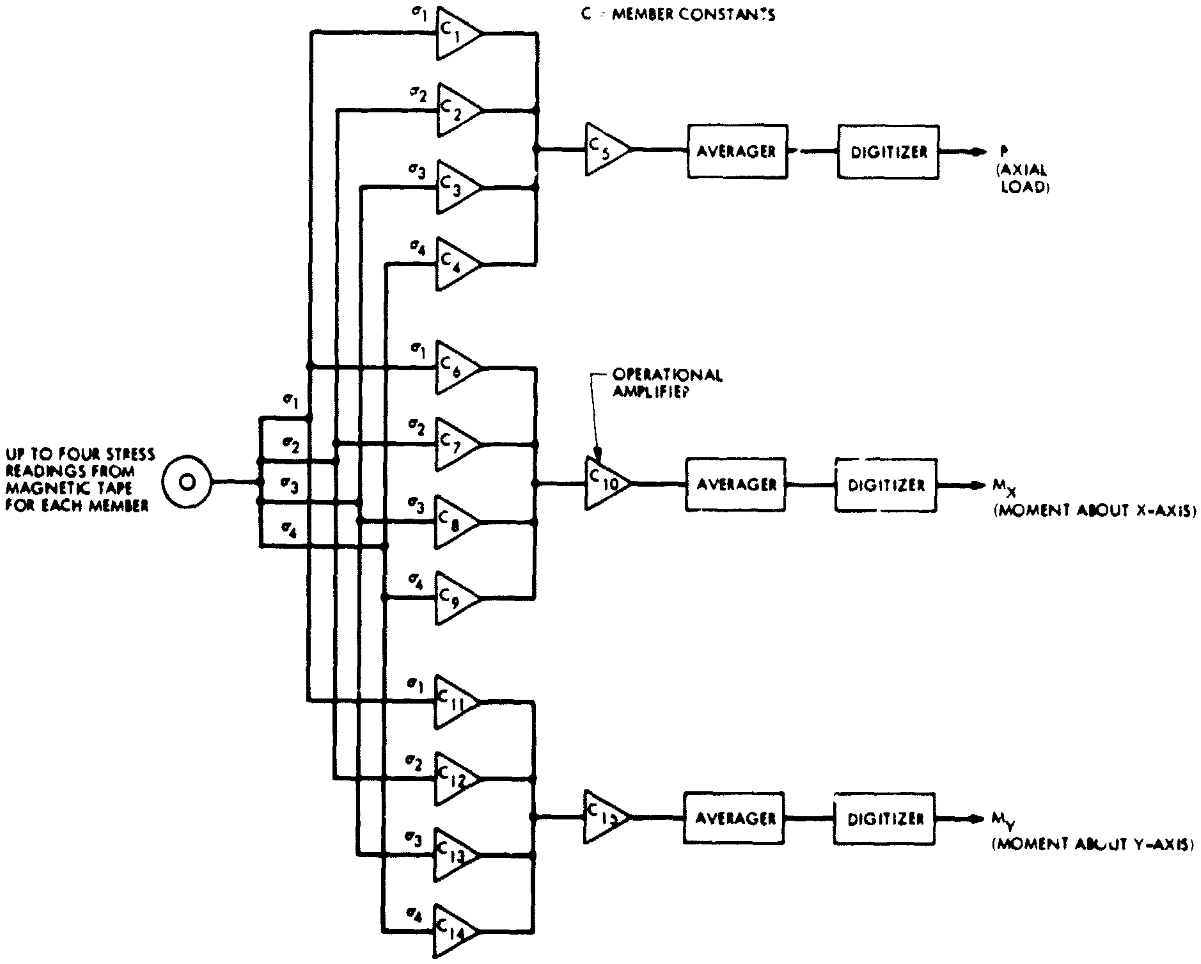

Fig. A-1. Analog load computation system

APPENDIX B

RIGID LANDER TESTING

I. SUMMARY

Initial forced vibration testing of the Viking 75 ODTM was conducted in the longitudinal axis using a rigid lander (RL). This test, a precursor to the LDTM/ODTM (Stack) Test, was accomplished October 26 through October 30, 1973. One third of type approval (TA) test levels were applied to the ODTM/RL using the same dynamic test facility and equipment to be later used on the LDTM/ODTM.

II. INTRODUCTION

The overall objective of the ODTM/RL test was to determine the readiness of JPL's dynamic test facility to conduct forced vibration testing on the LDTM/ODTM Stack. To support this objective, the following tasks were accomplished.

(1) Evaluation of the 36-channel peak select control channels.

(2) Determination of critical strain-gage control channels.

(3) Additional verification of the Viking Orbiter math model.

(4) Gathering of test data to support future PTO testing with the RL.

(5) Demonstration that hardware and handling procedures were adequate.

III. TEST PROGRAM

Except that the rigid lander was used instead of the LDTM, the test specimen and longitudinal test setup were the same as the LDTM/ODTM test.

A. TEST SPECIMEN

See Subsection II-A, main text.

B. IMPLEMENTATION

1. Longitudinal Test Setup

See Subsection II-B-1, main text, and Fig. B-1.

2. Lateral Test Setup

None.

3. Test Levels

All test runs on the ODTM/RL were made at 1/3 TA level or an input of 0.5 g (peak) over a frequency range of 7 to 200 Hz.

4. Vibration Control

See Subsection II-B-4.

5. Data Recording, Reduction

The allocation of dynamic recording channels is shown in Table B-1.

As with the LDTM/ODTM test, the 274 output signals were recorded on electromagnetic tape for all test runs. Forty-eight channels of control and housekeeping data were recorded in real time display on oscillographs for each test run.

The data reduction immediately following the rigid lander testing was to have been accomplished at the 914 data reduction facility. Format was to be as noted in Subsection III-A. Because of the limitations noted in Subsection III-A, it was necessary to playback the strain-gage data on slow-speed oscillographs and manually reduce the data using rulers, engineers, and many hours. Although arduous, the structural loads derived in this manner were accurate and contributed significantly to confidence in the test.

X-Y plots of the more critical control channels were furnished by 914 on a piecemeal basis. The first complete set of 36 plots, free from errors, was received approximately one week after delivery of the tapes to 914.

Measurement assignments and patch sheets are included in Appendix C.

6. Test Run Summary

Test sequence and run parameters are shown in Table B-2. A total of 15 separate test runs were made on the ODTM/RL during the period of October 26, 1973, through October 30, 1973. As with forced vibration tests of this type, test runs required only a few minutes whereas preparation for the test required hours.

IV. DISCUSSION OF TEST RESULTS

A. COMPARISON WITH RESPONSE ANALYSIS

Examination of Tables B-3 and B-4 will show that the test correlation with the response analysis of the ODTM/RL combination was excellent. This is especially true since the characteristics of the 36-channel peak select control system were not included in the response analysis.

In general, the frequency correlation was very close, often within a Hertz or less. The measured loads tended to be slightly higher than the predicted values.

Table B-1. Recording channel capability, tape recorder allocation

Data user	Peak select		Peak limit	Component response	Timing reference	Housekeeping	Total
	Input control	Response control					
ODTM/RL	12 (TR1)[a]	24 (TR2, 3, 4)	23	66 (78) 129 (140)	10		264
Test facility					2 (TR4)	8 (TR4)	10
Total	12	24	23	195	12	8	274

[a] Parentheses indicate tape recorder assignment.

Table B-2. Summary of ODTM/RL forced vibration test runs

Run No.	Date of run, 1973	Axis of excitation	Frequency range, Hz	Sweep rate octaves/min	Control acceleration g peak	Remarks
101	10/26	Z	128-200	2	0.5	Acceptable test.
102	10/26	Z	50-51	2	0.5	Abort on SD123 overtest circuit.
102-1	10/26	Z	50-60	2	0.5	Abort on Barry Serva-Level air pressure.
102-2	10/26	Z	55-61	2	0.5	Abort on control accelerometer 10 peak limit.
102-3	10/26	Z	55-61	2	0.5	Abort on control accelerometer 12 peak limit.
103	10/27	Z	128	2	0.5	Abort on control accelerometer 1 peak limit.
103-1	10/27	Z	128-50	2	0.5	Acceptable test.
104	10/27	Z	50-21	2	0.5	Abort on control accelerometer 5 peak limit.
105	10/27	Z	200-21	2	0.5	Acceptable test. Abort on control accelerometer 3 peak limit.
106	10/30	Z	23-22	2	0.5	Abort on control accelerometer 9 peak limit.
106-1	10/30	Z	23-21	2	0.5	Abort on control accelerometer 9 peak limit.
106-2	10/30	Z	23-12	2	0.5	Acceptable test. Abort on control accelerometer 4 peak limit.
107	10/30	Z	16-11	2	0.5	Abort on control accelerometer 1 peak limit.
107-1	10/30	Z	16-11	2	0.5	Abort on peak limit channel 355-S (Siamese tab).
107-2	10/30	Z	16-7-12	2	0.5	Acceptable test. Abort on control channel 4-peak limit.

Table B-3. ODTM/RL forced vibration test comparison of control channels

Run No.	Approximate Frequency, Hz	Control	Predicted by analysis		Comments[a]
			Yes	No	
105	200-35	All control accelerometers except 5, 6	X		
	35	Control No. 5		X	(1)
	33	Control No. 6	X		
	30	Control No. 11	X		
	28	Control No. 8	X		
	26	Control No. 6	X		
	25	Control No. 1	X		
	23	Control No. 6	X		
106-2	23	Control No. 1	X		
	22-18	Control No. 6	X		
	18-13	295-S Bedframe		X	(2), (3)
	13-12	Control No. 7	X		
107-2	16	295-S Bedframe		X	(2)
	15-12	Control No. 7	X		
	12	355-S Siamese tab		X	
	11-8	Control No. 1	X		(4)
	8-7-8	Control No. 7	X		
	8-11	Control No. 1	X		(4)
	12	355-S Siamese tab		X	

[a] (1) Bus main longeron stress control predicted at 34.4 to 35.0 Hz. Maximum stress reached 80% of peak select stress at 36 Hz.

(2) Bedframe predicted to be within 2% of controlling; i.e., at 98% of limit level.

(3) Solar panel outrigger stress control predicted at 13.77 to 13.83 Hz.

(4) Bus main longeron stress control predicted at 8.74 to 8.76 Hz.

Table B-4. Typical ODTM/RL loads derived from strain-gage measurements, com

Member	Comparison set 1						Comparison		
	Frequency, Hz		Load, N (lb)				Frequency, Hz		
	Analysis	Measured	Analysis		Measured		Analysis	Measured	Ana
VLCA									
752	13	12	3110	(700)	6000	(1350)	17	18-19	2670
753	9	9	4140	(930)	4000	(900)	15	15	3560
755	12	12	3690	(830)	5430	(1220)	—	—	—
Upper plane truss									
727	13	13	1110	(250)	670	(150)	14	14	580
730	8	8	1780	(400)	1510	(340)	15	15	440
732	—	—	—		—		—	—	—
742	9	9	1160	(260)	1200	(270)	13	15	1020
Main longeron									
Upper									
808	9	9	2800	(630)	3250	(730)	12	12	2670
837	9	9	3830	(860)	4000	(900)	12	12	2670
818	9	9	3420	(770)	3200	(720)	13	12	2800
828	8	8	3690	(830)	3650	(820)	12	12	3110
806	—	—	—		—		12	12	6360
Lower									
835	—	—	—		—		12	12	6540
816	—	—	—		—		13	12	5340
Lower diagonal									
839	12	12	2800	(630)	3020	(680)	15	15	2580
830	13	13	1330	(300)	1160	(260)	15	15	2670
Bedframe									
660	7-16	7-16	756	(170)		Low	—	—	—
664	18	13	2540	(570)	2400	(540)	18	18	2540
Propulsion module									
Side bipods									
P41	13	12	7250	(1630)	8980	(2020)	14	14	6230
P36	12	12	7700	(1730)	10,720	(2410)	13	13	5780
P04	12	13	5780	(1300)	7780	(1750)	14	14	5340
Top bipods									
7	12	12	4450	(1000)	6980	(1570)	16	18	3870
P03	12	12	1960	(440)		630	18	18	4230
Connectors									
P18	7-8	7-8	2670	(600)	2800	(830)	14	13	4090
P08	13	13	2670	(600)	3900	(880)	13	14	2670
P43	13	13	580	(130)	620	(140)	—	—	—
V-S/C-A									
686	9	8	2220	(500)	3830	(860)	12	12	4140
687	9	8	2400	(540)	3910	(880)	12	12	3870
688	8, 9	8	1910, 2800	(430, 630)	4670	(1050)	12	12	5920

FOLDOUT FRAME

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easurements, comparison with analytical predictions, 1/3 TA input, Z-axis, 8 – 40 Hz

Comparison set 2					Comparison set 3					
ency, Hz	Load, N (lb)				Frequency, Hz		Load, N (lb)			
Measured	Analysis		Measured		Analysis	Measured	Analysis		Measured	
18-19	2670	(600)	4000	(900)	24	22	3110	(700)	3690	(830)
15	3560	(800)	3960	(890)	24	22	4000	(900)	3420	(770)
—	—		—		20	22	3250	(730)	2890	(650)
14	580	(130)	670	(150)	22	22	3250	(730)	2000	(450)
15	440	(100)		Low	23	23	2490	(560)	2050	(460)
—	—		—		22	22	2670	(600)	2580	(580)
15	1020	(230)	1250	(280)	23	23	490	(110)		Low
12	2670	(600)	4890	(1100)	24	23	2540	(570)	3110	(700)
12	2670	(600)	4000	(900)	19	19	2540	(570)	3110	(700)
12	2800	(630)	3380	(760)	24	22	3110	(700)	3200	(720)
12	3110	(700)	3560	(800)	22	22	1780	(400)	1600	(360)
12	6360	(1430)	10,850	(2440)	21	19	3380	(760)	2300	(520)
12	6540	(1470)	9340	(2100)	20	19	890	(200)		Low
12	5340	(1200)	8140	(1830)	20	19	1330	(300)	1070	(240)
15	2580	(580)	2620	(590)	20	21	1600	(360)	980	(220)
15	2670	(600)	1600	(360)	22	21	1330	(300)	1380	(310)
—	—		—		20	22	2540	(570)	2400	(540)
18	2540	(570)	2800	(630)	—	—	—		—	
14	6230	(1400)	6810	(1530)	—	—	—		—	
13	5780	(1300)	6850	(1540)	24	22	4890	(1100)	5960	(1340)
14	5340	(1200)	6540	(1470)	23	22	5470	(1230)	8450	(1900)
18	3870	(870)	6490	(1460)	—	—	—		—	
18	4230	(950)		(1040)	—	—	—		—	
13	4090	(920)	4630	(880)	—	—	—		—	
14	2670	(600)	3600	(810)	23	22	2220	(500)	3900	(880)
—	—		—		23	23	580	(130)	890	(200)
12	4140	(930)	4230	(950)	13, 16	14	3670, 2360	(870, 530)	2980	(670)
12	3870	(870)	3690	(830)	12, 13	14	3670, 2540	(870, 570)	4180	(940)
12	5920	(1330)	5070	(1140)	12	15	5920	(1330)	5600	(1260)

FOLDOUT FRAME

2

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Fig. B-1. Viking 1975 ODTM/RL longitudinal (Z) axis test setup

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APPENDIX C

MEASUREMENT ASSIGNMENT SHEETS AND PATCH ASSIGNMENTS

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LDTM INSTRUMENTATION PATCH, Z-AXIS

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER 1-4	78	140	Φ	O-GRAPH 1-4	CONTROL PK. SEL.	PK. LIM.	REMARKS
DE[a]-052		2					6.79 GP	8.54 GP	Control Response (limiting)
073							3.99 GP	5.02 GP	
082							3.17 GP	6.28 GP	
301							6.23 GP	7.84 GP	
311							6.75 GP	8.5 GP	
DS[b]-328	500 μin./in.						278 μin./in	350 μin./in.	
DS-329	500 μin./in.						325 μin./in	409 μin./in.	
DS-330	500 μin./in.						270 μin./in.	340 μin./in.	
DE-309							2.23 GP	2.80 GP	
DS-332							520 μin./in.	655 μin./in.	
DS-333							234 μin./in	294 μin./in.	
111A	5-10								JPL Reference accelerometer
DE-076			6					5.02 GP	Peak Limit (Abort)
199								5.02 GP	
079								6.28 GP	
074								1.6 GP	
304								7.84 GP	
310								7.84 GP	
049								8.54 GP	
DS-331	1000 μin./in.							575 μin./in	
DE-307								7.84 GP	
312								2.86 GP	
308								8.5 GP	
043	10								Component Response
061	10								Analytical Comparison Group
064	10								
070	10								
313	30								
319	30								
111-A	5-10								JPL Reference Accelerometer
DE-044	10								Component Response
045	10								
050	10								
051	10								

[a] Accelerometer.

[b] Strain gage.

JPL 1385 8/73

LDTM INSTRUMENTATION PATCH, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER 1-4	78	140	Φ	O-GRAPH 1-4	CONTROL PK. SEL.	PK. LIM.	REMARKS
DE-058	10		6						Component Response
062									
063									
065									
066									
071									
072									
083									
075									
077									
080									
081									
200									
103									
106									
107									
108									
115									
118									
121									
122									
123									
148									
149									
150									
534									
635									
636									
302									
305									
309									
312	↓								
314	30								
315	10								
316	30								
↓ 317	30		↓						↓

JPL 1385 8/73

LDTM INSTRUMENTATION PATCH, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
DE-318	10		6						Component response
320	30								
321	10								
322	30								
323	30								
324	10								
325									
326									
327									
340									
407									
409	↓								
501	30								
502	10								
503									
504									
507									
508									
DE-509	↓		↓						↓

JPL 1385 8/73

LDTM INSTRUMENTATION PATCH, X AND Y AXES

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
DE^{a}-050	2	2					1.13 g	1.43 g	Control Response (limiting)
051	2						1.13	1.43	
074	2						1.13	1.43	
075	2						1.13	1.43	
080	2						1.13	1.43	
081	2						1.13	1.43	
302	10						6.75	8.50	
303	5						2.23	2.80	
309	5						2.23	2.80	
↓ 311	10						6.75 ↓	8.50 ↓	
DS^{b}-330	500 μin./in.						270 μin./in.	340 μin./in.	↓
		↓							JPL Reference Force Gage
DE-077	2		6					1.43 g	Peak Limit (Abort)
083	2							1.43	
305	10							8.50	
306	5							2.80	
308	10							8.50	
↓ 312	5							2.80 ↓	
DS-328	500 μin./in.							350 μin./in.	
329	500							409	
331	1000							573	
332	1000							655	
↓ 333	500 ↓							294 ↓	↓
DE-066									Analytical Comparison Group
315									
319									
320									
↓ 321									↓
DE-043									Component Input
044									
045									
049									
052									
↓ 053			↓						↓

[a] Accelerometer.

[b] Strain gage.

JPL 1386 8/73

LDTM INSTRUMENTATION PATCH, X AND Y AXES (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
DE-054			6						Component Input
058									
059									
060									
061									
062									
063									
064									
065									
070									
071									
072									
073									
079									
121									
122									
123									
137									
140									
141									
143									
144									
148									
149									
150									
175									
176									
177									
610									
611									
612									
634									
635									
636									
304									
307									

JPL 1385 8/73

LDTM INSTRUMENTATION PATCH, X AND Y AXES (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
313			6						Component Input
314									
316									
317									
318									
322									
323									
324									
325									
326									
327									
086									
087									
342									
106									
107									
108									

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, Z-AXIS

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL	PK. LIM.	
1-A[a]	10 G	1				✓	1.5 G	10.0 G	Input Controls
2-A	↓	1				✓	↓	↓	↓
3-A	↓	1				✓	↓	↓	↓
4-A	↓	1				✓	↓	↓	↓
5-A	↓	1				✓	↓	↓	↓
6-A	↓	1				✓	↓	↓	↓
7-A	↓	1				✓	↓	↓	↓
8-A	↓	1				✓	↓	↓	↓
9-A	↓	1				✓	↓	↓	↓
10-A	↓	1				✓	↓	↓	↓
11-A	↓	1				✓	↓	↓	↓
12-A	↓	1				✓	↓	↓	↓
MMA		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
288-S[b]	10.0 KSI	3				✓	6.9 KSI	9.9 KSI	Bedframe 660
289-S	↓	3				✓	↓	↓	Bedframe 660
294-S	↓	3				✓	↓	↓	Bedframe 664
295-S	↓	3				✓	↓	↓	Bedframe 664
128-S	↓	3				✓	3.5 KSI	5.1 KSI	Upper plane truss 726
129-S	↓	3				✓	↓	↓	Upper plane truss 726
140-S	↓	3				✓	4.1 KSI	5.9 KSI	Upper plane truss 730
141-S	↓	3				✓	↓	↓	Upper plane truss 730
134-S	20 KSI	3				✓	7.2 KSI	10.4 KSI	Upper plane truss 728
135-S	↓	3				✓	↓	↓	Upper plane truss 728

[a] Accelerometer.

[b] Strain gage.

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
10-S	20 KSI	3				√	7.2 KSI	10.3 KSI	VLCA 753
12-S	↓	3				√	↓	↓	VLCA 753
137-S	10.0 KSI	4				√	9.9 KSI	——	Upper plane truss 728
		4				√			V-S/C-A sum
563-P [c]		4				√			Oxidizer tank pressure
564-P		4				√			Fuel tank pressure
Shaker head		4				√			Housekeeping
Armature		4				√			↓
PA input		4				√			↓
Servo input		4				√			↓
Master		4				√			↓
Slave		4				√			↓
58-S	15 KSI-200			√					Main longeron Section A ⊥⊥ 808
59-S	↓			√					↓ 808
60-S	↓			√					↓ 808
560-S	↓			√					↓ 837
561-S	↓			√					↓ 837
562-S	↓			√					↓ 837
75-S	↓			√					↓ 818
76-S	↓			√					↓ 813
77-S	↓			√					↓ 818
91-S	↓			√					↓ 828
92-S	↓			√					↓ 828
93-S	↓			√					↓ 828
302-S	20 KSI			√				12.0 KSI	Primary truss bipod ├┤ P03
304-S	↓			√				12.0 KSI	P03
310-S	↓			√				12.0 KSI	P11
312-S	↓			√				12.0 KSI	P11
318-S	↓			√				12.0 KSI	P37
320-S	↓			√				12.0 KSI	Primary truss bipod ├┤ P37
346-S	15 KSI-200			√					Helium pressurant tank Support P28
347-S	↓			√					P28
348-S	↓			√					P28
349-S	↓			√					P28

[c] Pressure transducer.

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
342-S	15 KSI-200			✓					Helium pressurant tank support P82
343-S	↓			✓					↓ P82
344-S	↓			✓					↓ P82
345-S	↓			✓					↓ P82
131-S	10 KSI			✓				7.0 KSI	Upper plane truss 727
132-S	6 KSI-200			✓					↓ 727
133-S	↓			✓					↓ 727
1-S	20 KSI			✓				13.5 KSI	VLCA 750
2-S	↓			✓				13.5 KSI	↓ 750
3-S	↓			✓				13.5 KSI	↓ 750
7-S	↓			✓				11.0 KSI	↓ 752
8-S	↓			✓				11.0 KSI	↓ 752
9-S	15 KSI-200			✓					↓ 752
533-S	↓			✓					Scan platform diagonal support 182
534-S	↓			✓					↓ 182
535-S	↓			✓					↓ 182
536-S	↓			✓					↓ 183
537-S	↓			✓					↓ 183
538-S	↓			✓					↓ 183
138-S	↓			✓					Upper plane truss 728
139-S	↓			✓					↓ 728
145-S	20 KSI			✓				14.0 KSI	↓ 732
146-S	15 KSI-200			✓					↓ 732
350-S	6 KSI-500			✓					Helium pressurant tank support P32
351-S	↓			✓					↓ P02
352-S	↓			✓					↓ P49
353-S	↓			✓					Shear link P47
539-S	15 KSI-200			✓					Scan platform lateral brace 181
540-S	↓			✓					Scan platform lateral brace 181
541-S	↓			✓					Scan platform gimbal support 176
542-S	↓			✓					↓ 176
543-S	↓			✓					↓ 177
544-S	↓			✓					↓ 177
13-A	10 G			✓					Bus corner longeron
14-A	↓			✓					↓
15-A	↓			✓					↓

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER 1-4	78	140	Φ	O-GRAPH 1-4	CONTROL PK. SEL.	PK. LIM.	REMARKS
16-A	10 G			✓					Bus Corner longeron
17-A				✓					
18-A				✓					
19-A				✓					
20-A				✓					
21-A				✓					↓
22-A				✓					Power regulator
23-A				✓					
24-A				✓					↓
25-A				✓					DSS
26-A				✓					FDS
27-A				✓					Scan platform VIS
28-A				✓					
29-A				✓					
30-A				✓					
31-A				✓					
34-A				✓					
35-A				✓					
36-A				✓					↓
32-A				✓					MAWD
33-A				✓					
40-A				✓					
41-A				✓					
42-A				✓					↓
37-A				✓					IRTM
38-A				✓					
39-A				✓					↓
43-A				✓					Solar panels Outriggers
44-A				✓					
45-A				✓					
46-A				✓					
47-A				✓					
48-A				✓					
49-A				✓					
50-A				✓					
51-A	↓			✓					↓

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS	
		1-4	78	140	Φ		PK. SEL.	PK. LIM.		
52-A	10 G			✓					Solar panels	Outriggers
53-A	30 G			✓						Panel tip
54-A	100 G			✓						Panel tip
55-A	100 G			✓						Panel edge
56-A	100 G			✓						↓
57-A	100 G			✓						↓
59-A	30 G			✓						Outboard hinge
60-A	30 G			✓						↓
61-A	30 G			✓						↓
62-A	30 G			✓						↓
63-A	30 G			✓						Relay antenna
64-A	30 G			✓						↓
65-A	30 G			✓						↓
66-A	30 G			✓						Central location
67-A	10 G			✓					Propulsion module	Fuel tank tab
68-A	↓			✓						↓
69-A	↓			✓						↓
70-A	↓			✓						PCA
71-A	↓			✓						↓
72-A	↓			✓						↓
73-A	↓			✓						↓
74-A	↓			✓						↓
75-A	↓			✓						↓
76-A	↓			✓						↓
77-A	↓			✓						↓
78-A	↓			✓						↓
82-A	↓			✓						PIA
83-A	↓			✓						↓
84-A	30 G			✓						↓
85-A	30 G			✓						↓
86-A	10 G			✓						↓
87-A	30 G			✓						↓
88-A	10 G			✓						PMD
89-A	↓			✓						↓
90-A	↓			✓						↓
91-A	↓			✓						↓

JPL 1365 8/73

ODTM INSTRUMENTATION PATCH, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
92-A	10 G			✓					Propulsion module PMD
93-A	↓			✓					↓
94-A				✓					REA
95-A				✓					↓
96-A	30 G			✓					
97-A	10 G			✓					Bus
98-A	10 G			✓					

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, X AND Y AXES

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
1-A[a]	5.0	1				✓	1.5	4.0	Input control
2-A	↓	1				✓	↓	↓	↓
3-A	↓	1				✓	↓	↓	↓
4-A	↓	1				✓	↓	↓	↓
5-A	↓	1				✓	↓	↓	↓
6-A	↓	1				✓	↓	↓	↓
7-A	↓	1				✓	↓	↓	↓
8-A	↓	1				✓	↓	↓	↓
9-A	↓	1				✓	↓	↓	↓
10-A	↓	1				✓	↓	↓	↓
11-A	↓	1				✓	↓	↓	↓
12-A	↓	1				✓			
MMA		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
↓		2				✓			
288-S	10 KSI	3				✓	6.9 KSI	9.9 KSI	Bedframe 660
289-S	↓	3				✓	↓	↓	Bedframe 660
290-S	↓	3				✓	↓	↓	Bedframe 660
58-S	↓	3				✓	3.7 KSI	5.2 KSI	Main longeron 808
59-S	↓	3				✓	↓	↓	Main longeron 808
60-S	↓	3				✓	↓	↓	Main longeron 808
75-S	↓	3				✓	↓	↓	Main longeron 818
76-S	↓	3				✓	↓	↓	Main longeron 818
77-S	↓	3				✓	↓	↓	Main longeron 818
336-S	5 KSI	3				✓	1.6 KSI	2.3 KSI	Propulsion module bottom connector P43
176-S	10 KSI	3				✓	6.7 KSI	9.5 KSI	Bus ring 484

[a] Accelerometer.

[b] Strain gage.

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, X AND Y AXES (contd)

MEAS. NO.	RANGE F.S. (FK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
		3				✓			Armature current
193-S	10 KSI					4	6.7 KSI	———	Bus ring 620
563-P						4			Oxidizer tank pressure
564-P						4			Fuel tank pressure
						4			Armature current #11
						4			Armature current #12
						4			Armature current #13
						4			Armature current #14
						4			Power amplifier input
						4			Servo input
						4			Master
						4			Slave
560-S	10 KSI			✓				5.2 KSI	Main longeron Section A ⊥⊥ 837
561-S	6 KSI-500			✓					↓ 837
562-S	10 KSI			✓				5.2 KSI	↓ 837
91-S	10 KSI			✓				5.2 KSI	↓ 828
92-S	6 KSI-500			✓					↓ 828
93-S	10 KSI			✓				5.2 KSI	↓ 828
94-S	15 KSI-200			✓					Main longeron Section B + 830
95-S	10 KSI			✓				8.0 KSI	↓ 830
96-S	15 KSI-200			✓					↓ 830
551-S	10 KSI			✓				8.0 KSI	↓ 830
301-S	24 KSI-200			✓					↓ P03
302-S	20 KSI			✓				12.0 KSI	↓ P03
303-S	24 KSI-200			✓					↓ P03
304-S	20 KSI			✓				12.0 KSI	Primary truss bipod ├┤ P03
309-S	24 KSI-200			✓					↓ P11
310-S	20 KSI			✓				12.0 KSI	↓ P11
311-S	24 KSI-200			✓					↓ P11
312-S	20 KSI			✓				12.0 KSI	↓ P11
346-S	15 KSI-200			✓					Helium pressurant tank support P28
347-S	│			✓					↓ P28
348-S	│			✓					↓ P28
349-S	│			✓					↓ P28
342-S	│			✓					↓ P82
343-S	│			✓					↓ P82

JPL 1386 8/73

ODTM INSTRUMENTATION PATCH, X AND Y AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
344-S	↓			✓					↓ P82
345-S	↓			✓					↓ P82
131-S	6 KSI-500			✓					Upper plane truss 727
132-S	6 KSI-500			✓					Upper plane truss 727
133-S	↓			✓					↓ 727
1-S	20 KSI			✓				13.5 KSI	VCLA 750
2-S	↓			✓				13.5 KSI	↓ 750
3-S	↓			✓				13.5 KSI	↓ 750
7-S	15 KSI-200			✓					↓ 752
8-S	↓			✓					↓ 752
9-S	↓			✓					↓ 752
533-S	↓			✓					Scan platform diagonal support 182
534-S	↓			✓					↓ 182
535-S	↓			✓					↓ 182
536-S	↓			✓					↓ 183
537-S	15 KSI-200			✓					↓ 183
538-S	↓			✓					↓ 183
138-S	↓			✓					Upper plane truss 728
139-S	↓			✓					↓ 728
145-S	↓			✓					↓ 732
146-S	↓			✓					↓ 732
350-S	6 KSI-200			✓					Helium pressurant tank support P32
351-S	↓			✓					↓ P02
352-S	↓			✓					↓ P49
353-S	↓			✓					Shear link P47
539-S	15 KSI-200			✓					Scan platform lateral brace 181
540-S	↓			✓					↓ 181
541-S	↓			✓					Scan platform gimbal support 176
542-S	↓			✓					↓ 176
543-S	↓			✓					↓ 177
544-S	↓			✓					↓ 177
13-A	10 G			✓					Bus Corner longeron
14-A	↓			✓					↓
15-A	↓			✓					↓
16-A	↓			✓					↓
17-A	↓			✓					↓

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, X AND Y AXES (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
18-A	10 G			✓					
19-A				✓					
20-A				✓					↓
21-A				✓					Bus Corner longeron
22-A				✓					Power regulator
23-A				✓					
24-A				✓					↓
25-A				✓					DSS
26-A				✓					FDS
27-A				✓					Scan platform V'S
28-A				✓					
29-A				✓					
30-A				✓					
31-A				✓					
34-A				✓					
35-A				✓					
36-A				✓					↓
32-A				✓					MAWD
33-A				✓					
40-A				✓					
41-A				✓					
42-A				✓					↓
37-A				✓					IRTM
38-A				✓					
39-A				✓					↓
43-A				✓					Solar panels Outriggers
44-A				✓					
45-A				✓					
46-A				✓					
47-A				✓					
48-A				✓					
49-A				✓					
50-A				✓					
51-A				✓					
52-A	↓			✓					↓
53-A	30 G			✓					Panel tip

JPL 1386 8/73

ODTM INSTRUMENTATION PATCH, X AND Y AXES (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
59-A	30 G			✓					Outboard hinge
60-A	↓			✓					↓
61-A	↓			✓					↓
62-A	↓			✓					Solar panels Outboard hinge
63-A	↓			✓					Relay antenna
64-A	↓			✓					↓
65-A	↓			✓					↓
66-A	↓			✓					Central location
67-A	10 G			✓					Propulsion module Fuel tank tab
68-A	↓			✓					↓
69-A	↓			✓					↓
70-A	↓			✓					PCA
71-A	↓			✓					↓
72-A	↓			✓					↓
73-A	↓			✓					↓
74-A	↓			✓					↓
75-A	↓			✓					↓
76-A	↓			✓					↓
77-A	↓			✓					↓
78-A	↓			✓					↓
82-A	↓			✓					PIA
83-A	↓			✓					↓
84-A	30 G			✓					↓
85-A	↓			✓					↓
86-A	10 G			✓					↓
87-A	30 G			✓					↓
88-A	10 G			✓					PMD
89-A	↓			✓					↓
90-A	↓			✓					↓
91-A	↓			✓					↓
92-A	↓			✓					↓
93-A	↓			✓					↓
94-A	↓			✓					REA
95-A	↓			✓					↓
96-A	30 G			✓					↓
97-A	10 G			✓					Bus

JPL 1385 8/73

ODTM INSTRUMENTATION PATCH, X AND Y AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
98-A	10 G	π		✓					
				✓					Force No. 11
				✓					Force No. 12
				✓					Force No. 13
				✓					Force No. 14

JPL 1385 8/73

ODTM/RIGID LANDER INSTRUMENTATION PATCH, Z-AXIS

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
1-A	1.0 g	1				√	0.50 g	0.75g	Input Control
2-A		1				√			
3-A		1				√			
4-A		1				√			
5-A		1				√			
6-A		1				√			
7-A		1				√			
8-A		1				√			
9-A		1				√			
10-A		1				√			
11-A		1				√			
12-A	↓	1				√	↓	↓	↓
58-S	5.0 KSI	2				√	2.3 KSI	4.0 KSI	ODTM Peak Select / Main Longeron Sec A ⊥⊥ 808
59-S		2				√			808
60-S		2				√	2.3 KSI		808
560-S		2				√	2.3 KSI		837
561-S		2				√			837
562-S		2				√	2.3 KSI		837
75-S		2				√	2.3 KSI		818
76-S		2				√			818
77-S		2				√	2.3 KSI		818
91-S		2				√	2.3 KSI		828
92-S		2				√			828
93-S		2				√	2.3 KSI	↓	↓ 828
569-S		3	Run	107-2		√	2.5 KSI	3.5 KSI	Outriggers 721
268-S		3	354	S		√	2.3 KSI	4.0 KSI	L. Ring Stiffeners 809
277-S	↓	3	355	S		√	2.3 KSI	4.0 KSI	L. Ring Stiffeners 838
288-S	10.0 KSI	3				√	3.5 KSI	5.2 KSI	Bedframe 660
289-S		3				√			660
290-S		3				√			660
294-S		3				√			664
295-S		3				√			664
296-S	↓	3				√	↓	↓	↓ 664
336-S	5.0 KSI	3				√	1.5 KSI	2.5 KSI	Prop. S/S L. Brace P43
337-S		3				√			P43
338-S	↓	3				√	↓	↓	↓ ↓ P43

JPL 1355 8/73

ODTM/RIGID LANDER INSTRUMENTATION PATCH, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS	
		1-4	78	140	Φ		PK. SEL.	PK. LIM.		
		4				√			Housekeeping	
		4				√			↓	
		4				√			↓	
		4				√			↓	
		4				√			↓	
		4				√			↓	
563-P	200 PSI	4				√			Oxidizer Tank Pressure	
564-P	200 PSI	4				√			Fuel Tank Pressure	
566-S	5 KSI	4		Run 356-S	107-2	√	2.5 KSI	3.5 KSI	Outriggers (Axial)	712
567-S	↓	4				√	↓	↓	↓	706
568-S	↓	4				√	↓	↓	↓	708
570-S	↓	4				√	↓	↓	↓	710
55-S	6 KSI - 500			√					Main Longeron Sec. A ⊥⊥	806
56-S	↓			√					↓	806
57-S	↓			√					↓	806
104-S	↓			√					↓	835
105-S	↓			√					↓	835
106-S	↓			√					↓	835
72-S	↓			√					↓	816
73-S	↓			√					↓	816
74-S	↓			√					↓	816
88-S	↓			√					↓	826
89-S	↓			√					↓	826
90-S	↓			√					↓	826
107-S	15 KSI - 200		√						Main Longeron Sec. B	839
108-S	↓		√						↓	839
109-S	↓		√						↓	839
110-S	↓		√						↓	839
94-S	↓		√						↓	830
95-S	↓		√						↓	830
96-S	↓		√						↓	830
551-S	15 KSI-200		√						↓	830

JPL 1386 8/73

ODTM/RIGID LANDER INSTRUMENTATION PANEL, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS	
		1-4	78	140	Φ		PK. SEL.	PK. LIM.		
297-S	20.0 KSI		✓					12.0 KSI	Primary Truss Bipod ⊢	P04
298-S	20.0 KSI		✓					12.0 KSI		P04
299-S	24 KSI - 200		✓							P04
300-S			✓							P04
301-S			✓							P03
302-S			✓							P03
303-S			✓							P03
304-S	↓		✓							P03
321-S	20.0 KSI		✓					12.0 KSI		P41
322-S	20.0 KSI		✓					12.0 KSI		P41
323-S	24 KSI - 200		✓							P41
324-S			✓							P41
325-S			✓							P40
326-S			✓							P40
327-S			✓							P40
328-S	↓		✓							P40
305-S	20.0 KSI		✓							P12
306-S	20.0 KSI		✓							P12
307-S	24 KSI - 200		✓							P12
308-S			✓							P12
309-S			✓							P11
310-S			✓							P11
311-S			✓							P11
312-S	↓		✓							P11
313-S	20.0 KSI		✓							P36
314-S	20.0 KSI		✓							P36
315-S	24 KSI - 200		✓							P36
316-S			✓							P36
317-S			✓							P37
318-S			✓							P37
319-S										P37
320-S	↓								↓	P37
332-S	15 KSI - 200			✓					Heavy Connector ☐	P18
333-S	15 KSI - 200			✓					Heavy Connector ☐	P18

JPL 1385 8/73

ODTM/RIGID LANDER INSTRUMENTATION PANEL, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS		
		1-4	78	140	Φ		PK. SEL.	PK. LIM.			
334-S	15 KSI - 200			√					Heavy Connector	☐	P18
335-S				√					Heavy Connector	☐	P18
291-S				√					Bedframe	○	662
292-S				√							662
293-S				√							662
285-S				√							658
286-S				√							658
287-S				√					↓	○	658
329-S				√					Top Lateral Brace	○	P08
330-S				√							P08
331-S	↓			√					↓	○	P08
131-S	6 KSI - 500			√					Upper Plane Truss	○	727
132-S				√							727
133-S				√							727
128-S				√							726
129-S				√							726
130-S				√							726
149-S				√							742
150-S				√							742
151-S				√							742
152-S				√							746
153-S				√							746
154-S				√							746
1 0-S				√							730
141-S				√							730
142-S				√					↓	○	730
19-S				√					V-S/C-A	○	686
20-S				√							686
21-S	↓			√							686
22-S	15 KSI - 200			√							687
23-S				√							687
24-S				√							687
25-S				√							688
26-S				√							688
27-S				√							688
28-S	↓			√					↓	○	689

JPL 1385 8/73

ODTM/RIGID LANDER INSTRUMENTATION PANEL, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL	PK. LIM.	
29-S	15 KSI - 200			√					V-S/C-A ○ 689
30-S				√					689
31-S				√					690
32-S				√					690
33-S	↓			√					690
34-S	6 KSI - 500			√					691
35-S				√					691
36-S				√					691
37-S				√					692
38-S				√					692
39-S				√					692
40-S				√					693
41-S				√					693
42-S				√					693
43-S				√					694
44-S				√					694
45-S				√					694
46-S				√					695
47-S				√					695
48-S	↓			√					695
49-S	15 KSI - 200			√					696
50-S				√					696
51-S	↓			√					696
52-S	6 KSI - 500			√					697
53-S				√					697
54-S	↓			√					↓ ○ 697
1-S	15 KSI - 200			√					VLCA ○ 750
2-S				√					750
3-S				√					750
4-S				√					751
5-S				√					751
6-S				√					751
7-S				√				6.1 KSI	752
8-S				√					752
9-S				√					752
10-S	↓			√				↓	↓ ○ 753

JPL 1385 8/73

ODTM/RIGID LANDER INSTRUMENTATION PANEL, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS
		1-4	78	140	Φ		PK. SEL.	PK. LIM.	
11-S	15 KSI - 200			√				6.1 KSI	VLCA ○ 753
12-S				√				6.1 KSI	753
13-S				√					754
14-S				√					754
15-S				√					754
16-S				√					755
17-S				√					755
18-S	↓			√					↓ ○ 755
136-S	6 KSI - 500			√					Upper Plane Truss ⊥T 728
137-S				√					728
138-S				√					728
139-S				√					728
145-S				√					732
146-S				√					732
147-S				√					732
148-S	↓			√			Run 107-2		↓ ⊥T 732
354-S	20.0 KSI			√			10.0 KSI	18.0 KSI	Siamese Tab △ B33
355-S				√					B34
356-S	↓			√			↓	↓	B35
357-S	48 KSI - 100			√					B33A
358-S				√					B34A
359-S	↓			√					↓ △ B35A
									↓
134-S	6 KSI - 500			√					Upper Plane Truss (Axial) 728
135-S				√					728
143-S				√					732
144-S	↓			√					↓ (Axial) 732
552-S	2000 lb		√					2000 lb	Separation Bolts Upper Plane
553-S			√						
554-S			√						
555-S	↓		√						↓ ↓

JPL 1385 8/73

ODTM/RIGID LANDER INSTRUMENTATION PANEL, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER				O-GRAPH 1-4	CONTROL		REMARKS	
		1-4	78	140	Φ		PK SEL.	PK. LIM.		
556-S	2000 lb		√					2000 lb	Separation Bolts	Lower Plane
557-S	↓		√					↓	↓	↓
558-S	↓		√					↓	↓	↓
559-S	↓		√						↓	↓
70-A	2.5 g		√						Accelerometers	PCA
71-A	1.5 g		√						↓	↓
72-A	3.0 g		√						↓	↓
76-A	2.0 g		√						↓	↓
77-A	1.3 g		√						↓	↓
78-A	2.8 g		√						↓	↓
73-A	2.5 g		√						↓	↓
74-A	1.5 g		√						↓	↓
75-A	3.0 g		√						↓	↓
79-A	2.5 g		√						↓	↓
80-A	1.5 g		√						↓	↓
81-A	3.0 g		√						↓	↓
99-A	2.5 g		√						↓	↓
100-A	1.5 g		√						↓	↓
101-A	3.0 g		√						↓	↓
85-A	2.6 g		√						↓	PIA
86-A	3.1 g		√						↓	↓
87-A	3.1 g		√						↓	↓
88-A	1.5 g		√						↓	PMD
89-A	2.0 g		√						↓	↓
90-A	3.0 g		√						↓	↓
91-A	1.5 g		√						↓	↓
92-A	2.0 g		√						↓	↓
93-A	3.0 g		√						↓	↓
67-A	1.2 g		√						↓	Fuel Tank Tab
68-A	1.9 g		√						↓	↓
69-A	2.8 g		√						↓	↓
27-A	5.7 g			√					↓	Scan Platform
32-A	8.1 g			√					↓	↓
33-A	5.8 g			√					↓	↓
37-A	5.4 g			√					↓	↓
38-A	6.8 g			√					↓	↓

JPL 1385 8/73

ODTM/RIGID LANDER INSTRUMENTATION PANEL, Z-AXIS (contd)

MEAS. NO.	RANGE F.S. (PK.)	TAPE RECORDER 1-4	78	140	Φ	O-GRAPH 1-4	CONTROL PK. SEL.	PK. LIM.	REMARKS	
39-A	8.5 g			√					Accelerometers	Scan Platform
43-A	1.7 g			√						Outrigger
44-A	3.3 g			√						
45-A	4.8 g			√						
46-A	1.7 g			√						
47-A	5.5 g			/						
48-A	5.7 g			√						
49-A	2.7 g			√						
50-A	13.5 g			√						
51-A	3.0 g			√						
52-A	14.0 g			√						↓
53-A	2.9 g			√						Solar Panels
54-A	5.2 g			√						Solar Panels
94-A	2.4 g			√						PEA
95-A	3.0 g			√						
96-A	2.7 g			√						↓
28-A	9.6 g			√						Scan Platform
29-A	5.6 g			√					↓	Scan Platform

JPL 1385 8/73

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