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Aries Rocket Flight Vibration Environment, TEM-2, Multispectral Measurements Program

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1. INTRODUCTION

The purpose of this work was to obtain in-flight environment data on Aries. This report and the report in Reference 1 on TEM-1 (target engine measurement no. 1) address in-flight vibration. These measurements were obtained independently of the first flight, using all new vibration instrumentation and vehicle and payload hardware. The design was the same, with some minor exceptions in the payload sensor section configuration. The results from the second flight agree well with that obtained from the first, and are being used as a basis for lowering the flight acceptance vibration test levels for Aries. Three vibration pickups were used for this measurement. All accelerations were measured parallel to the flight axis and the pickup locations were similar to that in the TEM-1 flight.[1] (See Figure 1.)

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1. Steeves, R. G. (1979) Aries rocket flight vibration environment, multispectral measurements program, AIAA 79:0514.

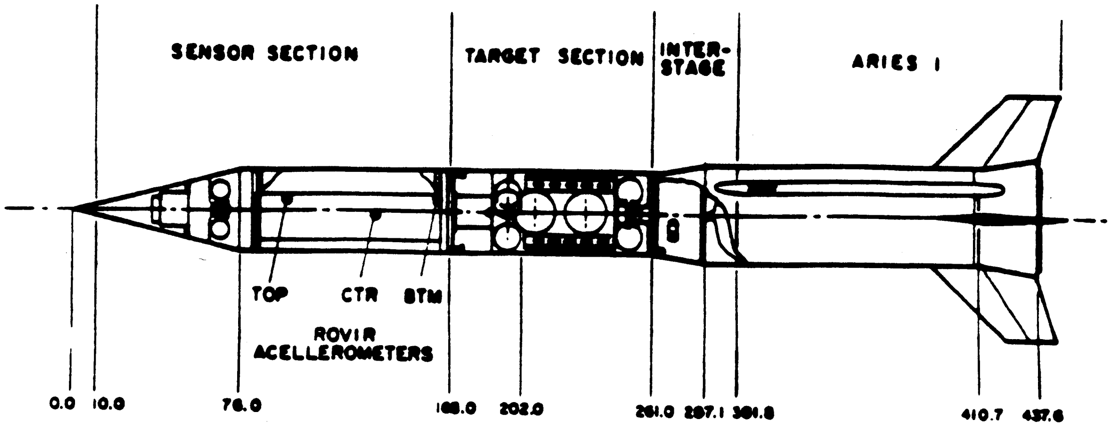

Figure 1. TEM-2 Vehicle

2. DATA ANALYSIS

Calibration of the ROVIR instrumentation (rocket-borne vibration recorder) against a control standard is presented in detail by Charron et al.[2] This calibration was conducted with three different types of transducer excitation: random vibration, transient wave shock (half sine), and shock pulse (for shock response spectra). Data from ROVIR was telemetered, received, and recorded at the telemetry ground station and then played back to a Time/Data Corp. digital vibration analyzer (see Table 1) for spectral and waveform analysis. These data were then compared with the analysis of the real time recorded control accelerometer data. A feature of the ROVIR design is a variable gain or gain break amplifier which permits acquisition of accelerations as high as 20 g's, but with very good resolution of data less than 1 g peak.

A more direct measure of ROVIR instrumentation calibration accuracy was obtained during sensor section system vibration flight acceptance tests at Acton Laboratories, Acton, Massachusetts, 12 March 1980.

In this test, directly monitored accelerometers were mounted very close to the ROVIR accelerometers in the flight structure. ROVIR data were then handled in the same way as in flight: that is, signal conditioned, telemetered, recorded, played back, and analyzed. These data were then compared to the direct monitor

2. Charron, R. W., Campbell, T. J., DiMilla, T. Jr., and Smart, L. P. (1978) Electronic Supporting Units for Sounding Rockets, AFGL-TR-78-0153, Sec. 3, AD A062241.

Table 1. Digital Vibration Control and Analysis System

System Hardware - TDV 53 PSS, Time/Data Corporation

Manufacturer	Model Number	Serial Number	Item Name
Digital	rx 01	WS11236	Floppy Disc Drive
Digital	pdp 11/35	0105011	Mini Computer
Tektronix	603	B102550	Storage Scope
Time/Data	1923-3001	5047	LSI (Digital Source Interface)
Time/Data	1923-3003	5048	ACE (Analog Conditioning Element)
Time/Data	1923-3014	5085	VACE (Vibration Analog Conditioning Element)
Ex-Cell-O Corp.	RR-600BBX/66X		High-Speed Paper Tape Reader
Teletype Corp.	3320 3JO		Teletype

System Software - Time/Data Corporation

Floppy Disc:		
#1923-0631-02	VR 31 TR - Random Vibration Control	Verified: 16 Dec 77
#DEC-11-CRTSA-E-YCI	RT 11 V020 - Floppy Disc Control	Verified: 17 Dec 76
Paper Tape:		
#1923-0401-05	VR 51 F - Random Vibration Control	Verified: 5 Aug 76
#1923-0319-06	VSST - Shock Spectrum Synthesis/TFF	Verified: 16 Aug 76
#1923-0321-07	VTWI - Transient Waveform Control	Verified: 16 Aug 76
#1923-0346-04	VSSW - Shock Spectrum Synthesis/WAE	Verified: 16 Aug 76
#1923-0318-06	VSAI - Shock Spectrum Analysis	Verified: 10 Feb 76

accelerometer data. See Figure 2 (ROVIR data) versus Figure 3 (monitor) for the center-mounted accelerometer, and Figure 4 (ROVIR) versus Figure 5 for the forward pickup. Flight data were not obtained from the aft pickup due to instrumentation failure. Figure 6 shows the input control excitation level for the flight acceptance test at Acton Laboratories. This same reference is shown on all ROVIR figures. Notice scale changes. The Acton analyses were done on a different computer than was used for ROVIR data analysis, but both used Time/Data machines. Note that agreement is very good, with differences being due primarily to 60 Hz system noise and the small difference in pickup mounting.

High-quality data were obtained from the TEM-2 launch at White Sands Missile Range, New Mexico, on 21 May 1980. Flight data (ROVIR) Figure 7 should be compared to Figure 2 to get a feeling of the flight vibration intensity versus that in testing. Note the comparison of spectra and overall 0.4545 grms flight versus 6.691 grms test. Flight data Figure 8 should be compared to Figure 4. Note, again, overall 0.4108 grms flight versus 1.913 grms test. Reference 1, flight number 1, shows that the center ROVIR accelerometer saw an overall 0.8051 grms and to top ROVIR accelerometer 0.2359 grms. Spectral shapes are comparable. The DOF number in each figure is a measure of the data smoothing, and in this case was a linear averaging of spectra from T-0 (start of test at full level for test and time of liftoff for flight). DOF is defined as:

$$DOF = 2NL$$

where

N = Number of spectral frames per display loop
L = Number of loop analyzed and displayed

The time shown is not particularly relevant because it is only the time elapsed since the computer analysis began. The data presentation or averaging was initialized by a reset command given the analyzer at liftoff. The flight data plotted here is the average random vibration environment between T-0 and T+17 sec and is representative of that observed during Aries boost phase.

Some spectral peaks in the flight data are due to system analysis background noise which varies due to the Air Force Geophysics Laboratory environment. This noise represents a valid data threshold for analysis purposes, and is as low as 0.07 grms (see Reference 1), and as high as that shown in Figure 9. Note that peaks occur at odd harmonies of 60 Hz.

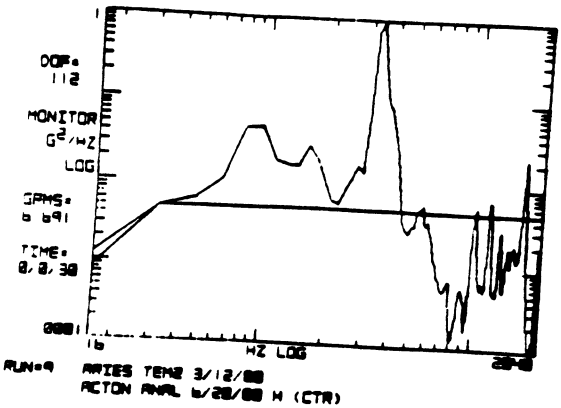

Figure 2. ROVIR (Center)

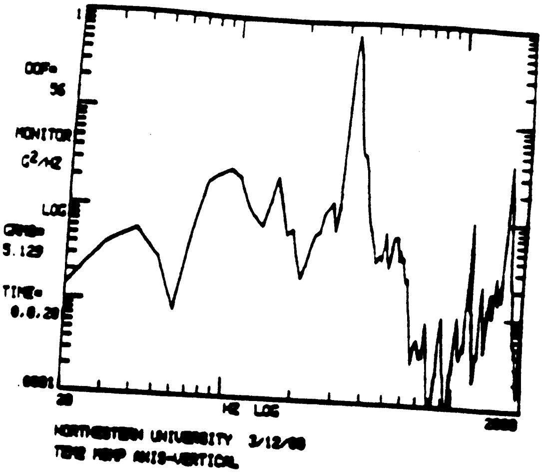

Figure 3. Acton (Center) Monitor

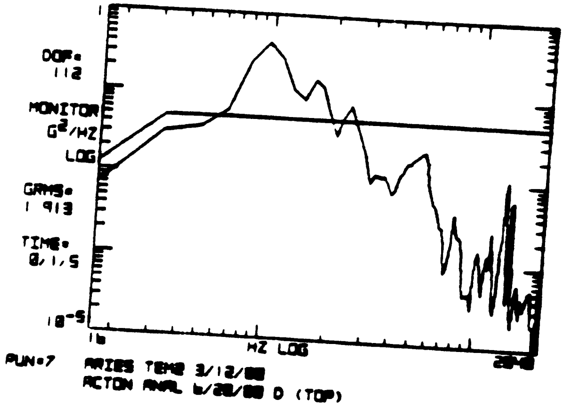

Figure 4. ROVIR (Top)

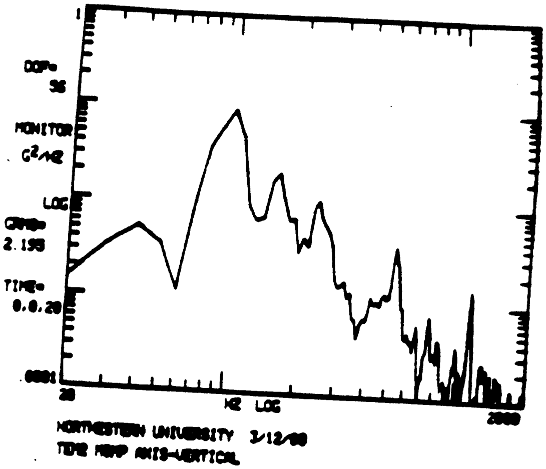

Figure 5. Acton (Top) Monitor

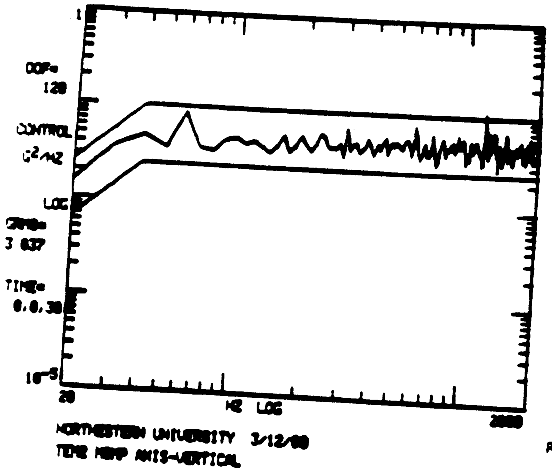

Figure 6. Acton Control Monitor

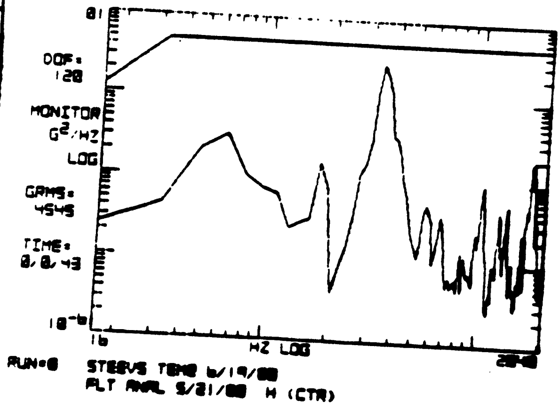

Figure 7. Flight Data, ROVIR (Center)

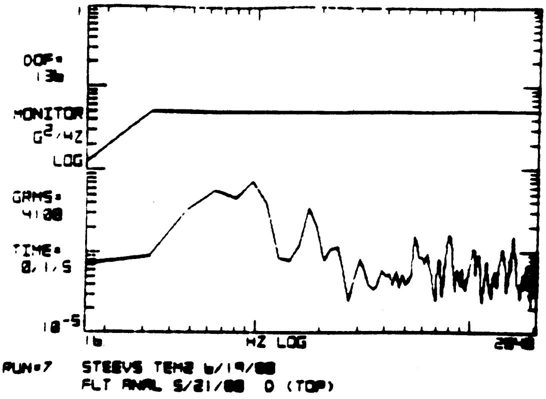

Figure 8. Flight Data, ROVIR (Top)

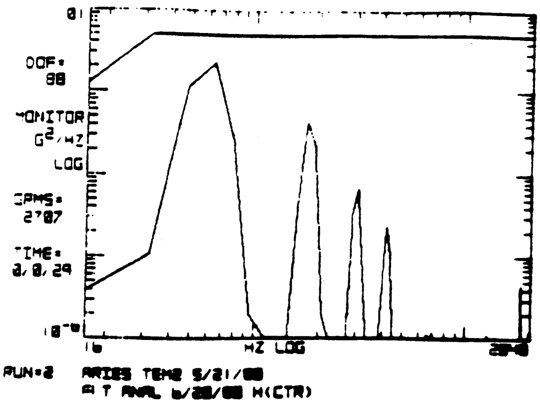

Figure 9. System Noise

3. QUALITATIVE INTERPRETATION

The TEM-2 data help confirm those qualitative interpretations drawn from the TEM-1 data.[1] They are: most vibration excitation in flight is caused by acoustical and aerodynamic excitation of the body skin, and vibration is probably fairly uniform in all axes. Only the flight axis was analyzed here. Vibration was near zero after about T+40 sec as the rocket was leaving sensible atmosphere. Motor burnout is at T+63 sec.

4. CONCLUSIONS AND RECOMMENDATIONS

Vibration levels recorded in flight for two Aries rocket launches agree well with each other and are well below test levels. The low vibration levels recorded in this payload configuration are probably due primarily to its segmented, heavy walled, rubber-gasketed skin panels. Structures with lower mass and lower damped skins could see higher levels. Test levels for TEM-2 were reduced on a trial basis as a result of the TEM-1 flight data analysis.

Since TEM-2 vibration is still significantly below even the reduced test levels, adoption of those reduced levels seems appropriate for all Aries payloads. Reduced vibration test levels as shown in Appendix A are recommended for future Air Force Aries payloads.

Vibration excitation at the payload base continues to be an economic compromise. Acoustic excitation would simulate the flight environment more accurately.

Appendix A

Vibration Test Specification

1. PURPOSE

These tests demonstrate the ability of components and system segments to withstand or, if appropriate, operate in the dynamic environment imposed during ground transportation, handling, and in flight. Qualification test levels include an additional margin of safety.

2. TEST DESCRIPTION

The component shall be mounted to a rigid structure through the normal mounting points of the component. The system segment shall be mounted to a rigid structure utilizing an appropriate adapter fixture. The components shall be tested in each of three orthogonal directions, one direction being parallel to the thrust axis. System segments shall be tested only along the thrust axis.

3. TEST LEVELS/DURATION

3.1 Qualification Tests

a. Component

Flat spectrum @ 0.1 g^2/Hz
100 — 2000 Hz with roll off below
100 Hz at 6 dB/oct to 20 Hz (~ 14.0 g)

b. System Segment

Flat spectrum @ 0.02 g^2/Hz
40—2000 Hz with roll off below
40 Hz at 6dB/oct to 20 Hz (~ 6.3 g)

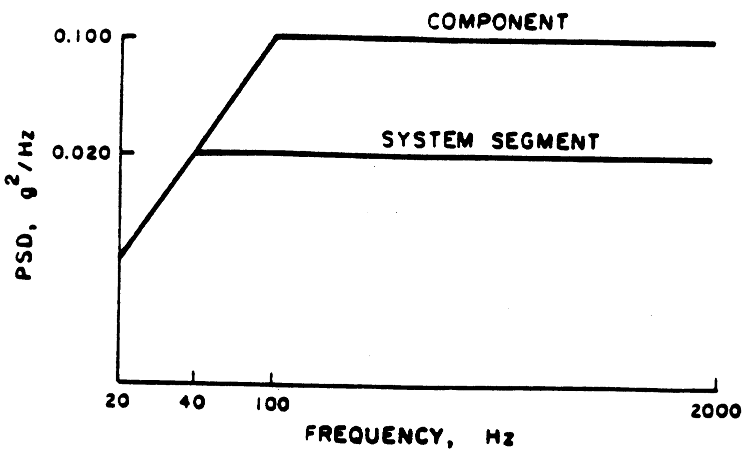

Figure A1. Aries Random Vibration Qualification Levels

c. Duration

Component vibration duration shall be 3 minutes in each of the three orthogonal axes. Test duration for the System Segment shall be 3 minutes along the thrust axis only.

d. Test Condition Tolerances

Power Spectral Density (50 Hz band or narrower)
20 to 500 Hz ± 1.5 dB
500 to 2000 Hz ± 3 dB
Random Overall g ± 1.5 dB

3.1.1 SUPPLEMENTARY DATA - QUALIFICATION

Random vibration levels specified are at least 6 dB above the maximum expected Aries flight random vibration envelope and as such are not recommended for flight hardware testing but are recommended to qualify a new design or design not previously flight qualified. Like units that are to be individually acceptance tested shall be individually qualification tested. Required component (except electroexplosive device) qualification tests may be conducted with waiver at the subsystem or system segment levels of assembly if such combined testing of

3.2 Acceptance Tests

a. Component

Flat spectrum @ 0.025 g^2/Hz
100—2000 Hz with roll off below
100 Hz at 6 dB/oct to 20 HZ (~ 7.0 g)

b. System Segment

Flat spectrum @ 0.005 g^2/Hz
100—2000 Hz with roll off below
40 Hz at 6 dB/oct to 20 Hz (~ 3.1 g)

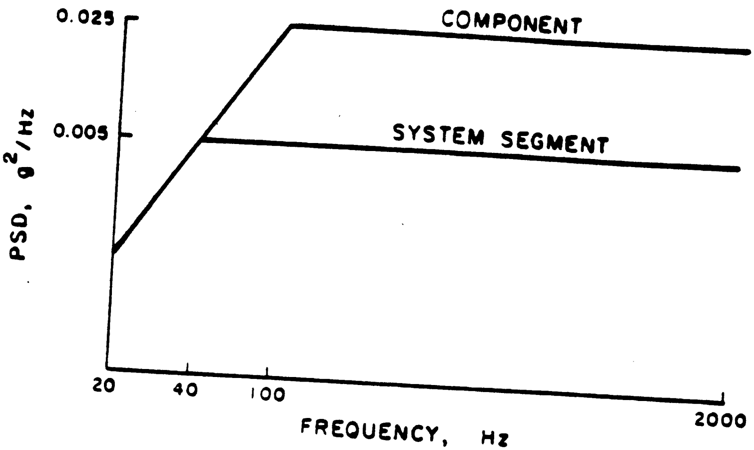

Figure A2. Aries Random Vibration Acceptance Level

c. Duration

Component vibration duration shall be one minute in each of the three orthogonal axes. Test duration for the System Segment shall be 1 minute along the thrust axis only.

d. Test Condition Tolerances

Same as 3.1d

3.2.1 SUPPLEMENTARY DATA — Acceptance

Acceptance testing shall be conducted with subsystems and subassemblies operating and monitored. The random vibration levels specified approximate the maximum Aries flight random vibration envelope and represent a reasonable conservative excitation level (system segment input) and structural response level (component input) for Aries flights. Like units that were individually qualification tested, if applicable, shall be individually acceptance tested. Required component acceptance tests may be conducted with waiver at the subsystem or system segment levels of assembly if such combined testing of components is cost effective, and can provide an equivalent or better test than individual component tests. Acceptance tests can be repeated on flight units without causing significant degradation. Any exception to the above requirements must receive a specific waiver from the Chief Systems Engineer, AFGL/LCR.