NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

*Technical Memorandum 33-427*

# *Observed Vibration Environment of a Panel Van for Representative Urban Road Conditions*

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## Preface

The work described in this report was performed by the Guidance and Control Division of the Jet Propulsion Laboratory.

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## Abstract

This report provides shock and vibration information for a single rear-axle panel van with leaf-spring suspension. Previous reports have given the measured characteristics of tandem-axle vans with air-ride suspensions, but little information was available on panel trucks. The equipment and procedures used in this test were similar to those noted above, but the statistical sampling of data was much smaller.

# Observed Vibration Environment of a Panel Van for Representative Urban Road Conditions

## I. Introduction

A panel truck, or van, was selected to carry the SEAN (Strapdown Electrostatic Aerospace Navigator) System components during the land navigation phase of the final testing and checkout. Prior to installation, however, the level of vibration and magnitudes of transmitted shocks for representative road surfaces were measured in order that the optimum position for delicate system components could be located, and also to provide data so that adequate isolation could be implemented for their protection.

## II. Description of Equipment

### A. Van

The van or panel truck to be instrumented was a GMC Model P4710P chassis with a fiberglass body built to JPL specifications. It was powered by a 293-in.$^3$, 6-cylinder engine developing 170 hp, and had an unladen sprung weight of 6270 lb. The total unladen weight of the van was 8270 lb, and gross vehicle capability was 18,000 lb (See Fig. 1). During the test the van carried simulated weight load of approximately 5000 lb including the weight of the three-man crew.[1] Mockups of SEAN System consoles containing lead bricks were used to simulate the approximate weight and center of gravity of the system

[1]Previous reports (Refs. 1 and 2) gave measured characteristics of tandem-axle vans.

**Fig. 1. SEAN System van and trailer**

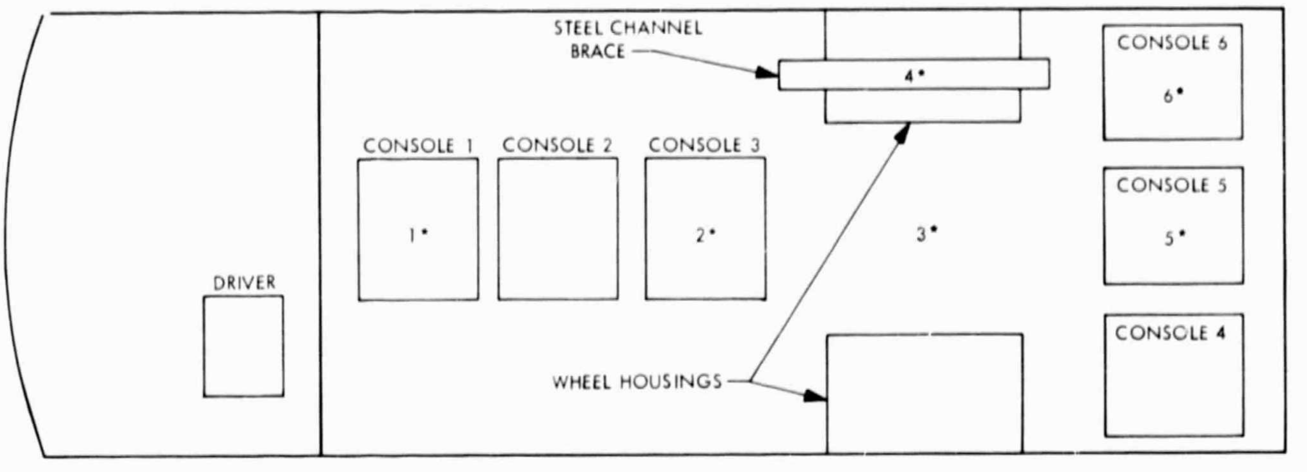


**Fig. 2. Console and sensor block locations**

components. The consoles were arranged as shown in Fig. 2. One of the consoles was shock-mounted, but the top was constrained only by tying it to the next console with nylon rope. The others were bolted to the floor.

In addition, a trailer containing the motor generator set that provides power to the SEAN System was towed. The combined weight of the M-G set and trailer was 4150 lb.

### B. Instrumentation

Four accelerometers of the piezoelectric crystal type were glued to each of three phenolic blocks. As shown in Fig. 3, each sensor block had one accelerometer with its sensitive axis in the longitudinal direction, one with its sensitive axis in the lateral, and two with their sensitive axes in the vertical direction. Only three sensor blocks were made up because a magnetic tape recorder with a 14-channel capacity was to be used.

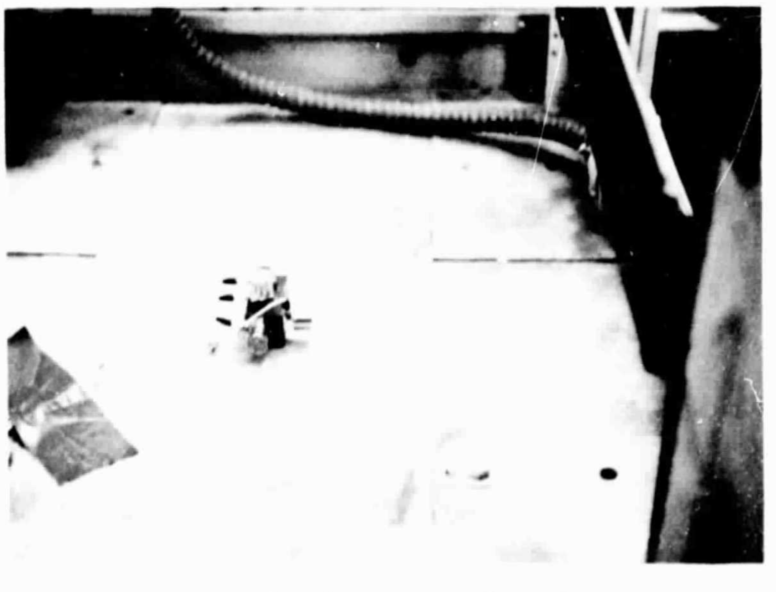

**Fig. 3. Accelerometer orientation**

Channels 1 through 12 on an FM magnetic tape recorder were used to record the accelerometer signals. The charge amplifiers were set so that the full-scale sensitivity on one signal in each of the orthogonal axes for the respective sensor blocks was 10 *g* zero to peak. The full-scale sensitivity for the remaining vertical signal from each block was set for 2 *g* zero to peak. The second scale was used to "blow up," or better display, the effects expected on the vertical axis. The tape was run at 1⅞ in./s giving a flat frequency response of 5–625 Hz.

The six positions to be monitored were selected and are shown in Fig. 2. Positions 1, 2, and 5 were located on the bases of simulated consoles that were bolted to the van floor. Position 3 was located on the floor over the rear axle, and position 4 was on a steel channel brace over the wheelwell. Position 6 was on the base of the shock-mounted console. A sensor block was glued at each of these positions when it was to be monitored. In each case the longitudinal, lateral, and vertical axes of the block were oriented to the corresponding axes of the van. Because of the recorder capacity, only three positions could be monitored at one time.

## III. Procedure

### A. Road Test

It was determined that the route selected for the test should incorporate the following four road conditions:

(1) Smooth roads.

(2) Moderately rough roads with bumps and dips.

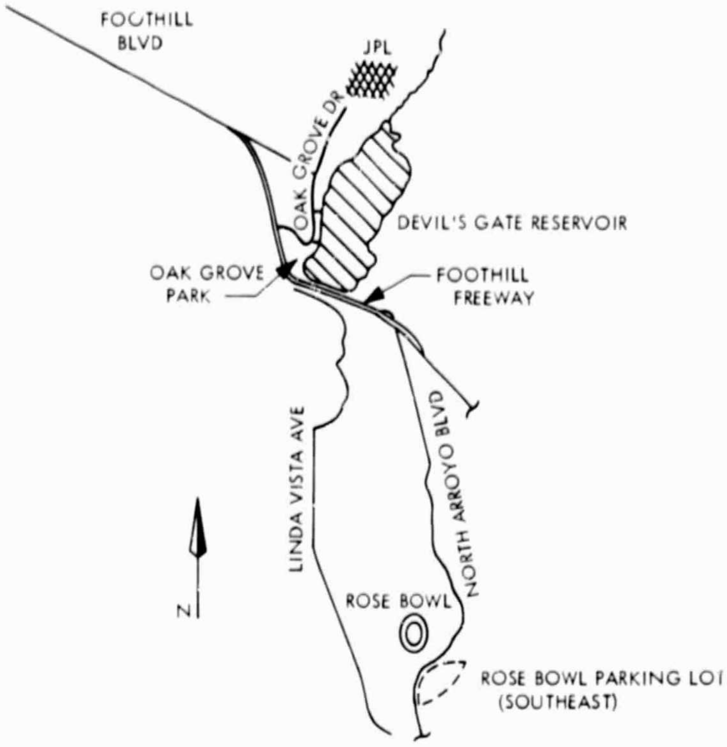


**Fig. 4. Road test locale**

(3) Rough surfaces with ruts, bumps, rocks, and holes.

(4) An abrupt dropoff such as a curb.

These conditions were available on city streets and off-road locations near JPL. Refer to the map shown in Fig. 4. Foothill Boulevard, the Foothill Freeway, and Oak Grove Drive were selected as smooth roads; North Arroyo Street was taken to be a moderately rough road; the southeast Rose Bowl parking lot was used as a rough surface; and a chuckhole 5 in. deep located in the parking lot at Oak Grove Park was used as the abrupt dropoff. Two runs were made over a course including these locations. For the first run the sensor blocks were placed in positions 1, 2, and 3, and for the second runs they were placed in positions 4, 5, and 6. Smooth roads were traversed at speeds up to 45 mph, moderately rough roads up to 35 mph, and rough roads up to 25 mph; the 5-in. dropoff was taken at approximately 5 mph during each run. Total driving time including both runs represents about 3 h. A voice description of situations encountered was logged on channel 13 of the tape so that the data could be correlated to events at a later time.

### B. Data Reduction

The first step in the data analysis was to dub the NASA time code on to channel 14 of the tape. This was done at 15 in./s instead of 1⅞ in./s, so a 1-s mark on the time code actually represented approximately 8 s of real-time data. The entire tape, including calibrations, was transferred to an oscillographic recording run at 2.5 in./s for a tape playback speed of 15 in./s.

The printout was scanned, and events from the voice track were correlated with the time code. Since 12 traces were being displayed on the readout, the scaling was small, and it was hard to determine precise amplitudes. However, it was obvious that position 1 had the most favorable shock and vibration characteristics. The worst position appeared to be position 5 at the rear center of the van. The decision was made to further analyze data for these two points only, since the data from the other locations fell in between. Also, since the magnitudes of shock and vibration inputs in the longitudinal and lateral directions appeared relatively small, further analysis was confined to vertical inputs.

Some 15 data samples representing all road conditions in positions 1 and 5 were selected from the original printout. The vertical channel signals having a 10-$g$ zero-to-peak scale were then read out onto a second oscillograph recording at 2.5 in./s, but at a tape playback speed of 1⅞ in./s. Amplitude scaling was also increased in order that peak effects could be scaled accurately.

To this point the expanded raw data samples had only been observed for peak effects without regard to frequency. The next step was to produce power spectral density plots for selected data. The portions of data reduced to PSD plots were partial segments of the expanded samples mentioned above for positions 1 and 5. Since it was felt that smooth and moderately rough road surfaces were the most representative for test purposes, PSD plots were made for these conditions only. This refinement of the data was concentrated in the low-frequency range, and a 0.244-cycle resolution was employed. The resulting plots showed the rms contributions of frequencies between 2 Hz and approximately 60 Hz. A digital computer program available at JPL was used to produce the PSD plots, and further details can be obtained from Ref. 2. The reference for the plots is 0 dB = $1g^2$/Hz.

The next phase of data analysis was to filter the original data from the vertical channel at position 1 to determine the specific $g$ level contributions of the 2–10-Hz and 125–135-Hz bandwidths.

The final phase of the analysis was directed toward determining the time duration of the peak amplitudes observed at positions 1 and 5. In order to achieve this, a third oscillographic printout was run for several of the worst amplitude conditions. The time scale was expanded again by uping the chart speed to 10 in./s.

## IV. Results

### A. Peak Amplitude Effects

Maximum *g* levels observed at various speeds and road conditions were scaled from expanded oscillographic data samples. Examples are shown in Figs. 5 and 6. The results are shown in Table 1.

### B. Vibrations Levels

The maximum observed rms *g* levels for the frequency range of 2 to 60 Hz over moderately rough roads were 0.1 *g* at position 1 and 0.2 *g* at position 5. Sample PSD plots showing these conditions are shown in Figs. 7 and 8.

**Table 1. Maximum *g* levels observed**

| Road condition and speed | Position 1 (front center), *g* | Position 5 (rear center), *g* |
|---|---|---|
| Smooth | | |
| Starting up | 0.9 | 0.7 |
| 20 mph | 0.9 | 2.7[a] |
| 25 mph | — | 1.8 |
| 45 mph | 1.2 | 1.3 |
| Coming to a stop | 1.2 | 1.0 |
| Moderately rough | | |
| 30 mph | 1.1 | 1.8 |
| Rough | | |
| 20 mph | 1.3 | 2.7 |
| 5-in. dropoff | | |
| 5 mph | 0.4 | 1.7 |

[a]Unusually high peaks on smooth roads are attributed to transitions in the pavement (i.e., manhole covers, joints, traffic signal trippers).

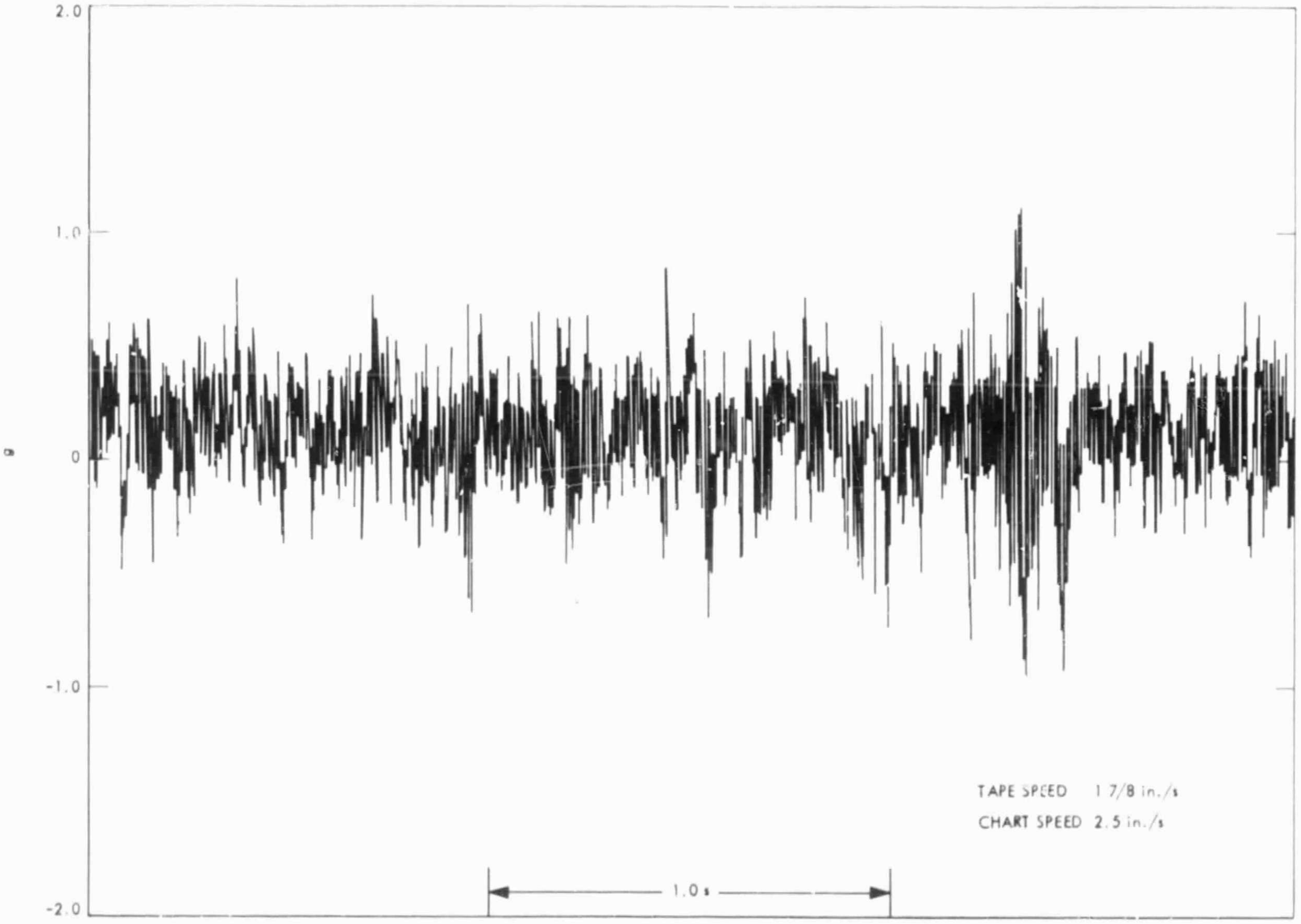


Fig. 5. Sample expanded data for position 1, moderately rough road, 30 mph

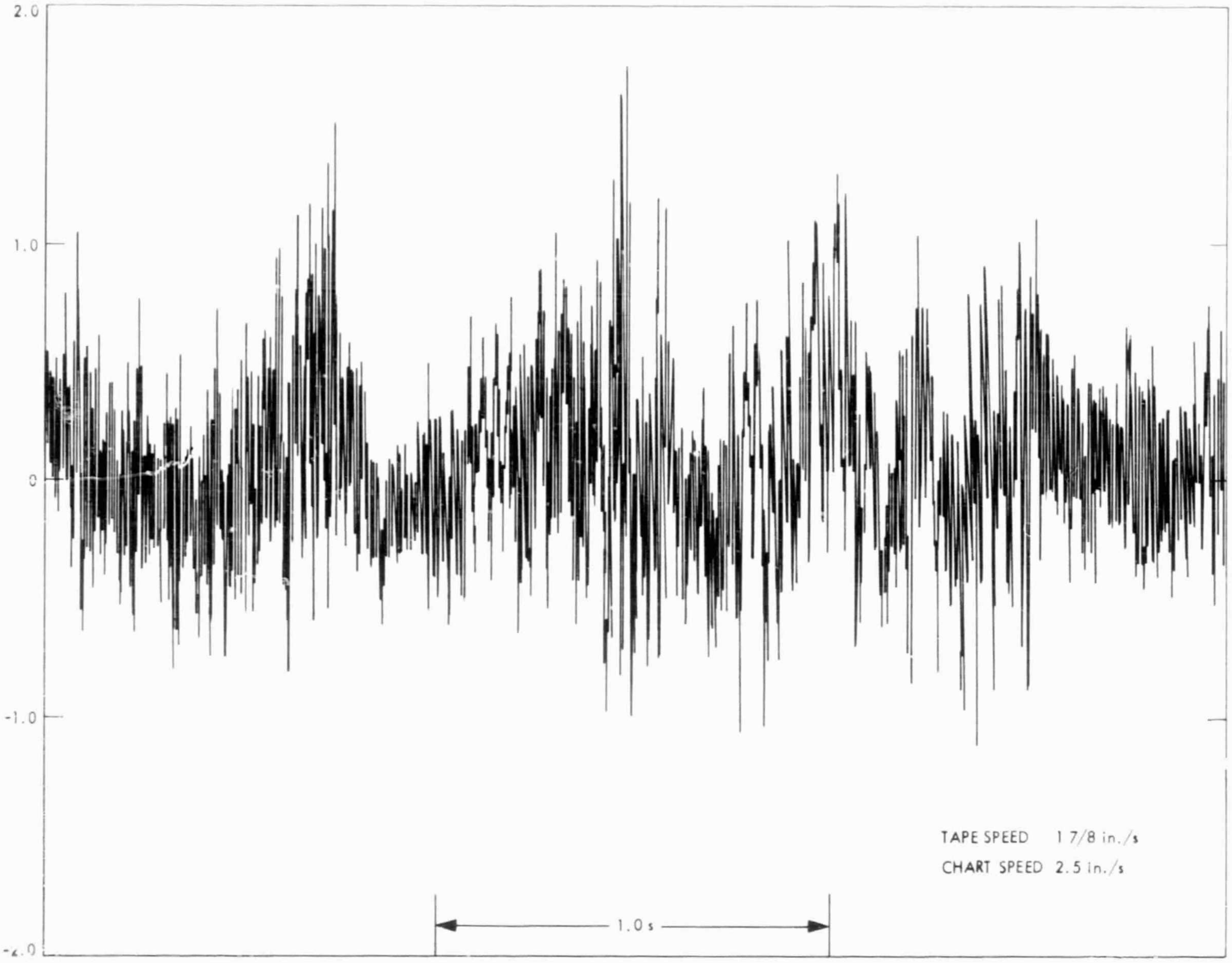


Fig. 6. Sample expanded data for position 5, moderately rough road, 30 mph

### C. Filtered Bandwidths g Contributions

The peak *g* reading observed for both the 2–10- and 125-Hz bandwidths was 0.07 *g*.

### D. Time Duration of Peak Amplitudes

The minimum duration of acceleration spikes that was markedly higher than ambient vibration was scaled to be approximately 2 millisec. The range of values for these observed times appeared to be from 2 to 10 millisec. The above figures were observed for both smooth and moderately rough road conditions. Samples of data expanded for time scaling that correspond to Figs. 5 and 6 are shown in Figs. 9 and 10.

## V. Conclusions

Both shock and vibration characteristics are smaller at a position as far forward as possible and laterally centered. Therefore, it is desirable to put the most delicate system components in this location.

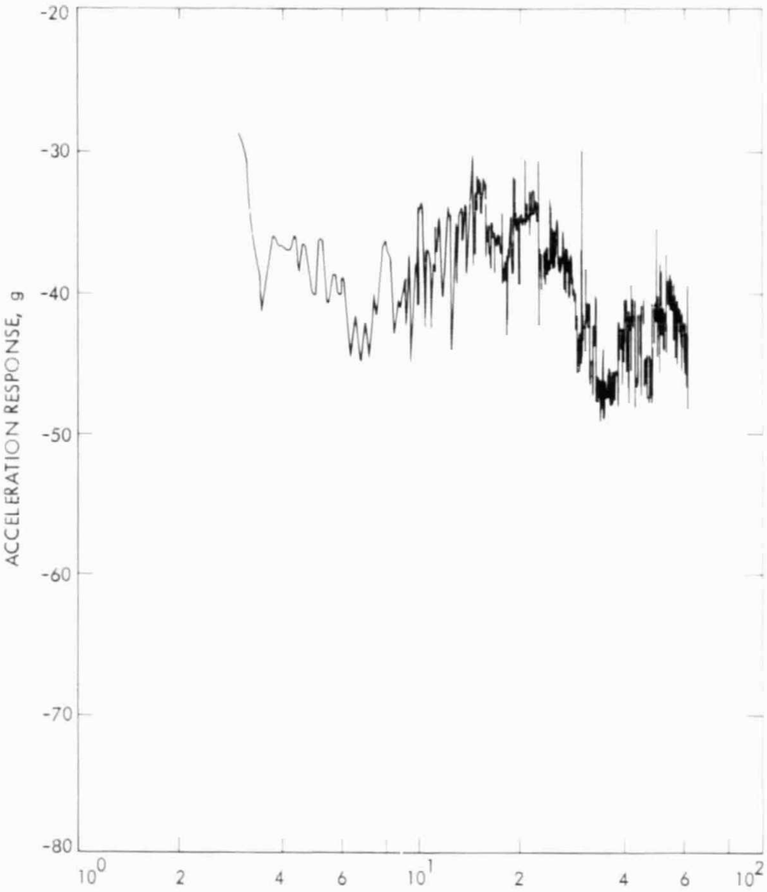


**Fig. 7. Sample PSD plot for position 1, moderately rough road, 30 mph**

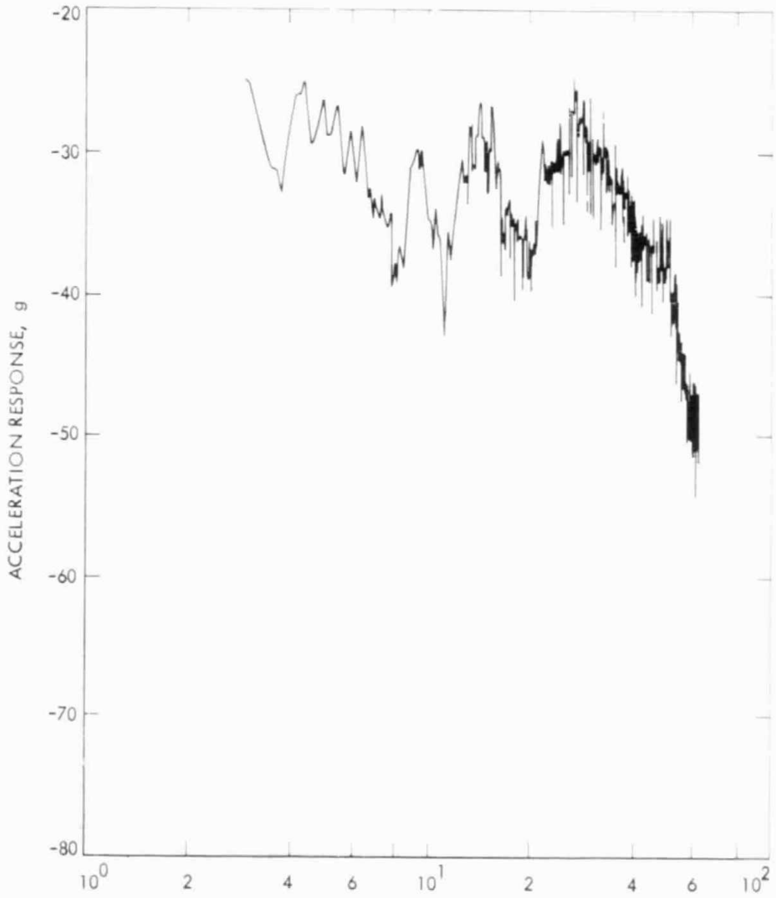


**Fig. 8. Sample PSD plot for position 5, moderately rough road, 30 mph**

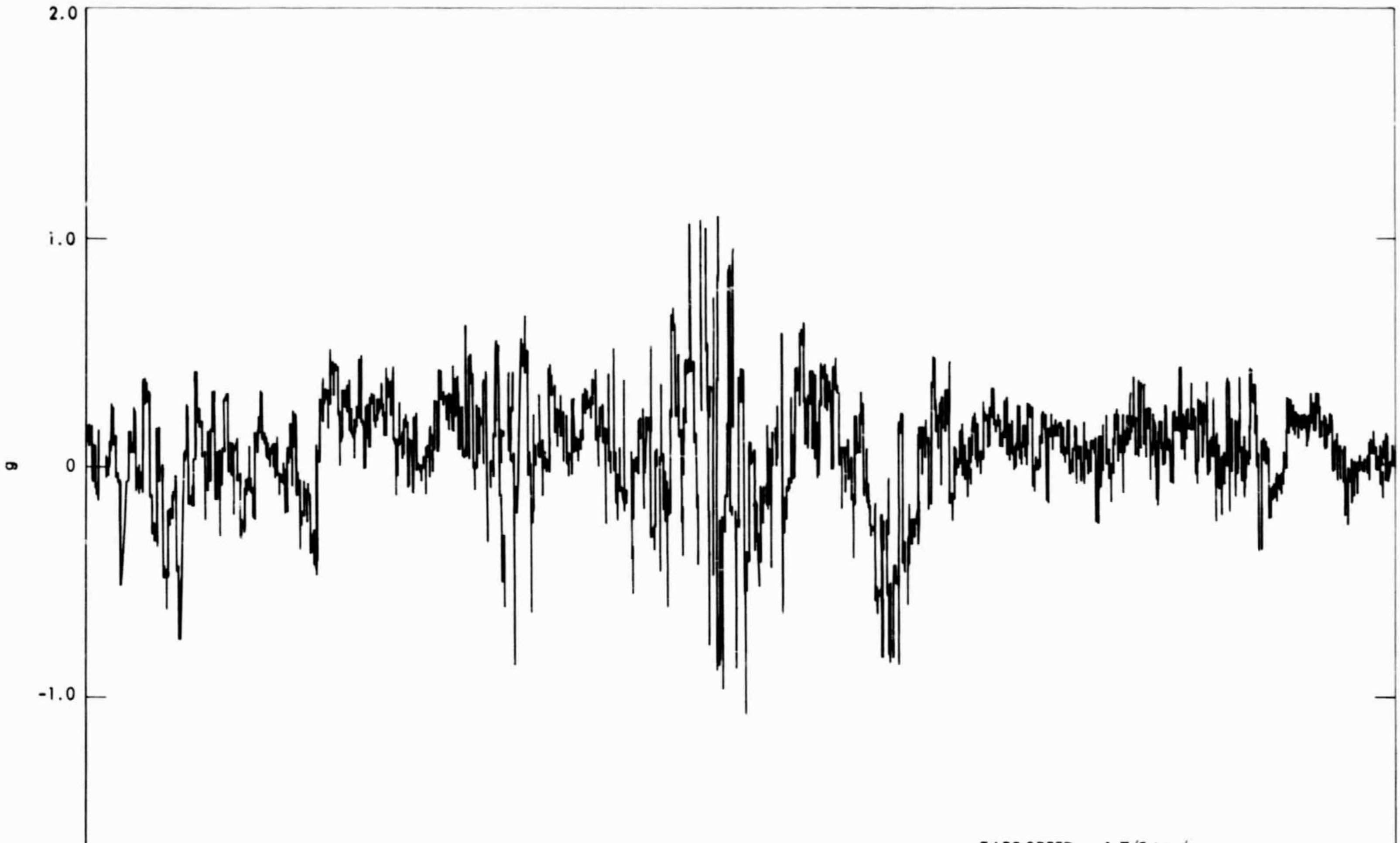


**Fig. 9. Sample data for position 1 (vertical), moderately rough road, 30 mph**

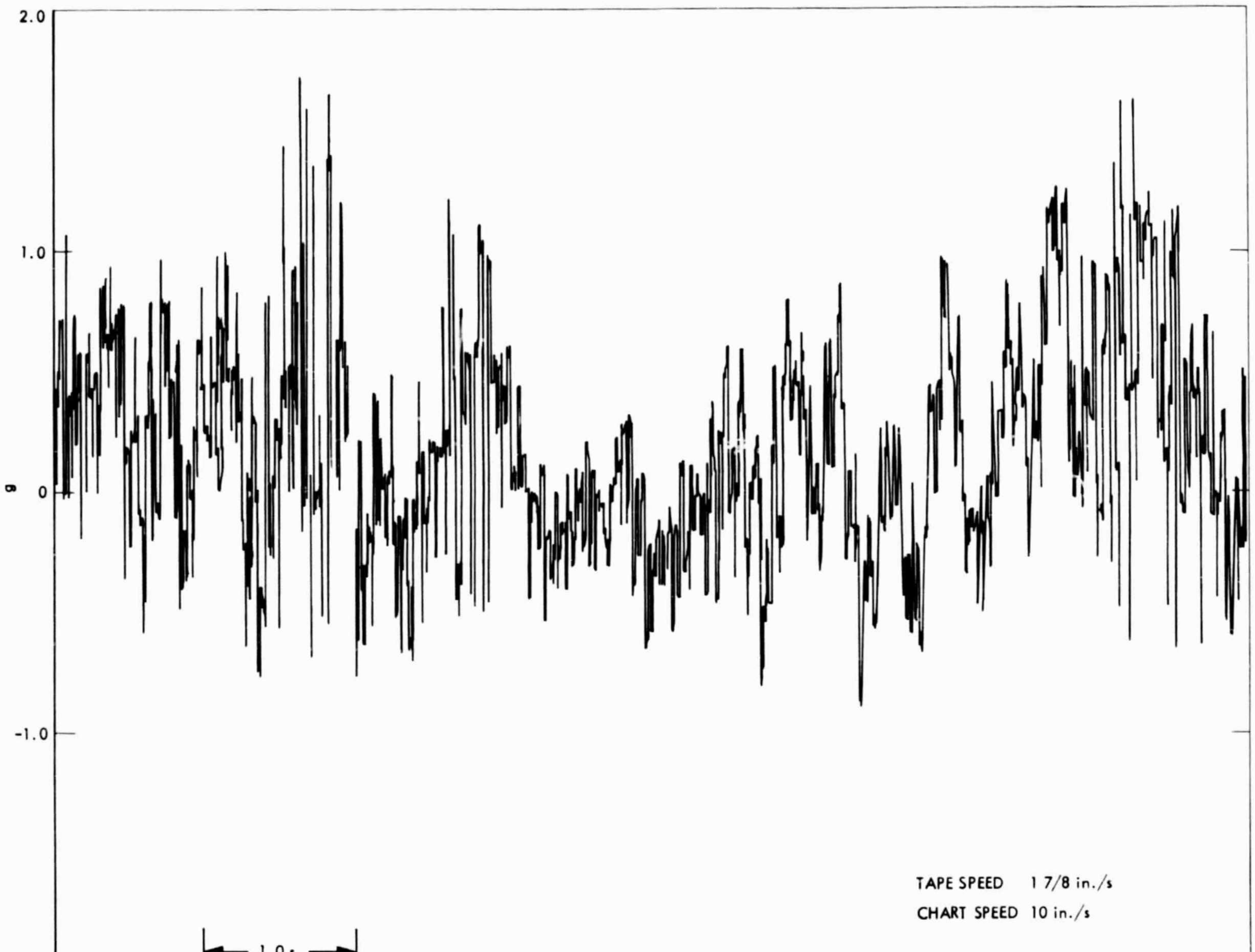


**Fig. 10. Sample data for position 5 (vertical), moderately rough road, 30 mph**

## References

1. Schlue, J. W., *The Dynamic Environment of Spacecraft Surface Transportation*, Technical Report 32-876. Jet Propulsion Laboratory, Pasadena, Calif., Mar. 15, 1966.

2. Schlue, J. W., and Phelps, W. D., "A New Look at Transportation Vibration Statistics," *The Shock and Vibration Bulletin*, Bulletin 37, Part 7. U.S. Naval Research Laboratory, Washington, D.C., Jan. 1968.