California Institute of Technology
Seismological Laboratory
Pasadena, California

Progress Report

May 15, 1969 - August 31, 1969

NASA GRANT NO.: NGR 05-002-129

PROJECT TITLE: Development of Performance Criteria and Functional Specifications for a Passive Seismic Experiment on Mars

PRINCIPAL INVESTIGATOR: Don L. Anderson

Seismometer-Development

A new package of three sensors based on the design of the earlier experimental model is currently being constructed. Attention is being given to reducing the weight and volume and to caging of the mass for vibration and shock survival. However, features are being retained to facilitate changes, replacements, and adjustments which would be replaced by "hard" assembly in flight models. Although shape factors for weight reduction, rigidity, etc., are being scrutinized, conventional and readily obtainable materials are being utilized to avoid delay. The effect of substitutions in future generation models is predictable. Figure 1 shows a single seismometer unit. Its weight is 3.8 oz. The dimensions of the unit are 1 1/8" x 1 1/8" x 2 3/4". It is estimated that three units can be packaged in a container with dimensions of 3" x 4" x 1 1/2".

Seismic Data Processor

The seismic data processor amplifies and conditions the seismic signal for presentation to the lander interface. It is designed to allow for three modes of operation:

1. High data rate, 20 samples/sec/channel, three channels. This mode is intended to be initiated by earth command at times when the telemetry can accommodate the bit rate.
2. Low data rate, 4 samples/min/channel, six channels. This is the normal operating mode where the microseism background is sampled within narrow frequency bands.

3. Moderate data rate, 1 sample/sec/channel, six channels. This mode is initiated either by Earth command or automatically upon the detection of a seismic event by the event trigger. In this mode some form of data compression must be used to preserve the wideband seismic information while consuming a minimum number of bits.

Work has continued on the construction of the Seismic Data Processor with the goal of performing integrated systems tests in conjunction with seismometers. Presently being assembled are the pre-amplifiers, amplifiers, filters, averaging circuits and the event trigger. These individual elements may be arranged such that the system takes on a number of configurations allowing for the several modifications in system concept which have evolved as more information on the lander has become available. The latest configuration presents to the lander, the direct wideband data and two channels of filtered and averaged data for each of the three seismic axes. The bandwidths of the low-pass filters are 4 hz and 0.5 hz. These two bandwidths are unique in that, due to the seismometer frequency characteristics, no additional amplifiers are needed to normalize the channels. No conditioning of power or scaling of the signal is performed because firm information on these points has not been received from the Prime Contractor for the Viking Project.

The circuitry is being assembled on 4 by 5 inch printed circuit boards for ease of assembly and handling and to allow flexibility in performing the systems tests. No attempt is being made at this time to package the electronics to meet the mechanical (weight, shock, and vibration) constraints of flight hardware. Although the power consumption of the data processor is still approximately 100 milliwatts, the weight, in its present form, of packaging is considerably over the approximate one pound allotted for the electronics.

Seismic Event Trigger

The Seismic Event Trigger is designed to detect an event when its amplitude exceeds a predetermined multiple of the average background level. It allows for an unknown or varying background by adjusting the trigger point so that it remains a fixed multiple of the average background. The multiple is selectable by Earth command.

Testing of the breadboard trigger has been performed using the vertical component* of the seismic signal which is telemetered from Glamis, California to the Seismological Laboratory in Pasadena. The trigger's ability to detect seismic events and to accommodate variations in the microseism level were excellent. The tests revealed, however, that on some small events, the trigger, after detecting the P-wave, would reset before the arrival of the S-wave, whereupon it would trigger again. This was corrected by the addition of a variable delay following the trigger. The delay is dependent on the length of time that an event operates the trigger and varies from zero for an impulse (typical of seismic noise which might cause false triggering)

*1 sec instrument with the velocity response peaking at 4 hz.

to approximately one minute for an event lasting three minutes or more. The result is that the trigger has an on time which varies from approximately two seconds for a false trigger to a maximum of four minutes for the longest event.

Figure 2 shows a 24-hour seismogram and the trigger output with nineteen earthquakes detected while accommodating a six times change in the microseism background over this period. For the Glamis signal, typically 80% of the trigger time represented earthquakes. The remaining 20% was due to "glitches" either of seismic or telemetered origin, or seismic events so buried in the microseisms that they were not useful.

Data Compression

As of this writing we are informed that 1.7 x 10^5 bits per day are allocated for the seismic experiment. This would allow six minutes of operation if the three axis seismic data were sampled at the 20 samples/second rate necessary for recovery of the wideband data. M. Nafi Toksoz is studying methods of data compression which will allow reasonable recovery of the wideband data while sampling at a moderate rate of one sample/second during times that the event detector signals the presence of a seismic event.

The most promising of the data compression schemes, which results in an approximate 10 to 1 compression, is one in which only the amplitude and time of peak values of the seismic wave are sampled. It is feasible to implement this technique electronically, but it places a great burden upon the lander in that it must service the seismic experiment and store data in a completely aperiodic manner in order to effect the savings in total bits. We have not proceeded on the circuitry to implement this system because the lander data acquisition unit is not versatile enough to handle this function and weight constraints preclude implementation by the experiment. The alternative to the lander providing aperiodic servicing is for the Seismic Data Processor to perform sampling and temporary data storage of up to 1000 bits for four minutes. This is not feasible within the weight and volume allocated to the seismic experiment.

Because of the foregoing, another approach to data compression has been developed which requires only that the lander be capable, upon the command of the event detector, of changing the sampling rate on the seismic channels from the low to the moderate rate. In an informal discussion with the representative of the Prime Contractor it was indicated that this is possible within their present framework.

This data compression scheme consists of a seismic event envelope detector and an axis crossing counter for each seismic axis. Two data words per sample are required which when sampled at one sample/second gives a 10 to 1 data compression. Reconstruction of the original seismogram is performed by passing the seismic envelope signal through an inverse filter and convolving with the instrument response according to the axis crossing count within each sampling interval.

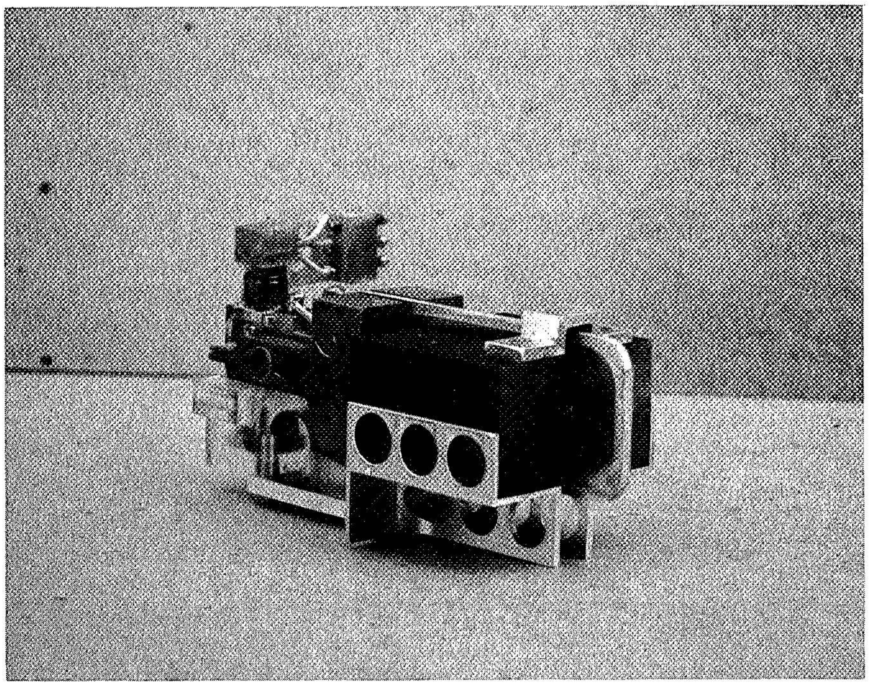
Implementing this system also makes multiple use of existing hardware in that the seismic envelope detector can be constructed out of the low-pass filter and averaging circuits already required.

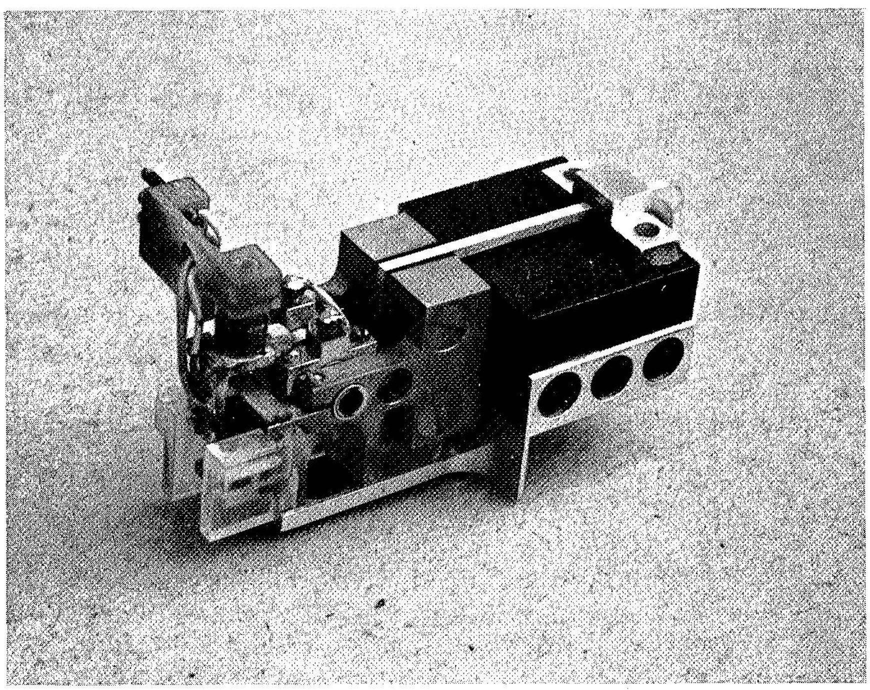
Only the addition of the axis crossing counter (approximately 10 milliwatts of power) and some electronic switches are required to implement and commutate the data compression system. A block diagram for one axis of the complete system is shown in figure 3. The seismic event trigger controls the position of the switches which in turn changes the system from two channels of filtered and averaged data to one channel for the seismic envelope and one for the axis-crossing count. For both the low and the moderate data rates, six channels of analog signals are presented to the lander interface for digitization and storage. Figures 4 and 5 show seismograms and the output from the envelope detector using the technique of figure 3.

Problem Areas

1. We need firm assurance from the Prime Contractor that the three modes of operation of the data processor are fully compatible with the lander's capabilities for commutation, sampling and storage of data.
2. We need firm information pertaining to the electrical interface with the lander as to signal levels, impedances and power conditioning.
3. The seismic data processor is designed around what we deem are flightworthy components. If, however, a mandatory parts list is in existence or is going to be generated, we should know about it as soon as possible so that we may incorporate these parts into our design, or have some influence on the parts which are approved for flight.

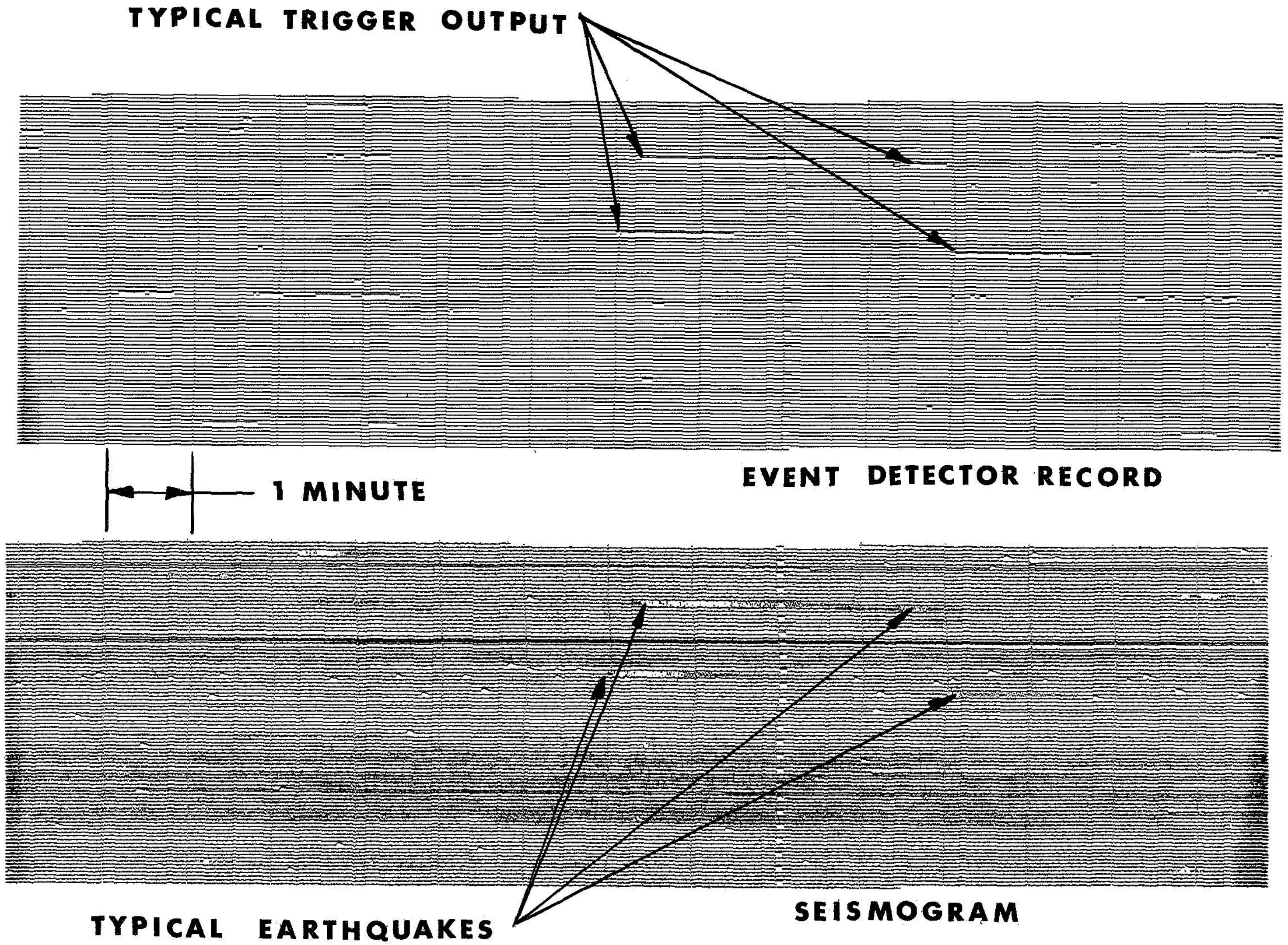
4. As mentioned earlier, the present electronic packaging of the data processor, although not designed as flight hardware, is considerably overweight. Further work is needed to reduce the weight to an acceptable level. No problem is anticipated in the sensor weight.





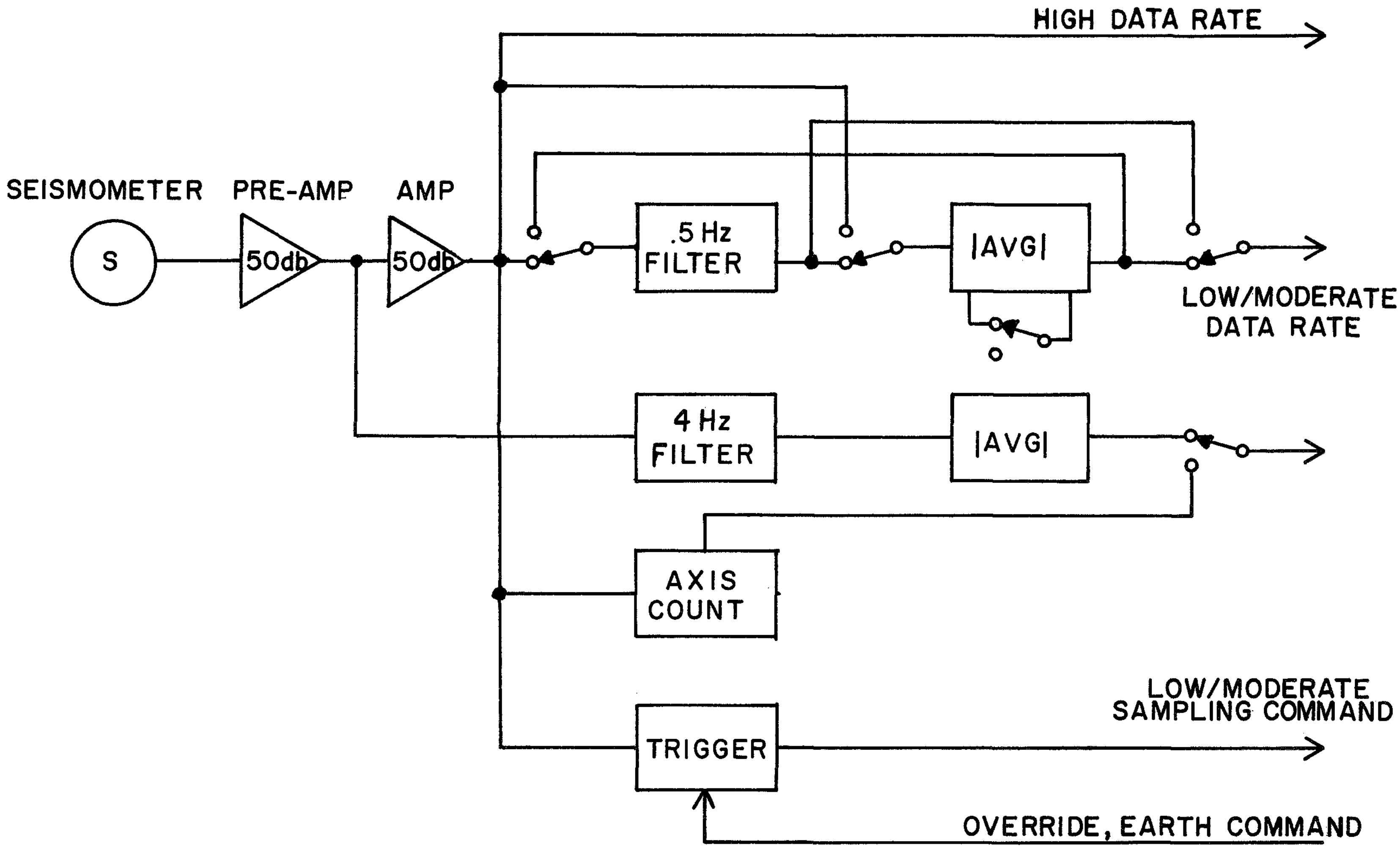
SEISMOMETER
SHOWN ACTUAL SIZE

FIGURE 1



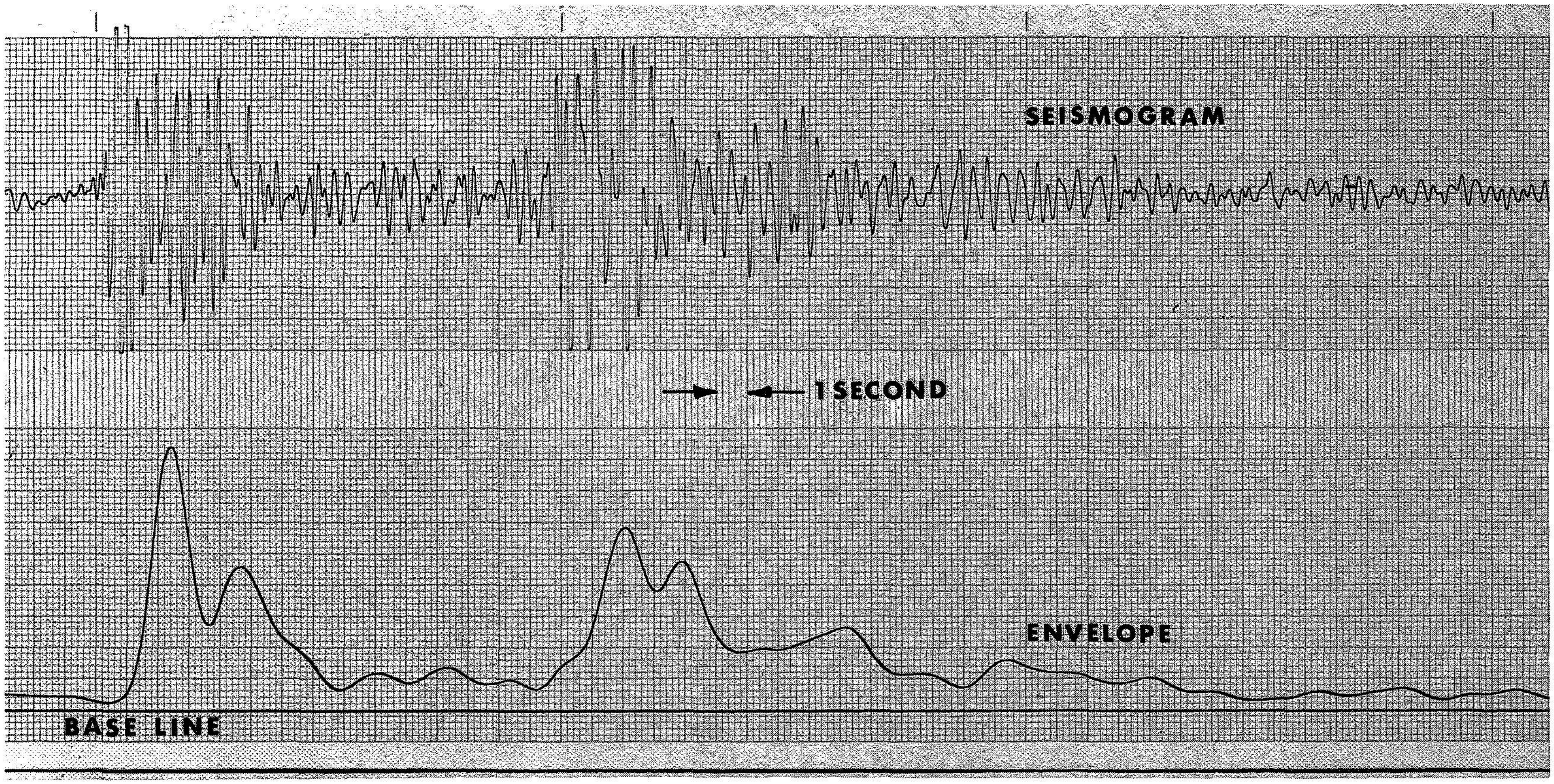
SEISMIC EVENT DETECTOR TEST

FIGURE 2



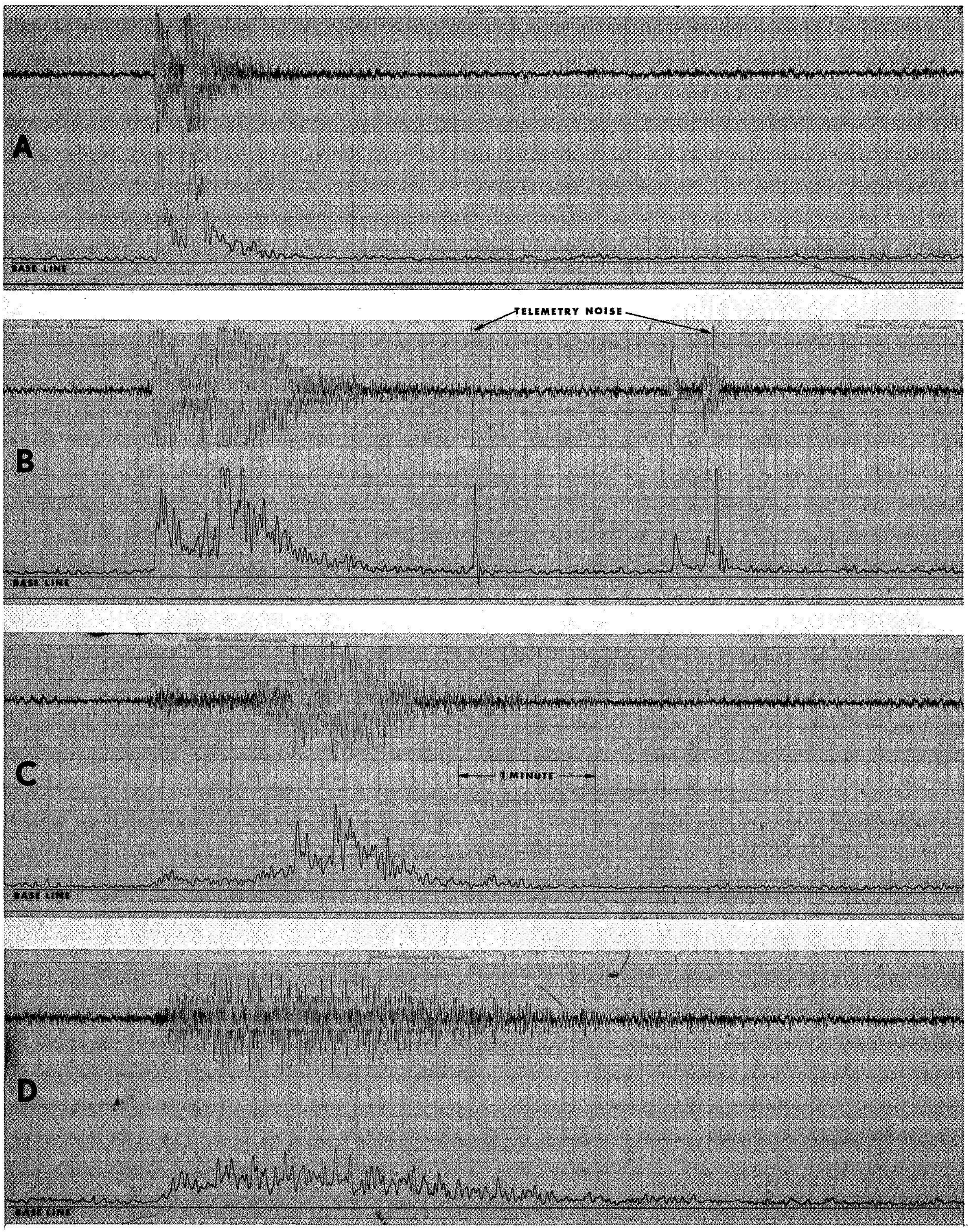
SEISMIC DATA PROCESSER SINGLE CHANNEL

FIGURE 3



SEISMIC ENVELOPE DETECTOR TEST

FIGURE 4



SEISMIC ENVELOPE DETECTOR

FIGURE 5