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TECHNICAL REPORT NO.67-1

LONG-PERIOD SEISMOGRAPH DEVELOPMENT

Quarterly Report No. 2, Project VT/6706

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TECHNICAL REPORT NO. 67-1

LONG-PERIOD SEISMOGRAPH DEVELOPMENT

Quarterly Report No. 2, Project VT/6706

by

Richard M. Shappee  
Burnard M. Kirkpatrick  
A. W. Simmons

Sponsored by

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15 January 1967

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### ABSTRACT

Details of the design of a long-period triaxial borehole seismometer were completed. Preparations were started for field use of the seismometer.

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### ABSTRACT

Details of the design of a long-period triaxial borehole seismometer were completed. Preparations were started for field use of the seismometer.

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## LONG-PERIOD SEISMOGRAPH DEVELOPMENT

### 1. INTRODUCTION

This report discusses the development of a long-period triaxial borehole seismometer, the system in which it will operate, and the design concepts of the uphole control apparatus.

The purpose of this report is to present the technical accomplishments of this project for the period from 1 October 1966 through 31 December 1966; it is submitted in compliance with paragraph 2, Data Requirements, of the Statement of Work to be Done, AFTAC Project Authorization, No. VELA T/6706 dated 15 February 1966. The project is under the technical direction of the Air Force Technical Applications Center (AFTAC) and under the overall direction of the Advanced Research Projects Agency (ARPA).

### 2. DEVELOPMENT OF A LONG-PERIOD TRIAXIAL BOREHOLE SEISMOMETER, TASK 1b

#### 2.1 INTRODUCTION

The concepts described in the last Quarterly Report (TR 66-94) have been followed in the design of the various portions of the seismometer. At the time of this report, the seismometer parts are being completed and assembly has been started. There are a few details to be completed which are described below. Figure 1 shows a block diagram of the system.

#### 2.2 STATUS OF WORK

##### 2.2.1 Seismometer

The tilt table design is complete and most of the parts are in our shop. Tilt is controlled in two planes at right angles to each other and normal to the direction of the sensitive element mast. Tilt can be controlled over a range of  $\pm 5$  degrees of arc in both the cross-axis and the sensitive-axis planes, at a rate of approximately 1 minute of arc per second of time.

Tilt is controlled in the two planes by two planetary-gear induction motors, each driving a worm-gear assembly which in turn is connected to a rack and

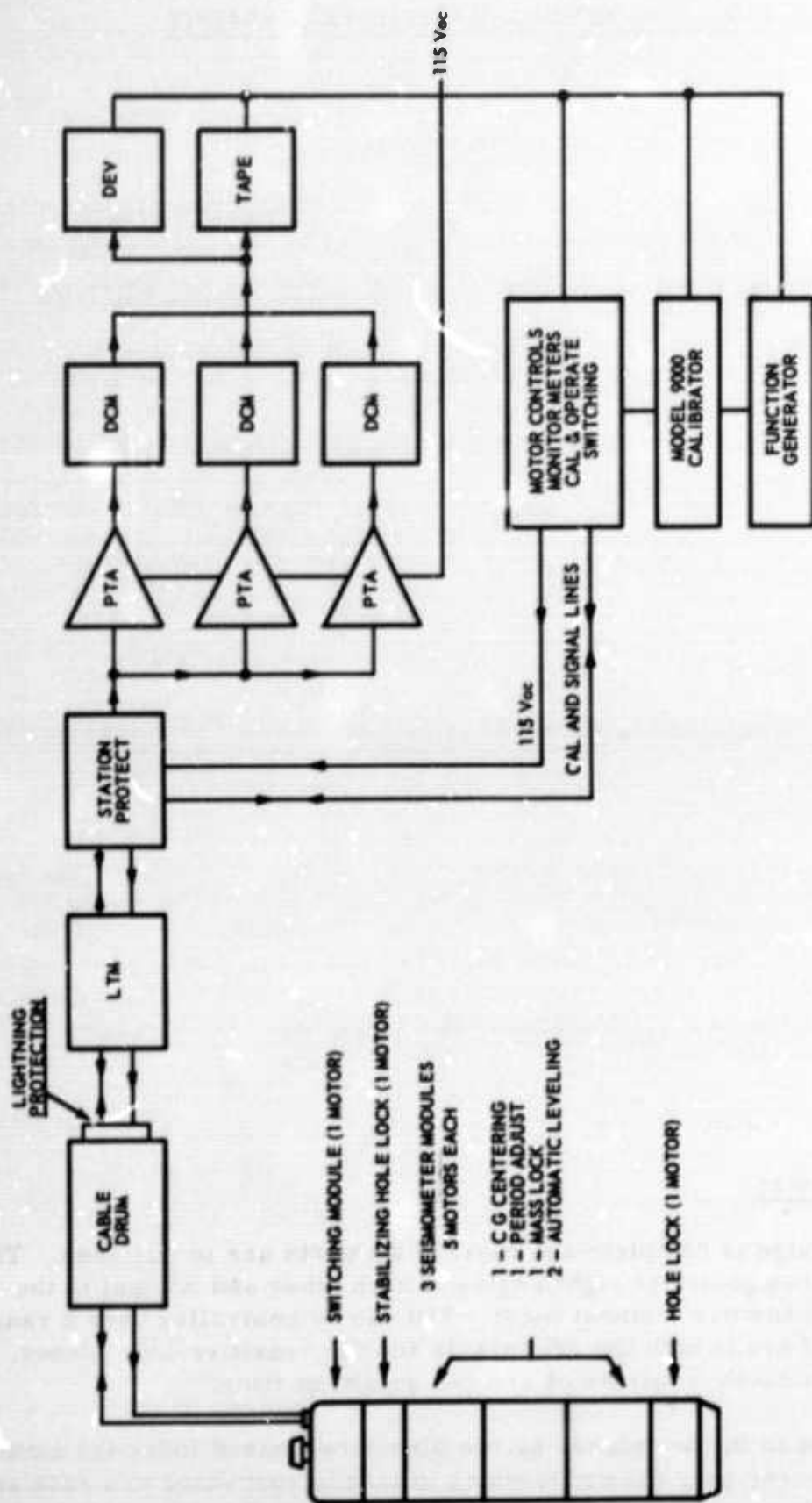


Figure 1. Long-period triaxial system, block diagram

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and pinion. Relative motion of the pinion along the rack forces the table of the tilt table to move relative to its base. The motion is rigidly locked by the worm and gear and by preloading the rack and pinion drive of the tilt table raceways.

The tilt table will automatically level so the sensitive element mast is vertical during seismometer operation. For raising and lowering in the hole, and for shipment, Microswitches will automatically orient the sensitive element relative to the case so that it can be locked. The vertical sensor for the tilt table has not yet been chosen. Four basic types are being considered: electrolytic-bubble, electrolytic-pendulum, electromagnetic-pendulum, and mercury switch. The electrolytic and mercury types are the most convenient, but, unfortunately, they are temperature sensitive. The electromagnetic-pendulum type involves some relatively complicated circuitry and is expensive.

As an aid in choosing the vertical sensor type and in judging the performance of the sensitive element design, a computer study of the LaCoste geometry has been initiated. The response of the geometry to slight tilts in both planes and to dimensional variations of its parts is being studied. Pending a final decision concerning the vertical sensor, Brunson tilt indicators will be used for the vertical reference purposes.

The sensitive element design has been completed with the exception of some details in the locking mechanism. The parts for which we have drawings are being manufactured, and some of the parts are now complete. We have rescheduled sensitive element completion for 15 January 1967.

Completion of the triflexure design was delayed pending a satisfactory prediction of its characteristics. The computer program being used in this analysis has been modified a number of times as our understanding of the triflexure improved. We now have a workable design which will use 0.011-inch thick Ni-Span C flexures mounted in an Invar housing. The internal load of the triflexure is such that, at the operating spring rate (which will cover the range 0.78-2.68 in.-lb/rad) and external load, all three flexures of the triflexure will be in tension. As the internal load is increased by springing that portion of the housing on which the main flexure is mounted, the spring rate of the triflexure will decrease, thereby lengthening the period of the seismometer.

Three pressure-tight cases of Randolite have been received and inspected. They appear to be satisfactory in every way. The actual weight of the Randolite case is 14 pounds 10 ounces as compared to the estimated 70-pound weight of an equivalent steel case. Preparations are presently being made to test the cases at operating pressure and temperature.

### 2.2.2 Installation and Down-Hole Cable

As mentioned in previous reports, installation of the seismometer in this program will be accomplished by lowering the instrument on a string of tubing. This concept will allow known orientation of the seismometer in the hole during the various tests that will be performed.

The tubing string for lowering is complete. This string consists of steel tubes, each 10 feet long with orienting fittings pinned on each end. These fittings are also used to connect the tubing lengths together as the seismometer is lowered into the hole. The total angular error in a 240-foot long string is not expected to exceed 1.8 degrees of arc.

The stinger "J" latch assembly, used to connect and disconnect the tubing to the seismometer, is complete and has been received from Manufacturing. The mating "overshot" assembly, which attaches to the lowering tubing string and mates with the J latch when lowering or raising the seismometer in the hole, is also complete.

A sample of cable from Precision Cable Company, Beaumont, Texas, has been tested and found satisfactory for down-hole use. Precision Cable Company can supply a custom cable to fit our specifications and delivery requirements and at a competitive price. The cable will have 48 #24 AWG stranded copper conductors arranged in 24 twisted pairs surrounding a strain relief member of 480 pounds breaking strength. Four of the pairs will be shielded for data and calibration use. The capacitance between any two conductors will not exceed 18 picofarads with an insulation breakdown exceeding 1000 Vdc. The cable is encased in a 1/8 inch thick polypropylene jacket for a total cable diameter of approximately 5/8 inch.

### 2.2.3 Electrical and Control Design

During the past quarter, specifications have been established for the electrical components required to operate and adjust the various elements and functions of the complete seismometer. Electrical circuitry has been designed for sequencing several functions, for motor control, and for automatic leveling and caging of the sensitive elements.

A minimum of 44 cable conductors are required between the seismometer and the surface instrumentation to operate 18 motors, 3 each data, calibration, and weight-lift circuits plus the indicator circuits. As mentioned earlier, we have selected a cable with 48 conductors.

We were unable to locate a waterproof connector that would accommodate 44 or 48 conductors and be of a suitable size. Therefore, we have designed a

connector shell that will accommodate a commercially available 48-pin insert, and will meet all of our requirements.

Ac induction-type motors were selected for this system because of their greater long-term reliability and their ability to operate over a wide voltage range. Sequencing and switching in each module will be accomplished by hermetically sealed relays.

Gravity-sensing leveling switch samples for the automatic leveling of the sensitive elements have been ordered and will be tested to determine the degree of accuracy of control possible. It is expected that tests will prove that 2 elements individually adjusted will improve the 9 minutes of arc now available with 1 element.

The connectors used to interconnect the modules will have 66 pins. Bendix makes a pressure-tight connector which fits the requirements and an appropriate number have been ordered. The large number of pins are necessary to provide sufficient through wiring in any one module to control any combination of modules stacked below it. The switching element positioned at the top of the stack provides for switching certain redundant functions within the seismometer modules and thus allows the number of uphole conductors to be reduced to 48.

### 3. PRELIMINARY TESTING OF THE LONG-PERIOD TRIAXIAL BOREHOLE SEISMOMETER, TASK 1c

In anticipation of the need to begin field testing of the seismometer on or about 15 March 1967, we wrote the Project Officer on 3 November 1966, requesting information about the availability of a suitable hole at the Uinta Basin Seismological Observatory (UBSO). In the same letter we suggested that if the UBSO hole would not be available by this time, that consideration be given to drilling a hole at the Tonto Forest Seismological Observatory (TFSO).

The Project Officer replied in his letter of 18 November 1966, and requested specific cost information to drill and case a hole at TFSO. At the time of this report, we are preparing cost figures for the following:

- a. Drilling and casing a hole at TFSO;
- b. Drilling and casing a hole in Montana in the LASA area;

c. Cleaning out the surface casing at our existing hole in Montana in the LASA area;

d. Drilling and casing a hole at UBSO.

Upon completion of our cost figures and after the Project Officer has made a decision, we will proceed to prepare a hole for use in this task.

APPENDIX to TECHNICAL REPORT NO. 67-1

STATEMENT OF WORK TO BE DONE

EXHIBIT "A"  
STATEMENT OF WORK TO BE DONE  
AFTAC Project Authorization No. VELA T/6706

11 MAR 1966

1. Tasks:

a. Experimental Investigation of Thermal Noise. Continue the experimental investigation, defined in Project VT/072, of thermal noise components in seismograph systems, using torsional pendulums and associated equipment available from that project. Determine experimentally the spectral distributions of thermal noise in seismograph systems and compare the experimental results with theoretical predictions, as those derived by the National Bureau of Standards, for example. Provide data and methods for determining the ultimate possible magnification of a seismograph. Work on this task is to be completed within 4 months of the initial authorization date.

b. Development of a Long-Period Triaxial Borehole Seismometer. Modify the "Melton" long-period triaxial seismometer developed under Project VT/072 to adapt it for routine operation in shallow (200-foot) boreholes. Reduce the seismometer's diameter so it will fit inside standard 13.375-inch outside diameter shallow-well casing. Develop and add a suitable level sensor and remotely-controlled levelling device.

c. Preliminary Testing of the Long-Period Triaxial Borehole Seismometer. Prepare a cased, shallow borehole at a VELA seismological observatory to be designated by the AFTAC project officer. Assemble handling equipment for installing the seismometer. Conduct preliminary tests of the modified instrument in the test hole to determine its stability and the effects of temperature and local tilting as functions of depth. Through the use of improved installation techniques, selective filtering, design improvement or other means, develop a method for operating the seismometer so that magnification in the 10 to 100 sec period band is limited only by propagating seismic noise.

d. Field Measurements with the Long-Period Triaxial Borehole Seismometer. Collect and analyze data to determine long-period signal and noise characteristics in shallow boreholes, to identify principal long-period seismic noise components, to ascertain depth-environmental effects, and to compare the performance of the triaxial borehole seismometer with standard long-period seismometers.

2. Data Requirements: Provide report as specified by DD Form 1423, with Attachment 1 thereto.

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Attachment 1 to DD Form 1423

REPORTS

AFTAC Project Authorization No. VELA T/6706

1. General: Provide monthly, quarterly, final, and special reports in accordance with sentence 1, paragraph 1 of Data Item S-17-12.0, AFSCM 310-1; however, if that data item conflicts with the instructions of paragraph 2 below, the latter will take precedence.

2. Reports:

a. Monthly Status Reports. A monthly letter-type status report in 16 copies, summarizing work for the calendar month, will be submitted to AFTAC by the 5th day of the following month. Each report will be identified by the data listed in paragraph 2e and will include, but not be limited to, the following subject areas:

(1) Technical Status. Include accomplishments, problems encountered, future plans, actions required by the government, and appropriate illustrations and photographs.

(2) Financial Status. The contractor will follow the provisions of Data Item A-15-17.0, AFSCM 310-1A (Cost Planning and Appraisal Unit), in submitting financial data.

For the last month of each report period covered by a quarterly progress report, the monthly status report need include only the financial information.

b. Quarterly Progress Reports. Quarterly progress reports in 50 copies, summarizing work for 3-month periods, will be submitted to AFTAC within 15 days after the close of each such period. Each report will be identified by the data listed in paragraph 2e and will include the notices listed in paragraph 2f. Each report will present a precise and factual discussion of the technical findings and accomplishments for the entire report period, using a format similar to that of the final reports under Contract AF 33(657)-9967, as well as the technical information ordinarily required in the monthly reports.

c. Final Reports. The final report on Task 1a will be submitted in 50 copies to AFTAC within 60 days after work on that project is completed; the final report on the remaining tasks will be submitted in 50 copies within 60 days after the completion of all work. Each report will be identified by the data listed in paragraph 2e and will include the notices listed in paragraph 2f. Each report will present a complete and factual discussion of the technical findings and accomplishments of the project tasks, using the quarterly-report format.

d. Special Reports.

(1) Special reports of major events will be forwarded by telephone, telegraph, or separate letter as they occur and should be included in the

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following monthly report. Specific items are to include, but are not restricted to program delays, program breakthroughs, and changes in funding requirements.

(2) Special technical reports may be required for instrument evaluations, project recommendations, and special studies when it is more desirable to have these items reported separately from the quarterly or final reports. Specific format, content, number of copies, and due dates will be furnished by this headquarters.

(3) All seismograms and operating logs, including pertinent information concerning time, date, type of instruments, magnification, etc., will be provided when requested by the AFTAC project officer.

e. Identification Data. All monthly, quarterly, and final reports will be identified by the following data:

AFTAC Project No. VELA T/6706.

Project Title.

ARPA Order No. 624.

ARPA Program Code No. 6F10.

Name of Contractor.

Contract Number.

Effective Date of Contract.

Amount of Contract.

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**13. ABSTRACT**

Details of the design of a long-period triaxial borehole seismometer were completed. Preparations were started for field use of the seismometer. (U)

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## KEY WORDS

Long-period borehole seismometer  
VT/6706

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