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TECHNICAL REPORT NO. 68-41

LONG-PERIOD TRIAXIAL SEISMOGRAPH DEVELOPMENT

Quarterly Report No. 9, Project VT/6706

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GEOTECH
A TELEDYNE COMPANY

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TECHNICAL REPORT NO. 68-41

LONG-PERIOD TRIAXIAL SEISMOGRAPH DEVELOPMENT
Quarterly Report No. 9, Project VT/6706

by

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and

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Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
ARPA Order No. 624

GEOTECH
A TELEDYNE COMPANY
3401 Shiloh Road
Garland, Texas

28 October 1968

<u>IDENTIFICATION</u>

AFTAC Project No:	VELA T/6706
Project Title:	Long-Period Seismograph Development
ARPA Order No.	624
ARPA Program Code No.	6F10
Name of Contractor:	Geotech, A Teledyne Company Garland, Texas
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Amount of Contract:	$396,247
Contract Number:	AF 33(657)-16406
Program Manager:	David B. Andrew BR 1-2561, Area Code 214

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ILLUSTRATIONS

ABSTRACT

The spectra and coherence of the noise as recorded by the triaxial and long-period seismographs at UBSO were computed. Plots of the amplitude ratio (or spectra ratio) and coherency of the noise are presented. Comparison of the amplitude ratio plots, from the recordings for wind free and windy days, indicates that the wind induced noise is attenuated, but not completely eliminated with the burial of a seismometer.

Assembly of the redesigned module is complete. The module has been tested and found to operate according to the design intent. The drawing package required to fabricate the production prototype seismometer is expected to be released during mid-October. Assembly of the seismometer is expected to begin during the month of December.

The shallowhole facility at Murphy Dome, Alaska, is presently under construction with completion expected early in October. Components required to complete the seismograph for Murphy Dome have been designed. Completion of the fabrication and testing of all components is expected by mid-October.

LONG-PERIOD TRIAXIAL SEISMOGRAPH DEVELOPMENT
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1. INTRODUCTION

This report describes the work performed by Geotech, A Teledyne Company, in accordance with the Statement of Work to be Done in AFTAC Project Authorization No. VELA T/6706, dated 11 March 1966. The project is under the technical direction of the Air Force Technical Applications Center (AFTAC) and the overall direction of the Advanced Research Projects Agency (ARPA).

The report discusses the progress made on the development of a long-period (LP) triaxial seismometer. The period covered by this report extends from 1 July 1968 to 30 September 1968 and concerns the field operation of the LP triaxial seismograph at the Sandia shallowhole test facility located at the Uinta Basin Seismological Observatory (UBSO) and the redesign and construction of an improved triax module at the Garland plant.

2. FIELD MEASUREMENTS WITH THE LONG-PERIOD TRIAXIAL BOREHOLE SEISMOMETER, TASK 1d

2.1 SPECTRAL ANALYSIS OF LONG-PERIOD SEISMOGRAPH AT UBSO

The spectra and coherence of the noise as recorded by the triaxial seismograph (200 ft depth) transformed into orthogonal outputs having north (NCT), east (ECT), and vertical (ZCT) sensitivity and the standard long-period (LP_2) seismograph (50 ft depth) at UBSO were computed. One sample was taken during a time when no noise from atmospheric disturbances was visible on the recordings (wind velocity less than 5 mph) and is illustrated in figures 1 and 2. The other sample was taken during a time when large amounts of wind noise was being recorded (wind velocities up to 30 mph) and the results are shown in figures 3 and 4.

The wind free recordings show high coherences and amplitude ratios (which is a means of illustrating spectra ratios) close to unity over the period range where large amplitude traveling seismic noise is present. For periods greater than 30 sec, the coherence decreases rapidly, indicating that with lower level traveling waves, the more predominant energy is represented by seismograph induced noise.

There are some unusual and presently unexplained results noticed in the illustrated amplitude ratio plots for the wind free samples. Specifically, the resonant peak at 64 sec for the north amplitude ratio plot and at 50 sec for the vertical amplitude ratio plot are not completely understood. In an effort to better understand these resonances, the spectra for the standard north and vertical seismographs as well as the triaxial transformed north and vertical seismographs were plotted. Abnormally high response was noticed on both the north and vertical standard seismograph spectra at the 64 sec and 50 sec periods respectively.

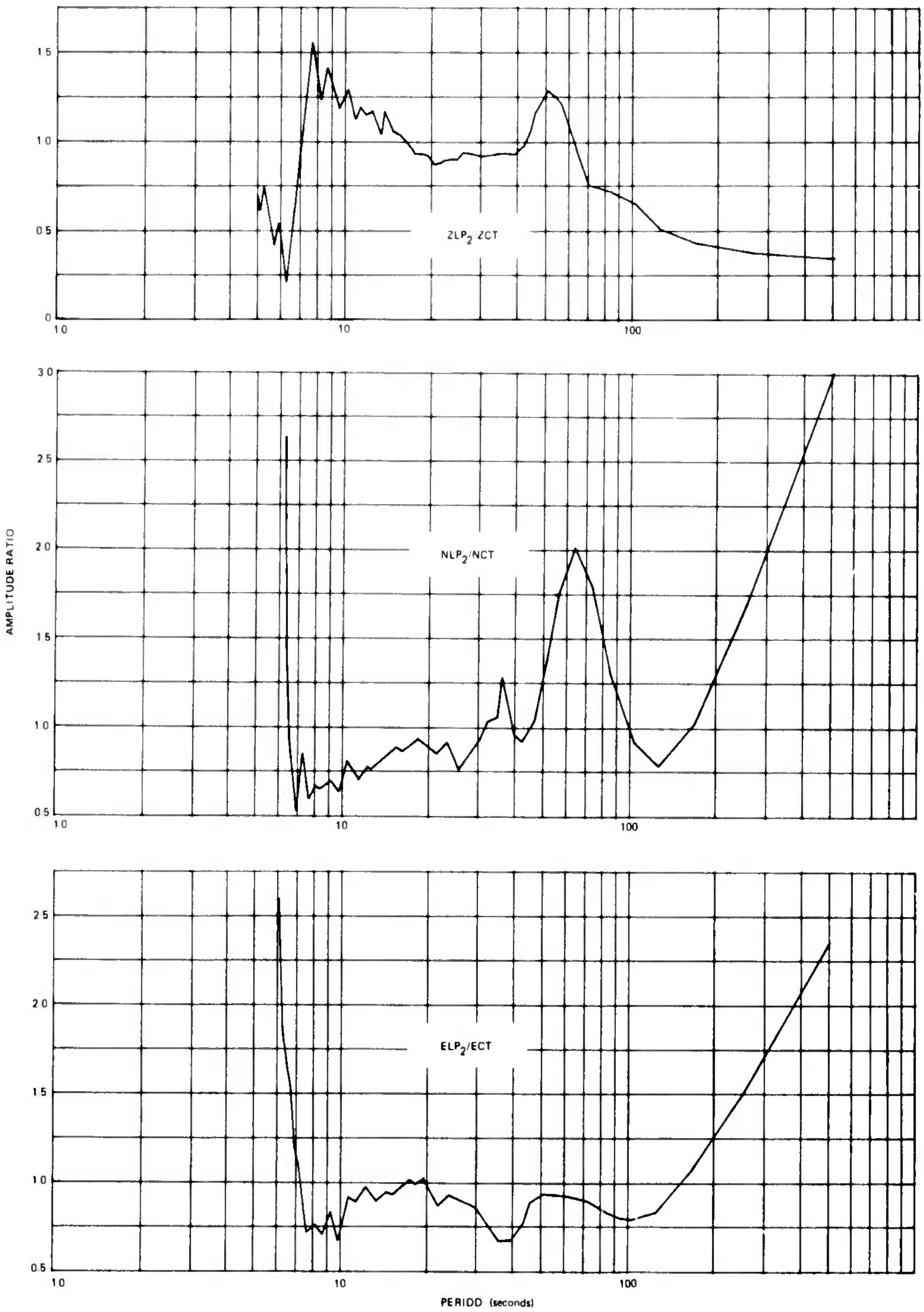

Figure 1. Amplitude ratio (or spectra ratio) of the noise as recorded by the triaxial transformed (NCT, ECT, ZCT) and the standard (NLP_2, ELP_2, ZLP_2) long-period seismographs operating at UBSO during a wind free (wind velocity less than 5 mph) period

G 4400

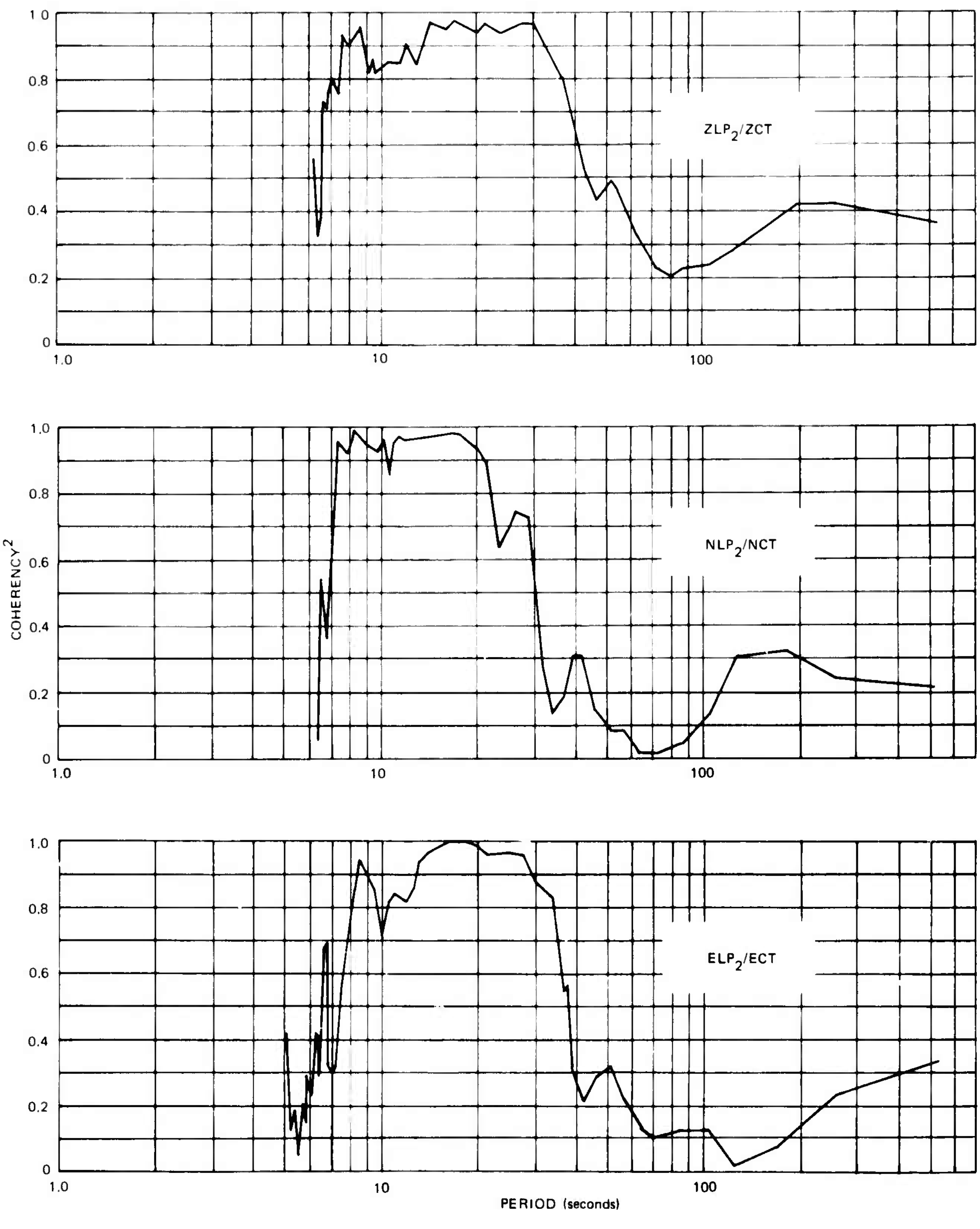

Figure 2. Coherency of the noise as recorded by the triaxial transformed (NCT, ECT, ZCT) and the standard (NLP_2. ELP_2, ZLP_2) long-period seismographs operating at UBSO during a wind free (wind velocity less than 5 mph) period

G 4401

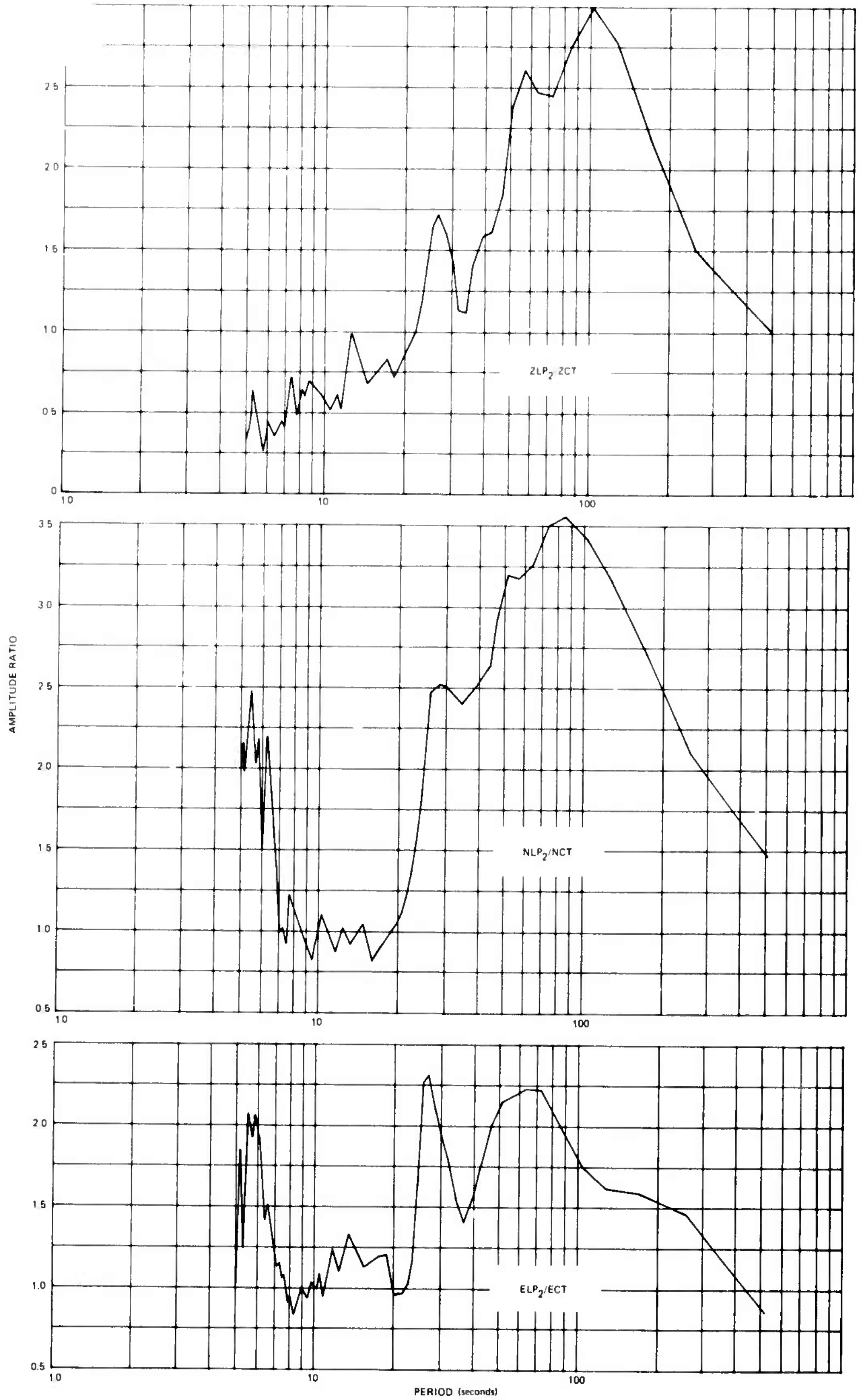

Figure 3. Amplitude ratio (or spectra ratio) of the noise as recorded by the triaxial transformed (NCT, ECT, ZCT) and the standard (NLP_2, ELP_2, ZLP_2) long-period seismographs operating at UBSO during a windy (wind velocity to 30 mph) day

G 4402

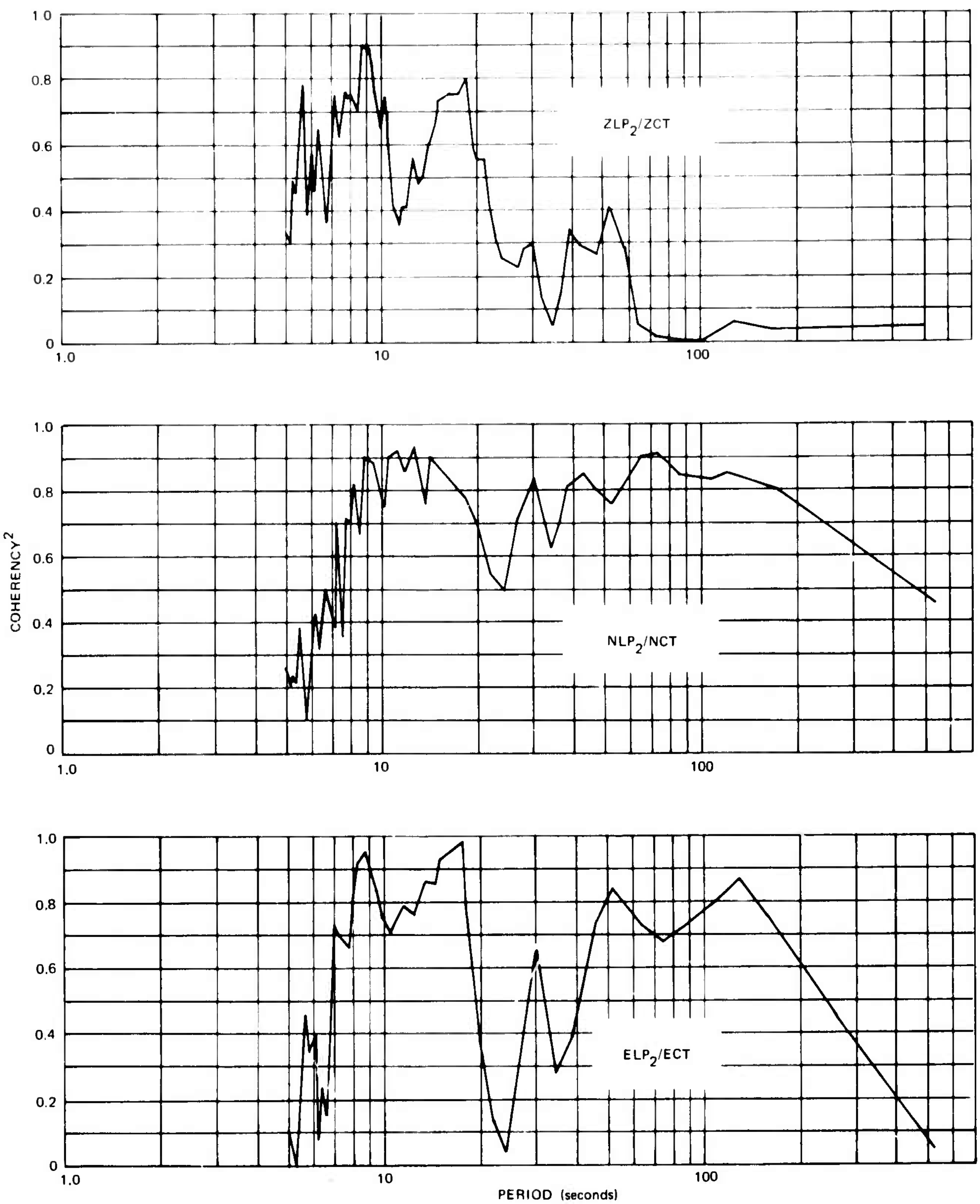

Figure 4. Coherency of the noise as recorded by the triaxial transformed (NCT, ECT, ZCT) and the standard (NLP_2, ELP_2, ZLP_2) long-period seismographs operating at UBSO during a windy (wind velocity to 30 mph) day

G 4403

Because of this, specific conclusions from the spectral analysis thus far performed have not been made. Comparison of amplitude ratio plots of the wind free and the windy days does indicate that the wind induced noise is attenuated, but not completely eliminated with the burial of a seismometer. Because of the overall inconclusiveness of these tests, we strongly recommend and propose that further spectral analysis of the triax and standard seismographs, soon to be installed and operated at Murphy Dome, Alaska, be performed.

2.2 OPERATION OF THE LONG-PERIOD SEISMOGRAPH AT UBSO

As recorded in Quarterly Report No. 8, VT/6706, the LP triaxial seismometer at UBSO was removed from the shallowhole at the conclusion of the report period and one module was undergoing repair at Garland, Texas. The repair was complete at the beginning of this reporting period and the module was subsequently shipped to UBSO. During the second week of July, a Geotech crew traveled to UBSO and installed spiral-4 cables between the initial borehole installation and the Sandia shallowhole facility.

The triax module arrived at UBSO on 13 July. After minor adjustments at the Central Recording Station (CRS), the module was taken to the subsurface cylindrical working area around the top of the borehole where the seismometer (three modules, the holelock, and stabilizer) was assembled. After all control circuits were checked, the instrument package was lowered to the bottom of the shallowhole (194 ft). A complete system checkout and calibration was performed and routine operation by station personnel began on 22 July 1968.

The safety brackets (mentioned in Quarterly Report No. 8, Project VT/6706), designed to prevent injury to personnel and damage to the instrument, were thoroughly tested during the installation of the instrument in the borehole previously occupied by the Sandia Corporation. These brackets proved to be adequate in every respect and will be used during all seismometer installation and removal operations in the future.

With satisfactory seismometer in tallation in the Sandia shallowhole facility, the work under this task is considered complete and further reporting is not contemplated.

3. EVALUATION AND MODIFICATION OF THE LONG-PERIOD TRIAXIAL BOREHOLE SEISMOMETER, TASK 1e

Assembly of the redesigned seismometer module is complete. At present the unit contains a certain amount of special wiring which must be removed before it will be available for field measurements. The special wiring was required to allow easy electrical access to the instrument during the Alaska Long-Period Array (ALPA) system demonstration to be held at Geotech's Garland plant early in October.

Figures 5, 6, 7, and 8 are photographs of the completed module. The unit has been considerably simplified, as can be seen if the figures are compared to figures 3 and 4 of Quarterly Report No. 5, Project VT/6706.

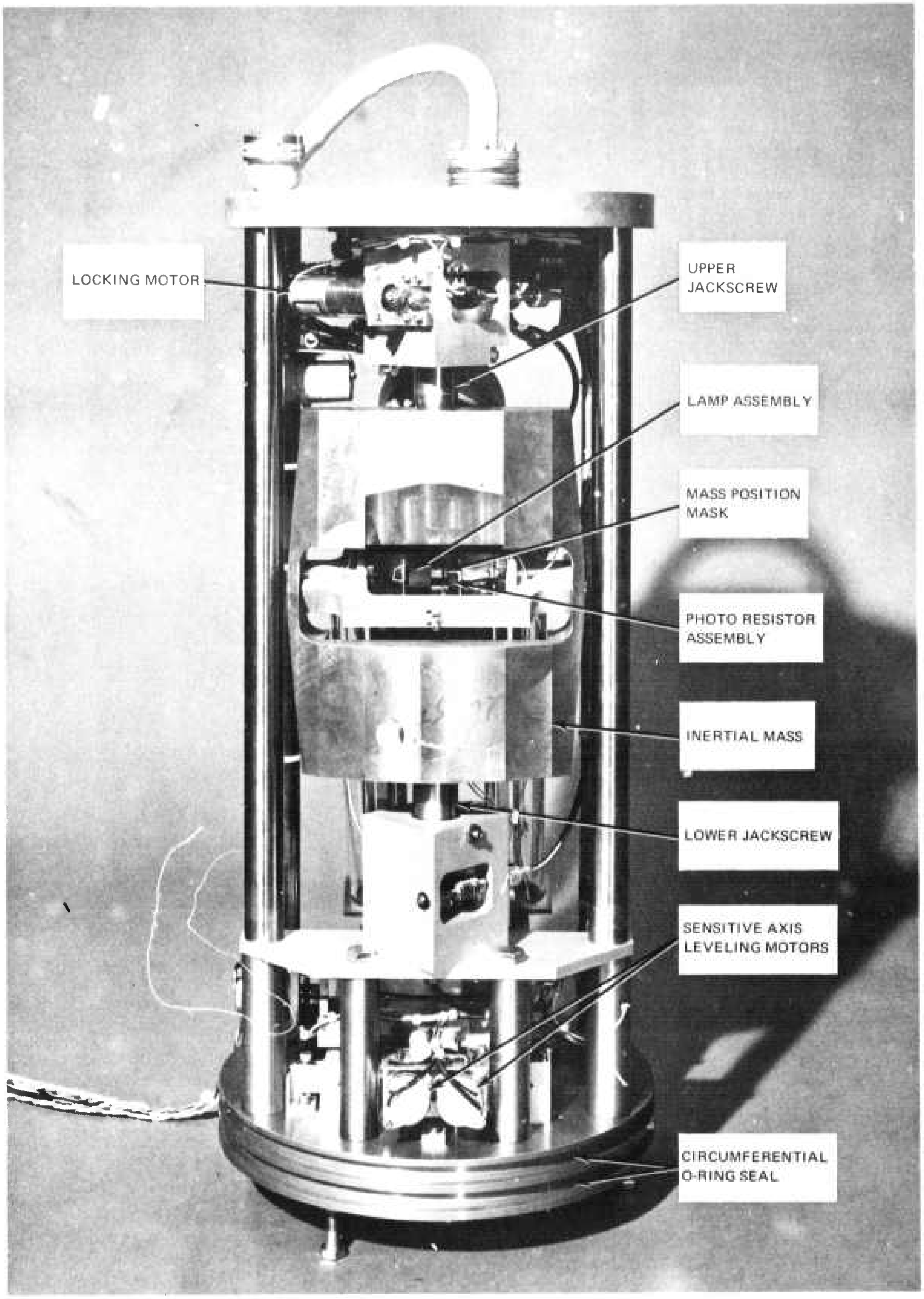

Figure 5. Front view of the redesigned module, Model 26310 Seismometer

G 4404

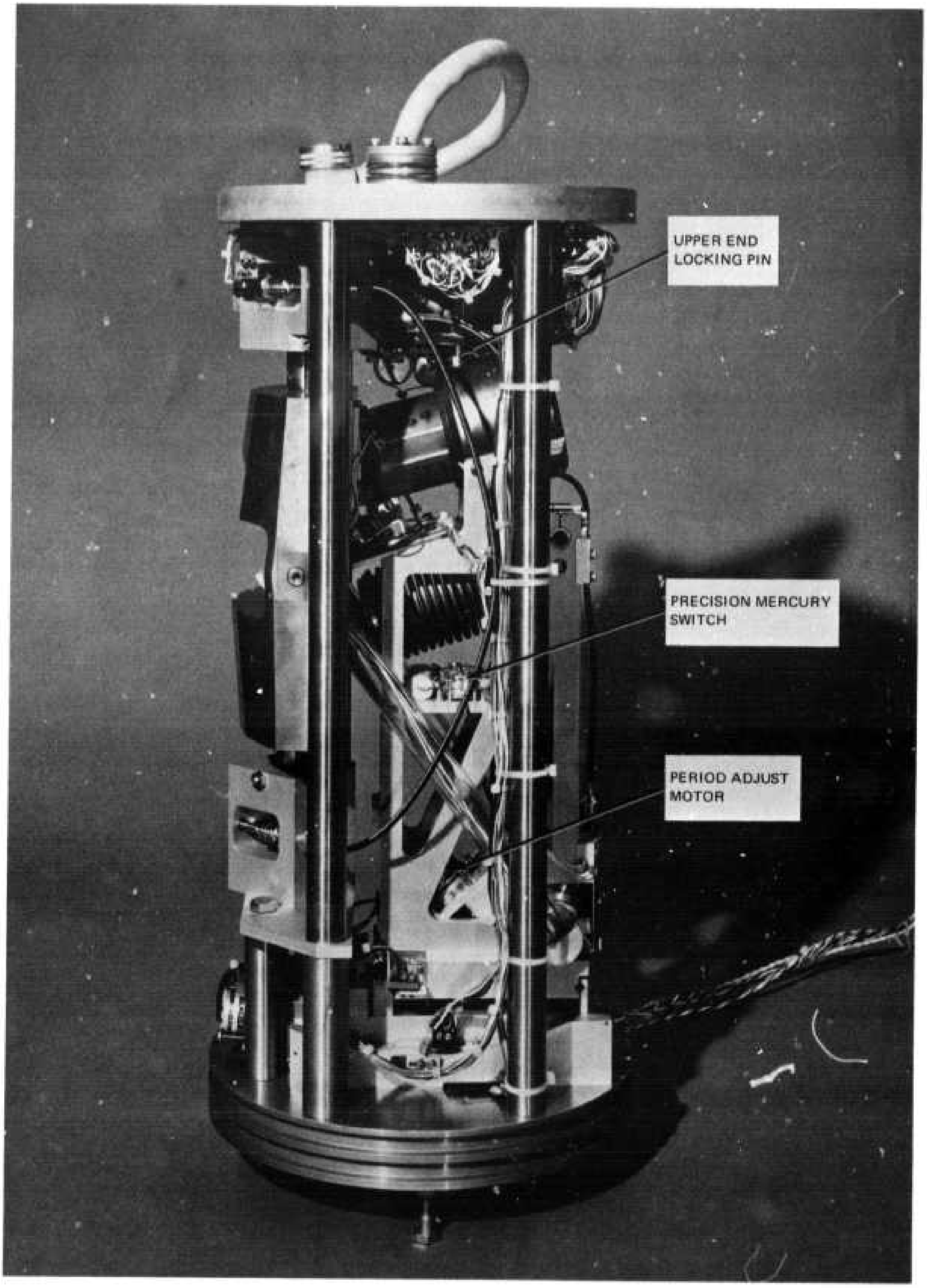

Figure 6. Right side view of the redesigned module, Model 26310 Seismometer

G 4405

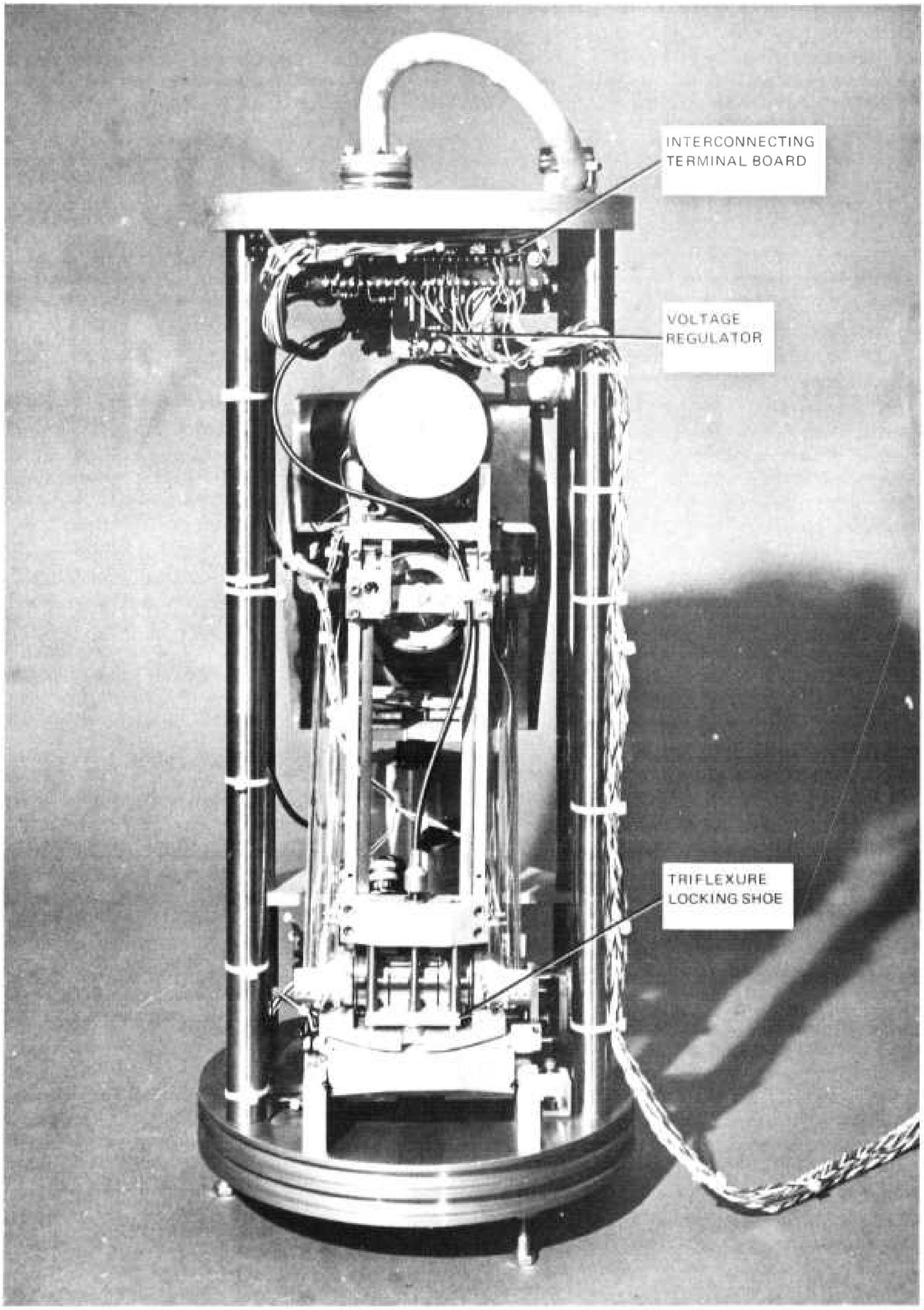

Figure 7. Rear view of the redesigned module, Model 26310 Seismometer

G 4406

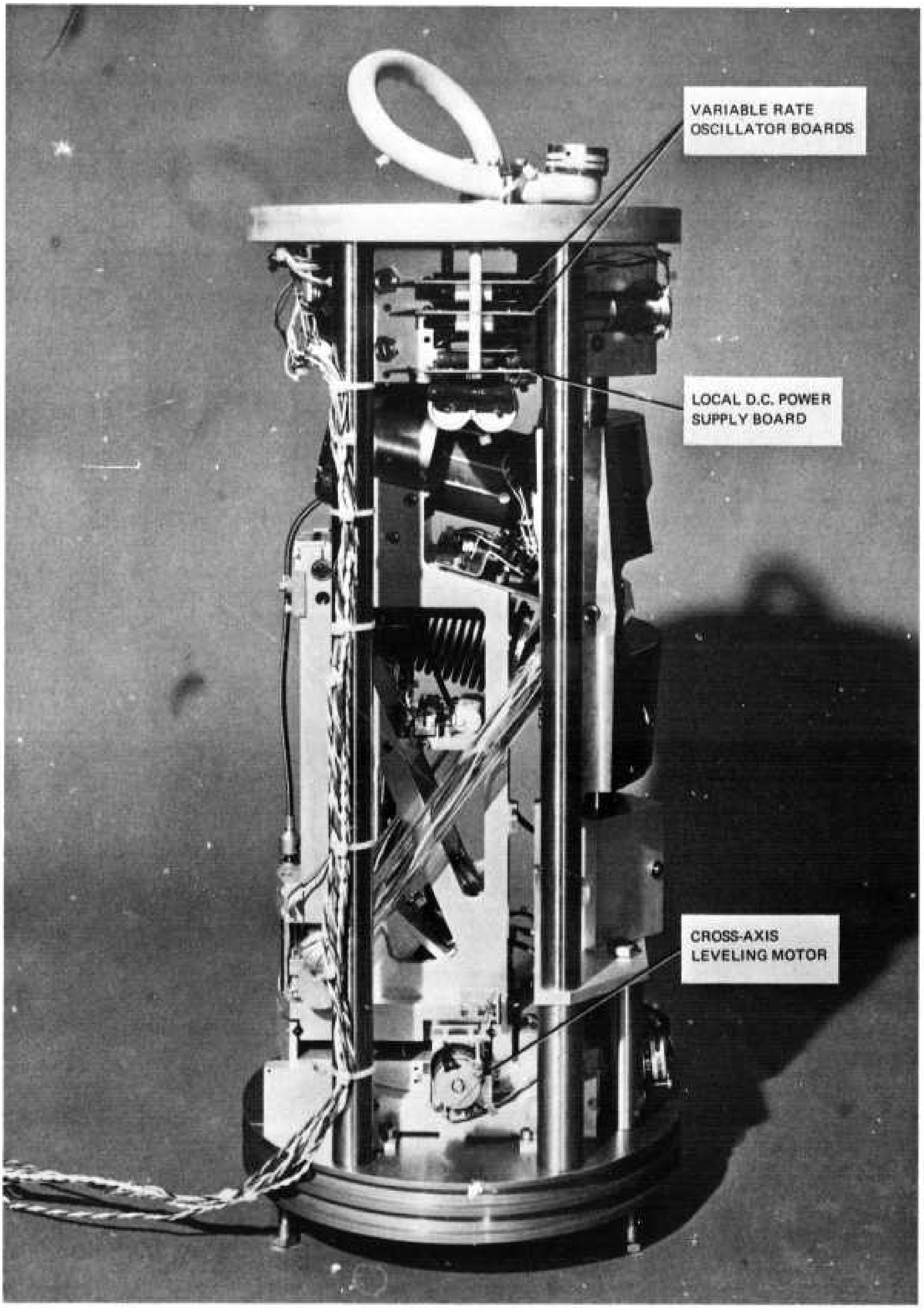

Figure 8. Left side view of the redesigned module, Model 26310 Seismometer

G 4407

Simplification of design has been made in a number of areas throughout the instrument, but is especially evident in the locking mechanism. Redesign of this mechanism allowed the module to be shortened by approximately 1-1/2 inches while improving the reliability of the locking function.

The redesign module has been tested for proper operation of its basic functions (mass lock and unlock, mass centering, and period adjust) and each operated according to the design intent. Preliminary tests of the data acquisition and control system proposed for ALPA have been conducted using the new module as the device to be controlled. A computer program operating upon the redesigned unit will turn the mass position monitor on and off, recenter the mass if it is out of position tolerance, measure the free-period, adjust the free-period if it is out of tolerance, and run a 10 point amplitude vs frequency response of the system. The two remaining controllable functions are mass unlock and lock. These functions are normally controlled at installation and further control of them is not expected until the instrument is removed from the borehole type vault.

The redesign module will be shipped to Alaska when the shallowhole facility (presently being prepared at Murphy Dome) is completed. After the engineering model of the triaxial seismometer (recently removed from UBSO and sent to Alaska) has been tested in the hole for approximately one month, the redesign module will be substituted for module No. 1 of the string and operational tests continued. This test will evaluate the performance of the module in its operational environment. If difficulties appear during the test, there will be sufficient time to make necessary changes in the design before a production quantity commitment of the seismometer has been made.

4. FABRICATE AND TEST ONE PROTOTYPE LP TRIAXIAL BOREHOLE SEISMOMETER, TASK 1f

A production drawing package is being prepared to facilitate the fabrication of one complete triaxial seismometer under this task. This package reflects the details of the redesign module as well as a new interface design between the seismometer modules. The drawing package required to fabricate the production prototype seismometer is expected to be released to production during mid-October. Assembly of the seismometer is scheduled to begin during the month of December. The new interface design utilizes a floating electrical connector in place of the short cable now used. Also, an O-ring face seal has been substituted for the circumferential O-ring seal (see figure 5). Because of the floating connector, the new interface design will reduce the hazard now experienced during the stacking of the seismometer modules for installation. The cost of the seismometer has also been reduced and its reliability increased since the short cable, and thus its large number of solder joints (at least 132), have been replaced with a 50 pin connector.

Both the load bearing and stabilizing holelock have been redesigned to improve the reliability of these units. The load bearing holelock has been reconfigured to permit engagement at any depth in the hole, rather than at the casing joints only (as required by the previous design). This will permit operation of the seismometer in cased holes utilizing welded casing joints as well as those that use threaded joints. Both holelocks now use a single extendable arm design, rather than the double arm design formerly used. Since the three point locking concept has been retained in the new design, the former reliability with which the seismometer was coupled to the hole is expected to be maintained.

5. FIELD MEASUREMENTS WITH THE PROTOTYPE LP TRIAXIAL BOREHOLE SEISMOMETER, TASK 1g

Considerable design effort was necessary to complete the seismograph that is scheduled for installation at Murphy Dome, Alaska. Components that were developed are described in the sections to follow.

5.1 COORDINATE TRANSFORMER

The output of each of the triaxial seismometer modules have a directional sensitivity which is, by design, oriented 35.3 degrees from the horizontal. Because of this, a reorientation of the triaxial seismometer output is necessary before it can be compared with a standard advanced LP system. This reorientation, or coordinate transformation, is accomplished by combining the three seismometer module output voltages in simple trigonometric relationships using solid state operational amplifiers for level control and voltage dividers to simulate trigonometric functions. The design, fabrication, and testing of the coordinate transformer is complete.

5.2 BOREHOLE SEAL AND VAULT PROTECTOR

Uncontrollable environmental conditions that will be encountered in this and future installations prompted the design of a borehole seal and vault protector as a single unit that is attached to the top of the shallowhole casing. This unit provides an electrical termination point between the seismometer and the control and data lines to the instrumentation van. It also provides lightening protection and test points which will allow the seismometer modules and holelocks to be operated with a portable controller at the borehole opening. The design and fabrication of this component is also complete.

5.3 SOLID STATE AMPLIFIER

The Geotech AS630 solid state amplifiers to be used in the new triaxial LP system have undergone minor modifications, adjustments, and tests to insure proper response. This was necessary when response requirements for the seismograph were established as equivalent to those of the ALPA system.

5.4 TRIAXIAL CONTROLLER

Experience has shown that a portable controller to operate seismometer motor circuits is not only a convenience but will be necessary in the particular area of the ALPA program. For this reason, two controllers will be provided. A rack mounted unit will operate in the instrumentation van and the other, a portable unit, will operate from a dc power source at the borehole opening.

The design of both of the controllers is complete. Fabrication of the portable controller is finished, but the rack mounted unit will not be completed until mid-October.

The shallowhole facility at Murphy Dome, Alaska, is presently under construction with completion expected early in October. A complete drilling report, exact borehole specifications, and photographs of the area will be published in subsequent progress reports.

APPENDIX to TECHNICAL REPORT NO. 68-41

STATEMENT OF WORK TO BE DONE

EXHIBIT "A"

STATEMENT OF WORK TO BE DONE

AFTAC Project Authorization No. VELA T/6706

1 - 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.

AF 33(657)-16406

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

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.

Name and phone number of Project Manager, Scientist, or Engineer.

f. Notices.

(1) All quarterly and final reports will include the following notices on the cover and first page or title page:

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AF 33(657)-16406

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(2) All quarterly and final reports will include a copy of DD Form 1473, Document Control Data - R&D (Reference AFR 80-29). AFTAC will designate the appropriate Availability/Limitations Notice for use on these forms.

3

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Security Classification

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13. ABSTRACT

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