TECHNICAL REPORT NO. 71-21

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Quarterly Report No. 1, Project VT/2704
Contract F33657-72-C-0013
1 July through 30 September 1971

Sponsored by

Advanced Research Projects Agency
Nuclear Test Detection Office
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TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas

15 October 1971

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This is a report of the work accomplished on Project VT/2704 from 1 July through 30 September 1971. It describes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona, research and test functions carried out at the TFSO, and research and development tasks performed by the Garland, Texas, staff using TFSO data.

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CONTENTS

		Page
	ABSTRACT	
1.	INTRODUCTION	1
	1.1 Authority	1
	1.2 History	1
2.	OPERATION OF TFSO	1
	2.1 General	1
	2.2 Standard seismograph of operating parameters	3
	2.3 Data channel assignments	3
	2.4 Completion and shipment of data	3
	2.5 Quality control	3
	2.5.1 Quality control of 16-mm film seismograms	3
	2.5.2 Quality control of analog FM magnetic-tape seismograms	6
	2.5.3 Quality control of ASDAS magnetic-tape seismograms	6
	2.5.4 Quality control of DGRDAS magnetic-tape seismograms	7
	2.6 Inspections	7
	2.7 Emergency power generator	7
	2.8 Facility maintenance	7
	2.9 Lightning storms	8
	2.10 Spiral-four cable	8
3.	INSTRUMENT EVALUATION	8
	3.1 Long-period triaxial system	8
	3.2 Short-period five-element station	8
	3.3 Digital gain-ranging data acquisition system	9
	3.4 Astrodata seismic data acquisition	9
	3.5 Multichannel filter	9
	3.6 Gravity feed chemical supply system	9
	3.7 Experimental lightning protection circuit	9
	3.8 Extended long-period seismograph	10
	3.9 Short-period shallow borehole seismograph	10
4.	PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS	10
	4.1 University of California	10
	4.2 Visitors	10
	APPENDIX - Statement of work to be done	

ILLUSTRATIONS

Figure		Page
1	Location of TFSO	2
2	Normalized response characteristics of standard seismographs at TFSO	5

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TABLES

1	Operating parameters and tolerances of standard seismographs at TFSO	4

ABSTRACT

This is a report of the work accomplished on Project VT/2704 from 1 July through 30 September 1971. It describes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona, research and test functions carried out at the TFSO, and research and development tasks performed by the Garland, Texas, staff using TFSO data.

OPERATION OF THE
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Quarterly Report No. 1, Project VT/2704
Contract F33657-72-C-0013
1 July through 30 September 1971

1. INTRODUCTION

1.1 AUTHORITY

The work described in this report was supported by the Advanced Research Projects Agency, Nuclear Test Detection Office, and was monitored by the Air Force Technical Applications Center (AFTAC) under Contract F33657-72-C-0013. The effective date of the contract is 1 July 1971; the Statement of Work for Project VT/2704 is included in the appendix to this report.

1.2 HISTORY

The Tonto Forest Seismological Observatory (TFSO) was constructed by the United States Corps of Engineers in 1963. TFSO was designed to record seismic events and to be used as a laboratory for testing, comparing, and evaluating advanced seismograph equipment and seismometric recording techniques. The instrumentation was assembled, installed, and operated until 30 April 1965 by the Earth Sciences Division of Teledyne Industries under Contract AF 33(657)-7747. On 1 May 1965, Geotech assumed the responsibility of operating TFSO. The location of TFSO is shown in figure 1.

2. OPERATION OF TFSO

2.1 GENERAL

Data are recorded continuously at the TFSO for 24 hours each day of the week. The instrumentation that accomplishes this, and other instrumentation that is used for special tests, have been operated and maintained during this report period by a staff of four technical people. Administrative work is handled by one half-time person. All work is being accomplished during a "normal shift" from 8:00 a.m. to 5:00 p.m., and a "late shift" from 9:30 a.m. to 6:00 p.m. The normal work shift is worked each Monday through Friday except holidays and is considered the regular work day by all personnel. The late shift is worked every day including Saturdays, Sundays, and holidays, and is staffed by one man on a rotational basis.

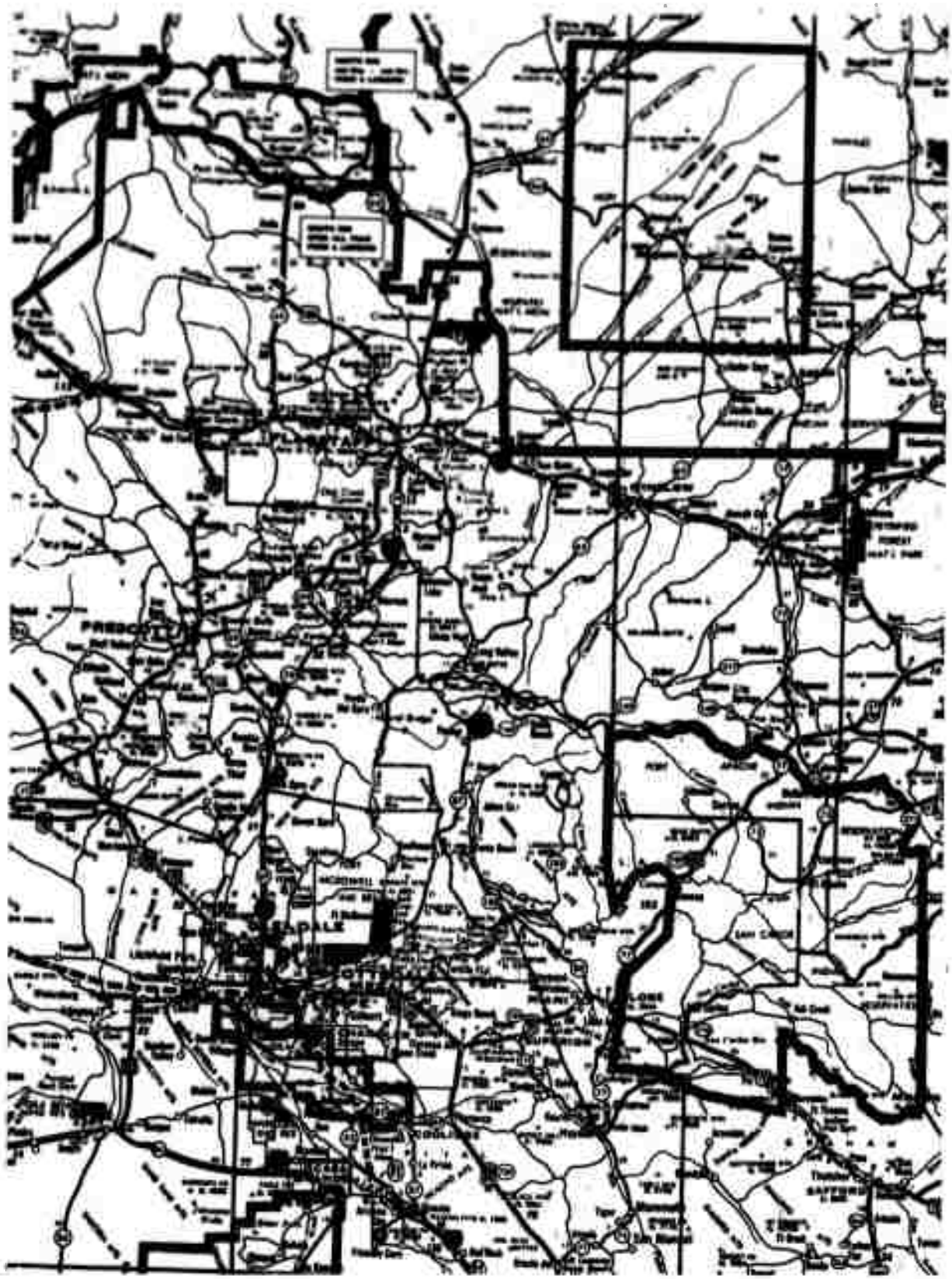

Figure 1. Location of TFSO

2.2 STANDARD SEISMOGRAPH OPERATING PARAMETERS

The operating parameters and tolerances for the TFSO standard seismographs are shown in table 1. Frequency response tests are made routinely and parameters are checked and reset to maintain the specified tolerances.

Normalized response characteristics of TFSO standard seismographs are shown in figure 2.

2.3 DATA CHANNEL ASSIGNMENTS

Each data format recorded at TFSO is assigned a Data Group number. When a data format is changed, a new Data Group number is assigned. Data Format Change Notices reporting changes in channel assignments were submitted to the Project Officer and to frequent users of the TFSO data during this report period.

2.4 COMPLETION AND SHIPMENT OF DATA

Six analog FM magnetic-tape units are used to record data for the AFTAC VELA Seismological Center (NYV). Before 1 March, tapes from these units had been sent weekly to our Garland, Texas, laboratory for quality control and had been shipped from Garland to SDL about 15 days after the end of the month in which they were recorded. Since 1 March, all FM tapes for six days were sent directly to SDL each week. Only tapes for one day were sent to Garland for quality control inspection and forwarding to SDL.

All ASDAS tapes, except two per week that were sent to Garland for quality control, were held at the observatory for a period of about eight weeks and then were recycled if not requested by a data user.

All Develocorder (16-mm film) seismograms, except quality control copies, were routinely shipped to SDL. One seismogram for each Develocorder was sent each week to our Garland, Texas, laboratory for quality control, then forwarded to SDL.

Copies of calibration and operational logs accompanied all data shipments.

2.5 QUALITY CONTROL

2.5.1 Quality Control of 16-mm Film Seismograms

Quality control checks of randomly-selected 16-mm film seismograms from Data Trunks 2, 4, and 8 and the associated logs were made in Garland. Items that were routinely checked by the quality control analyst include:

a. Film boxes - neatness and completeness of box markings;

b. Develocorder logs - completeness, accuracy, and legibility of logs;

Table 1. Operating parameters and tolerances of standard seismographs at TFSO

Seismograph				Operating parameters and tolerances				Filter settings		
System	Comp	Type	Model	Ts	ℎs	Tg	ℎg	Model	Bandpass at 3 dB cutoff (sec)	Cutoff rate at SP side (dB/oct)
SP[a]	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	---	---	2808-1	0.2 - 1.0	6
SP[b]	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	6824-1	0.1 - 100	12
SP[b]	H	Johnson-Matheson	7515	1.25 ±2%	0.54 ±5%	0.33 ±5%	0.65 ±5%	6824-1	0.1 - 100	12
SP	Z	Benioff	1051	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	6824-1	0.1 - 100	12
SP	H	Benioff	1101	1.0 ±2%	1.0 ±5%	0.2 ±5%	1.0 ±5%	6824-1	0.1 - 100	12
SP	Z	UA Benioff	1051	1.0 ±2%	1.0 ±5%	0.75 ±5%	1.0 ±5%	---	---	--
BB	Z	Press-Ewing	SV-282	12.5 ±5%	0.46 ±5%	0.64 ±5%	9.0 ±5%	6824-7	0.05- 100	12
LP	Z	Geotech	7505A	20.0 ±5%	0.77	---	---	30024	80 - 300	6
LP	H	Geotech	8700C	20.0 ±5%	0.77	---	---	30024	80 - 300	6

KEY

SP Short period
IB Intermediate band
LP Long period
UA Unamplified (i.e., earth powered)
BB Broad band

Ts Seismometer free period (sec)
Tg Galvanometer free period (sec)
ℎs Seismometer damping constant
ℎg Galvanometer damping constant

[a]37-element hexagonal array

[b]Linear array and 3 comp

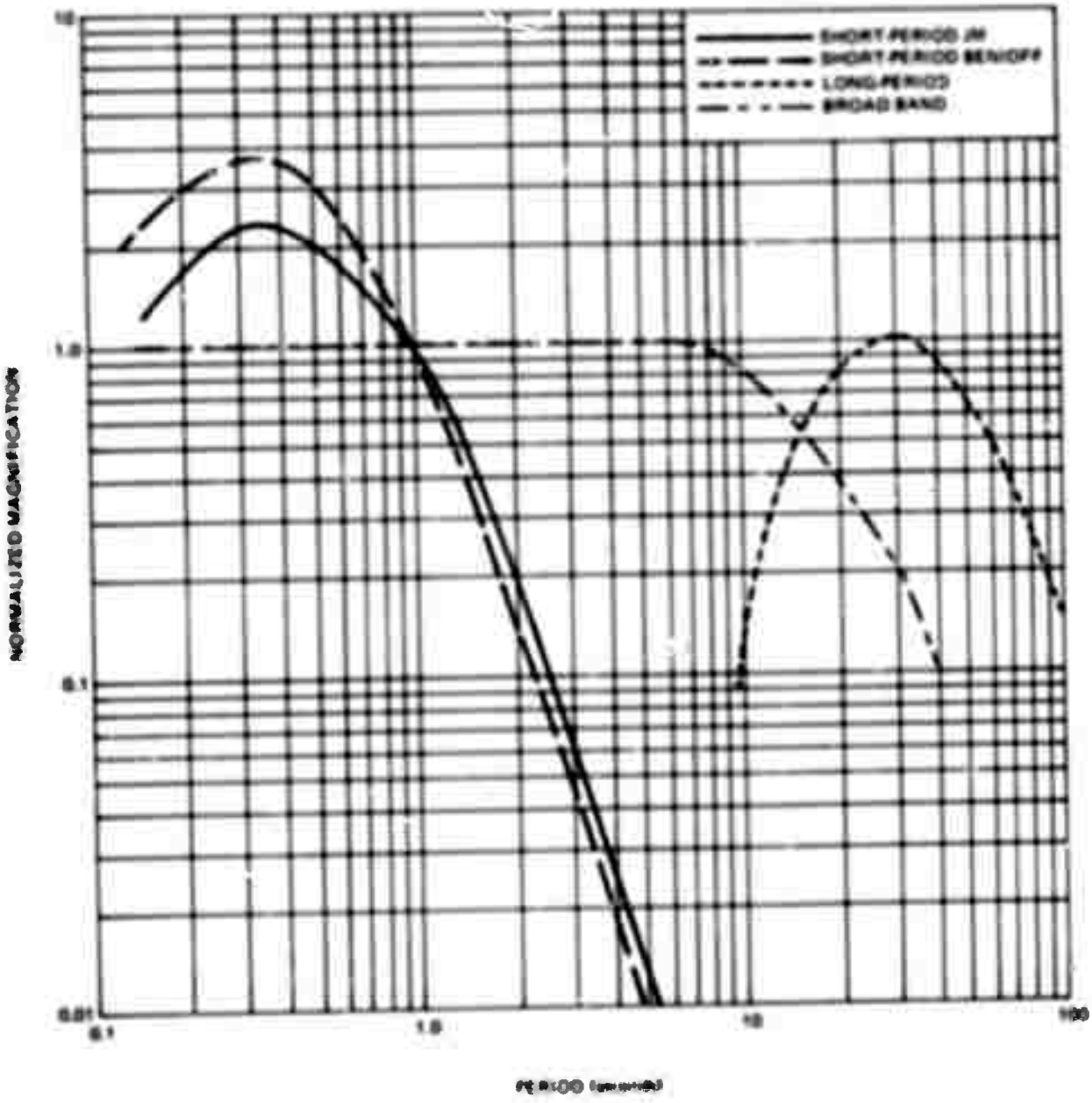

Figure 2. Normalized response characteristics of standard seismographs at TFSO

c. Film -

(1) Quality of the overall appearance of the record (for example, trace spacing and trace intensity);

(2) Quality of film processing:

d. Results of these evaluations were sent to the observatory for their review and comment.

2.5.2 Quality Control of Analog FM Magnetic-Tape Seismograms

Each week, quality control checks of three randomly-selected magnetic-tape seismograms are made in Garland and at TFSO to assure the recordings meet specified standards. The following items are checked;

a. Tape and box labeling;

b. Accuracy, completeness, and neatness of logs;

c. Adequate documentation of logs by voice comments on tape where applicable;

d. Seismograph polarity;

e. Level of the microseismic background noise;

f. Level of calibration signals;

g. Relative phase shift between array seismographs;

h. Level of system noise;

i. Oscillator alignment;

j. Quality of recorded WWV signal where applicable;

k. Time-pulse carrier;

l. Binary-coded digital time marks.

2.5.3 Quality Control of ASDAS Magnetic-Tape Seismograms

Quality control checks of ASDAS tapes are made routinely. At present, one tape from each of the two transports is checked weekly for the following items:

a. Neatness and accuracy of the associated logs;

b. Polarity errors;

c. Recording level of each channel;

d. Fidelity of reproduction;

e. Presence of header record and correct record length;

f. Tape parity errors;

g. Timing information.

2.5.4 Quality Control of DGRDAS Magnetic-Tape Seismograms

Quality control checks of DGRDAS tapes are made routinely. At present, one tape is checked each week for all items listed under section 2.5.3 and, in addition, for the following items:

a. Field transmission parity errors;

b. Central digital system parity errors;

c. Gain code errors.

2.6 INSPECTIONS

Mr. G. J. Riley, of the DCASD, Phoenix, Arizona, visited the observatory on 11 August to inspect government property classified as Industrial Plant Equipment and Other Plant Equipment.

Mr. L. R. Madden and Mr. P. Johnson, also of the DCASD, Phoenix, Arizona, visited the observatory on 24 August to conduct an inspection of all government property control procedures.

2.7 EMERGENCY POWER GENERATOR

The 100 kW diesel-powered generator was operated for a total of 7 hours and 18 minutes under full load conditions to furnish power for station operations during commercial power failures.

2.8 FACILITY MAINTENANCE

The TFSO facilities were maintained in accordance with sound industrial practices throughout the report period. This work included pest extermination, fire extinguisher inspection, work area cleaning, and lubrication and cleaning of the heating and air conditioning equipment.

2.9 LIGHTNING STORMS

The summer lightning season, during which a large number of lightning storms occur, began on 6 July and continued throughout the report period. Lightning, which was detected during 69 of the 92 days in this period, caused extensive damage to the TFSO equipment and the surrounding countryside, and frequently interrupted telephone and power service. An accurate count of equipment damage has not been assembled, as seismograph channel repairs have been undertaken on a priority basis, and some sites have not been inspected in detail.

Early in the season, the lightning storms were not often accompanied by rainfall. Due to lack of moisture, fire danger was high and the Tonto National Forest was completely closed from 2 July to 21 July. Twenty-four fires occurred simultaneously in the Tonto National Forest. All were brought under control quickly.

2.10 SPIRAL-FOUR CABLE

Forty-five of the cable assembly failures that occurred during July, August, and September have been repaired. This was accomplished by the replacement of 34 quarter-mile sections of cable, the cleaning of 8 hocks, and the replacement of 3 loading coils.

3. INSTRUMENT EVALUATION

3.1 LONG-PERIOD TRIAXIAL SYSTEM

The long-period triaxial system was operated routinely until 29 September when operational amplifiers and controls were added to the coordinate-transformed channels. After this was done, magnifications of the coordinate-transformed channels (ZTLP, NTLP, and ETLP) were adjusted to equal those of the corresponding LP1 channels (Z1LP, N1LP, and E1LP). The vertical channel magnifications were set to approximately 50K, the horizontals to approximately 25K.

3.2 SHORT-PERIOD FIVE-ELEMENT STATION

The short-period 5-element station was operated routinely until 17 July, when the automatic calibrator became inoperative. After it was repaired on 28 July, the station magnification was checked and found to be 20 percent low, indicating that one element might be inoperative. However, all elements were calibrated separately and were found to operate properly. The automatic calibrator output current was found to have changed value and was readjusted.

On 5 August, the U2 channel became noisy and was removed from the 5-element station summation, which operated as a 4-element station for the remainder of the report period. It is suspected that U2 became noisy because of lightning damage to the cable between the ROF and the U2 site. None of the 5-element station instrumentation has suffered lightning damage.

On the same day that U2 was removed from the summation channel, the grounds were removed from each of the remote site protective diodes. This circuit modification was made in the belief that it might remove several system ground loops and reduce the lightning interference in the signal channel.

3.3 DIGITAL GAIN-RANGING DATA ACQUISITION SYSTEM

The digital gain-ranging data acquisition system operated routinely throughout the report period. Its operation was interrupted only for routine cleaning, and for replacement of a parity bit generator, whose failure caused the generation of field transmission parity errors on channel 3.

3.4 ASTRODATA SEISMIC DATA ACQUISITION

The Astrodata seismic data acquisition system was operated routinely throughout the report period. Maintenance to the unit included routine cleaning and the replacement of belts, motor brushes, and a read card.

3.5 MULTICHANNEL FILTER

The multichannel filter, inoperative since April, was repaired and began recording on 15 July 1971, using format 19. Repairs were made to circuits in the paper recorder, the auxiliary processor, and the memory. It was operated routinely until 17 August when too few short-period channels were functional to justify continued operation.

3.6 GRAVITY FEED CHEMICAL SUPPLY SYSTEM

Three of the gravity feed systems used to supply chemicals to the Develocorder experienced a buildup of crystals in the fixer flow control valves. Replacement of these control valves appears to have corrected this problem.

3.7 EXPERIMENTAL LIGHTNING PROTECTION CIRCUIT

Operational tests were continued through July and August to determine the protective capabilities of the experimental circuit installed last January in power branch No. 2 of the short-period siesmograph array. By mid-August, operational data showed that the experimental circuit, which added ground-referenced diode protection to the channels Z12 and Z20, but left Z11 and Z13 through Z19 unchanged as controls, could be operated without introducing noise or unbalance in the power circuits. Furthermore, seven of the nine amplifiers

in the unchanged circuits were damaged by lightning, whereas neither Z12 nor Z20 were damaged, even though the cable to Z20 was struck by lightning. Following a review of these data with the Project Officer and with his approval, work was undertaken to add ground-referenced diode protection to channels Z11 and Z13 through Z19. Modifications to the power circuits for Z14 through Z17 were completed by the end of the report period.

3.8 EXTENDED LONG-PERIOD SEISMOGRAPH

Operation of the extended long-period seismograph, ZXLP, was resumed. This channel has been recording at a magnification of 140K since 6 July.

3.9 SHORT-PERIOD SHALLOW BOREHOLE SEISMOGRAPH

The shallow well seismometer was raised to the surface on 9 July. After repairs were made to correct leakage in the cable, the seismometer was lowered to a depth of 25 feet and parameter checks were made. The seismometer was then lowered to a depth of 171 feet on 21 July. All parameters are within assigned tolerances.

4. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS

4.1 UNIVERSITY OF CALIFORNIA

Mr. Don Miller, from the University of California at San Diego, visited TFSO on 12 July to pick up their equipment that had been left at TFSO on a standby basis.

4.2 VISITORS

The Project Officer visited the observatory during the interval 15 through 19 August. Operations of TFSO were reviewed.

APPENDIX to TECHNICAL REPORT NO. 71-21

STATEMENT OF WORK TO BE DONE

27 JAN 1971

STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/2704/B/ASD)

1. Objectives. The Tonto Forest Seismological Observatory (TFSO) is unique in its low level of background seismic noise and in its capability as a research center, being equipped with various film, paper and analog and digital recorders, a shake table, a large walk-in vault for instrument evaluation, and assorted test and measurement equipment. The purpose of this project is to operate this observatory as a source of high-quality seismological data for use in Government-sponsored research projects, to use the TFSO as a field test site for evaluation of new seismological instrumentation and procedures, and to support other research projects as identified by the project officer. This project should require a manning level of approximately five man-years.

2. Tasks.

a. Operation.

(1) Continue operating the TFSO according to established procedures (Standard Operating Procedures for TFSO, 1 Nov 1970), providing recorded data to the Government. Special data requirements anticipated will include, but not be limited to, recording signals from special events at the Nevada Test Site and supplying beam-formed or multichannel filtered data for use in evaluation of the effectiveness of the ARPA long-period arrays: Montana Large Aperture Seismic Array, Alaskan Long-Period Array, and Norwegian Seismic Array.

(2) Quality control the data acquisition systems and evaluate the seismic data recorded to determine optimum operating characteristics and perform research to improve operating parameters to provide the most effective observatory practicable. Major reconfigurations in equipment, those requiring more than 48 hours to remove, are subject to prior approval by the project officer.

(3) Provide use of observatory facilities and seismological data to requesting organizations and individuals as identified by the project officer.

(4) Maintain, repair, protect, and preserve the facilities of TFSO in good physical condition in accordance with sound industrial practice.

b. Instrument Evaluation.

(1) Evaluate the performance characteristics of experimental equipment identified by the project officer. This work involves investigation of such components as seismometers and amplifiers, combinations of components such as are involved in lightning protection

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improvement, and altered modes of operation such as radio transmission of data. These necessary investigations will be initiated only after advances in the state-of-the-art identify problems needing work. At present, the following areas for possible investigation are:

(a) Long-term field testing of a new version of the Geotech 23900 long-period seismometer incorporating an internal feedback system.

(b) Test and evaluation of a horizontal short-period array according to existing general operating procedures contained in Standard Operating Procedures for TFSO, 1 Nov 1970.

(c) Evaluation of an intermediate-frequency range system to be provided by the Government for recording of reflected body phases.

(d) Evaluation of special on-line signal detection algorithms.

(2) Maintain the equipment necessary to perform the above mentioned evaluations, including the shake table, signal conditioning and recording equipment, test and calibration instrumentation, and film viewers.

c. Upon identification and prior to the disposition of any equipment determined to be excess to the needs of the project, the contractor shall notify the project officer.

2