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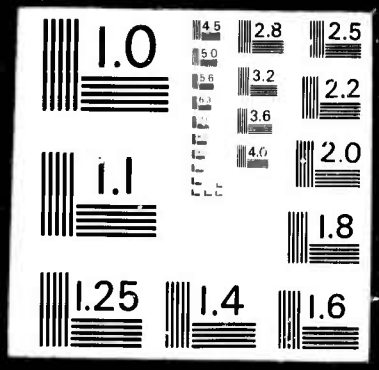

TECHNICAL REPORT NO. 70-32

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Quarterly Report No. 3, Project VT/0704
Contract F33657-70-C-0733
1 July through 30 September 1970

Sponsored by

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

TELEDYNE GEOTECH
3401 Shiloh Road
Garland, Texas

15 October 1970

IDENTIFICATION

AFTAC Project No:	VELA T/0704
Project Title:	Operation of TFSO
ARPA Order No:	624
ARPA Program Code No:	8F10
Name of Contractor:	Teledyne Industries, Geotech Division Garland, Texas
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Effective Date of Contract:	1 January 1970
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Program Manager:	B. B. Leichliter 271-2561, ext. 222

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ABSTRACT

This is a report of the work accomplished on Project VT/0704 from 1 July through 30 September 1970. Project VT/0704 includes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona. It also includes special research and test functions carried out at TFSO and research and development tasks performed by the Garland, Texas, staff using TFSO data.

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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 F33657-70-C-0733. The effective date of the contract is 1 January 1970; the Statement of Work for Project VT/0704 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. The observatory is manned for all of this time period except from 12:15 a.m. to 7:00 a.m. A full complement of personnel is on duty 8 hours per day, 5 days per week; at other manned times a skeleton operating crew is on duty.

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.

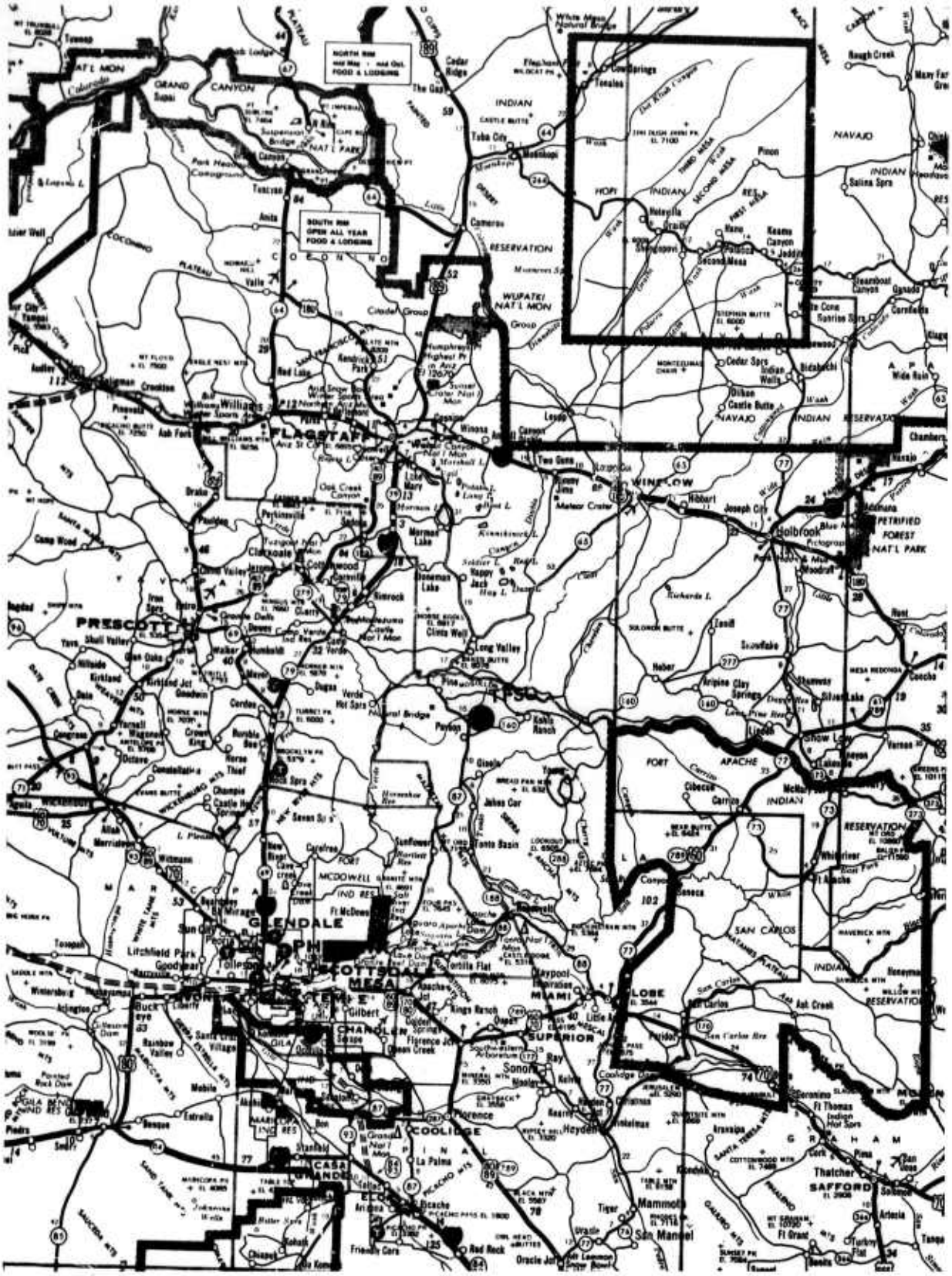

Figure 1. Location of TFSO

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

Seismograph				Operating parameters and tolerances				Filter settings		
System	Comp	Type	Model	Ts	λs	Tg	λg	Model	Bandpass at 3 dB cutoff (sec)	Cutoff rate at SP side (dB/oct)
SP	Z	Johnson-Matheson	6480	1.25 ±2%	0.54 ±5%	---	---	2888-1	0.2 - 1.0	6
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%	0.45 ±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

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

Ts Seismometer free period (sec)
Tg Galvanometer free period (sec)
λs Seismometer damping constant
λg Galvanometer damping constant

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 (VSC). Tapes from these units are sent weekly to our Garland, Texas, laboratory for quality control and are shipped from Garland to SDL about 15 days after the end of the month in which they were recorded.

All ASDAS tapes, except two per week, which 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 from 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;

c. Film -

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

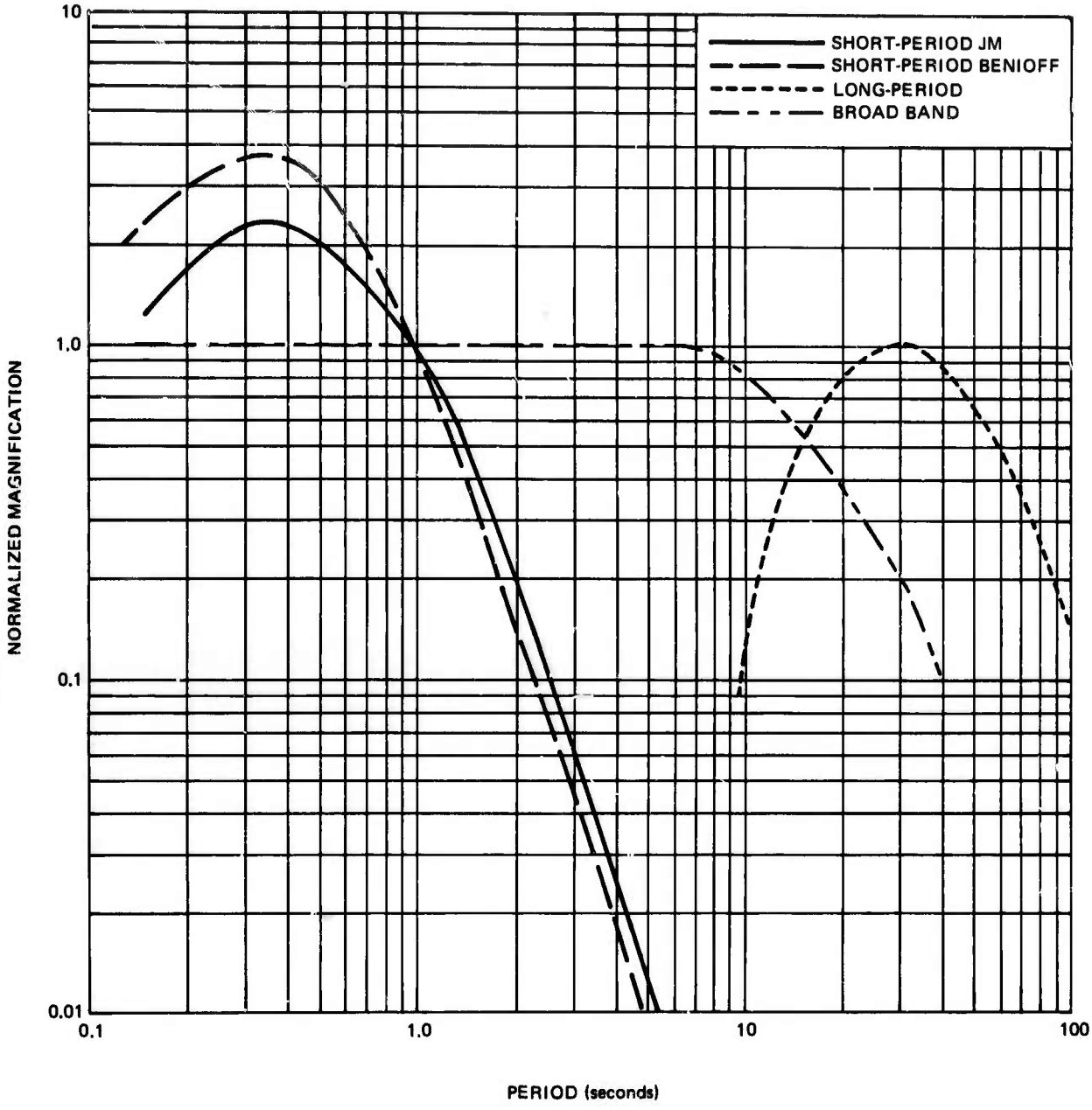

Figure 2. Normalized response characteristics of standard seismographs at TFSO

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(2) Quality of film processing;

d. Analysis - completeness, legibility, and accuracy of analysis sheets.

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 Digital Magnetic-Tape Seismograms

Quality control checks of digital 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. Parity errors;

c. Recording level of each channel;

d. Fidelity of reproduction;

e. Presence of header record and correct record length.

2.6 SECURITY INSPECTION

Mr. Kenneth G. Ozbolt, Office of Industrial Security, DCASD, Phoenix, Arizona, conducted a security inspection at TFSO on 3 September 1970. A letter from his office indicated that the TFSO security program was in conformance with the requirements of the DOD Industrial Security Manual.

2.7 GOVERNMENT PROPERTY

The government property used to telemeter data to the MIT Lincoln Laboratories was returned to MIT on 19 August.

Two Model RL-26 power cable reels, procured from surplus by the Project Officer, were received at TFSO on 19 August.

2.8 EMERGENCY POWER GENERATOR

The 100 kW standby generator, diesel power unit, Caterpillar Model 59825, was operated a total of 70.7 hours during this report period - 66.5 hours were due to commercial power loss and 4.2 hours for tests under full load.

2.9 RAINSTORM DISASTER

More than six inches of rain fell into the Payson, Arizona, area during the late afternoon of 5 September, overflowing creeks, sending torrents of water down canyons, flooding normally dry valleys, and causing widespread death and destruction. To date, 12 bodies have been recovered within a 30-mile radius of Payson. Dozens of homes and house trailers were washed away, and many roads were made impassable. Parts of Gila County were declared disaster areas by President Nixon. TFSO personnel used two radio-equipped, 4-wheel drive vehicles to assist the county sheriff in rescue and search operations.

The storm interrupted the operation of 29 short-period seismograph array channels and 12 long-period seismograph array channels at the TFSO. All

outages were caused by flood waters, none by lightning. Fighty-eight cables were broken or damaged, and six tank vaults were flooded. Repair work was undertaken immediately, and by 30 September, all channels except two short-period and one long-period were operating routinely.

Many seismograph array site access roads and cable trails were washed out and require repairs. Three roads are so badly damaged that sites to which they lead are inaccessible. All plans for road and cable trail repairs and land rehabilitation were coordinated with the U. S. Forest Service. Arrangements are being made to start bulldozer work during October.

2.10 FACILITY MAINTENANCE

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

2.11 DEVELOCORDER MAINTENANCE

Three chemical pumps failed and were repaired during the report period. The time in service for these units was 41, 151, and 228 days, or an average of 140 days. The new maintenance procedures, which have been followed since January 1970, appear to have lengthened average pump service life substantially (from less than 60 days to 140 days).

2.12 DAMAGE TO GOVERNMENT PROPERTY

Three observatory cables were intentionally damaged by being repeatedly shot. These occurrences were reported to Mr. M. Craig, Chief, Industrial Security, DCASD, Phoenix, Arizona, and to the FBI in Phoenix.

2.13 SPIRAL-FOUR CABLE

During this report period, the TFSO spiral-four cable assemblies suffered 166 failures. Three failures were due to vandalism, 67 to lightning, 88 to floods, and 8 to accidental cuts or breaks caused by workmen or their machinery. Repairs were accomplished by replacing 9 loading coils, making 93 splices, replacing 52 sections of cable, and cleaning 12 hocks.

3. EVALUATE DATA AND DETERMINE OPTIMUM OPERATIONAL CHARACTERISTICS

3.1 SHORT-PERIOD SEISMOGRAPH ARRAY

3.1.1 Lightning Protection

The annual lightning season began on 2 July and lasted throughout July and August. Severe local electrical storms, which occurred an average of three out of every four days during this period, damaged 16 short-period amplifiers (43% of the total number used). Damaged subassemblies within these amplifiers included 12 power converters, 4 voltage-controlled oscillators, and 6 operational amplifiers. It was noted that during the same time period, the long-period array amplifiers suffered a much smaller (14% of total number used) damage rate, and that no long-period power converters nor voltage-controlled oscillators were damaged. On the basis of these observations, the short-period array lightning protection circuit design is being reviewed to determine what changes might be made to reduce lightning damage.

3.1.2 Amplifier Modifications

During this report period, the output circuits of two amplifiers were modified to increase their output carrier levels. To date, 37 of the 43 amplifiers at TFSO have been modified. The remaining six amplifiers are installed in the inside ring of the array and transmit data to the CRB over short, low-attenuation cables.

3.2 LONG-PERIOD SEISMOGRAPH ARRAY

3.2.1 Lightning Protection

Despite the frequency and intensity of electrical storms during this report period, only three long-period amplifiers were damaged by lightning. In these amplifiers, damage was confined to three preamplifiers and one operational amplifier. No power converters were damaged.

A commercial power transformer at Diamond Point was damaged by lightning, causing a loss of power to the transmitter there and interrupting transmission of data from LP-5 for two days.

3.2.2 Terminal Blocks

As each long-period tank vault is opened for other work, the terminal board in the junction assembly is replaced. This job will be completed when the annual motor constant measurements are finished. The old board was found

to absorb moisture and to develop low resistance leakage paths between signal terminals, and also from signal terminals to ground. The new board is made of plexiglas, a better insulating material for this application.

3.3 ASTRODATA SEISMIC DATA ACQUISITION SYSTEM (ASDAS)

The ASDAS was operated routinely throughout the report period. All malfunctions that occurred during the report period were repaired with equipment on hand. A commercial power failure on 13 July apparently was preceded by a high voltage surge, for it caused extensive damage to the ASDAS power supplies and sense amplifier. The system was repaired and returned to operation on 18 July.

Head alignment was checked each month. All magnetic tapes were visually inspected for wrinkled edges or oxide scratches before being used to record data. Nineteen tapes were found to have wrinkled edges and were removed from service.

3.4 DIGITAL GAIN-RANGING DATA ACQUISITION SYSTEM (DGRDAS)

The work started in June to modify the DGRDAS was completed in August, and debugging work has been in progress since that time. The DGRDAS now records digitally on magnetic tape the 21 channels of seismic data produced by the long-period array.

4. ANALYZE DATA

The arrival time, period, and peak amplitude of events recorded at TFSO are reported daily to the Director of the Environmental Science Services Administration Coast and Geodetic Survey in Washington, D. C.

The number of events reported by TFSO during each month of the reporting period is shown in table 2.

Table 2. Events reported to the C&GS by TFSO for July, August, and September

Month	Local	Near regional	Regional	Teleseisms	Total
July	1	62	12	721	796
August	0	85	11	738	834
September	2	99	9	497	607

5. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS

5.1 CALIFORNIA INSTITUTE OF TECHNOLOGY

Mr. Ralph Gilman, California Institute of Technology, visited TFSO from 21 through 24 July to install and start operation of a horizontal long-period seismograph. TFSO personnel changed records daily and sent them to Mr. Gilman weekly until 30 September, when Mr. Gilman returned to TFSO to deactivate and remove the instrumentation.

5.2 UNIVERSITY OF UTAH

TFSO has continued to send copies of the daily station messages to Dr. Kenneth Cook, University of Utah.

5.3 UNIVERSITY OF CALIFORNIA, SAN DIEGO (UCSD)

Messrs. James C. Roberts and Robert W. Brooks, Princeton University, visited TFSO on 20 and 21 July to pick up the recorder that had been left in standby when UCSD deactivated a portion of their equipment earlier this year. The remaining operational equipment was serviced by UCSD representatives several times during this reporting period.

5.4 VISITORS

5.4.1 Defense Contract Administration Services District - Phoenix

Mr. George J. Riley visited TFSO on 4 August to conduct an Industrial Plant Equipment (IPE) inspection.

Messrs. L. R. Madden and B. R. Lucart visited TFSO on 13 August to conduct a government property inspection and to review property control procedures.

Mr. Paul Johnson visited TFSO on 3 and 29 September to check property that had been declared surplus.

5.4.2 Air Force Technical Applications Center

Dr. Carl F. Romney, AFTAC, and Mr. James E. Fix, Teledyne Geotech, visited TFSO on 18 September.

6. RESEARCH PROGRAMS

6.1 MULTICHANNEL FILTER (MCF)

The MCF, which operated routinely throughout the report period, was reprogrammed several times after tests showed that processing coefficients stored in the memory bank had been altered by lightning-induced power line voltage surges.

Following the requests of Dr. Blandford, SDL, the Fisher process normalization constant was changed on 3 August, and the MCF was reformatted on 21 August to beam its Fisher output to the Hudson Straits.

6.2 EXTENDED LONG-PERIOD SEISMOGRAPHS

The experimental long-period seismographs, ZXLP and ZYLP, were operated routinely throughout the report period.

6.3 FIVE-ELEMENT SHORT-PERIOD SEISMOGRAPH STATION

A letter report on the results of a computer and laboratory study of the performance characteristics of a 5-element short-period seismograph station was submitted to the Project Office during August. On the basis of this report, which theoretically and experimentally confirmed the feasibility of directly summing and then amplifying seismometer outputs, preparations were made to establish a field model of the station. By the end of this report period, the following work was accomplished:

a. A test plan for the work to be done was submitted to the Project Officer.

b. The five 23900 seismometers were set to periods of 0.9 Hz $\pm$1%.

c. Field cables to all sites were checked and made ready for operation.

d. Instrumentation was accumulated and modified as required for this installation.

e. The five shallow holes were drilled, cased, and cemented and are ready for seismometer installation. The following is a drilling log for these holes:

Site	Total depth in feet	Material from top to bottom of hole
Z4	8.5	6.0 ft weathered granite, 2.5 ft competent granite
Z60	8.5	6.0 ft weathered granite, 2.5 ft competent granite
Z64	8.0	5.5 ft clay and limestone, 2.5 ft competent limestone
Z68	18.0	16.5 ft intermittent limestone and clay stringers, 1.5 ft limestone
Z70	7.0	5.0 ft clay and limestone, 2.0 ft limestone

Field installation work will be started upon receipt of equipment and materials currently in use at the Geotech Garland laboratory, but scheduled to be shipped during the first week of October.

6.4 EXPERIMENTAL DEVELOCORDER PUMP

The experimental Develocorder pump operated throughout the report period without failure.

6.5 HIGH-FREQUENCY SEISMOGRAPH

The high-frequency seismograph, ZHF8, was damaged by lightning on 22 July and has been inoperative since that time.

6.6 SPRENGNETHER LONG-PERIOD SEISMOMETER

A report on an evaluation of the Long-Period Vertical Seismometer, Sprengnether Model S-5100V, has been prepared, approved by the Project Officer, and will be published during October.

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APPENDIX to TECHNICAL REPORT NO. 70-32

STATEMENT OF WORK TO BE DONE

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STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/0704/S/ASD) (32)

Tasks:

a. Operation.

(1) Continue operation of the Tonto Forest Seismological Observatory (TFSO), normally recording data continuously.

(2) At the beginning of the project, the required level of effort at the station will be approximately the same as the final level on Project VT/9702. By the end of calendar year 1970, routine operational requirements and support of developmental tasks will have been reduced to 50 percent, and by 1 Jul 1971, these requirements will have been further reduced to 20 to 25 percent of initial level.

(3) For the 12-month period from 1 Jan through 31 Dec 1970, conduct routine daily analysis of seismic data at the observatory and transmit daily seismic teletype reports to the US Coast and Geodetic Survey, Environmental Science Services Administration, Washington Science Center, Rockville, Maryland, using the established report format and detailed instructions.

(4) The contractor shall provide for the transmission to and recording at TFSO of strain data from the VELA Long-period strain project. This will entail a leased telephone line and installation of a GFP Zipagram system.

(5) Quality control and evaluate the seismic data to determine optimum operational characteristics and make changes in the operating parameters as may be required to provide the most effective observatory practicable. Addition and modification of instruments are within the scope of work; however, such instrument modifications and additions, data evaluation, and major parameter changes are subject to the prior approval of the Government. Included in this task will be evaluation of data processing procedures using the multichannel filter processor; signal processing, recording, and transmission system; and any other designated systems as directed by the Government.

(6) Provide observatory facilities and seismological data to requesting organizations and individuals after approval by the Government.

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

b. Instrument Installation and Evaluation. On approval by the Government, install and evaluate the performance characteristics of experimental or off-the-shelf equipment offering potential improvement in the performance of observatory seismograph systems. Operation and test of such instrumentation under field conditions should normally be preceded by laboratory test and evaluation.

c. Station Modification. As directed by the Government, incorporate new equipment into the system at TFSO. Removal of equipment should also be included in this task. Specific jobs under this task which shall be undertaken are:

(1) Install within the TFSO array the Model 30000 Observatory equipment consisting of seven long-period instruments and 13 short-period instruments with their accompanying electronics presently at Wichita Mountains Seismological Observatory (WMSO).

(2) Install radio links between six of the 30000 Observatory long-period sites (which should closely coincide with the present ring of long-period sites at TFSO) and the central recording station for transmission of data.

(3) Drill and case with 5-inch J55 casing 13 holes for installation at TFSO of Model 23900 instruments from the WMSO 30000 Observatory to a minimum depth of 10 feet below weathering or 10 feet into competent rock, whichever comes first. Install the instruments in the holes.

(4) Install a Government-furnished Zipagram system (12 channels) for multiplexing TFSO data to a central recording and processing facility.

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10. DISTRIBUTION STATEMENT

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13. ABSTRACT

This is a report of the work accomplished on Project VT/0704 from 1 July through 30 September 1970. Project VT/0704 includes the operation, evaluation, and improvement of the Tonto Forest Seismological Observatory (TFSO) located near Payson, Arizona. It also includes special research and test functions carried out at TFSO and research and development tasks performed by the Garland, Texas, staff using TFSO data.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Long-Period Array						
Short-Period Array						
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Multichannel Filter						