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OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Teledyne Geotech

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20 November 1972

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13. ABSTRACT

This is a report of the work accomplished on Project VT/3704 from 1 July through 30 September 1972. 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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TECHNICAL REPORT NO. 72-24

OPERATION OF THE TONTO FOREST SEISMOLOGICAL OBSERVATORY

Quarterly Report No. 1, Project VT/3704
Contract F33657-72-C-0800
1 July through 30 September 1972

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TELEDYNE GEOTECH
3401 Shiloh Road
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CONTENTS

ILLUSTRATIONS

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TABLES

OPERATION OF THE
TONTO FOREST SEISMOLOGICAL OBSERVATORY
Quarterly Report No. 1, Project VT/3704
Contract F33657-72-C-0800
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1. INTRODUCTION

1.1 AUTHORITY

The work described in this report was supported by the Advanced Research Projects Agency, Nuclear Monitoring Research Office, and was monitored by the Air Force Technical Applications Center (AFTAC) under Contract F33657-72-C-0800. The effective date of the contract is 1 July 1972; the Statement of Work for Project VT/3704 is included in the appendix of 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 responsilility 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.

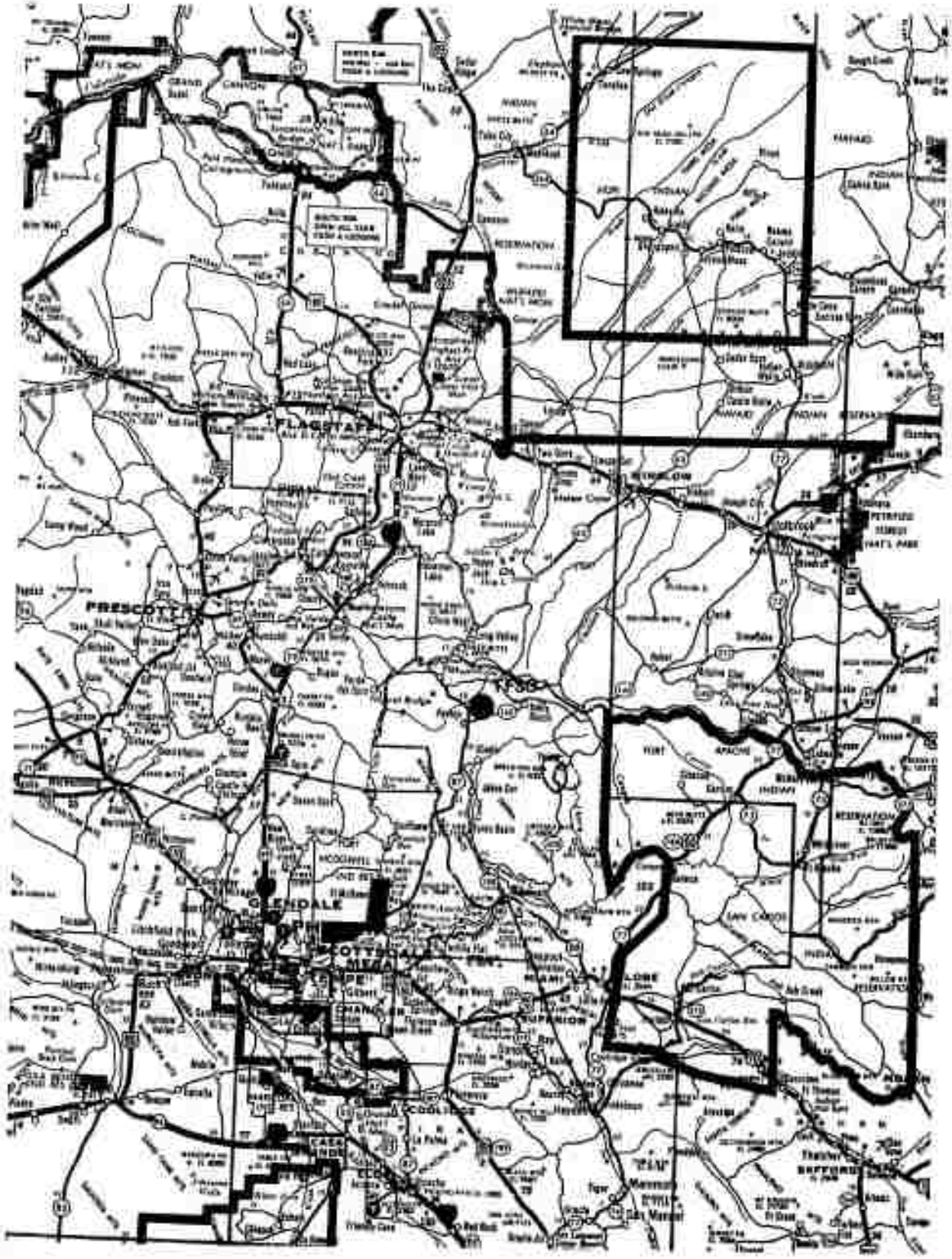

Figure 1. Location of the Tonto Forest Seismological Observatory

G 4970

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 ASSIGNMENT

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

Four analog FM magnetic-tape-units were used to record data for the VELA Seismological Center (NYV). Tapes from these units were shipped weekly. All tapes recorded on one day were shipped to our Garland, Texas, laboratory for quality control, then shipped to the SDL. All tapes recorded on the other six days were shipped directly to the 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 8 weeks and then were recycled, if not requested by a data user.

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

One DGRDAS tape was sent to Garland each week for quality control, then was forwarded to the SDL. All other tapes were shipped weekly to the SDL.

Copies of calibration and operational logs accompanied all data shipments.

2.5 QUALITY CONTROL

2.5.1 Quality Control of 16-Millimeter Film Seismograms

Quality control checks of randomly-selected 16-millimeter 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	λs	Tg	λg	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%	---	---	2888-1	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%	0.45 ±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
I8 Intermediate band
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

[a] 37-element hexagonal array

[b] Linear array and 3 comp

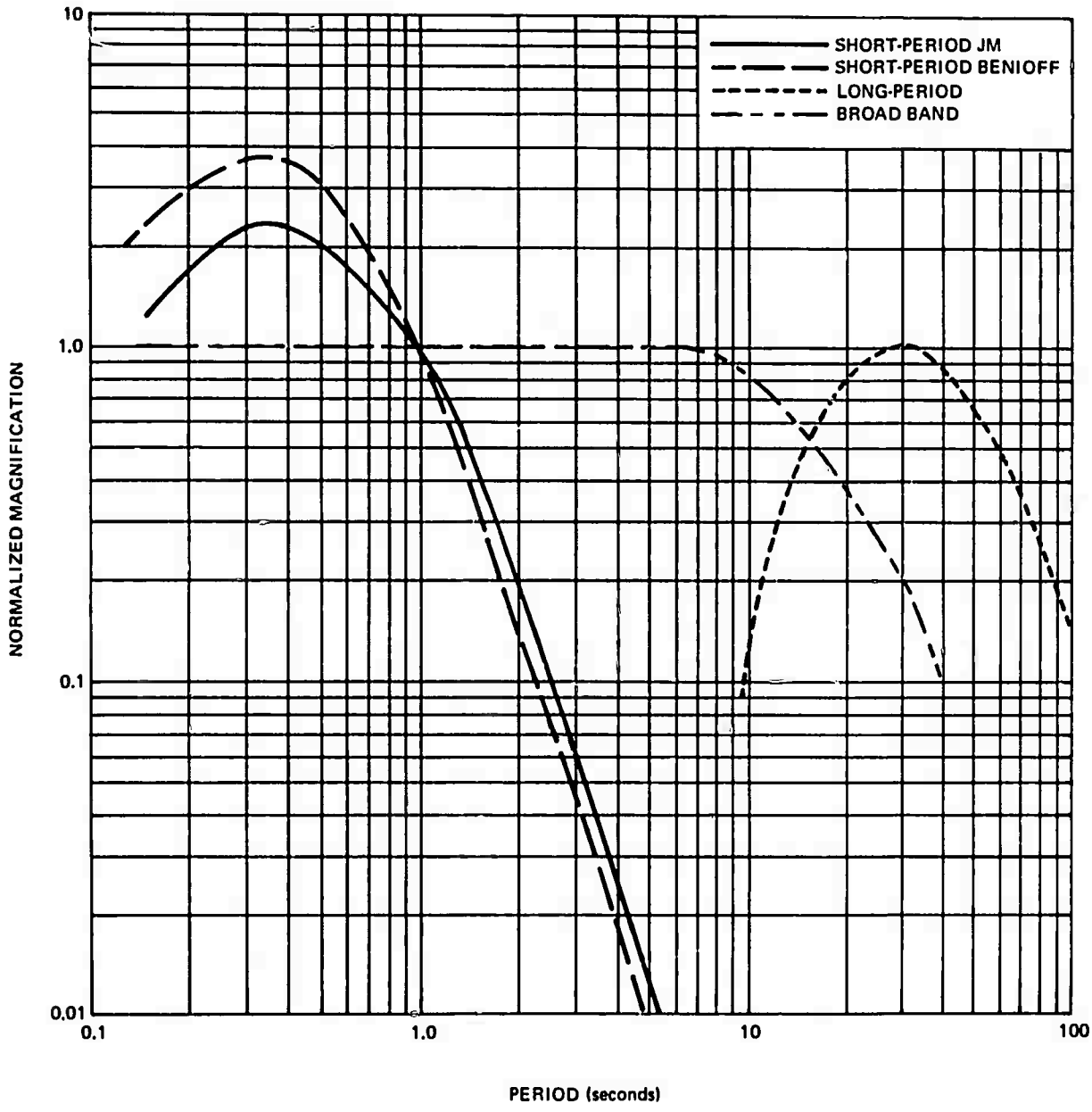

Figure 2. Normalized response characteristics of standard seismographs at TFSO

G 5048

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

A security inspection was conducted on 6 July by Mr. Ken Ozbolt, Chief, Industrial Security, Phoenix, Arizona. All phases of the TFSO security program were found to be in good order.

Mr. George Riley, of the DCASD, Phoenix, Arizona, conducted an industrial plant equipment inspection at the TFSO on 1 August.

Mr. Ray Madden, Property Officer from the DCASD, Phoenix, Arizona, conducted a property inspection on 17 August.

A real property inspection was conducted at the TFSO on 16 September by Mr. Thomas Muir.

2.7 EMERGENCY POWER GENERATOR

The 100 kW diesel-powered generator was operated for a total of 22.1 hours. All time was for operations under full load 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. The furnace ignition system failed on 9 August and was repaired the next day.

2.9 WEATHER

Lightning was observed on 49 days in the TFSO area during this quarter, and the temperature at the Central Recording Building varied from a minimum of 30°F to a maximum of 114°F. Rain fell during 29 days of this 92-day report period.

2.10 RELOCATION OF LP6

Amendments 7 and 8, authorizing the relocation of the LP6 site and releasing the S 1/2 of the S 1/2 of Sec. 26, T11N, R10E from the withdrawn area, were received from the Real Estate Division, U. S. Army Engineers, Los Angeles District in August. Construction of the new LP6 began 23 August, and vault excavations were completed on 24 August. The hole for the Lamont vault was excavated to a depth of 8 feet. Soft rock was found at a depth of 4 feet and continued to the 8-foot depth. The two holes for the conventional type vaults were dug to a depth of about 5 feet. The vaults were poured on 1 September, using 8 cubic yards of concrete. Construction of the access road, closing the old site, closing the old road by constructing water bars as flagged by the Forest Service, and patching of rough places in the existing road were completed during the month of September. The closing of the old road was monitored by a representative of the Forest Service.

2.11 SPIRAL-FOUR CABLES

The U. S. Forest Service telephoned TFSO on 22 August to notify observatory personnel that the cables on Houston Mesa had inadvertently been burned by the Forest Service during their burnoff of underbrush.

A total of eight 1/4-mile sections of cable were replaced, and 15 cables were spliced during the report period. Four cables were damaged by vandals, five were cut by construction vehicles, five were destroyed by fire from the Forest Service burn, and nine failed for unknown reasons.

An undetermined number of other spiral-four cables were damaged during this report period, but have not been repaired because of the limited manning of the observatory. Restoration of these other cables will be undertaken as quickly as work schedules will permit.

3. INSTRUMENT EVALUATION

3.1 DIGITAL GAIN RANGING DATA ACQUISITION SYSTEM

The digital gain ranging data acquisition system (DGRDAS) was inoperative from 1 through 7 July for repairs and adjustments, including the tightening of a loose pulley, and the replacement of one mechanical and three electronic components. During the remainder of the report, the DGRDAS was operated routinely except for cleaning and preventive maintenance.

3.2 ASTRODATA SEISMIC DATA ACQUISITION SYSTEM

The Astrodata seismic data acquisition system was operated routinely except for a short period of time when a belt, a motor, and some brushes were replaced and adjustments were made to vacuum controls, the capstan rollers, and the head alignment.

3.3 MULTICHANNEL FILTER

The multichannel filter (MCF) was operated from 1 July until 12 August, when it was shut down because there were not enough short-period channels operational to justify its continued operation. During its operational period, the MCF failed once and was repaired by the replacement of a fuse.

3.4 GRAVITY FEED CHEMICAL SUPPLY SYSTEM

The gravity feed chemical supply systems on the short-period Develocorders continued to operate without failures during the report period. Occasionally, adjustments were made to the drip rates. In some cases, simply pinching the hoses flushed out chemical buildups and corrected the flow rates.

Overdeveloping of the film on the long-period recordings continued on the long-period Develocorders until 25 August when the developer dilution was increased from 20:1 to 40:1 (40 parts water, 1 part developer).

3.5 EXTENDED LONG-PERIOD SEISMOGRAPH

The extended long-period seismograph, ZXLP, was operated routinely from 1 July to 5 August and has been inoperative during the remainder of the report period.

3.6 SHORT-PERIOD 37-ELEMENT SEISMOGRAPH ARRAY

Data from the short-period array channels Z1 through Z20 were recorded when they were available. Because of the high incidence of rainfall and severe lightning, and because the observatory is manned by a very small staff, the array channels were maintained operational for a very small portion of this report period. Channel outages are shown chronologically in figure 3. Repairs performed to restore the channels to operation included the following:

Component	Number of failures
Spiral-four cable	15
Power resistor (CRB)	2
Isolation filter	6
Amplifier	7

Cable failure was the leading cause of channel outage, and amplifier failure was the second leading cause. It should be noted that all amplifiers that failed were in channels Z1 through Z10. There were no amplifier failures in channels Z11 through Z20, whose power circuits had been modified for improved lightning protection before the beginning of this report period. Our Engineering Change Proposal No. 3, dated 29 September 1972, includes recommendations for improving lightning protection in the power circuits for channels Z11 through Z20.

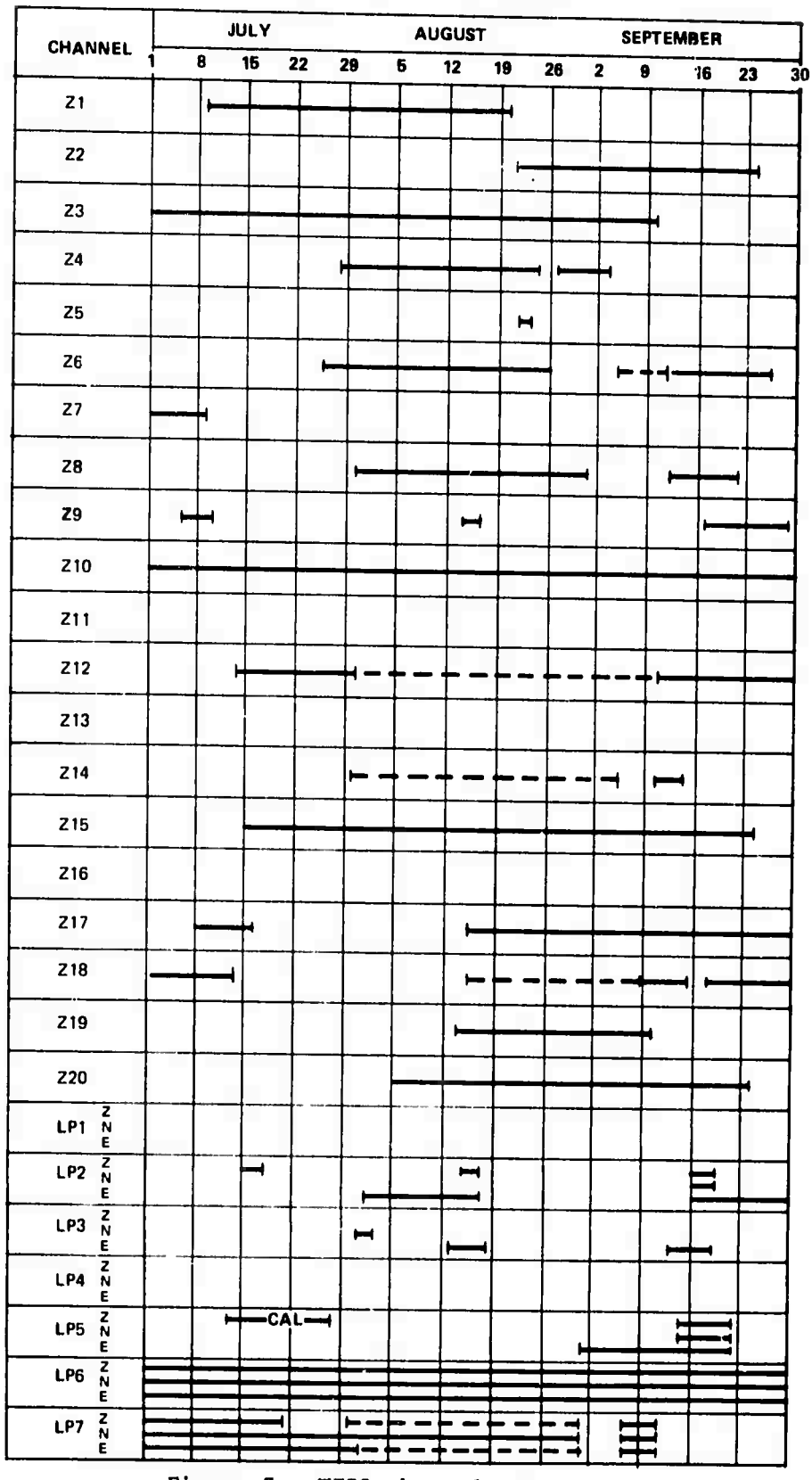

Figure 3. TFSO channel outage

3.7 LONG-PERIOD SEISMOGRAPH ARRAY

Long-period seismograph array data were recorded throughout the report period. As shown in figure 3, all LP6 channels were inoperative throughout the report period, and the LP7 channels were inoperative or noisy during most of that period. Outages in the remaining channels were relatively short, as the highest work priority was given to maintenance of channels in this array. The following repairs were performed:

Component	Number of failures
Microwave repeater	4
Seismometer (mass against stop)	5
Free-period relay	1
Power fuse (remote site)	2
Spiral-four cable	1

3.8 QUARTZ ACCELEROMETER

Work continued on the Block and Moore quartz accelerometer tests. A quartz spacer block for the horizontal unit and ten quartz suspension fibers were received from Worden Quartz Products, Inc., of Houston, Texas, early in July, and six quartz blanks, ready for fiber drawing operations, were received from the Frankford Arsenal in Philadelphia, Pennsylvania. The block and one fiber were installed in the horizontal accelerometer after three of the ten fibers were broken while learning the proper handling technique. The fiber for the vertical unit was installed with no difficulty. All work with the inner components of these units was done in the "clean room" facility at the Garland Plant. Parts were thoroughly cleaned and handled with white gloves to prevent introduction of contaminants which could cause problems in evacuation of the hard vacuum cans.

Dr. Robert D. Moore has been retained on a part-time basis as a consultant for the duration of this project. He visited the Garland plant on 19 and 20 July. In general, he was pleased both with our approach to the overall tests planned and with our methods of working on the accelerometers. He made several suggestions for further tests which will be included in the test plan. Also, he gave detailed instructions for the assembly, adjustment, and evacuation of the accelerometer.

By the end of July, the two instruments were ready for final assembly and vendors were being located for purchase or lease of the required evacuation and bake-out equipment. At that time, a second shipment of equipment from the University of California at San Diego was received at TFSO and was re-shipped to Garland. This shipment contained the soft vacuum cans and the thermal heater/isolators for the accelerometers.

In August, difficulty was experienced in tensioning the quartz fibers. All installed fibers broke when tensioned. Most held together intially when strung, but broke as long as several hours later. Following a detailed review of installation techniques and theoretical fiber strengths with Dr. Robert Moore and Ray Worden, it was concluded that all fibers had been weakened by exposure to moist air, and plans were made to prevent this from happening again. It was decided that, immediately after fabrication, each new quartz fiber would be placed into a glass tube which would be evacuated by a mechanical pump and sealed. The glass tube would be broken open just before the fiber was to be installed in the seismometer. If the installation and adjustments were not completed during one day, the partially assembled instrument would be protected from moisture by storing it in an evacuated bell jar overnight or until assembly work was to be continued.

Twenty-two quartz fibers were ordered from Worden Quartz Products, Inc., and a partial shipment of ten quartz fibers was received late in August. The fibers were hand-carried because they were packaged in evacuated glass tubes and could not be secured within the tubes. During an attempted installation of the first fiber, it was discovered that all ten had been improperly drawn and could not be used. The vendor agreed to repair or replace the defective units and to expedite the manufacture of the remaining part of the order. On 6 September, the defective units were returned to Worden and twelve more were picked up.

Dr. Robert Moore visited the Garland plant from 11 through 14 September. During that time the first of the new fibers was installed in the vertical accelerometer, the complete unit was assembled, and placed in the bell jar for preliminary tests under vacuum. The auxiliary damping paddles were found to interfere with full scale motion of the detector paddle. Also, the paddle damping, which had been noted during preliminary tests, was still evident even at pressures of about 5 torr (1 torr $\cong$ 1 mm of mercury). The accelerometer was then disassembled to adjust the auxiliary paddles and to check closely for foreign material which might cause the damping. During subsequent reassembly, the fiber was broken. After installing a new fiber, the completed unit was again placed in the bell jar and evacuated to about 5 torr. The detector plate was still overdamped. At Dr. Moore's suggestion, the bell jar was connected to the vacuum system of the Veeco Model MS90AB leak detector, which was leased for use on this program. When the pressure reached about 0.1 torr, the damping disappeared. From this, it was deducted that the damping originally noted in the vertical accelerometer was caused by a very small leak in its hard vacuum can. During future tests, damping as a function of pressure will be determined. This discovery has pointed out that the seal must be completely leak-free. Efforts will be made to assure this during final assembly.

While Dr. Moore was at Geotech, a thorough inventory was made of all parts and equipment received from Diax, Inc. It was found that some of the electronic items required repair and that some of the mechanical components required for operation were missing. With Dr. Moore's help, a complete list was made of these and all other items which will be necessary to put the two accelerometers in operation.

During the remainder of September, efforts were directed primarily toward the accumulation of the many detail parts. Sketches for missing components were made and fabrication of the parts was initiated. Vendors for the commercial parts were located and these items were ordered. It is expected that all necessary components will be on hand by mid-October, and that the accelerometers can be assembled and placed in initial operation soon after this.

3.9 LAMONT-DOHERTY SEISMOMETER ENCLOSURE

Operational testing of the Lamont vault continued during the report period. Recordings from the control channel were interrupted twice when the discriminator in that channel was damaged by lightning. Before August there was no consistent difference in the noise levels of the Lamont vault and control vault channels. At times the Lamont vault channel was noisier,,and at other times, the control vault channel was noisier. During August and September, however, the Lamont channel was rarely noisier than the control channel, and the control channel was frequently noisier than the Lamont channel. During quiet periods, both channels were equally quiet.

4. PROVIDE OBSERVATORY FACILITIES AND ASSISTANCE TO OTHER ORGANIZATIONS

4.1 TEXAS INSTRUMENTS

Texas Instruments (TI) personnel continued operational testing of the TI signal processor until 28 July. The processor was picked up from the TFSO on 5 August. Other equipment that was brought in by TI and was used to test the processor was stored at the TFSO. This material was picked up on 19 September by Mike Cowart.

4.2 TELEDYNE GEOTECH

Mr. O. D. Starkey, Teledyne Geotech, visited the TFSO from 4 August to 1 September and 11 through 19 September to test engineering models of his new force-balance long-period seismometers. Mr. T. D. Trosper continued this work from 19 September through the end of the report period.

4.3 VISITORS

Mr. Robert Armstrong, Assistant Ranger, USFS, Payson, District, visited TFSO on 24 July to confirm locations of TFSO cable trails for a comprehensive study the Forest Service was preparing on the Tonto National Forest.

Mr. Robert Andrews of Honeywell, Inc., visited TFSO on 24 August to inspect the condition of the six FM magnetic recorders in use there.

APPENDIX to TECHNICAL REPORT No. 72-24

STATEMENT OF WORK

PART II - THE SCHEDULE
SECTION F - DESCRIPTION/SPECIFICATIONS

STATEMENT OF WORK TO BE DONE
(AFTAC Project Authorization No. VELA T/3704/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 directed by the project officer. This project should require a technical manning level of approximately four 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. Evaluate the performance characteristics of experimental equipment identified by the project officer. This work includes investigation of the operational capability of dry film recorders, evaluation of the use of a single seismometer for obtaining both long- and short-period data, and study of altered modes of operation of cable

PART II - THE SCHEDULE SECTION F (Continued)

links and radio transmission of data. Additional investigations will be initiated as problems requiring investigation are identified. The total level of effort on this task will not exceed one man-year.

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.