QUARTERLY TECHNICAL SUMMARY REPORT, JANUARY-MARCH 1974

Royal A. Hartenberger

Teledyne Geotech

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This report summarizes the technical work, support, effort, and data services completed during the Quarter January through March 1974. The report is organized into Part A describing Operations and Maintenance functions (Tasks 1 through 4) and Part B describing Research (Tasks 5 through 8). In Part B, we describe only work represented by completed technical reports. Since the current contract replaced formerly separate contracts, the work

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SEISMIC DATA ANALYSIS CENTER QUARTERLY TECHNICAL SUMMARY REPORT JANUARY - MARCH 1974

AFTAC Project No.:	VELA VT/4709
Project Title:	Seismic Data Analysis Center
ARPA Order No.:	1620
ARPA Program Code No.:	3F10
Name of Contractor:	TELEDYNE GEOTECH
Contract No.:	F08606-74-C-0006
Date of Contract:	01 July 1973
Amount of Contract:	$2,152,172
Contract Expiration Date:	30 June 1974
Project Manager:	Royal A. Hartenberger (703) 836-3882

P. O. Box 334, Alexandria, Virginia 22314

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ABSTRACT

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A. OPERATIONS AND MAINTENANCE (Tasks 1 through 4)

1. Operations

During the quarter LASA data was recorded 93%, ALPA 97%, and NORSAR 95% of the available 2160 hours. Most of the outage noted for LASA was caused by computer failure at the LDC. Quality checking of the NORSAR transmission line produced the most significant outage for this link. Transmission error rate on the TAL for this report period was 1.0%.

2. Programming

a. EP and DP

During this quarter, a new version of the DP with changes to reduce low rate tape error was installed. After more than one month of operation, the error rate for low rate tapes was reduced by a factor of 20 to 1.

Changes were made to the EP system as a result of the elimination of the E and F rings at LASA. The event re-run package was changed to omit use of E and F rings. Also, the EP plot output format was revised to account for the missing subarrays to decrease the time required for EP plot preparation and plotting.

b. 360/44

The OS system generation was started. However,

some difficult problems unique to the 360 Model 44 have been found and we are working on them.

Errors affecting the machine accounting reports were found and corrected in the GRASP spooling package.

An accounting program was completed during this quarter. It is expected to improve our 360/44 utilization.

We have installed and are now supporting PL1 as an application language available on the IBM 360/44 system.

A subroutine was completed and catalogued to permit full use of the commercial instructions on the 360/40's. The macros "IF THEN ELSE" and "DOWHILE" were catalogued on the 360/44. They are to be used by Network Systems to support structured programming techniques.

The file maintenance program was modified to accept the new International Seismic Month data tape to keep our capabilities current with the development of this data base.

c. PDP-15

The PDP-15 required engineering changes to shorten memory I/O lines and the I/O bus length. These modifications were installed by DEC factory engineers and supported by the local field office. In addition, factory representatives from BUCODE

installed engineering updates to the 9-track tape units. The level of effort applied by vendor support amounted to about 40% of prime shift time.

A consultant to aid our staff in isolating operating system errors was obtained during this report period. His assistance was used during attempts to certify the hardware and system software modifications made throughout this quarter.

SWAP development has been postponed until the system hardware and software modifications have been certified.

The effort applied to the Varian software driver permits use of this device as a printer.

d. ARPA Network

A program has been written for the 360/91 to plot seismic data via network protocol on our graphics terminal. The purpose of this program is for demonstration and to help us understand network graphics conventions.

We have completed the coding and testing of our network software to transfer seismic data over the ARPA Network. Test results are as follows:

Stream Mode to UCLA----------14KB
Block Mode to UCLA----------1.4KB
Stream Mode to ILLIAC----------2.0KB.

The stream mode transfer rate to UCLA is close to the value computed by theoretical studies and controlled testing. The block mode transfer to UCLA produced a surprizingly low rate. This low rate has been found to be caused by the allocation logic in UCLA's software. We have discussed these transfer rates with their personnel. Changes to their system must be made prior to further testing.

e. Documentation

The following documentation was completed and delivered during the quarter:

360/Programs	PDP-15 Programs
EVENT	CALCOMP PLOT Package
M7APLOT	PLTPDP
	PLT360
	SWPXXX
	CLHAND

Updates to ISRSPS manuals 110S, 111S, 101, and 102 were completed and delivered.

3. Maintenance

Line voltage monitor equipment for the PDP-15 was installed for one month during this report period. Results of the data collected during this test are currently under investigation.

The VELA time code reader was replaced in the analog laboratory.

The magnifications of the LASA beam develocorder has been verified. The computed and measured gains now agree at 76K.

4. Data Services

a. Analog Processing

Tape compression, A/O conversion and special data playouts were routinely scheduled after we acquired an analog technician during this peiood. Currently, 30% of his time is spent on A/O conversions, and 30% on compression; his remaining effort is applied toward maintenance and satisfying specjal data requests.

b. Data Recipients

The SDAC/LASA weekly event summary was mailed to thirty individuals or institutions.

The following individuals and institutions received data from SDAC during the quarter:

MIT Lincoln Laboratory
U.S. Geological Survey, Menlo Park
Dr. John Lahr
Dr. William Bakun

Pennsylvania State University
Dr. Shelton Alexander

U. of Texas at Dallas, Dr. Mark Landisman
U. of Western Ontario, Mr. Avadh Ram
Dr. R. F. Mereu
ENSCO, Dr. E. Page
Institute of Geophysical Sciences,
Edinburgh, Dr. Graham Neilson
Texas Instruments
Electronic Signal Processing, Inc.,
Mr. J. Beardwood

Epicenter files have been routinely maintained as the data became available. LASA and NORSAR bulletin tapes have been converted to a format compatible with other epicenter files. This conversion allows a search to be made of the various epicenter files for common events. An Earthquake Research Laboratory (formerly NOAA, now USGS), LASA, and NORSAR collation file is routinely maintained. As of the end of the quarter, this collation file had been updated through 30 September 1973.

c. Tape Libraries

The SDAC seismic data library contains digital and analog magnetic tape and film recordings from the LASA, NORSAR, ALPA, and TFO arrays. It also contains analog tape and film from the seismic observatories and the LRSM sites operated early in the VELA program. In addition to the primary data described above, the library contains digital tapes either converted from analog data or reformatted from other digital data for selected events.

As of 31 March, there were approximately 30,000 digital tapes and 36,500 analog tapes in our library. The following catagories of digital tapes are permanently retained :

LASA Event	572
NORSAR Event	43
Long Period (LASA, NORSAR and ALPA)	4,038
Short Period LASA	3,508
NORSAR	812
Detection Log (International Seismic Month)	30
Extended Long Period	760
UBO Multiplexed	281
LASA Multiplexed	1,199
TFO Short Period	649
TFO Long Period	1,174
A/D and D/A Conversions	2,071
Miscellaneous	1,137

The following catagories of digital tapes are recycled or used in operations support:

LASA hi-rate tapes (LP and SP data)	8,843
Detection Log	14
Individual users and operations support	2,800

The analog library contains the following catagories of tapes:

Compressed tapes	9,330
Composite tapes	332
Tapes as recorded	18,000
Scheduled for compression	8,925

B. RESEARCH (Tasks 5 through 8)

Six reports were released for publication during the quarter. One of these, SAAC 10, represents work accomplished under a former contract; the remaining five reports concern work completed under the SDAC contract. A summary of each report follows.

1. Detection Threshold of the LASA, ALPA, and NORSAR Long-Period Network (SAAC 10)

Preliminary estimates of the network thresholds for the detection and measurement of Rayleigh waves were obtained in this study using long-period data recorded at LASA, NORSAR, and ALPA. A fast frequency-wavenumber detection processor, FKCOMB, was used for analysis. Events used in this study were obtained from the LASA/SAAC Daily Summary and the NORSAR Seismic Event Summary for the time period of 1 May 1971 to 30 April 1972. A combined ALPA-NORSAR-LASA capability was estimated using events from the Kurile Island Region, and a combined ALPA-NORSAR capability was estimated using Eurasian events. For the ALPA-NORSAR-LASA network, the equivalent body wave magnitudes at the 90% level of detection of Rayleigh waves from the Kuriles are as follows: ALPA, m_b = 4.3; NORSAR, m_b = 4.5; LASA, m_b = 4.5; and one out of three combined network, m_b = 4.0. From cumulative curves, the 90% level of detection of Rayleigh waves from the Kuriles are as follows: ALPA, M_s = 2.5; NORSAR, M_s = 2.9; and LASA, M_s = 3.0. For the ALPA-NORSAR network, equivalent

body wave magnitudes at the 90% level of detection of Rayleigh waves from Eurasia are as follows: ALPA, m_b = 4.7; NORSAR, m_b = 4.5; ALPA-NORSAR combined, m_b = 4.4. From cumulative curves, the 90% level of detection of Rayleigh waves from Eurasia are as follows: ALPA, M_s = 3.0; and NORSAR, M_s = 3.0. Thresholds were recomputed for the respective combined network wherein a sample was not deleted if a Rayleigh wave was masked at one array and was not detected at the other array. The equivalent m_b values at the 90% threshold were as follows: ALPA-NORSAR-LASA for Kuriles, m_b = 4.2; and ALPA-NORSAR for Eurasia, m_b = 4.5. The thresholds calculated for ALPA using f-k processing agree with those established using other methods such as matched filtering suggesting strongly that thresholds are geophysically real and not limited by processing methods.

2. A Comparison of the Location Refinement Techniques in the SDAC/LASA Event Processor (SDAC-TR-73-5)

Two techniques for refining locations, beampacking and crosscorrelation, which are programmed into the SDAC/LASA automated Event Processor (EP), are shown to produce equivalent array beam traces for LASA short period data. The crosscorrelation method requires an operational signal-to-noise threshold significantly above the SDAC/LASA detection threshold of 10db. In addition, the method yields unreliable locations for events with low coherence, such as events with low signal-to-noise ratios, mixed events, or events at short epicentral distances from the array. On the

other hand the beampacking method is independent of signal-to-noise ratio. Moreover, beampacking uses 15 to 20 percent less computer time than crosscorrelation and obtains locations with smaller location errors when compared to Worldwide Network locations.

This report also shows that the number of events reportable on the SDAC/LASA Daily Summary could be increased 15 to 20 percent by lowering the EP acceptance threshold from 14db to 12db. When operating the EP with a signal-to-noise acceptance threshold of 3 (10db), beampacking increased the number of verified events on the Daily Summary by approximately 30-40 percent over the number produced by crosscorrelation.

3. LASA Regional Travel-Time Corrections and Associated Nodes (SDAC-TR-73-6)

This report describes a new set of region corrections for LASA which more adequately covers the seismically active areas of the earth than did previous sets. The new set contains 183 calibration nodes versus 105 nodes on the set used in the SDAC/LASA system throughout 1972 and the first half of 1973. Each node contains the average relative travel-time residuals for each of the 21 subarrays at LASA which are valid over an area surrounding the location of the node. The corrections were generated from more than 1800 events using as a primary source of data the time shifts resulting from the crosscorrelation process in the SDAC/LASA Event Processor.

4. False Alarm Probabilities for Mixed Events (SDAC-TR-73-8)

The analysis of 1,471 P- and PKP codas indicates that the probability of an unexplained phase occurring in a coda of an event as recorded at a single station is 0.12 for a detection threshold on the order of 3.5db (signal-to-coda background). The average coda length is roughly 6 minutes (343 seconds) for the events examined. The probability, therefore, that the seismograms at four stations out of thirteen will exhibit unexplained phases in the coda of a given earthquake is 0.045. The probability that unexplained phases at four stations will yield a significant location solution is 0.032. Thus, with about 10,000 events occurring each year of magnitude $m_b \geq 4.0$, and with all of them examined for unexplained phases, we expect 15 false alarms per year. The probability that four or more stations will experience a false alarm is essentially the same as the probability that exactly four stations will experience a false alarm. For purposes of on-site inspection, residual travel-time errors $-3 \leq \varepsilon_i \leq 3$ seconds imply that an event can be located anywhere in an area 3.2×10^5 km^2 in size.

5. Seismic Distance-Amplitude Relations for Short-Period P, P_{diff}, PP and Compressional Core Phases for $\Delta > 90°$ (SDAC-TR-73-9)

Measurements of $\log_{10}(A/T)$ reported by the International Seismic Centre, the VELA Observatories, and the Long-Range Seismic Measurements Program are used

in this study to define an amplitude-distance curve for the maximum amplitude in the first few seconds of motion for the distance range $\Delta>90°$. In general terms, the corresponding phases are P, P_{diff}, and PKIKP. Some information is also obtained, however, for the phases PP and PKP_2.

6. Regional Attenuation of Short-Period P and S Waves in the United States (SDAC-TR-74-1)

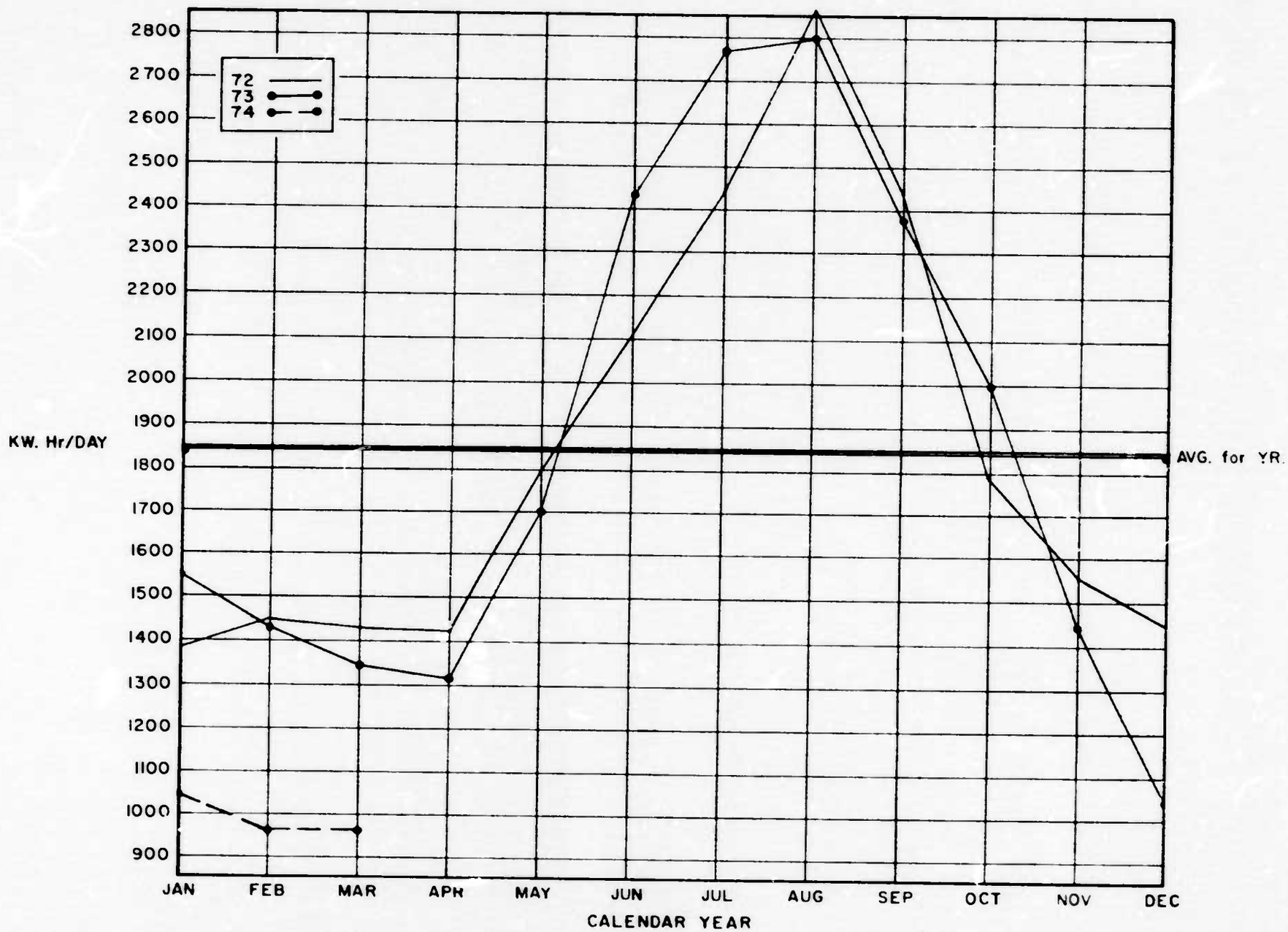
Regional distribution of anelastic attenuation beneath the United States was investigated using amplitudes and dominant periods of short period P and S waves originating from deep focus earthquakes in South America and the Circumpacific seismic belt, recorded at LRSM (Long Range Seismic Measurement) stations. The observed regional distribution pattern shows high attenuation in the western United States, including California, and a less pronounced high attenuation region in the northeastern United States. This distribution pattern is similar to that reported by Solomon and Toksöz (1970) for long period S waves, but differs from it sufficiently to indicate lateral variations in the frequency dependence of the average crust-upper mantle attenuation across the United States. The relative changes of short period P and S wave amplitudes can be sufficiently explained by assuming a complex shear modulus; no losses in compression are indicated.

C. ENERGY CONSERVATION

In accordance with national policy, we have taken a series of steps to conserve energy in our operations. We have reviewed our travel requirements to determine which trips are essential and to assure that only one person travels when more people are not actually required to accomplish a given mission. In the parts of our facilities where a special environment is not required for computers, we have taken measures to control heating and air conditioning. Specifically, we maintain heating thermostats at or below 68°F and cooling thermostats at 78°F; outside the work shifts we turn off the systems entirely.

We have made two studies to determine the effectiveness of our efforts. In an attempt to reduce electrical consumption, we have had a vigorous campaign to reduce lighting, the results of which are shown in Figure 1. As can be seen, the average for the first quarter for 1974 has been reduced about 30% from that for similar periods in 1972 and 1973.

After a campaign to reduce the use of fuel by employees coming to work, we have produced the following results: of all employees in the Alexandria Laboratories of Geotech 38% participate in car pools, 9% use the bus, 5% use motorcycles, and 10% walk or ride bicycles to get to work.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D. VISITING SCIENTISTS

During the quarter, scientists from France, Russia, and Sweden visited the Seismic Data Analysis Center. The results of these visits are summarized below:

Dr. Guy Kuster and Dr. Bernard Massinon of the Atomic Energy Commission of France (CEA) visited the Seismic Data Analysis Center in Alexandria, Virginia from 22 through 24 January 1974. We discussed with them the automatic detection algorithms used in the SDAC/LASA system and the Seismic Wave Analysis Program to be used with the PDP-15/50 system. They described their organization, the seismic network in France, and their plans to use a PDP-11/45 in their system. Unclassified documents were exchanged, and they expressed the desire to formalize an exchange of data between the two countries. They are particularly interested in receiving our SDAC/LASA Weekly Event Summary.

Dr. I. P. Passechnik and Dr. V. F. Pisarenko of the Academy of Sciences, U.S.S.R., visited the Seismic Data Analysis Center (SDAC) at 314 Montgomery Street, Alexandria, Virginia from 04 to 08 February, 1974, inclusive, to exchange technical information relative to seismic monitoring of underground nuclear explosions. Dr. E. Willis and Dr. C. F. Romney of the Defense Advanced Research Projects Agency were official hosts for the visit. During the week the ARPA representatives were supported in formal lectures and informal discussions

by the scientific staffs of Teledyne Geotech and Texas Instruments. The technical discussions concerned principally the detection, location, and identification of underground nuclear explosions and earthquakes and related subjects such as time-series analyses, source studies, and seismic instrumentation. In their lectures the Russian scientists described seismology in the Soviet Union, earthquake prediction, spectral analysis, the nature of the core-mantle boundary from PcP/P amplitude observations, and peaceful uses for nuclear explosions.

Dr. Dahlman, Mr. Israelson, and Mrs. Hornstrom of the Swedish Research Institute of National Defense visited the SDAC on 21 March 1974. Dr. Dahlman is a primary advisor on test ban negotiations and Director of the Hagfors Observatory; he is assisted by Mr. Israelson. Mrs. Hornstrom is a systems programmer. The primary purpose of their visit was to see the PDP-15 computer, because they expect delivery in May of a similar system. They were also interested in our research and analysis work. During the morning we discussed the role of the SDAC in the VELA Program and the SDAC/LASA system. The activities of the morning terminated with a tour of the facility. In the afternoon Dr. Dahlman described his organization and some of his research, and Mrs. Hornstrom was briefed on the PDP-15 system.