1764

SEMI-ANNUAL TECHNICAL SUMMARY REPORT

FOR

DATA ANALYSIS AND TECHNIQUE DEVELOPMENT CENTER

DATDC REPORT NO. 34

18 October 1962

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United ElectroDynamics, Inc.

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TABLE OF CONTENTS

INTRODUCTION

This report is the second Semi-Annual report and covers work performed under contract AF 33(657)-7427, project VT/2037, for the period 23 August 1962 to 15 October 1962. It is composed of two parts, corresponding to Tasks B and C of the contract work statement. Task A work, covering developing analytical techniques and analyzing data prior to the establishment of the Data Analysis and Technique Development Center, was completed prior to this period. For work performed under Task A see Semi-Annual Technical Summary Report, dated 23 August 1962.

Work performed under Task B is outlined in the categories of the appropriate work statement sub-tasks. Work performed under Task C is outlined in the general category of Technical Status.

For both Task B and C the discussion is limited to the work performed in the period covered by this report. Work previously reported is discussed only as it relates to the work performed for this period.

TASK -B- DESIGN AND ESTABLISH A DATA ANALYSIS AND TECHNIQUE DEVELOPMENT CENTER

1. Design a data processing system for manual and machine analysis of seismic data to accomplish the work specified under Task C:

Revisions have been made in the organizational structure and in the operating procedures in order to better carry out the concept of this sub-task. The Machine Analysis group has been transferred from the Data Analysis Section to the Computational Services Section and the Technical Services Section has been transferred into the Computational Services Section.

Since most of the equipment groupings are now or will soon be complete, and since the use of these equipment groupings are becoming more closely related to each other, it is desirable to assemble all machine operations, together with their attendant engineering and maintenance operations into one section.

Also, at the request of AFTAC, a separate group has been set up within the Data Analysis Section, having as its sole function the analysis of NTS explosions or earthquake events.

This group has the monthly capability to produce reports covering two preliminary visual analysis and two supplementary analysis covering a more detailed study of particularly interesting phenomena for explosions or earthquakes previously analyzed.

Equipment revisions needed to operate the data handling and processing system are discussed in sub-task 4.

2. Design a system for cataloguing and classifying data which includes means for rapid access to significant data. Provision is to be made for storage of the raw data and for furnishing copies to other participants in the VELA program:

A 1604 digital program routine has been written which provides a data cataloguing and classification system and which will also aid in data retrieval. Information as to data received is punched on IBM cards. The cards can be run through the digital computer which sorts the information according to time and/or location.

It is planned to store these data on magnetic tapes and catalogue data as received.

3. Obtain or prepare digital and analog computer programs for cataloguing, processing and analyzing the data:

Appendix I contains a complete list of all digital programs in use at the DATDC as of 12 October 1962.

Appendix II contains a list of the analog programs in use.

Appendix III contains a list of the digitized seismic tapes on file.

4. Upon obtaining approval from the government, procure and install the equipment necessary to operate the data handling and processing system:

The analog processing equipment for PSD's, tape copying and editing and oscillograph playouts, Assembly A of the Machine Analysis system was made operational during September 1962. Assembly B, for A-D conversion and tape editing is scheduled to be made operational during November 1962.

The EAI 231R Analog Computer was also made operational during September 1962.

Revisions to the equipment requirements are as follows:

A. Plans have been made to add a Develocorder to the Analog system. This will expand the capability of the Center to play-out data on 16mm film.

The Develocorder, Model 4000-S, has been ordered, together with its associated electronics, from the Geotechnical Corporation.

B. Development of a British-VELA UNIFORM Magnetic Tape Conversion Unit. This will provide the Center with a capability to translate existing British magnetic tape seismic recordings into the VELA-UNIFORM (IRIG) format, and conversely, to translate VELA-UNIFORM (IRIG) magnetic tape seismic recordings into the British format.

One set of British Playback and Record Heads have been received and mounted. They have been modified to be compatable with Minneapolis Honeywell tape transports. It is planned to obtain four additional British Playback and Record Heads; our present equipment will be modified and expanded in order to fully utilize this capability.

C. High speed card reader for digital computer. The present card reader, a CDC 1609, processes 100 cards per minute; it has proven to be too slow for the present and expected future work load. A new card reader, the CDC 088, has been ordered. It processes 650 cards per minute which is felt to be adequate for any future requirements. Delivery is expected in December 1962.

5. Establish the Data Analysis and Technique Development Center.

Construction of the permanent facility is well underway. Exterior walls are complete, the roof is on, floors are poured, major building equipment items are in, and plumbing and electrical work has started.

Close coordination is being maintained with the builder to assure that the special design features required for the DATDC are properly installed and that construction is completed as scheduled.

TASK -C- OPERATION OF THE DATA ANALYSIS AND TECHNIQUE DEVELOPMENT CENTER

1. Magnitudes

A statistical procedure has been established to determine a linear relationship between two variables under the assumption that the two variables are both in error, that they may be correlated, that the observations are made in groups, and that within each group individual observations of one or the other variable may be missing.

This problem relates specifically to determination of the relationship between different methods of computing seismic magnitudes.

The analysis has been programmed for the CDC 1604, and a test group of earthquake magnitudes run with the program. These preliminary results indicate that this analysis may yield more significant conclusions than previous methods.

2. Long-Period Wave Behavior

Preliminary analysis of the SEDAN records indicated that nearly all of the signals present on the LPZ and LPR records are due to Rayleigh waves, as evidenced by the retrograde elliptical particle motion and group velocities. Possibly due to dipping beds, topography, etc; the amount of Love wave energy present on the LPT was small, even in comparison with the Rayleigh wave energy. The Love wave can only be observed reliably at distances less than 1000 Km from the shot point.

Phase and amplitude spectra were computed for these waves by Fourier-Laguerre transforms to determine the dispersion and attenuation for a profile of stations. The dispersion and attenuation characteristics will permit a study of the source behavior for these waves by inverse filtering.

3. Phase Velocity in Terms of Group Velocity

From the established relation

$$\frac{1}{u} = \frac{1}{v} + \frac{T}{v^2} \frac{dv}{dT}$$

between the phase velocity v, the group velocity u and the period T, an explicit expression is derived for the phase velocity in terms of the group velocity of the form

$$v = \int_T^{\infty} T \left(\frac{dr}{r^2\, u(r)} \right)^{-1}$$

4. The Use of the Analog Computer to Enhance Phase Identification.

Difficulty is often encountered in the determination of the P_g and L_g phases and their arrival times in the analysis of component seismograms. Combinations of these component seismograms were sought to enhance character correlation of phases, phase arrival time determination, and signal, noise ratio. Mathematical combinations studied were: (R+T), (R+T+Z), (R-T), (Z+T), (RxT), (RxTxZ), R^2, (R^2+T^2), $(R^2+T^2+Z^2)$, $\sqrt{R^2+T^2}$, $\sqrt{R^2+T^2+Z^2}$ and (ZxT). The optimum combination for the objectives sought was $(R^2+T^2+Z^2)$. Residual graphs of Lg and P_g showed less scatter of points than those derived by film analysis.

A preliminary report is in process and evaluation of the $(R^2+T^2+Z^2)$, (R^2+Z^2) and (RxZ) combinations on other events is continuing.

5. Linear Array

A digital computer program for processing seismic data from linear arrays has been completed and applied to analysis of six earthquakes and four other seismic events. More seismic events are being digitalized, and an expanded version of the program is being coded.

As expected, some time was required in this project to test out different ideas and procedures, and to check the effects of varying parameters. The computer program now in use was designed without the benefit of the experience the project personnel have gained; it is felt that the expanded program will speed up the analysis considerably.

Preliminary results available at this date tend to support the expectation that linear arrays, processed by phasing and cross-correlation, can be useful in detection and identification of seismic signals, as well as in the process of deriving information about the structure and characteristics of the earth.

6. Power Spectral Densities

A comparison of the various analog and digital methods of computing power spectral densities (PSD's) is underway. A preliminary report in preparation shows the variations which occur in the PSD's computed by both analog and digital methods with different values of parameters such as bandwidth, integrating time, sweep time, and number of correlation lags.

7. Oscillogram Recording and Reproduction

The DATDC must be able to reproduce high quality oscillograms in large quantities. Encouraging results have been obtained using Dupont photo recording film, Lin-o-flex-1. Further experiments using this process are continuing.

8. Digital Plotter Routine

A generalized pen motion routine for the digital x-y plotter has been completed. This routine gives the capability to plot points or line graphs giving the coordinates with no operator intervention between plots.

APPENDIX I - DIGITAL PROGRAMS

The following is a list of programs and subroutines which are in use at the DATDC as of 12 October 1962.

A1 CMD   Multiplication and Division of Complex Numbers. FORTRAN. A package of subroutines for computing products and quotients of complex numbers.

A1 COMAG Modulus of a Complex Number. FORTRAN. Compute the modulus of a complex number and set error flag when exponential overflow occurs.

A2 DRIP   Double Precision Arithmetic. Perform double precision floating point arithmetic in 1604 language. Timing (average), add-500 microseconds, substract-500 microseconds, multiply 1000 microseconds, divide-1500 microseconds.

A2 CMPLXADD Floating Point Complex Add. Compute the sum of two floating point complex numbers. 9 locations. 173.6 microseconds, average.

A2 DPF   Double Precision Floating Point Arithmetic. FORTRAN. These routines allow a moderate amount of double precision floating point calculations to be made in the FORTRAN system. Add, subtract, multiply and divide. 419 locations.

C1 LAGUER   Laguerre Polynomial. Evaluate the Laguerre Polynomial for any real argument x and any order n. 130 238 (n-1) microseconds. 24 locations.

C1 LEGEND   Legendre Polynomial. Evaluate the Legendre Polynomial for any real argument x and any order n. 123 + 247 (n-1) microseconds. 25 locations.

C1 TCHEB   Tchebychev Polynomial. Evaluate the Tchebychev Polynomial for any real argument x and any order n. 109 81 (n-1) microseconds. 16 locations.

C2 POLYMUL Roots of Polynomial Equations by Mullers Method. FORTRAN. To find, using Mullers method, all the roots of a polynomial equation having arbitrary complex coefficients.

D1 TRAPZ   Trapezoidal rule integration, FORTRAN. Evaluates the integral of f (x) dx for a succession of f (x)s by the Trapezoidal rule. Space required = 164 locations. Timing = 850 microseconds average.

APPENDIX I - DIGITAL PROGRAMS (continued)

D5 EXTREM Multi-Dimensional Extremum Seeker. FORTRAN. This subroutine computes the maxima, minima, or saddle points for a single function of up to 20 parameters.

E1 INTERP Polynomial Interpolation. Approximate the value of an argument by a polynomial interpolation. 86 plus order of interpolation locations.

E1 ITPF1 NTH Order Floating Point Lagrangian Interpolation. Pass a polynomial of specified degree through n points. evaluate the polynomial at a given argument. 57 + n locations.

E2 LSQPOL Least Squares Polynomial Fitting Subroutine. FORTRAN. Given x(I), (x(1), x(2),...,x(m) and f(I), (f(1), f(2),...,f(m), where f (I) is the observed dependent variable and x (I) is the observed independent variable, the polynomial y = b (1) + b(2)*x+...+b(k+1)*x**k is fitted for all degrees of k, from k = 1 to k = k (max) with certain options.

E4 CENTRE Center a Record Subroutine. FORTRAN. This subroutine centers the record a(I) of n points into the record b(j) of m points and places zeroes on both sides.

E4 DETRND Removal of Mean and/or Linear Trend. FORTRAN. This subroutine removes the mean only or both the mean and linear trend of a series of n points, and returns the detrended series.

F1 MATINV Matrix Inversion with Accompanying Solution of Lin. Equ. Solves the matrix equation ax=b, where a is a square coefficient matrix and b is a matrix of constant vectors. The inverse a**-1 and the determinant of a are also computed. Space required =505 +n locations.

F1 GAUSS 3 Matrix Inversion by Gauss Method. FORTRAN. Inversion of a real matrix is accomplished by the Gauss method with row pivoting and back substitution.

F2 LINEQN Solution of Simultaneous Linear Algebraic Equations. FORTRAN. Solution of linear algebraic equations is accomplished by the Gauss method of elimination with row pivoting and back substitution.

APPENDIX I - DIGITAL PROGRAMS (continued)

G1 COEFFT Filter Coefficients for Band Pass Filter. FORTRAN. Given the center of band pass, half width of band, and roll off in terms of normalized frequency (frequency times the time increment), and the number of coefficients in half of a symmetric filter. Computes and returns the band pass filter coefficients.

G1 FILTER Filter Subroutine. FORTRAN. Applies given filter coefficients to a series of n points and returns the filtered series.

G1 FILDEC Digital Filter and Decimator Subroutine. FORTRAN. Filters and decimates a given series of n points with given filter coefficients and returns the filtered and decimated series.

G1 SQUASH Scaling Subroutine. FORTRAN. Finds and returns the maximum and minimum values of a series of n terms and then scales the series with a given maximum absolute value.

G1 RANGE Maximum and Minimum value Subroutine. FORTRAN. Finds and returns the maximum and minimum values of a series of n terms.

G1 NORMAL Normalize Subroutine. FORTRAN. Computes and returns a normalized series from a given series of n terms.

G2 AUTOCOR Auto-correlation Analysis. Given a series of values x(1), x(2),...x(n), this program will compute the product-moment correlation coefficient (auto-correlation) between successive terms, where the lag(k) goes from 0, 1, ..L. Space required - 1,781 locations.

G2 MANYCOR Correlation Analysis. Given m sets of data, this program calculates the mean, corrected sum of squares, variance, and standard deviation for each set. Also computes the regression coefficients, (linear) correlation coefficients, and the standard error of estimate for all possible combinations of sets of data. Space required = 9,15[illegible] locations.

APPENDIX I - DIGITAL PROGRAMS (continued)

G2 BIMD Multiple regression and Correlation Analysis FORTRAN. This program performs multiple regression and correlation analysis on a maximum of 30 variables. The maximum number of independent variables that can be deleted at one time is 28, the number of replacements is not limited. The program can make a log base 10, square root, or square transformation on any or all of the variables as desired. 17,572 unique storage locations, 4,958 common storage locations.

G4 AUTOV Autocovariance Subroutine. FORTRAN. Computes the autocovariance of a series of n terms with 1 lags.

G4 CRSCOV Auto-and-cross-covariance Subroutine. FORTRAN. Given two series x and y each of n points, computes auto-covariance of x and y and cross-covariance of x to y and y to x.

G5 RANDOM Fast Random Number Generator Subroutine. FORTRAN. One pseudo random, floating point number is produced for each call of the subroutine random (r). The numbers are uniformly distributed in the interval 0 to 1.

G6 TUKEY Tukey Spectru, Cross Spectra and Power Spectra. FORTRAN. This time series analysis program contains three basic subroutines. The first two, filter and removal of trend, prepare the data for the spectrum analysis subprogram. Tukey spectrum computes for the two simultaneous time series the cross (co-and quadrature-) spectra and the two power spectra. Phase and coherence are calculated. 15,000 locations.

G6 FOURTR Fourier Analysis Subroutine. FORTRAN. Computes the sine or cosine, smoothed or unsmoothed transform of a series of m terms.

G6 FOURAN Fourier Analysis Subroutine. FORTRAN. Given a time series of n points, computes sine transform, cosine transform, modulus a, modulus normed, log a, phase (fraction of a circle), and maximum value of the modulus.

J7 XY PLOT XY Plotter. FORTRAN. This routine plots x vs. y where x and y are arrays of data read in from cards or generated from equations within a program. Attached subroutines may be used to set the scales. 1438 locations without attached subroutines, 1544 locations with both subroutines. Print out on the IBM407 line printer.

APPENDIX I - DIGITAL PROGRAMS (continued)

K1 LOOK Analog to Digital Tape Preparation, FORTRAN. This program prepares a FORTRAN-62 binary tape of specified data from another binary tape obtained by analog to digital conversion of seismic data, and plots the resultant tape on the CDC 165 x-y plotter if desired.

Z1 ATODPLOT Analog to Digital Tape Plot. FORTRAN. This program prepares a binary tape suitable for plotting on the CDC x-y plotter from a binary tape obtained by analog to digital conversion of seismic data.

Z1 DIST Distance and Azimuth. FORTRAN. This program will compute the distance in degrees and in kilometers and the azimuth and back azimuth from an epicenter to a seismometer station.

Z1 ARRAY Linear Array. This program plots the cross-correlation of time shifted seismometer data, given the unshifted seismometer records as input.

Z1 FOULAGR 1 Fourier - Laguerre Transform. FORTRAN. This program expands a given time function in a series of Laguerre functions, and from the Laguerre expansion computes Fourier amplitude, phase, and power spectra.

Z1 VELQLAG Laguerre Expansion, Fourier Analysis. FORTRAN. This program computes the Laguerre expansion of surface waves recorded at stations along a profile, from the Laguerre expansion it computes Fourier spectra, and from the Fourier spectra it computes phase velocity, attenuation, and q as functions of frequency between pairs of stations.

APPENDIX II

231 R ANALOG COMPUTER PROGRAMS IN USE AT THE DATDC

1. Laguerre Filter.
2. Leaky Integrator (Average) Energy.
3. Hard Integrator (Absolute) Energy.
4. Cross Correlations.
5. Auto Correlations.
6. Sums of Signals.
7. Products of Signals.
8. Approximate Ratios of Signals.
9. Squares, Sums of Squares, and Square Roots of Sums of Squares of Signals.
10. Products of Signals.
11. Rectification and Special Filtering of Signals.

APPENDIX III - LIST OF DIGITIZED TAPES

CODE

LI = Element I of Linear Array

T = Timing

ST = Short Period Transverse

SR = Short Period Radial

SZ = Short Period Vertical

LZ = Long Period Vertical

LT = Long Period Transverse

STATION	DATE	DIST Km	EVENT	TIME INTERVAL	CONTENTS	SEISMOGRAM NUMBER
LC NM	12/10/61	258	GNOME	1858-1904	ST, SR, SZ, LT, LR, LZ, T	1
SV AZ	12/10/61	536	GNOME	1859-1905	ST, SR, SZ, LT, LR, LZ, T	2
FS AZ	12/10/61	757	GNOME	1859-1906	ST, SR, SZ, LT, LR, LZ, T	3
WM AZ	12/10/61	848	GNOME	1900-1908	ST, SR, SZ, LT, LR, LZ, T	4
TP NV	12/10/61	1254	GNOME	1900-1911	ST, SR, SZ, LT, LR, LZ, T	5
WMO	5/25/62	1600	EARTH-QUAKE	1455-1510	L1, 2, 5, 6, 7, T	7
WMO	6/03/62	5100	EARTH-QUAKE	1509-1530	L2, 3, 4, 5, 6, 7, T	8

APPENDIX III - LIST OF DIGITIZED TAPES (continued)

STATION	DATE	DIST Km	EVENT	TIME INTERVAL	CONTENTS	SEISMOGRAM NUMBER
WMO	6/03/62	4200	EARTH-QUAKE	1732-1736	L5, 6, 7 T	9
WMO	6/20/62	2700	EARTH-QUAKE	1323-1328	L0, 1, 2, 3, 4, 5, 6, 7, 8, 9, T	11
WMO	6/20/62	2700	EARTH-QUAKE	1331-1336	L0, 1, 2, 3, 4, 5, 6, 7, 8, 9, T	12
WMO	6/20/62	2700	EARTH-QUAKE	1348-1354	L0, 1, 2, 3, 4, 5, 6, 7, 8, 9, T	13
WMO	6/20/62	2700	EARTH-QUAKE	1658-1664	L0, 1, 2, 3, 4, 5, 6, 7, 8, 9, T	14
WMO	6/27/62	1600	HAY-MAKER	1803-1808	L0, 1, 2, 3, 4, 5, 6, 7, 8, 9, T	16
WMO	6/28/62	1600	MARSH-MALLOW	1700-1708	L0, 1, 2, 3, 4, 5, 6, 7, 8, 9, T	17
FS AZ	1/30/62	500	DOR-MOUSE	1758-1805	T, ST, SR, SZ	18
FS AZ	1/30/62	500	COL-LAPSE	1827-1833	T, ST, SR, SZ	19
SF AZ	1/30/62	600	DOR-MOUSE	1758-1805	T, ST, SR,	20
SF AZ	1/30/62	600	COL-LAPSE	1827-1833	T, ST, SR, SZ	21
SV AZ	1/30/62	720	DOR-MOUSE	1759-1806	T, ST, SR, SZ	22

APPENDIX III - LIST OF DIGITIZED TAPES (continued)

STATION	DATE	DIST Km	EVENT	TIME INTERVAL	CONTENTS	SEISMOGRAM NUMBER
SV AZ	1/30/62	720	COLLAPSE	1827-1834	T, ST, SR, SZ	23
ML NM	1/30/62	790	DORMOUSE	1759-1806	T, ST, SR, SZ	24
ML NM	1/30/62	790	COLLAPSE	1828-1834	T, ST, SR, SZ	25
TC NM	1/30/62	910	DORMOUSE	1759-1807	T, ST, SR, SZ	26
TC NM	1/30/62	910	COLLAPSE	1828-1834	T, ST, SR, SZ	27
LC NM	1/30/62	1025	DORMOUSE	1759-1808	T, ST, SR, SZ	28
LC NM	1/30/62	1025	COLLAPSE	1828-1836	T, ST, SR, SZ	29
AT NV	5/12/62	274	AARDVARK	1858-1903	SZ, LZ, LT, T	30
AT NV	5/12/62	274	COLLAPSE	2045-2052	SZ, LZ, LT, T	31
WI NV	5/12/62	482	AARDVARK	1859-1904	SZ, LZ, LT, T	32
WI NV	5/12/62	482	COLLAPSE	2045-2052	SZ, LZ, LT, T	33
FS AZ	5/12/62	483	AARDVARK	1859-1904	SZ, LZ, LT, T	34
FS AZ	5/12/62	483	COLLAPSE	2045-2052	SZ, LZ, LT, T	35
VN UT	5/12/62	672	AARDVARK	1859-1905	SZ, LZ, LT, T	36
VN UT	5/12/62	672	COLLAPSE	2045-2052	SZ, LZ, LT, T	37
PT OR	5/12/62	970	AARDVARK	1900-1907	SZ, LZ, LT, T	38
PT OR	5/12/62	970	COLLAPSE	2045-2055	SZ, LZ, LT, T	39
LC NM	5/12/62	1010	AARDVARK	1900-1907	SZ, LZ, LT, T	40
LC NM	5/12/62	1010	COLLAPSE	2045-2055	SZ, LZ, LT, T	41
SS TX	5/12/62	1494	AARDVARK	1901-1910	SZ, LZ, LT, T	42

APPENDIX III - LIST OF DIGITIZED TAPES (continued)

STATION	DATE	DIST Km	EVENT	TIME INTERVAL	CONTENTS	SEISMOGRAM NUMBER
SS TX	5/12/62	1494	COLLAPSE	2047-2056	SZ, LZ, LT, T	43
LP TX	5/12/62	1759	AARDVARK	1902-1911	SZ, LZ, LT, T	44
LP TX	5/12/62	1759	COLLAPSE	2047-2056	SZ, LZ, LT, T	45
SJ TX	5/12/62	1968	AARDVARK	1902-1913	SZ, LZ, LT T	46