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VELA NETWORK EVALUATION AND AUTOMATIC  
PROCESSING RESEARCH

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Texas Instruments Incorporated

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**VELA NETWORK EVALUATION AND AUTOMATIC PROCESSING RESEARCH**

**QUARTERLY REPORT NO.3**

**1 MAY 1974 TO 31 JULY 1974**

TEXAS INSTRUMENTS INCORPORATED

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## TABLE OF CONTENTS

SECTION	TITLE	PAGE
I.	INTRODUCTION AND SUMMARY	I-1
II.	VLPE EVALUATION AND NETWORK ANALYSIS	II-1
	A. CURRENT STATUS	II-1
	B. FUTURE PLANS	II-2
III.	SIGNAL DETECTION TECHNIQUES	III-1
	A. CURRENT STATUS	III-1
	B. FUTURE PLANS	III-1
IV.	SIGNAL ESTIMATION TECHNIQUES	IV-1
	A. CURRENT STATUS	IV-1
	B. FUTURE PLANS	IV-2
V.	FIRST-ZONE DISCRIMINATION TECHNIQUES	V-1
	A. CURRENT STATUS	V-1
	B. FUTURE PLANS	V-1
VI.	SYSTEM STUDY	VI-1
	A. CURRENT STATUS	VI-1
	B. FUTURE PLANS	VI-2
VII.	REFERENCE	VII-1

SECTION I  
INTRODUCTION AND SUMMARY

This third quarterly report summarizes progress made during the quarter from 1 May 1974 to 31 July 1974 on the VELA Network Evaluation and Automatic Processing Research program being carried out by Texas Instruments Incorporated at the Seismic Data Analysis Center in Alexandria, Virginia. The six tasks of the program are:

- Evaluation of the Very Long Period Experiment (VLPE) stations
- Investigation of the detection and discrimination characteristics of a seismic network using VLPE, NORSAR, and ALPA data
- Investigation of signal detection techniques
- Investigation of signal estimation techniques
- Investigation of discrimination techniques using first-zone data
- Simulation of a seismic surveillance system consisting of a network of seismic stations.

The software required for the first two tasks was developed under Contract F33657-67-C-1063. Most of the software for the remaining tasks are being generated under this contract.

Processing of a group of 403 Eurasian events using VLPE, ALPA, and NORSAR data was completed this quarter. Final analysis of the results is now underway. These data, combined with previous data, result in a data base of 1280 events with 8482 event-station combinations.

The evaluations of the Three-Component Adaptive processor and the application of matched filters to VLPE data have been completed. A report is in preparation.

Two other reports are in preparation and should be submitted for approval this quarter. The first is an analysis of the ambient noise field at each of the VLPE stations. The second will discuss the estimation of detection thresholds using noise statistics.

The Fisher detector program was completed and processing of Korean array data has begun. The primary focus of the processing will be on noise samples and low magnitude events with  $m_b$  less than 4.5.

The new adaptive beamforming program has been checked out and processing of ALPA data has begun. The new algorithm shows distinctly increased signal-to-noise ratio improvement over the other one. The capability to process Korean array data will be added within a few weeks.

The envelope detector study has been almost completed. A report is being prepared and should be submitted for approval this quarter.

The software development phase of the first-zone discrimination task has finally been completed. This task has been delayed somewhat by difficulties in verifying various analysis algorithms but that has now been finished and processing of data has begun.

The system study task is still in the software development stage. Checkout should be completed in about one month. The system simulator is essentially complete but the seismic earth model has to be integrated into the full simulator. The parameter update and interactive processing studies are being outlined. Interactive software for the PDP-15 computer has been developed to demonstrate matched filtering and data editing.



## SECTION II

### VLPE EVALUATION AND NETWORK ANALYSIS

#### A. CURRENT STATUS

During the past quarter, preliminary analysis of the 1973 event ensemble was completed using VLPE, ALPA, and long-period NORSAR data. The 1973 event ensemble consists of 403 Eurasian events occurring during January, February, March, and April 1973.

Preliminary analysis of the available and useable VLPE recordings yielded a total of 2395 event-station combinations for this ensemble. These data combined with those from earlier work (Lambert et al., 1973) give a total of 1280 Eurasian events and 5962 event-station combinations which will be utilized in the evaluation of the detection and discrimination capabilities of the individual VLPE stations and the VLPE network.

Analysis of the ALPA and long-period NORSAR data for these same 1280 events has yielded 2520 additional event-station combinations. Thus the evaluation of the VLPE, ALPA, and NORSAR combined network will be based on approximately 8482 event-station pairs.

Parameters obtained from this analysis include noise statistics, interfering event statistics,  $M_s \cdot m_b$  values, LQ/LR ratios, and data quality. These parameters are being reassessed and refined so that a better interpretation of the overall results can be realized. The evaluation of the Three-Component Adaptive processor and matched filters using VLPE data was completed. These studies were made using events from Central Asia, the Greece-Turkey region, and eastern Kazakh. A report on these studies is in preparation.

VLPE data quality has continued to improve. The data for the 1973 event ensemble had, on the average, 6 stations with available and useable data as compared to the average of 3.8 stations for the 1972 data. Horizontal component data remains less reliable than the vertical component data.

#### B. FUTURE PLANS

Routine data processing has been completed. The major effort is on the final analysis and interpretation of the results. Reports on the Three-Component Adaptive processor and matched filter results, VLPE station noise analysis, detection threshold estimation, and the VLPE station and network analysis results should be completed this quarter.

## SECTION III

### SIGNAL DETECTION TECHNIQUES

#### A. CURRENT STATUS

The short-period Fisher detector program was completed and checked out during this past quarter. Using synthetic data having both amplitude and phase distortion for testing, the detector output agreed with the theoretically predicted output.

At present, data is available from the Korean short-period array (KSRS) for the time period between April 29, 1973 and July 26, 1973. Events from this period with  $m_b$  magnitude estimates (PDE or SDAC) of less than 4.5 and epicentral distances between  $20^\circ$  and  $80^\circ$  have been selected for the evaluation of the Fisher detector.

The program produces a side-by-side comparison of the Fisher detector and conventional beam power detector in terms of signal-to-noise ratio. These results consequently yield a probability of detection as a function of detector threshold level. In a similar manner, intervals of noise data, free of known signals, are processed to obtain false alarm probabilities. Using these two sets of probabilities, the operating characteristics of the two detectors can be estimated.

An automatic channel quality-check algorithm has been designed to eliminate channels with abnormally high or low power. This algorithm will be evaluated concurrently with the detector evaluation.

#### B. FUTURE PLANS

As many signal and noise samples as possible will be processed through the Fisher detector in the time remaining. A report on the results will be submitted at the end of the contract.

## SECTION IV

### SIGNAL ESTIMATION TECHNIQUES

#### A. CURRENT STATUS

The new adaptive beamforming (ABF) program was completed and checked out during the last quarter. The new program differs from the old one (Barnard, 1973) in four major aspects. Floating-point calculations are used instead of fix-point. The new algorithm slows down instead of increasing its adaption rate in the presence of a coherent on-azimuth signal. The new program will accept ALPA, NORSAR long-period, and KSRS short-period data instead of only ALPA data. Finally, the new program can process two independent data samples in parallel to study the interfering event problem. In tests of the new program beamster outputs and ABF outputs with no filter update agreed with beamsteer outputs from the older program. The program phase which accepts the KSRS data is still being checked out.

Using the same six-channel ALPA data samples processed during the previous contract, the new ABF algorithm achieved greater signal-to-noise ratio improvements than the older algorithm. The best improvement occurred with strong, nearly ideal signals, while one weak event which had considerable signal dissimilarity across the array, showed only minor improvement. It is not possible, at this time, to attribute this result to the low signal-to-noise ratio or to the lack of signal similarity.

Some processing of 16-channel samples containing signals has been performed. In this processing, the single-channel prefilter used during the previous contract has been compared with a new prefilter especially designed for signal detection. In addition, the effect of varying the ABF filter length has been studied.

Substantial progress was made this quarter in the comparison of coherent and incoherent beamforming envelope detectors. The performance was measured in two passbands for 36 presumed explosions and 55 near-regional earthquakes at NORSAR. The usefulness of the Hilbert transform for envelope formation was examined using a few events. The relative detectability of the two processors was measured using simulated data comprised of scaled signals buried in noise.

#### B. FUTURE PLANS

After completing the examination of various ABF processing modes, the emphasis of the signal estimation task will be directed toward interfering-event processing. Efforts will be devoted to determining suitable convergence rates and quantifying the signal-to-noise improvement relative to beamsteering as a function of event azimuthal separation, relative arrival time, and relative event strength.

The majority of the processing for the envelope detector study was completed this quarter. The effort next quarter will be toward analysis of the results and preparation of a report.

## SECTION V

### FIRST-ZONE DISCRIMINATION TECHNIQUES

#### A. CURRENT STATUS

The major effort this quarter has been toward the development of the moving-window spectral analysis programs for short-period and long-period data. Other programs were written to permit combining successive edits of NORSAR short-period data into one large data file. These programs have been completed and checked out. Considerable progress was made toward verifying the algorithm used to obtain spectral ratios, complexities, and phase energy ratios.

There are approximately 40 first-zone events recorded at NORSAR for which we have both short-period and long-period data. Analysis of these events has begun.

#### B. FUTURE PLANS

The suite of 40 events constituting our data set will be analyzed this quarter. This will include reanalysis of events processed earlier during algorithm development.

## SECTION VI

### SYSTEM STUDY

#### A. CURRENT STATUS

The system study presently has four tasks. The first task is the development of a simulator for a surveillance system. The second is an analytical study of parameter updating by feedback of information from previous events. The third is a study of the role of interactive processing in a surveillance system. The fourth task is to develop and demonstrate the application of interactive programs to seismic analysis.

The simulator task consists of two parts. The first simulates seismic events generated in the earth in a way sufficient to realistically test and evaluate various modes of operating a surveillance system. The second part consists of simulated data processors, data files, and data transmission such as station detection processors, data collection processors, station data files, detection association processor, and station and central facility communication/control processors. Programming and analysis of the simulators are 85 percent completed.

The parameter update task is still in the planning and outlining stage. The initial approach is to identify the parameters requiring updating, and the interaction of system functions in which these parameters are used. The analysis of the role of interactive processing in the operation of a surveillance system is also still in the planning and outlining stage.

Phase one of the interactive software development task was completed during the last quarter. This phase consisted of developing a

basic interactive long-period matched filtering package on the PDP-15 computer at SDAC. The capability presently exists to perform chirp and bandpass filtering of event data from the Very Long Period Experiment (VLPE) network, with analyst options to select time windows and processing functions.

#### B. FUTURE PLANS

Programming of the simulator should be completed next month. Present schedules require that the report on the simulator must be written concurrently with the demonstration runs.

The interactive matched filtering package will be augmented with options to perform reference waveform filtering and compute event parameters such as surface wave magnitude, surface wave dispersion characteristics and RMS noise level.



## SECTION VII

### REFERENCES

- Barnard, T. E., 1973, Simulated On-Line Adoptive Processing Results Using Alaska Long Period Array Data, Special Report No. 2, Contract No. F33657-72-C-0725, Texas Instruments Incorporated, Dallas, Texas.
- Lambert, D. G., S. R. Prahl, and A. C. Strauss, 1973, Evaluation of the Noise Characteristics and the Detection and Discrimination Characteristics of the Very Long Period Experiment (VLPE) Single Stations and the VLPE Network, Special Report No. 14, ALEX (01) - STR-73-14, Contract No. F33657-72-C-0725, Texas Instruments Incorporated, Dallas, Texas.