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EXTENDED ARRAY EVALUATION PROGRAM

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Dallas, Texas

15 April 1973

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EXTENDED ARRAY EVALUATION PROGRAM

Quarterly Report No. 4

1 January 1973 to 31 March 1973

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13. ABSTRACT

This fourth quarterly report summarizes progress under the Extended Evaluation of ALPA, NORSAR, and VLPE program, Contract number F33657-72-C-0725. Work to date in the following areas is summarized:

- ALPA evaluation
- NORSAR long period evaluation
- NORSAR short period evaluation
- VLPE evaluation
- Network evaluation and system study

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SECTION 1
INTRODUCTION AND SUMMARY

This fourth quarterly report summarizes progress made during the last quarter, 1 January 1973 to 31 March 1973, on the Extended Evaluation of the ALPA, NORSAR, and VLPE Data Program being conducted by Texas Instruments Incorporated at the Seismic Data Analysis Center in Alexandria, Virginia. The program consists of the following five tasks:

- Continued evaluation of the Alaskan Long Period Array (ALPA)
- Continued evaluation of the long period Norwegian Seismic Array (NORSAR)
- Continued evaluation of the short period Norwegian Seismic Array
- Continued evaluation of the stations of the Very Long Period Experiment (VLPE) network
- Investigations of network processing and analysis techniques, and the seismic network systems study

The software required to perform the evaluation was developed under the previous contract F33657-69-C-1063.

ALPA evaluation for this quarter included the completion of the processing for 207 events from the June-August event list. This gives a total of 380 events processed from 1972. In addition, noise analysis over the entire year of 1972, a re-evaluation of S-wave detection performance for the Kurile-Kamchatka area and a study of reference waveform matched filtering was completed. Reports on the results of these studies are in preparation. An evaluation of the Lamont 2-component processor has been initiated.

Processing of NORSAR long-period event data from June and July 1972 was completed and yielded 156 events which gives a total of 324 events from 1972. Noise analysis was performed on noise samples taken at ten day intervals during 1972. Comparisons were made of MCF and beam-steer performance on signals and noise using both full and partial arrays.

This quarter, 87 additional events from the 1972 event list were processed using short period NORSAR data. Fifteen more noise samples have also been obtained. Distinct variations in subarray signal-to-noise ratios have been observed across the array for a series of events from Central Italy and the Kuriles. This effect is thought to be due to the strong curvature of the Moho beneath the array.

Analysis of the remainder of the 1972 summer events was completed using VLPE data. A report of the results is being prepared. Detection performance and magnitude measurements were made for various wave periods for each station. Detection performance of the VLPE stations as a network, with and without ALPA and NORSAR, was estimated.

Under the network evaluation task, analysis of signal blocking times for particular combinations of travel paths was begun. Matched filtering techniques are being applied to VLPE data to improve signal detectability.

The network systems study was begun this quarter. Effort during this quarter was devoted to definition of functional descriptions and tasks, and evaluation of present seismic systems and worldwide communication capabilities.

SECTION II
ALPA EVALUATION

A. CURRENT STATUS

All routine processing of 1972 events as recorded at ALPA was completed during this quarter. The 1972 data base totals 368 earthquakes and 12 presumed explosions. The total data base, including events processed previously in 1970 and 1971 may be broken down as follows:

	Earthquakes	Presumed Explosions	Total
1970	61	7	68
1971	96	13	109
January, 1972	54	0	54
February, 1972	74	1	75
March, 1972	38	2	40
June, 1972	78	1	79
July, 1972	68	1	69
August, 1972	56	3	59
Other, 1972	<u>0</u>	<u>4</u>	<u>4</u>
	525	22	557

Noise samples were selected every ten days throughout 1972. Power spectra and frequency-wavenumber spectra were computed to measure the RMS levels and directions of the microseismic noise.

The results of the event processing and noise analysis are being compiled and will be reported in Special Report No. 8 which is now being written.

Topics discussed include matched filter performance, S-wave detection capability (of Kurile-Kamchatka events), surface wave detection capability, behavior of standard discriminants, and noise analysis.

A detailed study of reference waveform matched filtering on Sinkiang region events was completed this quarter. The purpose of this study was to determine the effect of reference waveform length on matched filter performance. Three events were selected as reference waveforms with eight different filters being derived from each signal. These filters were then applied to approximately 21 test events. The results of this work will be reported in Special Report No. 5.

During this quarter a study of the Lamont two-component processor and the similarity detector was begun. The ability of the Lamont processor to produce increased signal-to-noise ratios compared to simple bandpass filtering is being examined. About 30 test events have been processed. The similarity detector and the square-law power detector are being studied so that the false alarm rates of these two detectors may be compared.

B. FUTURE PLANS

Routine processing of ALPA noise and events, will be discontinued. Investigation and evaluation of particular analysis techniques, such as the Lamont processor and similarity detector will continue.

SECTION III
NORSAR LONG PERIOD EVALUATION

A. CURRENT STATUS

Routine processing of 1972 events through July were completed this quarter. The number of events processed from the 1972 event list includes 314 earthquakes and 10 presumed explosions. The total data base for events recorded at NORSAR, including 1971 events are:

	Earthquakes	Presumed Explosions	Total
1971	49	10	59
January, 1972	52	0	52
February, 1972	69	1	70
March, 1972	38	2	40
June, 1972	83	0	83
July, 1972	72	1	73
Other, 1972	<u>0</u>	<u>6</u>	<u>6</u>
	353	20	383

Long noise samples were obtained at approximately ten day intervals throughout 1972. The majority of these samples are longer than four hours. Wavenumber analysis of these samples shows that while the average noise RMS level increases in the winter as reported last year, there is little indication of predominantly easterly noise. The directions of the noise at the lower microseismic peak (16 sec) tend to fall into three or four fairly well defined groups clustered between 220° to 360° azimuth from NORSAR.

This quarter, eleven noise samples were used to investigate the performance of multichannel and beamsteer processors for various array and subarray configurations. Array gains were computed for four configurations, using three passbands. In addition, MCF's were designed for and applied to several event signals to measure signal enhancement and noise reduction for comparison to beamsteering.

The results obtained during the past 12 months will be reported in Special Report No. 7 which is now in preparation.

B. FUTURE PLANS

Events from August 1972 will be processed to complete the summer event ensemble for NORSAR. A list of additional events for processing will be compiled.

SECTION IV
NORSAR SHORT PERIOD EVALUATION

A. CURRENT STATUS

Processing of NORSAR short period signal data to be included in Special Report No. 9 for 1972-1973 is almost completed. This quarter, 83 additional events from the first 80 days of 1972 and seven days from June and July have been edited, along with 15 noise samples. Subarray beams have been formed using plane-wave delays for all 168 events from 1972, and final array beams were produced for about 95 events from late 1971. Final array-beam processing is nearly complete on the 1972 events. All but three of the 1972 events processed to date have been taken from the common list of events used by ALPA, NORSAR, and the VLPE.

Twelve events from central Italy were examined in detail because the epicenter locations were in close proximity. These events were found to have a 0.5 Hz component which arrived two to six seconds before the 1.1 Hz component. This longer period component was clearly visible only on full array beams and not on individual single instruments. There is some evidence that the weakness of the early arrival may have caused slight errors in epicenter determination by USCGS.

Subarray beam signal-to-noise ratio (SNR) for the Italian events and a set of events from the Kuriles were plotted as a function of subarray location. These plots revealed strong variation in SNR across the array. Events from the same areas tended to produce the same pattern of SNR variation although these patterns were different for events from different areas. For example, with the events from Italy the subarrays in the eastern half of

of the array had signal-to-noise ratios averaging 5 dB more than the subarrays in the western half. For the Kurile events, two groups of subarrays had much higher signal-to-noise ratios. It is possible that these variations are caused by the curvature of the Moho beneath the array.

B. FUTURE PLANS

In the next quarter, further investigation will be made of the variation of subarray signal-to-noise ratios as a function of seismic region and its relationship to the velocity structure beneath the array and a detailed investigation will be made of regional variations of event spectra. Events from June and July of 1972 will be processed to provide a broader data base for the estimation of both regional and overall detection thresholds as well as for the studies already discussed.

SECTION V
VLPE EVALUATION

A. CURRENT STATUS

During this quarter, processing was completed on the June-August 1972 events using VLPE multistation data. A report is being written (Special Report No. 6) concerning the evaluation of the detection and discrimination capabilities of the VLPE single stations, the VLPE network, and the VLPE-ALPA-NORSAR combined network.

The data base for this report consists of the analysis of 548 events or 2130 event-station pairs. The results of techniques applied to this data base include the following:

- A description of the detection of Rayleigh waves as a function of magnitude (m_b) and distance (Δ) for a large ensemble of Eurasian events at (1) all available single VLPE sites, (2) the VLPE stations as a network and (3) the VLPE-ALPA-NORSAR networks combined.
- The mean relationship of M_s at 20 seconds versus m_b for VLPE single sites, the VLPE network, and the VLPE-ALPA-NORSAR combined network.
- The mean relationship of M_s at 40 seconds versus M_s at 20 seconds and also M_s at 30 seconds versus M_s at 20 seconds for VLPE stations.

B. FUTURE PLANS

Future studies will include regionalization of events and the application of "chirp" or reference waveform matched filtering and three-component processing for the purpose of examining in detail the detection and discrimination capabilities of each station.

SECTION VI NETWORK ANALYSIS

A. CURRENT STATUS

Reference waveform and chirp filter techniques applied to the VLPE seismograms have progressed slowly during this reporting period and results as of now are inconclusive. Selection of events for design of the matched filters for specific paths in Eurasia is progressing satisfactorily and preliminary results are expected by the next reporting period.

Special reports on long-period Rayleigh wave decay and vertical component noise have been submitted for open publication clearance. The Rayleigh wave study has been cleared, and further analysis of the effects of continental, oceanic, and mixed paths on the decay times is underway. The noise study is in the process of clearance, and a comparison report of simultaneous three-component (vertical and two horizontal seismographs) noise structure in the VLPE network is in final draft stage.

B. FUTURE PLANS

Model analysis of the "interference" or "signal blocking times" in the VLPE network using the Rayleigh wave decay results will continue, and some further noise analysis on new station data is planned. The major effort during the next reporting period will be to evaluate the reference event filters for improvement of VLPE station signal detection capability.

SECTION VII
SEISMIC NETWORK SYSTEMS STUDY

A. CURRENT STATUS

This quarter, work on the systems study was devoted primarily to planning of the study, including the outlining of the tasks and definition of the assignments. These tasks include a functional description of the network, definition of network configuration and requirements, and subsequent system analysis. Current assignments include analysis of short-period and long-period monitoring capabilities of selected networks, a survey of presently available communication systems, with options and costs, and a functional description of baseline hardware and software requirements.

B. FUTURE PLANS

We intend to determine the most economical system configuration consistent with the functional requirements of the system. This baseline configuration will have available options to upgrade capacity, response time, and other functions. All planning and analysis assignments under this task will be documented. In the near future, we will meet with the client to discuss preliminary results on the monitoring capability of the selected networks.