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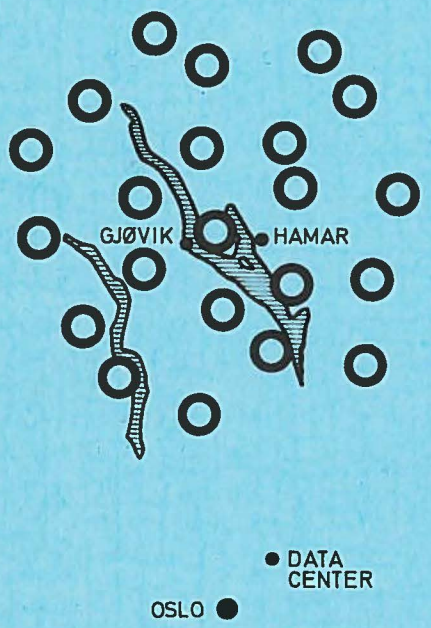
Royal Norwegian Council for Scientific and Industrial Research

PROGRESS REPORT
NORSAR PHASE 3

1st Quarter 1972



NORWEGIAN SEISMIC ARRAY

NORSAR

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NTNF/NORSAR
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NORSAR PHASE 3

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prepared by

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Status per 31 March 1972

The NORSAR project has been sponsored by the United States of America under the overall direction of the Advanced Research Projects Agency and the Technical Management of the Electronic Systems Division, Air Force Systems Command.

ARPA Order No. 800 Program Code No. IF10

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Amount of Contract	:	$ 1.396.883,-
Contract No	:	F-19628-70-C-0283
Contract Termination Date	:	June 30, 1972
Project Supervisor	:	Robert Major, NTNF
Project Manager	:	Per Tveitane (temporary)
Title of Contract	:	Norwegian Seismic Array (NORSAR) Phase 3

CONTENT

I SUMMARY

The report covers the period 1 January - 31 March, 1972, which is characterized by reparameterization of the Event Processor and research aimed mainly at improving the array detection capability.

The Overhead account in the NORSAR budget has been reduced from 50 to 35 per cent of NORSAR staff salaries. A relatively small number of field instrumentation malfunctions has been discovered. On an experimental basis 3 incoherent beams have been implemented in the Detection Processor. Presently, NORSAR reports an average of ca 13 events on a daily basis compared to around 8 events previously. Preliminary research results indicate that the incoherent beamforming has an event detection capability comparable to that of conventional array beamforming. However, the former has a superior regional coverage.

II ADMINISTRATION AND ECONOMY

A new contract with IBM/Norway for computer hardware service and maintenance covering the period 1 July 1971 - 30 June 1972 has been signed. Similar contracts with Norwegian Telegraph Administration (data communication lines) and Regnesenteret Blindern-Kjeller (NDPC housing facilities) are being negotiated. Mr. D.Madrigal , Property Officer, USAF has made an inspection of NORSAR equipment and the property control routines in use.

In the NORSAR budget a special overhead posting is used for covering office equipment and miscellaneous expenses. The amount of money allocated the Overhead account was previously 50 per cent of the NORSAR staff salaries. This was recently changed to 38 per cent as recommended by Mr. K. Perry, Defense Contract Audit Agency, after his visit to Kjeller in March 1972.

Expenditures in the period 1 January - 31 March 1972

1.	Operation & Maintenance		
	1.1 Data Processing Center	$ 125 412,-	
	1.2 Field Installations	$ 34 446,-	
	1.3 Data Communication	$ 17 007	$ 176 865
2.	Research & Development		$ 12 553
3.	Administration & Support		$ 13 859
		TOTAL	$ 203 277,-

III ARRAY MONITORING AND CONTROL - FIELD MAINTENANCE

The stability of the different parts of the field equipment has been high. A relatively low number of instrumentation malfunctions has been discovered, but none were critical for the acquired seismic data. The maintenance technicians are being trained in servicing electronic field units like LP seismometer amplifiers and especially the communication modems as this work is planned to be accomplished by NORSAR personnel in the future. One of the two spare SLEM units has been moved to the Field Maintenance Center (FMC) for routine testing and check-out. The data communication lines between the array and NDPC have operated very satisfactory in the reporting period.

Array Monitoring

In cooperation with IBM/FSD personnel at NDPC an evaluation of the analysis programs used in the remote array monitoring has been accomplished. Discrepancies between calculated and field measured values for a few of the SP and LP seismometer's characteristic parameters as damping and sensitivity have been disclosed. Concerning the SP instrumentation, the discrepancies were explained by systematic errors in the established calibration procedures. The discrepancies discovered for LP instrumentation (damping) are still unexplained and further investigation to diagnose and correct these is planned.

The established array monitoring schedules has been in effect in the reporting period with the exception of the detailed single frequency analysis of SP and LP channels (SACP). This program has mainly been used for monitoring instrumentation distortion which has been low. Henceforth, the SP and LP channels are presently checked bimonthly.

Array Maintenance

We are still troubled with fluctuations in damping (D) and natural frequency (NF) of the SP instruments. At present 36 seismometers are out of tolerances in D and/or NF. An investigation of the performance and quality of instrument components has been accomplished at the NORSAR MC. Although further studies is deemed necessary, a preliminary conclusion is that the present tolerance limits may be too tight considering the quality of some of the seismometer parts, especially springs. Tolerance criteria is being revised.

Instrument malfunctions discovered in the field have all been easily corrected. The main single type of error has been the Analog/Digital converters and amplifiers slightly out of adjustment.

IV COMPUTER CENTER OPERATION - DATA PROCESSING

The Detection Processor (DP) was recording data on-line for approximately 99% of real time in January and February, and 97% in March. In the latter case, power failures occurred on two occasions. Otherwise, some minor hardware problems and program updates accounted for the loss of recorded data. Total down time for DP was thus 35 hours in the period.

A number of tape drive problems were encountered in the period. An effort was made to modify the on-line software to reduce the probability of system breakdown in such cases. A malfunction in the time of day generator (TOD) caused the time on the data tapes to be 1 min 26 sec wrong from January 24 for a period of 10 days. The cause of this problem is unknown, but actions have been taken to check the TOD generator more regularly.

A SPS coding error was corrected March 13. This error had degraded the detection performance and caused some loss of Long Period data during several shorter time intervals dating back to when the system first became operational.

A new A-filter for the on-line DP (1.2-3.2 Hz) was implemented January 6. A new set of region corrections for the array beams was implemented January 27. These modifications resulted in a significant improvement in the on-line detection performance. An experimental processor to form a limited set of "incoherent array beams" (see section V) and monitor the detection performance of these beams was implemented on-line January 10.

Programming Efforts

A number of smaller errors in DP and EP were located and corrected in the reporting period. A study was initiated to try to reduce the amount of computer time spent on EP processing of local explosions. Up to 15 "events" of this type have previously been processed on the "worst" days.

Work is undertaken to prepare a full-scale implementation of incoherent beamforming on-line, as present investigations indicate that this method for seismic surveillance will improve the DP performance.

F. Ringdal visited SAAC January 31 - February 4 to discuss with Geotech plans for on-line data transmission from SAAC to NDPC via TAL. Formal specifications and an implementation schedule were agreed upon, and the necessary coding work was started both at NDPC and SAAC in February. This work is still in progress.

Routine Event Processing

During the reporting period considerable efforts have been invested in improving and reparameterizing certain portions of the Event Processor (EP). On the other hand, the debugging work has been modest compared to the previous months. The main EP changes have been the following:

- New time delay and epicenter calibration corrections were implemented January 25.

- The EP event acceptance threshold has been changed from 4.5 to 4.0 on February 21, and finally to 3.8 on March 7.

- The focal depth estimation algorithms has been omitted (Mar 1 The same holds for correlation routine which is used for signal alignment, when the detected events have a signal-to-noise ratio (SNR)< 5.0 (implemented March 14). In these cases only beampacking is used and the performance is satisfactorily.

The above changes and the new DP bandpass filter of 1.2-3.2 Hz (implemented January 6, 1972) have significantly improved the number of NORSAR reported events. For example, an average of 8 events per day was reported in 1971 while the present rate is around 13 events. This comparison do not take into account possible difference in noise levels and seismic activities.

The improved array detection performance requires more EP computer time, although this is not a critical problem for the time being. Actually, the above drawback has been partly

offset by given preference to beampacking for SNR < 5 and removing the option for focal depth estimation. Planned improvements in the beampacking algorithms would enable us to omit the correlation routine altogether, thus saving roughly 50 per cent out of present EP processing time of around 9 min for a single event.

V RESEARCH AND DEVELOPMENT

Research and development work in the reporting period have been focused on improving the NORSAR event detection capability. Moreover, some efforts have been spent on writing reports which are listed in the next section.

The main factors controlling the arrays event detection performance are large seasonal variations in the noise level for frequencies below 1.5 Hz, partial coherent P-signals across the array and hardware limited number of array beams to be deployed. This simply means that beamforming is not necessarily the most effective method for detecting small events and an alternative is incoherent beamforming which recently was implemented in the DP (see Section IV). Other notations of this particular processing scheme are spectraform [1] or envelope [2] beamforming. The operational principle of the incoherent beamforming is that the event detection tests are performed on the average of the 22 subarray beams. The main advantages of this special detection processor are a reduction of the noise variance by a factor of 22, modest signal losses at frequencies between 1.5 - 2.5 Hz and large regional coverage by deploying a small number of incoherent beams.

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1) R.T. Lacoss and G.T. Kuster: Processing a partially coherent large seismic array for discrimination, Tech.Note 1970-30, Linc.Lab., MIT, Nov 1970.

2) IBM 9th Quarterly technical report, integrated seismic research, signal processing system, Rep. ESD-TR-72-122, ARPA, Arlington, Virginia.

Preliminary analysis of three incoherent beams located in the Kurile Islands, Kamchatka and Aleutian Islands showed that their event detection performance is comparable to that of around 30 array beams deployed in the same regions. Actually, the incoherent beams detected some very small events (not processed by EP) which only could be verified by the LASA bulletins.

The above results have been based on the present DP band pass filter of 1.2 - 3.2 Hz. Even better results have been obtained for a 1.6 - 3.2 Hz filter utilizing off-line data processing. It should be noted that recently an option become available for choosing between two different band pass filters in the detection processor.

Theoretical comparisons of the two detectors indicate that in many cases NORSAR incoherent beamforming should have the best detectability for small events, i.e., SNR values close to the EP acceptance threshold.

A problem which the analyst encounters daily, is whether some of the small magnitude EP processed signals represent real events. Presently, we are investigating possible procedures for getting a more decisive and objective answer to the above problem. So far, the prediction error analysis technique has been considered. The preliminary results obtained are promising.

The most important aspect of the above problem, is that DP reports a large number of event detections which are left unprocessed by EP due to computer time requirements. On the other hand, we know positively from comparisons with the LASA bulletin that some of these detections represent real seismic events, i.e., not false alarms triggered by the background noise. What we really need, is a very

fast scanning processor which work well below the EP acceptance threshold (SNR = 3.8). Its main task should be to select those detections which are suitable for further processing by the conventional Event Processor.

IV MISCELLANEOUS

NTNF/NORSAR arranged a seminar on Seismology and Seismic Arrays in Oslo, November 1971, and altogether 28 talks were given. We are preparing a booklet containing papers presented at the seminar and so far we are promised or have actually received 21 manuscripts.

Dr. E. Hjortenberg, Geodætisk Inst., Copenhagen, Denmark visited NORSAR Data Processing Center, Kjeller in the interval January 24 - February 12, 1972.

In the reporting period 140 data tapes were sent to SAAC, 2 tapes to Dr. Pirhonen, Helsinki, Finland, and 2 tapes to Dr. Hjortenberg, Copenhagen, Denmark.

E. S. Husebye and H. Bungum attended a seminar on Seismic Discrimination in Cambridge, Mass., January 10 - 12, 1972, and the former gave a talk on event detection problems - . Before returning to Norway, two days were spent at SAAC, Alexandria for discussion of common seismic array problems.

Reports completed in 1st quarter 1972

E. S. Husebye (prepared): Contribution to the National Report of Norway for 1967 - 1971 from Norwegian Seismic Array (NTNF/NORSAR), IUGG Chronicle, in press.

E. S. Husebye (prepared): Progress Report NORSAR phase 3, 4th quarter 1971, NORSAR Techn. Rep. No 20, 1972.

H. Bungum and K. A. Berteussen: NORSAR event processor computer time requirement, NORSAR Tech. Rep.No 21, 1972.

E. S. Husebye (prepared): NORSAR research and development, 1 July 1970 - 30 June 1971, NORSAR Techn. Rep. No 23.

H. Bungum and K. A. Berteussen: An evaluation of the routine processing of events at NORSAR during the time period May - October 1971, NORSAR Techn. Rep. No 24, 1972.

D. Doornbos and E. S. Husebye: Array analysis of PKP phases and their precursors, Physics of the Earth and Planet. Sci., in press.

J. Filson and H. Bungum: Initial discrimination results from the Norwegian Seismic Array, Geophys J.R. astr. Soc., in press.

E. S. Husebye : Seismic arrays and seismology, Uppsala Univ. Press, in press.

O. Steinert: NORSAR - Et seismologisk observatorium av verdensstørrelse. Report of the Norwegian Foreign Office's Disarmament Committee, in press.

O. Steinert: NORSAR AM operating plan, NORSAR Techn. Rep. No 19, 1972.