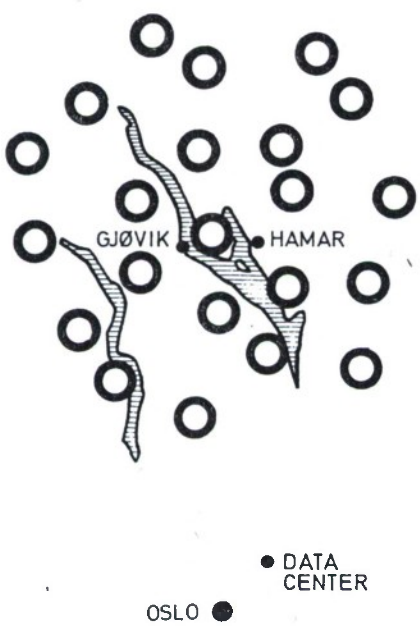
Royal Norwegian Council for Scientific and Industrial Research



NORWEGIAN SEISMIC ARRAY

NORSAR

P.O. Box 51 2007 Kjeller – Norway

ESD-TR-73-120

NTNF/NORSAR
Post Box 51
N-2007 Kjeller
NORWAY

NORSAR Technical Report No. 53

PROGRESS REPORT
NORSAR PHASE 3

4th Quarter 1972

Prepared by
E.S. Husebye
(Chief Seismologist)

5 February 1973

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, through contract F-19628-70-C-0283 with the Royal Norwegian Council for Scientific and Industrial Research.

This report has been reviewed and is approved.

Richard A Jedlicka, Capt USAF
Technical Project Officer
Oslo Field Office
ESD Detachment 9 (Europe)

ARPA Order No. 800 Program Code No. IF10

Name of Contractor	:	Royal Norwegian Council for Scientific and Industrial Research
Date of Contract	:	15 May 1970
Amount of Contract	:	$2.051.886
Contract No.	:	F-19628-70-C-0283
Contract Termination Date	:	30 June 1973
Project Supervisor	:	Robert Major, NTNF
Project Manager	:	Nils Marås
Title of Contract	:	Norwegian Seismic Array (NORSAR)

CONTENTS

SUMMARY

The report covers the period 1 October - 31 December 1972 which is characterized by improving, estimating and simulating the array detection capability. All activities related to field work, repair and maintenance of field instrumentation are now located in a single facility at Stange close to Hamar. The operational performance of the field equipment has been satisfactory also in this reporting period. The implementation of the incoherent event detector in the software system has improved the array's event detectability approximately 15 per cent. A daily bulletin is edited, and is solely based on event detector data. Observed and predicted NORSAR event detectability utilizing data from the first half of 1972 have been worked out. Also potential detectability improvements as a function of more flexible bandpass filtering have been investigated.

1. ADMINISTRATION AND ECONOMY

Proposal for operation of the NORSAR array covering the period 1973-75 has been worked out and submitted to the Air Force Office of Scientific Research.

Mr. D. Madrigal from Air Force Contract Maintenance Center (AFCMC) visited NORSAR in the period 17-26 October for the yearly Property System Survey. Mr. W. Glacken from Defense Contract Audit Agency (DCAA) visited NORSAR in the period 11-18 December for an "Interim Cost Audit".

Expenditures in the period 1 October - 31 December 1972:

1.	Operation & Maintenance		
	1.1 Data Processing Center	$ 101.172	
	1.2 Field Installations	35.302	
	1.3 Data Communications	51.319	$ 187.793
2.	Research & Development		13.221
3.	Administration & Support		17.544
	Total		$ 218.558

2. ARRAY MONITORING AND FIELD MAINTENANCE

The performance of the array's field instrumentation has been satisfactory throughout the period. With the exception of a large number of cable breakages caused by activity outside our control, the failure rates of the field equipment are as experienced previously. The moving of NORSAR Maintenance Center (NMC) from Brumunddal to Stange in the vicinity of Hamar was completed during the period. All activities related to field work, repair and maintenance of field instrumentation are now located in one single facility.

Array Monitoring

Two changes to the schedule for remote array monitoring have taken place. No distortions of any unit in the LP channels have been disclosed in the last year, and processing rate using the SACPLP program* has been relaxed to two times per year per subarray, starting in October 1972. The communication system control program CSCONTROL is from October onwards processed on request only.

Array Maintenance

Only two topics should be mentioned:

- Five SP seismometers - 09C01, 05B04 (twice), 02C05, and 05C03 - have been replaced.
- Table 1 shows amount of cable breakages within NORSAR during the period.

---

* Steinert, O., and A.K. Nilsen: Array Monitoring and Field Maintenance Report, NORSAR Technical Report No. 51.

Sub-Array	WHV Cable	Main Data Cable	Dates out of operation	
			From	To
01A	05	x	20 Sep	10 Oct
	05	x	28 Oct	30 Oct
04B	02		1 Sep	13 Oct
05B	02		18 Sep	16 Oct
	01		16 Oct	18 Oct
	05		20 Oct	2 Nov
	-	x	25 Oct	26 Oct
	02,03,06		2 Nov	7 Nov
09C	-	x	6 Oct	12 Oct

TABLE 1

Cable breakages at NORSAR during 4th Quarter 1972

3. COMPUTER CENTER OPERATION - DATA PROCESSING

Programming Efforts

A program was developed to extract information from the Detection Log tape and use the validity indicators contained there to produce fully automatic daily seismic detection reports. This bulletin has been available since 1 November and has shown a high degree of reliability compared to the unedited Event Processor output.

A program designed to extract information from the event tape and systematically compute detectability parameters for coherent and incoherent beamforming as a function of filter frequency and number of subarrays utilized was developed.

A few program corrections to array monitoring routines and Experimental Operations Console display were carried out.

Detection Processing

The Detection Processor (DP) was recording data on-line for approximately 99.7% of real time in October, 99.6% in November and 99.8% in December. Total down time was thus 7 hours in the period.

No serious problems with on-line system operation were encountered in the reporting period.

Incoherent beamforming showed a satisfactory detection performance in the first quarter of full operation. Especially good event detectability by this method was seen in the Mediterranean area, western Russia (presumed explosions) and Central Asia.

The Detection Processor A-filter (selected surveillance) was changed from 1.2-3.2 Hz to 1.4-3.4 Hz effective 23 November 0830 GMT. The reason was to offset some of the decrease in detectability caused by strong low frequency noise in fall and winter months.

The on-line transmission of data from SAAC to NDPC (TAL) was not satisfactory in the period, with periods of up to several days without any data being sent from SAAC. The reason for this is believed to be operational problems at SAAC during data transmission to NDPC, which have caused them to deliberately stop sending data at times. However, on-line data has been transmitted from NDPC to SAAC continuously throughout the period.

Event Processing

The number of reported events in Oct-Dec 72 is given in Table 2. With the exception of December, which had large earthquake swarms from the Philippines and Japan,

Month	Teleseismic	Core	Total
Oct 72	399	97	496
Nov 72	349	78	427
Dec 72	625	83	708

TABLE 2

NORSAR reported events in the 4th Quarter 1972

the number of reported events is somewhat smaller than for July-Sept 72. This is due to differences in the noise level; the autumn and winter storms off the west coast of Norway are the main sources of microseismic noise. As a consequence of this, the DP filter was changed from 1.2-3.2 Hz to 1.4-3.4 Hz on 23 Nov 72. This reduced the number of false alarms due to noise, but did not significantly increase the number of detected signals.

The previously mentioned DP bulletin, which is produced automatically every morning, covering data from the previous day, was implemented in the beginning of Oct 72. Some results from this experiment are given in Table 3, where false alarms and missed events are given relative to the edited EP bulletin. Again, the anomalous numbers for December are obviously due to the earthquake swarms that month. Besides that, the numbers indicate

Month	False Alarms	Misses
15-31 Oct	18%	24%
Nov	17%	20%
Dec	7%	17%

TABLE 3

A comparison between NORSAR
DP and EP bulletin event reporting

around 20% false alarms and 20% missed events. The DP bulletin is still in an experimental stage; it has not been advertised and is circulated to only one outside institution, Hagfors in Sweden. It is considered difficult to further improve the DP bulletin, except for location accuracy which is expected to be significantly better when a new beam set is implemented sometime in Jan-Feb 1973.

4. RESEARCH AND DEVELOPMENT

Research and development efforts have been focused on problems relevant to the NORSAR event detection capability and system evaluation as in the previous period. Moreover, the results obtained have recently been summarized in a number of NORSAR Technical Reports, which are listed in the next section.

The P-signals recorded by NORSAR are only partially coherent across the array. This means that the expected gain in signal-to-noise ratio (SNR) which is proportional to the square root of number of sensors used is not obtained during array beamforming operations. The corresponding signal energy loss increases with increasing frequency, and may severely degrade the array's detectability of very short period P-waves. This problem may be partly circumvented by replacing or supplementing the array beam traces with the average of subarray beam traces. The relative advantages of using the so-called incoherent beams are modest signal losses, better estimates of the noise variance and good areal coverage. The noise suppression is small as compared to array beamforming, but could partly be compensated for by using high frequency bandpass filtering. As mentioned previously, a supplementary event detector based on incoherent beams was implemented in the on-line system on

16 September 1972. Results from the first two months of parallel operation of the so-called coherent and incoherent event detectors are presented in Table 4. The improvement in the array's event detectability amounts to around 15 per cent, and for further details see the report by Ringdal et al, 1972.

Zone No.	Zone Name	EVENTS Total No.	COH.BF Only No.	INC.BF Only No.	COH.& INC. No.	COH.BF Total No.	COH.BF Total %	INC.BF Total No.	INC.BF Total %
1	Greece/Turkey	117	5	45	67	72	62	112	96
2	USSR/Centr.Asia	194	28	41	125	153	79	166	86
3	Japan/Kam./Aleu.	168	40	7	121	161	96	128	76
4	USA/Cent.America	64	31	1	32	63	99	33	51
5	Global I (All events)	1038	242	133	633	905	87	796	77
6	Global II (High Quality events)	546	24	25	497	521	95	522	95

TABLE 4

Events reported in the NORSAR seismic bulletin, 16 Sep - 15 Nov 1972. The table gives the total number and percent of events detected in different regions by the coherent and incoherent beamforming as well as the number of events detected only by one of these detectors.

The characteristic feature of a seismic array is real-time processing of data from a large number of sensors organized in a certain pattern on the surface of the earth. As is well known, when sensor separation increases, the signal similarity, in general, decreases. The consequence here is that when processing signals from a continental array or the global seismological network, the signal suppression is approximately equal to the noise suppression, resulting in a processing gain close to zero. One possible way to circumvent this problem might be to replace the individual signal trace by its envelope as we intuitively should expect this kind of signals to exhibit a large degree of signal similarity independent of sensor separation, seismometer type, etc. This hypothesis has been tested on WWSSN station records (two earthquakes and one explosion) and NORSAR subarray beams from many different events. Signal envelope similarity has been calculated through cross-correlation and coherency analysis. Typical cross-correlation values were around 0.75 units between WWSSN envelope signals. Similar results were obtained by joint analysis of 22 different NORSAR events in the distance range 3-145 deg. Moreover, using data on the P-wave amplitude variation in the teleseismic distance range and the theory for incoherent evnet detectors (Ringdal et al, 1972), reliable estimates on multiarray processing gains are obtainable. It is interesting to note that the above method is superior to previously proposed schemes based on joint detectability analysis of data from several arrays. The above topic is discussed in some detail in a recent report by Husebye et al, 1972.

Two investigations of the NORSAR array event detectability and system evaluation have been completed in the reporting period (Bungum, 1972, Berteussen and Husebye, 1972). The main results obtained are shown in Table 5. Moreover, the potential gain in event detectability by using more flexible bandpass filters is briefly discussed by Gjøystdal and Husebye, 1972.

Several types of noise investigations have been undertaken in the reporting period. The principal goals are NORSAR long periodic noise variations on an annual basis, diurnal noise level variations, and event detector false alarm rate fluctuation and prediction. Studies of microseismic sources and noise level variations on a global basis, are investigated by NORSAR research visitors H. Korhonen, Oulu University, and S. Pirhonen, Helsinki University. Drs. I. Noponen and D. Doornbos have continued their research on short period discriminant criteria and core phase precursor waves.

ZONE No.	ZONE Name	ZONE LIMITS Azi(deg)	Dist(deg)	OBSERVED m_b LEVELS No. of Events	50%	90%	PREDICTED m_b LEVELS No. of events for SL estimates	50%	90%
1	P-zone	0-360	30-90	1555	3.57	4.03	548	3.63	4.01
2	Atlantic	180-260	30-90	88	3.64	4.26	13	3.69	4.23
3	N.America	260-340	40-90	114	3.72	4.06	98	3.66	4.05
4	Aleutian Is.	340-15	30-90	131	3.40	3.90	17	3.62	3.95
5	Japan	15-70	50-90	738	3.66	4.07	236	3.61	3.95
6	C. Asia	40-110	30-90	211	3.21	3.69	58	3.45	3.87
7	Iran (1)	110-180	30-90	262	3.45	3.80	38	3.51	3.88
8	Iran (2)	110-130	35-50	188	3.42	3.78	31	3.49	3.83

TABLE 5

Observed and predicted m_b detectability levels for the NORSAR array. The observational data covers the interval Feb - June 1972.

5. MISCELLANEOUS

During the reporting period a number of scientists, whose names are listed below, have visited NORSAR Data Processing Center, Kjeller, for various research purposes.

Dr. I. Noponen, Seismological Institute, Helsinki, Finland
Dr. R.M. Sheppard, Seismic Discrimination Group, M.I.T., Cambridge, Mass., U.S.A.
Dr. H. Korhonen, Dept. of Geophysics, Oulu University, Oulu, Finland
Dr. S. Pirhonen, Seismological Institute, Helsinki, Finland
Dr. D. Doornbos, Utrecht University, Utrecht, the Netherlands
Professor Tsujiura, Earthquake Research Institute, Tokyo, Japan.

In the reporting period 96 data tapes were sent to SAAC.

H. Bungum and E.S. Husebye participated in the annual meeting of the Norwegian Geophysical Society at Nesbyen, 2-5 October. One talk was given.

Reports Completed in the 4th Quarter

No. 33 Ringdal, F., and O. Steinert: Travel Report from a "Course in Detection, Estimation and Modulation Theory, Brussels, 26/6-7/7-1972.

No. 35 Steinert, O.: Travel and Work Report on the Participation in the Erection of a WWSSN Station at 77°N in Northeast-Greenland

No. 36 System Operations Report, 1/1-71 - 30/6-71

No. 37 Husebye, E.S.: Progress Report 3rd Quarter 1972.

No. 38 Larsen, P.W.: Short Description and Service Instruction for Remote Centering Device

No. 39 Hansen, O.A.: Short Description and Adjustment Procedure for Water Detector Type AH 70H

No. 40 Steinert, O., and A.K. Nilsen: Array Monitoring and Field Maintenance Report, 1 Oct 71 - 30 June 1972

No. 41 Ringdal, F.: Travel Report from a Trip to Washington, D.C., and Boston in Connection with the ARPA Network Project

No. 42 Berteussen, K.A., and E.S. Husebye: Predicted and Observed Seismic Event Detectability of the NORSAR Array

No. 43 Husebye, E.S., F. Ringdal and J. Fyen: On Real-time Processing of Data from a Global Seismological Network

No. 44 Steinert, O.: Introduction to SP Analog Station

No. 45 Ringdal, F., E.S. Husebye, and A. Dahle: Event Detection Problems for a Partially Coherent Array

No. 46 Bungum, H.: Array Stations as a Tool for Microseismic Research

No. 47 System Operations Report, 1 July - 31 December 1971

No. 48 Gjøystdal, H., and E.S. Husebye: A Comparison of Performance between Prediction Error and Bandpass Filters

No. 49 Bungum, H.: Event Detection and Location Capabilities at NORSAR

No. 50 Husebye, E.S.: NORSAR Research and Development, 1 July 1972 - 30 June 1972

No. 51 Steinert, O., and A.K. Nilsen: Array Monitoring and Field Maintenance, 1 July - 31 December 1972

No. 52 Larsen, P.W.: Noise Modification for Discrete Inputs (in Norwegian)

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Royal Norwegian Council for Scientific & Industrial Research Post Box 51 N-2007 Kjeller, NORWAY	UNCLASSIFIED
	2b. GROUP N/A

3. REPORT TITLE

PROGRESS REPORT NORSAR PHASE 3, 4th Quarter 1972

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

1 October - 31 December 1972

5. AUTHOR(S) *(First name, middle initial, last name)*

E. S. Husebye

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
5 February 1973		

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
F19628-70-C-0283	ESD-TR-73-120
b. PROJECT NO.	
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	NORSAR Report No. 53

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Deputy for Planning and Technology Hq Electronic Systems Division (AFSC) L G Hanscom Fld, Bedford, MA 01730

13. ABSTRACT

The report covers the period 1 October - 31 December 1972 which is characterized by improving, estimating and simulating the array detection capability. All activities related to field work, repair and maintenance of field instrumentation are now located in a single facility at Stange close to Hamar. The operational performance of the field equipment has been satisfactory also in this reporting period. The implementation of the incoherent event detector in the software system has improved the array's event detectability approximately 15 per cent. A daily bulletin is edited, and is solely based on event detector data. Observed and predicted NORSAR event detectability utilizing data from the first half of 1972 have been worked out. Also potential detectability improvements as a function of more flexible bandpass filtering have been investigated.

DD FORM 1 NOV 65 1473

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT