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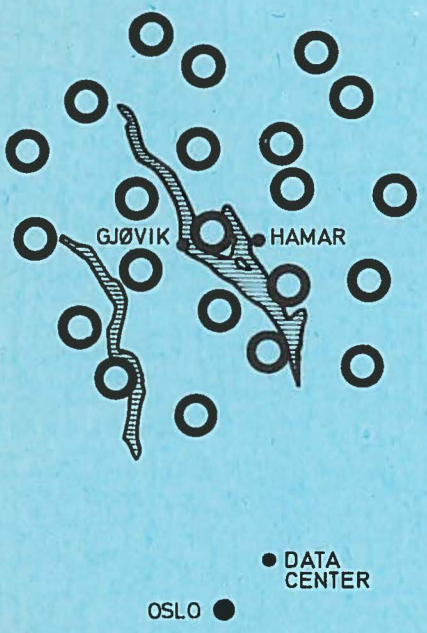
Royal Norwegian Council for Scientific and Industrial Research

PROGRESS REPORT
NORSAR PHASE 3

3rd Quarter 1971



NORWEGIAN SEISMIC ARRAY

NORSAR

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NTNF/NORSAR
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Norway

NORSAR Report No. 13
Budget Bureau No.22-R0293

PROGRESS REPORT
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Status per 30 September 1971

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

Name of Contractor	:	Royal Norwegian Council for Scientific and Industrial Research
Date of Contract	:	May 15, 1970
Amount of Contract	:	$ 1.300.883,-
Contract No.	:	F19628-70-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 July - 30 September, 1971, which is characterized by software debugging efforts, establishing of organizational procedures required for the routine NORSAR operation and research aimed at system improvements and array performance evaluation. From 1 September onwards the array was operated on a continuous basis, i.e., the data recording was down only when due to occasional system malfunctioning which occured 10 times during that month. Calibration of the field instrumentation is performed regulary, and the stability of SP seismometers is still somewhat problematic. Computer time is in short supply, but more efficient operational procedures are under development. External distributions of NORSAR seismic bulletins commenced in September. Array evaluation results indicate that NORSAR's present event detection capability could be improved. In principle it would be advantageous to work with higher signal frequencies (say 1.5 - 3.5 Hz), although linear array processing methods are less efficient in this part of the frequency domain.

II Administration and Economy

The operation of the NORSAR array requires external services of various kinds from mainly three companies. These are the Norwegian Telegraph Administration (NTA) for providing data communication lines, IBM/Norway for computer hardware service and maintenance, and Kjeller Computer Installation (KCIN) for housing facilities for NORSAR Data Processing Center (NDPC). New service contracts with the above companies covering the period 1 July 1971 - 30 June 1972 are being negotiated, and final agreements are likely to be achieved in the near future. The field maintenance contract with Noratom-Norcontrol A/S expired 30 September, and the field crew of 8 technicians was transferred to the NTNF/NORSAR staff.

Expenditures in the reporting period were:

1.	Operation & Maintenance		
	Data Processing Center	$ 65 590	
	Field Installations	" 53 090	
	Data Communications	" 72 385	$ 191 065
2.	Research & Development		" 12 900
3.	Administration & Support		" 18 460
		TOTAL	$ 222 425

III Array Monitoring and Control - Field Maintenance

NORSAR utilizes computerized procedures to the array monitoring and control functions, and the performance of the field instrumentation is supervised from the data center at Kjeller. The software calibration package has been developed by IBM, and a stepwise implementation started in January 1971. Further refinement of this work is planned.

As of today, complete monitoring of the 9 seismometers in one subarray requires approximately 2.5 hours of computer time.

A special Array Monitoring & Calibration group has been established at NDPC which is responsible for routine seismometer calibration, and supervision and coordination of the work of the field maintenance crew. The latter work was previously contracted to the Noratom-Norcontrol company, but will be transferred to NTNF/NORSAR, effective from 1 October, 1971.

We are still troubled by lack of stability in the performance of the SP seismometers. During the reporting period 39 SP-sensors were outside the tolerance limits for the instrument natural frequency while 76 seismometers did not meet the specifications regarding damping ratio. Corrective maintenance was carried out on 16 instruments and 21 sensors were replaced. Tele-Plan A/S has developed an equalization network circuit designed for compensating automatically for deviations in natural frequency and damping coefficients of the seismometers. One experimental unit of the above type has been installed in two SLEM channels at sub-arrays 05C and 07C on an experimental basis, and the results obtained here have proved promising.

The data communication lines between NDPC and field installations are considered to function satisfactory.

IV Computer Center Operation - Data Processing

A notable change in system operation took place during the reporting period as IBM's software development contract for the NORSAR array terminated as of August 31. In the months of July and August the on-line Detection Processor (DP) was down a considerable amount of time due to debugging efforts, while in September the system was operated with a minimum of interventions. In the latter interval the total number of stops due to system malfunctioning was 10, causing a loss of approximately 6 hours of data. Operational problems encountered here were notably tape drive problems and system overload.

Programming efforts

A procedure has been developed for displaying high rate tape data in an off-line mode on the Experimental Operations Console (EOC). This task is performable concurrently with normal job shop execution or Event Processor (EP) operation on the B-computer, and without significant delay in these operations. Several minor corrections were made in the EP programs, thus permitting data retention and tape copying jobs to be run in foreground while EP itself is working in two regions. Moreover, DP corrections and modifications were implemented in the reporting period.

A NORSAR Change and Control Board (CCB) has been established for record keeping and coordination of all changes to the hardware and software operation systems of the array. The change files previously kept by IBM were transferred to those of the new CCB.

The immediate future programming efforts will be focused on a few, very important aspects of array operation. High priority is given to developing proper procedures for data retention of selected events beyond the mandatory 9-month period.

Generation of a special low rate tape will be implemented in the on-line system. This type of tape will contain the recordings from the long period seismometers and data transmitted from SAAC to NDPC. Moreover, the above EOC display program will be modified to accept low rate tape data as input. We are also planning a critical evaluation of the CPU load and memory utilization for both the DP and EP computers as an initial step for future system improvements.

Finally, it should be noted that presently computer time is in short supply, and some of the above works are specifically aimed at reducing the load of routine data processing by introducing more efficient operational procedures.

Routine Event Processing

A workable version of the Event Processor (EP) package became operational in March 1971. From end of April the recorded events were regulary analyzed, and a complete seismic bulletin edited on a daily basis. In close cooperation with IBM personnel we participated in the debugging efforts of EP which was very intense in the first 2 months of the reporting period. An external distribution of a seismic event summary started the first week of September, and the number of recipients were ca. 50.

A number of bugs and desirable changes to EP has survived the reporting period. We are especially concerned with computer time allocation for routine event analysis, updating of beam deployment and beamsteering correction files, present set of system parameters and the possibility of changing the processing algorithm in case of weak events.

V Research and Development

Research and development work in the reporting period have been focused on improvements of the software systems, seismological investigations, and array evaluation. In

the latter case we are primarily concerned with NORSAR's capability of detecting and locating seismic events, and the precision in the epicenter parameters.

As the end of the reporting period NOAA* epicenter data for the months May and June became available, and immediately a comparison was undertaken between these data and those from the edited output of the Event Processor or our bulletins. In the above period 220 events out of larger populations have been analyzed by both NOAA and NORSAR. Out of these, 142 events were in the 30 - 90 deg NORSAR distance range, and 50% of them has a mislocation smaller than 200 km (90% smaller than 600 km). In other distance ranges the location errors were considerably larger, and is partly explainable in terms of phase identification errors and inaccuracies in the velocity calibration files in EP. In view of the above results, we are working on a procedure for simulating array location capabilities. Moreover, a new set of beam steering delay corrections and velocity calibration will be implemented in the system as soon as possible. A study of the observed body wave magnitudes shows a negative bias as compared to the NOAA estimates. This residual is especially pronounced for shorter epicentral distances,and is explainable in terms of energy losses during the beamforming process. This hypothesis has been confirmed by spectral analysis.

The distribution of NORSAR located events shows a 90% incremental reporting level around magnitude (M_b) 4.2, and a 90% cumulative level of $M_b = 4.1$.

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* National Oceanic and Atmospheric Administration, USA

These figures are around 0.3 magnitude units higher than the corresponding ones for LASA.

There are two main aspects of the array evaluation problem namely the performance in terms of outputs from the detection and event processors, and the potential of the unprocessed or original data. An illustrative example here is that data presently available indicates that LASA reports around 4 times more events than NORSAR does. (We have here not accounted for LASA's relative favourable location vis-a-vis seismic active regions). On the other hand, the NORSAR noise level for frequencies around 1.7 Hz is comparable to that of LASA. Moreover, frequency domain analysis of P-waves earthquakes and explosions in the teleseismic range give signal-to-noise ratio (SNR) maxima in the interval 3-6 Hz. During the reporting period the filter setting used for detection and event processing covers the frequency band 0.8 - 2.5 Hz, which means that the inherent event detection potential of the array was not fully utilized. Changing the band pass filters will not solve all our problems here, as the beam coverage and gains in SNR during beamforming decrease for increasing signal frequencies. For example, signal energy losses on the array beam level amount to around 10 - 15 dB for frequencies of 3 - 4 Hz. (These results are based on using a 10 sec signal window). Finally, we should like to remark that we are very much concerned about the discussed aspects of NORSAR evaluation, as these provide us with the proper background knowledge for improving data processing systems of the array.

A visiting seismologist, Dr. D. Doornbos is analyzing P-waves which have penetrated the Earth's core. Results

obtained so far indicate that current core models probably should be modified in order to account for more complex wave propagation phenomena than hitherto assumed.

VI Miscellaneous

NTNF/NORSAR will arrange a seminar on Seismology and Seismic Arrays in November 22 - 25, 1971. The attendance will probably comprise around 50 seismologists from 12 countries in Europe and North-America.

E. S. Husebye and H. Bungum participated in the XV General Assembly of the Internation Union of Geodesy and Geophysics arranged in Moscow, July 27 to August 12, 1971.

Visitors to NORSAR Data Processing Center, Kjeller during the reporting period, were:

D. Doornbos, Utrecht Univ., The Netherlands,
July 1 - Sep 30, 1971

M. Perl, Hebrew Univ. of Jerusalem, Israel,
Juli 1 - August 27, 1971
(NTNF scholarship)

P. Basham, Ottawa, Canada, July 6 - 7, 1971

E. Hjortenberg, Geodetic Inst., Copenhagen, Denmark,
July 6 - 17, 1971

H. Mach, Geotech/SAAC, Alexandria, Va, USA - July 26-27, 71

J. Minear, Triangle Res. Inst., Raleigh, S. Carolina, USA
July 29, 1971

I. Noponen, Helsinki Univ., Finland,
August 16 - Sep 30, 1971.

During the period 9 persons in the IBM, Federal System Division group at Kjeller left the project, with three programmers remaining. The latter personnel is working on a new IBM/ARPA contract, and will not be involved in system operation except on a more consultative basis.

In the period, 75 data tapes were sent to SAAC in response to requests. 1 data tape was sent to Geodætisk Institut, Copenhagen.