Royal Norwegian Council for Scientific and Industrial Research

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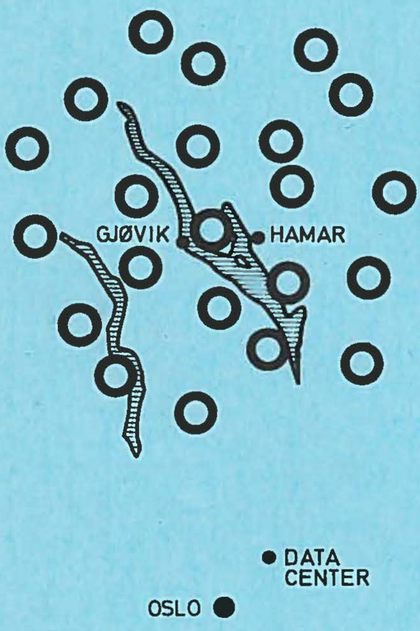
SYSTEM OPERATION REPORT

1 January - 30 June 1971



NORWEGIAN SEISMIC ARRAY

NORSAR

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NORSAR Report No. 36

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SYSTEM OPERATION REPORT

1 January - 30 June 1971

1 November 1972

The NORSAR research 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 Electronic Systems Division, Air Force Systems Command, through Contract No. F19628-70-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)

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CONTENTS

SUMMARY

Operation of the complete NORSAR system started in the beginning of 1971, following the completion of electronic equipment installations. This report, covering the period 1 Jan - 30 June 1971 is, accordingly, the first account of operation under assumed "normal" conditions. Of course, some operational experience had already been gained from interim operation ("Plan D") and successive transfer of subarrays to fully operative status. Reference is in this connection made to earlier reports, notably System Operation Report for second half of 1970 (NORSAR Report No. 15).

The period was characterized by testing and running--in of the system. Efforts by NORSAR's regular staff, in cooperation with IBM, were concentrated on optimizing the performance by debugging and improvements in the various fields, in particular with programming and field equipment performance.

1. INTRODUCTION

Regular operation of the complete NORSAR system started in the beginning of 1971, following completion of electronic equipment installations. This report, accordingly, is the first account of operation under assumed "normal" conditions. Of course, some operational experience had already been gained from interim operations ("Plan D") and successive transfer of subarrays to fully operative status. Reference is in this connection made to earlier reports, notably Operations Report for second half of 1970 (NORSAR Report No. 15).

From the start, the efforts of NORSAR's regular staff, in cooperation with IBM, were concentrated on optimalizing the performance. A great deal of work was done with debugging and improvements in the various fields, in particular with programming and field equipment performance.

2. FACILITIES

The NORSAR Data Processing Center (NDPC) is located at Kjeller, approximately 20 km outside of Oslo. All computer equipment is housed in a rented wing belonging to the Kjeller Computer Installation (KCIN). The wing, essentially, consists of a computer hall (260 m^2), modem room, punch room, customer engineer's office, four offices, halls and air conditioning installation. An additional approximately 220 m^2 of office space is provided in a nearby building assembled from prefabricated huts. A newly erected canteen building, belonging to KCIN, was rented as office space for resident IBM personnel.

The Maintenance Center (MC) is also located at Kjeller, on the nearby premises of the Institute for Atomic Energy

(IFA). These facilities are rented from IFA through Noratom-Norcontrol A/S, the subcontractor for field maintenance. Next to the MC are re-erected the prefabricated huts previously used at Øyer and Falldalen, as an extension of the workshop facilities. NORSAR also rents from IFA a warehouse for storing of equipment and material. For details about NDPC buildings, floor plans, etc., see NDRE Phase 2, Final Technical Report, Chapters 8 and 9.

In the array area, there is a rented workshop/storage facility in Brumunddal, approximately in the center of the array, and a rented cable storage in the same area.

3. ORGANIZATION, PERSONNEL

NORSAR is, from 1 July 1970, operated as an institution under the Royal Norwegian Council for Scientific and Industrial Research (NTNF), a government-controlled organization which runs about 25 scientific institutions of various sizes and purposes. Supervision of the project rests with the Director of NTNF. A 3-man Project Committee for NORSAR, appointed by NTNF, acts as a consultative body for NTNF on questions of project policy.

Day-to-day operations are performed by the NORSAR DPC staff, consisting of the following personnel:

Project Manager
Administrative Assistant
Technical Assistant
Secretaries (3-4)

Operations Manager
Operations Manager Assistant
Chief Programmer

Programmers (3)
Operations Seismologist
Operations Physicist
Computer Operation Supervisor
Operators (13)
Librarian

In addition, the Research and Development Group consists of the following personnel:

Chief Seismologist
Mathematician/Physicist
Programmers (2)

In the reporting period the Operations Manager temporarily acted as Project Manager.

Field maintenance is carried out by the subcontractor Noratom-Norcontrol A/S. The field group consists of 6 field technicians, 2 workshop technicians, and 2 men performing administrative and control functions. A separate report covering the field maintenance in the period is issued (NORSAR Report No. 32, Field Maintenance Report, 1 Jan - 30 Sep 1971).

In the period, 15-18 U.S. IBM/FSD personnel worked at NDPC.

4 NDPC ACTIVITY

4.1 Detection Processor Operation

During the reporting period the Detection Processor (DP) was operating on a semi-continuous basis. This means that an effort was made to keep the on-line system running except when it was necessary to take the system down for debugging purposes.

The initial set of parameters in the NORSAR DP was chosen based partly on ISRSPS SAAC experience, partly on analyses of interim NORSAR data. The DP performance was monitored very closely, and some basic parameters were later adjusted. Figure 1 summarizes the various DP deployments and significant parameter changes during the reporting period. This figure does not include the high frequency B-filter in the General Surveillance, which showed a very poor detection performance before it was removed 2 April.

The single most significant parameter change was the deployment of array beam set 310, comprising 331 on-line array beams, which was implemented 21 April 1971. Extensive studies aiming at improving the current parameter set were still going on by the end of the reporting period.

4.2 Event Processor Operation

During the reporting period, the Event Processor (EP) was developed from a very initial and non-operating stage to a version that was operating fairly regularly from medio April. An extensive development and debugging activity was required throughout all the reporting period, at the end of which there was still room for considerable improvement.

The IBM/NORSAR contract for development of DP and EP for NORSAR, specified that the programs developed for LASA should be given the necessary modifications in order to fit the different array configuration at NORSAR. The first order effects of the different configurations were allowed for, but it turned out soon that a freer approach could have been advantageous. For example, the possibility that a difference in the seismic data received at the two stations could require new approaches for the analysis was not allowed for, and this has later caused some problems. As compared to LASA, the data at NORSAR is first of all characterized by the great variety, both as a function of epicenter location and as a function of array sensor. The variation is observed first of all in frequency content, but also in complexity, signal shape, signal coherency and power versus time distribution. Also, a great variation is characteristic for the background noise. In addition to this, the main difference between LASA and NORSAR is that NORSAR observes a large number of local very high-frequent events, most of which are caused by cultural activity within or close to the array. This has caused some problems, since one is interested in the best possible coverage of high-frequent teleseisms but not if it results in more detections of local events, which the EP cannot handle. Also the relative lack of signal coherence across the array makes it difficult to use simple linear beamforming as the main source of signal enhancement and coherency as the main source for U-space location. The data received and analyzed so far has indicated that an incoherent beamforming might sometimes be a better approach, taking advantage of the fact that the subarray beam envelopes might be more coherent than the subarray beams themselves.

As soon as the first regular output from EP was available, work started on the evaluation of the results. From the month of April, the EP was operated regularly enough to initiate a daily and systematic review of the data. This review includes such changes as corrections to arrival time, amplitude and period, but most important is the review of the solution in geographic space, the epicenter estimation. There are always two main questions to be answered first: (1) is the detection true, and (2) is the solution acceptable. When the analyst considers the solution to be too uncertain, the event is rerun in EP if there is any improvement possible. There are two main error sources in the location estimation: (1) uncertainties in estimation of slowness and azimuth, and (2) uncertainties in the transformation to real space (as for core phases). The latter uncertainty will be reduced when better corrections are implemented.

For the various reasons given above, a more detailed analysis and evaluation of the EP results could not start before May 1971, thus covering only two months in this reporting period. A simple head count is done in the table below, where comparison also is made with NOAA (National Oceanic and Atmospheric Administration).

	May & June	Daily Average
NORSAR	494	8.1
NOAA	607	9.4
Common	235	3.9

The daily average at NORSAR was 8.1 events, with 6.8 in the teleseismic zone ($30^{o}<\Delta<90^{o}$). An average of 3.9 events per day were reported commonly by the two institutions.

Besides the head count, a comparison between magnitudes has also been made. Fig 2 shows the NOAA/NORSAR magnitude difference, where it is clear that the NORSAR magnitudes are significantly smaller for epicentral distances less than 30^{o}. A bias may also be existent for larger distances, but that needs more data and thorough testing.

Finally, a comparison between location estimates has been made. Fig 3 shows the incremental and cumulative distribution of NOAA/NORSAR location differences in the teleseismic zone ($30^{o}<\Delta<90^{o}$). It appears that the median (50%) location difference is 230 km, or about two degrees.

The main areas where improvements now can be expected are in a tuning of the filters and updating of the time delay and location correction. Later, incoherent beamforming and weighted beamforming would have to be considered.

4.3 Computer Utilization

The main tasks requiring computer time in the first half of 1971 are listed in Table 1 along with the associated time used per month. As can be seen from this table, both computers were heavily used from approximately 1 March. At this date, the IBM Systems Acceptance Test had been concluded, and an effort was made to start running the system through full routine processing on a continuous basis.

Routine Event Processing was initiated ultimo February, and constituted a major load on the secondary S/360 computer throughout the period.

SLEM tests required a significant amount of computer time in January and February.

No serious computer hardware problems or problems of operational nature were encountered during the period.

4.4 Programming

The main programming efforts in the period were centered around the development of the Detection and Event Processors. The NTNF personnel cooperated very closely with IBM on these matters, our main objective being to develop proficiency in the various aspects of the NORSAR software. NTNF also assisted IBM in the debugging phase both in locating software errors and in correcting discrepancies.

The specific areas where NTNF had a particularly large part of the responsibilities were the Detection Processing algorithms, the Detection Processor and SPS initialization, off-line EOC display programs, algorithms pertinent to the production of the Seismic Bulletin, Event Processor updating functions and support programs.

A major NTNF programming effort in the period was the implementation for the NORSAR array of the Long Period Signal Processing Package developed by Texas Instruments. One NTNF seismologist (E.S. Husebye) and one programmer (F. Ringdal) stayed with Texas Instruments at SAAC (Alexandria, Va.) from 24 February to 22 March to become familiar with the LP package. The programs were at the time not compatible to NORSAR processing requirements, and several modifications were necessary, notably in the area of initial data editing and error checking. The necessary adjustments were made by the NTNF staff, and the implementation of the LP package was finished by 1 July 1971.

4.5 Array Monitoring and Control

Routine remote array monitoring using the capabilities of the AM computer system at NDPC was initiated at the end of December 1970. The AM system was to be developed and analysis programs designed to utilize remote testing features of NORSAR in order to facilitate maintenance of the field installations. The system will permit recognition of deteriorating performance and discovery of malfunctions at an early stage.

The introduction of these new tasks implied training of NDPC operators to perform preliminary analysis of test data and establishing working procedures for NDPC personnel and field maintenance personnel, taking into account the new tools and refinement of the AM programs at hand.

From March 1970 the priorities for subarray visits and tasks to be accomplished in the array area and at FMC/Brumunddal were set by NDPC.

In the reporting period the field maintenance of NORSAR was directed by the consulting firm Noratom-Norconsult A/S. The final testing of the SLEM which were installed during the fall 1970, and development and testing of AM programs to be implemented in the system were accomplished by IBM/FD personnel in cooperation with NDPC personnel.

AM Package and Features Tested

The AM package in use in the reporting period consisted of the following four programs:

a) SLEM TEST provided the test capability for the SLEM hardware. The acquired data were listed without any preceding data analysis. Based on these data, the following tasks were accomplished:

   - control of the operation of external inputs, synchronization, identification and digital compression logic,
   - test generator amplitudes and frequencies,
   - common mode rejection of SP LTAs,
   - DC offset of LP and SP channels,
   - RSA/ADC performance,

   and determination of LP sensor mass position and free period.

b) SACP SP. The channel transfer function at a single frequency was obtained for SP channels by analyzing the channel output when a 1.0 Hz test signal was applied to the channel input. Characteristics of the output signal such as bias, frequency, amplitude (gain), and distortion were obtained.

c) CHANEV SP. The SP channel transfer function was determined by analysis of the channel output when a pseudo random pulse sequence was applied to the channel input. From this transfer function were obtained such channel parameters as filter characteristics, LTA time constant, RA-5 gain, RA-lower and upper 3 dB point, seismometer sensitivity, natural frequency and damping.

d) MISNO. The program tested the ability of the SLEM to reproduce all possible numbers within a given range. It verifies adjustment and performance of the RSA/ADC circuits.

Test Frequencies

Until medio March the SLEM TEST, SACP SP and CHANEV SP were run every second week to all subarrays, while MISNO was run ad hoc. Partly due to computer load in the last half of the reporting period and partly to our good experience with the stability of the equipment parameters tested, the test frequency of subarray monitoring was changed to one array monitoring cyclus every fourth week.

Communications

Communications lines are rented from the Norwegian Telegraph Administration (NTA). The NORSAR communications system is described in detail in NORSAR Report No. 15. Except for subarray interconnecting cables, all line operation and maintenance is covered by the subcontract with NTA.

During the report period, work has continued to adjust communications channels to comply with specifications (CCITT M102).

5. SEISMIC DATA DISTRIBUTION

Preparations for the weekly bulletin were done in the period. No regular data distribution was performed.

6. REFERENCES

Results from the various fields of NORSAR operation during this report period are published in detailed separate reports. These include:

1) Final Report on HS-10-1 ARPA Seismometer Equalizing Network, Teleplan Report, Feb 1971.

2) Synchronization Input to Time Code Generators, Teleplan Report, Jan 1971.

3) Monitoring of CTV Battery Current, Teleplan Report, Jan 1971.

4) Suppression of SP-Channel Noise, Teleplan Report, Dec 70/June 71.

5) Modem and Looping Control, DPC and CTV, Teleplan Reports, June 1971.

6) Monitoring of LPV Pressure, Teleplan Report, June 1971.

7) Field Maintenance Report, 1 Jan - 30 September 1971, NORSAR Technical Report No. 32.

8) Bungum, H., and E.S. Husebye: Errors in Time Delay Measurements, Pure and Appl. Geophys., 91, No. 8, pp. 56-70, 1971.

9) Bungum, H., and K.A. Berteussen: An Evaluation of the Routine Processing of Events at NORSAR during the Time Period May-October 1971, NORSAR Technical Report No. 24, March 1972.

Deployment Interval (Day-Hours)	Subarray Beam Deployment	Array Beam Deployment	A-Filter (Hz)	Limiting Level (nm)	STA Scaling 1 nm =	LTA/STA Scale factor	Turn on Threshold (dB)	Q/Q'	Stability Parameters (SS)	Voting M/N (GS)	Others
1971 $10^d\ 21^h$ to $36^d\ 07^h$	114 (SS) 115 (GS)	306 (300AB)	0.9-3.5	17 nm	128 qu (SS) 100 qu (GS)	16 (SS) 16 (GS)	8dB (SS) 7dB (GS)	3/3 (SS) 3/3 (GS)	T-4 samples U-2 rings	3/8	STA rate - 0 Int.window -
$36^d\ 16^h$ to $39^d\ 08^h$							9dB (SS) 7dB (GS)	1/1 (SS) 3/3 (GS)			
$39^d\ 16^h$ to $40^d\ 18^h$									T-3 samples ΔU-2 rings		
$40^d\ 18^h$ to $42^d\ 20^h$				8.5nm							
$42^d\ 20^h$ to $69^d\ 16^h$							10dB (SS) 7dB (GS)		T-4 samples ΔU-1 ring		
$69^d\ 16^h$ to $83^d\ 16^h$				34 nm	540 qu (SS) 400 qu (GS)	2 (SS) 2 (GS)			T-3 samples ΔU-2 rings		
$83^d\ 16^h$ to $92^d\ 15^h$											
$92^d\ 15^h$ to $111^d\ 19^h$											
$111^d\ 19^h$ to $207^d\ 12^h$	123 (SS) 124 (GS)	310 (331AB)			608 qu (SS) 444 qu (GS)						STA rate - 0. Int.window - 2

Fig 1. Detection Processor Deployment in 1971. Selected Surveillance (SS) and General Surveillance (GS) A-filter.

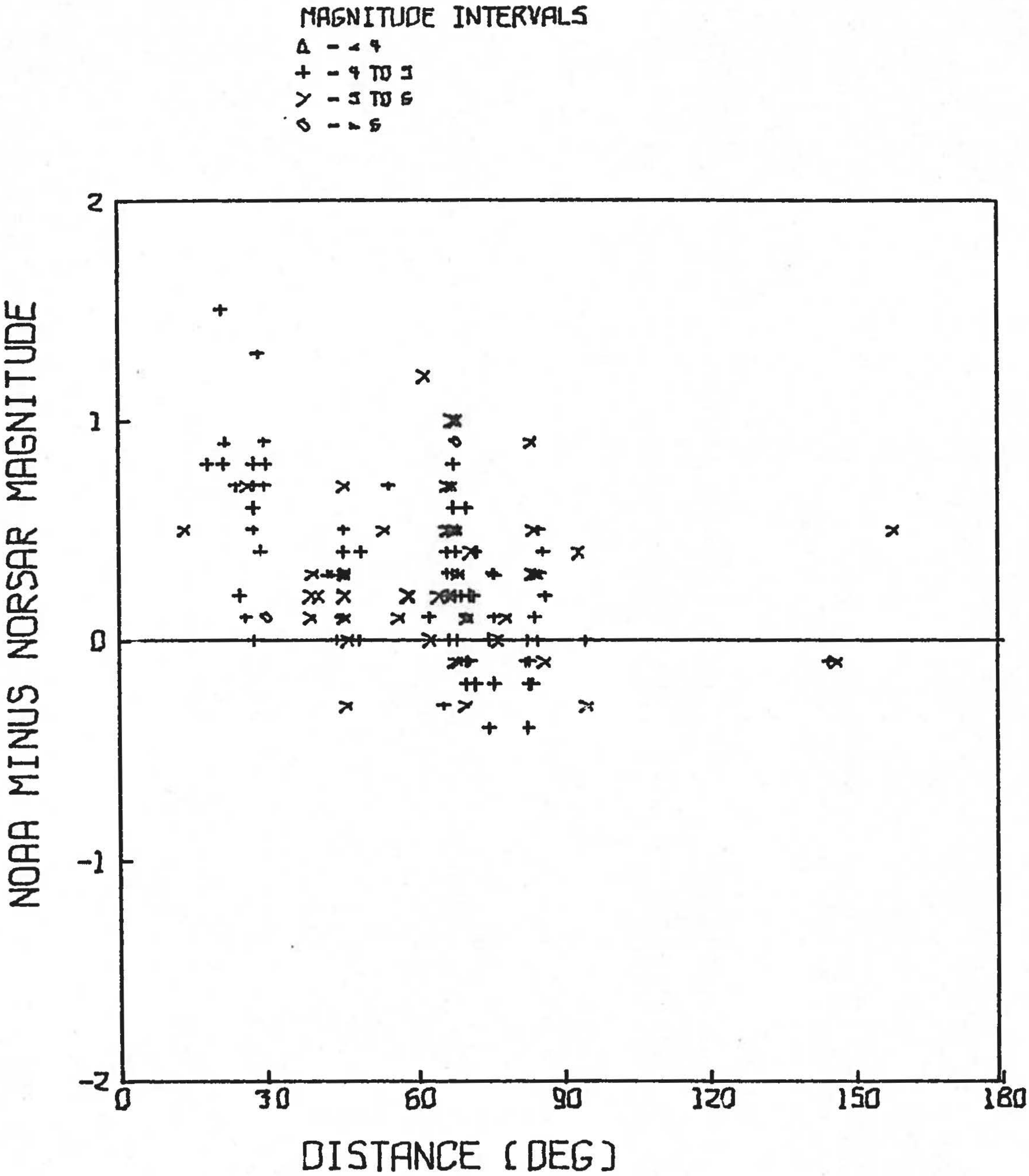

Fig 2. NORSAR/NOAA Magnitude Differences for May and June 1971.

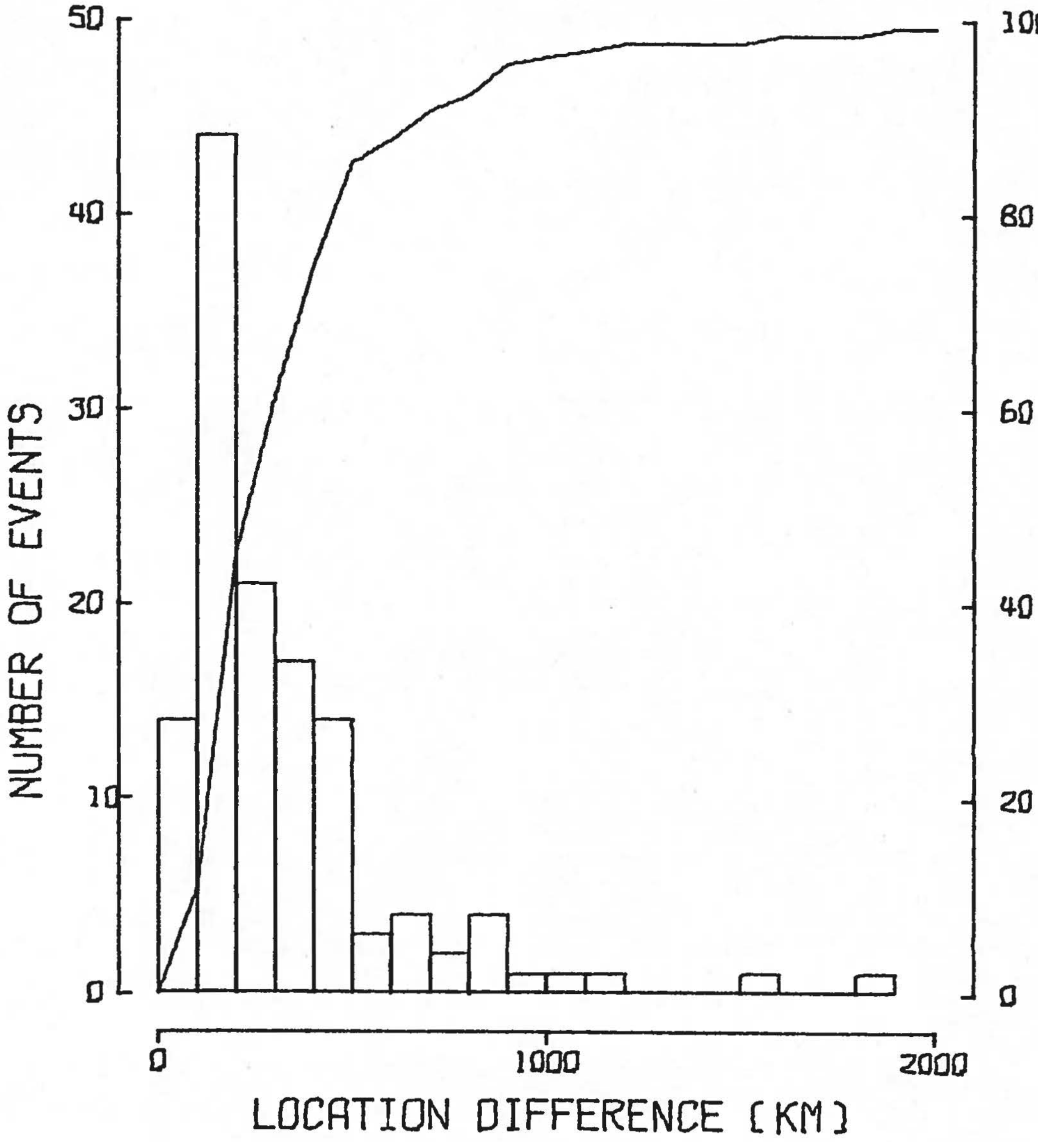

Fig 3. Incremental and cumulative distribution of location differences between NOAA and NORSAR for May and June 1971

	Computer	Jan	Feb	Mar	Apr	May	Jun	Total Hours
Job shop	A	233	150	14	47	30	241	715
	B	306	233	192	282	359	186	1548
SLEMTEST & Analyses	A	21	19		2		31	73
	B	281	198	126	105	168	43	921
Idle and Power Off	A	39	15			1	9	64
	B	96	94	6		1	9	206
C.E. Maint.& Machine Error	A	8	14	14	16	6	12	70
	B	5	5	13	24	10	13	70
On-line DP	A	437	456	711	607	646	262	3119
	B				24		385	409
DP test, Dumps, etc.	A	6	11	5	42	61	5	130
	B	30					7	37
Event Processing	A		7		6		160	173
	B	26	152	407	285	206	77	1153
Total Hours	A	744	672	744	720	744	720	
	B	744	672	744	720	744	720	

TABLE 1

Utilized computer time (no. of hours) on A and B Computer. January through June 1971.