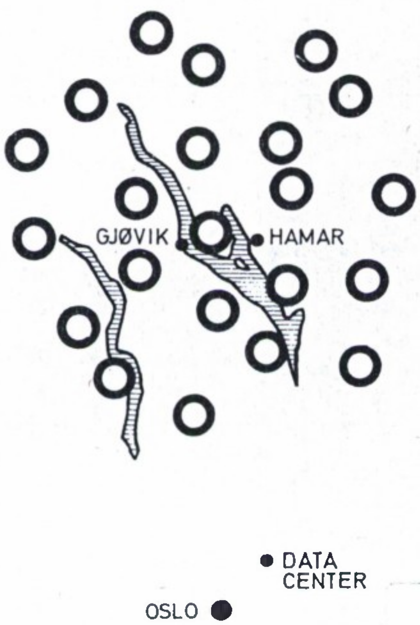

NORWEGIAN SEISMIC ARRAY

NORSAR

P. O. Box 51. 2007 Kjeller – Norway

ESD-TR-73-141

NTNF/NORSAR
Post Box 51
2007 Kjeller
NORWAY

NORSAR Technical Report No. 54

SYSTEM OPERATIONS REPORT
1 January - 30 June 1972

20 February 1973

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.

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13. ABSTRACT

This report covers the operation of the NORSAR system during the first half of 1972. Array monitoring and control and associated field maintenance are, according to contract, covered in a special report (NORSAR Report No. 40). A short summary of maintenance center activities is, however, presented.

No major problems were encountered in the period. Computer equipment shows good stability; this also applies to other (field) equipment once the right modus operandi is established. In particular, improvements have been achieved in the traditionally problematic field of short period seismometer and amplifiers.

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SUMMARY

This report covers the operation of the NORSAR system during the first half of 1972. Array monitoring and control and associated field maintenance are, according to contract, covered in a special report (NORSAR Report No 40). A short summary of maintenance center activities is, however, presented.

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1. INTRODUCTION

The Norwegian Seismic Array - NORSAR - was built in 1968-70, following an agreement between the Governments of the United States of America and Norway. The array is located in south-eastern Norway, with center approximately 100 km north of Oslo (Fig. 1.1). The array, consisting of 22 subarrays, is approximately 110 km in diameter. The subarrays (SA) are organized in an outer (14 SA) ring, an inner ring (7 SA) and one center SA. Each SA with diameter approximately 10 km, consists of 5 short period seismometers in boreholes varying in depth from 2 to 15 meters, a long period vault housing 3 long period seismometers (E-W, N-S, Vertical) and one short period seismometer, and a central terminal vault housing the main SA electronic equipment. Buried cables interconnect the various parts of an SA (Fig 1.2). Each SA is connected to the data center at Kjeller near Oslo via a dedicated telephone circuit, which is rented from the Norwegian Telegraph Administration.

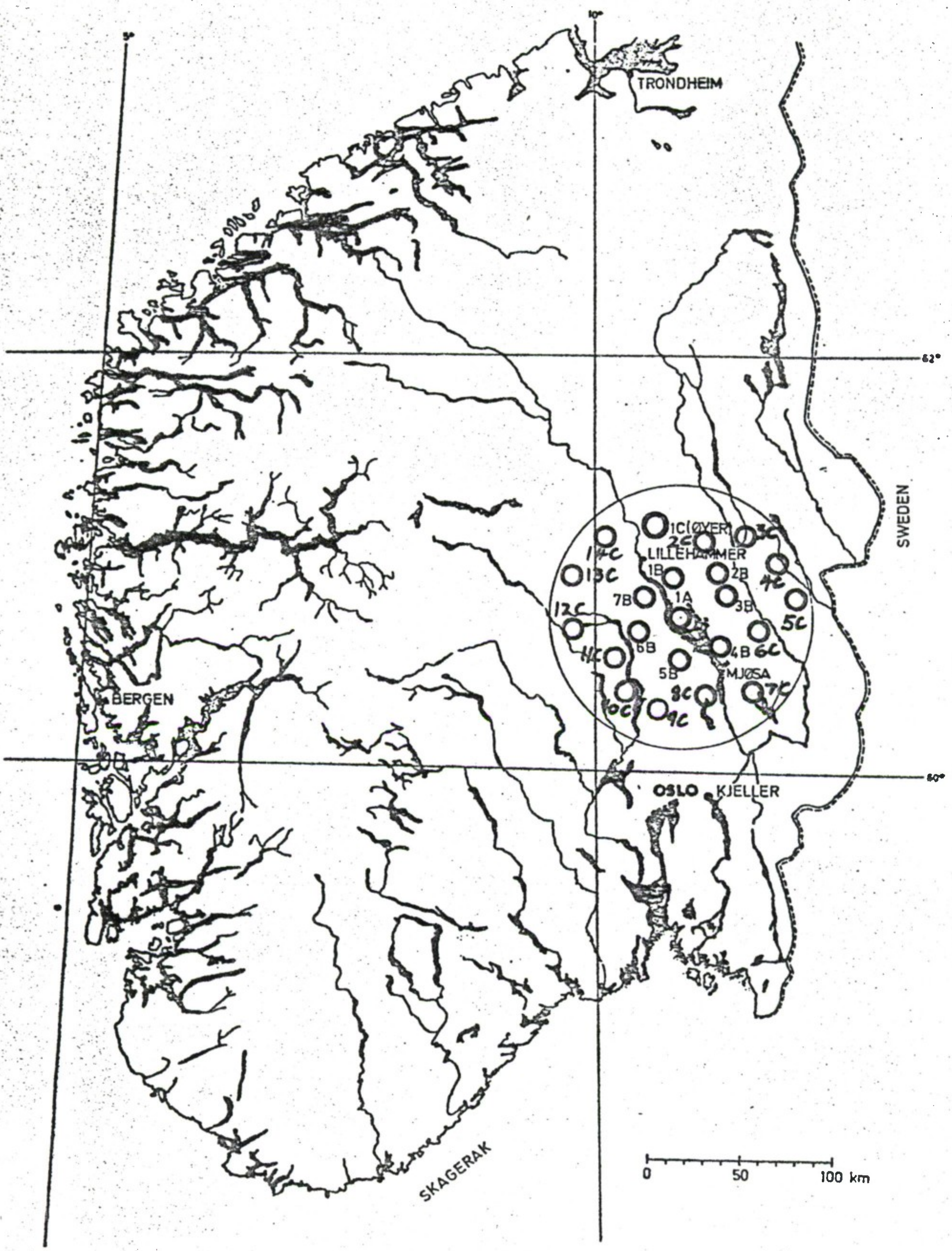


Figure 1.1 Southern Norway

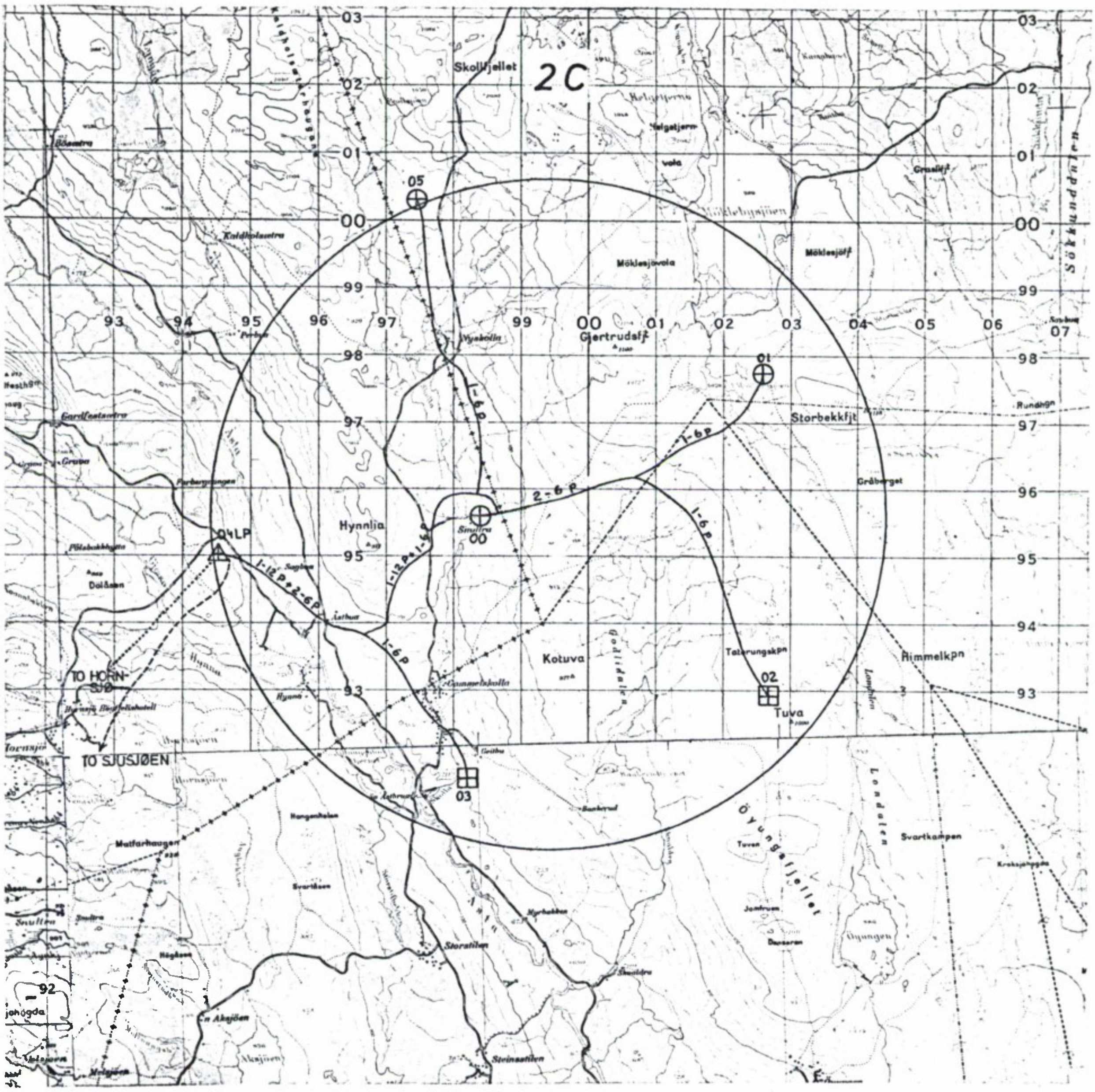


Figure 1.2 Typical Subarray

△ Central Area (LP and CTV Site) ——— Cable trench

□ Shallow (blasted) SP hole · · · • Power line

○ Deep (drilled) SP hole ·· – – • Telephone/ data line

The construction of the array was administered by the Norwegian Defence Research Establishment under contract with the United States Air Force, wherea the operation of the system, from 1 July 1970, is the responsibility of the Royal Norwegian Council for Scientific and Industrial Research, also under contract with USAF.

2. STATUS OF SYSTEM

2.1 Facilities

The Data Processing Center at Kjeller consists of a rented permanent building containing computer room, adjacent rooms for air conditioning, card punching, line termination, storage and six offices, and a semipermanent prefabricated office building with 17 offices and auxiliary rooms, part of which is U.S. Government property, part of it rented.

The maintenance center, with main workshop facilities, is located near the data center, partly in a rented house, partly in a semipermanent house similar to the office building. A large storeroom is rented from the neighboring Institute for Atomic Energy. A small field workshop is rented in the array area, also a storage area is rented for spare cable reels and bulk material. A new maintenance center is planned in the array area, whereby all workshop activities and storage (except cables) will be concentrated at one location. This will reduce operating costs and provide for better utilization of manpower and resources.

2.2 Personnel

The list below shows the total manning of NORSAR, with service time in the project for each incumbent. In addition, three IBM/FSD personnel stayed with the project in the report period, with special tasks and as advisers to the NORSAR staff. Part time work relating to accounting, payroll, etc., is being done by the RSCSIR head office.

Group	Position	Employed	Left
Administration	Project Manager	1 Apr 72	
	Adm. Secretary	1 Aug 70	
	Tech. Assistant	1 Nov 68	2 Jul 72
	Secretary	16 Oct 69	
	"	1 Oct 70	
	"	18 Oct 71	
Research	Chief Seismologist	1 Dec 68	
	Seismologist	27 Jul 70	
	Programmer	27 Sep 71	
	"	1 Mar 72	
Operations	Operations Manager	1 Jan 70	
	Oper. Manager Assistant	16 Mar 68	
	Chief Programmer	1 Jan 69	
	Programmer	20 May 70	
	"	1 Oct 68	
	"	28 Feb 69	
	"	1 Jan 71	29 Feb 72
	Librarian	7 Jun 71	
	Seismologist	1 Dec 69	
	Physicist	5 Sep 68	
	Oper. Supervisor	1 Aug 68	
	Syst. Operator	1 Aug 68	
	"	2 Sep 68	
	"	1 Jan 72	

Group	Position	Employed	Left
Operations (cont.)	Operator	11 Oct 71	
	"	1 Jan 71	
		20 Mar 72	
	"	17 Apr 72	
	"	30 Jul 68	
	"	29 Jun 70	
	"	13 Sep 71	
	"	21 Jun 71	1 Apr 72
	"	17 Feb 70	
	"	1 Jan 71	
Transferred from sub-contractor	Lab. Techn.	1 Oct 71	30 Apr 72
	"	1 Oct 71	30 Jun 72
	Field Techn.	1 Oct 71	
	"	1 Oct 71	
	"	1 Oct 71	
	"	1 Oct 71	
	"	1 Oct 71	
	"	1 Oct 71	

2.3 Equipment, Maintenance

2.3.1 NDPC Equipment

The computer installation consists of 2 IBM 360 Mod 40, a Special Processing System (SPS), and Experimental Operations Console (EOC) and various control and peripheral equipment. Floor plan and functional diagram of the installation are shown in Figs. 2.1 and 2.2 respectively.

Maintenance of computer equipment is subcontracted with IBM Norway. Table 2.1 indicates the maintenance activity in the period. Computer utilization is discussed in the next chapter. Equipment performance was reliable and stable.

Month 1972	C.E. Maint.		Power Down		Mach. Error		SPS* Fail.	EOC Fail.	TOD * Fail.
	A	B	A	B	A	B			
Jan	7	3			2	6			
Feb		3	1	11	3	15			
Mar		5	7	7	9	19	7		
Apr	1	4	1	1	14		7		2
May	10	2	1	1	3	10			
Jun	6	2	3	3		5			

* Down time included in other columns. TOD=Time of Day
A = A computer, B = B computer. C.E.=Custom Engineer

TABLE 2.1

Maintenance and Down Times (Hours)
Jan - Jun 1972

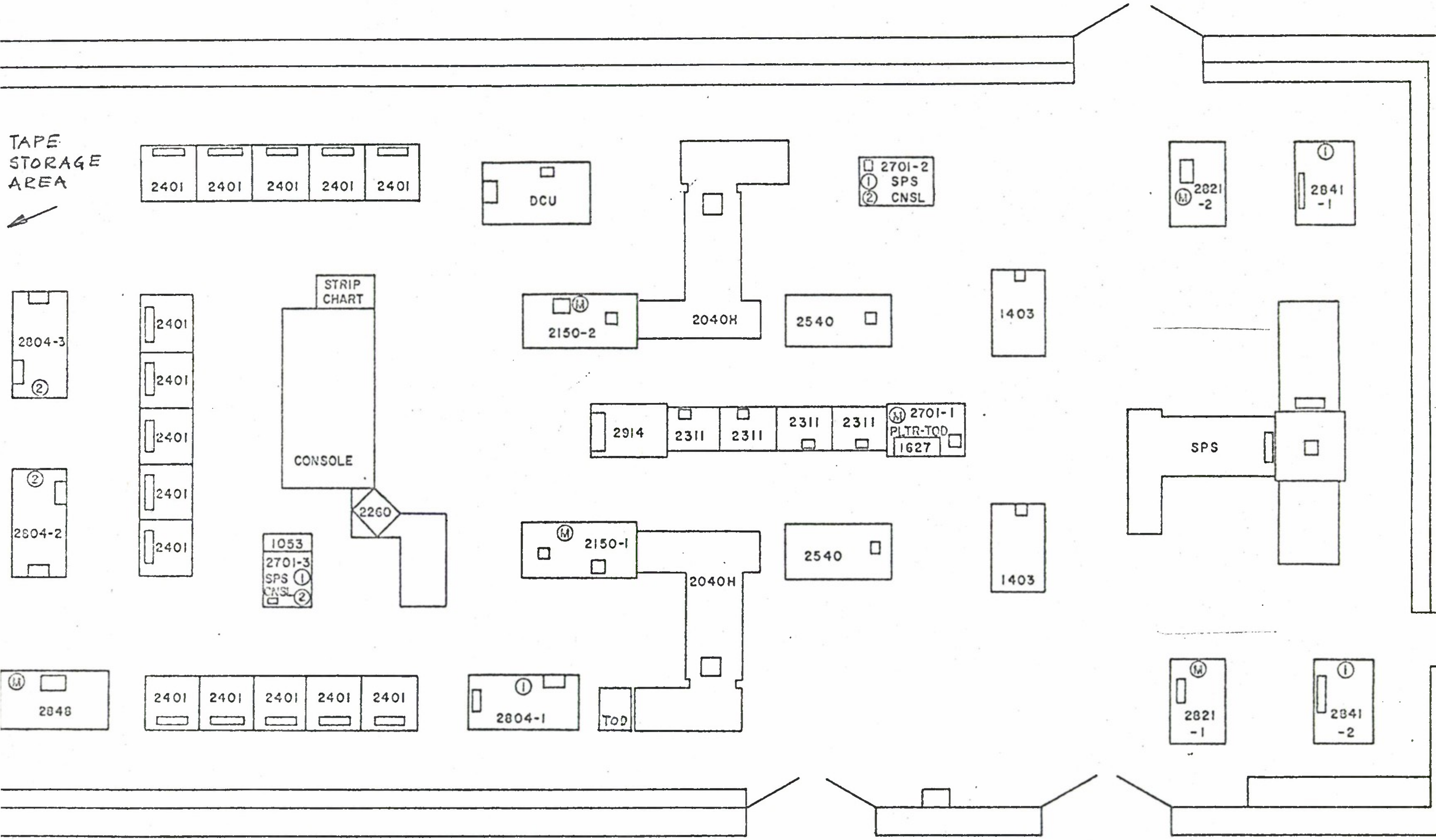


Figure 2.1 NDPC Computer Hall

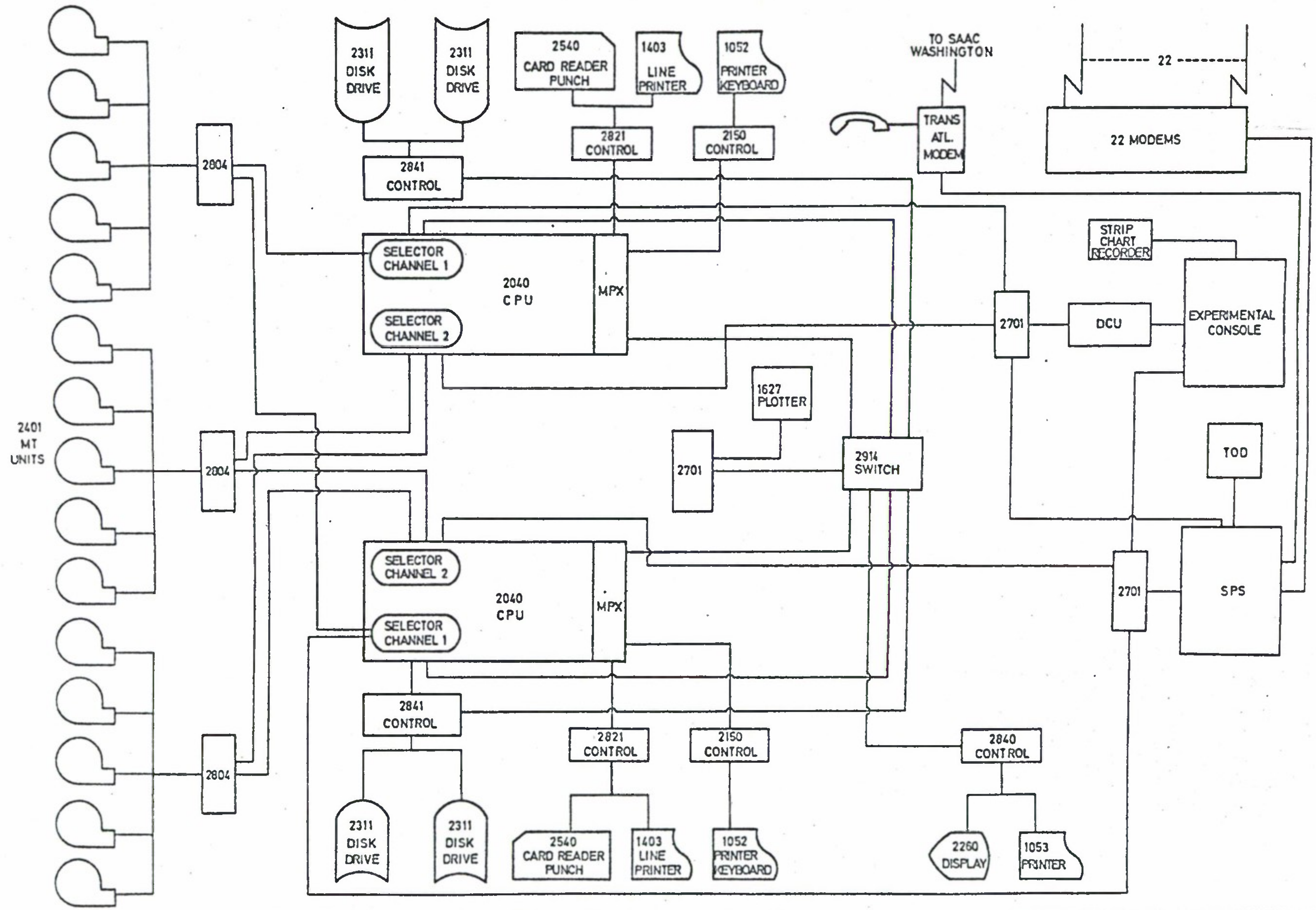


Figure 2.2 Functional Diagram of the Computer System

2.3.2 Communications

The communications system consists of 22 dedicated circuits, 2400 baud modems type ITT GH-2003B and auxiliary equipment. Lines are rented from the Norwegian Telegraph Administration. Line and modem maintenance is subcontracted with the NTA. The communications system is shown in Fig. 2.3. Table 2.2 shows communication outage for groups of subarrays in the period. The Trans-Atlantic Line (TAL) was in June rerouted from the satellite ground station at Goonhilly Downs in the United Kingdom to the new Scandinavian ground station at Tanum in Sweden and the Intelsat IV satellite. At the same time, a rerouting of this circuit in the USA was reported to have occurred. Communications between Kjeller and Tanum are by cable and microwavelink.

2.3.3 Field Equipment

Field equipment status and maintenance is covered by NORSAR report no. 40, "Array Monitoring and Field Maintenance Report, 1 Oct 71 - 30 June 72", thus only a summary of workshop activity at Kjeller is given here. Also, as one of the workshop technicians left in the middle of the period, the other at the end of the period, the activities were gradually transferred to the field workshop, pending the establishment of the new field maintenance center. One person from the data center worked part time at the workshop.

Summary of maintenance center activities 1 Jan - 30 Jun 1972:

1. SP seismometer
   Thirty-six seismometers were reconditioned/adjusted. Several of these had to be treated more than once before acceptance. After scrutinizing the procedures, this situation improved. New (wider) tolerance limits for frequency and damping were established by ESD; however, seismometers coming in for treatment were, of course, adjusted to as near nominal values as possible.

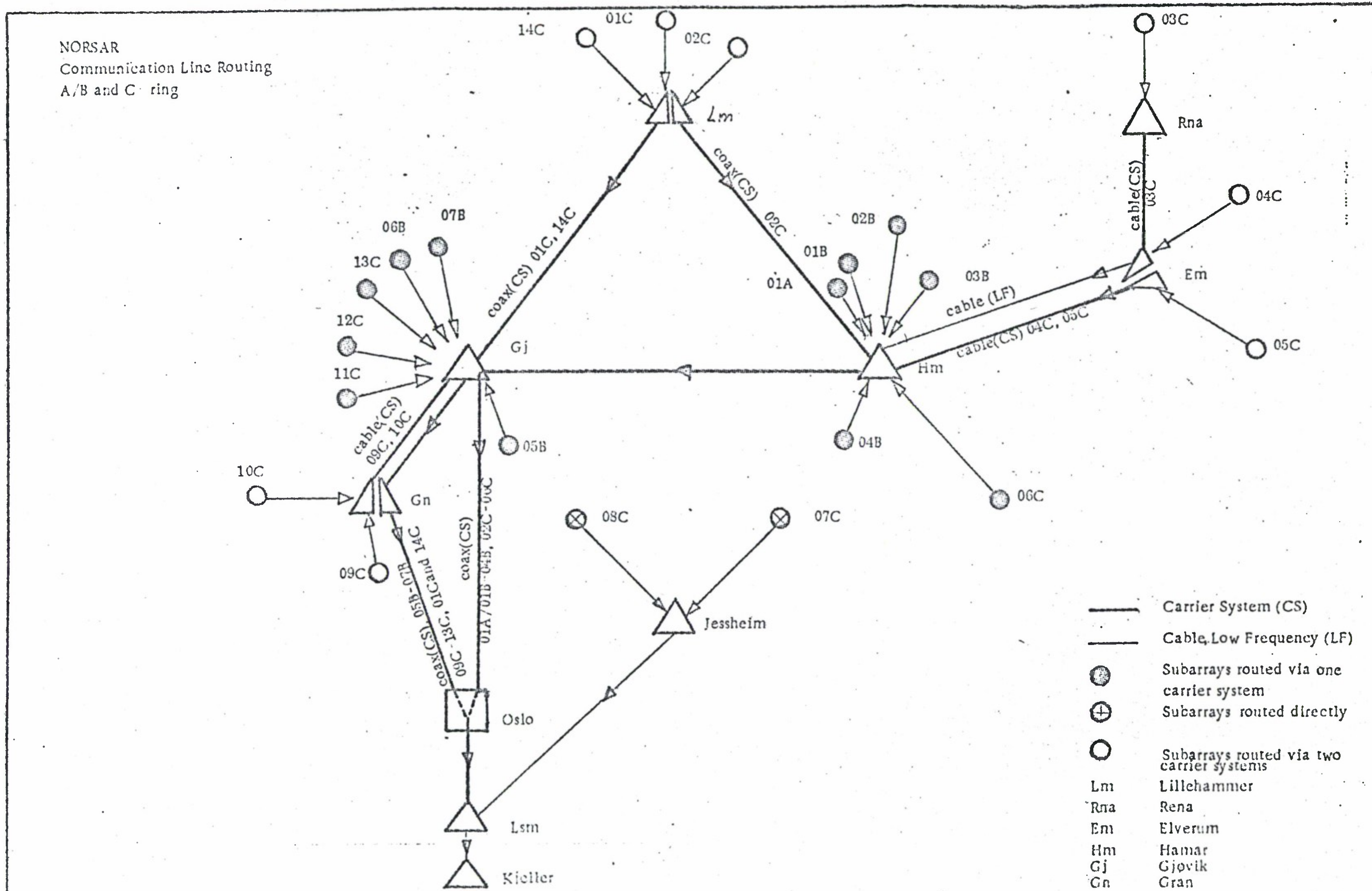


Figure 2.3 NORSAR Communications System

Sub-Arrays	Jan 1972	Feb 1972	Mar 1972	Apr 1972	May 1972	June 1972	Total hours Down
01A/01B-04B				11.6	1.1		12.7
02C-06C			2.0	10.8	1.1		13.9
05B-01C		0.5	1.1	7.7	17.0	1.6	27.9
09C-14C		0.5	1.1	10.0	20.2	1.6	33.4
01A-14C -7,8C		0.8	0.5	2.2	0.3	0.3	4.1
05B-07B			1.1		3.0		4.1
11C-13C			1.1				1.1

TABLE 2.2

Summary of Communication System Down (Groups of SA's)

2. RA-5 Amplifier

A special test set-up for RA-5 was finished. This consists of a board where amplifier subassemblies can be mounted, and where test points are easily accessible. Together with a detailed test procedure, this simplifies amplifier repair and tests considerably. Eight amplifiers were repaired and tested in the period.

3. LP Seismometer

One vertical seismometer reconditioned/adjusted.
Five remote centering devices repaired.

4. SLEM

Two Analog/Digital Converters adjusted.
One ADC sent back to factory under guarantee.
Three SP Line Terminating Amplifiers repaired.
Seven test generators repaired.
Four external power units repaired/adjusted.

5. Miscellaneous

One Ithaco (LP) amplifier sent to factory for repair.

Three junction boxes reconditioned and rewired.

In connection with SP seismometer reconditioning, detailed procedures were worked out, and detailed documentation of work on each seismometer, in the form of new data cards, were instituted.

A new sealing compound for SP seismometers was tested and accepted. This makes disassembly of seismometers much easier than before.

Investigations were made into the problem of CTV water alarm tripping without the presence of water. Adjustments improved the situation; however, further improvements are expected, possibly in the form of a new detector.

Investigations of missing numbers from 3B SLEM were made. The reason, noise from the power unit, was found, and the problem solved.

"Interface units" for use in line and modem tests were made.

An inventory control was performed by Mr. D. Madrigal, AFCMC Det 16, 9-16 Feb 72. In this connection, maintenance center spare parts stock and material control procedures were examined. As a result of this, the spare parts stock was partly reorganized. To keep better track of units and subunits, the number tagging system was extended to include several additional items, with corresponding history data cards for each unit.

3. NDPC ACTIVITY

3.1 Detection Processor Operation

3.1.1 General Considerations

During the reporting period, the mode of operation for the NORSAR Detection Processor (DP) was close to continuous, with DP taken down only when needed for program development purposes and parameter changes. As before, core dumps were taken when DP was subject to error stop for unknown reason, and the secondary computer was used for backup recording purposes to minimize loss of data due to system malfunctioning.

The most significant developments within DP in the reporting period were the implementation of trans-Atlantic communication SAAC to NDPC and an experimental "incoherent" event detector (Section 3.1.4).

3.1.2 Data Recording and DP Down Time

Figure 3.1.1 shows Detection Processor down time on a day-to-day basis for January-June 1972. The total

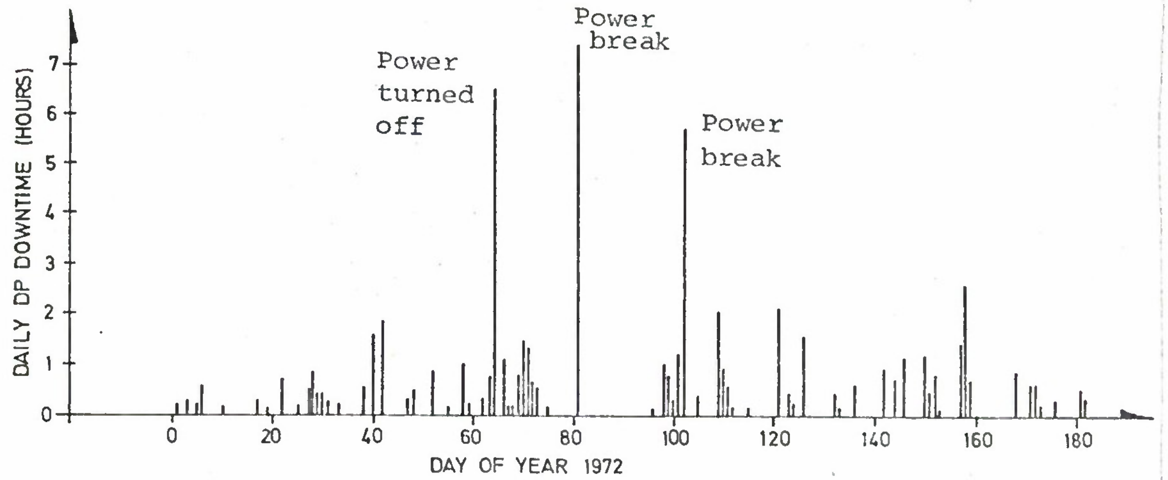


Figure 3.1.1 Daily Detection Processor Down Time January-June 1972

monthly recording time is given in Tables 3.1.1 and 3.1.2, together with statistics covering general computer usage.

It is seen that DP was operational for at least 97% of real time every month. A few outages of long duration account for most of the DP down time, and are mainly attributable to hardware conditions.

The number of system error stops and the associated mean time between failures are given in Table 3.1.2. System stops when DP was taken down deliberately have not been included here.

The 53 DP error stops in the reporting period were related to the following causes:

Tape drive problems	14	
Power breaks and related stops	11	
Disk controller	7	(all in March)
Other hardware problems	11	
Software errors	7	
Operator errors	3	

The average mean time between failures in the reporting period was 3.4 days.

	DP	EP	Job Shop	Data Retention Copying	Array Monitor-ing	DP Test	C.E. Maint.	Power Down	Idle	Mach Error	No. of jobs
Jan	731		2			2	7			2	6
Feb	688					4		1		3	
Mar	682	22	35	3	3			7		9	64
Apr	700					4	1	1		14	
May	719		11			1	10	1		3	46
Jun	679	5	23	2		2	6	3			84
Total hours	4199	27	71	5	3	13	24	13		31	200

COMPUTER A

	DP	EP	Job Shop	Data Retention Copying	Array Monitor-ing	DP Test	C.E. Maint.	Power Down	Idle	Mach Error	No. of Jobs
Jan	8	232	446	260	183		3		12	6	875
Feb	1	259	387	251	202		3	1		15	851
Mar	40	318	358	250	147		5	7		19	640
Apr	4	330	361	244	96	31	4	1			735
May	17	314	431	255	119	20	2	1		10	700
Jun	33	265	500	209	76	14	2	3		5	1000
Total Hours	103	1709	2483	1469	823	65	19	13	12	55	4801

COMPUTER B

DP Up Time: $\frac{(4199+103)\cdot 100}{4368}\,\% = 98.5\%$

EP Up Time: $\frac{(27+1709)\cdot 100}{4368}\,\% = 39.7\%$

TABLE 3.1.1

Computer Usage (hours per month) 1 January - 30 June 1972

	DP UPTIME (hours)	DP UP %	EP UPTIME (hours)	EP UP %	NO. OF DP ERROR STOPS	DP MTBF (days)
Jan	739	99.4	232	31.2	10	3.1
Feb	689	99.0	259	37.1	8	3.6
Mar	722	97.0	340	45.6	12	2.6
Apr	704	97.8	330	45.6	9	3.3
May	736	98.9	314	42.0	6	5.2
Jun	712	98.9	270	38.4	8	3.8
Total	4302	98.5	1736	39.7	53	3.4

TABLE 3.1.2

DP and EP Computer Usage
1 January - 30 June 1972

3.1.3 DP Operational Problems

The main DP problems in the reporting period are summarized in the following, together with the associated Discrepancy Report Number.

Several tape drive problems caused DP error stops, especially in January. (Discrepancy Report 465 and others) An effort was made to modify the on-line software to reduce the probability of system breakdown in such cases by having DP retry twice any unsuccessful write statement to a data tape. The situation seemed to improve later in the period.

An incorrect time on the time of day generator (TOD) caused the time on the data tapes to be 86 seconds wrong (too high) from 24 January, 1520 GMT, to 3 February, 1436 GMT, when the error was discovered. The cause of this problem remains unknown, but actions have been taken to check the TOD generator more regularly. (Discrepancy Report 497)

- An SPS coding error was corrected on 13 March. (Discrepancy Report 529) The problem related to a routine which is not frequently entered, and implied that an erroneous counter value would cause submultiplexed data to be inserted in the SPS filter buffer. Detection performance would then be degraded and LP data would be lost. This had happened during several shorter time intervals dating back to when the system first became operational.

- Hardware problems with the Disk Controller caused several DP error stops in March (Discrepancy Report 533).

- On several occasions (e.g. Discrepancy report 546) the SPS fans did not function properly after power breaks, causing considerable system down time. The fans have now been changed.

- Operator failure to mask faulty data channels from being included in the detection processing caused degraded DP performance during days 103-104 and again days 161-162 (Discrepancy Report 551). A routine has been established after these incidents to have a daily visual control of each data channel via the EOC display.

3.1.4 DP Algorithms and Parameters

The following significant DP programming changes took place in the reporting period.

- An experimental processor to form a limited set of "incoherent array beams" and monitor the detection performance of these beams was implemented on-line 10 January, 1200 GMT (Change Request 472). Incoherent beamforming is analogous to conventional beamforming, but array beamforming is performed after rectification of the subarray beams by the new method. Initially, three incoherent beams were steered towards the Aleutian-Kamchatka region, and they were redeployed to Turkey-Caspian Sea from 6 March.

- A new method to analyze channel gains (LP and SP) during array monitoring tests was implemented 8 March. This method compensates better for seismic noise superimposed on calibration signals than the one previously used, by averaging the amplitude of the calibration sine wave over several cycles rather than selecting the peak amplitude. (Change Request 464)

- Trans-Atlantic data communication from SAAC to NDPC was implemented 24 April. This work was done in cooperation with Geotech/SAAC, and implied an effective utilization of the Trans-Atlantic Link (TAL) for two-way data exchange. An outline of the types of data included in the transmission is presented in Table 3.1.5 (Change Request 502).

- An option to perform plotting from the on-line Detection Processor was implemented 19 June. The background for this development was the need that had emerged to provide extra plotting capability during periods of heavy Event Processing load (Change Request 567).

The parameter changes relevant to the on-line DP during the reporting period were as follows.

6 January, 1300 GMT

- A new bandpass filter, 1.2-3.2 Hz Butterworth, was applied to on-line data by the SPS from this date (Change Request 445). This change was based upon NTNF studies which suggested that the best-in-average signal-to-noise ratio on the array beams could be obtained in this frequency band. See Table 3.1.3 and 3.1.4 for scaling parameters associated to the new filter.

27 January, 1200 GMT

- A new set of region corrections for the NORSAR array was worked out late in 1971 based upon studies of systematically selected events with clean signal arrivals on all subarrays. This provided an opportunity to adjust the time delays used in the on-line array beamforming to better fit the true wavefront arrivals for events from different regions. The new time delays were implemented on the above date (Change Request 491). No change was performed in the U-space aiming points of the array beams.

- The Selected Surveillance detection threshold was set at 10.5 dB as the year started. It was lowered to 10 dB on 3 May, 1600 GMT, and again to 9 dB on 21 June, 0930 GMT (Change Request 581).

Table 3.1.3 Detection Processor Scaling (6 Jan 1972 - 23 Nov 1972)

SEIM = 6 SA = 22 B-BP 1.2-3.2 HZ SEL. SURV. 01/06/72

FILTER PARAMETERS

	THEORETICAL	IMPLEMENTED	DP INPUT	FILTER PROG INPUT
K	0.09853	1745 (1972)	0.05325	
A(0)	1	1	1	0.5325317E-01
A(1)	0	0	0	0.0
A(2)	-3	-3	-3	-0.1597595E 00
A(3)	0	0	0	0.0
A(4)	3	3	3	0.1597595E 00
A(5)	0	0	0	0.0
A(6)	-1	-1	-1	-0.5325317E-01
B(1)	-0.82855	-27150 (-27136)	-0.82855	-0.8285522E 00
B(2)	0.82274	26960 (26880)	0.82274	0.8227539E 00
B(3)	-0.48832	-16001 (-16000)	-0.48832	-0.4883118E 00
B(4)	0.50707	16615 (16640)	0.50707	0.5070496E 00
B(5)	-0.13681	-4483 (- 4480)	-0.13681	-0.1368103E 00
B(6)	0.05630	1845 (1920)	0.05630	0.5630493E-01

DSUM = 0.1072429E 01
D2SUM = 0.2014214E 01
CSUM = 0.1668583E-06
C2SUM = 0.4037914E 00
CABSUM= 0.1849206E 01
CEVEN = 0.9305243E 00

SCALING FACTORS

ALPHA =	0	MU =	-1
DELTA =	0	R =	3
BETA(SA) =	0	NU =	-2
RHO =	0	SIGMA =	-5
BETA(LA) =	-3	NFO =	6
S =	5	OMEGA =	0

GAINS

G(SA) = 0.245E 01
G(F) = 0.580E 01
G(LA) = 0.469E 01

GAMMA = -15

Coherent Beamforming Process Step:	Multiplier	Value 1.2-3.2 Hz Filter	Corresponding noise scaling
1. Input single seismometer values			23.4 qu/nm
2. Filter input shift (ALPHA)	2**ALPHA	0	23.4 "
3. Filter noise suppression (GF)	1/GF	5.8	4.0 "
4. Filter arithmetic scaling (FSCALE)	1/FSCALE	1.85	2.2 "
5. Filter output shift (DELTA)	2**DELTA	0	2.2 "
6. Subarray beamforming (GSA)	GSA=$\sqrt{6}$	$\sqrt{6}$	5.3 "
7. Subarray output shift (BETASA)	2**BETASA	0	5.3 "
8. Array beam preshift (RHO)	2**RHO	0	5.3 "
9. Array beamforming (GLA)	GLA=$\sqrt{22}$	$\sqrt{22}$	25.1 "
10. Array beam output shift (BETALA)	2**BETALA	-3	3.1 "
11. Rectification || $\sqrt{2/\pi}$	$\sqrt{2/\pi}$		2.5 "
12. Rectification shift (MU)	2**MU	-1	1.25 "
13. STA integration (STAW)=(R*S)	STAW	15	18.8 "
14. LTA scaling shift (ZETA)=(NU-SIGMA)	2**ZETA	3	150 "

TABLE 3.1.4

Detection Processor Scaling and Conversion Factors
6 January - 23 November 1972

Field	Description of Contents	Bytes
1	Control Characters	0-3
2	LASA Signal Arrival Queue Entry File	4-17
3	LASA Time (ISRSPS Format)	18-21
4	LASA LP Status and Repeat Indicator	22-28
5	LASA LP Data	29-130
6	ALPA Time (ISRSPS Format)	131-134
7	ALPA LP Status and Repeat Indicator	135-142
8	ALPA LP Data	143-256
9	LASA Off-line Results	257-282
10a	Program Coordination Data	283-294
10b	SP Data Request	283-291
11	Control Characters	295-298
12	Spare (encoded as zeros)	299

TABLE 3.1.5

Contents of data block transmitted on-line from SAAC to NDPC. One such block of 300 bytes is transmitted each second.

3.1.5 Detection Processor Performance

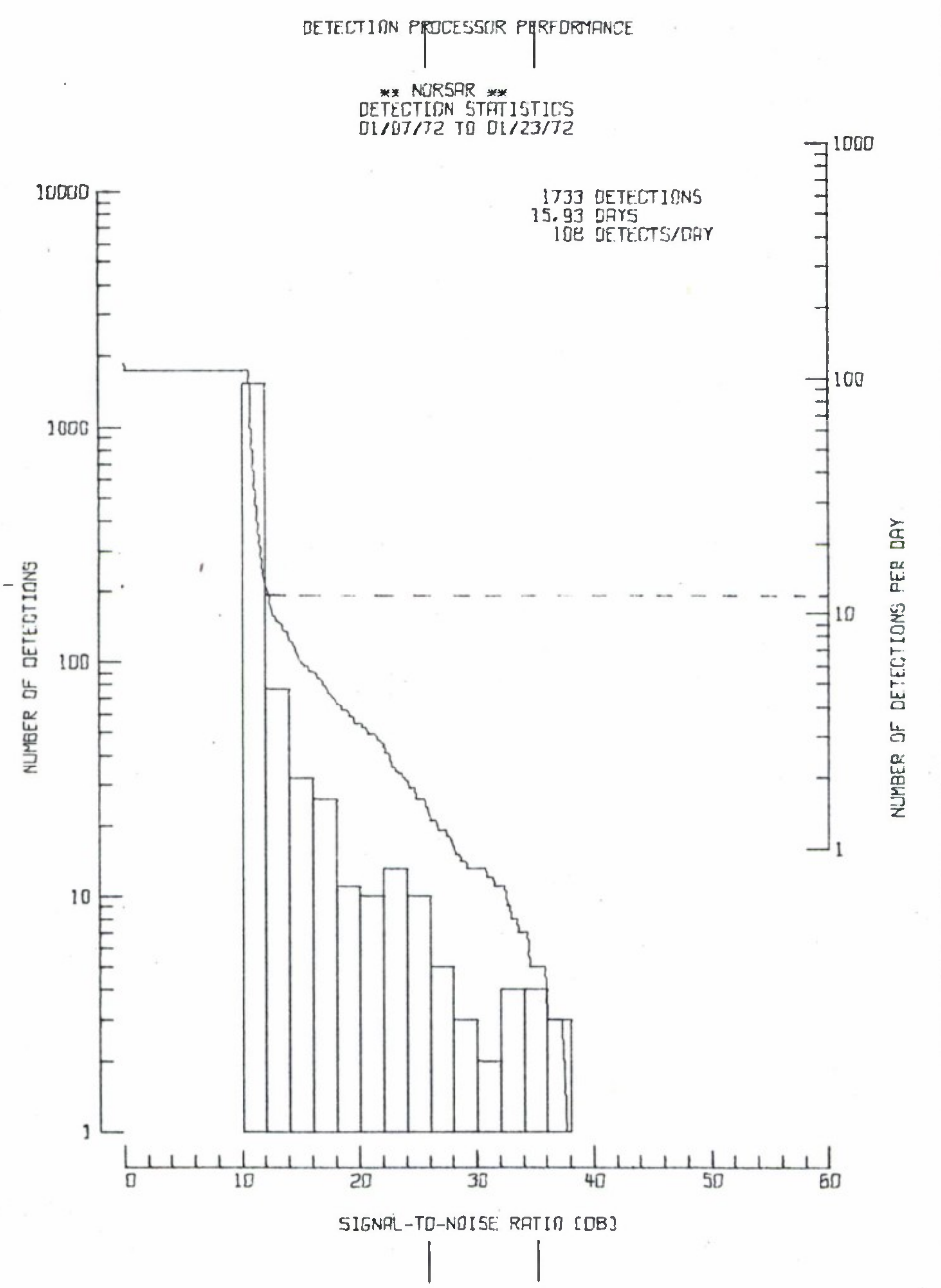
Statistics showing the number of on-line Selected Surveillance detections as a function of signal-to-noise ratio are shown in Figure 3.1.2, parts I-III. Individual detections closer in time than 30 seconds have been merged to one detection in these statistics.

Part I of the figure covers the period from the 1.2-3.2 Hz filter was implemented until the new region corrections were included in the beam set. Part II shows a similar period immediately after this change and Part III covers the remainder of the reporting period.

It is seen that the "break point" between a noise slope and a signal slope corresponds to approximatley 12 detections/day in the first period and 18-19 detections/day for the last two periods. This difference is significant and it is reasonable to assume that part of the improvement is a consequence of the new set of region corrections. Of course noise level variations and seismicity considerations make any conclusion somewhat uncertain.

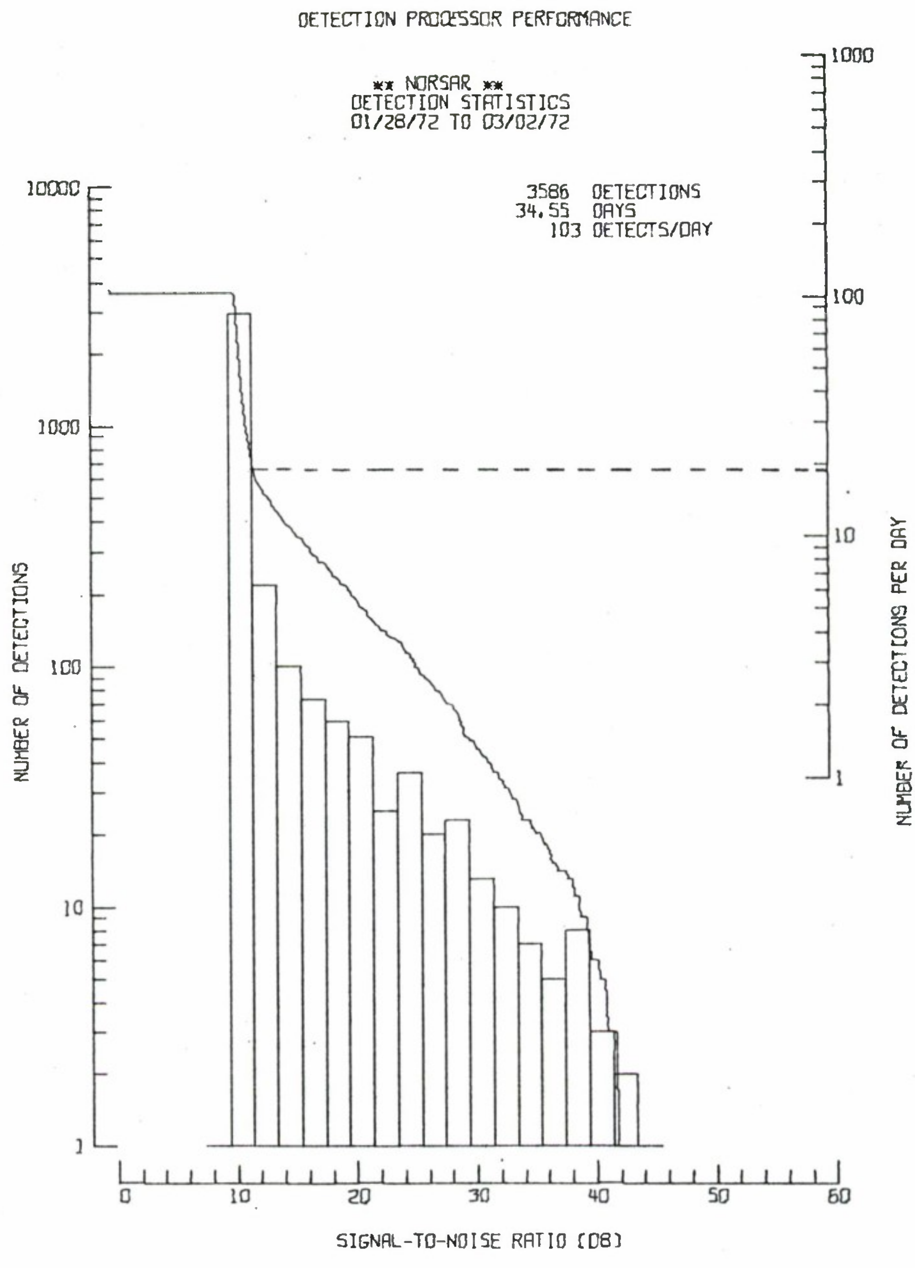
It is instructive to recall that during the last quarter of 1971, with the 0.9-3.5 Hz bandpass filter, the break point was consistently below 10 detections/day.

The number of Selected Surveillance (grouped) detections on a day-to-day basis in shown in Figure 3.1.3. Note that days 103-104 and 161-162 show abnormally low numbers due to system malfunctions (section 3.1.3). Otherwise, the detection rate is very stable in January through April, with a significant drop in May and part of June. This reflects lower false alarm rate caused by change in the seismic noise spectrum during these months.



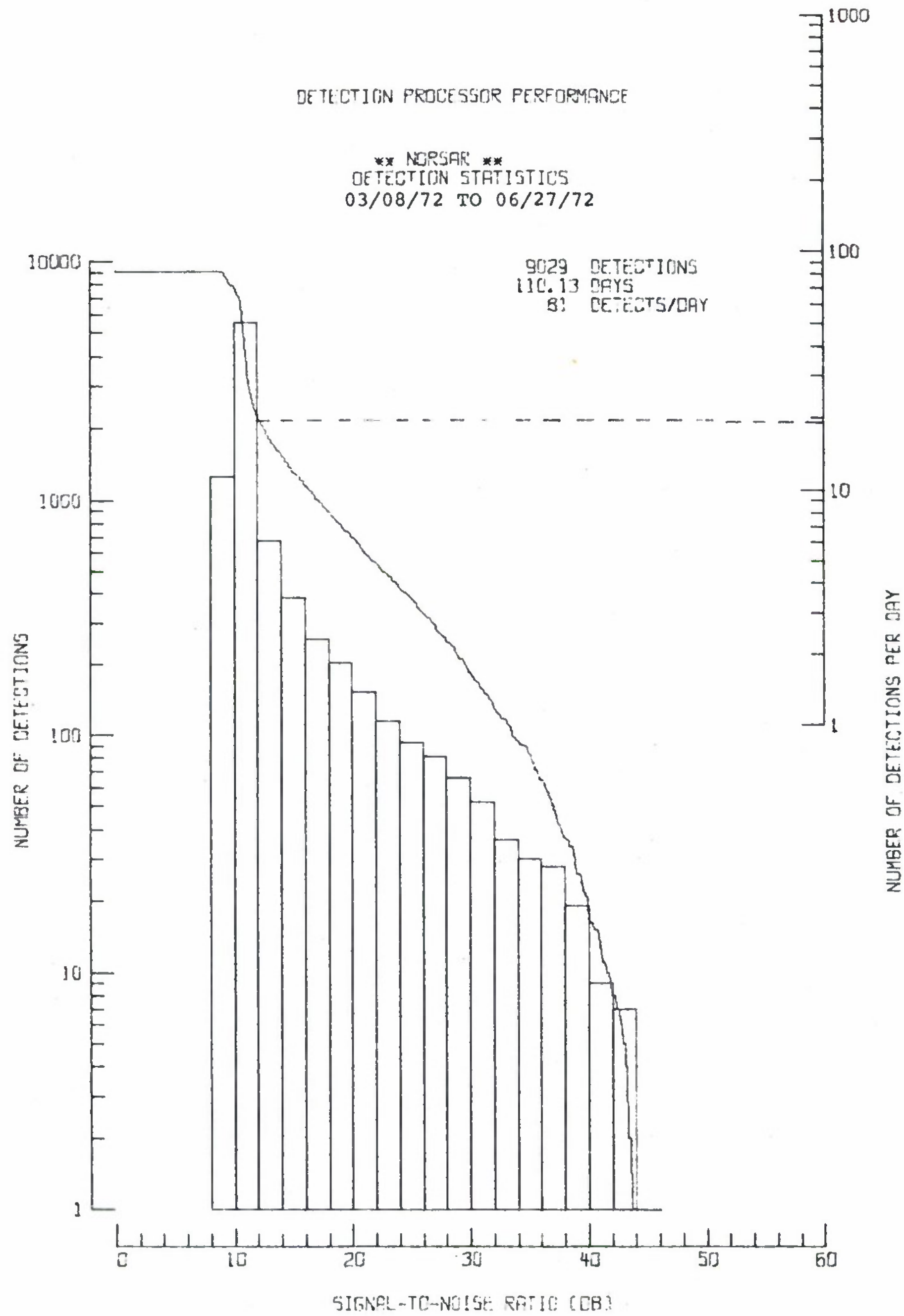
PART I

Figure 3.1.2 NORSAR Detection Statistics 1972



PART II

Figure 3.1.2 NORSAR Detection Statistics 1972



PART III

Figure 3.1.2 NORSAR Detection Statistics 1972

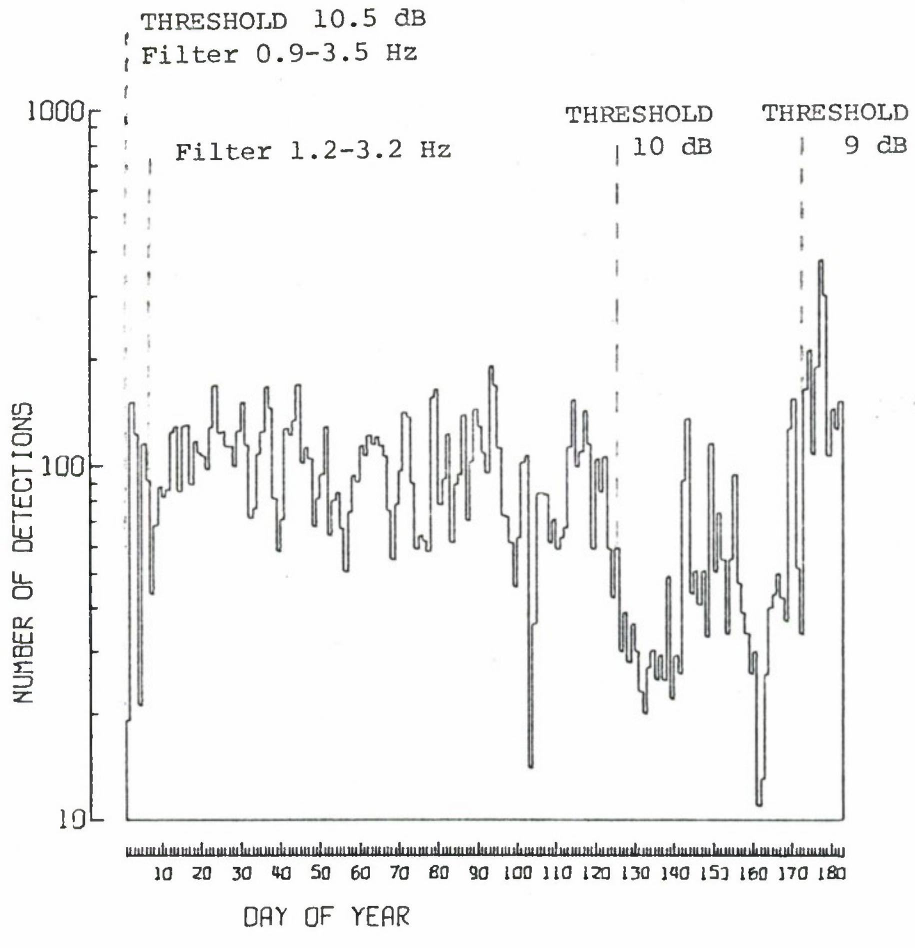


Figure 3.1.3 Daily Number of DP Detections January-June 1972

3.2 Event Processor Operation

3.2.1 General Considerations

The Event Processor (EP) was implemented during the first months of 1971, and all throughout that year the software system was more or less continuously in a state of change. The operation of EP became more stable in 1972, but the rate of change was still high. Most of the work with EP in this reporting period has been concentrated within the following areas

- development and implementation of new algorithms
- search for better parameter values
- changes in the editing and organization of output
- debugging.

In the daily analysis work there were not many changes in the procedures from the previous year, although gained experience improved the performance also here. Also in this reporting period was this work performed mostly by a professional seismologist, which is necessary if improvements beyond the trivial are desired.

Table 3.2.1 shows the number of processed events and what were the decisions of the analysts. The small number of detections rejected as noise, 4.9%, reflects that the EP threshold for most of the time was kept relatively high due to the pressure on computer time. The list of parameter changes in chapter 3.2.4 shows that the EP threshold during this reporting period was changed as follows:

1 Jan - 21 Feb	:	4.46 = 13.0 dB
21 Feb - 6 Mar	:	4.00 = 12.0 dB
6 Mar - 5 May	:	3.80 = 11.6 dB
5 May - 2 Jun	:	3.65 = 11.2 dB
2 Jun -		Initialization parameter.

Analyst Classification	Number of Processings	Percentage
Accepted as events	2913	63.7
Rejected as being:		
- Noise detections	224	4.9
- Local events	813	17.8
- Double processings	389	8.5
- Communication errors	235	5.1
Sum Processed	4574	100

TABLE 3.2.1

Analyst decisions for EP processings during the time period 1 Jan - 30 Jun 1972

There were two reasons why the threshold was lowered. Firstly, the change of filter and corrections in January (chapter 3.1.4) caused a drop in the break point between signals and noise (chapter 3.1.5), and the EP threshold could therefore be dropped while staying at the same false alarm rate. Secondly, as explained in chapter 3.2.2 changes were made in May which reduced the average computer time requirement per event by 63%, allowing more events to be processed by EP. Consequently, most of the processing rejected as noise occurred in May and June 1972. One should keep in mind here that operating at a threshold which gives few noise detections means that a significant number of real events are lost.

From Table 3.2.1 one can also see that the number of local events was quite high, 17.8% or 4.5 per day. Local events here can be anything within an epicentral distance of up to 10-13 degrees, but most of them were within the array siting area, and man-made. The equivalent number quoted in the previous reporting period was much lower, caused only by the fact that until early February 1972 many local events were included in the bulletin. (However, they were flagged as local and have never been included in any calculation of detectability.) Taking also into consideration that most of the double processing (8.5%), which means two or more EP processings on the same event, were caused by local events, and also that these took more than average time to process, it is clear that this represented a great problem and an obstacle to a more efficient use of EP. Consequently, a concentrated effort was initiated in the end of the reporting period in order to attack that problem and the problem of the EP processings that were triggered by errors in the communication system.

3.2.2 Computer Utilization

Table 3.1.2 shows that EP this reporting period was up 39.7 % of the time on the second computer, as compared to 37.9% in the previous period. Still, background partition(s) allowed simultaneous use of the computer. As reported in chapter 3.2.4, the beampacking procedure for estimation of location in inverse velocity space was modified, and later (May 1972) implemented as the only method used for all events with SNR < 20, which usually is around 80-90% of the events processed. According to a computer time analysis from which some results are shown in Table 3.2.2, that change reduces the computer time with 4m 49s per event. Also, the depth estimation (Cepstrum analysis) was dropped around the same time, and this gained another 1m 7s, while some extra high frequent beams which were added on the EP plot took 14s away, totaling up to a gain of 5 m 42s per event, or a 63% drop from the previous value of 9m 3s. Much of that gain was used in analysis of events closer to the detection threshold, by lowering of the EP threshold.

Where time was spent		
Package	Oct/Nov 71	07/05/72
spo 1 spo 2 spo 3	0m 47s 6m 36s 1m 40s	0m 34s 1m 7s 1m 40s
Spent per event	9m 3s	3m 21s
Where time was gained		
Reduced correlation No depth calculation More filtered beams		4m 49s 1m 7s - 14s
Gained per event		5m 42s

TABLE 3.2.2

Computer time in EP per event before and after some changes which were implemented in order to reduce the time requirement, and where the gain occurred.

3.2.3 Special EP Operational Problems

Since debugging and implementation of new algorithms in the Event Processor has continued, the operational problems have remained about the same as for the previous reporting period (July-December 1971).

Terminations or hangups of the EP system have occurred now and then, mainly in connection with major changes in the coding.

For various reasons discussed above, the lower SNR threshold for detections accepted for processing by EP (prethreshold) was changed several times during this period.

Consequently, it was then decided to have the prethreshold as a system parameter, displayed on the 1052 console to be optionally changed each time EP is taken up. In this way unnecessary off-line EP updating would be avoided.

3.2.4 EP Parameters and Algorithms

The following is a chronological list of changes made to EP parameters and algorithms in this reporting period:

7 January:
Coding was inserted that gives deviations in distance and azimuth in the Summary Report, if the event used the correlation procedure for solution refinement.

25 January:
The Region Correction and Calibration File was updated with new region corrections. The values are given in Table 3.2.3. See also Figure 3.2.1.

31 January:
A TRIGR macro was inserted in the EP controller. This macro is executed each time one or more detections are written to the Detection File. Its function is to activate and post a program in Foreground 1 waiting for such a post. This is done to activate the EP initialization program SUDLIN when EP is operating in the OFF-LINE mode.

2 February:

The variance estimate for region corrections (VSUBR2) was changed from 0.04 to 0.0289.

21 February:
The prethreshold value (PRTHRSH) was changed from 4.46 to 4.0.

NODE	UX	UY	UCX	UCY	01A	01B	02B	03B	04B	05B	06B	07B	01C	02C	03C	04C	05C	06C	07C	08C	09C	10C	11C	12C	13C	14C
1	-69	-120	-69	-120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	-120	-69	-120	-69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	-120	15	-120	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	-120	69	-120	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	-69	120	-69	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	120	0	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	69	120	69	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	120	69	120	69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	120	-69	120	-69	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	69	-120	69	-120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	1	-57	3	-58	0	-45	187	118	-113	-16	25	13	34	164	257	247	203	22	40	175	207	262	211	292	67	64
12	43	-20	43	-18	0	-26	36	55	187	2	34	11	-206	-145	-98	8	11	120	-303	-186	-154	-98	66	65	-10	-100
13	45	-10	44	-9	0	17	40	64	162	-127	51	86	-244	-85	-195	-11	89	51	-296	-200	-200	-89	115	88	-66	-173
14	57	-1	56	0	0	36	11	34	-26	-161	105	94	-206	-103	-146	16	85	110	-261	-149	-110	-51	3	96	-91	-143
15	-73	2	-72	0	0	-3	132	110	91	-60	104	-67	53	113	452	375	443	173	68	22	215	396	406	542	278	-16
16	-45	3	-41	4	0	-51	-35	-57	186	73	163	136	-23	-31	144	194	265	67	198	57	18	-85	27	299	335	42
17	-67	-1	-64	-2	0	19	120	31	117	5	504	-14	174	221	467	563	586	223	192	19	272	465	437	578	331	54
18	-74	25	-67	25	0	-63	107	21	81	-31	225	551	-51	3	495	530	545	77	79	47	154	396	385	435	303	-21
19	-71	-6	-71	-5	0	30	247	241	206	116	168	82	139	201	462	523	485	298	228	121	208	462	581	651	351	137
20	-71	-15	-73	-19	0	29	116	53	126	-8	-12	27	61	123	289	323	298	246	151	123	156	235	338	378	315	114
21	-64	-3	-61	-11	0	36	139	133	136	114	208	16	223	232	463	511	620	258	237	132	356	462	544	538	407	196
22	-45	-17	-37	-17	0	71	143	46	77	140	360	147	205	218	460	578	435	167	340	170	195	358	582	506	336	123
23	-58	-21	-55	-25	0	134	275	181	127	120	131	100	266	226	230	519	552	251	238	82	335	468	601	459	331	240
24	-43	-36	-37	-35	0	111	299	213	-48	-24	98	158	168	195	297	481	535	104	180	21	242	577	576	436	129	104
25	-30	-47	-26	-49	0	33	142	67	-117	-87	9	-48	76	150	160	313	311	-22	-96	-103	414	427	248	152	-51	4
26	-13	-21	-7	-22	0	10	-27	-91	-113	207	-94	-49	-252	-114	153	-17	-153	-156	-111	-26	-48	-204	-48	-22	12	-99
27	-22	-52	-21	-54	0	127	232	216	7	36	54	-123	153	242	169	360	352	52	-118	78	520	380	285	257	87	76
28	-65	-58	-56	-61	0	78	160	153	151	-52	1	42	120	194	0	-27	43	303	506	53	27	25	85	282	152	347
29	-14	-54	-11	-56	0	140	285	223	71	76	66	59	161	242	372	350	337	156	-16	216	488	373	334	343	216	64
30	-3	-56	0	-57	0	155	290	210	20	685	100	153	215	260	321	338	358	134	69	330	323	262	275	359	280	185
31	-36	-42	-31	-44	0	35	186	153	-31	10	113	77	115	190	254	341	381	45	89	-97	162	509	420	302	31	-17
32	-57	43	-47	44	0	-176	-191	-168	-55	-98	-201	-21	-135	-190	-212	-125	-152	-209	-35	-88	-196	-213	-171	-185	-106	14
33	0	105	3	113	0	-6	145	135	108	-38	-19	83	8	176	369	151	178	221	404	-52	132	260	270	312	334	129
34	-16	-16	-8	-14	0	4	-123	-105	93	205	-68	48	-211	-22	115	-19	-181	-161	-6	-79	-130	-239	-32	31	-24	-104
35	31	74	38	70	0	-49	54	55	109	15	20	-7	130	98	556	102	77	190	248	163	144	167	291	288	208	140
36	10	9	15	6	0	-15	172	229	71	-105	63	104	-140	0	-73	31	-1	95	22	-135	-66	15	76	125	25	21
37	34	-46	35	-35	0	-3	78	72	491	-80	20	-36	165	144	234	1	-132	32	25	73	67	152	165	112	-13	-18
38	15	-60	17	-60	0	10	68	67	-77	-72	31	-17	158	209	293	134	50	-93	135	253	139	250	238	66	-32	44
39	-21	-27	-15	-25	0	-32	49	-44	-187	175	56	32	-148	-14	145	106	-24	-220	-110	-77	2	-12	62	-11	-31	-222
40	-73	31	-64	32	0	-100	14	-26	52	-26	156	352	-76	-40	415	450	452	110	27	23	128	300	322	300	335	5
41	-89	-28	-87	-34	0	59	241	230	155	253	34	34	292	166	211	275	263	324	283	212	113	241	427	327	317	261
42	-72	43	-64	47	0	-193	-66	-55	-32	-62	99	162	-159	-118	293	344	609	8	98	-198	67	180	293	379	357	-23
43	38	0	41	2	0	82	11	-29	43	-155	25	76	-292	-169	-152	18	112	63	-280	-193	-156	-95	103	91	-137	-55
44	14	61	18	57	0	-147	-64	-61	-48	-83	-27	-189	163	170	102	84	166	19	354	-38	75	110	172	166	129	93
45	-13	-23	-6	-23	0	-19	-26	-124	-152	156	-102	-36	-262	-110	140	70	-182	-215	-71	-104	-112	-145	-66	92	-39	-209
46	-15	-30	-11	-32	0	-25	-7	-118	-188	155	-107	-20	-250	-97	158	100	-88	-302	-220	-30	-24	-134	41	31	-73	-253
47	-20	-12	-11	-12	0	-39	-222	-196	-12	-8	-54	-35	-293	-106	-21	-103	-156	-179	-57	-126	-268	-301	-103	-5	-78	-170
48	28	52	34	46	0	162	250	25	58	69	85	52	47	201	391	219	162	-4	213	185	210	222	345	149	232	57
49	-58	-2	-51	-2	0	30	114	95	196	204	320	126	192	227	534	512	574	195	246	186	229	526	270	619	399	143
50	-10	-54	-7	-56	0	171	273	179	69	293	61	77	165	233	421	369	307	137	12	277	397	350	310	349	258	79
51	25	-54	26	-52	0	-16	86	34	-75	-122	-16	-55	135	222	236	134	-19	-67	76	167	197	249	250	26	-90	26
52	24	-53	24	-95	0	-13	29	89	-8	-20	110	84	-15	19	85	216	139	70	15	-57	63	135	129	169	53	19

TABLE 3.2.3

Regional Corrections for 52 node points implemented 25 Jan 72. UX,UY is observed and UCX,UCY corrected locations in inverse velocity space, units ms/km. The last 22 columns give time delay corrections (Δ) in milliseconds for each of the 22 subarrays. The time delay for the i'th subarray (coordinates X_i, Y_i), pointing at UX,UY, is then computed through the formula $\tau_i = -[UX \cdot X_i + UY \cdot Y_i - \Delta_i]$

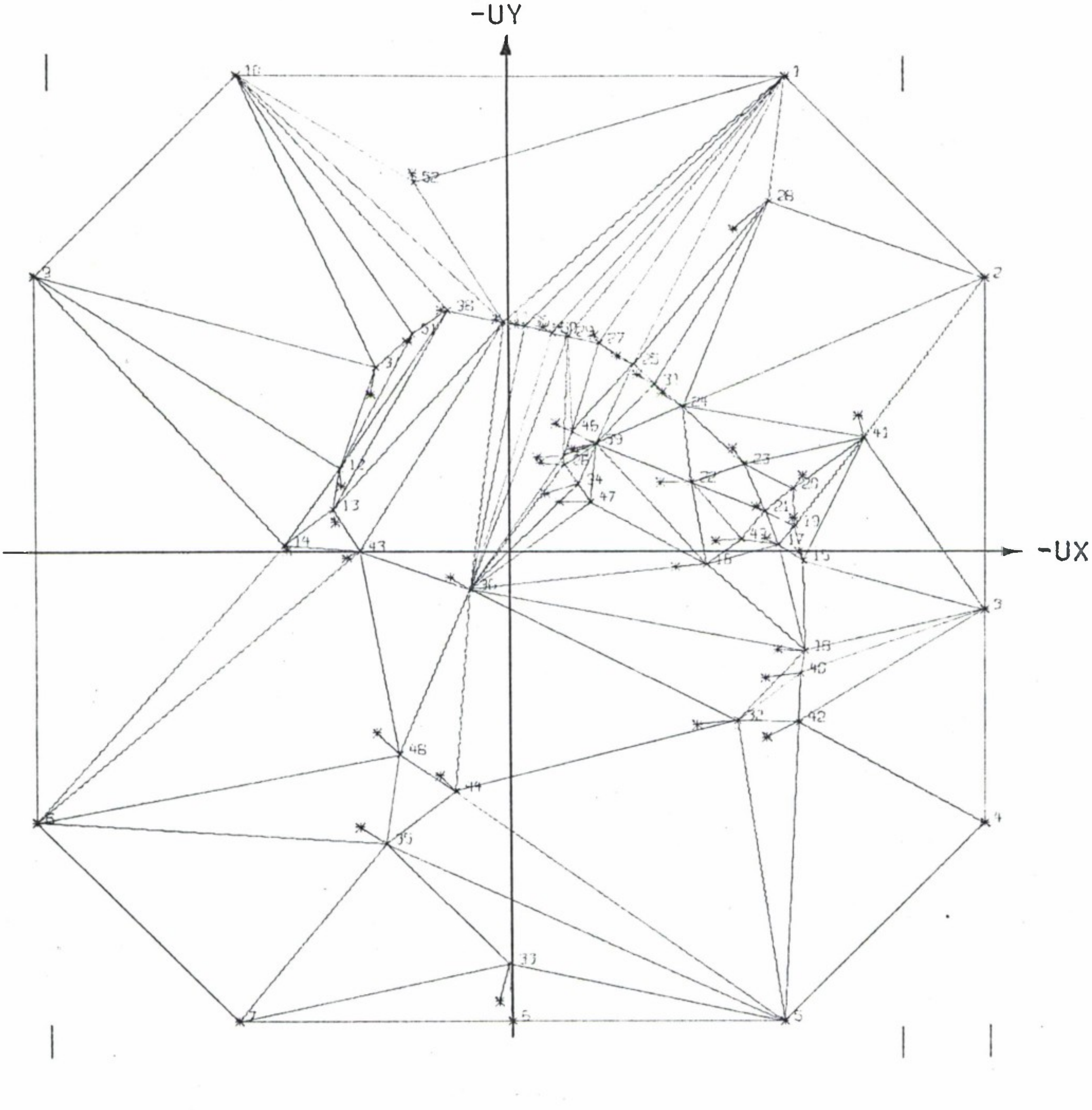


Figure 3.2.1 Location calibration values as implemented 25 Jan 72, plotted in inverse velocity space. For each node, the observed (node number) and corrected value (star) is indicated.

23 February:
Coding was inserted in the EP controller to flag as not to be processed all the General Surveillance detections not having beam numbers between 15 and 30, which were the most close-in beams. This was done after one realized that General Surveillance never gave extra events from regions already covered by Selected Surveillance.

The number of packed beam rings (NR3) was changes from 3 to 2.

1 March:
Some names in the Flinn & Engdahl region table were changed as a consequence of recent political changes in Africa and Asia.

Line zero of the bulletin, giving the date, was transmitted to the TAL file.

The DVALP2 parameter was changed to 0.6363 from 0.8095. This parameter, which is the same for each of the 3 passes through the correlation procedure, is multiplied to the matched filter gain, the mean square angular frequency and the subarray signal-to-noise ratio to give a first estimate of the precision of a subarray arrival time estimate

The default value of the plot length indicator (IPTYPP) was changed from 2 to 1.

7 March:
The prethreshold value was changed to 3.8 from 4.0.

If EP changes the phase of the solution from its original DP value, this is marked on the Summary Report.

The panel length for the short plot was changed.

The initial Event Family Grouping Force Wait time was set to zero (earlier value 5.10^8) to prevent EP hangup.

16 March:
The latitude, longitude and SNR for the original detection is printed out at the end of the Summary Report.

A lower threshold of 5.0 was set on the SNR ratio for those detections that use the correlation procedure for solution refinement. All detections with SNR ratio below this threshold would then use beampacking for their solution refinement.

The Cepstrum analysis to determine the event's depth was skipped by setting a variable IDEPTH to zero.

The algorithm to find the date within a leap year, in the Job Step 4 main routine, was corrected.

Each time a plot tape is created, a list of all the EPX-es having plot files on this tape is written on the 1052.

The Summary Report bit in the EDSD entry is not turned off before a normal return from the Summary Report packaged to the Summary Report sequencer has occurred.

Before the tape monitoring routine declares a unit to be down, it tries once more to read the volume label of the tape mounted on this unit.

The parameter NG4, which is the maximum number of samples on the beam envelope between the start of an event mode and its first peak if the event should be called "impulsive" was decreased from 35 to 15. Before that, all events had been classified as impulsive, and no "emergent" events ever occurred.

The parameter THSN4, giving the SNR upper limit for using "model fit" to determine the arrival time instead of "threshold pick", was increased to 100.0 from 50.0.

12 April:
The setting of the MTEDSD flag in Monitor Common, to signal that all the event data sets are in use, was corrected.

The line zero in the bulletin transmitted to the TAL was started with an EBCDIC zero, for identification purposes.

27 April:
Job Step 4 was restricted to execute in region A only, even if EP has region B available.

The EDSD-options for a rerun event was changed to X'E800' thereby releasing the Event Data Set after a Job Step 3 execution, and using the default values for filter and plot length.

The detected signal-to-noise ratio is written on the Summary Report.

The automatic updating of parameters in the D/B-file at editing time in Job Step 4, is avoided if latitude, longitude (or both) in line 2 has been changed (indicating a new solution found by the analyst).

4 May:
The beampacking procedure was modified according to ideas provided by Teledyne/Geotech/SAAC. The parameter MAXBP3, giving the maximum number of times to pack beams, was increased from 20 to 25. Region corrected delays are now computed for all the beams, not only the central. When the solution is on the inner-ring, beampacking is redone with a grid scaled down to 1/2 of the original. The halving of grid scale may be done twice.

The lower SNR threshold for events using the correlation procedure was increased from 5.0 to 20.0.

5 May:
The prethreshold was changed from 3.8 to 3.65.

2 June:
The coordinates for the 03C seismometers relative to the center seismometer were corrected.

Coding was inserted in the scheduler initialization routine MJSCHDI to display the prethreshold on the 1052 during initialization, thus allowing the operator to change the value optionally. The value in Monitor Common, now set to 3.65, is the default value given the prethreshold at a "fresh start". The current value will be the value loaded from the Monitor Common file at a "continued processing". The current value of the prethreshold was set to 3.55.

The weighted array beam was removed from the plot. Instead a filter array beam was plotted, using a 1.4-3.4 Hz BP-B filter.

Each plotted partial beam was reduced to consist of only one subarray beam, filtered with a 1.8-3.8 Hz BP-B filter.

The EP filter base was expanded to consist of 10 filters in all. The filters added were the following:

1.6 - 3.6 Hz BP-B
1.8 - 3.8 Hz BP-B
2.0 - 4.0 Hz BP-B

The algorithm for detection of later modes on the beam power envelope was changed, by doubling the threshold to be exceeded in order to have a later mode declared.

3.2.5 EP Performance Statistics

The performance of EP for this reporting period has been covered in some detail by Bungum (1972), where detectability and location accuracy are analyzed on a regionalized basis.

The number of events reported in the NORSAR Seismic Event Summary, on a monthly basis, is given in Table 3.2.4. The effect of the different changes discussed

Month	NORSAR Number of Events		NORSAR/NOAA Comparison $0^\circ<\Delta<180^\circ$			NORSAR/NOAA Location Difference (km) $30^\circ<\Delta<90^\circ$		
1972	$0^\circ<\Delta<180^\circ$	$30^\circ<\Delta<90^\circ$	NORSAR only	NOAA only	NORSAR & NOAA	Events	50%	90%
Jan	283	224	116	225	168	98	220	550
Feb	379	312	164	151	215	140	170	550
Mar	424	335	236	167	187	114	140	450
Apr	605	519	382	123	225	158	150	600
May	505	441	342	132	163	97	160	560
Jun	470	383	284	166	187	122	170	580
Jan-Jun	2666	2214	1524	964	1145	729	165	530

TABLE 3.2.4

Number of events reported by NORSAR for the time period Jan-Jun 1972, together with comparisons with the NOAA monthly listing of events.

above, and implemented in the beginning of the year, is quite clear. The same can be seen from Figure 3.2.2b where the number of reported events is displayed on a daily basis. Besides the system changes, some of the improvement is simply due to the gradual lowering of the processing threshold, which was made possible by the reduced requirements of computer time per event.

The main restriction to improved detectability is still, of course, the seismic background noise. Figure 3.2.2a here shows the average LTA over all on-line array beams after the new filter was implemented on 6 Jan 1972. The long term variability is still large, and it has been demonstrated that the noise peaks, sometimes lasting for days, are closely related to the large-scale meteorological activity off the coast of Norway, and must be interpreted as a leakage into the processing frequency band of the microseismic noise peaking at 6 seconds period. The day-to-day correlation between signals and noise can be easily verified from Figures 3.2.2a and b, and a closer study would show that there is no simple inverse linear relationship; when the noise level doubles, the number of events is cut down to more than half. The reason for this is that the short term variance of the noise increases with increasing noise power due to changes in the spectrum, and therefore affects the detectability more than the noise power alone could explain (Lacoss 1972).

The success of the filter change from 0.9-3.5 Hz to 1.2-3.2 Hz on 6 Jan 1972 is tied to the same phenomenon. Firstly, the change was made because it would decrease noise power and increase SNR, but equally important is the reducing effect it had on the variance of the noise.

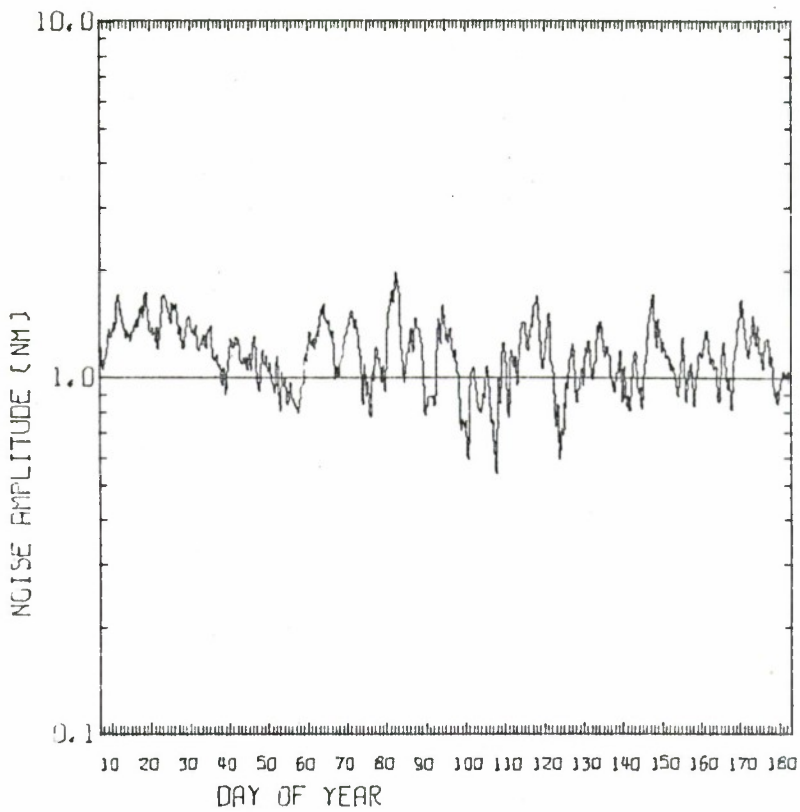


Figure 3.2.2a Average noise level at NORSAR within the processing frequency band 0.9-3.5 Hz, for the time period 1 January - 30 June 1972

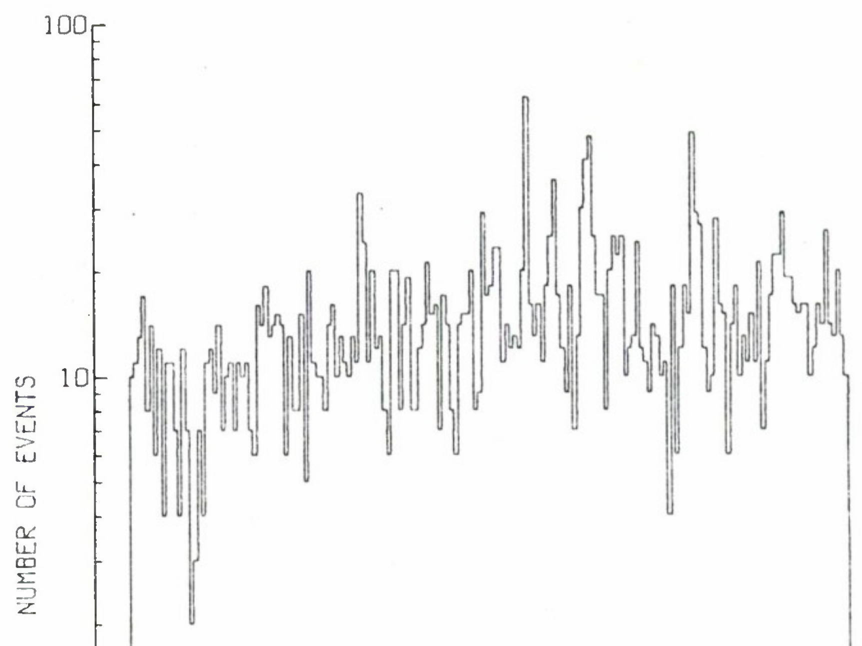


Figure 3.2.2b Daily number of events reported by NORSAR as a function of day of year for the time period 1 January - 30 June 1972

The distribution of the time series displayed in Figure 3.2.2b is given in Figure 3.2.3. Since the distribution is one-sided and far from normal, the average number of events per day (14.7) is not as informative as the median, which in this case is 12.6 events per day. The main reasons why the deviations from the theoretical distribution are so large must be the long term variation in background noise and the variations in seismicity due to earthquake swarms.

A comparison between NORSAR and NOAA is also presented in Table 3.2.4. One of the things the table shows is that NORSAR in this period reported 54% of the events reported by NOAA, while NOAA could confirm 43% of the events reported by NORSAR. The areas which NOAA covers better than NORSAR are the complete Western Hemisphere and of course areas in the core shadow zone as seen from NORSAR. NORSAR has a better coverage on the continent on which border it is located, namely Eurasia.

Table 3.2.4 also includes some results from a location comparison with NOAA. The decrease in the median location difference from 220 to 170 km from Jan to Feb is due to the implementation of new and better location corrections. The other important change which could change the location accuracy was the switch from correlation to beampacking in the solution refinement, implemented in the middle of May. This did not lead to any significant drop in location accuracy, especially taking into account that the value for July is 150 km.

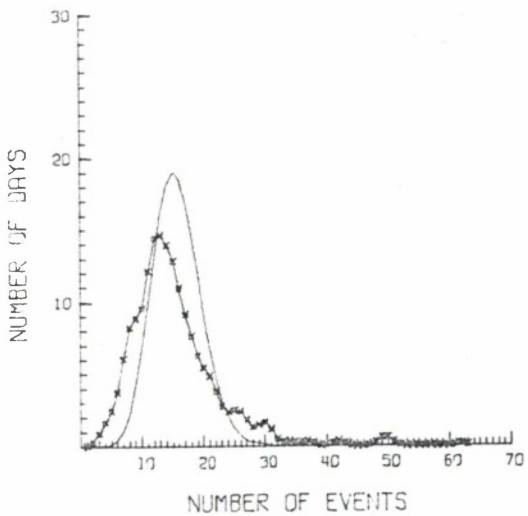


Figure 3.2.3 The number of days when N events are reported by NORSAR, as a function of N, for the time period 1 Jan-30 Jun 72. The smooth curve is the theoretical Poisson distribution, based on the same total number of events.

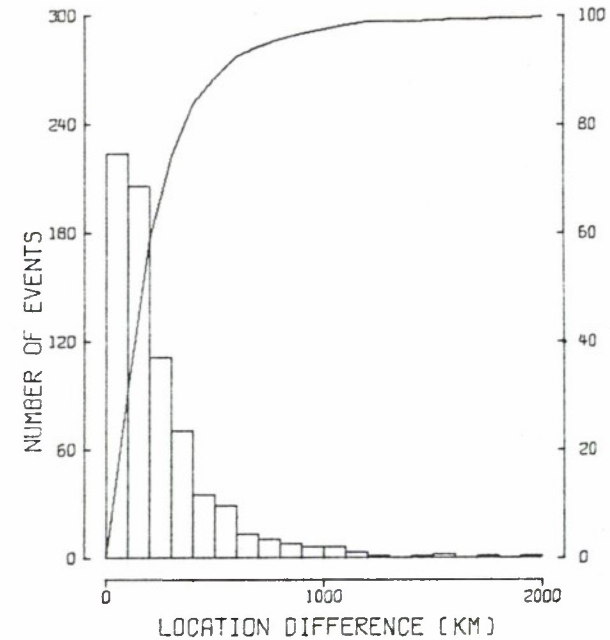


Figure 3.2.4 Incremental and cumulative distribution of location differences between NOAA and NORSAR for all events reported by both institutions in the time period 1 Jan - 30 Jun 72, located by NOAA within 30°-90° from NORSAR.

3.3 Change Control Board (CCB)

The CCB, meeting regularly every week, makes decisions on Change Requests and initiates investigations of reported discrepancies. Change Requests and Discrepancy Reports are filed by the board's secretary. An updated printout is presented at each meeting. Table 3.3.1 shows the activity of the CCB in the period. Table 3.3.2 shows the codes used in printouts.

Numbers of Requests for Status Code		
	Status pr. 1 Jan 72	Status pr. 30 Jun 72
A	84	186
B	9	1
C	9	22
D	13	3
E	20	41
I	14	15
L	5	4
R	1	2
U	6	1
W	3	2

TABLE 3.3.1

CCB Status

NTNF/NORSAR CHANGE CONTROL BOARD
DISCREPANCY REPORT (DR) AND CHANGE REQUEST (CR) DATA FILE

THE FOLLOWING CODES DESIGNATE
THE SYSTEM AFFECTED IN EACH CASE

EP - EVENT PROCESSOR	NH - NORSAR DATA CENTER HARDWARE
DP - DETECTION PROCESSOR (AND SPS)	CH - COMMUNICATION SYSTEM HARDWARE
AM - ARRAY MONITORING PROGRAMS	FE - FIELD EQUIPMENT
LP - LONG PERIOD SIGNAL PROCESSING	OP - OPERATIONAL PROCEDURES
OS - OTHER SOFTWARE	PC - PARAMETER CHANGE (DP AND/OR EP)

THE FOLLOWING CODES REFLECT THE
CURRENT STATUS OF EACH REQUEST

A - HAS BEEN ACCOMPLISHED
B - IS BEING IMPLEMENTED
C - HAS BEEN CANCELLED
D - HAS BEEN DEFERRED, BUT WILL BE RECONSIDERED
E - HAS BEEN ADEQUATELY EXPLAINED OR ANSWERED
I - IS BEING INVESTIGATED
L - LOW PRIORITY ITEM, TO BE SUSPENDED INDEFINITELY
R - HAS BEEN REJECTED
U - IS PRESENTLY UNRESOLVED
W - IS WAITING FOR IMPLEMENTATION

STATUS CODES CHANGED SINCE PREVIOUS DISTRIBUTION ARE MARKED *
NEW REPORTS SUBMITTED SINCE PREVIOUS DISTRIBUTION ARE MARKED **

CLOSED REPORTS UNTIL [illegible]/[illegible]1/72 ARE OMITTED FROM THIS LISTING

TABLE 3.3.2

3.4 Seismic Data Exchange

NORSAR weekly seismic bulletin is mailed to 50 institutions in 17 different countries. Bulletins are received regularly from 9 institutions.

NORSAR data tapes were distributed to the following during the period:

University of Copenhagen, Denmark	(2)
University of Helsinki, Finland	(2)
SAAC	(225)

3.5 Visitors

The following scientists visited NORSAR in the period indicated:

Dr. E. Hjortenberg, Geodetic Institute, University of Copenhagen, 24 January - 12 February 1972

Dr. R.T. Lacoss, Lincoln Lab, MIT, Cambridge, Mass., 4 April - 8 May 1972

Dr. D.J. Doornbos, Utrecht University, Utrecht, The Netherlands, 2 May - 30 June 1972

Mr. W. Ellis, IBM, Federal Systems Division, Gaithersburg, Maryland, USA, 8 May - 26 May 1972

Dr. I. Noponen, Seismological Laboratory, Helsinki University, 20 May - 30 June 1972

Dr. B. Søderstrøm, Defense Research Institute, Stockholm, Sweden, 29 May - 17 June 1972.

4. REFERENCES

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Bungum, H.: An evaluation of the routine processing of events at NORSAR. Proceedings from the seminar on Seismology and Seismic Arrays, NTNF/NORSAR, Kjeller, Norway, 30 Sep 1972

Lacoss, R.T.: Variation of false alarm rates at NORSAR, Semiannual Technical Summary, MIT Lincoln Lab, Cambridge, Mass., 30 June 1972.