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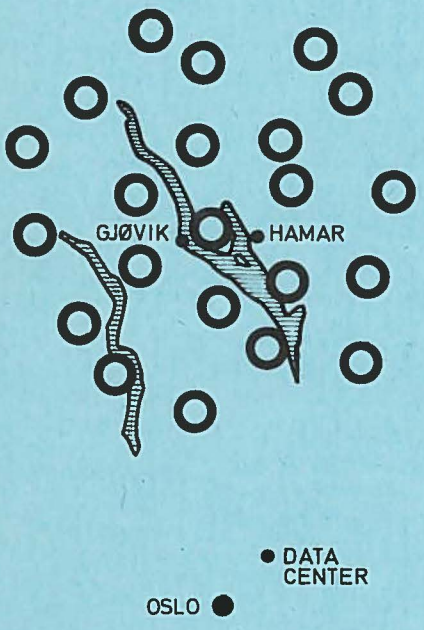
Royal Norwegian Council for Scientific and Industrial Research

THE NORWEGIAN SEISMIC ARRAY

by

E.S. Husebye



NORWEGIAN SEISMIC ARRAY

NORSAR

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1. Introduction

NORSAR (Norwegian Seismic Array) is a joint undertaking by the governments of Norway and the United States. The field work and instrument installations started in 1968 and were completed in the autumn 1970. The array is planned to be fully operational in spring 1971. The local responsibilities rest with the non-profit organization Royal Norwegian Council for Scientific and Industrial Research (NTNF). The cost of NORSAR and its operation up to July 1972 is mainly covered by Advanced Research Projects Agency (ARPA). IBM has developed the software for array monitoring, data acquisition and analysis on a routine basis.

2. NORSAR configuration and instrumentation

NORSAR is located around lake Mjøsa and comprises 22 subarrays (Fig. 1) each containing one LP (3-component) and 6 SP (vertical) seismometers. The types of LP and SP instruments used at NORSAR are similar to those at LASA.

From the seismometers the recorded earth motions are transmitted via trenched cables to the Central Terminal Vault (CTV) at the subarray center. The CTV is housing the Short and Long Period Electronic Module (SLEM) which multiplexes and digitizes the 9 seismometer outputs into a single bit stream. The sampling rate is 1 and 20 Hz for LP and SP seismometers respectively. The data is then transmitted by means of ordinary telephone lines (2400 bauds) to NORSAR Data Processing Center (NDPC) at Kjeller for further analysis. Time synchronization signals are sent each 0.05 sec the other way, i.e., from NDPC to the SLEM. Check of seismometers, SLEM and data transmission lines is performed by sending special commands from NDPC to signal generators (sine or pseudo random waves) which are part of the SLEM units. Remote calibration of the LP seismometers is optional. We should like to mention that one transatlantic link is used for on-line LP data transmission and data exchange between NORSAR and the LASA and ALPA data center in Alexandria, Virginia.

3. NORSAR Data Analysis

The data received at NDPC is processed and at the same time stored on magnetic tape for more permanent saving. The routine data analysis is performed in two steps, called detection (on-line) and event processing (off-line) (see Fig.2). It is dual computer configuration, i.e., the IBM 360/40 and peripheral equipment such as tape and disc drives used for detection are identical to those for event processing. This would ensure, to a very large extent, continuous data recording and on-line analysis capabilities.

3.1

Detection Processing (DP) comprises all functions associated with data acquisition and tape storage, array monitoring and analysis of the incoming data in real time. The latter consists essentially of deciding whether or not a detection of a seismic event should be declared. The detection algorithm performed individually on each subarray or array beam, is the following: The band filtered beam is rectified and integrated over a sliding time window (length around 2 sec), resulting in a short term "power" average (STA). A long term average (LTA) is calculated by a recursive algoritm, thus providing a noise estimate which in principle is based on the history of the beam from the time the system was activated. The ratio STA/LTA is calculated at a specified rate, and whenever it exceeds a predefined threshold a number of successive times, a detection is declared. During beamforming up to 400 array beams (Selected Surveillance) are deployed over the most interesting seismic regions. To ensure adequate coverage of the entire teleseismic regions, but at a lower detection capability, a General Surveillance is performed inparallell with the Selected Surveillance. The former is based on 8 different subarray beams. Display of sensor and beam traces on the Experimental Operations Console (EOC) is optional during detection processing (Fig.2).

3.2

Event Processing (EP) satisfies two objectives, namely, preparation of a daily bulletin based on a minimum number of seismic events and support of research through the formation of a seismic data base.

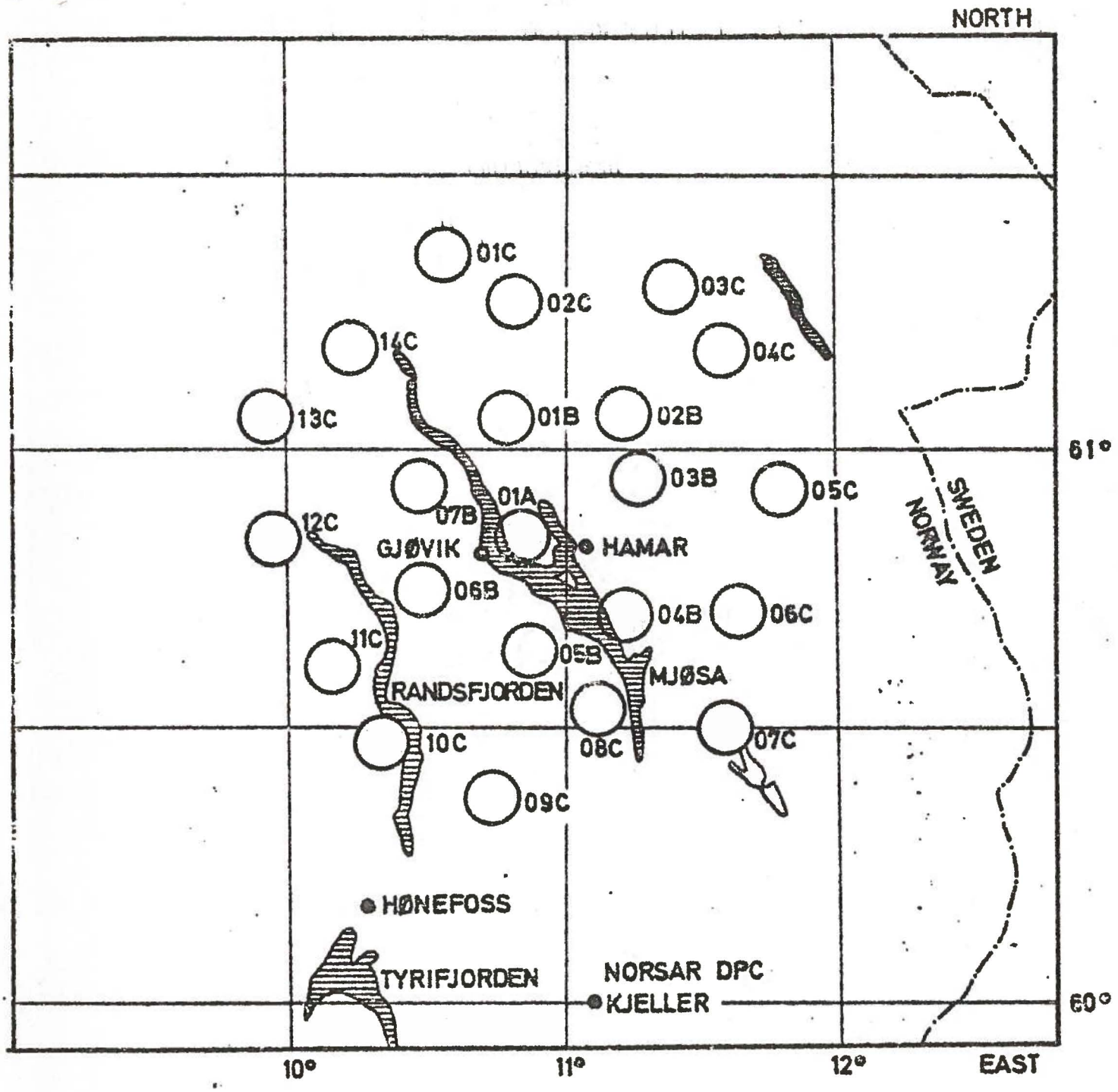
The EP receives the detections and the preliminary epicenter determinations from the DP, and applies algoritms required to assign a seismic phase identification to the detections reported and subsequent grouping the detections which belong to the same event. Basic signal parameters are then extrated from the array beam waveform. As the SP seismometers are essentially velocity measurements devices, the magnitude is estimated by an algoritm based on the assumption that signal power is proportional to the kinetic energy of P-waves. Arrival times are calculated either by treshold pick (emergent events) or by model fit (impulsive events). The signal dominant period is determined through power spectral analysis, while peak amplitude is computed from the estimates of magnitude and dominant period. Focal depth information is sought through a cepstrum analysis, taking into account the possibility of observing pP, sP and PcP phases. In addition to standard bulletin information, signal parameter extractions also include correlation coefficients, relative arrival times, and signal power on the subarray beam level, etc. So far, no LP processing is included in the EP analysis. Raw data and half processed data are stored on 9-track, 1600 or 800 bpi tapes, and tape copies are available on request.

Finally it should be stressed that NORSAR represents a dynamic seismic data analysis system, and we would always strive for improving and extending the data processing routines.

Figure Captions

Fig. 1. NORSAR Array Configuration

Fig. 2. Hardware configuration in NORSAR Data Processing Center (NDPC).


NORTH
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HAMAR
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04B
06C
11C
05B
MJØSA
RANDSFJORDEN
08C
07C
10C
09C
HØNEFOSS
TYRIFJORDEN
NORSAR DPC
KJELLER
SWEDEN
NORWAY
61°
60°
10°
11°
12°
EAST

Fig. 1

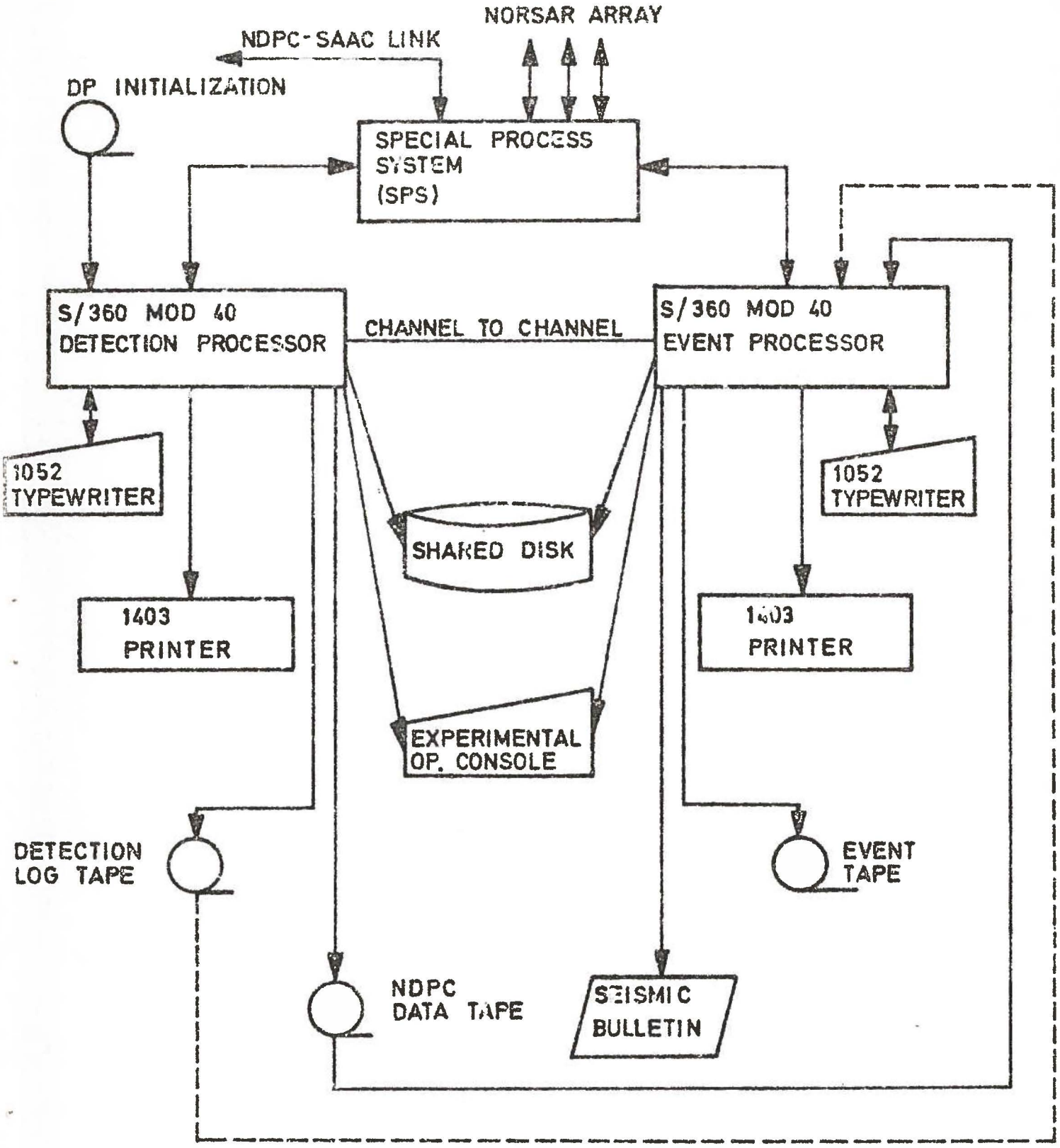
NORSAR ARRAY
NDPC-SAAC LINK
DP INITIALIZATION
SPECIAL PROCESS SYSTEM (SPS)
S/360 MOD 40 DETECTION PROCESSOR
CHANNEL TO CHANNEL
S/360 MOD 40 EVENT PROCESSOR
1052 TYPEWRITER
1052 TYPEWRITER
SHARED DISK
1403 PRINTER
1403 PRINTER
EXPERIMENTAL OP. CONSOLE
DETECTION LOG TAPE
EVENT TAPE
NDPC DATA TAPE
SEISMIC BULLETIN

Fig. 2