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United Nations Conference on Disarmament International Seismological Data Exchange Experiments

Part I
UK Participation

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CONTENTS

SUMMARY

In 1976 the United Nations Conference on Disarmament (CD) established an "Ad Hoc Group of Scientific Experts (AHGSE) to Consider International Co-operative Measures to Detect and Identify Seismic Events". This report (Part I) describes the work undertaken by the AHGSE under terms of reference defined by the CD together with various international data exchange experiments conducted by the AHGSE since it was formed. The AHGSE has provided scientific advice and technical recommendations via a series of major reports to the CD which were produced during the biannual meetings in Geneva. The recommendations describe a possible global system of seismological data exchange for monitoring compliance with a treaty banning nuclear tests.

As a member of the CD, the United Kingdom provides technical delegates for the AHGSE meetings from the MOD seismological research group located at Blacknest, AWE. This report describes the facilities used by the UK for participation in seismological data exchange experiments.

A brief account is given of the experiments conducted by the AHGSE and the resulting recommendations for a proposed global system for seismological data exchange. A detailed description of the large-scale experiment (GSETT-2) on the exchange of waveform data is given in Part II of the report.

1. INTRODUCTION

One of the problems which confronts the United Nations Conference on Disarmament (UNCD) is the practicality of monitoring compliance with a Comprehensive Test Ban Treaty (CTBT), should such a treaty come into force. At present nuclear tests are forbidden in all environments except underground. It is generally agreed that the only way of detecting at long range, explosions underground is from the seismic signals they generate. Although there remain problems in distinguishing between explosions and the many earthquakes that occur each year, particularly for low yield explosions (see for example CD 610[1]), any successful monitoring system will require as a first step a network of seismic stations and the data on the seismic signals detected by these stations will have to be transmitted expeditiously to data centres for processing and analysis. The UNCD recognised that a Global Monitoring Network would be required to provide seismological data for the location and identification of seismic disturbances. To define and establish the requirements of such a global network, considerable technical and seismological expertise would be needed, involving extensive research and experimentation. Consequently the Conference of the Committee on Disarmament (CCD), later the Committee on Disarmament (CD) and now the Conference on Disarmament (CD) proposed the formation of an "ad hoc" group of scientists to undertake a feasibility study.

On 22 July 1976 the CCD formed the "Ad Hoc Group of Scientific Experts (AHGSE) to Consider International Co-operative Measures to Detect and Identify Seismic Events". This comprised seismologists nominated by CCD member states and non-participating countries whose scientists could make a positive contribution to the Group's studies. Of the 38 countries represented at the AHGSE to date, 30 are CD member states and 8 are invited participants from non-member states (table 1).

The original terms of reference for this Ad Hoc Group of Scientific Experts are given in appendix A. The main task of the group was to specify the characteristics of an international monitoring system comprising a global network of seismological stations. They were also required to specify the type of data required, the transmission facilities and procedures to be used for a timely exchange of seismological data.

In March 1978 the AHGSE submitted a report (CCD/558[2]) based on these terms of reference to the CCD who decided that the AHGSE should continue its work by studying the scientific and methodological principles for a possible comprehensive experimental exercise involving a global network of seismological stations. Thus, in August 1979 the CD decided that the AHGSE should pursue its work under new terms of reference (see appendix A).

In its first report to the CCD [2] the AHGSE proposed a global network of stations that would transmit seismological data to National Data Centres (NDC) for onward transmission to International Data Centres (IDC) located in up to four different countries. To evaluate this concept an experiment was arranged under the auspices of the CD in which measurements such as times and amplitudes of signals observed on seismograms were transmitted to an Experimental International Data Centre (EIDC) so that a bulletin of located seismic disturbances could be produced for distribution to participating States. From the earliest discussions on the experiment many States suggested that the objectives of the AHGSE could best be met if the digital data of the detected seismic waveforms were made available to the EIDC. Eventually consensus was achieved on proposals for an experiment involving the exchange of waveform data. The AHGSE defined the alphanumeric data as Level I and waveform data as Level II data. The experiment which was principally concerned with the exchange of Level I data was designated GSETT-1* (Group of Scientific Experts Technical Test) and the experiment involving the exchange of Level II data for every seismic signal detected was designated GSETT-2. Figure 1 shows the distribution of countries participating in these experiments.

*The first GSE Technical Test was originally referred to as GSETT but with the advent of the 2nd GSE Technical Test, it became known as GSETT-1.

The MOD seismology group at Blacknest provides the UK delegates for AHGSE meetings in Geneva and participates on behalf of the UK in tests. In this report details are given of the GSETT-1 and -2 experiments with particular emphasis on the UK participation. To be able to participate, the UK had to develop various facilities and build up resources to be deployed at the UK NDC. This report describes how the data were recorded, analysed and transmitted to the EIDC and how the output of the EIDC was received back at the UK NDC. An account is given of the development of the UK facilities for participation in preparatory tests and the GSETT-2 experiment. Part II of the report will present an assessment of the results of the GSETT-2 experiment.

2. INTERNATIONAL DATA EXCHANGE EXPERIMENTS

2.1 The Global Network

The structure outlined by the AHGSE for a global monitoring network (CCD/558[2]) involved a small number of states acting as IDCs, and a NDC for each participating country which would report to these IDCs. Each NDC would provide seismological data from its designated National Seismic Station(s) (NSS) within a specified time for every seismic disturbance detected. A message containing specific parameters extracted for each detected disturbance would be constructed and transmitted expeditiously to one or more IDCs. The IDCs would collate all the parameter data received from NDCs and compute the origin time, location, depth and magnitude for as many seismic disturbances as possible. Figure 2 shows the experimental system designed to incorporate the elements described in CCD/558[2].

The Level I parameters were defined by the AHGSE in 1978 [2] and were regarded as the minimum seismological data required to locate and identify the nature of a seismic disturbance. They consist of various measurements (appendix B) obtained from an analysis of seismograms such as signal onset time, period and amplitude and, where possible, rough locations. Level II data are defined as the actual waveform from which Level I data are extracted. The first two reports to the CD (CCD/558 [2] and CD/43 [3]) recommend that the global monitoring network would require stations to report Level I data on a routine basis and Level II data on request. So if identification of a seismic event could not be made on Level I data alone, Level II data could be requested. Routine reporting of Level I data would require reliable and efficient computer-to-computer links for an effective global data exchange to take place.

One of the most widely available means of communications during 1981-83 was the WMO/GTS which is a global network utilising computer-to-computer, telex-to-computer and satellite communications (figure 3). This extensive network represented the kind of global network which could be used for seismological data exchange. Since the best way of assessing the effectiveness of a global network is to experiment with the network, a series of seismological data exchange tests were conducted between several AHGSE participants during 1978-1983. An account of UK participation in bilateral data exchanges is given by Grover [4]. Various recommendations on how a global network test should be structured emerged from the results of these bilateral tests.

2.2 The First GSE Technical Test (GSETT-1)

It was proposed in CD/43 [3] and CD/448 [5] that a Technical Test for the international exchange of Level I parameters should be conducted at the end of 1984, utilising the WMO/GTS network for data transmission. The AHGSE decided that the first Technical Test (GSETT-1) should be conducted over the period 15 Oct - 14 Dec 1984, with the first two weeks being designated as a preparatory phase to establish reliable communications. The main objectives of this GSETT-1 experiment were:

- to develop and test procedures for routine Level I data transmission from NDCs to EIDCs using the WMO/GTS;

- to transmit bulletins from EIDCs to NDCs using the WMO/GTS;

- to test retransmission procedures;

- to test procedures for the extraction of Level I parameters from Short Period (SP) and Long Period (LP) seismograms;

- to test EIDC procedures for archiving Level I data and compiling and distributing bulletins.

A full account of this experiment is given in the AHGSE Fourth Report to the CD [6]. A summary of the computer and communication facilities used at some of the NDCs is given in table 2.

The Blacknest Data Analysis Centre (BDAC) is the UK NDC and the array of SP seismometers at Eskdalemuir in Scotland (EKA) the designated UK NSS. In order to take part in the experiment, a system had to be designed which would enable the UK NDC to report the Level I data to an EIDC as quickly and efficiently as possible. Computer facilities at the NDC were acquired to provide facilities for interactive seismic analysis and data communications, utilising a direct link with the Meteorological Office at Bracknell to transmit data over the WMO/GTS to an EIDC.

2.3 Recommendations from GSETT-1

An assessment of the first Technical Test by the AHGSE identified a number of serious shortcomings in the system concept. One of the main conclusions was that the WMO/GTS is not 100% reliable for data transmission. However, this was not considered to be a major set-back to the development of a global network since the recommendations from the AHGSE were that no means of communication should be excluded from the investigation into reliable computer-to-computer communications. It was suggested that such links as packet switched networks implementing the CCITT X.25 protocol (see appendix C) should be looked at with a view to experimenting with rapid exchange of waveform data as well as Level I parameters extracted from that data.

In October 1986 the Canadian AHGSE delegation hosted a Workshop on the Exchange of Waveform Data and one of the recommendations to emerge was that the X.25 protocol should be used for computer-to-computer links wherever possible. If connection to a X.25 network was not possible then a direct dial-up link or a connection to the WMO/GTS was recommended.

The extraction of parameter data from analogue seismograms proved to be very labour intensive so it was recommended that wherever possible, the data should be recorded as continuous digital data which facilitates the interactive or automatic analysis of seismic data.

Another conclusion from the results of GSETT-1 was that it would be very useful for the EIDCs to have available the waveform (Level II) data for detected events so that EIDC analysts could look at the seismic signal and correct NDC measurements where necessary or measure additional phases to improve their hypocentre calculations.

It was proposed that the Level II data should be transmitted by the NDCs together with the Level I data for each day. Once the emphasis shifted from exchanging Level I data to exchanging Level II data, the implications on the requirements of the global network were considerable. For example, more reliable communications links would be necessary to cope with the increased volume of data being transmitted by the NDCs. It was generally agreed that the WMO/GTS could not cope satisfactorily with the expected volumes of data.

In addition to providing waveforms of detected signals it was also proposed that a means of requesting data from any NDC for a particular segment of time should be arranged. The EIDCs would certainly gain from being able to request such data from specific stations to check that signals received at the stations had not been excluded from an NDC report. These waveform data segments would also provide information on the seismic noise recorded at the station at that time. The procedures for making these data requests had to be fully defined by the AHGSE. Provision was also made for all NDCs to access waveforms held by the EIDCs should they require to do so.

Early discussions showed the need for standardisation in waveform formatting for exchange purposes - ie a standard format for the waveform file had to be agreed before any experimentation could take place. An initial format for waveform data was proposed to enable some preliminary bilateral testing to take place.

2.4 The Second GSE Technical Test (GSETT-2)

Following these developments a series of informal bilateral tests for the exchange of waveforms were conducted over a period of four years with a view to preparing for a global test (GSETT-2) to take place in 1990/1991. The UK carried out many bilateral tests using the various means available for data transfer and these are discussed in section 5. The results of the bilateral testing during this period enabled the various participants to improve their facilities and techniques in preparation for the GSETT-2. The experience gained during these tests also enabled the AHGSE to revise the initial concepts of the global system and design an upgraded global system incorporating the new concept of regular exchange of seismic waveform data [7].

Between 1986 and 1990 various improvements were made to the UK facilities. These included new communications links and new software and hardware, the emphasis during this development period being on building more automation into the system. The main priority was given to preparing and transmitting the data to the EIDCs as rapidly as possible. A detailed description of the procedures adopted by the UK for GSETT-2 is given in sections 3 and 4.

The AHGSE prepared instructions [8] on the procedures to be used in the GSETT-2. It was agreed that there would be four EIDCs located at seismic centres in Washington (USA), Moscow (USSR), Stockholm (Sweden) and Canberra (Australia).

Four phases were defined for the GSETT-2 experiment, two of which were intended as preparatory phases for testing the proposed procedures:

Phase I:	up to December 1989	-implementation of new equipment and procedures at NDCs and EIDCs
Phase II:	Jan-March 1990 June 1990 Nov/Dec 1990	-data exchange test -data exchange test (4 days) -data exchange test
Phase III:	April 22-June 09 1991	GSETT-2
Phase IV:	June 1991 onwards	Evaluation of GSETT-2 results

During Phases I and II, the NDCs developed and tested their NSS-NDC and NDC-EIDC communications links and their procedures for analysing, formatting and transmitting the data. At the same time the EIDCs developed and tested: (i) their inter-EIDC communications; (ii) their links with NDCs; and (iii) software for processing and analysis of data to produce bulletins.

By the end of 1990, the AHGSE had specified procedures for every aspect of NDC and EIDC processing and were prepared to undertake the GSETT-2 experiment. The scale of this experiment was unprecedented in seismological research, with so many participating states having to transmit waveform data to processing centres within 24 hours of recording and the EIDCs having to produce definitive bulletins of seismic events within one week. It was this need for rapid transmission and processing of data which made GSETT-2 such a large undertaking.

The UK participated fully in GSETT-2, reporting short and long period parameter and waveform data from the EKA station to the Washington EIDC for the designated 42 data days of the experiment. A brief summary of the results of the GSETT-2 experiment is given in section 5.

In spite of some shortcomings which were found in the GSETT-2 network and procedures, this experiment was a considerable achievement in demonstrating the methodology of the rapid collection, transmission and processing of seismic data.

3. UK FACILITIES FOR PARTICIPATION IN GSETT-2

3.1 National Seismic Station - Eskdalemuir

The EKA station is a medium aperture linear array of 20 short period seismometers with spacing of 0.9 km and an arm length of 9 km. Figure 4 shows the layout of the array which is designed for optimal detection of seismic disturbances in the distance range 500-3000 km. However, the array does detect signals from disturbances at teleseismic distances (greater than 3000 km) and the on-line automatic detector is specifically designed to detect these.

The analogue output of the 20 SP seismometers is frequency modulated and transmitted via cables to the recording laboratory where it is digitised at 20 samples per second and archived on magnetic tapes. A PDPD11/24 computer scans the 20 channels of data on-line and automatically detects signals from teleseismic distances. For each detected signal the waveform is stored on floppy disc and these files are transmitted by telephone line to the UK NDC on a daily basis. Since the automatic seismic detection system at EKA was designed for the detection of teleseismic events, a local/regional event (distance less than 3000 km) detector was set up at the NDC and its output incorporated into the analysis procedure.

The UK elected to report LP data for GSETT-2. LP seismograms are derived by filtering the output of a Mk IIIC broad band seismometer, located in pit R1 of the SP array, and transmitted via a leased telephone line to the NDC. The data are then digitised at 1 sample per second and archived on Exabyte video tape.

Four engineers are required to run the EKA station, providing weekend cover when necessary.

3.2 National Data Centre - Blacknest

The main tasks to be performed at the NDC are the analysis of seismograms, daily report formatting and transmission, and responding to requests for data from other NDCs or IDCs.

A demonstration of a Sun computer operating as a "Remote Seismic Terminal" by the US Delegation at the AHGSE meeting in February 1981 [9] illustrated the capabilities of such computers to perform many of the seismic analysis and data exchange tasks which a seismological centre would be required to perform in a treaty monitoring situation. The demonstration convinced the UK of the need to acquire and install a Sun 2/170 Workstation to enable the interactive analysis of seismograms and transmission of the extracted parameters for international data exchange to be automated. The system was installed in September 1984 just before the start of GSETT-1.

In the first few weeks of the GSETT-1, the Level I parameters were measured by hand from the detection files transmitted from EKA to the NDC then keyed into the Sun Workstation. This computer was only used to transmit the messages to the Meteorological Office at Bracknell (the UK node for the WMO/GTS) via a leased telephone line. The operation worked well but was time consuming for analysts. In the last two weeks of the GSETT-1, an interactive analysis program was installed on the Sun 2/170 to facilitate the extraction of Level I data which proved to be very successful and simplified the procedures at the NDC. The results of UK data transmission and reception during the GSETT-1 are summarised in table 3. The computer configuration employed at the UK NDC during GSETT-1 is shown in figure 5.

For participation in GSETT-1 the NDC was staffed by: 2 computer programmers, 1 seismologist, 3 analysts and 2 data processors. The experience gained in operating a NDC during GSETT-1 demonstrated the need to automate, as far as possible, the procedures for the analysis and transmission of the seismological data.

In the run-up time to the start of GSETT-2 the UK NDC was preparing to transfer all the tasks performed by the ageing PDP11 system on to a MicroVax computer. By the time GSETT-2 started the transfer was not complete and as a result a number of computer systems were needed to perform all the tasks required for participation in GSETT-2 (figure 5). The routine data processing was performed on the PDP11 and MicroVax. The interactive analysis tasks and data transmission operations were carried out on a Sun 3/160 system. (Note during GSETT-2 the Sun systems at the NDC were running Release 4.0.1 of the Sun Microsystems UNIX 4.2 BSD operating system which incorporates some UNIX 4.3 BSD enhancements (appendix D)).

Figures 6a and 6b show the data flow established for GSETT-2. The transmission of digital waveforms posed special problems and various arrangements were made so that the UK could fulfil all of its obligations during GSETT-2.

The waveforms from seismic disturbances detected by the array were transferred to the NDC, processed on the PDP and transferred to the Sun system for interactive analysis. To obtain waveforms from surface waves the LP Helicorder seismograms were examined and any signal observed was noted and the time period covering the arrival extracted from Exabyte tapes to provide a digital waveform for further analysis on the Sun system.

The Sun system proved to be a vital component of the NDC operation. It was used for the interactive analysis of the EKA teleseismic, local and LP detected seismic disturbances. Each 24 hour period of detected waveforms were analysed, the parameters extracted and messages formatted and transmitted, via the Sun, using the X.25 link to the Washington EIDC. This procedure was followed daily for the 42 consecutive data days of the GSETT-2 experiment.

Concurrent with the data processing and transmission, programs on the Sun computer were constantly monitoring incoming messages and alerting staff if a data request was received. As a result the requests for waveform data could be responded to quickly. All incoming messages, including bulletins sent by the EIDCs were logged and archived automatically.

The AHGSE recommended that the NDC database facilities should be accessible to other participants in the AHGSE. The X.25 packet switched data network (PSDN) link into the Sun computer provided interconnection between the UK NDC and other participants connected to a PSDN. For GSETT-2 the UK NDC created separate accounts for each of the participating countries, with usernames and directory structures arranged as recommended in the AHGSE document CRP 167 [10]. When an AHGSE member logged onto BDAC, a "welcome banner" was displayed (figure 7).

Improvements in automation meant the UK NDC required fewer staff during GSETT-2 than GSETT-1, ie, 1 programmer, 1 data processor, 1 seismologist and 2 analysts.

3.3 NDC Communications Links

The data from EKA were transmitted to the UK NDC via a leased Public Switched Telephone Network (PSTN) line using modems with a 4 channel multiplexer to increase the capacity of the data communications link. One channel was dedicated to file transfer of detected events and another channel used to transmit the 20 channels of SP array data which was used to detect local seismic disturbances. The cost of leasing this PSTN line is £7,237 per annum.

The four main methods of data transfer between NDCs and EIDCs recommended by the AHGSE are:

(a) X.25 computer-to-computer link (PSDN);

(b) WMO/GTS;

(c) dial-up computer-to-computer link (PSTN); and

(d) high quality dedicated links (eg, satellite).

Although the UK NDC could provide three out of four of these methods of data transfer, it was decided that for GSETT-2, the most reliable communications method would be the X.25 PSDN. Direct X.25 links were available to three of the EIDCs but not the Moscow EIDC.

Three serial ports on the Sun 3/160 computer were used for communications links: one connected to British Telecom's Packet Switch Stream (PSS) for X.25 access; one connected through a modem to a leased line to the Meteorological Office at Bracknell for WMO/GTS access; and one connected through a modem to the PSTN for dial-up facilities. This configuration allowed the UK NDC to experiment with three of the recommended means of waveform data exchange: X.25, WMO/GTS, dial-up.

The PSS link allowed access to the Blacknest account on the ARPANET Gateway machine at University College London (UCL) which provided an INTERNET electronic mail (email) facility which was used to receive bulletins from the EIDCs during GSETT-2.

For a connection to the PSS, the Sun computer has to act as a Packet Assembler Disassembler (PAD) and these functions are performed by the SunLink software developed by Sun Microsystems. The SunLink X.25 package includes X.29/X.3 facilities (appendix C) which define PAD functions and facilities interfacing between different makes of computer. This is essential for AHGSE applications due to the many different computer systems used by participants in data exchanges.

To execute data transfer an application layer must be used over the top of the X.25 software and the CCITT X.400 Recommendation is an example of such an application. The Message Handling System (MHS) enables users to exchange mail messages on a store-and-forward basis using the X.400 protocol. For GSETT-2 the UK NDC installed a X.400 MHS package on the Sun 3/160 and conducted successful bilateral tests in waveform data exchange with West Germany, Japan and Sweden using X.400.

During GSETT-2 the UK NDC system used a simple applications program over the SunLink X.25 to transfer data to and from remote machines. Programs were written to send and retrieve waveform data to and from all the AHGSE participants with PSDN connections. During GSETT-2, this facility was used daily to report Level I and Level II data to the Washington EIDC, and X.400 was used to receive bulletin data. An example of a program to perform a file transfer to the Vax machine in Germany (FRG) is shown in figure 8. The annual rental of the X.25 connection is around £6,000 and the data transmission costs during GSETT-2 were on average £700 per month.

4. DATA EXTRACTION AND TRANSMISSION

4.1 Automatic Event Detector

The automatic event detection system at EKA was installed in 1983 and comprised a PDP11/24 with a chart recorder and floppy disc units. The software was written in the Macro 11 language.

The details of the automatic event detector are given in Weichert [11], Key, Lea & Douglas [12] and New [13]. It uses standard array processing techniques where data from individual channels are summed together (beam formed) to produce a "beam" channel which has an improved signal-to-noise ratio.

Each time the program declares a detection, the beamed waveform data from the time segment containing the signal is stored on floppy disc. The beamed waveform data files are transmitted to the NDC. During GSETT-2, this file transfer process from the NSS to the NDC took place at the start of each day to enable the detected events from the previous day to be verified, analysed and transmitted to the EIDC.

4.2 Interactive analysis

Staff at the Centre for Seismic Studies in Washington developed a software package for interactive analysis of seismic waveforms [14] which allows the analyst to extract the specific parameters recommended by the AHGSE. This program, Graphical Parameter Measurement (GPM), is accompanied by routines which reformat the parameter data into standard message formats. To use this program the waveform data are read onto a Sun 3/160 computer via magnetic tape or data transfer and stored in a fixed format file on disc. The GPM program is then used to call up the data file and display the waveform on the screen. Figure 9 shows an example display of an analysis screen. A mouse-driven cursor is used to make measurements on the data which are labelled according to AHGSE format requirements. When the analyst quits the program, the measurements taken are written to a file on disc and then converted to the required format for data transmission. An example of a parameter message is shown in figure 10.

The GPM software was installed on the Sun 2/170 in September 1984 and after a short period of staff training was used to extract Level I parameters for transmission over the WMO/GTS during the latter part of the GSETT-1. At a later date GPM was installed on the Sun 3/160 and used throughout all the various phases of GSETT-2. However the message formatting routines required modification to accommodate data transmission via X.25.

4.3 Message Formatting

For GSETT-2 an agreed format for message exchange was adopted. The format for a file of waveform data (CRP 167 [10]), is shown in figures 11a to c. It was agreed by the AHGSE that the data should be ASCII (American Standard Code for Information Interchange)* and that there should be a "volume header" followed by three distinct sections for each waveform transmitted:

(a) Calibration Section

(b) Identification Section

(c) Data Section

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*Binary Waveform data exchange was considered but discarded as being impractical at present. To perform binary file transfer from computer-to-computer would require all the computers to interpret and handle binary data in exactly the same way. This is unlikely to occur in a network involving several machine types and several different operating systems.

This format had to be flexible enough to cater for multi-element array data as well as single component data and to accommodate evolutionary changes in instrumentation and processing techniques.

Certain recommendations and restrictions are defined in CRP 167 [10] regarding waveform data formatting. Summarising the general requirements:

(a) all data should be ASCII

(b) all header fields and all data values will be separated by a blank

(c) null values as opposed to zeros will be used to indicate the field is not applicable or not available

(d) no characters at all should cross the 80 character boundary

(e) there should be no embedded white space in alphanumeric fields

(f) in fixed format fields, all character data should be left justified and all numeric data right justified

(g) the first line of a section must start with either WEX1, CAL1, WID1 or DAT1.

Some requirements are dependent on the media being used for data transfer and appendix E outlines some of the different formats. An example of a waveform data file stored on disc on the Sun computer is shown in figure 12 which is the digital form of the signal shown in figure 8.

5. EXPERIMENTAL RESULTS

5.1 GSETT-1 results

The results of GSETT-1 are summarised in the AHGSE 4th Report to the CD [6]. 75 seismograph stations from 37 countries (figure 1 and table 4) contributed Level I data for this test sending data to one of the three EIDCs at Moscow, Stockholm or Washington DC. Only 25 out of the 75 seismograph stations recorded data in digital form, the majority making measurements from analogue recordings. 38 stations reported data from LP instruments. Slowness and azimuth parameters were only reported by 8 stations. Close to 22,000 *P*-wave onsets were reported.

A total of nearly 4,000 messages were transmitted during GSETT-1. Some countries experienced severe difficulties with transmission of data via WMO/GTS. Bulletins were produced by the EIDCs and distributed to participants via WMO/GTS.

The UK NDC received all but two of the bulletin messages transmitted by the EIDCs and received some parameter messages from 29 of the participating states. The UK NDC sent a total of 78 messages over the WMO/GTS during GSETT-1 and these are summarised in table 3.

5.2 Bilateral tests

In preparation for the digital waveform data exchange experiment many bilateral exchanges took place. Table 5 shows a summary of the results of bilateral exchange tests conducted by the UK NDC via PSDN links. Once the correct PAD settings had been established for a link between two centres, the connections were found to be efficient and the integrity of data was well preserved on transfer.

One of the bilateral tests that took place was an exchange of Level II data with the Swedish data centre using the WMO/GTS. The tests were successful [15] but the WMO/GTS restricts the number of characters in a message to 3800 characters. Frequent liaison with the Meteorological Office overcame this problem but this limitation on the length of a message would be a serious inconvenience when attempting to handle the large volumes of data involved in global data exchange.

Other data exchange tests carried out by the UK NDC via PSTN computer-to-computer links are summarised in table 6. At the time the bilateral tests were conducted only eleven NDCs operated dial-up facilities. The UK NDC could connect to 7 (four of which did not send a login prompt when the two modems were connected); 3 being logged into successfully. Waveform data files were then transferred to and from these 3 centres using a file transfer protocol (known as Kermit) during several bilateral tests in 1986/7. The data transfer was very slow but accurate and the file transfers were successful. However, dial-up links were not used by the UK NDC during GSETT-2. Only 14 of the AHGSE NDCs were equipped with PSTN facilities during GSETT-2 (CRP 167 [10]).

Finally some tests were made of the X.400 MHS and it was evaluated with respect to waveform data exchange applications. Some waveform files were exchanged successfully with the West German MicroVax computer, with a MicroVax computer in Stockholm and a Sun computer in Japan. The X.400 MHS proved very useful and was used to provide the link with the Stockholm EIDC during GSETT-2.

5.3 GSETT-2 results

An assessment of the GSETT-2 experiment is the subject of the second part of this report, but for convenience a brief summary is given here.

There were 34 participating states (see figure 1 and table 7) reporting data from 60 stations for 42 consecutive data days, at the end a further 7 processing days were included to allow the EIDCs to complete their work. The 60 stations are not uniformly distributed around the globe; most are located in the Northern Hemisphere. Of the 60 stations twelve are arrays and these proved to be a definite advantage over other stations both in supplying information on event locations and in their superior detection capacities. A large majority of the stations recorded data in digital form. LP data were reported by 36 stations, via 13 of the 34 NDCs. There were four EIDCs: Stockholm, Sweden; Canberra, Australia; Washington, USA; and Moscow, USSR each equipped with high-quality inter-EIDC communications links comprising satellite and X.25 connections. Almost all NDCs used some kind of computer-to-computer communications to report data to the EIDCs*. A few countries tried to use the WMO/GTS but this proved to be very inefficient. Only three NDCs had no computer-to-computer link and had to send telex reports to the EIDCs. Around 30,000 messages were received by the EIDCs during GSETT-2 containing 80,000 waveform segments from 48 stations. Some stations only reported parameter data. Some NDCs and EIDCs exercised the right to request additional waveform data from other stations and the EIDCs handled 2,600 waveform data requests altogether. The EIDCs produced a bulletin for each data day which was distributed to all NDCs. In all, a total of around 3,700 seismic epicentres were determined for the 42 days of the experiment.

The evaluation of the results of the GSETT-2 is continuing and the data collected will provide material for research for many years to come but there are some conclusions which can be drawn now:

(i) The distribution of seismic stations in the GSETT-2 network was not satisfactory for global monitoring as it lacked contributing stations in the Southern Hemisphere.

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*The various types of connection included satellite, packet switched data networks (X.25), Internet and dial-up.

(ii) The procedures at the EIDCs worked well and the bulletins were produced within the proposed time scale. However, the workload imposed by the analysis of waveform data proved somewhat larger than was expected and not all the reported waveform data could be analysed within the defined time scale. Further, many of the GSETT-2 participants felt that the seismological quality of the bulletins produced by the EIDCs could have been better.

(iii) Considering the complex and ad hoc nature of the communications in the GSETT-2 network, the system worked well with a high percentage of data being successfully transmitted. Where WMO/GTS links were used, it was clear that these could not cope with the large volume of Level II data to be transmitted confirming the earlier conclusion of the AHGSE.

The overall conclusion to date is that a sustained long-term test of a global network would require significant increases in resources and modifications to the procedures at both the NDCs and EIDCs.

6. DISCUSSION

6.1 UK Facilities

The UK participation in GSETT-2 was successful in that Level I and Level II SP and LP data for each of the 42 days were transmitted to the EIDC within the 24 hour limit and the UK NDC responded to all waveform data requests quickly and efficiently.

The development of the UK NDC had progressed steadily in the six years between GSETT-1 and GSETT-2 and the resulting successful participation was due in part to the automation which was built into the system. The detailed seismic analysis was performed interactively but most of the processing tasks were done to a certain extent automatically. This eased considerably the workload on the NDC staff and facilitated the record-keeping which is useful for evaluation of the test. The computer facilities were found to be adequate but not optimum in terms of data storage and processing speed.

6.2 General Discussion

Since GSETT-1, there have been many improvements in facilities at all participating stations, NDCs and EIDCs. The numerous bilateral tests, which proved vital to the success of GSETT-2, enabled better communications to be established and GSETT-2 showed how well the improved communications methods can work.

The main purpose of these tests is to evaluate the initial design concepts for a global network for data exchange, the principal components of which are:

(a) seismic station design;

(b) global network design;

(c) NDC procedures;

(d) EIDC procedures - bulletin formation - seismological processing;

(e) communications.

It appears that there were two main areas which require further improvement: the global network and seismological processing particularly at the EIDCs; these are being addressed in the full evaluation which is currently being made by the AHGSE. Part II of this report will present the aspects of these categories which were tested in GSETT-2.

7. FUTURE PLANS/RECOMMENDATIONS

7.1 UK Facilities

The UK NDC intends to continue improving both its NSS and NDC facilities by the introduction of further automation into its operations. A new detection system is being developed for EKA which will be directly linked to the UK NDC processing system. It was apparent during GSETT-2 that some of the event locations obtained by the automatic detection system were too coarse so improved beam-optimisation procedures are necessary to enable more accurate locations to be reported. The intention is that the only operator intervention needed will be in the interactive analysis of waveforms. There is no intention to make parameter extraction an automated process.

7.2 Global Network

With regard to the global network, the AHGSE is still evaluating the results of GSETT-2. When the evaluation is complete, the AHGSE hopes to be able to make recommendations to the CD regarding the specifications for a standard station and a revised configuration of the global network. It may be necessary for the various suggested improvements in the network to be tested and evaluated before final specific recommendations are made to the CD and it is therefore envisaged that several short-term international exchanges may take place during the evaluation of GSETT-2.

8. ACKNOWLEDGEMENTS

The author would like to thank all the staff at the UK NDC and NSS for their efforts and contributions during GSETT-1 and -2 and for their help in the preparation of this report. In particular special thanks are due to Mrs J Bojie for her help in producing some of the more complicated diagrams.

<u>REFERENCES</u>

1. United Kingdom, Report to the Conference on Disarmament. "Seismic Monitoring for a Comprehensive Nuclear Test Ban". CD/610 (1985).

2. 1st AHGSE Report to the Conference of the Committee on Disarmament. "International Co-operative Measures to Detect and Identify Seismic Events". CCD/558 (1978).

3. 2nd AHGSE Report to the Committee on Disarmament. "International Co-operative Measures to Detect and Identify Seismic Events". CD/43 (1979).

4. F H Grover: "The Experimental Operation of a Seismological Data Centre at Blacknest". AWRE Report O 38/78, HMSO, London (1978).

5. 3rd AHGSE Report to the Conference on Disarmament. "International Co-operative Measures to Detect and Identify Seismic Events". CD/448 (1984).

6. 4th AHGSE Report to the Conference on Disarmament. "International Co-operative Measures to Detect and Identify Seismic Events". CD/720 (1986).

7. 5th AHGSE Report to the Conference on Disarmament. "International Co-operative Measures to Detect and Identify Seismic Events". CD/903 (1989).

8. Ad Hoc Group of Scientific Experts. Conference Room Paper 190, 1989.

9. US Delegates Note to AHGSE session in Geneva, "A Remote Seismic Terminal", GSE/US/15, (February 1981).

10. Ad Hoc Group of Scientific Experts. Conference Room Paper No. 167, (1987).

11. D H Weichert: "Logarithmic Beam Forming for Supression of False Alarms in Seismic Detection". Geophys Res Lett, **2**, (4), (1975).

12. F A Key, T G Lea & A Douglas: "Seismometer Array Station Processors". AWRE Report O 36/76, HMSO, London (1976).

13. S V New: "An On-line Seismometer Array Processor". AWRE Report O 7/83, HMSO, London (1983).

14. J B Minster, R C Goff, J Berger, J Wang: "Prototype U.S. National Data Center.", Science Horizons Report, September (1984).

15. UK, Swedish Delegates Note to AHGSE session in Geneva. GSE/UK/SW/1, August (1981).

Glossary

AHGSE	Ad Hoc Group of Scientific Experts
Baud	Bits per second - modulation rate for data transmission
BDAC	Blacknest Data Analysis Centre
Beamforming	Process of applying time shifts to the output of array seismometers to compensate for the time the signal takes to cross the array, summing the shifted signals and dividing by the number of seismometers
Blacknest	Base of the MOD seismological research group
CCD	Conference of the Committee on Disarmament
CCITT	International Telegraph and Telephone Consultative Committee
CD	Committee on Disarmament/Conference on Disarmament
CTBT	Comprehensive Test Ban Treaty
EIDC	Experimental International Data Centre
EKA	Eskdalemuir seismic array station
GSETT-1	Group of Scientific Experts 1st Technical Test (originally known as GSETT)
GSETT-2	Group of Scientific Experts 2nd Technical Test
IDC	International Data Centre
Level I data	Parameters obtained from measurements on seismograms
Level II data	Digital waveform
Message Handling System	Protocol for message transmission on store and forward basis over X.25 links
MicroVax	Digital Equipment Corporation (DEC) micro-computer
NDC	National Data Centre
NSS	National Seismic Station
PAD	Packet Assembler/Disassembler
PSDN	Packet Switched Data Network
PSTN	Public Switched Telephone Network
Sun	Sun Microsystems Workstation computer
UNCD	United Nations Conference on Disarmament
WMO/GTS	World Meteorological Organisation Global Telecommunications System
X.25	CCITT Recommendation for packet switched network interfacing
X.400	CCITT Recommendation for MHS
X.3	CCITT Recommendation defining the functions of a PAD
X.29	CCITT Recommendation for interfacing with a PAD

List of Tables

TABLE 1

States Represented at AHGSE to date

States represented at AHGSE to date	
CD Member States	Invited Non-CD Member States
Algeria	*† Austria
† Argentina	*† Denmark
*† Australia	*† Finland
*† Belgium	*† New Zealand
* Bulgaria	*† Norway
*† Canada	† Spain
† China	† Switzerland
*† Czechoslovakia (Czech and Slovak Federal Republic)	† Turkey
*† Egypt	
*† Federal Republic of Germany) Germany	
* German Democratic Republic)	
*† Hungary	
*† India	
* Indonesia	
* Iran	
*† Italy	
*† Japan	
*† Kenya	
Mexico	
Mongolia	
*† Netherlands	
Nigeria	
*† Pakistan	
*† Peru	
† Poland	
*† Romania	
*† Sweden	
*† UK	
*† USA	
*† USSR (Russian Federation)	

* States participating in GSETT-1
† States participating in GSETT-2

TABLE 2

Reported Technical Facilities used for GSETT-1

Country	Computers	Software	FTP	Packet Network	Dial-up Baud	Electronic mail
Argentina	HP - 1000	UNIX	----	----	----	----
Australia	Sun 3/260 Sun 2/170 Sun 2/50	UNIX Sun 3.2 Sun 2.0	Kermit	AUSTPAC	V.22 1200	ACSNET
Austria	CDC Cyber 860 CDC Cyber 830 Honeywell Mini	NOS/VE GCPS6	IBM 3270 RMF	DATEXP	V.22 1200	----
Belgium	VAX 11/730	VMS 4.1	----	DCS	V.22 1200	----
Canada	VAX11/750 MicroVAX II	VMS 4.3	Kermit Saft	DATAPAC	V.22 300 1200	PSI
China	VAX 11/750	VMS	----	----	----	----
Denmark	RC 8000	BOSS	----	----	V.22 300 1200	----
F.R.G Hannover	VAX 11/8650 VAX 11/785 VAX 11/730 MicroVAX II	VMS 4.4	Kermit Saft DECNET DFN-FT	DATEXP	V.22 1200	DFN(EAN), UUCP,PSI ARPANET, BITNET,EARN
F.R.G. Grafenberg	Sun 3	UNIX	Kermit	DATEXP	----	----
Finland	Sun 3/260 VAX 8800	UNIX VMS	Kermit	DATAPAK	V.22 1200	EARN, BITNET, ARPANET, PSI
G.D.R.	----	----	----	----	----	----
Hungary	VT-20 IBM 3031	VM/CMS	----	----	----	----
India	Norsk Data 500	UNIX(possibly)	----	----	----	----
Italy	VAX 11/750 MicroVAX	VMS 4.5	DECNET Kermit	----	V.22 300 1200 2400	----
Japan	Sun 3/160C	UNIX	Kermit	VENUS-P	----	----
Netherlands	Burroughs A9	MCP	ICC-link DTS(B25)	----	V.22 300	----
New Zealand	VAX 11/780	VMS 4.5	----	PACNET	----	PSI, ARPANET
Norway	IBM 4381 PO2 MicroVAX II	VM/SP CMS Micro VMS	Kermit	DATAPAK	V.22 300 1200	ARPANET
Poland	PDP 11/40 IBM PC	?	----	----	----	----
Sweden	VAX 11/750 MicroVAX II	VMS 4.1 VMS 4.5	Kermit DECNET	DATAPAK	V.22 1200	PSI
UK	Sun 3/160 Sun 2/170 PDP 11/34A	UNIX Sun 3.4 UNIX Sun 3.4 RT11/3	Kermit UUCP Saft	IPSS	V.22 1200	ARPANET
USA	VAX 11/780	UNIX 4.3 BSD	Kermit	TYMNET	V.22 300 1200 2400	ARPANET,UUC PNET

TABLE 3

(a) Summary of Messages Received by UK NDC

Message Source	Presumed Total Messages Issued	Number Received	% Rec/Total
Australia	302	277	92
Australia (N49 series)	81	65	80
Austria	40	37	03
Belgium	38	25	66
Brazil	58	14	24
Bulgaria	50	41	82
Canada	234	216	92
Czechoslovakia	79	73	92
Denmark	33	25	76
Egypt	13	1	1
Finland	48	47	98
France	110	77	70
FR Germany	70	67	96
German DR	47	39	83
Hungary	70	57	81
India	61	32	53
Indonesia	49	31	63
Ireland	44	35	80
Italy	44	40	91
Japan	69	66	96
Netherlands	66	62	94
New Zealand	73	9	12
Norway	65	64	99
Peru	45	22	49
Romania	45	10	22
Sweden	177	176	99
USA			
(Series N40001-452)	452	434	97
(Series N40651-831)	181	181	
USSR	59	50	85
Zambia	63	31	49

(b) SUMMARY OF MESSAGES RECEIVED FROM EIDCs

Message Source/Type		Presumed Total Messages Issued	Number Received	% Rec/Total
MOSCEIDC	PEL(1)	41	40	98
"	FEB(2)	39	39	100
"	REC (3)	13	12	92
STOCEIDC	PEL	61	61	100
"	FEB	61	61	100
"	REC	14	14	100
WASHEIDC	PEL	65	65	100
"	FEB	61	61	100
"	REC	27	27	100

(1) PEL - Preliminary Event List
(2) FEB - Final Event Bulletin (3) REC - Recommendation message

(c) SUMMARY OF UK DATA TRANSMISSIONS

	Originals	Retransmissions	Total
No. of messages transmitted	61	17	78
No. of Lines transmitted	9,860	1,573	11,433
No. of characters transmitted	98,417	16,149	115,566

TABLE 4

Participation in GSETT-1 (1984)

States participating in GSETT-1	
Represented at AHGSE prior to test	Not representated at AHGSE prior to test
Australia Austria Belgium Bulgaria Canada Czechoslovakia Denmark Egypt Federal Republic of Germany Finland German Democratic Republic Hungary India Indonesia Iran Italy Japan Kenya Netherlands New Zealand Norway Pakistan Peru Romania Sweden UK USA USSR	Argentina Bolivia Brazil Colombia France Ireland Thailand Zambia Zimbabwe

TABLE 5

Waveform Data Exchange Tests conducted via Packet Switched Networks (PSDN)

Country	Connection made	Waveform Data Exchange			
		Sent	Retrieved	Received	Method
Australia	Yes	Yes	Yes	No	Type mode
Austria	PSS line refused	---	---	--	
Belgium	BAD address/refused	---	---	--	
Canada	Yes	Yes	Yes	Yes	Type mode
Finland	Yes	Yes	Yes	No	Type mode
FRG (IG)	Yes	Yes	Yes	No	Type mode
FRG (FIGNR)	Yes	Yes	Yes	No	Type mode
Italy	Yes	Yes	Yes	No	Type mode
Japan	Yes	Yes	Yes	No	Type/Kermit
New Zealand	Yes	Yes	Yes	No	Type mode
Norway	Yes	Yes	Yes	No	Type mode
Sweden	Yes	Yes	Yes	Yes	Type mode
USA	Yes	Yes	Yes	Yes	Type mode

TABLE 6

Waveform Data Exchange Tests conducted via Dial-up Lines (PSTN)

Country	Success of dialup connection	Waveform Data Exchange		
		Sent	Retrieved	Received
Australia	Yes	Yes (Kermit)	Yes (Kermit)	----
Austria	No reply	----	----	----
Belgium	No reply	----	----	----
Canada	On line but no login prompt	----	----	----
Denmark	No reply	----	----	----
Finland	Yes	----	----	----
FRG (IG)	No reply	----	----	----
Italy	Yes	----	----	----
Norway	Cannot use autodial as extension has to be requested	----	----	----
Sweden	Yes	Yes (Kermit)	Yes (Kermit)	No
USA	Yes	Yes (Kermit)	Yes (Kermit)	No

TABLE 7

Participation in GSETT-2 (1991)

States participating in GSETT-2	
Represented at AHGSE prior to Test	Not represented at AHGSE prior to Test
Argentina Australia Austria Belgium Canada China Czechoslovakia Denmark Egypt Finland Federal Republic of Germany India Italy Japan Kenya Netherlands New Zealand Norway Pakistan Peru Poland Romania Spain Sweden Switzerland Turkey UK USA USSR	Chile Cook Islands France Yugoslavia Zambia

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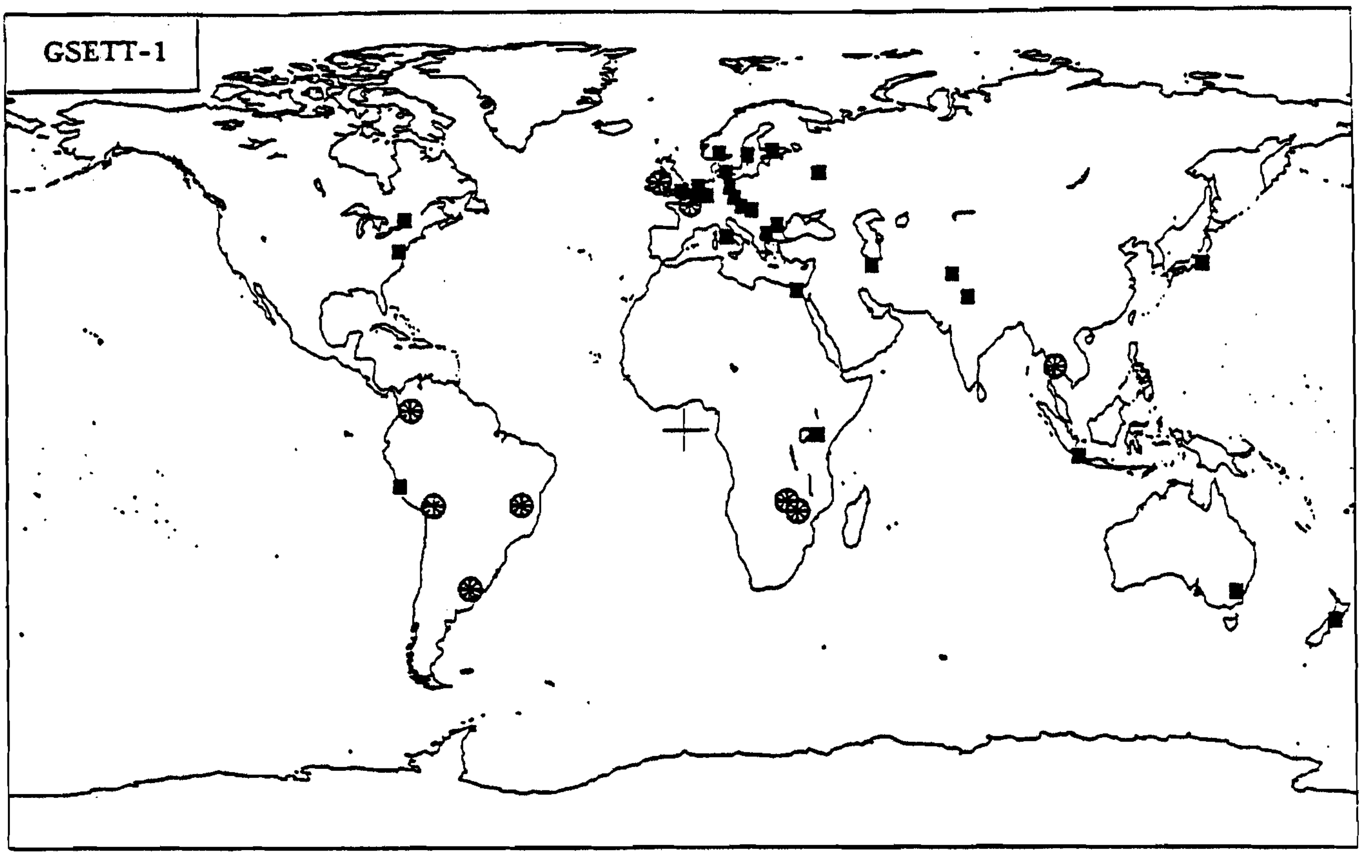


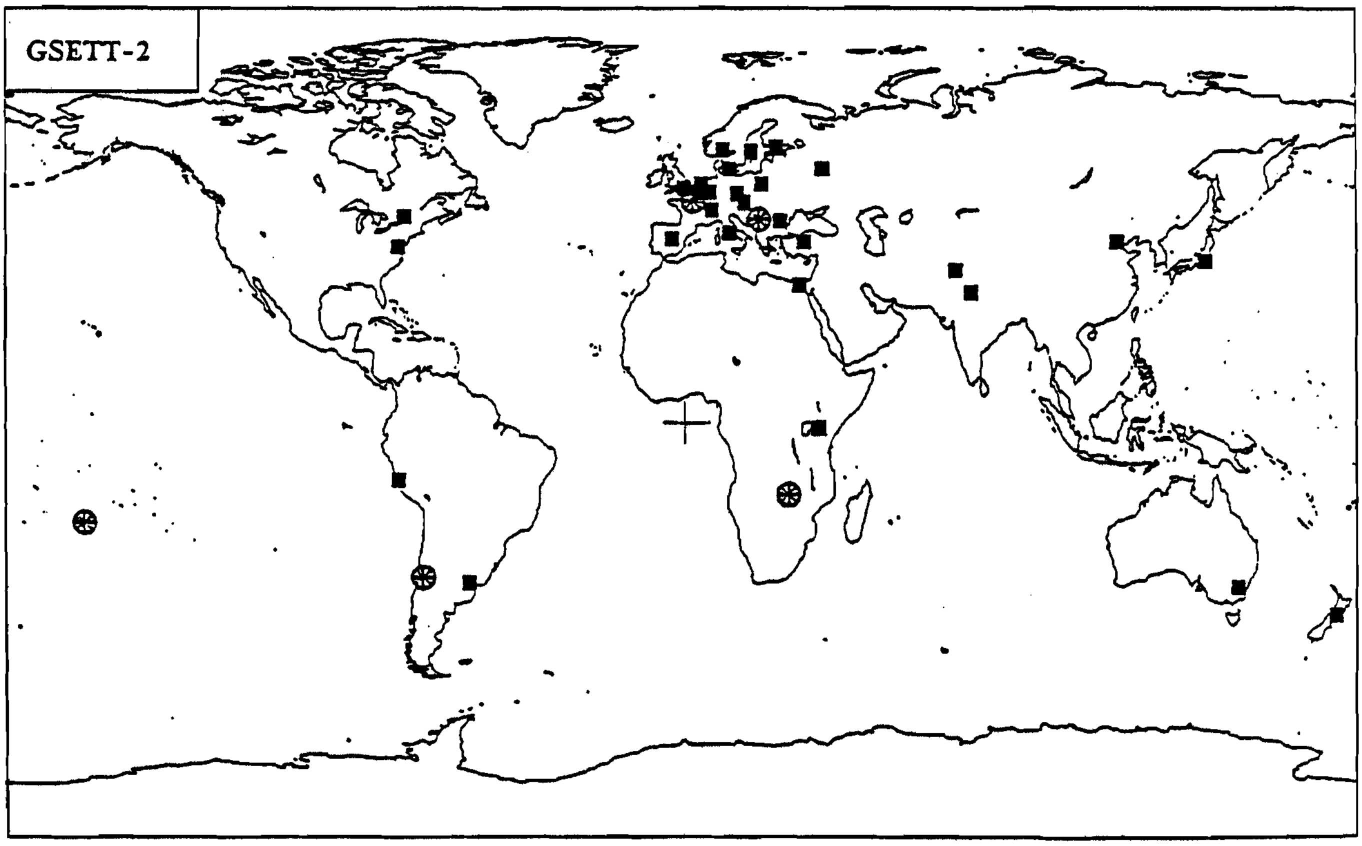


FIGURE 1. GLOBAL DISTRIBUTION OF PARTICIPANTS IN AHGSE TECHNICAL TESTS

Key

■ Participating States represented at meetings of AHGSE prior to Technical Test

⊛ Participating States not represented at meetings of AHGSE prior to Technical Test

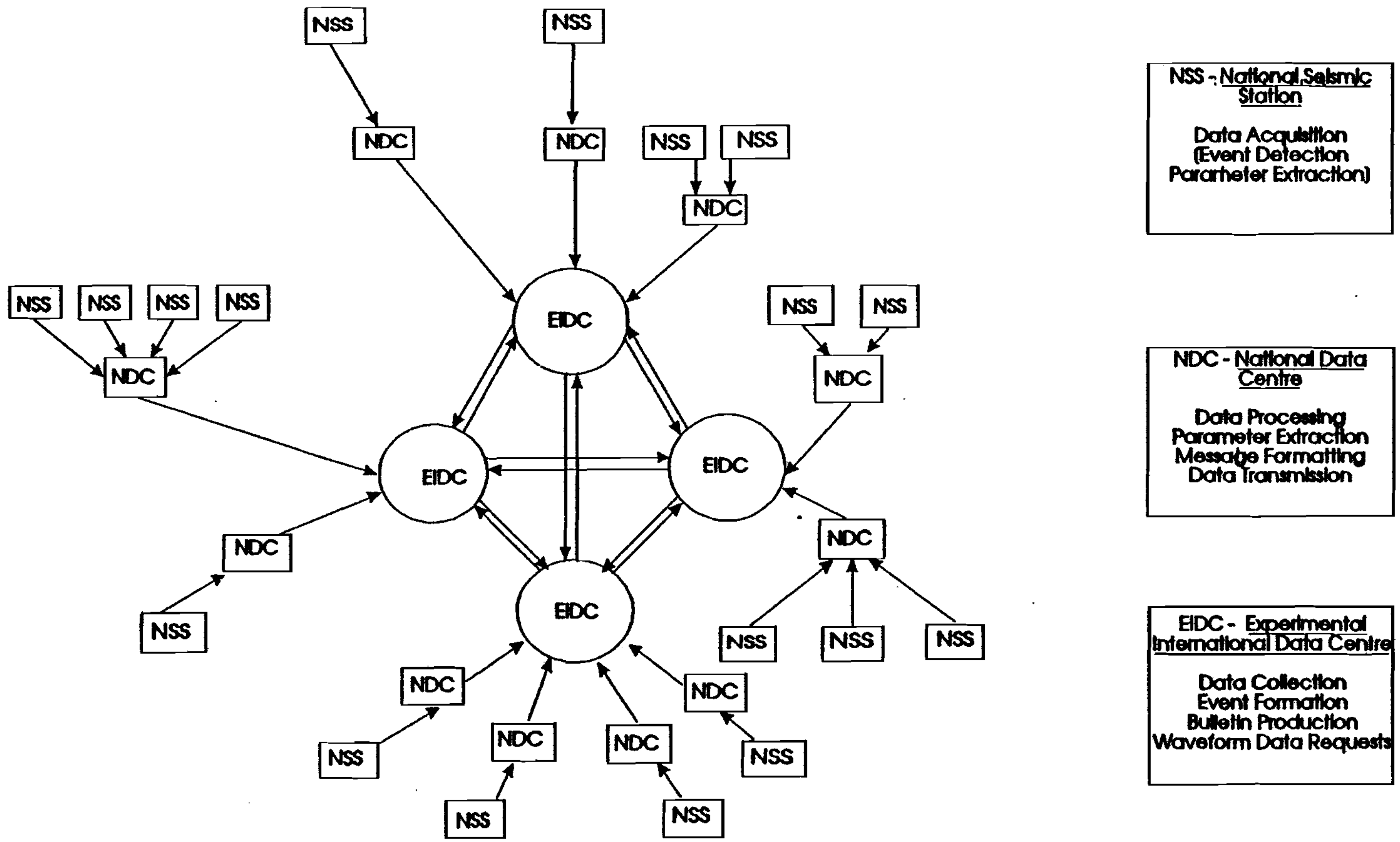


FIGURE 2. EXPERIMENTAL ARRANGEMENTS FOR GLOBAL DATA EXCHANGE

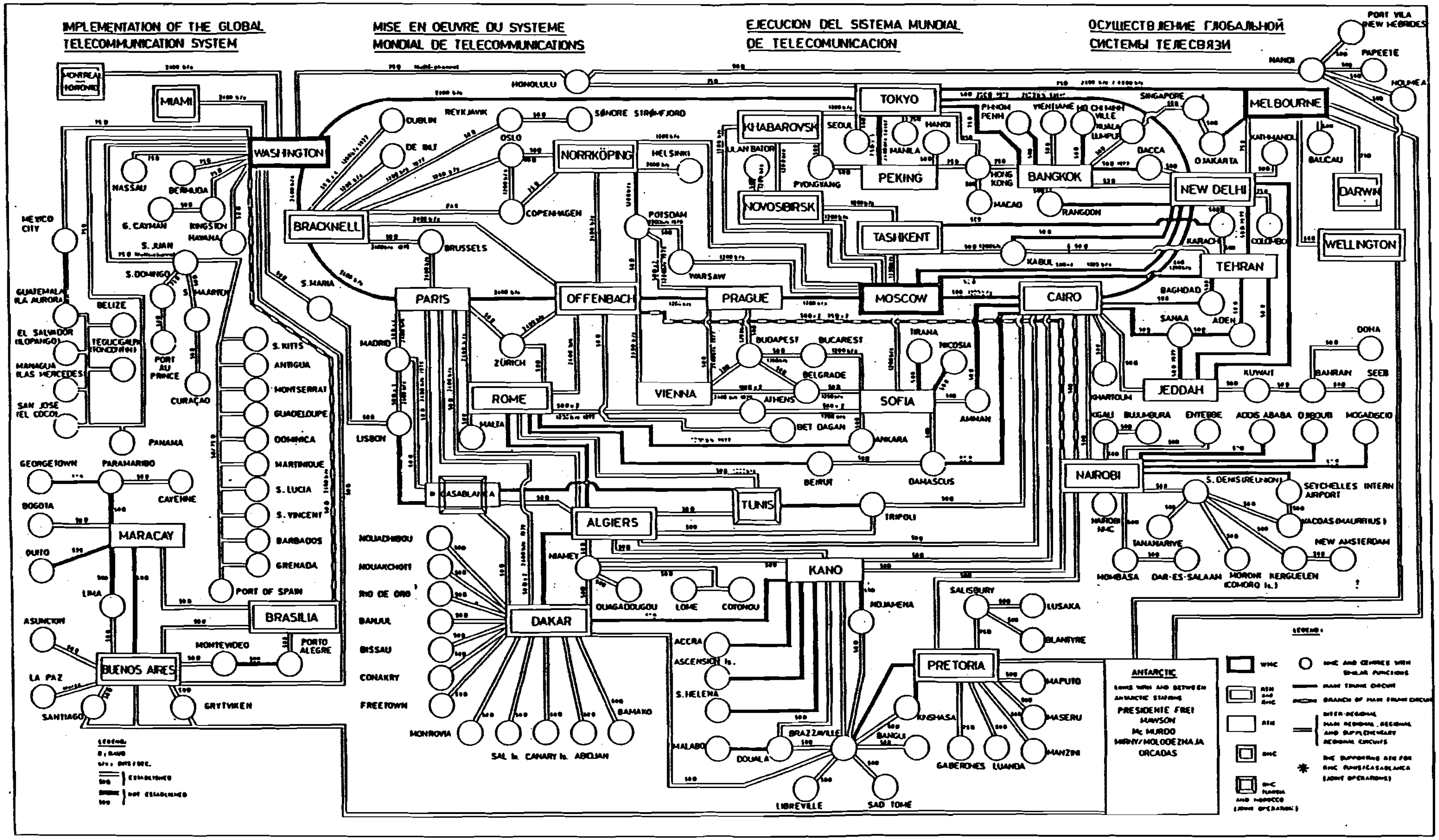


FIGURE 3. WORLD METEOROLOGICAL ORGANISATION GLOBAL TELECOMMUNICATIONS SYSTEM (WMO/GTS)

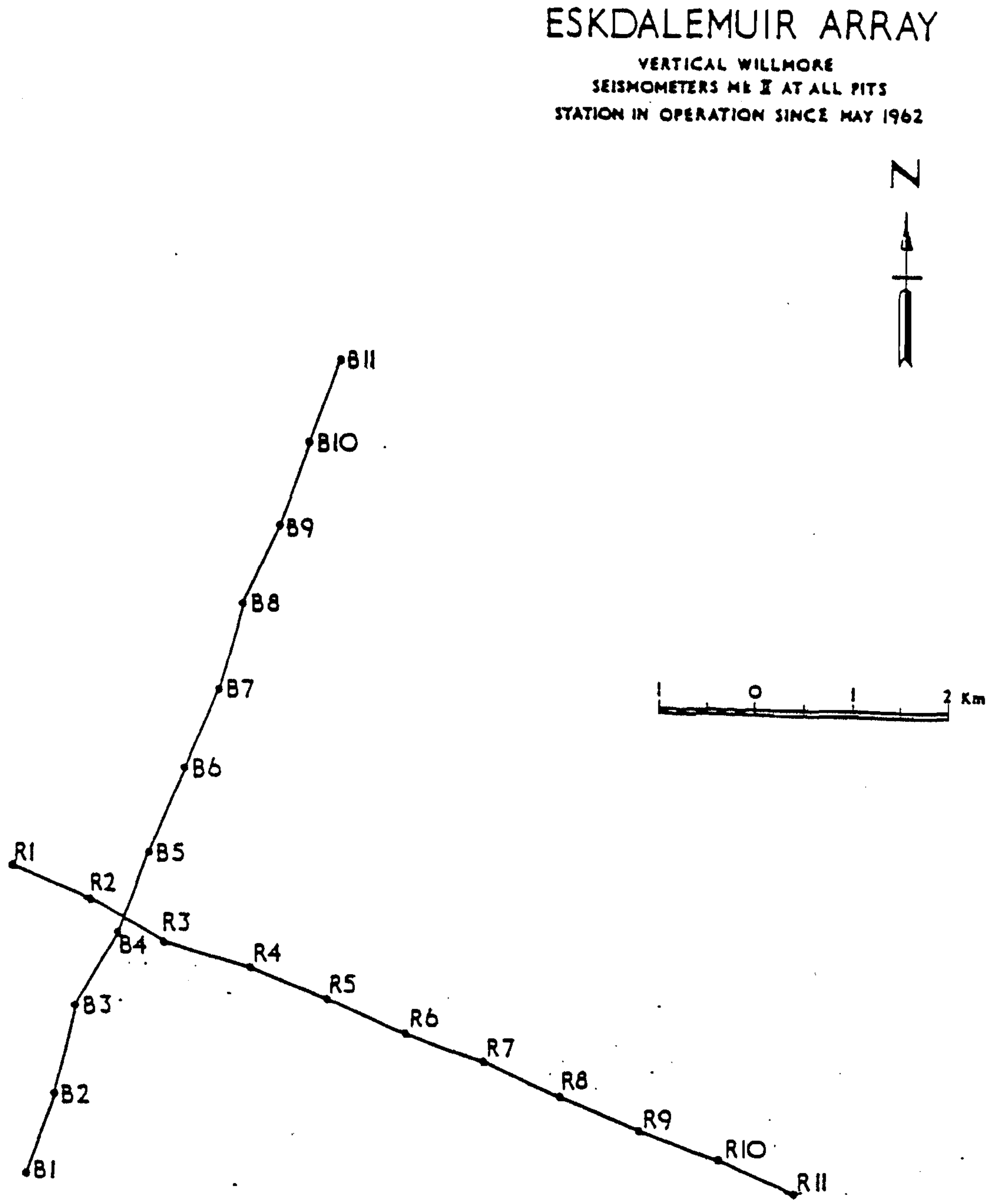


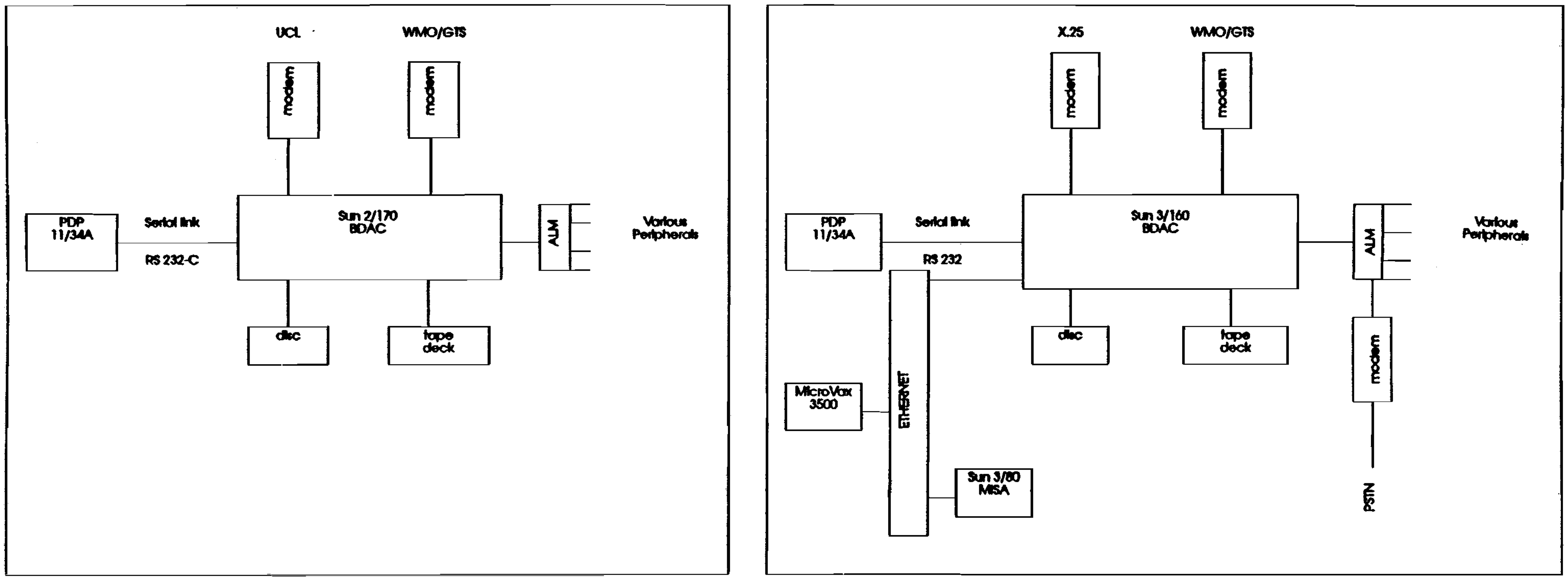
FIGURE 4. CONFIGURATION OF EKA ARRAY STATION

Data Reported

1. Short period array sum with single channel (for events detected by teleseismic detector)

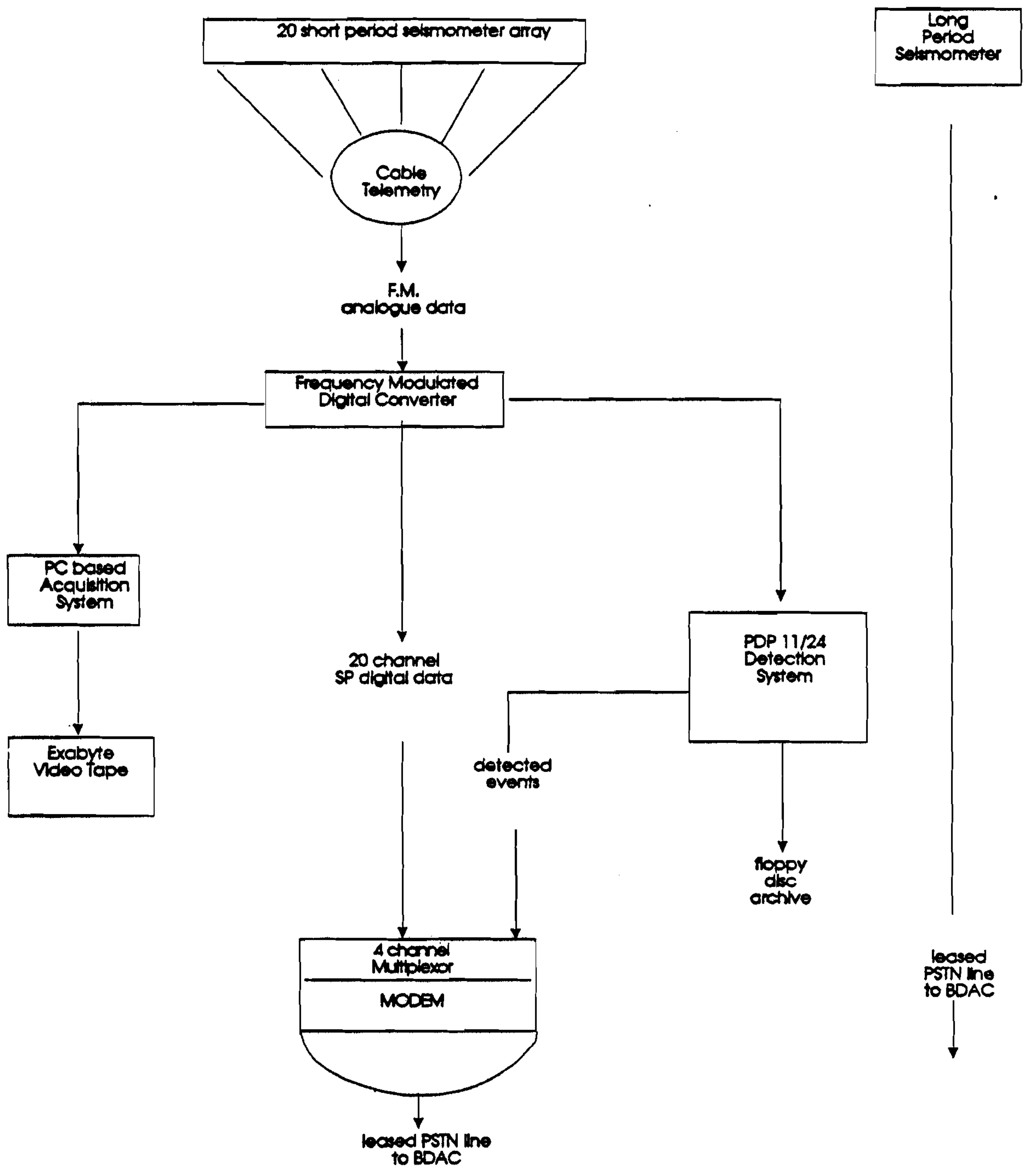
2. Short period single channel (for events detected by "local" detector)

3. Long period vertical (located at R1)



GSETT-1 (1984) GSETT-2 (1991)

FIGURE 5. BDAC COMPUTER SYSTEM CONFIGURATION



<u>FIGURE 6a. DATA FLOW FROM EKA (NSS) TO UK NDC</u>

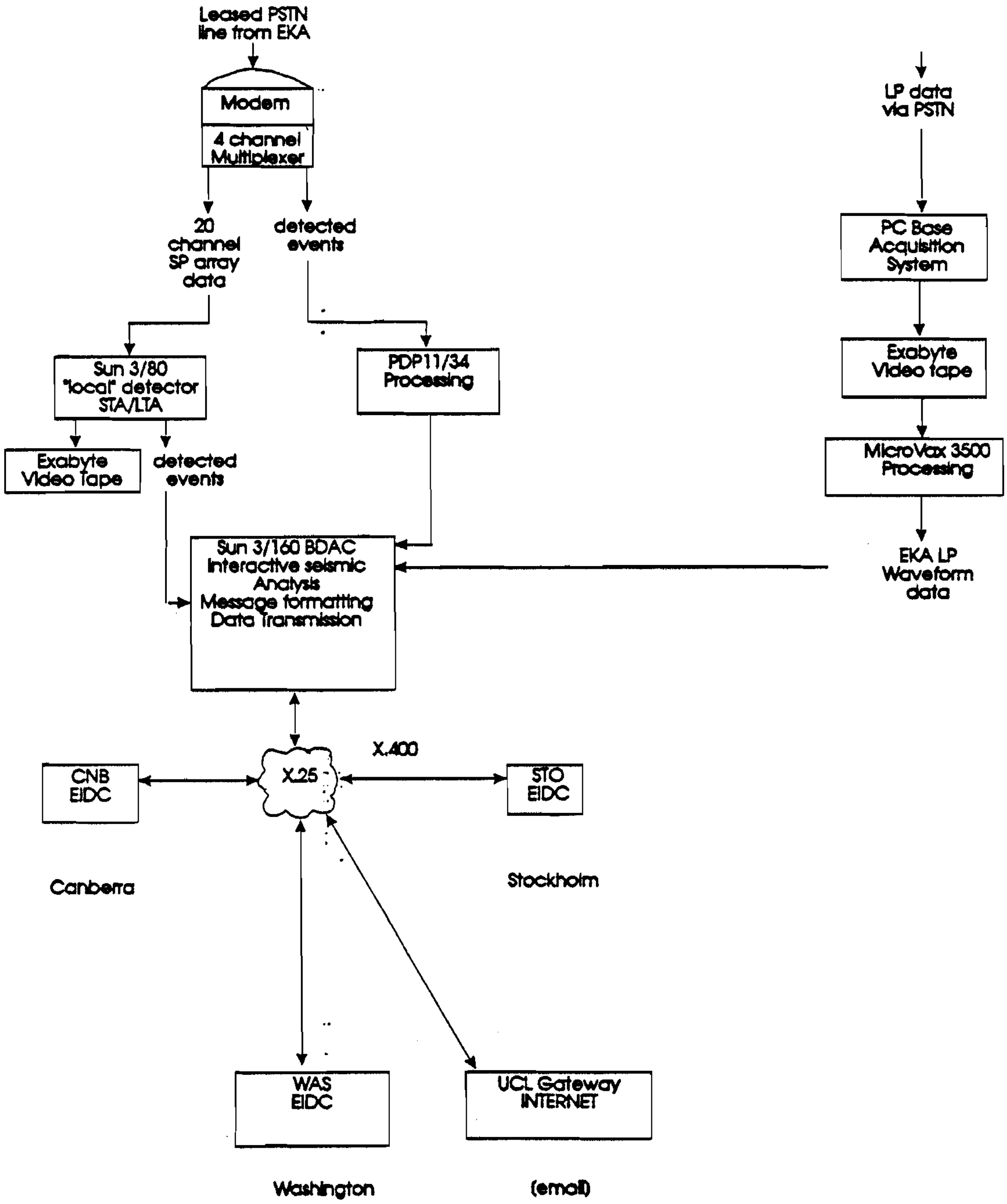


FIGURE 6b. DATA FLOW INTO AND OUT OF UK NDC

```
*************************************************************************
                        BLACKNEST DATA ANALYSIS CENTRE

                Welcome to the BDAC Sun 3/160 computer running

                        Sun Unix bsd 4.2 Release 4.0.1

*************************************************************************

               Enter the command 'cat README' when you see the

                                prompt 'gse>'

*************************************************************************
     AHGSE document database is in directory /u0/gse/AHGSE-docs.
                  Type in "cd/usr/bdac/gse/AHGSE-docs"
 and "more README" if you wish to access these lists of AHGSE documents

*************************************************************************
```

<u>FIGURE 7. "WELCOME BANNER" DISPLAYED WHEN USERS FROM OTHER NDC's ACCESS THE UK NDC FACILITY</u>

```
testpad << 'END'
     call 26245511013077
     dialog sername: **\r ssword: ******\r
     dialog "support" "\r"
     dialog UK> \r
     dialog UK> "set term/hostsync/noecho\r"
     dialog UK> "set prompt=%\r"
     dialog % dir\r
     dialog %
     put testwf.1 "create testwf.eka\r" ^Z
     dialog "" \r
     dialog % dir\r
     dialog % \rlogout\r
     exit
END
```

This program transfers the file testwf.1 to the West German computer and calls it testwf.eka. (The asterisks in the username and password definitions do not exist in the actual file but are used here to help preserve the security on the West German computer). It is written using Unix commands which simplify the programming code.

FIGURE 8. EXAMPLE OF FILE TRANSFER PROGRAM

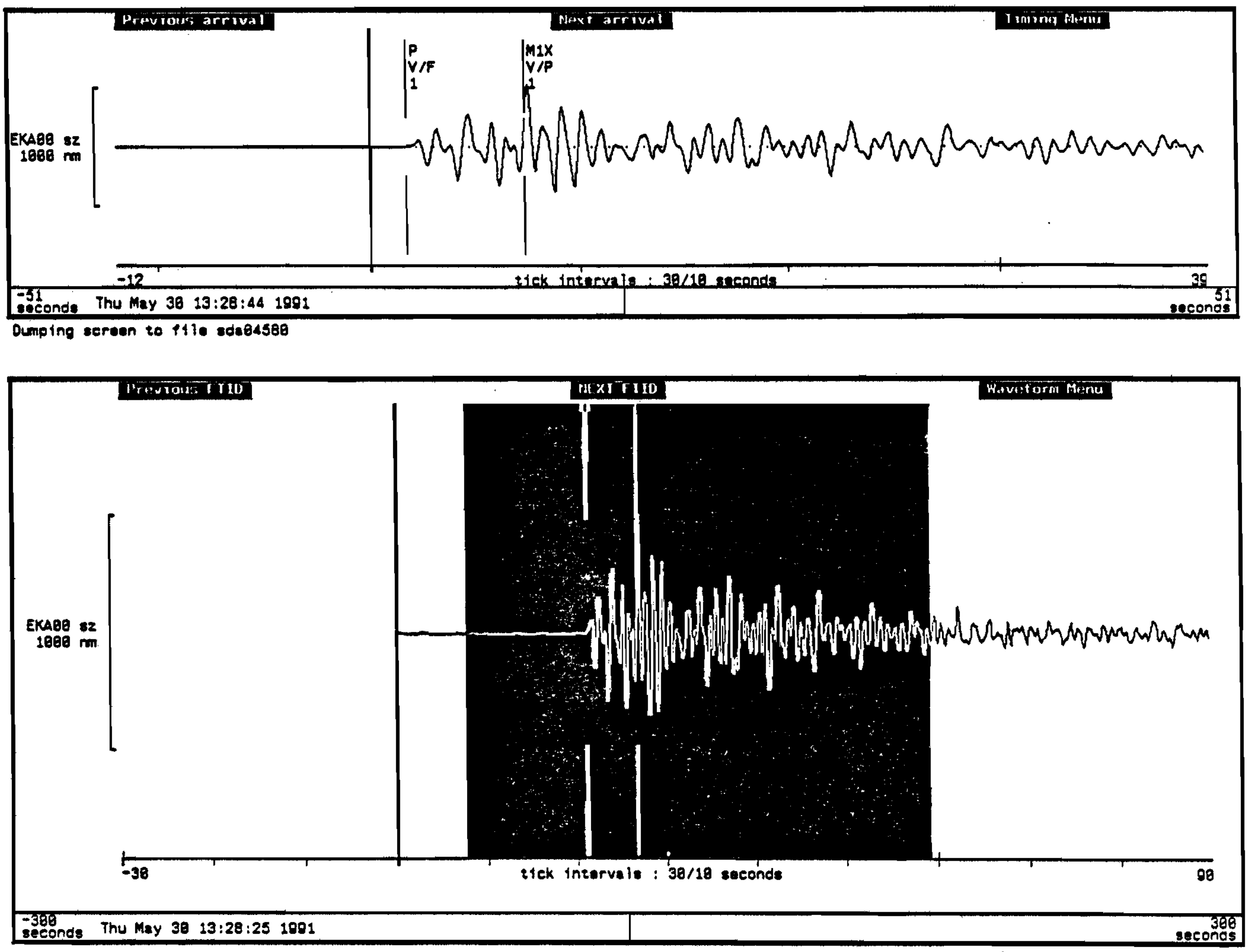


FIGURE 9. EXAMPLE ANALYSIS SCREEN
FROM GRAPHICAL PARAMETER MEASUREMENT (GPM) PROGRAM

```
GBR WAS 910531 1342 A   1
XP01 GBR WAS    563   19 910531 1342           910530
EKA BEG MAY30 000000 END MAY30 240000
MAY30
EKA EPG095140.3 XA5144.9 T0.30A2.10 ESG5147.2 ERG5150.6
LPZ NBT29A0.040 ((QB))
EKA LPZ LR XA095655.4 T30A0.175 ((NP))
((POSSIBLY CENTRAL ATLANTIC))
EKA EPG124637.9 XA4638.6 T0.29A2.90 ESG4658.4 ERG4705.8
LPZ NBT30A0.121 ((QB))
EKA IPC132846.3 XA2851.9 T0.74A232.40 SL06.17 AZ022 ((TB))
LPZ LR XA135405.3 T27A999999.000 ((CL))
((POSSIBLY KODIAK ISLAND))
EKA EPG145402.2 XA5402.9 T0.15A2.70 ESG5409.3 ERG5414.5 ((QB))
((NOISE IN CODA OF PREVIOUS EVENT))
EKA EPG150231.4 XA0232.1 T0.11A0.60 ESG0243.2 ((QB))
((NOISE IN CODA OF PREVIOUS EVENT))
EKA LPZ LR XA203415.1 T21A0.452 ((NP))
((POSSIBLY RYUKYU ISLANDS))
STOP
```

FIGURE 10. EXAMPLE EKA PARAMETER MESSAGE FROM GSETT-2 EXPERIMENT

Position	Field	Name	Format	Description
Line 1:				
1-4	1	header id	a4	must be "WEX1"
6-17	2	data id number	a12	any 12 "a" chars assigned by Center providing data, null = "-"
19-30	3	request id	a123	any 12 "a" chars. Corresponds to id number of message requesting data, null = "-"
32-37	4	max block size	i6	max block size, 8000, null = -1
39-80	5	reserved	a42	must be spaces
Line 2-N*:				
81-8000	-	as needed	a	any text

FIGURE 11(a). VOLUME HEADER FILE

Position	Field	Name	Format	Description
Line 1:				
1-4	1	header id	a4	must be "CAL1"
6-11	2	station or array name	a6	use ISC code, eg, NB2
13-20	3	channel id	a8	do not use
22-23	4	channel	a2	sz, lz, ln, etc., null = "-"
25-30	5	system type	a6	SRO, GS-13, etc., null = "-"
32-34	6	response type	a3	response type "PAZ" or "FAP", null = "-"
35-80		blank		
Instrument Response using Poles and Zeros Formulation (PAZ)				
Line 2:				
1-8	1	npole	i8	number of poles
Line 3 to N:				
N=npole+2	1	rpole	f or e	real part of pole
	2	ipole	f or e	imaginary part of pole
Line N+1:				
1-8	1	nzero	i8	number of zeros
Line N+2 to M:				
M=N+1+nzero	1	rzero	f or e	real part of zero
	2	izero	f or e	imaginary part of zero
Line > M:	-	as needed	a	additional explanatory information as needed (variable length)
or: Instrument Response using Frequency-Amplitude-Phase Formulation (FAP)				
Line 2:		ntrip	i8	number of triplets
1-8	1			
Line 3 to N:				
N=ntrip+2	1	frequency	f or e	frequency
	2	amplitude	f or e	amplitude
	3	phase	f or e	phase
Line > N:	-	as needed	a	additional explanatory information as needed (variable length)

FIGURE 11(b). CALIBRATION SECTION

Position	Field	Name	Format	Description
Line 1:				
1-4	1	header id	a4	must be "WID1"
6-13	2	segment start date	i8	yyyyddd, eg, "1984045", rt justified
15-16	3	start hours	i2	year * 1000 + day-of-year
18-19	4	start minutes	i2	hh
21-22	5	start seconds	i2	mm
24-26	6	start milliseconds	i3	ss
28-35	7	number of samples	i8	nnn
37-42	8	station name/channel	a6	nnnnnnnn
44-51	9	channel id	a8	use ISC code, eg, NB2
53-54	10	channel	a2	do not use
56-66	11	sample rate	f11.7	sz, lz, ln, etc, null = "-" samples per second
68-73	12	system type	a6	SRO, GS-13, etc, null = "-"
75-80	13	data format type	a6	"INTX" or "FLTX" where X is the width of the data field or "V" for variable
Line 2:				
81-89	1	calibration (gain)	f9.6	nm per digital count at calibration period, null=0
91-97	2	calibration period	f7.4	in seconds, null=-1
99-107	3	station latitude	f9.4	decimal degrees, north>0, null=-999
109-117	4	station longitude	f9.4	decimal degrees, east > 0, null=-999
119-127	5	station elevation	f9.4	km above sea level > 0, null=-999
129-137	6	depth of sensor beneath surface	f9.4	km > 0, null=-999
139-145	7	beam azimuth	f7.2	degrees measured clockwise from north, null=-1
147-153	8	beam slowness	f7.2	seconds per kilometer, null=-1
155-160	9	horizontal orientation	f6.1	orientation of horizontal sensors, measured clockwise from north, null=-1
Line 3,4:				
161-320	-	channel id's of contributing beam elements	a	10 15, etc, or with weights & time delays: 10 WGT1. TD1.32 15 WGT.9 TD.76
Line(s)>4:	-	as needed	a	any text

FIGURE 11(c): WAVEFORM IDENTIFICATION SECTION

```
WID1  1991150 13 28 25    0      3900 EKA    EKASUM    sz  20.0000000 EKADSP INT
 0.072300  1.0000     55.3332     -3.1588  356.0000 -999.0000     -1.00     -1.00     -
DAT1
      33        38        39        35        34        30        29        20        17
      21        22        21        18        17        13        11         6         0
     -10       -14       -20       -28       -31       -29       -27       -23       -20
     -18       -18       -19       -20       -20       -19       -21       -29       -33
     -35       -32       -31       -30       -26       -21       -18       -14       -12
       2         7        14        19        23        25        22        24        24
      30        28        29        29        31        28        30        34        33
      30        27        20        11         8         5         4         0        -4
     -16       -17       -17       -23       -23       -22       -18       -20       -20
     -19       -17       -16       -14       -10       -12       -11       -14       -15
      -5        -1        -1        -1         5         3         0        -2         0
       0         0        -1        -5         0         2         2         6         7
       0        -7       -12       -18       -16       -17       -15        -8         0
       9        14        21        26        31        31        30        26        19
       5        -2        -3        -3        -3        -2         0        -2        -4
      -6        -3        -4        -8        -6        -6       -10       -13       -13
     -23       -25       -22       -18       -15        -5         2        10        15
      12        15        19        18        19        12        12        10         8
       4         3         1        -3        -8       -15       -22       -23       -18
     -13        -8        -9        -7        -8        -6        -4         1         9
      18        22        23        18        10         8         3         3         5
       7         5         3         0        -4        -4        -3        -4        -9
      -9       -14       -17       -16       -14       -10       -10        -6        -2
      -2        -1        -2       -11        -4        -3        -7        -6         1
      -2        -4         3         4        -4        -5        -5        -6       -10
     -10        -6        -2        -2        -3        -1        -7       -10        -2
       6         6        12        16        24        24        25        34        33
      41        44        42        32        25        15         8         5         4
      -6        -8       -12       -18       -23       -26       -31       -33       -26
     -25       -25       -20       -16       -15       -16       -12       -11        -9
      -5       -10       -14       -20       -22       -26       -28       -24       -26
     -25       -22       -21       -19       -21       -18       -11        -5         3
      13        19        28        29        29        35        49        61        57
      59        61        52        48        46        39        27        19         4
      -2        -7       -14       -17       -17       -19       -21       -30       -27
     -27       -35       -32       -24       -17       -17       -18       -18       -18
     -13       -16       -10        -7        -7        -5        -3        -8       -16
     -15       -11        -2         7        11         9         1         1         3
      -4        -4        -8        -9       -11       -13       -16       -15       -16
     -16       -15       -15        -5         1         6         9        15        21
      28        32        30        27        30        27        21        14        15
      27        24        22        24        23        16        13        10         6
      -3         0         8        29        54        83       119       152       173
     211       241       286       369       497       661       805       871       808
     199      -340      -958     -1543     -1975     -2152     -2032     -1630     -1002
     561      1285      1819      2111      2153      1967      1614      1125       579
    -330      -559      -621      -519      -296       -32       169       213         2
```

FIGURE 12. EXAMPLE EKA WAVEFORM DATA FILE FROM GSETT-2 EXPERIMENT

LIST OF APPENDICES

APPENDIX A

TERMS OF REFERENCE OF THE AHGSE

Original Terms of Reference (1976)

"For the purpose of carrying out this investigation the Group should specify the characteristics of an international monitoring system inter alia including:

(1) A global network of seismological stations, selected from existing and planned installations;

(2) Data required from the stations to facilitate the analysis for detecting, locating and identifying seismic events;

(3) Transmission facilities for the timely exchange of data between seismological stations and data centres;

(4) Facilities, procedures and related financial implications with respect to contributing and receiving centres for detecting, locating and identifying seismic events throughout the world and facilitating the collation and dissemination of relevant documentation;

(5) The costs which would be incurred if an international monitoring system were established.

In addition to the items listed above, the Group would endeavour to estimate the detection and identification capability of such an international co-operative system. The estimates would be on the basis of available data or, where desirable and feasible, also on the basis of data obtained from experimental exercises involving the whole or part of the specified global network. The Group should not, however, assess the adequacy of such a system for verifying a comprehensive test ban. Rather it should provide factual results of its analysis for the benefit of Governments to assist them in making such an assessment and in directing future research. The responsibility of the Group would be purely scientific."

Revised Terms of Reference (1979)

"1. Recognising the valuable and important work carried out by the Ad Hoc Group in elaborating instructions and specifications for International Co-operative Measures to Detect and Identify Seismic Events, as presented to the CD in its report of July 1979, the CD decides that the Ad Hoc Group should continue its work on such measures, which might be established in the future for the international exchange of seismological data under a treaty prohibiting nuclear weapon tests covering nuclear explosions for peaceful purposes in a protocol which would be an integral part of the treaty.

2. This work should, inter alia, include:

- further elaboration, with the second report of the Group as a basis, of detailed instructions for an experimental test of the global system for international co-operative measures to detect and identify seismic events;
- further development of the scientific and technical aspects of the global system;
- co-operation in the review and analysis of national investigations into relevant matters such as:
    - the conditions for using the World Meteorological Organisation (WMO) Global Telecommunication System (GTS) for seismic data exchange;

- procedures to obtain desired data at individual stations under a range of conditions;

- the analysis and data handling procedures at the envisaged data centres; and

- methods of rapid exchange of waveform data.

3. The organisation and procedures of work of the Group should remain the same as defined by the decision of the CCD on 22 July 1976 and maintained by the Committee on Disarmament by its decision of 15 February 1979. The Ad Hoc Group will hold its first meeting under its new mandate late in January or early in February 1980.

4. The Committee on Disarmament invites WMO to continue its co-operation with the Ad Hoc Group".

APPENDIX B

DATA PROPOSED TO BE EXCHANGED AT LEVEL 1 (SHORT PERIOD INSTRUMENTS)

Short period Parameters (Body waves-Vertical Component)	Unit of Measurement	Precision of Measurement	Volume of Data (Computer Words)
a) Standard Parameters - All stations			
1. Arrival time	hour,min,s	0,1 s	3
2. First motion sign and clarity (if possible)			1
3. *Amplitudes A_i (i=1, ...4)	nm	0,1 nm	4
4. *Arrival times corresponding to each A_i	hour,min,s	0,1 s	12
5. *Periods corresponding to each A_i	s	0,1 s	4
6. Signal-to-noise ratio			1
7. Phase description,			1}
Amplitude	nm	0,1 nm	1} 6xn
Period	s	0,1 s	1}
Arrival time of secondary phases, e.g S, PcP, PP, ... (reported when possible)	hour,min,s	0,1 s	3} where n is the number of phases detected
8. Complexity (digital station only)			1
9. Spectral moment, ratio or vector (digital stations only)			1-6
b) Additional Standard Parameters - Arrays Only			
10. Apparent velocity	km/s	0,01 km/s	1
11. Epicentre azimuth and distance	degrees	0,01 deg	2
12. Epicentre latitude and longitude	degrees	0,01 deg	2
13. Estimated time at focus	hour,min,s	1 s	3
14. Magnitude m_b		0,1 unit	1

* The A_i, i=1,2, ...4 correspond to maximum amplitudes in the intervals 0-6 seconds, 6-12 seconds, 12-18 seconds and 18-300 seconds after P-wave arrival, respectively.

APPENDIX B (continued)

DATA PROPOSED TO BE EXCHANGED AT LEVEL 1
(LONG PERIOD AND BROAD-BAND INSTRUMENTS)

Long Period Parameters	Unit of Measurement	Precision of Measurement	Volume of Data (Computer Words)
a) Standard Parameters - All Stations			
(i) Body-waves (Vertical and horizontal components)			
1. Arrival time	hour,min,s	1 s	3
2. Maximum amplitude A_{max}	nm	1 nm	1
3. Arrival time of A_{max}	hour,min,s	1 s	3
4. Period corresponding to A_{max}	s	0.1 s	1
5. Noise amplitude A_N	nm	1 nm	1
6. Period corresponding to A_N	s	0.1 s	1
7. Phase identification, amplitudes, arrival times and periods for additional phases, eg, ScS, etc. (reported when possible)			6xn where n is the number of phases
(ii) Surface waves (Rayleigh-vertical and Love-horizontal)			
8. Arrival time	hour,min,s	1 s	3
9. Maximum amplitude A_{max}	nm	1 nm	1
10. Arrival time of A_{max}	hour,min,s	1 s	3
11. Period corresponding to A_{max}	s	1 s	1
12. Maximum amplitudes for periods 10, 20, 30, 40 s	nm	1 nm	4
13. Arrival times of maximum amplitudes at 10, 20, 30, 40 seconds	hour,min,s	1 s	12
14. Noise amplitude A_N	nm	1 nm	1
15. Period corresponding to A_N	s	1 s	1
16. Association to short period detection (if possible)			1
b) Additional Standard Parameters - Arrays Only			
17. Apparent velocity	km/s	0.1 km/s	1
18. Epicentre azimuth	degrees	1 degree	1
19. Magnitude M_s		0.1 unit	1

APPENDIX C

CCITT PROTOCOLS IMPLEMENTED IN SUNLINK X.25 SOFTWARE

To facilitate data communications between computers, methods for the handling of data transmission have to be specified. This involves defining various "protocols" for the different levels of interaction and issuing these as "standards". These standards (or "recommendations") specify the type of physical link to be employed and the way in which the data should be formatted for transmission across that link.

The International Standards Organisation (ISO) produced a seven layer model for Open Systems Interconnection (OSI) which is a basis for all communications recommendations. The seven layers are generalised below:

Layer 7 = Application

Layer 6 = Presentation

Layer 5 = Session

Layer 4 = Transport

—————————————————————— X.25

Layer 3 = Network (eg, Packet Switched Network)

Layer 2 = Data Link (LAPB/HDLC) (Frame)

Layer 1 = Physical

The X.25 protocol addresses layer 3 but any functions using layers above must have further protocols implemented. (X.400 addresses Layer 7).

Packet switching is an efficient means of computer-to-computer data transfer involving division of the data into blocks or "packets" with an identification tag on each packet which ensures its arrival at the intended destination. The packets from one file may become multiplexed (alternated) with many thousands of other packets over its transmission path but they will all be brought together at the final destination by the switching process. This type of data transmission is termed "time division multiplexing".

REFERENCE

International Telecommunications Union, CCITT Red Book, Volume VIII, Fascicles VIII.2,VIII.3,VIII.5, and VIII.7. "Data Communications Networks".

Recommendation X.25

X.25 defines how data terminal equipment (DTE) interfaces to data circuit terminating equipment (DCE) in the packet mode on public networks.

There are three levels of the X.25 protocol:

Level 3 - Packet Level

Provides addressing of DTEs and multiplexing of fully reliable end-to-end circuits.

Level 2 - Frame Level

Allows either Link Access Procedures (LAP) or Link Access Procedures (Balanced) (LAPB) to be used for interchange of data between DTE and DCE. LAP or LAPB are subsets of High Level Data Link Control (HDLC). [SunLink X.25 uses LAPB and duplex HDLC].

Level 1 - Physical Level

Two possible alternatives X.21 and X.21bis. X.21 is an electrical and signalling method which supports more flexible information exchange but has not gained full support of the communications industry. X.21bis defines how V.24 or RS232C can substitute for X.21. [SunLink X.25 uses X.21bis].

In the SunLink package, the X.25 service is accessed through the UNIX 4.2BSD socket mechanism by ordinary user processes. The package also implements the X.29/X.3 Recommendations.

Recommendation X.28

The DTE/DCE interface for a start-stop mode data terminal equipment accessing the PAD in a public data network situated in the same country. PAD parameters defined in X.3 are given.

Recommendation X.29

Defines procedures for exchange of control information and user data between packet mode terminal and PAD (Packet Assembler Disassembler).

Recommendation X.3

Defines the PAD facility in a public data network.

PAD Parameters:

Parameter	Description	CCITT Standard Value	
1	PAD recall using a character	1	(possible)
2	Echo	1	(echo)
3	Selection of data forwarding signal	126	(all chars+DEL)
4	Selection of idle timer delay	0	(no time out)
5	Ancillary device control	1	(uses XON/XOFF)
6	Control of PAD service signals	1	(signals sent)
7	Action of PAD on receipt of "break" signal	2	(reset)
8	Discard output	0	(normal data delivery)
9	Padding after carriage return (CR)	0	(no padding)
10	Line folding	0	(no folding)
11	Binary speed of start-stop mode		Speed of DTE
12	Flow control of PAD by start-stop mode DTE	1	(use of XON/XOFF)
13	Linefeed insertion after carriage return	0	(no LF insertion)
14	Linefeed padding	0	(no padding)
15	Editing	0	(no editing)
16	Character delete	127	(char 7/15 DEL)
17	Line delete	24	(char 1/8 CAN)
18	Line display	18	(char 1/2 DC2)
19	Editing PAD service signals	1	(edit)
20	Echo mask	0	(echo all)
21	Parity treatment	0	(no parity detection or generation)
22	Page wait	0	(disabled)

X.29 acts as a packet assembler/disassembler which passes character streams between an application program layered above X.29 and the X.25 protocol layered beneath. It also detects and communicates any changes in the host terminals characteristics (defined by the X.3 parameter set) to the remote end.

APPENDIX D

OVERVIEW OF UNIX

An operating system controls the way in which a computer executes the applications software for a user.

The UNIX operating system was initially developed by the Computing Science Research Group at Bell Laboratories, New Jersey, USA during the late 1960's/early 1970's. The objective was to design an operating system to facilitate effective programming research.

Dennis Ritchie and Ken Thompson wrote a UNIX kernel in C in 1973, which broke with the tradition that an operating system should be written in a low-level assembler language. By writing UNIX in C, the authors had produced a flexible and portable operating system which was not dependant on the environment in which it was developed.

There are three main parts to the UNIX operating system:

the kernel -

manages the resources of the computer such as memory, discs, tape drives, printers, etc.

the file system -

the organising structure for data storage

the shell -

the command interpreter which translates the user requests for system action.

UNIX is an interactive operating system, allowing user commands to be responded to immediately. UNIX is a multi-tasking operating system which can perform several processes at the same time, and it is also a multi-user system which allows more than one person to use the system at the same time.

UNIX uses a "hierarchical" file system or tree-structured file system which involves labelling some files as directories which contain lists of file names and signposts to where the files are stored.

UNIX has many utilities or "tools" for specific user applications such as text manipulation, document formatting, program compilation (in C, BASIC, Pascal and FORTRAN) and also for system administration applications such as monitoring disc usage.

There are several versions of UNIX which differ slightly although the main core is the same for all. A UNIX version for the DEC VAX computers is UNIX V32. Another UNIX version is that which was developed at the University of California at Berkeley called Berkeley UNIX. The UNIX 4.2 BSD (Berkeley Standard Distribution) which the Sun 3/160 runs is a Berkeley UNIX.

REFERENCE

"Introducing the UNIX System". McGilton & Morgan. McGraw-Hill, (1983).

APPENDIX E

WAVEFORM DATA FILE FORMATS FOR DIFFERENT MEDIA

(a) For files on disc:

(i) one end of file marker (EOF) is required at the end of a disc file

(ii) the files may contain Carriage Returns (CR), Line Feeds (LF) or End of Line (EOL) characters according to the requirements of the operating system

(iii) file names should include the ISO 3 letter country code.

VOLUME HEADER
Channel 1 CALIBRATION SECTION WAVEFORM IDENTIFICATION SECTION DATA SECTION
Channel 2 CALIBRATION SECTION WAVEFORM IDENTIFICATION SECTION DATA SECTION
EOF

(b) For files on magnetic tape:

(i) there should be no CR, LF or EOL characters but Inter Record Gaps (IRGs) may be used

(ii) files must be multiples of 80 characters

(iii) the maximum block size is 8000 characters

(iv) two EOFs are required at the end of a file but sections such as volume header and each channel's data should be separated by one EOF

VOLUME HEADER
EOF
Channel 1 CALIBRATION SECTION WAVEFORM IDENTIFICATION SECTION DATA SECTION EOF
Channel 2 CALIBRATION SECTION WAVEFORM IDENTIFICATION SECTION DATA SECTION
EOF
EOF

APPENDIX E (continued)

(c) For WMO/GTS transmission:

(i) same as format for disc but with correct WMO/GTS transmission header

(ii) end file with NNNN

(iii) the total number of characters in the message file must not exceed a value agreed upon with WMO

WMO/GTS ROUTING HEADER
VOLUME HEADER
Channel 1 CALIBRATION SECTION WAVEFORM IDENTIFICATION SECTION DATA SECTION
Channel 2 CALIBRATION SECTION WAVEFORM IDENTIFICATION SECTION DATA SECTION
NNNN

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