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The Experimental Operation of a Seismological Data Centre at Blackness

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SUMMARY

A short account is given of the development and operation of a unit within Blacknest which acts as a centre for handling data received from overseas seismological array stations and stations in the British Isles and also exchanges data with other centres.

The work has been carried out as a long-term experiment to assess the capability of small networks of existing research and development stations to participate in the monitoring of a possible future Comprehensive Test Ban treaty (CTB) and to gain experience of the operational requirements for Data Centres. A preliminary assessment of a UK National Technical Means (NTM) for verifying a CTB is obtained inter alia.

1. INTRODUCTION

BDAC (Blacknest Data Analysis Centre), a small unit within the Blacknest seismological research group of AWRE, has been carrying out a long-running experiment in data collection and data-base management. An initial objective of the work was to demonstrate an operational capability for a small but globally distributed network of "UK type" seismographic arrays to participate in monitoring compliance with a possible future Comprehensive Test Ban treaty (CTB).

In order to achieve this aim a number of new requirements fell upon an infra-structure which existed primarily for the acquisition and analysis of seismological data under research and development conditions. Principal among these new requirements were the establishment of faster lines of communication between Blacknest and recording stations, the organisation of a data-base to facilitate exchanges of data with other centres and the development of facilities to enable routine analyses to be made of seismic events occurring in areas of interest.

The work has been carried out on a long-term basis in order to gain practical experience of some of the problems which would be encountered in the operational monitoring of a CTB. Meanwhile, the objective has been widened to include and strengthen the data flow from a network of much nearer stations in the British Isles and to evaluate the contribution which such a network might offer towards enabling more prompt detections and assessments of particular events of interest to be made.

In this report short descriptions are given of data sources, the data-base, information exchange arrangements and communication links used in the experiment, together with an account of some results obtained from data analysis. Further details of particular items are given as appendices.

2. SOURCES OF DATA

2.1 Array station network

The advantages of a globally distributed network of recording stations for locating the sources of seismic disturbances have been well established (1), while the development of techniques using the phased outputs from seismometer arrays (2) has brought attendant inprovements in detection of weak seismic signals and identification of their likely origin.

As a result of long-standing arrangements for the exchange of data with controlling agencies which operate UK type seismometer arrays in India, Canada and Australia, data from the array stations in those countries, and from one array station in the UK, have for many years supplied an imput to Blacknest for research and development purposes*. The existence of this numerically small, but globally distributed, group of stations with established links to Blacknest provided the initial basis of the experiment outlined in this report.

In a research and development context bulk transmission of all recorded data by slow, low-cost links is generally adequate, but for the purposes of an experiment in operating a Data Centre a more rapid response is needed. However, due to the high cost of using rapid transmission links, it becomes necessary to limit the data transmitted by editing processes of one kind or another at the source. Facilities for processing data at the array stations had not been uniformly developed at the outset of this experiment because earlier established practice, suited to research and development, was for array processing procedures to be applied, as required, to the stations' magnetic tape recordings when they arrived at Blacknest. Each station had nevertheless evolved some local system for event detection suited to the particular requirements of its controlling agency and, with the co-operation of the respective agencies, advantage was taken of these existing systems to provide lists of recorded teleseismic events which could be sent at frequent intervals by an agreed rapid transmission route.

Basic data to be selected by the stations for transmission to the Data Centre were onset times, amplitudes and periods of recorded P-waves, together with beam number information, corresponding to rough locations of epicentres from stations which had array processing systems installed. These are essentially the Level 1 data defined in the report of the ad hoc group of scientific experts of the Conference of the Committee on Disarmament (3).

Initially, data from only two of the array stations, EKA and GBA, were available routinely.The data from EKA consisted of a daily listing of the required parameters of teleseismic events detected by an on-line correlator which produced an unphased summed output from the eight most centrally situated seismometers of the 21 element array, while the data from GBA were daily listings of events recorded by a single seismometer located centrally in the array. At this time, the data from these two array stations were supplemented by data supplied daily from two non-array stations, WOL, South England and SWD, Swaziland, so that some of the functions of a data centre could be implemented.

The general pattern of event reporting thereafter is illustrated in figure 1 which shows the number of event detections from the Array Station Network (ASNET) transmitted each month to BDAC and listed in the data-base

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*The names and locations of these four array stations are:-

GBA	GAURIBIDANUR, Kolar District, Karnataka, India
YKA	YELLOWKNIFE, North-West Territory, Canada
WRA	WARRAMUNGA, Tennant Creek, Northern Territory, Australia
EKA	ESKDALEMUIR, Langholm, Scotland

files. At the end of the first year of operation the transmission by telex of a daily log of events recorded by a single seismometer near to the centre of WRA array commenced. Because of the seismicity of the Banda Sea region north of Australia the number of seismic phases reported during the first month was excessive for the scope of the data-base which had been set up. These regional data had only minor relevance to the main purposes of the experiment and, accordingly, after November 1975, only those events judged by the analyst, who originated the event listings in Australia, to be P-waves from sources at an angular distance of more than 30^{o} from WRA were included in the reports.

Event bulletins produced by the "CANSAM" (4) on-line array processor at the YKA array station became available as a routine after July 1976, while from June 1977 the single instrument data from WRA were replaced by a locally edited daily bulletin containing "teleseismic" event detections produced by an SASP (5) seismometer array station processor. Teleseismic events were arbitrarily defined for this purpose as those which gave rise to P-waves travelling at surface speeds of 15 km/s or more across the array. Later, from October 1977 the complete detection list was transmitted to BDAC where the data were edited, as previously at WRA, to give a residual list of teleseismic wave detections for entry to the data-base files, ie, from this point onwards the number of items reported to BDAC exceeded considerably the number listed.

Apart from the atypical month of November 1975 the histogram of figure 1 indicates a generally upward trend in the number of seismic event reports listed to over 1000 per month resulting from both the establishment of a routine data link to the array stations and the developments to the WRA system. It is expected that, when EKA and GBA are equipped with array processing systems in the near future, further increases in the average number of reports received by BDAC from this network will occur. Also under a facility of the SASP system, transmissions of digital waveform information (CCD LEVEL II data) for recorded waves having particular beam identities can be made as required.

2.2 British Isles stations

A network of stations near, in global terms, to the Data Centre, can give valuable support to a thinly spread, world-wide network by enabling preliminary rough estimates of the locations of many events to be made with a more rapid response than may be possible with the extended network and by providing a reserve source of data when event reporting from the distant stations is inadequate.

The proportions of the British Isles are such that it is possible to define a network of useful dimensions, while remaining technically and financially feasible for the component stations to be connected to a centre (or centres) via the public telephone system, which is extensive. An experimental objective has been to assess the detection capabilities of individual stations and to evaluate the epicentre locating capabilities of particular groups of stations from which data were available, even although the ideal of a wholly "on-line" network, with its advantages of immediacy, common timing and common analysis technique, could not be fully realized.

For this purpose data from three short-period recording stations in South England, controlled by BDAC, WOL, CLB and POS, have been combined with data from BYB - a BDAC controlled station in Pembrokeshire, CWF at a site in the English Midlands under the control of the University of Leicester (6), from EKA - the UK array station in South Scotland - and from stations of the DIAS network (7) in Ireland operated by the Dublin Institute of Advanced Studies. In particular a token British Isles network, "BINET", from which useful preliminary results have been previously described (8), composed of three stations, WOL, EKA and an element of DIAS-NET, has been used as a basis for evaluation of epicentre location capability. Data are also regularly received from the Institute of Geological Sciences' Lowlands Network, LOWNET (9), in Scotland, under the exchange arrangements enumerated in section 3 of this report.

3. DATA FLOW

The seismic data flow into BDAC includes routine event listings supplied by the array stations, messages sent on a regular basis from other centres and on-line signal inputs from British Isles stations. These data, which are all received via rapid transmission links of one kind or another, are listed in table 1. Other data, including magnetic tapes and paper chart records, mailed to Blacknest from the array stations under the earlier established research and development arrangements with the controlling bodies, become available to BDAC in due course, together with seismological bulletins published by a number of other centres.

Part of the outward data flow from BDAC is in the form of data messages of various kinds to other centres and, in addition, a Seismic Event Summary is mailed regularly to several organisations. This is a hard-copy printout of a data-base file (BULLETIN) which is updated at weekly intervals and consists of two parts: the first part contains chronological listings of the raw data (onset times, amplitudes and periods as available) from four array stations, GBA, WRA, YKA and EKA, and one non-array station, WOL; the second part contains estimates of epicentres, origin times and magnitudes of particular seismic events selected by reason of their apparent location near to known nuclear test sites or in other normally aseismic areas. Definitions of items included in these Seismic Event Summaries are given at the beginning of each issue; a copy of the first page of an Event Summary is given in appendix A.

For a number of reasons, data in the mailed Weekly Event Summaries may lag behind the current data by a few weeks and, therefore, centres which have expressed a desire to receive a prompt supply of BDAC data are supplied under the various arrangements for more rapid transmission listed in table 2. A list of organisations which liaise with BDAC for supply or exchange of data is given in appendix B.

TABLE 1

Incoming Data Messages and other Routine Inputs to BDAC

(A) Array Station Data Messages

From	Data Sent	Rate	Route and Method of Transmission	Action in BDAC
EKA	List of SP detections from on-line 8 channel correlator	5/week	Telecopied via direct line to AWRE Comcen, teleprinted onwards to BDAC	Manually load data to data-base file
GBA	List of teleseisms picked from single SP seismo helicorder chart	3/week	GBA to BARC via radio link, BARC to BDAC by Telex via Comcen	Load teleprinted punched paper tape data to data-base via Blacknest PDP11
WRA	"SASP" detection list	5/week	Telex to BDAC via Comcen	Load teleprinted punched paper tape data to data-base via Blacknest PDP11
YKA	"CANSAM" detection list	2/week	YKA to DEMR Ottawa via datel transfer, DEMR to VSC Washington via datel transfer, VSC to BDAC via ARPANET	File transfer data from US ARPANET HOST at ISI to BDAC data-base on RL360/195 computer

(B) Other Data Messages

From	Data Sent	Rate	Route and Method of Transmission	Action in BDAC
IGS	List of recordings from "LOWNET" stations and ESK (Scotland)	1/week	Telex to BDAC via Comcen	Associate with other received data
DIAS	Teleseismic recordings from DIASNET stations	1/week	Telex to BDAC via Comcen	Associate with other received data
FOA	Hagfors (HFS) array data	4/week	Telex to BDAC via Comcen	Associate with other received data

(C) On-Line Data

From	Data Sent	Rate	Route and Method of Transmission	Action in BDAC
CWF	Single SP seismometer output	On-Line	Leased line (Direct to BDAC)	Visually analyse record charts
CLB	Single SP seismometer output	On-Line	Leased line (Direct to BDAC)	Visually analyse records charts
POS	Single SP seismometer output	On-Line	Leased line (Direct to BDAC)	Visually analyse record charts
WOL	Single SP seismometer output	On-Line	Leased line (Direct to BDAC)	Visually analyse record chards
EKA	Single SP seismome r output and Correlator Sum	On-Line	Leased line (Via Comcen)	Visually analyse record charts

TABLE 2

Outgoing Data Messages and other Routine Outputs from BDAC

To	Data Sent	Rate	Method of Transmission	BDAC Data-Base Special File Name
BARC	Latest data from EKA, YKA	5/week	Telex to Bombay	-
SDAC -VSC	Latest data from EKA, GBA, WRA, WOL	5/week	ARPANET file transfer	UKLATEST
NEIS	Latest data from EKA, GBA, WRA, WOL, CWF	5/week	ARPANET file transfer	NEIDAT
FOA	Latest data from WOL, WRA, GBA, EKA	4/week	Telex to Stockholm	ASN
CSEM	Latest data from WOL, EKA, GBA	2/week	Telex to Strasbourg	CSEM
IGS	Latest data from WOL, BYB, CWF	1/week	Telex to Edinburgh	-
DIAS	Latest data from WOL, BYB, CWF	1/week	Telex to Dublin	-
ISC	Any available in BDAC data-base files	As Required	File transfer within RC360/195 Computer	-
*	Seismic Event Summary	1/week	Mail	Bulletin

* General issue to collaborating organisations not receiving BDAC data via Telex or other active link.

4. DATA-BASE

A schematic diagram of the data flow through the BDAC data-base is given in figure 2. The data-base is concerned with the storage of raw data from the array station network (ASNET) and from some of the sites of a British Isles network (BINET). It also holds the results of epicentre determinations for selected events which have been derived via in-house processing on the Blacknest PDP11/34 ANDAC (Array Network Data Analysing Computer) facility, together with the magnitudes m_b and M_s for these events, as available. In addition, the data-base provides a number of different output files; some of these are specific to internal development; others are related to external requirements, either as general user files or as files tailored to the needs of particular organisations.

All the data involved are from openly-publishing, unclassified sources and the data-base is held on the Science Research Council's Rutherford Laboratory 360/195 computer complex, which may be freely accessed by accredited users via on-line terminals of the public switched telephone network (PSTN). Basic information about the structure of the data-base is available to new users, who make access to it, via a "Help" file. A copy of this file is included in appendix A. The 360/195 system is also a HOST computer of the ARPA network, which enables users of this network in the USA to gain access to the BDAC data-base files by agreement and offers the potential of access by users of other large computer networks which may develop links with the ARPA network. A short description of the ARPA network and a logical map of the system are given in appendix C.

Loading of input data from BDAC to the data-base files on the RL360/195 may be accomplished through a leased line link via University College London (UCL) which is also the gateway to the ARPANET, or by direct linkage to the Rutherford Laboratory through the PSTN. For data which are received in the form of hard-copy listings, the loading operation involves a combination of manual keyboard submission of the data from BDAC on-line terminals and automatic reformatting and error detection processing under the control of a "LOADER" program written within the "ELECTRIC" system protocol of the RL360/195. A detailed account of the LOADER and other data-base computer programs has been given by Blamey (10).

In the case of data which are available in the form of teleprinted punched paper tape, submission to the RL360/195 data-base is made under the control of an ANDAC computer program (11) which reads the tape, optionally edits out non-teleseismic events and transmits the resulting output to an RL360/195 input file for further processing via the LOADER program.

The CANSAM lists of detections from the Yellowknife array, YKA are held on file by a HOST computer of the ARPA network at USC-ISI to which they are relayed by courtesy of the Vela Seismological Center in Washington. Transfer of these data can be effected by using a version of a HOST to HOST data switching procedure, FTP, the File Transfer Protocol of the ARPANET (12) whereby, under the control of commands from a BDAC terminal, a YKA data file held by the USC-ISI HOST is switched, via the UCL LONDON TIP, to a file on the RL360/195 reserved for YKA data. An alternative procedure (13), controlled from a terminal of the Blacknest ANDAC computer, first transfers the data from the USC-ISI to an ANDAC floppy disc; a second operation sends the data to the YKA station file on the RL360/195. The latter method permits editing and reformatting of the data as required before onward transmission to the 360/195.

5. COMMUNICATION LINKS

The creation of fast, reliable data communication links are clearly of prime importance in the effective operation of Data Centres. Also, uniformity in data transmission methods would be a desirable aim for centres which became engaged in a fully operational role with obligations for making data exchanges with other centres. While the attainment of such links has remained a long-term objective for BDAC, the experimental basis of the operations conducted by the unit has led to some diversity in the links which have been employed at various times, thus allowing observation of the characteristics and comparative performances of various systems to be made.

5.1 Array stations

Figure 3 shows the present arrangements for transmission of data from array stations EKA, GBA, WRA and YKA to BDAC. The links with the first three of these stations use conventional systems and the signals traffic with them is handled by the AWRE communications centre (COMCEN), which is remote from Blacknest. Incoming signals from the array stations are teleprinted or telecopied (facsimile) from the COMCEN over a private leased line to BDAC; the content of the data signals sent by these stations has been given earlier in this report.

Data received via Telex are in the form of numerical listings and, in the case of the transmitted punched paper tape outputs from a SASP (as at WRA), may include waveform information for selected events. The link to EKA is a leased data quality telephone line which provides a direct multi-channel connection for a number of purposes. One channel of this link is used to transmit a daily signal to the COMCEN containing a list of the detections of an on-line correlator. Facsimile transmission is used on this channel thus providing a means of handling both numeric and analogue (waveform) material in documentary form.

The link through which the CANSAM data bulletins from station YKA are received is more complex. An important component of this link is the ARPA network, a resource sharing computer network principally within the continental United States, but with international extensions to nodes in Norway and the UK. The procedure for transferring CANSAM data files from the USC-ISI HOST, where they are temporarily stored, to the BDAC data-base via the ARPANET has already been described in section 4 in this report. The earlier stages in the complete chain involve, first, the transfer by the controlling agency, the Canadian Department of Energy, Mines and Resources, of the CANSAM bulletins from YKA to Ottawa where the data are held in a file on the Department's CYBER 7400 computer system. The second stage is a double operation carried out by the Vela Seismological Center in Washington who access the data by telephone line data transfer from the CYBER and then transmit them to a file on the USC-ISI HOST computer of the ARPANET on which the UK has a standing account.

5.2 British Isles stations

The schematic diagram in figure 4 shows current BDAC links with a number of individual stations and two networks within the British Isles with which arrangements for regular exchanges of data exist. With the exception of BYB, individual stations are linked via direct leased telephone line connections to Blacknest where the signals received are recorded on magnetic tape and paper charts; in this context the array station EKA is included as an element of a British Isles network linked directly to Blacknest via the COMCEN. The short period recording station WOL additionally serves as one point of a quadripartite Broad Band Array also connected to the Blacknest recording centre through telephone lines.

Eskdalemuir Observatory (ESK) and the Lowlands Network (LOWNET) constitute a group of stations in Scotland under the control of the Institute of Geological Sciences; the DIAS network operated by the Dublin Institute of Advanced Studies is situated to the west of Dublin. The present links with these two networks for exchanges of data are via Telex.

5.3 Other centres

Details of routine data exchanges between BDAC and several other national and international centres have been listed in tables 1 and 2. Further details of three transmission systems used in these exchanges, the ARPA network, Telex and Facsimile, are given in appendices C, D and E.

In addition to these exchanges, data have been transmitted to BDAC for trial periods from three organisations (FOA Sweden, JMA Japan and DEMR Canada) using the Global Telecommunication System (GTS) of the World Meteorological Organisation (WMO). A description of the GTS is given in appendix F and system diagrams are given in figures F1 and F2. Because of its world-wide coverage, use of the GTS for transmission of seismological data has been advocated by the AD HOC committee of experts of the CCD for monitoring in a CTB situation.

Exchanges of seismological data via air mail are also made with a number of the centres listed in appendix B which are not at present linked through any of the message arrangements listed in tables 1 and 2.

6. SOME RESULTS OF THE EXPERIMENT

The five stations EKA, GBA, WRA, YKA and WOL have been the main sources of data on which the BDAC experiment has been based, although the scope of the exercise has been widened to include data from other sources. The following summaries of data-base statistics and analyses results are based on experience with these five stations.

6.1 Event reports

The pattern of event reports received in BDAC up to the beginning of 1978 was illustrated diagrammatically in figure 1, the principal changes in the reporting status of the five stations during the period of operation were that YKA CANSAM reports did not become available until July 1976 and that the WRA SASP became operational in June 1977. Events listed by the BDAC data-base were "teleseisms" (as determined by either an analyst or a processing system at each station).

During 1977 rather more than 11500 items of data were reported from the stations and listed in the data-base (where for this purpose an item of data is a P-wave arrival time with its associated amplitude and period parameters). About 1% of the items reported during the year concerned events presumed to be underground explosions.

In the eight month period following the installation of the SASP at WRA the number of items reported and listed rose to an annual rate of around 13500.

6.2 Reporting of explosions

The totals of presumed underground nuclear explosions for each year during the period 1975 to 1977 are listed in table 3, together with the numbers reported by one or more of the five stations.

TABLE 3

Year	Total of Presumed Underground Nuclear Explosions	Number of Explosions Reported by One or More of the Five Stations	% of Total Reported
1975	35	25	71%
1976	36	29	80%
1977	42	32	76%

The criteria for obtaining yearly totals of presumed underground nuclear explosions include announcements made by governments or official agencies, information published by other agencies (NEIS, SIPRI (14)) and available supporting seismological data. The contents of table 3 and also of tables 4 and 5 following should be interpreted in the light of the information contained in figure 5 which shows the magnitude distributions of the total number of presumed underground nuclear explosions for the years 1975 to 1977 and of those which were reported to BDAC from the five station network during the period. Body wave magnitude data published by the NEIS were used as a basis for the graphs plotted in figure 5, except that in the case of a few explosions of low yield which NEIS reported without magnitude details, values for m_b were assigned which were estimates of a world-wide average value obtained by extrapolation from available single station data. Table 4 omits these explosions from the annual totals of presumed underground explosions and lists only those assigned magnitudes of $m_b = 4.5$ or over by the NEIS.

TABLE 4

Year	Total of Presumed Underground Nuclear Explosions $m_b \geq 4.5$	Number of Explosions Reported by One or More of the Five Stations	% of Total Reported
1975	30	24	80%
1976	31	29	93%
1977	33	30	91%

Table 5 lists the number of explosions of $m_b = 4.5$ or over which were reported to BDAC by 3 or more stations, enabling epicentre determinations to be made. The data cover a period from July 1976 to December 1977 during which reports from all five stations were available.

TABLE 5

Year	Total of Presumed Underground Nuclear Explosions $m_b \geq 4.5$	Number of Explosions Reported by Three or More Stations of the Network	% Located
July 1976 - December 1977	51	36	70%

6.3 Epicentre determination

Table 6 lists the locations of 26 underground explosions in the USSR in 1976 to 1977 for which NEIS data are available and which were recorded by an adequately distributed proportion of the five station group (array station network and WOL) for valid epicentre location. The geographical distribution of the array stations in relation to the USSR E Kazakh test site is shown in figure 6. The comparative listings of table 6 give the NEIS and BDAC versions of the origin times and epicentres of each explosion, together with the computed distance between the NEIS and BDAC epicentres in each case. The stations which comprised the network for a particular BDAC determination are indicated by the abbreviations W, E, G, WA and Y, representing Wolverton, Eskdalemuir, Gauribidanur, Warramunga and Yellowknife. The numbers of stations contributing to the NEIS solutions are also listed.

Table 7 similarly gives comparative listings of NEIS and BDAC epicentre determinations for 11 explosions at the USA Nevada Test Site (NTS).

The average distance between NEIS and BDAC computed epicentres for the USSR explosions in table 6 is slightly less than 10 km. BDAC epicentral positions are fairly systematically displaced to the South-East of the NEIS positions and, therefore, in terms of these particular comparisons, would be amenable to relocation procedures (none have been applied). The average distance between NEIS and BDAC epicentres of the NTS explosions in table 7 is 60 km in the case of those events for which YKA data were not available. For NTS explosions where YKA data were included in the determinations the average distance between BDAC and NEIS epicentres in about 20 km, with systematic displacements of BDAC positions to the North-East.

Figure 7 shows the results of epicentre determinations for ten explosions in the USSR E Kazakh test site area for which data have been available from a 3 element network of stations in the British Isles (BINET) composed of WOL, EKA and one of the stations of the DIAS network. The NEIS epicentres given for these events fall into two zones about 60 km apart. Points representing the NEIS epicentres in the two zones are enclosed within an open circle or an open triangle, respectively, in figure 7. The BINET epicentres for the events are plotted as small solid circles or triangles to indicate to which of the two NEIS epicentral zones they relate. A systematic southward and (generally) eastward displacement of BINET epicentres relative to NEIS locations is apparent, with separations between the mean positions of each set of BINET epicentres and the related NEIS epicentral zone centres of 150 and 110 km.

Computation of epicentres was carried out on the Blacknest ANDAC computer system using a program SPUR (15) for foci at zero depth.

TABLE 6

USSR Explosions

Event Date and Region	NEIS DATA Origin Time Epicentre Magnitude m_b No. Stations Used	BDAC DATA Origin Time Epicentre Average Magnitude m_b Stations Used*	Distance between NEIS and BDAC Epicentres
20 March 1976 E Kazakh	0403 39.3 50.05N 77.34E 5.1 96	0403 39.0 49.99N 77.36E 5.1 W, E, G, WA	6.9 km
21 April 1976 E Kazakh	0502 57.4 49.93N 78.82E 5.3 98	0502 57.1 49.84N 78.75E 5.3 W, E, G, WA	10.3
09 June 1976 E Kazakh	0302 57.6 50.02N 79.08E 5.4 76	0302 57.0 49.97N 79.02E 5.1 W, E, G, WA	7.3
04 July 1976 E Kazakh	0256 57.7 49.92N 78.95E 5.8 136	0256 57.3 49.82N 78.8E 6.1 W, E, G, WA	15.9
23 July 1976 E Kazakh	0232 57.9 49.79N 78.05E 5.1 72	0232 57.4 49.69N 78.02E 5.2 W, E, G, WA	10.5
29 July 1976 W Kazakh	0459 57.7 47.78N 48.12E 5.9 203	0459 57.9 47.79N 48.02E 6.3 W, E, G, Y	7.8
28 August 1976 E Kazakh	0256 57.5 49.97N 79.00E 5.8 157	0256 57.3 49.94N 78.89E 5.9 W, E, G, WA	8.9
29 September 1976 Novaya Zemlya	0259 57.4 73.4N 54.82E 5.8 216	0259 57.4 73.26N 54.89E 6.3 W, E, G, Y	15.1
20 October 1976 Novaya Zemlya	0759 57.7 73.42N 54.57E 5.1 93	0759 57.5 73.3N 54.82E 5.3 W, E, G, Y	15.1

Notes: *Abbreviations for stations used in epicentre determinations are:-
W = WOL, E = EKA, G = GBA, WA = WRA and Y = YKA

The number of stations used for computing magnitude may be less than the number for epicentre determination. (Data from two or more stations are used as available.)

TABLE 6 (Cont.)

Event Date and Region	NEIS DATA Origin Time Epicentre Magnitude m_b No. Stations Used	BDAC DATA Origin Time Epicentre Average Magnitude m_b Stations Used*	Distance between NEIS and BDAC Epicentres
05 November 1976 Central Siberia	0359 56.7 61.53N 112.71E 5.3 87	0359 56.1 61.46N 112.85E 5.3 W, E, G, WA, Y	10.3 km
23 November 1976 E Kazakh	0502 57.4 49.99N 79.01E 5.9 212	0502 57.0 49.95N 78.93E 5.9 W, E, G, WA, Y	7.3
07 December 1976 E Kazakh	0456 57.4 49.88N 78.91E 5.9 185	0456 57.2 49.87N 78.81E 5.8 W, E, G, WA, Y	7.1
30 December 1976 E Kazakh	0356 57.5 49.8N 78.14E 5.1 6.6	0356 57.4 49.76N 78.11E 5.2 W, E, G, Y	5.3
29 March 1977 E Kazakh	0356 57.7 49.79N 78.15E 5.4 125	0356 57.2 49.72N 78.05E 5.4 W, E, G, WA, Y	10.3
29 May 1977 E Kazakh	0256 57.8 49.94N 78.85E 5.6 183	0256 57.4 49.9N 78.69E 6.2 W, E, G, WA, Y	11.8
29 June 1977 E Kazakh	0306 58.0 50.03N 78.93E 5.3 132	0306 57.3 49.94N 78.9E 5.4 W, E, G, WA, Y	9.7
26 July 1977 Central Siberia	1659 57.6 69.53N 90.58E 4.9 101	1659 57.6 69.46N 90.83E 5.1 E, G, WA, Y	12.0
30 July 1977 E Kazakh	0156 58.0 49.78N 78.16E 5.3 68	0156 57.4 49.7N 78.08E 5.4 W, E, G, WA, Y	10.3

Notes: *Abbreviations for stations used in epicentre determinations are:-
W = WOL, E = EKA, G = GBA, WA = WRA and Y = YKA

The number of stations used for computing magnitude may be less than the number for epicentre determination. (Data from two or more stations are used as available.)

TABLE 6 (Cont.)

Event Date and Region	NEIS DATA Origin Time Epicentre Magnitude m_b No. Stations Used	BDAC DATA Origin Time Epicentre Average Magnitude m_b Stations Used*	Distance between NEIS and BDAC Epicentres
10 August 1977 L Baikal Region	2159 58.8 50.92N 110.76E 5.2 64	2159 58.0 50.89N 111.09E 5.1 E, G, WA, Y	23.3
17 August 1977 E Kazakh	0426 57.7 49.81N 78.15E 5.0 60	0426 57.2 49.77N 78.12E 5.0 W, E, G, WA, Y	5.0
20 August 1977 Central Siberia	2159 58.7 64.22N 99.58E 5.0 105	2159 57.9 64.03N 99.82 5.0 W, E, WA, Y	24.3
01 September 1977 Novaya Zemlya	0259 57.5 73.38N 54.58E 5.7 171	0259 57.3 73.25N 54.74E 6.2 W, E, G, WA, Y	15.4
05 September 1977 E Kazakh	0302 57.8 50.09N 78.96E 5.9 166	0302 57.2 50.01N 78.79E 5.9 W, E, G, Y	14.9
29 October 1977 E Kazakh	0306 57.7 49.84N 78.17E 5.5 169	0306 57.3 49.76N 78.08E 5.5 W, E, G, WA, Y	9.8
30 November 1977 E Kazakh	0406 57.5 49.96N 78.93E 5.9 227	0406 56.9 49.93N 78.8E 6.1 W, E, G, WA, Y	9.6
26 December 1977 E Kazakh	0402 57.4 49.88N 78.14E 4.9 59	0402 57.4 49.78N 78.02E 5.2 W, E, G, WA, Y	14.6

Notes *Abbreviations for stations used in epicentre determinations are:-
W = WOL, E = EKA, G = GBA, WA = WRA and Y = YKA

The number of stations used for computing magnitude may be less than the number for epicentre determination. (Data from two or more stations are used as available.)

TABLE 7

USA Explosions

Event Date and Region	NEIS DATA Origin Time Epicentre Magnitude m_b No. Stations Used	BDAC DATA Origin Time Epicentre Average Magnitude m_b Stations Used*	Distance between NEIS and BDAC Epicentres
09 March 1976 S Nevada	1400 00.1 37.31N 116.36W 6.0 240	1359 58.5 36.94N 115.58W 5.7 W, E, G, WA	80.4 km
14 March 1976 S Nevada	1230 00.2 37.31N 116.47W 6.3 298	1229 58.8 37.15N 115.81W 6.3 W, E, G, WA	61.6
17 March 1976 S Nevada	1415 00.1 37.26N 116.31W 6.1 241	1415 00.2 37.78N 116.46W 6.0 W, E, G, WA	59.6
17 March 1976 S Nevada	1445 00.1 37.11N 116.05W 5.8 217	1444 59.7 37.4N 115.92W 5.8 W, E, G, WA	33.4
27 July 1976 S Nevada	2030 00.1 37.08N 116.04W 5.3 121	2029 59.4 37.11N 115.87W 5.1 W, E, WA, Y	14.6
28 December 1976 S Nevada	1800 00.1 37.1N 116.04W 5.5 166	1800 00.0 37.24N 115.73W 5.4 W, E, G, Y	31.0
05 April 1977 S Nevada	1500 00.2 37.12N 116.06W 5.6 221	1459 59.7 37.21N 115.92W 5.7 W, E, G, WA, Y	15.1
25 May 1977 S Nevada	1700 00.1 37.09N 116.05W 5.3 180	1659 59.6 37.18N 115.85W 5.2 W, E, WA, Y	20.0
04 August 1977 S Nevada	1640 00.1 37.09N 116.01W 5.0 139	1639 59.8 37.19N 116.17W 5.1 W, WA, Y	17.7
09 November 1977 S Nevada	2200 00.1 37.07N 116.05W 5.7 216	2200 00.3 37.6N 116.25W 5.8 W, E, G, WA	61.4
14 December 1977 S Nevada	1530 0.2 37.14N 116.09W 5.7 193	1529 59.6 37.2N 115.87W 5.6 W, E, G, WA, Y	20.5

Notes: *Abbrevations for stations used in epicentre determinations are:-
W = WOL, E = EKA, G = GBA, WA = WRA and Y = YKA

The number of stations used for computing magnitude may be less than the number for epicentre determination. (Data from two or more stations are used as available.)

6.4 Magnitude determination

Body-wave magnitude of events for which amplitude and period data are available to BDAC are calculated from the Gutenberg-Richter (16) relationship:-

$$m_b = \log \frac{A}{T} + B(\Delta),$$

where A is the zero-peak displacement in nanometres of the maximum ground motion in the first few cycles of the P-wave arrival, T is the associated wave period in seconds and $B(\Delta)$ is a distance correction.

Values of magnitude m_b for selected events recorded by one or more of the four stations WOL, EKA, GBA and WRA, from which both amplitude and period data are routinely available, are held in a data-base file (PRELIDET), together with provisional epicentre determinations, and are subsequently published in Part 2 of the BDAC seismic event summaries.

In order to establish an approximate relationship for BDAC magnitudes with those obtained from a larger network, a comparison was made between BDAC and NEIS values for a number of presumed underground nuclear explosions in 1975 to 1977 for which both sets of data were available. The results of this comparison are illustrated in figures 8 to 11 in which BDAC magnitudes derived from two or more of the four stations reporting amplitude/period data are plotted against the NEIS values for explosions in particular source areas. These source areas are the USA Nevada Test Site, the USSR test sites at Novaya Zemlya and E Kazakh and a widespread zone of Central Siberia.

The BDAC values of m_b in these plots were derived from application of a least mean squares operation (17) on the individual station magnitude data for the events used, the resultant mean values being plotted against those published by the NEIS, using a procedure based on the method of York (18) to obtain a least mean squares best fitting straight line.

6.5 Data communications

Except for the few sets of comparative tests carried out in connection with the WMO/GTS system, any evaluation of the performance of data communications systems used by BDAC rests largely on qualitative assessments of experience with them. Within this experience there is little evidence of significant levels of information corruption occurring in any of the systems used for data transmission. This view is supported by the results of the tests to evaluate the GTS network in which data sent via that network were supplied in duplicate by some other method. These tests included:-

(a) An eight months period in 1977/1978 when data from the HFS array in Sweden were received via both the GTS and commercial Telex.

(b) A five month period of 1978 for which copies of data put out over the GTS from station MAT in Japan were supplied via mail.

(c) A seven week period of 1978 when YKA CANSAM data from Canada were received via both ARPANET and the GTS.

The usefulness of the observations made in these tests was limited by the arbitrary basis of comparisons in (a) and (c) (indicating only the presence of an error, but not necessarily in which system), by the fact that one system, the GTS, was always a component of the comparisons, by the restricted scope of the exercise (primarily intended for evaluation of the GTS) and by the shortness of one of the tests.

Nevertheless, the comparison established that, while a small number of discrepancies could be detected over a period, gross corruptions of data groups within messages received did not occur on any of the three systems used during the period of observations. A major failure in the GTS performance in the communication of seismological data, as far as these limited experiments were concerned, however, was that not all the messages originated (and delivered via the other routes) were received. The data loss due to this deficiency was serious, amounting to about 25% of the total number of messages originated in the case of both HFS and MAT data; also a few messages received via the GTS from HFS had been terminated before the end of data transmission. None of the data sent from Canada via the GTS were lost and only one numerical discrepancy was noted when compared with data received via the ARPANET, but no special significance could be attached to this result because only seven messages were transmitted at weekly intervals in this test, compared with the very much larger number sent from MAT (daily) and HFS (several times per week) in tests extending over much longer periods.

7. DISCUSSION

This experiment has been concerned with the integration of various facilities, existing and new, internal and external, to provide a framework (ie, data centre, data-base, recording station network and associated communication links) within which to gain practical experience of problems arising from engagement in inter-dependent operations of this kind. To the extent that such an exercise is a co-operative venture, with different motivations among the constituents and a state of continuing development existing in many component parts of the framework, it becomes open-ended. While later additional objectives may be attained, some earlier aims remain unfulfilled. Under the terms of reference set out for the exercise the reasons for achievement or non-achievement of particular aims are valid experimental findings to be set alongside other purely technical results. Some brief comments on the results obtained to date are given in the following sections, under the general headings used earlier in the text.

7.1 The array station network

A principal objective was to demonstrate an operational capability for this network. The performance of these stations was well known and documented throughout many years of research and development by the agencies concerned. What was required, therefore, was not just a re-determination of array station capability, but to ascertain how well this inherent capacity could be translated into reliable and speedy reporting and transmission of data for storing, dissemination and use in combined analytical operations at a data centre.

Although much of this requirement has been realized, a limitation on full achievement of the objectives has been the divergence in the status of the array stations. Thus, while it has been possible to demonstrate the availability of Level 2 data from two arrays (EKA and WRA), it has not yet been possible to obtain all the basic parameters at Level 1 which are required to carry out routine diagnostic procedures at the data centre. In particular, body wave magnitude results have been restricted to the three stations which have supplied details of period (EKA, GBA and WRA) while promptly available R-wave data for calculation of M_s have been confined to BDAC sources in the UK. Application of the m_b:M_s diagnostic has been correspondingly limited.

Detection of events by ASNET is less than the theoretical optimum because only two stations (YKA and WRA) utilise full array power by means of station processors - which provide summed array detections and alert the Data Centre to events of interest by transmitting beam numbers corresponding to approximate epicentral locations. The average threshold detection level for a SASP has been conservatively set at m_b 4.5 (4). Reference to figure 5 shows that, in the routine reporting of events, the attainment of a reporting level of 90% of the total presumed nuclear explosions corresponds to magnitudes of around m_b 5.0. It may be reasonably expected that network detection performance will improve on the present interim results when station processors are installed at all the arrays.

Although the global coverage of stations used by the International Seismological Centre for epicentre determination is more extensive, the determinations published by the NEIS have been used as the basis for comparison with BDAC results in tables 6 and 7, because of their availability for use within the timescale covered in this report. The NEIS do not claim an absolute accuracy for their epicentres better than a few tenths of a degree, but the relative location of epicentres is taken to be consistent. In turn, the BDAC epicentres exhibit a good degree of consistency with those of the NEIS, particularly in the case of explosions at the E Kazakh test site for which the ASNET stations are well distributed within the source window zone of 30 to 90^o distance from the test area. Source-receiver calibration data in the form of published co-ordinates of master events in areas of interest are required for translation of this relative consistency into optimum accuracy of location.

7.2 British Isles stations

While contributions to seismology have not been wholly insignificant, the British Isles have not evolved a well-developed network of seismological stations, because perhaps, formerly, the stimulus for creation of national networks tended to correspond with a country's geographical location near to seismically active regions. Experience in the BDAC experimental programme has underlined the value of the complementary role which can be played by local stations in supporting the seismological monitoring task of a global network.

From the viewpoint of third zone monitoring the British Isles are favourably placed in relation to much of the world's land mass, figure 12, and the major question for a National Technical Means (NTM) based on stations within the British Isles is one of detection capability. In this context, preliminary studies of detection performances of internal UK stations indicate that high non-cultural noise levels may in some cases be matched by high signal amplitudes.

The basis for site selection should, therefore, be signal-to-noise ratio rather than apparent noise level, but with avoidance of proximity to sources of cultural noise.

Accuracy of timing of seismic wave arrivals is of paramount importance for a network having necessarily limited dimensions. The scatter in the epicentre determinations of a three-point British Isles network, illustrated in figure 7, demonstrates the limitations in location accuracy resulting from small network size and uncertainties in teleseismic wave arrival times picked (at two of the three sites) from recordings of single instruments operating in the seismically noisy environment of the British Isles. In order to improve both detection performance and accuracy of arrival time measurement, each site of a tripartite network in the British Isles would ideally possess a multi-element array of simple low cost design; logistic considerations would in this case become a major factor in choice of site location.

In an alternative and more easily envisaged network, composed of single recording points, it would be possible to achieve a system of rather greater dimensional extent and to compensate for occasional signal blackouts at particular sites by a sufficiently numerous density of sites in the network. It would be essential for each recording point to be on-line to a centre to gain the benefits of common timing and waveform analysis procedures.

7.3 Data flow and data-base

The data handling operations in the experiment so far have been confined mainly to Level 1 data, which have consisted principally of the basic parameters of recorded P-waves. An extension of the functions of the present data-base to deal with other basic parameters and Level 2 data is feasible and may be of a lower order of difficulty to accomplish than the routine acquisition of these data.

Access to any of the available BDAC data is a simple operation for users who can connect to the data-base and this does not add to the work load of BDAC. Transfer of data to organisations without this access involves action by BDAC in the preparation, formatting and despatch of messages. A future requirement for supply of data (other than by mailed bulletins) on a larger-scale than is maintained at present would raise many problems of internal organisation. A further question which arises in this connection is a possible move by the seismological community towards adoption of a universally agreed format by all agencies engaging in the exchange of seismological data. This is a problem of predictable difficulty, not least for BDAC, but which will require a solution particularly if proposals to utilise the GTS for routine exchanges of data meet with international agreement.

7.4 Communication links

In the communication of data BDAC has made use of several systems, namely:-

Telex - a public service facility with extensive world coverage, which is business oriented.

The ARPA network - a research oriented system in the USA which has developed international links, operated under the aegis of a US official department.

The GTS - a special purpose, non-public service system with extensive international links.

Leased telephone lines - a hired public service facility.

Facsimile - a pictorial transmission technique using the public telephone network.

The experience with these systems tends to reflect the underlying structure and terms of reference under which they operate. Thus, in the case of Telex a high level of reliability results from an addressed message system using well established send-receive procedures operating under internationally agreed standards as a public service. Maximum efficiency in data transmission is gained when the Telex medium is interfaced at input and output by paper tape handling devices to minimise data rate and minimise errors and human intervention. The limitations are those which arise from a system which is restrained to specifications which guarantee its international availability and reliability. It would be too slow for very large quantities of data and questions of cost effectiveness would arise.

Computer networks, such as the ARPA network, offer the users the advantage of direct access to data-bases without the restrictions imposed by interfacing through an intermediating (PTT) system. More control remains with the user than is at present possible with a public service system, and intended actions can be modified and extended as circumstances dictate, but in contrast with a public service, ease of access, reliability and system availability of the ARPA network (as experienced in the UK) are affected by its own developing status.

Because of its specific application to the movement of large quantities of geophysical data (a large Regional Hub may be dealing with 2×10^{-6} message groups per day) the GTS would appear to be especially suited to the requirements of international exchange of seismological data. The costs of sending messages through this system may be less easily defined than the charges for service through a PTT, since the seismological and meteorological functions may fall within the same government department (UK) or even within the same agency (Japan). At present, however, the GTS appears to be an unreliable medium for the communication of seismological data, the adverse results of the BDAC tests of the system being borne out by the experience of other seismological agencies.

Factors which aid the apparent reliability of the system as far as meteorological data are concerned are: the systematic issue of messages at exact times and regular intervals, including NIL messages for a message due time at which there are no available data; allocation of serial numbers to messages by the originating centres; automatic recognition and routeing of messages from the message headings; exactitude of message headings.

Leased telephone lines have been used for data transmission from several recording sites to Blacknest for long periods, without serious problems. Several qualities of circuits are available from the Post Office, but the standard rate speech quality circuits have proved to be adequate for single or dual mode for transmissions from recording stations.

Facsimile devices use the public telephone network and the reliability of the technique is consistent with that of the telephone service. Transmission of numerical data and waveforms when required has been carried out for several years without major problems between station EKA and BDAC via AWRE. Successful transatlantic test transmissions have also been made.

8. CONCLUDING SUMMARY

(a) This experiment has provided practical experience at Blacknest with the operational requirements for data centres in monitoring a CTB and with the associated problems of rapid collection of data and data-base management.

(b) Several methods of data communication have been evaluated through regular usage over adequate periods of time.

(c) The characteristics and performance of a small but globally distributed network of seismological stations has been assessed through the medium of routine data reports. Parameters studied include:-

(i) Volume of data to be processed annually at the centre.

(ii) Detection of nuclear explosions.

(iii) Epicentre location capability for explosions.

(iv) Network body-wave magnitudes.

(d) Attention has been given to furthering the development of UK National Technical Means for monitoring a Nuclear Test Ban. The performances of recording stations already deployed in a provisional network are under assessment and estimates of the epicentre location capability of a three-point network of British Isles proportions have been obtained from co-operative exchanges of data.

(e) Using existing or newly-established links, BDAC liaises with 20 other centres in various arrangements for the supply or exchange of data. Where appropriate, mutually agreed methods for more effective transfer of data have been implemented.

(f) Data exchanges have so far been confined to dealing with the basic parameters of seismic signals (CCD Level 1); a capacity to deal with additional information (CCD Level 2) such as waveforms has been demonstrated though not fully exploited.

(g) In summary, BDAC has well-established data communications links with a network of array stations, an on-line link to the UK array station and to stations of a local network. Data-base facilities have been established which are accessible to other agencies via the public telephone network and to the USA via the ARPA network, while regular liaison with several other centres is maintained through various media. From its present posture BDAC is equipped to develop or modify its experimental programme as circumstances may require.

9. ACKNOWLEDGMENTS

A detailed list of all those individuals and organisations who have in some way given support in this work would be too difficult to attempt.

Thanks are due to all the organisations named in appendix B of this report for the supply of data and the help and co-operation received in this and other ways is gratefully acknowledged.

Particular acknowledgment is made to the directorates of the three overseas arrays and to our colleagues and friends who are involved in some way with operations at all four array stations. Also the co-operation received from colleagues in the British Isles in ensuring the supply of data has been greatly valued.

I am indebted to Dr H I S Thirlaway for support at all times, to Blacknest colleagues Messrs F A Key and J Young for a great deal of help in computing matters and to Messrs A Douglas and P D Marshall for their advice during preparation of this report.

Most especially, I thank my colleagues of the small BDAC group whose dedicated efforts have contributed much to any success gained in the course of this experiment.

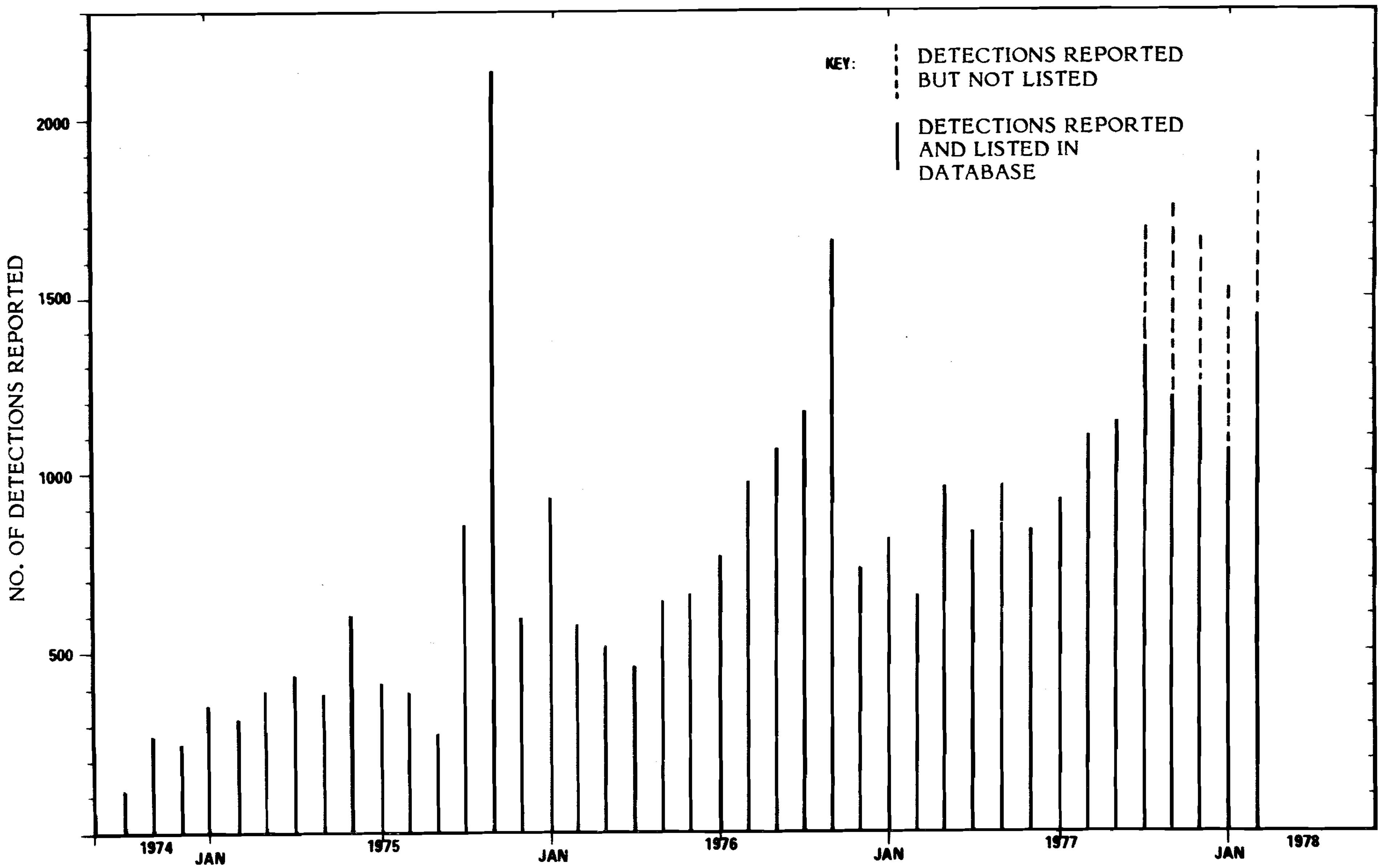


FIGURE 1. HISTOGRAM OF DETECTIONS REPORTED TO BDAC

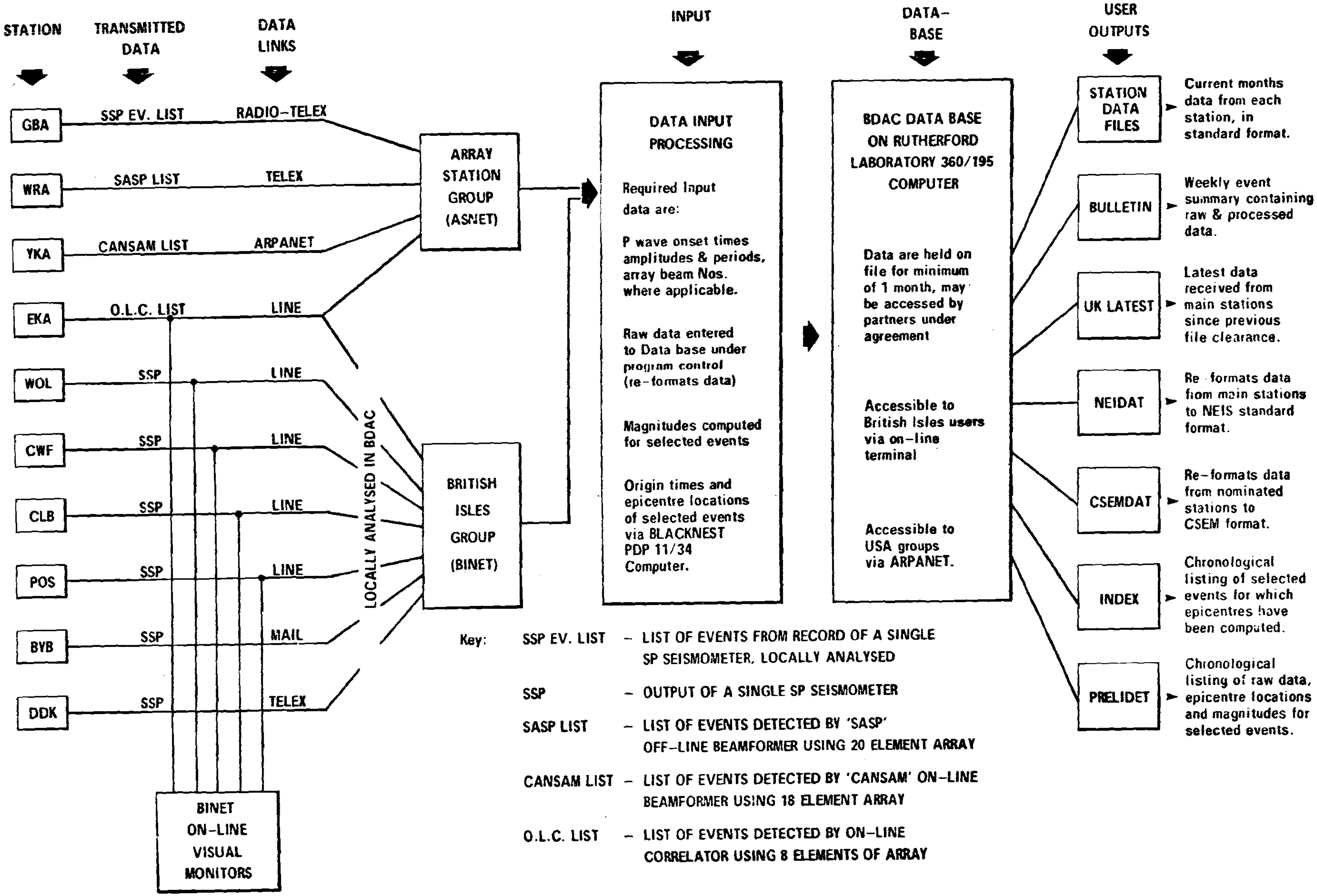


FIGURE 2. Data Flow Through Blacknest Data-Base

SEISMOLOGICAL ARRAY STATIONS

EKA	Seismological Array Station, Eskdalemuir, Scotland
GBA	BARC Seis Array Station, Gauribidanur, India
WRA	Warramunga Seis Station, Northern Territory, Australia
YKA	Canadian Govt Seis Station, Yellowknife, NWT, Canada

SITES CONNECTED TO ARPANET

☐	Computer base linked to Arpanet
(I)	Interface Processor Computers of the Aipanet
SDAC	Seismic Data Analysis Centre, Alexandria, Virginia
USC–ISI	University S California Information Sciences Inst. California
UCL	University College, London
NORSAR	Kjeller, Norway

COLLABORATING ORGANISATIONS

ANU	Australian National University, Canberra Australia
BARC	Bhabha Atomic Research Centre, Trombay, India
DEMR	Dept of Energy, Mines and Resources, Ottawa, Canada
VSC	Vela Seismological Centre, Alexandria, Virginia

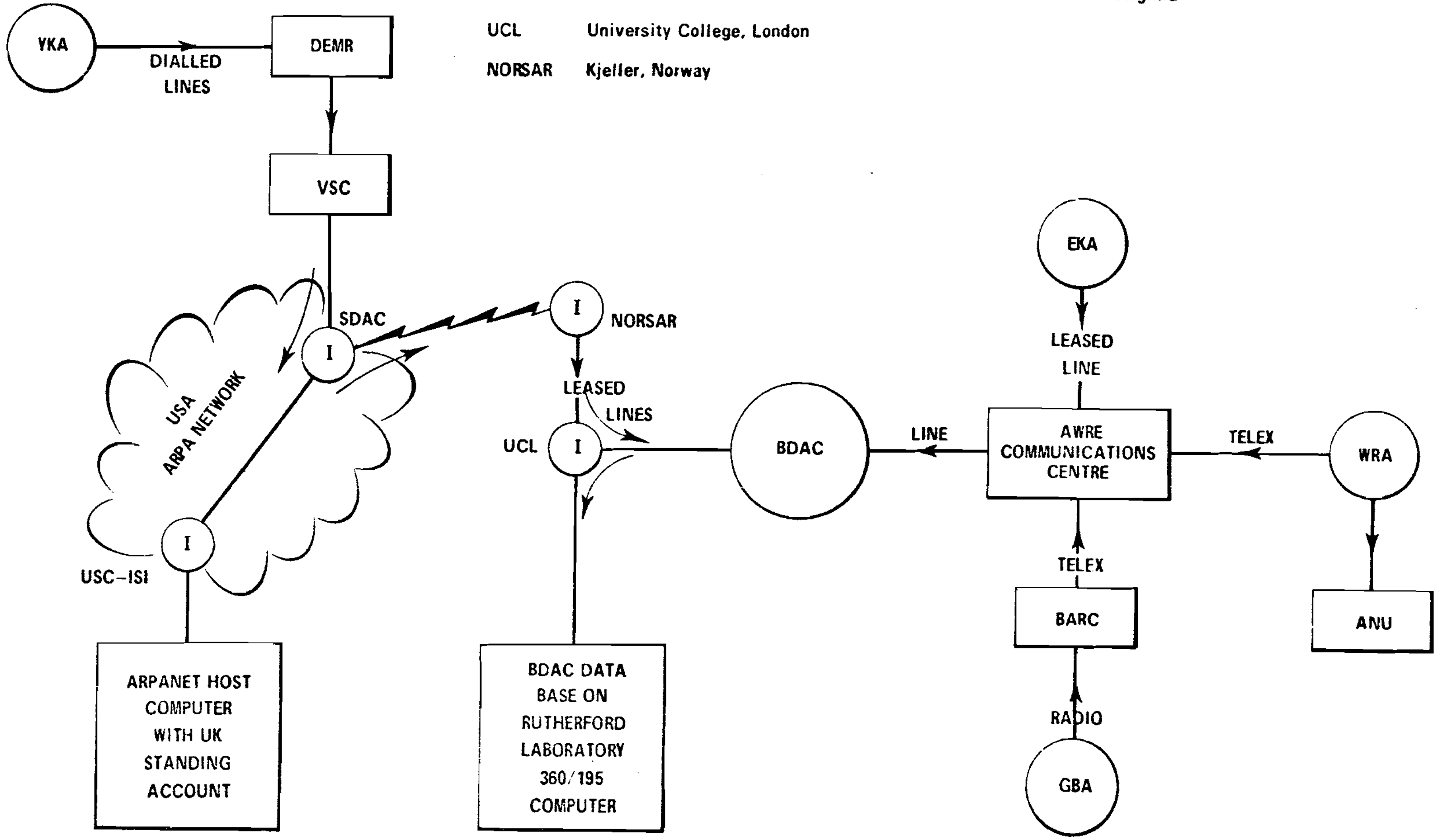
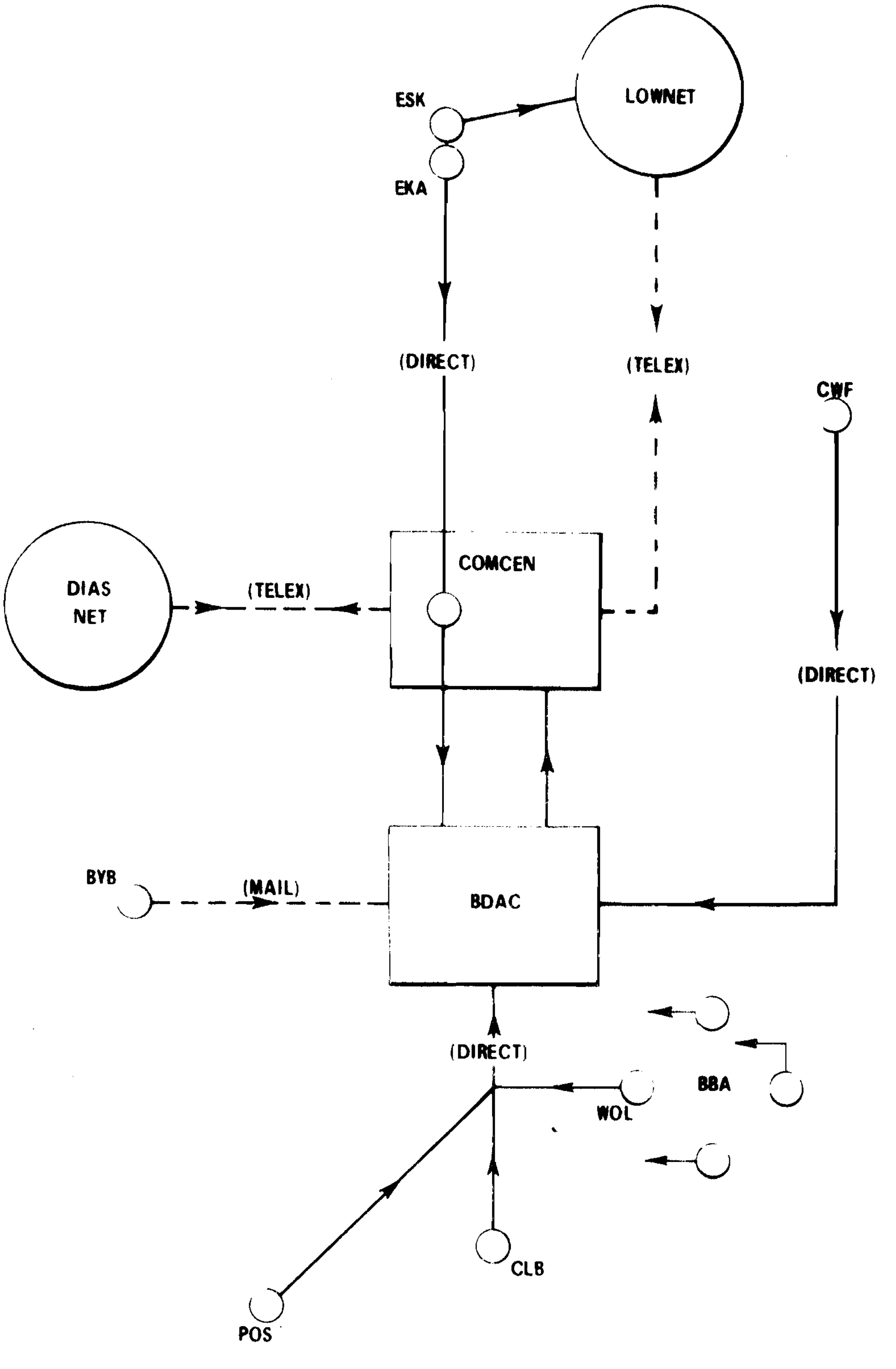


FIGURE 3. BDAC Links to Array Stations and ARPA Network



KEY:	LOWNET	LOWLANDS NETWORK, EDINBURGH, SCOTLAND
	DIAS NET	DUBLIN, IRELAND
	BBA	BLACKNEST BROAD BAND (4 ELEMENT) ARRAY
	EKA	SEISMOLOGICAL ARRAY STATION, ESKDALEMUIR, SCOTLAND
	ESK	ESKDALEMUIR OBSERVATORY, LANGHAM, SCOTLAND
	WOL, CLB POS, CWF, BYB	STATIONS WITH SINGLE SHORT PERIOD SEISMOMETERS
	COMCEN	AWRE COMMUNICATIONS CENTRE

FIGURE 4. Links to Stations & Networks in the British Isles

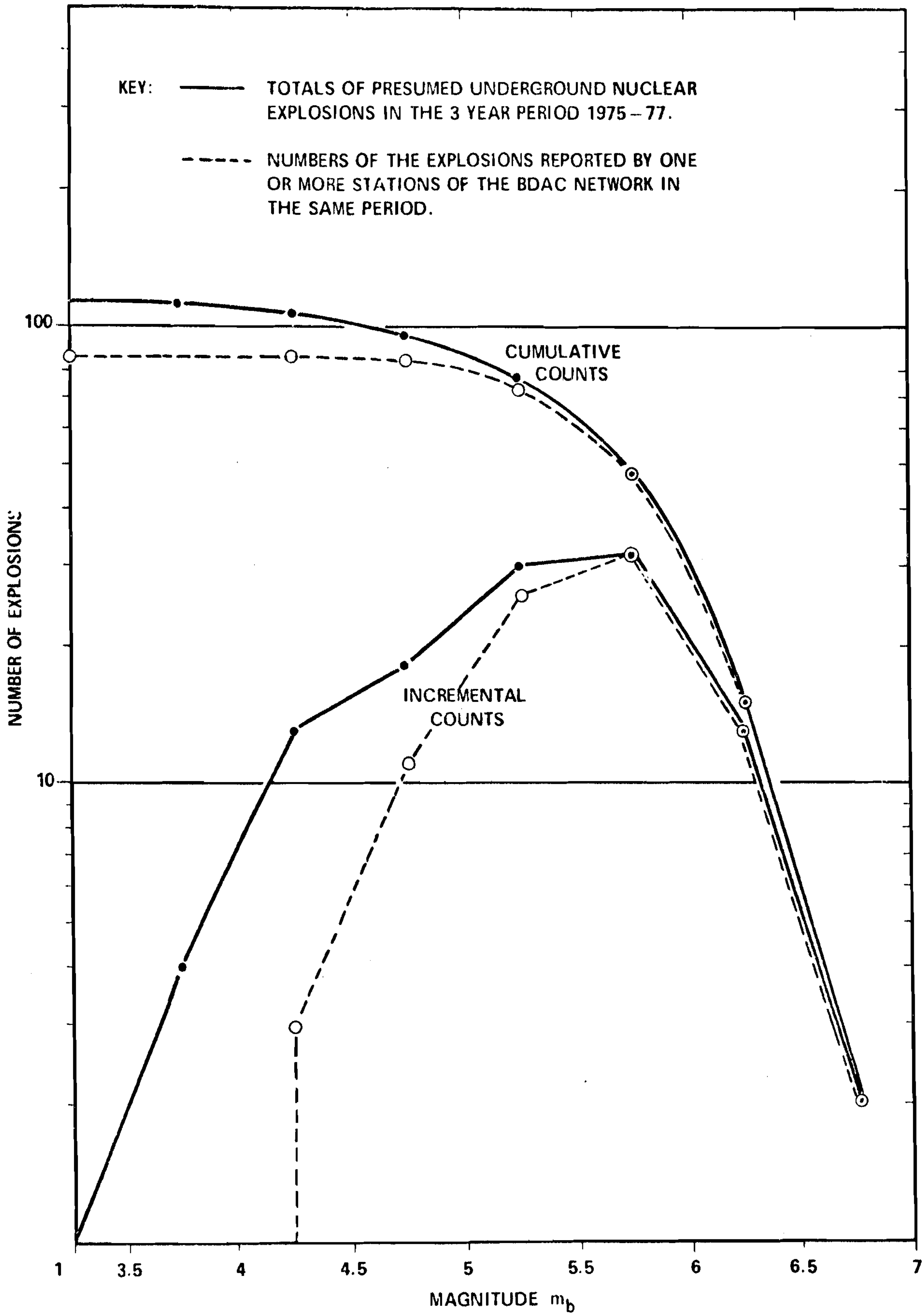


FIGURE 5. INCREMENTAL AND CUMULATIVE COUNTS FOR TOTALS OF PRESUMED UNDERGROUND NUCLEAR EXPLOSIONS AND OF THOSE REPORTED TO BDAC DURING THE 3 YEAR PERIOD 1975 TO 1977

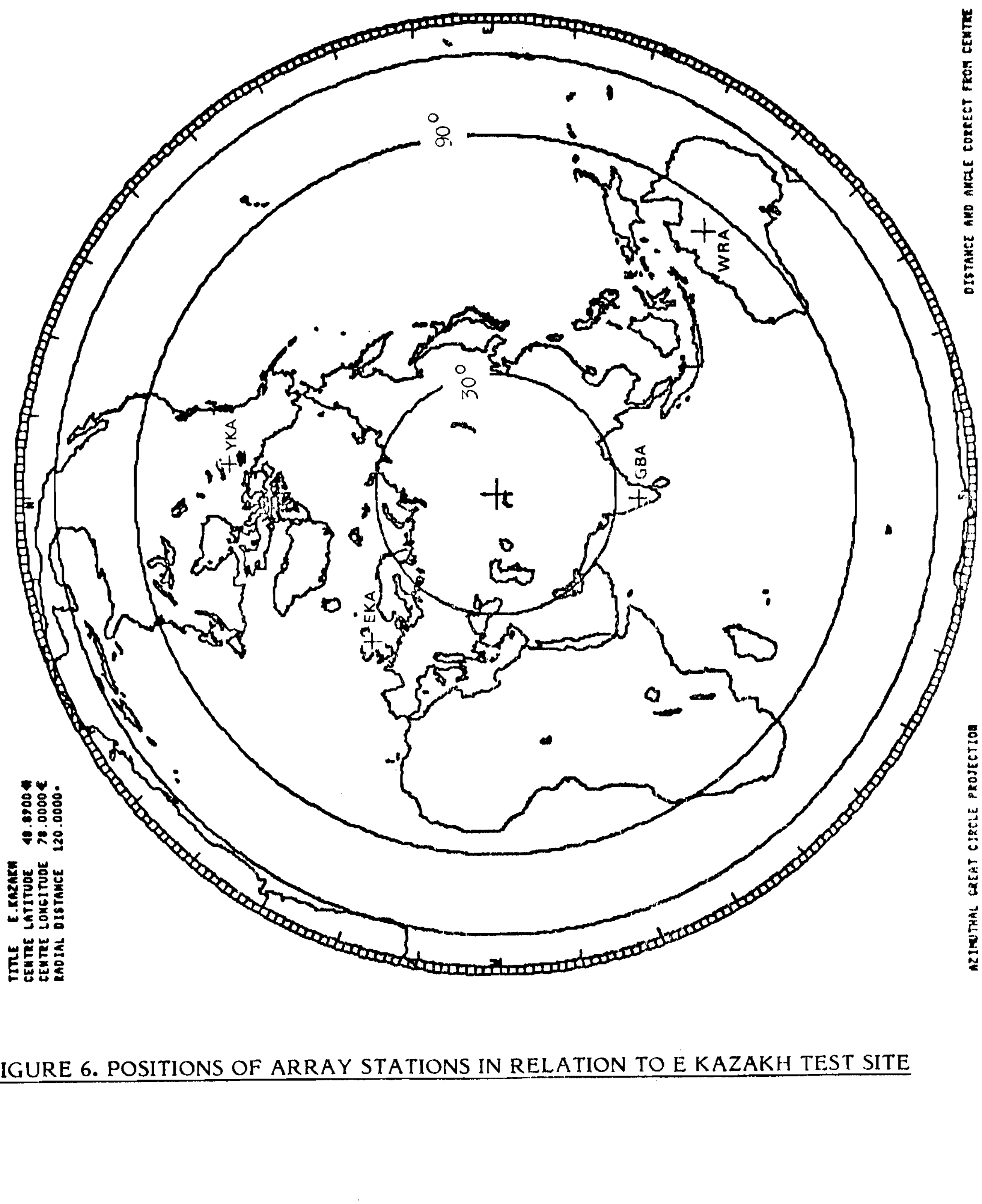


FIGURE 6. POSITIONS OF ARRAY STATIONS IN RELATION TO E KAZAKH TEST SITE

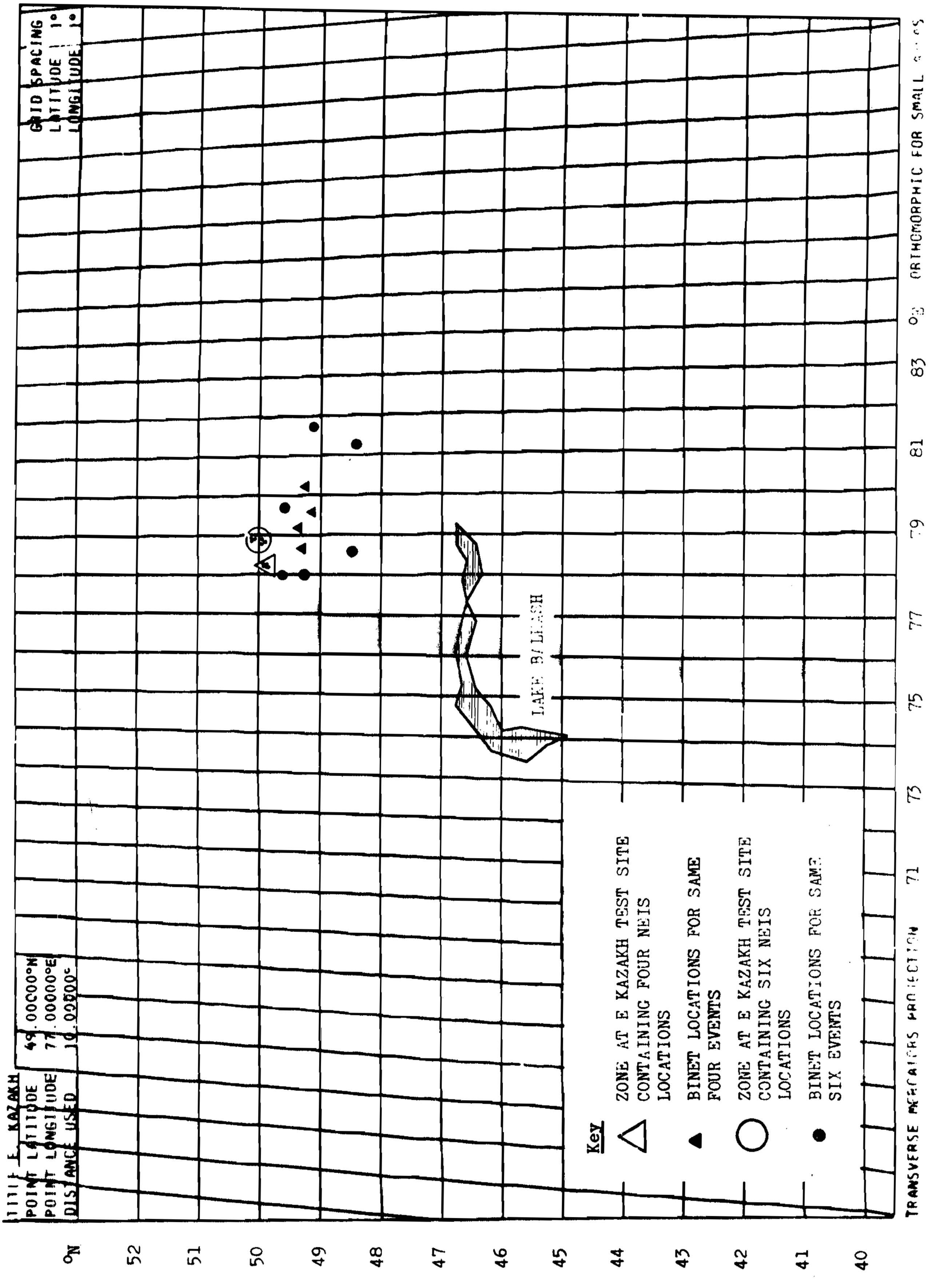


FIGURE 7. BINET EPICENTRE DETERMINATIONS FOR 10 EXPLOSIONS AT E KAZAKH TEST SITE

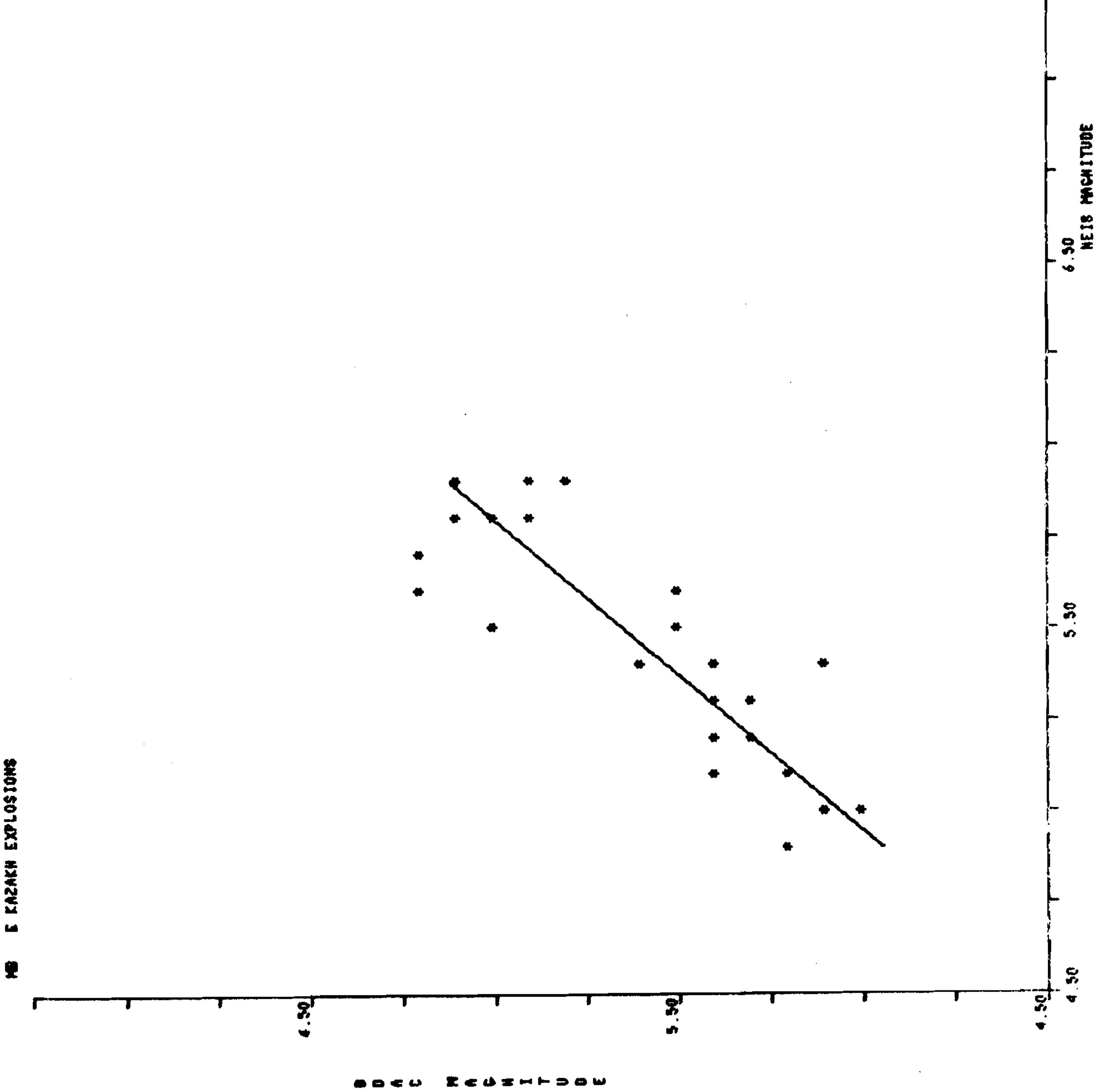


FIGURE 8. BDAC MAGNITUDES VERSUS NEIS MAGNITUDES FOR EXPLOSIONS AT E KAZAKH TEST SITE

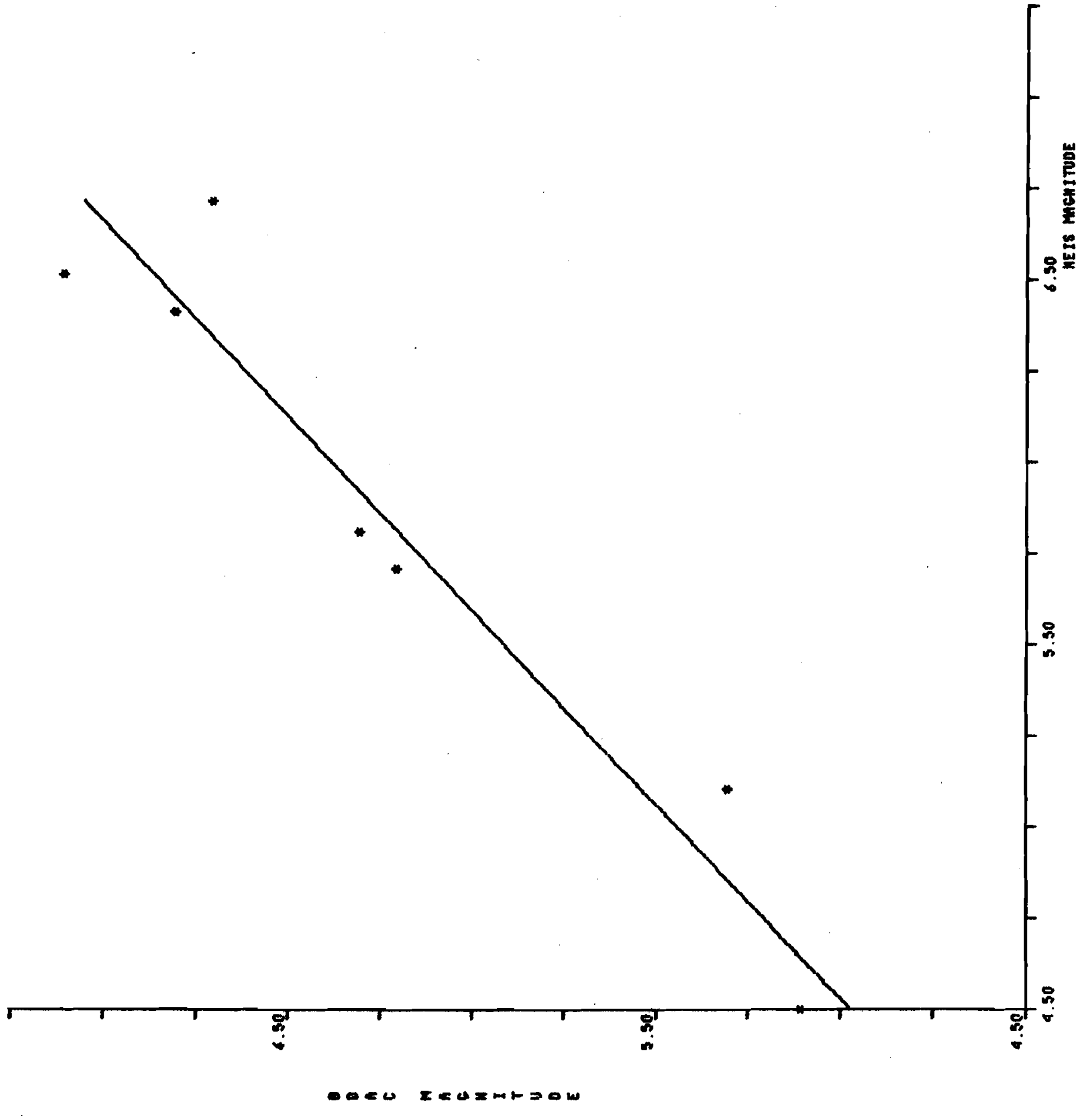


FIGURE 9. BDAC MAGNITUDES VERSUS NEIS MAGNITUDE FOR EXPLOSIONS AT NOVAYA ZEMLYA TEST SITE

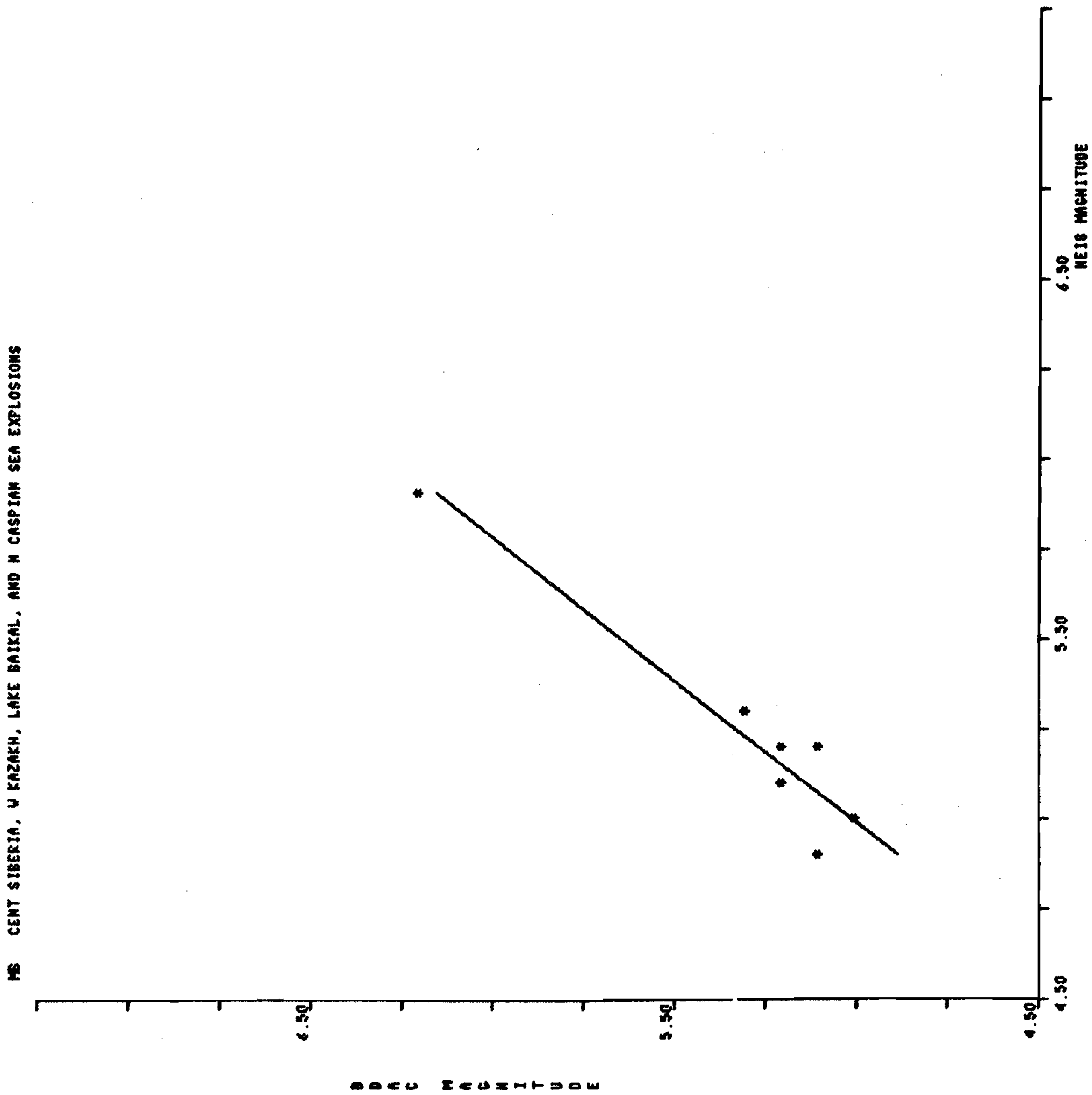


FIGURE 10. BDAC MAGNITUDES VERSUS NEIS MAGNITUDES FORUSSR EXPLOSIONS IN W KAZAKH, CENTRAL SIBERIA AND LAKE BAIKAL AREAS

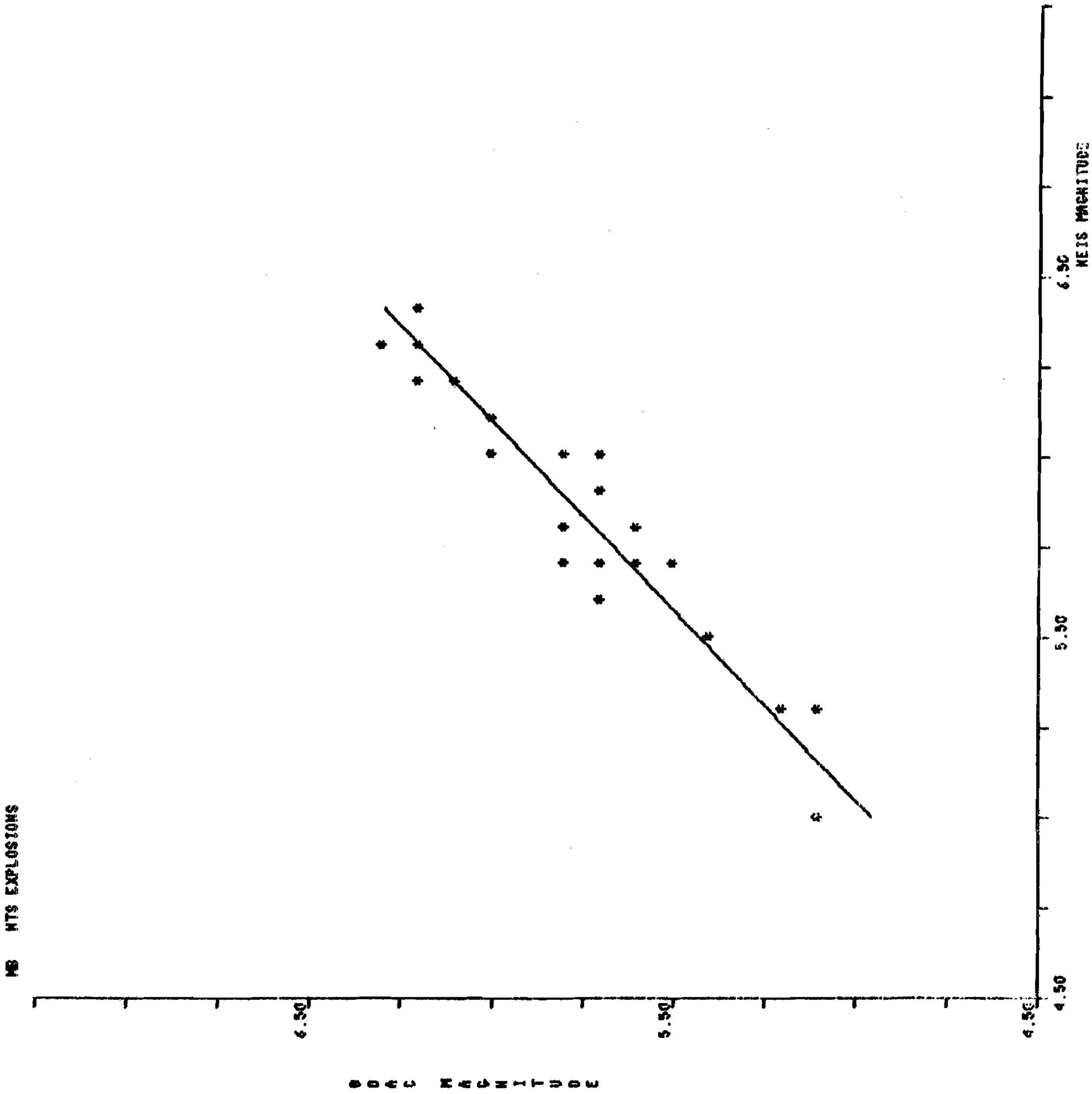


FIGURE 11. BDAC MAGNITUDES VERSUS NEIS MAGNITUDES FOR USA EXPLOSIONS AT NEVADA TEST SITE

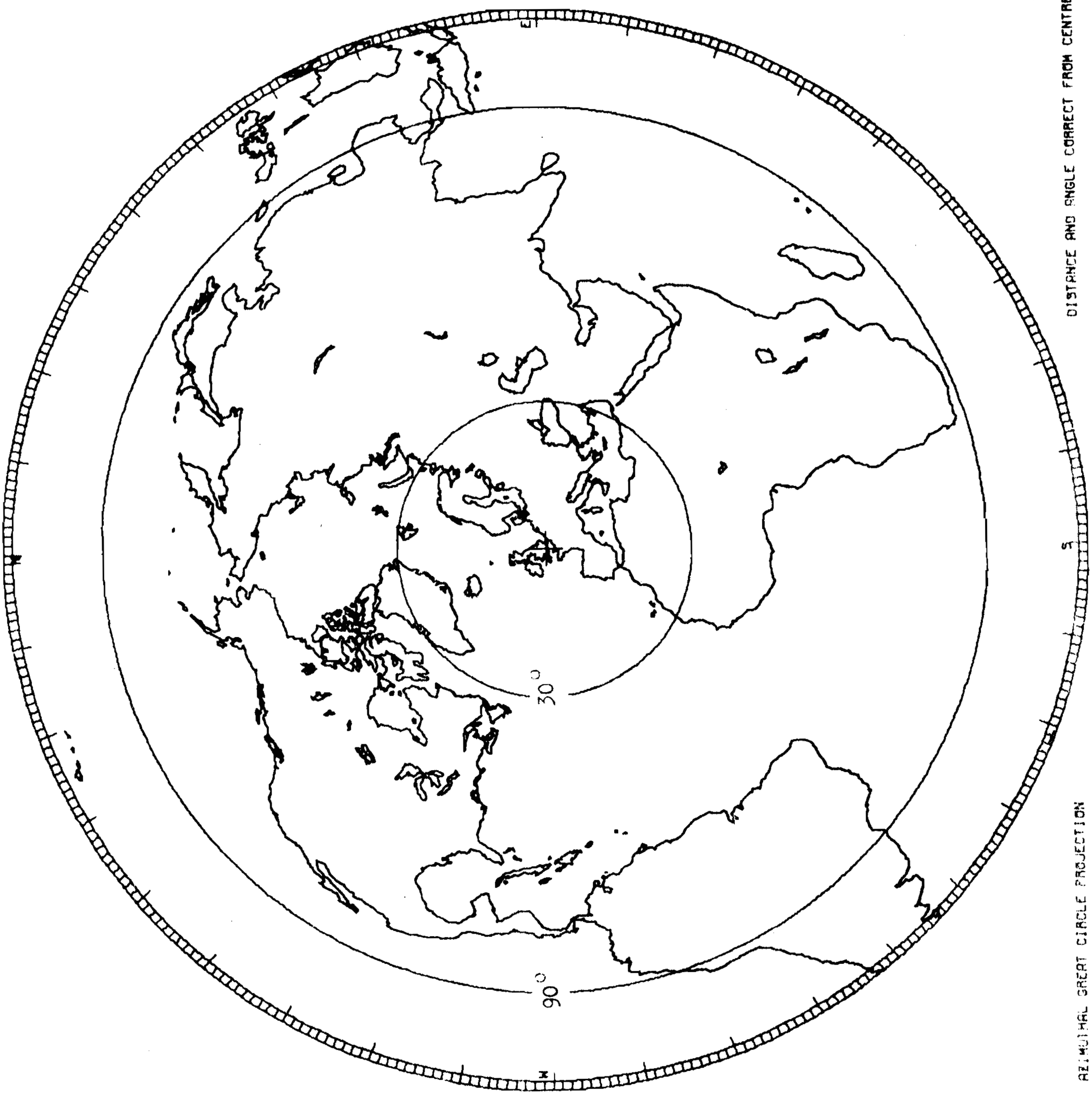


FIGURE 12. THE SOURCE WINDOW (ZONES WITHIN 30° - 90°) FOR THE BRITISH ISLES

APPENDIX A

A1. USER INFORMATION FOR BLACKNEST SEISMIC EVENT SUMMARIES

ISSUED BY: BLACKNEST DATA ANALYSIS CENTRE PE-MOD BLACKNEST, BRIMPTON, NR READING RG7 4RS BERKSHIRE, ENGLAND.

PART 1 LISTS OF DETECTIONS

DATES AND ARRIVAL TIMES OF OBSERVED SEISMIC WAVES ARE GIVEN IN SEPARATE CHRONOLOGICAL LISTS FOR EACH CONTRIBUTING STATION. AMPLITUDE,PERIOD AND BEAM NUMBERS ARE GIVEN FOR THOSE STATIONS SUPPLYING THESE DATA.

NOTES
1.EVENT DETECTIONS ARE INCLUDED AT THE DISCRETION OF A LOCAL ANALYST OR ARE SELECTED BY AN ON LINE PROCESSOR.
2.NORMALLY ONLY TELESEISMIC P-WAVES ARE REPORTED.
3.CURRENT FORMAT OF THESE DATA LISTINGS IS BDAC 5.

PART 2 ANALYSIS OF DATA FROM SELECTED SEISMIC FOCI

ESTIMATES ARE GIVEN OF THE EPICENTRES,ORIGIN TIMES AND MAGNITUDES OF SEISMIC FOCI LOCATED CLOSE TO NUCLEAR TEST SITES OR IN ASEISMIC AREAS.THESE ESTIMATES ARE MADE USING ONLY THE DATA FROM THE STATIONS LISTED UNDER EACH FOCUS.

JEFFREYS AND BULLEN(1958) TRAVEL TIME TABLES ARE USED IN THE CALCULATION OF EPICENTRES AND ORIGIN TIMES;ALL FOCI ARE ASSUMED TO BE AT THE SURFACE.BECAUSE ONLY A SMALL NUMBER OF STATIONS ARE USED THE UNCERTAINTIES IN THE ESTIMATES WILL OFTEN BE LARGE.

FOR ARRAY STATIONS THE ARRIVAL TIMES GIVEN ARE THOSE AT THE ARRAY REFERENCE POINTS.WHEN ARRIVAL TIMES ARE AVAILABLE FROM FEWER THAN 3 STATIONS,THE PUBLISHED EPICENTRES ARE DERIVED FROM THE ROUGH ESTIMATES OF THE EPICENTRAL AZIMUTH AND DISTANCE OBTAINED AT EACH ARRAY STATION.

SUBSEQUENT ADDITIONS OR REVISIONS TO PART 2 OF PREVIOUSLY ISSUED BULLETINS MAY BE MADE.

EXPLANATION OF COLUMN HEADINGS

AMP.	AMPLITUDE (NANOMETRES 1/2 PEAK TO PEAK)
PER.	PERIOD (SECONDS)
BEAM NO.	BEAM NUMBER(KEY ET AL 1977) (WEICHERT & HENGER 1975(YKA))
REGION	REGION NAME (FLINN & ENGDAHL)
LAT.	LATITUDE OF EPICENTRE (DEGREES)
LONG.	LONGITUDE OF EPICENTRE (DEGREES)
MB	BODY WAVE MAGNITUDE (GUTENBERG & RICHTER 1956)
MS	SURFACE WAVE MAGNITUDE (MARSHALL & BASHAM 1972)

STATION REFERENCE POINTS FOR REPORTED ARRIVAL TIME DATA			INSTRUMENT CONFIGURATIONS FOR ARRIVAL TIME DATA REPORTS
WOL	51 18 46N	01 13 22W	SINGLE SHORT PERIOD SEISMOMETER
EKA	55 19 59N	03 09 33W	UNPHASED SUM OF 8 SHORT PERIOD SEISMOMETERS
*GBA	13 36 15N	77 26 10E	SINGLE SHORT PERIOD SEISMOMETER
WRA	19 56 52S	134 21 03E	PHASED ARRAY SUM OF UP TO 20 SHORT PERIOD SEISMOMETERS
YKA	62 29 36N	114 36 19W	PHASED ARRAY SUM OF UP TO 18 SHORT PERIOD SEISMOMETERS

*NOTE: ALTERNATIVE LOCATIONS MAY SOMETIMES BE USED AT STATION GBA. WHEN THIS OCCURS, ADDENDA GIVING DETAILS OF THE CHANGES WILL BE INCLUDED AT THE END OF PART 1 OF THE SUMMARY.

DATA ARE SUPPLIED BY COURTESY OF THE FOLLOWING ORGANISATIONS:

GBA DATA: BHABHA ATOMIC RESEARCH CENTRE, SEISMOLOGY SECTION, MOD.LABS., TROMBAY, BOMBAY 400 085, INDIA.

WRA DATA: THE AUSTRALIAN NATIONAL UNIVERSITY, RESEARCH SCHOOL OF EARTH SCIENCES,INSTITUTE OF ADVANCED STUDIES,PO BOX4 CANBERRA,AUSTRALIA

YKA DATA: DEPARTMENT OF ENERGY MINES AND RESOURCES, EARTH PHYSICS BRANCH, DIVISION OF SEISMOLOGY & GEOTHERMAL STUDIES,OTTAWA,CANADA K1A OY3

A2. USER HELP FILE FOR BDAC DATA-BASE

HELP IS A SUBDIRECTORY OF 3WMAINDR AND CONTAINS SIX FILES H1 TO H6
WITH CONTENTS AS FOLLOWS:-

H1 STATION EVENT LISTS.
H2 EPICENTRE AND MAGNITUDE DETERMINATIONS.
H3 BULLETIN DETAILS.
H4 EXPLANATIONS OF BULLETIN COLUMN HEADINGS AND STATEMENTS IN EVENT LISTS.
H5 LOCATION OF REPORTING STATIONS & INSTRUMENTATION DETAILS.
H6 ADDRESSES OF CONTRIBUTING STATIONS.

PLEASE USE THE COMMAND 'TYPE FL=H1'(OR H2,ETC.) TO OBTAIN THE PARTICULAR HELP SECTION REQUIRED.

NOTE:ANY COMMANDS OF THE FORM 'TYPE----' REFERRED TO IN THE TEXT OF FILES H1 TO H6 CAN BE IMPLEMENTED AFTER THE INITIAL USE OF THE SET DIRECTORY COMMAND 'SETD C=3WMAINDR'.

H1 STATION EVENT LISTS

CHRONOLOGICAL LISTS OF TELESEISMIC P WAVE ARRIVALS[*] ARE HELD IN SEPARATE MONTHLY FILES FOR EACH CONTRIBUTING STATION.
THE CURRENT FORMAT FOR THESE LISTS IS BDAC 5.
IN THIS FORMAT COLUMNS IN THE LISTED DATA READING FROM LEFT TO RIGHT GIVE:
MONTH,DAY,HRS,MINS,SECS+TENTHS,AMP(NM 1/2PEAK TO PEAK),PERIOD(SECS),
BEAM NUMBER(S) (FOR ARRAY STNS WHEN AVAILABLE)

DATA RETENTION IN FILES WITH IMMEDIATE ACCESS IS NOT LESS THAN 31 DAYS.
TO PRINT OUT CURRENT DATA FOR A STATION USE THE COMMAND 'TYPE' FOLLOWED BY FL=STATION CODE.CURRENT MONTH(S) NAME & YEAR.
E.G.'TYPE FL=WOL.JAN78" OR 'TYPE FL=EKA.FEB78"
TO LIMIT PRINT-OUT TO N LINES OF DATA ADD ',NL=N' TO THE COMMAND
E.G.'TYPE FL=GBA.FEB78,NL=10'WILL PRINT OUT 10 LINES OF GBA FEB DATA

EARLIER DATA ARE ARCHIVED FOR A NOMINAL 2 YEAR PERIOD.

[*NOMINAL TERMS OF REFERENCE.EVENTS ARE INCLUDED AT DISCRETION OF LOCAL ANALYST OR SELECTED BY LOCAL ON-LINE PROCESSOR]

H2 EPICENTRE AND MAGNITUDE DETERMINATIONS

DETAILS OF DETERMINATIONS OF EPICENTRES,ORIGIN TIMES & MAGNITUDES OF EVENTS LOCATED IN THE PROXIMITY OF NUCLEAR TEST SITES OR IN ASEISMIC AREAS ARE HELD IN TWO FILES,INDEX & PRELIDET. ESTIMATES ARE BASED ONLY ON THE DATA REPORTED IN THE STATION EVENTS LISTS AND ARE PROVISIONAL.

THE INDEX FILE CONTAINS CHRONOLOGICAL LISTINGS OF EVENTS IN THE ABOVE CATEGORY FOR WHICH DETERMINATIONS HAVE BEEN MADE.A SINGLE LINE ENTRY FOR EACH EVENT GIVES THE DATE,SEISMIC REGION,COMPUTED ORIGIN TIME AND EPICENTRAL CO-ORDINATES.THIS FILE PROVIDES A SUMMARY OF DETERMINATIONS MADE IN THE CURRENT YEAR AND ACTS AS AN INDEX FOR THE PRELIDET FILE. THE PRELIDET FILE CONTAINS ENTRIES IN THE SAME ORDER AS LISTED IN THE FILE INDEX.THE COMPLETE ENTRY FOR EACH EVENT LISTED CONTAINS DATE, SEISMIC REGION,COMPUTED ORIGIN TIME AND EPICENTRAL CO-ORDINATES AS IN FILE INDEX,FOLLOWED BY P WAVE ARRIVAL TIMES,AMPLITUDES,PERIODS, MAGNITUDES MB & MS(WHEN AVAILABLE) FOR EACH STATION CONTRIBUTING TO THE EPICENTRE LOCATION GIVEN.

TO PRINT OUT THE CURRENT INDEX FILE USE THE COMMAND'TYPE FL=INDEX78'
TO PRINT OUT THE PRELIDET FILE USE'TYPE FL=PRELIDET'
IF'PRELIDET' DATA FOR ONE PARTICULAR EVENT ONLY IS REQUIRED THE USER CAN PROCEED AS FOLLOWS:-

A)OBTAIN EVENT TITLE FROM FILE INDEX78
B)OBTAIN THE LINE NUMBER OF THE ENTRY FOR THE EVENT IN FILE 'PRELIDET' USING THE COMMAND'TYPE FL=PRELIDET,NL=1:'TITLE FROM INDEX78''
WHERE'TITLE FROM INDEX78' IS AS MANY CHARACTERS(PACKED CLOSE TOGETHER IS O.K.)AS ARE NEEDED TO DISTINGUISH IT FROM NEIGHBOURING LINES.
C)SUBTRACT ONE FROM THE LINE NUMBER GIVEN BY THIS PRINT-OUT AND LET THIS NUMBER BE NN.WITH THIS INFORMATION USE THE FOLLOWING COMMAND TO GET THE REQUIRED PRINT-OUT
'TYPE FL=PRELIDET(NO),LINENUM=NO,NL=11,LN=NN'

H3 BULLETIN DETAILS

BULLETIN IS A COMPOSITE FILE CONTAINING THE TITLE PAGES AND THE TWO SECTIONS (PART 1 & PART 2) OF THE PUBLISHED BLACKNEST SEISMIC EVENT SUMMARY.

PART 1 HOLDS SEQUENTIAL EXTRACTS OF DATA FROM EACH OF THE SEPARATE STATION EVENT LISTS IN FORMAT BDAC5. THESE EXTRACTS HOLD ALL DATA REPORTED IN THE 7 DAY PERIOD BETWEEN THE DATES GIVEN IN THE BULLETIN HEADINGS.

PART2 HOLDS EPICENTRE AND MAGNITUDE DETERMINATIONS FROM THE PRELIDET FILE WHICH HAVE NOT BEEN INCLUDED IN EARLIER BULLETIN COMPILATIONS.

TO PRINT OUT THE CURRENTLY AVAILABLE BULLETIN USE THE COMMAND 'TYPE FL =BULLETIN'.TO LIMIT TO N LINES ADD',NL=N' TO THE COMMAND.

THE BULLETIN FILE IS NORMALLY UPDATED AT WEEKLY INTERVALS.THE BULLETIN COVERING THE WEEK PRECEDING THE CURRENT BULLETIN PERIOD IS ALSO AVAILABLE ON IMMEDIATE ACCESS VIA THE COMMAND 'TYPE FL=PREVBULL'

EARLIER BULLETINS ARE ARCHIVED.

DATA CURRENTLY LISTED IN THE EVENT SUMMARY ARE FROM THE FOLLOWING STATIONS EKA,WOL,GBA,WRA,YKA
STATION SWD CLOSED DOWN 20MAR76,DATA UP TO THIS DATE REMAINS IN ARCHIVES.
AT PRESENT ONSET TIMES ONLY ON FILE FROM STATION YKA.

H4 EXPLANATION OF COLUMN HEADINGS & STATEMENTS IN EVENTS LISTS

AMP.	AMPLITUDE (NANOMETRES 1/2 PEAK TO PEAK)
PER.	PERIOD (SECONDS)
REGION	REGION NAME (FLINN & ENGDAHL)
LAT.	LATITUDE OF EPICENTRE (DEGREES)
LONG.	LONGITUDE OF EPICENTRE (DEGREES)
MB	BODY WAVE MAGNITUDE (GUTENBERG & RICHTER 1956)
MS	SURFACE WAVE MAGNITUDE (MARSHALL & BASHAM 1972)
NO DATA	NO EVENTS REPORTED BY STATION ANALYST.THIS NORMALLY REFERS TO THE 24HR PERIOD COMMENCING AT 0000 HRS ON THE DATE GIVEN UNLESS OTHERWISE STATED IN THE LIST.
OUTAGE A	USABLE VISUAL RECORD NOT AVAILABLE TO ANALYST MAGNETIC TAPE RECORD NORMALLY AVAILABLE IN DUE COURSE.
OUTAGE B	SYSTEM DOWNTIME,NO RECORDS(VISUAL OR MAG.TAPE) AVAILABLE.

H5 LOCATION AND INSTRUMENTATION DETAILS FOR REPORTING STATIONS

STATION REFERENCE POINTS FOR REPORTED ARRIVAL TIME DATA			INSTRUMENT CONFIGURATIONS FOR ARRIVAL TIME DATA REPORTS
CWF	52 14 17.8N	01 18 26.1W	SINGLE SHORT PERIOD SEISMOMETER
WOL	51 18 46N	01 13 22W	SINGLE SHORT PERIOD SEISMOMETER
EKA	55 19 59N	03 09 33W	UNPHASED SUM OF 8 SHORT PERIOD SEISMOMETERS
GBA	13 36 15N	77 26 10E	SINGLE SHORT PERIOD SEISMOMETER
WRA	19 56 52S	134 21 03E	PHASED ARRAY SUM OF UP TO 20 SHORT PERIOD SEISMOMETERS
YKA	62 29 36N	114 36 19W	PHASED ARRAY SUM OF UP TO 18 SHORT PERIOD SEISMOMETERS

H6 ADDRESSES OF CONTRIBUTING ORGANISATIONS

THIS DATA-BASE IS MAINTAINED BY BLACKNEST DATA ANALYSIS CENTRE(BDAC)

POSTAL ADDRESS
BDAC
PE-MOD BLACKNEST
BRIMPTON,READING RG7 4RS
BERKSHIRE
ENGLAND.

TELEPHONE 07 356 4111 EXT.6257(F.H.GROVER)
" " " EXT.7714(C.BLAMEY)

TELEX 848104/5 (VIA AWRE ALDERMASTON)

FACSIMILE 07 356 5328 (TELECOPIER TERMINAL)

ARPANET ADDRESS UK AT USC-ISI(ATTN:GROVER BRE)

DATA FROM UK STATIONS WOL AND EKA CONTROLLED BY BDAC
OTHER DATA SUPPLIED BY COURTESY OF THE FOLLOWING ORGANISATIONS:-

GBA DATA: BHABHA ATOMIC RESEARCH CENTRE,SEISMOLOGY SECTION, MOD LABS.,TROMBAY BOMBAY 400 085,INDIA.

WRA DATA: THE AUSTRALIAN NATIONAL UNIVERSITY,RESEARCH SCHOOL OF EARTH SCIENCES,INSTITUTE OF ADVANCED STUDIES,PO BOX 4 CANBERRA,AUSTRALIA.

YKA DATA: DEPARTMENT OF ENERGY MINES AND RESOURCES,EARTH PHYSICS BRANCH,DEPARTMENT OF SEISMOLOGY & GEOTHERMAL STUDIES, OTTAWA,CANADA K1A OY3.

CWF DATA: UNIVERSITY OF LEICESTER,DEPT. OF PHYSICS, UNIVERSITY ROAD,LEICESTER LE1 7RH,U.K.

APPENDIX B

ORGANISATIONS WITH WHICH BDAC LIAISES FOR SUPPLY OR EXCHANGE OF DATA

Name and Address of Organisation	Abbreviated Title
Australian National University Research School of Earth Sciences Institute of Advanced Studies PO Box 4, Canberra, Australia	ANU
Bhabha Atomic Research Centre Seismology Section, MOD Labs Trombay, Bombay 400 085 India	BARC
Centre Seismologique Europeo-Mediterranean 5 Rue René Déscartes F67084, Strasbourg CEDEX France	CSEM
Department of Energy, Mines and Resources Earth Physics Branch Department of Seismology and Geothermal Studies Ottawa, Canada K1A OY3	DEMR
Dublin Institute for Advanced Studies School of Cosmic Physics, Geophysical Section 5 Merrion Square Dublin 2, Ireland	DIAS
Försvarets Forskningsanstalt (National Defence Research Institute) S104 50, Stockholm 80 Sweden	FOA
Institute of Geological Sciences Murchison House, West Mains Road Edinburgh EH9 3LA United Kingdom	IGS
International Seismological Centre Newbury RG13 1LA Berkshire United Kingdom	ISC
Japan Meteorological Agency Department of Observations, Seismological Division 1-3-4 Ote-machi Chiuoda-ku, Tokyo Japan, 100	JMA
Commissariat à l'Énergie Atomique Laboratoire Dêtection et Geóphysique BP 136, 92120 Montrouge France	LDG

Name and Address of Organisation	Abbreviated Title
Pakistan Meteorological Agency Geophysical Centre Post Box No. 2, Quetta Pakistan	
US Geological Survey National Earthquake Information Service Box 25046, Denver Federal Center, Stop 967 Denver, Colorado 80225, USA	NEIS
Royal Norwegian Council for Scientific and Industrial Research, NTNF/NORSAR PO Box 51, 2007 Kjeller Norway	NORSAR
Seismological Institute Box 517 S-751 20 Uppsala Sweden	
Seismological Observatory Villavei 9 N-5014 Bergen U Norway	
University of California Seismographic Stations Berkeley, California 94720 USA	
University of Leeds Department of Earth Sciences The University, Leeds LS2 9JT United Kingdom	
University of Leicester Department of Geology University Road, Leicester LE1 7RH United Kingdom	
Vela Seismological Center 312 Montgomery Street Alexandria, Virginia 22314 USA	VSC
Zentralinstitut für Physik der Erde Institutsteil Jena 69 Jena, Burgweg 11 DDR	ZIPE

APPENDIX C

THE ARPA NETWORK

The ARPA network is one of several packet-switching computer networks now in existence. It has wide geographical coverage in that, while the main body of the network is in the continental USA, there are extensions via satellite links to Hawaii and to Norway and the United Kingdom.

The network consists of more than 100 service computers of various kinds called HOSTS which are linked to specialised store and forward computers of a communications sub-network, the ARPANET. Three types of communication computer are in use in this sub-net, IMPs (Interface Message Processors), which can be connected to up to 4 HOSTS, TIPs (Terminal Interface Processors) which can be connected to 3 HOSTS and can handle up to 64 terminals, and the PLURIBUS, a larger multiprocessor type which permits the attachment of many more HOSTS and terminals. Connections to a TIP can be via telephone lines at a wide range of bit rates.

The UK connection to the ARPANET is via a TIP situated at the Department of Statistics and Computer Science, University College London (UCL). As the UK ARPANET Contractor, the task of UCL has been to supervise interaction between the various bodies concerned in the UK, Norway and the USA and to develop the UK node as a non-commercial user service facility, while carrying out research into the operation of computer networks (19).

The arrangements at UCL are rather different than at most other sites of the ARPANET in that the site does not itself provide any significant HOST facilities, but instead, by means of front-end computers (PDP9s), provides links to REMOTE HOST computers and acts as a GATEWAY to other networks. One such REMOTE HOST is the Science Research Council's IBM 360/195 computer complex at Rutherford High Energy Laboratory, Chilton, Berkshire. The UCL PDP9 software interfaces the normal RHEL 360/195 workstation procedures with the ARPANET protocols thus relieving the 360/195 of any requirements for specialised software. In this way the RHEL 360/195 functions as a SERVER HOST of the ARPA network, enabling access to the 360 to be made via a terminal attached to any USER HOST in the network.

A logical map of the network is shown in figure C1. The principal links in this network in so far as the present activities of BDAC are concerned are:-

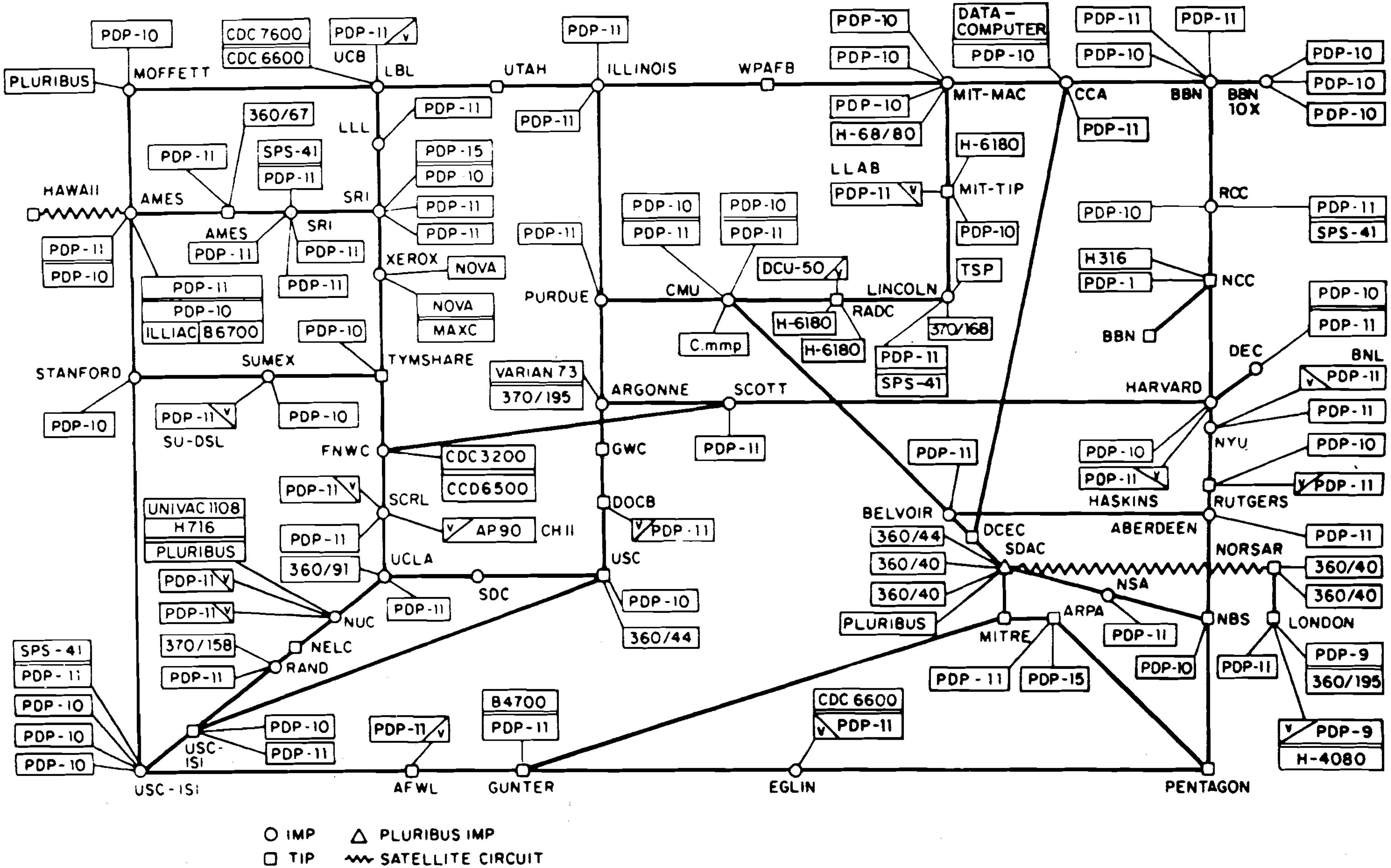
RHEL 360/195 - LONDON (UCL) TIP (2.4 kbps)

LONDON TIP - NORSAR TIP (9.6 kbps)

NORSAR TIP - SDAC PLURIBUS (9.6 kbps, nominal)

SDAC PLURIBUS - USC-ISI TIP (56 kbps)

Transfers of data held by a HOST computer at ISI can be initiated, via a 1.2 kbps link from BDAC to LONDON TIP, to BDAC data-base files on the RHEL 360/195 and the BDAC data-base is regularly accessed by users attached to SDAC.



(PLEASE NOTE THAT WHILE THIS MAP SHOWS THE HOST POPULATION OF THE NETWORK ACCORDING TO THE BEST INFORMATION OBTAINABLE, NO CLAIM CAN BE MADE FOR ITS ACCURACY)

FIGURE C1. LOGICAL MAP OF THE ARPA NETWORK

APPENDIX D

TELEX

A Telex system which used the existing public telephone network was first introduced in the UK on a very small-scale in 1932, but the basis of the present service was laid in 1952 when the British Post Office brought into operation a dedicated network alongside the original system. The new system was rapidly enlarged to a point where use of the public telephone network could be phased out leading to the commencement in 1958 of a fully automatic service with subscriber dialled calls on a wholly separate network based on 51 inland exchanges.

The present day Telex Service is very internationally orientated with 40% of all UK originated calls being international and, consequently, it is estimated (20) that the 66000 subscribers to the UK Telex system generate a similar number of international calls as the 14 million subscribers to the much larger public telephone network.

International Telex communication is now available to over 170 countries, with subscriber dialled calling available to 100 of these, representing 98% of the 54 million current total of international calls. All UK international traffic is routed through an international GATEWAY exchange in London.

With such a high proportion of Telex activity involving international traffic, co-operation on technical aspects at the international level is especially important and the degree of co-operation achieved via international consultative bodies, such as the Comite Consultatif International Telegraphique et Telephonique (CCITT), has been greater than in other areas of telecommunication. For this reason, although the standard Telex transmission speed of 50 bit/s may be considered slow by current state-of-art standards in other fields, it seems unlikely that the UK network will be independently upgraded because of the significant cost factors which would be involved in the provision of speed/code interfacing with other networks,

The internationally standardised rate of 50 bit/s provides a maximum information transmission speed of $6\frac{2}{3}$ characters/s; the requirement for synchronising two communicating teleprinters involves using some of the available data bits as start and stop signals for each transmitted 5 bit character. Telex networks throughout the world have adopted the International Telegraph Alphabet No. 2 (ITA2) whereby, by means of "letter shift" and "figure shift" characters, sufficient combinations are available in a five bit code for transmission of all necessary alphabetical and figure characters, and punctuation marks and control characters such as line-feed and carriage return symbols.

Standard teleprinters currently provided by the Post Office are equipped with paper tape punches and readers for automatic operation and produce hard-copy available in two printing colours with up to five copies obtainable by use of multiply paper. Punched paper tape messages may be prepared "off line" and, since automatic paper tape transmission is faster than manual typing, the maximum available information transmission rate of about 70 words/min can be exploited by using pre-prepared tapes - this minimises the charges for line time in international calls.

Each Telex terminal has a unique "ANSWER-BACK" code comprised of the terminal number followed by some appropriate combination of letters. Calls are initiated by dialling a required number and the called terminal automatically responds by transmitting its "ANSWER-BACK" code indicating that it is ready to receive a message. The code of the calling terminal is then transmitted to the distant installation by pressing the "HERE IS" key of the machine and transmission of the message can then proceed either by manual typing from a keyboard or via automatic transmission of a pre-prepared paper tape. At the end of a call it is usual to confirm the connection with an exchange of "ANSWER-BACK" codes by depression of "HERE IS" and "WHO ARE YOU" keys at the calling terminal. No speech facilities are available on Telex and an appropriate printed service signal (from an internationally standardised set of control signals) is received in the case of an unsuccessful call attempt.

Telex charges are based on a unit payment for a number of seconds transmission time over a given distance. For example, at present rates of charges, calls up to 35 miles distance are allowed 60 s transmission time per $2\frac{1}{2}$p unit and, over 35 miles, 20 s transmission time per unit. Calls to Europe cost in the range 15 to 30 p/minute and distant international calls (USA, Australia, Japan) are charged at 90 p/minute. Since it requires approximately 1 min to transmit 1 m of perforated paper tape on auto-transmit, a rule of thumb is that calls to distant stations cost around £1 per metre of tape generated.

APPENDIX E

FACSIMILE

Facsmile can be defined as a technique for transmitting an accurate copy of a sheet of paper containing information from one point to another using telecommunications. As such it provides a means of transmitting data which exists in an otherwise non-machine-readable form.

Facsimile appears to be at a point in development reached some years earlier by Telex. It uses the public switched telephone network (PSTN) and, therefore, has the potential for rapid growth as a means of data communication. Although the technique has been in use for about 40 years, machines have not been widely available until the present decade. There are a multiplicity of machines and manufacturers, with wide variation in techniques and standards, but a number of larger manufacturers are producing machines which are compatible and meet standards which conform to the recommendations of international consultative bodies such as the CCITT.

The first generation of machines designed for general use, now classified as Group 1 (1968), transmit A4 sized copy over the PSTN in either 6 minutes or 4 minutes (coarse scan). Compatible Group 1 machines use a frequency modulated system with a carrier of 1700 ± 400 Hz, the extremes of 2100 and 1300 Hz representing black and white in the original copy. An important parameter in maintaining compatibility is the "index of co-operation" which is a value derived from the diameter of the rotating drum of a facsimile machine and the number of scan lines in a given length.

Standards were laid down in 1976 for Group 2 machines which are designed to take advantage of higher quality telecommunication circuits and reduce line time costs by transmission of A4 size copy in 3 minutes, or 2 minutes at coarse scan. Group 2 machines use a more complex system of modulation (am/pm/vsb) in a so-called "duo binary" mode of data transmission (21) which allows operation at the double speed without line distortion effects. Some manufacturers produce machines which combine Group 1 and Group 2 standards thereby enabling the user to maintain links with all other installations on a world-wide basis.

Standards for "sub-minute", third generation (Group 3) machines have yet to be established. In order to achieve much faster transmission speeds over narrow band telephone circuits it is likely that sacrifices in resolution of intermediate (grey) tones of the transmitted material will be necessary, with only two tone, black and white, copy being available at the highest rates. Group 3 machines are at present in an evolutionary stage; digital techniques are likely to be used in their development and automatic unattended operation will be a growing requirement.

The cost of transmitting information by Facsimile (based on 320 words per A4 sheet) at the present Group 1 4 min rate is about the same as by Telex both for inland and international destinations. With the advent of faster machines and its advantage of being able to send pictorial as well as textual material, Facsimile seems likely to offer significant advantages in some applications of data communications.

APPENDIX F

WMO GLOBAL TELECOMMUNICATION SYSTEM

The global telecommunication system (GTS) of the World Meteorological Organisation (WMO) has defined functions of collection of observational data, distribution of the data to National, Regional and World Meteorological Centres and transmission of processed information between centres (22). It is organised on a 3 level basis:-

(a) A main trunk circuit and its branches (figure F1) which link together three World Meteorological Centres (WMCs) and ten designated Regional Telecommunications Hubs (RTHs).

(b) Regional telecommunications networks (which may be associated with RTHs not on the main trunk and Regional Centres not combined with RTHs).

(c) National telecommunications networks - associated with National Meteorological Centres (NMCs).

In principle, the telecommunications networks are engineered as an integrated system for the collection, exchange and distribution of meteorological data on a world-wide basis with the aim of dealing effectively with the requirements of all national meteorological services and also of World and Regional Meteorological Centres.

The network makes use of existing cables, landlines, radio and telephone facilities. For operational and financial reasons, standard telephone type circuits and radio links having similar characteristics are preferred for transmission of medium and high-speed data. In general, the network uses dedicated circuits, leased from national PTTs (Post, Telephone and Telegraph Authorities). The complete system is based on a hierarchical interconnection of centres, ie, NMCs, RMCs, RTHs, WMCs (figure F2), the larger centres (WMCs, RMCs, RTHs) having equipment for selection, switching and editing in order to provide national centres with the data they require.

F1. FUNCTIONS

The World Centres and Regional Hubs have similar telecommunications functions for collection of observational data within their respective zones of responsibility and relaying data as internationally agreed over the main trunk and its branches.

National Centres have responsibilities for collecting data within their own territories and transmitting the information to an associated RTH.

Centres are not restricted in choice of equipment installed for data handling, but the GTS requirements for compatible interfacing with the network must be observed. Present rates of transmission for network data (in the main trunk circuits) are typically around 2400 baud. Transfers of data, of which a considerable volume may be facsimile material, are accomplished by store and forward techniques or by direct through-switching operations.

F2. UK NATIONAL METEOROLOGICAL CENTRE

The National Meteorological Centre for the UK is at Bracknell, Berkshire and is also an RTH on the main trunk of the GTS with facilities for dual mode message switching (simultaneous message receiving and outputting). Bracknell also acts as a Regional Meteorological Centre (RMC) with equipment for data processing additional to the mandatory telecommunications facilities provided for the requirements of the GTS network.

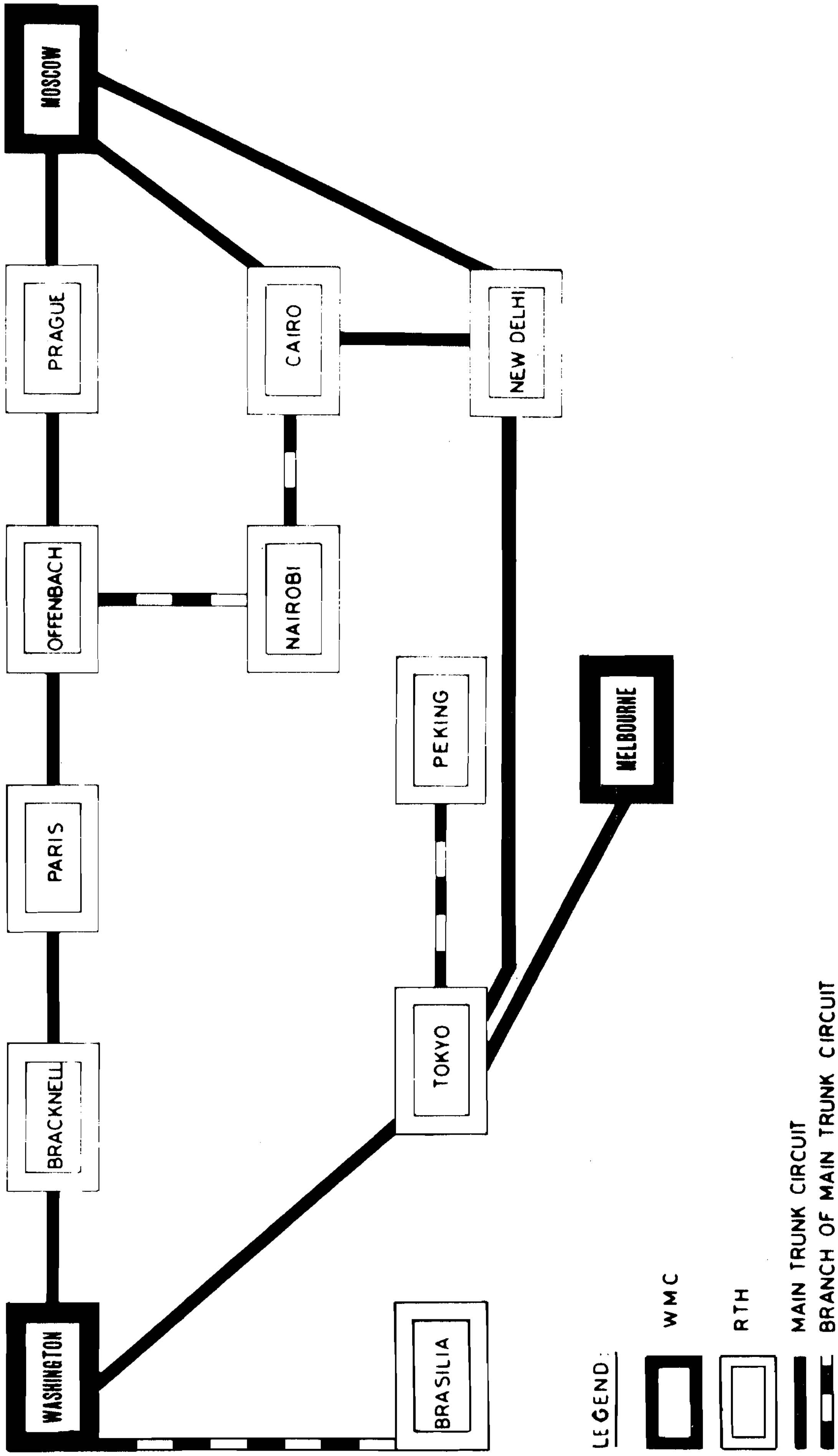


FIGURE F1. SCHEMATIC DIAGRAM OF THE MAIN TRUNK CIRCUIT OF THE WMO GLOBAL TELECOMMUNICATIONS SYSTEM

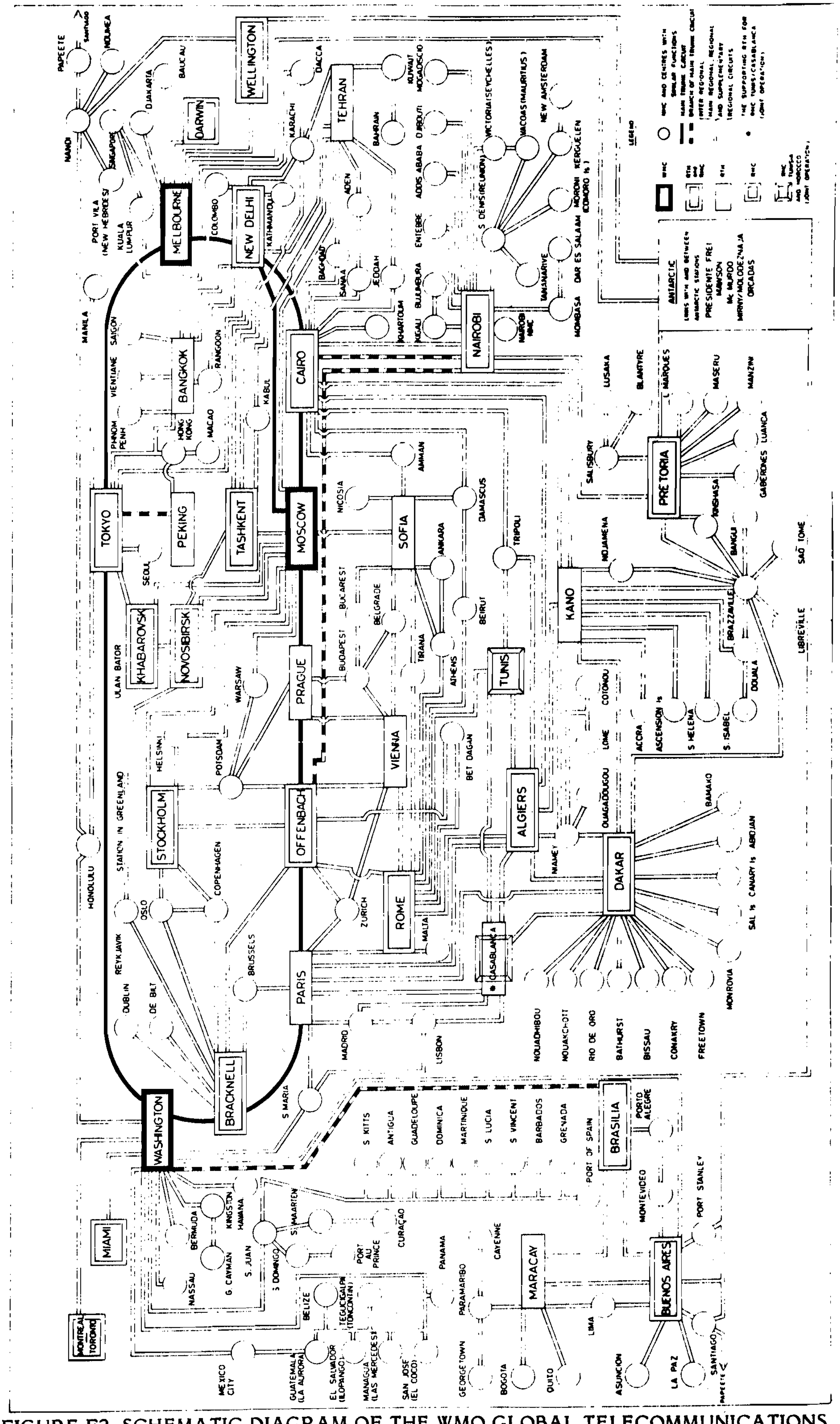


FIGURE F2. SCHEMATIC DIAGRAM OF THE WMO GLOBAL TELECOMMUNICATIONS SYSTEM

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Some Metric and SI Unit Conversion Factors

(Based on DEF STAN 00-11/2 "Metric Units for Use by the Ministry of Defence", DS Met 5501 "AWRE Metric Guide" and other British Standards)

Quantity	Unit	Symbol	Conversion
Basic Units			
Length	metre	m	1 m = 3.2808 ft 1 ft = 0.3048 m
Mass	kilogram	kg	1 kg = 2.2046 lb 1 lb = 0.45359237 kg 1 ton = 1016.05 kg
Derived Units			
Force	newton	$N = kg\ m/s^2$	1 N = 0.2248 lbf 1 lbf = 4.44822 N
Work, Energy, Quantity of Heat	joule	J = N m	1 J = 0.737562 ft lbf 1 J = 9.47817×10^{-4} Btu 1 J = 2.38846×10^{-4} kcal 1 ft lbf = 1.35582 J 1 Btu = 1055.06 J 1 kcal = 4186.8 J
Power	watt	W = J/s	1 W = 0.238846 cal/s 1 cal/s = 4.1868 W
Electric Charge	coulomb	C = A s	-
Electric Potential	volt	V = W/A = J/C	-
Electrical Capacitance	farad	F = A s/V = C/V	-
Electric Resistance	ohm	Ω = V/A	-
Conductance	siemen	$S = 1\ \Omega^{-1}$	-
Magnetic Flux	weber	Wb = V s	-
Magnetic Flux Density	tesla	$T = Wb/m^2$	-
Inductance	henry	H = V s/A = Wb/A	-
Complex Derived Units			
Angular Velocity	radian per second	rad/s	1 rad/s = 0.159155 rev/s 1 rev/s = 6.28319 rad/s
Acceleration	metre per square second	m/s^2	1 m/s^2 = 3.28084 ft/s^2 1 ft/s^2 = 0.3048 m/s^2
Angular Acceleration	radian per square second	rad/s^2	-
Pressure	newton per square metre	N/m^2 = Pa	1 N/m^2 = 145.038×10^{-6} lbf/in^2 1 lbf/in^2 = 6.89476×10^3 N/m^2
	bar	bar = 10^5 N/m^2	- 1 in. Hg = 3386.39 N/m^2
Torque	newton metre	N m	1 N m = 0.737562 lbf ft 1 lbf ft = 1.35582 N m
Surface Tension	newton per metre	N/m	1 N/m = 0.0685 lbf/ft 1 lbf/ft = 14.5939 N/m
Dynamic Viscosity	newton second per square metre	$N\ s/m^2$	1 $N\ s/m^2$ = 0.0208854 $lbf\ s/ft^2$ 1 $lbf\ s/ft^2$ = 47.8803 $N\ s/m^2$
Kinematic Viscosity	square metre per second	m^2/s	1 m^2/s = 10.7639 ft^2/s 1 ft^2/s = 0.0929 m^2/s
Thermal Conductivity	watt per metre kelvin	W/m K	-
Odd Units*			
Radioactivity	becquerel	Bq	1 Bq = 2.7027×10^{-11} Ci 1 Ci = 3.700×10^{10} Bq
Absorbed Dose	gray	Gy	1 Gy = 100 rad 1 rad = 0.01 Gy
Dose Equivalent	sievert	Sv	1 Sv = 100 rem 1 rem = 0.01 Sv
Exposure	coulomb per kilogram	C/kg	1 C/kg = 3876 R 1 R = 2.58×10^{-4} C/kg
Rate of Leak (Vacuum Systems)	millibar litre per second	mb 1/s	1 mb = 0.750062 torr 1 torr = 1.33322 mb

*These terms are recognised terms within the metric system.