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Data Management System for the China Digital Seismograph Network

by

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1 Introduction

The United States Geological Survey (USGS) and the State Seismological Bureau (SSB) of the Peoples Republic of China (PRC) signed an Agreement of Understanding in 1983 whereby they would jointly install a network of nine digitally recording seismograph stations in the PRC. In addition, a Data Management System (DMS) capable of processing the network data would be located in Beijing. Most of the hardware, with the exception of the seismometers, was purchased by the USGS and assembled at the Albuquerque Seismological Laboratory (ASL). All of the software for both the field systems and the DMS was developed at the ASL. Project costs were evenly divided between the two sides. Under the terms of the agreement the USGS would receive copies of station tapes from five of the field stations. This data would be included in the Network-Day Tapes produced at the ASL. The Chinese would assemble their own Network-Day Tapes at the DMS using data from all nine stations.

The object of the Data Manangement System (DMS) is to process the station tapes from the China Digital Seismograph Network (CDSN), check them for quality, correct them when necessary and then reassemble the data into day tapes which would contain all of the data from all of the stations for a specific calendar day. These tapes are then distributed to various research groups for seismic analysis. The original is archived at the DMS. A key element in the design of the DMS for the CDSN was to make it very similar to the data processing system at the Albuquerque Seismological Laboratory (ASL). This would allow much of the software in use at the ASL to be ported to the DMS with a minimum amount of change.

The data processing equipment at the ASL in 1983 consisted of two PDP 11/34's and one PDP 11/70 all manufactured by the Digital Equipment Corporation (DEC). At that time we were using Version 6 of the UNIX operating system distributed by the University of Califoria at Berkley. In view of this, we decided that the DMS would use a DEC PDP-11 processor and the newly released version of UNIX referred to as Version 7, Berkeley Software Distribution 2.9. This approach provided almost complete compatibility between the DMS to be located in Beijing and the Data Processing System at the ASL. Future events would show that UNIX Version 7 was significantly different from Version 6 and the software conversion was not as straight forward as we had anticipated.

To maintain compatibility with data from existing networks and also to minimize software development, the station tape format selected for the CDSN was virtually identical to that developed by the Sandia National Laboratories for the Regional Telemetry Seismic Network (RSTN). This format consists of a 16-bit data word with 14 bits containing the mantissa and two bits containing a gain range code which provide a maximum amplitude of plus 1,048,448 to minus 1,048,576 digital counts. A detailed description of this format can be found in Appendix A. The field stations were designed to produce continuous long-period data sampled once per second, triggered broadband data sampled 20 times per second, triggered short-period data sampled 40 times per second, and continuous very-long-period data sampled once every 10 seconds. This produces an average output of slightly more than two megabytes per station per day. The very-long-period (VLP) data is stored in a separate buffer during the data processing and is assembled into network-month tapes which contain all of the VLP data from the China network for an entire month recorded on a single tape.

In September 1983 an initial visit was made to China to discuss the overall project with their scientists and engineers. Power reliability, maintenance requirements, and the availability of supplies were a few of the questions that had to be resolved before we could make final decisions. We were advised that power reliability in Beijing was good, but we also agreed that all computer installations require an uninterruptable power system (UPS). Maintenance for DEC hardware is available in Beijing; however, it is controlled through the DEC office located in Hong Kong. Our meetings with the Chinese indicated that although their personnel were highly qualified all equipment, parts and supplies would have to furnished through the USGS.

All of the hardware was assembled at the ASL and thoroughly tested prior to shipment to China. In order to avoid possible damage during transit the computer hardware was packed with great care and shipped via air freight directly to Beijing. Fortunately it arrived in excellent condition and was installed in March 1986. This coincided with the installation of the first field station at Baijatuan located just outside of Beijing and enabled the Chinese to immediately check the quality of the data. Final software installation was completed in June 1986 and the DMS has operated satisfactorily since that time. The primary maintenance problem has been the RA60 disk drives which are used to store station data prior to assembly into network-day tapes. We are planning to replace them with Winchester drives in early 1988.

2 Hardware, Design and Assembly

When the CDSN program was initiated it was decided to use a DEC model PDP 11 type processor as this would be essentially identical to the existing hardware at the ASL. Our technicians were familiar with its operational characteristics, and our software would run on it without major modifications. After determining that DEC had the only maintenance available in Beijing, it was decided to use DEC peripherals as much as possible. The primary exception to this was the CRT terminals which are Tektronix Model 4112 with graphics capability. Tektronix terminals are used at the ASL for displaying seismic waveforms and our software is written for these terminals. In addition, Tektronix does have an office in Beijing and maintenance support is locally available. The other non-DEC items include the cartridge tape drives, manufactured by the 3M Corporation for reading the field tapes, and the digital plotter from Nicolet Zeta. Most of the hardware was purchased in 1984 and early 1985. A block diagram of the hardware configuration is shown in Figure 1.

2.1 PDP 11/44 Processor

In 1983 the primary 16-bit processor manufactured by DEC was the PDP 11/44. As the main function of the DMS is to process the data from nine field stations and assemble this data into network-day tapes the 11/44 is a very good choice. It is sufficiently fast, very reliable and has an excellent record of maintainability. A network of nine digitally recording

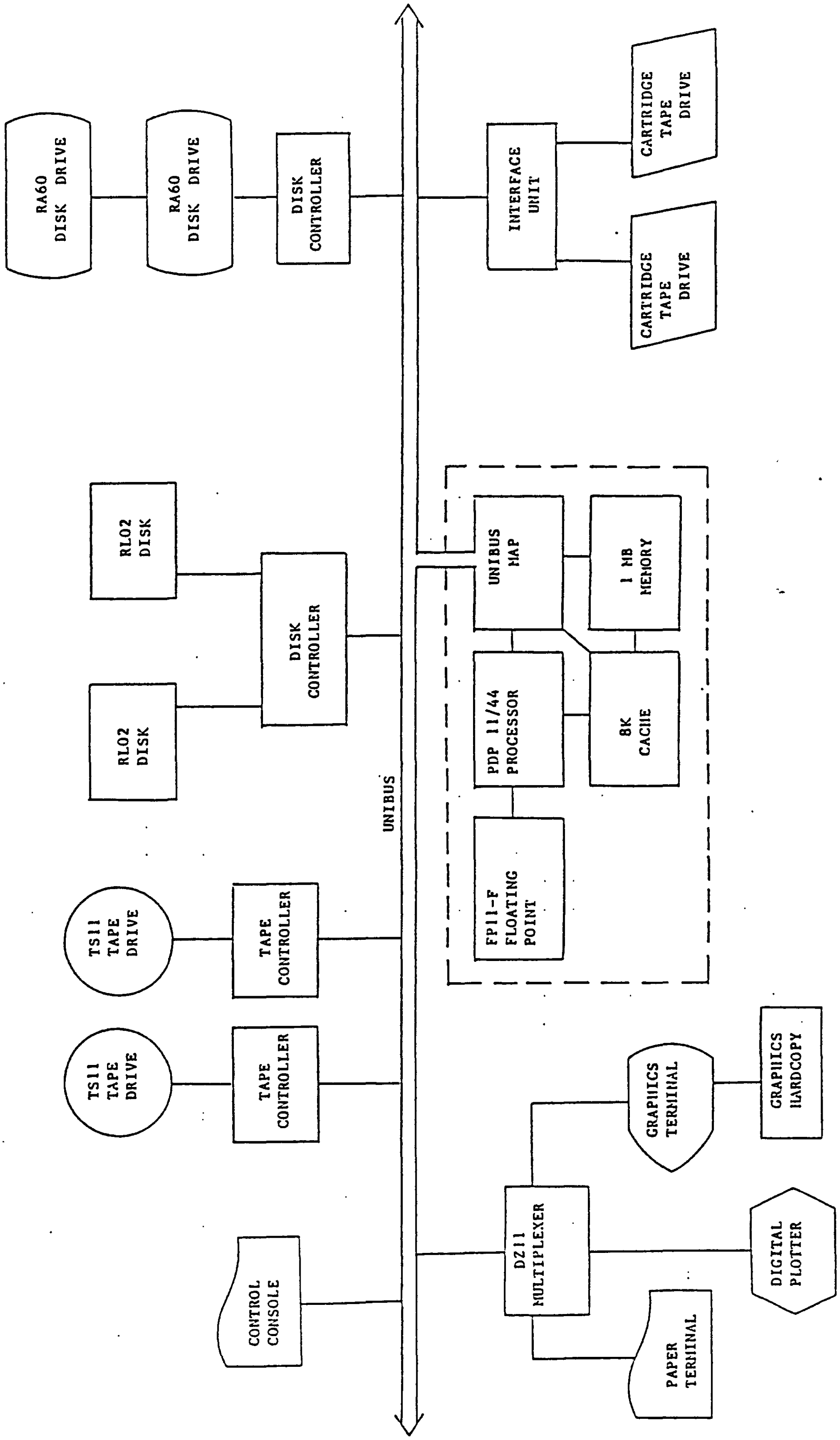

Figure 1: Data Management System Block Diagram

stations means that only two or three station tapes and a maximum of two network-day tapes need to be processed each day. A floating point processor and one megabyte of memory were included. Standard 11/44 specifications include 8K of cache memory.

2.2 RL02 Disk Memory

The RL02 disk memory was selected because it was the only small disk memory available for the 11/44. As the RL02 has only 10 megabytes of memory, a dual disk system for a total of 20 megabytes was included. These units have removable 10-megabyte cartridges so additional programs can be stored on spare cartridges. The software for processing station tapes and assembling the network-day tapes, plus the UNIX operating system can easily be stored on the RL02's. They have proven to be very reliable, and thus far have not required any special maintenance.

2.3 RA60 Disk Memory System

In order to assemble network-day tapes a memory system is required which has the capacity to hold a minimum of 15 days of network data. For the CDSN this would amount to at least 300 megabytes of disk storage. During 1983 DEC introduced two large disk memory systems which would fulfill these requirements. These were the RA-81 Winchester disk with a capacity of 450 megabytes, and the RA60 memory system which used a removable disk pack and had a capacity of 205 megabytes. Our initial selection was the RA-81 Winchester, but we were unable to obtain an export license for this unit. The only alternative was to use two RA60 drives for a total of 410 megabytes of storage. Unfortunately these drives have proved to be a high maintenance item and we have decided to replace them with a RA81 Winchester as the export license restrictions appear to have been eased in the past few years. Beijing has a relatively severe air pollution problem, particularly during the winter months when much coal is burned. The RA60 drives have a very small head-to-disk clearance and the DMS has experienced several head crashes. Winchesters with a sealed airflow system should require considerably less maintenance.

2.4 HCD75 Cartridge Tape Drive and Controller from 3M Corporation

All field data is recorded on 3M cartridge tape drives using preformatted cartridge tapes which have a capacity of 65 megabytes. In order to process these tapes at the DMS, identical cartridge tape drives were required. The tape drives require a 3M controller/formatter, and the system requires an interface unit for the 11/44 processor. This interface unit proved to be one of the most difficult items to locate, and is discussed in more detail in the following paragraph. The 3M controller/formatters occasionally developed a problem which would insert two additional bytes of data into a record. There has also been a relatively high failure rate with these units. These problems when combined with the difficulty in locating a reliable interface caused a considerable delay with our software program as we could not reliably read the field tapes into the data processing system. As the cartridge tape drives are such a critical part of the DMS, duplicate systems each consisting of two tape drives, one formatter/controller and one interface unit, were installed.

2.5 Cartridge Tape Drive System Interface Unit From Secondary Computer Storage Company

Finding a reliable interface unit for the cartridge tape drive system was a very difficult problem. The first company we approached provided an interface which proved to be unreliable, and after a number of complaints we were advised that they would no longer manufacture nor support these interfaces. The second company supplied a complete package including the cartridge tape drive, a formatter and interface, but unfortunately they could only read tapes which they had written. This was obviously not acceptable as their units could not read the field tapes. The third company was Secondary Computer Storage located in Lansdale, Pennsylvania, and their interface has proved satisfactory. One limitation imposed by this interface is that it will not allow cartridge-to-cartridge copies through one formatter/controller. Two tape drives can be connected to one controller, but the interface limits usage to only one of them. Therefore, a complete duplicate system was required in order to make cartridge-to-cartridge tape copies.

2.6 TS-11 Magnetic Tape Drive From DEC

As the production of network-day tapes from the CDSN data was one of the requirements of the DMS, two nine-track tape drives were required. One to write the initial day tape, and the second for making copies. In addition, using the cartridge tape drives in the start/stop mode is an extremely slow process as the tape must back up after reading each record before it can read the next record. It is considerably faster to copy data from the cartridge tapes to nine-track reel tapes in a streaming mode and then do the necessary editing and correcting. The TS11 drives were selected primarly because service was available for them in Beijing, and their specifications were satisfactory for the data processing requirements. These drives have a tape density of 1600 bpi and a speed of 45 ips.

2.7 LA120 Paper Terminals From DEC

Two of these paper terminals, which have a speed of 180 characters per second, were included for the DMS. These terminals are very reliable and provide a clear readable output.

2.8 Model 4112 CRT Terminals From Tektronix

These are graphics terminals and are used primarily to display seismic waveforms to check the quality of the data. Tektronix was selected as the supplier because their terminals are used at the ASL and our software is designed to work with them. In addition, Tektronix does have an office in Beijing and service is available locally. A Tektronix hardcopy unit, Model 4612, was also supplied. This allows the operators to make hardcopy plots of the graphic displays for future reference. These terminals were also furnished with an extra port for connection to a Model 4662 Tektronix flatbed digital plotter. Any display on the terminal screen can be transferred to the digital plotter providing a much better hardcopy which can be used in reports.

2.9 Zeta 8 Digital Plotter From Bruning Computer Graphics

The Zeta 8 digital plotter uses either fanfold or rolled paper and can provide digital plots of seismic events three feet in length or greater as desired. The primary for reason choosing a Zeta plotter was that we had several in operation at the ASL which have proven to be extremely reliable. Unfortunately, the plotter that was shipped to China broke down shortly after installation and ultimately had to be returned to the factory for repair.

2.10 Uninterruptable Power System from La Marche

An UPS is an absolute requirement for any data processing system. Power fluctuations are a fact of life and can cause considerable problems to computer electronics. The system installed in Beijing was manufactured by La Marche and has a capacity of 10 KVA, single phase with an output 220 volts, 50 Hz. A bank of Exide batteries will supply approximately 15 minutes of power in case of a complete electrical outage, sufficient for an orderly shutdown. This system consists of two large and very heavy consoles which were shipped surface to Beijing and arrived in good condition. It has operated without problem since the computer installation in February 1986.

2.11 Spare Parts Requirements

In order to set up a maintenance agreement with the DEC office in Hong Kong a complete set of spare parts for all DEC hardware is required on site. Their contracts cover labor only and the customer must supply all necessary parts. A fairly complete set of spare parts was also supplied for all other hardware in the DMS. Supplies such as paper, ribbons, pens, labels and magnetic tape were also furnished. The DMS could operate for at least one year with the original shipment of spare parts and supplies.

2.12 DMS Training At The ASL

In June 1984 seven Chinese scientists and engineers arrived at the ASL for preliminary training on the CDSN. Four received training on the DMS, and the other three on the field recording stations. The four Chinese assigned to the DMS were Mu Qiduo, Chen Qiang, Huang Yulin and Li Wenguang. As most of the hardware for the DMS was manufactured by DEC, two of the engineers, Huang Yulin and Li Wenguang, attended DEC training courses in Boston, Massachusetts. These courses covered the 11/44 and all of the DMS DEC peripherals. Eight weeks of continuous training courses in a foreign language must have been extraordinarily difficult, but both of them survived in good spirits. Messrs. Mu and Chen received all of their training at the ASL. They were specifically interested in the UNIX operating system and the operations of the data processing system. The training program at the ASL lasted for 12 weeks. Although it was another 18 months before the actual DMS installation, this training proved extremely beneficial as all the essential Chinese personnel were able to start working with the system immediately.

2.13 Hardware Installation in Beijing

Figure 2: Data Processing System at Data Management Center

Shipping computer systems overseas requires extreme care in packaging. All of the hardware, particularily such items as tape and disk drives, were carefully locked in position with advice and assistance from DEC field engineers. Crates were assembled using 3/4 inch plywood lined with styrofoam plus additional bracing for those items left mounted in the cabinets. The DEC field engineers recommended that the RA60 disk drives remain mounted in the cabinet. All of the DMS equipment was shipped air freight to Beijing and fortunately arrived in very good condition. The installation team consisted of two technicians from the ASL with assistance from the Chinese. The UPS had been shipped six months earlier and was installed and operating when the computer system arrived. All of the hardware had to be moved up a short flight of five or six steps and down a hallway to the computer room. This was not a difficult task for the computer hardware where the heaviest cabinet may have weighed 300 pounds. However, it remains a mystery how the Chinese managed to move the UPS up those steps as one of the racks weighed in excess of 1,500 pounds. The actual installation went quite smoothly taking approximately seven working days to cable and check out the various hardware items.

Figure 3: Graphics Terminals at Data Management Center

Figures 2 and 3 show the computer system installed in the Data Manangement Center in Beijing. The UNIX operating system, together with some of the data processing software, came on line and ran without difficulty. A full week was spent instructing the Chinese in the operation of both the hardware peripherals and the software programs necessary to process station tapes. While the DMS was being installed another team from the ASL was installing the first field station at the Baijataun Observatory located about 30 kilometers from Beijing. It was essential that the DMS process this data immediately in order to advise the installers if the station was working properly. It also provided an opportunity for training the computer operators with data from one of the CDSN stations. The network-day tape software was not finished at this time and a second trip was scheduled for June to complete the software installation and to conduct further training.

3 Software

The software supplied for the DMS was very similar to that presently in use at the ASL. It was written by the Lisle Computer Corporation of Albuquerque, New Mexico, which had previously supplied corresponding software for the ASL. When this project was initiated it was decided to switch our UNIX operating system from Version 6 to Version 7 using the Berkeley Software Distribution 2.9. Version 7 had more features than Version 6 and much better documentation. This changeover was more difficult than we had anticipated as there were substantial differences between the two versions and unfortunately quite a few bugs were discovered in the newer version. Another unexpected problem occurred when we discovered that no software drivers existed for a number of the DMS peripherals. These included the RA60 disk drives, the HCD-75 cartridge tape drives, the TS-11 tape drives and the Zeta 8 digital plotter. The most difficult problem revolved around the RA60 disk drives and their associated UDA50 controller as DEC advised us that the controller information was proprietary and could not be released. It required considerable persuasion, plus signing a document of confidentiality before we received the information which allowed us to write the software driver. These problems when combined with the difficulties in obtaining a reliable interface for the cartridge tape drives delayed work on much of the CDSN software until well into 1985. The primary difference between the existing software at the ASL and the revised software for the DMS was the addition of the VLP data. This required extensive code modification to the network-day tape software as it was decided to combine all of the VLP data into a network-month tape. This also proved to be a difficult piece of software to verify as it required data from several stations for a full month before we could be certain that it was working properly.

The software required to process network data and assemble it into day tapes is basically divided into two phases or sections. The first phase processes the station tapes, checks them for quality, corrects the header data when necessary, and stores the final version on a 9-track tape until all of the data is received and ready to be assembled into network-day tapes. The second phase is reassembling the data into the network-day or network-month tape, and distributing copies of these tapes to the data users.

3.1 Station Tape Processing

The standard procedure when processing station tapes is to review the data and check it for quality within four or five days of its arrival. This initial review is extremely important as it can detect problems in the data that require immediate correction. The computer operators can advise station personnel of the problem, and they can take corrective action with a minimal loss of data. Figure 4 is a flow chart of how field tapes from the CDSN

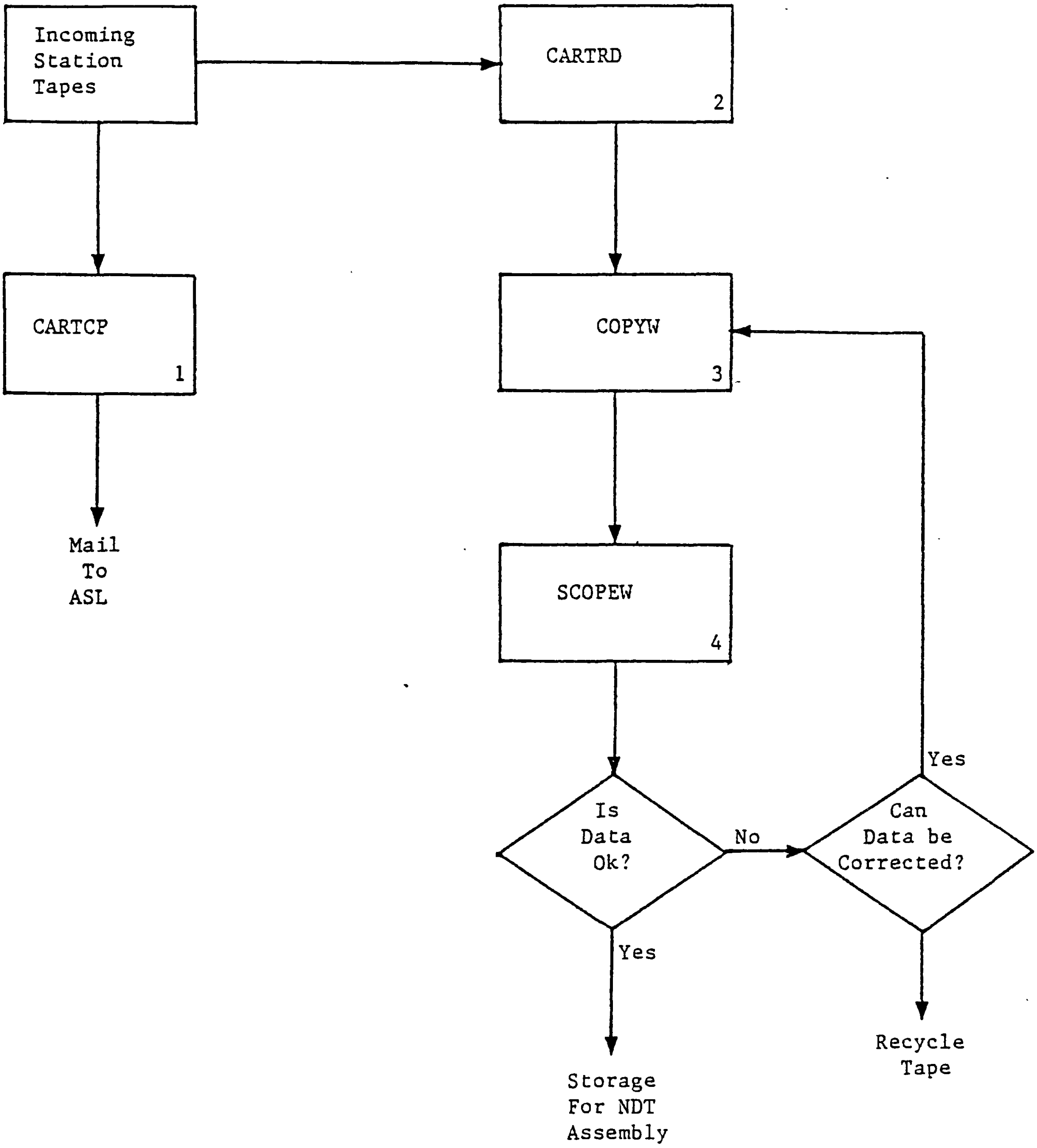

Figure 4: Flow Chart for Processing Station Tapes

are processed by the DMS. The first step is to make a direct copy of the station tapes using the program CARTCP and forwarding these copies to the ASL. Our agreement with the Chinese states that data from five stations (Beijing, Lanzhou, Kunming, Urumqi, and Hailar) will be copied and forwarded to the USGS as quickly as possible. The next step is to copy from the field cartridge tape onto a 10-1/2 inch diameter reel tape at 1600 bpi using the program CARTRD. Both CARTCP and CARTRD make use of large blocks of data consisting of approximately 25 records when making copies. It approaches a streaming operation. Processing cartridge tapes on a record-by-record basis is extremely slow as they are not designed for efficient start/stop operations. It is much faster to copy the data onto a reel tape and process the data on a standard start/stop tape drive. The following two programs COPYW and SCOPEW are used to edit and correct header information and to check the quality of the data.

3.1.1 COPYW

This program is designed to note any errors which may occur in the header portion of each record such as time, station ID, number of channels and sample rate. An initial edit is made using COPYW which lists any of the above errors that may be present plus other problems such as long or short records, tape parity errors and incorrect end-of-file markers. This edit is carefully reviewed by the computer operator, and, if necessary, corrections are made using a tape-to-tape copy option. During this correction process the program is very interactive with the computer operator. Various options are available particularly when it concerns time corrections, and considerable skill is required to make consistently correct decisions. The final station tape copy should not contain any correctable errors. Any unusual or consistent problems should be reported to the Network Maintenance Center (NMC). The actual seismic data is never adjusted or corrected.

3.1.2 SCOPEW

This program reviews the quality of the data through graphic displays of seismic waveforms on the Tektronix terminals. Normally samples of all channels are taken near the beginning, middle and end of the station tapes. SCOPEW provides the option of displaying both the time and the amplitude in digital counts of the seismic waveforms on the graphic display. This enables the operator to pick accurate arrival times for seismic events and their various phases, and also to display amplitudes to assist in determining magnitudes. Calibrations are reviewed in a similar manner providing a convenient method of checking sensitivities. If any abnormalities are noted in the data displays, the computer operator advises the NMC, and supplies copies of the waveform displays for their analysis. When all the processing for a specific tape is complete, the station log, both the original and final (corrected) tape edits plus the hard copies of the seismic waveforms are stored in a file folder for future reference. This file is carefully reviewed before the data is processed into day tapes to decide if any comments are required for the station log. The final corrected version of the station tape is temporarily stored until it is time to assemble the appropriate network-day tapes.

3.2 Network-Day Tape Software

The day tapes produced by the DMS are identical in format to those produced at the ASL. They contain all the necessary information on calibration, timing and other station parameters so that the data can be evaluated without any accompanying descriptive material. A description of this format can be found in Hoffman (1980). Network-day tapes are normally assembled 50 to 60 days after real time. This provides sufficient time for the data to be recorded at the stations, mailed to the data processing center and checked for quality. However, before the first network-day tape can be written, a file system must be established for each station in the network. These files contain all pertinent station information and provide storage areas in disk memory for the data. This is normally a one-time requirement. These files are created using the program DTPERM.

3.2.1 DTPERM

The first step in organizing a network-day tape program is to establish the file structure. DTPERM will add, modify or release file systems for each station in the network. When new files are added all necessary station information such as parameters, sensitivities, transfer functions plus any necessary comments are entered. Most of this station information is contained in both the station and data logs which are an integral part of every network day tape. In addition, separate storage files are set up in disk memory for the different modes of data (LP, SP, BB) plus a special file for the VLP month data. After these files are established they rarely have to be modified, unless major changes are made at the station. Once the file system has been created the software required to produce the day tapes consists of a series of programs each with a specific task. Figure 5 is a flow chart of how these programs are used in the day tape assembly. All of these programs are interactive with the computer operator and require specific information before they become operational.

3.2.2 DTREAD

This program reads data from the station tapes into disk memory. It immediately advises the computer operator of any time gaps between the existing data in memory and the start of the new tape thereby reducing the possibility of reading in the wrong tape. As the data is read in, the long-period, short-period, broadband and very-long-period components are separated into different buffers, and the data records are reformatted in order that the day tapes might start at 0000 universal time (UT). Normally sufficient data from all stations are read into memory in order that several day tapes may be written sequentially before more station tapes have to be read in.

3.2.3 DTLOG

After all of the station tapes have been read in it is frequently necessary to make some comment regarding data quality. Various components may have problems such as noisy

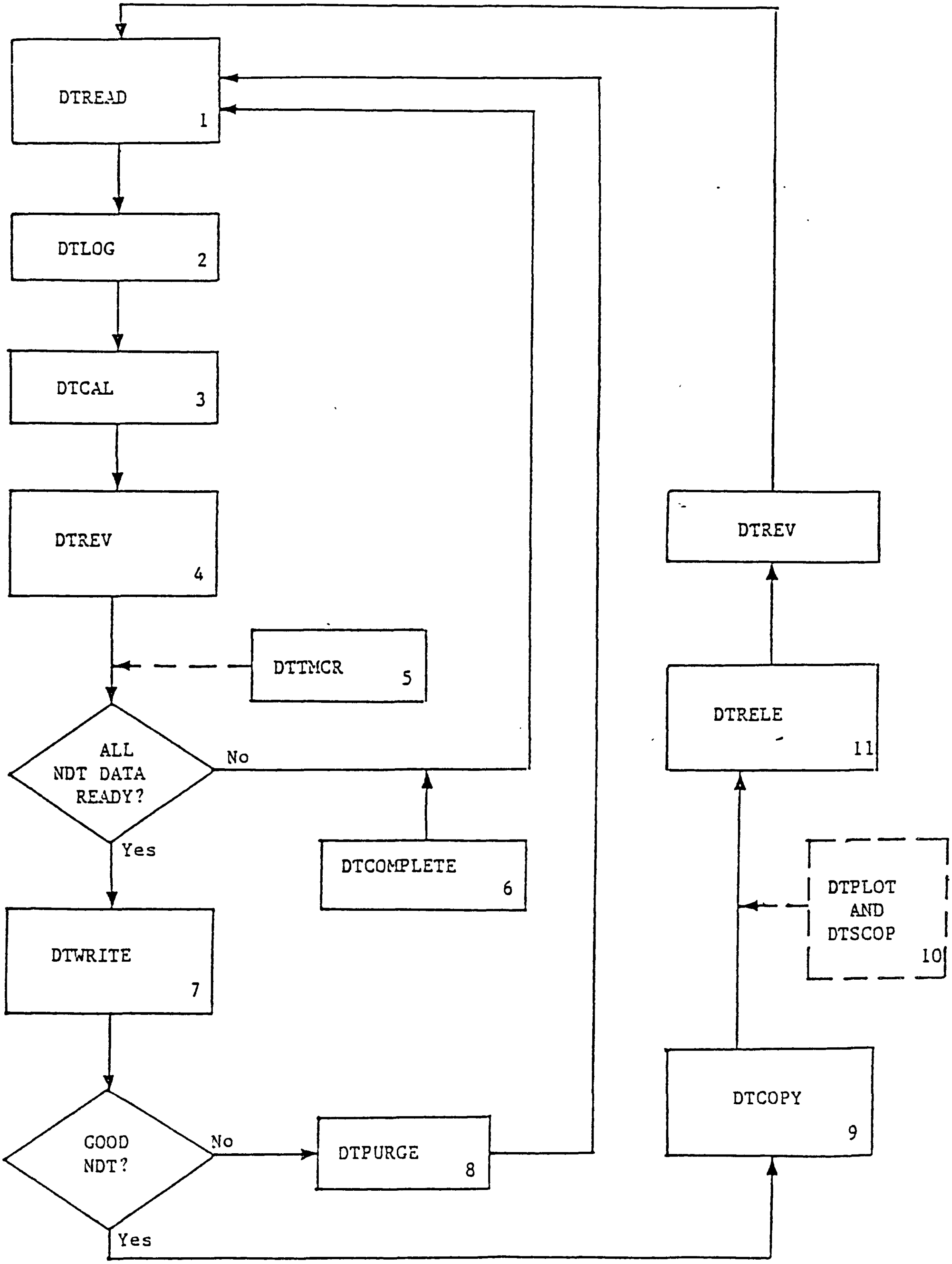

Figure 5: Flow Chart for Processing Network Day Tapes

amplifiers or bad calibrations. Any of these problems which affect the quality of the data should be noted in the comments section of the station log on the network-day tape. DTLOG enables the operator to add these comments and also provides the option of printing out complete station and data logs to ensure their correctness.

3.2.4 DTCAL

On occassion it is necessary to change the sensitivity of a particular component. DTCAL provides this capability.

3.2.5 DTREV

After all of the required station data has been read into disk memory DTREV will provide a list of exactly what data is available in memory for each station in the network. A comparsion of this listing with the dates on the appropriate station tapes will advise the computer operator if it is time to begin the production of network-day tapes. In addition, all of the station comments are recorded so the operator may review them and make changes when necessary. Information on the status of the month tape containing the very-long-period data is also furnished on the listing.

3.2.6 DTTMCR

This is a time-correction program which is normally not required in assembling the CDSN day tapes. All time corrections are automatically entered by DTREAD; however, on occassion it may be necessary to manually enter a specific time correction.

At this point the operator must decide if he is ready to start writing the network-day tapes. The standard format for the day tapes requires 26 hours of data extending from 0000 UT until 0200 UT of the following day. The station data must be complete for the entire time frame or it will not be included in the day tape. If a particular station has a long time gap between tapes that extends for more than one day, the software will not recognize the last station day as being complete as only a portion of that day has been written to memory.

3.2.7 DTCOMPLETE

If only a partial day of data is available for a station, DTCOMPLETE is used to signal the system that no more data is available, and this station day should be considered complete. For relatively short data gaps between tapes of less than one day, the following station tape could be read into the system. The DTREAD program will list the time gap between the two tapes and ask the operator if the missing data will be supplied later. If the operator answers no, then DTREAD will automatically complete that partial day. When the gap between tapes extends for several days DTCOMPLETE should be used. As an aid to the analyst the station log contains a table listing any data gaps in excess of one hour.

3.2.8 DTWRITE

When DTREV shows that all of the available data from the network for a specific day or month are properly stored in memory, DTWRITE transcribes the data onto magnetic tape. It also produces all the necessary logs to enable the data user to proceed with his analysis without any additional information. These include (1) a tape log which is the first record on the tape and lists all of the stations contained on the tape in their proper order, (2) a station log listing all station parameters, timing errors, data gaps in excess of one hour plus any appropriate comments and (3) data logs containing necessary transfer functions together with component sensitivities. These logs are included as part of the network-day tape. They can also be listed on a paper terminal if desired during the DTWRITE program. If any errors are encountered while the day tape is being written, they will be listed by the terminal. When the day tape is completed, the console messages are reviewed to determine if the day tape is satisfactory. When problems do occur, normally a few records from one of the stations have been scrambled and the data must be replaced. When this happens the existing data for that station must be purged, and then read back into the system.

3.2.9 DTPURGE

When station data is purged from memory, it must be done in 24-hour blocks for a particular calendar day. DTPURGE will remove one or more days from memory for a specific station. If this becomes necessary then the data must be replaced using DTREAD, and the subsequent programs such DTLOG, DTCAL and DTREV may be used to ensure that the data is correct so the day tape can be written.

3.2.10 DTCOPY

After the original day tape is produced, several copies are normally required for distribution to the data users. The original should be archived at a safe location convenient to the DMS. This archive is essential as requests for copies of day tapes may be received several years after they have been written. DTCOPY also checks for quality and produces a listing of any required tape logs.

3.2.11 DTSCOP and DTPLOT

Occassionally it is necessary to check the quality of the data on the day tape or to produce the plots of specific events for some data users. DTPLOT and DTSCOP provide the capability of searching the network-day tapes and producing either digital plots or CRT displays of the seismic data.

3.2.12 DTRELE

After the network-day tapes have been written and copied the data must be released from memory in order to make room for the production of more day tapes. DTRELE releases all the data from all stations for a specific calendar day. After the data has been released, DTREV is normally run which will advise the computer operator of exactly what data remains on the disk and which station tapes are required to be read into the system to produce the next network-day tape.

3.3 Software Installation

Figure 6: Software Training at Data Management Center

Actual software installation is, of course, relatively straight forward. All of the software was transported to Beijing on two digital tapes, one containing the operating system and the other the various programs. A number of modifications had to be made as the peripherals at the DMS were different than those at the ASL where the final versions were written. In particular, the Tektronix terminals contained a number of features that required considerable software changes in order to fully incorporate them. Most of the time was spent training the Chinese computer operators on how to process the station tapes and assemble the network-day tapes. Learning how to correct errors on the station tapes, plus understanding how all of the day tape programs work together, is a difficult task. When all of the instructions are in a foreign language it becomes much more difficult. In addition to all the various programs, the training had to encompass hardware operations and some of the basics of the UNIX operating system. A great deal of patience and understanding was displayed by both sides and the training went remarkably well (Figure 6). While the software was being installed at the DMS another team from the ASL was installing the field stations and forwarding the test tapes to Beijing for evaluation. This provided the opportunity to work with actual field data which made the training considerably more interesting. As might be expected with such a large amount of software, occasional modifications and corrections are necessary. When these changes are required, digital tapes containing the updated programs are mailed from the ASL complete with instructions on how to enter the new code. This has proved to be a quick and satisfactory arrangement.

4 Cartridge Tape Copy System

The cartridge tape copy hardware as originally furnished with the PDP 11/44 consisted of two systems each containing two cartridge tape drives, one 3M controller/formatter and the interface unit. When making a cartridge-to-cartridge copy, it was necessary to use both systems as the interface unit would not allow two tape drives connected to one formatter to make copies between each other. Consistent maintenance problems with both the 3M controller/formatter and the interface units made the cartridge-to-cartridge copying procedures very slow and unreliable. In order to alleviate this problem a new copy system was developed which used an Intel microprocessor, an Intel interface unit plus the 3M controller/formatter and two 3M cartridge tape drives. With this arrangement cartridge-to-cartridge copies could be made through a single controller/formatter and the Intel system. A Kennedy Model 9000 magnetic tape drive was also included to provide the capability of going from cartridge tape to reel tape. This copy system not only provides essential backup for forwarding data to the ASL on a timely basis, it also provides more time on the 11/44 for processing the station tapes and developing programs for more detailed data analysis. Figure 7 shows this tape copy system installed and operating at the DMS. A DEC LA120 terminal is used to enter the commands and list output messages.

5 Summary

The design, installation and maintenance of the DMS has been a most interesting project. Working with the Chinese engineers and technicians has been both educational and enjoyable. In a remarkably short time they have learned to process station tapes and assemble network-day tapes on an almost routine basis. This is not a straightforward task. There are many problems that can occur with digital data, and many corrections and reviews are required before a network-day tape is produced. Both sides agreed at the start of the

Figure 7: Cartridge Tape Copy System at Data Management Center

program that the DMS would be very similar to the data processing system at the ASL in both hardware and software. However, technology changes rapidly. As a result virtually all of the peripherals at the DMS have different characteristics from those at the ASL. Although not a critical problem it does have to be taken into consideration when making software modifications. With the exception of the RA60 disk drive the hardware has worked quite well. The RA60s will be replaced with a Winchester drive in the near future. The maintenance agreement with DEC in Hong Kong is essential and will be continued. There are rumors that a DEC office will be opened in Beijing within the next few years which will be very helpful. A final training program for both DMS and station personnel is scheduled for Albuquerque in early 1988. The DMS training will concentrate on the management and organization of a data processing system plus some instruction on the data processing techniques developed over the years at the ASL. At that time, aside from routine tasks concerning maintenance or supplies, the DMS project will be complete.

6 References

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7 Acknowledgements

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Appendix A. China Digital Seismograph Network (CDSN) Tape Format

The CDSN data are recorded on 3M Model HCD-75 high capacity cartridge tape drives. These cartridge tapes are preformatted with a record length of 1024 bytes. To maintain record lengths similar to those used in the Global Digital Seimograph Network (GDSN), two 1024 byte records will be combined to form one 2048 byte seismic data record. Each of these records will contain 20 bytes or 10 words of header information and 2028 bytes or 1014 words of 16-bit binary data.

The CDSN data are recorded as 16-bit gain-ranged data words with two bits defining the gain factor and a 14-bit mantissa. The gain factor is an unsigned integer with the following values:

Gain Code	Gain Factor
00_2 (0)	128
01_2 (1)	32
10_2 (2)	8
11_2 (3)	1

The mantissa is always a positive integer. The absolute amplitude in digital counts can be derived as follows:

$$Amplitude_{counts} = (Mantissa - 8192) \times \frac{128}{GainFactor}$$

Maximum amplitude of the CDSN data is $+1,048,576$ to $-1,048,448$ digital counts. Header information is contained in the first 20 bytes of each record, primarily in BCD (Binary Coded Decimal) code. Detailed description of the header data for the short-period, broad-band, long-period, and very long-period records are attached. All record types are multiplexed in the following order: Z, NS, EW. Each record contains 1014 data words or 338 samples per channel. Short-period (SP) records are 8.45 seconds in duration. Broad-band (BB) records are 16.9 seconds in duration. Long-Periods (LP) are 5 minutes and 38 seconds long. Very long-period (VLP) records are 56 minutes and 20 seconds in length.

TAPE FORMAT FOR CHINA DIGITAL SEISMOGRAPH NETWORK
LONG PERIOD RECORDS

WORD	BYTE	MSB BIT 7 BIT 6 BIT 5 BIT 4	BIT 3 BIT 2 BIT 1 BIT 0 LSB	
1	1	100'S STATION ID (BCD)	10'S STATION ID (BCD)	ID BYTE
	2	1'S STATION ID (BCD)	10'S DIGIT OF YEAR (BCD)	
2	3	1'S DIGIT OF YEAR (BCD)	100'S OF DAYS (BCD)	
	4	10'S OF DAYS (BCD)	1'S OF DAYS (BCD)	
3	5	10'S OF HOURS (BCD)	1'S OF HOURS (BCD)	TIME OF THE FIRST SAMPLE IN RECORD
	6	10'S OF MINUTES (BCD)	1'S OF MINUTES (BCD)	
4	7	10'S OF SECONDS (BCD)	1'S OF SECONDS (BCD)	
	8	100'S MILLISECONDS (BCD)	10'S OF MILLISECONDS (BCD)	
5	9	STATE OF HEALTH	NO. OF CHANNELS (BCD)	
	10	CONFIGURATION	SET FOR CAL	STATUS BYTE
6	11	± SIGN TIME CORRECTION	100'S MS TIME CORECTION (BCD)	CLOCK ADJUSTMENT
	12	10'S MS TIME CORRECTION (BCD)	1'S MS TIME CORRECTION (BCD)	
7	13			
	14	CALIBRATION CODE		
8	15	10'S SEC CALIBRATION TIME (BCD)	1'S SEC CALIBRATION TIME (BCD)	HEADER 10 WORDS START OF CALIBRATION
	16	100'S MS CALIBRATION TIME	10'S MS CALIBRATION TIME	
9	17	10'S SAMPLE RATE (BCD)	1'S SAMPLE RATE (BCD)	SAMPLE RATE BYTE
	18	0.1'S SAMPLE RATE (BCD)	10 000'S (BCD)	S.P. AMPLITUDE VERTICAL DATA VALUE
10	19	1 000'S (BCD)	100'S (BCD)	
	20	10'S (BCD)	1'S (BCD)	
11	21	GAIN CODE	6 MSB'S OF 14 - BIT DATA COUNT	1014 DATA WORDS
	22	8 LSB'S OF 14 - BIT DATA COUNT		

TAPE FORMAT FOR CHINA DIGITAL SEISMOGRAPH NETWORK

SHORT PERIOD RECORDS

WORD	BYTE	MSB BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	LSB BIT 0	
1	1	100'S STATION ID (BCD)				10'S STATION ID (BCD)				ID BYTE
	2	1'S STATION ID (BCD)				10'S DIGIT OF YEAR (BCD)				
2	3	1'S DIGIT OF YEAR (BCD)				100'S OF DAYS (BCD)				
	4	10'S OF DAYS (BCD)				1'S OF DAYS (BCD)				
3	5	10'S OF HOURS (BCD)				1'S OF HOURS (BCD)				TIME OF THE FIRST SAMPLE IN RECORD
	6	10'S OF MINUTES (BCD)				1'S OF MINUTES (BCD)				
4	7	10'S OF SECONDS (BCD)				1'S OF SECONDS (BCD)				
	8	100'S MILLISECONDS (BCD)				10'S OF MILLISECONDS (BCD)				
5	9	STATE OF HEALTH				NO. OF CHANNELS (BCD)				
	10	CONFIGURATION			SET FOR BEGINNING OF EVENT				SET FOR CAL	STATUS BYTE
6	11	1'S OF MINUTES (BCD)				10'S OF SECONDS (BCD)				TIME OF PICK SP EVENT
	12	1'S OF SECONDS (BCD)				1/10TH OF SECONDS (BCD)				
7	13	1'S SECONDS				1/10TH SECONDS				PERIOD OF E.D.
	14	CALIBRATION CODE								
8	15	10'S SEC CALIBRATION TIME (BCD)				1'S SEC CALIBRATION TIME (BCD)				START OF CALIBRATION HEADER 10 WORDS
	16	100'S MS CALIBRATION TIME				10'S MS CALIBRATION TIME				
9	17	10'S SAMPLE RATE (BCD)				1'S SAMPLE RATE (BCD)				SAMPLE RATE BYTE
	18	0.1'S SAMPLE RATE (BCD)				100 000'S (BCD)				AMPLITUDE E.D.
10	19	10 000'S (BCD)				1 000'S (BD)				
	20	100'S (BCD)				10'S (BCD)				
11	21	GAIN CODE		6 MSB'S OF 14 - BIT DATA COUNT						1014 DATA WORDS
	22	8 LSB'S OF 14 - BIT DATA COUNT								

TAPE FORMAT FOR CHINA DIGITAL SEISMOGRAPH NETWORK

BROAD BAND PERIOD DATA

WORD	BYTE	MSB BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	LSB BIT 0	
1	1	100'S STATION ID (BCD)				10'S STATION ID (BCD)				ID BYTE
	2	1'S STATION ID (BCD)				10'S DIGIT OF YEAR (BCD)				
2	3	1'S DIGIT OF YEAR (BCD)				100'S OF DAYS (BCD)				TIME OF THE FIRST SAMPLE IN RECORD
	4	10'S OF DAYS (BCD)				1'S OF DAYS (BCD)				
3	5	10'S OF HOURS (BCD)				1'S OF HOURS (BCD)				
	6	10'S OF MINUTES (BCD)				1'S OF MINUTES (BCD)				
4	7	10'S OF SECONDS (BCD)				1'S OF SECONDS (BCD)				
	8	100'S MILLISECONDS (BCD)				10'S OF MILLISECONDS (BCD)				
5	9	STATE OF HEALTH				NO. OF CHANNELS (BCD)				
	10	CONFIGURATION			SET FOR BEGINNING OF EVENT				SET FOR CAL	STATUS BYTE
6	11	1'S OF MINUTES (BCD)				10'S OF SECONDS (BCD)				TIME OF PICK 68 EVENT
	12	1'S OF SECONDS (BCD)				1/10 TH OF A SECONDS (BCD)				
7	13	1'S OF SECONDS (BCD)				1/10 TH OF A SECONDS (BCD)				PERIOD OF E.D.
	14	CALIBRATION CODE								
8	15	10'S SEC CALIBRATION TIME (BCD)				1'S SEC CALIBRATION TIME (BCD)				START OF CALIBRATION
	16	100'S MS CALIBRATION TIME				10'S MS CALIBRATION TIME				
9	17	10'S SAMPLE RATE (BCD)				1'S SAMPLE RATE (BCD)				SAMPLE RATE BYTE
	18	0.1'S SAMPLE RATE (BCD)				100 000'S (BCD)				AMPLITUDE E.D.
10	19	10 000'S (BCD)				1 000'S (BCD)				
	20	100'S (BCD)				10'S (BCD)				HEADER 10 WORDS
11	21	GAIN CODE		6 MSB'S OF 14 - BIT DATA COUNT						1014 DATA WORDS
	22	8 LSB'S OF 14 - BIT DATA COUNT								

TAPE FORMAT FOR CHINA DIGITAL SEISMOGRAPH NETWORK
VERY LONG PERIOD RECORDS

WORD	BYTE	MSB BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	LSB BIT 0	
1	1	100'S STATION ID (BCD)				10'S STATION ID (BCD)				ID BYTE
	2	1'S STATION ID (BCD)				10'S DIGIT OF YEAR (BCD)				
2	3	1'S DIGIT OF YEAR (BCD)				100'S OF DAYS (BCD)				
	4	10'S OF DAYS (BCD)				1'S OF DAYS (BCD)				
3	5	10'S OF HOURS (BCD)				1'S OF HOURS (BCD)				TIME OF THE FIRST SAMPLE IN RECORD
	6	10'S OF MINUTES (BCD)				1'S OF MINUTES (BCD)				
4	7	10'S OF SECONDS (BCD)				1'S OF SECONDS (BCD)				
	8	100'S MILLISECONDS (BCD)				10'S OF MILLISECONDS (BCD)				
5	9	STATE OF HEALTH				NO. OF CHANNELS (BCD)				
	10	CONFIGURATION							SET FOR CAL	STATUS BYTE
6	11									
	12									
7	13									
	14	CALIBRATION CODE								
8	15	10'S SEC CALIBRATION TIME (BCD)				1'S SEC CALIBRATION TIME (BCD)				START OF CALIBRATION HEADER 10 WORDS
	16	100'S MS CALIBRATION TIME				10'S MS CALIBRATION TIME				
9	17	10'S SAMPLE RATE (BCD)				1'S SAMPLE RATE (BCD)				SAMPLE RATE BYTE
	18	0.1'S SAMPLE RATE (BCD)								
10	19									
	20									
11	21	GAIN CODE		6 MSB'S OF 14 - BIT DATA COUNT						1014 DATA WORDS
	22	8 LSB'S OF 14 - BIT DATA COUNT								