TECHNICAL PLAN

FOR A

NEW GLOBAL SEISMOGRAPHIC NETWORK

INCORPORATED RESEARCH INSTITUTIONS FOR SEISMOLOGY

AND THE

UNITED STATES GEOLOGICAL SURVEY

CONCURRENCE

This Technical Plan for a New Global Seismographic Network represents the coordinated position of the organizations responsible for implementation and operation of the Global Seismograph Network. The Plan will be amended or modified periodically with the concurrence of the responsible organizations.

Incorporated Research Institutions for Seismology

By Robert A. Phinney

Robert A. Phinney
President

Date Sept 12, 1990

United States Geological Survey

By Robert L. Wesson

Robert L. Wesson
Chief, Office of Earthquakes, Volcanoes, and Engineering

Date 9/24/90

National Science Foundation

By Ian D. MacGregor

Date 12/24/90

1. INTRODUCTION

A major initiative is underway to modernize the global seismograph network by deploying a new generation of broadband seismograph systems and improving data collection and data management facilities. The deployment of the Global Seismograph Network (GSN) is being funded by the National Science Foundation (NSF) and led by the Incorporated Research Institutions for Seismology (IRIS) in cooperation with the U.S. Geological Survey (USGS). Once deployed, the management, maintenance, and upgrading of the GSN will be funded by the USGS and NSF. IRIS is a non-profit consortium of 61 universities in the United States, which includes virtually every university with a research program in seismology. IRIS was established in 1984 for the purpose of creating and managing new research facilities in seismology. IRIS acts as the agent for the National Science Foundation for the development of national research facilities in seismology. The goals and objectives of the IRIS program to upgrade the global seismograph network are documented in a report published in 1984, entitled *Science Plan for a New Global Seismographic Network.* As stated in the report, "the goal of a new generation global seismograph network is to produce broadband, wide dynamic-range digital data from a global network of at least 100 stations and provide for the timely collection and distribution of these data to a wide variety of users." The authors of the Science Plan also used the term 'evolutionary' to characterize the new network, in the sense that it must be upgradable and supportable well into the twenty-first century.

IRIS and the USGS share a common purpose in developing the new GSN to support seismological research. In 1984 a cooperative agreement was adopted by IRIS and the USGS to coordinate joint activities and contributions undertaken to develop and manage the new GSN (see Appendix 7). The agreement was later appended to an Interagency Accord on Implementation of the Committee on Science Engineering and Public Policy Recommendations for Research Initiatives in Seismology, which was signed by the Defense Advanced Research Projects Agency (DARPA), the USGS, and NSF. Within the framework of the IRIS/USGS Cooperative Agreement, IRIS will provide scientific leadership for the program, establish a data management center, and support a university component of the GSN, whereas the USGS will be the primary organization with responsibility for deployment and operation of the new GSN. NSF will provide funding through IRIS and the USGS for development, deployment, and upgrading, and the USGS will provide long-term support for stations and facilities deployed and operated by the USGS.

This Technical Plan addresses those issues of planning that affect coordination between IRIS and the USGS, and defines the organizational responsibilities and support of a university component of the GSN — the IRIS/IDA Network operated by the University of California at San Diego, individual university seismic stations, and other university subnetworks which may come into existence in the future.

The Global Seismographic Network is generally understood to comprise all of those global networks that produce and freely exchange high-resolution broadband data. Indeed, other networks, such as the French GEOSCOPE network, were taken into consideration during development of an IRIS siting plan. Within the context of this document, however, the term GSN refers only to the IRIS contribution to the Global Seismographic Network.

A great deal of work has been accomplished by IRIS and its standing committees, the USGS and other active participants in the program. Design goals and specifications for the instruments have been developed, sites have been selected, a prototype GSN data system (IRIS-2) has been delivered for testing and an initial version (IRIS-1) has been deployed, the IRIS PASSCAL portable data logger (IRIS-3) has been deployed at GSN sites in the Soviet Union, very broadband seismometers have been deployed, a standardized data format has been created, international organizational contacts have been developed, and substantial progress has been made in improving and establishing data collection centers and the IRIS data management center. At the same time, it has become clear that some program goals must be recast in the light of diminishing budget expectations. While these constraints will adversely affect the program schedule, they need not compromise basic system design goals or the quality of the collected data.

The establishment of a global network of standardized seismographs is a complex, multi-faceted program involving system development and testing, the selection, negotiation, and preparation of suitable sites, training, the installation of instruments under a variety of unusual conditions, and the development of data collection and network support facilities. Fortunately, the foundation for the new GSN already exists because there are global networks in place — the World-Wide Standardized Seismograph Network (WWSSN) and the Global Digital Seismograph Network (GDSN), operated by the USGS, and the International Deployment of Accelerometers (IDA) network, operated by the University of California at San Diego (UCSD). Most of the GSN systems will be installed at existing stations because of the availability of facilities and experienced personnel, and new stations will be installed to improve the global coverage. To enhance the noise characteristics of the network, surface vaults at many existing stations may need to be replaced by underground vaults or borehole facilities, and at new locations low-noise siting will be emphasized. In addition to the networks of existing stations, there are maintenance and data collection facilities in place that need not be duplicated. Past experience in network management and operations is another valuable asset that makes it possible to anticipate requirements with considerable accuracy.

The deployment of the new GSN is the first phase of a program that is intended to provide the scientific community with high-quality seismological data well into the twenty-first century. In some respects, the second phase of the program, which is to operate the network, to upgrade the network with new technology when warranted, and to provide for continued improvement of seismometer siting to minimize noise, is even more challenging. Past experience has clearly shown the difficulty of obtaining adequate funds to support a global seismograph network after it has been installed, much less of obtaining funds for improvements. The reason for this is also clear; the existing networks were deployed by a sponsoring agency without any plan for long-term support. The new GSN will fare no better if long-term support with well-defined organizational responsibilities is not part of current planning.

Among the requirements set forth in the IRIS/USGS cooperative agreement is the preparation of a Technical Plan for the New Global Seismographic Network. The purpose of this Plan is to translate the scientific goals and objectives of the GSN program into plans for instrumentation, station siting, deployment, operation and maintenance, data collection, data management and distribution, budget and schedule, and organizational responsibilities. Since there will be several organizations involved in the deployment and operation of the GSN, another purpose of this document is to establish common procedures and standards to be used during the deployment, testing, and operation of the GSN data systems. Uncertainties with respect to the level of funding for the program require flexibility in planning the deployment of the network. Elements of this Plan will require periodic updating by IRIS and the USGS. Amendments to the Plan will be adopted by agreement of both IRIS and the USGS.

2. NETWORK CONCEPT

The new GSN, much like its predecessors, will be a global infrastructure comprising the station instrumentation, data collection facilities, data management and distribution facilities, and maintenance support. All of these elements, which are shown schematically in Figure 2.1, are necessary to operate the network, and the support facilities must be in place as the first stations are installed.

Many of the GSN data acquisition systems will be installed at existing manned observatories where they will be operated by host organizations. The host organization is a key participant in the network, not only in providing operating facilities and personnel but in sponsoring the cooperative program in foreign countries. Often the host organization is also a data user and depends upon the station to provide data for local earthquake studies. Some of the GSN data systems will be installed at remote unmanned sites from which the data must be retrieved by satellite telemetry, and some will be installed at manned sites where there is no interest in the local utilization of the data. The configuration of the GSN data system will be tailored to specific site requirements.

Real-time satellite telemetry between the GSN stations and the data collection center continues to be an important program goal, although it is now apparent that the implementation of satellite telemetry will be delayed except in special cases. IRIS is working to complete an agreement with NASA in which GSN telemetry requirements will be included in NASA baseline plans for their Earth Observing System (EOS) to be launched in the mid-1990s.

Data from some stations will be accessible via telephone dial-up. At these sites the IRIS Data Management Center and seismologists will be able to view and retrieve segments of recent seismic data from a buffer memory. Transmission of messages, computer commands and files between the stations and the data collection center will ease the maintenance of the network.

Data will be recorded at the stations on high-density tape cartridges. The cartridges will be mailed about every two weeks to a data collection center where the station data will be loaded into a computer, and reviewed for quality and accuracy. Data Collection Centers have been upgraded at the USGS Albuquerque Seismological Laboratory (IRIS/USGS DCC) in New Mexico and at the University of California at San Diego (IRIS/IDA DCC). Validated data are then staged to a buffer for prompt transmission to the IRIS Data Management Center. All IRIS data are routinely provided to the IRIS/USGS DCC, where they are merged with other GSN data and data from other networks in a mass store facility. The data collection centers are part of the network data acquisition system in the sense that much of the work there in validating data accuracy, calibration, timing and similar functions are extensions of quality-control processes that begin at the stations. For the same reasons, it is important that the data collection and network maintenance centers be collocated so that there is close and effective communication between the centers. After the network data are processed at the data collection center they are formatted and ready for bulk distribution to other data centers.

A network maintenance center fills the basic support functions for the network by providing supplies, training, replacement components and parts, and on-site technical assistance when needed. The center will be in frequent communication with the stations and will respond quickly to requests for assistance.

Data management centers (DMCs) will provide an important interface between the network and the data users. Most data users are selective in their requirements and need data management support to retrieve signals of interest from the rapidly expanding global data base. Rapid access to data after quality control and assurance procedures are completed is another DMC concern. One of the important functions of the data management centers will be to provide researchers with selected data via a convenient format and medium; for example, event data on compact disks, or customized data sets via electronic transfer. Efficient data management and distribution is a challenging task considering that the data base may be growing by as much as a gigabyte per day when the GSN is fully operational. Fortunately, much of the preparatory work has been accomplished by IRIS and the USGS. For example, IRIS has established a DMC in Austin, Texas at the University of Texas and the USGS has established a DMC in Golden, Colorado at the National Earthquake Information Center (NEIC). The IRIS DMC will archive all continuous and triggered GSN data immediately following quality control and assurance at the Data Collection Centers and will provide for rapid access to the GSN database for all users. The USGS DMC at NEIC will continue to produce sets of seismic data on CD-ROM media from all seismic events larger that a certain threshold, collected from the GSN and other networks within a year following the events.

3. STATION INSTRUMENTATION PLAN

3.1 DESIGN GOALS AND CONSIDERATIONS

The selection of station instrumentation is the most important decision that will be made in the GSN program. The Science Plan described the GSN data requirements in terms of resolution, bandwidth, and dynamic range, and these were the most important system attributes considered by the IRIS Standing Committee for the GSN (SCGSN). One of the important early tasks of the SCGSN was to translate the general scientific goals for the GSN into design goals for the GSN data acquisition and collection systems. This work was published in draft form as The Design Goals for a New Global Seismographic Network and distributed widely for comment and suggestions. The design goals were then used as the basis for preparing specifications for a GSN data system. The specifications were issued as part of a request for proposals by IRIS, and, after competitive evaluation of the responses, a contract was awarded in April 1987 to Gould, Inc. (acquired in 1988 by Martin Marietta, Inc.) for development of a GSN prototype data system (less seismometers). The prototype system was delivered to the Albuquerque Seismological Laboratory in November 1988 for test and evaluation. The first production units (IRIS-2 systems) became available for deployment in mid-1990. Concurrent with the development of the GSN prototype, Quanterra Inc. has produced a compatible, abridged version of the system which has been successfully operated (IRIS-1).

In a separate development through the IRIS portable array program, PASSCAL, specifications were drawn in 1986 by a joint IRIS and USGS committee for a portable seismic data logger to be used in large scale portable array experiments (up to 1000 elements) to image the Earth. After a competitive evaluation a contract was awarded to Refraction Technology Inc. (RefTek) in 1987. Delivered and tested in 1988, a version of the PASSCAL data logger, designated the IRIS-3, immediately was put to use as a GSN data logger in the Soviet Union at five sites. Although not presently meeting the full design goals of the original GSN specification, the IRIS-3 instrument nonetheless is systematically evolving to meet the full design goals. The SCGSN adopted the IRIS-3 as a data logger for the IRIS/IDA Network in 1989.

The development of the GSN system design goals and specifications was a deliberate process that drew upon a broad range of scientific and engineering expertise to insure that the latest applicable technology is used to create a digital broadband seismograph system that will produce much higher quality data than are now available and be supportable and upgradable well into the twenty-first century. The key requirements for the new network station instrumentation were listed in the design study as follows:

- Bandwidth sufficient to record the entire spectrum of teleseismic signals;
- Dynamic range sufficient to resolve ground noise and to record the largest teleseismic signals;
- Digital data acquisition with real-time or near real-time data telemetry;
- Low noise instrumentation and environment;
- Linearity;
- Standardization of system modules.

From a data user standpoint, the most important of these requirements are likely to be bandwidth and dynamic range. The recently-developed very broadband (VBB) seismometers coupled with the new high resolution 24-bit digital encoders make it possible for the first time to record signals from a teleseismic event in a single data stream. At locations where additional bandwidth or dynamic range is appropriate, very-short-period (VSP) and low-gain (LG) seismometers will be included with the data system. Seismometers consistent with GSN design goals are selected by SCGSN for deployment after testing and evaluation at the USGS Albuquerque Seismological Laboratory with recommendation to SCGSN.

The resolution of small signals for purposes of detection has been one of the objectives spurring the improvement of sensor technology and is important in the context of broadband data as detailed source mechanism studies are applied to events of small magnitude. The amplitude of self noise will be one of the important criteria used in the evaluation and selection of sensor systems for the GSN. The choice of low-noise recording sites is a goal but one that must often be compromised because of the need for stations at critical geographic locations (e.g., islands and coastal regions). The use of borehole seismometers is expected to reduce the levels of recorded noise on islands and at other sites, and the separated version of GSN data systems (with local telemetry between the sensors and recording station) will be used where appropriate to avoid cultural noise.

Ideally, signals recorded on GSN systems will be linear through the full 140 dB amplitude range specified for the system, but this is not presently achievable. As specified in the Design Goals, the linearity should be such that signals near the ground noise minimum can be resolved in the presence of ground noise at other frequencies near the expected ground noise maximum; that is, distortion levels below -80 dB. Most of the broadband seismometers have measured distortion levels between -80 and -90 dB. This is one area of sensor technology that would bear improvement so that full advantage can be taken of the high resolution digital encoders.

Standardization of station hardware and software was considered a key requirement during the design study to reduce maintenance complication and cost. As stated in the Design Goals: "Past experience with operating seismic networks, regional or global, has graphically demonstrated the disadvantages of constructing a network from a diversity of individual stations with differing characteristics." The standardization of data format has already been accomplished. At the urging of the IRIS SCGSN, a standard data format, called the Standard for the Exchange of Earthquake Data (SEED), has been developed by the USGS with input from IRIS and the international scientific community. Widely reviewed, the SEED format has been adopted for use by the Federation of Digital Broadband Seismograph Networks. The SEED format for recording data at the GSN stations will also be used in the distribution of GSN data by the Data Management Centers, as well as in the exchange of the data among Federation data centers.

Several other design considerations were important in developing design goals and specifications for the GSN system. Modular system design is important for providing the flexibility to configure data systems for particular locations. At some GSN locations local telemetry links between the sensor system and recording system will be required, whereas at others the systems will be co-located. Many sites are at active seismological observatories with an interest in using the broadband seismic data for local analysis, whereas other sites may be remote and essentially unmanned with little or no interest in the data locally. The configuration of a GSN data system will be tailored to meet the site requirements. System design will permit separation of the sensors and the recording system using wire, fiber optic links, telephone circuits, or radio links, so that the sensors can be positioned away from sources of cultural noise.

Modularity, the fullest possible use of off-the-shelf components, and a standard bus will make the IRIS-1 and -2 systems easy to support and upgrade in the future. Ideally, the entire data system can be replaced over the years piece by piece as the need arises. The use of off-the-shelf, commercially available modules reduces a potentially costly dependence on the system manufacturer when design changes and modifications are needed in the future. On the other hand, the IRIS-3 system developed by RefTek is the chosen IRIS PASSCAL instrument is part of an evolving product line of the company. Using more proprietary components than the IRIS-2 system, the IRIS-3 system nonetheless uses industry standard I/O interfaces. However, with the broader customer base the RefTek line will continue to stay at the leading technological edge without relying solely on IRIS for development funds.

Reliability and maintainability are clearly important design considerations. The reliability of a data acquisition system depends on many factors, including equipment design, local interest in the data, adequacy of spare components at the station, turnaround repair time, training, stability of local line power, and environmental conditions. The methods used in this program to deal with the factors affecting station reliability include the use of proven equipment, built-in diagnostics, operator training, robust backup power systems, and use of fiber optic cables where lightning is a problem. A data availability of 90% is the minimum acceptable goal for the GSN.

Local utilization of the GSN data can have a very dramatic impact on network operations. Past experience in operating the WWSSN and GDSN networks clearly shows that the reliability and survivability of stations is much higher when the data are accessible and useful to the host organization. This is the most important reason for the durability of the WWSSN. In contrast, the GDSN stations are much more difficult and expensive to support because at most stations the digital data are not generally available for local use, so there is little incentive to keep the systems operating. The GSN data systems are designed to provide local access to the digital data. All of the data stored in the buffer memory will be accessible for display and analysis on the system monitor, and a plotter will be provided to make hard copies. All of the data in near-real time will be accessible at the station through a data access port for processing or recording on station-furnished equipment, and host organizations located at some distance from the station may retrieve data from the buffer memory via the dial-up circuit. The GSN data processor will have analog outputs (where needed) to simulate the WWSSN short- and long-period signals. The output signals may be recorded on the existing WWSSN thermal recorders.

3.2 BASIC GSN DATA SYSTEMS

3.2.1 General

Many of the concepts used in developing and configuring hardware and software for the GSN data system evolved from VBB seismograph systems developed at Harvard University by J. Steim (1986) and the IDA group at UCSD. The basic GSN data system being manufactured by Martin Marietta is often referred to as the IRIS-2 system. IRIS-1 systems are essentially updated copies of the original Harvard system with some modifications. IRIS-1 systems, previously available through Gould Inc., are now available through Quanterra Incorporated. The IRIS-2 systems can be operated in several different configurations and with several hardware options. Fully configured, the IRIS-2 data acquisition system can replace virtually all of the instrumentation currently operated at a typical seismological observatory. The IRIS-3 system is based upon the IRIS PASSCAL seismic data logger and is manufactured by RefTek with most of the software development done by the IDA group at UCSD.

Block diagrams of the basic GSN data systems are shown in Figure 3.1 and 3.2 for the IRIS-2 and IRIS-3 systems, respectively.The concept of using separate data acquisition and processing modules permits the sensor systems to be installed at remote sites when necessary with recording at station facilities that are often located in noisy environments. It is expected that approximately one-third of the GSN stations will be operated with a local telemetry link. The link may be a few kilometers of fiber optic cable or thousands of kilometers over a satellite circuit.

The data acquisition (DA) module comprises the sensor subsystems, digitizer/calibrators, a timing subsystem, and a microprocessor for data acquisition control and data formatting. Time critical operations will all take place in the DA module so that intermodule transmission delays will not be of concern. Data will be formatted into packets, time tagged, then forwarded to the data processing (DP) module. The DP module will comprise a second microprocessor, buffer memory, digital recorders, data access ports, a single-channel analog recorder, CRT terminal, printer, optional plotter, and optional analog recorders. A full duplex 2400-baud serial circuit will be adequate for transmission of continuous broadband data between the DA and DP modules; higher capacity circuits (up to 19.2K baud) will be needed to handle optional VSP and LG data.

3.2.2 Sensor Subsystems

All of the GSN data systems will be equipped with a triaxial VBB sensor subsystem having a flat velocity response from at least 0.25 to 360 seconds period and a dynamic range at 20 seconds of at least 140 dB. The type of VBB sensors used (borehole or vault type) will be site dependent. Streckeisen STS-1 VBB sensor subsystems have already been deployed at several stations. Other candidate VBB

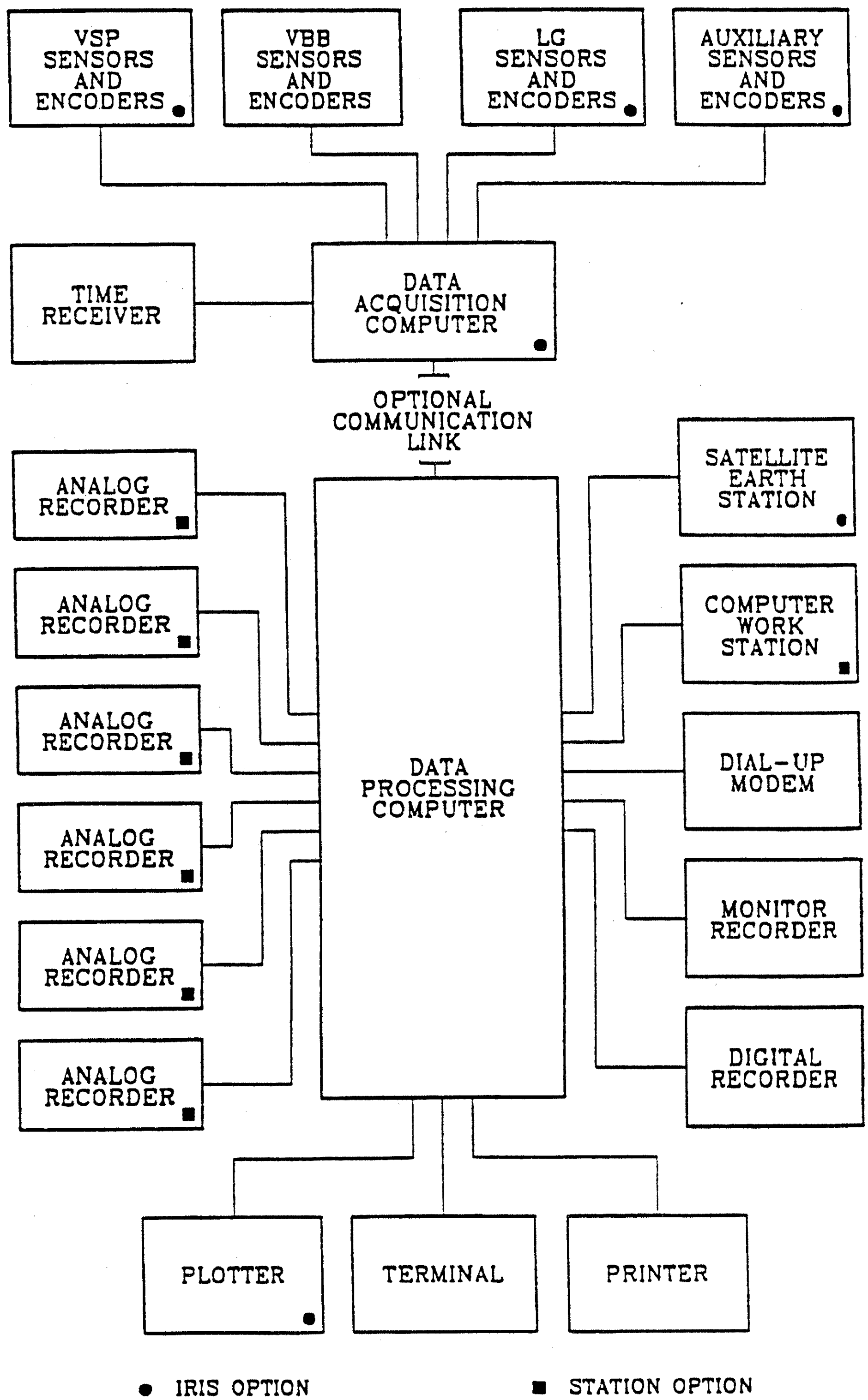

Figure 3.1 Block diagram of IRIS-2 system with separated data acquisition (DA) and data processing (DP) modules.

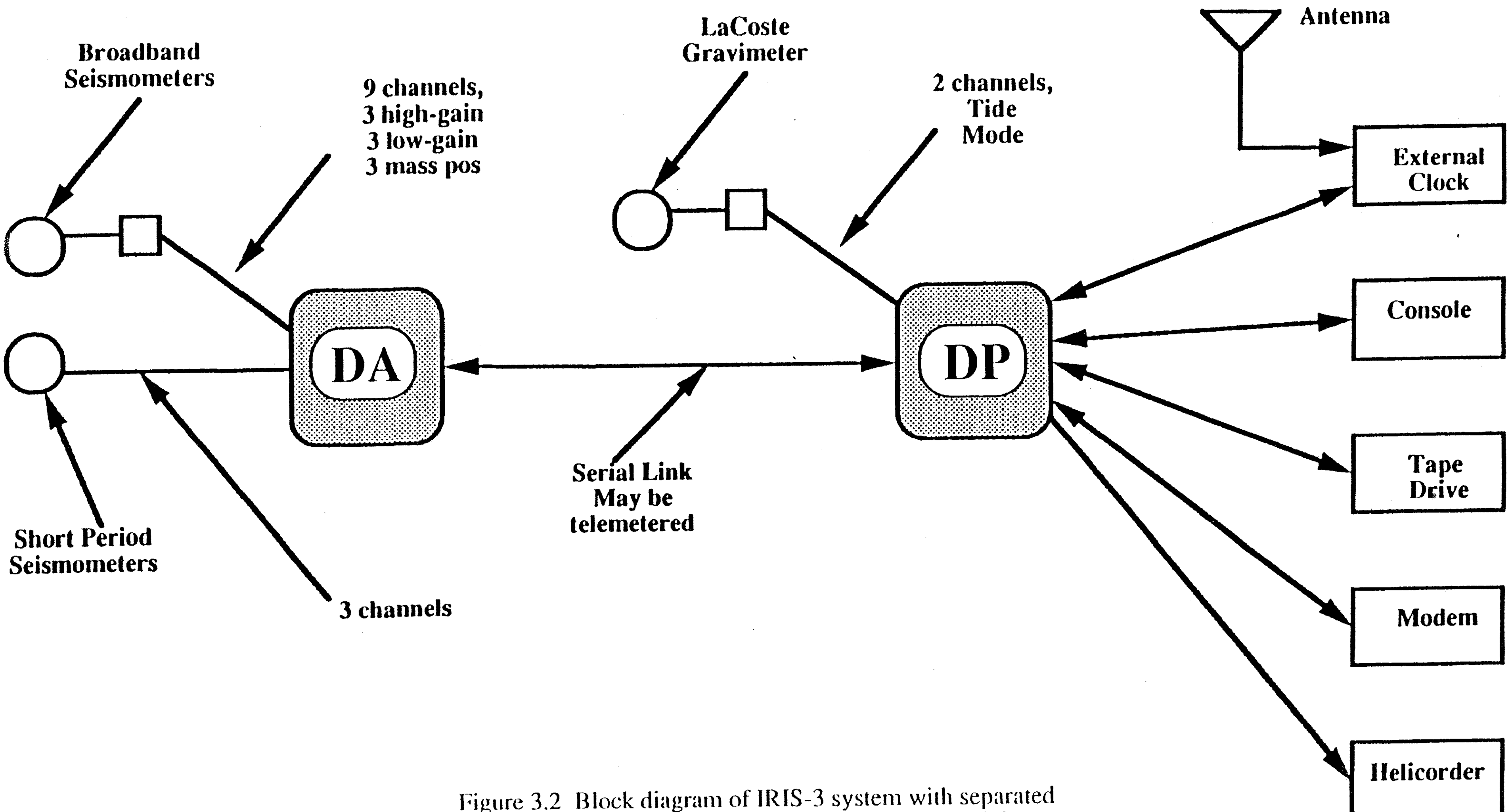

Figure 3.2 Block diagram of IRIS-3 system with separated data acquisition (DA) and data processing (DP) modules.

sensors that may be used in vaults include the Güralp CMG-3 and the Streckeisen STS-2 sensors now under development. The choice will depend primarily on an evaluation of dynamic range, linearity, and other technical factors. Borehole seismometers will be used at Seismic Research Observatories (SRO) stations where boreholes already exist and at island sites and other sites where the drilling costs are not prohibitive. The Teledyne-Geotech KS 36000 borehole seismometers now operated at the SRO stations will be modified to produce broadband (0.25 to 360 sec) signals. Candidate seismometers for use at new borehole sites include the Guralp CMG-3 and STS-2 packaged for borehole operation and the Teledyne-Geotech KS 54000 that has been developed for use in the Global Telemetered Seismograph Network (GTSN). VBB signals will be digitized at a rate of 20 samples per second (sps), compressed in the DA processor, then recorded or transmitted in a continuous data stream.

Some stations will be equipped with triaxial very-short-period (VSP) sensor subsystems. Geotech GS-13 sensors have been deployed at several IRIS-1 sites, and Geotech 54100 borehole sensors are in use at some IRIS-3 sites in the Soviet Union. Other VSP sensors are under consideration Desirable characteristics include a response flat to velocity from 1 to at least 40 Hz, and a sensitivity adjustable to accommodate differences in background noise levels. The digitization rate will be at least 100 sps and may be set as high as 200 sps depending on station configuration. An automatic signal detector will be used to detect events in the VSP signals, and only detected events will be stored in buffer memory, recorded on site, or transmitted. Some stations will also be equipped with triaxial low-gain (LG) sensor subsystems to record ground motion from major earthquakes that overdrive the VBB sensors. Kinemetrics FBA-23 accelerometers have been installed at the seismic station PASI in Pasadena California, and other sensors are under consideration. The digitization rate of the LG signals will be at least 50 sps and only detected events will be stored in the buffer memory, recorded on site, or transmitted.

The GSN data system will also accommodate other types of sensor signals, such as wind velocity and direction, barometric pressure, and magnetic and gravity field. However, there are no current plans to install these types of additional sensors during the initial deployment of the network. Data from IDA gravimeters will be recorded from current IDA sites occupied and upgraded as part of the GSN.

3.2.3 Digitizer Units

Each data system will be equipped with digital encoders to convert analog outputs of the sensor subsystems to digitally encoded signals. Digitizers will be located close to the sensor subsystems and cabled to the DA processor through up to 100 meters of wire or fiber optic cables.

A Martin Marietta EDME (enhanced delta modulation encoder) four-channel high-resolution digitizer/calibrator (HRDCU) will be used to encode the VBB signals in the IRIS-2 system. The EDME has a dynamic range of 140 dB and 24-bit resolution. It samples at a high rate, digitally filters the signal with a corner at 8 8.2 Hz, and provides an output rate of 20 sps. In addition to this function, the HRDCU generates calibration signals that can be applied to the sensors on command and encodes the calibration signal on the fourth EDME channel. The Quanterra quantagrator, which also meets GSN design performance goals, is used in several IRIS-1 systems and may be optionally used in the IRIS-2 systems. A Hewlett-Packard 24-bit digitizer is currently being integrated into the IRIS-3 system by RefTek, and can serve also as an optional digitizer for the IRIS-1 and -2 systems.

An optional 6-channel digitizer/calibrator (LRDCU) will be furnished with IRIS-2 systems that include optional VSP or LG sensors. Sampling rate will be selectable at 50, 100, or 200 sps, with maximum throughput of 600 sps. The LRDCU will have a dynamic range of at least 96 dB and 16-bit resolution. The LRDCU will also include a calibrator and records the input calibration signal on a seventh channel. The Streckeisen 16-bit digitizer is currently used at several IRIS-1 sites to record VSP and LG channels. The PASSCAL/IRIS-3 digitizer samples with 16-bit resolution at 1000 sps per channel and uses a digital signal processing (DSP) chip to digitally filter the data to a lower desired sample rate and concomitant increased resolution. The IRIS-3 system also contains a calibrator.

Each data system can be equipped with an auxiliary 16-bit digitizer unit (AUXDU), which would be used to sample mass position outputs of the VBB sensors and other low-rate data channels that may be added in the future.

3.2.4 Data Acquisition Processor

The DA processor in the IRIS-2 system utilizes a 32-bit Motorola 68030 central processing unit (CPU) and other hardware modules attached to a standard VME bus. The Microware OS-9 operating system is designed for real-time applications. Application software is written in a high-level language (PASCAL) to simplify future modifications and enhancements that are certain to be made. In the IRIS-3 system a Motorola CMOS 68000 CPU is used in conjunction with an Analog Devices ADSP2100 digital signal processing chip within a custom real-time operating system. Application software is written in the high-level C language. The principal functions of the DA processor are to control timing, collect digitized data from the digitizers, time tag data blocks, compress VBB signals, perform automatic event detection, and transmit data to the data processing module. Software will be stored in programmable read-only memories. The DA module may be operated in a remote, unattended site and will be capable of automatic reboot when power comes up after a lengthy failure that exceeds the capacity of the remote backup power subsystem. In sites where the separation of data acquisition and data processing functions by a telemetry link are not required, these functions may be co-located to minimize hardware. In these cases the DP functions are performed by a DA/DP system using DA hardware. The IRIS-1 systems are essentially co-located IRIS-2 systems, whereas the IRIS-3 systems may be configured in either manner.

3.2.5 Timing Subsystem

The timing subsystem is synchronized to signals transmitted by the Omega navigational system. Timing is within 10 milliseconds of Universal Time. .Backup timing signals are provided by an internal oscillator if the Omega signals fade. GOES clocks may also be used but are limited to the western hemisphere. The timing subsystem is self synchronizing and does not require any operator intervention; thus, it may be used at unattended sites. The Omega clocks are much less expensive than clocks synchronized by the Global Positioning Satellite (GPS), and will be used in the network for several years. However, they will have to be replaced when the Omega navigational system is replaced by the GPS positioning system.

3.2.6 Data Processing Processor

The DP processor hardware is similar to the DA processor hardware The major functions of the DP processor are data manipulation, system diagnostics, calibration, and data processing. The DP processor receives data packets from the DA processor;

performs decompression, filtration, and decimation of the VBB data to produce long-period (LP) and very-long-period (VLP) digital signals that are stored and recorded together with the VBB signals; generates and time tags the analog signals recorded on the monitor recorder and the optional WWSSN recorders; formats event detection parameters for storage and printout; monitors state-of-health (SOH) information and reports errors to the operator; distributes the data packets to various storage, recording, and transmission functions; and provides for operator monitoring and control. The DP processor has excess capacity that is available for additional tasks in the future.

3.2.7 Communications Link in Separated Systems

Both the IRIS-2 and IRIS-3 systems may be configured as separated systems with Data Acquisition and Data Processing modules communicating over a telemetry link. This permits the seismometers to be located at quieter sites more isolated from cultural noise, while at the same time permitting the host organization easy access for recording the data. The telemetry link can be wire or fiber optic cable, a dedicated telephone circuit, a radio frequency channel, or a satellite channel. The data are packetized and time tagged at the remote site. Using a 9600-baud modem, a voice-grade circuit will support telemetry of continuous VBB and VSP data. A buffer memory in the DA is used to store VBB, LP, and VLP continuous and event data, as well as VSP and LG event data (if available). The standard buffer memory will typically store at least 10 minutes of data when all channels are operational, and up to two hours continuous data when optional VSP and LG channels are not used. To extend these limits, more memory may be added to the systems. Transmission errors caused by noise bursts and outages are typically of short duration, ten minutes or less. The data packets are verified error-free on receipt or re-transmission is requested. If a circuit outage persists and the buffer fills, data will be lost. In the IRIS-2 system data streams are prioritized, such that on a buffer-full condition the packets may be systematically discarded based upon priority to minimize total loss of data. For example, up to 24 hours of continuous LP and VLP data and VBB event data in the IRIS-2 system can be saved in the standard buffer for automatic re-transmission when the circuit is reestablished.

3.2.8 Buffer Memory

A hard disk with at least a 40-megabyte capacity is furnished with each IRIS-1 or -2 data system for on-line storage of digital data and information. The IRIS-3 may optionally be configured with a hard disk. Where implemented the buffer memory will store 24 hours of VBB data, LP data, VSP event data, and LG event data, event parameters, SOH and other information, and up to 30 days of VLP data. The buffer memory has two purposes: to provide access to current data by station personnel and data centers (via the dial-up port), and to serve as a buffer when large earthquakes increase the data rate above the capacity of a real-time telemetry link. Normally, a station is expected to generate about 6 - 7 megabytes of compressed data per day.

3.2.9 Digital Recording Subsystem

Digital data are currently recorded on magnetic media, but optical media can potentially be used. The IRIS-1 and -2 systems use high-density (150-Mbyte) tape cartridges. Each cartridge will store over two weeks of data, and two cartridge drives are provided so that cartridges may be changed without loss of data. Automatic switch over will occur if the on-line cartridge fills with data or fails. The IRIS-3 system uses the high-density helical-scan Exabyte cassettes, except where export restrictions force the use of 9-track tape (i.e., in the Soviet Union). A single recorder is currently used to record two weeks of data (one week at 9-track tape sites), and data are buffered in memory when the medium is being changed. At all sites SOH and diagnostic information, message text, and all operator commands and logs will be recorded on the tape with the data. It will not be necessary for any paper logs to accompany the tapes to the DCC. The SEED format is used to construct the data records. Higher density media may be adopted in the future, but to insure timeliness the data will always be sent to the DCC at intervals no greater than two weeks.

3.2.10 Real-Time Data Access

Each data system is designed such that real-time transmission of all data, information, and message text can be implemented in the future. Message text will be received at the station on a return link.

3.2.11 Dial-Up Data Access

Each IRIS-1 and -2 data system is equipped with a dial-up port and 9600-baud modem designed for full duplex operation through a commercial telephone circuit. The dial-up link will be used by the host organization or data centers to request data segments stored in the buffer memory or to exchange message text with the station operator. Access will be controlled through the use of a password. Dial-up access for the IRIS-3 system is being developed.

3.2.12 Local Data Access

All of the data and information generated by the IRIS-2 GSN system is available through a 9600-baud serial port in real time so that station personnel may connect the GSN system directly to work stations or other on-site computer facilities. The IRIS-3 system uses a standard SCSI interface.

3.2.13 Operator Terminal and Control

The GSN systems are equipped with a terminal and printer for operator control. The terminal may be used by the operator to check or set the time; view event, error, or status logs; set, change, or display event detection parameters; re-center the VBB seismometers; exchange message text over the real-time or dial-up ports; initiate calibration and run a calibration analysis; select channels for the monitor recorder; select simulated responses (WWSSN, SRO, and other) for analog recording; and view a continuously updated display showing a snapshot of all data channels, UTC time, space remaining on the on-line tape cartridge, status of event detectors, tape error rates, messages, status and error messages, and seismometer mass position. The IRIS-1 and -2 systems have the capability to display and plot selected waveforms stored in the buffer memory on the console graphics screen. Additionally, the IRIS-2 system can display selected channels in quasi-real time on the graphics screen. However, normal operation of the GSN system does not require operator intervention except to replace tapes at biweekly intervals or service any analog recorders that may be used at the station. Hand-held terminals are used to provide to access at remote DA sites.

3.2.14 Monitor Recorder

A single-channel recorder is provided with each GSN system so that any of the active channels (VBB, LP, VLP, or VSP) can be selected for recording by the operator. The monitor recorder is used to record tests and sensitivity adjustments, to evaluate signal detection parameters, and to provide a continuous analog record of any channel at the discretion of the operator.

3.2.15 Analog Recording Subsystem

Up to six analog output channels are available from the DP processor for local recording on conventional seismograph recorders provided by the station. WWSSN and Seismic Research Observatory (SRO) stations have four to six analog recorders available that can be used for this purpose. Software simulations of WWSSN and SRO SP and LP responses derived from the VBB signals are currently available at IRIS-1 and -2 sites for recording and signals with other response characteristics can be implemented in the future at all GSN sites.

3.2.16 Digital Plotter

A digital plotter will be furnished at stations that require data for local analysis. The plotter will be used to record signals, such as local events of interest extracted from the buffer memory, or data derived from processed signals, and may be used at some stations to produce 24-hour seismograms.

3.2.17 Station Power Subsystems

An uninterruptible power subsystem (UPS) will be provided at each station. The UPS will condition the local power and provide four hours of battery backup in event of a power failure. The power required for a fully-configured IRIS-2 GSN system is about 750 watts during normal operation (including six analog recorders). A separate smaller UPS will be provided with the DA module when it is located at a separate site. Power required at a remote sensor site is from 10 to 275 watts depending on the configuration of the IRIS-2 system and 1.5 to 5 watts the IRIS-3 system. All system equipment is designed to operate from local power, so that a failure in the power subsystem will not result in a complete failure of the data system.

3.2.18 Lightning Protection

Lightning has been one of the principal causes of catastrophic system failures at seismograph stations. In the GSN system all data lines are protected with Zener diodes and DC power lines are protected with a combination of Zener diodes and gas arresters. The use of fiber optic cable for signals lines will further reduce susceptibility to lightning-induced failures.

3.2.19 Mechanical Configuration

Station recording equipment, including the monitor recorder, for the IRIS-2 system is housed in a single 6-foot cabinet. A table is provided for the terminal and printer. Analog recorders, if used, will be mounted in separate racks. The UPS charger, inverter, and controls are mounted in an 18-inch cabinet with batteries in a separate rack. Normally, the UPS is located in a separate, well-ventilated room or shed. The digitizers, which will be located near the seismometers, are mounted in a sealed box. Similar configurations are used for IRIS-1 and -3 systems. At separated seismometer sites or in difficult environments the DA or DA/DP module will also be housed in a sealed enclosure.

3.2.20 Calibration

Calibration signals applied to the VBB seismometers are generated in the IRIS-2 system within the HRDCU and recorded on a fourth EDME encoder (which also serves as a spare). Calibration input signals for the optional VSP and LG sensors are provided by the LRDCUs, and separate channels are available for separate recording of the input signals. Step functions, random binary signals, and sine waves at discrete frequencies are all available as inputs to the sensor calibration circuits in both the IRIS-2 and -3 systems. Since both the sensor input and output signals are measured and recorded, the determination of the sensor transfer functions can be automated in the data system using techniques developed and used by E. Wielandt (1986a, 1986b) in which the input signal convolved with a trial transfer function is matched to the sensor output signal using least-squares fitting. Quantization error, noise, instrument drift, and non-linear behavior can also be identified using this method. Calibration will be performed at periodic intervals to be determined. Sine-wave calibration is also used to adjust magnification of analog recording. The IRIS-1 systems currently have limited calibration capabilities.

3.2.21 Exportability

To meet export restrictions to certain countries, some modules on the GSN systems will need to be modified to meet requirements. In these cases the system's modularity will permit the replacement of key components with exportable components. For instance, the high density tape cartridge drives may be replaced in some instances by lower density reel tapes; or a high-speed microprocessor chip may be downgraded to an acceptable, lower-performance chip which can still function. For example, the IRIS-3 system has been installed in the Soviet Union using 9-track magnetic tape for recording. By maintaining an up-to-date awareness of current exportability requirements, systems can be deployed and upgraded to maintain state-of-the-art standards within these export limitations.

3.3 REMOTE GSN DATA SYSTEMS

Several of the proposed locations for GSN systems are remote sites that may be unattended or minimally attended by local personnel whose sole responsibility is to change tape cartridges on a biweekly basis. In these cases power drain may be an important consideration, and it will not be necessary to provide local access to either digital or analog data except for maintenance purposes. The IRIS-3 systems is designed for these circumstances. A remote IRIS-2 data system is also desirable for use at these locations. In either case a remote GSN data system is expected to have most of the following salient features.

- VBB sensors and optional VSP and LG sensors.
- VBB dynamic range of 140 dB at 20 seconds
- VSP and LG dynamic range of at least 96 dB.
- Low power (< 100 watts); DC powered.
- RAM-based buffer memory of at least 10 MBytes.
- Both real-time and dial-up ports.
- Optional cartridge or disk recording.
- SEED data format.
- Calibration procedures same as basic GSN system.
- Port for portable terminal.
- Switchable DAC for monitoring signals.
- Automatic mass positioning.

- Backup power.
- Lightning protection.
- Sealed, weather-proof enclosures.

If a remote station is not connected to the DCC via a satellite telemetry link, a dial-up communication link between the station and the DCC will be very desirable, not only to retrieve data segments, but to run diagnostics and perhaps to download software, and change station operating parameters. Ideally, the remote GSN system hardware and software will be similar to that used in the basic GSN system to simplify long-term maintenance.

4. STATION SITING PLAN

4.1 SITE SELECTION

The task of developing a station siting plan for the new GSN stations was assigned to an IRIS SCGSN Site Selection Subcommittee, and the results were reported in 1986 as the 5-Year Siting Plan IRIS Contribution to the Global Digital Seismographic Network. In early 1989, IRIS SCGSN updated and modified the current siting plan. The principal criterion used for siting was to obtain a uniform global distribution of stations. The surface of the Earth was divided into 128 equal areas approximately 18° by 18° at the equator. It was found that 90 of the blocks contained seismograph stations that regularly reported arrival times to the International Seismological Centre (ISC) and that an additional 25 blocks contained oceanic islands on which it would be possible to place remote seismograph stations, so that uniform global coverage is a feasible goal with at least 115 land based stations.

Blocks were generally eliminated from consideration if they contained existing or planned stations expected to produce broadband digital data; that is, stations of the China Digital Seismograph Network (CDSN), the Global Telemetered Seismograph Network (GTSN), the GEOSCOPE network, and the Canadian network. Prospective sites were identified in many, but not all, of the remaining blocks. A complete listing of the prospective sites was published with the Minutes of the SCGSN, March 1986. Primary consideration was given to any station within the region that has participated in the WWSSN, GDSN, or IDA networks, since these stations have trained personnel and established facilities. Preference for operational stations that have demonstrated past interest and performance has resulted in duplication within some blocks but only where this was judged to be appropriate.

Fifty-one proposed sites for the new GSN equipment were selected in the 1986 5-year siting plan, and the Subcommittee recommended that nine additional sites be selected later from within the conterminous United States. Several modifications to the siting plan, principally additions, have been made since the Subcommittee submitted its initial recommendations. As the result of an agreement between IRIS and the USSR Academy of Sciences, five broadband stations were installed in the Soviet Union in 1988. Also, several stations have been added to the list where host organizations have contributed to the purchase of equipment — these include university operated stations. The current distribution of proposed IRIS GSN stations is shown in Figure 4.1 together with planned GTSN stations. Only a few of the host organizations have been contacted officially concerning the possible establishment of a GSN station and some further modifications in the siting plan may be expected pending the outcome of these queries.

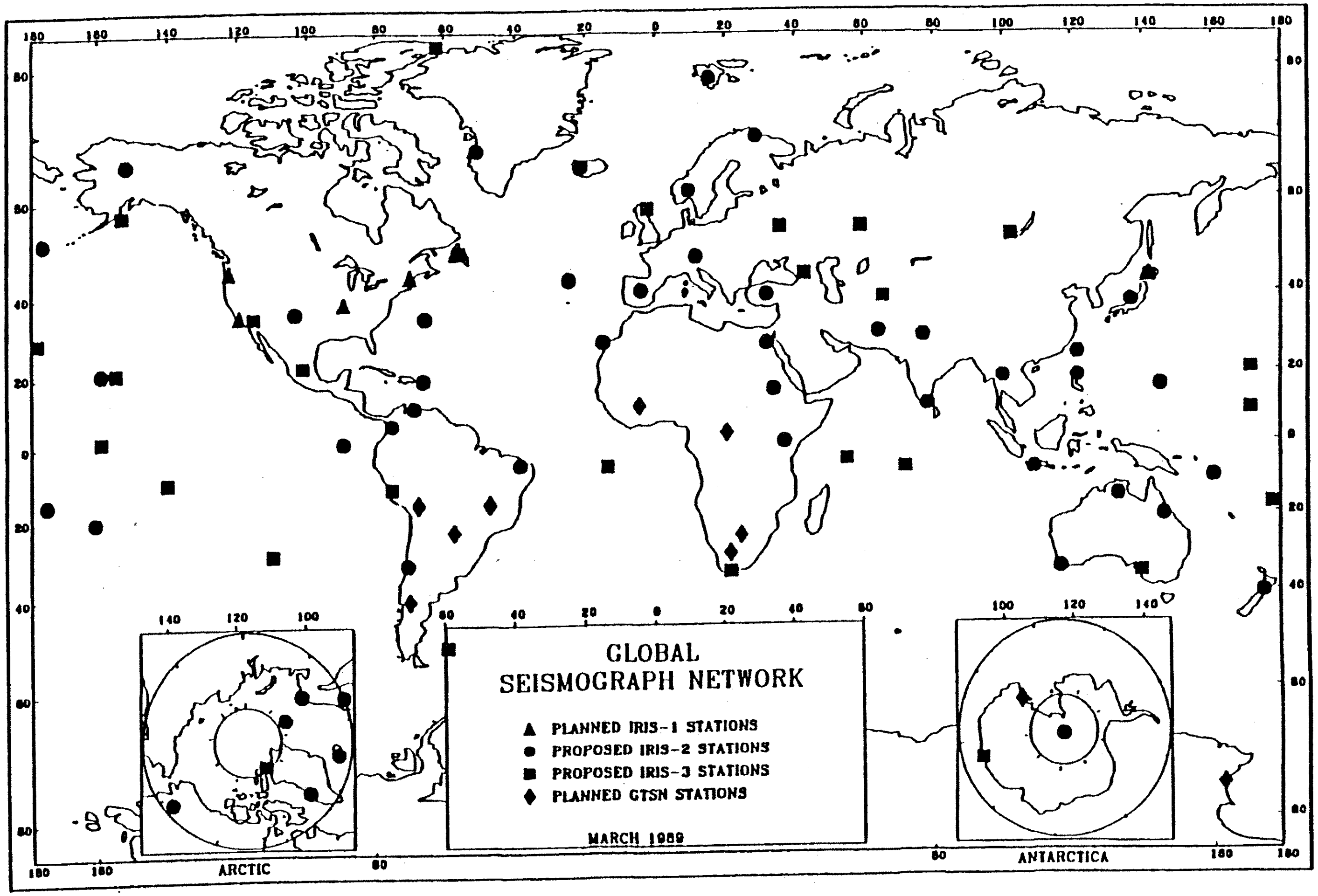

Figure 4.1 Map showing locations of planned IRIS GSN stations. IRIS-1 systems are installed at several IRIS member Universities. The USGS is responsible for deployment and support of the IRIS-2 systems. The IRIS/IDA group at the University of California at San Diego is responsible for deployment of the IRIS-3 systems. In addition, planned locations for GTSN stations are shown.

The working plans shown in Figure 4.1 represent the first major installment in the long term goal of uniform global coverage. With a minimum of 115 stations, uniform coverage can be achieved, excluding only those areas which will require ocean-bottom deployments. There is a great interest in providing coverage even in these difficult oceanic environments, but such discussion is beyond the scope of this Technical Plan. Beyond a minimum 115 stations for uniform coverage, there will be areas of greater station density, such as in the United States. Other networks — for example, GEOSCOPE and the Canadian Network — will provide coverage in many areas of the globe, and such efforts are welcomed and encouraged.

4.2 SITE REQUIREMENTS

4.2.1 General

Apart from geographic considerations, an ideal station site for a GSN VBB station would have a deep subsurface vault, isolation from cultural noise, stable and reliable power, and a trained, highly motivated technical staff. Few of the proposed sites have all of these attributes, the need for uniform coverage often outweighing specific factors affecting the quality and reliability of the data.

4.2.2 Seismometer Vault

Seismometer emplacement is one of the key factors affecting data quality, especially in the long-period band. It cannot be emphasized too strongly that the quality of data recorded from a particular station will depend primarily upon the quality of the seismometer placement. Surface deformation caused by wind and solar heating can contaminate horizontal-component LP signals to the point of uselessness. Long-period data from the GDSN and CDSN networks clearly demonstrate an order of preference for seismometer emplacement: (1) subsurface vault greater than 100 m in depth; (2) borehole of at least 100 m in depth; (3) subsurface vault greater than 10 m in depth; (4) surface vault. Surface vaults are usually unsatisfactory — the resulting data will likely be excessively noisy. Geologic factors are important as well, surface deformation being a function of the rigidity of the rock. A broadband sensor installed in a surface or shallow subsurface vault on unconsolidated sediment has very limited usefulness. Deep subsurface vaults are in active or inactive mines. Development of new subsurface vaults is prohibitively expensive, but efforts should be made to locate potential subsurface vaults in the vicinity of the proposed station sites where improved facilities are needed. Experimentation with "posthole" or other shallow burial techniques may provide alternatives for sites where deep boreholes or adequate vaults are not practical.

There are boreholes at all of the SRO stations, and they will continue in use with the new instrumentation. The cost of drilling and casing a borehole varies over a wide range ($8,000 - $250,000) depending mostly on the availability of a drill, the worst case being remote island sites where the drill must be barged in. Despite the cost, the construction of boreholes at new station sites that lack vaults or at existing sites that have poor vault facilities is highly desirable. Even shallow boreholes or postholes drilled into bedrock would be preferable to surface vaults resting on unconsolidated sediments.

4.2.3 Seismic Noise

Natural microseisms are unavoidable at stations operated near coasts and on islands. Broadband recording at such locations was not practical until the introduction of sensors and encoders with dynamic range and linearity sufficient to accommodate the high signal levels in the microseismic bands without affecting resolution in other bands. The GSN system has these characteristics making it unnecessary to suppress microseismic noise using band-limited recording.

Cultural noise can be avoided to some extent, although circumstances often dictate compromise. Many of the existing stations worldwide were constructed over 25 years ago during the early years of the WWSSN program, and in most cases the locations were relatively isolated from cultural activities. Since then few have escaped encroachment, and almost none have been relocated to quieter sites. The best solution for a noisy station, where feasible, is to locate the sensors in an isolated vault or borehole and telemeter the signals back to the recording station. The GSN system has been specifically designed for this mode of operation. Stations where local telemetry is currently employed or where telemetry is recommended are noted in Table 4.1. Past experience has shown that line-of-sight radio-frequency (RF) telemetry links are much more reliable than telephone circuits. However, some of the links are expected to be thousands of kilometers in distance, and both satellite and microwave circuits will be used. Site testing is appropriate where new sensor sites are to be selected.

4.2.4 Station Facilities

The participating station is expected to provide a vault or borehole for the sensor systems, a communication circuit if local telemetry is employed, facilities for the recording system and UPS equipment, and power to operate the data system. Some stations will require financial support for site preparation work.

Boreholes used for broadband seismometers are generally drilled to a depth of 100 m, cased with 7-in steel casing, cemented, and sealed. Vertical offset must be less than 4° for use with the SRO-type seismometer. It is essential that the borehole be watertight, and it is preferable that it be airtight. Detailed specifications for the drilling and finishing of a borehole are available at ASL.

Installed in a vault, the sensor systems will require less than three square meters of floor or pier space. The vault should be thermally isolated from daily temperature fluctuations, and it should be dry. The VBB vertical-component sensors are sealed and therefore unaffected by pressure changes in the vault. More detailed vault specifications will be available at ASL.

The recording equipment should be located in an enclosed dust-free room or instrument rack that is maintained at a temperature between 20 and 25°C year round. Air conditioning is essential in most regions of the world. The amount of space required depends on the use of analog recorders. For safety reasons, the UPS batteries should be located in a separate well-ventilated room or shed. The UPS rack is often placed in the battery room as well because of the inverter noise.

Power required for the IRIS-2 system with 6-channel analog recording will vary from about 750 watts when the batteries are on trickle charge to about 1000 watts when the batteries are on full charge following an outage. Much of the power is consumed in the UPS system. Power required at a remote sensor site is 10-275 watts, depending upon configuration. Power failure is the most common cause of station downtime in the global networks. The UPS systems are designed to provide 4-hours of battery backup when line power fails, at both the recording station and at the remote sensor site.

5. NETWORK DEPLOYMENT PLAN

5.1 INTRODUCTION

Deployment of the network involves more than the shipment and installation of the data systems. It begins with the development or modification of station agreements, involves site preparation, preparation and shipment of the data systems, preparation of field teams, training, system installation, and ends when the network is fully operational. The deployment of the GSN is a major operation that requires intensive planning and effective management. Delays caused by poor planning can be very costly.

5.2 STATION AGREEMENTS

Agreements between the Network Manager and the host organization form the basis of cooperation. The model for these agreements is represented by USGS practice, which is discussed herein. Initial contact with a station is by a letter to the host organization requesting their participation in the program. The letter includes a statement of the scientific objectives, a description of the instrumentation, an outline of site requirements, operational requirements, and proposed support for the station, and a summary of benefits that the host organization will receive by participating in the program. Informal letter agreements or amendments to existing agreements are preferred, although more formal agreements are required in certain cases. It is also necessary in some cases to follow up the initial letter with a visit to negotiate specifics. Agreements that require ministerial approval, which are often the case when stations are operated by government organizations, may take as long as a year to conclude, so the process must begin at least a year before scheduled deployment.

A typical station agreement will define USGS and host organization responsibilities as follows:

<u>USGS Responsibilities</u>

- Site preparation (in some cases).
- Delivery of equipment to the site.
- Installation of equipment.
- Training of station personnel.
- Provision of supplies and parts.
- Technical assistance and periodic maintenance visits.
- Return of original data, if desired.

<u>Host Responsibilities</u>

- Site preparation (in some cases).
- Furnish vault and recording facilities and power to operate the equipment.
- Assist with importation of equipment.
- Assist with installation of equipment.
- Operate equipment and notify the network maintenance center of any problems.
- Mail data and logs promptly to the DCC.

The disposition of the equipment is also addressed in the station agreement. Title to the WWSSN and GDSN equipment has been retained by the USGS in the case of domestic stations and given to the host organization in the case of foreign stations. In most cases the IRIS/IDA Network maintains title to equipment at foreign sites.

5.3 SITE PREPARATION

A detailed site plan will be developed for each station in cooperation with the host organization. Important considerations are the vault type, the system configuration (separated or local), type of telemetry, if used, analog recording requirements, and commercial power specifications. The site plan will include layouts showing the location of sensor systems, recording equipment, power equipment, and the power and signal cables. It will list any special requirements for extra length cables, fiber optic cables, new conduit, air conditioning, building modifications, and so forth. Most stations that have not been upgraded for the past 25 years require some site preparation work, most commonly new power lines, power line transformers, and air conditioning.

Major site preparation work at new sites and a few of the existing stations may include construction of a borehole or vault, major modification or construction of recording facilities, and the construction of roads and power lines. In most cases, this work will have to be funded by IRIS. In the past, for example, the USGS has contracted locally for construction work with the help of the host organization; alternately, the USGS has provided funds for site preparation to the host organization through the Embassy in the form of a grant. In either case, intensive monitoring is required to see that the work is completed satisfactorily and on schedule. Acceptance tests on boreholes are especially important and must be performed by a Network representative using proper test equipment.

5.4 PREPARATIONS FOR INSTALLATION

The GSN station equipment will be installed by a two-man installation team with assistance from local station personnel. Training in the data system and in the variety of sensor systems that will be employed by the GSN will be provided by ASL or IRIS/IDA support personnel with input by the system manufacturer.

Each team will be provided with an installation kit that will contain tools, test equipment, report forms and other items needed for installation. The kit will also contain a supply of critical spare parts and boards. The first IRIS-2 production system will be installed at the Albuquerque Seismological Laboratory as station ANMO. This will serve as additional training for the installation teams, and it will provide an opportunity to evaluate installation procedures, tests, and reports. An IRIS-3 system is similarly deployed at the Pinon Flat Geophysical Observatory.

Each IRIS-1 and -2 production system will be configured at the factory for a specific station location, fully assembled and tested, then packed for export shipment. Packing methods and materials have been specified such that the shipment can be stored outside without damage. Any damage sustained during shipment as a result of improper packing or defective mechanical design is the responsibility of the manufacturer. IRIS-3 systems are configured at the IRIS/IDA Network Maintenance Center in La Jolla, CA; then tested and shipped to the site. Shipping damage is doubly expensive because it often prolongs the field installation.

5.5 SYSTEM INSTALLATION

The time required to install a GSN data system is expected to be three or four weeks depending on the complexity of the station and the type of sensor systems specified for the site. The first week is typically used to complete minor site preparation work, install and test the sensor systems, and assemble the data recording equipment; the second week to perform the component and system tests and complete the installation report; and the third week to monitor system performance and train local personnel in daily operation and maintenance, board replacement, log keeping, communication with the network maintenance center and DCC, data shipping, and other important activities. The training at IRIS-1 and -2 sites includes software as well as hardware and covers procedures used to retrieve, display, plot, and process the data.

5.6 FIELD REPORTS

Because of the importance of information concerning the station, installation test results, and test records, a special Installation Report form will be developed specifically for the GSN network by the USGS and IRIS/IDA. Following formats used with the WWSSN, GDSN, and CDSN networks, the report will contain a brief history of the station, a description of the vault and recording facilities, coordinates and elevation of the sensor systems, local geologic setting, local topographic setting, a description of nearby cultural or natural sources of seismic noise, an assessment of power reliability, a list of all equipment with serial numbers and sensitivity constants, where appropriate, calibration and test instructions in cookbook form, and test results. Maps, photographs, test records, and test tapes will be submitted and filed with the report. A recommended installation report form will be developed prior to deployment of the IRIS-2 systems. The IRIS Data Management Center will maintain an up-to-date catalog of the information contained in these reports for all GSN stations.

5.7 U.S. TRAINING FOR STATION PERSONNEL

During the deployment of the GDSN network, operators from each of SRO and ASRO stations were brought to ASL for six weeks of intensive training in the operation and maintenance of the data systems. The training was effective in some cases, but not in others because of language barriers and because of the great diversity of technical capability on the part of the station personnel. Nevertheless, the program was highly beneficial because close working relationships were established between the station operators and ASL support personnel. The operators became familiar with station support and data collection operations at ASL, realized the importance of logs and the necessity of sending data in promptly, and became more aware of the importance of their role in the program.

Budget permitting, a similar training program will be conducted at ASL or IRIS/IDA for GSN station personnel. In this case, more emphasis will be placed on software and data handling. In fact, because of capability of the GSN system for off-line computer processing and the potential for local data analysis, scientific personnel are likely to take much more interest in the station operation and may want to participate in the training.

6. NETWORK OPERATION AND MAINTENANCE PLAN

6.1 INTRODUCTION

The deployment of a new network is a milestone, not the final objective. A network will not survive long without adequate operational support after the stations are installed. Subsistence-level support includes resupply, replacement of defective parts and components, and limited on-site technical assistance. Past experience clearly demonstrates that subsistence-level support is not adequate; it promises a steady deterioration of data quality and availability and premature obsolescence. If the GSN is to be the dynamic scientific resource envisioned during its conception, there must be more than subsistence-level support. The agency responsible for the network must continue developmental engineering, provide the funds needed to make improvements, continue training, and manage the network as an integrated scientific facility rather than an odd collection of independent stations. The GSN will be equipped with the most versatile seismograph system ever deployed in a global network. It was intentionally designed to evolve with advances in technology. The GSN will remain a state-of-the-art network as long as it is adequately supported.

Two Network Maintenance Centers have been established. The USGS Network Maintenance Center established many years ago at the Albuquerque Seismological Laboratory will serve as the maintenance center for the component of the IRIS GSN deployed and operated by the USGS. ASL will also serve as maintenance center for GSN stations in the university subnet which operate IRIS-1 or IRIS-2 systems. The IRIS/IDA Network operates a maintenance center at the University of California at San Diego. IRIS/IDA will also serve as maintenance center for GSN stations in the university subnet which operate IRIS-3 systems. The IRIS/IDA Network Maintenance Center is an element of the IRIS's PASSCAL instrument maintenance network, which currently also includes the PASSCAL Maintenance Center at Lamont-Doherty Geological Observatory in Palisades, New York.

6.2 STATION OPERATION

The GSN data systems have been designed to function with minimum operator intervention. Timing, calibration, mass positioning, and log keeping are all automated, as are all of the other routine functions with the exception of analog record changing where necessary and biweekly replacement of the tape cartridges. The primary daily activity of the operator will be to monitor the status of the system. It is expected that the buffered event data will be used in place of seismograms for local analysis as application software becomes available. This will be encouraged to insure active participation by station personnel in the operation of the GSN system.

The station operator becomes especially important and cost effective when a problem or failure occurs at the station, and of course these events are inevitable. The operator will be trained to isolate a failure to board level and to replace defective modules and boards. If a replacement unit is available at the station, downtime is minimized; if not, the operator will immediately request a replacement by express mail from the network maintenance center.

The level of replacement parts initially assigned to a station represents an important trade off between deployment costs and network reliability. A high level of station spares is expensive at the outset, but it significantly reduces the amount of data lost when there is a failure. Unfortunately, it is not easy to predict which components are most likely to fail, and some experience is valuable before a large investment is made in spare boards and modules. In recent experience with digital systems, most board failures have been associated with line power problems, either transients that penetrate the power conditioning equipment or stray currents caused by poor grounding. The manufacturer of GSN data systems will provide a list of recommended station spares, and discretion will be used in making an initial selection.

6.3 FUNCTIONS OF A NETWORK MAINTENANCE CENTER

6.3.1 Introduction

A network maintenance center (NMC) is the operational headquarters of a network. It is in frequent communication with the stations and provides all of the support and assistance needed to keep the stations in operation. It also provides close support to field teams that may be installing or servicing stations. The NMC operates in partnership with the data collection center, on which it relies for detection of problems in data quality and calibration.

6.3.2 Station Resupply

The NMC keeps inventories of supplies and spare parts for each station in the network as well as an inventory of depot supplies. Supplies are purchased in bulk quantities, then parceled out in shipments to the stations well before they are needed. In practice, this is a substantial effort considering the amount of purchasing involved and the diverse shipping procedures that must be used to avoid delays in customs. Often, different shipping procedures are used for routine supplies and emergency replacement parts.

6.3.3 Equipment Repair

Equipment repair and reconditioning is one of the vital functions of the NMC. Some defective equipment must be returned to the supplier for repair, but most of the GSN equipment will be repaired in the electronics shop of the NMC, saving considerable time and expense and reducing the number of spares required. Virtually any digital board can be repaired in the ASL electronics shop or PASSCAL Maintenance Center if circuit and function diagrams are available, and special facilities are available for testing seismometers. A GSN data system will be used in the shop as a test bed for diagnosing problems and checking boards and modules after they have been repaired. Skilled technical personnel and the test system must be in place early in the deployment phase. If the GSN systems behave normally, there will be a relatively high board failure rate initially that will subside after a burn-in time of several months.

6.3.4 Documentation

The NMC staff maintains the station files. This includes installation reports, maintenance reports, correspondence and messages, shipping documents, export licenses, and any other material related to station operation. The NMC staff also maintains the manuals, source code, drawings, schematics, and other documentation describing the data systems, maintains detailed records of system modifications on a station-by-station basis, and maintains statistics on component failures.

6.3.5 Training

The NMC staff prepares and conducts training classes for new support personnel and for station personnel at the station or at the NMC. Many possibilities exist for distributing training courses, special instructions, and menu-driven diagnostics to the stations on floppy disks. There is a recurring need for operator training because of turnover that occurs at the stations.

6.3.6 Engineering Support

The first modification performed on a new data system inevitably precedes the first station installation, and modifications are a continuing practice thereafter. Engineering support for the network is needed to monitor system performance, to identify design problems, and to design, test, and evaluate hardware and software changes that will improve data quality and reliability.

This activity increases in importance as the equipment ages and becomes more difficult to support. Typically, there is heavy dependence on the system supplier for engineering support during the early stages of deployment, but this dependence must not continue indefinitely. The IRIS-1 and -2 GSN data systems have been specifically designed to reduce dependence on the primary supplier. The use of off-the-shelf modules, application software written in a high-level language, and a standard bus contributes significantly to effective network support and makes it much easier to introduce subsequent enhancements made possible by new technology. The IRIS-3 system will depend upon the broad support base in the network of PASSCAL instrumentation maintenance centers for the 1000 digital recorders in the PASSCAL program.

6.3.7 Field Maintenance

On-site maintenance by a skilled technician is a vital component of network support. Despite the best design, diagnostic support, spare boards, and training, stations will develop problems that cannot be corrected by station personnel. Direct lightning strikes, power system failures, and problems with borehole seismometers usually require expert assistance. At some stations the skill level of the operator is not adequate to deal with more common problems. Ideally, field technicians will be within one or two days travel of all but the most remote stations. When not engaged in emergency visits, they will routinely visit stations to update hardware and software modifications and train new station operators. Field support is expensive, but it is a key element in maintaining an acceptable level of data availability. It is the only way of supporting remote, unattended stations.

6.3.8 Communications

Good communications between the NMC and the supported stations are essential. Telex is the most common form of communication used at present. Where dial-up circuits can be established, the NMC will be able to communicate directly with a GSN data system to exchange message text with the operator, monitor system operation, run diagnostics, download software, and check data quality. Dial-up circuits will be especially important for communicating with stations that are serviced only biweekly by an unskilled attendant.

7. DATA COLLECTION PLAN

7.1 INTRODUCTION

The basic functions of a data collection center were institutionalized with the establishment of the WWSSN. Seismograms were collected from the stations, reviewed for correct labeling, calibration, and quality, then microfilmed, archived, and organized for efficient retrieval, and finally copies were distributed to data users on request. The original seismograms were returned to the stations, and the stations were advised of any defects or problems noted during the data review. These functions changed little with the advent of digital recording in the early 1970's. Since then the volume of digital data and the complexity of the operations have both increased substantially, but the only functional change has been that the DCC now does not normally distribute data directly to the end users. Data management centers have been developed to merge data from several networks and to organize the database to permit more rapid and efficient access by the end user.

Network management, maintenance, and data collection are linked organizationally by necessity. Data collection centers are integral parts of network operation because of the importance of data review in monitoring and maintaining station performance. Each organization responsible for maintenance of a network must also be responsible for collecting and reviewing the data; thus, there are separate DCC's for IRIS stations supported by the USGS and IRIS stations supported through the IRIS/IDA operation at the University of California at San Diego. A DCC has been operated at the Albuquerque Seismological Laboratory since the earliest deployment of digital stations. The ASL DCC serves as the data collection center for all IRIS-1 and -2 sites in the GSN, including USGS deployments and university subnetwork sites. The IRIS/IDA DCC was established with the onset of IRIS/IDA operations in 1987 and serves as the data collection center for all IRIS-3 sites in the GSN, including IRIS/IDA deployments and other university subnetwork sites.

A need to develop a new data collection system at ASL to process data from the GSN stations was dictated by the extraordinary increase in data volume that will occur over the next few years. At the present time, the ASL DCC processes approximately 30 megabytes of data each day, collected principally from the GDSN and CDSN networks. Assuming that in a few years the USGS is responsible for processing data from 50 GSN stations, the GTSN network, and the CDSN network, the volume of data will approach 400 megabytes per day. Similarly, with the IDA Network of long-period gravimeters expansion into a network of broadband, three component seismometers, a six-hundred-fold increase in data is impending. New concepts, new hardware, new software, additional personnel, and automation are all needed to cope with the expanding volume of network data.

The concepts used to plan the new DCCs are described in The Design Goals for a New Seismographic Network. They are based on well-established functional requirements and the need for a versatile system that can be easily expanded as data volume increases. Since the capacity to process network data must be in place before the network is deployed, the development of a new IRIS/USGS data collection center was given a high priority. New hardware has been purchased by IRIS, used hardware has been scavenged from the former DCC, and application software has been developed at ASL. An optical mass store purchased by IRIS has been installed to serve as the primary archive in building the network volumes, and a SUN computer has been installed on the DCC computer network for communications (data and electronic mail) with the IRIS DMC and IRIS/IDA DCC. As a result, the new

IRIS/USGS DCC is already in operation. Still to be installed are the hardware and software needed to receive and process real-time data, a requirement that was given lower priority consistent with current plans to defer the implementation of satellite telemetry. The IRIS/USGS DCC was not intended to be a unique facility; it may be duplicated by other organizations operating networks, with storage and throughput capacity scaled according to need. New hardware — SUN and microVAX computers, tapes and disk systems — has also been purchased from both IRIS and private UCSD funds to meet the growing needs of the IRIS/IDA DCC, which is also presently operational.

7.2 FUNCTIONS OF A DATA COLLECTION CENTER

7.2.1 Introduction

The IRIS data collection centers have been designed to perform the following tasks:

- data acquisition
- time and format validation and correction
- data quality validation
- distribution of validated data to the IRIS DMC
- communicating problems
- backup archiving
- returning original data to the stations
- data format conversion
- status reports and database maintenance.

The IRIS/USGS Data Collection Center at ASL has also.been designed to perform the following additional tasks:

- network volume assembly and quality assurance
- final archiving
- distribution of network volumes

These tasks are summarized briefly below.

7.2.1 Data Acquisition

The data stream from the new GSN stations will consist of continuous compressed VBB, LP, and VLP signals, optional compressed VSP and LG event data, logs, and message text. Initially, all of the data will arrive on high-density cartridges, helical scan Exabyte cassettes, or — in the case of Soviet data — 9-track tape reels. The tapes will normally contain up to two weeks of data and, except in unusual circumstances, should arrive at the DCC within 60 days of the recording date. Data from a few remote stations, such as those in Antarctica, will arrive late, and procedures will be established for processing and archiving late data. The ASL DCC will continue to receive data from other networks, usually on magnetic tape, but often written in different formats.

When satellite telemetry is implemented, real-time data may be received simultaneously at a DCC and the IRIS Data Management Center and monitored at the DCC to verify system performance. Quasi-real time telemetry may be implemented using a file-transfer protocol between the Soviet Data Center in Obninsk and the IRIS/IDA DCC. Except at remote, unattended sites, there will be redundant site recording of the telemetered signals, at least until the reliability of the communication circuits have been substantiated. The telemetered and site recorded data will be merged into a single data stream at the IRIS DMC and as the network volumes are assembled at the ASL DCC.

Data collected at the IRIS/IDA DCC will be shipped on a weekly basis to the IRIS/USGS DCC at ASL to be included in regular and late network volumes — this transfer may occur via the IRIS DMC, if such and action provides for more timely data availability to the seismological community. When direct satellite telemetry is established among the DCCs and IRIS DMC, electronic transfer will occur shortly following data quality control and assurance.

7.2.2 Time and Format Validation and Correction

Data tapes and cartridges from the seismic station received at the DCC are read and loaded into a disk staging area. During this process the data records are checked for continuity, correct format, correct timing, correct record lengths, hard read errors, and correct header information. State-of-health and parametric values are monitored. A subsidiary index is created, providing a standard interface to the data and headers, and also providing the ability to utilize quick random disk access techniques. All corrections are made in the subsidiary index, not in the main data file. This increases system throughput and provides audit control and error recovery.

Except for time errors, all corrections and salvaging operations are performed automatically as the data are loaded into disk. After the data records are in the disk, a time edit list is produced that lists any time errors and provides a summary of data record quantities. Timing errors are the most common form of errors in the GDSN data, usually caused by transients that affect the clock, operator error in setting time, or gaps in the data. Corrections can be made to repair time errors using either an automatic editor that contains a library of programs to repair common errors, or a manual screen-oriented editor to refine automatic corrections or repair errors that cannot be handled by the automatic editor.

7.2.3 Data Quality Validation

After any corrections needed have been made to the record headers, an evaluation is made of data quality. In its simplest form, which is currently implemented, a series of waveform plots are made automatically to display a sampling of data for evaluation, and calibration signals are automatically plotted and checked for stability. The original seismic data are not modified in any way. When needed, comments are placed in the data logs to alert data users to data or calibration anomalies. Occasionally data are considered unusable and marked to be left off the network volume. In some instances, excessive amounts of data are recorded on a triggered channel as a result of defective field detector parameters, special tests, or microseismic storms. These signals are re-detected at the DCC to reduce the amount of data on the network volume, although the complete original data stream is stored in the station backup archive.

Data qualification procedures will be improved and refined following the completion of DCC system development. RMS values will be sampled to detect changes in noise levels and spike detectors will be used to alert the operator to anomalous data. Comparison of recorded and synthetic waveforms will reveal polarity reversals and gross time errors, which have been surprisingly difficult to detect in the past.

7.2.4 Distribution of validated data to the DMCs

After data from a seismic station have been validated by the DCCs, they are staged over the local computer network to a disk buffer, where it is collected for transmission to the IRIS Data Management Center. The data are transferred to high-density helical scan magnetic cassettes (e.g., Exabyte media) and shipped by overnight mail to the DMC. After the data have been successfully entered into the DMC archive, acknowledgment is sent from the DMC to the DCC and the transmitted data are deleted from the staging buffer. Data transfers from DCC to the IRIS DMC occur weekly, and more frequent transmittals may eventually be requested. When direct satellite telemetry links are in place, the data will be transmitted nearly immediately following validation. Data transmission to the USGS DMC will generally originate from the DCC at ASL and will be by real-time links or by the physical transfer of high-density media.

7.2.5 Communicating Problems

Problems and defects found during initial review and edit or during quality control are reported promptly to the maintenance center so that steps can be taken to rectify any operational difficulties at the stations. The DCC also serves as the communications interface between the network operators and the data centers and users. The data users are the final evaluators of network performance, and their feedback to the DCC is needed to maintain data quality. Serving as focus for many user inquiries regarding the seismic data, the IRIS Data Management Center will log all inquiries received and will forward the same to the appropriate Data Collection Center for response.

7.2.6 Backup Archive

After all processing of the data from a station tape is completed, each station file in its original format, its indexes, statistics, and status reports are backed up. Since the original data and the index are both backed up, the data archive is complete.

7.2.7 Return of Original Data

Some host organizations request that recorded data be returned to the station. Either the original or a corrected version of the data will be compiled from the backup archive and returned to those stations requesting it.

7.2.8 Data Format Conversion

Although a standard format has been adopted for the GSN and other broadband stations, much of the station data entering the DCCs during the next several years will be in non-standard format. All data will be converted to the SEED format prior to transmittal to the IRIS DMC and the network volume assembly and final archiving at ASL. Further, all data from new GSN sites (IRIS-1, -2, and -3 systems) will be converted at the originating DCC to SEED format using Steim data compression until this standard format is implemented on all systems in the field.

7.2.9 Status Reports and Database Maintenance

Long-term statistical reports are produced in numeric or graphic form to present an overall history of the network or stations. Traffic analysis and inventory reports are produced to indicate recent performance of the network, including uptime and data promptness. Programs running during production evaluate event detectors and field equipment operation and manage network volume production. A disk pool manager operates in the background manipulating the station data staging areas and network file storage so that intervention is not necessary. Several databases are kept which contain key information for the assembly of the network volume. Other databases track the progress or location of data in the system.

7.2.10 Assembly of Network Volumes (ASL)

All data are demultiplexed and repacked into a network volume format, in which the data from all stations in the network are combined into time span units, normally days. The network volume is written entirely in the SEED format. At this stage the corrected information in the subsidiary indices are combined with the original seismic data. It is also at this stage that telemetered data, which have been stored in disk, and site-recorded data will be merged into the single data stream that will be retained. A decision will be made as to which of the redundant data streams is most suitable for permanent archive.

7.2.11 Final Archiving (ASL)

After assembly into the network volume format, the data will be written on the optical mass store, which will have been segmented into a number of consecutive days for storage. Initially, each optical disk in the mass store will hold up to 20 days of network data, but fewer than 5 days of data when the network is fully deployed. The mass store will hold 50 optical disks, so a considerable amount of data may be stored on line. The optical disks will be the final archive media. The entire tape archive at ASL, which dates back to 1971, will be transferred to optical disks.

7.2.12 Distribution of Network Volumes (ASL)

Network volumes are principally written for transmission of data to the USGS DMC in Golden, Colorado, for the production of the event oriented CD-ROM media. Currently, network volumes containing one to three days of data written on 6250 bpi tapes are compiled and used for distribution of the data to the USGS DMC and other data centers. With the increasing volume of data from the GSN and other networks, higher density magnetic or optical media will need to be used for the transfer in the future. Network volumes are usually sent to the USGS DMC at sixty days after real time. Data arriving too late to make this cut-off are accumulated for production of late network volumes. These late volumes will be produced as needed for up to 150 days after real time (or later in unusual circumstances). All data on the regular and late network volumes will be used by the USGS DMC at NEIC in the production of the Event CD-ROMs or other data distribution.

7.3 GSN DATA FLOW

7.3.1 INTRODUCTION

This section details the flow of data for the GSN from the seismic stations to the Data Collection Centers and thence to the Data Management Centers.

7.3.2 IRIS/USGS SITES

Data will be recorded on magnetic tape cartridges, with approximately two weeks of data per cartridge. Tapes are to be shipped to the IRIS/USGS Data Collection

Center promptly. The station field tapes are currently written in a variety of formats which depend upon the data logger — DWWSSN, SRO, ASRO, CDSN, IRIS-1. All data received at the IRIS/USGS DCC are converted to SEED format after quality control and assurance — a process which currently takes about four days. All field tapes will be written in the standard GSN format as soon as possible. All new IRIS-1 and IRIS-2 stations will be installed with GSN format, and existing IRIS-1 stations will be retrofitted to write GSN format. DWWSSN, SRO, ASRO, and CDSN data formats will be retained in the SEED data format.

The GSN format is a subset of SEED — defined by the SEED working group implementors from ASL, IDA, NEIC, IRIS and UTIG — using a record size of 4096 bytes with Steim data compression and with logical records flushed daily to initiate a new logical record at zero hours UTC.

7.3.3 IRIS/IDA Sites

Non-Soviet Data will be recorded on magnetic tape cartridges, with approximately two weeks of data per cartridge. Tapes are to be shipped to the IRIS/IDA Data Collection Center promptly. Soviet data are recorded on a magnetic medium of the highest density which is exportable. Data shipments from the Soviet Union to IDA are covered under the protocol between the USSR Academy of Sciences and IRIS. The station field tapes at Soviet and non-Soviet IRIS/IDA sites are currently written in an IDA format. After quality control and assurance at the IRIS/IDA DCC — a process which currently takes one to two weeks — all IRIS/IDA data are promptly shipped to the IRIS/USGS Data Collection Center in GSN format. IRIS will make provision to implement the GSN format on the IRIS-3 data logger used by IDA. After proper testing and verification of the GSN format software, it will be installed by the IRIS/IDA group on all IRIS-3 data loggers as soon as possible.

IDA gravimeter data recorded at IDA sites will continue to be processed by the IDA data collection center using existing operational procedures. All IDA gravimeter data will be promptly sent to both the IRIS and USGS Data Management Centers after quality control and assurance. At IRIS/IDA sites using the IRIS-3 data logger with GSN format, the IDA gravimeter will be recorded as an additional channel which will be forwarded with the other data channels to the IRIS/USGS DCC.

The data flow from IRIS/IDA DCC to IRIS/USGS DCC will take place in weekly transfers of magnetic tape, preferably Exabyte cassettes. The current IDA station tape will be converted to a network SEED volume wherein the network consists of the single station. Each weekly tape will contain a number of network SEED volumes, corresponding to all of the data which has undergone quality assurance since the previous weekly transfer.

7.3.4 Other IRIS University Sites

At university sites which use a data logger based on the IRIS-1 or -2 systems, station tapes will be shipped to and processed by the IRIS/USGS DCC. For universities which use a data logger based upon the IRIS-3 system, the station tapes will be shipped to the IRIS/IDA DCC and processed as with other IRIS/IDA data.

7.3.5 IRIS/USGS Data Collection Center

After data quality control and assurance procedures and reformatting to SEED, all data processed originally at the IRIS/USGS DCC are staged to a buffer for transmittal to the IRIS DMC and also written to a local optical mass store. For data processed originally at the IRIS/IDA DCC and sent to the IRIS/USGS DCC, no additional quality control and assurance procedures will be done. The IRIS/IDA data are staged to a buffer for transmittal to the IRIS DMC and also written to the local optical mass store. Data transfers to the IRIS DMC will occur weekly, though more frequent transmittal may be requested. Data transfer will take place via magnetic tape, preferably by Exabyte cassettes.

At sixty days after real time, network volumes spanning a day (or some shorter time unit) will be produced by the DCC from the accumulated station data on the optical mass store. Data which arrive too late to make this sixty day cut-off will be accumulated for production of late network volumes. These late volumes will be produced as needed for up to 150 days after real time (or greater in unusual circumstances). All regular and late network volumes are sent to the USGS DMC at the National Earthquake Information Center in Golden, Colorado, for production of event-oriented data distributions, such as the Event CD-ROMs.

7.3.6 IRIS Data Management Center

All data received from the IRIS/USGS and IRIS/IDA Data Collection Centers are logged by the database management software and archived in the local mass store. Rapid access to all IRIS data which have passed quality control and assurance procedures is very important to the IRIS community. IRIS DMC will work to improve system throughput to provide timely access. When system performance makes it practical, IRIS DMC may request more frequent transfer of data than current weekly transfer arrangements between DCCs and DMC. IRIS DMC may elect to receive all data directly from the IRIS/IDA DCC and then forward the data in a timely manner to IRIS/USGS DCC for production of network time volumes. IRIS may install satellite telemetry to make possible electronic transfer of data immediately after quality control and assurance.

8. DATA MANAGEMENT PLAN

8.1 INTRODUCTION

The success of the GSN will ultimately depend on and be judged by the extent that seismic data produced by the GSN are used by the scientific community to discover new information about earthquakes and the Earth's interior. It is important, therefore, that seismic data from the GSN be available to the scientific community in a form that is easily and quickly accessible. The primary purpose of the data management system is to provide this easy access to GSN data. The goal is to make it possible for a researcher to concentrate primarily on the analysis and interpretation of data rather than the assembly of usable data sets.

Demands for GSN data from the scientific community can be divided into three categories. The first category of data requests are those that can be met by standard event-based collections of data that are routinely produced and distributed to all interested users on media such as CD-ROM approximately five months after real time. The assembly and distribution of standard GSN event data sets will be the responsibility of the USGS Data Management Center. The second category of data requests require the assembly of special sets of data from an archive of all continuous and triggered GSN data. Examples of these requests include earthquake source and receiver studies, studies of events in particular regions, seismic phases with particular propagation paths, and Earth structure studies in certain distance ranges. Many of these custom data requests have characteristics such that the interest from the scientific community is too restricted to justify routine production of these data sets. Users need to be able to generate custom data requests using a data base management system. Special request data sets will be the responsibility of the IRIS Data Management Center. The third category of data requests concerns timely access and availability of the data. Following an earthquake or other seismic event of interest, many users wish to have access to data as soon as possible. Providing for rapid access to seismic data following validation and quality control procedures at the Data Collection Centers will be the responsibility of the IRIS Data Management Center.

8.2 IRIS DATA MANAGEMENT CENTER

8.2.1 Functions of the IRIS Data Management Center

The functions of the IRIS DMC relative to GSN data are twofold: first, to assure that all special data requests from the scientific community are promptly satisfied in a manner which makes the data easily accessible; and second, to provide for rapid access to the validated data from the Data Collection Centers. The IRIS DMC will be required to handle and distribute digital data that span the spectrum from fixed network recordings (GSN and sub-sets from other U.S. and foreign networks) to controlled-source portable array recordings generated by PASSCAL experiments and selected data from other U.S. or foreign experiments. To satisfy user requests for special sets of GSN data, it will be necessary for the IRIS DMC to archive all continuous and triggered data from the GSN. The IRIS DMC will also serve as the continuous data archive for the Federation of Digital Broad Band Seismograph Networks (FDSN).

8.2.2 Parameter Data Base

The bulk of the data to be held by the IRIS DMC will consist of digitized waveforms, although a smaller data set must exist to make the waveform data usable. This "parameter data base" must maintain a comprehensive data directory that provides an index to data holdings at the center. The system must provide rapid and easy access to bulletin hypocenters and associated phase data, and to other derived data such as focal mechanisms and moment tensor solutions.

The parameter data base will also have detailed seismic station information obtained from current Installation Reports from the ASL and IRIS/IDA Network Maintenance Centers, as well as from updated information from other university participants in the GSN, and FDSN contributing sites. The data base will contain information regarding the host organization for the station (including address, telephone, E-mail, fax or telex numbers), a brief history of the station, a description of the vault and recording facilities, coordinates and elevation of the sensor systems, local geologic setting, local topographic setting, a description of nearby cultural or natural sources of seismic noise, an assessment of power reliability, a list of all equipment with serial numbers and sensitivity constants, calibration and test results, and a listing of test records and test tapes available at the NMC. Maps and photographs of the site should also be available to the user.

The management system should allow both casual and detailed inquiries into the location and nature of PASSCAL experiments. The parameters should include: geographic location, source/receiver heights, source types (including earthquakes, explosives, vibroseis, and airgun), receiver types and sensors used. Data base relations for passive earthquake experiments should be capable of cross-referencing global catalogs.

8.2.3 Waveform Data Base

The digitized waveform data will form a large and rapidly growing data set that must be properly treated in order to remain accessible and usable. The IRIS DMC must provide large on-line random-access storage and off-line mass storage capability for digital waveform data from GSN and PASSCAL stations and arrays worldwide.

8.2.4 Data Base Management System

The IRIS DMC will develop and maintain an effective data base management system (DBMS) to retrieve, on request and in a timely manner, parameter and waveform data in an integrated form, independent of its storage location. The system must provide the versatility to meet a variety of types and combinations of features specified by data users in the form of "seismological queries". In addition to this larger service, the DBMS should allow the general user to construct subsidiary data bases for specific research projects. The IRIS DMC should provide for rapid archiving of data with a retrieval architecture structured to accommodate specific user needs and frequency of use.

8.2.5 Data Distribution

The IRIS DMC will provide a system for preprocessing of data including filtering, spectral estimation, sorting, and hardcopy display. This capability will be provided through utilities such as SAC, AH, and SierraSeis, and will exist as a facility that can be used by individual researchers.Data will be distributed from the IRIS DMC in SEED format. A SEED conversion utility will also be distributed as needed to convert the SEED format into selected other formats such as SAC. Data will be distributed on a variety of physical media including 9-track tape, helical scan tape, 1/4" tape cartridges, or when applicable, electronically.

8.3 USGS DATA MANAGEMENT CENTER

8.3.1 Function of the USGS Data Management Center

The function of the USGS DMC relative to GSN data is to assure that all standard event-based collections of data are routinely produced and distributed to the scientific community. Event data window size will be a predetermined function of the magnitude of the event and frequency content or the sampling rate of the data. The USGS DMC will also be required to process event data from foreign networks. In particular, data from stations of the Federation of Digital Broad Band Seismic Networks (FDSN) will be collected and distributed, since the USGS DMC is the DMC for event data from the FDSN. The USGS DMC will therefore archive event data from all FDSN stations (including the GSN stations).

8.3.2 Parameter Data Base

The USGS DMC now has an extensive parameter data base. Since the USGS DMC is part of the National Earthquake Information Center (NEIC), it has ready access to the daily determination of hypocenters made for earthquakes occurring around the world. A large amount of parameter information is received each day at the NEIC from hundreds of globally distributed seismograph stations.

8.3.3 Waveform Data Base

The event waveform data base will be archived on a large mass storage system at the USGS DMC. This data base will be accessed to produce the standard event-based collections of data.

8.3.4 Data Distribution

The primary form of distribution of event-based waveform data will be on media such as the CD-ROM.

8.4 IRIS/USGS DATA EXCHANGE

The USGS will, on a timely basis, provide the IRIS DMC with all continuous and triggered data received by ASL from the GDSN, CDSN and GTSN networks. IRIS will provide continuous and triggered data from the university GSN network to the USGS on a timely basis. Continuous and triggered data from the university network will be archived at the IRIS/USGS DCC together with data from the USGS network.

8.5 COOPERATION BETWEEN DATA MANAGEMENT CENTERS

Close cooperation between the IRIS DMC and the USGS DMC will be essential if full advantage is to be taken of the capabilities and resources of both DMC. Only with good cooperation between the DMC can the scientific community receive the complete benefits of easy access to global digital seismic data.

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APPENDIX 1.

ORGANIZATIONAL RESPONSIBILITIES

1. INTRODUCTION

The importance of the new GSN to the seismological community makes it absolutely essential that the deployment and long-term support of this vital research facility be carefully planned by those involved in research and operations and adequately funded by the Federal agencies committed to the program. In order to make this possible the responsibilities and operational roles of the agencies and institutions involved must be clearly defined at the outset so that the necessary steps can be taken to plan facilities, program future funding, and conserve current resources.

The NSF and the USGS are the two primary funding agencies committed to the deployment and long-term support of the GSN.

The responsibility for the development of the new GSN has been primarily that of the NSF. The 1983 research briefings for departments and agencies of the Federal government by the Committee on Science, Engineering, and Public Policy (COSEPUP) recommended that "...the National Science Foundation act as overall coordination and lead agency for funding such an array and that the operation be overseen by a university consortium." The consortium has manifested itself in the form of IRIS, which acts as a representative of the research community in setting the scientific goals of the GSN and the agent for NSF in specifying and purchasing the equipment. Because of the broad university membership in IRIS, NSF is assured that the GSN will provide seismological data to meet research requirements through the next decade and into the twenty-first century.

The USGS currently supports and maintains several global networks that it installed. The USGS has continued to support the operation of these networks with internal funds because it recognizes the importance of these data to basic seismological research and finds such support consistent with its overall charter. The USGS maintains the Albuquerque Seismological Laboratory to support the development, installation, and maintenance of the global and national seismograph networks.

2. OPERATIONAL RESPONSIBILITIES

The responsibility for deployment, operation and maintenance of the GSN is shared by the USGS and IRIS. The GSN will be deployed, managed and supported by the USGS, by the IRIS/IDA Network, and by universities designated by the IRIS Standing Committee for the Global Seismographic Network. Of the currently proposed GSN stations, the two networks (IRIS/USGS and IRIS/IDA) will comprise those stations listed in Table A1.1. The list is tentative; final siting decisions will weigh deployment, operation and maintenance costs. The USGS will operate a network maintenance center and a data collection center at the Albuquerque Seismological Laboratory to support the IRIS/USGS network which includes affiliated universities operating IRIS-1 and -2 GSN systems. IRIS will operate a network maintenance center and a data collection center through IRIS/IDA at U.C. San Diego to support the IRIS/IDA network and affiliated universities operating IRIS-3 GSN systems. The IRIS/IDA network maintenance center will be a part of the

PASSCAL instrumentation maintenance network of IRIS. The USGS will operate a data management center at NEIC in Golden, Colorado, and IRIS will operate a data management center at the University of Texas, Austin. Methods of exchanging data between the USGS and IRIS data centers have been set forth in Section 8 of the Technical Plan.

3. FUNDING RESPONSIBILITIES

The primary funding agencies for the GSN are the NSF and the USGS. Other Federal agencies may provide funds for station deployment but are not likely to be involved in long-term support of the network.

NSF will provide funds through IRIS and the USGS for the development and deployment of the GSN stations and support facilities. This includes the cost of instrumentation, site preparation, training, engineering, installation, shipping and any other costs associated with network deployment; the cost of equipping the network maintenance center; and the cost of developing and equipping the data collection center. NSF will provide funds through IRIS for the long-term support of the university subnetwork. NSF will also provide funds for major improvements to the GSN network through the USGS and IRIS following initial deployment.

The USGS will provide funds for the operation and maintenance of the stations in the IRIS/USGS subnetwork, which includes affiliated universities operating IRIS-1 and -2 GSN systems, for operation of the network maintenance center and data collection center located at Albuquerque, and for operation of the data management center in Golden.

In general the responsibilities of NSF and the USGS are as given in Article 1 of the Interagency Accord (see Appendix 8). Costs for the implementation of this Technical Plan for three years are given in Table A2. These costs will be reviewed annually by GSN Program Managers in IRIS and USGS, and reviewed by IRIS, NSF, and USGS officials during June of each year. Responsible officials at NSF and USGS will meet at least annually or as otherwise required to establish agency commitments to cover these costs.

Table A1.

IRIS/USGS SITES	IRIS/IDA SITES
Adak, Alaska	Alert, NMT, Canada
Afiamalu, W. Samoa	Ascension Island
Akureyri, Iceland	Adelaide/Tasmania, Australia
Albuquerque, NM	Antarctica site
Ankara, Turkey	Arti, USSR
Baguio, Philippines	Diego Garcia, Indian Ocean
Bermuda	Durango, Mexico
Bogota, Columbia	Easter Island, Chile
Caico, Brazil	Erimo, Japan
Canary Islands, Spain	Eskdalemuir, Scotland
Caracas, Venezuela	Falkland Islands
Cathedral Caves, Missouri	Fiji
Charters Towers, Australia	Frunze, USSR
Chiangmai, Thailand	Garm, USSR
Christmas Island	Hawaii Island
College, Alaska	Irkutsk, USSR
Corvallis, Oregon	Kislovodsk, USSR
Galapagos Island, Ecuador	Kodiak Island
Garni, USSR	Kwajalein Island
Godhavn, Greenland	Marquesas
Grafenburg, W. Germany	Midway Island
Guam, Marianas Islands	Naña, Peru
Harvard, MA	Newfoundland, Canada
Honiara, Solomon Islands	Obninsk, USSR
Kevo, Finland	Piñon Flat, California
Khartoum, Sudan	Seychelles
Kingsbay, Spitzbergen Island	Sutherland, South Africa
Kipapa, Hawaii	Wake Island
Kodaikanal, India	
Kongsberg, Norway	
Lembang, Indonesia	
Matsushiro, Japan	
Middle East	
Nairobi, Kenya	
Narrogin, Australia	
New Delhi, India	
New Site, Australia	
Pasadena, California	
Peldelhue, Chile	
Ponta Delgada, Azores	
Quetta, Pakistan	
Rarotonga, Cook Islands	
San Juan, Puerto Rico	
South Karori, New Zealand	
South Pole, Antarctica	
Taipei, Taiwan	
Toledo, Spain	
US Stations (5)	
USSR Stations (4)	

Table A2.

GSN Five-Year (1991-95) Costs*
for 100 Station Network Installation

Costs in $K	1991	1992	1993	1994	1995	1996
Spare Parts Depot Inventory	300.0	312.0	324.4	337.4	325.9	0.0
Operation and Maintenance	1021.3	1453.4	1918.5	2418.5	2939.6	3269.8
Site Works & Installation	3127.7	3252.8	3382.9	3518.2	3397.6	0.0
Seismometers & Data Loggers	2999.7	3119.6	3244.4	3374.2	3258.5	0.0
Yearly Totals ($K)	7448.7	8137.8	8870.2	9648.3	9921.6	3269.8
Five Year Total — $44,026.6K						

*see Appendix 2 for detail.

APPENDIX 2.

GSN BUDGET ESTIMATES

1. Cost Detail — Budget for a 100 Station GSN

GSN Budget Table 1 presents the detailed costs for completing a 100 station GSN in five years. The expenditures include: (1) the costs for upgrading the existing base of 31 stations to full design goal standards; (2) the costs for establishing 46 additional sites selected in the Technical Plan on the basis of good coverage and logistics; (3) 23 undesignated new vault and borehole sites which require additional site survey work before they can be specified with certainty. These twenty-three additional sites will all be in remote, difficult locations in order to fill in gaps in the global coverage The costs for the 23 undesignated sites are extrapolated on the basis of logistics experience, assuming a mix of about one-third new vaults and two-thirds new boreholes, and assuming the use of IRIS-2 data loggers.

GSN Budget Table 2 details equipment and logistics requirements for the 100 station GSN costed in *GSN Budget Table 1*. The attached *Legend* annotates the specific entries in *GSN Budget Table 2*.

The budget rationale for operations and maintenance of the GSN is discussed in detail in the Appendices 3 and 4 of the Technical Plan, and is based upon over twenty years experience in operating seismic networks by the USGS and the academic community. Costs are twofold and are presented in *GSN Budget Table 3*. A spare parts inventory must be developed by equipping the Network Maintenance facilities while the stations are being installed. Experience has shown that the inventory needed is about 10% of the capital equipment costs. Yearly maintenance costs are illustrated by the requirements for a 60 station network. Yearly operations and maintenance costs are extrapolated from the average cost per station and the installed base of stations each year.

GSN Budget Table 1 — Cost Detail for 100 station GSN (in $K)

	Seismic Station	Site Survey	Site Preparation	Site Installation	Broad-band Seismometers	Data Logger	Auxiliary Seismometers	S.O.H. Telemetry and GPS Timing	Total
1	Adak, Alaska	25	151	35	115	95	15	20	456
2	Adelaide, Australia			7		15	15	5	42
3	Afiamalu, W. Samoa			7			20	20	47
4	Akureyri, Iceland	25	151	35	115	95	15	5	441
5	Albuquerque, NM								0
6	Alert, Canada			7		15	15	20	57
7	Ankara, Turkey	5	26	35	15		15	5	101
8	Arti, USSR			7		15		20	42
9	Ascension Island	25	276	35	115	50	15	20	536
10	Bermuda	25	151	35	115	95	20	5	446
11	Bogota, Columbia	5	26	35	15	95	15	20	211
12	Brasilia, Brazil			7		15	15	5	42
13	Caico, Brazil	25	276	35	115	95	20	20	586
14	Canary Islands, Spain	25	101	35	42	95	20	20	338
15	Caracas, Venezuela	5	46	35	42	95	20	5	248
16	Cathedral Caves, Missouri			7		95			102
17	Charters Towers, Australia			7			20	5	32
18	Chiangmai, Thailand	5	26	35	15	95	20	20	216
19	Christmas Island	25	276	35	115	95	20	20	586
20	College, Alaska			7			20	5	32
21	Corvallis, Oregon			7		95	15		117
22	Diego Garcia, Indian Ocean	25	151	35	115	50	15	20	411
23	Durango, Mexico	25	101	35	42	50	10	20	283
24	Easter Island, Chile			7		15	15	20	57
25	Erimo, Japan			7		15	10	5	37
26	Eskdalemuir, Scotland			7		15	15	5	42
27	Falkland Islands	25	151	35	115	50	15	20	411
28	Fiji	25	101	35	42	50	10	5	268
29	Flin Flon, Canada			7		15	15	5	42
30	Frunze, USSR			7		15		20	42
31	Galapagos Island, Ecuador	25	276	35	115	95	20	20	586
32	Garm, USSR			7		15		20	42
33	Garni, USSR							20	20

GSN Budget Table 1 — Cost Detail for 100 station GSN (in $K)

34	Godhavn, Greenland	5	46	35	42	95	20	20	263
35	Grafenburg, Germany	5	26	35	15	95	20	20	216
36	Guam, Marianas Islands	5	26	35	15	95	15	5	196
37	Harvard, MA								0
38	Hawaii Island	25	101	35	42	50	10	5	268
39	Honiara, Solomon Islands	25	276	35	115	95	15	20	581
40	Irkutsk, USSR			7		15		20	42
41	Kevo, Finland		46	35		95	20	5	201
42	Khartoum, Sudan	25	276	35	115	95	20	20	586
43	Kingsbay, Spitzbergen Is.	25	101	35	42	95	20	20	338
44	Kipapa, Hawaii			7				5	12
45	Kislovodsk, USSR			7		15		20	42
46	Kodaikanal, India	5	46	35	42	95	20	20	263
47	Kodiak Island	25	276	35	115	50	10	20	531
48	Kongsberg, Norway	5	21	35			20	5	86
49	Kwajalein Island	25	276	35	115	50	15	20	536
50	Lembang, Indonesia	5	46	35	42	95	15	20	258
51	Marquesas	25	276	35	115	50	15	20	536
52	Matsushiro, Japan			7		95	15	5	122
53	Mawson, Antarctica	25	101	35	42	50	15	20	288
54	Middle East	25	151	35	115	95	20	20	461
55	Midway Island	25	276	35	115	50	15	5	521
56	Nairobi, Kenya	25	276	35	115	95	15	20	581
57	Naña, Peru			7		15	10	20	52
58	Narrogin, Australia			7			20	5	32
59	New Delhi, India	25	151	35	115	95	15	20	456
60	New Site, Australia	25	151	35	115	95	20	5	446
61	Obninsk, USSR			7		15		20	42
62	Palmer Station, Antarctica	5	21	35	42	95	20	20	238
63	Pasadena, California								0
64	Peldehue, Chile	5	21	35		95	15	20	191
65	Philippines	5	46	35	42	95	15	20	258
66	Piñon Flat, California					15			15
67	Ponta Delgada, Azores	25	151	35	115	95	15	20	456
68	Quetta, Pakistan	5	46	35	42	95	15	20	258

GSN Budget Table 1 — Cost Detail for 100 station GSN (in $K)

69	Rarotonga, Cook Islands	25	276	35	115	95	20	20	586
70	San Juan, Puerto Rico		46	35	42	95	15	5	238
71	Seychelles	25	276	35	115	50	15	20	536
72	South Karori, New Zealand			7			15	5	27
73	South Pole, Antarctica			7			20	20	47
74	Sutherland, South Africa			7		15	15	20	57
75	Taipei, Taiwan	5	26	35	15	95	15	5	196
76	Toledo, Spain	5	46	35		95	20	5	206
77	Wake Island	25	276	35	115	50	15	5	521
78	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
79	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
80	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
81	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
82	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
83	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
84	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
85	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
86	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
87	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
88	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
89	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
90	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
91	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
92	Undesignated Site, Borehole	25	276	35	115	95	20	20	586
93	Undesignated Site, Vault	25	101	35	42	95	20	20	338
94	Undesignated Site, Vault	25	101	35	42	95	20	20	338
95	Undesignated Site, Vault	25	101	35	42	95	20	20	338
96	Undesignated Site, Vault	25	101	35	42	95	20	20	338
97	Undesignated Site, Vault	25	101	35	42	95	20	20	338
98	Undesignated Site, Vault	25	101	35	42	95	20	20	338
99	Undesignated Site, Vault	25	101	35	42	95	20	20	338
100	Undesignated Site, Vault	25	101	35	42	95	20	20	338
	100 Station Totals ($K)	$1,380	$11,410	$2,625	$5,384	$6,400	$1,510	$1,490	$30,199

GSN Budget Table 2.

Site Requirements for 1991+

	Seismic Station	Site Survey	Site Preparation	Site Installation	Broad-band Seismometers	Data Logger	Auxiliary Seismometers	S.O.H. Telemetry and GPS Timing
1	Adak, Alaska	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+LGseismo	StdC+GPS
2	Adelaide, Australia			ReInstall		IRIS3mod	HFseismo	GPS
3	Aliamalu, W. Samoa			ReInstall			LRDCU+HFseismo	StdC+GPS
4	Akureyri, Iceland	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+LGseismo	GPS
5	Albuquerque, NM							
6	Alert, Canada			ReInstall		IRIS3mod	HFseismo	StdC+GPS
7	Ankara, Turkey	Visit	SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	SROmod		LRDCU+LGseismo	GPS
8	Arti, USSR			ReInstall		IRIS3mod		StdC+GPS
9	Ascension Island	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	HFseismo	StdC+GPS
10	Bermuda	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	GPS
11	Bogota, Columbia	Visit	SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	SROmod	IRIS2	LRDCU+LGseismo	StdC+GPS
12	Brasilia, Brazil			ReInstall		IRIS3mod	HFseismo	GPS
13	Caico, Brazil	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
14	Canary Islands, Spain	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
15	Caracas, Venezuela	Visit	ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	GPS
16	Cathedral Caves, Missouri			ReInstall		IRIS2		
17	Charters Towers, Australia			ReInstall			LRDCU+HFseismo	GPS
18	Chiangmai, Thailand	Visit	SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	SROmod	IRIS2	LRDCU+HFseismo	StdC+GPS
19	Christmas Island	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
20	College, Alaska			ReInstall			LRDCU+HFseismo	GPS
21	Corvallis, Oregon			ReInstall		IRIS2	LRDCU+LGseismo	
22	Diego Garcia, Indian Ocean	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	HFseismo	StdC+GPS
23	Durango, Mexico	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS3	LGseismo	StdC+GPS
24	Easter Island, Chile			ReInstall		IRIS3mod	HFseismo	StdC+GPS
25	Erimo, Japan			ReInstall		IRIS3mod	LGseismo	GPS
26	Eskdalemuir, Scotland			ReInstall		IRIS3mod	HFseismo	GPS
27	Falkland Islands	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	HFseismo	StdC+GPS
28	Fiji	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS3	LGseismo	GPS
29	Flin Flon, Canada			ReInstall		IRIS3mod	HFseismo	GPS
30	Frunze, USSR			ReInstall		IRIS3mod		StdC+GPS
31	Galapagos Island, Ecuador	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
32	Garm, USSR			ReInstall		IRIS3mod		StdC+GPS
33	Garni, USSR							StdC+GPS
34	Godhavn, Greenland	Visit	ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
35	Grafenburg, Germany	Visit	SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	SROmod	IRIS2	LRDCU+HFseismo	StdC+GPS
36	Guam, Marianas Islands	Visit	SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	SROmod	IRIS2	LRDCU+LGseismo	GPS
37	Harvard, MA							
38	Hawaii Island	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS3	LGseismo	GPS
39	Honiara, Solomon Islands	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+LGseismo	StdC+GPS
40	Irkutsk, USSR			ReInstall		IRIS3mod		StdC+GPS
41	Kevo, Finland		ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies		IRIS2	LRDCU+HFseismo	GPS
42	Khartoum, Sudan	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
43	Kingsbay, Spitzbergen Is.	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
44	Kipapa, Hawaii			ReInstall				GPS
45	Kislovodsk, USSR			ReInstall		IRIS3mod		StdC+GPS
46	Kodaikanal, India	Visit	ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
47	Kodiak Island	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	LGseismo	StdC+GPS
48	Kongsberg, Norway	Visit	SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies			LRDCU+HFseismo	GPS
49	Kwajalein Island	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	HFseismo	StdC+GPS

50	Lembang, Indonesia	Visit	ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+LGseismo	StdC+GPS
51	Marquesas	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	HFseismo	StdC+GPS
52	Matsushiro, Japan			ReInstall		IRIS2	LRDCU+LGseismo	GPS
53	Mawson, Antarctica	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS3	HFseismo	StdC+GPS
54	Middle East	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
55	Midway Island	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	HFseismo	GPS
56	Nairobi, Kenya	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+LGseismo	StdC+GPS
57	Nafia, Peru			ReInstall		IRIS3mod	LGseismo	StdC+GPS
58	Narrogin, Australia			ReInstall			LRDCU+HFseismo	GPS
59	New Delhi, India	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+LGseismo	StdC+GPS
60	New Site, Australia	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	GPS
61	Obninsk, USSR			ReInstall		IRIS3mod		StdC+GPS
62	Palmer Station, Antarctica	Visit	SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
63	Pasadena, California							
64	Peldehue, Chile	Visit	SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies		IRIS2	LRDCU+LGseismo	StdC+GPS
65	Philippines	Visit	ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+LGseismo	StdC+GPS
66	Piñon Flat, California					IRIS3mod		
67	Ponta Delgada, Azores	NewSurvey	NewBorehole1+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+LGseismo	StdC+GPS
68	Quetta, Pakistan	Visit	ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+LGseismo	StdC+GPS
69	Rarotonga, Cook Islands	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
70	San Juan, Puerto Rico		ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+LGseismo	GPS
71	Seychelles	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	HFseismo	StdC+GPS
72	South Karori, New Zealand			ReInstall			LRDCU+LGseismo	GPS
73	South Pole, Antarctica			ReInstall			LRDCU+HFseismo	StdC+GPS
74	Sutherland, South Africa			ReInstall		IRIS3mod	HFseismo	StdC+GPS
75	Taipei, Taiwan	Visit	SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	SROmod	IRIS2	LRDCU+LGseismo	GPS
76	Toledo, Spain	Visit	ExistVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies		IRIS2	LRDCU+HFseismo	GPS
77	Wake Island	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS3	HFseismo	GPS
78	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
79	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
80	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
81	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
82	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
83	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
84	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
85	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
86	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
87	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
88	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
89	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
90	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
91	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
92	Undesignated Site, Borehole	NewSurvey	NewBorehole2+SiteTelemetry+LoggerTest+SeismoTest	NewInstall+Shipping+StaSupplies	BoreholeSeismo	IRIS2	LRDCU+HFseismo	StdC+GPS
93	Undesignated Site, Vault	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
94	Undesignated Site, Vault	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
95	Undesignated Site, Vault	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
96	Undesignated Site, Vault	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
97	Undesignated Site, Vault	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
98	Undesignated Site, Vault	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
99	Undesignated Site, Vault	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS
100	Undesignated Site, Vault	NewSurvey	NewVault+SiteTelemetry+LoggerTest	NewInstall+Shipping+StaSupplies	STS1Seismo	IRIS2	LRDCU+HFseismo	StdC+GPS

GSN Budget Table 2 — Legend

Catagory	Entry	Cost ($K)	Note
Site Survey			
	NewSurvey	25	New site survey
	Visit	5	Site visit
Site Preparation			
	NewBorehole1	125	New borehole at site with services
	NewBorehole2	250	New borehole at difficult site
	ExistBorehole	3	Re-use of existing borehole
	NewVault	80	Prepare new seismic vault
	ExistVault	25	Refurbish existing seismic vault
	SiteTelemetry	16	Site telemetry between seismometers recording facility
	LoggerTest	5	Acceptance test for data logger
	SeismoTest	5	Acceptance test for seismometer
Site Installation			
	NewInstall	25	New equipment installation
	ReInstall	7	Revisit site to install additional equipment
	StaSupplies	5	Station supplies
	Shipping	5	Shipping costs
Broad-band Seismometers			
	STS1Seismo	42	Streckeisen STS-1
	BoreholeSeismo	115	Geotech KS54000
	SROmod	15	Broadband modification cost for existing KS36000
Data Logger			
	IRIS2	95	IRIS-2 station processor
	IRIS3	50	IRIS-3 station processor
	IRIS3mod	15	Upgrade existing IRIS-3 with 24-bit digitizer
Auxiliary Seismometers			
	LRDCU	5	Additional 16-bit digitizer/calibrator channels
	HFseismo	15	High-frequency seismometers
	LGseismo	10	Low-gain seismometers for strong ground motion
State-of-Health Telemetry and GPS Timing			
	StdC	15	Comsat Standard C system or equivalent
	PolarTelem	15	Polar telemetry via ATS satellite
	GPS	5	Global Positioning System clock

GSN Budget Table 3

Network Maintenance

Spare Parts Depot Inventory: 10% of Installed Hardware Cost

Yearly Recurring Costs for 60 Station Network	$K/year	$K/year/station
Network Maintenance Team Leader	63	1.0
Field Engineers (6)	315	5.3
Bench Technicians (5)	250	4.2
Engineering (shop) Technician (1)	50	0.8
Supply/Shipping Clerk (1)	35	0.6
Clerk/Typist (1)	30	0.5
Supplies & Parts	90	1.5
Factory Repair	60	1.0
Travel Expenses	420	7.0
Communications	60	1.0
Shipping	60	1.0
Component Replacement	180	3.0
Yearly Totals	$1,613	$27 K/Station

2. Summary Budget

The summary budget presents the costs for establishing a 100 station GSN within five years. In calculating the five-year budget, a 4% rate of inflation is assumed for the second through the fifth years.

GSN Budget Table 4.

GSN Five-Year (1991-95) Costs
for 100 Station Network Installation

Costs in $K	1991	1992	1993	1994	1995	1996
Spare Parts Depot Inventory	300.0	312.0	324.4	337.4	325.9	0.0
Operation and Maintenance	1021.3	1453.4	1918.5	2418.5	2939.6	3269.8
Site Works & Installation	3127.7	3252.8	3382.9	3518.2	3397.6	0.0
Seismometers & Data Loggers	2999.7	3119.6	3244.4	3374.2	3258.5	0.0
Yearly Totals ($K)	7448.7	8137.8	8870.2	9648.3	9921.6	3269.8
Five Year Total — $44,026.6K						

APPENDIX 3.

REQUIREMENTS FOR THE IRIS/USGS NETWORK MAINTENANCE CENTER AT ASL

1. Introduction

A network maintenance center has been operated at ASL since the deployment of the WWSSN more than 25 years ago, and it will continue to support other networks as well as the new GSN. The requirements of an NMC based on past experience are summarized below. Most of the personnel and facilities needed to operate the GSN NMC are already in place and will be used to support the GSN as GSN equipment replaces GDSN equipment at the stations. The only new requirements are specific to the GSN data system.

2. Personnel

The following personnel are required to support a network of 60 operational stations:

- NMC Manager
- Engineer/Programmer
- Maintenance Team Leader
- Field Technicians (6)
- Bench Technicians (5)
- Engineering (shop) Technician
- Supply/Shipping Clerk
- Clerk/Typist

The field and bench technicians are the only categories in which the level of staffing is a linear function of the number of supported stations. Additional engineering and programming support is needed during deployment or when major system modifications or new instruments are being developed and tested.

3. Test Equipment and Facilities

Two GSN data systems are needed for network support. One of these systems, less seismometers, will be installed in the electronics shop and used as a test bed for fault diagnosis of defective components, for testing boards and modules that have been repaired, and for developing diagnostic procedures that can be used in the shop or at the stations. The second data system, in this case the prototype system, is needed for evaluating system performance, the training of field teams and operators, development and evaluation of system modifications, and development of programs for station use in local processing of the data. This will be a complete system with seismometers but only operated intermittently; that is, it cannot be considered an operational station. It will be most heavily used during the early stages of the program for training and evaluation.

The major facilities required by the NMC are an electronics shop, an instrument shop, a good vault, and a pair of boreholes available for testing. The electronics shop must be well equipped with general purpose test instruments and digital test equipment, including the special equipment used to isolate defective components on a board. Some test equipment is developed or programmed specifically for the supported systems. The instrument shop is needed for fabricating and assembling mechanical equipment, including such things as plugs and seals for boreholes, calibration devices, and equipment racks, and for repairing mechanical equipment. The vault and boreholes are needed for testing seismometers and for evaluating new sensor systems. All of these facilities are currently available at ASL except for any special test equipment needed specifically for the GSN data recording system and seismometers.

4. Depot Spares

The depot inventory is an essential resource that keeps the network operating; it consists of operating supplies, consumable small parts, and a floating stock of major boards and modules that are continuously cycled to the stations as replacements, returned, repaired, and placed back on the shelf. The spare parts needed to support field installation must be in place at the outset, the only alternative being to cannibalize production systems. Initial stocking of spare parts and modules for the first 10 systems will be based generally on recommendations of the system manufacturer in the case of the data recording system, and on parts for other equipment at the minimum level needed to keep the program moving if failures occur. An estimate of the initial parts and modules needed is as follows:

Data recording system components and boards	$ 72.2K
STS VBB sensor subsystem	39.0K
STS sensor subsystem component parts	15.0K
Modified KS 36000 electronics (2)	30.0K
VSP sensor subsystem and parts	23.0K
LG sensor subsystem	10.0K
Miscellaneous electronic parts	15.0K
Station supplies	15.0K

Subsequent stocking of depot spares should be budgeted at the rate of $80.0K for each 10 additional stations installed. This sparing level is somewhat less than 10% of total hardware cost (10% to 20% is common), but failure experience develops rapidly, and, after initial stocking, purchases of spare modules and boards, which are the most expensive items, can be more selective.

5. Recurring Support Requirements

Apart from personnel costs, the major costs of operating and maintaining a global network are for replenishment of supplies and parts, factory repair, travel of field technicians, communications, and shipping. These costs are estimated to be as follows.

Supplies & parts	1.5K/station/year
Factory repair	1.0K/station/year
Travel Expenses	70.0K/field technician/year
Communications	1.0K/station/year
Shipping	1.0K/station/year

In addition to these routine support requirements, it is important to program funds for component replacement beginning four or five years after initial deployment. A funding rate of 2.5K/station/year is sufficient for updating electronic components that become obsolete or difficult to support; it is not a sufficient level of funding for wholesale replacement of major subsystems, such as seismometers or digital encoders.

6. Administrative Support

Management and operation of a seismograph network requires more than technical facilities and expertise. There is a substantial administrative burden associated with the support of a global array of stations, especially when there is the diversity of instrumentation that presently exists in the global networks. There is a current active inventory of more than 4,000 line items of parts, components, and supplies at ASL needed to support the WWSSN and GDSN networks, a total number of individual items in the tens of thousands. The stock must be purchased expediently to maintain minimum levels, they must be controlled effectively, stored or warehoused, packed and crated, and finally shipped using a variety of methods depending on cost and urgency. ASL makes an average of 1,000 shipments each year that will vary in size from a single recorder pen to a complete seismograph system. These and related administrative tasks are not trivial in either the numbers of personnel involved or cost. Clearly, the management and support of a global network requires a balanced organization that can handle both technical and administrative tasks.

APPENDIX 4.

IRIS/IDA Network Maintenance and Data Collection Center

1. Introduction

The IRIS/IDA network will be operated and maintained by personnel of the Network Maintenance and Data Collection Center (NM&DCC) located at the Institute of Geophysics and Planetary Physics in La Jolla, CA. This center has been developed over the past 14 years since the inception of Project IDA in 1975. As the IRIS/IDA component of the GSN is implemented over the next five years, some expansion of these facilities are planned.

2. Personnel

The personnel of the NM&DCC are listed below. This represents staffing for about a 20 station IRIS/IDA component of the GSN planned over the next five years.

Personnel	% Effort
Principal Investigator	50
DCC Director/Programmer	100
Project Chief	100
IDA Engineer	50
Technician #1	100
Technician #2	100
Computer Operator	100
Research Assistant	100/50
Administrative Assistant	30

3. Equipment and Facilities

Facilities for the NM&DCC are provided currently in the IGPP building at Scripps Institution of Oceanography. During the course of the next five years, it is expected that a new building will be constructed nearby proving expanded facilities for these activities.

3.1 Network Maintenance

The IRIS/IDA stations are maintained by a technical staff under the direction of the IRIS/IDA Project Chief. On the average, it is expected that each technician will maintain about 10 stations visiting each about every second year. Experience, however, has demonstrated that there is a large variance in the level of effort required to maintain each station to the point where occasionally a station is closed down. Upgrades to existing stations and the installation of new stations will require additional technical assistance.

The principal equipment items that will be maintained at the NMC are:

Lab Test Equipment
Field Maintenance Kits (3)
Spare Seismometers (2 sets)
Spare IRIS-3 Data Loggers (2)
Spare IRIS-3 boards (3 each variety)
Spare Tape decks (2 Exabyte, 2 9-track)
Spare Omega clocks (2)

3.2 Data Collection

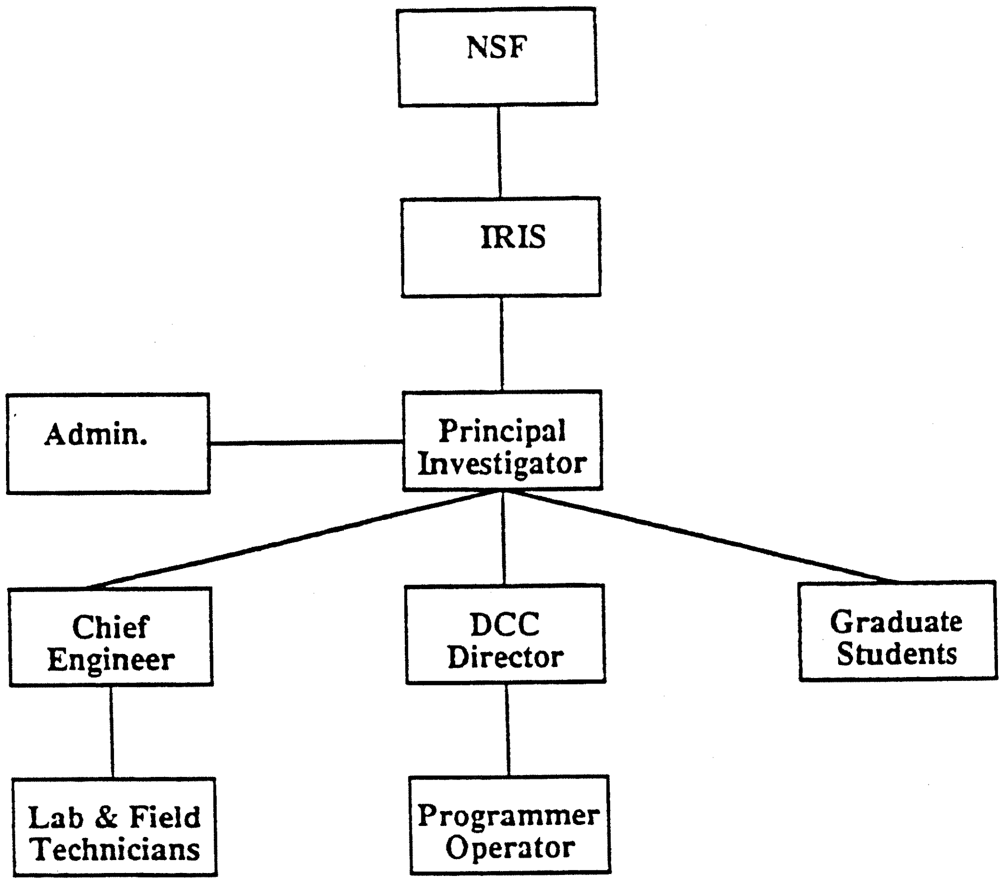
The IRIS/IDA Data Collection will be operated by the DCC Director and his (her) staff of programmer and computer operator support. The DCC is designed to handle the anticipated ~250MB of data collected daily from the IRIS/IDA component of the GSN (see box). Data is recorded at the stations on a variety of magnetic media which include 9-track tapes, 8mm video tape, and cartridge tape. Data is processed by a network of SUN3, SUN4, and microVAX computers and their associated peripherals. During the course of the next five years, it is anticipated that some stations will telemeter their data to the DCC in near real-time.

All raw data from the stations undergoes standard quality control processing to insure data integrity and provide early indications of equipment malfunctions or other problems with the stations. On line channel calibrations and station maintenance histories are maintained as part of the overall data set.

The DCC will produce network volumes the standard SEED format that will be distributed to the IRIS Data Management System for archiving and distribution.

4. Management

The IRIS/IDA component of the GSN is organized as illustrated in the following figure. It is managed under the Principal Investigator(s) by the Project Chief and the DCC Director. They are aided by an administrative staff, working with the normal University administrative infrastructure (accounting, purchasing, contracts & grants, etc.). In addition, shared laboratory facilities are provided by multi-project group within IGPP.



IRIS/IDA
Organization

APPENDIX 5.

REQUIREMENTS FOR THE IRIS/USGS DATA COLLECTION CENTER AT ASL

1. Data Collection System

Although many desirable features have been included in the design of the new DCC data collection system, the major attributes sought were expandability, reliability, and automation. A flexible, expandable system is desirable so that capacity, investment, and technology can be tailored to current requirements, making it less costly and less susceptible to rapid technological obsolescence. A flexible system design also makes it possible for others to duplicate the data collection system for their own use. Reliability is an essential attribute of the data collection system. The flow of data from the network is relentless. A prolonged failure, as has occurred in the past, can mean weeks or months of overtime catch-up work. Expandability and reliability are both enhanced by splitting the computational load between several high-performance microprocessors. Operated in a cluster, the processors appear to the user as a single large computer, but a failure or maintenance of one microprocessor will not seriously affect system operations. It is, of course, essential that the system always have 25% to 50% excess data handling capacity.

Much of the desired automation is achieved through development of software that will reduce the need for operator intervention as the data are processed. The most important step in achieving automation from the standpoint of hardware is to reduce tape handling to the minimum. Ideally, the only tapes handled are the station tapes, mounted once. The optical mass store is the key piece of equipment needed to reduce tape handling. It provides the space needed to permanently store processed data in its final format while waiting for all of the station data to arrive.

A block diagram illustrating the IRIS/USGS DCC hardware configuration is shown in Figure 1. In its current configuration, the DCC consists of three Digital Equipment Corporation (DEC) Microvax II's attached to a local network interconnect (DELNI). The DELNI is a concentrator that allows up to eight Ethernet compatible devices to be grouped together. Each Microvax contains an Ethernet to Q-bus high performance communications controller called a DEQNA that connects the processor to the Ethernet Local Area Network through the DELNI. With Ethernet as a high speed communications system, and with DEC cluster software which allows any peripheral to be used with any processor, the three Microvaxes appear to the user as one large processor. Each processor has several disk drives attached providing a total of 3.5 gigabytes of working disk storage for the system. There are also four tri-density tape drives, two 3M tape cartridge drives, and two Archive cartridge drives for reading station data, and three DEC TK50 tape drives. The mass store, a Sony "jukebox" style optical disk drive, serves both as an archive and as an on-line storage system for a minimum of six months of network data. The Microvax 2000 workstation functions primarily as a network analysis system for data quality evaluation, and is connected through the DELNI to function as a system processor if needed. The Sun 3/160 workstation functions as a telemetry processor, electronic mail terminal, and programmer's workbench. Other buildings at ASL are connected to the DCC system on an Ethernet link through fiber-optic cables. An additional function of the DCC is to provide general-purpose computer support to the laboratory. Clustered VAX/VMS is used as the operating system. All application software is written in the C language. The Sun system provides a UNIX environment that can be used to modify application software for UNIX-based systems. A backup power system has been in operation at

ASL for several years. It provides 10-15 minutes of uninterrupted battery power for the computers when line power fails, sufficient to allow an orderly shutdown during working hours.

With the installation of the optical mass store and the satellite terminal for transmitting data to the DMC, the initial assembly of DCC hardware will be very nearly complete. One important item that must yet be installed is a non-destructive fire suppressant system to protect both the data collection system and the archived data. In addition to this, a few items of hardware needed include a plotter, memory for the workstation, replacement UPS batteries, and optical disks for the mass store. Some software is needed for the satellite communications with the DMC and for optimizing disk operations. If data volume increases as planned, in two years it will be necessary to supplement the DCC with a fourth Microvax processor.

Current development of the DCC does not include capability for acquisition of real-time data from the IRIS stations. The basic hardware requirements for reception and processing of real-time data will include receiving equipment, a dedicated Microvax III, additional working disk, high-density tape drives or some other media for data storage in event of a disk or DCC failure, and a diesel generator for backup power.

2. Personnel Requirements

The types and numbers of personnel needed to operate the DCC when the data input level reaches 300 megabytes per day are as follows:

DCC Manager
Data Analyst
Programmer
Computer Technician
Senior Computer Operator
Computer Operator (3)
Clerk

Six of these slots are currently filled at ASL; the others will be filled when warranted by the workload. It may be necessary to operate two shifts each day to utilize the hardware more efficiently, although the computer hardware will operate with automated programs around the clock.

3. Recurring Support Requirements

The major annually recurring non-personnel costs of DCC operations for supporting an IRIS network of 60 stations are expected to be as follows:

Hardware and software maintenance	$ 50.0K
Supplies	40.0K
Communications	30.0K
Equipment Replacement	75.0K

A planned and adequately funded program of equipment replacement is essential. The amount of data that must be processed each day by the DCC will not allow much margin for equipment failures or maintenance downtime, and future technological developments that increase operational reliability and efficiency should be exploited.

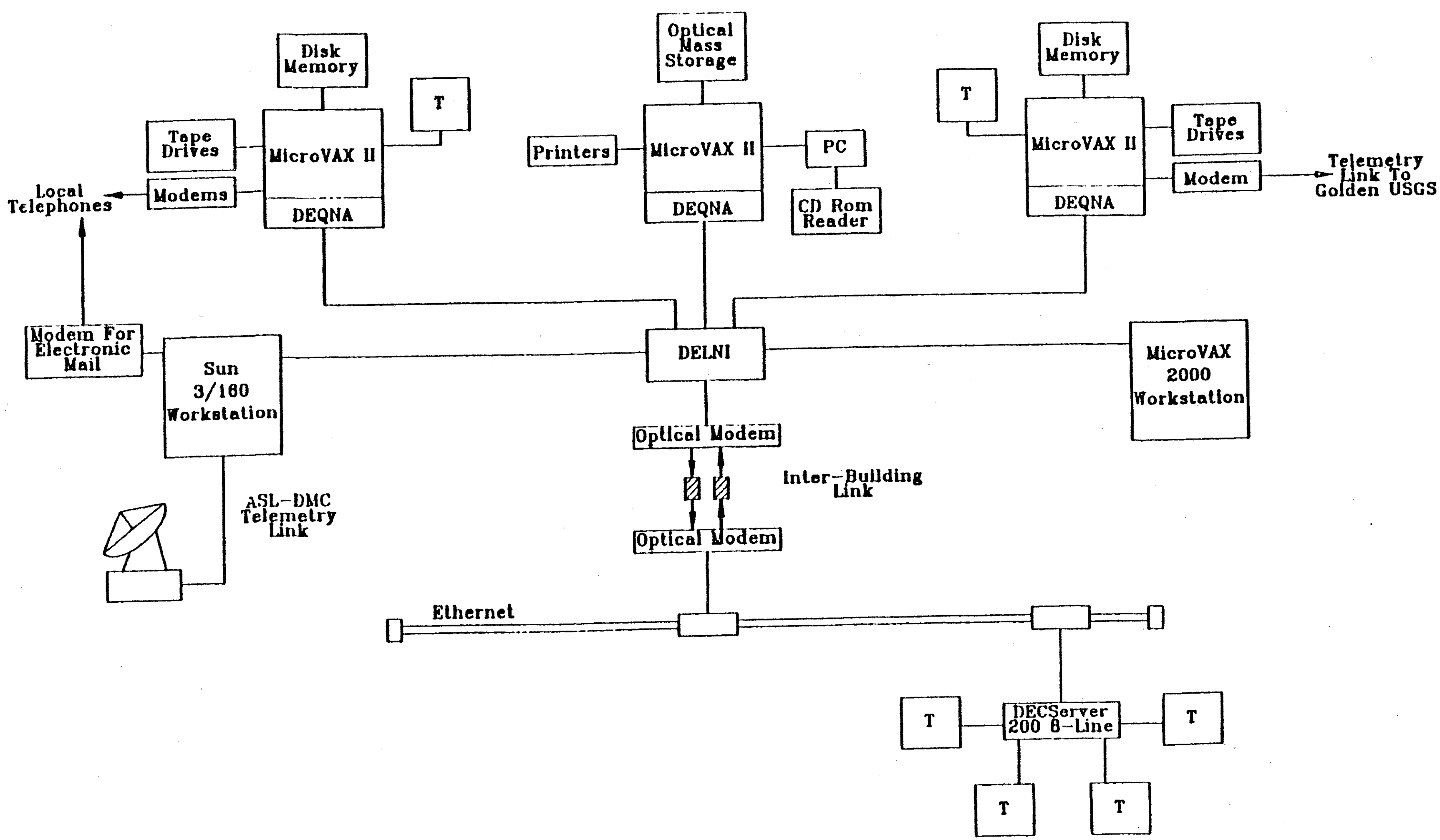


Figure 1. Block diagram showing major components of the IRIS/USGS Data Collection Center.

APPENDIX 6.

IRIS/IDA MEMORANDUM OF UNDERSTANDING

1. Introduction

This cooperative agreement establishes a coordinated position between the Incorporated Research Institutions for Seismology (IRIS) and the Institute of Geophysics and Planetary Physics, University of California San Diego (IGPP/UCSD) concerning joint activities relating to the establishment and operation of a new Global Seismographic Network (GSN) sponsored primarily by the National Science Foundation (NSF).

IRIS is a consortium of non-profit research institutions that has been organized for the purpose of promoting and guiding major initiatives to improve facilities for seismological observations and research. UCSD is a member university of IRIS, and faculty and staff of IGPP constitute the interested parties of UCSD.

This agreement pertains principally to the specific IRIS goals of:

- The establishment of a new Global Seismographic Network of 100 modern broadband seismograph systems with satellite communication links for telemetry of the data in real time to data centers.

- The support of an ongoing research and development program directed towards the creation and continued evolution of the IRIS Global Seismographic Network.

The purpose of this agreement is to establish guidelines that will govern program coordination and the division of IRIS and IGPP/UCSD responsibilities. This agreement is not intended to limit IRIS or IGPP/UCSD in any research activities or in developing other joint activities that may be mutually beneficial.

2. Background

For the past two decades, IGPP/UCSD has had an active program for the development of seismographic instrumentation and global seismographic network operations. In the mid 1970's, with private and NSF support, it began Project IDA, the deployment of a worldwide digital seismographic network designed specifically to provide the scientific community with data to study the Earth's normal modes. Since then, data from this network has been used for a wide variety of studies encompassing a range of subjects from the Earth's deep structure to the physics of earthquakes.

Currently, the IDA network, consists of 23 stations operating in 16 countries. It is one of the three existing global digital seismographic networks, comparable in size and longevity to the USGS Global Digital Seismographic Network. It is also a network designed specifically to support academic research and as such, its operators have a long-standing interest in supporting the objectives stated in the IRIS report entitled *Science Plan for a New Global Seismographic Network.* The contribution of the resources of the IDA network, through the active involvement of Project IDA in development of the GSN network, will substantially reduce program costs and help to insure the success of the IRIS initiative.This agreement is meant to govern the activities of IGPP/UCSD in the integration of Project IDA as the IRIS/IDA component of the GSN. In what follows, the IRIS/IDA component of the GSN and IGPP/UCSD will be referred to simply as IDA.

3. Responsibilities

3.1 Technical Plan

IRIS and IDA, with the participation of the USGS will develop a *Technical Plan for a New Global Seismographic Network*, which will serve as a master planning document for the implementation of the GSN. It will include details of the instrumentation and station deployments as well as data flow. This document will be include plans for the first five year's activities through 1993 but will reviewed periodically and amended as required.

3.2 Program Coordination

Advise on and oversight of the IRIS GSN program will be undertaken by the Standing Committee on the Global Seismographic Network (SCGSN). A member of the IRIS/IDA team will be an ex-officio member of the SCGSN.

IRIS/IDA activities within the overall IRIS program will be coordinated by the IRIS headquarters staff, through the Manager of the GSN program and the Principal Investigator(s) of the IGPP/UCSD program.

3.2 Funding

IRIS and IGPP/UCSD will jointly develop yearly budgets for the operations and maintenance of the IRIS/IDA network and its related facilities. RIS will include the costs of these activities as part of its requests for funds from the National Science Foundation for overall IRIS activities. IGPP/UCSD activities will be conducted under an IRIS sub-award which will constitute the contract between these two parties.

APPENDIX 7.

IRIS/USGS COOPERATIVE AGREEMENT

Introduction

This cooperative agreement establishes a coordinated position between the U.S. Geological Survey (USGS) and the Incorporated Research Institutions for Seismology (IRIS) concerning joint activities that will be undertaken to develop and manage a new global seismographic network sponsored primarily by the National Science Foundation (NSF).

IRIS is a consortium of non-profit research institutions that has been organized for the purpose of promoting and guiding a major initiative to improve facilities for seismological observations and research. Major goals that pertain to this agreement are: (1) to establish a permanent global network of 100 modern broadband seismograph systems with satellite communication links for telemetry of the data in real time to data centers; (2) to establish the data collection facilities needed to organize and distribute the data to research institutions throughout the world; and (3) to establish a scientific data processing center to serve as a nucleus for processing and analyzing the large volume of data that will be created. The technical program will involve both the upgrading of existing networks and data management facilities and the installation of new stations and facilities. The objectives and benefits of the new seismograph network are described in an IRIS report entitled *Science Plan for a New Global Seismographic Network.*

One of the important roles of the USGS is to provide earthquake information and data services to the public. The USGS Albuquerque Seismological Laboratory has a 23-year history in the development, installation, and management of global seismograph networks, including the World-Wide Standardized Seismograph Network (WWSSN) and the Global Digital Seismograph Network (GDSN), together with the data processing facilities needed to collect, merge, and distribute the data to research scientists. The existing networks, and the cooperative agreements under which the stations are operated in more than 60 countries, constitute a valuable infrastructure from which a modern telemetered network can evolve. The past work at the Albuquerque Laboratory in this field has led to the formation of a cadre of experienced personnel and development of extensive technical and logistical network support facilities. The contribution of these resources through the active participation of the USGS in development and management of the new network will substantially reduce program costs and help to insure the success of the IRIS initiative.

Since the USGS and IRIS have common goal~ and objectives with respect to global seismograph networks and related activities, it will be advantageous to set up a cooperative arrangement whereby each organization contributes to the program. The purpose of this agreement is to establish guidelines that will govern program coordination and the division of IRIS and USGS responsibilities. This agreement is not intended to limit the USGS or IRIS in developing or operating other networks or performing related activities.

JOINT RESPONSIBILITIES

IRIS and the USGS will jointly develop a "Technical Plan for a New Global Seismographic Network", which will serve as the master planning document for development of the new network. Material for the plan will be drawn from the Science Plan, the work of IRIS Technical Committees, and other sources. The document will be revised and updated periodically to reflect current planning, scheduling, and budgeting.

Instrumentation Plans and Concepts

The development of concepts, plans, and preliminary budget estimates for network instrumentation, communication, and data collection will be a joint responsibility of IRIS and the USGS. It is understood that the development of concepts and plans will be assigned by IRIS to Technical Committees established under the IRIS Standing Committee for the Global Seismic Network. The USGS will be represented on the Committees that are responsible for planning tasks that may involve the USGS.

Network Configuration Plans

The development of network configuration plans and priorities for siting new stations, relocating existing stations, and selecting existing stations to be upgraded with new instruments will be a joint responsibility of IRIS and the USGS. It is understood that this planning may be assigned to an IRIS Technical Committee on which the USGS will be represented.

Data Collection and Initial Distribution

The establishment of procedures to be used for collection and initial distribution of the network data, the determination of any costs that may be assessed for the data, and the selection of organizations that will receive network data on a regular basis will be a joint responsibility of IRIS and the USGS. The USGS and IRIS may provide network data to other organizations and individuals as well. IRIS also plans to establish a seismological data center which will institute procedures for general distribution of the data.

Data Exchange

The establishment of formal data exchange agreements with international scientific organizations or foreign governments will be a joint responsibility of IRIS and the USGS.

Technical Evaluation of Proposals

Any source evaluation boards convened for the purpose of evaluating major technical proposals submitted by commercial firms for network instrumentation and related hardware and software will include representatives of IRIS and the USGS, and may include outside experts as well.

Funding

IRIS will initiate requests to NSF for the additional funds needed for

IRIS and USGS activities related to the development, installation, and operational support of the new or upgraded network and associated communication and data collection facilities. The USGS will endeavor to provide funds at least at current levels to support the existing or upgraded networks and related activities.

IRIS RESPONSIBILITIES

Scientific Guidance

IRIS will provide the guidance needed to insure that the data produced by the new network and the procedures used to organize and distribute the data adequately meet the needs of the scientific community.

Technology Studies

IRIS will initiate and fund technology studies that may be needed to investigate or develop innovative techniques for the acquisition, telemetry, or management of network data.

Scientific Data Center

IRIS will plan and initiate the establishment of a scientific data center that will be used for the processing and analysis of network data for research purposes.

Plans and Priorities

IRIS will have responsibility for final approval of the Technical Plan, detailed instrumentation plans and specifications for new network instruments and new data collection facilities, and for network configuration plans and priorities for siting new stations and selecting existing stations to be upgraded.

USGS RESPONSIBILITIES

The USGS will be responsible for the management and administration of tasks that may be assigned to the USGS within the context of this cooperative agreement, including the following.

Test and Evaluation

The USGS will be responsible for performing test and evaluation of new instruments and systems purchased by or for the USGS. Test plans may be developed jointly and results will be provided to IRIS.

Station Agreements

The USGS will be responsible for negotiating and executing agreements with individual stations or foreign governments for operation of network

stations and communication facilities. The USGS is responsible for decisions regarding the modification of existing agreements with stations in the USGS managed network.

Station Sites

The siting of new stations (at locations designated by IRIS) and any site testing or site preparation that may be required will be the responsibility of the USGS working together with the host organization.

Installation and Training

The installation of station and communication equipment and the training of station operators will be the responsibility of the USGS.

Network Support

The USGS will be responsible for the management and support of the network and communication facilities, a depot maintenance center, and any regional maintenance centers that may be established.

Data Collection

The USGS will be responsible for management and operation of the data processing facilities used to collect, validate, organize, merge, and distribute the digital data to data centers.

Earthquake Information

The USGS will develop and perform routine standardized processing of network data for earthquake information which will continue to be published and disseminated by the National Earthquake Information Center.

PROGRAM COORDINATION

Policy and Management Coordination

IRIS and the USGS will each designate a Program Coordinator from their respective organizations. The IRIS/USGS Program Coordinators will resolve issues of policy and management that affect the joint activities; they will establish the management procedures needed for general review and oversight of the activities assigned to the USGS; and they will establish the administrative arrangements that may be needed in the performance of joint activities.

Technical Coordination

IRIS and the USGS will each designate a Technical Coordinator from their respective organizations. The IRIS/USGS Technical Coordinators will establish liaison between IRIS and the USGS on technical matters during the planning and establishment of the network; they will work closely with the Technical Committees to insure that the interrelated work of the various Committees is coordinated and integrated; and they will be jointly responsible for drafting the Technical Plan.

Signed:

Thomas V. McEvilly
University of California, Berkeley
Acting President and Chairman,
Board of Directors
Incorporated Research Institutions
for Seismology

August 30, 1984

Dallas L. Peck
Director
U.S. Geological Survey

November, 16 1984

APPENDIX 8.

SUPPLEMENTARY ARTICLES OF THE INTERAGENCY ACCORD

Article 1

USGS AND NSF ROLES AND RESPONSIBILITIES IN THE GLOBAL DIGITAL SEISMIC ARRAY AND DATA MANAGEMENT

It is agreed that a major element in the program for implementing the Committee on Science, Engineering, and Public Policy (COSEPUP) recommendations is the development of the Global Digital Seismic Array (GDSA), with the goal of 100 low-noise, wide-band, high dynamic range worldwide stations to be telemetered in near real-time to a central data collection facility. It is also agreed that, while IRIS will play a leading role in the planning, design, prototype testing, siting and operational oversight of the new GDSA, it is clear that much of the new array will be built on existing and new U.S. Geological Survey (USGS) stations, and thus be jointly managed and supported by the National Science Foundation (NSF) through the Incorporated Research Institutions for Seismology (IRIS) and the USGS.

Previous Agreement:

This Article acknowledges the existence of the IRIS/USGS Cooperative Agreement, signed in August 1984, which sets out in some detail the joint and individual responsibilities of IRIS and USGS, and the plan for program coordination. The Agreement (appended hereto) is considered to be a part of this Article, and its provisions are mutually acknowledged as being in effect.

USGS Role in New Global Digital Seismic Array

The USGS role and responsibilities in implementing the new GDSA can be summarized in the following list of plans for participation:

1. Participate through various IRIS committees and assist otherwise in the design of the station instrumentation, the Data Collection Center, and the network configuration.

2. Install and maintain the majority of the new GDSA stations, including all new stations resulting from upgrades at present USGS-maintained stations. Other GDSA stations could include existing university-operated stations, foreign networks being run by other countries, and any special situations where it may not be possible to have formal U.S. Government involvement or where it may be advantageous to have a university-to-university arrangement.

3. Operate the primary Data Collection Center for the GDSA stations. The Center would be collocated with the Albuquerque Seismological Laboratory,

4. Provide data from the USGS-operated Data Collection Center to the IRIS-operated scientific Data Management Center.

NSF Role in the Global Digital Seismic Array

The NSF role and responsibilities in implementing the new GDSA stations can be summarized as follows:

1. Provide substantial funding for the new GDSA development, deployment, and for operation of IRIS-operated facilities.

2. Provide substantial funding for the IRIS scientific Data Management Center.

3. Insure coordination of IRIS activities with appropriate Government agencies.

4. Provide oversight for IRIS program.

Joint Agreements

1. The NSF and USGS jointly agree that the NSF-sponsored IRIS Data Management Center will be used for the processing and analysis of network data for research purposes and will not duplicate the operational activities and services of the USGS-sponsored National Earthquake Information Center.

2. The NSF and USGS jointly agree to seek through their own budget processes the funds necessary to carry out their own activities and functions as called for by this agreement. In the event that transfer of funds between these agencies occurs, such transfer will be made directly and not through a third party.

3. The NSF and USGS agree that the USGS will be responsible for negotiating and executing agreements with individual stations or foreign governments for operation of network stations and communication facilities.

Signed:

Dallas L. Peck, Director
U.S. Geological Survey
Department of the Interior
U.S. Geological Survey

February 24, 1986

Erich Bloch, Director
National Science Foundation

February 3, 1986