U.S. Department of the Interior
U.S. Geological Survey

REPORT OF THE

REVIEW OF THE GLOBAL SEISMOGRAPH NETWORK PROGRAM

OF THE U.S. GEOLOGICAL SURVEY

By

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1. Introduction

The Global Seismograph Network (GSN) is a network of some 120 modern seismograph stations distributed worldwide. GSN data are used in national and global seismic monitoring, providing the U.S. Geological Survey (USGS) National Earthquake Information Center (NEIC) and other centers with critical information. Data from the GSN are used also in basic research on the structure and properties of the Earth and in the characterization of earthquakes and other seismic disturbances. GSN stations all meet standard performance specifications and all provide data in a standard format to a data center for further distribution to the scientific community.

The development of the GSN was funded by the National Science Foundation (NSF) and the Department of Defense (DOD) and managed by the Incorporated Research Institutions for Seismology (IRIS). The International Deployment of Accelerometers (IDA) Group of the Institute of Physics of the Earth at the University of California, San Diego, and the Albuquerque Seismological Laboratory (ASL) of the USGS install and maintain GSN stations. Since 1998, Congress has provided funding through an appropriation to the USGS for the maintenance of those GSN stations installed by the USGS. During the past 18 months, several parties have criticized the USGS for not doing its share in support of maintenance of the GSN.

As a result of this criticism, a small ad hoc committee was established in June 2000 by the USGS to review the status and operations of the GSN. Committee members were Professors Barbara Romanowicz of the University of California, Berkeley and Goran Ekstrom of Harvard University, and Drs. Kaye Shedlock, Ray Buland, and John Filson all of the USGS. The committee met for a 1½-day meeting in late June at the offices of the Seismological Laboratory of the University of California at Berkeley. Also present at the meeting on the first day were Charles Hutt and Harold Bolton of the USGS ASL staff who presented various materials relevant to GSN operations at ASL.

The final chapter of this report gives the findings and recommendations of the review committee; however, in order to set these recommendations in context, this report also contains some background material relevant to the GSN and a substantial fraction of the material presented to the committee by the ASL staff.

2. Program Background

2.1 Worldwide Standard Seismograph Network

In 1959, the United States Government, acting on the recommendations of high-level scientific panels, launched the "VELA" Program, a research effort aimed at improving national capabilities to detect and identify foreign nuclear explosions detonated underground and at high altitudes. The execution of the VELA Program was assigned to the Advanced Research Projects Agency (ARPA) of the Department of Defense. An early goal of the VELA Program was to provide data for seismic research from an unclassified, comprehensive global network of seismic stations of uniform design and recording characteristics. ARPA assigned the responsibility for this ambitious program, the Worldwide Standard Seismograph Network (WWSSN), to the U.S. Coast and Geodetic Survey (USCGS). In order to execute the program, the USCGS established a facility in Albuquerque, New Mexico, known today as the Albuquerque Seismological Laboratory.

The WWSSN was an amazingly successful program. It provided seismological data for its intended purpose as well as for the emerging concept of plate tectonics. Nevertheless, once the WWSSN was completed, the issue of its long-term maintenance arose due to the policy of ARPA to initiate and develop scientific capabilities, but not necessarily maintain them over the long term.

2.2 The USGS and Modernization of the WWSSN

In 1973, most of the seismological activities of the USCGS were transferred to the USGS, including the WWSSN and ASL. In 1978, after several years of partial support for the WWSSN from NSF, the USGS assumed responsibility for the maintenance of the WWSSN under the National Earthquake Hazards Reduction Program (NEHRP). Meanwhile, ARPA began to experiment with means to modernize and expand the capability of the WWSSN, mainly through digital recording and broader bandwidth and dynamic range. These efforts (notably the High Gain Long Period Program, the Seismic Research Observatories, and the Digital WWSSN) resulted in a piecemeal, non-uniform modernization of the WWSSN. ASL carried out most of this work, along with the maintenance of the WWSSN. Again the issue of how to maintain the new digital instrumentation arose. In 1980, the USGS assumed this responsibility by reprogramming funds within its NEHRP allocation.

The primary recording medium for the new digital seismic stations was magnetic tape; one tape holding upward of 10 days of data from a single station. Although efficient from a recording standpoint, raw station tapes were awkward to use in research. The USGS developed and distributed network-day tapes that merged all of the station data during a given day onto a single tape. This proved to be an effective and popular means of distributing the new digital data.

2.3 NSF, IRIS, and the GSN

As the seismological research community exploited the advantages of the available digital data, that community began to campaign for a complete modernization of the entire WWSSN. The modernization required was outside the resources of the USGS. In the mid-1980s, with the endorsement of NSF, a group of university-based scientists formed the Incorporated Research Institutions for Seismology (IRIS), dedicated to, among other things, raising the funds and providing the management for a complete replacement of the WWSSN. The new network was called the Global Seismograph Network. The salient features of the GSN were new, broadband seismometers and new digitizers with high resolution and recording range. The GSN was implemented through the ASL and the IDA group at University of California, San Diego, by the transfer of funds either through IRIS or directly from NSF.

The GSN effort led by IRIS has been as successful as the original WWSSN was 20 years earlier. Data from GSN stations have been used to define the three-dimensional structure of the Earth and to provide routine and rapid characterization of earthquake sources. GSN data provide the basis for much of the global scale seismological research carried out today on Earth structure, composition, and processes. The GSN has also become an extremely important contributor to national and global earthquake monitoring. Although the general public and other USGS cooperators and customers are almost completely unaware of the existence of the GSN, they are all increasingly dependent on the NEIC rapid notification and information services that depend, in part, on GSN data.

Agreements describing the division of responsibilities in the GSN effort were concluded between IRIS and the USGS in 1984 and between NSF, USGS, and DOD in 1986. Briefly, these responsibilities are:

- NSF/IRIS is responsible for capital equipment, installation, and upgrades to the GSN.

- USGS is responsible for operation and maintenance of the GSN stations it has installed (approximately 70% of the 120 GSN stations).

- NSF/IRIS and the USGS jointly agree on siting plans and overall management of the GSN.

2.4 Discussion

The most important and persistent problem vexing the development and operation of global seismic systems has been the responsibility for long-term maintenance. Government agencies charged with supporting basic scientific research, such as NSF and ARPA, are willing to support the technological development and installation of these networks, but they find it difficult to accept responsibility for their long-term operation. Agencies, such as the USGS, that can justify long-term, domestic seismic monitoring under their more applied scientific programs, have found it very difficult to raise the funds for operation of global networks, leaving alone the issue of funds needed for their modernization.

The GSN, to date, has proven a model of interagency cooperation in the installation and operations of global seismic systems. The agreements under which this cooperation was begun have served all parties well but should be reviewed and revised as necessary.

3. Current Program

3.1 The USGS and GSN

In 1998, a precedent was set when Congress provided, in a separate appropriation or "line item," $3.8 million to the USGS for maintenance of the GSN. This was due to an intense effort by IRIS and by USGS officials who were willing to argue the case for their Agency's role in global seismic monitoring. For the first time in the long history of the United States involvement in global seismic monitoring, an Agency was given funding explicitly for the operations and long-term maintenance of that monitoring.

3.2 USGS Management

The USGS has recently adopted "matrix management" as its model for the allocation of funding and personnel resources. Under this model, appropriated funds are allocated by a "Program Coordinator" to an operational unit that manages the personnel and reallocates funding to execute a program, or tasks within a program, as defined by the Program Coordinator. Operational units, called "teams" in some cases, are managed on a regional basis, reporting to a regional executive who is in turn responsible to a Regional Director. A team is considered a "cost center"—an administrative level at which financial authority is granted and accountability is expected. All cost centers can tax received funds with an "overhead" assessment. Allocation of funds and personnel within a team is usually based on a project—a unit of research or operational activity focused on a single topic or task. A project can consist of a few to up to 30 personnel with funding ranging from $100,000 to up to $3 million.

In the USGS today, the GSN maintenance is considered a single program with an assigned Program Coordinator responsible for the allocation of funds and ultimately, for the defense, justification, and performance of the program. The program is carried out solely by ASL, which is managed as a part of a project within the Central Region Geologic Hazards Team. The Chief of ASL reports to the Seismic Networks Project Chief, who in turn reports to a Team Chief, who reports to a "regional executive" in the Central Region, who reports to a Regional Director, who reports to the Director. Most of the direct oversight of ASL comes from the chief of the Seismic Networks Project. Most of the oversight of the GSN program comes from the Program Coordinator.

3.3 ASL versus the GSN

The ASL has worldwide renown as a center of excellence in testing, fabrication, installation, and maintenance of seismic systems. Most commercial and academic developers have their new seismic instrumentation tested at the ASL facility. In the past, ASL has done considerable work for other agencies on a reimbursable basis, which has helped it develop into its present admirable state. Many USGS employees and other interested parties consider ASL a "national facility" and expect it be supported as such.

Nevertheless, Congress appropriates funds to the USGS GSN program for GSN maintenance, not to maintain ASL. When ASL has a large cash flow from many reimbursable projects, it can support functions not strictly necessary for the success of any individual project, but for the effective execution of all of them and for the success of ASL as a whole. When the sources of income of ASL shrink to a few or one large program, conflicts of purpose may arise. In some cases, a single program may not be able to justify the greater needs of ASL as a national facility. Today the USGS GSN support of ASL is almost triple the total of funding from all other sources.

3.4 External Considerations

The USGS GSN program is fairly unique in all Government programs in that it is dedicated to the maintenance of equipment owned by another agency, NSF. IRIS raised the funds for the purchase and installation of the GSN equipment through proposals to and subsequent grants from NSF and DOD through NSF. IRIS continues to feel responsibility for and ownership over GSN equipment. The USGS GSN maintenance program consists entirely of funds appropriated to the USGS through the Department of Interior budget cycle and congressional appropriation committees. However, IRIS, through its management structure and GSN Standing Committee, continues to exert considerable influence over ASL management regarding GSN affairs.

3.5 Discussion

Internal USGS Management. Other options exist for execution and management of the GSN program by the USGS. Although some of these options may not be practical, they include:

- Using a service contract for GSN maintenance, independent of ASL.
- Making ASL a single project within the existing team.
- Making ASL a separate "cost center," the organizational equivalent of a team with the ASL chief reporting directly to a regional executive or other manager.

The first option is probably not practical nor politically feasible. The second option is little different from the status quo. The third option has the advantages of allowing ASL to set its own assessment (overhead) policy and receive all of the benefits from this policy. The disadvantage of this option would be loss of proximate supervision or oversight of ASL activities.

External Considerations. Although the USGS usually follows the advice of the IRIS GSN Standing Committee, it has no formal obligation to do so. The USGS has representation on that body, but it has no voice in its overall membership and agenda. Nevertheless, the GSN Standing Committee serves the research community well and if it did not exist, the USGS would need to form a body to gain advice from the seismological research community on the GSN. There is no apparent need for the USGS to form a separate committee to address GSN issues; however, the USGS role in forming the existing committee should be reviewed and possibly strengthened in the revision of the interagency GSN agreements.

4. Operations and Functions

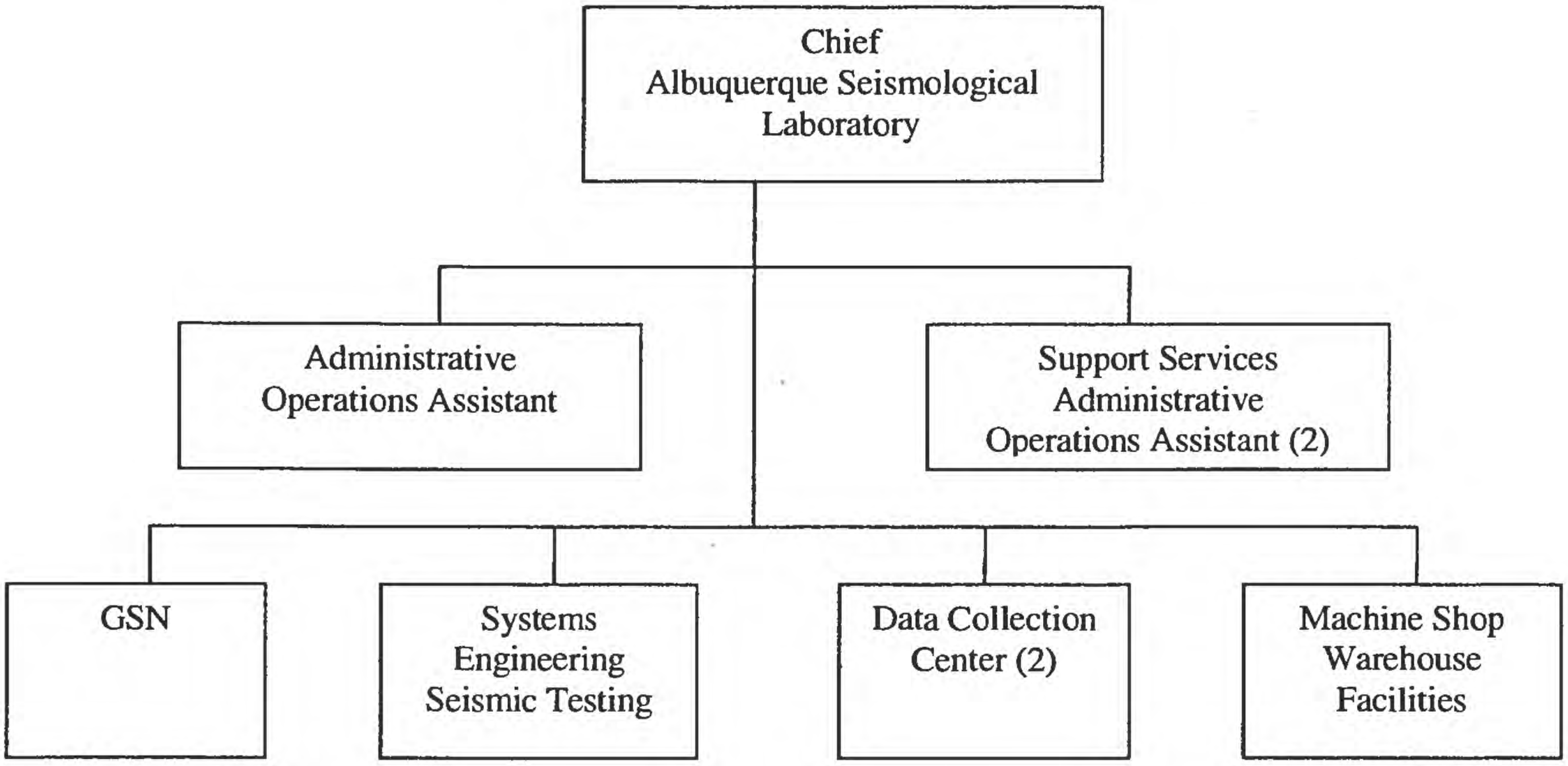
4.1 General

The functions of ASL, as shown in the organizational chart, Figure 4.1, fall into five broad categories:

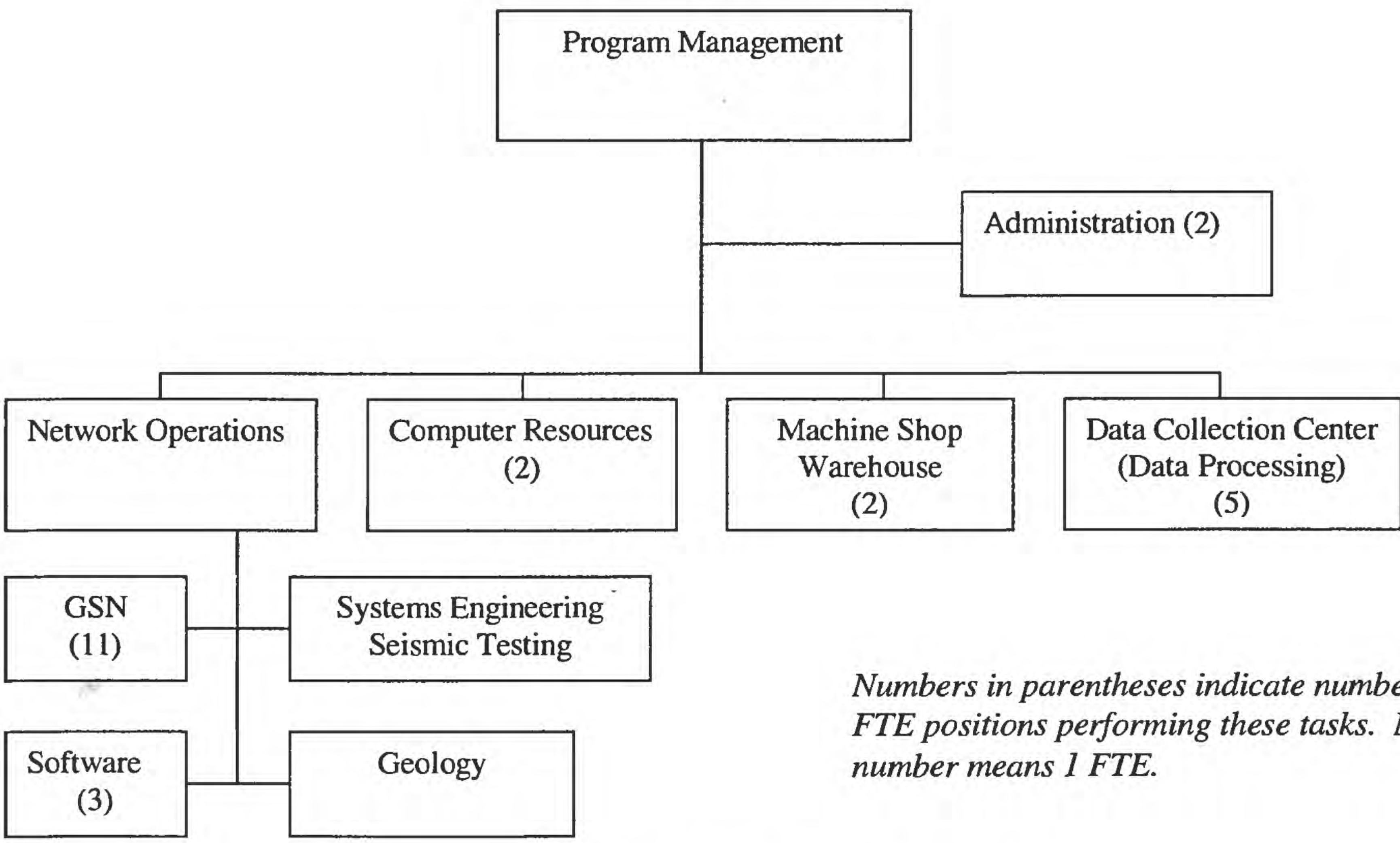
- Management and Administration
- Network Operations
- System Engineering and Testing
- Data Collection Center
- Warehouse, Machine Shop, and Facilities.

Although we examined all of these, this report discusses only those functions where the committee recommended changes or felt that the ASL/GSN role needed clarification.

ASL Organizational Chart
USGS Personnel



ASL Organizational Chart
Contract Personnel



Numbers in parentheses indicate number of FTE positions performing these tasks. No number means 1 FTE.

Figure 4.1 ASL Organizational Chart

4.2 Data Collection Center

All data from USGS GSN stations are received, either electronically or by the physical transfer of magnetic tape, at the Data Collection Center (DCC). The most important function of the DCC is to quickly identify and isolate data problems and notify the Network Operations Group of the nature of the problem. Quoting from a report prepared by Robert Woodward (formerly of ASL), "The primary goal of the ASL DCC quality control (QC) effort is to ensure that ASL operated stations produce the maximum possible amount of high-quality, problem free data. Thus our highest priority is given to eliminating problems at the source: catching problems as quickly as possible, working with the field engineers to get these problems solved, and then verifying that the solutions are successful. The second goal of the QC effort is to repair data and/or document problems such that problem data become usable data. The third goal of our QC work is to document historical data problems. Such work typically results in flagging questionable or defective data."

All data are reviewed and for any problems or irregularities in such criteria as:

- Sensitivity
- Timing
- Polarity
- Orientation, and
- General instrument calibration and data quality

In addition, the DCC puts extensive effort into:

- Review and maintenance of the station information data base,
- Data analysis for troubleshooting special problems,
- Data analysis to resolve historical data problems.

4.3 Network Operations

The network operations are a critical function to a successful GSN maintenance program. The overall goal is to ensure high data availability from all GSN stations. This is achieved by keeping all GSN stations operating properly and providing useable data flowing from the stations. To attain this goal and meet the objectives, network operations must either quickly fix malfunctions in GSN stations and the related infrastructure, or keep problems from occurring through an aggressive preventive maintenance program.

ASL has physical access to only one of the GSN stations, the one located at the ASL facility. The rest at remote sites are operated by "host" organizations that supply the local technical support and infrastructure such as buildings, power, and security. In effect, the GSN is the "parent network" on which each station depends for support. Each host organization must provide the suitable local environment and support necessary for station operations. The relationship is completely symbiotic; no GSN station can operate successfully without adequate support from both the local host organization and from the network operations group at ASL.

The most important tasks of the network operations function are:

- Provide to each host organization the necessary training, equipment, advice, and monetary support to keep the local environment suitable for GSN station operations.

- Fix problems with individual stations as they occur, either through consultation with the host organization or through a visit by ASL network operations staff.

- Provide routine maintenance of all GSN stations.

The first of these tasks is the most important. The ASL operations staff has to develop rapport with, but also the trust and respect of, the host organization. In many cases, a problem with an individual station can be fixed through a telephone call or e-mail exchange with the host. More difficult problems may require sending a new or replacement part to the station through express mail. Serious problems will require a visit by ASL personnel. The most serious problems involve the chronic partial or complete failure of the host organization at a site not easily accessible. This may be caused by political or economic unrest or a natural disaster not the fault of the host.

Other important ASL functions related to network operations are engineering and testing, software support and depot parts, and record maintenance. Every new or replacement part must be tested before it is sent to the field. These tests are not only on the part itself, but also testing on a system similar to that in which the part will be installed. There are over 25 separate configurations in the various species of GSN systems. This came about because, although the systems have similar operating characteristics, they evolved over a period of years and the individual components are not identical. The maintenance and documentation of these operating systems are a difficult task and important to the performance of the entire network.

A related task is the keeping of the performance and maintenance records of each station. To troubleshoot a problem at a station, an accurate and current anatomy and "medical history" of the station is essential. ASL keeps comprehensive records on the installation of each station, characteristics of the local environment and host institution, the type of problems arising, maintenance required and performed, and spare parts shipped and installed.

ASL also manages an extensive, on-site spare parts depot that allows rapid access to needed parts without going to the manufacturer. Extensive records are kept on the usage of parts so that replacements can be ordered before the on-site stock is depleted.

4.4 Discussion

DCC. The work of the ASL DCC is essential for quality control and for identifying and correcting station problems. Other activities of the DCC should be reviewed carefully in light of their contribution to the overall GSN maintenance effort.

Network Operations. Currently there is no plan at ASL for routine maintenance of GSN stations. The natural consequence of this is that ASL operations are "Event Driven." Station problems are addressed as they occur. Site visits for both routine and emergency maintenance purposes are worked into other travel as frequently as possible. Rarely is a foreign trip made to address problems at a single station. This approach does allow for more cost effective maintenance, counterbalanced with some decrease in the overall GSN performance record. ASL needs to develop a station performance goal for the GSN and a plan and schedule to meet that goal that realistically incorporates the necessary tradeoffs.

5. Budget, Costs, and Personnel

5.1 ASL/GSN Budget Overview

The congressional appropriation to the USGS for GSN operations in Fiscal Year (FY) 2000 was $3,464,000[3]. These funds were distributed as indicated in Table 5.1. This table indicates that the net funding available to ASL for GSN operations and salaries is $2,591,700. (Third row from bottom, right column.)

Table 5.1 USGS GSN Budget (FY 2000)

	Gross Funds ($1,000)	Net Funds ($1,000)
Total Appropriation	3,464.0	
Bureau/Division Funds	83.8	
Space	36.0	
Remaining	3,344.2	
Bureau/Division Assessments (11.5%)		384.6
Team Assessment (11%)		367.9
Remaining for USGS Salaries and GSN Operations		2,591.7
USGS Salaries (ASL)	691.0	535.5
Operating Expenses (ASL)	2,653.2	2,056.2

5.2 Other ASL Income Sources

ASL has other sources of income as summarized in Table 5.2. These sources include about $1.4 million from other Federal agencies and about $250,000 restored to ASL from USGS assessment

[3] In FY2000 there was a "restructuring" of the USGS budget in which costs of facilities and other "overhead" costs were presented as a separate budget item. Funding requested for programs, such as the GSN, which had contained overhead costs in previous years, was reduced accordingly. Despite this restructuring, USGS programs are still charged a reduced overhead or assessment.

accounts. The table shows almost no USGS salaries are charged against the reimbursable work for other agencies. The non-salary USGS costs are lumped under "Supplies and Materials" in budget summary accounts provided by ASL. Some of these funds are directed toward the large technical services contract. The total net funding from these sources is about $1.6 million or about 39 percent of the total net funds available for ASL salaries and operations.

Table 5.2 Other ASL Income
(FY 2000 Net)

	Funding Agency	USGS Salaries	Equipment and Service Contract
GSN Installations	NSF/IRIS	0	$486,467
China Network	DOE	0	$590,069
GTSN	USAF	$7,866	$176,290
CTBT/IMS O&M	DOD/DTRA	0	$129,528
USGS Overhead	USGS	$86,209	$158,994
Total		$94,075	$1,541,348

Although reliable records are not available, the current non-USGS funding for ASL is much less than it has been in recent years. In the 1980s and 1990s, ASL was involved in the Global Telemetered Seismic Network Program sponsored by the Air Force, and in the 1990s ASL was involved in the development phase of the GSN. During the 1990s, non-USGS funding for ASL was generally between $2 to $4 million per year.

5.3 Costs ASL/GSN Operations

The FY 2000 costs of ASL/GSN operations charged against the USGS/GSN program are shown in Table 5.3. The largest costs are the USGS salaries and technical services contract. The largest of the other costs are stipends to host organizations that provided the local support for GSN stations. The costs shown in Table 5.3 are all net costs and do not include the overhead and other costs charged, at higher levels in the USGS, against the GSN program shown in Table 5.1.

Table 5.3 ASL Operational Costs (FY 2000 Budgeted)	
Description	**Cost $**
Meeting Travel	15,421
Shipping and mailing	31,500
Communications	38,100
Technical Services Contract	1,778,379
USGS Salaries	530,585
Miscellaneous	2,500
GSN Operational Supplies	20,000
GSN hardware and software	30,000
Non-ADP ops equipment	25,802
Stipends to GSN Stations	107,300
Other	7,884
Total	2,587,471

Table 5.4 ASL Personnel Assigned to USGS GSN		
	Grade	**FTE**
Supervisory Geophysicist	GS-14	0.93
Geophysicist	GS-14	1.00
Geophysicist	GS-13	1.00
Electronics Engineer	GS-13	1.00
Computer Specialist	GS-12	1.00
Engineering Technician	GS-12	1.00
Admin. Operations Asst.	GS-6	1.00

5.4 Personnel and Salary Costs

As of August 2000, there were nine full-time government employees at ASL. The salaries of two USGS administrative personnel are paid by team assessments. The salaries of the remaining seven of these employees are charged to the USGS GSN program, except for one month's time of the ASL chief. Thus, for the most part, the salaries of all USGS personnel at ASL are paid by the USGS. The titles and grades of the ASL/GSN personnel are given in Table 5.4.

In addition to the nine government employees, there are 29 employees working under a technical services contract. The salary charges to the USGS for contract employees is $2,166,228; thus, approximately $390,000 of contract salaries must be charged to the reimbursable or overhead funding sources listed in Table 5.2. It is noted that 18% of the contract salary costs are charged to reimbursable accounts, which make up 39% of ASL funding.

The personnel provided under the technical services contract during the last 4 years are listed in Table 5.5.

Table 5.5 Contract Personnel at ASL

Type	1997	1998	1999	2000
Program Manager	1	1	1	1
Digital Field Engineer	9	8	7	5
Senior Digital Field engineer	5	5	4	6
Computer Programmers	1	1	1	1
Senior computer Programmers	2	1	1	1
Computer Center Manager	1	1	1	1
System Administrator	1	1	1	1
Computer Operators	2	0	1	1
Senior Computer Operators	1	1	1	1
Geophysicist/Geophysical Engineers	2	2	2	1
Electronic/Computer Engineers	2	2	2	2
Electronic/Mechanical Facilities Tech.	1	1	1	1
Warehouseman/Janitor	1	1	1	1
Secretary	1	1	1	1
Supply/Shipping Specialist	1	1	1	1
Quality Control Specialist	1	1	1	1
Senior Quality Control; Specialist	0	0	0	1
Filed System Database Specialist	1	1	1	1
Seismic electronic Technician	1	1	1	0
Total	34	30	29	28

5.5 Non-GSN and Non-Reimbursable Costs

ASL takes on certain activities that can be considered as service to the seismological community, which have nothing to do with GSN maintenance and for which ASL and the USGS receive no reimbursement. These voluntary activities include testing of seismological equipment and the capture of seismological data sets that are on media that face physical deterioration or cannot be accessed because of technological obsolescence of reading devices. All of these community service activities are laudable; however, if they are provided at no cost, they draw resources away from the primary task of ASL—maintaining the GSN.

5.6 Discussion

General. The management model that has evolved at ASL is one with a few Government employees and a large number of contract employees. The chief advantage of this model is in flexibility in staff size and skill mix. The chief disadvantage is cost. Overhead costs (22% on the gross) are levied by the USGS on the large technical services contract and the contractor also burdens salary costs by about 70%. Thus, for every $1 that goes into a contract employee's paycheck, the GSN program has to pay $2. In addition, the contract is so large that it has its own management structure with a program manager, administrative support, and its own supervisory hierarchy.

ASL charging policy. In FY 2000, ASL received an income of about $1.4 million from non-USGS sources. However, only $8,000 in USGS salary costs was charged against this income. Approximately 18% of the contract salary costs are charged against non-USGS income sources; yet these sources make up 39% of ASL net income. It is clear that other agencies whose work is supported at ASL are getting a very good deal and, as a result, the GSN program may be suffering. Virtually no USGS salaries are charged to these agencies, and, additionally, it is possible that they are not paying their share of the contract salaries.

Community Service. ASL provides, at no cost, services to the seismological community that draw resources away from its main task of maintaining the GSN. ASL is well qualified to perform many of these tasks, but it should not be asked to undertake them without additional and adequate support. However, if there is a demonstrable connection between certain of these activities and network performance, these should be continued.

6. Performance and Performance Versus Costs

6.1 General Considerations

The generally accepted measure of performance for seismic network operations is data availability. For the purposes of this review, data availability for an individual station is computed summing the number of available data samples from the three long-period channels (sampled at one sample per second) for each day for each year and dividing by three times the number of seconds in a year. The data availability of a single station is expressed in terms of a percent. The total network data availability is computed by averaging the data availability percentages for each station over the number of stations in operation of a period of time.

6.2 Actual Performance and Performance Versus Cost

The annual statistics for data availability for the past 4 years are given in Appendix 1 to this report. The average network performance for the USGS/GSN stations over this period is 73%. In Appendix 1, the USGS/GSN stations are grouped by geographic area and this grouping provides some interesting insights into the problems of maintaining seismic networks. For example, the geographic region with consistently high performance is China (92.3% over the past 4 years and 92.6% over the past year) followed closely by stations in Europe (91.1% over the past year). Stations in the United States and Russia have performed almost equally over the past year (83.8% and 80.6%, respectively). Some stations are chronic poor performers, such as the ones in Armenia and Mexico.

Performance versus cost for individual stations during the period of April 1999 through March 2000 is shown in Figure 6.1. This figure presents interesting data. The straight line in the figure is a linear fit to the cost versus data availability data and shows an inverse trend, that is the more spent on a station the less likely it is to have high data availability. Of course, this trend is governed by a few stations and draws attention to the fact that a lot of money can be spent on a few stations with chronic problems that may never be fixed.

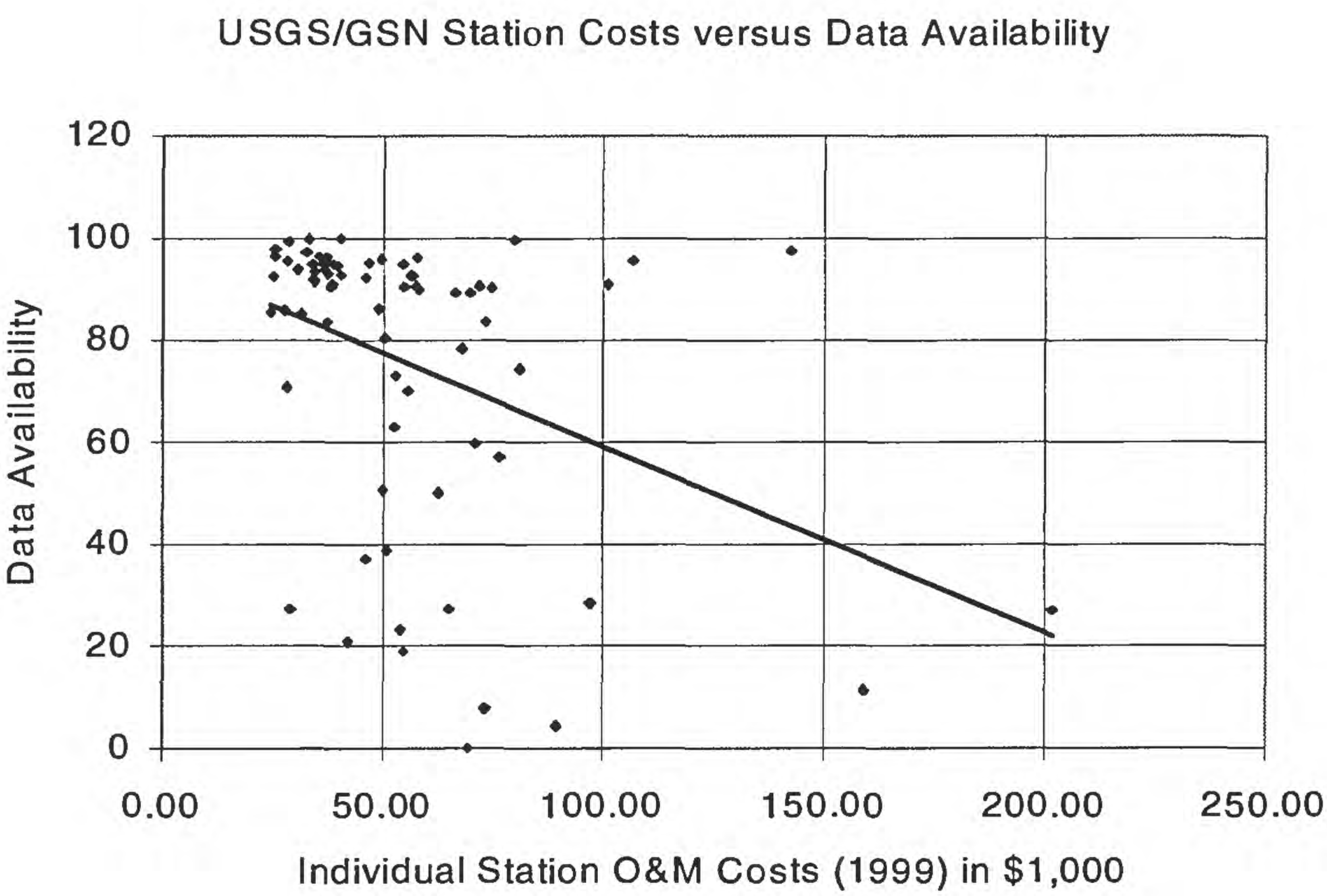


Figure 6.1 GSN Station Costs versus Data Availability

6.3 Actual Costs per Station

The cost data for each station for the time period April 1999 through March 2000 provided by ASL are given in Appendix 2. These data were used in Figure 6.1

The maintenance costs for individual stations were difficult to derive from these data because apparently costs for installation or upgrades were included. Also, the personnel costs per station were prorated to individual stations based on the total salary funds available and an estimate of the attention needed to each station. The assessment rate varies for each station although the total assessment is about right. If we assume the equipment costs are those paid for by IRIS/NSF for installations and upgrades, the average spent on each station for maintenance is about $38,000 net. Note that this per station cost estimate <u>includes</u> the DCC staff and operations, which are necessary to monitor station performance.

6.4 Ideal Operational Model

One of the members of the review panel, Ray Buland, introduced a model for the performance of seismic network operations. This model is somewhat intuitive, but it is a useful tool for estimating what changes in network performance might be expected from additional resources. The basic form of the model is:

$$U = 100 / [\ 1 + a * (N/COST)^{b}\ ]$$

Where:

U =	network data availability in percent.
N =	number of stations
COST =	gross cost total of network operations in $millions
a =	a network dependent constant, and
b =	3/2.

As an example, this model is applied to the USGS/GSN operations using the data for the period from April 1999 through March 2000: U=78%, N=79, and Cost = $3.4 million, yielding a=0.00252. Running the model for various levels of cost gives a result shown in Figure 6.2. The results are intuitively satisfactory, i.e. they show that at higher levels of performance, each increment of marginal gain in performance will require more incremental cost than the last increment.

Buland's model will not be explored further here, but it is suggested as a means to compare efficiency in network support and as a means to estimate performance gain or loss from changes in that support.

During the late 1980s and early 1990s, ASL was asked, by another Federal agency, to install and maintain a network of 10 GSN-type stations in the southern Hemisphere. The client required a data availability rate of 90% or higher and the maintenance cost was about $100,000 per station. Buland's model predicts that if ASL is required to achieve 90% or greater data availability for the GSN under its current operating procedures, the cost will be about $8 million, or about $100,000 per station.

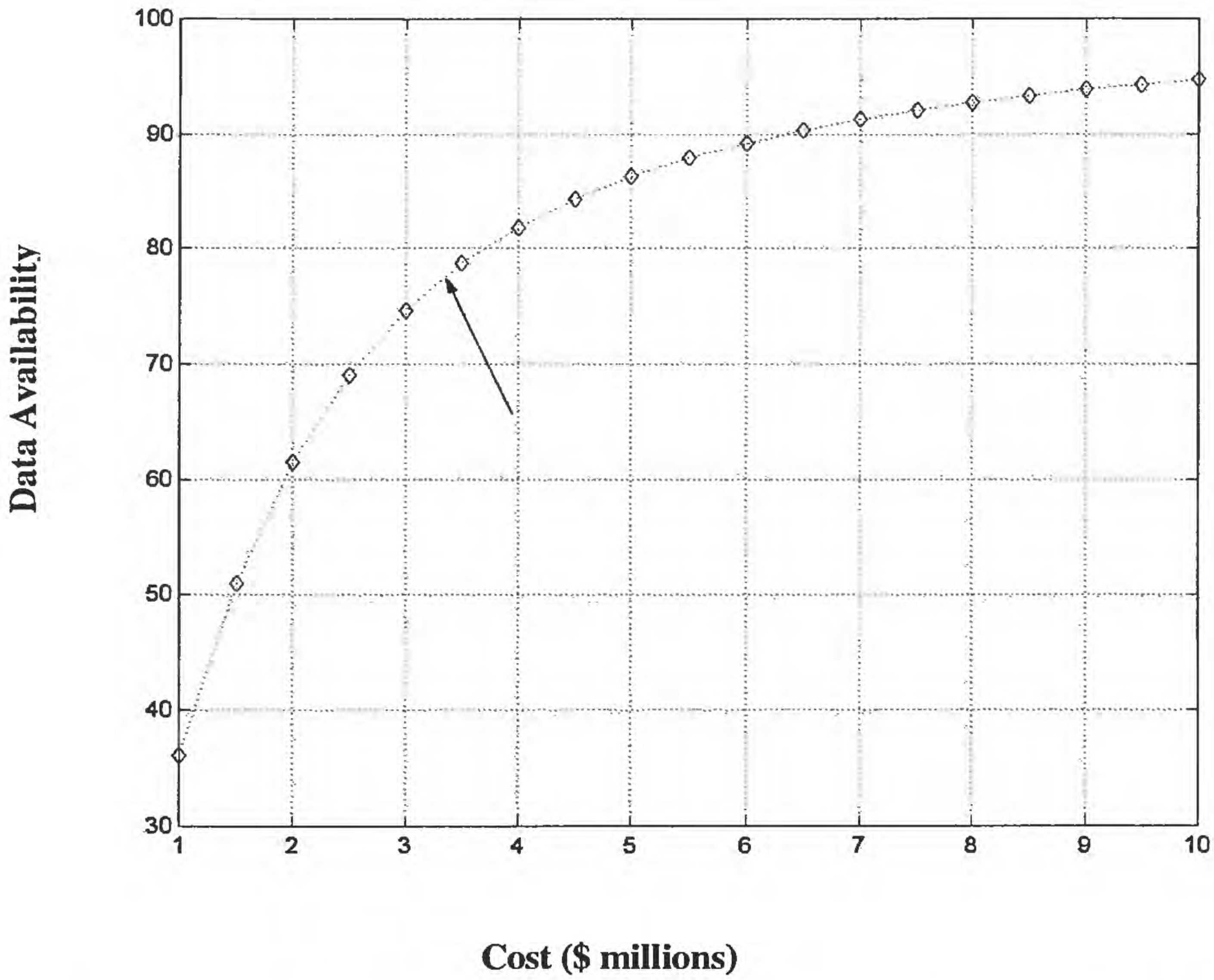


Figure 6.2 Ideal model (Buland's) of seismic network performance (data availability in %) as a function of maintenance cost in $ millions. The arrow shows the current ASL performance.

6.5 Discussion

Station Performance. As pointed out above, the GSN stations in China have the best record as a national or regional group. This may be due to the particular attention paid to these stations by a single field engineer who has worked with the host operators for over 15 years. This shows what can be done with enough effort and attention. Other regional groups, such as Africa, have a relatively poor record. This may be due to host conditions, communications, or travel difficulty. Other stations with poor performance records are harder to understand. For example, during the past year Harvard and Corvallis have the some of the poorest records of the entire USGS GSN. There are no apparent reasons for these poor performance records. This situation illustrates that well-trained, motivated people ensure high performance of stations. Lack of interest by those with responsibility for station maintenance and data delivery can result in poor performance.

Station Maintenance Costs and Performance. Cost and performance data show that, in the case of a number of stations, substantial funds are being spent with little return in data availability. The average maintenance expenditure per station based on the ASL experience with the GSN is about $50,000 per year (including the DCC effort and all USGS overhead), which yields a data availability rate of about 80%. If a higher data availability rate is sought, the maintenance costs should be expected to be substantially higher.

7. Findings and Recommendations

7.1 General

Finding: The review committee viewed ASL an excellent facility for the USGS to use in the execution of its GSN Program. The technical competence, dedication, and professionalism of both the Government and contract staffs are of the highest quality. However, there is a difference between the GSN as a USGS program and the ASL as a USGS facility. In most cases, what is generally good for ASL also benefits the GSN, but this may not be strictly true in all cases

Recommendation: ASL management must continue to maintain the high morale and competence of the Government and contract staff. Concurrently, ASL management must recognize that the overriding objective of the GSN program is high performance of existing GSN stations.

7.2 USGS Management

Finding: The GSN is a "line item" in the USGS budget with high visibility in the national and international seismological communities. However, this "line item" currently is executed by ASL and is managed as part of a project that is headquartered in Golden, Colorado. It is possible that ASL has not been getting the line management oversight that is required and that the GSN program has suffered because of this possibility. The USGS should review the placement of ASL in its management structure. The review panel considered the following options:

- Establish a service contract for GSN maintenance independent of ASL
- Leave ASL as a part of a project under the USGS team management in Golden, Colorado
- Create a new project within the Golden, Colorado, team based solely on ASL, with the project chief and certain administrative tasks residing in Golden
- Make ASL a separate "cost center," the organizational equivalent of a team, with the ASL chief reporting directly to a regional executive or other USGS manager.

Recommendation: The review panel recommends that a new project, based solely on ASL, be created under the Golden team. This will spread the burden of ASL management and planning and help with the integration of ASL into other USGS seismic monitoring activities.

Finding: The review panel notes that the USGS charges a 22% overhead (12% at the Headquarters level and 10% at the team level) on the large service contract (about $2 million), which is essential to the GSN maintenance effort at ASL. Since the contract employees require no administrative attention and receive no benefits from the USGS assessments, this policy is difficult to understand. Combined with the burden the contract company charges, this results in about a 100% assessment on all contract salaries.

Recommendation: The USGS management must, at least, justify its assessment policy toward the ASL service contract and, if not justifiable, the assessment rate on the service contract should be reduced or eliminated.

7.3 ASL activities not related to the GSN

Finding: It appears to the committee that non-USGS programs at ASL are not carrying their share of the USGS and contract salaries. It is also apparent that ASL is asked by various interests to perform tasks that are not related to GSN maintenance but the costs are borne by the GSN program. These tasks have involved testing of equipment, development of displays, and training. All of these tasks are worthy, but they can detract from the central mission of the GSN Program. There is no strict way to control these conflicting pressures except through judicious management practices.

Recommendation: ASL management should charge other agencies their fair share of work performed at ASL. These charges should be reviewed at least at one other management level in the USGS. ASL should resist taking "community service" tasks at the cost of the missions of its core programs. The seismological community should ensure that ASL is provided with the proper support to perform these tasks. ASL management must take care to balance un-funded requests for service with its GSN maintenance responsibilities and other funded tasks.

7.4 Personnel

Finding: Currently there are seven USGS and 23 contract employees directly supported by the USGS GSN Program to maintain the existing 79 stations. This implies 2.6 stations per person. This appears high and may reflect personnel levels that were more appropriate in the recent past when ASL received higher levels of outside funding. It also appears that there may be some duplication of personnel assignments between the Government and contract employees.

Recommendation: ASL and higher-level USGS management should review the personnel supported with USGS GSN funding at ASL and make reassignments or reductions as justified.

7.5 GSN Maintenance

Finding: The committee views field engineers as essential for the GSN maintenance mission and one engineer per 10 stations was considered adequate. The committee noted that a maintenance plan and schedule are not in use. The panel developed the following model annual budget for maintenance of a single station.

Function	*Model*	*Actual (Average)*
Field Engineer (1 FTE per 10 Stations)	*10,000*	
Quality Control (1 FTE per 20 Stations)	*5,000*	
Management and Administration (1 FTE per 20 Stations)	*5,000*	
Warehouse and shipping support (1 FTE per 20 Stations)	*5,000*	
Total Personnel	*25,000*	*33,700*
Travel and Shipping	*5,000*	*2,180*
Supplies	*3,000*	*0*
Stipend (may vary)	*3,000*	*1,390*
Communications	*2,000*	*1,090*
Total net	*38,000*	*38,360*
Overhead (22% of Gross)	*10,720*	*11,150*
Total Gross	*48,720*	*49,510*

Recommendation: Adequate funding for station maintenance should be approximately $50,000 (gross) per year per station under current operating conditions at ASL. This does not mean that economies cannot be achieved in the current operations.

Recommendation. A multiyear strategy and an annual plan for network maintenance must be developed and carried out by ASL management.

7.6 Performance - I.

Finding: The review panel set no specific performance goal for the GSN, although 80% data availability was generally considered satisfactory. The panel recognized that very high data availability goals would be prohibitively expensive. It was also recognized that substantial resources are being spent on stations with chronic problems or an unsuitable host environment.

Recommendation: The GSN Standing Committee should review the performance histories of all GSN stations and the committee should consider recommending closing or moving stations with chronic poor performance records.

7.7 Performance - II.

Finding: Of all of the foreign GSN regional groups, the performance record of the GSN stations in China is exemplary. The stations in Russia also perform quite well.

Recommendation: ASL should try to model its management practices in other GSN regions to those used in China. This may mean assigning one field engineer to a regional group of stations.

7.8 Replacement of GSN Equipment

Finding: The committee noted that ASL management has requested that the USGS provide funds for the replacement or amortization of GSN equipment, even though NSF owns this equipment. It is unlikely that the USGS will request substantial additional funding from Congress to replace GSN equipment owned by another agency. Nevertheless, the review panel recognizes that if older equipment is not replaced, the maintenance costs will increase with time. If older equipment becomes technically unsupportable due to lack of manufacturers support, the network performance will fall and maintenance costs will increase drastically.

Recommendation: The USGS should not be held responsible for replacing obsolete GSN equipment. IRIS, NSF, and the community of users of GSN data must address this issue. IRIS should ask its GSN Standing Committee to review GSN equipment replacement needs and to make a recommendation on GSN equipment replacement policy.

7.9 Agreements

Finding: Although the cooperative effort between IRIS, NSF, and USGS is working well, the agreements that govern this cooperation are dated.

Recommendation: The review panel recommends that IRIS, NSF, and USGS review existing agreements on the GSN and revise or renew them as needed.

7.10 Funding

Once all of the planned GSN stations come online (approximately Fall 2001), the USGS/ASL will be responsible for 90+ stations. The natural consequence of this, given the approximately $50,000/year/station Operation and Maintenance costs documented in this report, is that the USGS/ASL will need $4,500,000+/year to continue to operate the GSN at the preferred level. The USGS, NSF, and IRIS need to work together to increase the available funds to match this amount by FY 2002, and to increase with the rate of inflation thereafter throughout the life of the GSN. If these efforts fail, ASL must seek economies in operations that give the highest priority to network performance.

8. Epilogue

Since this review was begun in June 2000, dramatic changes have taken place at ASL. The site, which ASL had occupied and developed for nearly 40 years, had to be abandoned due to a precipitous increase in the cost of the lease. ASL was forced to move to temporary facilities and arrangements for permanent facilities in Albuquerque are being developed. Of course, certain crucial elements of the ASL facility cannot be moved. These include boreholes, vaults, and concrete piers for seismometers, some of which have served as the testing laboratory for seismic equipment for over 3 decades.

All of the staff of ASL, both Government and contract employees, were affected by the move. They all worked very hard during this period and continue to suffer inconvenience in their workplace surroundings. The move presented many complex logistical and managerial problems that were all solved. The continuity of operations was not interrupted significantly. This is a tribute to the professionalism and loyalty of all the ASL staff, and to the leadership of its managers.

This report has attempted a high-level review of ASL operations regarding the maintenance of the GSN. It provides a critical review of some aspects of these operations and of some other matters related to ASL. These criticisms are offered in good faith toward improving ASL operations and maintenance of the GSN. Although the forced relocation of ASL is generally lamentable, it presents the opportunity to more easily implement changes that may strengthen ASL and allow it to not only survive, but to grow and prosper, and to continue its record of service to the national and worldwide seismological communities.

Acknowledgements. This report benefited from valuable reviews and comments from Kent Anderson, Ray Buland, Goran Ekstrom, Bob Hutt, Barbara Romanowicz, David Simpson, Harley Benz, and John Unger.

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Appendix 1: Station Performance

Station Code	Station Site	Location	10/95 - 10/96	7/96 - 7/97	7/97 - 7/98	1/99 - 1/00	Station Average
FURI	Furi, Ethiopia	Africa			91.4%	78.1%	84.8%
KMBO	Kilima, Mbogo, Kenya	Africa	89.5%	85.0%	61.9%	50.0%	71.6%
KOWA	Kowa, Mali	Africa			21.0%	4.4%	12.7%
LSZ	Lukasa, Zambia	Africa	15.3%	7.9%	25.5%	0.0%	12.2%
MSKU	Masuku, Gabon	Africa				26.9%	26.9%
TSUM	Tsumeb, Namibia	Africa	88.9%	85.1%	82.9%	89.1%	86.5%
CASY	Casey, Antarctica	Antarctic	2.9%	60.3%	56.%	20.9%	5.0%
PMSA	Palmer Station, Antarctica	Antarctic	93.6%	99.2%	80.7%	99.8%	93.3%
SPA	South Pole, Antarctica	Antarctic	90.9%	86.9%	61.0%	95.5%	83.6%
GNI	Garni, Armenia	Armenia		35.3%	24.6%	7.7%	22.6%
CTAO	Charters Towers, Australia	Australia	80.5%	95.1%	70.1%	85.7%	82.8%
NWAO	Narrogin, Australia	Australia	89.0%	95.1%	89.3%	92.6%	91.5%
BJT	Beijing, China	China	89.6%	90.3%	93.4%	93.0%	91.5%
ENH	Enchi, China	China			88.5%	89.3%	88.9%
HIA	Hailar, China	China	93.5%	90.9%	96.6%	93.8%	93.7%
KMI	Kunming, China	China	91.%	95.5%	90.9%	93.4%	92.9%
LSA	Lhasa, China	China	85.9%	92.4%	93.0%	90.5%	90.4%
MDJ	Mudanjiang, China	China		97.6%	90.6%	94.6%	94.3%
SSE	Sheshan, China	China	88.1%	96.2%	91.7%	91.4%	91.8%
WMQ	Urumqi, China	China	97.3%	96.3%	95.2%	96.2%	96.2%
XAN	Xi'an, China	China	89.9%	94.1%	90.1%	91.8%	91.5%
GRFO	Grafenberg, Germany	Europe	95.4%	94.0%	99.8%		96.4%
KBS	Kingsbay, Spitsbergen	Europe	96.1%	97.7%	97.4%	90.2%	95.3%
KEV	Kevo, Finland	Europe	80.6%	90.7%	91.9%	96.3%	89.9%
KIEV	Kiev, Ukraine	Europe	77.0%	88.4%	75.8%	70.0%	77.8%
KONO	Kongsberg, Norway	Europe	90.1%	93.0%	93.1%	97.3%	93.4%
PAB	Sna Pablo, Spain	Europe	85.8%	91.4%	89.2%	95.0%	90.4%
SFJ	Sondre Stromfjord, Greenland	Europe	57.7%	67.5%	74.9%	97.5%	74.4%

Station Code	Station Site	Location	10/95 - 10/96	7/96 - 7/97	7/97 - 7/98	1/99 - 1/00	Station Average
MAJO	Matsushiro, Japan	Japan	95.9%	91.3%	50.5%	94.8%	83.1%
MAKZ	Makanchi, Kazakstan	Kazakstan	43.3%	37.1%	75.4%	72.9%	57.2%
TEIG	Tepich Yucatan, Mexico	Mexico		24.7%		27.3%	26.0%
ULN	Ulaanbaatar, Mongolia	Mongolia	58.1%	86.7%	68.9%	63.1%	69.2%
RAR	Rarotonga, Cook Is., New Zealand	New Zealand	96.7%	100.0%	97.4%	90.9%	96.2%
SNZO	South Karori, New Zealand	New Zealand	91.8%	48.6%	79.3%	85.4%	76.3%
AFI	Afiamalu, Western Samoa	Pacific Island	49.9%	7.7%	31.6%	38.9%	32.0%
HNR	Honiara, Solomon Is.	Pacific Island	89.5%	49.7%	38.6%	50.6%	57.1%
PAYG	Puerto Ayora, Galapagos Islands	Pacific Island			89.7%		89.7%
PMG	Port Moresby, Papua New Guinea	Pacific Island	96.4%	87.9%	59.9%	83.4%	81.9%
PTCN	Pitcairn, South Pacific, UK	Pacific Island		84.2%	73.3%	18.9%	58.8%
XMAS	Kiritimati, Kiribati	Pacific Island			95.8%	86.0%	90.9%
DAV	Davao, Phillippines	Philippines	94.5%	80.3%	91.1%	95.8%	90.4%
BILL	Billibino, Russia	Russia	17.4%	71.1%	89.6%	94.9%	68.3%
MA2	Magadan, Russia	Russia	50.8%	75.4%	80.7%	59.7%	66.6%
PET	Petropavlovsk, Russia	Russia	86.0%	92.5%	88.4%	83.4%	87.5%
TIXI	Tiksi, Russia	Russia	9.0%	46.3%	39.5%	74.3%	42.3%
YAK	Yakutsk, Russia	Russia	88.6%	97.5%	76.6%	90.8%	88.4%
YSS	Yuzhno, Sakalinsk	Russia	79.4%	92.1%	91.6%	99.7%	90.7%
BOCO	Bogota, Columbia	South America	56.7%	12.2%			
PTGA	Pitinga, Brazil	South America	75.8%	62.3%	71.1%	28.4%	59.4%
RCBR	Riachuelo, Brazil	South America				90.5%	90.5%
SDV	Santo Dominga, Venezuela	South America	62.3%	74.8%	86.1%	11.3%	58.6%
INCN	Inchon, South Korea	South Korea	45.0%	65.2%	77.5%	57.1%	61.2%
CHTO	Chiang Mai, Thailand	Tailand	98.3%	96.8%	98.5%	97.8%	97.8%

Station Code	Station Site	Location	10/95 - 10/96	7/96 - 7/97	7/97 - 7/98	1/99 - 1/00	Station Average
TATO	Taipei, Taiwan	Taiwan	84.0%	86.0%	98.9%	70.6%	84.9%
ANTO	Ankara, Turkey	Turkey	46.0%	16.2%	71.0%	0.0%	33.3%
ADK	Adak, Alaska	USA	76.4%	57.7%	91.3%	23.3%	62.2%
ANMO	Albuquerque, New Mexico	USA	92.8%	95.9%	92.2%	99.3%	95.0%
CCM	Cathedral Caves, Missouri	USA	58.6%	85.9%	89.5%	90.4%	81.1%
COLA	College, Alaska	USA	89.0%	73.1%	77.2%	92.2%	82.9%
COR	Corvallis, Oregon	USA	91.1%	88.2%	97.6%	37.1%	78.5%
GUMO	Guam, Mariana Islands	USA	90.3%	94.6%	93.5%	92.7%	92.8%
HKT	Hockley, Texas	USA	85.6%	70.4%	88.4%	85.1%	82.4%
HRV	Harvard, Massachusetts	USA	91.0%	84.8%	84.6%	27.3%	71.9%
JOHN	Johnston Island, USA	USA				95.3%	95.3%
KIP	Kipapa, Hawaii	USA	50.9%	71.0%	78.1%	94.8%	73.7%
MIDW	Midway Island, USA	USA				80.3%	80.3%
POHA	Pokakuloa Camo, Hawaii	USA				96.0%	96.0%
SJG	San Juan, Puerto Rico	USA	83.8%	83.3%	88.8%	100.0%	89.0%
SSPA	Standing Stone, Pennsylvania	USA	85.8%	87.4%	79.6%	93.6%	86.6%
TUC	Tucson, Arizona	USA	90.1%	85.6%	69.0%	92.4%	84.3%
WAKE	Wake Is, USA	USA		78.5%	94.1%	90.5%	87.7%
			76.2%	76.5%	79.1%	73.3%	76.1%
SBA						95.5%	95.5%
TBT			5.0%	3.2%	0.0%	0.0%	2.0%

Appendix 2: Station Costs

Station	Travel	Equip	Shipping	Stipends	Comm	Total Non-Personnel Costs	Personnel O&M Costs	Total Costs (net)	USGS Assessment	Total Costs (gross)
ADK	6.56	5.09	2.05	0.00	0.00	13.70	29.32	43.02	11.01	54.03
AFI	0.00	0.49	0.51	0.20	0.00	1.20	38.27	39.47	11.32	50.79
ANMO	0.00	0.00	0.00	0.00	0.00	0.00	21.90	21.90	6.36	28.26
ANTO	0.00	0.00	0.00	0.00	0.00	0.00	34.64	34.64	10.06	44.69
BILL	0.00	0.00	0.00	5.75	0.00	5.75	36.41	42.16	12.24	54.39
BJT	5.39	0.00	0.00	0.00	0.00	5.39	23.38	28.77	8.35	37.12
CASY	0.00	0.45	0.23	0.60	0.00	1.28	31.31	32.59	9.33	41.92
CCM	0.00	4.90	0.05	0.00	0.00	4.95	38.56	43.51	11.21	54.72
CHTO	0.00	0.90	0.15	0.00	0.00	1.05	18.87	19.92	5.52	25.44
COLA	0.00	0.75	0.03	3.00	0.00	3.78	32.03	35.82	10.18	46.00
COR	0.00	0.45	0.03	0.00	0.00	0.48	35.36	35.83	10.27	46.11
CTAO	0.00	0.99	0.16	0.00	0.00	1.15	20.19	21.34	5.91	27.25
DAV	0.00	6.05	0.23	0.00	0.00	6.28	33.42	39.70	9.77	49.47
DWPF	0.00	1.39	0.06	2.80	0.00	4.24	29.48	33.72	9.39	43.11
ENH	0.00	2.20	0.31	0.00	0.00	2.51	49.30	51.81	14.40	66.22
FURI	0.00	15.95	1.13	1.70	0.00	18.78	37.48	56.26	11.70	67.96
GNI	0.00	3.45	0.26	5.75	6.00	15.46	42.15	57.61	15.72	73.33
GRFO	0.00	0.00	0.00	0.00	0.00	0.00	19.54	19.54	5.67	25.21
GUMO	0.00	1.92	0.24	3.00	0.60	5.75	25.83	31.58	8.61	40.19
HIA	0.00	0.00	0.00	0.00	0.00	0.00	23.66	23.66	6.87	30.53
HKT	0.00	0.45	0.02	0.00	0.00	0.47	23.67	24.14	6.88	31.02
HNR	0.00	0.41	0.09	0.00	0.00	0.50	38.06	38.56	11.08	49.63
HRV	0.00	0.00	0.00	0.00	0.00	0.00	22.41	22.41	6.51	28.92
INCN	0.00	9.56	0.19	0.00	0.00	9.75	51.66	61.41	15.06	76.47
JOHN		1.47	0.06	2.80	0.00	4.33	32.08	36.41	10.14	46.55
KBS	8.14	21.45	0.80	0.00	0.00	30.39	32.28	62.67	11.97	74.64
KEV	0.00	4.16	0.06	0.00	0.00	4.22	24.00	28.22	6.99	35.20
KIEV	0.00	2.17	0.89	5.75	0.00	8.81	34.81	43.62	12.03	55.66
KIP	2.63	2.28	0.08	2.00	0.00	6.99	23.31	30.30	8.14	38.44
KMBO	0.00	10.93	0.88	2.88	0.00	14.68	36.21	50.89	11.60	62.49
KMI	0.00	0.00	0.00	0.00	0.00	0.00	26.56	26.56	7.71	34.27
KONO	4.24	0.43	0.11	0.00	0.00	4.77	20.44	25.22	7.20	32.41
KOWA	13.64	0.00	2.23	4.50	0.00	20.37	49.10	69.47	20.17	89.63
LSA	0.00	0.00	0.00	0.00	0.00	0.00	29.33	29.33	8.51	37.84
LSZ	0.00	9.13	1.97	1.40	0.00	12.50	43.39	55.89	13.58	69.47
LVC	7.21	15.20	2.06	0.00	0.00	24.47	38.88	63.35	13.98	77.34
MA2	0.00	10.15	0.08	5.75	11.71	27.69	29.54	57.24	13.67	70.91
MAJO	0.00	2.83	0.05	0.00	0.00	2.87	23.92	26.79	6.96	33.75
MAKZ	0.00	0.38	0.07	1.18	0.00	1.63	39.39	41.02	11.80	52.82
MDJ	1.60	0.00	0.00	0.00	0.00	1.60	28.79	30.40	8.83	39.22
MIDW	0.00	0.86	8.92	1.20	0.00	10.97	28.11	39.09	11.10	50.19
MSKU	12.07	64.90	16.42	4.03	5.07	102.49	68.38	170.87	30.77	201.64
NWAO	0.00	7.51	0.23	0.00	0.00	7.74	37.69	45.42	11.01	56.43
PAB	0.00	1.11	0.15	0.00	0.00	1.26	27.00	28.26	7.88	36.14
PAYG	7.67	2.15	0.52	0.00	5.07	15.41	29.95	45.37	12.55	57.91

Station	Travel	Equip	Shipping	Stipends	Comm	Total Non-Personnel Costs	Personnel O&M Costs	Total Costs (net)	USGS Assessment	Total Costs (gross)
PET	0.00	1.30	0.72	5.75	11.71	19.48	37.47	56.95	16.16	73.11
PMG	0.00	0.99	0.50	0.00	0.00	1.49	27.41	28.90	8.10	37.01
PMSA	0.00	0.88	0.03	0.00	0.00	0.91	24.73	25.64	7.19	32.83
POHA	0.00	0.00	5.58	4.30	4.30	14.18	30.61	44.79	13.00	57.80
PTCN	0.00	9.05	0.06	1.60	0.00	10.71	33.66	44.37	10.25	54.62
PTGA	6.46	0.77	0.07	0.00	0.00	7.30	68.23	75.53	21.71	97.24
RAR	0.00	0.87	0.60	0.00	0.00	1.47	28.31	29.78	8.39	38.17
RCBR	7.06	10.98	4.00	1.00	0.00	23.04	35.18	58.22	13.72	71.93
RSSD	0.00	1.32	0.03	5.00	0.00	6.35	37.33	43.68	12.30	55.98
SBA	0.00	1.35	0.33	0.00	0.00	1.68	20.42	22.10	6.03	28.13
SDV	5.59	72.81	0.89	0.00	0.00	79.29	60.33	139.62	19.40	159.02
SFJ	7.41	60.53	3.92	0.00	0.00	71.85	52.29	124.15	18.47	142.62
SJG	0.00	4.08	0.09	0.70	0.00	4.87	27.18	32.04	8.12	40.16
SNZO	0.00	0.88	0.10	0.00	0.00	0.97	18.06	19.03	5.27	24.30
SPA	4.14	34.90	1.05	0.00	0.00	40.09	50.53	90.63	16.18	106.81
SSE	0.00	0.00	0.00	0.00	0.00	0.00	26.46	26.46	7.68	34.14
SSPA	0.00	1.10	0.04	0.00	0.00	1.14	27.43	28.58	7.98	36.55
TATO	0.00	4.41	0.15	0.00	0.00	4.56	18.21	22.77	5.33	28.10
TBT	0.00	0.00	0.00	0.00	0.00	0.00	37.00	37.00	10.74	47.74
TEIG	0.00	0.95	0.05	2.40	2.40	5.80	44.85	50.65	14.43	65.08
TIXI	0.00	0.04	0.00	5.75	11.71	17.50	45.36	62.86	18.24	81.10
TSUM	0.00	7.61	0.67	0.00	0.00	8.27	47.49	55.76	13.98	69.74
TUC	0.00	0.40	0.01	0.00	0.00	0.41	18.94	19.35	5.50	24.85
ULN	0.50	7.40	2.10	1.00	0.00	11.00	31.32	42.31	10.14	52.45
WAKE	0.00	3.64	0.05	10.00	0.00	13.69	31.59	45.27	12.09	57.36
WMQ	0.00	0.38	0.01	0.00	0.00	0.39	28.41	28.80	8.25	37.06
XAN	0.00	0.60	0.00	0.00	0.00	0.60	25.88	26.48	7.51	33.99
XMAS	0.00	4.01	0.02	1.20	0.00	5.23	33.59	38.82	10.11	48.92
YAK	0.00	0.03	0.04	5.75	11.71	17.52	60.83	78.35	22.74	101.09
YSS	0.00	1.87	0.40	5.75	11.71	19.73	42.55	62.28	17.54	79.82
Totals	100.32	445.57	62.82	104.48	82.01	795.19	2531.72	3326.92	836.52	4163.44
Average	**1.36**	**5.94**	**0.84**	**1.39**	**1.09**	**10.60**	**33.76**	**44.36**	**11.15**	**55.51**