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REGIONAL SEISMIC TEST NETWORK (RSTN) OPERATIONS FINAL REPORT

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ABSTRACT

This Regional Seismic Test Network (RSTN) Operations Final Report is a history of the operations of this project. It is intended for those who were directly involved in the RSTN project, as well as for those who are involved in other similar projects.

Included is a history of problems experienced at each station, functions performed by the System Control and Receiving Station (SCARS), and the performance of some crucial equipment.

ACKNOWLEDGMENT

The Regional Seismic Test Network (RSTN) was a very successful project, and I would like to thank all those who contributed to its success. I would specially like to thank Jim Durham for his support in having this report written and published. I would also like to thank him and Dale Breding for their support and guidance on this report. In addition, I would like to thank the EG&G SCARS staff for continuing their work with minimal supervision so that I could devote the majority of my time to this report. I would like to thank all the authors referred to in this report for allowing me to include their work. Above all I would like to express my appreciation to all the Sandia personnel who supported, encouraged, and recognized the inputs made by the EG&G SCARS operations staff on the RSTN project.

EXECUTIVE SUMMARY

The intent of this report is to provide a history of the operations of RSTN throughout its lifetime. This includes, for each of the five stations, a description of their location (Figure 1); dates of their installation, shutdown, and transfer (Table 1); and dates, details, and solutions of problems they experienced (Tables 2-6).

In addition, this report includes a description of the System Control and Receiving Station (SCARS), its functions and performance. The RSTN data was collected on 2400-ft, 1600-bpi magnetic tapes at SCARS. The tapes were stored in a temperature- and humidity-controlled area acceptable for tape storage and the data they contain is currently being transferred to optical disk for permanent storage. The RSTN data was also received at the Lawrence Livermore Nationaltional Laboratory (LLNL) and the Center for Seismic Studies (CSS). The short-period and long-period vertical-axis data was sent to the United States Geological Survey (USGS) via a multiplexed telephone line. The RSTN data was event-detected for USGS at SCARS for inclusion in their day tapes. SCARS recorded statistics on the operational hours of the high-power amplifiers (Table 7) and RSTN data availability (Table 8). Calibration of the seismometers was performed throughout their RSTN lifetime. Data outages experienced at SCARS were attributable to equipment failures, power outages, severe weather, and the malfunctioning of the communications terminal (CT). SCARS received numerous RSTN data requests from a variety of users (Tables 9 and 10). SCARS also provided tours for many groups and organizations. Part of the tours included viewing an 8-minute videotape of the RSTN project. Detailed information about items mentioned in this paragraph is provided in Section 7. Additional information is contained in the many publications written about the RSTN project (see the list of References).

Also discussed in this report is some of the vital RSTN equipment (Sections 8-14). The baffle system performed well at all stations maintaining nominal operating temperatures at all times in the uphole logics (Section 8). The gel-cell batteries performed better than the lead-acid and Gould batteries. Eventually all the lead-acid and Gould batteries were replaced with gel-cell batteries (Section 9). There were a total of seven receiver/transmitter (R/T) units. These were cycled between the stations as needed, with the Regional Station Cumberland Plateau (RSCP) acting as the test facility for the R/T units as they were cycled through Motorola for modification (Section 10). All the seismometers proved to be very satisfactory and stable in both amplitude and phase for all five RSTN stations (Station 11). The Uphole (UH) and Geotech (GT) state-of-health (SOH) signals experienced malfunctions, but the seismic data was not affected. The downhole (DH) SOH signal did not experience any problems (Section 12). The thermoelectric generators (TEGs) performed satisfactorily in all but extremely cold climates (-50° F). The TEGs operated on propane with the brief exception of two TEGs in RSSD. These TEGs operated on JP-4 fuel as part of a test, since propane is not universally available overseas (Section 13). The voice box was used to assist during installations at the RSTN sites. The overall performance of the voice box did not meet the remote communications requirements for the RSTN project (Section 14).

CONTENTS

APPENDIX

ILLUSTRATIONS

TABLES

ACRONYMS AND ABBREVIATIONS

AFTAC	Air Force Technical Applications Center
ASL	Albuquerque Seismological Laboratories
BBC	British Broadcasting Corporation
BPSK	Bi-Phase Shift Key
CT	Communications Terminal
DH	Downhole
DHL	Downhole Logic
DOE	Department of Energy
DOY	Day of Year
FACT	Facility for Acceptance Calibration and Testing
GMT	Greenwich Mean Time
GT	Geotech
LLNL	Lawrence Livermore National Laboratory
PDM	Power Distribution Module
PEM	Power Environmental Module
PTL	Pilot Tracking Loop
QPSK	Quadri-Phase Shift Key
RSCP	Regional Station Cumberland Plateau
RSNT	Regional Station Northwest Territories
RSNY	Regional Station New York
RSON	Regional Station Ontario
RSSD	Regional Station South Dakota
RSTN	Regional Seismic Test Network
RSS	Regional Seismic Stations
R/T	Receiver/Transmitter
SCARS	System Control and Receiving Station
SNL	Sandia National Laboratories
SOH	State of Health

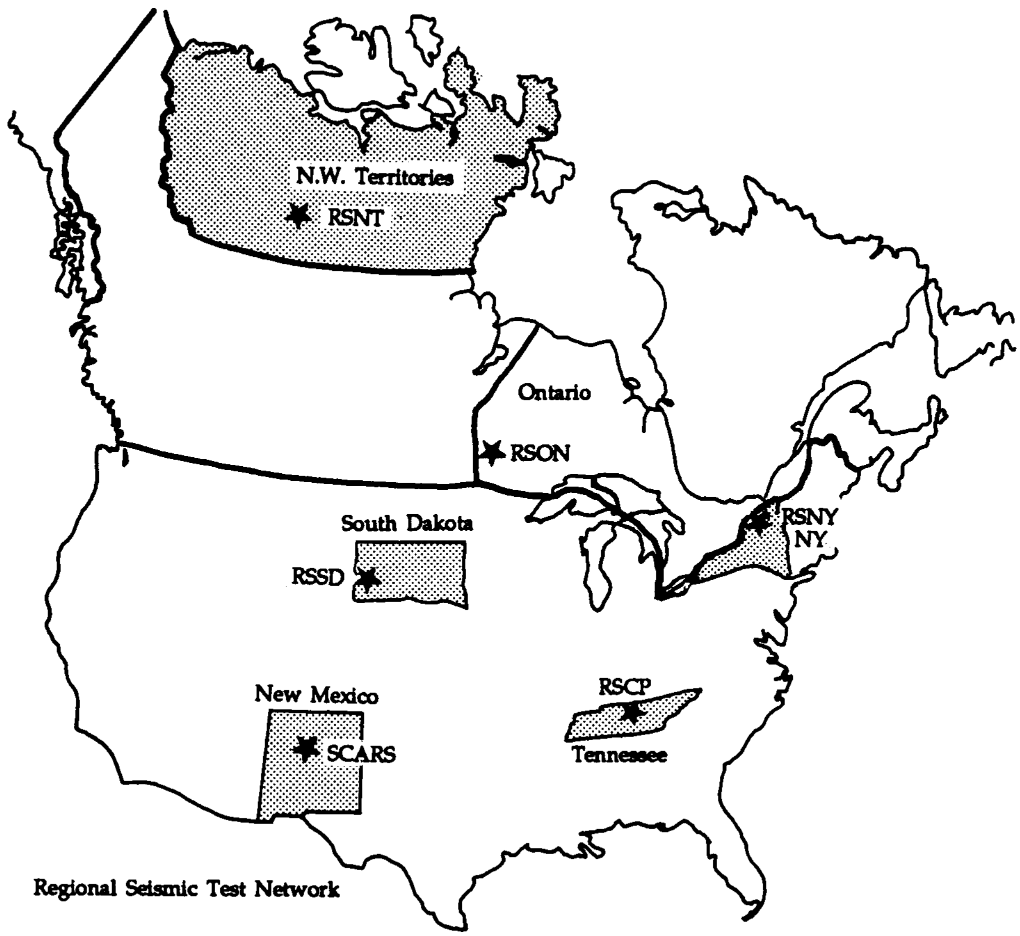
ACRONYMS AND ABBREVIATIONS (CONCLUDED)

SSA	Solid-State Amplifier
TEG	Thermoelectric Generator
TSP	Time and Space Processing, Incorporated
TWT	Traveling-Wave Tube
UH	Uphole
UHL	Uphole Logic
USGS	United States Geological Survey

1. RSTN REMOTE STATIONS

The RSTN system consists of five remote stations located in North America; three in the United States and two in Canada. These are Regional Station Cumberland Plateau (RSCP), Regional Station New York (RSNY), Regional Station South Dakota (RSSD), Regional Station Ontario (RSON), and Regional Station Northwest Territories (RSNT). Figure 1 shows the location of each remote station and the holelock depths of the seismometers.

Each of the RSTN remote stations is a self-contained, unmanned facility capable of monitoring seismic activity, converting it into digital information, and then transmitting this information by satellite to the System Control and Receiving Station (SCARS).



RSSD - Black Hills Station, South Dakota, USA
44 07'13 5"N - 104 02'10.3"W; 6760 ft. Elevation; Holelock Depth 360 ft.
RSNY - Adirondack Station, New York, USA
44 32'53.4"ZN - 74 31'46.8"W; 1498 ft. Elevation; Holelock Depth 328 ft.
RSON - Red Lake Station, Ontario, Canada
50 51'32"N - 93 42'08"W; 1330 ft. Elevation; Holelock Depth 335 ft.
RSNT - Yellowknife Station, Northwest Territories, Canada
62 28'47"N - 114 35'30"W; 625 ft. Elevation; Holelock Depth 354 ft.
RSCP - CPO Station, Tennessee, USA
35 36'00"N - 85 34'08"W; 1906 ft. Elevation; Holelock Depth 328 ft.
SCARS - System Control and Receiving Station, New Mexico, USA
35 03'08"N - 106 32'46"W

Figure 1. Locations of RSTN remote stations.

Table 1. Dates of remote station installation, shutdown, and transfer.

Remote Station	Activity	Date
RSCP	Installed	October 1978
	Became an RSTN station	June 1981
	Taken off the air	October 21, 1986
	Transferred to USGS	January 13, 1987
RSNT	Installed	February 1982
	Received license to transmit	October 1982
	Taken off the air	September 29, 1987
	System brought to Albuquerque	March 28, 1988
RSSD	Installed	August 1981
	Taken off the air	June 23, 1987
	Transferred to USGS	June 23, 1987
RSNY	Installed	September 1981
	Taken off the air	December 2, 1986
	Transferred to USGS	September 30, 1987
RSON	Installed	January 1982
	Received license to transmit	October 1982
	Taken off the air	July 1, 1988
	Transferred to USGS	October 19, 1988

2. REGIONAL STATION CUMBERLAND PLATEAU (RSCP)

The Regional Station Cumberland Plateau, located in central Tennessee, was in operation from October 1978 until October 1986. Its history is outlined in Table 2.

Table 2. Significant activities and problems at RSCP.

Date	Equipment	Activity or Problem
Oct 1978	System	The system was installed. The configuration included KS36000 and S600 seismometers with long-period, mid-period, short-period, and high frequency capabilities. RSCP is equipped with 14 gel-cell batteries and four 60-watt TEGs.
Mar 1980	System	Configuration no longer included high frequency data. The short-period data was changed from 20 samples per second to 40 samples per second.
Jun 1981	System	RSCP became part of the RSTN system. It has a detailed alarm system with the building and all gates equipped with entry alarms connected to the local sheriff's office and SCARS.
Jul 1981	UHL	RSCP was retrofitted with the new above-ground electronics. It was operational in this mode from July to November 1981.
Nov 1981	UHL	The UHL box was sent to RSSD as a replacement.
Jun 1982	UHL	RSCP was refitted with a Model II power distribution module, an uphole logic package, and a receiver/transmitter. The existing Model I Downhole equipment is completely functional and compatible with the newer Model II above-ground equipment; however, the transfer function is different.
Jul 1982	R/T	In addition to being an operating RSTN station, RSCP was also being used as a test facility for R/T units when they were returned from Motorola following modification updates.

Table 2. Significant activities and problems at RSCP (Continued).

Date	Equipment	Activity or Problem
Aug 1982	Alarm	As a result of the lightning strikes, there was extensive damage to the local burglar alarm sensors and three false-access alarms were set off.
Oct 1982	SOH	Geotech state-of-health monitors at RSCP malfunctioned, and as a result the GT/SOH commutator positions assumed readings of 0 to -2.0 volts. Power had to be cycled several times to order the bubble memory.
Jan 1983	SOH	The GT/SOH commutator positions readings were corrected after the J103 card was disconnected and then reconnected.
Mar 1983	Station Facilities	The number of bullet holes increased in the administrative building adjacent to the site, and a section of building perimeter fence was stolen.
Mar 1983	Alarm	The access alarm was set off at SCARS and at the local sheriff's office. Examination of the area revealed the dome door was closed and locked, but the hasp pin had been pushed out of place, and the dome door switch was not functioning. The electronics vault was not opened, and there was no other evidence of disturbance.
Apr 1983	SOH	The uphole SOH experienced an offset in its temperature and tilt readings, and the wind direction sensors malfunctioned.
Jul 1983	Antenna Drive	The antenna drive system, which had been operational since July 1981, was disconnected.
Jul 1983	SOH	Following a routine maintenance of RSCP, the GT/SOH malfunctioned.
Aug 1983	SOH	The malfunctioning UH/SOH and GT/SOH were corrected after the power was recycled.
Nov 1983	R/T	During replacement of the R/T, the uphole logic developed a problem, and two separate driver cards which served as interfaces with the R/T were found to have been faulty. When RSCP was turned on, an excessive DC offset in the mid-period and long-period appeared.

Table 2. Significant activities and problems at RSCP (Continued).

Date	Equipment	Activity or Problem
Dec 1983	Voice Box	The voice box was used at RSCP with complete success.
Dec 1983	Baffle	The baffle system has maintained operating temperatures in the Tennessee climate, which is hot during the summer.
Dec 1983	Batteries	One of the gel-cell batteries had one corroded terminal.
Feb 1984	Batteries	The faulty battery was replaced.
Jun 1984	Weather	Lightning strikes at RSCP resulted in extensive damage to the uphole lightning protection cards, and as a result the downhole package was not functional.
Aug 1984	UHL/DHL	Both the uphole and downhole packages were removed and sent to Albuquerque for repairs. However, the KS36000 seismometers in the Geotech package could not be locked before removal, which resulted in mechanical damage. During subsequent troubleshooting three burned PC boards were found in the power distribution module, and the downhole system was not sending data or responding to commands.
Oct 1984	Alarm	The alarm system at RSCP conformed to those at the other sites. It would only have the dome door and vault alarms reporting to SCARS.
Apr 1985	DHL	RSCP had been out of service since June 1984 following the lightning storm that disabled it. It was decided to expend the manpower on assembly and check-out of the new Model II downhole system rather than on repair of the damaged package. The new KS36000 and S750 seismometers were installed on April 4, 1985, which completed the upgrade for RSCP and made it identical to the other four stations. In addition, the transfer function became the same for all stations.
Apr 1985	Batteries	Five defective batteries were removed.
Apr 1985	TEG	One TEG had a short in the thermopile.

Table 2. Significant activities and problems at RSCP (Continued).

Date	Equipment	Activity or Problem
May 1985	DHL	The system was completely operational following its installation in April, but it was reported that RSCP appeared to have an orientation problem. A subsequent survey report indicated that the downhole package had been set 30 to 40 feet above the hole lock. This was corrected on May 8, 1985 by installing new wedges in the stabilizer and then putting the package back downhole to the proper depth. Tests were conducted and the orientation was verified to be correct.
May 1985	Demodulators	Two defective demodulators for RSCP were replaced.
May 1985	SOH	The GT/SOH commutator positions assumed readings of -9.99 volts.
Aug 1985	R/T	The R/T changed to a new frequency, as a result of an oscillator being out of lock. The R/T was replaced.
	SOH	The GT/SOH commutator positions readings were corrected after power was recycled.
Oct 1985	TEG	Two TEGs stopped functioning correctly. The problem was corrected by replacing the valves on each of the two malfunctioning TEGs.
Jan 1986	R/T	The R/T shifted off frequency again and had to be replaced. It was replaced with an advanced version that uses bi-phase shift keyed (BPSK) modulation for the command link. It uses less power: 90 watts of prime power as compared with the 120 watts of prime power used by the old units.
Mar 1986	PTL	Several data gaps occurred, since the PTL error voltage was selected from a power supply which does not follow the diurnal frequency fluctuation of the satellite due to the spring equinox.
Mar 1986	R/T	RSCP drifted out and in for 10 days and then the station stopped functioning. The R/T was replaced. The problem was in the up/down converter.

Table 2. Significant activities and problems at RSCP (Concluded).

Date	Equipment	Activity or Problem
Apr 1986	SOH	The Geotech state-of-health electronics were left disconnected because of a malfunction in the power supply of the power distribution module.
Aug 1986	Cable	An electrical storm caused the cable from the uphole logics to the R/T to burn in several places, resulting in the station becoming inoperable.
Aug 1986	TEG	Following another electrical storm RSCP went out of service. The problem was identified as a hole in one TEG and two limiters that malfunctioned. The TEG was replaced and RSCP was left operating from a power supply until the limiters could be repaired.
Sep 1986	Cable	RSCP stopped functioning again, and the problem was identified as a faulty AC power cable. The cable was repaired.
Sep 1986	TEG	Two limiters were installed. Some connectors on the lightning board were repaired and two batteries were disconnected.
Sep 1986	DHL	The KS36000 seismometer stopped operating. There was an electrical storm in the area which damaged the power supply in the KS package.
Oct 1986	DHL	When the downhole system was pulled for repairs the KS seismometer could not be locked, which resulted in mechanical damage.
Oct 1986	System	RSCP was the first RSTN station to be taken off the air as an RSTN site.
Jan 1987	Transfer	The KS36000 seismometer was reinstalled at RSCP and at the same time the USGS equipment was installed.
Jan 1987	DHL	The KS seismometer was installed with an orientation of 73 degrees, but it was later discovered that the orientation should have been 55.6 degrees. This was scheduled to be corrected the next time the system is pulled for repairs.

3. REGIONAL STATION NORTHWEST TERRITORIES (RSNT)

The Regional Station Northwest Territories, which was located in northwestern Canada, was in operation as a remote station from February 1982 until September 1987. Its history is outlined in Table 3.

Table 3. Significant activities and problems at RSNT.

Date	Equipment	Activity or Problem
Feb 1982	System	The system was installed. The configuration included KS36000 and S750 seismometers with long-period, mid-period, and short-period capabilities. It is equipped with four 60-watt thermoelectric generators.
Mar 1982	Antenna	The antenna drive system was disconnected to prevent any unnecessary problems. With the decreased antenna travel time from one position to the other, the position electronics could become confused and drive the antenna to the shut-off stops.
Oct 1982	Satellite	SCARS administrators received notice of approval of the Canadian satellite license.
Oct 1982	TEG	The propane pressure started to drop slowly, causing the TEGs to assume varying output voltages. The problem was corrected by installing a new regulator.
Feb 1983	Data	RSNT experienced a malfunction in its handling of real-time and delayed data.
Mar 1983	DHL	The downhole logic package malfunctioned. It was sent, along with the R/T, the UHL package, and the PDM, to Albuquerque, where a shorted capacitor in the power on/reset circuitry of the downhole microprocessor was discovered.
May 1983	DHL	The DHL, R/T, UHL, and PDM were reinstalled at RSNT.
May 1983	TEG	An excessive bit-error rate occurred after the equipment was reinstalled at RSNT. Subsequent checks revealed a short in one TEG.

Table 3. Significant activities and problems at RSNT (Continued).

Date	Equipment	Activity or Problem
May 1983	Batteries	Six new Gould Watchman batteries were installed at RSNT.
Aug 1983	SOH	The UH/SOH malfunctioned, and as a result the temperature readings assumed a 70-degree offset.
Nov 1983	TEG	All four TEGs stopped functioning.
Dec 1983	TEG	The local custodian was able to restart the four TEGs, but the station still would not operate. He cycled power and reseated the PC boards in the UHL, which restored the system to service.
Dec 1983	TEG	The readings for the TEGs were low. A subsequent check revealed that the nitrogen pressurizing system had a leak that caused all TEGs to stop working. Also, the gas box was filled with ice. These problems were corrected and the system was returned to operation.
Dec 1983	TEG	The TEGs stopped functioning again because the orifices were plugged or very dirty. The orifices were cleaned and relighted, and the system resumed operating normally.
Dec 1983	TEG	The TEGs experienced problems with ice in the lines and their overall performance was poor. The lines were cleared and the system resumed operation.
Dec 1983	Station Facilities	There was evidence of vandalism. The fence gate lock at RSNT was shot off and the door handle showed signs of tampering, but the dome was unopened. Otherwise the site was undisturbed.
Jan 1984	TEG	The regulator iced up. A careful check into the problem revealed that the cause of the previous TEG outages was the moisture given off by the main regulator. Corrections were made and the system resumed normal functioning.
Feb 1984	UHL	The UHL package and the UHL power supply card in the power distribution module were replaced.
	SOH	The replacement of the card corrected the offset in the temperature readings.

Table 3. Significant activities and problems at RSNT (Continued).

Date	Equipment	Activity or Problem
	Vault	The vault door microswitch and a missing bolt in the vault vent stack brace were replaced.
	TEG	The TEG exhaust stacks were shortened to approximately 8 feet, and the stack caps were enlarged to reduce the probability of moisture freezing in the stacks. A missing vent stack bottom cap was replaced. A hose approximately 18 inches long was attached to the vent to move the actual opening away from the ice area. The primary fuel regulator was replaced and mounted outside beneath the fuel cabinet in an attempt to reduce the amount of moisture condensed and frozen on the regulator. The main propane line filter element and the broken glass on the fuel pressure gauge in the fuel cabinet were replaced. The orifice in each TEG was replaced, and the filters were inspected but did not need to be replaced. The fuel regulator for TEG No. 1 and TEG No. 2 vaporizer were replaced. The TEGs were all adjusted for optimum output.
	Batteries	The batteries were checked and serviced. Each battery required the addition of distilled water.
Apr 1984	SSA	The redundant function solid-state amplifier (SSA) is providing very good data transmission.
Sep 1984	TEG	The main regulator froze five times during this month, causing some or all the TEGs to stop working. A possible cause of the main regulator freezing was water in the propane supply.
Oct 1984	TEG	A two-stage regulator system was installed to reduce the pressure differential on the main regulator. This was done to spread out the temperature drop and reduce icing. If there is water present in the propane it will be less likely to freeze with this configuration.
Nov 1984	TEG	A problem with fuel-cabinet regulator freezing prompted another modification. This time the regulator was removed and stainless steel flex lines from the Power Environment Module (PEM) bulkhead valves to the vaporizers were installed to eliminate this problem. The cartridge in the main line propane filter

Table 3. Significant activities and problems at RSNT (Continued).

Date	Equipment	Activity or Problem
		was replaced. TEG No. 3 had a short in the thermopile and was replaced with a new TEG. The ceramic spacer/insulator ring on the back of the TEG No. 4 burner was broken, so the burner assembly from TEG No. 3 was installed in TEG No. 4. The propane filter in each TEG was cleaned or replaced and the TEGs were adjusted for optimum output. The wiring error in No. 1 power limiter was corrected and the bus voltage was set to 27.2 volts on No. 1 power limiter and 27.4 volts on No. 2 power limiter.
	Batteries	Charging during high temperatures resulted in excessive water loss. The batteries were replaced with 55 ampere/hour gel-cell batteries. The battery cables also had to be replaced, since gel-cell batteries require flag-type rather than post-type terminals.
	Vault	The door microswitches were replaced with magnetic proximity switches.
Feb 1985	DHL	The downhole package was pulled and sent to Albuquerque for repairs. The system had lost frame synchronization on the real-time data stream with the delayed data being good for 15 minutes, when all data stopped. As was the failure of February 25, 1983, this was the result of a shorted capacitor in the power on/reset circuitry of the downhole microprocessor.
Feb 1985	Clock	There were three problems with the clock: (1) the data clock distribution in the uphole logic unit had been operating intermittently; (2) the clock had stopped being distributed to the bubble memory and uphole logic processor; and (3) the clock to the remote terminal modulator had stopped on several occasions, as evidenced by the lack of modulation on the RF carrier spectrum. UHL cards 15 and 18 were replaced in an effort to correct these problems. The effort was unsuccessful, so the UHL package was pulled and sent to Albuquerque for further troubleshooting.

Table 3. Significant activities and problems at RSNT (Concluded).

Date	Equipment	Activity or Problem
Mar 1985	GMT	RSNT would not operate properly. There was no GMT in the data and the RSNT would not respond to downhole commands. The bubbles cycled normally and uphole commands worked well. The malfunctions indicated a problem in both the uphole and downhole logic packages, so both were returned to Albuquerque for repair. When no problem could be found with the two units, the PDM was shipped to Albuquerque. No problems were found with this unit, either.
	TEG	During the trip, propane tanks 2 and 3 were opened and flushed with methyl hydrate, and anhydrous methanol was put in the tanks in preparation for refueling the next day. These tanks were refueled to 85 percent capacity. Anhydrous methanol was put into tank 1 along with propane. Tank 1 was refueled to 77 percent capacity, since the tank vapor pressure equalled the tanker pump capacity at that point.
Apr 1985	PDM	During the reinstallation of the downhole, uphole and PDM equipment at RSNT, it was discovered that the loss of GMT was due to a faulty J101 connect in the PDM. During this trip a propane leak was discovered. There was a small hole in the side of the rigid line. It was replaced with a flex line that runs from the fuel cabinet to the dome.
Jan 1986	Station Facilities	There were two instances of vandalism. The lock on the gate to RSNT was shot at, but remained in working order. The door knob was missing from the front compound building.
May 1986	System	RSNT stopped working. The power at the site was recycled and the station began operating normally. The problem was not identified.
Sep 1987	System	RSNT was taken off the air as an RSTN station. It was scheduled to be disassembled and shipped to Albuquerque in the spring of 1988. At a later date it will be shipped to a designated site and transferred to USGS.
Mar 1988	System	The RSNT system was shipped to Albuquerque.

4. REGIONAL STATION SOUTH DAKOTA (RSSD)

The Regional Station South Dakota (RSSD), located in southwestern North Dakota, was in operation from August 1981 until June 1987. Its history is outlined in Table 4.

Table 4. Significant activities and problems at RSSD.

Date	Equipment	Activity or Problem
Aug 1981	System	The system was installed. The configuration included KS36000 and S750 seismometers with long-period, mid-period, and short-period capabilities. Analysis of the short-period seismic data derived from the S750 channels indicated a phase difference of 180 degrees from the published seismic response functions. It was equipped with three 120-watt thermoelectric generators. It was used as a test site for jet-fuel-fired (JP-4) TEGs.
Nov 1981	UHL	An interface problem with the RF receiver transmitter unit resulted in the replacement of the UHL package. This package was replaced with the UHL package from RSCP.
Aug 1982	SOH	RSSD experienced a malfunctioning carrier monitor in its GT/SOH monitor system.
Oct 1982	SOH	RSSD had malfunctioning carrier monitors in its Geotech state-of-health monitor system. This was only a monitor problem which would be repaired when the downhole package required other maintenance.
Nov 1982	TEG	TEG fuel pressure varied abnormally. The station periodically faded out and then cames back on-line.
Dec 1982	Batteries	Low-charge capacities were discovered in the batteries at RSSD. While voltage measurements were being made, one battery exploded and the station stopped operating. A study was conducted to determine the cause of the low capacity of the batteries and to locate a suitable replacement.

Table 4. Significant activities and problems at RSSD (Continued).

Date	Equipment	Activity or Problem
Jan 1983	TEG	The regulators in the fuel cabinet and on TEG No. 3 were leaking propane. The fuel cabinet regulator was replaced and the screw plug on the TEG regulator was tightened, which corrected the problem.
	Batteries	New batteries were installed at RSSD.
	R/T	A device designed by Sandia was attached to the R/T to facilitate reading various voltages in the R/T.
Feb 1983	SOH	The GT/SOH commutator positions assumed readings of 10 volts.
Aug 1983	DHL	RSSD has developed an excessive DC offset in the mid-period and long-period data. The offset is present in all four gain-range levels.
Sep 1983	SOH	The GT/SOH commutator positions assumed normal readings for 20 days, then assumed readings of 0 volts.
Oct 1983	Tanks	The jet fuel tanks were flushed and filled with propane fuel.
Nov 1983	Antenna	The antenna drive cable was disconnected from the PDM to prevent any unnecessary problems, and a dummy plug was inserted which electrically confirms that the station is looking at the right spot. With the decreased antenna travel time from one position to the other, the position electronics could erroneously drive the antenna to the shut-off stops.
Nov 1983	TEG	TEG No. 2 went out, and the custodian at RSSD was unable to relight it. Apparently some jet fuel was in the line.
Nov 1983	TEG	Jet fuel was drained from TEG No. 2 fuel line. It was determined that the main cause was that the propane supply line was left on the liquid side of the tank. The propane feed line was moved from the liquid valve to the gas valve. An element in the main propane line filter was replaced, filters and jeweled orifices were

Table 4. Significant activities and problems at RSSD (Continued).

Date	Equipment	Activity or Problem
		replaced in each TEG, the thermocouple on TEG No. 2 was replaced, and each TEG was adjusted for optimum output.
Jun 1984	DHL	The DC offset in the vertical axis data was diagnosed as a defective card in the downhole logic package. The DHL43 card was replaced. When the repaired DHL package was put back downhole, the test-set controller would not unlock the KS36000. The cable connecting the KS36000 to the DHL was reversed, which allowed the KS36000 to unlock.
	Vault	The door microswitches were replaced with magnetic proximity switches.
Jun 1984	R/T	RSSD stopped transmitting on three occasions. The R/T was found to be the source of the problem, but a working replacement was not available.
Jun 1984	SOH	The GT/SOH commutator positions assumed readings of 10 volts.
Sep 1984	R/T	RSSD stopped transmitting on 13 occasions. Again the source of the problem was identified as the R/T, but a working replacement was still not available.
Jun 1985	R/T	The original R/T at RSSD has continued to shut down occasionally during hot weather, and was the source of numerous transmitting problems. A modified R/T unit was used to replace the original R/T unit. (Now all five stations are equipped with the modified R/T.)
	SOH	The GT/SOH readings were normal after the R/T was replaced and power was recycled.
Jun 1985	DHL	In June 1984 when the DHL package was pulled to reverse the KS36000 connecting cable, it was reinstalled with an error in its orientation; the upper package was not oriented the same as the KS36000 package horizontals. A year later the problem was identified and the DHL package was pulled. The upper package was rotated 180 degrees to align the S750 seismometers with the KS36000 seismometers, and the packages were

Table 4. Significant activities and problems at RSSD (Continued).

Date	Equipment	Activity or Problem
		reconnected and lowered into the hole lock. As a result of the orientation problems experienced in 1985, a "drop weights from an aircraft" test was conducted.
Aug 1985	SOH	The GT/SOH commutator positions assumed readings of 10 volts.
Sep 1985	R/T	RSSD stopped functioning. Voltage measurements indicated a failure in a local oscillator circuit and a possible failure in a reference module in the R/T.
Oct 1985	R/T	The oscillator and reference module were replaced, but the R/T still did not operate, so it was crated and shipped to Albuquerque.
	Batteries	New 80-ampere/hour gel-cell batteries were installed.
	SOH	The GT/SOH commutator positions assumed readings of 0.02 volts.
Oct 1985	R/T	The repaired R/T was reinstalled at RSSD and the station began operating normally.
	Voice Box	Attempts to communicate with SCARS from the RSSD site using the voice box were unsuccessful. The problem was sheared connector pins on a power supply of the voice box. This was corrected and the voice box operated satisfactorily.
Nov 1985	PDM	The mid-period and long-period data from RSSD was missing. A card in the PDM was replaced, which corrected the problem.
	SOH	The GT/SOH commutator positions readings were once again normal.
Dec 1985	R/T	RSSD stopped operating as a result of a faulty R/T.
Feb 1985	R/T	The R/T was replaced. The problem with the R/T was identified as a failure in the up/down converter.

Table 4. Significant activities and problems at RSSD (Concluded).

Date	Equipment	Activity or Problem
Mar 1986	PTL	Several data gaps occurred, since the PTL error voltage was selected from a power supply which does not follow the diurnal frequency fluctuation of the satellite due to the spring equinox.
Aug 1986	SOH	The GT/SOH commutator positions assumed readings of 10 volts.
Dec 1986	TEG	RSSD experienced a drop in the bus voltage and one TEG stopped working. Six days later the station ceased operation.
Feb 1987	TEG	The burner of TEG No. 2 was filled with oil and had failed, and two batteries had shorted cells. As a result, the station stopped operating. The problems were corrected and RSSD resumed normal operation.
	SOH	The GT/SOH commutator positions readings were once again normal.
Jun 1987	System	A series of calibrations were sent to RSSD and analyzed, and the results verified that the station was operating within the acceptable limits. The following day RSSD was the third station to be taken off the air as part of the transfer of the RSTN stations to USGS. The UHL package, PDM, and R/T were shipped to Albuquerque. The antenna dish was disassembled and stored in the dome. The dome was rotated to the new azimuth for USGS and the TEGs were adjusted for more power output. The USGS equipment locked into the satellite, but experienced some equipment problems. USGS could read only one of their two satellite ports.

5. REGIONAL STATION NEW YORK (RSNY)

Regional Station New York was located in northern New York State. It operated as a remote station from September 1981 until September 1987. See Table 5 for an outline of its history.

Table 5. Significant activities and problems at RSNY.

Date	Equipment	Activity or Problem
Sep 1981	System	The system was installed. The configuration included KS36000 and S750 seismometers with long-period, mid-period, and short-period capabilities. Analysis of the short-period seismic data derived from the S750 channels indicate a phase difference of 180 degrees to the published seismic response functions. The system was equipped with three 120-watt thermal electric generators.
Jan 1982	R/T	RSNY had an R/T unit that functioned only intermittently.
Jan 1982	TEG	Moisture in the propane line resulted in the TEGs going out.
Apr 1982	R/T	The new R/T unit was damaged in transit to RSNY. As a result, the original, malfunctioning R/T unit was left in place with the transmitter being forced in the ON position.
Jul 1982	R/T	The R/T was scheduled to be removed and sent to Motorola for modification updates, when its receiver signal strength went to zero. The R/T from RSCP was removed and installed at RSNY, but this did not correct the problem at RSNY. This problem was subsequently corrected when the cause was identified as a failed low-noise amplifier (LNA) and the LNA was replaced.
Aug 1982	SOH	RSNY had a problem with the GT/SOH monitors; all commutator positions assumed an offset.
Aug 1982	TEG	Failures occurred that were due to the TEGs. As a result the propane lines were flushed and some water was discovered. The regulator was replaced.

Table 5. Significant activities and problems at RSNY (Continued).

Date	Equipment	Activity or Problem
	Batteries	The batteries were very corroded and the connections were cleaned.
Nov 1982	Batteries	Five of the six batteries at RSNY were low which resulted in the loading of the TEG system and erratic operation of the TEGs. Two temporary batteries were installed.
Jan 1983	Demod/ phone	RSNY was on a modem from FACT because of a demodulator at SCARS. A faulty phone line on RSNY resulted in long outages.
Jan 1983	Batteries	The batteries at RSNY were replaced with Gould batteries which are designed for a stand-by type installation like the RSTN stations. The dome temperature probes were relocated to an area between the batteries. This area was scheduled to be monitored more closely through the hotter months to see if there is an overcharging effect.
Mar 1983	R/T	The R/T at RSNY was replaced following problems with the GMT.
		A device designed by Sandia was attached to the R/T to facilitate reading of the various voltages.
	Antenna	The polarization on the antenna feed horn and pressurized wave guide was changed.
Dec 1983	DHL	RSNY developed an excessive DC offset in the mid-period and long-period data. The offset was present in all four gain range levels.
Jan 1984	R/T	A TWT failed in the R/T. The power output dropped to a minimum operating level, at which time it was switched to the redundant solid-state amplifier. A replacement R/T was not available.
Jul 1984	DHL	Two cards in the downhole logic package and one card in the power distribution module were replaced, which corrected the problem with the offset in the seismic data.
	Batteries	Batteries had very low water levels.

Table 5. Significant activities and problems at RSNY (Concluded).

Date	Equipment	Activity or Problem
	Vault	The door microswitches were replaced with magnetic proximity switches.
Aug 1984	R/T	The malfunctioning R/T at RSNY was replaced.
Apr 1985	SOH	The GT/SOH commutator positions assumed readings of 10 volts.
Dec 1985	Batteries	The existing batteries were replaced with 80-ampere/hour gel-cell batteries.
	TEG	New filters were installed in the TEGs.
Mar 1986	PTL	Several data gaps occurred since the PTL error voltage was selected from a power supply which does not follow the diurnal frequency fluctuation of the satellite due to the spring equinox.
Aug 1986	DHL	The downhole logic package was pulled to check the orientation of the seismometers. The conclusion was that the seismometers were in error 17 degrees clockwise. The appropriate changes were made to correct the orientation.
	SOH	The Geotech state-of-health electronics were repaired after the downhole package was pulled.
Dec 1986	System	A series of calibrations was sent to RSNY, analyzed, and the results verified that the station was operating within the acceptable limits. The following day RSNY became the second station to be taken off the air as an RSTN site for transfer to USGS. The site was left with one TEG operating to prevent battery discharge and to protect the batteries from freezing; the other two TEGs were shut down. The UHL package, the PDM, and the R/T were brought to SCARS. The antenna dish was disassembled and stored in the dome.
Sep 1987	System	RSNY was transferred to USGS; it was the third station transferred.

6. REGIONAL STATION ONTARIO (RSON)

Regional Station Ontario, located in south central Canada, operated as a remote station from January 1982 until October 1988. Activities and problems that occurred during this period are shown in Table 6.

Table 6. Significant activities and problems at RSON.

Date	Equipment	Activity or Problem
Jan 1982	System	The system was installed. The configuration included KS36000 and S750 seismometers with long-period, mid-period, and short-period capabilities. Analysis of the short-period seismic data derived from the S750 channels indicate a phase difference of 180 degrees from the published seismic response functions, with the exception of the east axis. It is equipped with three 120-watt thermal electric generators.
Mar 1982	Antenna	The antenna drive system at RSON was disconnected to prevent any unnecessary problems. With the decreased antenna travel time from one position to the other, the position electronics could erroneously drive the antenna to the shut-off stops.
Aug 1982	SOH	Problems occurred with the Geotech monitor; all commutator positions assumed readings of 10 volts.
Aug 1982	TEG	TEG No. 2 failed and required complete replacement. With the difficulties involved in shipping into Canada, replacement was delayed somewhat and in the meantime another TEG failed. The batteries dropped below the safe operating threshold for the converter limiter that was still on-line, causing it to fail. When the third TEG was relighted and put on-line, the load was too great for its converter limiter, resulting in failure.
Sep 1982	TEG	TEG No. 2, converter limiters No. 1 and No. 3, and the main regulator were replaced.
	SOH	When the power was cycled the Geotech SOH readings of 10 volts and the distorted seismic data were corrected.

Table 6. Significant activities and problems at RSON (Continued).

Date	Equipment	Activity or Problem
Sep 1982	PDM	The power distribution module failed, affecting all the uphole temperature readings, the tilt meters, and the wind speed and direction readings. As a result, the 12-volt power supply was replaced, which corrected the problem.
Oct 1982	Satellite	SCARS administration received notice of approval of the Canadian satellite license.
Oct 1982	DHL	The downhole package was pulled and the problem with the half gain in the SPN axis seismometer was identified as the KS short-period circuitry in the DHL package. When the package was reinstalled it seated properly, making the polarity of the data correct. It is assumed that when the package was originally installed the orientation key lodged on the top of the hole lock was exactly 180 degrees out of phase from true orientation.
	TEG	The thermopile of TEG No. 1 and No. 3, the orifice of TEG No. 3, and the converter limiter of TEG No.2 were all replaced.
	R/T	The R/T at RSON was replaced too.
	Batteries	Two of the six batteries had charge levels that were too low.
Nov 1982	SOH	The uphole state-of-health commutator positions had problems; there were no temperature, tilt, nor wind readings.
Feb 1984	R/T	The malfunctioning R/T was replaced with a modified R/T. The problem was in the up/down converter.
	PDM	The UHL power supply card in the PDM was replaced.
	TEG	The filters in the TEGs were replaced and the TEGs were adjusted for optimum output.
	Batteries	New Gould batteries were installed. These batteries are designed to operate in a float-type installation as a backup power system.

Table 6. Significant activities and problems at RSON (Continued).

Date	Equipment	Activity or Problem
	SOH	The uphole state-of-health commutator position readings were corrected following the above maintenance at the site.
Jun 1984	Electrical Power	A direct or near hit from lightning at RSON resulted in the station becoming inoperative. The station was reactivated by cycling the main power.
Sep 1984	TEG	RSON stopped functioning and was put back on the air by replacing converter limiter No. 1 and resoldering the output wire from the thermopile of TEG No. 1.
	PDM	The temperature (state-of-health) power supply card was replaced in the PDM.
	Batteries	The battery water level was very low.
Jun 1985	SOH	The Geotech state-of-health commutator positions assumed readings of 10 volts.
Jun 1985	DHL	RSON developed a DC offset in its east axis data from the KS36000 seismometer.
Jul 1985	R/T	The R/T at RSON malfunctioned and shifted frequency.
Aug 1985	DHL	The DHL 43 card was replaced, which corrected the DC offset problem.
	R/T	The R/T was replaced.
	Batteries	The TEG voltage readings were abnormal because the battery charger was drawing too much power. To correct this problem four batteries were disconnected.
	SOH	The Geotech state-of-health commutator positions were corrected following the above maintenance.
Dec 1985	Batteries	New 80-ampere/hour gel-cell batteries were installed at RSON.

Table 6. Significant activities and problems at RSON (Continued).

Date	Equipment	Activity or Problem
Mar 1986	TEG	RSON stopped operating. A hole had burned through the plate on the thermopile of three TEGs. This apparently allowed some of the thermocouples to be destroyed, which reduced the power output to the TEGs, resulting in the station going out of service. Three new TEGs ordered.
	Batteries	All six batteries were disconnected and taken to a local station to be recharged and stored until the crew returned to the site with the new TEGs.
Apr 1986	TEG	Three new TEGs and three new TEG fuel filters were installed.
	Batteries	One new battery and five recharged batteries were installed. (One battery would not hold the charge.)
	System	RSON was put back on the air and began operating normally.
Dec 1987	R/T	RSON was inoperative as the result of a failure in the up/down converter at SCARS.
Dec 1987	DHL	The DHL 43 card was replaced.
Dec 1987	System	SCARS ceased recording data from RSON, the only station still in operation.
Jan 1988	R/T	The TWT malfunctioned.
May 1988	RF	RSON was out of operation while work on the transponder was performed.
Jun 1988	Seismometers	It was discovered and verified that in December 1987, when a card in the DHL package was replaced and the package reinstalled, the polarities of the S750 N-S and E-W seismometers were swapped.
Jun 1988	System	A series of calibrations was sent to RSON in preparation for the shutdown.
Jul 1988	System	RSON taken off the air as an RSTN site; it was the last station shut down.

Table 6. Significant activities and problems at RSON (Concluded).

Date	Equipment	Activity or Problem
Oct 1988	System	RSON became the fourth station to be transferred to USGS. The dome was rotated 10.3 degrees to the west for the USGS satellite, the power output on the TEGs was increased for USGS use, converter limiter No. 3 was replaced, and the USGS antenna and electronics were installed. Hasps and padlocks were installed on the dome door. The RSTN antenna dish was disassembled and stored in the dome. The uphole electronics were removed and shipped to Albuquerque.

7. SYSTEM CONTROL AND RECEIVING STATION (SCARS) OPERATIONS

The RSTN digital information was transmitted by satellite to a System Control and Receiving Station (SCARS). Commands were sent from SCARS by satellite to initiate calibration, to switch to backup components, or to perform other functions needed for proper operation of an RSTN station.

In June 1981, RSCP was the first station to officially become part of the RSTN system. By October 1982, SCARS was recording data from all five RSTN stations 24 hours a day. All five stations were then calibrated by the 78-day series, seismic events were detected via a United States Geological Survey (USGS) program, and short period and long period analog data were sent in real time to the USGS in Golden, Colorado (see Paragraph 7.2 below). In October 1986, the shutdown of the RSTN stations began and in January 1987, the transfer of the stations to USGS began. In December 1986, SCARS discontinued recording RSTN data on a daily basis, but continued to monitor the state-of-health (SOH) values for the remaining RSTN stations, provide USGS with the analog signals, and provide the Center for Seismic Studies (CSS) with GMT. Between January and December 1987, SCARS resumed recording RSTN data 24 hours a day from the remaining operational stations. After this time SCARS continued to monitor the SOH values, provide USGS with the analog signals, and CSS with GMT until the last RSTN station, RSON, was shut down on July 1, 1988. The transfer of the RSTN stations was completed on October 19, 1988, when the last of the four scheduled RSTN stations, RSON, was transferred to USGS, RSNT was the only station not scheduled to be directly transferred to USGS. Once USGS selects a site, the equipment from RSNT will be shipped and transferred to USGS (see Table 1).

7.1 TAPES

The RSTN data was recorded on 2400-ft, 1600-bpi magnetic tapes and sealed with tape bands. In January 1983, SCARS began rewinding each tape once each year using a magnetic tape cleaner/inspector in the archive rewind mode. This measure was taken to preserve the integrity and prolong the life of each tape.

The preservation of the RSTN data has always been of great concern. In September 1986, the RSTN tapes were shipped to a facility where the temperature and humidity were acceptable for tape storage. In addition, research was conducted to find a better medium. The optical/laser disk offered the highest reliability. The lifetime of these disks is estimated to be 10 years, with high-quality preservation of data ensured. Thus in August 1987, the copying of all RSTN data from magnetic tape to optical/laser disk began.

Each RSTN data tape was analyzed, and the computer listings produced by the analysis programs were stored for later use. In February 1984, SCARS began microfilming all the analysis listings. This has provided SCARS users with a very systematic means of accessing this information.

7.2 DATA

The RSTN data was also received at the Lawrence Livermore National Laboratory (LLNL) and CSS via a receive-only Communication Terminal (CT).

The CSS received a copy of each data tape from SCARS. CSS was functioning as the archiving and distribution center.

In 1982, SCARS began sending short-period and long-period vertical axis data to the USGS in Golden, Colorado, via a multiplexed telephone line in support of their National Earthquake Information Service. The USGS was using RSTN seismic data to contribute to their publication of Preliminary Determination of Epicenters. The USGS was pleased with the data quality and uptime as well as the geographical location of the remote sites. SCARS continued to provide USGS with this data during the shutdown and transfer of the stations.

The RSTN data was event-detected at SCARS for USGS. SCARS created a station tape of events via a USGS program. This station tape was then sent to the Albuquerque Seismological Laboratories (ASL) where a day tape was created. The day tape was then sent on to USGS in Golden, Colorado, and several universities for general seismic analysis.

SCARS has collected RSTN spectral history data since 1981. SCARS plotted the spectrum data monthly and the timehistory data weekly. Spectral history plots for each RSTN station are available in Appendix B. Included in the spectral history plots are vertical and horizonal north and east plots for each RSTN station.

7.3 STATISTICS AND OPERATIONS

SCARS recorded statistics of the number of high-power amplifier (HPA) operational hours for each station. The operational hours for the HPA is divided into two groups: the traveling-wave tube (TWT), which is the primary amplifier, and the solid-state amplifier (SSA), which is used as a backup in case the TWT fails. Table 7 shows the hours accumulated through September 30, 1986 on the TWT and the SSA, and the total for each station.

Table 7. HPA operational hours.

	TWT	SSA	Total
RSCP*	7,366	22,368	29,734
RSNT	5,082	32,089	37,171
RSSD	26,734	17,049	43,783
RSNY	20,259	25,128	45,387
RSON	15,733	24,349	40,082

* Operation hours accumulated after the station was retrofitted with new uphole electronics. Prior to retrofitting (June 1982) RSCP had accumulated a total of 26,612 operational hours.

SCARS tabulated a summary of the adjusted merged downhole time gaps that occurred from January 1983 through September 1986. The downhole gap summaries were adjusted by charting the explainable gaps separately. Table 8 reflects the effective data availability rate for each station during the above-mentioned period when such statistics were calculated.

Table 8. RSTN data availability.

RSCP	99.9998%
RSNT	99.999%
RSSD	99.997%
RSNY	99.999%
RSON	99.999%

SCARS monitored all of the state-of-health (SOH) values available in order to assess the proper operation of the remote seismic stations (RSS). The following monitors (UH/SOH) were particularly important for the assessment:

Main bus current	IBUS
Main bus voltage	VBUS
Digital control status	CTRS
Digital system status	SYSS
TWT power supply	VTWT
TWT amplifier baseplate temperature	TTWT
Solid-state amplifier baseplate temperature	TSSA
High-power amplitude output power	PHPA
Downhole logic current	IDHL
Thermoelectric generator voltages	VTG1 VTG2 VTG3 VTG4

Three UH/SOH values were monitored when commands were sent from SCARS to a station to verify that the commands were entered correctly, accepted, and executed. The values monitored were the digital control status (CTRS), which displayed how the station was going to be set up according to the commands sent; the digital system status (SYSS), which displayed the current configuration, and the digital exceptional status (EXCS), which displayed fast-changing digital monitors.

7.4 CALIBRATION

The series of calibrations of the seismometers was initially a 14-day series. All axes of all seismometers were calibrated in octave steps throughout the frequency band at full-scale amplitude. This series of calibrations was performed on all stations after installation and continued until the station could be included in the start of the 78-day series. All calibration information sent to the RSTN stations was saved on magnetic tape.

The 78-day calibration series calibrated all stations, all axes, and all channels in half-octave frequency step over the frequency range of 0.0078 Hz to 16.0 Hz and plus and minus step functions at full-scale amplitude. Only one axis was calibrated at any time. Even octave calibrations were processed and analyzed daily. By October 1982, all five RSTN stations were being calibrated by the 78-day series.

In July 1984, SCARS replaced the 78-day calibration series with the 16-day calibration series. The new calibration series eliminated the half octave calibrations, kept all stations in the standard configuration at all times, and calibrated three axes at a station at any given frequency simultaneously. In addition, the 16-day calibration series included 12 even octave steps from 0.0078 Hz to 16.0 Hz at 10 volts, plus step and minus step at 5 volts.

7.5 DATA OUTAGES

The data outages attributable to SCARS were the result of computer equipment failures, power outages (scheduled and unscheduled), severe weather, and the communications terminal (CT).

Malfunctioning tape drives and controller resulted in data loss. Many scheduled power outages have also resulted in the loss of data and at times resulted in the damage of equipment. On one occasion the power was shut off 30 minutes prior to the announced time, before the systematic shutdown of SCARS had been completed. Then when the power was re-established it returned at 90 volts which caused damage to several pieces of equipment.

Power outages caused by lightning storms were also a source of data outages at SCARS. Also during, very wet snowfall that covered the antenna at SCARS, the pilot tracking loop could not maintain lock, resulting in data loss until the antenna was wiped off and dried out.

The CT was also a source of data loss. Problems with the CT included failure of the traveling-wave tube high-power amplifier and the malfunctioning of the up/down converter on several occasions.

7.6 DATA REQUESTS

SCARS provided a variety of users a large amount of data. The RSTN data segment requested by the users were copied onto magnetic tape from the original RSTN data tape and then the copied tape was analyzed to verify its contents and quality. If requested, corresponding plots and/or listings were included as part of the package. Through 1988 SCARS provided 14 organizations a total of 2764 events of RSTN data. Tables 9 and 10 show the breakdown according to time and organization.

7.7 TOURS

SCARS hosted many groups and organizations for formal tours. The visitors were generally interested in how the data was recorded at SCARS, the output of the continuous helicorders, the concept of seismic stations, and the detection of nuclear events. The backgrounds of the visitors varied, and we tailored our presentations to them accordingly.

One type of tour was designed for students. It detailed the practical application of mathematics, science, and engineering. Groups given this tour included state-wide and area high school students

students, Native American engineering students from the University of New Mexico and Albuquerque Technical Vocational Institute, students from the Southwestern Indian Polytechnic Institute, entrants in the International Science and Engineering Fair, State and Regional Science Fair winners, and students from El Rito Community College.

A second kind of tour given at SCARS was to acquaint people from other professions with the type of work we were involved in at SCARS. Groups given this tour included secretaries from the Department of Energy (DOE) and Sandia National Laboratories (SNL), Quality Assurance Managers from SNL, participants in the summer Teacher Enrichment Program, secondary science teachers from the Topeka, Kansas, Public Schools System, and the president and department chairmen of Stark Technical College in Canton, Ohio.

A third variety of tour given at SCARS was designed for persons involved in the seismic field or the news media. This usually involved groups that brought in, with prior approval, filming equipment. They included local and national news personnel, personnel from the British Broadcasting Corporation (BBC), and personnel from the Air Force Technical Applications Center (AFTAC).

7.8 VIDEOTAPE

Part of the tour included viewing the 8-minute videotape of the RSTN project. This tape was produced and edited by EG&G Energy Measurements in Las Vegas, Nevada, in 1983.

This tape discusses the concept of RSTN stations, the ability and methods used by SCARS to command the stations, the equipment used at the remote stations and at SCARS, and the means by which data was collected and transferred from each station to SCARS for recording.

7.9 PUBLICATIONS

SCARS has provided the seismic community with many publications of the RSTN project. These include quarterly reports since April 1982 by EG&G, The National Seismic Station (SAND81-2134), The Data User's Guide for the Regional Seismic Test Network (RSTN) (SAND82-2935), the SCARS RSTN Software Guide (EGG-10282-6003), Seismic Test Network Research Symposium Proceedings (SAND85-1243), and Proceedings of the 1986 RSTN/NORESS Research Symposium (Conference 8604196), Regional Seismic Test Network: Follow-on Development Recommendations (November 1985), and Regional Seismic Background Noise at the Norwegian Regional Seismic Array (SAND87-1188). See the list of References for further information.

Table 9. RSTN data requests, 1979-1988, by calendar quarters.

	No. of Requests	No. of Events
1979 - 1983	38	655
1st Quarter 1984	4	147
2nd Quarter 1984	2	138
3rd Quarter 1984	6	314
4th Quarter 1984	7	182
1st Quarter 1985	11	104
2nd Quarter 1985	5	38
3rd Quarter 1985	3	14
4th Quarter 1985	20	234
1st Quarter 1986	11	218
2nd Quarter 1986	7	279
3rd Quarter 1986	17	119
4th Quarter 1986	8	119
1st Quarter 1987	5	21
2nd Quarter 1987	1	1
3rd Quarter 1987	7	109
4th Quarter 1987	0	0
1st Quarter 1988	3	56
2nd Quarter 1988	0	0
3rd Quarter 1988	4	7
4th Quarter 1988	3	9
	162	2764

Table 10. RSTN data requests, 1979-1988, by requesting organization.

	No. of Requests	No. of Events
Center for Seismic Studies	41	118
Energy, Mines, and Resources, Canada	11	88
Lawrence Berkeley Laboratory	4	55
Lawrence Livermore National Laboratory	44	1506
Los Alamos National Laboratory	5	48
Sandia National Laboratories	45	775
Seismological Laboratory, California Institute of Technology	1	3
Seismological Survey SR of Slovenia, Yugoslavia	1	7
Sierra Geophysics	1	1
United States Geological Survey	3	44
Universidade De Brasilia	2	4
University of California, Berkeley	1	79
University of Michigan	2	35
Woodward-Clyde Consultants	1	1
	162	2764

8. BAFFLE SYSTEM

The remote stations are required to operate at extreme temperature differentials through all seasons. In addition, complete equipment interchangeability between stations is required. To accomplish this, the sensitive uphole electronic equipment is installed in an insulated vault. The temperature of this vault is maintained by a baffle system. The main heat source for the vault, the RF equipment, is located in the bottom of the vault. The baffle located in the top will open or close automatically and is controlled by the internal vault temperature encouraging or constricting fresh air flow through a bottom vent.

This system has proven to be completely functional and trouble-free on all the stations. The only modification required was the installation of a defuser panel over the fresh-air inlet. This prevents supercooling of the lower RF package.

In the extremely cold conditions at Yellowknife (RSNT), the baffle system has provided a 100-degree differential from outside to the uphole logic equipment. Nominal operating temperatures also have been maintained by the baffle system at RSCP in the more temperate climate of Tennessee.

9. BATTERIES

The batteries are placed in parallel with the thermoelectric generators to provide back-up power in the event of complete failure of the TEGs. The batteries can provide at least 24 hours of power, which allows time for repairs to be made to the TEGs without the loss of seismic data from the station.

Gel-cell batteries were originally installed at RSCP, while lead-acid batteries were installed at the other four stations. The lead-acid batteries experienced numerous failures resulting from shorting of cells and boiling of the electrolyte. The lead-acid batteries were replaced with Gould float batteries designed for stand-by installations such as the RSTN stations. Similar problems persisted with the Gould batteries and they were eventually replaced. New 80- or 55-ampere/hour gel-cell batteries were installed at all five RSTN stations. The gel-cell batteries performed well at all the stations.

10. RECEIVER/TRANSMITTER (R/T) UNITS

Initially the RSTN system consisted of six receiver/transmitter (R/T) units. One was located at each of the five stations, with a spare. A seventh, which is an advanced version, was added in April 1986.

Five of the six R/T units were cycled through Motorola for updates and modifications. The modified R/T units were placed back into operation as follows:

R/T	Date Placed In Operation	Station
R/T-2	February 1983	RSCP
R/T-3	June 1985	RSSD
R/T-4	April 1985	RSCP
R/T-5	February 1982	RSNT
R/T-6	February 1984	RSON
R/T-1	No updates and modifications	

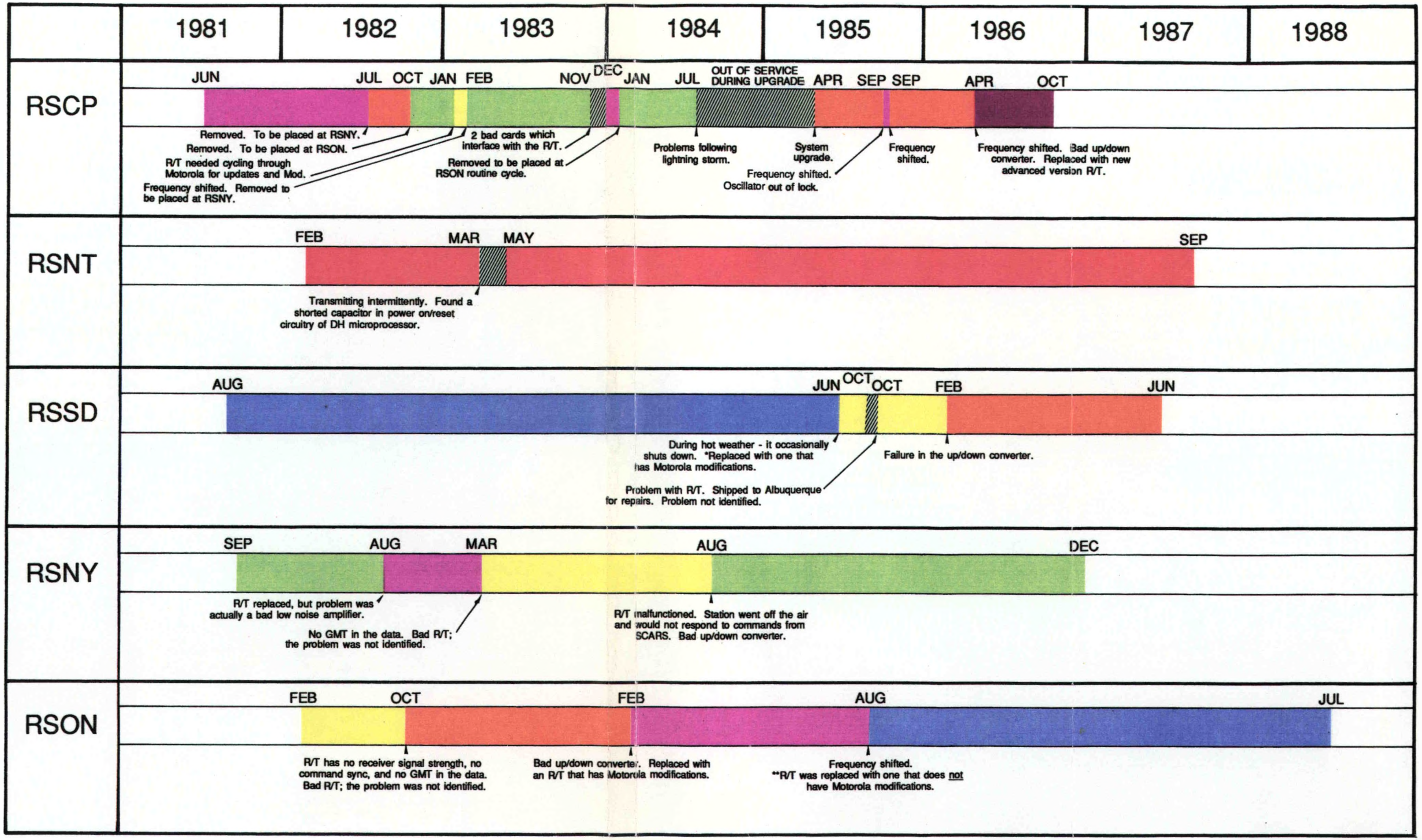
RSCP, while an operating RSTN station, was also used as a test facility for R/T units as they were cycled through Motorola for modification updates. On four occasions, R/T units which had performed well at RSCP were removed and installed at other stations which were experiencing problems with their R/T units.

There were four occasions in which a station was left with no R/T unit. Three incidents involved R/T units that were taken to a site as replacements, but did not correct the existing problem. As a result the two units were returned to Albuquerque for check-out and repairs, thus leaving the station inoperable until a working replacement was available. The fourth incident involved a station that was scheduled to be taken out of service for upgrading, but before that occurred a lightning storm caused damage to the R/T unit. The unit was returned to Albuquerque for repairs while the station underwent modifications.

The R/T units experienced a variety of problems. The up/down converter malfunctioned twice on R/T-3 and R/T-4; the frequency shifted once on R/T-3, twice on R/T-4 and R/T-6; intermittent transmitting problems were experienced once on R/T-1 and R/T-5; and three unidentified problems occurred with the R/T units, two on R/T-3 and one on R/T-6. In two instances an R/T unit was suspected of malfunctioning when in fact another piece of equipment had malfunctioned. The history of the problems with the R/T units is summarized in Figure 2. Table 11 shows which R/T units were replaced at each station and the reason for their replacement.

RSTN

RECEIVER/TRANSMITTER UNITS



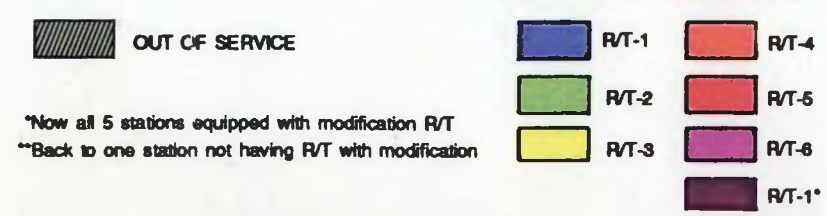


Figure 2. Problems involving Receiver/Transmitter (R/T) units.

Table 11. Problems involving the Receiver/Transmitter (R/T) units.

	Unit	Date Placed In Operation	Date Removed	Reason For Removal
RSCP				
	R/T-6	Jun 1981	Jul 1982	Removed to be placed at RSNY.
	R/T-4	Jul 1982	Oct 1982	Removed to be placed at RSON.
	R/T-2	Oct 1982	Jan 1983	Unit was sent to Motorola for updates and modifications.
	R/T-3	Jan 1983	Feb 1983	Frequency shifted. The unit was removed, to be placed at RSNY.
	R/T-2	Feb 1983	Nov 1983	The station malfunctioned, and the R/T unit was suspected to be the cause.
	Station	Nov 1983	Dec 1983	The station was out of service. Existing and replacement R/T units did not correct the malfunction. Both were shipped to Albuquerque for check-out and repairs. The problem was actually two faulty cards which were interfaced to the R/T unit.
	R/T-6	Dec 1983	Jan 1984	Removed to be placed at RSON.
	R/T-2	Jan 1984	Jul 1984	A lightning storm in the area resulted in damage to the R/T unit.
	Station	Jul 1984	Apr 1985	RSCP was out of service during system upgrades.
	R/T-4	Apr 1985	Sep 1985	Frequency shifted and the oscillator was out of lock.
	R/T-6	Sep 1985	Sep 1985	Frequency shifted.
	R/T-4	Sep 1985	Apr 1986	Frequency shifted. The R/T unit had a faulty up/down converter.
	R/T-1*	Apr 1986	Oct 1986	This R/T unit is an advanced version. This station was taken off the air.

Table 11. Problems involving the Receiver/Transmitter (R/T) units (Continued).

Unit	Date Placed In Operation	Date Removed	Reason For Removal
RSNT			
R/T-5	Feb 1982	Mar 1983	The station was transmitting intermittently, and the R/T unit was suspected of malfunctioning. The problem was actually a shorted capacitor in the power on/reset circuitry of the DH microprocessor.
Station	Mar 1983	May 1983	Since it was thought that the R/T unit had malfunctioned, the unit was shipped to Albuquerque for check-out and repairs.
R/T-5	May 1983	Sep 1987	This station was taken off the air.
RSSD			
R/T-1	Aug 1981	Jun 1985	During hot weather the R/T unit occasionally malfunctioned. It was replaced with one that has Motorola modifications. All five stations were currently equipped with modified R/T units.
R/T-3	Jun 1985	Sep 1985	An oscillator and a reference module in the R/T were replaced, but the R/T unit still did not operate.
Station	Sep 1985	Oct 1985	Existing and replacement R/T units were shipped to Albuquerque for check-out and repairs.
R/T-3	Oct 1985	Feb 1986	The R/T unit had a faulty up/down converter.
R/T-4	Feb 1986	Jun 1987	The station was taken off the air.
RSNY			
R/T-2	Sep 1981	Aug 1982	The station malfunctioned, and the R/T unit was suspected. The problem was actually a faulty low-noise amplifier.
R/T-6	Aug 1982	Mar 1983	There was no GMT in the data. The R/T unit was replaced, which corrected the problem, but the cause of the problem was not identified.

Table 11. Problems involving the Receiver/Transmitter (R/T) units (Concluded).

Unit	Date Placed In Operation	Date Removed	Reason For Removal
R/T-3	Mar 1983	Aug 1984	The station went off the air and would not respond to commands from SCARS. The cause was a defective up/down converter.
R/T-2	Aug 1984	Dec 1986	RSNY was taken off the air.
RSON			
R/T-3	Feb 1982	Oct 1982	The R/T unit had no receiver signal strength, no command synchronzation, and no GMT in the data. The unit was replaced, which corrected the problem. The unit had a defective up/down converter.
R/T-4	Oct 1982	Feb 1984	Command synchronization was lost. The receiver signal strength was low, and the radio-frequency output levels were low. The R/T unit had a faulty up/down converter. The existing R/T unit was replaced with one that has the Motorola modifications.
R/T-6	Feb 1984	Aug 1985	Frequency shifted.
R/T-1	Aug 1985	Jul 1988	This R/T unit does not have the Motorola modifications.

11. SEISMOMETERS

All the seismometers have proven to be very satisfactory and stable in both amplitude and phase at all five RSTN stations. The seismometer configuration for RSCP in October 1978 included a Teledyne Geotech model KS36000 and Teledyne Geotech model S600 seismometers with long-period, mid-period, short-period, and high-frequency bands. In March 1980, the high-frequency band was eliminated and the short period changed from 20 samples per second to 40 samples per second. Then in April 1985, new KS36000 and S750 seismometers were installed, which completed the upgrade for RSCP and made it identical to the other four stations. In addition, the transfer function was now the same for all stations.

The seismometer configuration at the remaining four RSTN stations consists of a Teledyne Geotech model KS36000 and Teledyne Geotech model S750 seismometers with long-period, mid-period, and short-period bands. The KS36000 was selected for all the other bands. In April 1985, all S750 seismometers were selected as the primary configuration for all the short-period axes to take advantage of the better high-frequency response.

Orientation problems have occurred at the RSTN stations. After installation, analyses of the RSON short-period seismic data derived from the S750 channels indicate a phase difference of 180 degrees in the short-period horizontal components. It is believed that the reversed phase of these components was the result of the package originally being installed with the orientation key lodged on the top of the holelock exactly 180 degrees out of alignment from the true orientation. On October 23, 1982 (DOY 296), this package was reinstalled and seated properly, correcting the orientation. On April 11, 1985 (101), the new KS36000 and S750 seismometers at RSCP were installed 30 to 40 feet above the holelock, resulting in what appeared to be an orientation problem. This was corrected on May 8, 1985 (128) by installing new wedges in the stabilizer and lowering the package to its proper depth. The S750 seismometer at RSSD was also installed incorrectly by 180 degrees. In June 1985, the DHL package was rotated 180 degrees to align the S750 seismometer with the KS36000 seismometer, which corrected the orientation. On August 19, 1986 (231) it was determined that the seismometers at RSNY were in error 17 degrees clockwise. The orientation was corrected at that time. The origin of this error is unknown. On January 13, 1987 (13), the KS36000 seismometer at RSCP was reinstalled with an orientation of 73 degrees, but it was later discovered that the orientation should be 55.6 degrees. This was not corrected since the DHL package did not have to be pulled before it was transferred to USGS. On December 9, 1987 (343), the polarities of the S750 N-S and E-W seismometers at RSON were swapped. This was not corrected, since the DHL package did not have to be pulled before it was transferred to USGS. The reversed polarity does not pose a problem since USGS does not presently use the S750 seismometers.

Problems with locking the seismometers have also occurred at the RSTN stations. After an electrical storm in June 1984, the DHL package at RSCP was mechanically damaged when the KS36000 seismometer could not be locked before its removal. Following another electrical storm in September 1986 at RSCP, the KS36000 seismometer could not be locked before its removal, resulting in mechanical damage to the DHL package.

The seismometers at RSCP have experienced a regional weather-related problem. On September 7, 1986 (250) the KS36000 seismometer experienced damage to its power supply as a result of an electrical storm.

12. STATE-OF-HEALTH

The RSTN state-of-health (SOH) consists of three parts; the uphole (UH), downhole (DH), and Geotech (GT). The SOH signals for any of the five RSTN stations can readily be displayed on the computer terminal in real-time. Monitoring these SOH signals facilitates identification of malfunctions or degradation of equipment, thus enabling the correction of the problems. Appendix A of this report details the subcommutation definition for the RSTN SOH.

The RSTN stations have experienced malfunctions with the UH/SOH and GT/SOH signals. None of these problems affected the seismic data.

12.1 UPHOLE STATE-OF-HEALTH (UH/SOH)

The state-of-health of the above-ground system is contained in the UH/SOH word. The information in the lower 12 bits of the UH/SOH word is subcommutated every 64 seconds. The Subcom ID is the lower 6 bits of TIME2.

Three remote stations experienced one UH/SOH problem each. RSCP, Station 1, experienced an offset in its temperature and tilt readings, and the wind direction sensors malfunctioned in April 1983. On August 11, 1983 RSCP stopped functioning. When it began to operate again on August 16, 1983 the UH/SOH values were correct. Recycling the power had corrected the problem.

RSNT, Station 2, experienced an offset of 70 degrees in its temperature readings in August 1983. This problem was corrected in February 1984 when the power supply card was replaced.

RSON, Station 5, experienced problems with its UH/SOH power supply, which resulted in receiving no temperature, tilt, and wind readings in November 1982. This problem was corrected in February 1984 when the power supply was replaced.

In April 1986, the SOH electronics at RSCP were disconnected because of a malfunction in the power supply of the Power Distribution Module (PDM). When the station was taken off the air in October 1986, no repairs had been made to the power supply.

12.2 DOWNHOLE STATE-OF-HEALTH (DH/SOH)

The downhole information is subcommutated every 32 seconds in the lower 12 bits of the DH/SOH word. The Subcom ID is the lower 5 bits of TIME2. There were no DH/SOH problems experienced during the RSTN lifetime.

12.3 GEOTECH STATE-OF-HEALTH (GT/SOH)

The Geotech state-of-health information is subcommutated every 16 seconds in the lower 14 bits of the GT/SOH word. The Subcom ID is the lower 4 bits of TIME2.

Four stations experienced a total of 13 GT/SOH errors during their RSTN lifetime. RSCP experienced three GT/SOH problems. In October 1982, RSCP experienced erroneous readings of 0 to -2.0 volts in its GT/SOH entries. These were corrected in January 1983 when the J103 card was disconnected and then reconnected. The second incident occurred in July 1983, when following routine maintenance of RSCP the GT/SOH malfunctioned. This was corrected in August 1983 when the station stopped functioning and was later restored to service; recycling the power corrected the problem. The third GT/SOH problem at RSCP occurred in May 1985, when the GT/SOH entries assumed readings of -9.99 volts. This problem was corrected in August 1985, after new batteries were installed, the R/T was replaced, and the power was recycled.

RSSD experienced six GT/SOH problems. In August 1982, RSSD experienced a malfunctioning carrier monitor in its GT/SOH monitor system. Then in February 1983, the GT/SOH entries assumed readings of 10 volts. On September 2, 1983 the problems appeared to correct themselves, but on September 22, 1983 all GT/SOH values went to 0 volts. Then June 22, 1984 the GT/SOH entries assumed readings of 10 volts. In June 1985, the problem was corrected after the downhole package was pulled for maintenance, the power was recycled, and the R/T was recycled. In August 1985, the GT/SOH entries assumed readings of 10 volts once again. In September 1985 the station stopped operating. When it was brought back into operation in October 1985 the GT/SOH readings were were 0.02 volts. In November 1985, the GT/SOH entries were corrected after PDM Card 9 was replaced, restoring power to the DH/SOH. In August 1986, the GT/SOH once again assumed readings of 10 volts. RSSD was out of service between December 23, 1986 and February 9, 1987. When it was placed in operation again the GT/SOH entries were correct.

RSNY experienced two GT/SOH problems. In August 1982 the GT/SOH entries assumed a positive offset. In August 1983 an attempt to correct this problem by recycling power failed. Then in April 1985 the GT/SOH entries assumed readings of 10 volts. The readings were corrected in August 1986 when the downhole package was pulled for maintenance and the power was recycled.

RSON experienced two GT/SOH problems. In August 1982, the GT/SOH entries assumed readings of 10 volts. This was corrected in September 1982, when the power was recycled. In June 1985, the GT/SOH entries once again assumed readings of 10 volts. This was corrected in August 1985 when the downhole package was pulled for maintenance and the power was recycled.

13. THERMOELECTRIC GENERATORS

The thermoelectric generators (TEGs) have proven to operate satisfactorily in all but extremely cold climates, i.e. below -50 degrees. The RSTN thermoelectric generator configuration consisted of four 60-watt TEGs for RSCP and RSNT, and three 120-watt TEGs for RSSD, RSNY, and RSON. All the RSTN TEGs operated on propane with the exception of two TEGS in RSSD. These two TEGs operated on JP-4 fuel from August 1981 until November 1983 as part of a test to determine if the use of JP-4 is feasible, since propane is not universally available overseas.

Weather was a source of problems for the TEGs at two stations. Electrical storms in the RSCP area resulted in the shorting of the converter limiter and damage to a thermopile. During extremely cold weather at RSNT the station had to be turned off because of icing in the line and the temperature being below necessary limits for propane to vaporize. In addition, to bring the station back into operation, a portable heater had to be used to heat the TEGs to permit vaporizing action of the propane. These circumstances indicate that the TEGs do not perform well in extremely cold climates.

Moisture in the propane was a problem at two stations. RSNT was plagued with what appeared to be water in the propane, causing the main regulator to freeze. Numerous modifications were made at different times in an attempt to alleviate this continuing problem. These include cleaning and replacing the main regulator, moving it outside the fuel cabinet, installing a two-stage regulator system, and removing the main regulator completely. These modifications had only marginal success. The problem was finally traced to a small hole in the side of the buried rigid line that ran from the fuel cabinet to the dome. During the initial installation of RSNY, moisture in the propane line was a problem. The moisture was introduced into the system either upon delivery of the tanks or during installation hookup. This problem was corrected by flushing all the lines several times with alcohol.

There were problems with the main regulator at two stations. At RSSD the main regulator had to be replaced after it began leaking propane into the atmosphere. The main regulator at RSNY was replaced following the drop in propane pressure and the TEGs assuming varying output voltages.

The two TEGs operating on JP-4 at RSSD proved to be unreliable. The technology for that type of TEG had not advanced enough. They were replaced with propane-operated TEGs in November 1983.

A problem occurred following the conversion of the JP-4 tanks to propane. Some JP-4 fuel had been left in the two JP-4 fuel tanks and one of the TEG propane feed lines was erroneously connected to the liquid valve instead of the gas valve, and a jeweled orifice on another TEG was very dirty, thus not allowing the liquid fuel to pass and sustain combustion. The feed line to the misconnected TEG was switched to the gas transfer valve, the orifice was cleaned, the filter was changed, and the output was balanced on the other malfunctioning TEG.

Other problems were experienced by the TEGs. Valves on two TEGs at RSCP malfunctioned, resulting in the TEGs going out and eventually in the station stopping operation. The burner of one

TEG at RSSD filled with oil, causing the bus voltage to drop and the TEG to fail. A TEG failed at RSON and the batteries dropped below the safe operating threshold for the converter limiter that was still on line, causing it to fail. The third TEG was relighted and put on-line, but the load was too great for its converter limiter, resulting in its failure. Many broken strands in the output wire from the TEG thermopile resulted in the bus voltage slowly dropping, and even-tually caused the station to stop functioning. The bus voltage at RSON dropped below the minimum required for transmission; a hole had burned through each plate on the thermopile, apparently allowing some of the thermocouples to be destroyed and thus reducing the power output to the TEGs.

14. VOICE BOX

The voice box has been used to enhance troubleshooting and system installations at the RSTN sites, by providing a means of direct communication between the site and SCARS. The original concept of the voice communications was to use BPSK (bi-phase shifted keyed) modulation from SCARS to the RSTN site and to use QPSK (quadri-phase shifted keyed) modulation from the site to SCARS. The data link from the site to SCARS was to have voice and seismic data multiplexed for transmission over the same r-f carrier. The success of the voice link has been marginal. Attempts were made to use BPSK modulation from the site to SCARS to improve the performance of the voice link.

The majority of the voice box failures were identified to be in the performance of the TSP voice digitizing system. The units were extremely sensitive to temperature and to AC line voltage noise. Three voice units were utilized in the attempt to have two units which would operate. On several occasions the voice equipment would operate in tests from FACT to SCARS, but when taken to the field the units would not operate.

It is believed that the system concept of the voice communications is a viable and sound approach to the remote communications requirements. The TSP equipment as used in the RSTN program does not come close to achieving the performance required.

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APPENDIX A

RSTN STATE-OF-HEALTH (SOH) FORMAT

This was extracted from the Data Users' Guide for the Regional Seismic Test Network (RSTN), pages 43-50, with permission of the compiler.

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6. RSTN State-of-Health (SOH) Format

This chapter details the information contained in the three SOH words: UH/SOH, DH/SOH, and GT SOH.

6.1 UH/SOH Real-Time Status

The state of health of the above ground system is contained in the UH/SOH word.

The most significant four bits contain the information shown in Table 6.1. They are transmitted with each 1-second frame of data. If an intrusion occurs, the 2^{12} bit comes on and will remain on until reset by means of a command from SCARS. The 2^{14} bit is activated if the remote uphole logic does not recognize the sync word in the command link.

Table 6.1 Real-Time Status

Bit	Definition
2^{12}	Intrusion Alarm: INSTRUSION = 1
2^{13}	Command Source, Remote/$\overline{\text{Local}}$: LOC = 0
2^{14}	Command Sync: NO SYNC = 1
2^{15}	Command in Queue: QUEUE EMPTY = 0

6.2 UH/SOH Analog Monitors

The information in the lower 12 bits of the UH/SOH word is subcommutated every 64 s. The Subcom ID is the lower 6 bits of TIME2, TIME1, or the 28-bit time. Table 6.2 defines the monitors. For each analog monitor with a constant-scale factor:

$$\text{TLMV} = 5.0 - \text{Value}_{10} \bullet 0.002442$$
$$\text{Reading} = \text{SF} \bullet \text{TLMV}$$

where

Value_{10}	=	Monitor value in Base 10 (0 to 4095)
TLMV	=	Raw data reading in telemetry volts
SF	=	Scale factor
Reading	=	Monitor value in the proper engineering units

6.3 UH/SOH Control Status

The control status (Table 6.3) is the indication of how the uphole logics microprocessor is trying to control the surface system. RSTN does not contain tape recorders; therefore, those bits can be ignored. The following notes apply:

- The antenna position will be changed automatically upon loss of M out of N command sync patterns for 30 min. For RSTN, M = N = 8 (set by SCARS), which means total loss of the command link for 30 min.
- HPA override can be changed only by command from SCARS.
- HPA override, when on, holds the HPA off unconditionally.
- HPA on/off control bit has control of the HPA if HPA override is off and the HPA temperature is within operational limits. This control bit is on except during an antenna move operation.

Table 6.2 UH/SOH Master Frame Subcommutation Definition

Subcom ID	SCARS Mnemonic	Scale Factor	Engr Units	Definition
00	CTRS	—	—	Control status (digital)
01	SYSS	—	—	System status (digital)
02	EXCS	—	—	Exceptional status (digital)
03	+5SP	2.0	Vdc	UHL +5-V power supply
04	-5SP	2.0	Vdc	UHL -5-V power supply
05	+12V	5.0	Vdc	UHL +12-V power supply
06	-12V	5.0	Vdc	UHL -12-V power supply
07	+5SB	2.0	Vdc	+5-V bubbles power supply
08	+16V	6.5	Vdc	+16-V bubbles power supply
09	-16V	6.5	Vdc	-16-V bubbles power supply
10	EXCS	—	—	—
11	TUHL	100.0	°F	UHL temperature
12	TUPV	100.0	°F	Upper vault temperature
13	TOUT	100.0	°F	Outside temperature
14	TDME	100.0	°F	Inside temperature dome (batteries)
15	TLWV	100.0	°F	Lower vault temperature
16	CTRS	—	—	—
17	SYSS	—	—	—
18	EXCS	—	—	—
19	TN/S	2.9	Deg	Satellite antenna platform tilt (north/south)
20	TE/W	2.9	Deg	Satellite antenna platform tilt (east/west)
21	SWND	20.0	MPH	Wind speed
22	DWND	72.0	Deg	Wind direction 0° to 360°
23	VTWT	1.0	Vdc	TWT power supply
24	ICOL	10.0	W	Combined collector power (TWT)
25	IHEX	①	mA	Helix current
26	EXCS	—	—	—
27	TTWT	①	°F	Traveling-wave tube amplifier (TWT) baseplate temperature
28	TSSA	①	°F	Solid-state amplifer (SSA) baseplate temperature
29	SPHE	800.0	Hz	Static phase error
30	SRVR	①	dBm	Receiver signal strength
31	PHPA	①	W	HPA (high power amplitude) output power
32	CTRS	—	—	—
33	SYSS	—	—	—
34	EXCS	—	—	—
35	PTEG	4.0	Psi	TEG fuel pressure
36	GD36	—	—	Unused (ground)
37	GD37	—	—	Unused (ground)
38	GD38	—	—	Unused (ground)
39	VTG1	2.0	Vdc	TEG #1 voltage Sta 3–5 SF=8.0
40	VTG2	4.0	Vdc	TEG #2 voltage Sta 3–5 SF=8.0
41	VTG3	6.0	Vdc	TEG #3 voltage Sta 3–5 SF=8.0
42	EXCS	—	—	—
43	VTG4	8.0	Vdc	TEG #4 voltage Sta 1 + 2 only
44	GD44	—	—	Unused (ground)
45	VBUS	8.0	Vdc	Main bus voltage
46	GD46	—	—	Unused (ground)
47	IBUS	15.6	A	Main bus current

Table 6.2 (Cont)

Subcom ID	SCARS Mnemonic	Scale Factor	Engr Units	Definition
48	CTRS	—	—	—
49	SYSS	—	—	—
50	EXCS	—	—	—
51	IDHL	2.0	A	Downhole logics current
52	IUHL	2.0	A	Uphold logics current
53	IRTM	10.0	A	Remote-transmitter module current
54	ITRM	2.0	A	Tape-recorder module current (not in RSTN)
55	DD55	—	—	DDU (digital delay unit) status word 0 or 1
56	GD56	—	—	Unused (ground)
57	GD57	—	—	Unused (ground)
58	EXCS	—	—	—
59	GDUL	—	—	Unused (UHL ground)
61	TCTR	—	—	Tape-recorder TAC time per track
61	DD61	—	—	DDU status word 0 or 1
62	UHP	—	—	UHL parameters 0 to 3
63	DWLP	—	—	Dwell position

Note:

1. For these analog monitors, the following is the conversion from TLMV to engineering units:

Subcom ID	Conversion	
25	mA	$\approx 0.6 \cdot \text{TLMV} - 0.5$
27	°F	$\approx 73 - 13.0 \cdot \text{TLMV}$
28	°F	$\approx 73 - 13.0 \cdot \text{TLMV}$
30	dBm	$\approx 37 \cdot e^{(1.25 - \text{TLMV})} - 115$
31	W	$\approx 5.0 \cdot \text{TLMV} - 8.0$ accuracy poor for TLMV <2.0

When the UH/SOH monitor is commanded to dwell, all 64 positions are overwritten with the monitor designated by Subcom 63 except for 00, 01, 02, 10, 16, 17, 18, 26, 32, 33, 34, 42, 48, 49, 50, 58, and 63.

Table 6.3 Control Status Word

Bit	Definition
2^0	Recorder Track Select 2^0
2^1	Recorder Track Select 2^1
2^2	Recorder Track Select 2^2
2^3	Recorder Track Select 2^3
2^4	Antenna Position, A/$\overline{\text{B}}$ A = 1
2^5	HPA Select, SSA/$\overline{\text{TWT}}$: SSA = 1
2^6	Data Mode, Dwell/$\overline{\text{Normal}}$: DWELL = 1
2^7	Spare
2^8	HPA Override, On/$\overline{\text{Off}}$: ON = 1
2^9	HPA, On/$\overline{\text{Off}}$: ON = 1
2^{10}	Recorder Override, On/$\overline{\text{Off}}$: ON = 1
2^{11}	Recorder, On/$\overline{\text{Off}}$: ON = 1

6.4 UH/SOH System Status

The system status (Table 6.4) is a reflection of the actual condition of the uphole systems.

6.5 UH/SOH Exceptional Status

The exceptional status (Table 6.5) is also a reflection of the actual condition. However, these are events that could be transient, or on/off quickly. The uphole logics will latch these to ensure their transmission to SCARS before resetting them.

Table 6.4 System Status Word

Bit	Definition
2^0	Recorder, Forward/$\overline{\text{Reverse}}$: FORWARD = 1
2^1	Vault Door, Open/$\overline{\text{Closed}}$: OPEN = 1
2^2	Dome Door, Open/$\overline{\text{Closed}}$: OPEN = 1
2^3	Antenna Position A
	A = $\genfrac{}{}{0pt}{}{1}{0}$, B = $\genfrac{}{}{0pt}{}{0}{1}$, IN-MOTION = $\genfrac{}{}{0pt}{}{0}{0}$
2^4	Antenna Position B
2^5	HPA Selected, SSA/$\overline{\text{TWT}}$: SSA = 1
2^6	Data Mode, Dwell/$\overline{\text{Normal}}$: DWELL = 1
2^7	TWT dc Power, On/$\overline{\text{Off}}$: ON = 1
2^8	Clock Select, Downhole/$\overline{\text{Up-Hole}}$: DH = 1
2^9	HPA, On/$\overline{\text{Off}}$: ON = 1
2^{10}	Spare
2^{11}	Recorder, On/$\overline{\text{Off}}$: ON = 1

Table 6.5 Exceptional Status Word

Bit	Definition
2^0	Recorder Head Current Low On selected track
2^1	Recorder Head Current High
2^2	Recorder Slack Tape
2^3	Recorder Capstan Servo Unlock
2^4	Beginning of Tape
2^5	End of Tape
2^6	Spare
2^7	UHL Reboot
2^8	RTM — RCVR Clock Sync Failure
2^9	RTM — AFC Lock Failure
2^{10}	RTM — XMTR LO Failure
2^{11}	RTM — RCVR LO Failure

6.6 UH/SOH UHL Parameter Words

The uphole parameters (Table 6.6) are used by the UHL for decision-making. These can be changed upon command from SCARS.

6.7 UH/SOH Digital Delay Unit Status

The digital delay unit, DDU, is controlled by its own microprocessor. It performs an evaluation of the bubble memory units and the random-access memory (RAM) units. If any are declared inoperative, it can take them offline. Their status is reported in two DDU status words (Table 6.7). Either word can be in Subcom ID 55; the other will be in Subcom ID 61.

Table 6.6 UHL Parameter Word

2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
Address				Parameter Value							

Address:

0 = M (Max. Framedrop) – – – 02_{16}
1 = N (Frame Window) – – – – 08_{16}
2 = Rev. (NSSUH Software Rev. # – – –
3 = DP (Dwell Position) – – – – 00_{16}

} Initial Values

$4\text{-}F_{16}$ = Unused
Rev. # Format: Rev 1.2 ≡ 12_{16}

Table 6.7 DDU Status Words

WORD 0

2^{11}	2^{10}, 2^9, 2^8, 2^7	2^6	2^5, 2^4	2^3, 2^2, 2^1	2^0
0	Delay	Ft.	Grp.	Device ID	$\bar{B}/R$

Delay: Number of MEMORY Units on Line
1 Unit ≈ 111 Seconds @ 2400 BPS

RAM Failure: Faulty Device Identified By $\bar{B}/R$ = 1 and Device ID. (ft. and GRP. Field Not Used.)

SBS-10 Failure: Faulty DEVICE Identified by $\bar{B}/R$ = 0

Group Number = 1, Device ID = 0 to 7 } Identifies one of the eight primary bubbles as FAILED

Group Number = 0, Device ID = 0 to 3 } Identifies one of four spare bubbles as FAILED

Ft. – Failure Type – – 0 = DATA Error
1 = TURN ON Error

WORD 1

2^{11}	2^{10}, 2^9, 2^8, 2^7	2^6, 2^5, 2^4	2^3	2^2, 2^1, 2^0
1	Inoperative CNT.	Spare CNT.	GRP.	Device

GRP. and Device: SBS-10 Currently Active

Spare CNT.: Number of Redundent SBS-10 Memory Units on Stand-by

Inoperative CNT.: Number of Memory Units Declared Unusable by DDU Test Algorithms.

NOTE: CNT. is Count

6.8 DH/SOH Monitors

The information in the lower 12 bits of the DH/SOH word is subcommutated every 32 s. The Subcom ID is the lower 5 bits of TIME2/TIME1, or 28-bit time. Table 6.8 defines the monitors. For each analog monitor with a constant-scale factor:

TLMV = 5.0 $Value_{10}$ • 0.002442
Reading = SF • TLMV

where

$Value_{10}$ = Monitor value in base 10 (0 to 4095)
TLMV = Raw data reading in telemetry volts
SF = Scale factor
Reading = Monitor value in the proper engineering units

Table 6.8 DH/SOH Master Frame Subcommutation Definition

Subcom ID	SCARS Mnemonic	Scale Factor	Engr Units	Definition
00	GD00	1.0	—	Unused (ground)
01	TEMP	100.0	°F	Upper borehole canister temperature
02	GD02	1.0	—	Unused (ground)
03	PRES	*	psia	Upper borehole canister pressure
04	VL1M	5.0	Vdc	+5-V seismic electronics supply monitor
05	V1MN	1.0	Vdc	±15-V (summed) seismic electronics supply monitor
06	VL2M	5.0	Vdc	+5-V seismic electronics supply monitor
07	V2MN	1.0	Vdc	±15-V (summed) seismic electronics supply monitor
08	VL3M	5.0	Vdc	+5-V seismic electronics supply monitor
09	V3MN	1.0	Vdc	±15-V (summed) seismic electronics supply monitor
10	VL4M	5.0	Vdc	+5-V seismic electronics supply monitor
11	V4MN	1.0	Vdc	±15-V (summed) seismic electronics supply monitor
12	+15V	5.0	Vdc	+15-V digital electronics supply monitor
13	LMEV	1.0	Vdc	±15-V (summed) LPE & MPE A/D converter supply monitor
14	-15V	5.0	Vdc	-15-V digital electronics supply monitor
15	LMNV	1.0	Vdc	±15-V (summed) LPN & MPN A/D converter supply monitor
16	+12V	5.0	Vdc	+12-V digital electronics supply monitor
17	LMZV	1.0	Vdc	±15-V (summed) LPZ & MPZ A/D converter supply monitor
18	-12V	5.0	Vdc	-12-V digital electronics supply monitor
19	OPEN	1.0	—	Unused (open circuit)
20	+5VL	5.0	Vdc	+5-V digital electronics supply monitor
21	SPEV	1.0	Vdc	±15-V (summed) SPE A/D converter supply monitor
22	-5VL	5.0	Vdc	-5-V digital electronics supply monitor
23	SPNV	1.0	Vdc	±15-V (summed) SPN A/D converter supply monitor
24	RDYA	1.0	Vdc	Authentication memory A eraser armed
25	SPZV	1.0	Vdc	±15-V (summed) SPZ A/D converter supply monitor
26	RDYB	1.0	Vdc	Authentication memory B eraser armed
27	GDL7	1.0	—	Unused (ground)
28	TRGA	1.0	Vdc	Authentication memory A eraser triggered
29	GD29	1.0	—	Unused (ground)
30	TRGB	1.0	Vdc	Authentication memory B eraser triggered
31	GD31	1.0	—	Unused (ground)

NOTE: For Subcom ID 03 (PRES), the following is the conversion from TLMV to engineering units.

*psia = (TLMV -1) 3.745

6.9 GT SOH Monitors

The information in the lower 14 bits of the GT SOH word is subcommutated every 16 s. The Subcom ID is the lower 4 bits of TIME2/TIME1, or 28-bit time. Table 6.9 defines the monitors for each analog monitor:

TLMV = 10 - $Value_{10} \cdot 0.001221$
Reading = SF • TLMV

where

$Value_{10}$ = Monitor value in $base_{10}$ (0 to 16383)
TLMV = Raw data reading in telemetry volts
SF = Scale factor
Reading = Monitor value in the proper engineering units

Table 6.9 GT SOH Master Frame Subcommutation Definition

Subcom ID	SCARS Mnemonic	Scale Factor	Engr Units	Definition
00	MMZ	1.0	Vdc	KS-36000 Z mass monitor
01	MMN	1.0	Vdc	KS-36000 N mass monitor
02	MME	1.0	Vdc	KS-36000 E mass monitor
03	CAL	1.0	Vdc	Calibration monitor
04	PRES	1.5	Psia	Lower borehole canister pressure
05	TEMP	100.0	°F	Lower borehole canister temperature
06	CRZN	1.0	Vdc	Carrier monitor Z and N summed
07	CRZE	1.0	Vdc	Carrier monitor Z and E summed
08	CLIP	1.0	Vdc	Indicates that one or more KS-36000 carrier signals is over amplitude
09	VCZ	5.0	Vdc	±15-V (summed) Z supply monitor
10	VCN	5.0	Vdc	±15-V (summed) N supply monitor
11	VCE	5.0	Vdc	±15-V (summed) E supply monitor
12	VLZ	1.0	Vdc	+5-V logic supply monitor, Z
13	VLN	1.0	Vdc	+5-V logic supply monitor, N
14	VLE	1.0	Vdc	+5-V logic supply monitor, E
15	VLC	2.5	Vdc	+5-V (multiple summed) supply monitor

APPENDIX B

REGIONAL SEISMIC TEST NETWORK SPECTRAL HISTORY DATA

This was extracted from Seismic Background Noise at the Norwegian Regional Seismic Array, pages 47-54, with permission of the author.

Dale R. Breding
Sandia National Laboratories

APPENDIX

Regional Seismic Test Network Spectral History Data

The System Control and Receiving Station (SCARS) and the Norwegian Regional Seismic Array (NRSA) have used similar methods to collect spectral history data—SCARS since 1981, when the Regional Seismic Test Network (RSTN) was installed, and the NRSA since 1984. Plots of these data are included for comparison as Figures A1 through A15. No other report on RSTN history data is anticipated.

Note the following comments about the RSTN history data:

- The scales for the RSTN data differ from those for the NRSA data. Subtract 120 dB from the RSTN data to compare them directly to the NRSA data.
- The noise model for the RSTN data is not as quiet as the model for the NRSA data. This reflects the thinking in 1981 versus the additional knowledge gained after Lajitas and NRSA were installed.
- The Regional Seismic Station, Tennessee (RSCP) has only a few spectra because data were used only since the RSCP was upgraded to a complete RSTN in 1985.
- The rise in the RSCP spectral data between 2 and 3 Hz seems to be real. This phenomenon could be a cultural noise source since it does not appear in the minimum values.
- The Regional Seismic Station, Yellowknife (RSNT) horizontal north and east data have a much wider distribution than the other stations. This also seems to be real because it occurs in more than a few spectra.

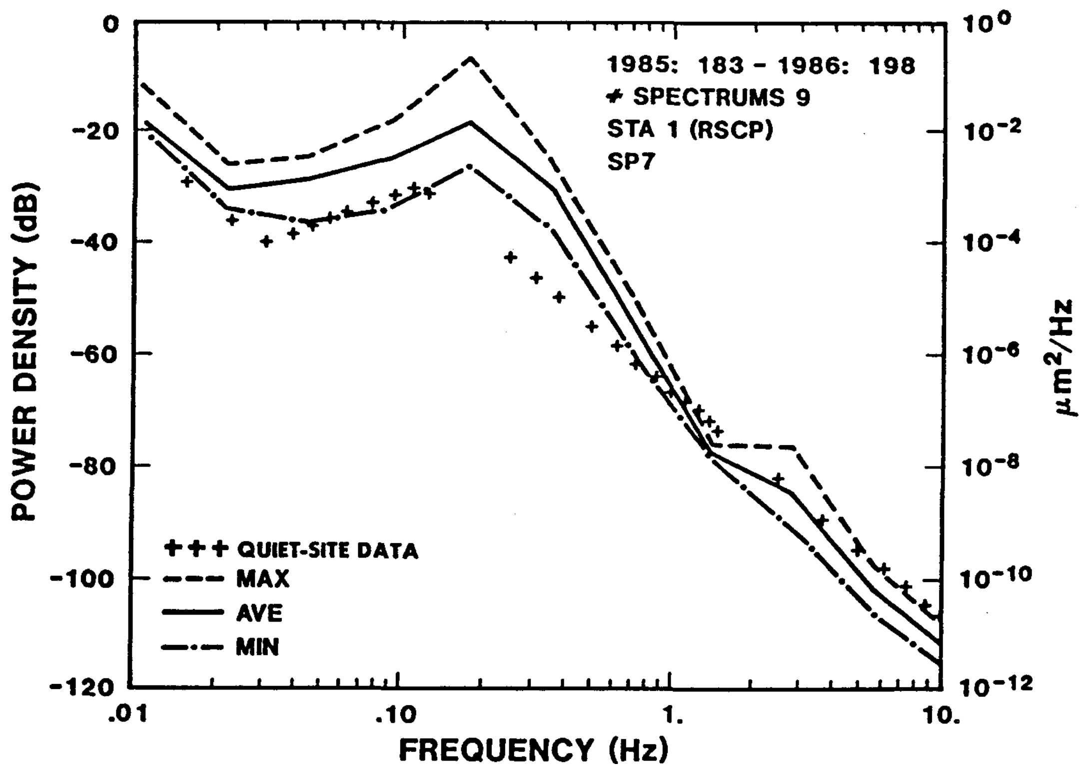


Figure A1. RSCP History Data, Vertical

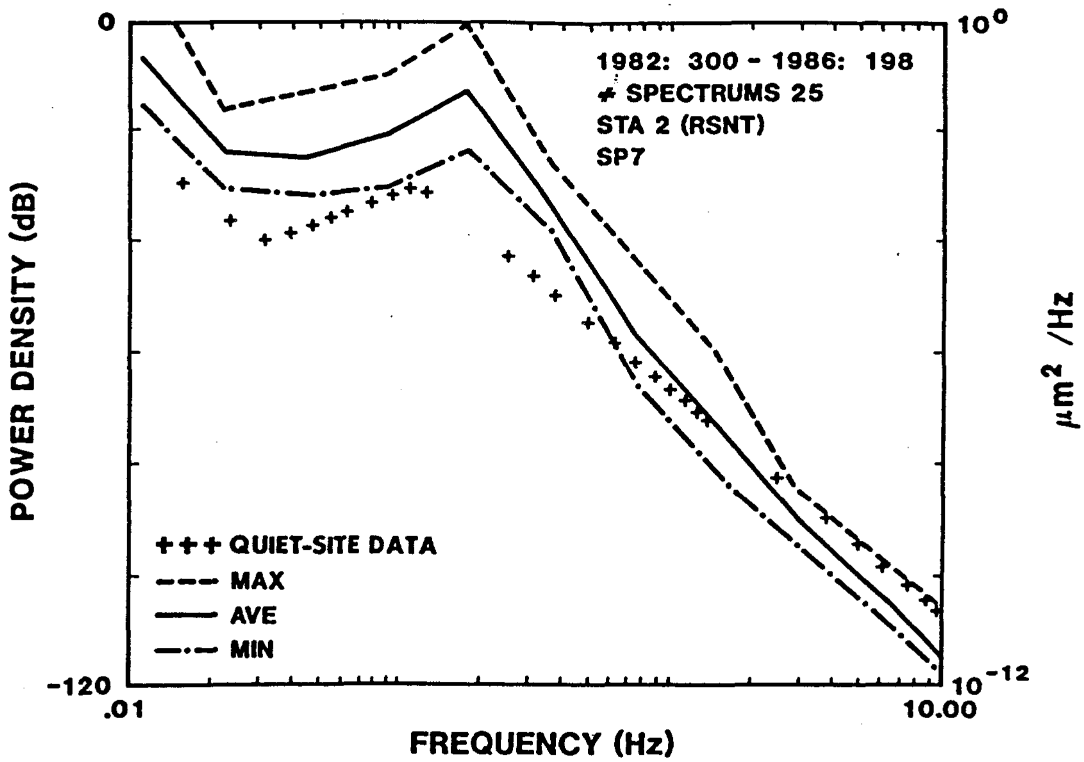


Figure A2. RSNT History Data, Vertical

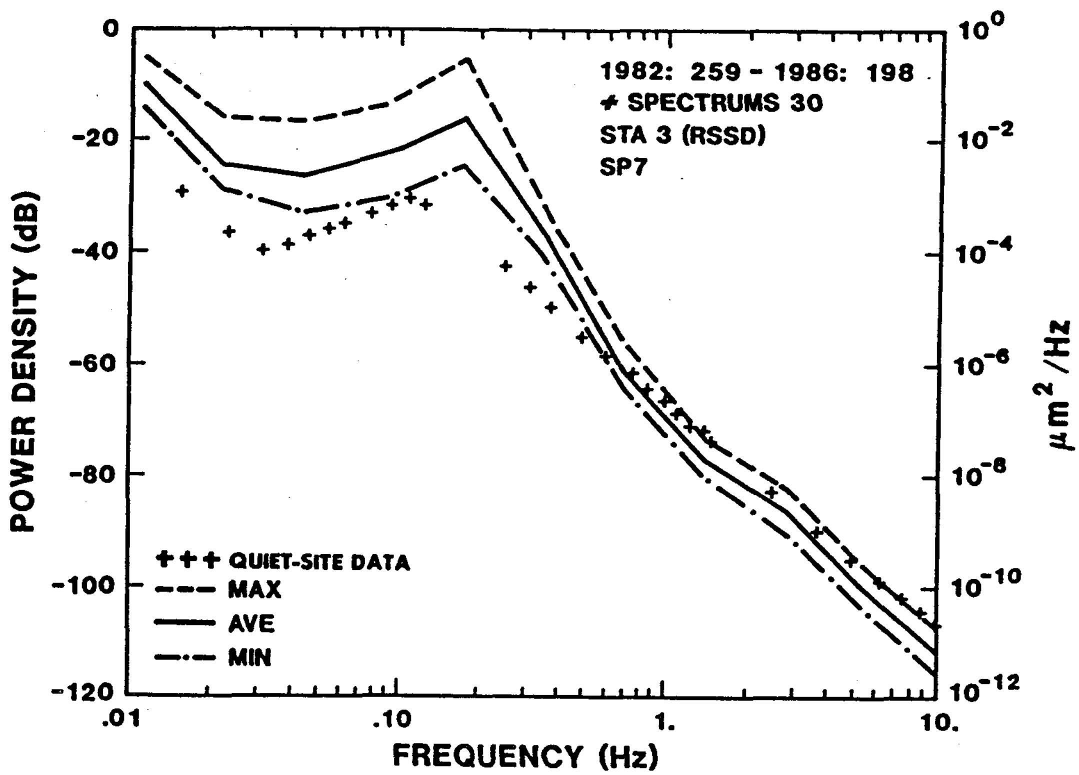


Figure A3. RSSD History Data, Vertical

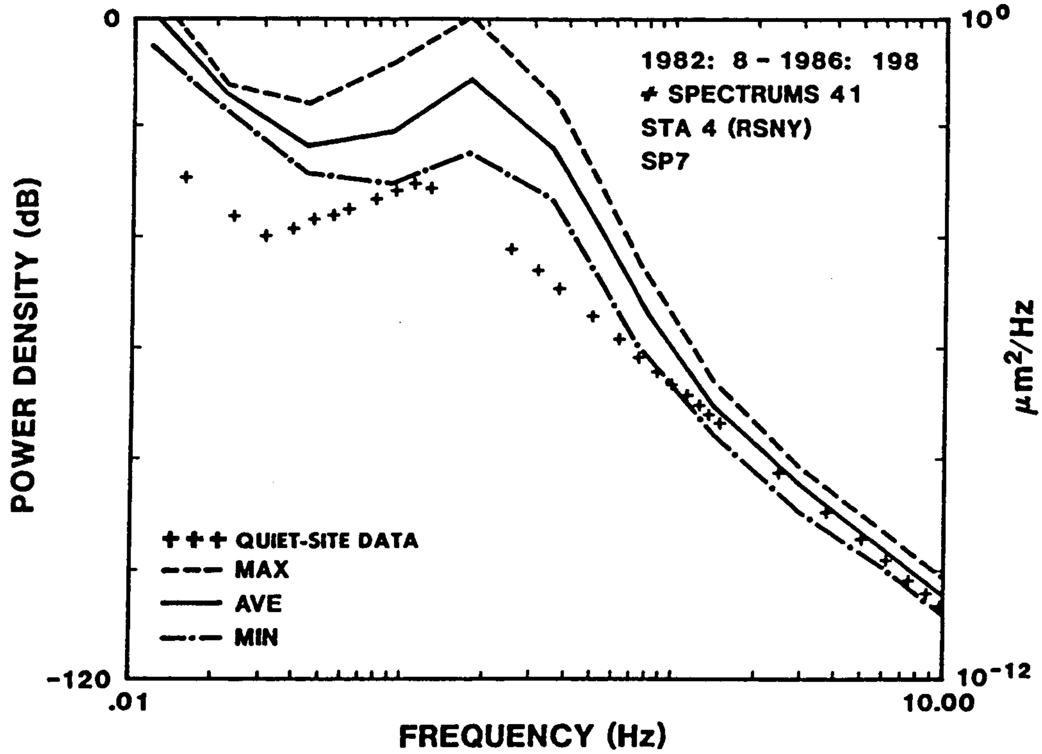


Figure A4. RSNY History Data, Vertical

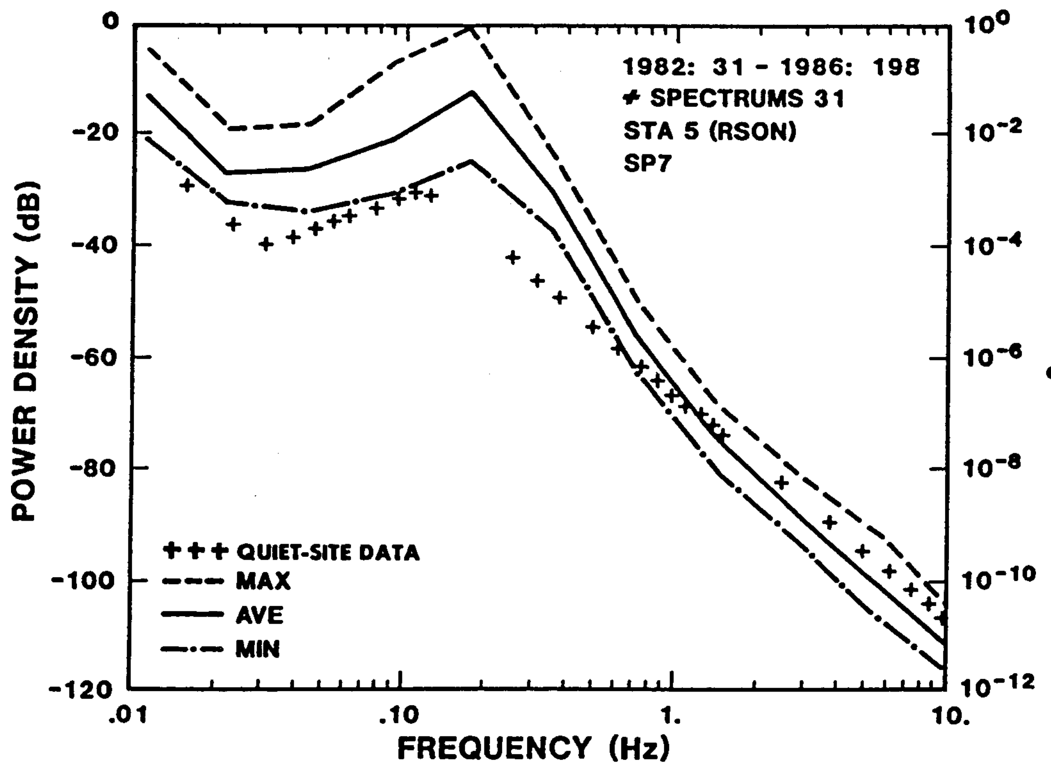


Figure A5. RSON History Data, Vertical

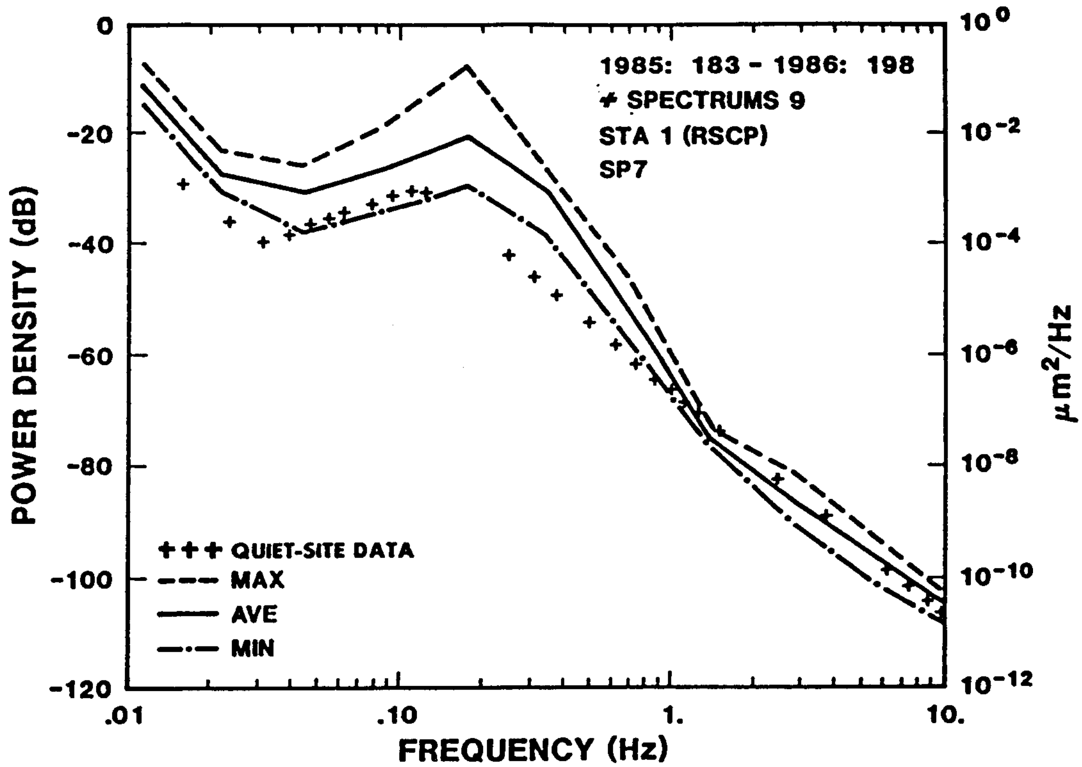


Figure A6. RSCP History Data, Horizontal North

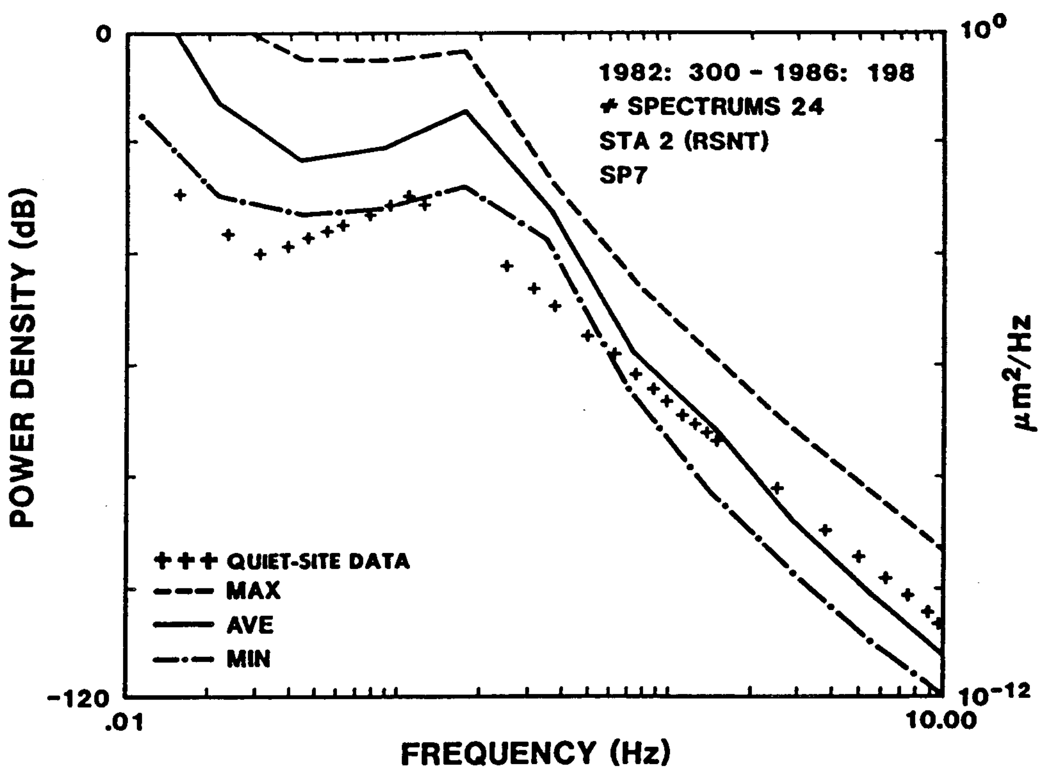


Figure A7. RSNT History Data, Horizontal North

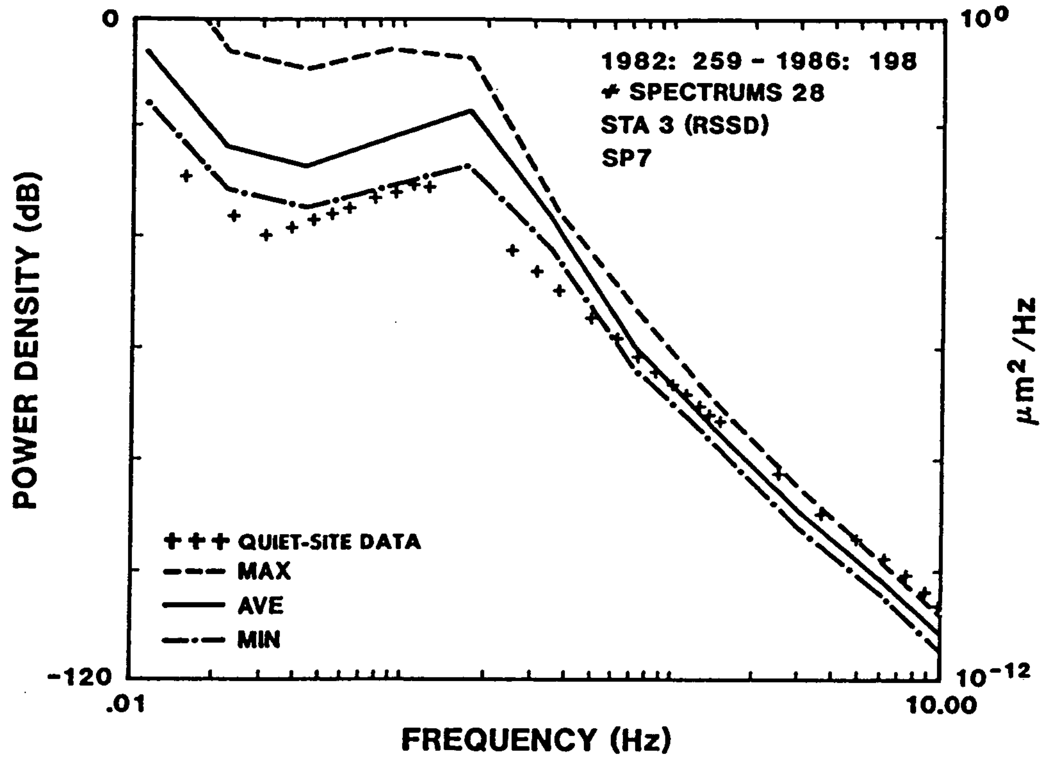


Figure A8. RSSD History Data, Horizontal North

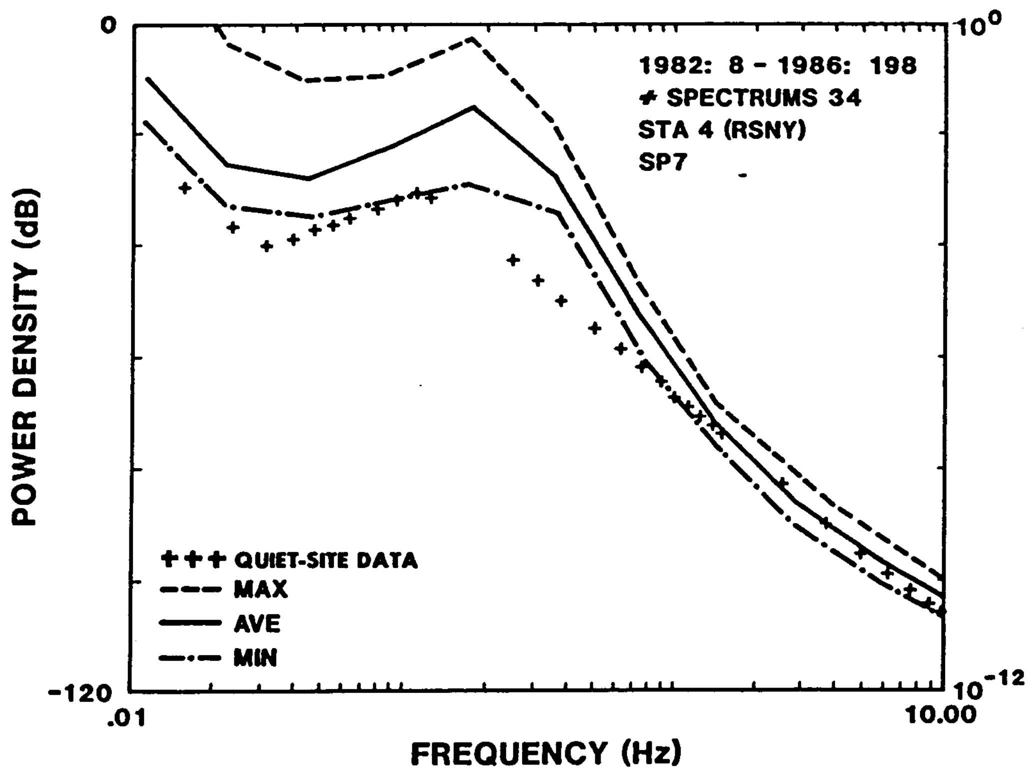


Figure A9. RSNY History Data, Horizontal North

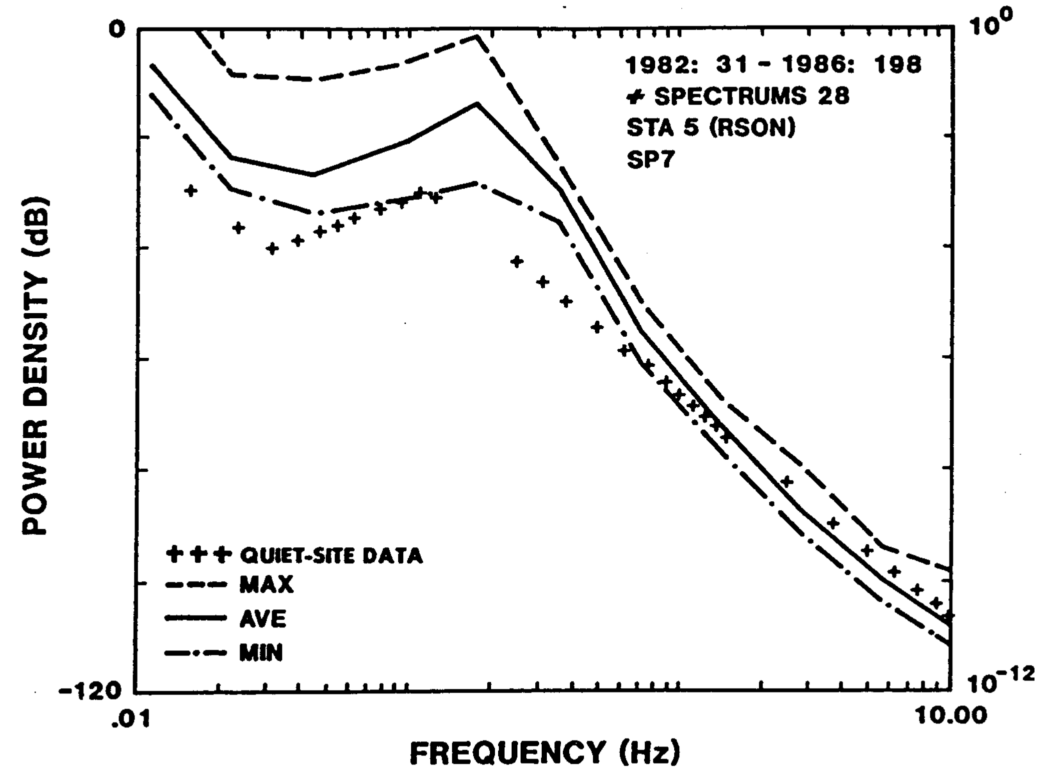


Figure A10. RSON History Data, Horizontal North

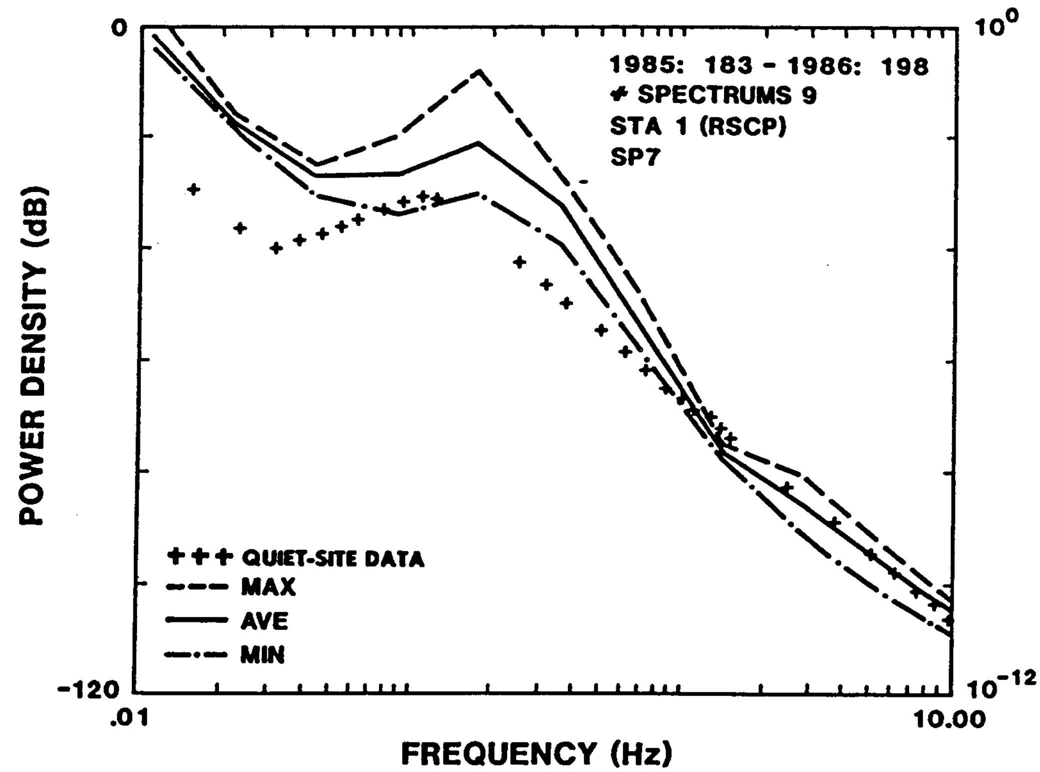


Figure A11. RSCP History Data, Horizontal East

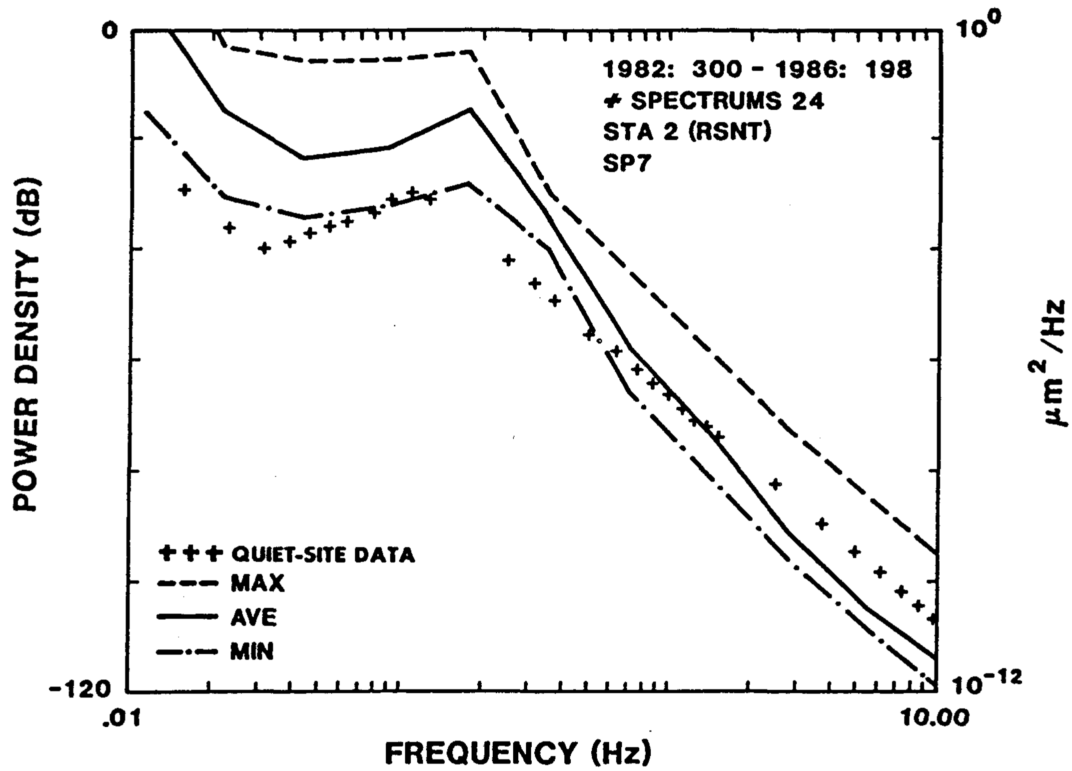


Figure A12. RSNT History Data, Horizontal East

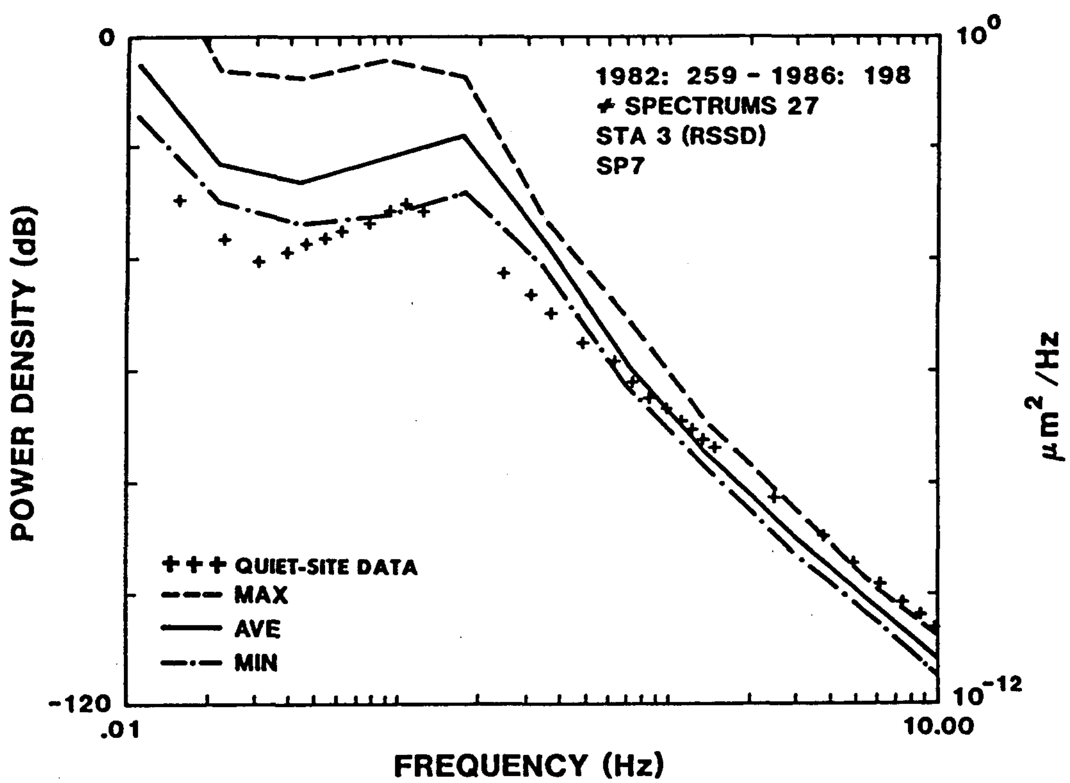


Figure A13. RSSD History Data, Horizontal East

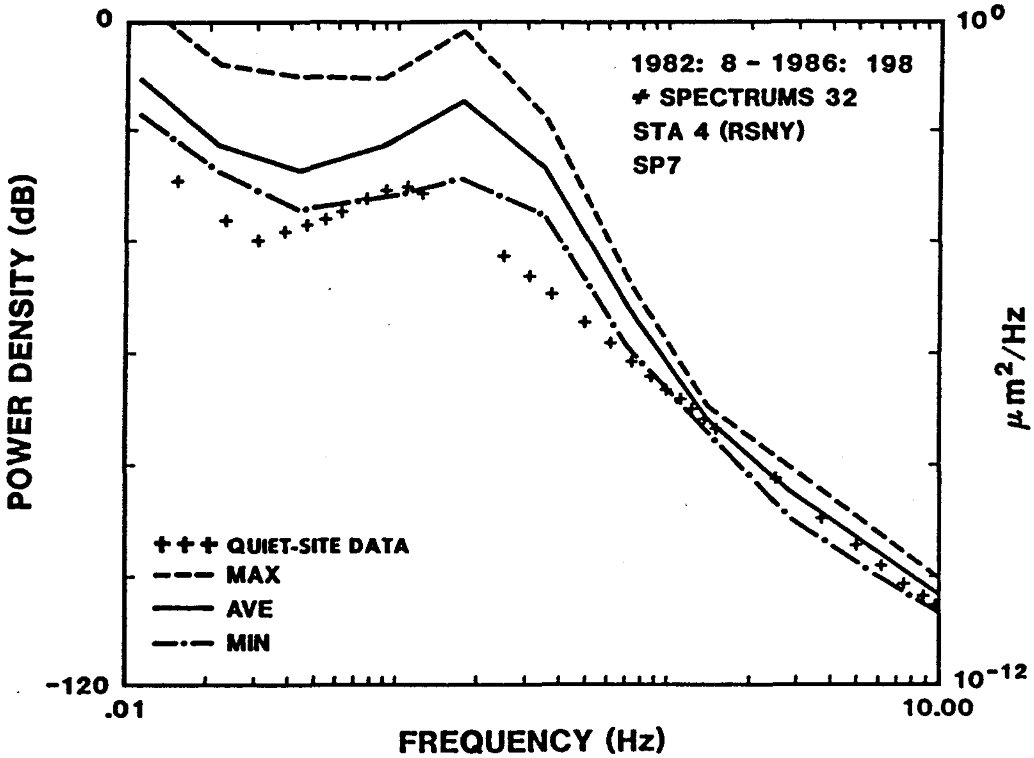


Figure A14. RSNY History Data, Horizontal East

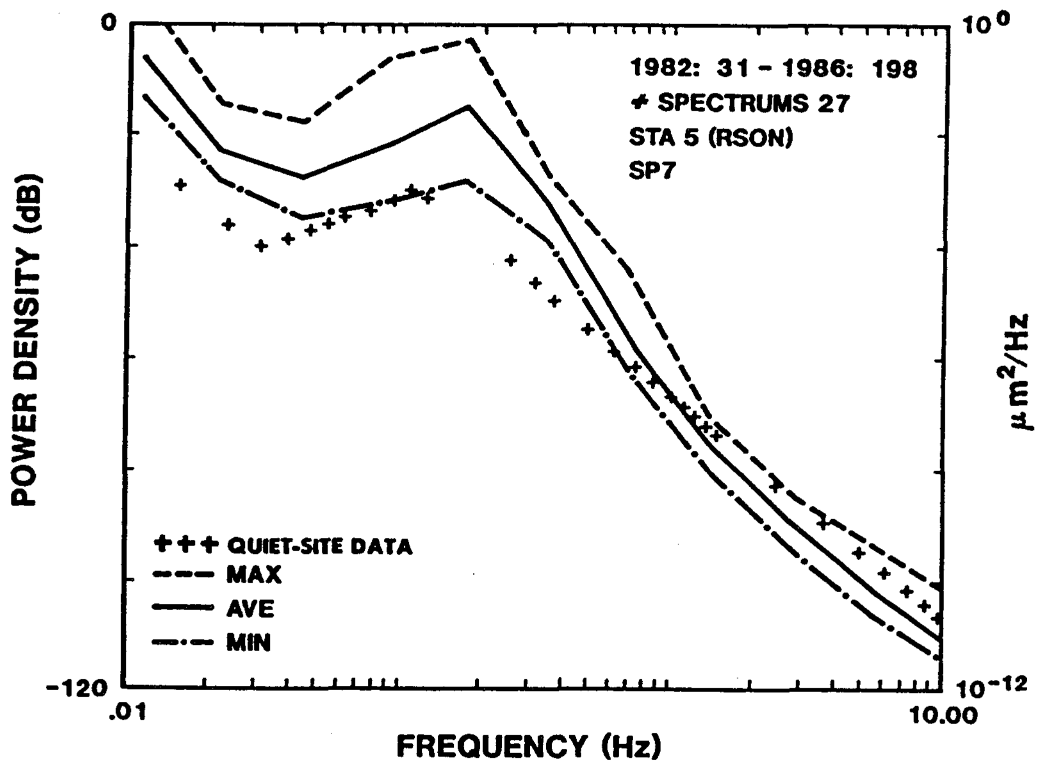


Figure A15. RSON History Data, Horizontal East

APPENDIX C

REGIONAL SEISMIC TEST NETWORK REPORTS

C.1 Tape Archiving
Jim R. Payne, EG&G Kirtland Operations, March 1983

C.2 Experience with RSTN Tape Archiving at SCARS
Sally J. Harrer, EG&G Kirtland Operations, March 1986

C.3 Satellite Interruptions
Jim R. Payne, EG&G Kirtland Operations, March 1983

C.4 Sun Transit Outages
Bobby Corbell, Sandia National Laboratories, June 1983

C.5 RSTN Engineering Evaluation
B. Dean Pershall, Sandia National Laboratories, January 1988

C.6 A/D Converter Failures
Dale R. Breding, Sandia National Laboratories, June 1984

C.7 Summary of Corrections Needed for Accurate Backazimuth Estimation Using Regional Seismic Test Network Data
K. K. Nakanishi and S. P. Jarpe, Lawrence Livermore National Laboratory, October 1988

C.1 TAPE ARCHIVING

Jim R. Payne, EG&G Kirtland Operations, March 1983

This was extracted from the Regional Seismic Test Network Quarterly Report, January - March 1983, EGG-10282-6001, pages 14-15, with permission of the author.

TAPE ARCHIVING

An action item created at the January 1983 RSTN Technical Committee meeting was to look into archiving RSTN data tapes.

Several sources were consulted on the matter, including Sandia and Vela Seismological Center (VSC). VSC is presently archiving RSTN tapes and has provided written reports on how to reliably archive magnetic tapes.*

Information from the reports and local sources had several recommendations in common that will affect the archive tape reliability. They are as follows:

1. Use a good quality recording tape.
2. Store tapes in a controlled temperature and humidity environment.
3. Store tapes in proper canisters or tape bands.
4. Clean and calibrate tape machines often.
5. Make sure there are no extraneous radio frequencies or magnetic fields in the storage area.
6. Control tension on tape machines during rewind.
7. Rewind archived tapes periodically to reestablish stacking tension.
8. Avoid recording on the first 100 meters of the tape.

The above recommendations are effective for archival periods of 4 to 6 years.

The reports contained other recommendations for long periods of storage (30 years), the implementation of which would be more difficult. Those recommendations require the use of special recording tape, difficult to manage tape creation procedures, and a shielded vault with an air filtration system.

SCARS always has followed most of the recommendations presented in these reports. The ones not implemented are #7 and #8. SCARS has now begun a procedure for rewinding the tapes on a yearly basis using the magnetic tape cleaner/inspector machine in the archive rewind mode, taking care of recommendation #7. Recommendation #8 would be difficult to implement. SCARS physically cannot give up 100 meters on each tape.

The error detection technique and the data quality standards used in these reports are similar, but not exactly like the ones required for RSTN tapes. RSTN tape quality should be judged strictly on data recovery. Procedures are currently being followed that should allow data tapes to be archived for at least 4 years.

The oldest tape recorded at SCARS in the present multistation format was in 1980, day 45. An analtap was done on the tape when it was stored and an analtap was done exactly 3 years later. The recent analtap shows 36 more GMT gaps. All other information on the two reports is identical. Other tapes of the same vintage show similar results.

*The following people and agencies contributed information on tape archiving.

Cosby, P. A., Graham Magnetics Incorporated
Jones, Thomas L., Wolf Research & Development Corporation
Manly, William A., Cobaloy Company
McKenna, R. T., Goddard Space Flight Center
Petersen, J. M., Graham Magnetics Incorporated
Poland, William B. Jr., NASA/Goddard Space Flight Center
Prine, Gilbert E., Litton Industries
Slack, Maynard W., E. I. DuPont de Nemours & Company

C.2 EXPERIENCE WITH RSTN TAPE ARCHIVING AT SCARS

Sally J. Harrer, EG&G Kirtland Operations, March 1986

This was extracted from the Proceedings of the 1986 RSTN/NORESS Research Symposium, Conference 8604196, pages 300-301, with permission of the author.

EXPERIENCE WITH RSTN TAPE ARCHIVING AT SCARS

Sally J. Harrer
Verification Support
EG&G Kirtland Operations
Albuquerque, NM

The question of the quality of RSTN tape storage at SCARS occurred after a data request was made and only one of the three events could be copied. Two of the events were not completed because of the condition of the tapes necessary to fill the request. This prompted a discussion of the conditions under which the tapes were being stored and whether these were contributing to the difficulty in reading the data from the tapes.

An in-depth study was made concerning the incompleted data request. In the first case 14 tapes, covering the time in question, were reanalyzed and the results showed a definite pattern (4 good, 1 bad, 1 good, 1 bad, 2 good, 1 bad, 4 good). During this period of time the data was being collected on two magnetic tape drives. Thus the most logical conclusion is that one of the tape drives may not have been writing data properly onto tape.

In the second case, 23 tapes were reanalyzed and the results also showed a definite pattern (4 good, 1 bad, 3 good, 1 bad, 2 good, 1 bad, 3 good, 1 bad, 2 good, 1 bad, 4 good). During this period of time the data was being collected on four magnetic tape drives. This again suggests that one of the tape drives may not have been writing data properly onto tape.

Another study was performed to check if the condition of good tapes had changed during the course of time. One good tape, i.e. a tape that had no downhole gaps and no GMT gapes for each station, was selected from each quarter starting with 1981. The original analysis for 3 quarters of 1981 and 1 quarter of 1982 were not found; therefore, this study includes only 16 tapes. In this small sampling, 87.5 percent of the tapes remain in excellent condition. But it is important to note that the 12.5 percent tapes that have a problem are from earlier years, which may indicate that time, print-through, quality of tapes and/or cleaning and rewinding the tapes for archiving are factors in tape preservation. The results are as follows:

YEAR	NO. OF TAPES ANALYZED	NO. OF GOOD	NO. OF BAD
1981	1	0	1
1982	3	2	1
1983	4	4	0
1984	4	4	0
1985	4	4	0
Total	16	14	2

archiving are factors in preserving the tapes. The results are as follows:

YEAR	NO. OF TAPES ANALYZED	NO. OF GOOD	NO. OF BAD
1980	10	7	3
1981	12	9	3
1982	12	11	1
1983	12	10	2
1984	12	12	0
1985	12	12	0
1986	3	3	0
Total	73	64	9

As indicated in the studies above, problems do exist with the RSTN data tapes. In summary, some contributing factors are as follows:

1. TAPE DRIVE - Write current can be out of spec sufficiently to cause the tape not to be written at its optimum level. The tape drives do read back what they write, but they could be within the acceptable range and yet not strong enough for another tape drive to read.

2. PRINT-THROUGH - If a tape is rewound at a very high rate, thus causing a tight pack, or if a tape is hung on a rack for a prolonged period of time, that data from adjacent layers of tape tends to transfer to the next later, causing what is called "print-through."

3. DEFECTIVE TAPES - There was a period of time when the new tapes used at SCARS were not of the best quality and, as a result, many of the data tapes were unreadable or difficult to read.

4. ENVIRONMENT - In the uncontrolled environment under which we store our data tapes, time can be a factor in the quality of the data tapes.

Of course, there are some measures we could and do take to help prevent any loss of data from our tapes. In March 1983, a program was developed to test each tape for write and read ability, prior to any merged data being written onto the tape. Since January 7, 1983 we have been running each RSTN data tape through a special machine (Computer-Link) that cleans and rewinds the tapes for archiving. Prior to this we had been manually rotating each tape so that each one hung at a different position. But a very important measure which we are not currently addressing is the environment where RSTN tapes are stored; such a place where the temperature and humidity are controlled is not currently available at SCARS.

C.3 SATELLITE INTERRUPTIONS

Jim R. Payne, EG&G Kirtland Operations, March 1983

This was extracted from the Regional Seismic Test Network Quarterly Report, January - March 1983, EGG-10282-6001, pages 19-20, with permission of the author.

SATELLITE INTERRUPTIONS

All synchronous satellites undergo spring and autumn eclipses part of each day for a 46-day interval during the vernal and autumnal equinoxes. Although the satellite has ample battery backup for these periods, there is a cooling effect on the electronics, slightly affecting the satellite oscillators. Figure 4 shows the geometry of a geosynchronous satellite at equinox. During the last satellite eclipse on Westar III, SCARS had the pilot tracking loop (PTL) on the communications terminal (CT) disabled for the first few days and a power supply installed. This resulted in a higher than normal error rate during the eclipse. The power supply was removed, and the PLT was allowed to function normally for the remainder of the 46 days and the rest of the quarter. During normal operation with the PTL functional, the CT is designed to adjust for a ± 25 kHz shift in satellite oscillators. This seemed adequate and was proven by continous data recording capabilities at SCARS. The PTL concept will compensate for satellite eclipses in narrow band communications links.

A more serious, but briefer, interruption is the sun transit outage, which occurs when the pointing angles from a given earth station to the satellite and the sun are so near coinciding that both are within the earth terminal antenna beamwidth (see Figure 4). The shadow of the satellite is then falling near the earth terminal. The RSTN earth stations perceive the sun as a disc which is the source of extreme thermal noise. This perception of noise results in a reduction in the received carrier-to-noise ratio below the demodulator specifications, causing a total outage during the transit's maximum effect.

SCARS experienced a total outage on days 64, 65, 66, and 67. The outages occurred at 18:02Z to 18:10Z, 18:03Z to 18:09Z, 18:02Z to 18:09Z, and 18:02Z to 18:10Z. With the real-time and delayed data transmission design of the RSTN, all data were recovered through these periods with a net result of no lost data.

The equinoxes and the sun transit outage will have an effect on the receiving abilities at each site and SCARS during two different times of the year. A program is being developed to determine when RSTN data may be affected by these interruptions.

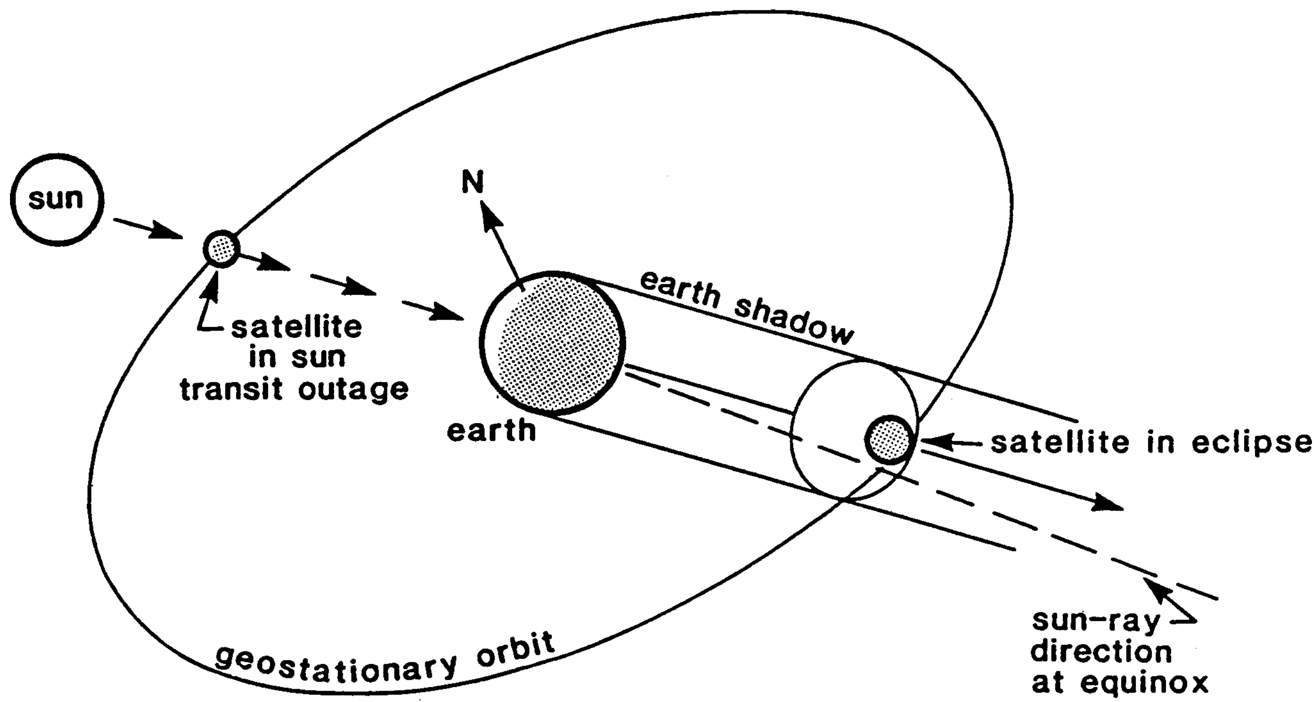


Figure 4. Geometry of a Geosynchronous Satellite Showing Sun Transit Outage and Eclipse Effect

C.4 SUN TRANSIT OUTAGES

Bobby Corbell, Sandia National Laboratories, June 1983

This was extracted from the Regional Seismic Test Network Quarterly Report, April- June 1983, (EGG-10282-6002), pages 36-39, with permission of the author.

Sun Transit Outages

When the pointing angles from a given earth station to the satellite and to the sun are such that both are within the earth terminal antenna beam width, a condition exists which is called sun transit outage. The sun is a source of extreme thermal noise to an r-f receiver. During the sun's transit through the earth terminal's antenna beamwidth, the noise received by the earth terminal increases. On the RSTN project, communication links are operated with low margins for link contaminates such as fading, scintillation, atmospheric conditions, sun transit outages, etc.

To examine the effects of sun transit outages on the RSTN system, data were studied for the spring of 1983. A system model was needed to model the sun transit. The system model used for calculations of the sun transit outages assumes the earth station antenna beam to be a cone with its vertex at a specified site and the vertex angle equal to the 3-dB beamwidth of the antenna at that site. Also, the sun is described as a disk with a normalized diameter equal to 0.267 degrees. A program developed by G. W. Hughes (Sandia Labs) finds the times of first and last contact of the sun's visible disk with the cone. The model is represented in Figure B-1.

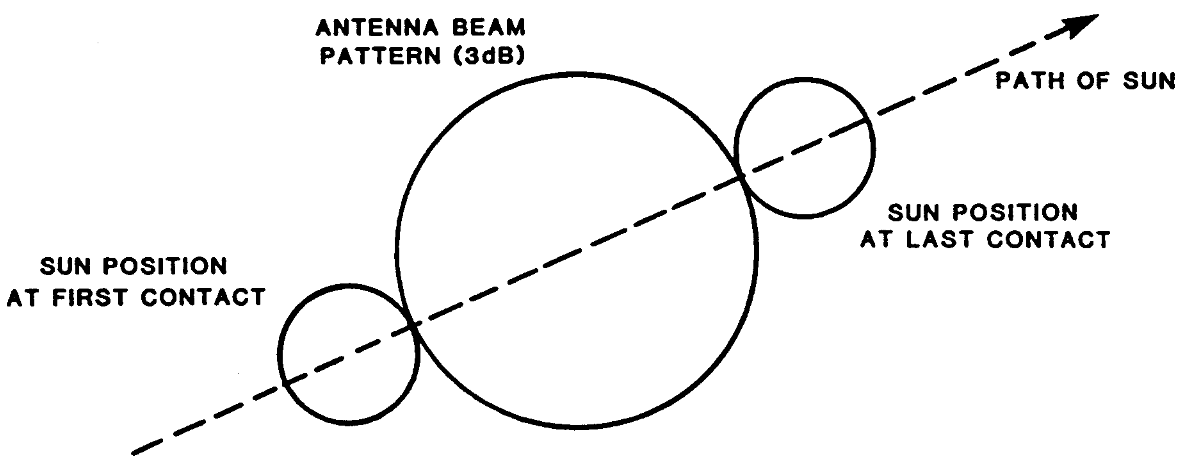


Figure B-1. Sun Transit Model

Table B-1 contains the dates, times of immersion and emersion, and durations of the sun transit for reception from SCARS. The statistics history through these times were examined for real-time and delayed data reception. RSCP, RSSD, and RSON were examined. The station stats were reviewed for periods of interference (unauthentication) and periods of data gaps in the real-time and delayed data streams. The periods of interference and gaps were averaged for the three stations each day. Table B-2 presents the predicted outage times, interference times, and data gap times.

Table B-1. Times of Sun's Immersion and Emersion as Seen from SCARS

YR	MON	DA	DAY	YRDAY	IMMERSION	EMERSION	DURATION
83	MAR	5	SAT	64	18:04:11	18:09:42	5:31
83	MAR	6	SUN	65	18:03:23	18:10:02	6:38
83	MAR	7	MON	66	18:03:23	18:09:33	6:10
83	MAR	8	TUE	67	18:04:26	18:08:01	3:34

Table B-2. Predicted Outage Times, Interference Times, and Data Gaps

DAY	PREDICTED[1]	INTERFERENCE[2*]		DATA GAP[3*]
64	5:31	D	5:27	3:54
		R	5:21	4:02
65	6:38	D	6:49	5:32
		R	6:44	5:45
66	6:10	D	6:49	5:49
		R	6:49	5:40
67	3:34	D	5:49	4:29
		R	5:51	4:33

[1]Predicted duration for sun transit outage.

[2]Duration around predicted times of unauthentication hits real-time (R) and delayed (D).

[3]Duration of gaps in real-time and delayed data.

*Average of RSCP, RSSD, RSON.

From Table B-2, the duration of sun transit outages predicted compare closely with actual system interference and data gaps in the real-time and delayed data streams for data being transmitted during the predicted universal coordinated time (UTC). The gap in delayed data was data with time approximately 15 minutes earlier. An example will demonstrate, using RSSD times:

DAY 65	IMMERSION	EMERSION
Predicted	18:04:11	18:10:02
INTERFERENCE		
Real-Time Data	18:03:03	18:04:39
Delayed Data	17:48:11	17:54:57

For days 64, 65, and 67, the sun transit outages were removed from the data as the merged tape was processed. The merged tape for day 66 did have data gaps during the time of predicted outages. The cause of the gaps on day 66 was that the PTL error voltage was changed suddenly for troubleshooting of RSNY.

As a summary, there are predictable outages due to the sun transit of the antenna beam. In the RSTN system, using delayed data allows for recovery of the data through these times.

Table B-3 gives predicted times of sun transit outages for SCARS, LLL, and DARPA receivers. The earth station coordinates for each site used in the calculations also are listed.

Table B-3. Fall 1983 Predicted Sun Transit Outages

SCARS	106° 32' 46" W	35° 3' 8" N
LLL	121° 42' 38" W	37° 41' 7" N
DARPA	77° 2' 29" W	38° 48' 49" N

YR	MON	DA	DAY	YRDAY	IMMERSION	EMERSION	DURATION
SCARS							
83	OCT	6	THU	279	17:40:55	17:46:10	5:15
83	OCT	7	FRI	280	17:39:58	17:46:32	6:34
83	OCT	8	SAT	281	17:39:49	17:46:08	6:19
83	OCT	9	SUN	282	17:40:35	17:44:48	4:13
LLL							
83	OCT	7	FRI	280	17:33:35	17:39:00	5:25
83	OCT	8	SAT	281	17:32:55	17:39:05	6:10
83	OCT	9	SUN	282	17:33:05	17:38:22	5:16
DARPA							
83	OCT	8	SAT	281	17:56:01	18:01:57	5:56
83	OCT	9	SUN	282	17:55:41	18:01:43	6:01
83	OCT	10	MON	283	17:56:16	18:00:35	4:19

C.5 RSTN ENGINEERING EVALUATION

B. Dean Pershall, Sandia National Laboratories, January 1988

This was extracted from the RSTN Engineering Evaluation Report, with permission of the author.

RSTN Engineering Evaluation

Introduction

The five RSTN Data Delay Units (DDU) have surpassed all design objectives for field operation. On the average, each DDU has accumulated over 5.5 years of operating time. During this time, none of the DDUs have experienced a hardware failure requiring module repair or replacement. All bubble anomalies have been attributable to soft errors, nearby lightning strikes, or below-limit (0°C) operating temperatures, and have served to verify the versatility of the controlling software.

Original Design Objectives

A unit was required to preserve in electronic memory 15 minutes of data to compensate for 95% of the disruptions in data transmission via the satellite data links. A 3-year maximum lifetime with a 1-year MTBF was desired, and the DDU memory had to be nonvolatile as well as have a high bit density. The DDU operating temperature range was specified to be 0°C to 50°C. A secondary goal was to evaluate the usefulness of Magnetic Bubble Memories for space, defense, etc., applications.

Data Storage Statistics

The following table depicts the total operating hours accumulated and the total number of data bits stored per remote station effective August 31, 1986.

Station Name	Operating Hours	Total Number of Bits Stored
RSCP	55,818	482,267,520,000
RSNT	37,171	321,157,440,000
RSSD	43,783	378,285,120,000
RSNY	45,387	392,143,680,000
RSON	40,082	346,308,480,000
TOTAL	222,241	1,920,162,200,000

Since August 31, 1986, the five stations have accumulated an additional 26,680 operating hours, effective December 31, 1987. This represents an additional 227,059,200,000 bits stored, providing a grand total of 2,147,221,400,000 bits stored by the five stations. Combining the total operating hours with the additional hours reveals that each DDU has operated for an average of 5.68 years with no failures.

Data Anomalies

All the DDU data anomalies have been induced by nearby lightning strikes, soft errors, or below-limit operating temperatures. Bubble memories are sufficiently sensitive to electromagnetic interference that a nearby lightning strike during a bubble write/read operation can cause one or more sync word failures. Six such failures cause a bubble memory to be taken off-line. Another cause of these anomalies is the tendency of these particular bubble memories (Western Electric) to have "soft errors", i.e., one bit out of a million could be in error and could occur during the sync word often enough to cause or contribute to one or more sync word failures. Finally, a seemingly prevalent source of these anomalies was someone leaving the vault door open during cold weather long enough to lower the DDU temperature below (sometimes well below) the minimum recommended operating temperature, causing bubble after bubble to be taken off-line. In each case, the bubble memory taken off-line was subjected to an automatic self-test, passed the test, and was reinstated for further use.

Redesign Recommendations

The design goals for a redesigned DDU would remain essentially unchanged except that today's technology would allow a much wider operating temperature range. Also, experience has taught us that magnetic bubble memories are not the most practical choice compared to the currently available memory devices due to the magnitude of electronics required to drive bubble memories and the subsequent power required. Considering the memory capacity available today, CMOS RAM would be the optimum choice, and battery backup would provide nonvolatility. Furthermore, the length of delay could be increased as required. The removal of the narrow operating temperature range and the use of denser and faster memories would allow a much simpler DDU design. Hence, the entire DDU should fit on three or no more than four logic boards and should require only a small fraction of the power consumed by the original unit. Active redundancy is then a viable alternative. Switching between redundant units could be accomplished by built-in logic detecting a predetermined number of consecutive ones or zeros. If, however, there is command capability, switching could be accomplished remotely.

C.6 A/D CONVERTER FAILURES

Dale R. Breding, Sandia National Laboratories, June 1984

This was extracted from the Regional Seismic Test Network Quarterly Report, April - June 1984, (EGG-10282-6009), pages 42-47, with permission of the author.

A/D CONVERTER FAILURES

In routine operations in SCARS a DC offset voltage was observed in Station 3 (RSSD) MPZ and LPZ bands (see RSTN Quarterly Report, April 1984, EG&G-10282-6008). In a closer investigation, it was found to have occurred on 83:234 (see Figure B-1). On day 84:150 a series of calibrations was sent to analyze this offset. Figure B-2 reveals that as the gain decreases the offset increases.

Table B-1 lists the values scaled from Figure B-2.

Table B-1. Station 3 (RSSD) MPZ & LPZ

Gain Range Level (Volts)	Gain Range	RSSD Offset (Volts)
	X 128	.0037 (Figure B-1)
.0819	X 32	.015
.327	X 8	.06
1.31	X 1	.5

From the above information it was concluded that the offset was at the input to the A/D converter on the DHL 43 card. Figure B-2 also shows an irregular (non-smooth) signal on the positive sides of the calibration signals.

During the week of 11 June 1984 a crew was at RSSD and replaced the DHL 43 card. This fixed the offset problem, and RSSD operation was normal on 15 June 1984.

Follow-up measurements on the DHL 43 returned from RSSD revealed:

- A slight sensitivity change, from 10 micro-volts/count to 9.53 micro-volts/count.
- An offset of .467 volts internal to the A/D converter chip.

This .467 volt offset appears as different levels on each gain range because the de-range formula, Figure 2.8 in the Data User's Guide, reflects it back to the input of the DHL 43 card.

Since this offset was not severe, 5 percent of full-scale, the de-range formula in SCARS could have been changed to take it into account. Therefore, in an NSS situation the downhole electronic package could have been changed at the next regular maintenance visit. The only penalties would be for the sensitivity change, also 5 percent, and a 5 percent full-scale decrease for large amplitude signals before saturation.

Offset data and calculations for RSNY are as follows:

Table B-2. Station 4 (RSNY)
MPN & LPN

Gain Range Level (Volts)	Gain Range	RSNY Offset (Volts)*	RSNY Offset (Volts)**
	x 128	.0222	.0222
.0819	x 32	.0888	.08
.327	x 8	.3552	.3
1.31	x 1	2.84	2.5

*Calculated from .0222 volts and gain range changes 4, 16, 128.
Note from RSSD: 0.0037 x 128 = 0.4736 volts.
**Scaled from the offsets observed in Figure B-3.

Based on these data we expect a 2.84 volt offset in RSNY during the follow-up analysis after we retrieve the DHL-43 from NY. This is scheduled late in July.

The combined operational hours of all the A/D converters used in the RSTN is 658,320 hours. These two offset failures are the only noted failures during that time.

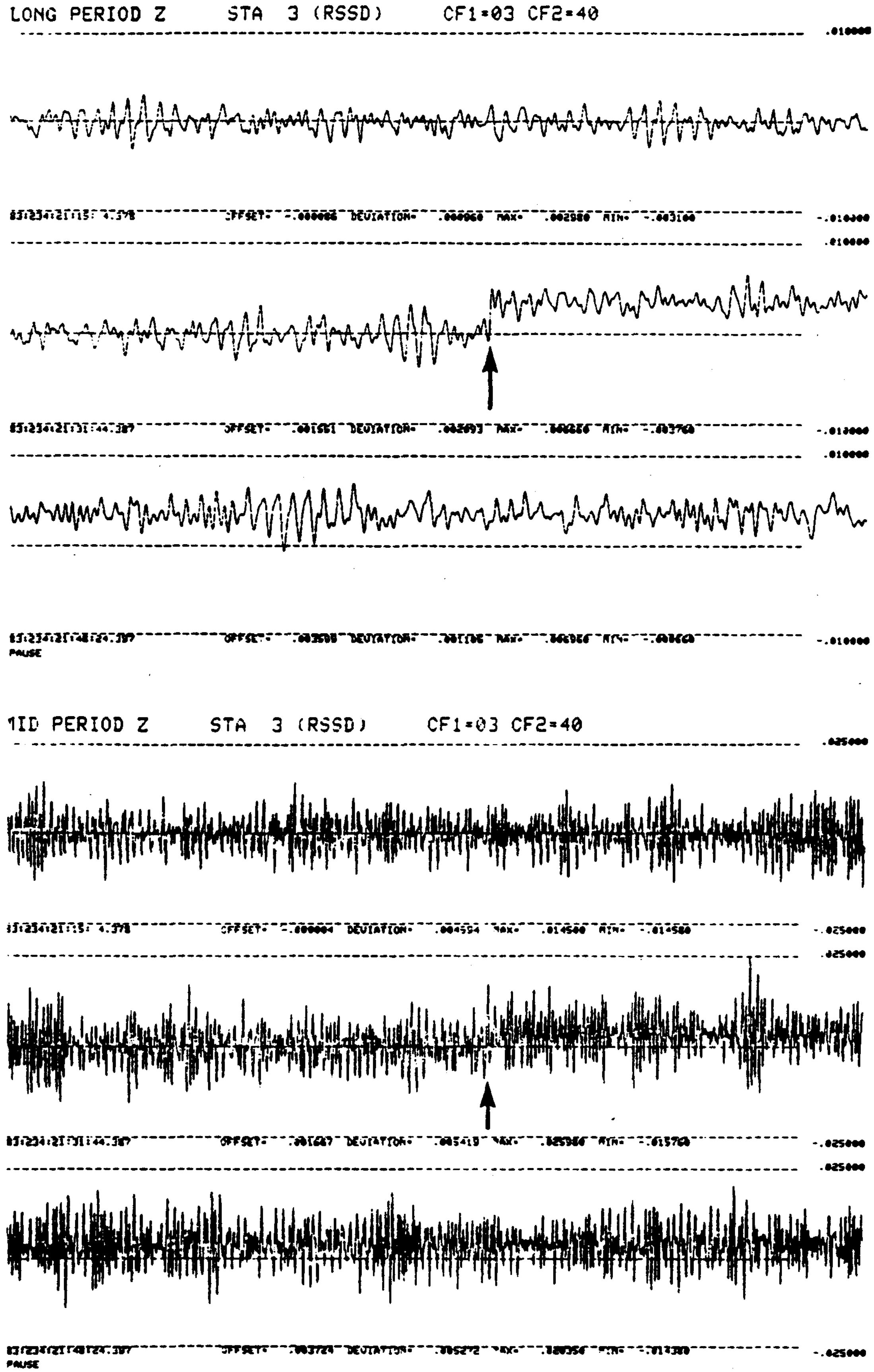


Figure B-1. RSSD Time Series Plots

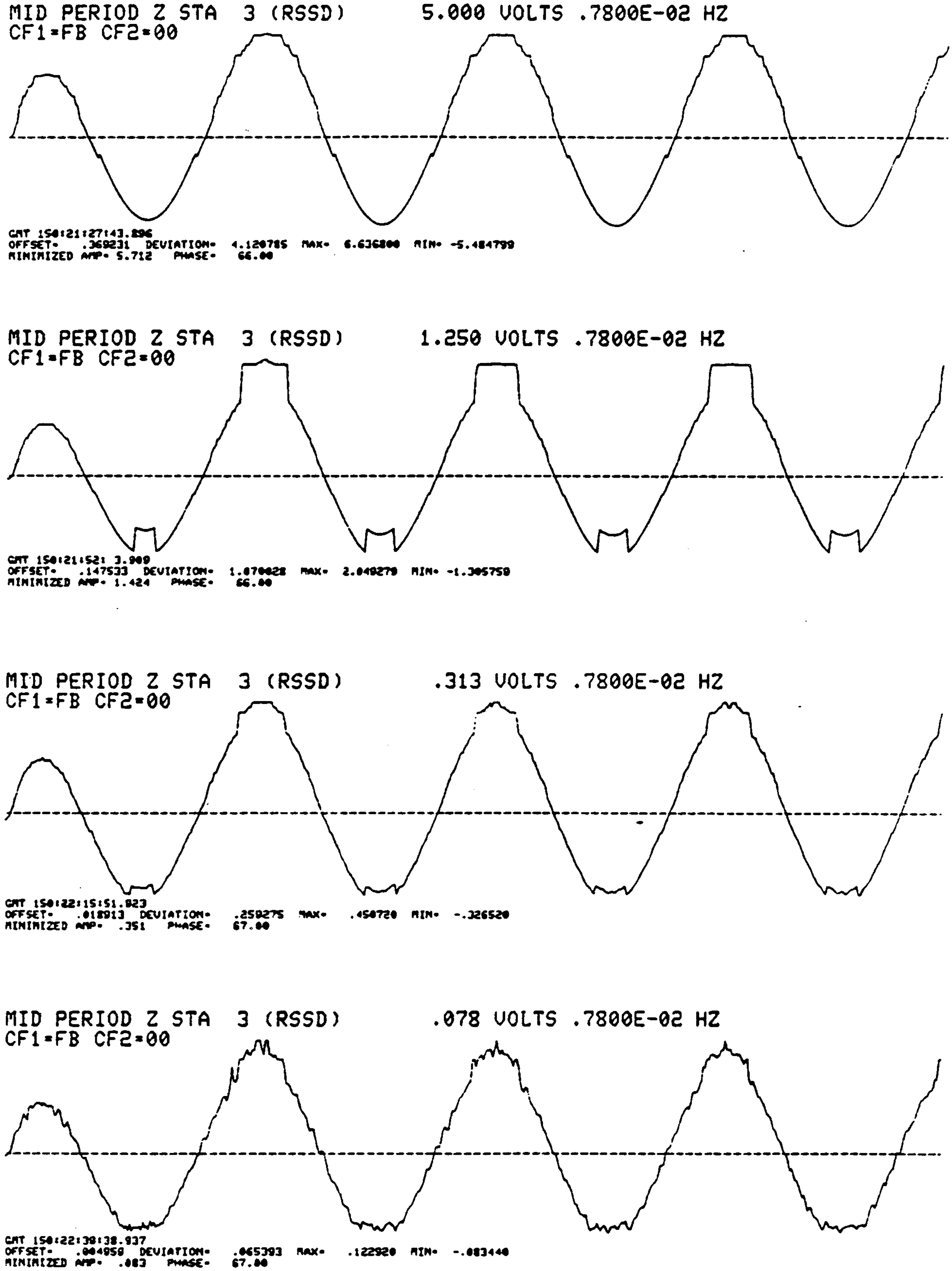
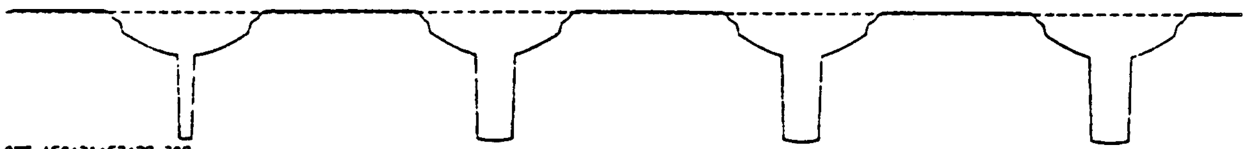


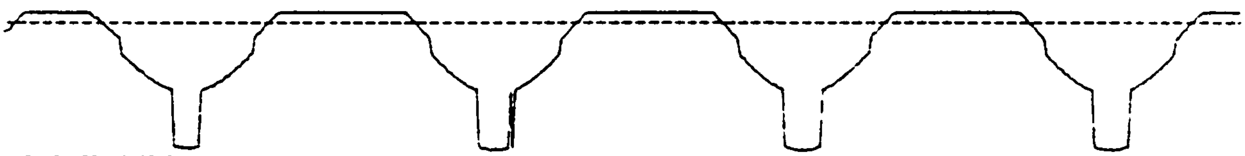
Figure B-2. RSSD Calibration Plots

MID PERIOD N STA 4 (RSNY) 1.250 VOLTS .7800E-02 HZ
CF1=FB CF2=00



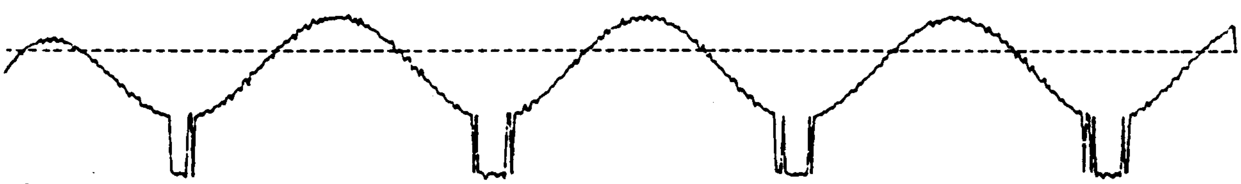
GMT 150:21:52:39.309
OFFSET= -.710351 DEVIATION= 1.171547 MAX= .051010 MIN= -3.879680
MINIMIZED AMP= 1.230 PHASE= 66.00

MID PERIOD N STA 4 (RSNY) .313 VOLTS .7800E-02 HZ
CF1=FB CF2=00



GMT 150:22:16:27.314
OFFSET= -.128351 DEVIATION= .214025 MAX= .050980 MIN= -.617760
MINIMIZED AMP= .268 PHASE= 66.00

MID PERIOD N STA 4 (RSNY) .078 VOLTS .7800E-02 HZ
CF1=FB CF2=00



GMT 150:22:40:13.321
OFFSET= -.030627 DEVIATION= .055675 MAX= .046290 MIN= -.158200
MINIMIZED AMP= .068 PHASE= 66.00

Figure B-3. RSNY Calibration Plots

C.7 SUMMARY OF CORRECTIONS NEEDED FOR ACCURATE BACKAZIMUTH ESTIMATION USING REGIONAL SEISMIC TEST NETWORK DATA

K. K. Nakanishi and S. P. Jarpe, Lawrence Livermore National Laboratory, October 1988

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SUMMARY OF CORRECTIONS NEEDED FOR ACCURATE BACKAZIMUTH ESTIMATION USING REGIONAL SEISMIC TEST NETWORK DATA

BY K. K. NAKANISHI AND S. P. JARPE

The Regional Seismic Test Network (RSTN) was developed and operated by Sandia National Laboratories (SNL) for the U.S. Department of Energy to provide an engineering test of the National Seismic Station (Stokes, 1982). RSTN consisted of five single borehole, broadband, three-component stations providing well-calibrated continuously recorded digital data. The five stations were located in the eastern United States and Canada (Fig. 1). RSTN data were recorded in three frequency bands; a long-period band covering 0.015 to 0.055 Hz, a mid-period band covering 0.05 to 1.0 Hz, and a short-period band covering 1.0 to 10 Hz.

The RSTN was operational for approximately 4 yr between 12 September 1982 and 30 September 1986. Although primarily designed as an engineering testbed, the RSTN provided extremely reliable and high-quality data that has been extensively used by the seismic community. Most of the RSTN stations continue to operate under the administration of the U.S. Geological Survey.

The purpose of this letter is to consolidate previously unreported corrections and characteristics of the RSTN that may affect the accuracy of backazimuth estimations. These variations also affect wave polarization studies and attempts to decompose wave fields into their components of motion. We will report on the deviations of actual instrument response from the nominal response and variations in the orientations of the seismometer packages that have been found during the evaluation of RSTN.

VARIATIONS FROM THE NOMINAL RESPONSE

SNL conducted periodic calibrations of the instruments, and thus the responses of the RSTN instruments are well known. Results are published by EG&G, Inc. (1982) in the RSTN Quarterly Reports. For the long- and mid-period bands, four of the stations match the nominal response as published in Breding (1983). The RSCP long- and mid-period responses before 13 May 1985 were different from the other RSTN stations and can also be found in Breding (1983). A comparison of the calibration information indicates that the responses of all of the long- and mid-period instruments changed very little between September 1982 and September 1986. There are, however, several significant variations from the nominal responses of the short-period instruments.

There are two sets of three-component seismometers which provide data in the short-period band. Either a Teledyne Geotech KS36000 or a Teledyne Geotech S750 was used to supply short-period data. For RSCP before May 1985, only the KS36000 was used in the short-period band. The polarities of all of the S750 seismometers with the exception of the east component of station RSON are reversed. Table 1 summarizes the polarity and amplitude information; a positive number indicates no polarity reversal, and a negative number indicates a reversal.

For the short-period band, the actual response of the KS36000 vertical component at RSNT is 0.85 that of nominal and that of the KS36000 north component at RSON is 0.5 that of nominal. Backazimuth estimation using raw, uncorrected short-period data may result in significant errors in the estimate. Figure 2 illustrates the

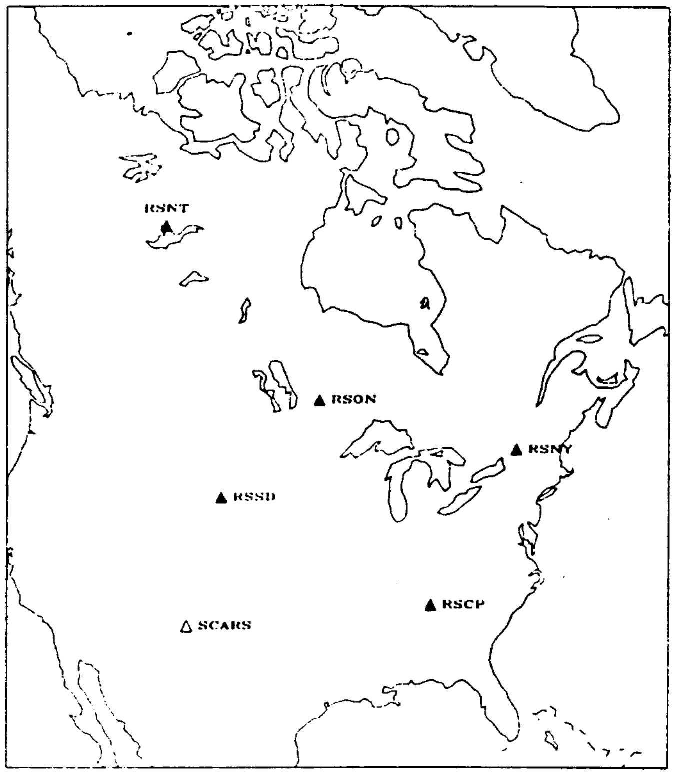

FIG. 1. Map of the RSTN station locations along with Sandia's System Control and Receiving Station (SCARS).

TABLE 1

POLARITY AND ACTUAL AMPLITUDE AS COMPARED TO NOMINAL RESPONSE

Station-Component	LP KS36000	MP KS36000	SP KS36000	SP S750	SP S600
CP-Z	+1	+1	+1	−1	
CP-N	+1	+1	+1	−1	
CP-E	+1	+1	+1	−1	
CP-Z					+1
CP-N					+1
CP-E					+1
NT-Z	+1	+1	+0.85	−0.8	
NT-N	+1	+1	+1	−0.75	
NT-E	+1	+1	+1	−1	
SD-Z	+1	+1	+1	−1	
SD-N	+1	+1	+1	−1	
SD-E	+1	+1	+1	−1	
NY-Z	+1	+1	+1	−1	
NY-N	+1	+1	+1	−1	
NY-E	+1	+1	+1	−1	
ON-Z	+1	+1	+1	−0.85	
ON-N	+1	+1	+0.5	−0.9	
ON-E	+1	+1	+1	+1	

A negative number indicates a reversal in polarity. Values are ratio of actual peak amplitude to nominal amplitude. A value of "±1" means that the magnitude of the response was within 4 per cent of nominal.

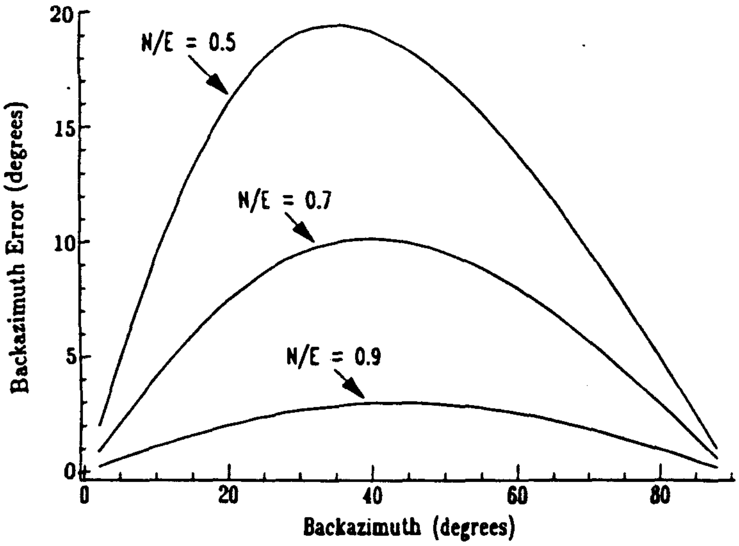

FIG. 2. Error in backazimuth estimation as a function of true backazimuth for uncorrected mismatches in amplitude response for the horizontal components. *N/E* values are ratios of the actual amplitude response values for the horizontal components.

backazimuth error as a function of backazimuth for various mismatches in horizontal component responses. For the case of data recorded on the RSON KS36000 seismometer, if an event is actually at a backazimuth of 40°, a backazimuth estimate using uncorrected data would be in error by as much as 20°.

The only instrument that varied significantly over time is the RSNT short-period north component using the S750 seismometer. Calibration records show that the amplitude response was 0.65 of nominal from its first date of operation to 31 March 1983 when, during repair at Albuquerque, SNL changed the response to 0.9 of nominal. There is no calibration information available from the third quarter of 1984 to the third quarter of 1985, when the calibration indicated a response of 0.75 of nominal. It is possible that the response changed during the first quarter of 1985, when several repairs to the RSNT downhole package were performed.

BACKAZIMUTH ERRORS FROM INSTRUMENT PACKAGE MISORIENTATION

Independent observations by T. Owens (personal communication), J. Carter (personal communication), R. Baumstark (personal communication), and ourselves indicated that significant systematic backazimuth errors were found when using data from RSNY. In August 1986, a field crew from SNL, EG&G, and Holmes & Narver extracted the downhole package from RSNY and resurveyed the holelock. RSNY was found to be rotated 17° clockwise (to 17° E of N). The downhole package was reoriented on 21 August 1986.

In order to see if the other RSTN stations were aligned correctly, we performed two kinds of tests. In the first test, we looked at the backazimuth estimates from large teleseisms and compared them to the backazimuths computed from their known locations. For the second test, we compared the backazimuth from the downhole package to the backazimuth for the same event determined from portable seismometers located near the wellhead. In the case of RSNT, we used data from the Yellowknife array. We found that all of the RSTN stations were oriented within one or two degrees of the true direction with the exception of the above mentioned RSNY.

Our experience from these tests suggests that the most desirable way to seismically verify the orientation of a downhole seismometer package is to perform the uphole-downhole test using large teleseismic sources. A more easily accomplished test, which we have also found to be suitable, is to compare estimated and geometric backazimuths for large teleseisms from several different directions. A possible drawback of this method is that earth structure could deflect the incoming seismic waves from their expected path, but we have not encountered this problem with the RSTN stations.

SUMMARY

In the course of evaluation and validation of the RSTN as a possible in-country seismic monitoring network, several corrections were needed for computing backazimuths. We have summarized the departure of actual from nominal instrument response, and indicated the amount of error in backazimuth estimates that could result from these departures. Finally, we have verified the orientation of the downhole seismometer packages using seismic means. The previously announced misorientation of RSNY was confirmed by survey and corrected.

ACKNOWLEDGMENTS

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