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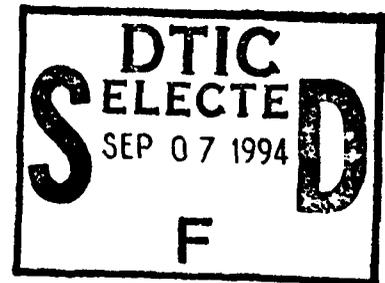
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PL-TR-94-2106

**DESIGN, EVALUATION, AND
CONSTRUCTION OF TEXESS AND
LUXESS, AND RESEARCH IN MINI-ARRAY
TECHNOLOGY AND USE OF DATA
FROM SINGLE STATIONS AND SPARSE
NETWORKS**

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October 1993

Scientific Report No. 1

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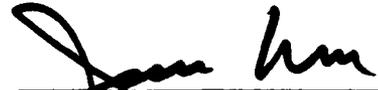
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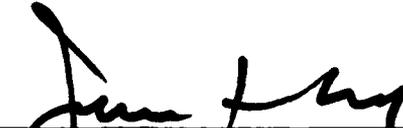
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This technical report has been reviewed and is approved for publication.



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13. ABSTRACT (Maximum 200 words) Objectives are: (1) conduct research in seismic mini-array technology and use of data from single stations and sparse networks, and (2) design, evaluate and construct 2 mini-arrays - TEXESS (Texas Experimental Seismic System) in southwest Texas and LUXESS (Luxor Experimental Seismic System) which is northeast of Luxor, Egypt. TEXESS was installed by SMU personnel in August 1993. The array consists of 9 sensor sites, which include a central 3 component, short-period seismometer installation in a vault at the hub, and 8 vertical short-period seismometer installations in boreholes. In addition to the short-period instrumentation at the hub, a posthole KS 54000 long-period seismometer, owned by SMU, was installed in a shallow borehole. Advancements include: 1) placement of seismometers and electronics in boreholes to reduce pier and vault construction costs; 2) solar power at each site rather than a central-power source; 3) GPS receivers for time data at each seismometer site to replace central timing from the Hub; 4) radio links from seismometer sites to the Hub to replace cable links and associated construction costs; 5) modular equipment to facilitate the installation and maintenance of the array. <p style="text-align: center;">DTIC QUALITY INSPECTED 3</p>			
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SUMMARY

Personnel contributing to this contract are: (1) Dr. Eugene Herrin, Principal Investigator, (2) Paul Golden, Project Director, (3) Karl Thomason, Chief Engineer, (4) Nancy Cunningham, Director - Computer Laboratory, (5) David Anderson, Systems Analyst, (6) Dyann Anderson, Administration, (7) Dick Arnett, Consultant, (8) Herbert Robertson, Consultant, and (9) Jack Swanson, Consultant. Ph. D. students include: (1) Chris Hayward, (2) Relu Burlacu, and (3) Zenglin Cui. Dick Kromer of Sandia Laboratory assisted in specification-verification tests at TEXESS.

Objectives

Objectives of the contract are twofold: (1) to conduct research in seismic mini-array technology and use of data from single stations and sparse networks and (2) to design, evaluate, and construct two mini-arrays, TEXESS (Texas Experimental Seismic System) in Southwest Texas and LUXESS (Luxor experimental Seismic System), which is northeast of Luxor, Egypt. These two tasks are dubbed CLIN 1 and CLIN 2.

CLIN 1 objectives are to: (1) conduct research in the use of single station and sparse network data in detecting and identifying small seismic events, (2) conduct research to develop optimum configurations and processing techniques for a nine-element mini-array, and (3) to continue development of an unmanned intelligent seismic station.

CLIN 2 objectives are to: (1) acquire hardware and software, (2) install TEXESS, (3) perform site surveys and choose location for LUXESS, (4) test TEXESS and perform verification tests prior to de-installation, (5) de-install TEXESS, (6) complete civil work in Egypt, (7) install and test LUXESS, (8) de-install data acquisition, analysis and archiving equipment and ship to Helwan, Egypt, data center, and (9) install and test data acquisition, analysis and archiving equipment and ship to Helwan data center.

Technical Problem

The German Experimental Seismic System was dedicated in 1992 and represents an upgrade for regional arrays. Although GERESS was technologically advanced over NORESS and ARCESS, which were earlier regional arrays, because of greater sensitivity and wider dynamic range, there was a considerable effort that resulted in increased costs for pier and vault construction and trenching for power cabling. Now in TEXESS, there are innovations in emplacement techniques, which include the installation of sensors in shallow boreholes instead of vaults and the use of solar power at each site to eliminate cabling from a central-power source, incorporated in TEXESS have reduced array-installation costs by an order of magnitude. TEXESS is, therefore, a proposed design for a GSE-Alpha station because of these cost-cutting innovations. In addition to design, construction, installation, and operation, of TEXESS, research will be undertaken to develop new means of taking data and handling the data.

General Methodology

In GSE/US/84, February 1993, entitled "Technical Concepts for an International Data Exchange System," the GSE established the design goals of a future system. Goals are as follows:

1. Provide *prompt* access to all *essential* data
2. Provide *convenient* access to all *available* data
3. Provide direct access to all data at authorized national and global facilities
4. Accomplish goals with realistic manpower and budget resources.

The new concept of a global system for data exchange calls for an Alpha Network of 40-60 stations, primarily arrays; plus much greater than 60 Regional or Beta Stations; plus Local and National Networks or Gamma Stations.

SMU began research on mini-array technology in 1991 on a previous contract. The proposed design was along the lines of an Alpha Station consisting of an array containing nine sites. Advancements over the GERESS design included the following:

1. The placement of seismometers and electronics in boreholes to greatly reduce construction costs for piers and vaults
2. The use solar power at each site rather than a central-power source
3. The use GPS receivers for time data at each seismometer site to replace central timing from the Hub,
4. The employment of radio links from seismometer sites to Hub to replace cable links and associated construction costs
5. The use of modular equipment to facilitate the installation and maintenance of the array.

Four shallow boreholes about 7 meters deep and 11-5/8-in. in diameter were drilled and cased with standard 8-in. pipe. Special equipment and techniques were developed to lower and level seismometers in the boreholes. A prototype solar power array and directional antenna were also developed for installation at LTX.

Technical Results

The limited program described above was successful and SMU was granted on 26 April 1993 Contract No. F19628-93-C-0057 to design, evaluate, and construct two nine element experimental mini-arrays: TEXESS and LUXESS.

Important Findings and Conclusions

The SMU mini-array research program that was begun in 1991 under the previous contract proved the feasibility of the proposed design and methodology described above.

Significant Hardware Development

Preliminary research has led to the following hardware developments:

1. The development of seismometer emplacement techniques in boreholes, including remote seismometer locking and closed circuit video monitors to ensure leveling eliminated the need for vaults

2. Advancements in computer applications and radio modems allow all necessary electronic components to fit inside a 8-in. casing to provide physical protection and a more stable environment for the electronics
3. The use of Global Positioning Satellite (GPS) receivers to obtain timing accurate to within 20 μ s of world time assuring time synchronization of the array
4. The use of modern digital radio modems allows the system to perform as a local area network referred to as a RAN (Radio Area Network); radio polling software provides wide bandwidth intra-array communications while requiring two base-station radios; the need for expensive buried fiber-optic cable is eliminated
5. A NEMA enclosure is mounted on top of the borehole and is used to house the batteries and as a mount for the solar-power array; the GPS receiver and radio antenna are mounted above it.

Special Comments

The task of adapting the solar-panel arrays at Lajitas to the LUXOR environment is simplified somewhat in that both TEXESS and LUXESS are at approximately the same latitude, 30 deg North; both are in arid climatic zones; and both have about 3,500 annual hours of sunshine. As a result, there would be no need to modify the prototypic TEXESS design because of differing environmental conditions at LUXESS.

Implications for Further Research

Previous studies indicate a needed for: (1) research to develop optimum configurations and processing techniques for a nine-element short-period array, (2) research in discrimination of nuclear events using autoregressive (AR) modeling techniques on Lg data, and (3) research in measuring 20-second Rayleigh waves at regional distances using high-resolution, wide-dynamic-range, short-period, seismic-array data and broadband KS 36000 data.

CLIN 1 -- RESEARCH

Array Research

Conduct research to develop optimum configurations and processing techniques for a nine-element short-period array,

Azimuth estimates for regional events recorded at GERESS show standard deviations of the order of ± 15 degrees using RONAPP processing as part of the IMS. This scatter is surprisingly large and, in fact, is comparable to the azimuth scatter for a single 3- component station. An array with an aperture of 4 km should provide much more precise estimates of azimuth, perhaps with standard deviations of a few degrees. This level of precision will be required before calibration techniques can be used to determine azimuth bias related to horizontal refraction.

For a sparse array, say 9-elements, with an aperture similar to GERESS, beam forming or f-k methods such as those used in RONAPP can be expected to produce even more scatter in azimuth estimates. We have begun the development of array processing techniques similar to those described by Bernard Massinon in his description of a proposed array in France which he presented at the recent GERESS symposium in Bavaria.

Discrimination Research

Conduct research in discrimination of nuclear events using autoregressive (AR) modeling techniques on Lg data

The aim of this research is to develop a fast and robust method for discriminating between earthquakes and industrial explosions based on differences observed in the spectral content of the regional waveforms. It is based on parametric estimation of the power spectral density using the autoregressive (AR) Burg algorithm of order 3, which provides a fast method of emphasizing spectral differences.

Conduct $M_S:m_b$ research by measuring 20-second Rayleigh waves at regional distances using high-resolution, wide-dynamic-range, short-period, seismic-array data and broadband KS 54000 data.

The $M_S:m_b$ discriminant has been investigated by a number of researchers for both regional and teleseismic events and explosions. Bases for the discriminant are (1) that explosions emit more energy in the form of high-frequency body waves and (2) that earthquakes emit more energy in surface waves having low frequency radiation; therefore, an $M_S:m_b$ plot displays a significant separation of the two populations. The problem with the method is that of identifying small explosions; that is, the problem boils down to seismograph sensitivity. With the installation of new high-dynamic-range seismographs at TEXESS, planned research includes the determination of M_S from small earthquakes at regional distances using the TEXESS array data recorded by short-period GS-13 seismometers and a posthole, long-period KS 54000 seismometer.

CLIN 2 -- DESIGN, EVALUATION, AND CONSTRUCTION OF TEXESS AND LUXESS

Experimental-Array Program

Background

SMU undertook a mini-array research program in 1991 on the previous contract to study the S/N improvement that can be attained by the shallow burial of sensors in an array at Lajitas, and to study means of providing a laboratory-pier environment in a borehole. This research is described in SMU-R-92-396, and is excerpted here.

Experimental Arrays

There are two experimental arrays under consideration. One in Egypt approximately 100 km east of the city of Luxor, to be named the Luxor Experimental Seismic Station (LUXESS), and one at the existing Lajitas (LTX) station, designated the Texas Experimental Seismic Station (TEXESS).

TEXESS will be available for use as an open array as defined by the United Nations Conference on Disarmament Group of Scientific Experts (UN/CD GSE).

After the preliminary work described in the Background section, we have begun the construction of TEXESS at the LTX site to evaluate a new open, modular, low cost seismic system. The remaining array sites were selected in December 1992. Since the term experimental array could have different meanings, we will define it to mean a low-cost array capable of resolving azimuth and phase information for regional events, as well as enhancing signal to noise ratio for teleseismic events. We have designed the array with a central, 3-component station, an inner ring with 3 vertical stations having a radius of 0.5 km, and an outer ring of 5 vertical stations having a radius of 2 km. Our goal is to thoroughly test a complete array in the harsh environment of southwest Texas and then build an array in Egypt, LUXESS, using the previously tested equipment from TEXESS. In addition, the data acquisition and archiving hardware and software that is used during testing of the TEXESS array will be used at the LUXESS hub during installation and testing before being shipped to an Egyptian data center in Helwan, thereby assuring the Egyptian users a stable, fully debugged system. The LUXESS hub will be powered by a 400 watt thermal-electric generator (TEG) system that has been running the LTX station for the past four years. We propose that the data from LUXESS be transmitted by satellite to both Helwan, in full duplex mode, and to the Norwegian Data Acquisition Center at NORSAR for integration into the IMS data base. After completion of the installation and verification tests at LUXESS, we would reinstall identical equipment at TEXESS and perform verification tests.

Borehole Engineering

The first step in developing a low cost array was to reduce costs significantly from the GERESS installation costs. We developed a new technique for installing GS-13 vertical seismometers in shallow boreholes instead of large underground vaults. We drilled 4 boreholes at the LTX station to test the feasibility of this technique. The following is a brief explanation of the design and procedure. Boreholes 11-5/8 inch in diameter and approximately 20 ft.

deep are drilled to accommodate standard 8 inch steel casing required to install the GS-13 seismometers. The casing was lowered into the hole in which 6 inches of concrete slurry had been poured. The slurry was wet enough so that the bottom of the hole would cure into a level pad on which the GS-13 would be placed. After allowing 24 hours for the slurry to set up, the annulus was cemented from top to bottom to provide a solid bond to the surrounding rock. The seismometer was leveled on the surface and the mass unlocked prior to installation. A 12 volt power supply connected across the main coil of the seismometer electrically drove the mass to the stop to protect the instrument as it was lowered into the hole with a low speed, 12-vdc winch. After the instrument was in place a telescope was used to inspect the bubble level of the seismometer to determine if it were level. If not, the seismometer could be moved around on the bottom until it is determined to be within one degree of level. Future installations may utilize a video camera with a zoom lens and a monitor for leveling. The preamplifier, digitizer and radio modem were then suspended from the cap of the casing as shown in Figure 1a. Figure 1b shows a prototype solar power array and directional antenna installed at LTX. Future installations will use a NEMA enclosure mounted on the borehole cap with a solar panel mounting on top. The use of power cables and fiber-optic cabling eliminated the need for expensive and destructive trenching at the array.

Functional Requirements

When we first began to evaluate systems for use in an array, we developed certain functional requirements and performance specifications based on past experience with the GERESS array and US GSE seismic network. Above all, the system was to be open and modular. The modules may be configured as a single station, a sparse network of stations, or elements of an array. At LUXESS and TEXESS we will configure the modules as arrays. Each element will synchronize itself to world time via GPS receiver, and will require little power, so that it can be solar powered. A radio area network (RAN) will handle intra-array communications making each element completely self-contained making it practical to rearrange array elements. The 'HUB controller' is a simple digital multiplexer that can communicate with any Unix computer. As an open array, any researcher should find it simple to

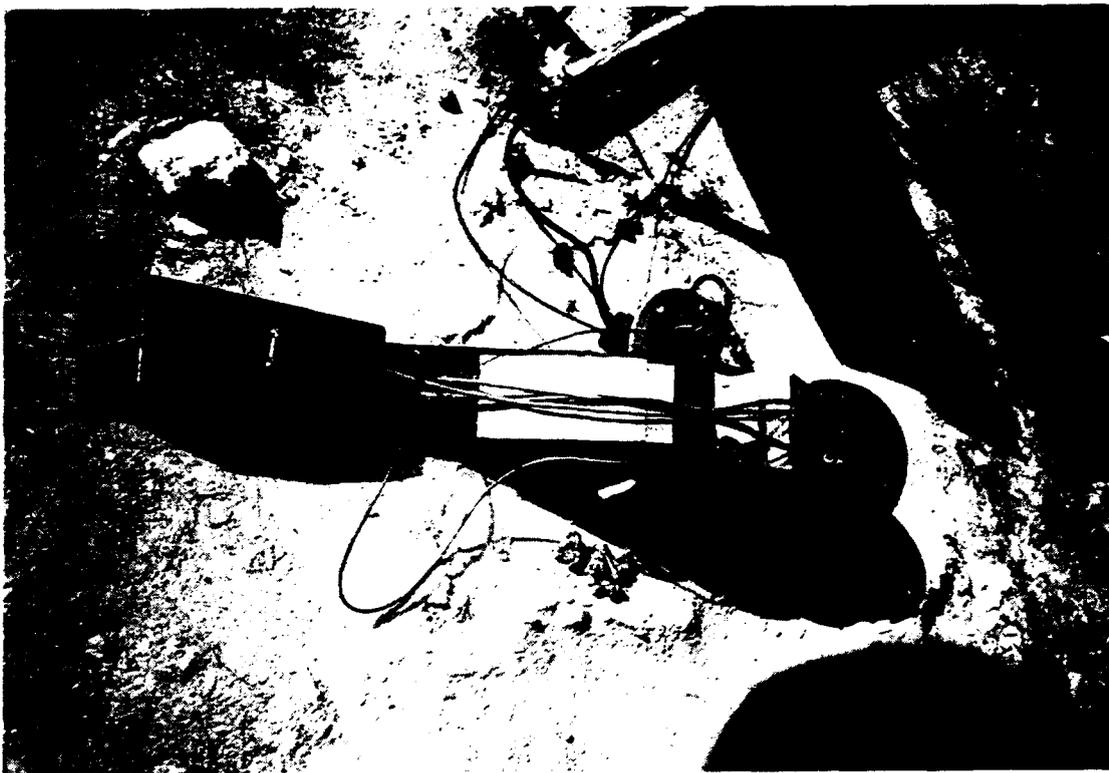


Figure 1a. Photograph of prototype borehole data acquisition and communication equipment mounted on the carrier strip ready for installation in the borehole.

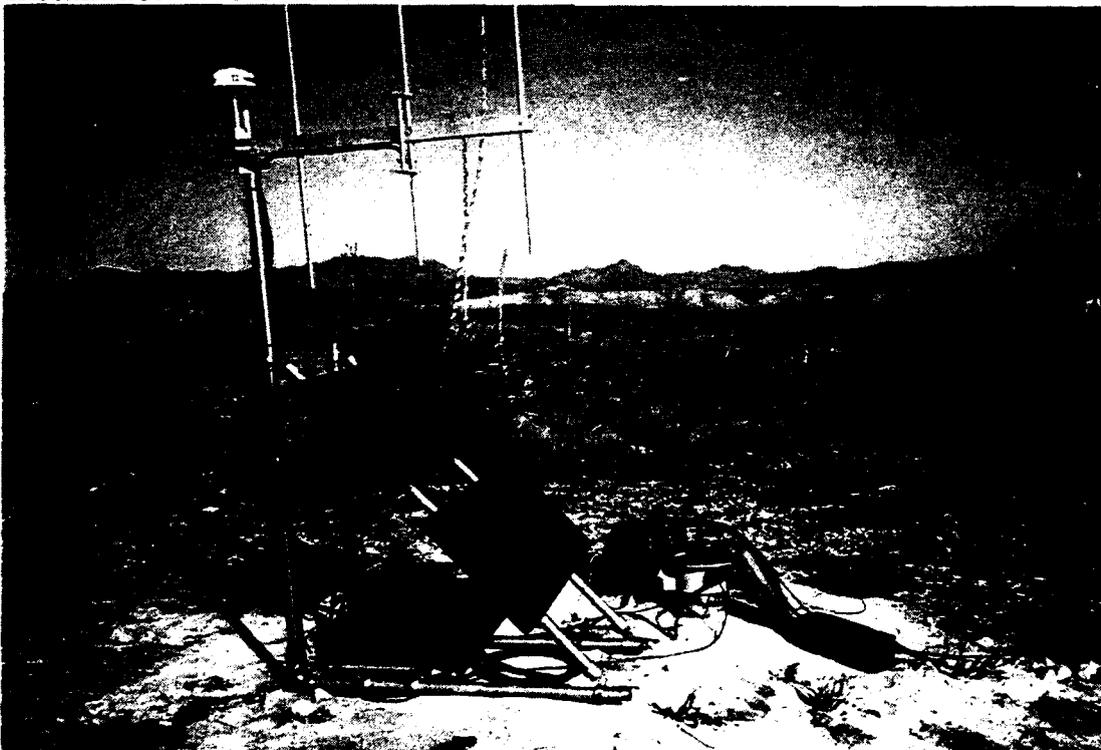


Figure 1b. Photograph of a prototype solar power array and antenna mounting being tested at the LTX station.

access the system, retrieve data segments, and examine system configuration and status. Maintenance will be simple because only a few interchangeable modular components need to be tested and replaced in the field. Finally, the system will be robust so that it will be immune to, or will recover quickly from, user errors, an absolute requirement for a truly open station. The following summarizes the functional requirements the new array:

1. Each data sample shall be time tagged to within 1 millisecond of world time. We require the use of a GPS timing receivers at each element for this purpose.
2. All electronic equipment except the GPS receiver and radio antenna shall fit within 8 inch schedule 40, 28 lbs per foot, seamless steel pipe (inside diameter 7.981 inches).
3. Digitization equipment at each element of the array shall require an average of less than 7 watts of power at 12 vdc. This includes GPS receivers, but excludes communication equipment (modems, converters, radios, etc.).
4. Intra-array communication shall be by RF modems using RS-232 communication protocol. The currently selected radio modem is Repco, Model SLQNAD (9600 baud). Only two sets of frequencies will be needed for TEXESS and LUXESS because polling or sequencing procedures will be used.
5. The array data concentrator shall communicate with each element of the array and the satellite communication equipment. Satellite communication equipment will require RS-232, RS-449(422) or V.35 communication protocol. During initial tests the data concentrator will communicate directly with the Science Horizon's (SHI) Communications Interface Module (CIM) via RS-422 interface. 12 vdc power at the array hub will be provided by a 400 watt TEG system that has been tested and operated at LTX for four years.
6. Each element of the array shall accept commands from the Science Horizon's central workstation including; calibration, time set, reinitialize and sample rate change. In addition, each element shall respond to requests from

the workstation for information on calibration schedules, time, state-of-health and channel configurations.

7. Each element shall transfer data to the data concentrator with an error correcting protocol such that data loss during adverse atmospheric conditions is normally less than one data second per element per day. Such protocol shall include reasonable recovery procedures such that the system continues to operate properly.

8. The array may be considered 'open' by the United Nations Conference [Committee] on Disarmament, Group of Scientific Experts (UN/CD GSE) and as such should provide the capability of processing data in a manner prescribed by that group. In addition, there is a requirement to store up to two weeks of continuous data for retrieval by other researchers as close to the data source as communications will allow. For these reasons, though it is not a requirement, it is desirable that the data concentrator be expandable such that it could process and store data and communicate via standard computer protocol with outside researchers.

9. The ability of each element of the array to perform on-board data processing is also not required, but would be a desirable function. If this capability exists, then the capability to download additional software modules through the workstation and data concentrator would be required.

Performance Specifications

In addition to the functional requirements, we have developed the following performance specifications:

Any new seismic data acquisition equipment being used in an array configuration must at least meet the GERESS data acquisition specifications as given in SMU Quarterly Technical reports, "Results of the GERESS Verification Test," October, 1991 and Quarterly Technical Report, May, 1992, sponsored by the Defense Advanced Research Projects Agency contract #MDA 972-89-C-0054, i.e.,

1. Analog to digital converters shall have a true dynamic range greater than 116 dB (20 bits range) at a sample rate of 40 sps (passband of 0.003 - 16.0 Hz), and should provide the data in a 24 bit format.
2. Total system noise floor should be no greater than 8 counts rms in the passband 0.003 - 16.0 Hz.
3. Channel crosstalk shall be less than -116 dB.
4. Time skew between channels of different elements shall not exceed +/- 50 microseconds.
5. Time jitter between consecutive samples of any single channel shall not exceed +/- 50 microseconds.
6. Each element shall have the capability to inject a calibration signal into the brick preamplifier calibration circuit thereby calibrating the GS-13 seismometer. A sine wave signal at amplitudes from 0.1 mv to 4500 mv, a known pseudo-random noise signal, and a pulse signal of arbitrary time duration at amplitudes from 0.1 to 4500 mv shall be available. Sine wave frequencies shall include, but need not be limited to, the following frequencies:

0.01 Hz
0.02 Hz
0.05 Hz
0.10 Hz
0.20 Hz
1.00 Hz
2.00 Hz
5.00 Hz
10.0 Hz
15.0 Hz
20.0 Hz

7. The data concentrator shall transmit data to the satellite communication or SHI CIM equipment 99.5% of the time on an annual basis and provide 99.8% error free seconds performance.

8. The system must meet the specifications over the full extremes of temperature and humidity when the equipment is installed in its operating environment. Elements of the array will be installed in steel boreholes. The data concentrator will be in an open building, protected from the elements but with no air conditioning, dust control or pest control. Therefore the equipment should operate properly within a temperature range of 0 to 50 C. In addition, borehole humidity could be 100% "condensing."

System components that meet the functional requirements are available now commercially, as off-the-shelf modules, and we have purchased two elements and the 'hub controller' (CIM II) from SHI to evaluate their performance specifications. Though the hardware is currently available, we anticipate some software development will be needed during system evaluation and for customization.

We performed initial tests in November 1993 and we plan thorough testing during the summer months at the LTX station. From our experience in developing, installing and operating the US GSE network for GSETT 2, we know that the system can only be tested when it is in operation and data is being delivered to researchers. Only then, will all the problems be properly addressed and resolved. These are the reasons we intend to test and operate the array at LTX for some period of time before installation in Egypt. However, even after testing the new array hardware, there is a need for software research.

Processing Techniques

It is clear that new processing techniques will be required for a nine element array as compared to a large 25 element array such as GERESS. We are currently using GERESS data for this purpose. By choosing different elements of the array, say just the D-ring or some of the C and part of the D, we can simulate different array configurations. A brief outline of one proposed

processing technique and some preliminary results are presented in the previous section on array research.

Power-Source Development

One of the biggest expenses in an array installation is the establishment and distribution of suitable power. Given a power supply, then there is the problem of laying out both power and data cabling. An independent, modular power source for each element of the array similar in concept to those used in 3-D exploration-geophysical data acquisition would be ideal. Unfortunately, battery power wouldn't be practical for an array requiring continuous power.

The problem of supplying an independent, local power supply was solved at the Lajitas CD Station (LTX) with the installation of a thermoelectric generator (TEG). In a TEG, d-c power is obtained via the Seebeck Effect by heating a suitable thermocouple. At LTX, propane is used to heat a lead-tellurium thermocouple. About 400 Watts of a-c power is obtained using a dc-to-ac converter. LTX can be operated continuously for about 3 months on a 1,000-gallon tank of propane.

Because a TEG would be somewhat impractical for the elements of a foreign-desert array, research and development at SMU has resulted in the design of a cost-efficient, solar-power supply for installation at each mini-array site; however, there is still a need for a TEG at the Hub.

SMU Research

Solar panels manufactured by Solarex Corporation were installed on the roof of the Heroy Building at SMU to investigate the feasibility of using solar power in the field. Specifically, research was needed to determine the number of panels and of batteries that would be needed to provide continuous, uninterrupted power to a Teledyne Geotech RDAS-200.

Solar-Panel-System Design

Silicon photovoltaic cells, developed by Bell Labs in 1954, produce d-c voltage in proportion to the cell area exposed to direct sunlight. Power is on the order of 100mW/cm². The objective of system design is to minimize the size of the panel array and storage-battery capacity and maximize electrical output based on the expected solar energy for a particular latitude, region, and solar regime. This is easier said than done! Several factors must be considered in the design of a solar-power array: (1) the annual hours of sunshine, (2) general climatic conditions, and (3) capability of heliotropic array tracking. For example, solar regimes in humid areas would be much different from those in arid areas because occultation of a portion of a solar-panel array by clouds can cause a power drain on the unocculted cells. That is to say, the panel design for cloudy areas would have to account for this perturbation effect. If heliotropic tracking were impractical, then the array would have to be designed to maximize the solar flux. This usually involves tilting the panels at an angle normal to the expected incidence angle of rays from the sun at a particular site.

Borehole-Instrumentation Development

The new array concept is based on the installation of a seismic sensor, preamplifier, digitizer, and radio modem in a borehole rather than in a vault. This has resulted in the development of specialized electronics and borehole equipment including Science Horizons' AIM24 digitizer, a winch for lowering the seismometer into a borehole, a specialized grouting technique for providing a level surface, a video system for precision leveling, and a specialized capping system for solar power.

AIM24 Digitizer

Science Horizons, Inc. has designed two digitizers, AIM24-1 and AIM24-3, for single channel and three channel digitization respectively. AIM24 is designed to produce 24 bits of digital data from an analog sensor. Salient features include a Motorola 68302 CPU, a Crystal Semiconductor 5322/5323, 24-bit, analog-to-digital converter, a 16-bit calibration channel, an oscillator that is

phase locked to GPS time, an RS232 configuration port, and a maximum sample rate of 3840 sps. AIM24-1 dimensions are 6" x 4" x 14," which makes it suitable for borehole installation. Appendix 2 contains the specifications of the AIM24-1 and -3.

Digital I/O ports include a master CIMBus connector and a high-speed Async, SDLC, or ADCCP RS422 or RS232 interface. In this particular array application, the digital data is fed to a radio modem within the borehole for transmission from the remote borehole site to the array hub at LTX. Power for the borehole equipment is provided by the solar array shown in figure 1b.

Winch Design

A prototype winch and boom assembly was designed by Karl Thomason, Chief Engineer, for installation of a seismometer in a borehole (see Figure 2 of SMU-R-92-396). The assembly features a Model EX1 Superwinch with a 12 vdc motor that is bolted below the flange. The boom with a 3" sheave is bolted to the flange on the opposite side of the hole from the winch motor.

TEXESS AND LUXESS

Acquisition of Hardware and Software

The First and Second Quarterly R & D Status Reports cover the acquisition of hardware and software. TEXESS and LUXESS equipment lists are presented in Appendices 1 and 2.

Array Hardware

Figure 2 is the TEXESS system diagram. The array consists of nine sensor sites, which includes a central three-component, short-period seismometer installation in a vault at the hub, and eight vertical short-period seismometer installations in boreholes. Major hardware acquisitions are 11 GS-13 seismometers, 11 brick preamplifiers, 8 AIM 24/1 digitizers (ADC's), 1 AIM 24/3 ADC, 9 GPS receivers, 9 digital radio modems and antennas, 9 power sources (solar arrays and batteries), and 9 NEMA enclosures and solar-array mounts. In addition to the short-period instrumentation at the hub, a posthole KS 36000 long-period seismometer, owned by SMU, was installed in a shallow borehole. The term *posthole* has been coined for the installation to indicate that the instrument is leveled manually rather than remotely.

Computer Hardware

The TEXESS graphics configuration consists of the following components:

1. A Sun SparcStation 10 with 32 MB RAM, 19" monochrome monitor, 424 MB hard drive, and a 3.5" floppy drive,
2. A 32 MB RAM upgrade,
3. A CD ROM reader,
4. A 2.1 GB SCSI drive,
5. A 2.5 GB 8mm tape-drive subsystem, and
6. A Science Horizon's CIM II

The graphics configuration at SMU consists of the same basic hardware.

Software

The following software has been acquired from Science Horizons Inc:

1. SAVE & XAVE,
2. Open Station,
3. GSE data source. and
4. VISTA

Hub Power

1. Commercial Power, and
2. UPS/UBS backup power.

Install TEXESS

Layout

TEXESS is designed with a central, 3-component station, an inner ring with 3 vertical stations having a radius of 0.5 km, and an outer ring of 5 vertical stations having a radius of 2 km. Figure 3 is a map of TEXESS.

Installation

As mentioned in the section on Borehole Engineering, the first four holes of TEXESS were drilled in 1991. The remaining holes were drilled the week of 16 May 1993. Subsequent trips to Lajitas were made by SMU personnel to oversee civil work at the hub; install the UPS/UBS power system; install computer hardware and software; and install borehole sensors, borehole electronics, solar-power systems, GPS receivers, and radio antennas. Final installation of TEXESS by SMU personnel took place during the week of 22 August 1993, and the first event recorded by the array was a local earthquake at 0745 UTC on 31 August.

Accomplishments during this final-installation phase include:

1. Installation of electronic components at sites
2. Installation of lightning protection
3. Installation of a GS 13 in a 40-foot borehole at site C1 [rather than 20-foot holes at the other sites]
4. Installation of hub radio system
5. Verified hub-to-site communication
6. Determined a number of software problems due to an old version of SAVE
7. Configured the site for RDAS recording and verified that it is possible to monitor RDAS data locally
8. Tested remote configuration option on AIM's
9. Installed new AIM 24/3 and brick amplifiers in the vault at site A0
10. Transmitted all data back to SMU by Satcom link.

Perform Site Surveys and Choose Locations for LUXESS

SMU has received official communications from the National Research Institute of Astronomy and Geophysics (NRIAG) Helwan, Egypt, requesting a draft Memorandum of Understanding (MOU). SMU personnel are scheduled to travel to Egypt in Spring 1994.

Test TEXESS Prior To De-installation

System fidelity tests were conducted by Chris Hayward and Dick Kromer during the week of 14 November 1993. During this period, engineering refinements were made by Karl Thomason.

De-install TEXESS

During the early part of the week of 21 November, SMU principals made an inspection trip to TEXESS in order to make plans for de-installation, packing, and international shipment.

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