INFRASOUND SIGNAL LIBRARY

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ABSTRACT

We have been retrieving old infrasound recordings from the archives at Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL). The archives at SNL hold many boxes of paper strip-chart records collected by the Blast Prediction Unit during the era of atmospheric nuclear testing at the Nevada Test Site (NTS), between 1953 and 1961. The NTS tests were typically recorded using either single or dual sensors, at about a dozen sites from the Control Point on NTS to as far away as Bishop, California. From the SNL holdings, we have selected events spanning a wide range in yields, from well below 1 kiloton to as high as 74 kilotons. Data from these tests should be valuable for studies of the scaling of infrasound signals with source size. In addition, we have selected the few available high-altitude tests, to address the variation of the signals with source altitude. We are digitizing all of the available signals for each selected test, using a continuous-feed scanner and a commercial software package designed for digitizing well logs. To date, we have recovered over 100 traces. Los Alamos has operated 4-element infrasound arrays in New Mexico and Utah since the early 1980s. These stations have recorded numerous underground NTS tests, as well as many chemical explosions, earthquakes, and a few bolides across the western United States (US). Most of the recordings prior to the mid-1990s were archived on 9-track magnetic tapes. The age of the tapes and the scarcity of the obsolete tape drives combine to make these data difficult to recover. We obtained a 9-track drive that we can operate from a Unix workstation. We have retrieved nearly 2 gigabytes of data from the old tapes, and expect to double this amount. Prior to completing this project later this year, we will enter many of the signals we have retrieved in the familiar National Nuclear Security Administration (NNSA) schema, including the origin, site, sitechan and wfdisc tables. These tables and the binary waveform files will then be made available to the monitoring research community, and some will be incorporated in the NNSA Knowledge Base (KB).

OBJECTIVES

Our objectives have been to recover valuable infrasound recordings of atmospheric and underground nuclear tests and other events from the archives at Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL); to digitize the SNL strip-chart records and extract the files from the LANL 9-track tapes; to convert the signals we recover to the current NNSA schema; and to provide the resulting signal library to the infrasound monitoring research community. The collection will provide reference information on known events that should help to improve the analysis of data from the infrasound network under development for the International Monitoring System.

RESEARCH ACCOMPLISHED

Nuclear testing at the Nevada Test Site (NTS) began in 1951. Throughout the 1950s, most tests at NTS were detonated above ground. SNL established a Blast Prediction Unit (BPU) in 1951 to monitor the off-site pressure waves from these tests, primarily in order to minimize damaging overpressures in the surrounding communities, including Las Vegas, Nevada (Reed, 1974). The BPU designed an infrasound recording system that used commercial pressure sensors and strip-chart recorders. The recorders added a time code along the bottom of the chart; fiducial pulses were added to the pressure signals at the shot time and at 5-minute intervals thereafter. This system was typically deployed at 10—12 sites, mostly in Nevada, Utah, and California (Figure 1), for all subsequent atmospheric nuclear tests. In addition, many of the Project Plowshare cratering tests were recorded, as well as numerous underground tests. Nearly all of the original paper records have been preserved in SNL's archives.

Because of the renewed international interest in infrasound monitoring, we have been working to digitize some of the old records and make these data available to researchers.

The original paper records are 9 cm wide but can be many meters in length (see Fig.ure2 for a sample). As a result, they are not readily reproduced nor can they be conveniently handled on common digitizing tables. We procured a system developed for digitizing paper well logs, which are similar in shape. It employs a continuous-feed scanner that generates a scanned image file for each paper record and a software package for digitizing the traces from the image. Once the time and amplitude axes are defined for the software, it can automatically follow a trace with reasonable success. The operator monitors the progress to ensure that the program follows the desired trace and validates the fidelity of the end result. Finally, the software writes the digitized signal to a text file as a series of paired time and amplitude values.

Our initial emphasis has been to digitize signals from atmospheric tests spanning a wide range in yields to support studies of scaling relationships. For this, we began with the tests of Operation Teapot in the spring of 1955. This series included several events with yields from 1 kt to 43 kt, all detonated a few hundred feet above ground. For comparison, we have done a single record from the 13.5 Mt surface event Yankee in the Pacific, and signals from the cratering test Ess. We have also retrieved the signals from the test HA, detonated at an altitude of 11 km above sea level. Records from this and the few other high-altitude tests should be useful for studying the variation of the signals with source altitude and perhaps for improving the infrasound-based energy estimates for bolide events. Table 1 lists the tests whose signals we have digitized to date. We have extracted about 15 traces per test from the available stations, some of which used two sensors separated about 1 mile along the direction from NTS. We have at present over 100 digitized traces in hand and we hope to process a few more events under the current funding for this effort.

The last step in preparing these data for use in the Knowledge Base will be to convert the text output files to binary waveform files, and to generate the appropriate tables for capturing the necessary event, station and waveform information. The tables will follow the well-established NNSA schema, which will make the signals readily useable by a wide array of analysis programs.

Table 1. Tests for which SNL infrasound records have been digitized.

Date	Name	Location	Yield
May 4, 1954	Yankee	Bikini Atoll	13.5 Mt
Feb 18, 1955	Wasp	NTS	1 kt
Mar 7, 1955	Turk	NTS	43 kt
Mar 12, 1955	Hornet	NTS	4 kt
Mar 22, 1955	Bee	NTS	8 kt
Mar 23, 1955	Ess	NTS	1 kt
Mar 29, 1955	Wasp Prime	NTS	3 kt
Apr 6, 1955	HA	NTS	3 kt

Los Alamos National Laboratory has operated infrasound arrays in Nevada, New Mexico, and Utah since the early 1980s. These were mostly four-element arrays, with three sensors arranged in a triangle and the fourth at the center. In some cases, seismic data were also recorded at the same sites. Over the years, these arrays have recorded a variety of acoustic events, including underground nuclear tests at NTS and subsequent cavity collapses, conventional explosions both above and below ground, moderate-sized shallow earthquakes, space shuttle reentries, and possibly some bolides. The recordings also contain some unique events such as a boundary-layer turbulence experiment conducted in Boulder, Colorado by the National Oceanic and Atmospheric Administration (NOAA). Data from the LANL stations were written to 9-track magnetic tapes until the mid-1990s, and many boxes of these tapes have been preserved at LANL. However, the 9-track drives have since become obsolete, and it is now difficult to obtain a working unit. We were fortunate to find a drive in the property reapplication yard at SNL. Connected to a Unix workstation, this drive is again operational and can successfully read most of the LANL tapes, despite their advancing age. We began by selecting tapes most likely to contain interesting events and are currently reading them. So far, we have retrieved about 2 Gb of data from these tapes. A number of different formats were used for the files; we have definitions for most of the formats and expect to identify the remaining ones. Figure 3 shows the signals recorded by the four elements of the array in Los Alamos, New Mexico following the underground test Barnwell, detonated at NTS on December 8, 1989. As with the digitized SNL traces, the signals from these tapes will be converted to the formats used by the NNSA Knowledge Base, complete with tables of event, station, and waveform information.

The holdings at LANL contain two additional data sets of potential interest, both comprised of paper records that will require digitization. The first of these consists of select events from the infrasound network operated by the Air Force Technical Applications Center (AFTAC) from the 1950s to the 1970s. This set includes nearly 100 records from atmospheric explosions and bolides, which are the most important impulsive natural sources of infrasound. The second data set represents a series of large-scale explosions sponsored by the Defense Nuclear Agency and conducted at White Sands Missile Range. These tests had charge weights of 24 to 4,880 tons and were executed between 1981 and 1993. They were recorded at the LANL arrays and usually at 2 to 4 mobile stations. We do not anticipate digitizing any of these signals under the current project, but they could be retrieved if follow-on efforts are warranted.

CONCLUSIONS AND RECOMMENDATIONS

Because the nuclear powers have effectively discontinued testing, both above and below ground, the archived pressure signals at SNL and Los Alamos provide invaluable reference data for the future International Monitoring System (IMS) infrasound network. Though the recordings are now decades old (and some are over 50 years old), most can still be recovered and converted to current digital formats. Under this project, we have retrieved a significant number of the signals of highest interest, but these represent well below half of the available holdings. We will keep the digitizing platform and the 9-track tape drive while they remain serviceable. We recommend that the effort to recover the remaining infrasound signals be continued.

REFERENCES

Cox, E. F. and J. W. Reed (1957), Long-Distance Blast Predictions, Microbarometric Measurements, and Upper-Atmosphere Meteorological Observations for Operations Upshot-Knothole, Castle, and Teapot, *Report* WT-9003, Sandia Corporation, Albuquerque, NM.

Reed, J. W. (1974), Archiving Guide to Microbarograph Records of Nuclear and Chemical Explosion Tests, *Report* SLA-74-0210, Sandia Laboratories, Albuquerque, NM.

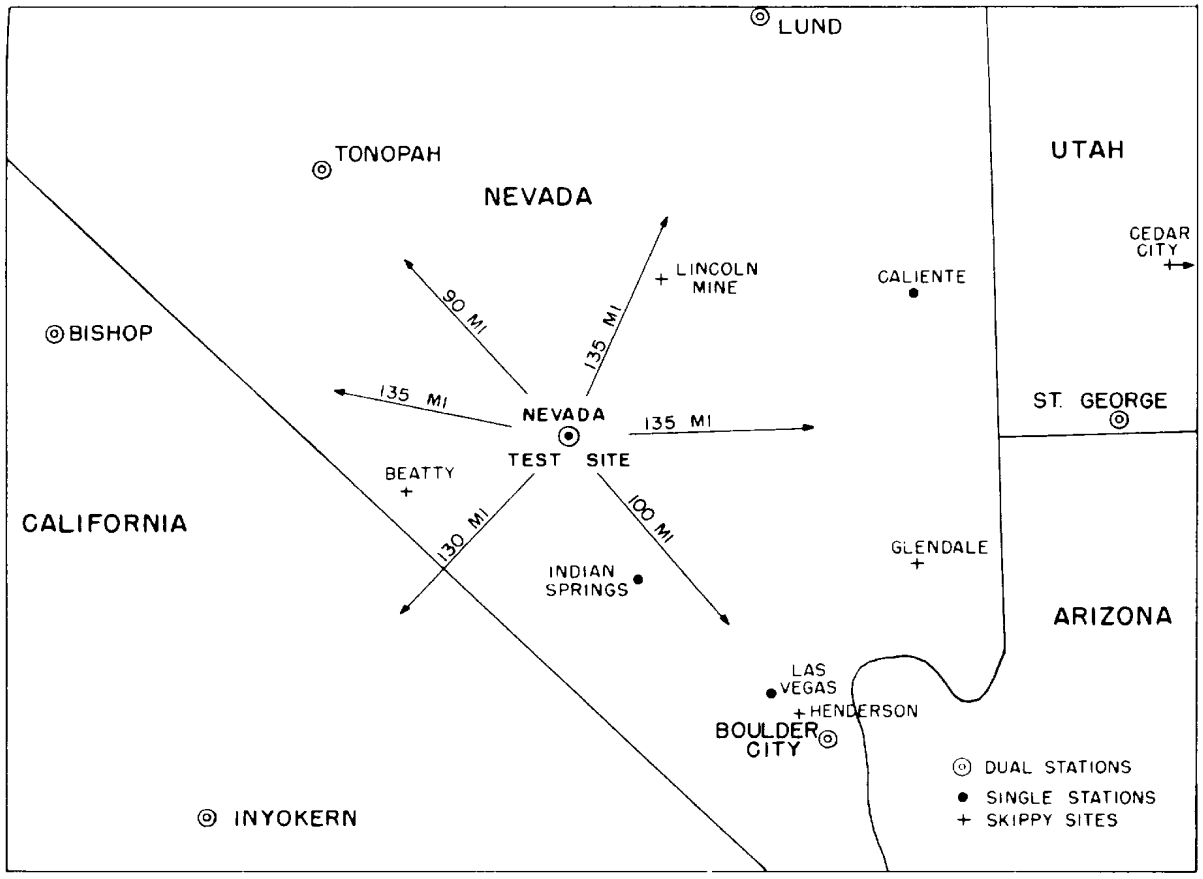

Figure 1. Map of microbarograph station locations used during 1955 (Cox and Reed, 1957).

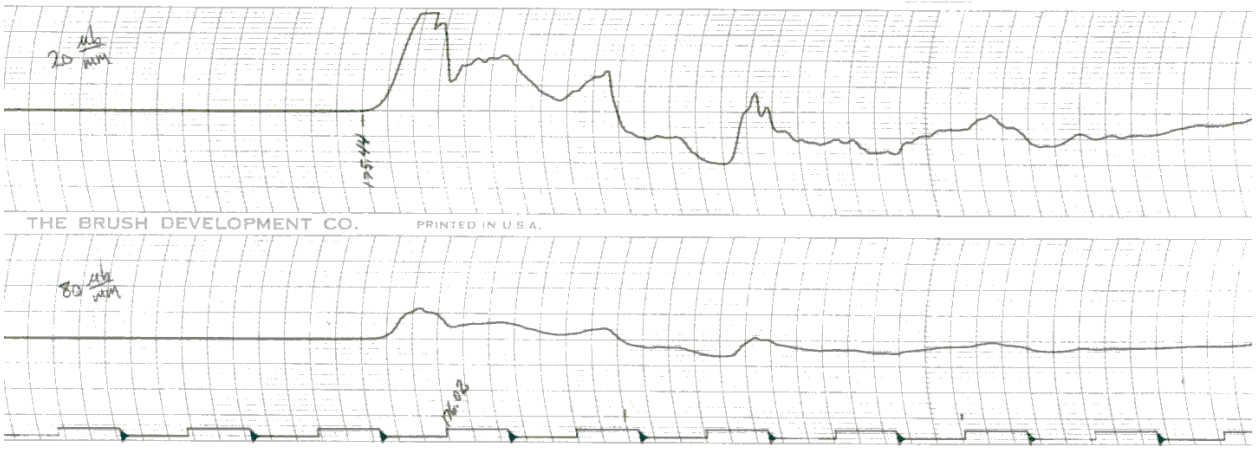

Figure 2. A portion of the strip chart from Indian Springs, NV for the NTS test HORNET, 3/12/1955.

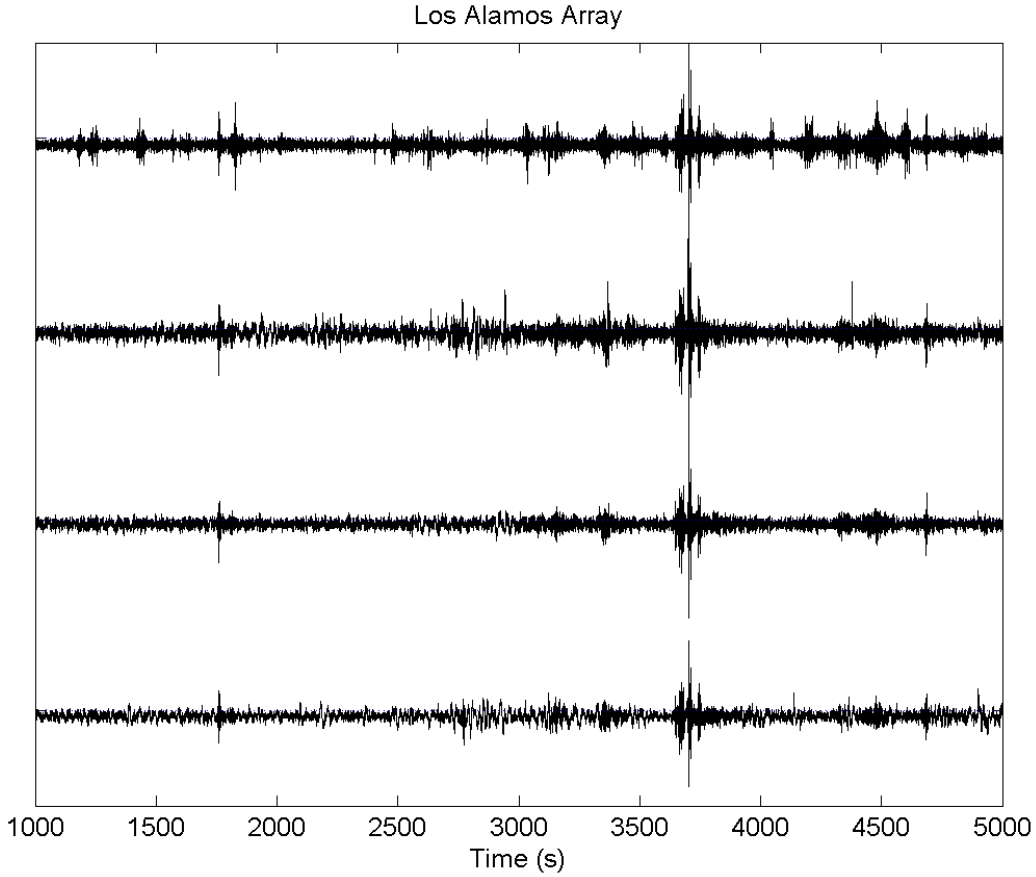

Figure 3. Los Alamos Array recordings for the NTS test BARNWELL, December 8, 1989.