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INFRASOUND RECORDS FROM U. S. ATMOSPHERIC TESTS

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ABSTRACT

The United States conducted over 100 atmospheric nuclear tests at the Nevada Test Site from 1951 through 1962. Some of the earliest tests caused unexpected damage, primarily broken glass and cracked plaster, in Las Vegas and other surrounding communities. To address this problem, Sandia initiated a program to monitor and predict the pressure waves around NTS. Infrasound recording systems were developed, then fielded for all tests beginning with Operation Buster in October 1951. Investigators soon discovered that near-surface temperature inversions and wind profiles caused the damaging pressures in Las Vegas. A typical test was recorded at about a dozen stations from the Control Point on NTS to as far away as Pasadena, CA. In addition, some tests in the South Pacific were monitored, as well as numerous chemical explosions. Strip charts recorded signals in the frequency band from 0.05 to 30 Hz, and the paper tapes were archived at Sandia in the early 1970s. The NTS events ranged in yield from below 1 ton to 74 kilotons; source altitudes varied from near ground level (including some cratering experiments) to as high as 11 km. The resulting data contain a wealth of information on the source function, yield scaling and regional propagation of infrasound signals from atmospheric explosions. The renewed interest in infrasonic monitoring for CTBT verification has prompted us to exhume some of the archived records. We plan to digitize the signals from several tests and evaluate their applicability to CTBT issues. In addition, we will collect any existing parametric measurements for these records (arrival times, amplitudes, etc.). All data will be converted to CSS database format and made available to the research community. If appropriate, the resulting information could also be included in the Knowledge Base under development for CTBT monitoring.

Key Words: Infrasound, Detection, Identification

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OBJECTIVE

The International Monitoring System (IMS) proposed for verifying compliance with the Comprehensive Test Ban Treaty will include an infrasound network for detecting explosions in the atmosphere. Infrasound stations have been used for this purpose in the past, but the primary focus at that time was on low-frequency signals from megaton-size tests. Relatively few infrasound records are available from kiloton-size events, which will be of most concern for CTBT monitoring. Between 1951 and 1962, the United States conducted over 100 atmospheric and near-surface nuclear tests at the Nevada Test Site (Figure 1), with yields ranging from under 1 ton to 74 kilotons. Pressure waves from these tests were routinely recorded at several sites in the southwestern US. This collection of data can be exploited to address a number of issues for infrasonic monitoring by the IMS. Information on yield scaling, source functions, regional-distance propagation and variability due to weather could all be derived from it. We have initiated an effort to make these data more readily accessible to the monitoring research community. We intend to digitize the original paper records from a number of tests, and produce data files of the signals in the widely used CSS database format.

RESEARCH ACCOMPLISHED

Atmospheric nuclear tests at NTS in the early 50's occasionally resulted in damage to some buildings in Las Vegas and other surrounding communities. Most of the early damage claims filed against the Atomic Energy Commission involved broken windows (especially large plate-glass ones) and cracked plaster. Even this relatively minor damage was unexpected, based on anticipated pressures for the yields and distances involved. Such effects in Las Vegas jeopardized continued operations at NTS, and were thus taken rather seriously. A Blast Prediction Unit (BPU) was formed at Sandia National Laboratories in 1951, and tasked with collecting pressure data from subsequent tests, determining the cause of the damaging pressures, and improving predictions of pressure amplitudes (Reed, 1974). Over the next two decades, this group recorded nearly 15,000 pressure signals from nuclear tests, chemical explosions and sonic booms. This program was discontinued in the early 70's, and all of the original recordings still existing at that time went into permanent archives at Sandia.

The first step for the BPU was to develop an infrasound recording system, or microbarograph, suitable for recording a very wide range of overpressures and operating in a variety of environments (Sandia Corp., 1953). The resulting system (Figure 2) employed a twisted Bourdon tube pressure sensor, with an adjustable bleed plug for controlling the low-frequency response. As with modern infrasound stations, an array of porous hoses helped to reduce noise from localized turbulence. An adjustable amplifier boosted the sensor signal, then a variable bandpass filter removed noise outside the desired frequency band. The low-frequency cutoff could be set at 0.01, 0.03, 0.1 or 0.3 Hz, and the high-frequency cutoff at 1, 3, 10 or 30 Hz. The filter output went in parallel to two more amplifiers, which resulted in high-gain and low-gain signals with an amplitude ratio of 4. Finally, a strip-chart recorder wrote the signals onto paper tape, along with a timing code. This chart usually ran at 25 mm/sec; pressure at full deflection of the pen (±20 mm) varied from 4 μb to 48 mb, depending on the amplifier setting. Under optimal conditions, the designers believed the system could detect pressure signals as small as 1 μb.

For a typical NTS atmospheric shot in the 50's, the BPU operated about 12 infrasound stations in Nevada, Utah and California (Figure 3). Six of these were 'dual stations' (or 2-element arrays) with 2 sensors separated by about 1 mile along a line from NTS. These stations could measure phase velocities of the wavefronts. This helped in identifying arrivals and provided information on the structure of the upper atmosphere. Several tests in the South Pacific were monitored as well. These were generally larger than the NTS events, so the stations would be installed at greater ranges. All stations were manned during the tests. An analog computer provided raypath predictions based on atmospheric soundings of temperature and wind profiles made several hours before a test (Durham, 1955). One-ton chemical explosions were detonated 1 and 2 hours prior to a test, to check on actual propagation conditions and assist selection of gains. Recording began prior to the shot time, and extended for several minutes past the time of the first arrival. The resulting paper tapes were many meters in length, so they were cumbersome to reproduce. Because of this, the original tapes are the only existing copies of the raw data from these operations.

Investigators soon discovered that both winds and near-surface temperature inversions contributed to the damaging pressure amplitudes (Cox, Plagge and Reed, 1954). Both situations cause more of the blast energy to be refracted towards the ground than would a wind-free, standard atmospheric model. Subsequent to this discovery, tests were postponed under such conditions. This effectively solved the problem of blast-wave damage claims from communities around NTS. Winds, of course, also affected patterns of radioactive fallout from atmospheric tests. Fallout would persist as a serious problem until the Limited Test Ban Treaty (LTBT) stopped atmospheric testing, and claims related to fallout effects continue today.

During the 60's, and particularly after signing of the LTBT in 1963, acoustic signals from a wider variety of sources were investigated. The BPU recorded many of the larger underground tests. The Plowshare program conducted numerous cratering experiments, using both nuclear and chemical explosions. NASA and the Air Force studied sonic booms from aircraft, and the Navy studied signals from underwater HE explosions. HE shots were also used to improve understanding of source altitude effects, upper atmosphere propagation and surface reflections. In 1974, all available microbarograph records entered the permanent retention archives at Sandia. The tapes are now stored in 29 boxes, and each box includes a list of the tests it contains. Reed (1974) provides an overview of the archive contents along with brief comments on the various experiments that were conducted.

Because the data from the era of atmospheric testing should be directly applicable to CTBT monitoring issues, we intend to retrieve the records of selected events from the archives. We plan to digitize the signals, to facilitate interpretation of the waveforms and comparison with modern infrasound data. In addition, we will collect any available arrival time and amplitude measurements compiled during the original projects. The digital waveform data and the parametric information will be formatted following the CSS database standard, so that they may become readily available to the CTBT research community.

We have assembled a computer-based system for this effort. The first step in digitizing the waveforms is to scan a strip chart record. For this we use a continuous-feed grayscale scanner controlled by a PC. An example of a scanned image appears in Figure 4, which shows the first arrival of the pressure wave at Indian Springs, NV from the atmospheric test HORNET on 3/12/55. A commercial software package used in the oil industry for digitizing well logs then reads the image file. After defining the axes for the chart, the operator controls the sampling of the signal. The time values must next be corrected for curvature caused by the finite length of the chart recorder's pen arm. The final step involves converting the results into CSS format, the *de facto* standard among CTBT researchers.

CONCLUSIONS AND RECOMMENDATIONS

Infrasonic monitoring of atmospheric events will play an important role in CTBT verification. Compared to seismic analysis of underground events, experience with data from infrasound networks is quite limited. This is especially true for signal frequencies above 0.1 Hz from kiloton-size explosions. Because such data are somewhat rare, we believe the pressure records collected around NTS during the years of atmospheric testing represent a valuable resource. We propose to digitize the signals from several explosions representing different yields, altitudes and weather conditions. The data will then be readily accessible by the CTBT research community.

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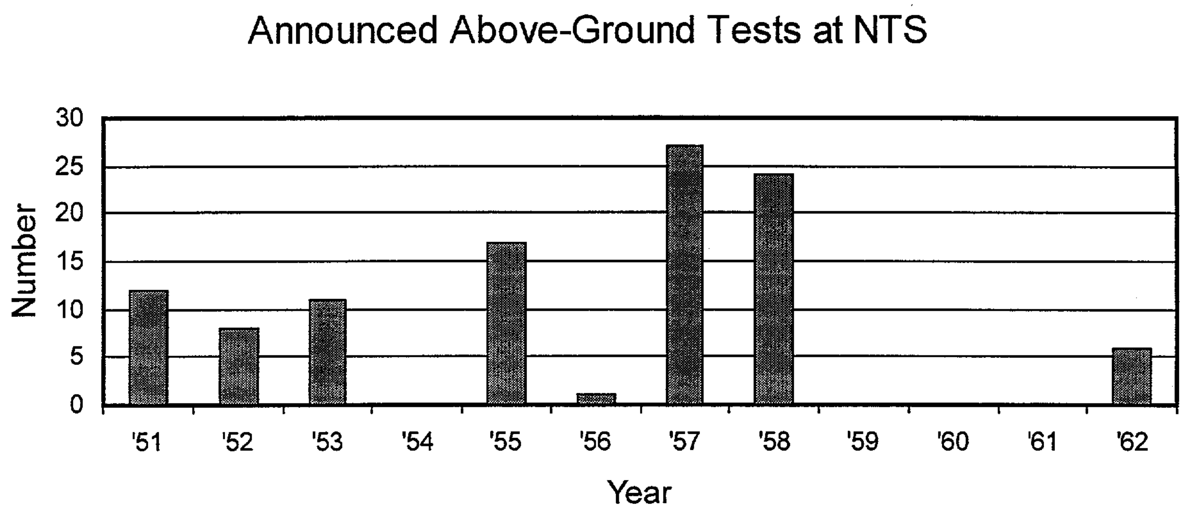

Figure 1. Number of announced atmospheric and cratering tests per year at NTS, 1951-1962.

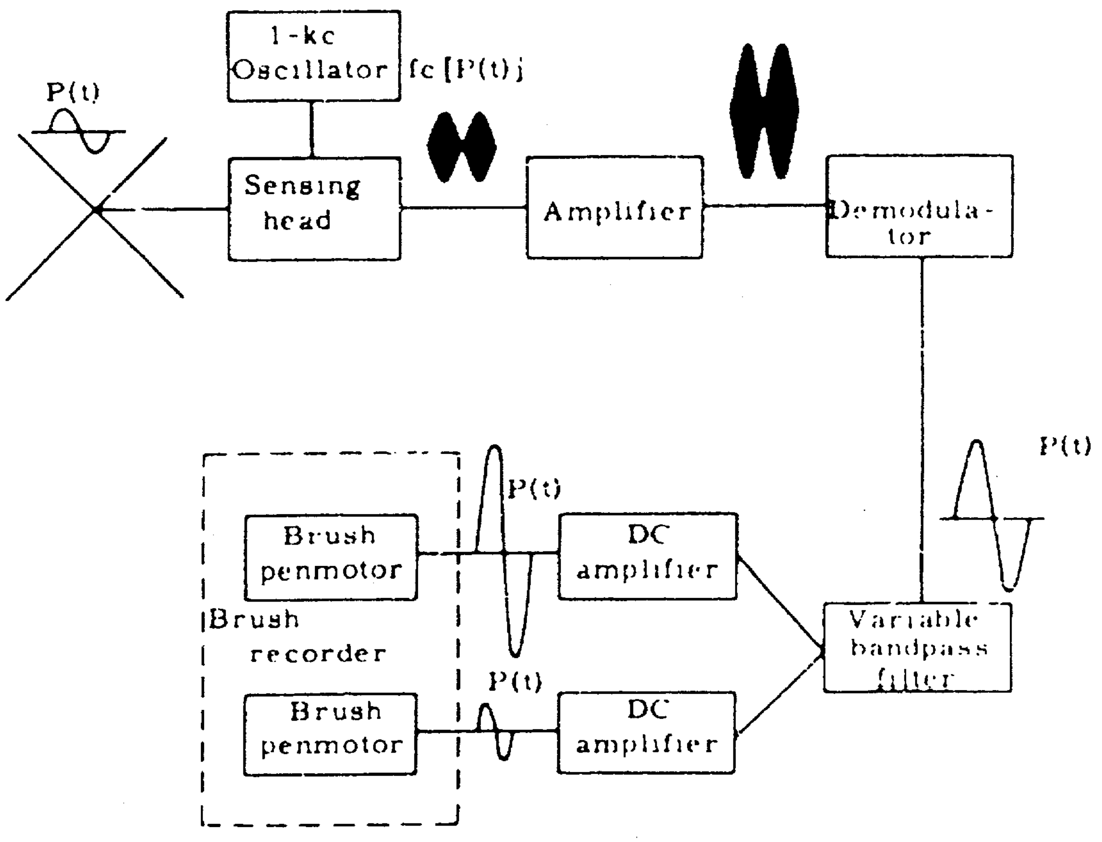

Figure 2. Schematic of the Sandia microbarograph system used for NTS atmospheric tests.

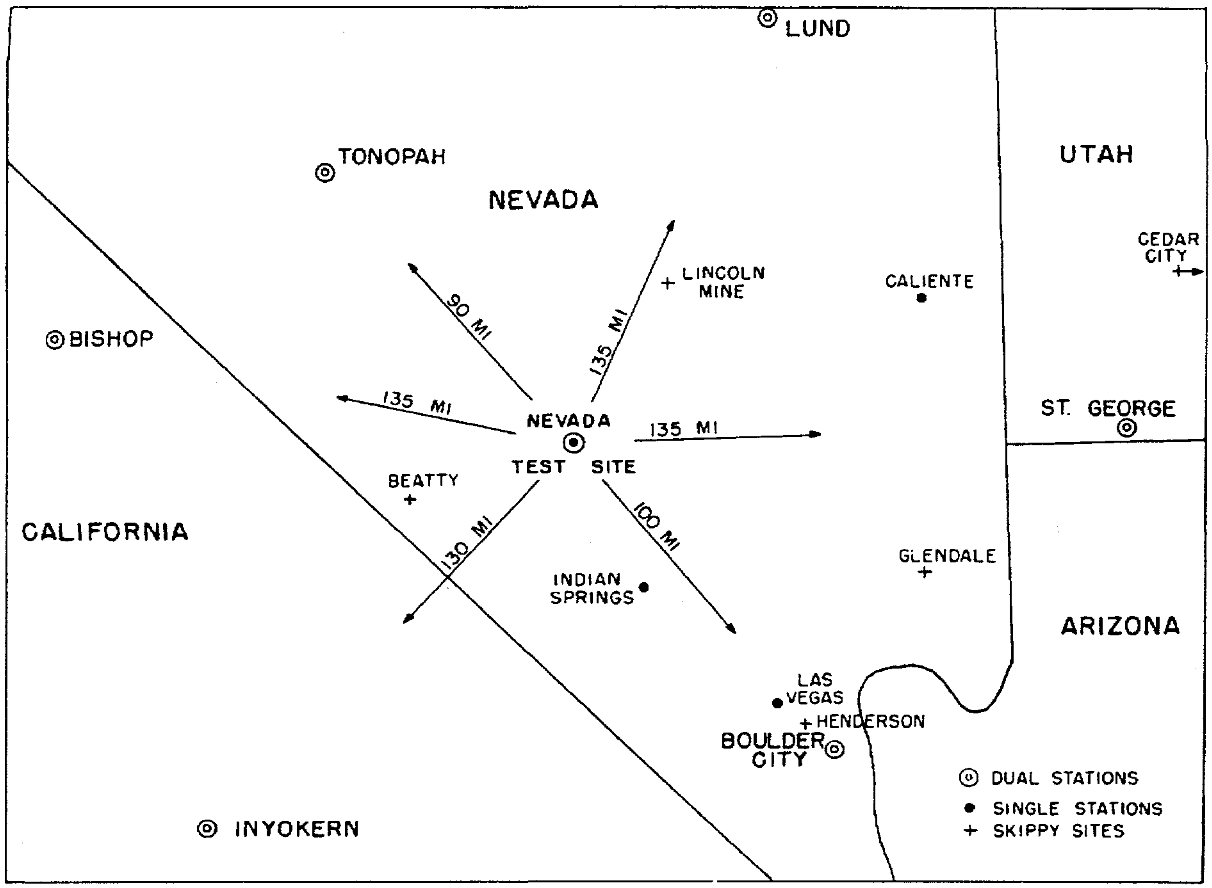

Figure 3. Map of microbarograph station locations used during 1955 (Cox and Reed, 1956).

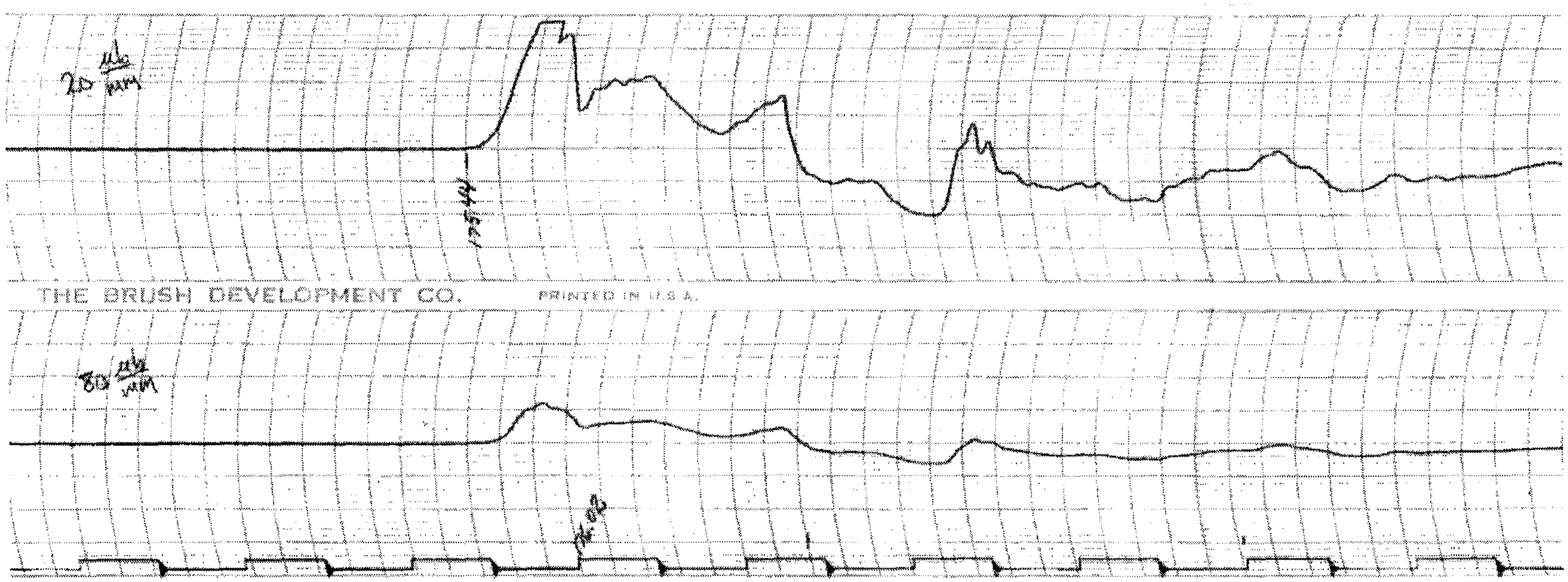

Figure 4. A portion of the strip chart from Indian Springs, NV for the NTS test HORNET, 3/12/55. Upper and lower traces record the high- and low-gain pressure channels, respectively.