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Operations
Praetorian, Phalanx, Fusileer, and Grenadier

Events
HURON LANDING/DIAMOND ACE, MINI JADE, TOMME/MIDNIGHT ZEPHYR, MIDAS MYTH/MILAGRO, and MISTY RAIN

23 September 1982 - 6 April 1985

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United States Underground Nuclear Weapons Tests
Underground Nuclear Test Personnel Review

Prepared by Defense Nuclear Agency

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13. ABSTRACT *(Maximum 200 words)*

This report is a personnel-oriented history of DoD participation in underground nuclear weapons testing up to and during Operation Praetorian, Phalanx, Fusileer, and Grenadier; Events HURON LANDING/DIAMOND ACE, MINNI JADE, TOMME/MIDNIGHT ZEPHYR, MIDAS MYTH/MILAGRO, and MISTY RAIN, 23 September 1982 to 6 April 1985. It is the seventh in a series of historical reports which will include all DoD underground nuclear test participation from 1962 forward. In addition to these historical reports, a restricted distribution report will identify all DoD and DoD affiliated participants, military, civilian, and DoD contractors, and will list their individual dose data.

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Praetorian	Phalanx
Fusileer	Grenadier
HURON LANDING	DIAMOND ACE
MINI JADE	TOMME
MIDNIGHT ZEPHYR	MIDAS MYTH
MILAGRO	MISTY RAIN

SUMMARY

Six Department of Defense (DoD)-sponsored underground nuclear tests were conducted from 23 September 1982 through 6 April 1985 to study weapons effects. All six were tunnel events. HURON LANDING and DIAMOND ACE were unique because this was the first time two devices were fired simultaneously (two microseconds apart) and in close proximity (40 feet apart). TOMME/MIDNIGHT ZEPHYR and MIDAS MYTH/MILAGRO were also somewhat different. TOMME was a Lawrence Livermore National Laboratory (LLNL) event while MIDNIGHT ZEPHYR was a DoD add-on that evaluated a low-yield testbed. MIDAS MYTH was a DoD event while MILAGRO was the name designated by Los Alamos National Laboratory (LANL) for their front-end physics experiments. The following table summarizes data on these events.

OPERATION	PRAETORIAN	PHALANX		FUSILEER	GRENADIER
EVENT	**HURON LANDING/ DIAMOND ACE**	**MINI JADE**	**TOMME/ MIDNIGHT ZEPHYR**	**MIDAS MYTH/ MILAGRO**	**MISTY RAIN**
DATE	23 Sep 82	26 May 83	21 Sep 83	15 Feb 84	06 Apr 85
LOCAL TIME (hours)	0900 PDT	0730 PDT	0800 PDT	0900 PST	1515 PST
NTS LOCATION	U12n.15 & bypass	U12n.12	U12n.18	U12t.04	U12n.17
TYPE	Tunnel	Tunnel	Tunnel	Tunnel	Tunnel
DEPTH (feet)	1,339/1,335	1,243	1,325	1,181	1,273
YIELD[1]	Low	Low	Low	Low	Low

[1] Low indicates less than 20 kilotons.

No accidental releases of radioactive effluent were detected onsite or offsite after any of the events discussed in this volume. However, controlled releases (planned releases where effluent was filtered before being released through the tunnel ventilation system) were detected onsite from the HURON LANDING/DIAMOND ACE and MINI JADE events. A controlled release from the MISTY RAIN event was detected offsite.

As recorded on Area Access Registers, 22,763 individual entries to radiation exclusion (radex) areas were made after the above DoD test events. Of this number, 2,127 entries were by DoD-affiliated personnel (military, DoD civilian, and DoD contractor). The remainder were made by the Department of Energy (DOE)[2], other government-agency, and other contractor personnel.

The average gamma radiation exposure per entry for all participants was 1.3 milliroentgen (mR). The average gamma radiation exposure per entry for DoD-affiliated participants was 1.6 mR. The maximum exposure of a non-DoD participant during an entry was 180 mR. The maximum exposure of a DoD-affiliated participant was also 180 mR. These maximum exposures both occurred during the MIDAS MYTH/MILAGRO event.

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[2] DOE's predecessors were the Atomic Energy Commission (AEC), 1 January 1947 to 19 January 1975; and the Energy Research and Development Administration (ERDA), 19 January 1975 to 1 October 1977.

PREFACE

The United States Government conducted 194 nuclear device tests from 1945 through 1958 during atmospheric test series conducted at sites in the United States and in the Atlantic and Pacific Oceans. The U.S. Army's Manhattan Engineer District (MED) implemented the testing program in 1945. In 1947 its functions were assumed by the Armed Forces Special Weapons Project (AFSWP) and the Atomic Energy Commission that administered the program from 1947 until testing was suspended by the United States on 1 November 1958.

Of the 194 nuclear device tests conducted, 161 were for weapons-related or effects purposes, and 33 were safety experiments. An additional 24 nuclear experiments were conducted from December 1954 to February 1956 in Nevada. These experiments were physics studies using small quantities of fissionable material and conventional explosives.

President Eisenhower had proposed that test ban negotiations begin on 31 October 1958, and had pledged a one-year moratorium on United States testing to commence after the negotiations began. The Conference on Discontinuance of Nuclear Weapons Tests began in Geneva on 31 October 1958, the U.S. moratorium began on 1 November, and the AEC detected the final Soviet nuclear test of their fall series on 3 November 1958. Negotiations continued until May 1960 without final agreement. No nuclear tests were conducted by either nation until 1 September 1961 when the Soviet Union resumed nuclear testing in the atmosphere. The United States began a series of underground nuclear tests in Nevada on 15 September 1961, and U.S. atmospheric tests were resumed on 25 April 1962 in the Pacific.

The United States conducted four atmospheric tests in Nevada during July 1962, and the last U.S. atmospheric nuclear test was conducted in the Pacific on 4 November 1962. The Limited Test Ban Treaty, which prohibited tests in the atmosphere, in outer space, and underwater, was signed in Moscow on 5 August 1963. From resumption of United States atmospheric testing on 25 April 1962 until the last atmospheric test on 4 November 1962, 40 weapons-related and weapons-effects tests were conducted as part of the Pacific and Nevada atmospheric test operations. The underground tests that resumed on 15 September 1961 have continued on a year-round basis through the period of this report.

In 1977, 15 years after atmospheric testing stopped, the Centers for Disease Control (CDC)[3] noted a possible leukemia cluster within the group of soldiers who were present at the Nevada Test Site (NTS) during the SMOKY test, one of the Nevada tests in the 1957 Plumbbob series. After that CDC report, the Veterans Administration (VA) received a number of claims for medical benefits filed by former military personnel who believed their health may have been affected by their participation in the nuclear weapons testing program.

In late 1977, the DoD began a study to provide data for both the CDC and the VA on radiation exposures of DoD military and civilian participants in atmospheric nuclear testing. That study has progressed to the point where a number of reports describing DoD participation in atmospheric tests have been published by the Defense Nuclear Agency (DNA) as the Executive Agent for the DoD.

On 20 June 1979, the United States Senate Committee on Veterans Affairs began hearings entitled Veterans Claims for Disabilities from Nuclear Weapons Testing. In addition to requesting and receiving information on DoD personnel participation and radiation exposures during atmospheric testing, the Chairman of the Senate Committee expressed concern regarding exposures of DoD participants in DoD-sponsored and DOE underground nuclear tests.

The Chairman requested and received information from the Director, DNA, in an exchange of letters through 15 October 1979 regarding research on underground testing radiation exposures. In early 1980, DNA initiated a program to acquire and consolidate underground testing exposure data in a set of published reports similar to the program then underway on atmospheric testing data. This report is the seventh in a series regarding participation

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[3] The Center for Disease Control was part of the Department of Health, Education and Welfare (now the Department of Health and Human Services). It was renamed the Centers for Disease Control on 1 October 1980.

and radiation exposures of DoD military and civilian participants in underground nuclear test events.

SERIES OF REPORTS.

Most reports in this series discuss DoD-sponsored underground tests in chronological order, after presenting introductory and general information. The reports cover all underground tests identified as DoD-sponsored in ANNOUNCED UNITED STATES NUCLEAR TESTS, (NVO-209) published each year by the DOE Nevada Operations Office, Office of Public Affairs, except one category. The category of events not covered were nuclear test detection experiments in a program named VELA-UNIFORM. Generally reentries after these tests were not performed, so significant exposure of participants to radiation did not occur.

One report will discuss general participation of DoD personnel in DOE underground nuclear events, with specific information on those events which released radioactive effluent to the atmosphere and where exposures of DoD personnel were involved.

A separate set of volumes (comprising one report) is a census of DoD personnel and their radiation exposure data. Distribution of this volume is limited by provisions of the Privacy Act.

METHODS AND SOURCES USED TO PREPARE THE VOLUMES.

Information for these reports was obtained from several locations. Classified documents were researched at Headquarters, DNA, Washington, D.C. Additional documents were researched at Field Command/DNA, Phillips Laboratory (a 13 December 1990 consolidation of the Air Force's Space Technology Center, Weapons Laboratory, Geophysics Laboratory, and Astronautics Laboratory), and Sandia National Laboratories, Albuquerque, New Mexico. Most of the radiation measurement data were obtained at the DOE, Nevada Field Office (DOE/NV), and its support contractor, Reynolds Electrical & Engineering Company, Inc. (REECo), both in Las Vegas, Nevada.

Unclassified records were used to document underground testing activities when possible, but, when necessary, unclassified information was extracted from classified documents. Both classified and unclassified documents are cited in the References Section at the end of each report. Locations of the referenced documents also are shown. Copies of most of the unclassified references have been entered in the records of the Coordination and Information Center (CIC), a DOE facility in Las Vegas, Nevada.

Radiation measurements, exposure data, event data, and offsite reports generally are maintained in hard copy or microfilm form at the REECo facilities adjacent to the CIC or as original documents at the Federal Archives and Records Center, Laguna Nigel, California. The Master File of all available personnel exposure data for nuclear testing programs on the continent and in the Pacific from 1945 to the present is maintained by REECo for DoD and DOE.

ORGANIZATION OF THIS VOLUME.

A summary of this volume appears before this Preface and includes general objectives of the events, characteristics of each event, and data regarding DoD participants and their radiation exposures.

Section 1, "Introduction," following this Preface and the Table of Contents discusses the historical background, underground testing objectives, DoD and DOE organizational responsibilities, and locations of NTS underground testing areas.

Section 2, "Underground Testing Procedures," explains the basic mechanics of underground testing, including containment problems and procedures, emplacement types, diagnostic techniques, the purpose of effects experiments, tunnel and drilling area access requirements, industrial safety considerations, radiological safety procedures, telemetered measurements of radiation levels, and air support requirements.

A section on each event covered by this volume follows in chronological order. Each event section contains an event summary, a discussion of preparations and event operations, an explanation of safety procedures implemented, and listings of monitoring, sampling, and exposure results.

A reference list and appendices to the text, including a Glossary of Terms (Appendix A) and a list of Abbreviations and Acronyms (Appendix B), follow the event sections.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

FIGURES

FIGURES (Continued)

FIGURES (Continued)

TABLES

SECTION 1

INTRODUCTION

The first United States nuclear detonation designed to be fully contained underground was the RAINIER tunnel event. The event was conducted by the University of California Radiation Laboratory (UCRL) for the AEC at the Nevada Test Site (NTS) on 19 September 1957. This was a weapons-related experiment with a relatively low yield of 1.7 kilotons (kt). The second tunnel event with a significant nuclear yield was a safety experiment on 22 February 1958, also conducted at NTS by UCRL for the AEC. This experiment, the VENUS event, resulted in a yield of less than one ton. These two tunnel events and five additional safety experiments with zero or only slight yields were the beginning of the United States underground nuclear testing program, currently the only type of nuclear detonation testing permitted by treaty. The first DoD-sponsored underground nuclear weapons-effects test was the 5.7 kt HARD HAT event conducted by the Defense Atomic Support Agency (DASA) on 15 February 1962 at NTS.

1.1 HISTORICAL BACKGROUND.

While technical conferences between the United States and the Soviet Union on banning nuclear detonation tests continued, and concern regarding further increases in worldwide fallout mounted, a number of nuclear tests were conducted underground during 1958 in Nevada. Prior to the United States testing moratorium, six safety experiments in shafts, five safety experiments in tunnels, and four weapons-related tests in tunnels were conducted by user laboratories. Radioactive products from several of these tests were not completely contained underground. Containment of nuclear detonations was a new engineering challenge. Understanding and solving the majority of containment problems would require years of underground testing experience.

When the United States resumed testing on 15 September 1961, the first 32 tests were underground, including a cratering experiment with the device emplaced 110 feet below the surface. The Dominic test series in the Pacific and the Sunbeam test series in Nevada during 1962 were the last atmospheric nuclear detonations by the United States.

The commitment of the United States to reduce levels of worldwide fallout by refraining from conducting nuclear tests in the atmosphere, in outer space, and underwater was finalized when the Limited Test Ban Treaty with the Soviet Union was signed on 5 August 1963. On 31 March 1976, the Soviet Union and the United States agreed to limit the maximum yield of underground tests to 150 kt. Currently, yields are reported as within a particular range; less than 20 kt, less than 150 kt, or 20 to 150 kt.

1.2 UNDERGROUND TESTING OBJECTIVES.

The majority of United States underground tests have been for weapons-related purposes. New designs were tested to improve efficiency and deliverability characteristics of nuclear explosive devices before they entered the military stockpile as components of nuclear weapons.

In addition to weapons-related tests, safety experiments with nuclear devices also were conducted by user laboratories. These experiments tested nuclear devices by simulating a nuclear detonation using conventional high explosives in a manner which might occur in an accident during transportation, handling, or storage of weapons.

Nuclear weapons-effects tests (NWET) sponsored by DoD were conducted to determine the vulnerability or survivability of military systems or components when exposed to one or more effects of a nuclear detonation. The major emphasis of NWET was on collecting radiation-effects data for strategic systems such as Pershing, Polaris, Minute Man, etc. The nuclear devices for these tests were provided by DOE weapons-development laboratories and were designed to be similar to the actual nuclear components used in nuclear weapons. Actual weapon configurations were only used in a few events. Military systems, structures, materials, electronics experiments, and other related experiments were provided by DoD and DOE agencies. Many of these tests were complex and involved greater numbers of participants than other categories of tests previously mentioned. Personnel from DNA, other government organizations, user laboratories and contractors, and DoD contractor agencies were involved.

Some tests were designed to study the response of hardened structures or geologic formations to shock waves generated by nuclear detonations. Many tests were designed to study the response of military components to effects of radiation produced by nuclear weapons. Such tests required a direct line-of-sight between the nuclear device and the experiments. Some of the radiation-effects tests required the simulation of high altitude conditions (up to exoatmospheric). These tests involved installation of experiments inside large steel line-of-sight (LOS) pipes, hundreds of feet in length, with maximum diameters of several feet. Large vacuum pumps were utilized to reduce pressure inside the pipes to the desired level. Other radiation-effects tests utilized scatterers to direct the radiation to experiments outside the pipe.

DoD weapons-effects tests HURON LANDING/DIAMOND ACE, 23 September 1982, through MISTY RAIN, 6 April 1985, conducted during Operations Praetorian, Phalanx, Fusileer, and Grenadier are discussed in this volume.

1.3 DOD TESTING ORGANIZATIONS AND RESPONSIBILITIES.

Administering the underground nuclear testing program was a joint DOE-DoD responsibility. The similar nature of the DOE and DoD organizational structure, during the period of this report, is shown in Figure 1-1.

1.3.1 Defense Nuclear Agency.

Headquarters of DNA is located near Washington, D.C., and is composed of personnel from each of the Armed Services and civilian DoD employees. It was originally established as the Armed Forces Special Weapons Project (AFSWP) to assume residual functions of the Manhattan Engineer District. This action was initiated through issuance of a joint Army Navy memorandum, dated 29 January 1947, which was retroactive to 1 January 1947 (when the Atomic Energy Commission was activated). The responsibility for DoD nuclear weapons-effects testing was assigned to AFSWP. The

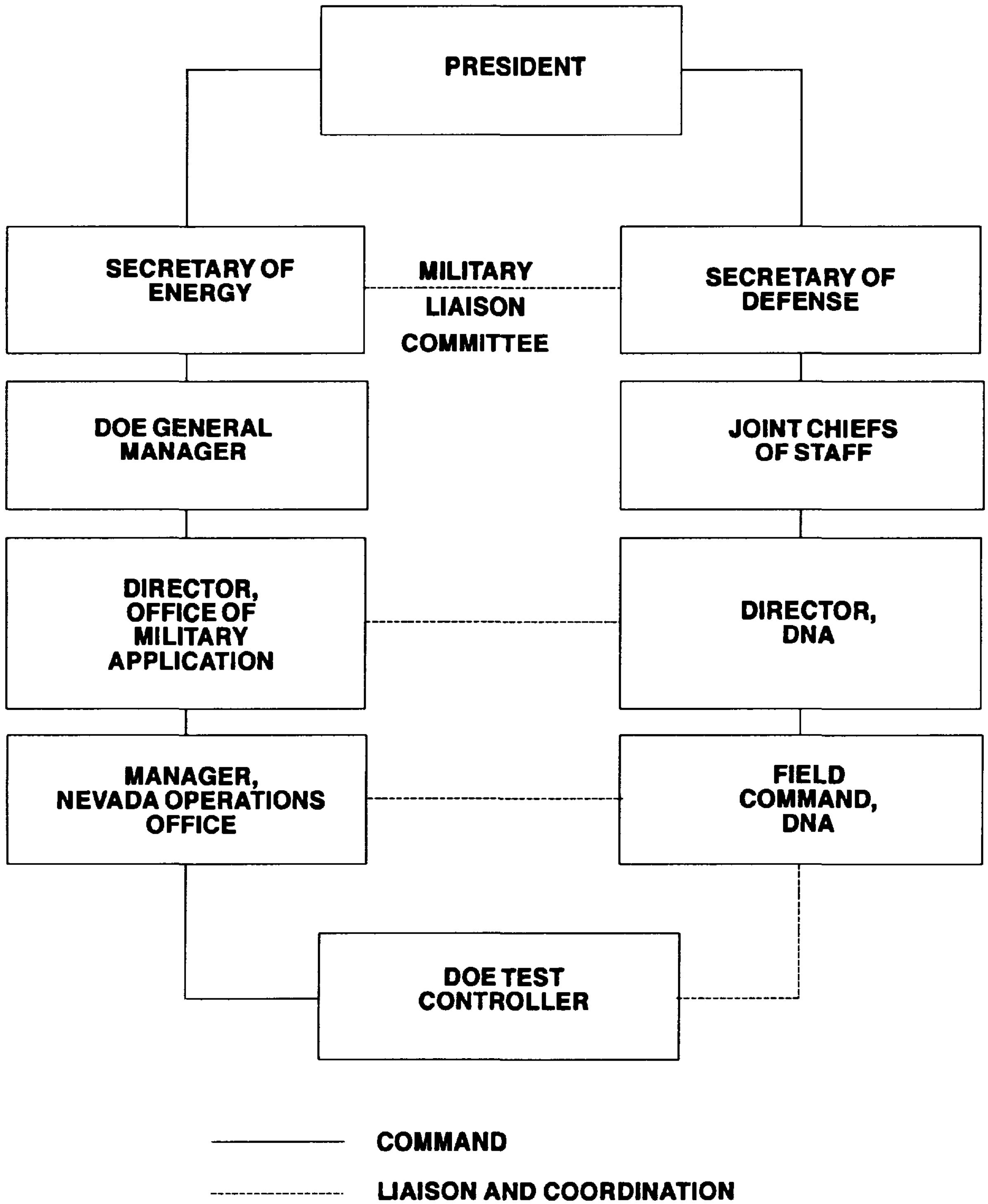

Figure 1-1. Federal government structure for continental nuclear tests (1982-1985).

National Security Act of 1947 had become law when the Secretary of Defense issued a memorandum on 21 October 1947 to the three Service secretaries confirming the previous directive of 29 January, and thus, AFSWP officially represented all of the services. AFSWP was charged with providing nuclear weapons support to the Army, Navy, and Air Force. As originally chartered, AFSWP was directly responsible to each of the three Service chiefs. In 1951, the Air Force Special Weapons Center (AFSWC) located at Kirtland Air Force Base (KAFB), Albuquerque, New Mexico, was assigned the responsibility by DoD to provide specific support to the AEC for continental nuclear testing (see Section 1.3.2). This command was not directly related to AFSWP; however, the two organizations coordinated several support tasks.

By issuance of General Order No. 2, Headquarters, DASA (HQ/DASA), dated 6 May 1959, AFSWP became DASA. Under its new charter, DASA was responsible to the Secretary of Defense through the Joint Chiefs of Staff (JCS).

DASA's five major areas of responsibility for the DoD included:

1. Staff assistance to the Office of the Secretary of Defense, through the JCS.

2. Research in weapons effects.

3. Atomic tests.

4. Weapons-related tests.

5. Assistance to the Services.

Responsibilities of HQ/DASA included providing consolidated management and direction for the DoD nuclear weapons-effects testing program. Technical direction and management of field operations for DoD nuclear weapons-effects testing activities were delegated to Field Command, DASA (FC/DASA), located at Sandia Base, now KAFB in Albuquerque, New Mexico. From 6 May 1959 until 1 July 1964 the Weapons Effects Test Group (WETG) of FC/DASA was responsible for nuclear weapons-effects testing and seismic detection research (VELA-UNIFORM) for the Director, DASA. This organization maintained close liaison with the AEC/Nevada

Operations Office (NVOO). Personnel from FC/DASA became the military members of the joint AEC-DoD testing organization at the NTS and other Continental United States test locations. Participation of DoD agencies and their contractors in nuclear field tests was coordinated and supported by FC/DASA. On 1 July 1964, the testing organization in Albuquerque was designated as the Weapons Test Division (WTD), a Division of HQ/DASA. On 1 August 1966, WTD's name was changed to Test Command, DASA, and it became a separate command under HQ/DASA, remaining in Albuquerque. The responsibility for technical direction and management of field operations for nuclear effects tests remained in effect during these changes in organization. During this period, WTD and TC/DASA maintained an engineering and support branch (designated the Nevada Branch) at the NTS and a liaison office at AEC/NVOO. The Nevada Branch maintained liaison with AEC/NVOO and supervised FC/DASA activities at NTS. On 12 May 1970, the Commander, FC/DASA assumed additional command of TC/DASA.

On 29 March 1971 (effective 1 July 1971), the Deputy Secretary of Defense directed the reorganization of DASA as a result of cutbacks recommended by the "Blue Ribbon Panel" survey of agency activities. In his Executive Memorandum, DASA was retained as a defense agency under the new title, "Defense Nuclear Agency." Also on 1 July 1971, FC/DASA was redesignated as FC/DNA, and TC/DASA became TC/DNA. While the responsibilities and manning levels at Field Command were reduced during this transition, Test Command remained essentially the same.

On 1 January 1972, TC/DNA was discontinued and personnel were transferred to FC/DNA. The responsibility for technical direction and management of field operations for nuclear weapons-effects tests were transferred to the newly formed Test Directorate (Field Command Test, FCT), of FC/DNA. The Nevada Branch of TC/DASA was changed to the Test Construction Division of Test Directorate (FCTC), and the responsibility for the liaison office at AEC/NVOO was transferred to FCTC. In 1980 a Containment Division (FCTK) was added to Test Directorate to plan and supervise the containment research program for DNA; and in 1982 the Test Directorate Safety Engineer (FCTS) was added as a separate office. (See Figure 1-2.)

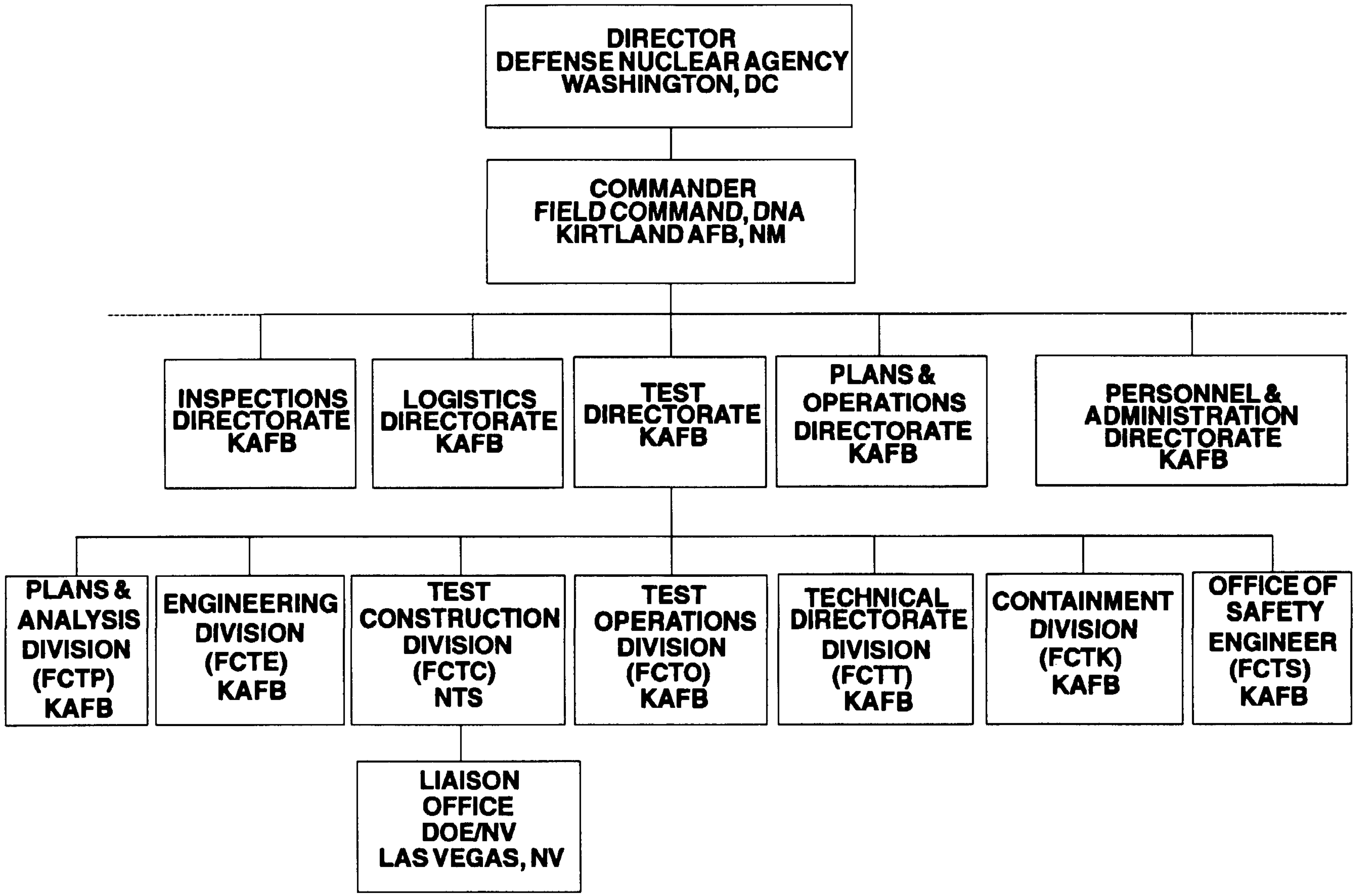

Figure 1-2. Partial organization chart of Field Command, Defense Nuclear Agency (1982-1985).

1.3.2 Air Force Support.

Until 1 July 1974, AFSWC provided air support to the Nevada Test Site Organization (NTSO) during nuclear tests at the NTS. Detachment 1, of the 4900th Test Group provided aircraft for shuttle service between KAFB, New Mexico, and Indian Springs Air Force Auxiliary Field (ISAFAF) in Nevada. They also provided aircraft and crews to perform low-altitude cloud tracking, radio relay support, and courier missions. On 1 July 1974, AFSWC's air support responsibility, along with Detachment 1, 4900th Test Group, was transferred to the 57th Fighter Weapons Wing (FWW), Tactical Air Command (TAC), at Nellis Air Force Base (NAFB), Nevada. AFSWC continued to support the Air Force's nuclear research and development (R&D) mission until 1 April 1976, when it was deactivated. The nuclear R&D mission was transferred to the Air Force Weapons Lab (AFWL), KAFB, New Mexico, at this time. Detachment 1 remained at ISAFAF and continued to provide support to the NTS; however, personnel, aircraft, equipment, and supplies became the responsibility of the 57th FWW. Support was formalized by Interservice Support Agreements between the Tactical Fighter Weapons Center (as represented by the 57th FWW) and FC/DNA, acting as the agent of the Departments of Defense and Energy for receiving aeronautical support at NTS. On 1 November 1983, Detachment 1, 4900th Test Group was deactivated and replaced by the 4460th Helicopter Squadron (HS) which was activated at ISAFAF. The 4460th was the largest helicopter unit in TAC with six UH-1N helicopters and 77 personnel authorized. Operations provided by the 4460th HS during the period of this report were:

A. An airborne security inspection of pre-closed areas on D-1.

B. A D-day airborne safety inspection and Test Controller standby mission to be flown prior to D-11 hours and to cover the downwind area for personnel and livestock locations. (The standby portion of this mission was for rapid evacuation of personnel and/or reentry of scientific personnel, if necessary.)

C. A D-day helicopter airborne closed-circuit television mission to provide a stable platform for both television and color photography coverage of surface ground zero at zero time.

D. A D-day helicopter cloud surveillance to provide initial data for immediate "onsite" decisions regarding safeguard actions. (Not to be considered as "cloud tracking.")

E. Damage survey flights, as required, and other support flights as requested by the Test Controller and as operationally feasible by the 57th FWW Deputy Commander for Operations.

F. Normal technical support and laboratory photography flights, as required, including survey of preshot, postshot, and new construction areas.

G. An airborne security inspection to cover the NTS boundary, checking the locked barricades, and looking for areas where intruders might have gained access to the NTS unobserved.

H. Operational orientation tours and management surveillance flights as requested by higher headquarters of either activity.

1.3.3 DOE-DoD Relationships.

DoD was responsible for establishing criteria for nuclear weapons, developing and producing delivery systems, developing nuclear weapons plans and forces, providing defense against nuclear attack, and obtaining nuclear weapons-effects data through DNA. DOE was responsible for research, development, production, and supply of nuclear weapons to the Armed Forces in quantities and types specified by the JCS. Quantities and types of weapons were described in the Nuclear Weapons Stockpile Memorandum, signed by the Secretary of Defense and Secretary of Energy or his alternate and approved by the President. DOE in association with DoD, also was responsible for providing field nuclear test facilities in the Continental United States and islands in the Pacific.

The principal points of field coordination between DoD and DOE were at the Nevada Operations Office (NV) in Las Vegas and at NTS. From the beginning of the DoD underground nuclear weapons-effects test program (the first test was HARD HAT in February 1962) through the period covered by this volume, Field Command (or Test Command) was the fielding agency for DoD-DNA and served as the primary point of contact with the Nevada office of the DOE. DOE/NV represented DOE in the field for all Continental tests. The DOE nuclear weapons-development laboratories fielded underground tests as part of the weapons-development program; DNA fielded underground tests at NTS to obtain weapons-effects data. Because the NTS was a DOE installation, the Manager, NV, was responsible for all operations there.

For each DoD-sponsored test, HQ/DNA coordinated requirements with the military services. Requirements for testing to determine the nuclear vulnerability or hardening of military systems or components were submitted by these organizations. As part of long-range underground nuclear weapons-effects test planning, HQ/DNA developed a schedule of specific events designed to satisfy military requirements. One or more of the DoD agencies were cosponsors and usually active participants in each DoD underground test. Many of the nuclear weapons-effects tests also included active participation by one or more of the DOE laboratories in vulnerability/survivability experiments for nuclear warheads, warhead electrical systems, and limited-life components (LLC). The initial approval of DoD experiments and the selection of the nuclear source (device) for each test was accomplished at the HQ/DNA level. A request for the appropriate nuclear device and associated support was forwarded by HQ/DNA to the Director, Division of Military Application, DOE. The DOE assigned one or more of the weapons-development laboratories to provide the device support.

Following initial planning, the responsibility for detailed planning, engineering, fielding, execution, and reporting was assigned to FC/DNA. Field Command formed a Test Group staff for each test. The Technical Director (normally a military officer assigned to FC/DNA or AFWL) was appointed by HQ/DNA. The Test Group Director and other members of the staff were appointed by FC/DNA. The Test Group Engineer normally was selected from FCTC, Nevada Branch.

The Test Group staff developed detailed test plans and schedules. Engineering and construction plans were developed by the Nevada Branch and coordinated with the Nuclear Test Organization (NTO)[4]. Final engineering designs were developed by DOE contractors at NTS - Holmes & Narver, Inc. (H&N), and/or Fenix & Scisson, Inc. (F&S). Engineering drawings were approved by FCTC and NTO prior to actual construction. Construction was performed by the principal DOE support contractor - REECo. FCTC and members of the Test Group staff monitored construction activities. The FC/DNA Test Group staff coordinated development of technical experiments and initiated action to obtain required support equipment (e.g., steel LOS pipe and mechanical closures). The Test Group staff reviewed the technical support requirements submitted by experimenter agencies and submitted consolidated requirements to the Nevada Operations Office which, in turn, advised the NTO of future requirements.

During the construction phase, the Test Directorate's Containment Division (FCTK) began collecting containment-related information. During drilling or mining operations, rock cores were analyzed for bulk density, moisture content, grain density, porosity (determined by the difference between bulk and grain densities), unconfined compressive strength, triaxial compression (for a variety of confining pressures), ultrasonic shear and compressive wave velocities, carbon dioxide content, presence of clay which could swell, and other features. Testing was done for DNA primarily by the H&N Testing Lab at NTS (Mercury) and Terra Tek, a DNA contractor located at Salt Lake City, Utah, as part of the DNA containment-research program.

Geologic features of the tunnels were examined and mapped as construction progressed, usually by a DOE contractor. Several months prior to the planned event, FC/DNA prepared a document which contained a general description of the test, site geologic information, types and locations of mechanical closures, details of concrete plugs, a summary of analytical calculations, and other related test history. This document was reviewed by Containment Evaluation Panel (CEP; see Section 2.1.3) members and

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[4] Assumed the functions of the Nevada Test Site Organization (NTSO) in 1982.

formally presented by FC/DNA to the CEP for categorization and recommendation for execution.

The FC/DNA Test Group staff normally moved to NTS a few months prior to the planned event execution date (three to six months depending on the complexity of the test). Prior to arrival of DoD experimenter personnel, the Nevada Operations Office, in conjunction with the Test Group staff, made arrangements to provide required instrumentation and recording facilities, office space and equipment, communications equipment, vehicles, photography, and other support items. Housing and food services for DoD personnel at NTS were provided by REECo. Upon arrival at NTS, DoD personnel were briefed on safety and security by the Test Group staff and other DoD and DOE personnel. These briefings included radiation safety control policies, procedures, and equipment. Experimenter agencies were provided with copies of FC/DNA security and safety plans.

Under the supervision of the Test Group staff, experimenter personnel installed experiments and checked out instrumentation cables and recording systems. A series of electrical dry runs were conducted from the participating (user) laboratory control room and DNA monitoring room at the Control Point (CP) complex (see Section 1.5) to determine that all signals and remotely-controlled equipment were functioning properly. After all systems were declared ready, permission was requested from the DOE to install the nuclear device. Installation and check out were conducted by the participating device-development laboratory with DOE security safeguarding the device and other classified materials. The next activities consisted of placing stemming materials in preplanned locations and checking all containment features.

When the test facility was ready for event execution, control of the entire test and experiment area was transferred to the DOE/NV Test Controller and his staff. When the Test Controller was satisfied that all conditions were satisfactory to detonate the device, he gave permission to the user laboratory to arm the device and initiate the final countdown.

The Test Controller and his staff at the CP monitored the countdown, detonation, and postevent response of remotely-controlled radiation monitoring equipment. When released by the Test Controller, REECo Radiological Safety (Radsafe) teams entered the area to monitor for radiation and other safety hazards. After assurance that reentry could be accomplished, the Test Controller released experimenters to collect recorded data from surface areas. All of these operations were conducted in accordance with postshot plans developed by the DOE Test Controller staff, the DoD Test Group staff, and Nevada Branch personnel, unless post-event conditions required modifications.

For tunnel events, initial reentry into the tunnel was authorized by the DOE Test Controller after it was determined that conditions were safe for reentry operations. Tunnel reentry was controlled by Nevada Branch personnel with assistance from Sandia National Laboratories (SNL) health physicists, REECo Radsafe personnel, and REECo construction personnel. After the tunnel was declared safe for experiment recovery, the Test Group staff assumed control of the area. Based on REECo Radsafe monitoring data, FC/DNA personnel determined when it was safe to remove the experiments. Experimenters then removed experiments for analysis and documentation of results.

1.4 DOE ORGANIZATIONS, CONTRACTORS, AND RESPONSIBILITIES.

1.4.1 Atomic Energy Commission.

The AEC was created by the Atomic Energy Act of 1946 in July, the same month the JCS were conducting Operation Crossroads with assistance from the U.S. Army's Manhattan Engineer District. On 1 January 1947, MED was deactivated and the AEC and AFSWP assumed its functions. The Atomic Energy Act was revised in 1954 and has been amended extensively since.

The AEC established headquarters (AEC/HQ) offices in Washington, D.C., and operations offices in areas that were centers of AEC operations. In areas of lesser activity, area offices, branch offices, and field offices were established. The Director of the Division of Military Application (DMA) in AEC/HQ was delegated responsibility for the nuclear-weapons development and testing program. The Director of DMA was always a flag officer from one of the armed forces, as specified by the Atomic Energy Act of

1954, and he was an Assistant General Manager in the AEC organization.

In 1951, the Director of DMA designated and delegated his responsibility for conduct of on-continent tests to the Test Manager of the AEC Santa Fe Operations Office (SFOO) near Los Alamo Scientific Laboratory. Later in 1951, SFOO was moved to Albuquerque. With delegated authority from the Director of DMA, the Manager, SFOO, designated Test Managers for on-continent tests. The same authority applied when SFOO became the Albuquerque Operations Office (ALOO) in 1956. The AEC Las Vegas Field Office (LVFO), established in 1951, managed the Nevada Test Site (called the Nevada Proving Ground from 1952 to 1955) for the Test Manager. LVFO became a Branch Office in 1955, an Area Office in 1960, and the Nevada Operations Office (NVOO, later shortened to NV) in 1962, with the Manager, NVOO, or his representative designated as Test Manager. In 1972, the Test Manager became the Test Controller.

In 1977 the Division of Military Application (DMA) was changed to the Office of Military Applications (OMA). OMA initiated the chain of authority and approval for detonating each nuclear device by requesting that each user laboratory and DNA submit proposed test programs to OMA. This request was made in the spring of each year for tests to be conducted in the next fiscal year. OMA consolidated proposed test programs, developed a test program proposal while consulting with DoD, and generated a program approval request. OMA then presented the proposed test program to the National Security Council (NSC) Ad Hoc Committee on Nuclear Testing. Chaired by the NSC, this committee included representatives of the DoD, JCS, Department of State, Arms Control and Disarmament Agency, Office of Management and Budget, Office of Science and Technology, and Central Intelligence Agency. After incorporating informal committee comments, OMA forwarded the proposed program from the Secretary of Energy to the President through the NSC. The NSC solicited and incorporated formal comments in its recommendation to the President.

Test program approvals were requested at six month intervals. Approval of tests for the first six months was received at the beginning of each fiscal year. The process was repeated six months later for tests in the last half of the fiscal year.

Presidential approvals were signed by the Assistant to the President for National Security Affairs. Subsequently, test program authority messages were sent from the Director OMA to the user laboratories, DNA, and DOE/NV.

Authority to detonate each nuclear device was handled separately and individually. The technical content of detonation authority requests originated in presentations to the CEP by the user laboratory or DNA. After recommendations by the CEP, the Manager, NV, requested detonation authority from OMA. Required information in each request included statements on compliance with treaties, environmental impact, public announcement plans, test program authority, and any particularly noteworthy aspects of the test. After OMA and additional DOE reviews, the Manager, NV was notified of detonation authority approval.

1.4.2 Nevada Test Organization.

As stated in Chapter 0101 of the Nuclear Test Organization (NTO) Standard Operating Procedure (NTS SOP Chapter 0101, Appendix C[5]), the NTO included DOE, DoD, user laboratory, contractor, agency, and organizational personnel who participated in or provided support for test operations at the NTS. The Manager, NV, headed the NTO and appointed the Test Controller who was assigned full responsibility for the safe conduct of each nuclear test. (See Figure 1-3.) The Test Controller was supported by the NTO, which was a continuing task organization whose composition could be readily changed in response to the needs and technical objectives of each test.

The Continental Test Organization (CTO)[6] was part of the original Nevada Test Site Organization. However, it was disestablished on 1 August 1962, with its responsibilities (e.g., Military Deputy to the Manager, NVOO) being assumed by WETG, FC/DASA, Weapons Test Division (WTD)/DASA, TC/DASA, and subsequently by Test Directorate, FC/DNA. During the period of this report, when the

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[5] DOE NTS SOP Chapter 0101 superseded AEC NTSO SOP Chapter 0101-01 on 18 August 1982.

[6] See DNA 6320F, Operations Nougat and Whetstone for additional information.

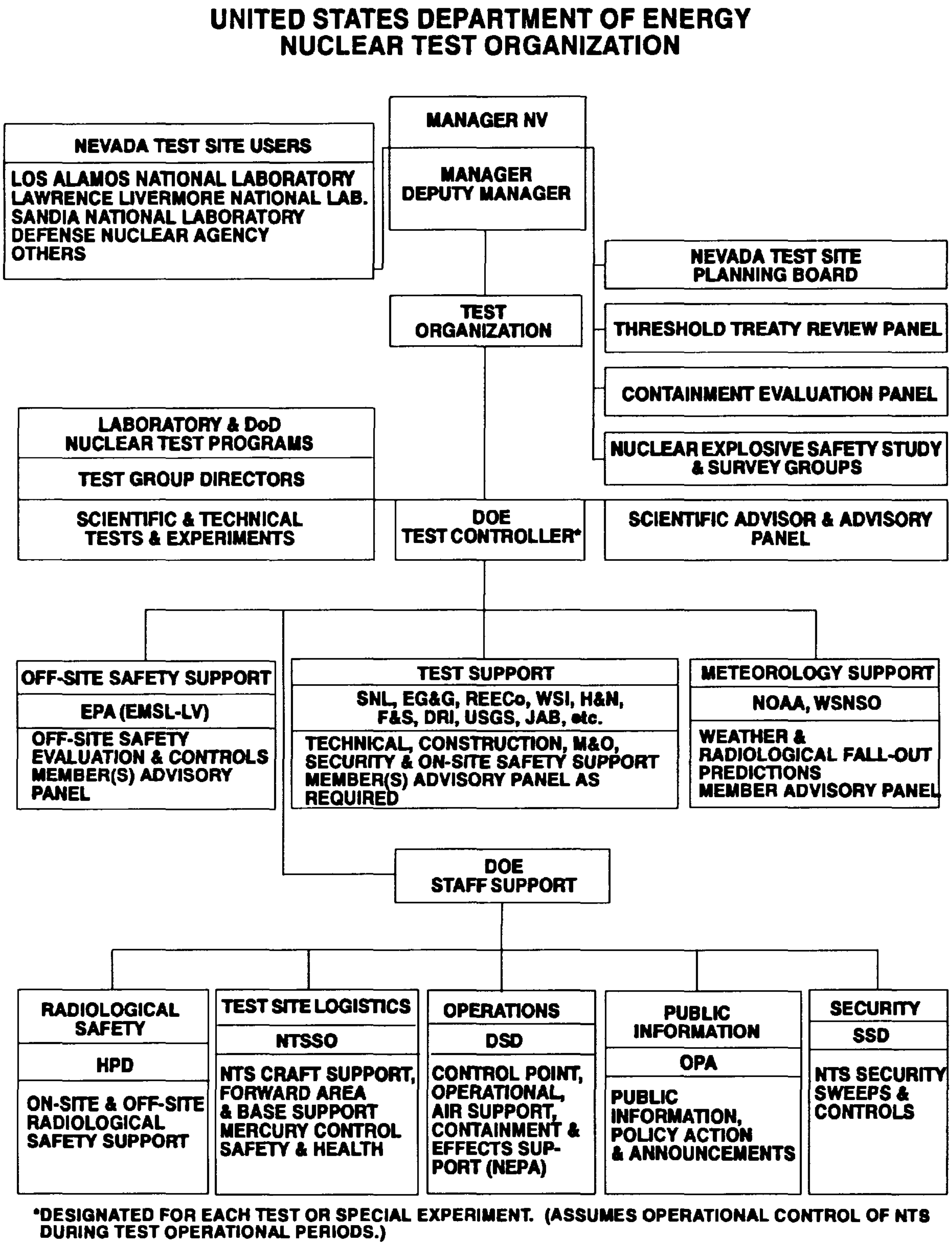

Figure 1-3. Nevada Test Organization (1982-1985).

NTSO was changed to the NTO, and Test Directorate, FC/DNA, was reorganized, the Deputy for Military Matters position was deleted from the NTO organization chart. Responsibilities of that position for coordinating DoD programs and support to the NTO were transferred to the Test Construction Division, FC/DNA, at Mercury, NV.

1.4.3 NTO Radiological Safety.

The Test Controller was responsible for protection of participating personnel and offsite populations from radiation hazards associated with activities conducted at NTS. By mutual agreement between the Test Controller and a scientific user (see Section 1.4.4), control of radiation safety within the area assigned for a particular activity was delegated to the user's Test Group Director during the period of time when such control could have had a direct bearing on the success or failure of the scientific program.

The onsite radiological safety support contractor (REECo Radsafe) was responsible to the Director, Health Physics Division, for both routine and test event radiological safety coordination onsite as detailed in Appendix D, DOE NTS SOP Chapter 0524[7], "Radiological Safety." During events, the Test Manager, NV, delegated control of radiation safety in the immediate test area to the user Test Group Director when the Director requested control. When this occurred, each Radsafe coordinator was responsible to the Test Group Director through his radiological safety organization for support in his test area.

The U.S. Environmental Protection Agency (EPA), was responsible to the Test Controller for operation of the offsite radiological safety program.

1.4.4 NTS Scientific Users.

The NTS scientific users were DNA (for nuclear weapons effects) and the development laboratories: Los Alamos National Laboratory (LANL), Lawrence Livermore National Laboratory (LLNL), and Sandia

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[7] DOE NTS SOP Chapter 0524 superseded AEC NTSO SOP Chapter 0524 on 23 July 1982.

National Laboratories (SNL). LANL and LLNL were primarily involved in weapons-development testing while SNL conducted a limited number of weapons-effects tests and supported weapons-development tests. A brief description of these laboratories follows:

A. LANL was established early in 1943 as Los Alamos, Project Y, of the MED for the specific purpose of developing an atomic bomb. Los Alamos scientists supervised the test detonation of the world's first atomic weapon in July 1945 at the Trinity site in New Mexico. Los Alamos became Los Alamos Scientific Laboratory (LASL) in January 1947 when the AEC and AFSWP were activated to replace the MED. LASL was renamed LANL on 29 December 1979 when Congress passed a bill changing LASL, LLL, and SLA to national laboratories. The Laboratory's continuing assignment was to conceive, design, test, and develop nuclear components of atomic weapons. The contract under which LANL performed work for DOE was administered first by the AEC's Santa Fe Operations Office and later by the Albuquerque Operations Office. The laboratory was operated by the University of California.

B. LLNL (originally the University of California Radiation Laboratory [UCRL], then the Lawrence Radiation Laboratory [LRL], the Lawrence Livermore Laboratory [LLL], and finally LLNL) was established as a second DOE weapons laboratory at Livermore, California, in 1952. The Laboratory's responsibilities were parallel to those of LANL. Devices developed by LLNL first were tested in Nevada in 1953, and LLNL-developed devices have been tested in each Continental and Pacific series since. The contract under which LLNL performed work for DOE was administered by their San Francisco Operations Office. This Laboratory also was operated by the University of California.

C. SNL has also undergone several name changes; it was established in 1945 as Z Division of Los Alamos. In April 1948, it was named Sandia Laboratory, Branch of Los Alamos Scientific Laboratory; and in November 1949 it assumed its identity as a full-fledged weapons research institution operated by Sandia Corporation (SC), a non-profit subsidiary of Western Electric. In May 1956 it was renamed Sandia Laboratory, Albuquerque (SLA) adding a Livermore Branch in March 1956 (to provide closer support to LLL). SLA also operated the ballistics test facilities for the AEC at the Tonopah Ballistics Range (now Tonopah Test Range) in September 1956. In 1969, the name was changed to Sandia Laboratories (SL), and in 1979 it was changed to Sandia National Laboratories. SNL's role was to conceive, design, test, and develop the non-nuclear phases of atomic weapons and do other work in related fields.

1.4.5 Test Support Organizations.

In keeping with its policy, DOE used private contractors for maintenance, operations, and construction (including military and civil defense construction) at the NTS. NV personnel administered all housekeeping, construction, and related services activity, but performance was by contractors. Major support contractors were the following:

Reynolds Electrical & Engineering Company, Inc., was the principal DOE operational and support contractor for the NTS, providing electrical and architectural engineering, state-of-the-art large diameter and conventional shaft drilling, heavy-duty construction and evacuation, mining and tunneling, occupational safety and fire protection, radiological safety, toxic gas and explosive mixture monitoring, communications and electronics, power distribution, occupational medicine, and other support functions. REECo maintained offices in Las Vegas and extensive facilities necessary to operate at NTS.

Edgerton, Germeshausen & Grier, Inc., (renamed EG&G, Inc. in 1966) was the principal technical contractor, providing control point functions such as timing and firing, and diagnostic functions such as scientific photography and measurement of detonation characteristics. In addition, EG&G personnel manned the DoD monitor room. EG&G support facilities were maintained in Las Vegas and at NTS.

Holmes & Narver, Inc., performed architect/engineer services for the NTS and was the principal support contractor for AEC's off-continent operations. H&N had a home office in the Los Angeles area and also maintained offices in Las Vegas and at NTS.

Fenix & Scisson, Inc., of Tulsa, Oklahoma, was a consultant architect/engineer for drilling and mining operations in connection with underground nuclear testing since 1963. The company was involved in design of many underground structures and in the field of deep, large-diameter hole drilling. Las Vegas Branch activity was conducted from offices in Las Vegas and Mercury, Nevada.

Numerous other contractors, selected on the basis of lump-sum competitive bids, performed various construction and other support functions for DOE and DoD.

1.5 THE NEVADA TEST SITE.

An on-continent location was selected for conducting nuclear weapons tests. Construction began at what was called the Nevada Test Site in December 1950, and testing began in January 1951. The name was changed to the Nevada Proving Grounds (NPG) in March of 1952 and again changed to the Nevada Test Site on 31 December 1954.

The original boundaries were expanded as new testing areas and projects were added. Figure 1-4 shows the present NTS location bounded on three sides by the Nellis Air Force Range. NTS encompassed about 1,350 square miles in 1985. This testing location was selected for both safety and security reasons. The arid climate, lack of industrialization, and exclusion of the public from the Nellis Air Force Range resulted in a very low population density in the area around NTS.

The only paved roads within the NTS and Nellis Air Force Range complex were those constructed by the government for access purposes. NTS testing areas were physically protected by surrounding rugged topography. The few mountain passes and dry washes where four-wheel drive vehicles might enter were posted

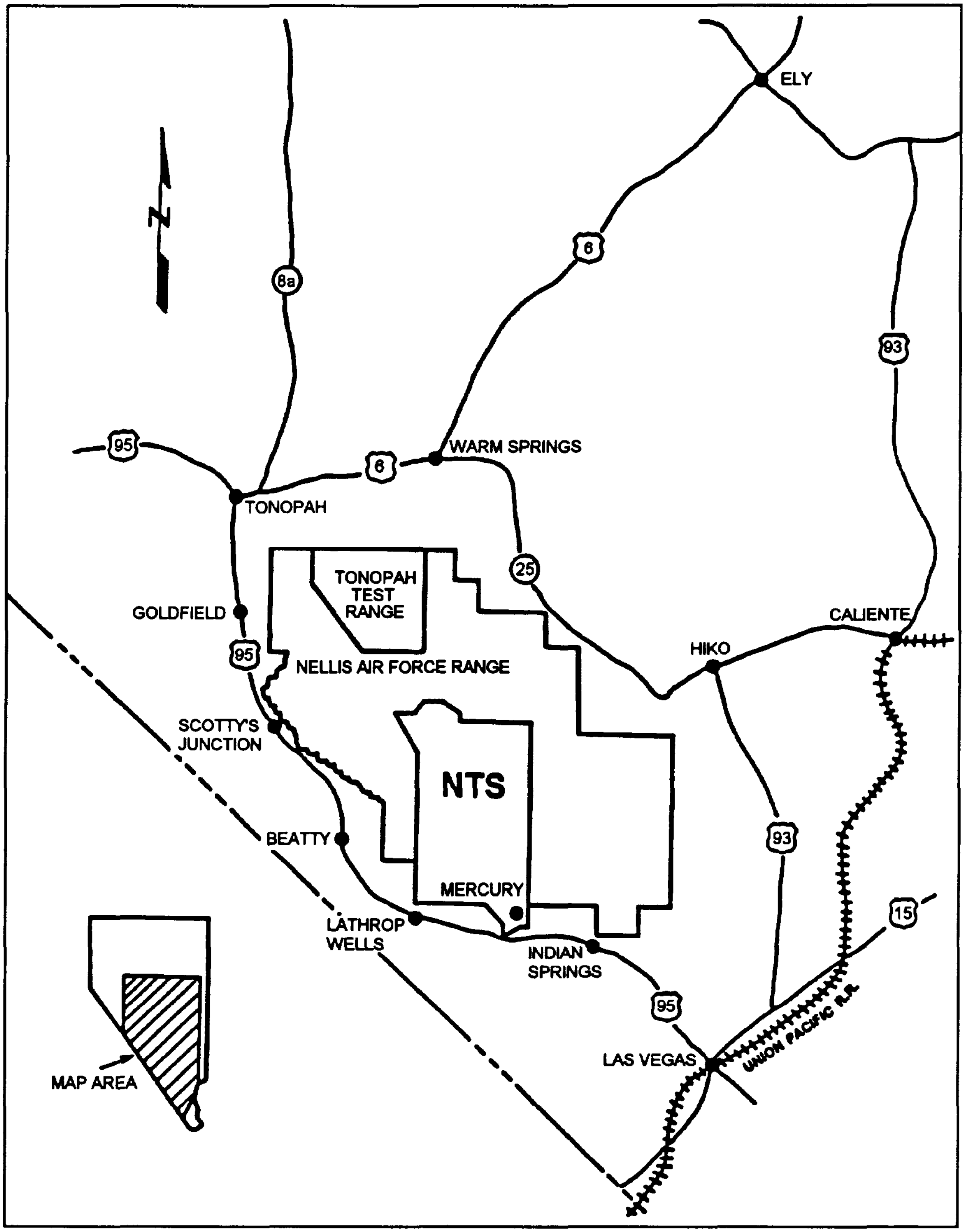

Figure 1-4. Nellis Air Force Range and the NTS.

with warning signs and barricades. NTS security force personnel patrolled perimeter and barricade areas in aircraft and vehicles. Thus, unauthorized entry to NTS was difficult, and the possibility of a member of the public inadvertently entering an NTS testing area was extremely remote.

Figure 1-5 shows the NTS, its various area designations, and the locations of the six events covered by this volume. In a location designation such as "U12n.07" the "U" signifies an underground location, "12" identifies the area at NTS, "n" denotes the tunnel, and "07" indicates the drift number.

A low mountain range separates the base camp, Mercury, from the location of early AEC and DoD atmospheric tests at Frenchman Flat in Area 5. This area was also later used for DoD underground testing. The elevation of Frenchman Dry Lake in the middle of the Flat is about 3,100 feet.

A mountain pass separates Frenchman Flat from Yucca Flat testing areas. The pass overlooks both Frenchman and Yucca Flats and contains the CP complex of buildings including Control Point 1 (CP-1) and Control Point 9 (CP-9) where timing and firing for most underground nuclear tests were performed, and Control Point 2 (CP-2) where radiological safety support was based.

Yucca Flat testing areas include Areas 1, 2, 3, 4, 7, 8, 9, and 10. Underground tests were conducted in some of these areas and generally were shaft emplacement types. The elevation of Yucca Dry Lake at the south end of Yucca Flat is about 4,300 feet. To the west of Yucca Flat, in another basin, is the Area 18 testing location. Some DoD atmospheric tests were conducted in Area 18, and one DoD cratering event, DANNY BOY, was conducted on Buckboard Mesa in this area at an elevation of about 5,500 feet. Area 16 is in the mountains west of Yucca Flat toward Area 18. The single Area 16 tunnel complex (at an elevation of about 5,400 feet) was a DoD underground testing location.

Rainier Mesa is in Area 12, northwest of Yucca Flat. The top of the Mesa is at an elevation of about 7,500 feet. All DoD tunnel emplacement events on NTS that were not in the Area 16 tunnel complex or the Area 15 shaft and tunnel complex were in Rainier

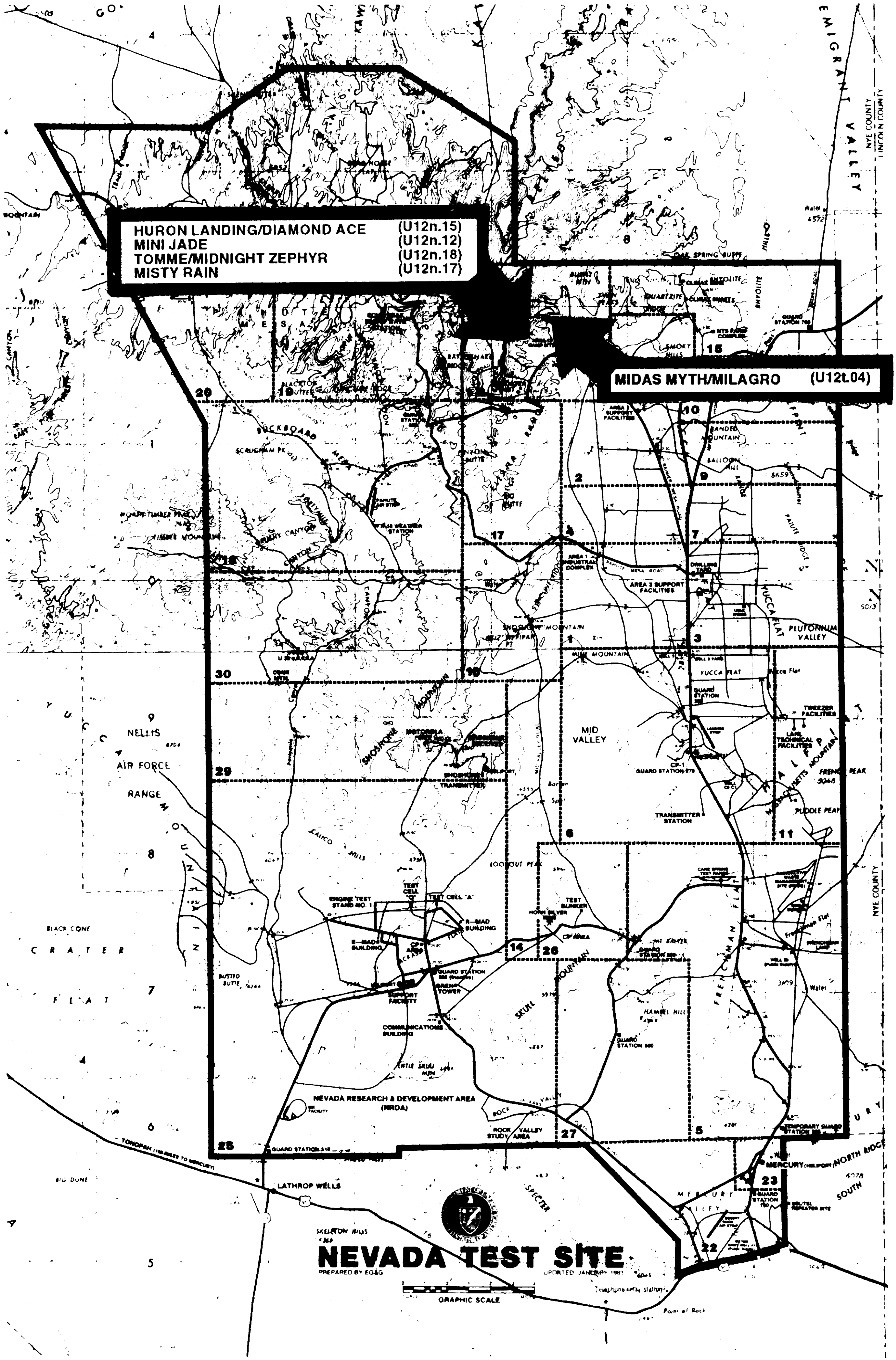

Figure 1-5. Nevada Test Site.

Mesa and adjoining Pahute Mesa. The major Rainier Mesa tunnel complexes were B, E, G, N, and T tunnels. Parts of T tunnel were constructed in the adjoining Pahute Mesa.

Area 15 is in the foothills at the north end of Yucca Flat. The deeper of the two access shafts drops 1,500 feet below the surface elevation of 5,100 feet. There were three events conducted in Area 15, all sponsored by DoD. HARD HAT and TINY TOT were discussed in DNA Report 6320F, Operations Nougat and Whetstone, while PILE DRIVER was discussed in DNA Report 6321F, Operations Flintlock and Latchkey.

SECTION 2

UNDERGROUND TESTING PROCEDURES

Underground tests conducted at the NTS prior to 1962 were primarily for weapons-related purposes (including safety tests). These tests were controlled by the AEC and conducted by LASL or LLL. Experience gained in the area of underground radioactivity containment during these tests provided the basic concepts for development of containment plans for DoD/DNA-sponsored underground nuclear weapons-effects tests which followed. These DoD tests were generally more complex than earlier AEC tests and required the development of new containment concepts and hardware.

A primary consideration in all underground tests was the safety of test participants and the general public, especially regarding exposures to radioactive materials. This chapter discusses, in general terms, containment problems and procedures, types of emplacement, diagnostic techniques, effects experiments, area access requirements, industrial and radiological safety, radiation measuring systems, and air support requirements.

2.1 CONTAINMENT PROBLEMS AND PROCEDURES.

Completely containing radioactive material underground while accomplishing diagnostic measurements and effects experiments proved to be a major engineering challenge. Original efforts considered only detonation containment in competent rock formations. It was necessary to modify the original efforts to consider zones of weakness in rock caused by faults and containment failures resulting from diagnostic and experiment structures. Under certain conditions, particularly the presence of clay or a high water content in rock near the detonation point, residual stress could be lower, allowing a stronger-than-normal shock wave, that could adversely affect containment. Some containment failures were partially attributable to additional overpressure from secondary gas expansion, i.e., steam pressure. The major containment features and problems that evolved are discussed below.

2.1.1 Vertical Shaft Containment.

Some of the first shaft safety experiments were in unstemmed shafts with concrete plugs penetrated by cable and instrumentation holes. When nuclear yields were produced, these emplacements did not completely contain the debris. The first method used to fully contain nuclear detonations in shafts was stemming, e.g., filling the shaft with aggregate and sand after device emplacement.

Keyed concrete plugs at different depths in the shaft stemming sometimes were used. The shaft diameter was enlarged at the plug construction location so the poured concrete plug would key into the ground surrounding the shaft and provide more strength against containment failure. Combinations of concrete and epoxy were used later, and epoxy replaced concrete as a plug material for some shaft emplacements.

Radiochemical sampling pipes, LOS pipes, and other openings in stemming and plug containment features had to be closed rapidly after detonation to prevent venting of radioactive effluent to the atmosphere. Closure systems driven by high explosives, springs, or hydraulics were developed to seal the openings. After some of these early systems did not prevent releases of effluent to the atmosphere, use of openings to the surface for diagnostic or experiment purposes was discontinued for several years until technology improved.

Some scientific and other cables from the device emplacement to the surface were another source of containment problems. While these cables could be embedded in concrete and epoxy, which helped prevent leakage along the outside of the cables, radioactive gases under high pressure traveled along the inside of cables as a conduit to the surface. This problem was solved by embedding the inner components of these cables in epoxy or other materials at appropriate locations (such as in concrete plugs) in a technique known as gas blocking.

Many containment problems were caused by unanticipated geologic and hydrologic conditions at particular test locations. Even careful and rigorous calculations, engineering, construction, and preparations were inadequate in the presence of unsuitable geologic settings.

Another similar problem was the presence of higher-than-anticipated water content in rock formations surrounding or near the detonation point. This problem caused greater shock transmission plus secondary gas expansion when the water turned to steam. In addition, presence of sufficient iron in the test configuration caused the disassociation of water with subsequent greater secondary gas expansion from hydrogen gas. A result was much higher and longer sustained pressure from the detonation point toward the surface and the possibility of subsequent failure of geologic or constructed containment features.

Recognizing and understanding geologic and hydrologic conditions at each test location was necessary before these containment problems could be solved. As additional information became available through drilling and intensive geologic studies, these problems were lessened by investigations of proposed detonation locations and application of detailed site-selection criteria.

2.1.2 Tunnel Containment.

As with shaft detonations, containment methods used for tunnel events were designed keeping the basic characteristics of a nuclear detonation in mind. Tunnel configurations were constructed with device emplacements strategically located to cause sealing of the access tunnel by force of the detonation. Additional containment features were used to contain radioactive debris.

One of the original user laboratory stemming configurations consisted of one or more sandbag plugs installed a short distance from the projected self-sealing location toward the tunnel entrance (portal). Two plugs, each about 60 feet in length, were a typical installation. The sandbag plugs were later changed to solid sand backfill plugs extending several hundreds of feet from the device location. In many cases, the sand stemming had short sections of air voids between the plugs. Closer to the portal, a keyed concrete plug with a metal blast door was constructed. The blast door was designed to contain any gases (with pressure up to

75 pounds per square inch [psi]) that might penetrate the sandbag plugs.

Also as with shaft detonations, the unknown presence of undesirable geologic and hydrologic conditions sometimes caused venting of radioactive effluent either through the overburden (ground above the tunnel) to the surface, through fissures opened between the detonation point and the main tunnel, or through the plugs and blast door to the main tunnel vent holes and portal. More substantial containment features evolved as containment problems became better understood and tunnel events became more complex.

The first DoD tunnel test was MARSHMALLOW (1962). Stemming for that event consisted of four sandbag plugs extending out to a distance of a few hundred feet from the nuclear device (similar to earlier AEC tunnel events). A Gas Seal Door (blast door) was installed in the main access drift. The next DoD tunnel test, GUMDROP (1965), used sand backfill (with a few air gaps) out to a few hundred feet. As DoD tunnel testing continued, sand plugs were gradually replaced with various grout mixtures. Some grout mixtures were designed to match the strength and shock propagation of the native tunnel material (usually ash-fall tuff) while other grout mixtures were designed to be weaker and form a solid stemming plug shortly after device detonation.

Also, as tunnel testing continued, the Gas Seal Door (GSD) no longer was used as a containment device. It was replaced by strong concrete plugs 10 to 20 feet thick, referred to as Overburden Plugs (OBP), and later renamed to more adequately describe their function i.e., Drift Protection Plugs (DPP). These plugs were keyed into the tunnel wall and some were designed to withstand overpressures up to 1,000 psi and temperatures up to 1000°F. Some of the plugs were penetrated with electrical cables and steel pipes, and a small access hatch was constructed. All of these penetrations were gas sealed (or capped) to provide protection against possible gas seepage through the plug.

Use of horizontal line-of-sight (HLOS) pipes in tunnel events necessitated development of additional closure systems. The HLOS pipe tunnel and its access tunnels generally were separated from the main tunnel by one or more concrete plugs. These closure systems primarily were for protection of the experiments inside the HLOS pipe, but they were also considered useful features for the formation of a stemming plug.

The tunnel volume outside the pipe was filled by stemming or grouting, while the experiments inside the HLOS pipe were protected by mechanical closure systems. Various closure systems were used, including compressed air or explosive-driven gates and doors which closed off the HLOS pipe from the detonation within a small fraction of a second after detonation time. Another type of mechanical closure was the tunnel and pipe seal (TAPS) unit, first used on the DOOR MIST event. The TAPS was a heavy steel door that was released at shot time and fell to the closed position in less than one second. When a drift was successfully stemmed, containment was generally achieved. However, even if a drift failed to stem properly, radioactive material could still be contained underground. Failure of an experiment drift to stem properly usually resulted in data loss and, in some cases, experiment loss.

In 1972 DNA developed a containment concept that was to become the standard for future underground nuclear tests. This concept, known as the nested or three-vessel containment concept, is the most successful containment system used to date. It was used for all the events discussed in this report except for MISTY RAIN which used the two-vessel containment system. While exact containment features vary for each event, the following provides a general description of the three-vessel concept:

Vessel I was the stemmed area. Most of the open tunnel volume surrounding the working point, including the main and access drift, were filled with rock-matching grout (RMG) while some areas further from the WP (in both the bypass and LOS drifts) were filled with superlean grout (SLG). The remainder of the main and bypass drifts out to the end of the stemming, and also the Mechanical Auxilary Closure (MAC) and Gas Seal Auxilary Closure (GSAC) access drifts, were filled with high-strength grout (HSG), or concrete. The MAC, GSAC, and TAPS units themselves were normally surrounded with structural concrete. In some cases specific mixtures of grout were used, i.e., SLG and HSG, or HSG with high-strength groutcrete or concrete. Steel stemming bulkheads were used to seal off sections of the drift allowing it to be filled one section at a time. The power gas block and cable gas block were filled with groutcrete. All voids were completely filled by pressure grouting at the back or top of the drift. High-stress valves were installed in all lines which penetrated the stemmed area, and all cables were gas blocked by using standard DNA gas-blocking procedures. Vertical cable holes were typically stemmed with RMG above the tunnel invert followed by cement grout, epoxy, and coarse stemming material.

Vessel II consisted of the Drift Protection Plugs (DPP). Several massive containment structures consisting of reinforced concrete plugs designed to withstand pressures of 1000 psi and temperatures of 1000°F were installed in the tunnel complex as a backup in the event that the drifts failed to stem properly or radioactive material seeped through the stemmed areas. Typical of these plugs were the DPP, the Mechanical Drift Protection Plug (MDPP) and the Cable Drift Protection Plug (CDPP), each of which was reusable. All mechanical penetrations through the containment had valves or seals which met or exceeded the containment criteria of the structures themselves. The DPP was a high-strength concrete plug keyed into the tunnel rock (normally filled with HSG during button-up activities). The MDPP was used for most of the mechanical and electrical penetrations out of Vessel II. The CDPP used gas-blocking to prevent leakage or radioactive gases along or through cables from the diagnostic and experiment locations. Utility pipes, such as for compressed air, that passed through Vessels I and II were also sealed by closure systems.

Vessel III was that portion of the tunnel main drift protected by a Gas Seal Plug (GSP) and Gas Seal Door (GSD). The GSP sealed the entire tunnel and was designed to withstand pressures of 500 psi and temperatures of 500°F. Penetrations of the GSP were sealed using the same techniques as the DPP. The GSP contained a trainway door which would normally remain open until tunnel button-up occurred prior to event detonation. The steel GSD, on the portal side of the GSP, was installed in a reinforced concrete plug which was keyed into the rock. The GSD was closed during button-up activities, and a 10 psi pressure was applied between it and the GSP as additional reassurance against low-pressure leaks.

2.1.3 Containment Evaluation Panel.

When containment problems were particularly difficult, the AEC began to change its emphasis on conditions under which detonations should be conducted.

The Manager, AEC/NVOO had primary responsibility for the underground containment of radioactivity from underground tests. Containment of the DoD-sponsored tests was a joint effort on the part of AEC, DoD, and contractor scientists and engineers. To carry out this responsibility, on 17 December 1963, AEC/NVOO established a Test Evaluation Panel (TEP) to review plans for each test as presented by user testing organizations for each test program. The chairman of this panel represented the Manager, NVOO, and membership consisted of two representatives (one voting member plus an alternate) from each of the user testing organizations (LASL, LLL, SLA, and FC/DNA) plus specialists from contractor and other government organizations such as the U.S. Geological Survey (USGS). Other AEC/NVOO contractor personnel were available to present information in their areas of expertise (e.g., mining and drilling operations).

On 19 March 1971, testing was suspended because containment failure had caused serious venting of a laboratory test (BANEBERRY). During this time the TEP, under a formal charter, was changed to the Containment Evaluation Panel (CEP). The CEP, as an independent agent, evaluated the containment design of each proposed nuclear test, assuring that all relevant data available for proper evaluation was considered. They were instructed to give increased emphasis to containment of radioactive materials. The panel membership was enlarged by the addition of a hydrologist, a geologist with expertise in underground nuclear phenomenology (both nominated by their respective organizations and approved by the Manager, NVOO), and consultants representing additional areas of expertise. These permanent advisors were representatives of the EPA, the National Oceanic and Atmospheric Administration's Air Resources Laboratory (NOAA/ARL), and REECo. Each underground testing organization was represented as before.

Prior to a formal meeting of the CEP, each user planning a nuclear test prepared documents (i.e., a prospectus) describing its proposed tests with particular emphasis on containment considerations, and submitted these documents to each panel member for review. This information then was presented by the users to the CEP, generally at the following monthly meeting. Details of the containment plan were reviewed and compared to previous successful experiences. Each CEP member (or alternate) was requested to submit a written statement describing the details considered favorable or unfavorable to achieve successful containment.

During the period covered by this report, evaluations to estimate the probability of successful containment conformed to specific guidance from OMA at HQ/DOE. Each CEP member used this guidance to categorize each test as one of the following:

CATEGORY A

Considering all containment features and appropriate historical, empirical, and analytical data, the best judgement of the member indicates a very high confidence in successful containment.

CATEGORY B

Considering all containment features and appropriate historical, empirical, and analytical data, the best judgement of the member indicates a lesser but still adequate degree of confidence in successful containment.

CATEGORY C

Considering all containment features and appropriate historical, empirical, and analytical data, the best judgement of the member indicates some doubt that successful containment will be achieved.

CATEGORY D

Unable to categorize.

The Manager, NV, was advised of the findings of the evaluation in order to provide a basis on which to request detonation authority. He forwarded a written report on each CEP meeting, containing the statements of each voting member and consultant, to

HQ/DOE for review and recommendations for approval to execute each event. The detonation authority request package also included the chairman's summary, the prospectus, and a transmittal letter with other pertinent event data, such as approval dates.

2.1.4 Test Controller's Advisory Panel.

Careful consideration of each event by the CEP to avoid releases of radioactive effluent to the atmosphere was followed by additional precautions prior to event execution. If an unanticipated release of effluent from an underground detonation occurred, it was necessary to ensure protection of onsite participants and the offsite population. The Test Controller's Advisory Panel was composed of a scientific advisor and representatives from each organization which could contribute information to this protection goal.

This panel met at several readiness briefings in advance of each event and in the Control Room prior to and during execution of each event. The D-1 Containment Briefing provided a technical review of containment adequacy only, without considerations of cost, schedules, or test objectives. Panel members briefed the Test Controller's representative on other aspects of test activities and meteorological conditions which he considered in his decision on whether a test should be conducted. Information presented by the panel included the status of test participants in the test area. Permission to arm and detonate the nuclear device was not given until all participants (other than those at approved manned stations) were clear of the controlled test area.

Weather conditions were considered in detail. Wind speeds and directions at increasing altitudes above ground were measured with weather balloons at stations around NTS, both preceding and during each test. Measurements were used to calculate and present information on where an unanticipated release of effluent might be transported off the NTS and what the levels of radiation might be in the predicted effluent cloud.

Actual locations of population centers, each dairy cow, and numbers of people at ranches and mines in the projected direction of the effluent cloud were identified and evaluated. EPA personnel in the offsite areas notified mining people to be above ground for safety purposes at the anticipated detonation time of tests which might cause a ground control hazard. This information and numbers of people who might need to be advised to stay under cover or be evacuated were presented for consideration. EPA personnel started offsite air samplers and placed radiation dosimeters in offsite locations before detonation time. Readiness information included capability for advising state officials to institute a milk diversion program if cattle, feed, or milk might become contaminated, and to replace milk and dry feed for localized family dairy cows.

The status of standby aircraft for effluent cloud sampling and tracking capability was presented. Communications between offsite weather stations and EPA personnel were checked to assure proper operation.

Radsafe personnel onsite assured that remote radiation monitoring stations in the test area and in other NTS areas were functional. Data from these stations, the weather stations, offsite EPA personnel, and personnel clearing the test area were displayed in the Control Room for continual visual examination by the Test Controller and the Advisory Panel. In addition, closed-circuit television cameras were operational on the ground and in helicopters in the test area to detect any visual indications of possible effluent release and provide capability for immediate response action by the Test Controller and the Advisory Panel members.

If the Test Controller decided that the projected effluent direction was close to populated areas, or weather conditions were not stable enough to determine the direction of any released effluent after detonation, the approval to arm and detonate was not given. The test was either postponed for another day or placed on hold until conditions were favorable.

Conditions were considered favorable when (1) projected effluent direction was toward sparsely populated areas, (2) weather conditions were relatively stable, (3) EPA personnel could contact the few residents in the projected effluent direction and advise them of protective action to be taken, and (4) impact on milk supply from dairy cattle would be minimal. In addition, all essential equipment, personnel, and procedures were required to be in readiness status or activated before permission to arm and detonate was given.

Permission to arm usually was given at least two hours before scheduled detonation to allow time for arming, securing of the test configuration and containment systems, and departure of the arming party from the test area. The detonation, however, could be delayed at any moment up to detonation time, or postponed until another day or time when conditions might be more favorable.

The Test Controller and the Advisory Panel received information, watched visual displays, and communicated with their field personnel up to and after detonation for a sufficient time to assure that venting had not occurred. Remote radiation detection instrument readings and closed-circuit television of the test area were monitored to detect any indication of effluent release.

When all other indications of venting were negative and the Test Controller decided personnel could approach the test location, (e.g., subsidence craters had formed for shaft detonations, and cavity collapse had occurred for tunnel emplacements, as indicated by geophones) initial radiation survey teams entered the test area to assure that effluent had not been released or that any radiation levels were low enough for experiment data recovery to begin. For tunnel tests, reentry of the tunnel itself (after initial survey of the surface areas, recovery of data, and approval by the DOE Test Controller) was a matter for separate and careful consideration by the Test Group Director and radiological safety personnel.

2.1.5 Effluent Release Procedures.

If radioactive effluent was released from an underground event, established procedures were initiated in accordance with DOE NTS SOP Chapter 0524, "Radiological Safety" (see Appendix D). Immediately upon detection of possible venting and effluent release after a detonation, the following procedures were initiated:

A. For some tests, Radsafe survey teams were at manned stations in the test area. These teams were released to make radiation measurements to be used in determining direction and radiation levels of radioactive effluent.

B. Aircraft were standing by to sample and track the effluent. Data reported were further used to refine information on effluent direction and radioactivity concentrations.

C. EPA monitors in offsite areas, previously stationed in the projected path of any released effluent, were advised of actual effluent direction and radioactivity measurement data and directed to move sampling and dosimeter equipment, perform ground radiation surveys, and notify residents and workers in the effluent path of any necessary precautionary measures, such as remaining in buildings or evacuating the area temporarily.

D. Capabilities were held in readiness to advise state officials to implement a milk diversion program. If this was necessary, Nevada and neighboring state officials could be advised to impound and replace milk supplies possibly contaminated through the cattle feed pathway, and hold impounded milk for the decay of probable contaminants (radioiodines) before using it for other purposes. On a localized basis, EPA personnel were ready to replace family dairy cow milk with fresh milk, and analyze milk for concentrations of specific radionuclides. Dry feed supplies also could be replaced for family dairy cattle if required.

E. Capabilities were in readiness for thyroid monitoring of offsite individuals possibly exposed to radioiodines from the effluent. These mobile monitoring stations could be used in the offsite areas for screening measurements to determine if any offsite residents or workers exhibited thyroid radioactivity and should be transported to Las Vegas facilities for more precise thyroid measurements and dose assignment.

Each of the above procedures was established to avoid or minimize exposure of the offsite population and maintain any such exposures below the radiation protection standards for individuals and population groups in uncontrolled areas, as established in DOE NTS SOP Chapter 0524.

While the above procedures were initiated, additional onsite procedures also were implemented. Radsafe survey teams, when released by the Test Controller, surveyed the test area in sufficient detail to plot gamma radiation isointensity lines on NTS maps and provide specific intensity measurements at experiment stations on the surface and at other locations of interest. These data were used by the Test Controller in releasing personnel to enter radiation areas in the controlled area and by the Test Group Director in determining when surveys of his immediate test area and recoveries of experiment data could be accomplished. These decisions were based on calculations of personnel gamma radiation doses from survey data, radiation intensities at recovery locations, and estimated times in the area to assure that exposures would be limited only to those necessary and would be below the standards established in DOE NTS SOP Chapter 0524.

Some tunnel tests that did not result in venting of radioactive effluent to the atmosphere did have a failure of the containment system within the tunnel. High radiation levels then existed in locations where reentry personnel needed to enter to accomplish data recovery. Procedures developed to minimize exposures of reentry and recovery personnel included the placement of remote radiation detectors located at strategic tunnel complex locations, remote tunnel atmosphere samplers that removed tunnel air to locations outside the tunnel for analysis, and tunnel air filters that would allow controlled purging of tunnels before reentry with only controlled gaseous radionuclide releases to the atmosphere.

Remote monitoring and sampling equipment provided information on radiation levels, toxic gases, and explosive mixtures necessary to determine whether tunnel ventilation should be accomplished before reentry. Tunnel ventilation filters stopped particulate radioactivity and activated charcoal in the filters absorbed most of the radioiodines, thus allowing primarily only radionuclides of the noble gases, such as xenon, to be released to the atmosphere. (Exposure to radionuclides of the noble gases is far less hazardous than exposure to other fission products.) Release of this radioactive material to the atmosphere in a gradual, highly-controlled manner during tunnel ventilation to protect reentry personnel was subject to approval by the Test Controller.

2.2 EMPLACEMENT TYPES.

The DoD conducted six underground tests which are covered in this report. Table 2-1 lists the events and pertinent data. All six DoD events conducted during Operations Praetorian, Phalanx, Fusileer, and Grenadier were tunnel events. Both tunnel and shaft emplacement types are discussed in this section. An emplacement type not discussed in this report was one that resulted in the excavating or ejecting of material from the ground surface to form a crater (see Crater Experiment in the Glossary of Terms). A DoD cratering event, DANNY BOY, was conducted in 1962 during Operation Nougat (see DNA 6320F).

2.2.1 Vertical Shaft Emplacement.

A vertical shaft nuclear detonation was intended to be contained underground. The shaft was usually drilled, but sometimes mined, and it may have been lined with a steel casing or have been uncased. The nuclear device was emplaced at a depth calculated to contain the explosion. At detonation, a cavity was formed by vaporized and melted rock. Pressure from the hot gases in the cavity held surrounding broken rock in place until the cavity area cooled sufficiently to decrease pressure. As broken rock fell into the cavity formed by the detonation, a chimney was formed. If the chimney of falling rock reached the surface, a subsidence crater was formed. Figure 2-1 shows a typical subsidence crater.

If a device was placed too deeply in the alluvium of Frenchman or Yucca Flat for the detonation yield, or the depth was correct but the yield was much less than anticipated, a subsidence crater might not form; that is, the chimney might not reach the surface. This was a problem during early years of underground testing when it was necessary to move drill rigs into subsidence craters soon after tests for cavity sample recovery purposes. If a subsidence

Table 2-1. DoD events - 23 September 1982 through 06 April 1985.

OPERATION	PRAETORIAN	PHALANX		FUSILEER	GRENADIER
EVENT	**HURON LANDING/ DIAMOND ACE**	**MINI JADE**	**TOMME/ MIDNIGHT ZEPHYR**	**MIDAS MYTH/ MILAGRO**	**MISTY RAIN**
DATE	23 Sep 82	26 May 83	21 Sep 83	15 Feb 84	06 Apr 85
LOCAL TIME (hours)	0900 PDT	0730 PDT	0800 PDT	0900 PST	1515 PST
NTS LOCATION	U12n.15 & bypass	U12n.12	U12n.18	U12t.04	U12n.17
TYPE	Tunnel	Tunnel	Tunnel	Tunnel	Tunnel
DEPTH (feet)	1,339/1,335	1,243	1,325	1,181	1,273
YIELD[8]	Low	Low	Low	Low	Low

[8] Low indicates less than 20 kilotons.

Figure 2-1. A typical subsidence crater.

crater did not form, drill rigs could not be moved to the surface ground zero (SGZ). When directional drilling from outside the crater was implemented, lack of a subsidence crater in alluvium became less of a problem. Experience gained with depth of device burial also reduced the chance of subsidence craters not forming in the alluvium. The depth of burial, for both shaft and tunnel tests, was scaled to the maximum credible yield, usually significantly larger than the expected yield. However, the minimum depth of burial was 600 feet.

Most vertical shaft underground tests conducted by DoD included a vertical line-of-sight (VLOS) pipe system to the surface and a mobile tower on the surface that contained the weapons effects experiments (see Figure 2-2). The VLOS pipe system contained several mechanical closures designed to prevent the release of radioactivity into the atmosphere. These closures were open at the time of detonation but closed within milliseconds to stop the flow of material up the pipe. The open volume between the VLOS pipe and the wall of the drill hole was filled with sand and other materials. One or more non-porous material plugs were placed around the pipe. Electrical cables which went downhole were gas blocked to prevent gas seepage to the surface. Effects experiments were contained in a mobile tower on the surface that was moved away from the hole after device detonation but before surface collapse (formation of the subsidence crater). One problem was the possibility of seepage after surface collapse if some pathway to the surface developed. Some radioactive effluent was released into the atmosphere during several VLOS DoD tests.

2.2.2 Tunnel Emplacement.

Tunnel emplacement nuclear detonations were intended to be completely contained. The nuclear device was emplaced in a mined drift (tunnel) at a depth designed to contain the detonation. The native material at tunnel elevation was ash-fall tuff for events covered in this volume. Chimneying of broken rock to the surface was rare because there was a layer of welded rhyolitic ash-flow tuff at and below the surface of Rainier Mesa. This tuff has a higher density than the ash-fall tuff and is more competent (has more strength) than the alluvium material in Frenchman and Yucca Flats. In addition, tunnel emplacements

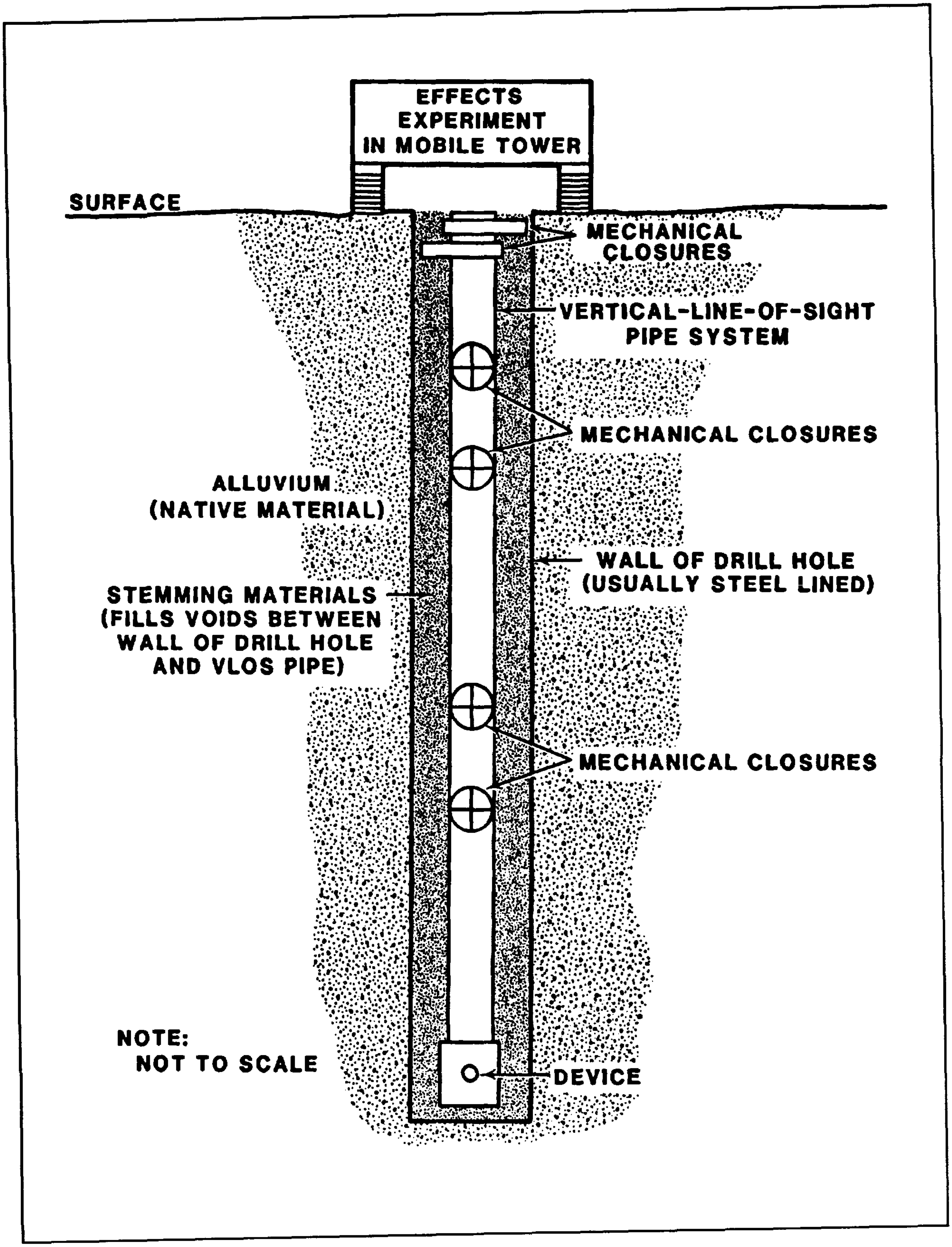

Figure 2-2. Vertical LOS pipe configuration.

were buried deeper than required for containment, and the collapse chimney rarely extended to the surface. Tunnel emplacements were in one of several configurations: at the end of a single horizontal tunnel into a mountain or mesa, at the end of a drift (tunnel) within a tunnel complex, at the end of a horizontal tunnel driven from a vertical shaft, or in a cavity mined from a horizontal tunnel or vertical shaft.

Each of the events covered by this report (except for the MINI JADE event) included HLOS pipe systems placed in horizontal drifts in tunnel complexes (see Figure 2-3). Each device was placed close to the end of a drift inside a tunnel complex. An HLOS pipe system (some over 1,000 feet in length), including several mechanical closures and one or more test chambers (which contained effects experiments), were installed in the drift. The mined area surrounding the HLOS pipe was filled (stemmed) with various mixtures of grout to a distance of several hundred feet from the device location. This closure of the HLOS pipe in the stemmed area was the primary containment system. Ground shock and expansion of the gaseous cavity material exerted pressure on the tunnel walls and stemming materials to form a stemming plug, closing the tunnel and HLOS pipe immediately after detonation. All electrical cables and other penetrations within the stemmed area were gas blocked carefully to prevent or minimize seepage of radioactive gases through the stemming plug. The mechanical closures in the HLOS pipe were designed primarily to protect the effects experiments; however, they also had some effect on the formation of the stemming plug. The secondary (or backup) containment system included two or more concrete plugs, which were strategically keyed into the tunnel walls to prevent leakage of radioactive gases outside the tunnel should the primary system fail. These concrete plugs were designed to withstand the maximum expected pressure and temperature.

DNA has led the development of tunnel containment systems and has maintained continuing research and development programs to improve containment of tunnel events.

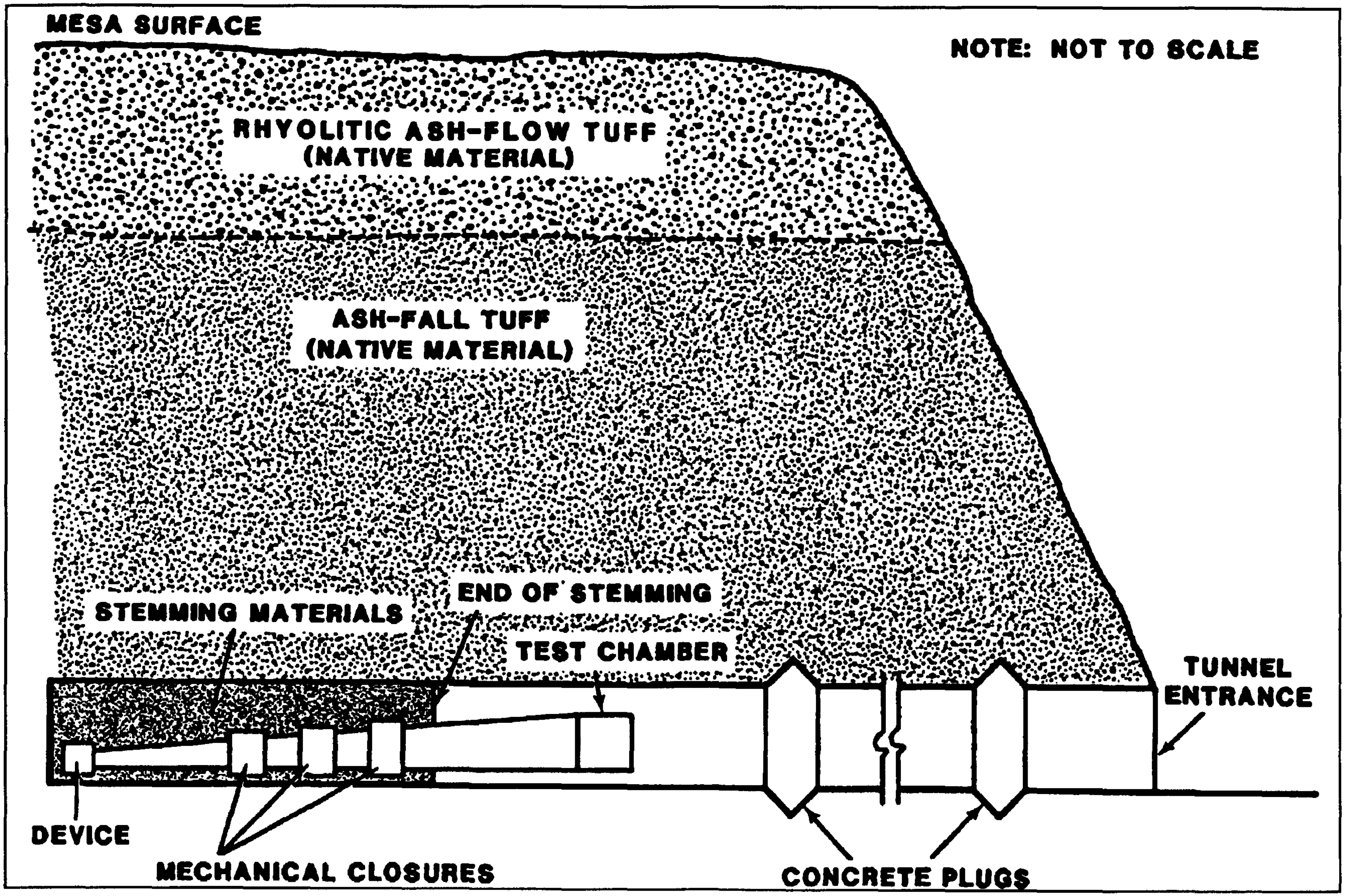

Figure 2-3. Horizontal LOS pipe configuration.

2.3 DIAGNOSTIC TECHNIQUES.

The transition from atmospheric to underground testing substantially reduced the release of radioactive materials to the atmosphere, and required the development of new diagnostic techniques. During the atmospheric tests, high speed photography recorded fireball growth and aircraft collected samples from the radioactive cloud for diagnostic measurement analysis. Because such systems could not be used on underground tests, several new diagnostic techniques were developed (some of which are discussed in the following subsections).

2.3.1 Radiation Measurements.

Measurements of radiation from an underground detonation were made possible by the development of a system of remote detectors and cabling that sent signals to recording facilities located at the surface. Detectors, using various physical characteristics of the radiations to be measured, were installed near the nuclear device. High-specification coaxial cable and connectors carried the measurement signals to the surface where electronic equipment, film, and magnetic tape recorded the signals or transmitted the signals by microwave to the CP.

Detector signals were on the way to recording equipment billionths of a second after a detonation, before the detectors were destroyed. These measurement systems required the most advanced electronic technology available. Considerable research and development were necessary to acquire and refine these capabilities.

2.3.2 Radiochemical Measurements.

Because clouds from atmospheric detonations no longer were available to sample for diagnostic purposes, techniques were developed to obtain samples of debris from underground detonations for radiochemical analyses and subsequent yield determinations. The first systems were radiochemical sampling pipes leading directly from the device emplacements to filtering equipment at the surface. These pipes required closure systems to prevent overpressure from venting radioactive effluent into the atmosphere after samples were collected.

While these systems functioned as intended for most detonations, the systems did not function properly during all tests, and some radioactive effluent was released into the atmosphere. Subsequently, routine use of radiochemical sampling pipes to the surface was discontinued for a time until technology improved.

A major radiochemical sampling method which continued in use for shaft and tunnel detonations was postevent core drilling. The objective of this drilling was to obtain samples of solidified radioactive debris which had collected in a molten pool at the bottom of the cavity produced by the detonation and cavity gas. This method required and resulted in the development of precise directional drilling techniques and several advancements in the science of core drilling and radiochemical analysis.

2.4 EFFECTS EXPERIMENTS.

DoD/DNA events were conducted primarily to obtain nuclear weapons effects data. The effects of blast, shock, and thermal and nuclear radiations had been investigated earlier during atmospheric and underwater tests. Military equipment, structures, and materials had been exposed to various nuclear effects. The transition to underground testing required development of new test techniques. One important new technology was the simulation of high altitude (to exoatmospheric) conditions for radiation-effects experiments.

This simulation technique involved placing experiments inside test chambers and providing a low-pressure atmospheric condition from the nuclear device to the experiments. This was achieved by using large vacuum pumps to reduce pressure inside the steel LOS pipe to match the pressure of the desired altitude. Another technique was the use of scatterers to direct radiation to experiments located outside the LOS pipe.

In addition to collecting radiation-effects data, other DNA NWET objectives were to: (1) provide the desired nuclear-effects environment; (2) measure and document nuclear environments of interest; (3) protect the experiments from damage, such as debris or ground shock; (4) contain radioactive gases and debris underground; and (5) manage the tests in a cost-effective manner.

Scientific improvements were made in achieving these objectives. Cost effectiveness was accomplished primarily by designing facilities for maximum reuse.

Experiments were categorized as passive or active. Passive experiments involved placing experiment equipment in test chambers, exposing the equipment to the desired nuclear environment, removing the equipment, and analyzing it to obtain effects results. Active experiments utilized various sensors and high-speed electronic recording equipment to obtain data. Many active experiments also involved recovery and analysis to obtain effects results.

2.5 TUNNEL AND DRILLING AREA ACCESS REQUIREMENTS.

Access to underground work and drilling sites was controlled for a number of reasons. During construction, safety of both workers and visitors in these locations could have been jeopardized by carelessness or seemingly harmless activities of untrained and uncontrolled workers or visitors. When security-classified materials were in these locations, only personnel with appropriate security clearances were permitted access to the area. The presence, or anticipated presence, of radioactive material in a location required access control for radiological safety purposes. Access requirements established for the above purposes are discussed below.

2.5.1 Tunnel Access Control.

During construction and preparation for a DoD event in a tunnel or other underground work site, the tunnel Superintendent was responsible to the REECo Project Manager for safety of personnel underground. From 1962 forward, Radsafe and tunnel logbooks usually were used to record names and radiation exposure information for only those persons entering a tunnel during postevent reentry and recovery operations. In the early 1970s, as a result of the Mine Safety and Health Act, tunnel logbooks were expanded to list all persons entering the tunnel (i.e., visitor, mining, drilling, Radsafe, etc.). Visitors and other personnel, who were not assigned to work in the tunnel, obtained permission for entry from the Superintendent or his representative. They were appraised of tunnel conditions and safety regulations and were listed in the logbooks. In the event of an accident or other emergency condition underground, the logbook provided information on numbers of personnel and their locations.

When classified material was in the tunnel prior to an event and during initial reentry after an event, the DoD Test Group Director, or his representative, was responsible for entry and safety of personnel underground. Security personnel checked for proper security and entrance clearances, maintained records of all personnel entering the tunnel, and safeguarded the device and other classified material. The check point was often well inside the portal thus allowing several activities at various work sites to be conducted simultaneously.

After detonation, aerial damage surveys to determine the accessibility of the various recovery stations were required before surface reentry operations were begun. When the reentry teams were given permission to depart Gate 300 (a check point set up in Area 3, just north of the turnoff to the CP, also known as Guard Station 300; see Figure 1-5) by the Test Controller, radiation and industrial hygiene surveys were conducted on the mesa and in the portal areas before any personnel were allowed in these areas.

Before underground recovery operations began, a listing was made of hazardous elements whose performance degradation; functional failure; or physical, chemical, or electrical properties constituted a posttest hazard within the test system complex. General requirements and standards governing safety were based on the FCTC "Safety and Health Compliance Guide for Underground and Nuclear Effects Tests." Hazardous elements were defined to include active experiments and/or hardware containing radioactive, explosive, fire hazard, pressure vessel, evacuated container, electrical, toxic, and/or chemically hazardous components.

Instructions on the proper procedure, should a potential hazard have become a real hazard as a result of detonation, were made available to the underground reentry team and recovery personnel. Situations where permission was to be given before the tunnel reentry team would be allowed to proceed (including checking pressure and sampling gas on the working point (WP) side of the

GSP, opening the OBP manway doors, and removing the insulation materials from inside the OBP crawl spaces) were outlined in detail prior to reentry. Permission to proceed was given by a responsible party outside the tunnel complex on the basis of information transmitted by the reentry team. The required condition of the tunnel before experimenter personnel were allowed access to the test chambers was also outlined specifically.

Before experiments were released to the experimenters, each experiment was monitored for radioactivity and triple-bagged to reduce the spread of contamination inside the tunnel. Swipe samples were taken on experiments and equipment being removed from the tunnel area to verify that contamination standards were not exceeded. Experiments and equipment with higher-than-allowed removable contamination levels were taken to the Test Support Compound, which was equipped to disassemble radioactive/contaminated materials. Shipment from the Test Support Compound was restricted to organizations that were licensed to store and handle radioactive materials.

Control of tunnel access reverted to tunnel management personnel after reentry and recoveries. Entry procedures and use of the tunnel logbook were then implemented as discussed previously.

Additional access controls were instituted for radiological safety purposes after an event or during construction and event preparation when radioactivity from a previous event could be encountered. Part or all of a tunnel complex could be established as a radiation exclusion (radex) area.

All persons entering radex areas were logged on an "Area Access Register" form. Names and organizations represented were listed. Radiation exposures from reports for the year and quarter were listed upon entry. (The use of previous radiation exposure data was to assure that personnel approaching current radiation exposure guide limits would not be allowed to enter radex areas when they could potentially accumulate exposures above those levels.) Self-reading pocket dosimeter measurements were added upon exit.

Before entering into a radex area, personnel were dressed in anticontamination clothing and respiratory protection as needed for the particular radiological conditions in the tunnel. Upon exit, the anticontamination clothing was removed, personnel were monitored for radioactive contamination, and decontamination was accomplished, if necessary.

2.5.2 Drilling Area Access Control.

Access to drilling areas was controlled by the drilling superintendent and the DoD Test Group Director for the same reasons as access to underground workings was controlled. While drilling an emplacement shaft and during postevent drillback operations to recover radioactive core samples, personnel safety and compliance with safety regulations were emphasized continuously.

During preevent drilling activities, all visitors were required to contact the drilling superintendent before entry to the drilling site. Names of visitors and the purpose of each visit were entered in the daily drilling report, and it was assured that visitors wore hard hats and understood safety regulations.

The laboratory that provided the device controlled access to the area, assisted by the security force personnel, when classified materials (including the nuclear device) were brought into the area for emplacement. After the event, when the drill site was a radex area, during classified material removal or postevent drilling, both security and radiological safety access controls were in effect as discussed under "Tunnel Access Control" (paragraph 2.5.1 above).

2.6 INDUSTRIAL SAFETY CONSIDERATIONS.

Implementation of an effective industrial safety program was an important part of any heavy construction operation. Mining and drilling operations had a particularly high accident potential. These operations at the NTS involved additional safety problems resulting from detonation-induced unstable ground conditions and the potential for encountering toxic gases, explosive mixtures, and radioactivity.

Miles of underground workings were constructed at several locations. More depth of vertical big holes (three-foot diameter or larger) were drilled than the known total drilled in the rest of the world. Directional and core drilling to recover radioactive debris samples after underground nuclear detonations advanced the science of these drilling techniques. These operations often were accomplished under unusual conditions with accompanying difficult safety problems.

The lost-time accident frequency, however, for the NTS support contractor employing most of the NTS personnel (REECo) was only one-tenth of the frequency for the heavy construction industry at large (as determined by annual surveys and reports of 300 heavy construction corporations). This excellent safety record was attained by continuing attention to indoctrinating and training NTS personnel, investigating and determining causes of accidents at the NTS, implementing and enforcing safety regulations, and, most important, maintaining the safety awareness of NTS personnel.

Safety was a joint effort by DOE, DNA, and their predecessors, and by the many other government agencies and contractors at NTS. Administered by REECo, the safety program enjoined all NTS personnel to conduct operations safely, and was exemplified by signs at the portal of a typical DoD tunnel complex as shown in Figure 2-4, one of which states, "Safety With Production is our Goal."

The safety procedures for all NTS operations are voluminous and cannot be included in this report. Appendix E of this volume (General Tunnel Reentry Procedures for Defense Nuclear Agency and Sandia Laboratories Nuclear Tests, published by Sandia National Laboratories) is an example of a pertinent safety procedure. As this procedure indicates, several aspects of industrial safety are interrelated. Information on monitoring levels of radioactivity and personnel exposures to radiation is presented in Section 2.7, "Radiological Safety Procedures."

Monitoring of toxic gases and checks for explosive mixtures were an important aspect of safety in underground workings, on drill rigs, and in drill hole cellars (the enlarged evacuated area

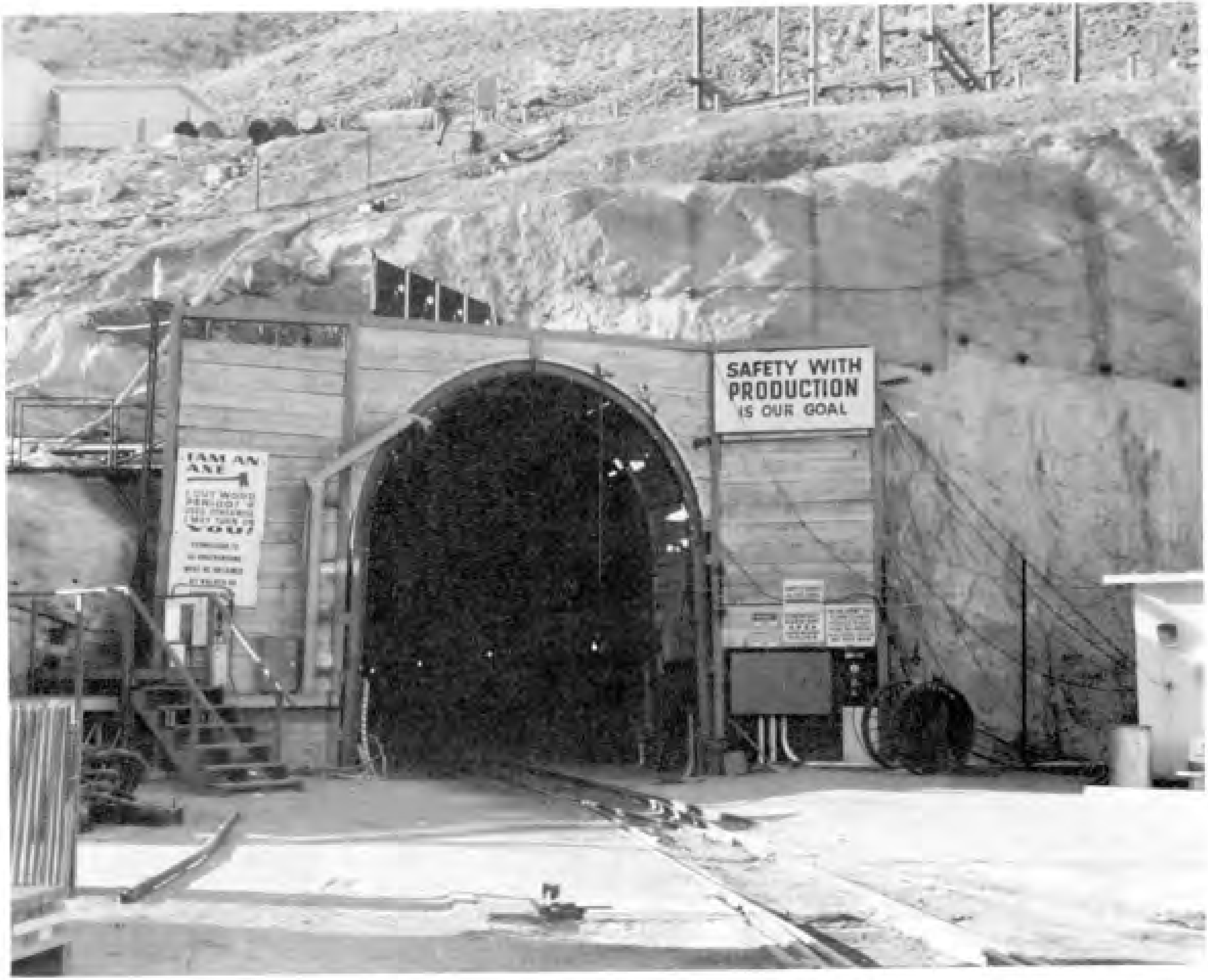

Figure 2-4. Portal of a typical DoD tunnel complex.

under the drill rig platform used for valving and other equipment). Toxic gases and explosive mixtures were created by both nuclear detonations and mining and drilling operations. The Draeger multi-gas detector and MSA explosimeter were able to detect such gases. The Fyrite or J&W oxygen indicator also was available to determine the oxygen content of the working atmosphere. The GPK was a combination oxygen indicator and explosimeter and was the instrument most commonly used by tunnel monitoring personnel throughout the period covered by this report. Requirements were that tunnel and drill rig breathing atmosphere contain at least 19.5 percent oxygen. During the period covered by this report, it was required that the breathing atmosphere contain less than the levels of toxic gases and percentage of the lower explosive limit (LEL) listed below. Explosimeter instruments were calibrated with 5.6 percent methane in air (adjusted for atmospheric temperature and pressure) as 100 percent of the LEL for methane mixtures with air. Less than 100 percent of the LEL is not an explosive mixture of a gas or gases.

Gases	**Maximum Concentrations**
Carbon Monoxide, CO	50 ppm
Carbon Dioxide, CO_2	5,000 ppm
Nitrogen oxide plus nitrogen dioxide, $NO+NO_2$	25 ppm
Nitrogen dioxide, NO_2	5 ppm
Explosive mixtures	10% of the LEL

Procedures for controlling percentages of the LEL and toxic gases after each event are discussed in the event sections (Sections 3 through 7) as appropriate.

2.7 RADIOLOGICAL SAFETY PROCEDURES.

Procedures were developed in an effort to evaluate radiological, toxic, and other hazards and to protect workers and the public from unnecessary exposures. The following were the primary written procedures and implementation methods used at the NTS from 1982 through 1985.

2.7.1 The U.S. Department of Energy, Nevada Test Site - Standard Operating Procedure (NTS SOP 0524).

Chapter 0524, Radiological Safety, of this procedure (Appendix D) defined responsibilities and established criteria and general procedures for radiological safety associated with NTS programs under normal test conditions. (Environmental Protection, Safety, and Health Protection Program for DOE Operations, DOE Order 5480.1A, Chapter IX, also includes Radsafe criteria under emergency conditions.)

Some of the major areas discussed in Chapter 0524 are film badge procedures, radiation surveys, entry into controlled areas, and radiation exposure guides. Roles of the onsite REECo Environmental Sciences Department and the offsite EPA are also defined in NTS SOP Chapter 0524.

2.7.2 The Standard Operating Procedure for the Environmental Sciences Department, REECo.

These SOPs were reviewed and/or updated annually to address in more detail the radiological safety aspects discussed in the latest revision of NTS SOP Chapter 0524.

2.7.3 Implementation of Radiological Procedures.

The required equipment, devices, and capabilities for monitoring radiation levels in the environment and monitoring external and internal exposures of personnel are described as follows:

A. Portable Radiation Detection Equipment.

- Eberline PAC-4G (alpha)
- Eberline PAC-4S (alpha)
- Eberline E-520 (beta and gamma)
- Ludlum Model 101 (beta and gamma)
- Ludlum 14C (beta and gamma)
- Ludlum Model 19 Micro-R-Meter (gamma)
- Technical Associates Cutie Pie (beta and gamma)
- Eberline Model RM-19 Radiation Detector (gamma)
- Eberline Model PIC-6A (gamma)
- Eberline Model PNR-4 (fast and slow neutrons)

- Eberline Model PRM-5 (alpha, beta, and gamma)
- FIDLER, used with PRM-5 (low energy x-ray and gamma)
- Teletector Model 6112 (beta and gamma)
- Eberline E-140 (beta and gamma)
- Bendix T-290 Tritium Monitoring Detector
- Bendix T-446 Tritium Monitoring Detector
- TRITON Model 111 (tritium)

B. Air Sampling Equipment.

- Model 102 semi-portable sampler
- Satellite sampler
- Hurricane high-volume portable sampler (Gelman)
- Vacuum pump low-volume portable sampler (Gelman)
- Gast Model 2565 high-volume, high-flow sampler
- Gast Model 1550 high-volume, low-flow sampler

C. Laboratory Analysis Capability.

The Environmental Sciences Laboratory analyzed air, soil, water, surface swipe, nasal swab, urine, and wound swab samples for some or all of the following activities: gross alpha and beta, gross fission products, tritium, strontium-90, plutonium-239, and spectrographic analysis for specific gamma-emitting radionuclides. The laboratory also analyzed some of the above mentioned samples for nonradioactive materials, such as beryllium, through use of an emission spectrograph and by wet chemistry procedures. A spectrophotometer was used to analyze for other materials.

D. Monitoring of Personnel Exposures.

The NTS combination personnel dosimeter and security credential holder was placed in use in 1966 to provide the increased personnel dosimetry capability necessary to meet the radiation exposure problems associated with nuclear rocket testing and underground nuclear detonations. The holder was designed to accommodate a DuPont type 556 film packet, a fast neutron packet (containing Kodak NTA film), an identification plate, criticality accident components, the security credential, and a snaptype clip. The complete package had capabilities for determining beta, gamma, x-ray, thermal neutron, fast neutron, high-range gamma, and high-range neutron doses. Components for criticality accidents (unintentional or accidental nuclear fissioning of device critical materials) included materials which could detect and measure neutron and gamma radiation exposures above the ranges of the film packets. In March 1971, with the discontinuance of the DuPont film, NTS dosimetry operations converted to the Kodak Type III film. This film packet contained two component films, one low range and one high range. Gamma exposure ranges of the two components were 30 mR to 10 R and 10 R to 800 R, respectively. The other components of the film badge, with the exception of the elimination of the Kodak NTA film from the film packet, remained essentially the same. In 1979 the Albedo neutron dosimeter, a TLD component system, was adopted at the NTS. This dosimeter was superior to the NTA film because it was a more sensitive dosimeter that responded to a much wider neutron energy range. The Albedo dosimeter was not part of the film dosimeter packet, but was only issued to those personnel who had a potential for exposure to a neutron source. The Albedo had its own holder which had to be worn flush with the body at all times. The NTS combination personnel dosimeter, including the Albedo dosimeter, and the security credential holder are shown in Figure 2-5. In April 1984 the I.D. plate was eliminated and replaced by a bar-code issue system.

Film badges were exchanged routinely each month for all individuals and upon exit from a radex area when it was suspected that an individual had received 100 mR or more of exposure.

Personnel entering radex areas also were issued self-reading pocket dosimeters which indicated accumulated exposure. Upon exit, pocket dosimeter readings were entered on an Area Access Register and added to the yearly and quarterly accumulated exposures from the automated daily NTS radiation exposure report for use until results of film packet processing were included. Pocket dosimeter readings were used as estimates because such readings

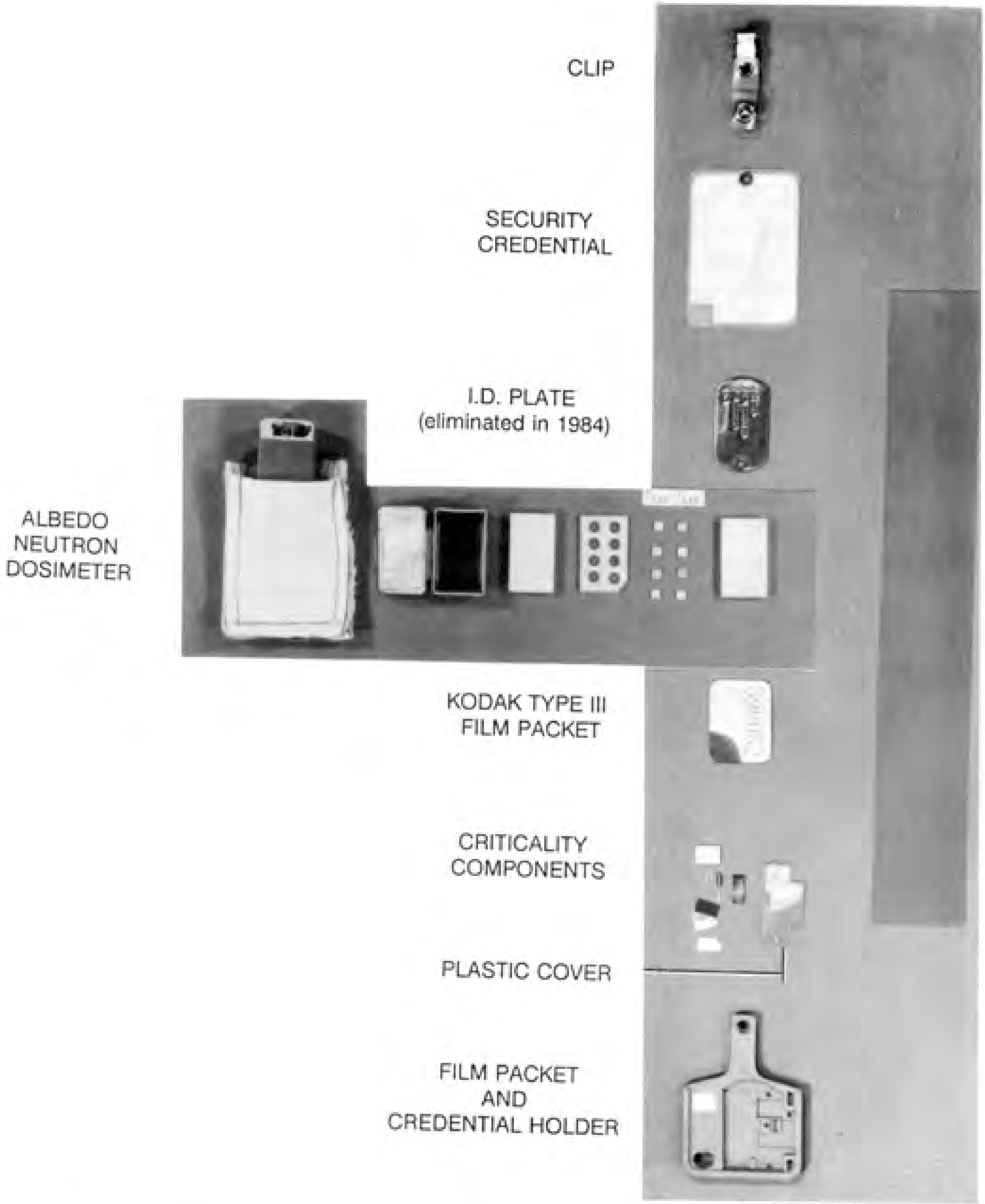

Figure 2-5. NTS combination personnel dosimeter and security credential holder.

were less accurate than the doses of record determined by processing film packets.

This use of Area Access Registers helped to maintain personnel exposures below the whole body exposure guides in Chapter 0524, 3 rem per quarter and 5 rem per year. Personnel whose accumulated exposure was in excess of 2.5 rem per quarter or 4.5 rem per year (as recorded on the exposure report plus any pocket dosimeter readings since the report) were advised not to enter radex areas, and their supervisory personnel were so notified. Personnel involved in DoD events covered in this report had accumulated doses substantially below these control guides.

2.7.4 Additional Methods Used to Control Radex Areas.

A daily log book was maintained by Radsafe monitors for each radex area location. These logs were used to record the following information:

A. Work accomplished - Which people worked where and what work was accomplished were briefly described. Any unusual conditions, such as equipment failure and operational difficulties, were listed.

B. Visitors - First and last names of visitors were entered. Their destination and the reason for their visit were included where possible. The time they entered and exited the area and results of personnel monitoring were recorded.

C. Unusual occurrences - Any unusual events which occurred during the shift were recorded. Included in this type of entry were accidents, high-volume water seepage, or any other occurrences of an unusual nature.

D. Surveys and samples - Routine surveys and samples were recorded as routine. However, the requester's name was required for special surveys and samples.

E. Date and signature - The date and shift were entered at the beginning of the work period and the logbook was signed before leaving the shift.

Personnel leaving radex areas removed anticontamination clothing and equipment and placed them in special containers for later laundering or disposal at the designated NTS burial site. Personnel then were monitored to assure radiation levels were below those listed in Part 1 of DOE NTS SOP Chapter 0524, "Radiological Safety" (see Appendix D). Personnel decontamination was accomplished if radiation levels were above specified limits. Decontamination usually was accomplished by vacuuming, removing radioactive particles with masking tape patches, washing hands or localized skin areas with soap and water, or showering with soap and water.

Vehicles and equipment removed from radex areas were monitored to assure that they met criteria for unconditional release on or off the NTS (less than 0.4 mrad/h fixed beta plus gamma at contact and/or 1,000 disintegrations per minute [dpm] per 100 cm^2 of non-removable plutonium alpha; and less than 1,000 dpm/100 cm^2 of removable beta plus gamma and/or 100 dpm/100 cm^2 of swipeable plutonium alpha). Items exceeding these limits but below radex area levels could be conditionally released and moved onsite only.

2.8 TELEMETERED MEASUREMENTS OF RADIATION LEVELS.

Beginning in the early 1960s, various applications of radiation measurement telemetry were developed at the NTS to determine radiation levels at critical underground and surface areas following nuclear detonations. Multi-detector systems with range capabilities from 1 mR/h to 1,000 R/h and from 100 mR/h to 100,000 R/h continuously monitored locations of concern after being calibrated and emplaced prior to each event. Ion chamber detectors were hard-wire linked by telephone trunk lines to exposure rate meters at a central console in CP-2. Detector locations were as far as 35 miles from this console. In 1974, these conditioned phone lines were supplemented by portable transmission stations. The detector was hard-wired into an area trailer and the signals were sent by microwave or hard-wire link to the Control Point.

These remote radiation monitoring systems provided data for reentry personnel participating in radiation surveys and recovery operations after each nuclear device detonation. The systems aided in substantially reducing exposure of personnel involved in reentry programs and were useful in detecting any venting or leakage of radioactive effluent to the atmosphere from an underground detonation.

2.8.1 Telemetry System in Use.

During the time period covered by this report, radiation telemetry systems developed and used at NTS had specific applications depending upon distance, terrain, environment, and operational needs. The detection units and components in use for DoD events in this report were part of the remote area monitoring system (RAMS). The principal piece of equipment used to form a RAMS was the RAMP-4. The RAMP-4 was a multichannel, hard-wire linked, remote area gamma radiation monitoring (telemetry) system, designed and modified by Radsafe and produced by Victoreen Instrument Corporation. It consisted of a probe (Figure 2-6), which used a Neher-White radiation sensing element, hard-wired to an area trailer which sent microwave or hard-wire transmissions to communicate with the readout console (Figure 2-7) up to 35 miles away, and terminals which provided a printout of readings at set time intervals.

The readout covered six logarithmic decades (two three-decade scales) to provide a usual range of 1 mR/h to 1,000 R/h with a relative accuracy of ± 15 percent over the temperature range of -10° to 150°F up to 35 miles away, and terminals which provided a printout of readings at set time intervals. Extended range RAMS units provided a range from 100 mR/h to 100,000 R/h.

A permanent array of 30 to 40 telemetry stations throughout the NTS, as designated by DOE, were maintained and operated continuously during operational periods. Temporary telemetry arrays for DoD events varied between 15 and 50 stations depending upon the area or tunnel event location.

Figure 2-6. Neher-White RAMS Probe.

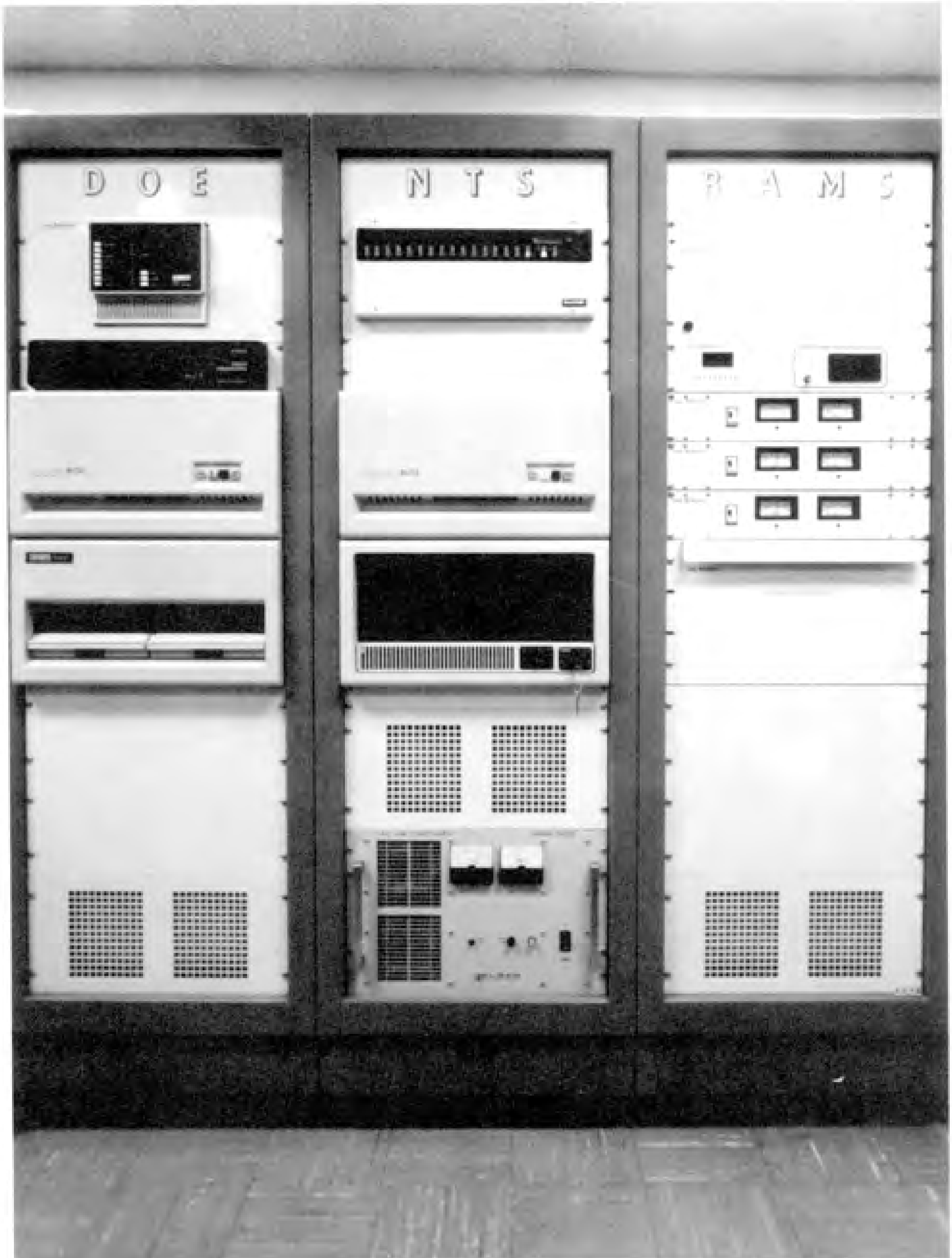

Figure 2-7. RAMS readout console.

2.8.2 Remote Area Radiation Detection Monitoring Support.

Approximately 20 detector units were positioned in the test area before a shaft event to continuously monitor radiological conditions and assess exposure rates before the test area was entered after detonation. Detectors were placed in circular arrays at appropriate distances from surface ground zero (SGZ) which varied with device yield and predicted wind direction (see Figure 2-8). RAMS units for tunnel events were placed somewhat differently based on each tunnel layout. Variable numbers of detectors were used aboveground and underground during tunnel events and are discussed in each event section. The additional 30 to 40 permanently established remote radiation detector stations operated continuously at living areas, work areas, and other locations throughout NTS (Figure 2-9). Event-related temporary telemetry detectors operated from zero time until it was determined that release of radioactivity probably would not occur, or until any released radioactivity had decayed to near-background levels at the telemetry stations. For some of the earlier events, readout locations were positioned near the forward control point (FCP) or at locations where telephone lines were available, in addition to the readouts located at CP-2.

Radiation telemetry data were supplemented with information collected through a mobile air sampling program. Model 102 air sampling units were used to obtain samples of any radioactive effluent released at event time or during the postevent drilling operations. Prior to each nuclear detonation experiment, at least one sampler was placed at a specified location in the test area and remained in position until drillback operations were completed or the Test Group Director authorized removal.

2.9 AIR SUPPORT REQUIREMENTS.

During this period of time, direct support for DoD underground tests was provided to NTO by elements of the 57th FWW, stationed at ISAFAF, (Detachment 1 of the 4900th Test Group during HURON LANDING/DIAMOND ACE, MINI JADE, and TOMME/MIDNIGHT ZEPHYR; and the 4460th Helicopter Squadron during MIDAS MYTH/MILAGRO and

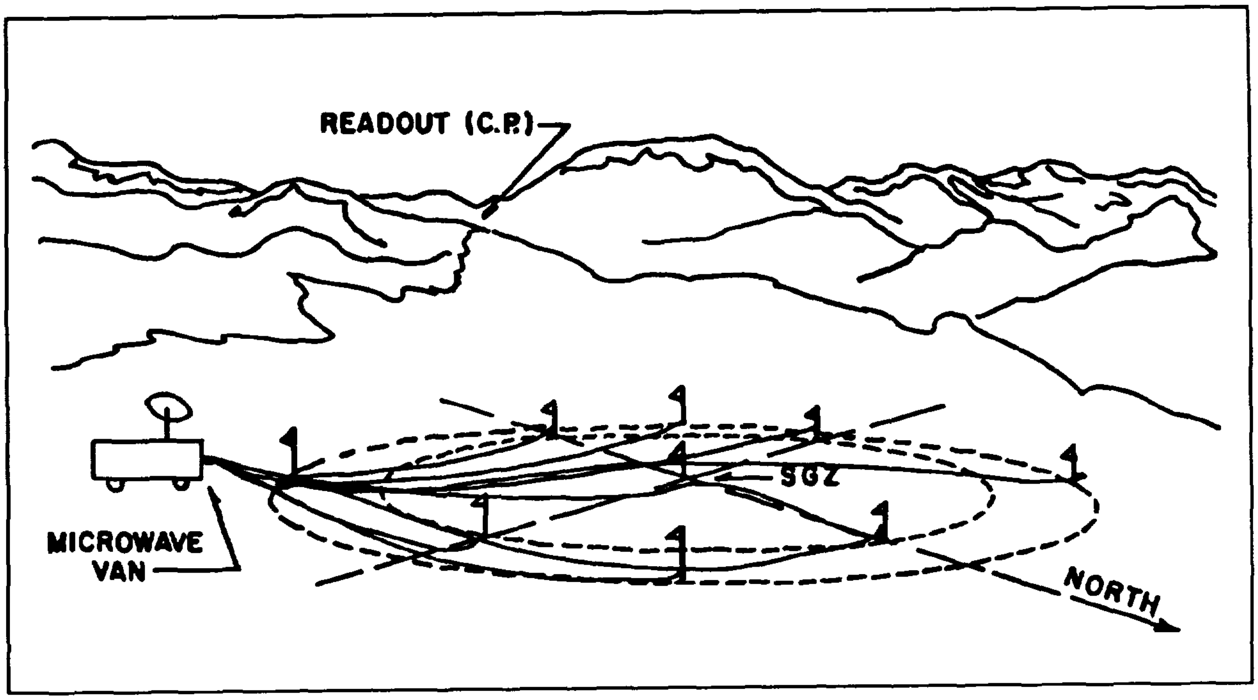

Figure 2-8. Typical remote radiation detection monitoring system for shaft emplacement site.

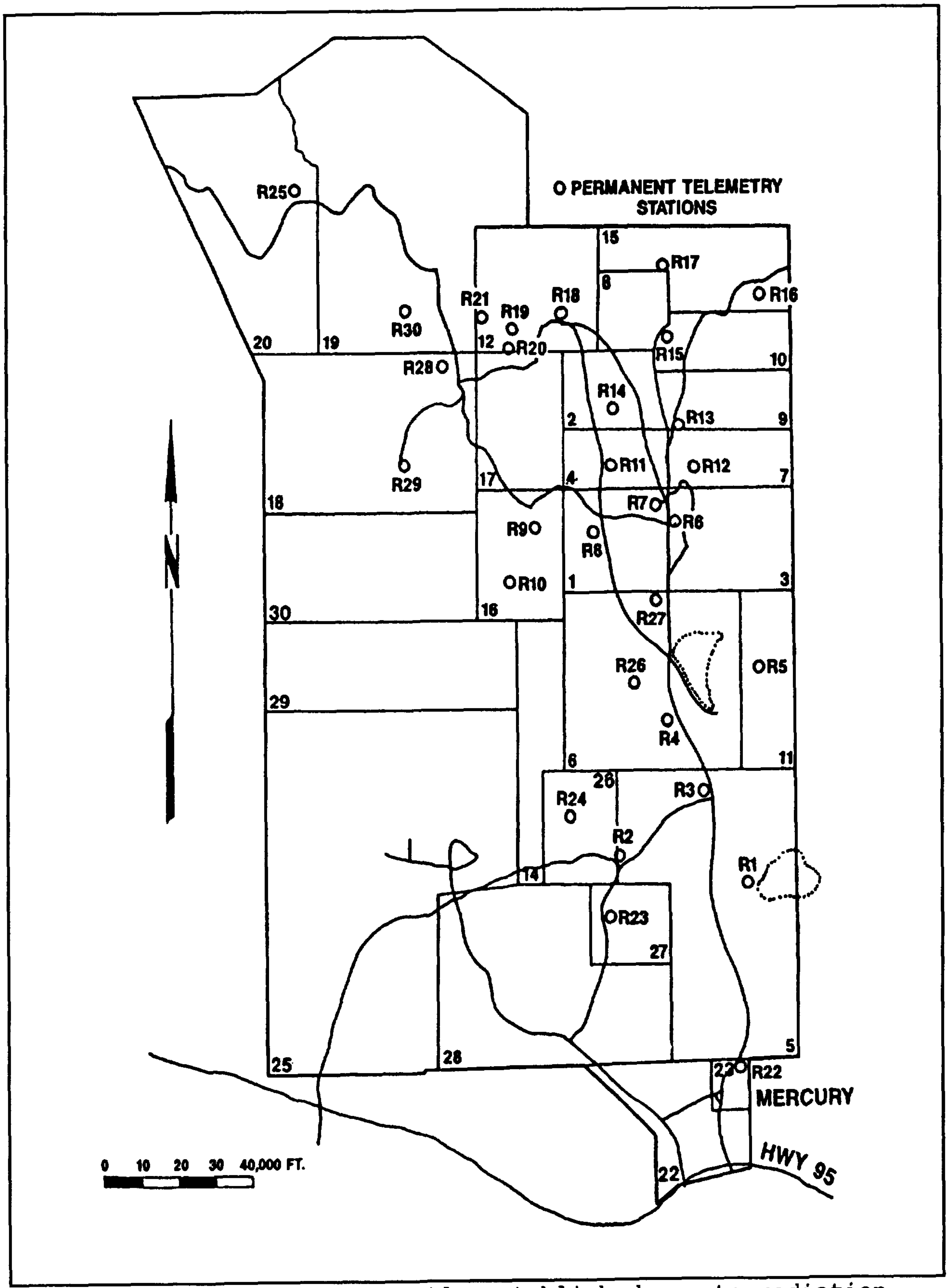

Figure 2-9. Typical permanently-established remote radiation detection stations operated continuously throughout the NTS.

MISTY RAIN). Less air support was required as the probability of venting radioactive effluent to the atmosphere decreased with development of more effective containment techniques.

2.9.1 Changes in Air Support Requirements.

After 1962, Air Force cloud-sampling and cloud-tracking aircraft generally were not required except for cratering events conducted by the DOE where radioactive effluent clouds were anticipated. Passage of the radioactive effluent through variable amounts and temperatures of rock and other media selectively retained some radionuclides underground, and changes occurred in the fission product ratios previously used during calculation and analysis of atmospheric detonation cloud samples. The value of analyzing particulate and gaseous cloud samples to determine characteristics of a detonation decreased accordingly.

The first change in cloud tracking and sampling support was to a lighter Air Force aircraft, the U-3A, with an Air Force pilot and EPA monitor. The EPA monitor also performed aerial monitoring of selected locations near surface ground zero and along the path of any effluent cloud. This air support later was performed by EPA and contractor personnel in their own aircraft. No accidental releases of radioactive effluent were detected onsite or offsite after the test events covered in this report.

Perimeter sweeps continued to be conducted daily by Air Force and Security personnel, during reasonable flying weather, to assure that unauthorized vehicles were not entering the NTS over rough terrain or around security barricades on secondary roads. The L-20 aircraft, used prior to 1968, were replaced by helicopters and other aircraft. Air security sweeps of the immediate test area were conducted for a few hours before each detonation to assist in clearing the test area and to assure that unauthorized vehicles were not approaching it from directions not controlled by manned security stations.

Air support for photography missions during test events and initial radiation surveys after each event did not change. Helicopters with Air Force pilots generally were used with contractor and military photographers and Radsafe monitors.

2.9.2 Radsafe Support for Indian Springs Air Force Auxiliary Field Personnel.

Radsafe support facilities had been established about 20 miles southeast of Mercury at ISAFAF during earlier atmospheric testing. REECo provided all Radsafe support functions at the NTS. This included monitoring personnel stationed at the ISAFAF Radsafe Quonset facility and maintaining a complete stock of film dosimeters (badges), radiation detection instruments, and anticontamination clothing and equipment for use by air and ground crews. In 1974, after the responsibility for air support to NTS was transferred from AFSWC to the 57th Fighter Weapons Wing (see paragraph 1.3.2), helicopters continued to be supplied and manned by personnel stationed at ISAFAF. Radsafe personnel were not involved with these monitoring and photography support aircraft until they arrived at their NTS staging areas.

Radsafe monitors issued and exchanged film dosimeters, issued self-reading pocket dosimeters, provided anticontamination clothing and respiratory protection equipment, monitored aircraft and personnel after events, decontaminated personnel, and assisted ground crew personnel with decontamination of aircraft at the NTS when necessary.

2.9.3 Radsafe Support for Helicopters.

Special helicopter Radsafe procedures were implemented for helicopters which staged from pads at the NTS, located east of Mercury highway near the CP area and near the Test Controller's FCP established for a particular underground event. Helicopter pilots usually landed at these locations and were briefed on their scheduled or other operational missions.

If the mission involved possible contamination of the helicopter, Radsafe monitors lined the floor with plastic (or kraft paper) secured with masking tape to facilitate decontamination. Film badges and pocket dosimeters were issued to pilots and crew members, and anticontamination clothing was available if needed.

Upon completion of missions, helicopters returned to the landing pads where they were checked for radiation and, if necessary, decontaminated by Radsafe monitors. Pilots and crew members were monitored and decontaminated as necessary at an adjacent forward Radsafe base station (or at CP-2) where pocket dosimeters were collected and read. Film badges were exchanged if exposures of 100 mR or more were indicated by pocket dosimeters.

SECTION 3

HURON LANDING/DIAMOND ACE EVENTS

3.1 EVENT SUMMARY.

HURON LANDING and DIAMOND ACE were jointly-sponsored (DoD and both LANL and LLNL) weapons-effects tests conducted essentially simultaneously at 0900 hours PDT on 23 September 1982. Each test had a yield of less than 20 kilotons. The HURON LANDING device was detonated in the U12n.15 LOS drift of the N tunnel complex at a vertical depth of 1,339 feet, and was located only 40 feet from the DIAMOND ACE device which was at a vertical depth of 1,335 feet (see Figure 3-1). This was the first time that two underground nuclear detonations were conducted essentially simultaneously in the same tunnel complex. The purpose of the HURON LANDING (DoD/LANL) event was to test the survivability of military hardware in a nuclear detonation environment. The DIAMOND ACE (DoD/LLNL) event was a source-development test and evaluated the low-yield testbed concept.

Approximately one hour after detonation, a small amount of radioactive gas seeped into the U12n.15 LOS drift between the end of the stemming and the Overburden Plug (OBP) where the gas was contained. When ventilation to the mesa was established, a controlled[9] effluent release of the contained gases occurred. This effluent release, consisting of xenons and kryptons, occurred from approximately H+28 until H+36 hours and was detected onsite only.

3.2 PREEVENT ACTIVITIES.

3.2.1 Responsibilities.

Safe conduct of all HURON LANDING/DIAMOND ACE project activities in Area 12 was the responsibility of the DNA Test Group Director

[9] The radioactive gas was passed through a filtering system where most of the particulates were removed before the gas was released through the tunnel ventilation system.

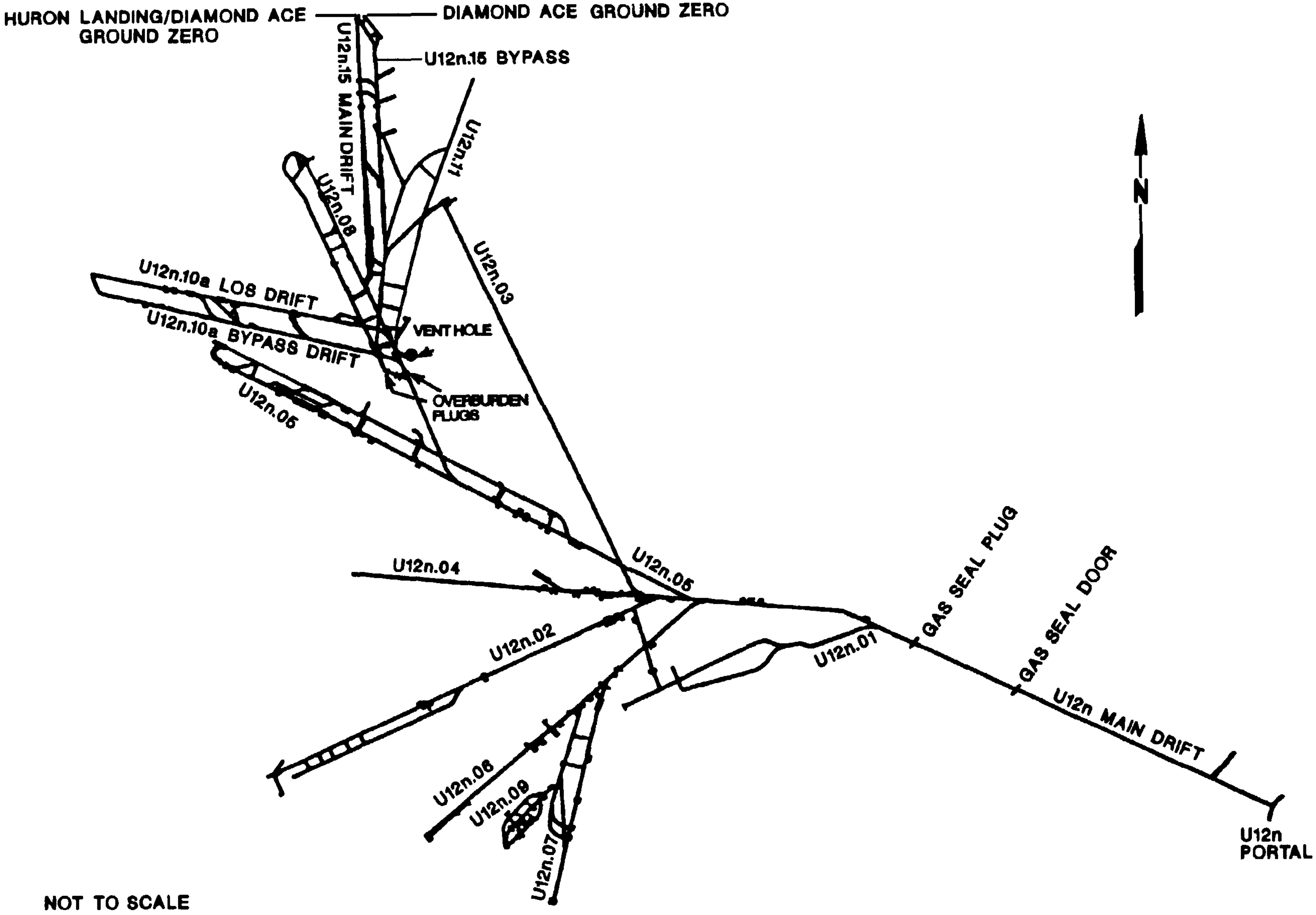

Figure 3-1. HURON LANDING/DIAMOND ACE events - tunnel layout.

(TGD), subject to controls and procedures established by the DOE Test Controller. The DOE Test Controller was responsible for safety of the public and onsite personnel during the test.

Project agencies were responsible for designing, preparing, and installing experiments, or delivering them to the installation contractor. After the event, these agencies were responsible for removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

Device safety and security procedures in the working point (WP) area and the timing and firing control room were in accordance with DOE Order 5610.3, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." The LANL TGD had overall responsibilities for all operations involving the HURON LANDING device as well as the timing control and the arming and firing of HURON LANDING closures and experiments. Operations involving the DIAMOND ACE device were the responsibility of the LLNL TGD under the overall control of LANL. Both the LANL and LLNL TGDs were responsible to the DOE Test Controller for radiological safety within the designated area of the WP from device emplacement until detonation. After detonation, the DOE Test Controller relieved both the LANL and LLNL TGDs of their responsibilities. The DOE Test Controller approved the controlled venting of the tunnel complex and returned the responsibility for project activities back to the DNA TGD.

3.2.2 Planning and Preparations.

A. Tunnel Facilities Construction.

Some mechanical hardware and system components, including the tunnel and pipe seal (TAPS) and vacuum pumps, were reused from the MINERS IRON event. The U12n.15 complex consisted of two LOS drifts (one for each event), the bypass drift, two zero rooms, a muffler, two auxiliary closures, TAPS, and four test chambers. The 1230-foot long HURON LANDING LOS pipe diverged from a diameter of eight inches close to the device to 231.5 inches at the end of the pipe, while the DIAMOND ACE LOS pipe was only 100 feet long. The DIAMOND ACE drift was connected to the HURON LANDING bypass drift by three crosscut drifts; one for access to the WP for device insertion; one for access to the side pipe experiments; and the third for access to the LLNL and SNL experiments at the back of the LOS pipe (Figure 3-2.). The main OBP was located at 1,335 feet from the HURON LANDING WP in the U12n.08 main drift.

Remote gas sampling capabilities were incorporated during construction as well as water, power, drain, and pressurization lines. Provisions to manually take gas samples from the WP side of the Gas Seal Door (GSD), Gas Seal Plug (GSP), and main OBP were made during postevent reentry.

Construction activities began in February 1981 with the mining of the HURON LANDING LOS drift in conjunction with equipment recovery operations for the MINERS IRON event. Mining of the U12n.15 bypass drift began in April 1981 and was completed in June. Mining of the LOS drift to the HURON LANDING WP was completed in October 1981 when cable installation began and concrete pours for the Modified Auxiliary Closure (MAC), Gas Seal Auxiliary Closure (GSAC), and TAPS inverts were completed. DIAMOND ACE drifts were also completed in October. In addition, HURON LANDING LOS pipe installation began in October 1981 and was completed in May 1982. The DIAMOND ACE LOS pipe installation began in March 1982 and was completed in June 1982.

Experiments and related hardware installations began in April 1982 and were completed in August. The experimenter organizations included: SNL, conducted zero room nuclear effects experiments involving magnetic hydrodynamic effects from shock waves; LANL, conducted continuous reflectometry for radius time experiments (CORRTEX) which measured the position of shock waves as a function of time; Kaman Sciences Corporation (KSC), fielded experiments to measure radiation driven responses of hardware for a missile system design; and Lockheed Palo Alto Research Laboratory (LPARL), conducted x-ray diagnostic experiments. Bendix Corporation (BENDIX), Physics International (PI), Science Applications International (SAI), and the Air Force Weapons Laboratory (AFWL) all fielded

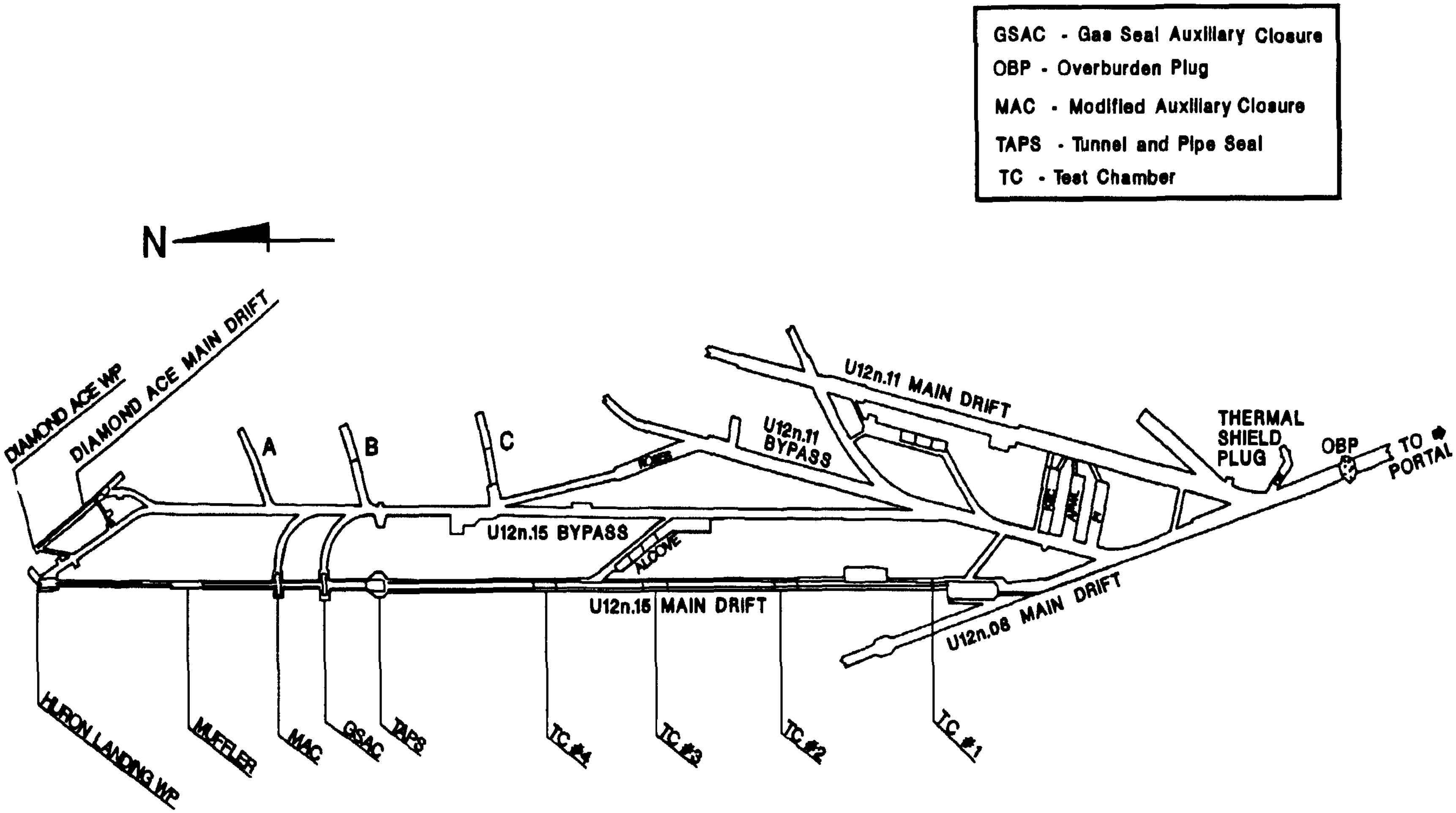

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Figure 3-2. HURON LANDING/DIAMOND ACE events - tunnel and pipe layout.

supporting experiments which included: advanced ballistic reentry studies where various hardware was exposed to a nuclear environment; a structures experiment where six minimally hardened tunnel test sections (located in the A, B, and C drifts mined from the U12n.15 bypass drift) were tested for response to ground motion; advanced weapons-components experiments; device radiation output measurements; and containment measurements.

The stemming plan for the U12n.15 complex is shown in Figure 3-3. The HURON LANDING WP was stemmed with rock-matching grout and magnetite sand. The U12n.15 LOS (main) drift was stemmed to 550 feet with rock-matching grout, superlean grout, and concrete, while the U12n.15 bypass drift was stemmed with desert fines and then with rock-matching grout, superlean grout and concrete out to 500 feet. The DIAMOND ACE WP, which had an air void in the zero room, was stemmed with desert fines while the DIAMOND ACE LOS drift was stemmed with both desert fines and rock-matching grout. Figure 3-4 shows stemming near the HURON LANDING WP end of bulkhead.

Dry run participation began in early September. A successful mandatory full-participation dry run (MFP) was conducted on 8 September after which final device preparation and final stemming commenced. A final inspection of the U12n.15 LOS pipe complex and experiments was held on 20 September followed by final stemming and button-up operations.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during these events were in accordance with DOE Manual Chapter 0524 and requirements of responsible DoD representatives. Radsafe provided monitoring and equipment support.

Prior to the test, detailed radiological safety reentry plans were prepared and issued to participating agencies. Air sampling equipment was positioned in the test area.

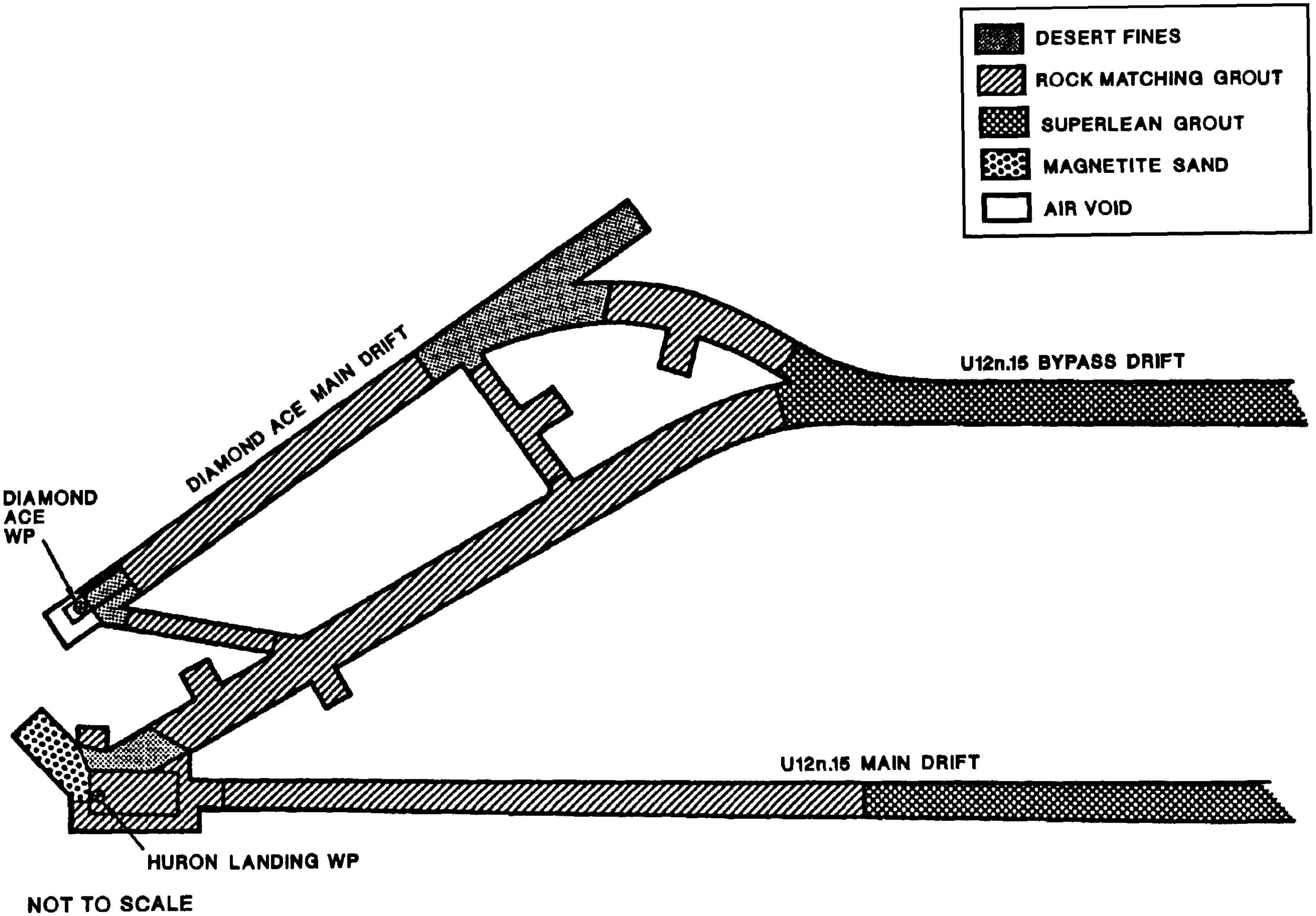

Figure 3-3. HURON LANDING/DIAMOND ACE events - stemming plan.

Figure 3-4. HURON LANDING/DIAMON ACE events - view toward working point end of bulkhead.

Radsafe monitors were briefed regarding surface reentry, manned stations, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in reentry parties as needed. Radsafe personnel were also standing by at Gate 300 prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment and material, portable instruments, and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination, as required.

Available anticontamination materials and equipment included head covers, coveralls, cloth shoe covers, totes, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves, and masking tape.

C. Telemetry and Air Sampling Support.

In addition to the permanent RAMS units, 40 temporary units provided surface and underground coverage for HURON LANDING/DIAMOND ACE. Table 3-1 and Table 3-2 list the locations of surface and underground RAMS, respectively. The location of both surface and underground RAMS units are shown in Figure 3-5 and Figure 3-6, respectively. All RAMS units were installed a minimum of five days prior to scheduled device detonation.

EPA operated continuous monitoring stations at 29 locations in the offsite area. All the stations had high-volume air samplers with collectors for particulates and reactive gases, 16 had tritium and noble gas samplers, and 19 had pressurized ion chamber gamma-rate detector/recorder systems in operation. Thirty-one EPA personnel were fielded for offsite surveillance activities.

D. Security Coverage.

Device security procedures in the WP area and the timing and firing control room were in accordance with DOE Order

Table 3-1. HURON LANDING/DIAMOND ACE events RAMS unit locations 23 September 1982.

SURFACE

STATION NUMBER	LOCATION
From the U12n Portal:	
1	At the Portal
2	On the filter system
3	On the ventline
4	On the drain line
5	400 feet N 16° E azimuth
6	275 feet N 89° E azimuth
7	365 feet S 16° E azimuth
8	480 feet S 12° W azimuth
9	560 feet S 48° W azimuth
10	420 feet N 69° W azimuth
11	1,370 feet S 43° E azimuth
From Cable Downhole:	
12	At cable rise building
13	180 feet N 42° E azimuth
14	140 feet S 34° E azimuth
15	370 feet S 31° W azimuth
16	80 feet N 85° W azimuth
17	At the vent hole
From the U12n.15 SGZ:	
18	234 feet S 00° E azimuth
19	500 feet S 60° E azimuth
20	500 feet S 60° W azimuth

Table 3-2. HURON LANDING/DIAMOND ACE events RAMS unit locations 23 September 1982.

UNDERGROUND

STATION NUMBER	LOCATION
From the U12n.15 main drift unless otherwise indicated:	
21	655 feet into the drift
22	524 feet into the drift
23	350 feet into the drift
24	90 feet into the drift
25	600 feet into the U12n.15 bypass drift
26	340 feet into the U12n.15 bypass drift
27	185 feet into the U12n.10 main drift
28	350 feet into the U12n.11 main drift
29	85 feet into the S-curve of U12n.08 bypass drift
30ER[10]	85 feet into the S-curve of U12n.08 bypass drift
31	At the vent drift, vent hole side of plug
32	435 feet into the U12n.08 drift from the U12n.05 drift
33	600 feet into the U12n.05 drift
From the U12n portal unless otherwise indicated:	
34	2,600 feet into the U12n main drift
35	235 feet into the U12n gas seal plug bypass drift
36ER[10]	235 feet into the U12n gas seal plug bypass drift
37	1,700 feet into the U12n main drift
38	1,200 feet into the U12n main drift
39	50 feet to the ventline rise from the U12n main drift
40	200 feet into the U12n main drift

[10] ER - Extended Range (instrument capable of reading 100 mR/h to 100,000 R/h).

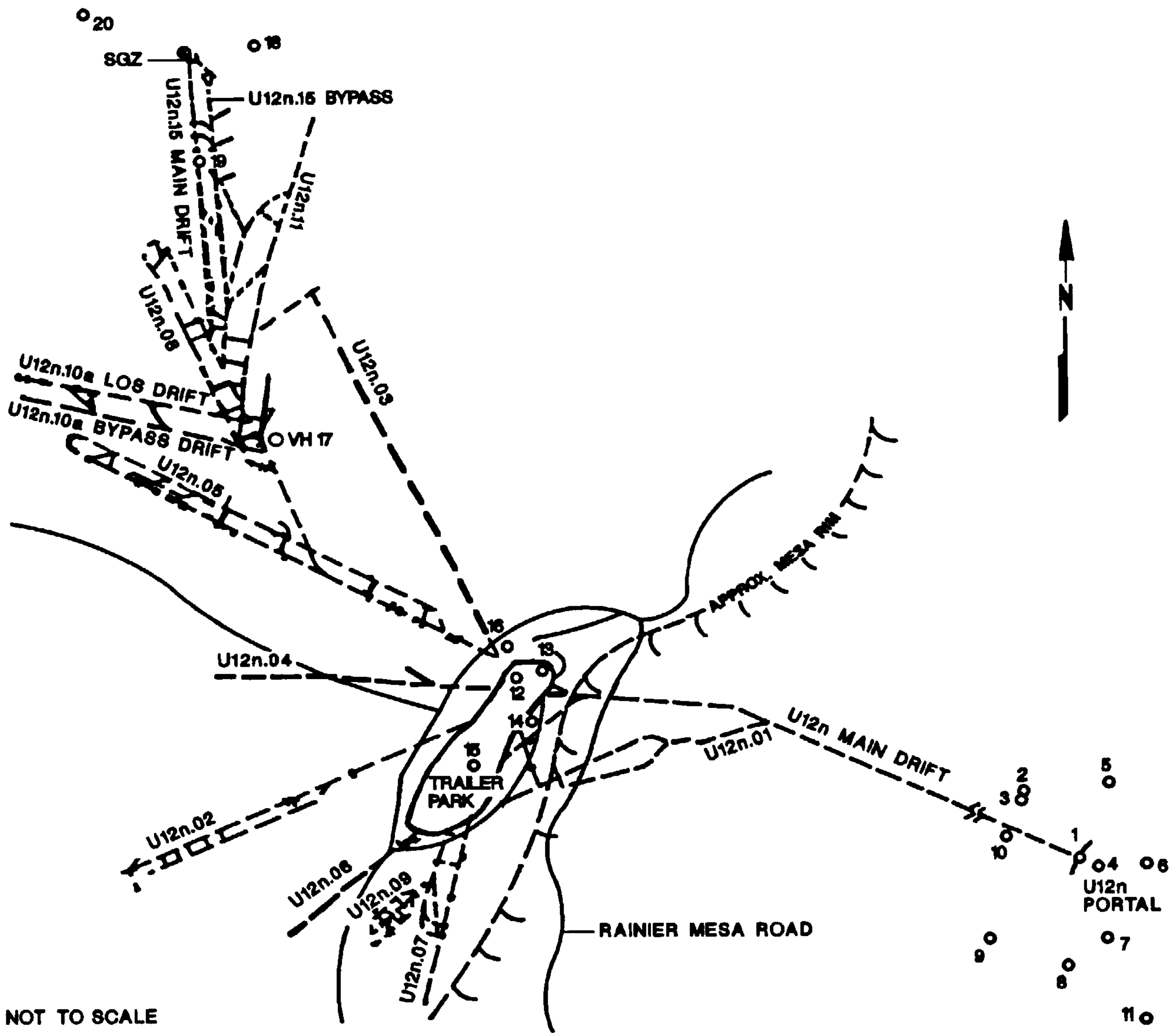

Figure 3-5. HURON LANDING/DIAMOND ACE events - surface RAMS.

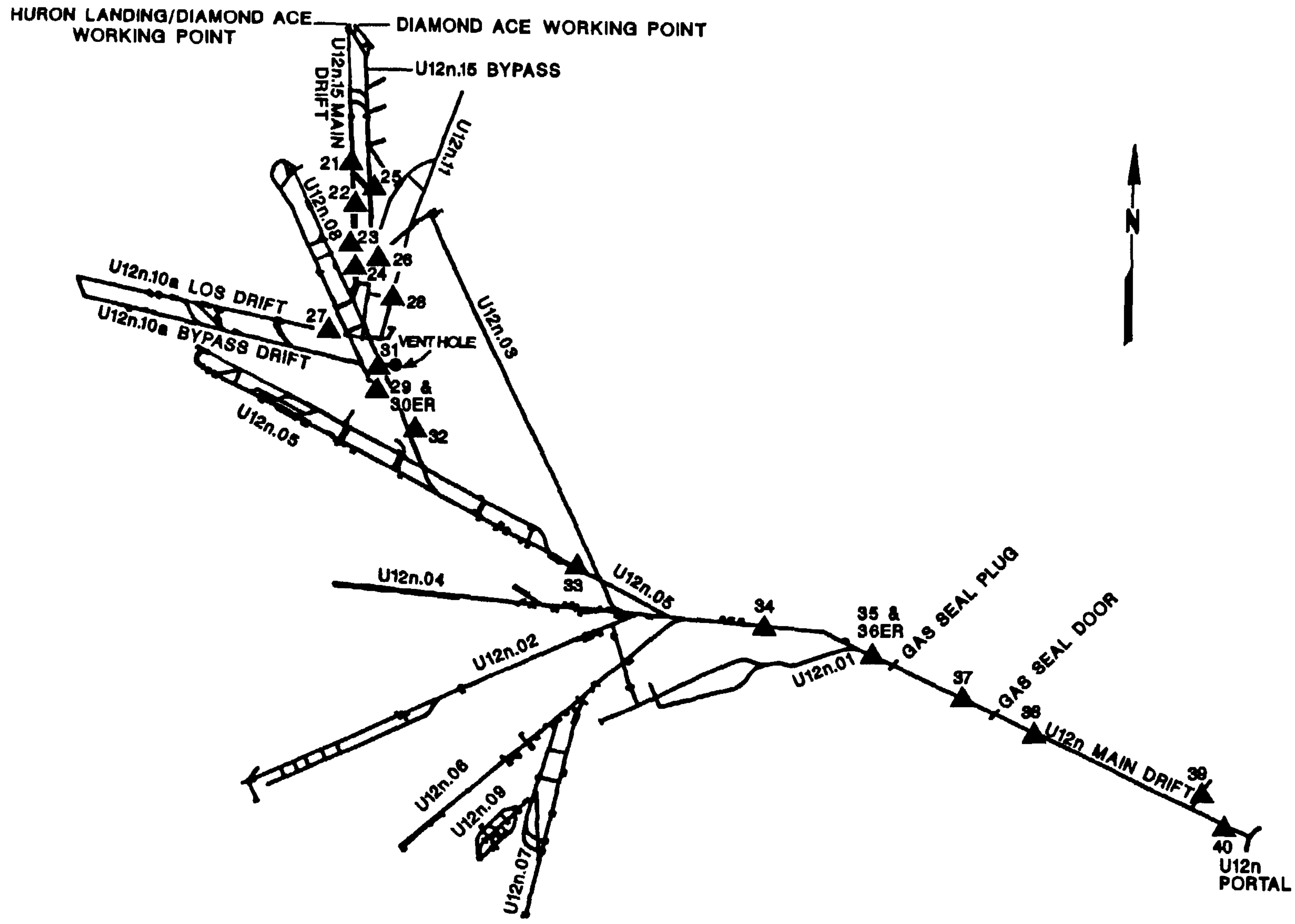

Figure 3-6. HURON LANDING/DIAMOND ACE events - underground RAMS.

5610.3, and DOE Order 5610.3-26, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." Beginning on D-1, all personnel entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges. After control was established, all through traffic was diverted around the controlled area by use of screening stations. In accordance with the "Test Controller's Operations and Security Plans," contractors and agencies were to have all personnel not connected with this event out of the closed area before the final security sweep began.

E. Air Support.

Three UH1N helicopters and crews were provided by the USAF for cloud tracking and the Test Controller's use, if needed. In addition, the USAF provided a C-130/C-135 and crew on standby status for cloud sampling. The EPA used an OV-10A Bronco before the event for obtaining meteorological information and this aircraft and crew, along with a Turbo Beech and crew, were standing by to undertake tracking duties, if necessary.

3.3 EVENT-DAY ACTIVITIES.

3.3.1 Preshot Activities.

On 22 September 1982, at 2400 hours, all persons except the arming party, the tunnel button-up party, the mesa button-up crew, and the security guards were out of the tunnel and clear of the muster area. At 0430 hours, permission was granted to arm the device. By 0800 hours button-up was complete.

A readiness briefing was held at 0700 hours on 23 September 1982, in anticipation of planned test execution at 0900 hours that day. Conditions for the test were favorable, and all personnel were mustered out of the area by 0800 hours. The countdown started as planned and proceeded through zero time.

The HURON LANDING/DIAMOND ACE devices were detonated simultaneously (two microseconds apart) at 0900 hours PDT on 23 September 1982. No indication of cavity collapse was evident on the geophones after zero time. This probably meant that collapse may have occurred immediately and was obscured by the initial ground shock noise.

3.3.2 Test Area Monitoring.

Telemetry measurements began at 0900 hours on 23 September 1982. RAMS unit numbers 23 and 24, in the U12n.15 main (LOS) drift, were immediately inoperative and remained so throughout the test period. Responding to the neutron activation of the LOS pipe, surrounding tuff and grouts, and experiments, RAMS unit numbers 21 and 22 read 150 R/h and 18 R/h, respectively, immediately after detonation. Readings decreased rapidly as normal activation product decay occurred.

At 1030 hours RAMS unit numbers 25-29, located in the U12n.15 bypass drift, the U12n.10 and U12n.11 main drifts, and the U12n.08 S curve started to rise indicating a slight seepage of radioactive gas into the U12n.15 LOS drift between the end of stemming and the OBP. The reading on RAMS unit number 28, located in the U12n.11 drift, was 4 mR/h. By 1330 hours readings had increased on (1) RAMS unit number 25 to 1.6 R/h, (2) RAMS unit number 26 to 300 mR/h, (3) RAMS unit number 27 to 4 mR/h, (4) RAMS unit number 28 to 50 mR/h, and (5) RAMS unit number 29 to 4 mR/h.

On 24 September 1982, at 1247 hours, the mesa ventline fans were turned on and a controlled ventilation of the tunnel complex occurred. RAM unit number 17, located at the base of the ventline system, was reading 5.1 mR/h. All RAMs units were secured at 0830 hours on 27 September 1982, with all operative units reading background except for RAMS unit number 22 which was reading 1 mR/h.

3.3.3 Initial Surface Radiation Surveys and Recovery Activities.

Four reentry teams (two teams to survey the mesa trailer park, one team to survey the portal area, and one team to survey the portal area ventilation system) were released from gate 300 at 1045 hours on the day of the detonation. By 1140 hours both the mesa trailer park and portal survey teams completed initial surveys. No radiation levels above background (0.04 mR/h) were detected. Mesa and portal data recovery was completed by 1630 hours. Data recovery teams included SNL, EG&G, LANL, SAI, and H&N. D-day reentry survey operations were terminated by 1700 hours. Figure 3-7 shows an overview of the N tunnel mesa and portal areas.

3.4 POSTEVENT ACTIVITIES.

3.4.1 Tunnel Reentry Activities.

At 0703 hours on 24 September (D+1), a work party entered the tunnel proceeding as far as the GSP. Ventilation was established at 0812 hours at the GSP by opening the 36-inch and 40-inch turntubes to the portal side of the OBP. No toxic gas, positive LEL, or radiation levels above background were detected. The oxygen level was a normal 21 percent and no respiratory protection was required at that time.

The manway door through the OBP was opened at 1051 hours on 24 September. Readings on the working point side of the OBP in the 36-inch crawlway were 10 mR/h, however no toxic gas or positive LEL levels were detected. The back-up reentry team, wearing self-contained breathing apparatus, then proceeded to walk out the U12n.08 drift to the Thermal Shield Plug where the carbon monoxide (CO) concentration measured 30 ppm, the oxygen level was 19 percent, and no positive LEL indication was detected. The back-up reentry team then opened the downhole ventline closure and established controlled ventilation to the vent pad on the mesa. All reentry teams were on the portal side of the GSP before the ventilation fans on the mesa were turned on at 1247 hours.

Both the initial reentry and back-up teams, wearing self-contained breathing apparatus, returned to the OBP at 1420 hours on 24 September. The initial reentry team then proceeded to walk out the U12n.08 LOS drift to the ROSES drift and shield wall. A maximum reading of 5 mR/h was detected five feet from the shield wall. However, no positive toxic gases or LEL levels were detected in either the U12n.08, U12n.11, ROSES drifts, or the

Figure 3-7. HURON LANDING/DIAMOND ACE events - N tunnel mesa and portal areas.

crosscuts No. 1 and No. 2 in the U12n.15 bypass. Readings inside test chamber No. 1 were 170 mR/h, 50 ppm CO, and 10 percent of the LEL. A six-inch ventline was hooked up to the valve on top of the LOS pipe at test chamber No. 1 to exhaust air inside of the LOS pipe. The readings at the valve on top of the LOS pipe were 35 percent of the LEL, 200 ppm CO, and 20 percent oxygen. The reentry team then proceeded toward test chambers No. 3 and No. 4 via the U12n.15 bypass drift. The maximum readings inside test chambers No. 3 and No. 4 doors (at arm's length) were 80 mR/h, 21 percent oxygen and a slightly positive LEL indication. A positive air flow into the LOS pipe at test chamber No. 3 and No. 4 doors was noted. The reentry team then returned to test chamber No. 1 and secured the door to increase the air flow into the LOS pipe from test chambers No. 3 and No. 4 doors. By 1751 hours on 24 September all personnel were on the portal side of the OBP.

On 25 September, an LOS pipe walkout team, wearing self-contained breathing apparatus, departed the OBP for the HURON LANDING LOS pipe. The team entered the LOS pipe at test chambers No. 3 and No. 4 to check the pipe and the TAPS door. The LOS pipe was caved in between test chamber No. 4 and the vent port. The partially-collapsed LOS pipe was accessible to test chamber No. 4 and the TAPS. The TAPS door was intact. Maximum readings at the top and left side of the door on the seal were 90 mR/h, 100 ppm CO, and 20 percent LEL. Laboratory analysis of smear samples taken on instrumentation and other items in the U12n.15 bypass, the LOS drift, and the user alcoves showed radioactivity levels were slightly above background.

After the LOS pipe walkout teams completed their surveys, the Scientific Assessment (SA) Team entered the LOS pipe at test chamber No. 1, where the maximum reading was 40 mR/h. The SA team, wearing full-face respirators with HEPA filters and full anticontamination clothing, completed their survey and were out of the tunnel by 1600 hours on 25 September.

Work continued in the test chambers to clean-up and remove instrumentation until all reentry and instrument recoveries were completed on 7 October.

3.4.2 Postevent Mining.

Work began on mining out the GSP at 0005 hours on 25 September. By 0125 hours on 27 September, the miners, dressed in full anticontamination clothing, had blasted out the GSP and were cleaning up debris. By 2300 hours on 27 September miners had laid the trainway, reestablished air and water lines at the GSP, and were removing the OBP. Maximum readings at the OBP were 0.05 mR/h. No positive LEL or toxic gas levels were detected.

Mining continued in the U12n.08, U12n.15 LOS, and crosscut drifts. By 1400 hours on 1 October, the miners had completed the major work on the OBP and shielding walls at test chambers No. 2, No. 3, and No. 4. The trainway through the OBP and the walkway through the shielding walls at crosscuts No. 1 and No. 2 were reestablished. Mining in the U12n.15 LOS drift and surveying and gas sampling in the test chambers continued throughout October 1982.

Reentry mining operations in the HURON LANDING U12n.15 bypass drift were started on 8 October. Miners began rockbolting at the "C" structure (Figure 3.2) to reinforce the tunnel walls on 12 October as reentry mining continued. By 29 October general clean-up, grading and laying track at the "C" structure, and other reentry mining activities in the U12n.15 bypass drift were essentially complete.

In late October 1983 mining resumed in the U12n.15 bypass drift as work on the "A" structure (Figure 3-2) began. The maximum exposure rate was 0.05 mR/h, and air sampling data showed zero percent CO, zero percent of the LEL, and 21 percent oxygen. Mining continued intermittently in the U12n.15 LOS pipe, and in the No. 1 and No. 2 crosscuts.

By the spring of 1985, mining was completed to the HURON LANDING WP area. Additional containment-related studies were conducted at that time.

3.4.3 Postevent Drilling.

Control of the postevent drilling area was established on the mesa with a base station and appropriate barricades at 1400 hours on 2 October. Drilling began at 1235 hours on 3 October on the first of five drill holes. Twelve core samples were taken from postshot (PS) No. 1A hole between 1710 hours and 2015 hours on 4 October. Sampling of PS No. 1AA, PS No. 1AB, and PS No. 1AC drill holes was done between 1132 hours on 5 October and 0216 hours, on 7 October from which 12, 13, and 23 samples were taken, respectively. No samples were taken from the PS No. 1AD, because LLNL personnel determined no further sampling was necessary. No LEL or toxic gas levels were detected during postevent drilling. The abandonment valve was closed and the operation was completed at 1211 hours on 7 October. By 1345 hours on 7 October the air sampling equipment on the drilling rig was shut down and personnel began moving equipment out of the area. A total of 60 core samples were taken from these drill holes with the maximum intensity at contact being 10.5 R/h.

3.4.4 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were then recorded in the monitors' logbook.

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. Industrial safety codes for mining, tunneling, and drilling, were established by REECo and emphasized during all operations. A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive material, or any other operation with the potential for personal injury. Each individual involved in such an operation was required to know the contents of the applicable procedures.

The portal construction area and the tunnel were mandatory hard hat and foot protection areas (safety shoes, boots, DOE-issued miner's boots, or toe guards). All personnel on initial tunnel reentry teams were certified in the use of the Draeger self-contained breathing apparatus and had used the McCaa two-hour breathing apparatus. Standard safety rules and regulations, as spelled out in the "U.S. Bureau of Mines Manual," were observed. All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Material Command Regulations (AMCR 385-100).
2. Appropriate DOE Orders in the 5400 and 5600 Series concerning Environmental Protection, Safety & Health Protection, and Defense Programs, respectively.
3. Individual safe operating procedures (by experimenter organization).
4. HURON LANDING/DIAMOND ACE Safety Regulations.

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DoD safety coordinator.

3.5 RESULTS AND CONCLUSIONS.

Telemetry measurements began at 0900 hours on 23 September 1983, with the maximum intensity being 150 R/h from activation products as measured on RAMS unit number 21 at 0900 hours on 23 September. All telemetry stations were secured at 0830 hours on 27 September.

The initial radiation surveys began at 1045 hours on 23 September and were completed at 1140 hours. No radiation above background was detected at the mesa trailer park area or at the tunnel complex portal.

Reentry into the tunnel began at 0703 hours on 24 September. A maximum reading of 170 mR/h was detected inside test chamber No. 1. The maximum toxic gas concentration and LEL percentage detected during initial reentry were 200 ppm CO and 35 percent of the LEL, respectively, measured at the valve on top of the LOS pipe at test chamber No. 1.

Postevent drilling from the mesa for recovery of core samples began at 1235 hours on 3 October and was completed when the abandonment valve was closed at 1211 hours on 7 October. Sixty core samples were taken and the maximum intensity at contact was

10.5 R/h. No underground core sampling operations were conducted.

Personnel exposure data from self-reading pocket dosimeters were documented on Area Access Registers during individual entries to HURON LANDING/DIAMOND ACE radex areas over a non-continuous time frame beginning 23 September 1982, and ending 30 August 1983. Pocket dosimeters showed some indication of possible radiation exposure to DoD-affiliated personnel. Film badges worn by these reentry personnel indicated that five individuals received some gamma exposure most likely from the HURON LANDING/DIAMOND ACE event. The minimum detectable gamma exposure with the NTS film badge dosimeter was 30 mR. Area Access Register data are summarized below.

Participants	Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All	1,284	160	3.4
DoD	97	160	12.1

SECTION 4

MINI JADE EVENT

4.1 EVENT SUMMARY.

MINI JADE was a DoD-sponsored weapons-effects test conducted at 0730 hours PDT on 26 May 1983. The test had a yield of less than 20 kilotons. The MINI JADE device was detonated in the U12n.12 drift of the N tunnel complex in an 11-meter radius hemispherical underground cavity at a vertical depth of 1,243 feet (Figure 4-1). The purpose of the MINI JADE event was to determine some aspects of energy coupling into earth materials from a near-surface nuclear detonation and test instrumentation development.

Within one minute of detonation a small amount of radioactive gas seeped into the tunnel and spread to the Drift Protection Plug (DPP)[11] where the gas was contained. When ventilation to the mesa was established, a controlled effluent release of the contained gases occurred. This effluent release, consisting of xenons, occurred from approximately H+5.2 days to H+6.2 days and was detected onsite only.

4.2 PREEVENT ACTIVITIES.

4.2.1 Responsibilities.

Safe conduct of all MINI JADE project activities in Area 12 was the responsibility of the DNA Test Group Director (TGD), subject to controls and procedures established by the DOE Test Controller. The DOE Test Controller was responsible for safety of the public and onsite personnel during the test.

Project agencies were responsible for designing, preparing, and installing experiments, or delivering them to the installation contractor. After the event, these agencies were responsible for

[11] After 1982, the Drift Protection Plug replaced or was used in conjunction with the Overburden Plug. The DPP provided an improved containment feature by exerting lower in situ pressures in large-volume vessel containment low-yield tests.

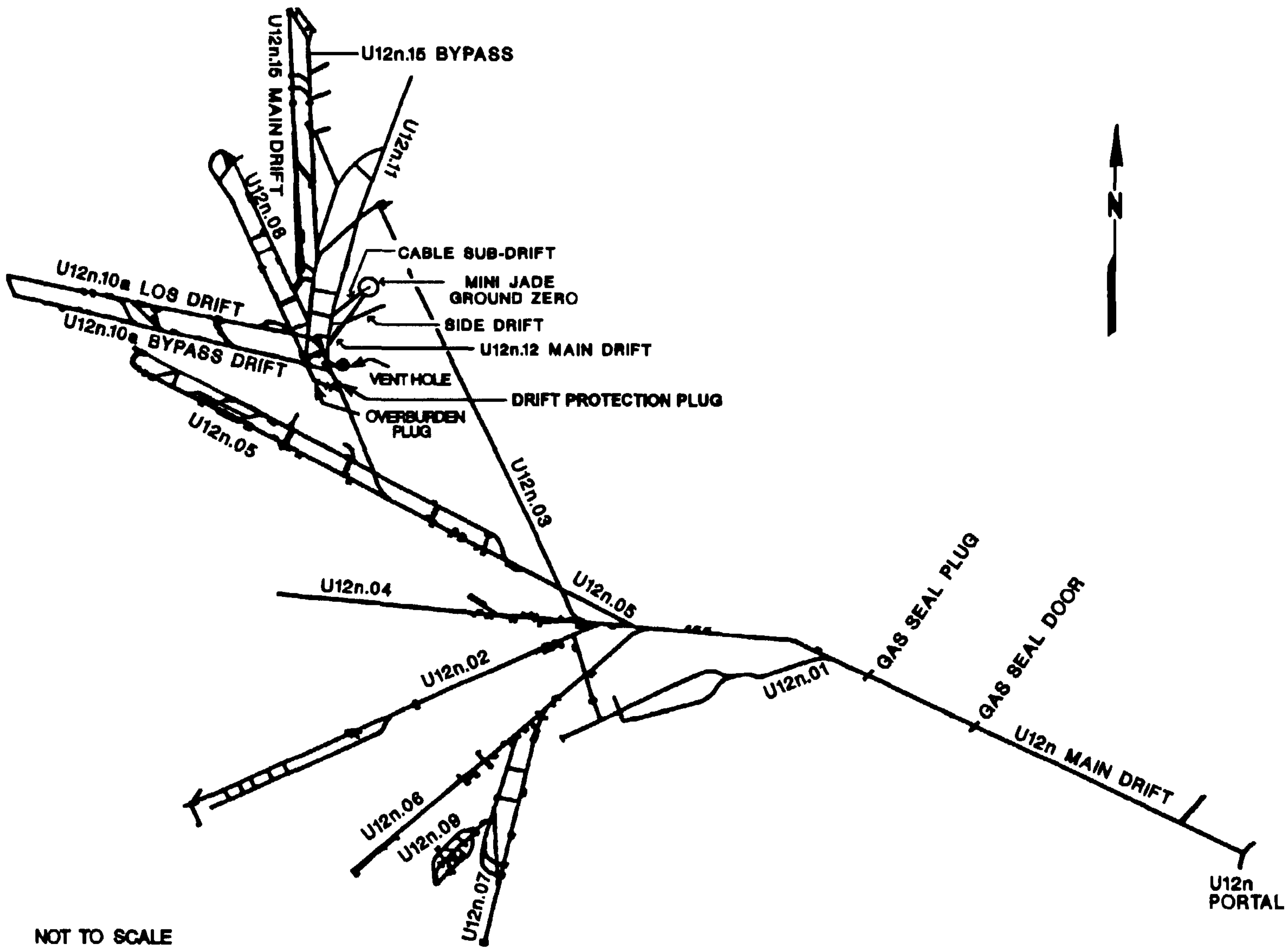

Figure 4-1. MINI JADE event - tunnel layout.

removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

Device safety and security procedures in the working point (WP) area and the timing and firing control room were in accordance with DOE Order 5610.3, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." The LANL TGD had overall responsibilities for all operations involving the MINI JADE device. The DNA TGD was responsible to the DOE Test Controller for radiological safety within the designated area of the WP from device emplacement until detonation. After detonation, the DOE Test Controller returned the responsibility for project activities to the DNA TGD. However, the controlled ventilation of the tunnel complex was done with the approval of the DOE Test Controller.

4.2.2 Planning and Preparations.

A. Tunnel Facilities Construction.

The U12n.12 complex consisted of the main drift which provided access to an 11-meter radius hemispherical cavity; the side drift; the cable subdrift; the cavity with a specially-prepared testbed; the drill alcove; the instrument and support alcoves; and the Recorder and Oscilloscope Sealed Environment System (ROSES) drift as seen in Figure 4-2.

There was no line-of-sight pipe traditionally associated with tunnel events. The MINI JADE testbed consisted of three major regions: (1) the one-meter cavity invert, (2) the Test Instrumentation Development (TID) bucket, and (3) the cavity region below one meter. Excavation of a one-meter deep region over the entire cavity invert was made to facilitate the placement of gauges in the TID bucket region (i.e., the high-stress region, directly beneath the device, containing a high concentration of gauges.) The process used to aid in the emplacement of these gauges included: (1) constructing a fiberglass container; (2) installing gauges and support structures to which cables were attached; (3) drilling holes through the side of the fiberglass container to facilitate attachment

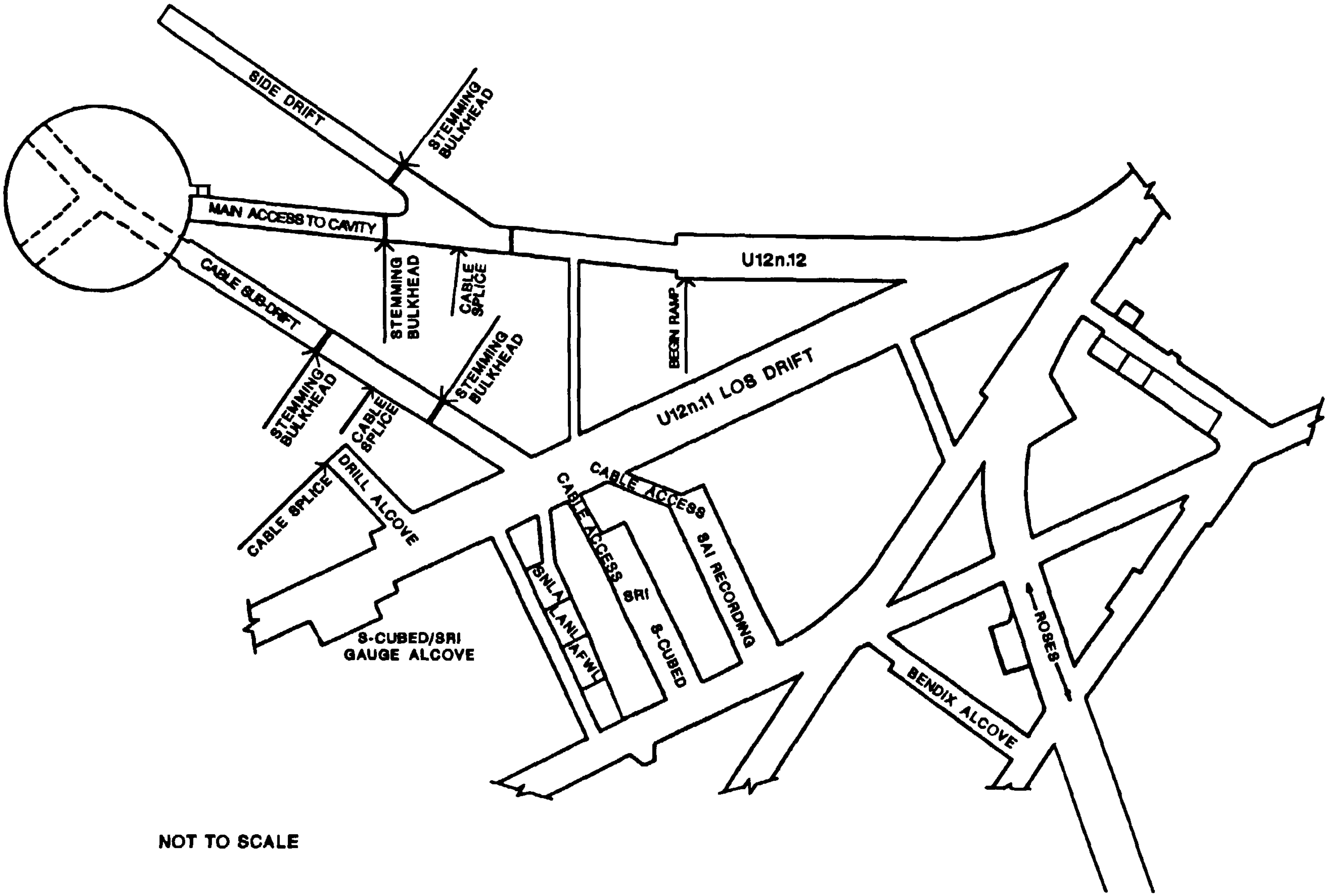

Figure 4-2. MINI JADE event - U12n.12 complex and stemming layout.

of horizontal cables in the one-meter region; (4) backfilling grout in the TID bucket up to one meter above the grout-tuff interface; and (5) removing the fiberglass container and support structures when the grout cured. Below the one-meter grout region was a ten-meter deep region of relatively undisturbed tuff permeated by drill holes that contained experimenter gauges. The cable subdrift provided access to this region. Figure 4-3 shows the TID bucket and gauges.

These experimenter gauges installed in this region were placed in an extensive array of 42 drill holes. Auxiliary drifts were mined near the cavity to support placement of gauges and cable runs through the drill holes into the cavity. All drill holes in the tuff were filled with HPNS-2 grout (not the same grout used in the one-meter region) because tests had shown that this grout was similar to the tuff regarding stress and wave propagation characteristics.

Mining of the U12n.12 LOS drift, subdrift and drill alcove was done simultaneously beginning in October 1982, with the work completed by mid-December 1982. By the end of January 1983 all drilling and TID bucket spading was complete. During February the cavity invert grout was poured and installation of the bulkhead and trainway in the Gas Seal Plug (GSP) was completed. The manways and annulus for the anchor plugs in both the subdrift and side drift were installed and the drill alcove was stemmed in March. In addition, work in the ten-meter lower region, which included gauge installation, grouting all drill holes and cavity invert, and stemming the drill alcove, was completed in March. Ramp construction for the device was completed in April and by early May the shielding of the ROSES drift was completed and all experiments were in place.

Additional facilities incorporated during construction were remote gas sampling capabilities as well as water, power, drain, and pressurization lines. Provisions to manually take gas samples from the WP side of the Gas Seal

Figure 4-3. MINI JADE event - TID bucket and gauges.

Door (GSD), the GSP, and the DPP were made during post-event reentry.

The nine fielding organizations conducting experiments for this event were: S-CUBED, conducted studies to increase the capability to predict ground shock, air blast and containment occurrences; Stanford Research Institute International (SRII), conducted long-duration stress and particle velocity studies; Sandia National Laboratories (SNL), conducted airblast, ground shock, radiation diagnostics, decoupled ground wave, and containment studies; Science Applications Incorporated (SAI), studied particle velocity, shock velocity, shock time-of-arrival (TOA), and magnetic field and gamma radiation flux; LANL, conducted continuous reflectometry for radius time experiments (CORRTEX) to measure fireball growth and shock propagation through the invert; JAYCOR, conducted Source Region Electromagnetic Pulse (SREMP) studies involving the collection of cable-coupling data (Figure 4-4); Applied Research Associates (ARA), measured peak stress generated by device detonation at various anticipated stress levels; the Air Force Weapons Laboratory (AFWL), conducted experiments to measure particle motion under stress in a nuclear environment; and Field Command Defense Nuclear Agency (FCDNA), conducted tunnel environment and containment studies and cable plant noise measurements.

Signal dry runs began in March 1983. The mandatory full-participation (MFP) dry run was successfully completed on 19 May 1983. From 20 May to 25 May 1983, mandatory signal dry runs were held daily to insure that all systems were functioning properly. At 0230 hours on 26 May, final arming took place after which button-up activities began.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during this event were in accordance with DOE Manual Chapter 0524 and requirements of responsible DoD representatives. Radsafe provided monitoring and equipment support.

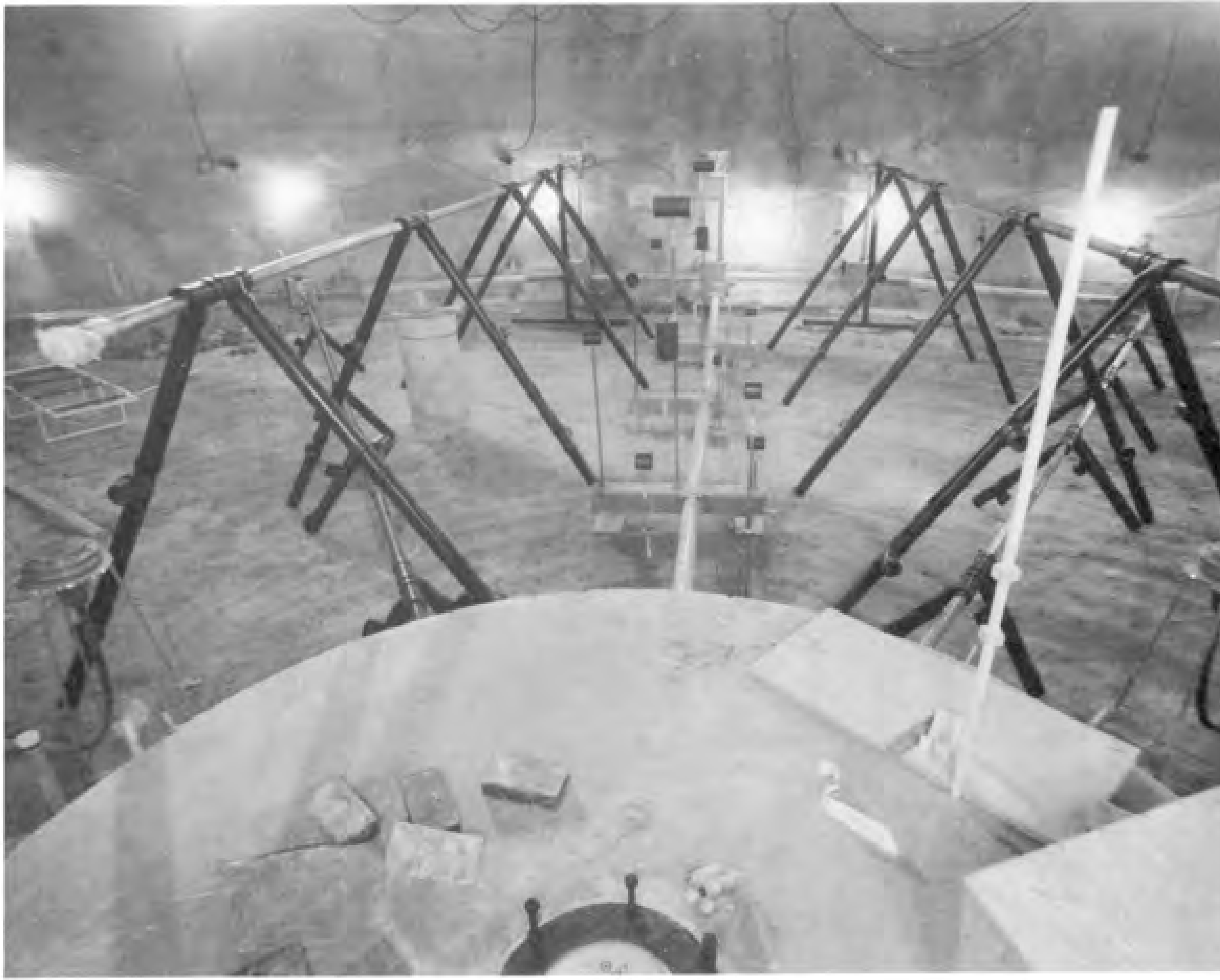

Figure 4-4. MINI JADE event - SREMP experiment.

Prior to the test, detailed radiological safety reentry plans were prepared and issued to participating agencies. Air sampling equipment was positioned in the test area. Radsafe monitors were briefed regarding surface reentry, manned stations, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in reentry parties as needed. Radsafe personnel were also standing by at Gate 300 prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment and material, portable instruments, and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination, as required.

Available anticontamination materials and equipment included head covers, coveralls, cloth shoe covers, totes, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves, and masking tape.

C. Telemetry and Air Sampling Support.

In addition to the 39 permanent RAMS units, 31 temporary units provided surface and underground coverage for MINI JADE. Table 4-1 and Table 4-2 list the locations of surface and underground RAMS, respectively. The location of both surface and underground RAMS units are shown in Figure 4-5 and Figure 4-6, respectively. All RAMS units were installed a minimum of five days prior to scheduled device detonation.

EPA operated continuous monitoring stations at 30 locations in the offsite area. All the stations had high-volume air samplers with collectors for particulates and reactive gases, 16 had tritium and noble gas samplers, and 22 had pressurized ion chamber gamma-rate detector/recorder systems in operation. Twenty-seven EPA personnel were fielded for offsite surveillance activities.

Table 4-1. MINI JADE event RAMS unit locations 26 May 1983.

SURFACE

STATION NUMBER	LOCATION
From the U12n Portal unless otherwise indicated:	
1	On the drain line
2	400 feet N 16° E azimuth
3	275 feet N 89° E azimuth
4	365 feet S 16° E azimuth
5	480 feet S 12° W azimuth
6	560 feet S 48° W azimuth
7	420 feet N 69° W azimuth
8	1,370 feet S 43°E azimuth
9	At cable rise building
10	On the vent hole
From the U12n.12 SGZ:	
11	350 feet N 00° E azimuth
12	350 feet S 60° E azimuth
13	350 feet S 60°W azimuth

Table 4-2. MINI JADE event RAMS unit locations 26 May 1983.

UNDERGROUND

STATION NUMBER	LOCATION
From the U12n.12 drift unless otherwise indicated:	
14	225 feet into the U12n.12 main drift
15	40 feet into the U12n.12 cable subdrift
16	500 feet into the U12n.11 main drift
17	150 feet into the U12n.11 main drift
18	320 feet into the U12n.11 bypass drift
19	400 feet into the U12n.10 main drift
20	185 feet into the U12n.10 main drift
21	85 feet into the S-curve of the U12n.08 bypass drift
22ER[12]	85 feet into the S-curve of the U12n.08 bypass drift
23	435 feet into the U12n.08 main drift
From the U12n main drift unless otherwise indicated:	
24	600 feet into the U12n.05
From the U12n portal unless otherwise indicated:	
25	2,600 feet into the U12n main drift
26	235 feet into the U12n gas seal plug bypass drift
27ER[12]	235 feet into the U12n gas seal plug bypass drift
28	1,700 feet into the U12n main drift
29	1,200 feet into the U12n main drift
30	50 feet into the ventline rise from the U12n main drift
31	200 feet into the U12n main drift

[12] ER - Extended Range (instrument capable of reading 100 mR/h to 100,000 R/h).

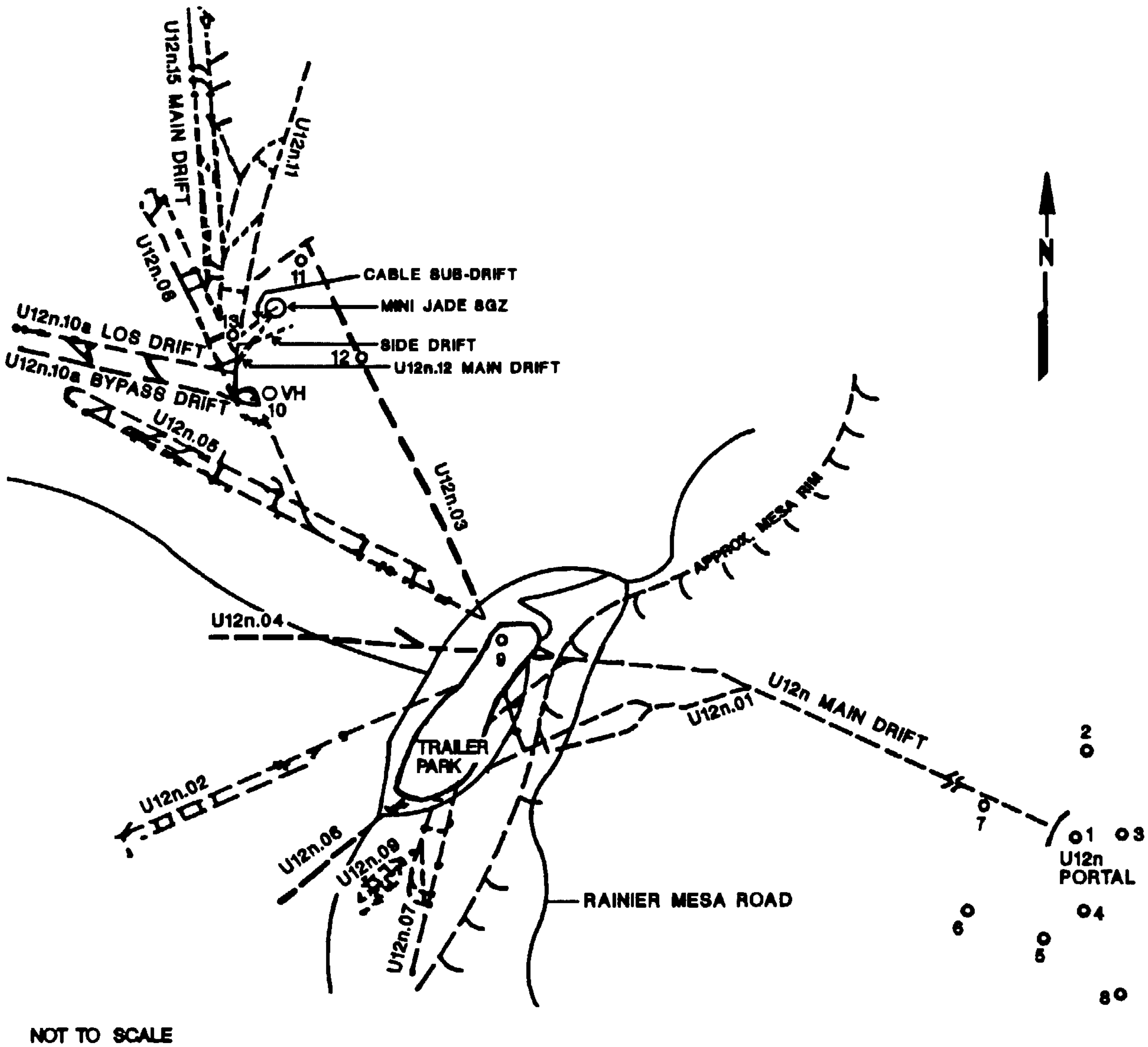

Figure 4-5. MINI JADE event - surface RAMS.

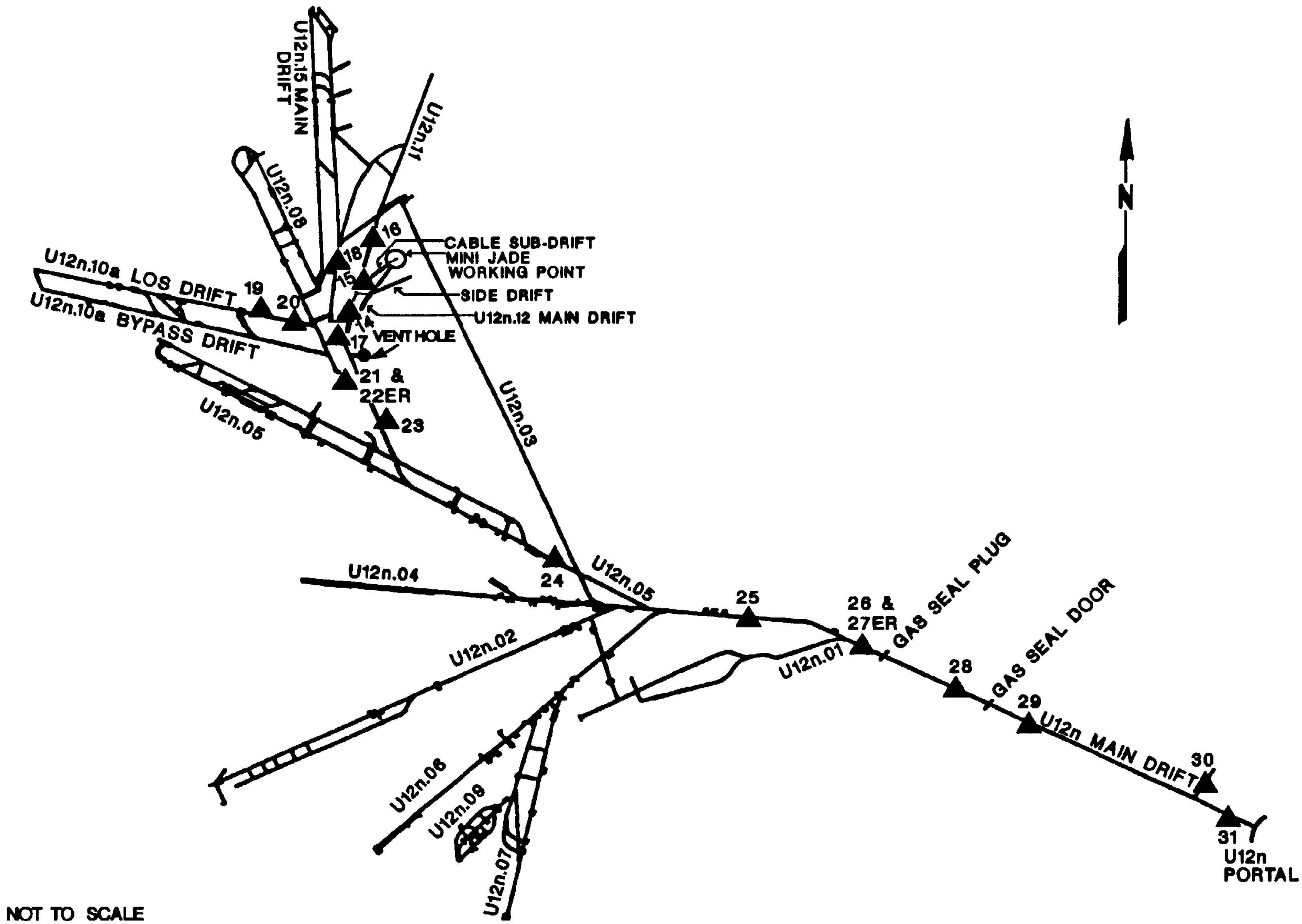

Figure 4-6. MINI JADE event - underground RAMS.

D. Security Coverage.

Device security procedures in the WP and in the timing and firing control room were in accordance with DOE Order 5610.3, and DOE Order 5610.3-26, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." Beginning on D-1, all personnel entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges. After control was established, all through traffic was diverted around the controlled area by use of screening stations.

In accordance with the "Test Controller's Operations and Security Plans," contractors and agencies were to have all personnel not connected with this event out of the closed area before the final security sweep began.

E. Air Support.

Three UH1N helicopters and crews were provided by the USAF for cloud tracking and the Test Controller's use, if needed. In addition, the USAF provided a C-130/C-135 and crew on standby status for cloud sampling. EG&G provided one Turbo Beech and one Twin Bonanza aircraft and crews for tracking duties, if necessary.

4.3 EVENT-DAY ACTIVITIES.

4.3.1 Preshot Activities.

By 25 May 1983 at 2400 hours, all persons except the arming party, the tunnel button-up party, the mesa button-up crew, and the security guards were out of the tunnel and clear of the muster area. At 0230 hours on 26 May permission was granted to arm the device. By 0615 hours button-up was completed.

A readiness briefing was held at 1400 hours on 25 May 1983, in anticipation of the planned test execution at 0730 hours the next day. On 26 May conditions for the test were favorable, and all personnel were mustered out of the area by 0630 hours. The countdown started as planned and proceeded through zero time.

The MINI JADE device was detonated in the U12n.12 drift at 0730 hours PDT on 26 May 1983.

4.3.2 Test Area Monitoring.

Telemetry measurements began at 0730 hours on 26 May 1983 with all RAMS stations reading background. All RAMS stations remained operational throughout the test and subsequent readout period. All stations except for unit numbers 14-22 read background throughout the entire readout period. Units 14-22 showed increased readings immediately after zero time due to a possible leak in the U12n.12 main drift manway plug.

At H+2.3 minutes RAMS unit number 14, located in the U12n.12 main drift, indicated a maximum reading of 233 R/h. However, by 0900 hours the reading had decreased to 12.6 R/h. RAMS unit number 17, located in the U12n.11 main drift, showed increased readings immediately after zero time and at H+22 minutes recorded a maximum reading of 30.4 R/h. This diminished to 12.1 R/h by H+2 hours. By 1230 hours, RAMS units 14 and 17 readings were 4.1 R/h and 3.8 R/h, respectively.

Readings decreased rapidly, and all RAMS units were secured at 1530 hours on 31 May 1983. At that time all units read background except for numbers 14 and 17 which read 0.2 mR/h and 0.1 mR/h, respectively.

4.3.3 Initial Surface Radiation Surveys and Recovery Activities.

Initial reentry teams departed from the Test Director's barricade at Gate 300 at 0841 hours on 26 May 1983. A mobile base station was provided for area control and equipment supply. By 0922 hours, the initial survey teams in both the U12n portal area and Rainier Mesa cable rise building and ventilation pad had completed the initial surface survey. No radiation levels above normal area background were detected.

Survey teams, consisting of geologists, industrial hygienists and radiation safety monitors, stood by at the N tunnel portal and on the mesa during data recovery and remote gas sampling of the tunnel. The mesa survey was completed by 1045 hours and no readings were above background levels. Industrial hygiene personnel continued taking remote gas samples from the WP side of the DPP with the maximum reading being 7 mR/h at contact with the sampling container. These operations were completed by 1600 hours. By 1610 hours on 26 May 1983 all personnel were checked out of the event location.

4.4 POSTEVENT ACTIVITIES.

4.4.1 Tunnel Reentry Activities.

At 0807 hours on 27 May 1983 (D+1), the 13-member work party, dressed in anticontamination clothing, entered the tunnel and proceeded as far as the GSP. Ventilation at the GSP was established at 0859 hours by opening the 36-inch and 40-inch turntubes to the portal side of the DPP. No toxic gas, or positive LEL levels were measured. No radiation levels above background (0.04 mR/h) were detected. The oxygen level was a normal 21 percent.

The reentry team arrived at the DPP at 0938 hours. The reading on the portal side of the DPP, at the top side of the turntube, was 0.6 mR/h with traces of carbon monoxide (CO). The manual valve on the portal side of the DPP was opened to take remote gas samples from the working point side of the DPP. Maximum readings were 4 mR/h (resulting from the seepage of radioactive gas into the tunnel almost immediately after event detonation), 3 percent of the LEL level, and 40 ppm CO.

The work teams completed their assignments and departed the DPP at 1011 hours for the GSP. By 1030 hours on 27 May all personnel were on the portal side of the GSP. No respiratory protection was required for this initial reentry. The tunnel was secured until 31 May 1983.

At 1915 hours on 31 May the reentry, backup, and rescue teams, dressed in anticontamination clothing, departed the portal area for the GSP. The reentry team proceeded to the DPP and arrived at 0948 hours where readings on the portal side of the DPP were background, and no toxic gases or positive LEL were detected. At 1107 hours the 36-inch turntube was opened on the DPP. The reentry team, wearing self-contained breathing apparatus, proceeded to the working point side of the DPP where the reading was 0.3 mR/h and the oxygen level was a normal 21 percent. The reentry team then opened the downhole ventline closure and established ventilation to the mesa at 1153 hours before proceeding out of the U12n.12 main drift (cavity access plug) area. A maximum reading of 1.5 mR/h was detected five feet from the cavity access plug. By 1306 hours ventilation had been reestablished at both the ROSES shield wall in the U12n.10 drift and in the U12n.18 drift (shown in Figure 5-2). By 1400 hours all teams were on the portal side of the DPP.

The Scientific Assessment and Data Recovery Teams entered the tunnel at 1445 hours 31 May 1983, and completed their work that same day.

4.4.2 Postevent Mining and Drilling.

Work began on mining out the GSP at 1830 hours on 31 May and was completed at 0200 hours on 1 June. By 0030 hours on 3 June the miners had completed major work on the DPP and had completed rehabilitation of the U12n.12 main and subdrifts. Miners and radiation safety personnel, wearing self-contained breathing apparatus, sprayed all work areas on the WP side of the DPP with a sodium silicate sealant to control the resuspension of contaminated particulate matter. In addition, sealant was sprayed in tunnel drifts adjacent to the MINI JADE complex. Contamination in the TOMME/MIDNIGHT ZEPHYR ground zero and drift areas resulted in cleanup and spraying being done in these areas simultaneously with postevent mining in the MINI JADE main and subdrifts. By mid-June 1983 mining activities for MINI JADE had ceased and work continued in preparation for TOMME/MIDNIGHT ZEPHYR.

Mining resumed on 15 October 1983, at the U12n.12 main, subdrift, and drill alcove bulkheads (see Figure 4.2) and continued until late November. Hydraulic fracture (HYDRAFRAC) holes were drilled and samples were taken to determine the environment of the yet unmined sections of the drifts. Readings taken during this period indicated a normal 21 percent oxygen level; CO levels as high as 1500 ppm; a maximum 30 percent LEL level; and maximum radiation levels of 200 mR/h.

Drilling operations continued so that monitoring of the MINI JADE cavity environment, for subsequent reentry into the cavity, could begin. A hole was drilled from the U12n.11 drift into the cavity to vent the contained gases, and cavity ventilation began on 17 October 1983. Remote sampling showed initial readings of 30 percent of the LEL, 300 ppm CO, and 17 percent oxygen. The radiation level was 1.5 mrad/h. By 19 October purging of the filtered cavity gases, through the U12n.11 drift and out the U12n.08 chimney, was completed. At that time readings indicated that the MINI JADE cavity had no toxic gases or positive LEL levels, 21 percent oxygen, and the radiation level was 1 mrad/h.

Work continued, and on 28 November miners, wearing full-face masks and anticontamination clothing, broke through the center of the face of the MINI JADE cavity and inserted an air sampler head. The next day DoD personnel entered the cavity access drift to make an evaluation. On 30 November when a Pan Am photographer was present, the exposure rate inside the cavity was 7 mR/h. Sampling and picture-taking continued until 13 December 1983 when this area of the tunnel was shut down.

No drilling to recover zero point core samples was conducted from the mesa or the tunnel for this event.

4.4.3 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were then recorded in the monitors' logbook.

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. Industrial safety codes for mining, tunneling, and drilling, were established by REECo and emphasized during all operations. A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive material, or any other operation with the potential for personal injury. Each individual involved in such an operation was required to know the contents of the applicable procedures.

The portal construction area and the tunnel were mandatory hard hat and foot protection areas (safety shoes, boots, DOE-issued miner's boots, or toe guards). All personnel on initial tunnel reentry teams were certified in the use of the Draeger self-contained breathing apparatus and had used the McCaa two-hour breathing apparatus. Standard safety rules and regulations, as spelled out in the "U.S. Bureau of Mines Manual," were observed.

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Material Command Regulations (AMCR 385-100).
2. Appropriate DOE Orders in the 5400 and 5600 Series concerning Environmental Protection, Safety & Health Protection, and Defense Programs respectively.
3. Individual safe operating procedures (by experimenter organization).
4. MINI JADE Safety Regulations.

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DoD safety coordinator.

4.5 RESULTS AND CONCLUSIONS.

Telemetry measurements began at 0730 hours on 26 May 1983, with the maximum exposure rate being 233 R/h detected on RAMS unit number 14 at H+2.3 minutes. All telemetry stations were secured at 1530 hours on 31 May with only unit numbers 14 and 17 reading above background.

The initial radiation surveys began at 0841 hours on 26 May and were completed at 0922 hours. No radiation above background was detected at the mesa cable rise building or at the tunnel portal area.

Reentry into the tunnel began at 0807 hours on 27 May. The maximum readings from remote gas sampling were 4 mR/h, 3 percent

LEL level, and 40 ppm CO. Initial reentry and data recovery was completed by 31 May 1983.

Postevent mining and sampling began on 31 May and continued sporadically until 13 December. Mining activities were hampered by contamination resulting from resuspension of particulates. Spraying sealant in the tunnel allowed miners to continue MINI JADE postevent operations while continuing to prepare for the upcoming TOMME/MIDNIGHT ZEPHYR event. Maximum readings during mining operations were 21 percent oxygen; 1500 ppm CO; 30 percent LEL level; and radiation levels of 200 mR/h.

Personnel exposure data from self-reading pocket dosimeters were documented on Area Access Registers during individual entries to MINI JADE radex areas over a non-continuous time frame from 4 June 1983 to 12 September 1983. Although pocket dosimeters showed some indication of possible radiation exposure, film badges worn by reentry personnel indicated no evidence of any gamma exposures. The minimum detectable gamma exposure with the NTS film badge dosimeter was 30 mR. Area Access Register data are summarized below.

Participants	Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All	5,832	85	0.1
DoD	178	18	0.1

SECTION 5

TOMME/MIDNIGHT ZEPHYR EVENT

5.1 EVENT SUMMARY.

TOMME/MIDNIGHT ZEPHYR was a DoD-sponsored testbed development event conducted at 0800 hours PDT on 21 September 1983. The LLNL-sponsored TOMME test, with the DNA add-on experiment, MIDNIGHT ZEPHYR, had a yield of less than 20 kilotons. The TOMME/MIDNIGHT ZEPHYR device was detonated in the U12n.18 drift of the N tunnel complex at a vertical depth of 1,325 feet (Figure 5-1). The purpose of the event was to evaluate the stemming and containment design of a low-yield testbed, using a shorter-than-normal HLOS pipe. This testbed design concept could reduce tunnel test costs and provide greater flexibility in conducting experiments.

The TOMME/MIDNIGHT ZEPHYR event was satisfactorily contained. However, some radioactive gases seeped into the tunnel, but radioactivity decayed to background levels before tunnel ventilation began. There was no radioactive effluent release from this event.

5.2 PREEVENT ACTIVITIES.

5.2.1 Responsibilities.

Safe conduct of all TOMME/MIDNIGHT ZEPHYR project activities in Area 12 was the responsibility of the DNA Test Group Director (TGD), subject to controls and procedures established by the DOE Test Controller. The DOE Test Controller was responsible for safety of the public and onsite personnel during the test.

Project agencies were responsible for designing, preparing, and installing experiments, or delivering them to the installation contractor. After the event, these agencies were responsible for removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

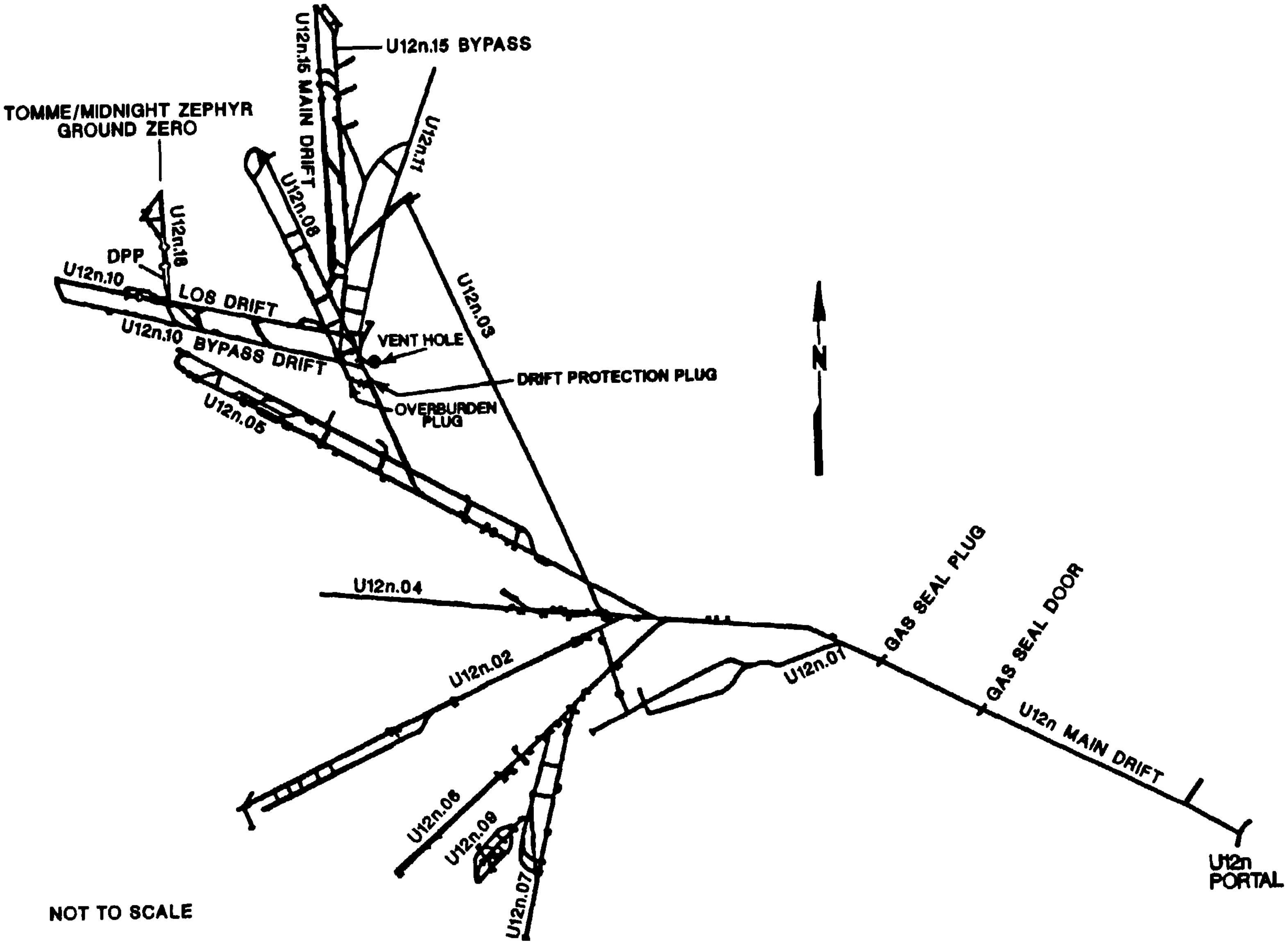

Figure 5-1. TOMME/MIDNIGHT ZEPHYR event - tunnel layout.

Device safety and security procedures in the working point (WP) area and the timing and firing control room were in accordance with DOE Order 5610.3, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." The LLNL TGD had overall responsibilities for radiological safety within the designated area of the WP from device emplacement until detonation in accordance with provisions of Chapter 0524, NTS-SOP. After detonation, the DOE Test Controller relieved the LLNL TGD of the responsibility and returned it to the DNA TGD.

5.2.2 Planning and Preparations.

A. Tunnel Facilities Construction.

The U12n.18 complex was mined from the U12n.10 main drift and used previously-constructed or rebuilt tunnel containment plugs; instrumentation, recording, and experiment alcoves. The complex included: (1) an access for a keyway for a late-time installation of a Drift Protection Plug (DPP); (2) vacuum and cable gas block alcoves; (3) access to the TOMME Drift; (4) the TOMME Drift; (5) the MIDNIGHT ZEPHYR Drift; and (6) the drift for Sandia National Laboratories (SNL) side pipe as seen in Figure 5-2.

The TOMME and MIDNIGHT ZEPHYR drifts each had an air void existing around the working point (WP) to approximately four feet from the device where stemming began. The TOMME drift, which contained five additional air voids, was stemmed first with rock-matching grout to approximately 67 feet; then with superlean grout to 95 feet, and finally with high-strength grout to the end of stemming. The MIDNIGHT ZEPHYR drift was stemmed with rock-matching grout and superlean grout. Figure 5-3 shows the invert at the MIDNIGHT ZEPHYR end of stemming facing in the direction of ground zero.

A high-strength grout plug (keyed into the drift) was placed where the MIDNIGHT ZEPHYR stemming joined the access drift high-strength grout. A Facility Drift Protection Plug (FDPP), located in the U12n.18 drift, provided additional containment protection for this area of the tunnel complex. The TOMME/MIDNIGHT ZEPHYR event also

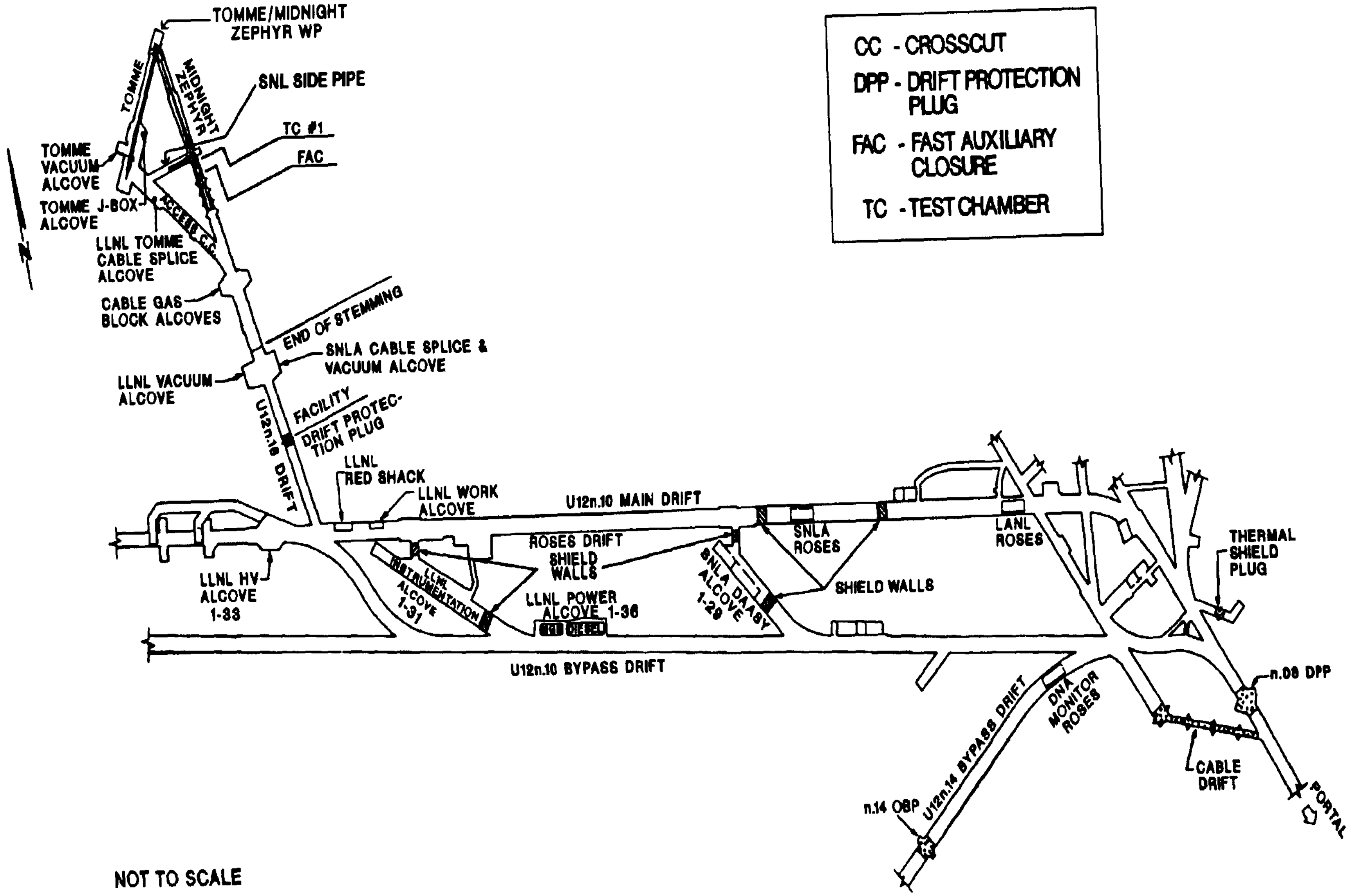

Figure 5-2. TOMME/MIDNIGHT ZEPHYR event - tunnel and pipe layout.

Figure 5-3. TOMME/MIDNIGHT ZEPHYR event - end of stemming looking toward MIDNIGHT ZEPHYR ground zero.

utilized six previously-constructed containment plugs (i.e., the U12n.08 Cable Drift Plug, the Thermal Shield Plug (TSP), the structures drift Cable Downhole Plug, the U12n.03 plug, the U12n.14 plug, and the U12n.08 DPP) which were reconstructed, in some instances, after the MINI JADE event was executed. The Gas Seal Plug (GSP) and the Gas Seal Door (GSD), in the main access drift, provided additional protection. Following the MINI JADE event, the grout inside the GSP trainway was removed. The grout was replaced prior to execution of the TOMME/MIDNIGHT ZEPHYR event.

In January 1983, when a decision was made to move the TOMME/MIDNIGHT ZEPHYR event from U12t tunnel to U12n tunnel complex to avoid scheduling problems with the upcoming MIDAS MYTH/MILAGRO event, mining of the U12n.18 drift began. By the end of February, alcoves for vacuum pumps and cable block alcoves were mined, and hardened HLOS pipe sections were fabricated. Installation of HLOS pipe sections began in March, along with successful testing and installation of support instrumentation.

The TOMME/MIDNIGHT ZEPHYR event complex design included the TOMME drift, an access and experiment drift, and the HLOS pipe with six vacuum systems. The MIDNIGHT ZEPHYR portion contained an experiment drift that supported the HLOS pipe system. Portions of the U12n.10 drift were allocated for experimenter-support equipment.

In May when MINI JADE was executed, it was immediately apparent that some radioactive gases had seeped into the TOMME/MIDNIGHT ZEPHYR section of the tunnel complex. Cleanup measures, such as painting and spraying sealant to reduce particulate resuspension, were implemented. Personnel working in the area donned anticontamination clothing (antiCs) and wore self-contained breathing masks during sealing and decontamination activities. Fixing of contaminant was not completely successful, consequently, construction of TOMME/MIDNIGHT ZEPHER was completed with all personnel wearing antiCs.

By the end of August, the HLOS pipes were installed; the Fast Auxiliary Closure (FAC), had been tested and installed in the closed position; experimenter data transmission cables and timing and firing cables were in place; vacuum and timing and firing systems were tested and certified operational; and signal dry runs were held on a daily basis throughout the month.

On 30 August the initial joint mandatory, full-participation/full-power, full-frequency (MFP/FPFF) dry run was conducted. Follow-up dry runs were performed after several adjustments were made, and the system was declared satisfactory on 31 August. Signal dry runs continued on a daily basis in September with the final dry run (FDR) being held on 20 September. By 1800 hours on 20 September button-up activities had begun.

Additional facilities incorporated during construction were remote gas sampling capabilities as well as water, power, drain, and pressurization lines. Provisions to manually take gas samples from the WP side of the GSD, GSP, and the DPP were made during postevent reentry.

Organizations conducting experiments for this event were: Sandia National Laboratories (SNL), conducted low-yield testbed studies (i.e., the DNA add-on experiment, MIDNIGHT ZEPHYR) and containment-related measurements; General Research Corporation (GRC), conducted Test Instrumentation Development (TID) stress measurement studies; and LANL, conducted a continuous reflectometry for radius time experiment (CORRTEX) to measure the position of in-ground shock waves as a function of time.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during this event were in accordance with DOE Manual Chapter 0524 and requirements of responsible DoD representatives. Radsafe provided monitoring and equipment support.

Prior to the test, detailed radiological safety reentry plans were prepared and issued to participating agencies. Air sampling equipment was positioned in the test area. Radsafe monitors were briefed regarding surface reentry, manned stations, and security station requirements.

Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in reentry parties as needed. Radsafe personnel were also standing by at Gate 300 prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment and material, portable instruments, and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination, as required.

Available anticontamination materials and equipment included head covers, coveralls, cloth shoe covers, totes, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves, and masking tape.

C. <u>Telemetry and Air Sampling Support</u>.

In addition to the 39 permanent RAMS units, 36 temporary units provided surface and underground coverage for TOMME/MIDNIGHT ZEPHYR. Table 5-1 and Table 5-2 list the locations of surface and underground RAMS, respectively. The location of both surface and underground RAMS units are shown in Figure 5-4 and Figure 5-5, respectively. Figure 5-6 shows RAMS unit detailed locations in the U12n.18 complex. All RAMS units were installed a minimum of five days prior to scheduled device detonation.

EPA operated continuous monitoring stations at 29 locations in the offsite area. All the stations had high-volume air samplers with collectors for particulates and reactive gases, 16 had tritium and noble gas samplers, and 21 had pressurized ion chamber gamma-rate detector/recorder systems in operation. Twenty-eight EPA personnel were fielded for offsite surveillance activities.

Table 5-1. TOMME/MIDNIGHT ZEPHYR event RAMS unit locations 21 September 1983.

SURFACE

STATION NUMBER	LOCATION
From the U12n Portal unless otherwise indicated:	
1	On the drain line
2	400 feet N 16° E azimuth
3	275 feet N 89° E azimuth
4	365 feet S 16° E azimuth
5	480 feet S 12° W azimuth
6	560 feet S 48° W azimuth
7	420 feet N 69° W azimuth
8	1,370 feet S 43° E azimuth
9	In the cable rise building
10	On the vent hole
From the U12n.18 SGZ:	
11	354 feet N 00° E azimuth
12	367 feet S 60° E azimuth
13	325 feet S 60° W azimuth

Table 5-2. TOMME/MIDNIGHT ZEPHYR event RAMS unit locations 21 September 1983.

UNDERGROUND

STATION NUMBER	LOCATION
From the U12n.18 main drift:	
14	130 feet into the U12n.18 main drift
15	40 feet into the U12n.18 main drift
From the U12n.08 main drift unless otherwise indicated:	
16	850 feet into the U12n.10 main drift
17	400 feet into the U12n.10 main drift
18	185 feet into the U12n.10 main drift
19	Alcove I-31 in the U12n.10 main drift
20	Alcove I-31 in the U12n.10 main drift
21	Alcove I-31 in the U12n.10 main drift
22	Alcove I-31 in the U12n.10 main drift
23	Alcove I-29 in the U12n.10 bypass drift
From the U12n.08 bypass drift unless otherwise indicated:	
24	500 feet into the U12n.10 bypass drift
25	250 feet into the U12n.10 bypass drift
26	85 feet into the U12n.08 S-curve of the bypass
27ER[13]	85 feet into the U12n.08 S-curve of the bypass
28	435 feet into U12n.08 main drift from U12n.05 drift
From the U12n main drift:	
29	600 feet into the U12n.05 main drift
From the U12n portal unless otherwise indicated:	
30	2,600 feet into the U12n main drift
31	235 feet into the U12n gas seal plug bypass drift
32ER[13]	235 feet into the U12n gas seal plug bypass drift
33	1,700 feet into the U12n main drift
34	1,200 feet into the U12n main drift
35	50 feet into the ventline rise from U12n main drift
36	200 feet into the U12n main drift

[13] ER - Extended Range (instrument capable of reading 100 mR/h to 100,000 R/h).

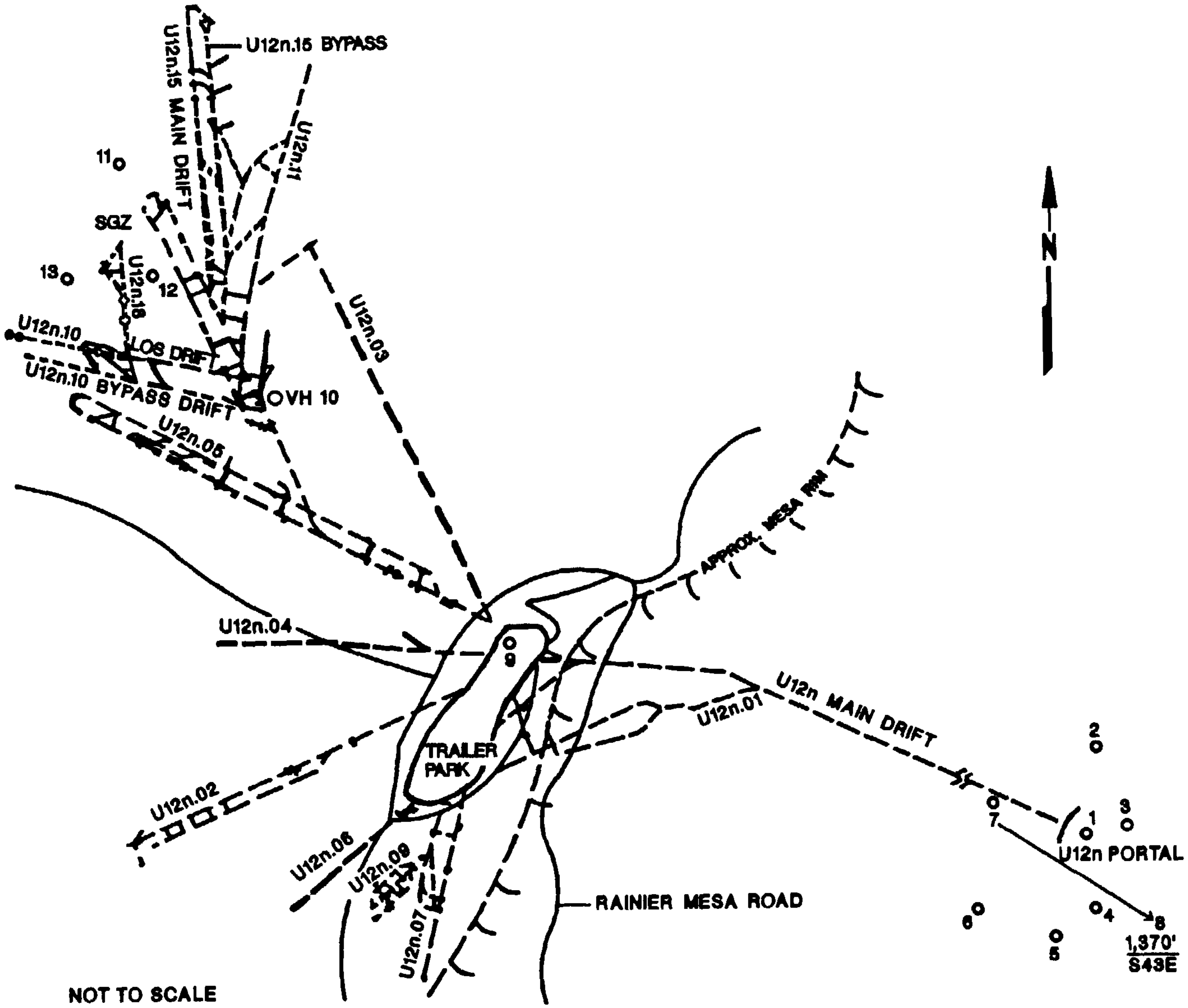

Figure 5-4. TOMME/MIDNIGHT ZEPHYR event - surface RAMS.

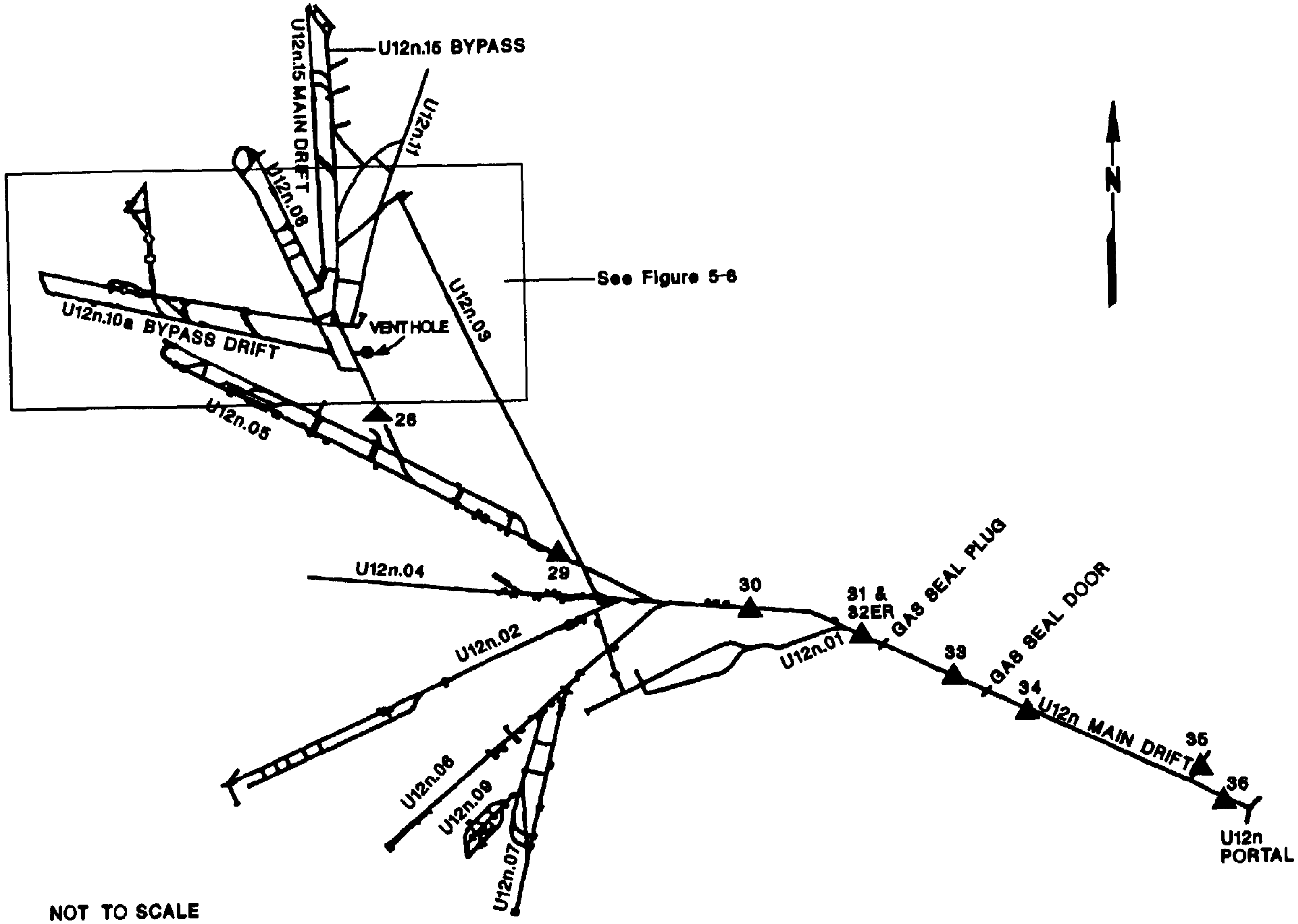

Figure 5-5. TOMME/MIDNIGHT ZEPHYR event - underground RAMS.

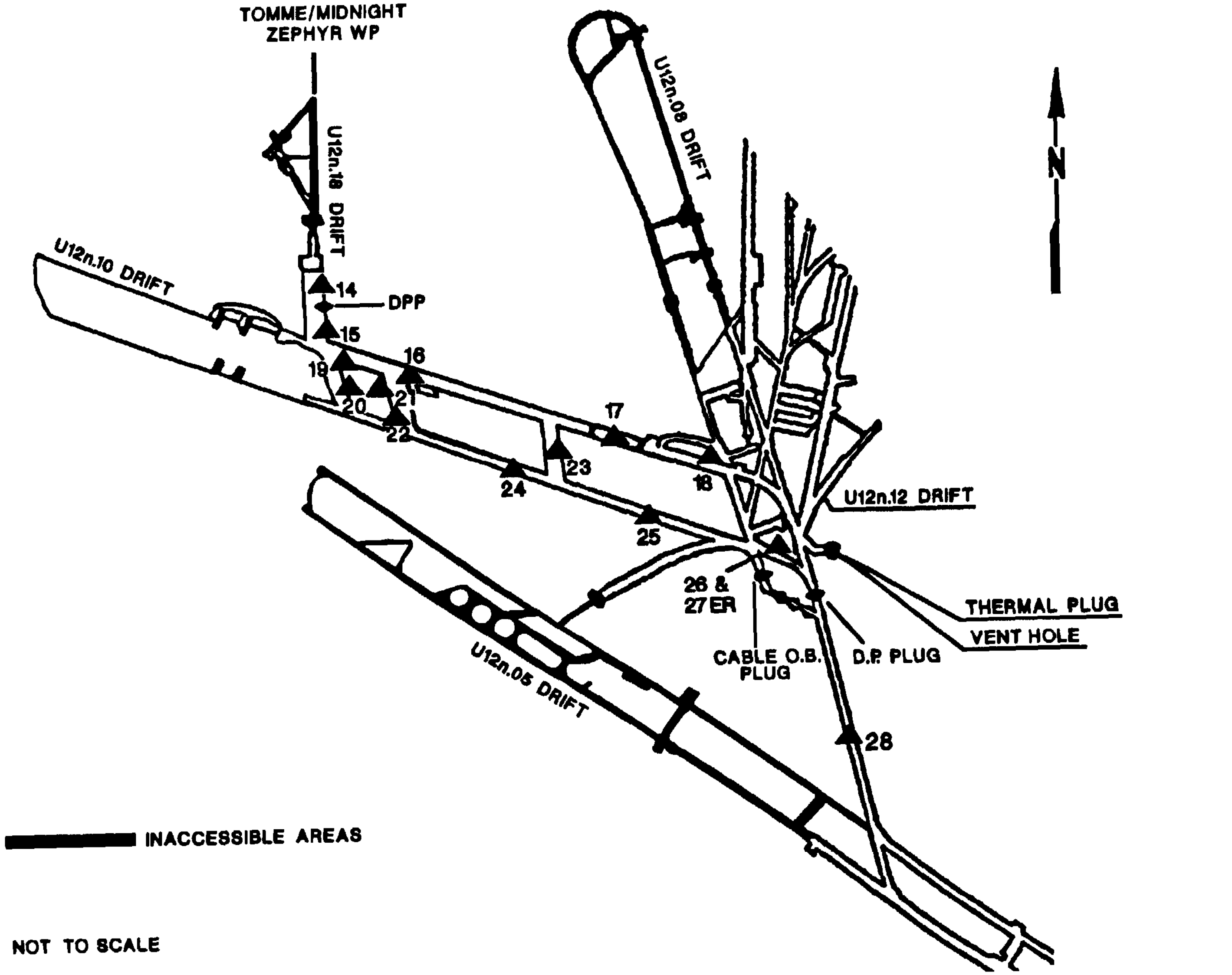

Figure 5-6. TOMME/MIDNIGHT ZEPHYR event - underground RAMS, U12n.18 complex.

D. Security Coverage.

Device security procedures in the WP and in the timing and firing control room were in accordance with DOE Order 5610.3, and DOE Order 5610.3-26, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." Beginning on D-1, all personnel entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges. After control was established, all through traffic was diverted around the controlled area by use of screening stations.

In accordance with the "Test Controller's Operations and Security Plans," contractors and agencies were to have all personnel not connected with this event out of the closed area before the final security sweep began.

E. Air Support.

Three UH1N helicopters and crews were provided by the USAF for cloud tracking and the Test Controller's use, if needed. In addition, the USAF provided a C-130/C-135 and crew on standby status for cloud tracking. EG&G provided one Turbo Beech and one Twin Bonanza aircraft and crews for tracking duties, if necessary.

5.3 EVENT-DAY ACTIVITIES.

5.3.1 Preshot Activities.

By 20 September 1983 at 2400 hours, all persons except the arming party, the tunnel button-up party, the mesa button-up crew, and the security guards were out of the tunnel and clear of the muster area. At 0330 hours on 21 September permission was granted to arm the device. By 0630 hours button-up operations were complete.

A readiness briefing was held at 0530 hours on 21 September 1983, in anticipation of the planned test execution at 0800 hours the same day. Conditions for the test were favorable and all personnel were mustered out of the area. The five-minute countdown began at 0755 hours and proceeded without interruption through zero time.

The TOMME/MIDNIGHT ZEPHYR device was detonated in the U12n.18 drift at 0800 hours PDT on 21 September 1983. SNL geophones indicated cavity collapse occurred between H+35 and H+36 minutes.

5.3.2 Test Area Monitoring.

Telemetry measurements began at 0800 hours on 21 September 1983. RAMS unit number 16 became inoperative immediately and remained so throughout the test period. All RAMS units, except numbers 14, 15, and 19 read background throughout the readout period and all units, except number 16, remained operational throughout the test and subsequent readout period.

RAMS unit number 14, located on the WP side of the DPP in the U12n.18 drift, indicated increased readings beginning at H+1 hour and 20 minutes and by H+6 hours the reading was 311 mR/h. Unit numbers 15 and 19 had maximum readings of 0.3 mR/h at H+8 hours and 0.2 mR/h at H+9 hours, respectively. Some seepage of radioactive gases into the U12n.18 drift was indicated by these increased readings. However, radioactive decay occurred before tunnel ventilation began, and no radioactive effluent was released from this event. All RAMS units were secured at 1000 hours on 23 September 1983, at that time, all units read background levels except for unit number 14, which read 1.5 mR/h.

5.3.3 Initial Surface Radiation Surveys and Recovery Activities.

Initial reentry teams departed from the Test Controller's barricade at Gate 300 at 1100 hours on 21 September 1983. A mobile base station was provided for area control and equipment supply. By 1137 hours, the initial survey teams in both the U12n portal area and Rainier Mesa cable rise building and ventilation pad had completed the initial surface survey. No radiation levels above normal area background were detected.

Survey teams, consisting of geologists, industrial hygienists, and radiation safety monitors, stood by at the N tunnel portal and on the mesa during data recovery and remote gas sampling of the tunnel. No toxic gases or explosive mixtures were detected in tunnel atmosphere gas samples. Data recovery and gas sampling were completed by 1430 hours. The mesa and portal areas were secured and all personnel had checked out of the event location by 1530 hours on 21 September 1983.

5.4 POSTEVENT ACTIVITIES.

5.4.1 Tunnel Reentry Activities.

Initial tunnel reentry operations began at 1047 hours on 22 September 1983 (D+1), when the reentry work team proceeded to the GSP. Ventilation at the GSP was established at 1123 hours by opening the 36-inch and 40-inch turntubes to the portal side of the DPP. No toxic gases or positive LEL levels were observed. No radiation levels above background (0.04 mR/h) were measured, and the oxygen level was a normal 21 percent. No respiratory protection was required.

The reentry, backup, and rescue teams proceeded through the GSP at 1158 hours, and the DPP manway door was opened at 1331 hours. Air samples taken from the WP side of the DPP in the 36-inch crawlway showed no indication of toxic gases, positive LEL, or above-background radiation levels. The backup reentry and rescue teams moved to the portal side of the DPP at 1345 hours while the primary reentry team proceeded through the U12n.08 drift to the TSP opening where readings showed background radiation levels. The reentry team then opened the downhole ventline valve and established ventilation to the vent pad on the mesa before proceeding to the portal side of the DPP. At 1410 hours, the ventilation fans on the mesa were turned on. No respiratory protection was required for this initial reentry.

At 1425 hours, the reentry team, now wearing self-contained breathing apparatus, proceeded to walk out the U12n.08 drift, the U12n.10 main drift, the 1-29 SNL alcove, the 1-36 LLNL power alcove, the 1-31 LLNL instrumentation alcove, the crosscut, and the LLNL Red Shack arriving at the FDPP at 1500 hours. There were no toxic gases or positive LEL levels detected. Radiation readings indicated background levels, but the oxygen level was below normal at 20 percent. Analysis of gas samples taken from the WP side of the FDPP indicated 1000 ppm carbon monoxide (CO) and 35 percent of the LEL. The radiation reading was 0.3 mR/h.

By 1536 hours, the reentry team had removed their self-contained breathing apparatus and continued to take smear samples on instrumentation in various user alcoves and on equipment in both the U12n.10 main and bypass drifts. By 1639 hours, the team had returned to the portal side of the DPP. Laboratory analysis of the smear samples taken showed no radioactivity above background levels.

At 1720 hours the Data Recovery teams entered the tunnel. Data recovery was completed by 1900 hours.

5.4.2 Postevent Mining.

Work began on mining out the GSP at 1900 hours on 22 September and was completed at 0815 hours on 23 September. By 27 September, miners had cut out the 26-inch turntube at the U12n.08 DPP and had begun work in the crosscuts to the user alcoves. Readings indicated no radioactivity levels above background and no toxic gases or positive LEL levels. By 2100 hours on 28 September miners were hand mucking and spading at the FDPP (U12n.18). Swipes taken at the FDPP indicated no radiation levels above background.

On 4 October at 1030 hours miners and users were wearing self-contained breathing apparatus when ventilation was established at the FDPP. Readings taken with a portable survey instrument showed radiation levels were at background levels inside the crawltube. Air sample data showed 100 ppm CO, 25 percent of the LEL, and 17.5 percent oxygen. Mining continued in the U12n.10 drift, the crosscuts, and at the U12n.18 FDPP. The turntube was removed at the FDPP on 14 October. By 8 November, the miners had reached the stemming bulkhead, several rounds were fired, and by 1330 hours on 9 November, the bulkhead was breached. A gas sampler was attached to the preexisting sampling line in the bulkhead at the end of the stemming. Readings showed no toxic gases, no positive LEL, and a normal 21 percent oxygen. No radiation above background levels was detected. Mining and cleanup continued in the U12n.18 drift. By 18 January 1984, miners, wearing supplied air breathing apparatus, had cut into the MIDNIGHT ZEPHYR LOS pipe, connected air and water lines, and began hand bailing water and slush from the LOS pipe into barrels. Radiation readings were 0.5 mR/h from the water barrel and 8 mR/h from the bottom of the slush barrel. The next day Radsafe and industrial hygiene personnel entered and surveyed the LOS pipe and took bagged samples. Maximum readings showed 100 ppm CO and 50 percent of the LEL at the top of the FAC. The radiation level measured 1.5 mR/h. On 23 January 1984, DNA personnel and Pan Am photographers, dressed in double anticontamination clothing and full-face respirators, entered the LOS pipe to check the FAC and photograph the area, respectively. Probe drill hole core samples, taken in both the TOMME and MIDNIGHT ZEPHYR drifts during February, showed radiation levels below 0.2 mR/h. Mining continued on the WP side of the FAC and in the TOMME LOS drift. By mid-March all mining activities, including equipment removal and debris cleanup, had been completed.

5.4.3 Postevent Drilling.

Control of the postevent drilling area was established on the mesa with a base station and appropriate barricades at 1320 hours on 22 September 1983. Drilling began at 0840 hours on 23 September 1983, on the first of three drill holes. Postshot (PS) hole No. 1A was drilled to over 1,500 feet. Core sampling began at 1747 hours on 24 September and was completed at 2107 hours that same day. Sixteen core samples were taken with the maximum gamma intensity being 30 R/h. The maximum reading on the platform recorder was 3.0 mR/h when removing the rotating head. When this operation was completed, the exposure rate returned to background levels within three minutes. Core sampling on PS hole No. 1AA began at 1325 hours on 25 September at a depth of 1,532 feet and was completed at 1607 hours that same day. A total of nine samples were taken with the maximum gamma intensity being 20 R/h. The third hole, PS hole No. 1AAB, was sampled on 26 September beginning at 0105 hours. The work was completed at 0245 hours the same day. Core sampling depth was over 1,500 feet. Eight samples were taken with a maximum gamma intensity being 15 R/h. The abandonment valve was closed at 0700 hours on 26 September. Shutdown and cleanup continued with equipment being moved to the Decontamination Pad. This operation was completed, and all personnel were out of the area by 0535 hours on 27 September

1983. Cementback operations were not completed until September 1985.

One exploratory hole was drilled from tunnel level to obtain core samples. Drilling on reentry (RE) hole No. 1 in 1-33 alcove off the U12n.10 main drift began on 12 October. This 350-foot hole was drilled toward the back corner of the instrumentation void of the TOMME LOS drift (Figure 5-2). Drilling was completed on 8 November. Air sampling analysis throughout this time showed no toxic gases and no positive LEL. Radiation readings taken on numerous core samples were at background levels.

5.4.4 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were then recorded in the monitors' logbook.

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. Industrial safety codes for mining, tunneling, and drilling, were established by REECo and emphasized during all operations. A written standard operating procedure was required for each operation involving explosives, toxic materials, radioactive material, or any other operation with the potential for personal injury. Each individual involved in such an operation was required to know the contents of the applicable procedures.

The portal construction area and the tunnel were mandatory hard hat and foot protection areas (safety shoes, boots, DOE-issued miner's boots, or toe guards). All personnel on initial tunnel reentry teams were certified in the use of the Draeger self-contained breathing apparatus and had used the McCaa two-hour breathing apparatus. Standard safety rules and regulations, as spelled out in the "U.S. Bureau of Mines Manual," were observed.

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials were handled, stored, and transported in accordance with applicable sections of the following documents:

1. Army Material Command Regulations (AMCR 385-100).
2. Appropriate DOE Orders in the 5400 and 5600 Series concerning Environmental Protection, Safety & Health Protection, and Defense Programs respectively.
3. Individual safe operating procedures (by experimenter organization).
4. TOMME/MIDNIGHT ZEPHYR Safety Regulations.

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DoD safety coordinator.

5.5 RESULTS AND CONCLUSIONS.

Telemetry measurements began at 0800 hours on 21 September 1983, with the maximum reading of 311 mR/h detected on RAMS unit number 14 at H+6 hours. All telemetry stations were secured at 1000 hours on 23 September with only unit number 14 reading above background.

The initial radiation surveys were completed by 1137 hours on 21 September. No radiation above background was detected at the Rainier Mesa cable rise building and ventilation pad or at the tunnel portal area.

Reentry into the tunnel began at 1047 hours on 22 September. The reentry team, wearing self-contained breathing apparatus, recorded a maximum reading of 0.3 mR/h on a gas sample taken from the WP side of the FDPP. Analysis showed 35 percent of the LEL and 1000 ppm CO. Initial reentry and data recovery was completed by 1900 hours that same day.

Postevent mining and sampling began on 22 September and was completed by mid-March. The maximum radiation level recorded was 8 mR/h from the slush from the MIDNIGHT ZEPHYR LOS pipe. Toxic gas levels of 100 ppm CO and 50 percent of the LEL were encountered by personnel surveying in the MIDNIGHT ZEPHYR LOS pipe at the top of the FAC.

Three postshot holes were drilled from the mesa beginning on 22 September. Thirty-three core samples were taken with the maximum gamma intensity being 30 R/h. This operation was completed on 27 September. One 350-foot reentry exploratory hole was drilled from the 1-33 alcove off the U12n.10 main drift toward the back corner of the instrumentation void of the TOMME LOS drift. Work began on 12 October and was completed on 8 November. Radiation readings on core samples taken were at background levels.

Personnel exposure data from self-reading pocket dosimeters were documented on Area Access Registers during individual entries to TOMME/MIDNIGHT ZEPHYR radex areas over a non-continuous time frame from July through September 1983. Although pocket dosimeters showed some indication of possible radiation exposure, film badges worn by reentry personnel indicated no evidence of any gamma exposures The minimum detectable gamma exposure with the NTS film badge dosimeter was 30 mR. Area Access Register data are summarized below.

Participants	Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All	6,338	11.0	0.0
DoD	125	0.0	0.0

SECTION 6

MIDAS MYTH/MILAGRO EVENT

6.1 EVENT SUMMARY.

MIDAS MYTH/MILAGRO was a DoD-sponsored nuclear weapons-effects test conducted at 0900 hours PST on 15 February 1984. The test had a yield of less than 20 kilotons. The MIDAS MYTH/MILAGRO device was detonated in U12t.04 drift of T tunnel complex, at a vertical depth of 1,184 feet below the mesa surface and 4,749 feet from T tunnel's portal (Figure 6-1). The purpose of the MIDAS MYTH event was to test the survivability of military hardware in a nuclear-detonation environment. MILAGRO was the LANL front-end physics experiments, sponsored by DOE. The purpose of the MILAGRO test was to evaluate device performance, radiation output, and containment-measurement techniques.

MIDAS MYTH/MILAGRO was satisfactorily contained, and no atmospheric release occurred. Low concentrations of fission gases were recorded in the tunnel complex by RAMS and remote gas sampling, but radioactivity levels had decayed to background by the time of manned reentry. Data was recovered from the portal recording station (PRS) and the LANL recording trailer on the mesa. Data recovery operations were interrupted at H+3.25 hours by an unexpected surface subsidence at the U12t Milagro trailer park that occurred when the cavity collapsed. The zero time ground shock was higher than expected, causing severe damage to the tunnel, experiments, instrumentation, and facilities. In spite of this, data recovery from the PRS was accomplished by 1900 hours on 15 February 1984.

6.2 PREEVENT ACTIVITIES.

6.2.1 Responsibilities.

Safe conduct of all MIDAS MYTH/MILAGRO project activities in Area 12 was the responsibility of the DNA Test Group Director (TGD),

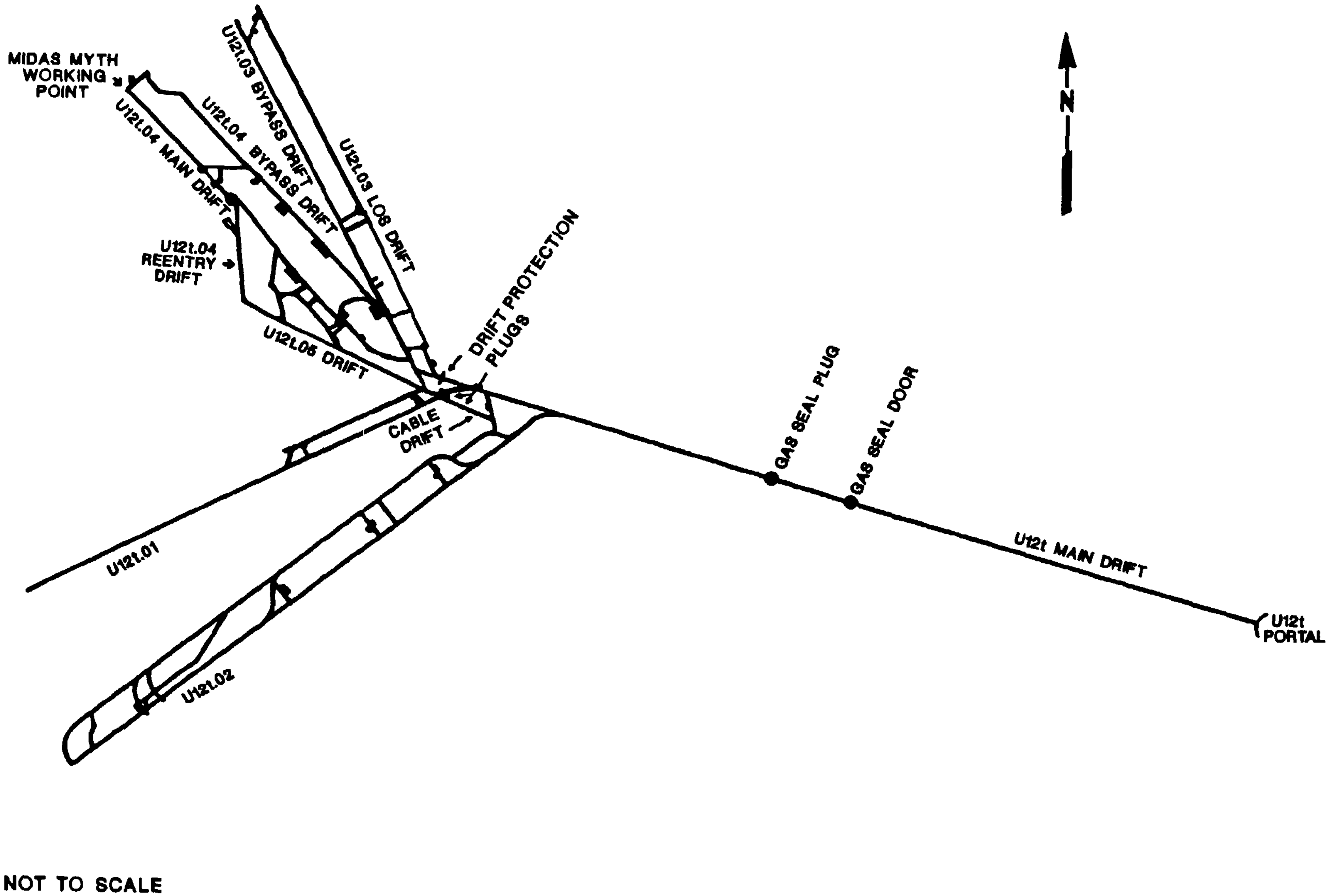

Figure 6-1. MIDAS MYTH/MILAGRO event - tunnel layout.

subject to controls and procedures established by the DOE Test Controller. The DOE Test Controller was responsible for the safety of the public and onsite personnel during the test.

Project agencies were responsible for designing, preparing, and installing experiments, or delivering them to the installation contractor. After the event, these agencies were responsible for removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

Device safety and security procedures in the working point (WP) area and the timing and firing control room were in accordance with DOE Order 5610.3, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." The LANL TGD had overall responsibilities for all operations involving the MIDAS MYTH/MILAGRO device. LANL was also responsible to the DOE Test Controller for radiological safety within the designated area of the WP from device emplacement until detonation. After detonation, the DOE Test Controller relieved LANL of their responsibilities. The DOE Test Controller authorized reentry operations to begin and issued the responsibility for project activities back to the DNA TGD.

6.2.2 Planning and Preparations.

A. Tunnel Facilities Construction.

Some mechanical hardware and system components, including the Cable Drift Protection Plug (CDPP) and the Device Protection Barrier were reused from the HUSKY PUP event. The U12t.04 complex consisted of one LOS drift, a bypass drift, a muffler, two auxiliary closures, the tunnel and pipe seal (TAPS), one zero room, three test chambers, four diagnostic pipes, and a vacuum pumping and monitoring station. The LOS pipe diverged from a diameter of eight inches close to the device to 156 inches at the back of test chamber (TC) No. 1.

Remote gas sampling capabilities were incorporated during construction as well as water, power, drain, and pressurization lines. Provisions to manually take gas samples from the WP side of the Gas Seal Door (GSD) and the DPP were made during postevent reentry.

Construction activities began in May 1982 with mining of the MIDAS MYTH drift. Mining of the U12t.04 bypass drift began June 1982 and was completed in November. Mining of the LOS drift to the MIDAS MYTH/MILAGRO working point (WP) was completed in December 1982 when cable installation began and concrete pours for the Modified Auxiliary Closure (MAC), Gas Seal Auxiliary Closure (GSAC) and TAPS inverts were completed. Installation of the LOS pipe began in February 1983 and was completed in August 1983 (Figure 6-2). In November 1983, the MILAGRO area was completely grouted and the LANL Recorder and Oscilloscope Sealed Environmental System (ROSES) was installed in the U12t.04 bypass drift. In December, the installation of fiber optic cables was completed.

The stemming plan for the U12t.04 complex is shown in Figure 6-3. Stemming operations began in July 1983. Rock-matching grout, superlean grout and high-strength groutcrete were pumped into all void areas from the MIDAS MYTH/MILAGRO WP to a distance of 550 feet. The drift was backfilled first with rock-matching grout to 156 feet, then with superlean grout to 295 feet, and finally with high-strength groutcrete to 550 feet. The U12t.04 bypass drift was also stemmed in the same manner from the MIDAS MYTH WP to a distance of 500 feet. All penetrations into the stemmed areas of the drifts (e.g., cables and water lines) were gas blocked to prevent the seepage of radioactive gases outside the stemmed region of the drifts.

Experiment and related hardware installation began in September 1983 and was completed by January 1984. The experimenter organizations included: Los Alamos National Laboratory (LANL), conducted a series of experiments referred to as MILAGRO (front-end diagnostic experiments which included device diagnostics, weapon physics, and hydrodynamic measurements); Science Applications International (SAI), conducted an energy-coupling experiment;

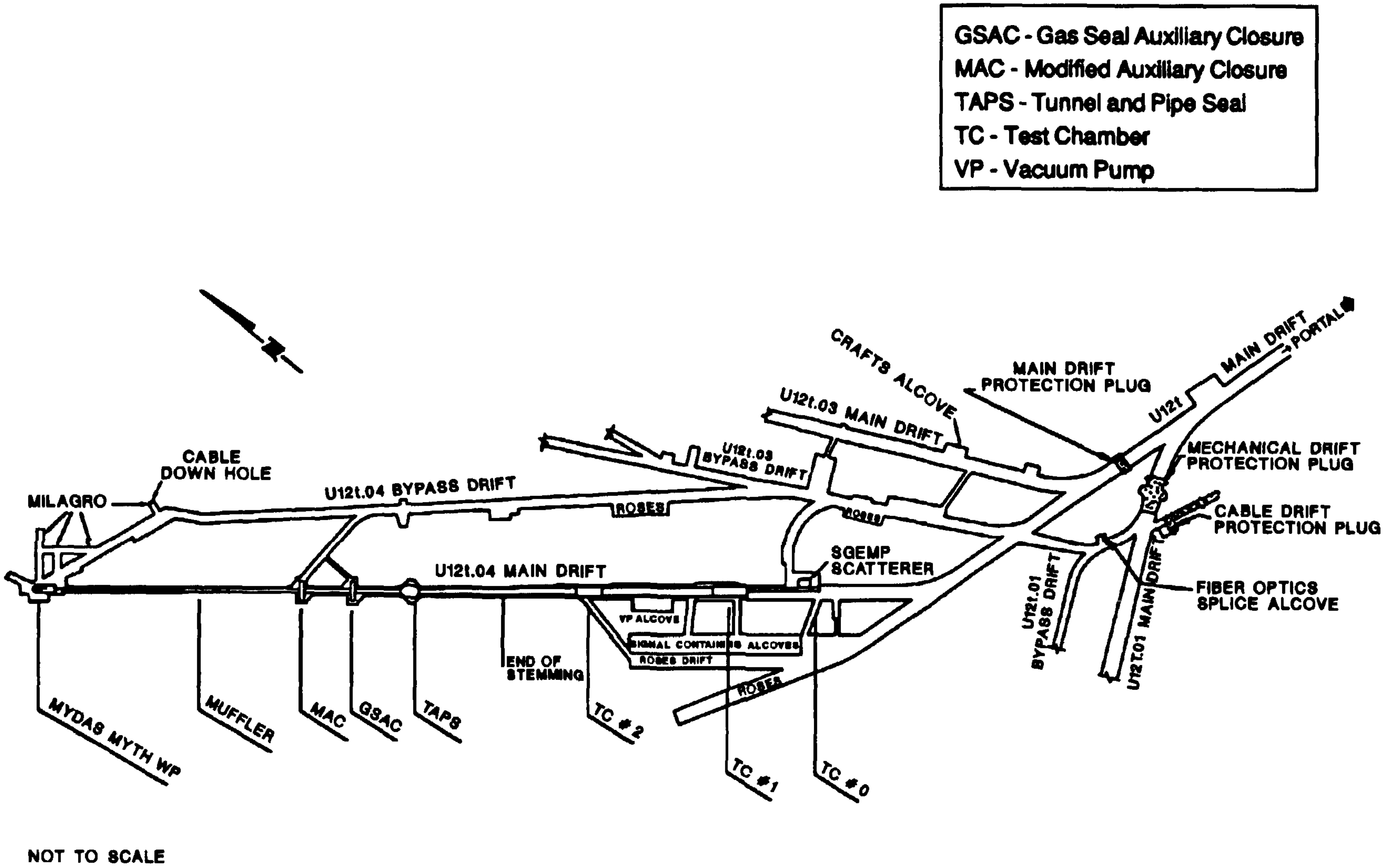

Figure 6-2. MIDAS MYTH/MILAGRO event - tunnel and pipe layout.

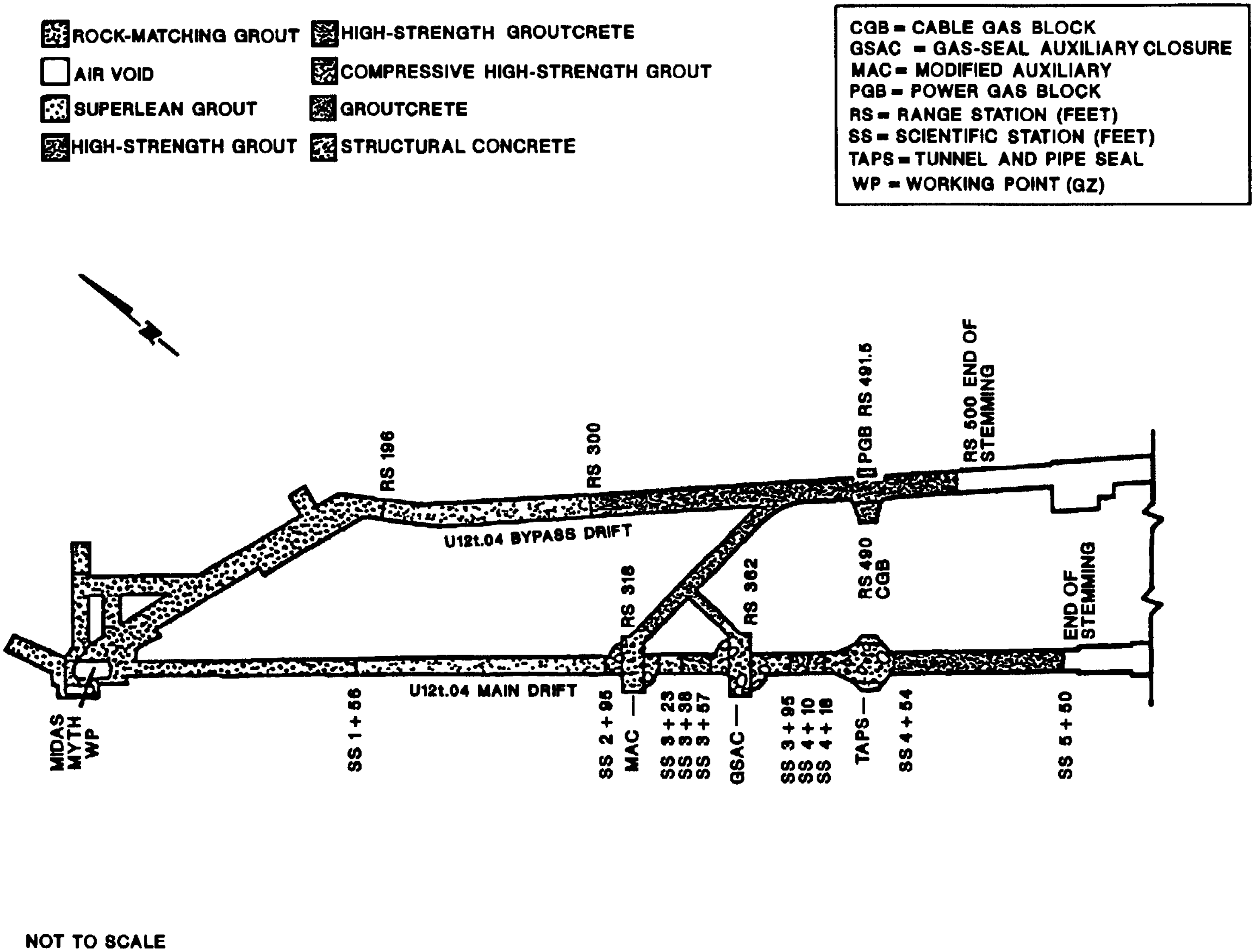

Figure 6-3. MIDAS MYTH/MILAGRO event - stemming plan.

Sandia National Laboratories (SNL) and Lockheed Palo Alto Research Laboratory (LPARL), performed device radiation output measurement experiments (Figure 6-4). The Defense Nuclear Agency (DNA) supported the following experiments: JAYCOR, conducted an air-modified source-generated electromagnetic pulse (SGEMP) experiment to verify analysis methods for SGEMP calculations (Figure 6-5); APTEK, fielded a prototype gauge and conducted an experiment on impulse coupling; General Electric (GE), conducted an Advanced Antenna Window Correlation experiment; McDonnel Douglas Astronautics Corporation (MDAC), conducted a shielding compatibility experiment; General Research Corporation (GRC), conducted experiments on space components and instrumentation verification; and TRW Systems, conducted experiments on solar cells.

Signal dry run participation began in January 1984. A successful mandatory full-participation dry run (MFP) was conducted on 31 January after which final device preparation and final stemming commenced. A final dry run was successfully conducted on 14 February 1984, and preparations were made to execute the test on the following day. At 0130 hours on 15 February 1984, final arming took place after which button-up activities began.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during these events were in accordance with DOE Manual Chapter 0524 and requirements of responsible DoD representatives. Radsafe monitors were briefed regarding surface reentry, manned stations, and security station requirements. Radsafe monitoring teams and supervisory personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in reentry parties as needed. Radsafe personnel were also standing by at Gate 300 prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment and material, portal instruments, and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination, as required.

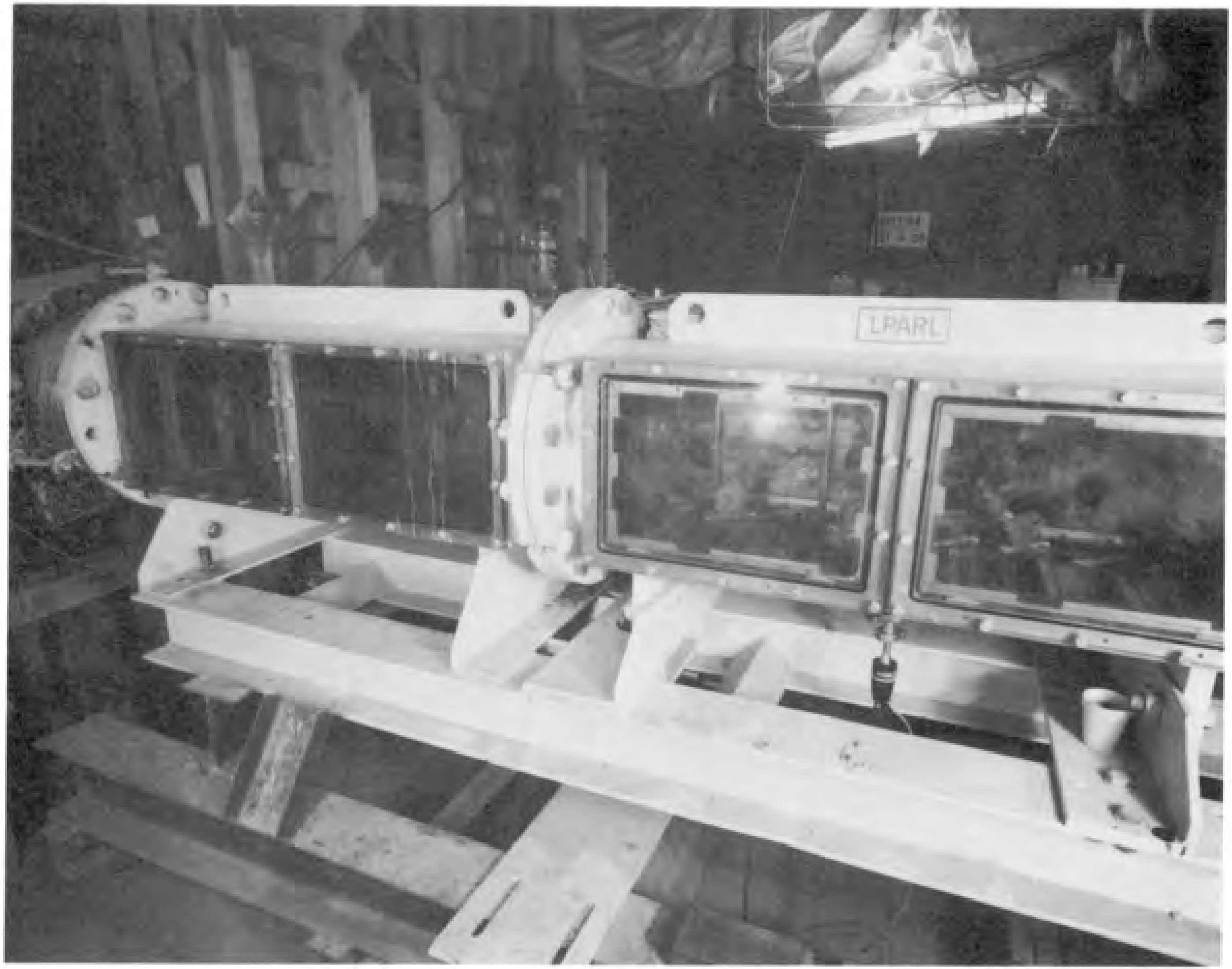

Figure 6-4. MIDAS MYTH/MILAGRO event - LPARL radiation output measurement experiment.

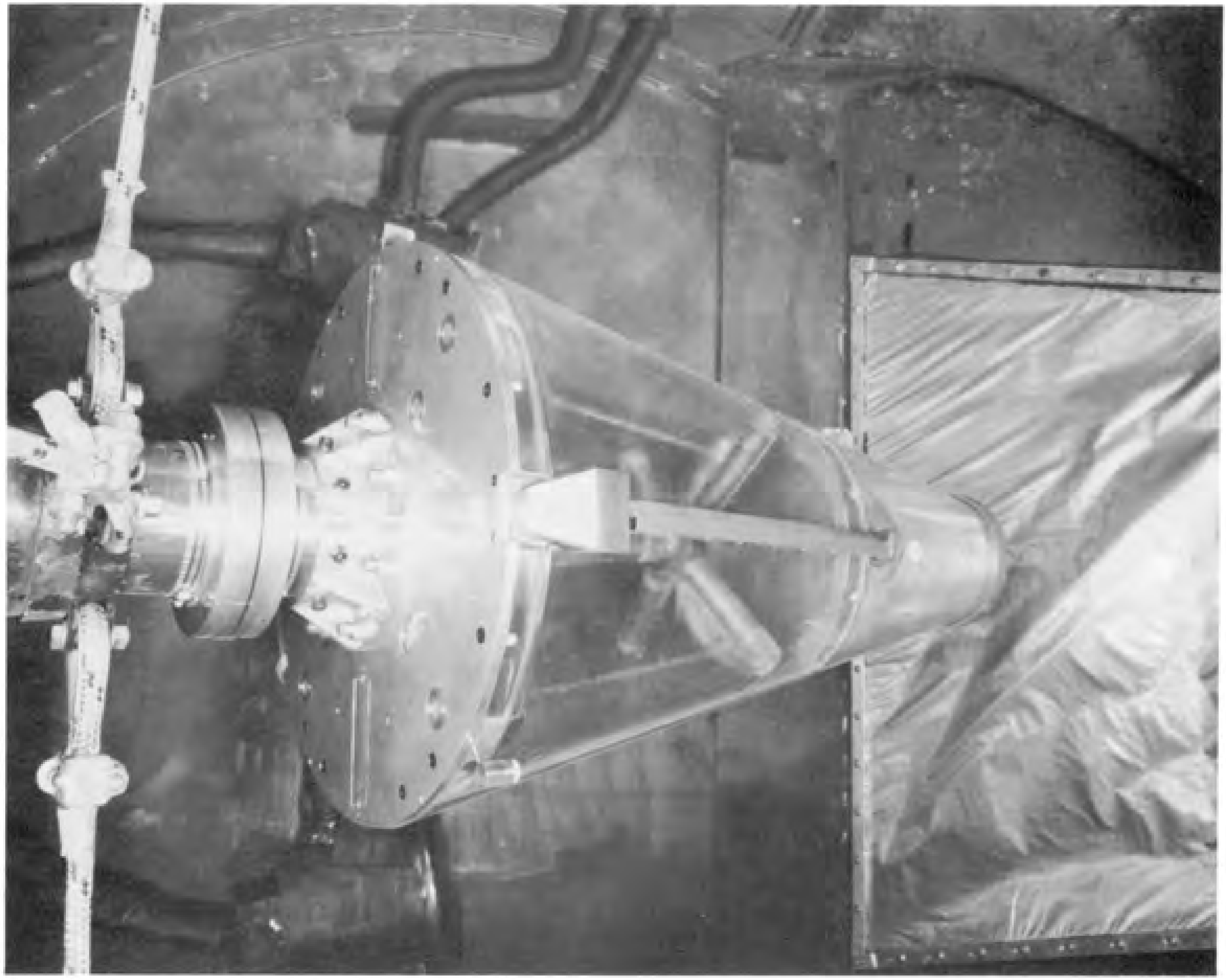

Figure 6-5. MIDAS MYTH/MILAGRO event - JAYCOR SGEMP experiment.

Available anticontamination materials and equipment included head covers, coveralls, cloth shoe covers, totes, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves, and masking tape.

C. Telemetry and Air Sampling Support.

In addition to the 40 permanent RAMS units, 38 temporary units provided surface and underground coverage for MIDAS MYTH/MILAGRO. Table 6-1 and Table 6-2 list the locations of surface and underground RAMS, respectively. The location of both surface and underground RAMS units are shown in Figure 6-6 and Figure 6-7, respectively. The U12t.04 complex RAMS unit locations are shown in Figure 6-8. All RAMS units were installed a minimum of five days prior to scheduled device detonation.

EPA operated continuous monitoring stations at 29 locations in the offsite area. All the stations had high-volume air samplers with collectors for particulate and reactive gases, 16 had tritium and noble gas samplers, and 19 had pressurized ion chamber gamma-rate detector/recorder systems in operation. Thirty-one EPA personnel were fielded for surveillance activities.

D. Security Coverage.

Device security procedures in the WP area and the timing and firing control room were in accordance with DOE Order 5610.3, and DOE Order 5610.3-26, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." Beginning on D-1, all personnel entering or exiting the controlled area were required to stop at muster or control stations for issue of stay-in badges. After control was established, all through traffic was diverted around the controlled area by use of screening stations. In accordance with the "Test Controller's Operations and Security Plans," contractors and agencies were to have all personnel not connected with this event out of the closed area before the final security sweep began.

Table 6-1. MIDAS MYTH/MILAGRO event RAMS unit locations 15 February 1984.

SURFACE

STATION NUMBER	LOCATION
From the U12t portal unless otherwise indicated:	
1	At the portal
2	On the ventline, 224 Feet S 75° W azimuth
3	On the ventline, 224 feet S 75° W azimuth
4	333 feet N 09° W azimuth
5	344 feet N 68° E azimuth
6	289 feet S 76° E azimuth
7	389 feet S 09° E azimuth
8	323 feet S 43° W azimuth
9	564 feet N 74° W azimuth
10	653 feet S 81° E azimuth on the drain line
11	2,005 feet S 88°E azimuth
12	In the cable splice building
13	At MILAGRO cable hole
From the U12t.04 SGZ:	
14	314 feet N 00° E azimuth
15	502 feet S 60° E azimuth
16	591 feet S 65° W azimuth

Table 6-2. MIDAS MYTH/MILAGRO event RAMS unit locations 15 February 1984.

UNDERGROUND

STATION NUMBER	LOCATION
From the U12t.04 drift unless otherwise indicated:	
17	445 feet into the U12t.04 LOS drift
18	285 feet into the U12t.04 LOS drift
19	200 feet into the U12t.04 LOS drift
20	200 feet into the U12t.04 ballroom
21	25 feet into the U12t.04 TC-1 alcove
22	4,145 feet into the U12t.05 drift from the portal
From the U12t.03 bypass drift:	
23	310 feet into the U12t.04 bypass drift
24	194 feet into the U12t.04 bypass drift
From the U12t.05 main drift unless otherwise indicated:	
25	100 feet into the U12t.03 bypass drift
26	60 feet into the U12n.04 SGEMP CC from U12t.04
27	220 feet into the U12t.03 main drift
28	250 feet into the U12t.01 main drift
29	125 feet into the U12t cable access CC
30ER[14]	125 feet into the U12t cable access CC
31	150 feet into the U12t.07 main drift from U12t.02
From the U12n portal unless otherwise indicated:	
32	3,320 feet into the U12t main drift
33	2,800 feet into the U12t main drift
34	2,240 feet into the U12t main drift
35ER[14]	2,240 feet into the U12t main drift
36	1,800 feet into the U12t main drift
37	900 feet into the U12t main drift
38	100 feet into the U12t main drift

[14] ER - Extended Range (instrument capable of reading 100 mR/h to 100,000 R/h).

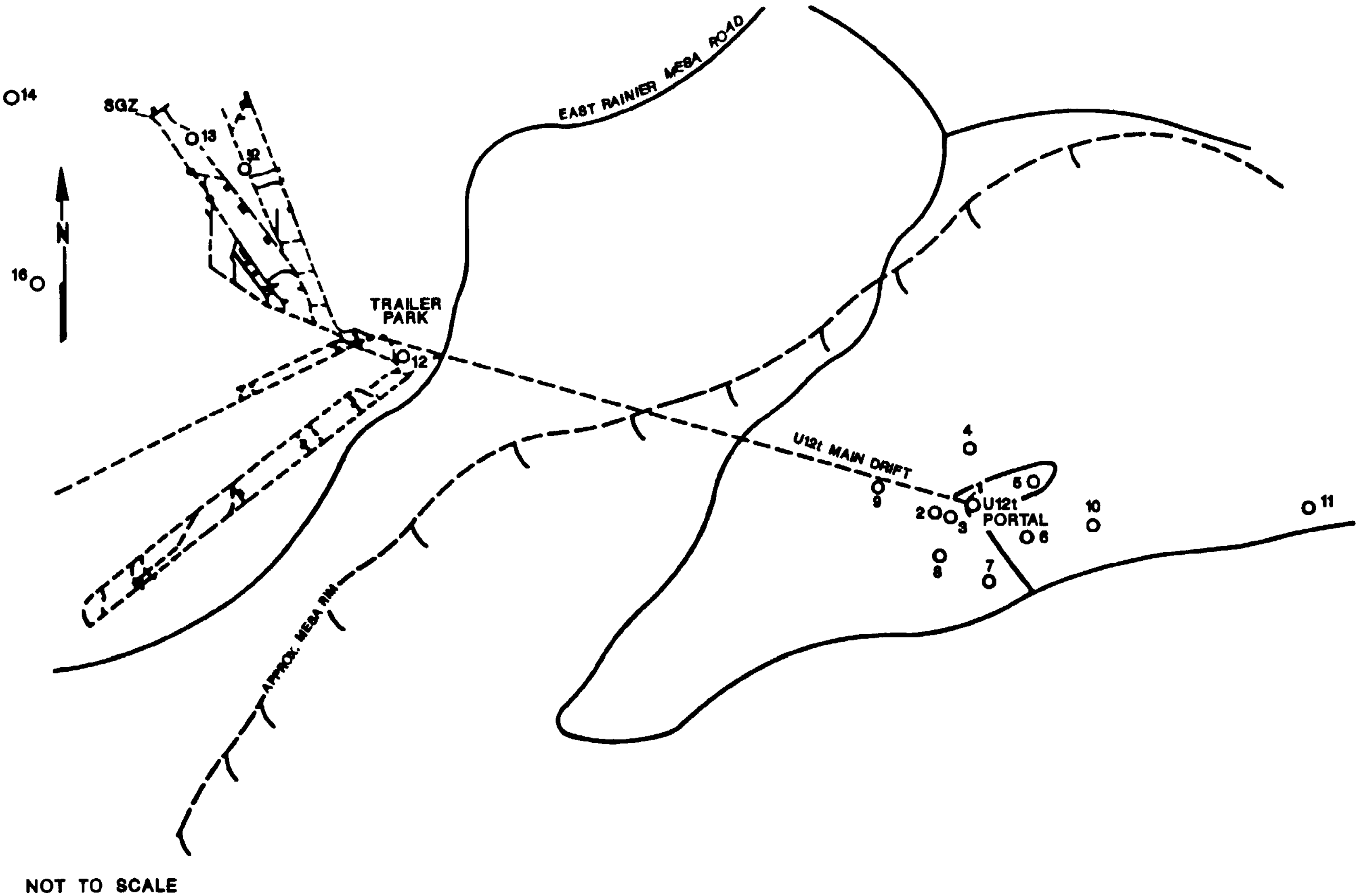

Figure 6-6. MIDAS MYTH/MILAGRO event - surface RAMS.

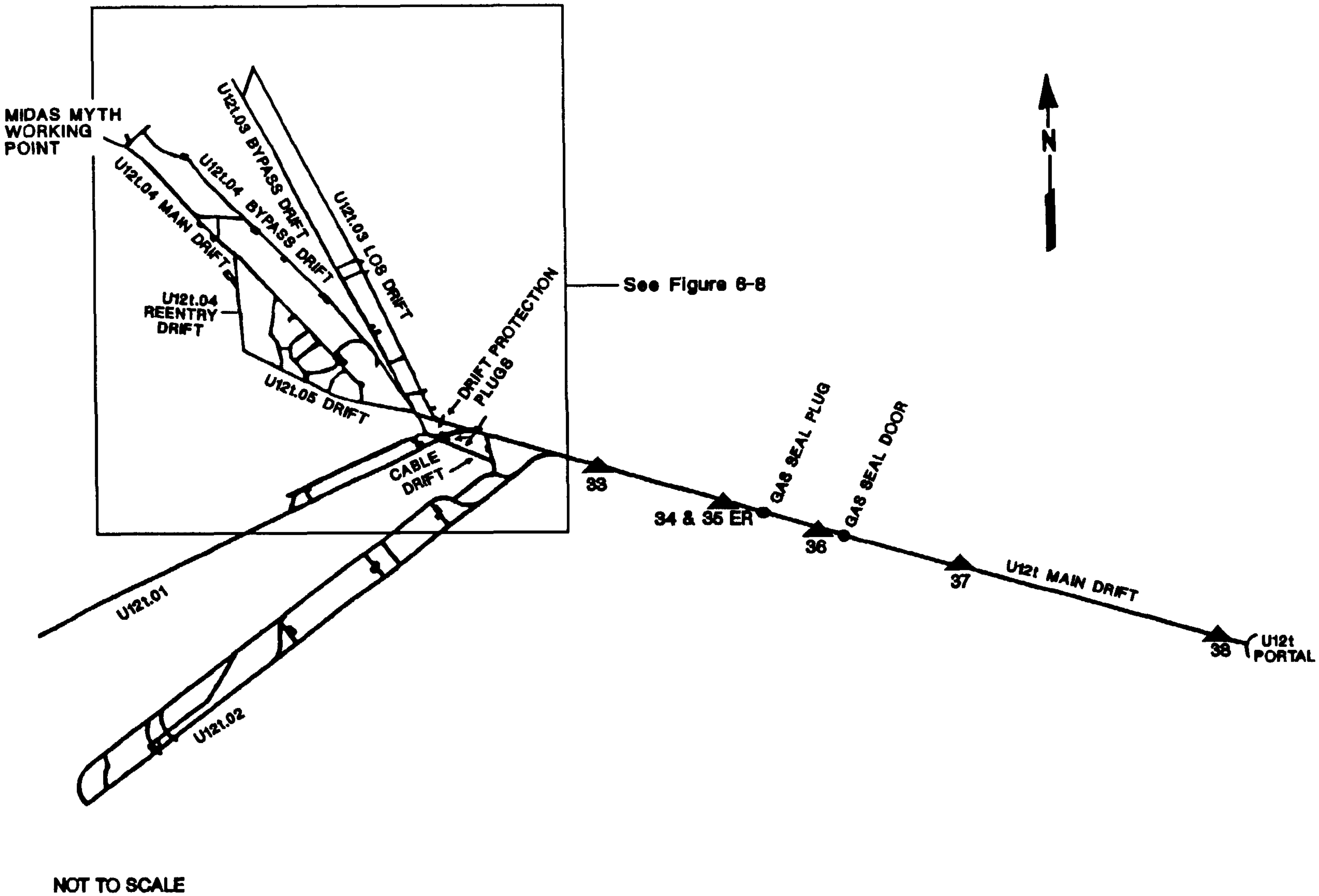

Figure 6-7. MIDAS MYTH/MILAGRO event - underground RAMS.

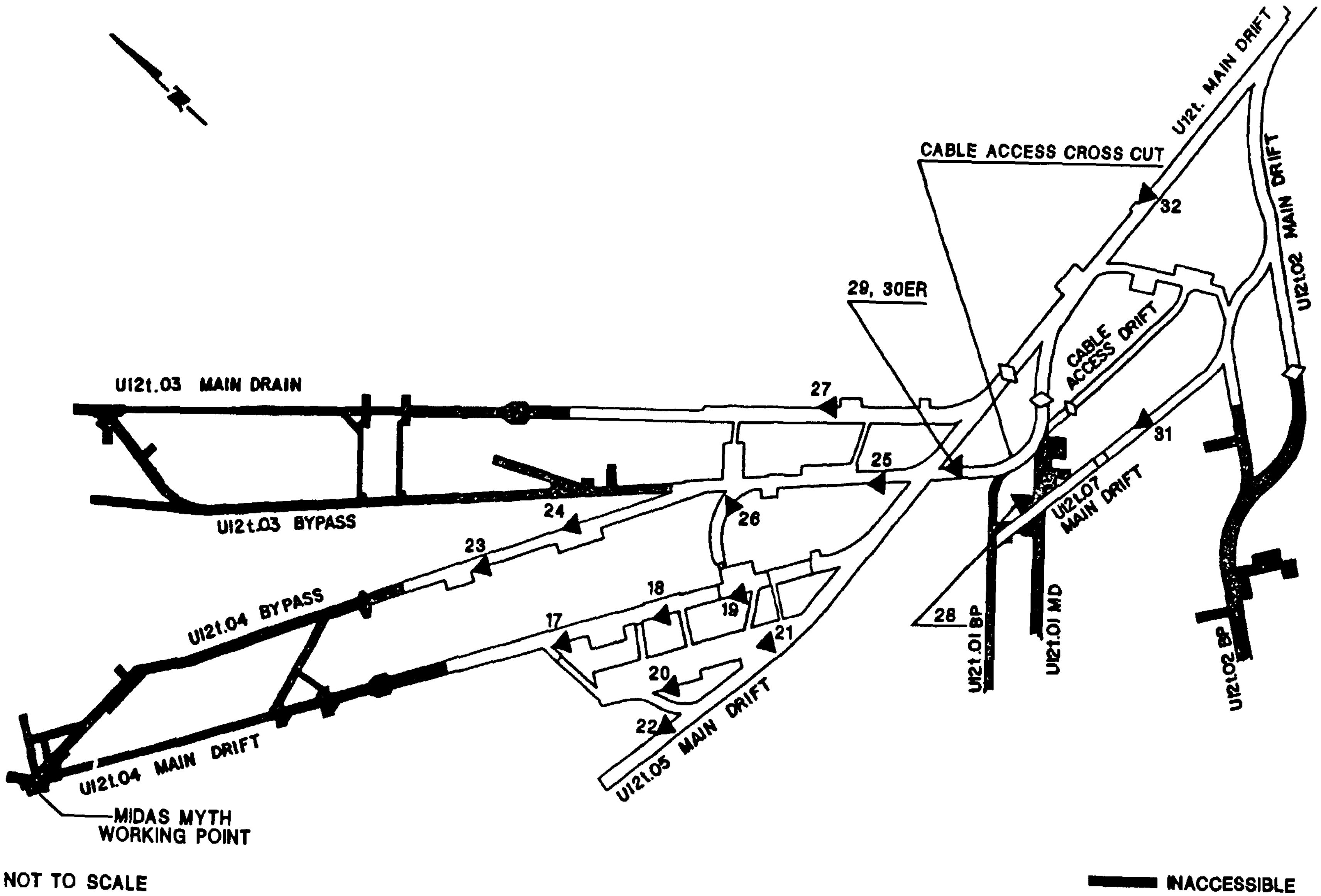

Figure 6-8. MIDAS MYTH/MILAGRO event - underground RAMS U12t.04 complex.

E. Air Support.

Three UH1N helicopters and crews were provided by the USAF for cloud tracking and the Test Controller's use, if needed. In addition, the USAF provided a C-130/C-135 and crew on standby status for cloud sampling. EG&G provided one Turbo Beech and one Twin Bonanza aircraft and crews for tracking duties, if necessary.

6.3 EVENT-DAY ACTIVITIES.

6.3.1 Preshot Activities.

By 14 February 1984 at 2400 hours, all persons except the arming party, the tunnel button-up crew, the mesa button-up crew, and the security guards were out of the tunnel and clear of the muster area. At 0130 hours on 15 February, permission was granted to arm the device. By 0615 hours button-up was completed.

A readiness briefing was held at 1400 hours on 14 February 1984, in anticipation of the planned test execution at 0700 hours the next day. A faulty fiber optics decoder power supply needed replacement on the morning of 15 February, causing a two-hour countdown delay. The countdown started at 0845 hours, and the MIDAS MYTH/MILAGRO device was detonated in the U12t.04 drift at 0900 hours PST on 15 February 1984.

6.3.2 Test Area Monitoring.

Telemetry measurements began at 0900 hours on 15 February 1984. At H+1 minute, underground RAMS units 17, 18, 19, 20, 22, 23, 24, and 28 became inoperative and remained so for the entire event period. All other RAMS units remained operational throughout the event and subsequent postevent periods. Due to ground subsidence on the mesa, the surface RAMS units 12 through 15 became inoperative at H+3.25 hours. All RAMS units, except unit 21, read background throughout the entire readout period. RAMS unit 21 recorded the maximum reading of 0.43 mR/h at H+2 minutes. By H+1 hour, the reading decreased to background levels.

6.3.3 Initial Surface Radiation Survey and Recovery Activities.

Initial surface reentry teams departed from the Test Controller's barricade at Gate 300 at 1007 hours on 15 February 1984. A mobile base station was provided for area control and equipment supply. By 1101 hours initial survey teams in both the U12t portal yard, ventilation pad, and on the mesa had completed the initial surface survey. No radiation levels above the normal background levels were detected.

Survey teams stood by in both the U12t tunnel portal and U12t Milagro trailer park during data recovery and gas sampling of the tunnel atmosphere. At approximately 1225 hours, the U12t.04 surface ground zero area and the Milagro trailer park subsided (Figure 6-9). This subsidence produced a crater 18 feet deep, injuring several survey team members and resulting in the only fatality that ever occurred from a DoD-sponsored event. One survey team member died as a result of complications from injuries sustained when subsidence occurred.

The initial survey teams, consisting of geologists, industrial hygienists, and radiation safety monitors, accompanied by data recovery teams, relocated to the access roads, to the U12t portal, and to the U12t Milagro trailer park. The portal gas sampling team reentered the portal at 1645 hours. No toxic gases or positive LEL levels were detected from remote gas sampling of the tunnel atmosphere. Data recovery and gas sampling were completed at 1900 hours. All personnel had checked out of the event location by 2035 hours on 15 February 1984.

6.4 POSTEVENT ACTIVITIES.

6.4.1 Tunnel Reentry Activities.

Initial reentry operations began at 0909 hours on 17 February 1984 (D+2), with all team members dressed in anticontamination clothing. The work team went as far as the GSD. Ventilation was established at 0951 hours by opening the manway at the GSD to the portal side of the GSP. No toxic gases, positive LEL, or radiation levels above background (0.04 mR/h) were detected. The

Figure 6-9. MIDAS MYTH/MILAGRO event - mesa trailer park subsidence damage.

oxygen level was a normal 21 percent. No respiratory protection was required for this initial reentry.

At 1315 hours the reentry team, backup reentry, and rescue teams departed the portal for the GSP. The manway door was opened through the GSP at 1340 hours on 17 February 1984. Air sampling data taken in the 24-inch turntube on the WP side of the GSP showed no positive toxic gases, LEL, or radiation levels above background.

The reentry team proceeded to the portal side of the main DPP at 1411 hours. Wearing self-contained breathing apparatus, the reentry team opened the 24-inch and 36-inch turntubes, and established ventilation at 1633 hours. Readings inside the 24-inch turntube were 0.06 mR/h, 5 ppm carbon monoxide (CO), and 5 percent of the LEL.

At 1645 hours on 17 February 1984, the reentry team proceeded through the main DPP in an attempt to walk out the U12t.05 main drift and the U12t.04 ballroom. As a result of unexpectedly high ground shock on 15 February, an unprecedented amount of damage to the LOS pipe, tunnel, ballroom, alcoves, and ROSES was discovered. The invert in the U12t.05 main drift and in the ballroom was heaved upward, impeding reentry operations. Readings taken 15 feet away from the thermal shield wall at the U12t.04 LOS drift were 2 mR/h, 50 ppm CO, 5 percent of the LEL, and 20 percent oxygen. The reentry team returned to the portal side of the main DPP at 1739 hours. All teams exited the tunnel at 1809 hours on 17 February 1984.

At 1052 hours on 29 February 1984, a reentry team, wearing self-contained breathing apparatus, entered the LOS pipe at TC No. 1 to check the LOS pipe and tunnel conditions. The LOS pipe was collapsed, but access to test chambers and test alcoves was possible. The maximum reading at TC No. 1 door was 2 mR/h. No toxic gases or positive LEL levels were detected. The oxygen level in the LOS pipe was a normal 21 percent.

Scientific assessment teams entered the LOS pipe at TC No. 1 wearing full-face respirators with HEPA filters and full anticontamination clothing at 1300 hours on 29 February 1984. The teams completed their work that same day.

6.4.2 Postevent Mining.

Extensive rehabilitation to the U12t main drift (inside the DPP) and its subdrifts started at 0110 hours on 18 February 1984. Miners wearing anticontamination clothing broke through the DPP bulkhead at 0555 hours on 19 February 1984. Readings taken during this period indicated a normal oxygen level and no toxic gases or positive LEL levels. Rehabilitation efforts were completed as far as the ballroom in the U12t.04 drift complex by 0215 hours on 28 February 1984.

Mining operations continued simultaneously with experiment recovery and reentry operations. Mining began at the U12t.04 LOS drift shield wall on 14 March 1984. Rockbolting, cribbing, track laying and hanging wire mesh were performed to refurbish the drift. LOS rehabilitation was completed on 22 March 1984. Radiation readings were background, with 10 ppm CO, 20 percent oxygen and no positive LEL levels detected.

Mining of the U12t.04 reentry drift required drilling probe holes to detect toxic gases and radiation levels. Initial probe readings indicated background radiation and no toxic gases or positive LEL levels. Alpine mining of the U12t.04 reentry drift began 12 April 1984. Mining operations continued on a heading toward ground zero (GZ) until late June 1984, when contaminated water began seeping from the WP side of the bulkhead wall in the U12t.04 reentry drift. Mining operations were terminated due to radioactive water seepage problems.

6.4.3 Postevent Drilling.

No postevent drilling from the mesa occurred for core samples. However, a drilling area was established in U12t.04 reentry drift on 24 April 1984. Drilling began towards the cavity at 1615 hours on 1 May on the first of three drill holes. Thirty-six core samples were taken from U12t.04 Reentry (RE) No. 1A between 2130 hours on 1 May and 1430 hours on 15 May 1984. Sampling of RE No. 2 occurred between 1100 hours on 30 May 1984 and 1000 hours on 14 June 1984. Radiation, toxic gases and positive LEL levels were detected in both RE No. 1A, and RE No. 2. The maximum readings were 2 mR/h, 2000 ppm CO, and 100 percent of the LEL. Both holes were grouted to contain contamination.

On 27 June 1984, drilling operations were temporarily interrupted to evaluate several core samples recovered from hole RE No. 3. Among the core samples recovered was a glassy material extracted from RE No. 3 at a distance of 422 feet into the drill hole. Core samples were sent to LANL for analysis.

In conjunction with the core sample evaluations there were drilling difficulties associated with contaminated material seeping from RE No. 3. High pressure steam and radioactive hot water seeped from the return line of the drill rig at RE No. 3. Readings inside the return line tank indicated a radiation level of 100 mR/h, no toxic gases, and zero percent of the LEL. Drilling operations were reevaluated to determine the severity of the contamination and the dangers it posed to the entire U12t complex.

Consequently, drilling operations were terminated on 29 June 1984. Radiation containment operations began in the U12t.04 complex with the sealing of the U12t.04 reentry drift. Reentry and recovery operations were completed in mid-March 1985.

6.4.4 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were then recorded in the monitors' logbook.

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. Industrial safety codes for mining, tunneling, and drilling were established by REECo and emphasized during all operations. A written standard operating procedure was required for each operation involving explosives, toxic material, radioactive material, or any other operation with the potential for personal injury. Each individual involved in such an operation was required to know the contents of the applicable procedures.

The portal construction area and the tunnel were mandatory hard hat and foot protection areas (safety shoes, boots, DOE-issued miner's boots, or toe guards). All personnel on the initial tunnel reentry teams were certified in the use of the Draeger self-contained breathing apparatus and had used the McCaa two-hour breathing apparatus. Standard safety rules and regulations, as spelled out in the "U.S. Bureau of Mines Manual," were observed.

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials were handled, stored and transported in accordance with applicable sections of the following documents:

1. Army Material Command Regulation (AMCR 385-100)
2. Appropriate DOE Orders in the 5400 and 5600 Series concerning Environmental Protection, Safety & Health Protection, and Defense Programs respectively.
3. Individual safe operating procedures (by experimenter organization).
4. MIDAS MYTH/MILAGRO Safety Regulations.

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were required to wear safety glasses or other eye protection which had been approved by the DoD safety coordinator.

6.5 RESULTS AND CONCLUSIONS.

Telemetry measurements began at 0900 hours on 15 February 1984. Several RAMS units were lost due to the higher than expected ground shock. The maximum reading was 0.43 mR/h detected on RAMS unit number 21 at H+2 minutes. By H+1 hour RAM unit 21 recorded background levels.

The initial radiation surveys began at 1007 hours on 15 February 1984, and were completed by 2035 hours. No radiation above background level was detected at the mesa cable rise building, the Milagro trailer park, or at the tunnel portal area.

Reentry into the tunnel began at 0909 hours on 17 February 1984. The maximum readings from remote gas sampling analysis showed 50 ppm CO and 5 percent of the LEL. The maximum radiation level was 2 mR/h. Initial reentry was completed as far as the LOS drift 29 February 1984; data recovery was completed 27 March 1984; and final recovery was conducted in March 1985.

Postevent mining and drilling began on 18 February 1984, and continued until 29 June 1984. Mining activities progressed slowly due to extensive damage in the U12t tunnel complex. Mining operations were terminated in June 1984, as a result of radioactive water problems in the U12t.04 reentry drift. The maximum radiation reading of 100 mR/h was recorded at drill hole RE No. 3.

Personnel exposure data from self-reading pocket dosimeters were documented on the Area Access Registers during individual entries to MIDAS MYTH/MILAGRO radex area over a non-continuous time frame from 15 February 1984, to 2 April 1986. Although pocket dosimeters showed some indication of possible radiation exposure, film badges worn by reentry personnel indicated no evidence of any gamma exposure. The minimum detectable gamma exposure with the NTS film badge dosimeter was 30 mR.

Area Access Register data are summarized below.

Participants	Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All	2,764	180	3.1
DoD	314	180	2.0

SECTION 7

MISTY RAIN EVENT

7.1 EVENT SUMMARY.

MISTY RAIN was a DoD-sponsored nuclear weapons-effects test conducted at 1515 hours PST on 6 April 1985. The test had a yield of less than 20 kilotons. The MISTY RAIN device was detonated in U12n.17 drift of N tunnel complex at a depth of 1,273 feet below the mesa surface (Figure 7-1). The purpose of the MISTY RAIN event was to test the survivability of military hardware in a nuclear detonation environment.

At H+10.5 minutes, RAMS units located within the tunnel complex indicated the presence of radioactivity in the alcoves and drifts associated with the test. This caused a delay in tunnel reentry until 9 April 1985, and subsequent operations were hampered. When ventilation to the mesa was established, a controlled effluent release, consisting of xenons and kryptons occurred.

7.2 PREEVENT ACTIVITIES.

7.2.1 Responsibilities.

Safe conduct of all MISTY RAIN project activities in Area 12 was the responsibility of the DNA Test Group Director (TGD), subject to controls and procedures established by the DOE Test Controller. The DOE Test Controller was responsible for the safety of the public and onsite personnel during the test.

Project agencies were responsible for designing, preparing, and installing experiments, or delivering them to the installation contractor. After the event, these agencies were responsible for removing samples, analyzing instrument and sample data, and preparing project reports on experiment results.

Device safety and security procedures in the working point (WP) area and the timing and firing control room were in accordance with DOE Order 5610.3, "Program to Prevent Accidental or

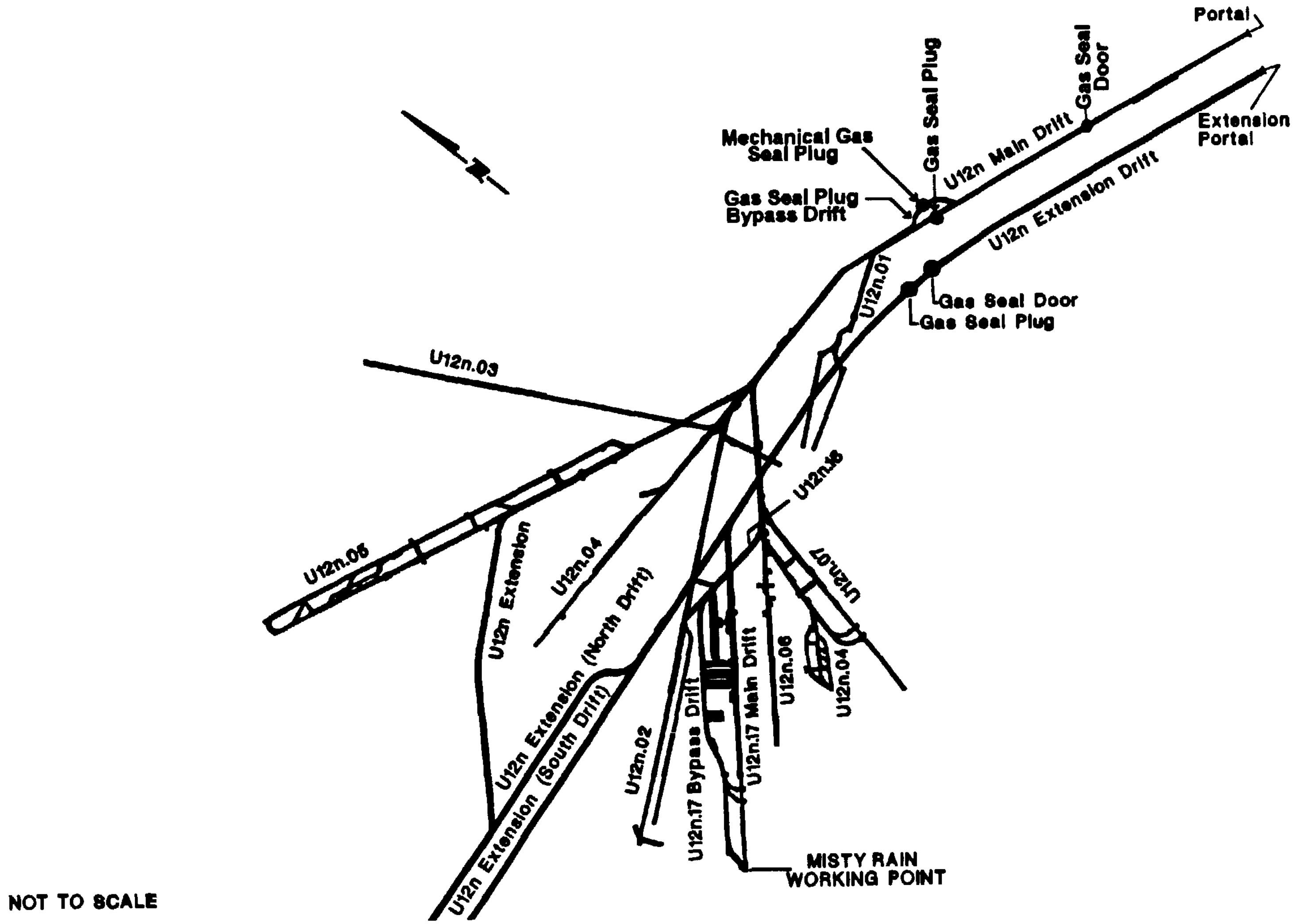

Figure 7-1. MISTY RAIN event - tunnel layout.

Unauthorized Nuclear Explosive Detonations." The LLNL TGD had overall responsibilities for all operations involving the MISTY RAIN device. LLNL was also responsible to the DOE Test Controller for radiological safety within the designated area of the WP from device emplacement until detonation. After detonation, the DOE Test Controller relieved LLNL of their responsibilities. The DOE Test Controller approved the controlled venting of the tunnel complex, and returned the responsibility for project activities back to the DNA TGD.

7.2.2 Planning and Preparations.

A. Tunnel Facilities Construction.

Some mechanical hardware and system components, including several sections of LOS pipe recovered from the MINERS IRON event, were reused. The U12n.17 complex, a two-vessel containment system, consisted of one LOS drift, a bypass drift, two access drifts, a muffler, two auxiliary closures, tunnel and pipe seal (TAPS), one zero room, one test chamber, and a vacuum pumping and monitoring station (Figure 7-2).

Remote gas sampling capabilities were incorporated during construction as well as water, power, drain, and pressurization lines. Provisions to manually take gas samples from the WP side of the Gas Seal Door (GSD) were made during postevent reentry.

Construction activities began in November 1982 with the mining of the U12n.16 drift. Mining of the U12n.17 main LOS drift began in March 1983 and was completed in December. During that time, concrete pours for the Modified Auxiliary Closure (MAC), the Gas Seal Auxiliary Closure (GSAC), and the TAPS inverts were completed. In April 1983, mining began in the U12n.17 bypass drift and by July 1983 an extension drift[15] was mined to meet the requirements for accommodating the source-generated

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[15] The main drift diameter was not large enough to accommodate some experimental hardware designs. Therefore, a larger-diameter extension drift was mined for hardware emplacement.

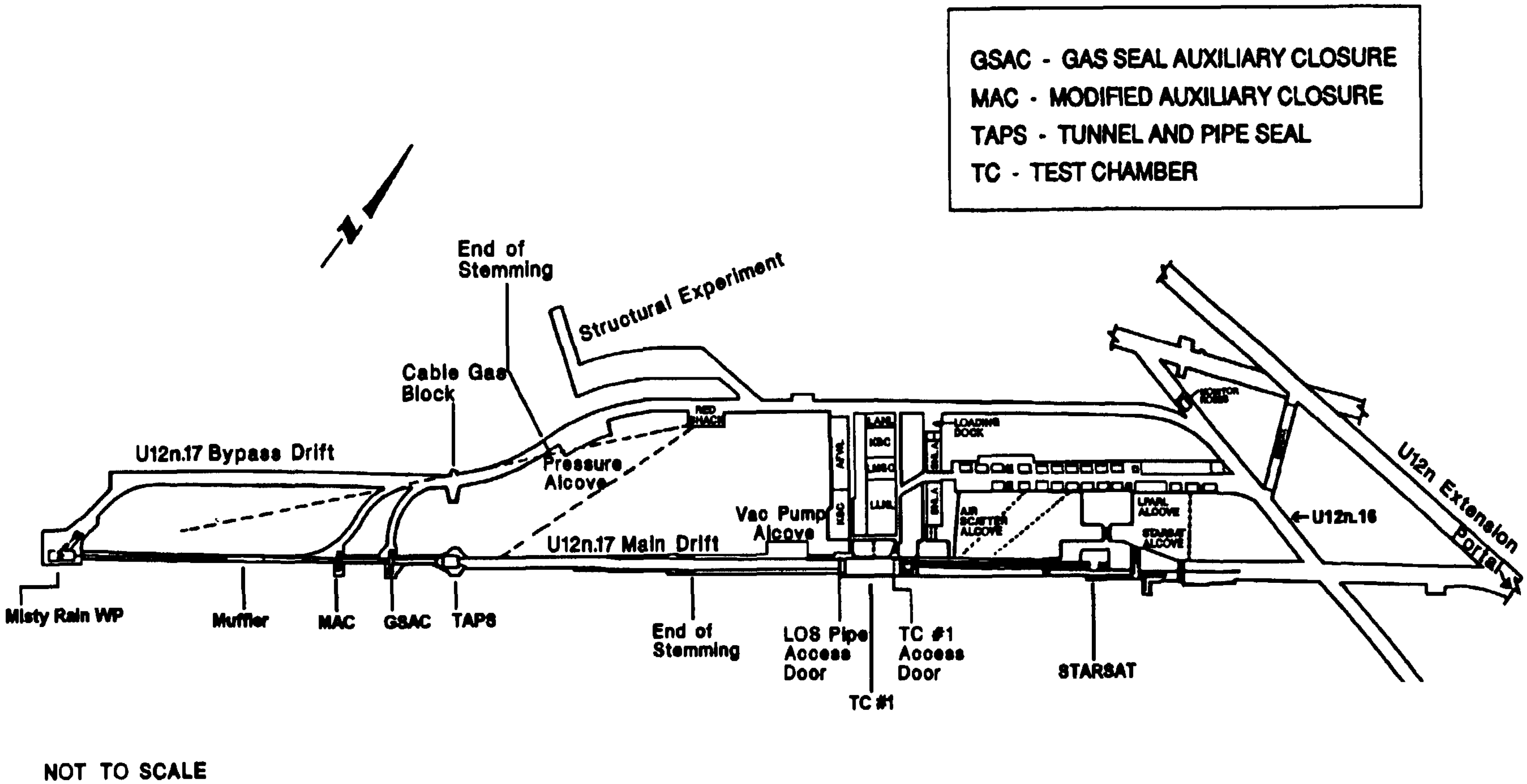

Figure 7-2. MISTY RAIN event - tunnel and pipe layout.

electromagnetic pulse test analysis and research satellite (STARSAT) chamber (Figure 7-3). The Recorder and Oscilloscope Sealed Environmental System (ROSES) drift and instrumentation alcoves were mined from November 1983 until completion in March 1984. Installation of the LOS pipe began in February 1984 and was completed in December 1984.

Several experiment modifications and hardware fabrications caused an increase in construction efforts. In May 1984 an additional 200 feet in the bypass drift was mined for the tunnel hardening experiment, and in August 1984, the MK5 matrix for the Navy was modified resulting in changes to the interior of the test chamber. These projects were completed by February 1985. In January 1985 the ROSES were installed, and fiber optic cables were connected.

The stemming plan for the U12n.17 complex is shown in Figure 7-4. Stemming operations began in July 1984 when rock-matching grout, superlean grout, desert fines sand, comprehensive high-strength grout, and high-strength groutcrete were pumped into all void areas from the MISTY RAIN WP to a distance of 705 feet in the U12n.17 main drift. The main drift was backfilled first with desert fines sand behind the WP; then with rock-matching grout to 157 feet; and then with superlean grout over a rock-matching grout invert from 157 feet to 292 feet. Between the MAC, GSAC, and TAPS sections, concrete, superlean grout, high-strength groutcrete, and comprehensive high-strength grout were poured to 459 feet. Finally, high-strength grout filled the remaining 246 feet of the stemmed portion of the main drift after device emplacement. The U12n.17 bypass was also stemmed in the same manner out to 500 feet. All penetrations into the stemmed areas of the drifts (e.g., cables and water lines) were gas blocked to prevent the seepage of radioactive gases outside the stemmed region of the drifts.

Experiment and related hardware installation began in November 1984 and was completed by February 1985. The experimenter organizations included: Lockheed Palo Alto Research Laboratory (LPARL), Sandia National Laboratory (SNL), and Lawrence Livermore National Laboratory (LLNL),

Figure 7-3. MISTY RAIN event - STARSAT chamber.

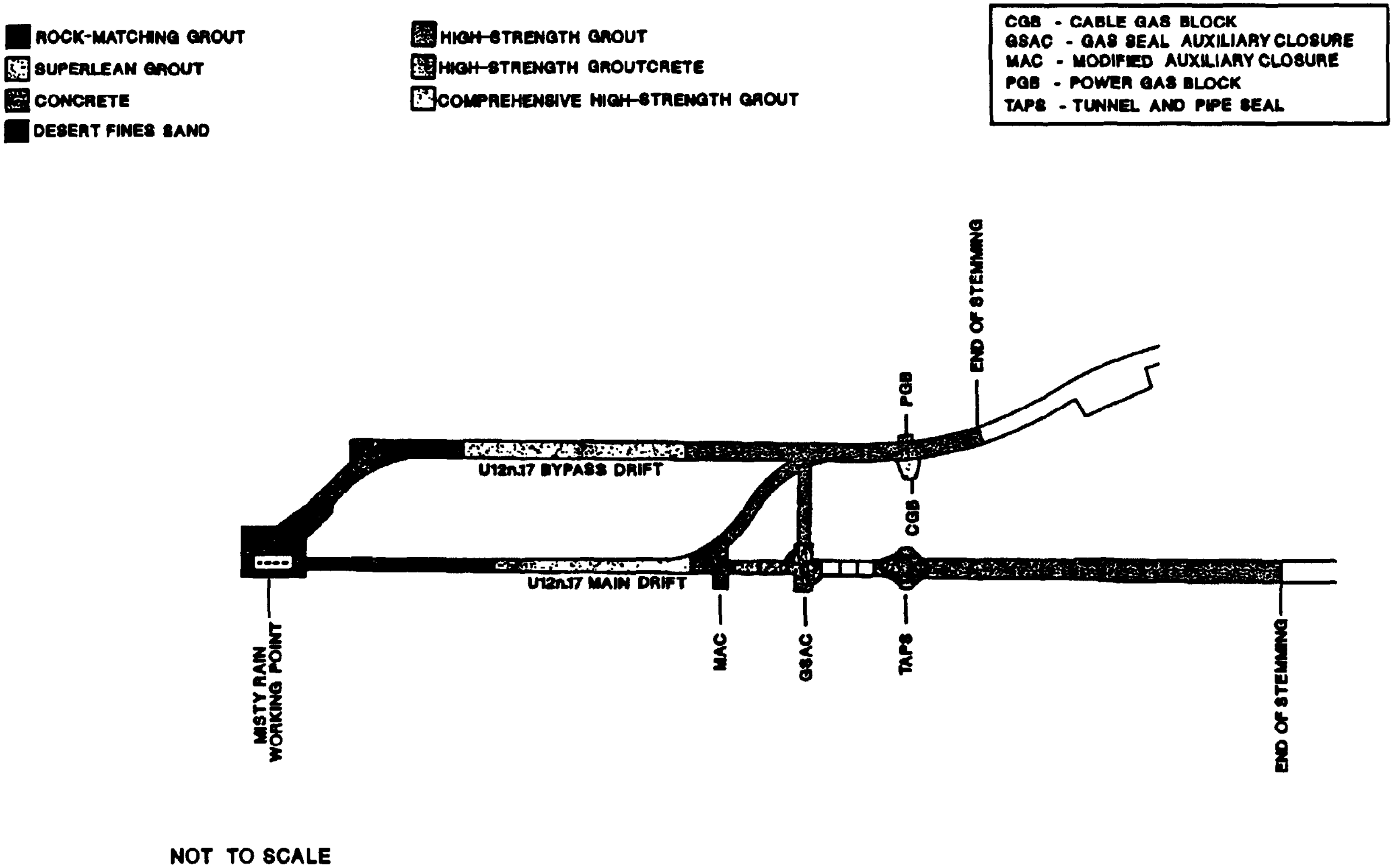

Figure 7-4. MISTY RAIN event - stemming plan.

all performed phenomenology experiments addressing source-generated electromagnetic pulse (SGEMP) and thermomechanical and structural responses; and Los Alamos National Laboratory (LANL), performed the source simultaneity front-end experiment. The Defense Nuclear Agency (DNA) sponsored the following experiments: General Electric Company, Federal and Electronics System Division (GEFE), performed the spacecraft system experiment, which evaluated the DNA full-scale STARSAT (Figure 7-5); Mission Research Corporation (MRC), conducted an antenna analysis measuring SGEMP effects; Kaman Sciences Corporation (KSC), performed STARSAT signal measurement experiments; and Scientific Application International Corporation (SAIC), fielded a radiation diagnostics measurement experiment and a wide band fiber-optics experiment. The US Navy Strategic Systems Project Office (SSPO) also fielded an experiment.

Signal dry runs began in November 1984. A successful mandatory full-participation dry run (MFP) was conducted on 21 March 1985, after which final device preparation and final stemming commenced. A full frequency, full power dry run was also successfully conducted on 28 March 1985, and preparations were made to execute the test on 2 April 1985.

At 0100 hours on 2 April, during final button-up operations, a significant air leak was discovered at the GSP on the WP side in the U12n extension drift. Immediate repairs were required, and the test was rescheduled for 4 April 1985. However, tunnel repairs did not support this date, and the test was again rescheduled for 6 April 1985.

B. Radiological Safety Support.

Procedures for radiation exposure and contamination control during these events were in accordance with DOE Manual Chapter 0524 and requirements of responsible DoD representatives. Radsafe monitors were briefed regarding surface reentry, manned stations, and security station requirements. Radsafe monitoring teams and supervisory

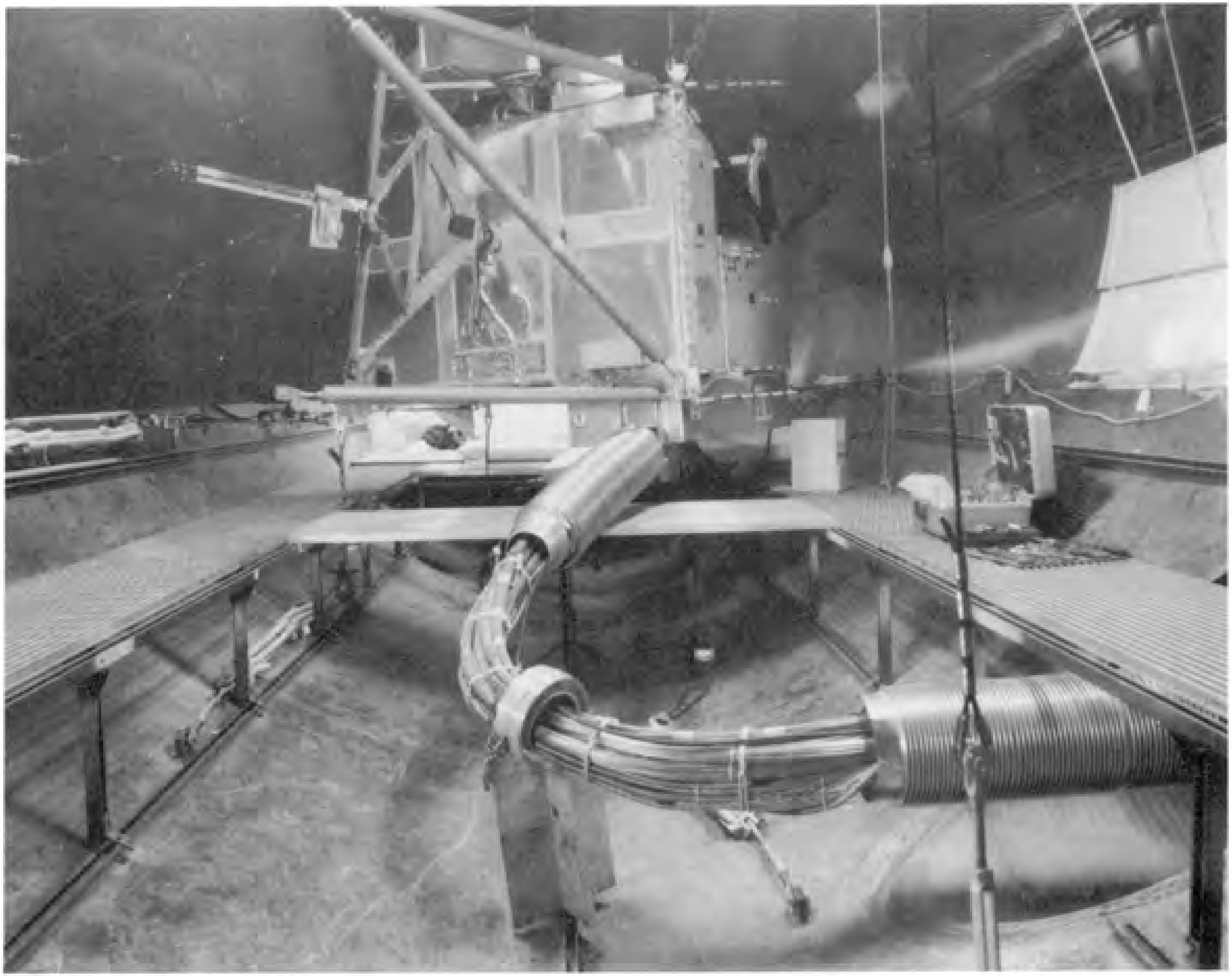

Figure 7-5. MISTY RAIN event - STARSAT experiment.

personnel were provided to perform initial radiation surveys, conduct aerial surveys by helicopter, and participate in reentry parties as needed. Radsafe personnel were also standing by at Gate 300 prior to detonation to perform surveys and provide emergency support as directed; provide and issue anticontamination equipment and material, portable instruments, and dosimeters; operate area control check stations; and perform personnel, equipment, and vehicle decontamination, as required.

Available anticontamination materials and equipment included head covers, coveralls, cloth shoe covers, totes, full-face masks, supplied-air breathing apparatus, plastic suits, plastic bags, gloves, and masking tape.

C. Telemetry and Air Sampling Support.

In addition to the 40 permanent RAMS units, 40 temporary units provided surface and underground coverage for MISTY RAIN. Table 7-1 and Table 7-2 list the locations of surface and underground RAMS, respectively. The location of both surface and underground RAMS units are shown in Figure 7-6 and Figure 7-7, respectively. The U12n.17 complex RAMS unit detailed locations are shown in Figure 7-8. All RAMS units were installed a minimum of five days prior to scheduled device detonation.

EPA operated continuous monitoring stations at 29 locations in the offsite area. All the stations had high-volume air samplers with collectors for particulate and reactive gases, 16 had tritium and noble gas samplers, and 22 had pressurized ion chamber gamma-rate detector/recorder systems in operation. Twenty-eight EPA personnel were fielded for surveillance activities.

D. Security Coverage.

Device security procedures in the WP area and the timing and firing control room were in accordance with DOE Order 5610.3, and DOE Order 5610.3-26, "Program to Prevent Accidental or Unauthorized Nuclear Explosive Detonations." Beginning on D-1, all personnel entering or exiting the

Table 7-1. MISTY RAIN event RAMS unit locations 06 April 1985.

SURFACE

STATION NUMBER	LOCATION
From the U12n Portal unless otherwise indicated:	
1	On the drain line
2	400 feet N 16° E azimuth
3	275 feet N 89° E azimuth
4	365 feet S 16° E azimuth
5	480 feet S 12° W azimuth
6	560 feet S 48° W azimuth
7	420 feet N 69° W azimuth
8	1,370 feet S 43° E azimuth
9	3,559 feet S 34° W azimuth (at B tunnel portal)
10	On the vent hole
From the U12n.17 SGZ:	
11	400 feet N 00° E azimuth
12	400 feet S 60° E azimuth
13	400 feet S 60° W azimuth

Table 7-2. MISTY RAIN event RAMS unit locations 06 April 1985.

UNDERGROUND

STATION NUMBER	LOCATION
From the U12n extension drift unless otherwise indicated:	
14	545 feet into the U12n.17 main drift
15	450 feet into the U12n.17 main drift
16	250 feet into the U12n.17 main drift
17	185 feet into the U12n.17 main drift
18	80 feet into the U12n.17 main drift
19	610 feet into the U12n.17 bypass drift
20	320 feet into the U12n.17 bypass drift
21	U12n.17 TC-1 alcove
22	U12n.17 SNLA alcove
23	330 feet into the U12n.17 ROSES drift
24	290 feet into the U12n.17 ROSES drift
25	170 feet into the U12n.17 ROSES drift
26	200 feet into the U12n.16 drift from the U12n-.06 drift
From the U12n main drift:	
27	600 feet into the U12n.06 drift
28[16]	4,000 feet into the U12n extension drift
29	600 feet into the U12n.05 drift

[16] From the U12n portal extension.

Table 7-2. MISTY RAIN event RAMS unit locations 06 April 1985 (Continued).

UNDERGROUND

STATION NUMBER	LOCATION
From the U12n portal unless otherwise indicated:	
30[17]	2,900 feet into the U12n extension drift
31[17]	2,300 feet into the U12n extension drift
32	2,600 feet into the U12n main drift
33	235 feet into the U12n gas seal plug bypass drift
34ER[18]	235 feet into the U12n gas seal plug bypass drift
35	1,700 feet into the U12n main drift
36	1,200 feet into the U12n main drift
37	200 feet into the U12n main drift
38[17]	1,200 feet into the U12n extension drift
39[17]	200 feet into the U12n extension drift
40	50 feet into the U12n ventline rise

[17] From the U12n portal extension.

[18] ER - Extended Range (instrument capable of reading 100 mR/h to 100,000 R/h).

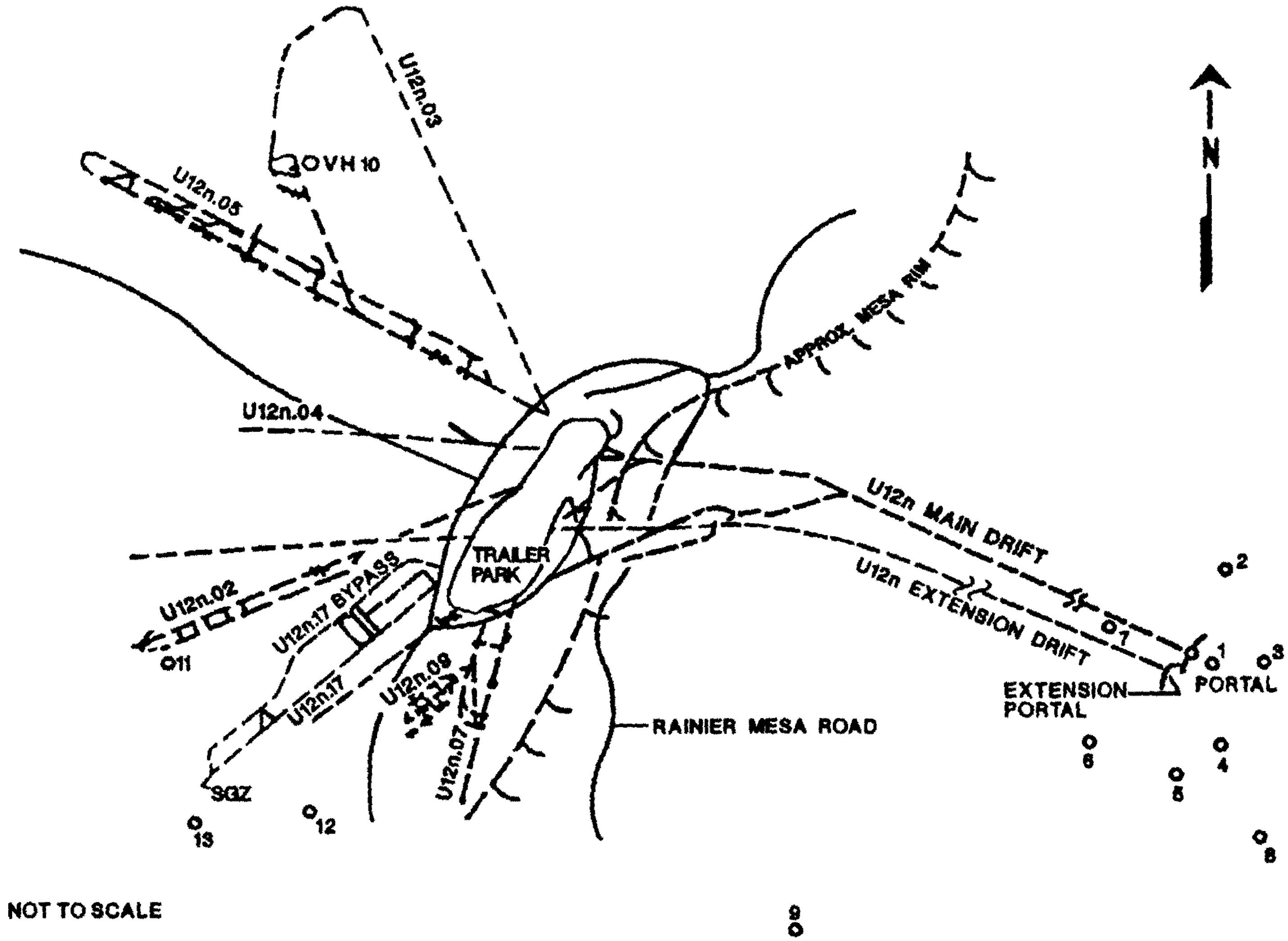

Figure 7-6. MISTY RAIN event - surface RAMS.

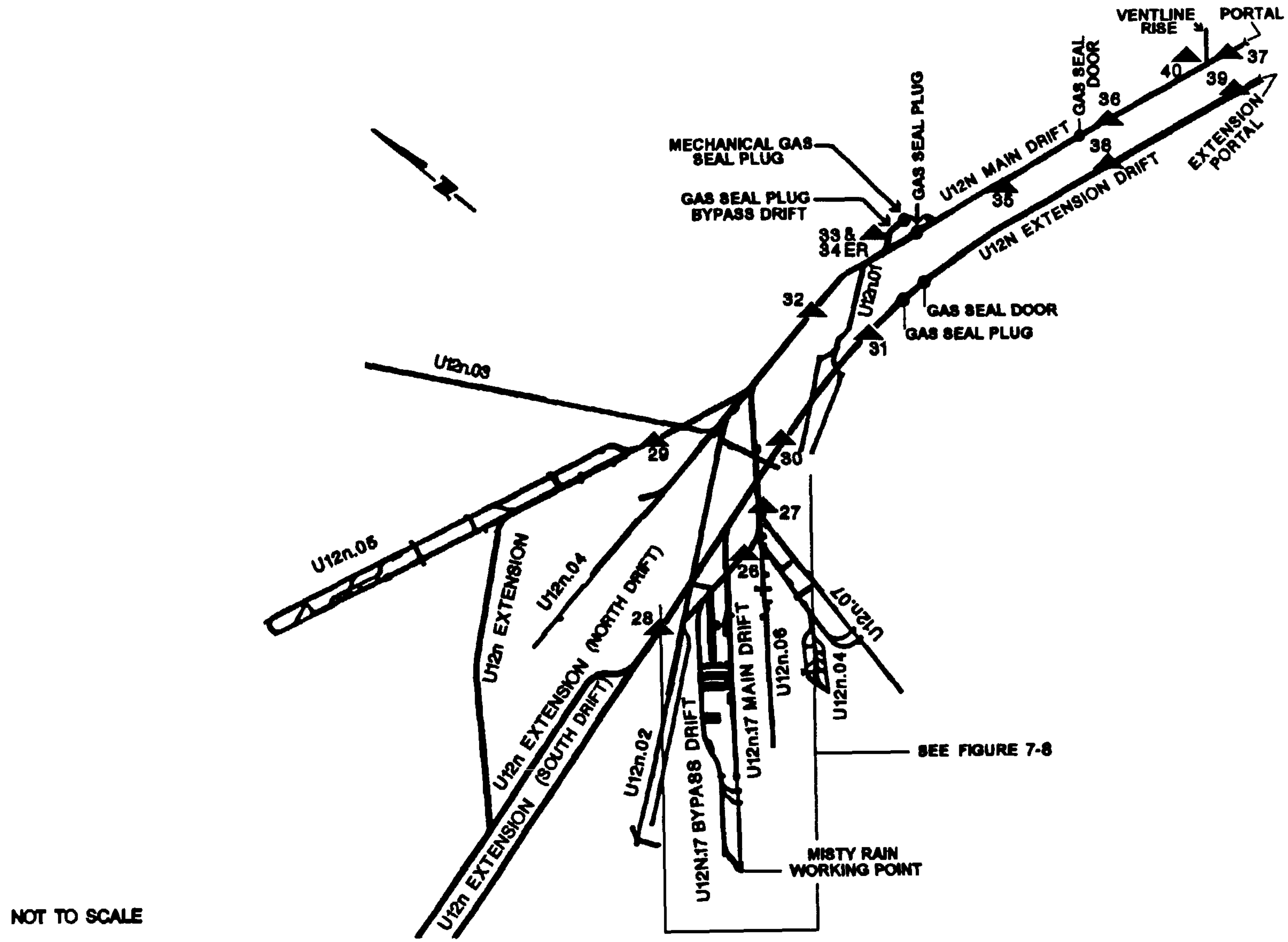

Figure 7-7. MISTY RAIN event - underground RAMS.

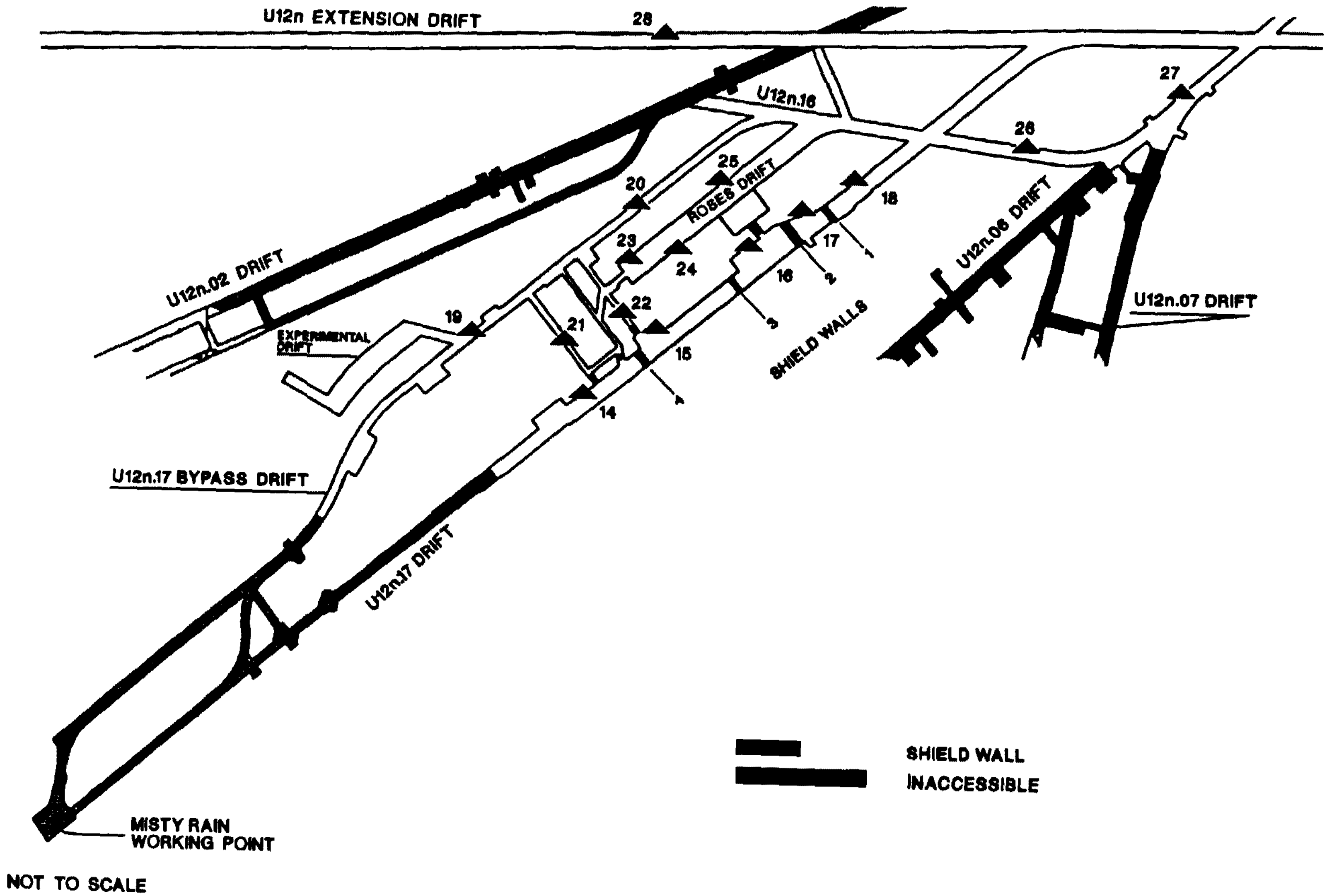

Figure 7-8. MISTY RAIN event - underground RAMS U12n.17 complex.

controlled area were required to stop at muster or control stations for issue of stay-in badges. After control was established, all through traffic was diverted around the controlled area by use of screening stations. In accordance with the "Test Controller's Operations and Security Plans," contractors and agencies were to have all personnel not connected with this event out of the closed area before the final security sweep began.

E. Air Support.

Three UH1N helicopters and crews were provided by the USAF for cloud tracking and the Test Controller's use, if needed. In addition, the USAF provided a C-130/C-135 and crew on standby status for cloud sampling. EG&G provided one Turbo Beech and one Twin Bonanza aircraft with crews for tracking duties, if necessary.

7.3 EVENT-DAY ACTIVITIES.

7.3.1 Preshot Activities.

By 5 April 1985, at 2400 hours, all persons excepts the arming party, the tunnel button-up crew, the mesa button-up crew, and the security guards were out of the tunnel and clear of the muster area. At 0315 hours on 6 April, permission was granted to arm the device. By 0800 hours button-up was completed.

A readiness briefing was held at 1400 hours on 5 April 1985, in anticipation of the planned test execution of 0900 hours the next day. Adverse weather conditions on 6 April 1985, caused a six-hour countdown delay. The countdown started at 1510 hours, and the MISTY RAIN device was detonated in the U12n.17 drift at 1515 hours PST on 6 April 1985.

7.3.2 Test Area Monitoring.

Telemetry measurements began at 1515 hours on 6 April 1985, and immediately, RAMS units 14, 16, and 19 became inoperative. All other units, except for units 15, 17, 18, and 20 through 32, recorded background radiation levels throughout the entire readout period. All RAMS units on the WP side of the GSP that were operational indicated readings above background levels.

RAMS unit 18 read 19.5 R/h at H+10 seconds, and unit 15 read 1000 R/h at H+11 minutes. Ventilation of the tunnel complex began on 9 April. As a result, readings on RAMS units 15 and 18 had decreased to 4.4 mR/h and 1 mR/h, respectively by 1040 hours on 10 April. All RAMS units were secured at 1510 hours on 12 April 1985. At this time unit 15 was reading 0.9 mR/h; all other units indicated background radiation levels.

7.3.3 Initial Surface Radiation Survey and Recovery Activities.

Initial surface reentry teams departed from the Test Controller's barricade at Gate 300 at 1652 hours on 6 April 1985. A mobile base station was provided for anticontamination clothing and equipment supply. By 1732 hours both the mesa trailer park and portal survey teams completed the initial surface surveys. No radiation levels above normal area background were detected.

Survey teams, consisting of geologists, industrial hygienists, and radiation safety monitors, stood by in the U12n tunnel portal and at the mesa trailer park during data recovery and gas sampling of the tunnel atmosphere. These operations began in the U12n complex at 1804 hours. By 1831 hours on 6 April remote gas sample data taken from the WP side of the GSP indicated 2,000 ppm of carbon monoxide (CO), 100 percent of the LEL, and 15 percent oxygen. The radiation reading on the sampling bag was 1 R/h. Remote samples taken from the LOS pipe indicated a radiation level of 80 mR/h, 200 ppm CO, 35 percent of the LEL and 15 percent oxygen. This work was completed at 1945 hours on 6 April 1985.

7.4 POSTEVENT ACTIVITIES.

7.4.1 Tunnel Reentry Activities.

Ventilation operations began on 8 April 1985 in the U12n tunnel complex. At 1450 hours a nine-member reentry team entered the tunnel complex to check tunnel pressures between the GSD and GSP. By 1518 hours both the GSD and the GSP valves were opened.

Readings indicated a normal 21 percent oxygen level, background radiation levels, no toxic gases and no positive LEL levels. At 1545 hours the team exited the tunnel, closing the GSD manway door from the portal side. Ventilation preparation continued until 9 April 1985 with the installation of filters and sampling ports and the calibration of the ventlines.

At 1025 hours on 9 April, a work crew entered the tunnel wearing antiCs and self-contained breathing apparatus. The team opened the GSD manway door and proceeded towards the GSP. At 1053 hours the team entered the GSP bypass drift and recorded negative pressure readings and background radiation levels. The team then opened the 42-inch crawltube door at the GSP and took swipes of the inside of the tube. Work continued and tunnel ventilation began at 1134 hours on 9 April lasting for approximately 24 hours, with gases being pumped through both the portal and mesa ventlines.

On 10 April 1985 the work crew reentered the tunnel to remove bolts from the GSD. They began laying rails and hooking up waterlines to the portal side of the GSP. Both the initial reentry and back-up teams, wearing double anticontamination clothing and self-contained breathing apparatus, returned to the GSP at 1149 hours on 10 April 1985. The initial reentry team then proceeded from the portal side of the GSP to the U12n.17 shield wall (shown in Figure 7-8). Readings at the U12n.17 shield wall No. 1 were 1 mR/h, 500 ppm CO, 100 percent of the LEL, and 18 percent oxygen. At 1225 hours, water was drained from the ventlines penetrating through the shield wall and the turntubes were opened at the shield wall. All teams returned to the portal area, and personnel were released at 1330 hours.

On 12 April 1985 the reentry team, wearing double anticontamination clothing and self-contained breathing apparatus, proceeded toward the U12n.17 shield walls No. 1 and No. 2. Maximum readings detected at shield wall No. 2 were 0.2 mR/h, 100 ppm CO, 15 percent of the LEL, and 20 percent oxygen. At 1035 hours, the reentry team opened test chamber (TC) No. 1 door. Readings inside the door were 10 mR/h, 30 ppm CO, and 10 percent of the LEL. The reentry team continued to walk out the U12.17 bypass drift and the crosscuts checking general tunnel conditions. The structural experiment drift had extensive damage as a result of the collapsed back. The reentry team returned to the ROSES drift and STARSAT alcove where the radiation reading was 0.4 mR/h. All personnel departed the tunnel at 1125 hours. Later that day a work team, wearing double anticontamination clothing and full-face respirators, established utilities to the tunnel. This work was completed by 1520 hours.

On 16 April 1985 the scientific assessment teams and data recovery teams entered the U12n.17 LOS and bypass drifts, wearing double anticontamination clothing and full-face respirators with GMR-I canisters, to assess conditions and begin recovering experiments. The scientific assessment teams completed their initial operations that day. However, experiment recovery operations continued until 10 May 1985.

7.4.2 Postevent Mining.

Work began on the mining of the GSP at 1415 hours on 10 April 1985 and was completed at 1700 hours on 15 April 1985. On 19 April 1985, miners wearing double anticontamination clothing and full-face respirators began rehabilitating the U12n.17 main drift and subdrifts. Miners mucked the inverts, painted the walls, rockbolted drift ribs, hung wire mesh, and poured pea gravel in each drift.

By August 1985 mining activities were progressing simultaneously at the TAPS, GSAC, MAC, and muffler. Mining was conducted using conventional mining techniques (drill and blast), and probe holes were drilled ahead of the working face for early contamination detection. Samples collected from the face of the muffler crosscut indicated a radiation reading of 175 mR/h, and no toxic gases or positive LEL levels. A radiation reading of 60 mR/h was recorded after drift rehabilitation.

From September 1985 through August 1986 a series of hydraulic fracture (HYDRAFAC) holes were drilled in the heading and ribs of the U12n.17 bypass drift. Each HYDRAFAC hole was initially drilled to a four-inch diameter and then sampled to analyze geological conditions and determine residual stresses. Data recorded during this period indicated a normal oxygen level, no toxic gases, no positive LEL levels, and radiation readings less than 2.0 mR/h.

Mining progress was hampered because of the necessity for protective clothing and the reduction of shift work. Mining operations were discontinued in December 1986 to allow for geological studies in the U12n.17 complex.

7.4.3 Postevent Drilling.

No postevent drilling for core samples occurred from the mesa. However, a drilling area was established in the U12n.17 bypass drift on 30 April 1986. Drilling began on 1 May 1986, on the first of two drill holes. Thirteen core samples were taken from the U12n.17 bypass drift reentry (RE) hole No. 1, (at the experimental drift crosscut) between 1010 hours on 1 May 1986 and 2120 hours on 14 May 1986. RE No. 2 was located at the cross section of the TAPS in the U12n.17 main drift. Twenty-nine core samples were collected between 1630 hours on 3 June 1986, and 1425 hours on 18 June 1986. Radiation readings on all core samples were at background levels, and gas sampling indicated no toxic gases or positive LEL levels.

7.4.4 Industrial Safety.

Checks for the presence of toxic gases and surveys to measure radiation and LEL levels were made on each shift. The results were then recorded in the monitors' logbook.

Appropriate safety measures were taken to protect mining personnel and prevent unsafe conditions. Industrial safety codes for mining, tunneling, and drilling were established by REECo and emphasized during all operations. A written standard operating procedure was required for each operation involving explosives, toxic material, radioactive material, or any other operation with the potential for personal injury. Each individual involved in such an operation was required to know the contents of the applicable procedures.

The portal construction area and the tunnel were mandatory hard hat and foot protection areas (safety shoes, boots, DOE-issued miner's boots, or toe guards). All personnel on the initial tunnel reentry teams were certified in the use of the Draegar self-contained breathing apparatus and had used the McCaa two-hour breathing apparatus. Standard safety rules and regulations, as spelled out in the "U.S. Bureau of Mines Manual," were observed.

All explosives, electro-explosive components, solid propellants, toxic materials, and radioactive materials were handled, stored and transported in accordance with applicable sections of the following documents:

1. Army Material Command Regulation (AMCR 385-100)
2. Appropriate DOE Orders in the 5400 and 5600 Series concerning Environmental Protection, Safety & Health Protection, and Defense Programs respectively.
3. Individual safe operating procedures (by experimenter organization).
4. MISTY RAIN Safety Regulations.

All personnel engaged in handling, storing, assembling, or installing explosives, propellants, or electro-explosive devices (or observers of those operations) were require to wear safety glasses or other eye protection which had been approved by the DOD safety coordinator.

7.5 RESULTS AND CONCLUSIONS.

Telemetry measurements began at 1515 hours on 6 April 1985, and several RAMS units became inoperative immediately. The maximum reading on unit number 15 was 1000 R/h at H+11 minutes. This reading decreased rapidly and when all units were secured on 12 April unit number 15 read 0.9 mR/h. All other units indicated background radiation levels.

The initial radiation surveys began at 1652 hours on 6 April 1985, and were completed by 1732 hours that same day. No radiation above background level was detected at the mesa trailer park or at the tunnel portal area. However, remote sampling of the tunnel atmosphere on the WP side of the GSP in the GSP bypass drift showed a radiation reading of 1 R/h; the toxic gas level was 2000 ppm CO with only 15 percent oxygen.

Reentry into the tunnel began at 1404 hours on 10 April 1985. The reentry team, wearing double anticontamination clothing and self-contained breathing apparatus, measured toxic gas levels of 500 ppm CO at the shield wall in the U12n.17 main drift. On 12 April, the reentry team encountered a maximum radiation reading of 10 mR/h inside the door of TC No. 1. The team surveyed the damage in the structural experiment drift before departing the tunnel.

Postevent mining began on 10 April and continued intermittently until December 1986. HYDRAFRAC holes were drilled to analyze geological conditions and determine residual stresses. Normal oxygen levels, no toxic gases or positive LEL levels were indicated, and radiation readings were less than 2.0 mR/h. When these operations ceased in December 1986, geological studies on the sediment formations in the U12n.17 complex were conducted.

Drilling and core sampling in the U12n.17 bypass drift began on 1 May 1986, on the first of two drill holes. Forty-two core samples were taken at the experimental drift crosscut and at the cross section of the TAPS in the U12n.17 main drift. This work was completed on 18 June 1986. Radiation readings on all core samples were at background levels, and gas sampling indicated no toxic gases or positive LEL levels.

Personnel exposure data from self-reading pocket dosimeters were documented on the Area Access Registers during individual entries to MISTY RAIN radex area over a non-continuous time frame from 06 April 1985 to 09 December 1986. Pocket dosimeters showed some indication of possible radiation exposure to DoD-affiliated personnel. Film badges worn by reentry personnel indicated that one individual received some gamma exposure most likely from the MISTY RAIN event. The minimum detectable gamma exposure with the NTS film badge dosimeter was 30 mR.

Area Access Register data are summarized below.

Participants	Entries Logged	Maximum Exposure (mR)	Average Exposure (mR)
All	6,545	175	2.1
DoD	1,413	150	1.1

SECTION 8

REFERENCES

References are not indicated within the text of this report. However, key references are included in this list by section or part. Most unclassified references are available at the DOE/NV Coordination and Information Center (CIC). Security-classified references are located at the DNA/HQ Technical Library in Alexandria, Virginia, but are available only to persons with appropriate security clearances and a need-to-know justification for this information.

The CIC is operated by REECo, the custodian of DoD and DOE nuclear testing personnel dosimetry records and other reference documents on DoD participation in atmospheric, oceanic, and underground nuclear weapons events. Arrangements may be made to review available references for this report at the CIC by contacting one of the following:

Health Protection Division
U.S. Department of Energy
Nevada Field Office
Post Office Box 98515
Las Vegas, NV 89193-8515
(702) 295-0961

or

Coordination and Information Center
Reynolds Electrical & Engineering Co., Inc.
Post Office Box 98521 M/S 548
Las Vegas, NV 89193-8521
(702) 295-0731

Major source documents can also be purchased through the National Technical Information Service (NTIS) listed below:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
(703) 487-4650

References available through public bookstores and libraries, through the U.S. Government Printing Office, and only at the CIC are listed without asterisks. Asterisks after references or groups of references indicate availability as follows:

- *   Available through the NTIS and the CIC.
- **   Located in the REECo Historical Records Center adjacent to the CIC, available through the CIC, and may be subject to Privacy Act restrictions.
- *** Located in the DNA/HQ Technical Library, and subject to security clearance requirements.

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31. REECo Health Protection Department Field Record Archives are maintained chronologically and by event and include the following:

   a. Procedures, Reentry Plans, Radsafe Plans, and Schedules of Events.**

   b. Correspondence.**

   c. Reports, including onsite Radsafe and offsite USEPA event reports.**

   d. Exposure reports, Radsafe logbooks, Area Access Registers, radiation survey forms, telemetry forms, and other sampling and dosimetry forms.**

APPENDIX A

GLOSSARY OF TERMS

Access Drift	A passageway tunnel, usually parallel to the LOS drift, also known as the bypass, cable, reentry, or work drift, also in which cables from various experiments in the LOS pipe were laid on their way to being connected to the downhole cables in the cable alcove, and which was used for access to the main experiment (LOS) drift during construction and recovery phases of a test.
Activation Products	Nuclides made radioactive by neutrons from a nuclear detonation interacting with usually nonradioactive nuclides. Also called "induced activity."
Activity Radioactivity	Decay of radioactive material, usually expressed in disintegrations (of atoms) per minute (dpm).
Advisory Panel	A group of experts formed to advise the Test Manager (and later the Test Controller) concerning operational and safety factors affecting a test detonation.
AFSWC	The Air Force Special Weapons Center, located at Kirtland Air Force Base, Albuquerque, New Mexico. AFSWC provided air support to the AEC Test Manager for NTS testing activities.
AFSWP	The Armed Forces Special Weapons Project was activated on 1 January 1947, when the AEC was activated, to assume residual functions of the U.S. Army Manhattan Engineer District (see DASA).

Air Support	This included aircraft, facilities, and personnel required for various support functions during testing. Included were cloud sampling, and tracking, radiation monitoring, photography, and transport of personnel and equipment.
Alpha Particle	A particle emitted spontaneously from the nucleus of a radionuclide, primarily a heavy radionuclide. The particle is identical to the nucleus of a helium atom, having an atomic mass of four units and an electric charge of two positive units.
Alpine Miner	A continuous mining machine using a moveable boom with rotating cutting head.
Anticontamination Clothing	Outer clothing worn to prevent contamination of personal clothing, contamination of one's body, and the spread of contamination to uncontrolled areas.
Atmospheric Test Series	Series of U.S. nuclear tests conducted from 1945 through 1962, when most nuclear device detonations were conducted in the atmosphere.
Attenuation	The process by which photons or particles emitted by radionuclides are reduced in number or energy while passing through some medium.
Back	The top (ceiling) of a tunnel.
Background Radiation	There are three meanings for this term. The applicable meaning is determined by the context. The definitions are: 1) The radiations of man's natural environment, consisting of cosmic rays and those radiations which come from the naturally radioactive nuclides of

the earth, including those within one's body.

2) A level of radiation (above natural background radiation) that existed in a test area or location prior to a test.

3) Radiation levels extraneous to an experiment (the area exposure rate).

Ballroom	A large alcove in a tunnel used for placement of recording equipment (sometimes referred to as a Dance Hall).
Ball Valve	A rotating valve designed to close off and provide a gas seal in an LOS pipe in less than one second after detonation. It could be pneumatic, hydraulic, or spring driven.
Beta Particle	A negatively charged particle of very small mass emitted from the nucleus of a radionuclide, particularly from fission product radionuclides formed during nuclear detonations. Except for origin, the beta particle is identical to a high-speed electron. This may also be a positively charged particle of equal mass called a positron.
Bypass Drift	See Access Drift.
Bulkhead	Originally a navy term meaning a wall across a ship's hull or a passageway, usually containing a hatch or door. In this context, wall or embankment constructed in a mine or tunnel to protect against earth slides, fire, water, or gas.
Button-Up Activities	Procedures which consist primarily of completing the stemming; accomplishing the

	electrical checklist of tunnel portal and trailer park facilities; closing the OBP, gas seal plug, and gas seal door inside the tunnel; clearing the controlled area; and preparing command post and monitoring stations for the actual nuclear detonation.
Cable Drift	See Access Drift.
Cal-Seal	High-density, high-strength, quick-drying, and resilient commercial sealant.
Cassette	A holder or container for a sample, an experiment, or a group of experiments.
Cavity Invert	See Invert.
Cellar	The excavated, large-diameter initial part of a drilled hole, over which the drill rig is placed and where valving and other equipment are located.
Chamber	A natural or man-made enclosed space or cavity.
Check Points or Check Stations	Geographic locations established and staffed to control entry into and exit from restricted areas.
Chimney	A roughly cylindrical volume of broken rock, formed by the collapse of the overburden. Occurs when decreasing gas pressure in the cavity formed by the nuclear detonation cannot support the weight of the rock.
Chromatograph	A piece of equipment used to analyze mixtures of chemical substances by chromatographic absorption.

Cloud Sampling — The process of collecting particulate and gaseous samples from an effluent cloud to determine the amount of total airborne radioactivity and specific radionuclides in the cloud for subsequent analysis of detonation characteristics. This type of sampling usually was accomplished by specially equipped aircraft.

Cloud Tracking — The process of monitoring and determining the drift or movement of an effluent cloud, usually performed by radiation monitoring and visual sighting from aircraft.

Collar — See "Shaft Collar."

Console — A cabinet or panel containing instrumentation for monitoring or controlling electronic or mechanical measurement devices.

Construction Station — The distance in feet along the tunnel from the portal or a particular junction, usually expressed in hundreds of feet plus remaining whole feet. Construction station 350 is expressed as CS 3+50, or simply station 3+50.

Containment — The act of preventing release of any radioactive effluent into the atmosphere or parts of a tunnel complex beyond the stemming and other containment features. It is used in reference to the stemming, TAPS, OBP, or the gas seal plug. An event is said to have been "contained" if no effluent is released to the atmosphere or if no radioactive material is released underground beyond the stemmed portion of the tunnel.

Containment Assessment Drift — Another name for an access or reentry drift.

Contamination — This is defined in two ways as follows:

1) May refer to the presence of fixed or removable radioactive material at a location. Contamination usually is caused by creation, distribution or contact with fission and activation products from a nuclear detonation or that material incorporated with particles from the test environment or device debris.

2) The term may also refer to the deposition on, or spreading of radioactive materials to undesirable locations, personnel, structures, equipment, or other surfaces outside a controlled area.

Controlled Release — Radioactive gas is passed through a filtering system to remove most particulates before the gas is released into the atmosphere through the tunnel ventilation system.

Crater — This is the depression formed on the earth's surface by a near-surface, surface, or underground detonation. Crater formation can occur by the scouring effect of airblast, by throw-out of broken surface material, or by surface subsidence resulting from underground cavity formation and subsequent rock fall, or chimneying, to the surface.

Crater Experiment — A test designed to breach and excavate the ground surface, thereby forming an ejecta crater (as opposed to a sink or subsidence crater).

DAC — An experiment protection system no longer used. The DNA Auxiliary Closure (DAC) was a system for closing the LOS pipe milli-seconds after device detonation.

Dance Hall	A large alcove used for data recording equipment.
DASA	AFSWP became the Defense Atomic Support Agency (DASA) in 1959. See AFSWP and DNA.
D-Day	The term used to designate the day on which a test takes place.
D+1	The first day after a test event. D+2 is the second day after detonation, D+3 is the third day, etc.
Decontamination	The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination, (2) letting the material stand so that the radioactivity is decreased as a result of radioactive decay, or (3) fixing and covering the contamination to attenuate the radiation emitted.
Device	Nuclear fission (or fission and fusion) materials together with arming, fusing, firing, high-explosive, canister, and diagnostic measurement equipment that have not been configured into an operational weapon.
DNA	An acronym for the Defense Nuclear Agency, successor to DASA in 1971.
DoD	An acronym for the U.S. Department of Defense, the federal executive agency responsible for the defense of the United States. Included in this group are the

military services and special joint defense agencies.

Dose	A quantity of ionizing radiation energy absorbed by a medium. For a person, dose units are in rem or rad.
Dose Rate	An amount of ionizing radiation energy that an individual or material could absorb per unit of time. Dose rates are usually expressed as rad or rem per hour. Subdivisions of a rad or rem also are used, e.g., mrem/h means millirem per hour. (A millirem equals one thousandth of a rem.)
Dosimeter	A device used to measure radiation doses. Devices worn or carried by individuals are called personnel dosimeters.
dpm	Disintegrations per minute, which is a measure of radioactivity.
Draeger Breathing Apparatus	See Scott-Draeger.
Draeger Multi-Gas Detector	An instrument used to detect toxic gases. A sample of the ambient atmosphere is drawn through a selected chemical reagent tube, which indicates the concentration of a particular toxic gas by changing color.
Dressed Out	Personnel dressed in anticontamination clothing and any associated equipment.
Drift	A horizontal or inclined passageway excavated underground. It is used interchangeably with the term "tunnel" at the NTS.
Drill Hole Designations	These are defined as follows: From the surface -

PS-1V: Post-shot drill hole number 1-vertical

PS-1D: Post-shot drill hole number 1-directional

PS-1A: Post-shot drill hole number 1-angle

Each 'S' added after any of the above notations indicates a "sidetrack" or change of direction in the drill hole.

From underground locations sample recovery core holes are referred to as RE (Reentry) No. 1, RE No. 2, etc. ("DNRE" means the reentry hole was DNA requested.)

Dry Run	A rehearsal of the functions occurring in the minutes before and during an event. All timing and firing signals are sent in the proper sequence from the Control Room at CP-1. Each run begins with the first required timing and firing signal (normally minus 15 minutes) and ends with the firing signal. The audio countdown is transmitted over Net 1 (DNA) and on other nets as agreed upon with appropriate agencies. There are various types of dry runs depending on the degree of participation required of the agencies involved.
Effects Experiments	These are experiments with the purpose of studying the effects of a nuclear detonation environment on materials, structures, equipment, and systems. They include measurements of changes in the environment caused by the nuclear detonation, such as ground movement, air pressures (blast), thermal radiation, nuclear radiation, and cratering.
Event	See test.

Exoatmospheric	This refers to the area outside the gaseous mass which envelopes the earth.
Explosimeter	A battery-operated detector calibrated to indicate the concentration in the ambient atmosphere of explosive gases and vapors as a percent of the lower explosive limit (LEL) of hydrogen gas (four percent concentration in air) or methane gas (five percent in air).
Exposure	A measure, expressed in roentgens (R), of ionization produced by gamma or x rays in air. (This may also be represented by subdivisions of R; e.g., 1/1000 R = 1 milliroentgen [mR].)
Exposure Rate	Exposure rate is radiation exposure per unit of time, usually per hour, but it may be stated in smaller or larger units (e.g., R/sec, mR/h, R/day).
Face	The end of a tunnel or other excavation that is being worked to advance the tunnel.
FDR	A successful final dry run (FDR) is the last dry run before a test is detonated.
Film Badge	A dosimeter used for the indirect measurement of exposure to ionizing radiation. It generally contains two or three films of differing sensitivity. Films are wrapped in paper or other thin material that blocks light but is readily penetrated by radiations or secondary charged particles resulting from the radiations to be measured. Film packets generally have at least one metal filter or may be in holders with multiple filters. After being worn as a film badge or film dosimeter, films are developed and the degree of

	darkening (or optical density) measured indicates the radiation exposure. Film dosimeters commonly are used to indicate gamma and x ray exposures, but also can be designed to determine beta and neutron doses.
Fission	The process whereby the nucleus of a particular heavy element splits into (generally) two nuclei of lighter elements, with accompanying release of energy and neutrons. The most important fissionable, or fissile, materials are uranium-235 and plutonium-239. Fission is caused by the absorption of a neutron in the nucleus.
Fission Products	A general term used for the complex mixture of radioactive nuclides (see Radionuclides) produced as a result of nuclear fission.
Fissionable Material	A synonym for fissile material, also extended to include material that can be fissioned by fast neutrons only, such as uranium-238. Used in reactor operations to mean reactor fuel.
Forward Control Point	A geographic location in the forward test area, usually adjacent to the closed (or secured) test area.
Front-End Experiments	Those experiments located in the immediate vicinity of the working point.
Full Power Full Frequency (FPFF) Dry Run	This is similar in intent to a mandatory full participation dry run. The FPFF is sometimes combined with the hot dry run (HDR). This run is optional with the device engineer. When this run is conducted, the LOS pipe is under vacuum, telephones and intercoms are disconnected, and tunnel utility and instrumentation power

are operated in event-day configuration. All instrumentation is hooked up and operated in event-day configuration (simulators are not used).

Fusion — The combination of two very light nuclei (of atoms) to form a relatively heavier nucleus, with an accompanying release of energy, is called fusion. (It also is also known as thermonuclear fusion.)

Gamma Photons — Electromagnetic radiations of high energy that are emitted from the nuclei of radionuclides. These photons are sometimes referred to as bundles of energy, and usually accompany other nuclear reactions, such as fission, neutron capture, and beta particle emission. Gamma photons, or rays, are identical with x rays of the same energy, except that x rays result from orbital electron reactions rather than being produced in the nucleus.

Gamma Shine — This occurs when a measurable gamma radiation intensity from an approaching radioactive cloud or passing cloud is noted, as opposed to measurements from or in gamma emitting fallout. This also includes gamma radiation scattered by air molecules, as opposed to direct radiation from a gamma source.

Gas Blocking — The application of approximately 10 psi of pressure between the Gas Seal Door and the Gas Seal Plug, during button-up procedures as an additional reassurance against low-pressure leaks. Embedding the inner components of cables in epoxy at appropriate locations, such as concrete or epoxy plugs.

Gas Seal Door	A steel door on the portal side of the Gas Seal Plug. It is closed during button up, with about a 10 psi gas pressure applied between the Gas Seal Plug and the Gas Seal Door as an additional reassurance against low-pressure leaks.
Gas Seal Plug	A containment feature within the tunnel complex; generally it is designed for 500°F and 500 psi. The Gas Seal Plug is sometimes referenced as the "hasty plug." This plug is similar to the Overburden Plug, but it is placed closer to the portal and seals off the entire tunnel complex from the portal.
Gate 300	Permanent security station in Area 6 near the Control Point facilities, at which reentry and recovery personnel wait during execution of an event. After reentry parties were released from this gate. They moved to the FCP and again awaited release.
Geiger-Müeller Counter	An instrument consisting of a Geiger-Müeller tube and associated electronic equipment used to detect, display and sometimes record nuclear radiation levels.
Geophone	An instrument used to detect vibrations in rock or soil. At NTS, it is used remotely to detect rock falls, earth movement, and cavity collapse underground. It provides audible signal and visual display data.
Ground Zero	A term used during atmospheric testing to denote a point on the surface of the ground directly below or coinciding with an atmospheric detonation point (see surface ground zero and zero point).

Grout	A cementing or sealing mixture of cement and water to which sand, sawdust, or other fillers may be added. Some organic epoxy compounds are used where high strength or a controlled setting is desired.
H-hour	"Time zero" or the exact time of detonation to the minute, second, or fraction of a second; as opposed to H + 1 which implies one hour after detonation (unless otherwise noted in seconds or minutes).
Hot Line	A location on the edge of a radex area where personnel exiting remove anticontamination clothing and equipment, are monitored for contamination, and are decontaminated as necessary before release. This term also was used to denote the centerline of a fallout pattern.
HYDRAFRAC (Hydraulic Fracture)	Injection of a dye-containing fluid under pressure into rock which causes areas of the rock to open (i.e., crack) allowing the fluid to permeate the rock. The cracks can be traced upon mining into the area.
Invert	The bottom (floor) of a tunnel or other underground excavation (as in cavity invert).
Ion	An atomic particle or part of a molecule bearing an electric charge. Usually a positively charged ion and a negatively charged ion are formed as a pair (e.g., a negatively charged electron is displaced from its positively charged remaining atom).
Ionizing Radiation	This includes any particulate or electromagnetic radiation capable of producing ions, directly or indirectly, in its

passage through air or matter. Alpha and beta particles produce ion pairs directly, while the electrons of initial ion pairs produced by gamma and x rays in turn produce secondary ionization in their paths. Neutrons may displace a positively charged part of a nucleus, such as a proton or alpha particle which produces secondary ionization.

Isotopes	This refers to different types of atoms within the same element, all reacting approximately the same chemically, but differing in atomic weight and nuclear stability. For example, the element hydrogen has three isotopes; normal hydrogen (the most abundant) heavy hydrogen (deuterium), and radioactive hydrogen (tritium).
Keyed Concrete Plug	This refers to a concrete plug placed in an excavated area of greater diameter than the shaft or tunnel cross section such that the concrete is poured into the surrounding rock, thus providing greater strength against overpressure from the nuclear detonation.
Leukemia Cluster	An apparent but unexpected or extraordinary group of leukemia cases within some number or group of persons.
Long Line	The longest air sampling pipe into the tunnel which does not connect to the LOS pipe.
LOS Pipe	An evacuated pipe that extends from the device to the test chambers. It may be either horizontal or vertical, and in it are experiment protection devices and experiments.

Mandatory Full Participation (MFP) Dry Run	This is a dry run peculiar to DoD events. Its purpose is threefold: first, to check all experiments with the event site electrical system in its shot configuration; second, to check for electrical crosstalk between experiments; and third, to operate all recording, timing, and monitoring equipment as closely to shot configuration as is possible. The pipe is under vacuum and the tunnel and portal instrumentation trailers are cleared of personnel. After a successful MFP dry run, all interconnections necessary to place experiments into shot configuration from the MFP configuration are made. Timing, firing, and monitoring system junction boxes are locked and no changes are made except with the express approval of device systems personnel and the Technical Director.
Manhattan Engineer District	The U.S. Army predecessor organization to the U.S. Atomic Energy Commission and the Armed Forces Special Weapons Project.
Manned Stations	Locations inside the closed and secured area which are occupied by authorized personnel during an event.
McCaa 2-Hour Breathing Apparatus	A self-contained respiratory device that supplies two hours of breathing oxygen.
mR	Milliroentgens, a radiation exposure term meaning thousandth of a roentgen (R). (Also, see Exposure.)
mrad/h	A radiation intensity term traditionally used to show that gamma plus beta was being measured.
Mucking	Removal of broken rock from mining operations (also used loosely for drilling operations).

Muffler	An experiment protection component of the HLOS Vacuum System which is designed to break up high-energy flow within the HLOS system.
Noble Gases	Inert gases which do not react with other elements at normal temperature and pressure (i.e., helium, neon, argon, krypton, xenon, and, sometimes, radon).
Nuclear Device (vs. weapon or bomb)	A device in which most of the energy released in a detonation results from reactions of atomic nuclei, either fission, or fission and fusion. A device under development (see Device) is not considered a weapon or bomb. Both A- (or atomic) bombs and H- (or hydrogen) bombs could be called atomic weapons because both involve reactions of atomic nuclei. However, it has become customary to call weapons A-bombs if the energy comes from fission, and H-bombs if most of the energy comes from fusion (of the isotopes of hydrogen or other light nuclides - see definition). A developmental nuclear device is not a weapon or weapon component until it can be mated to a delivery system.
Nuclear Device Tests	Tests carried out to supply information required for the design, improvement, or safety aspects of nuclear weapons, and to study the phenomena and effects associated with nuclear explosions.
Nuclear Weapon Tests	Tests that provide development and weapons effects information, and may or may not utilize a deliverable nuclear weapon.
Offsite	Radiation detected offsite is radioactivity occurring outside the Test Range Complex, an area that includes both the

Nevada Test Site and the adjacent Nellis Air Force Range.

Onsite — A notation that radioactivity was detected onsite only is made for tests from which there was an unplanned release of radioactivity into the atmosphere that was not detectable beyond the boundaries of the Test Range Complex.

Overburden — As used in connection with NTS tunnels, this is the consolidated and unconsolidated rock above a tunnel vertically to the surface; thus, it is the burden of rock over a tunnel.

Overburden Plug — A containment feature within the tunnel complex. It is now a high-strength concrete plug keyed into the tunnel rock near the test location and is generally designed to withstand 1000°F and 1000 psi. It originally was named because it was constructed to represent the same containment strength as the rock above the tunnel, or overburden.

Party Monitors — Radiation (Radsafe) monitors assigned to reentry and recovery parties or groups.

Portal Recording Station — The Portal Recording Station (PRS) is a building located outside of the tunnel where fiber optic cables are terminated and event data is recorded.

ppm — The term parts per million is used when determining concentrations of toxic gases or other materials. It refers to either relative weight, such as micrograms of a material per gram of medium, or relative volume, such as cubic centimeters or milliliters per cubic meter.

Privacy Act	The Privacy Act of 1974 is part of Public Law 93-579. This is an Act to amend Title 5, U.S. Code, by adding Section 552a, which is to safeguard individual privacy from the misuse of federal agency records, to provide that individuals be granted access to records concerning them which are maintained by federal agencies, to establish a Privacy Protection Study Commission, and for other purposes.
rad	An acronym for "radiation absorbed dose," a unit of absorbed dose of ionizing radiation. A dose of one rad means the absorption of 100 ergs of energy from ionizing radiation per gram of absorbing material (e.g., body tissue).
Radex Area	A radiation exclusion (radex) area is any area which is controlled for the purpose of protecting individuals from exposure to radiation and/or radioactive materials.
Radiation Exposure	Exposure to radiation may be described by a number of terms. The type of radiation one is exposed to is important in establishing doses. External exposure can be from beta particles, neutrons, gamma and x rays; internal exposure is received from radionuclides deposited within the body which may emit alpha, beta, gamma, or radiation and irradiate various body organs. (See Dose and Exposure.)
Radioactive Effluent	This includes the radioactive material, steam, smoke, dust, and other particulate or gaseous debris released to the atmosphere from an underground nuclear detonation.

Radioactive or Fission Products	A general term for the complex mixture of radionuclides produced as a result of nuclear fission. (See Activation Products.)
Radionuclides	A collective term for all types of radioactive atoms of various elements, as opposed to stable nuclides. (See Isotopes).
Recovery Operations	Process of finding and removing experiments, by-products, or data from the test area after a test event.
Red Shack	An underground (usually) intermediate point provided for the device laboratory's use in checking out and exercising the arming and firing system.
Reentry Drift	See Access Drift.
rem	An acronym for "roentgen equivalent man or mammal." A rad multiplied by the quality factor (QF) of a particular radiation equals the rem dose. Current QF values are one for x, gamma, and beta radiations, 10 for all neutrons, and 20 for alpha particles.
Rib	This refers to the side of the drift. The right or left rib is determined with one's back to the portal.
Rock Bolting	A method whereby rock bolts (i.e., threaded steel rods) are inserted into a drilled hole to pin the rock to the rib or back to reinforce the tunnel walls. The bolts are driven into the wall perpendicular to the shaft. The ends project far enough for end plates to solidify the structure.
roentgen	A special unit of exposure. It is defined precisely as that quantity of gamma or x rays that, when completely stopped in

air, will produce positive and negative ions with a total charge of 2.58×10^{-4} coulombs in one kilogram of dry air under standard conditions.

Safety Experiments — Device tests conducted to determine the safety of nuclear weapons during transportation and storage. During these tests, elements of the conventional high-explosive portions of the devices were detonated to simulate accidental damage and to determine the potential for this damage to result in significant nuclear yield. Data gained from the tests were used to develop devices that could withstand shock, blast, fire, and other accident conditions without producing a nuclear detonation.

Sandbag Plugs — Barriers that are used in tunnels and are constructed of sandbags to help contain underground detonations and minimize damage to underground workings.

Sandia Auxiliary Closure (SAC) — A device used to seal an HLOS pipe after a nuclear detonation.

Scatterer Station — A point along an LOS pipe where the radiation flux is deflected into an area off the LOS pipe as required for the testing or exposure of scatterer area experiments.

Scientific Station — The distance in feet along the HLOS pipe measured from the zero point. These distances are generally expressed in whole numbers or to the nearest complete hundredths of feet (if fractional). Scientific Station 650 is expressed as SS 6+50; Scientific Station 390.65 is expressed as SS 3+90.65.

Scott-Draeger Self-Contained Breathing Apparatus	This includes a self-contained recirculating unit, complete with "full view" apparatus facepiece, compressed oxygen cylinder, breathing bag, carbon dioxide absorber, and pressure demand regulator. It is used when an extended exposure to an extremely hazardous or oxygen deficient atmosphere, or both, is required. This unit is capable of sustaining the wearer, under normal usage, for four to four and one-half hours; however, pertinent approved schedules limit NTS use to two hours.
Seismic Motion	Earth movement caused by an underground nuclear detonation, similar to that of a minor earthquake.
Shaft	A long narrow passage sunk into the earth, usually vertically, but inclined for some mining operations. Shafts for device emplacement, ventilation, or access to underground workings may be drilled or mined.
Shaft Collar	The area immediately around the shaft at ground level, usually cemented, which supports the headframe and other equipment.
Shielding Walls	Walls or barriers used to protect equipment or instrumentation from heat, blast, and radioactivity.
Slushing Operations	The process of moving broken rock with a scraper or scraper bucket. May be used on the surface or underground, where ore or waste rock is slushed into hoppers or other locations for removal. (See Mucking.)
Spalling	Rock disintegration by evidenced flaking, chipping, peeling, or loosening of layers on the outside edges. It may be caused immediately after detonation by rock

stressing near the detonation point. It also may result later, after continued stressing from temperature change expansion and contraction. Spalling also may result or begin when rock containing moisture is raised to a high temperature and expanding vapor creates fractures.

Stemming	The materials used to back-fill or plug the emplacement shaft, drift, or LOS drift to contain overpressure and radioactive material from a nuclear detonation.
Surface Ground Zero	The location on the ground surface directly above an underground zero point or directly below an airburst.
Survey	In the tunnels, a survey might include taking radiation readings with a portable instrument, checking for the presence of an explosive mixture with an MSA explosimeter or GPK, determining toxic gas levels with Draeger tubes, and/or checking for tunnel hazard and damage (also called a "walkthrough" or "walk-out"). Radsafe personnel made the radiation surveys. Radsafe or industrial hygiene personnel (both in the REECo Environmental Sciences Department) monitored LEL and toxic gas levels, and tunnel mining and construction personnel performed walk throughs usually accompanied by Radsafe and/or industrial hygiene support personnel. (See tunnel walk-out.)
TAPS	The tunnel and pipe seal is an experiment protection feature along the LOS pipe which allows the experiments to be exposed to the desired levels of radiation while being protected from later arriving debris. It contains a massive steel door which closes after ground shock passes to

	form a 1000°F and 1000 psi seal. The TAPS also includes the high-strength concrete plug which surrounds the metallic shroud of the door.
Test	The preparations for, and actual testing of, a nuclear device. This includes arming and firing, detonation, concurrent measurements and effects, and later measurements and studies.
Test Chamber	A section of the LOS pipe in which experiments are placed. It may or may not be enlarged, depending upon the test design.
Test Controller	This person was a DOE official designated by the Manager, Nevada Operations Office, to assume responsibility for the field operations involved in conducting a nuclear test at the Nevada Test Site.
Testing Organizations	Organizations conducting nuclear tests at the NTS (see DoD, DNA, LASL, LLL, and SL).
Thermal Shield Plug	A bulkhead built to close off a drift (usually the LOS pipe drift) that protects equipment and instruments on the portal side of the bulkhead. Construction and containment features of the bulkhead are determined by the nature of the event.
Tonopah Test Range	TTR is located in the northwest corner of Nellis Air Force Range near Tonopah, Nevada.
Trailer Park	Areas near a tunnel portal or on the Mesa where instrumentation or instrumentation support trailers are parked.

Tunnel	At NTS, this refers to a horizontal underground excavation driven on a predetermined line and grade to some specific target.
Tunnel Access	This refers to the entering of a tunnel or tunnel complex upon approval of the Test Controller or Test Director during test operations, or upon approval of the Tunnel Superintendent during routine operations.
Tunnel and Pipe Seal	See TAPS
Tunnel Complex	This includes the complete set of underground workings and support equipment comprising one tunnel test area.
Tunnel Walk-Out	A visual, walking inspection of the tunnel or tunnel complex, usually performed as a part of the initial reentry after a detonation, to check for damage and hazards prior to allowing general access to the underground workings.
Turntube	In the tunnels at the NTS, this refers to a crawlway through a containment barrier (i.e., bulkhead, blast wall, or plug.) After an event, the crawlway is used for access through the barrier until the manway can be opened.
Type N Canisters	These canisters are used with face masks to absorb carbon monoxide.
Underground Structures Program	This refers to the fabrication and construction of test structures underground for the purpose of detonation effects evaluation.
User	Any organization conducting nuclear tests at the NTS. (See Testing Organizations.)

VELA UNIFORM	Department of Defense (DoD) program designed to improve the capability to detect, identify, and locate underground nuclear explosions.
Venting	Release of radioactive material, gases, steam, smoke, dust and other particulate debris through a zone of weakness from the detonation-formed cavity into the atmosphere.
Weapons Effects Experiments	Experiments with the purpose of studying the effects of a nuclear detonation environment on materials, structures, equipment, and systems. They include measurements of the changes in the environment caused by the nuclear detonation, such as ground movement, air pressures (blast), thermal radiation, nuclear radiation, and cratering.
Weather Briefings	A part of the readiness briefings, which are meetings of test-associated administrators, advisors, and other technical personnel prior to each test event for the purpose of evaluating weather conditions and forecasts on event day, and making decisions on any operational schedule changes necessary for safety reasons.
Work Drift	See Access Drift.
Working Point	The location in the emplacement hole centered in the nuclear device.
Workings	An excavation or group of excavations made in mining, quarrying, or tunneling, used chiefly plural, such as "the workings extended for miles underground."
x rays	Electromagnetic radiations produced by orbital electron reactions, as opposed to

emission of gamma photons by nuclei of atoms. Otherwise, x rays are identical with gamma photons of the same energy.

Yield	The total effective energy released by a nuclear detonation. It is usually expressed in terms of equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation (including residual radiation), thermal radiation, and blast and shock energy. Actual distribution depends upon the medium in which the explosion occurs and the type of weapon or nuclear device used.
Zero Point	The location of the center-of-burst of a nuclear device at the instant of detonation. The zero point in tests covered by this volume is always below ground.

APPENDIX B

ABBREVIATIONS AND ACRONYMS

The abbreviations and acronyms in the following list are used in this ninth volume of the DoD UNTPR reports. Additional information and definitions may be found in the text and in the Glossary of Terms.

AA	Agbabian Association
AEC	Atomic Energy Commission
AEC/NVOO	AEC Nevada Operations Office
Aerojet	Aerojet General Corporation
AES	Auxiliary Experiment Station
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
AFWL	Air Force Weapons Laboratory
ALOO	Albuquerque Operations Office
AMC	Army Material Command
ASN	Air Surveillance Network
ASR	Alcove splice rack
AVCO	AVCO Corporation
AWRE	Atomic Weapons Research Establishment
BAC	Boeing Aircraft Corporation
BKG	Background radiation measurement
BMO	Ballistics Missile Office
CAPCo	Corrales Applied Physics Company
CASES	Merritt Cases, Inc.
CC	Crosscut

CCTV	Closed-circuit television
CDC	Centers for Disease Control (formerly the Center for Disease Control)
CEP	Containment Evaluation Panel
CIC	Coordination and Information Center
CO	Carbon monoxide
CORRTEX	Continuous Reflectometry for Radius Time Experiments
CP	Control Point
CP-1	Control Point, Building 1
CP-2	Control Point, Building 2
CTO	Continental Test Organization
DAC	DNA Auxiliary Closure
DASA	Defense Atomic Support Agency
DMA	Division of Military Application
DNA	Defense Nuclear Agency
DNRE	DNA Reentry
DoD	Department of Defense
DOE	Department of Energy
DOE/NV	Department of Energy, Nevada Operations Office
dpm	Disintegrations per minute
DPP	Drift Protection Plug
Draper	C.S. Draper Laboratory
EDAC	Engineering Decision Analysis Company
EG&G	EG&G, Inc. (formerly Edgerton, Germeshausen, and Grier)
EMP	Electromagnetic pulse
EPA	Environmental Protection Agency
ERDA	Energy Research and Development Administration

ES	Experiment Station
ESD	Environmental Sciences Department, REECo
ETI	Effects Technology, Incorporated
F&S	Fenix & Scisson, Inc.
FAC	Fast Auxiliary Closure
FCDASA	Field Command, Defense Atomic Support Agency
FCDNA	Field Command, Defense Nuclear Agency
FCP	Forward Control Point
FCT	Field Command Test
FCTC	Field Command, Test Construction (Division of Test Directorate)
FCTE	Field Command, Test Engineering Division
FCTK	Field Command, Test Containment Division
FCTO	Field Command, Test Operations Division
FCTP	Field Command, Test Plans & Analysis Division
FCTS	Field Command, Test Office of Safety Engineer
FCTT	Field Command, Technical Directors Division
FDPP	Facility Drift Protection Plug
FDR	Final dry run
FPFF	Full-power-full-frequency (dry run)
FWW	Fighter Weapons Wing
GE	General Electric Corporation
GM	Geiger-Müeller
GRC	General Research Corporation
GSAC	Gas Seal Auxiliary Closure
GSD	Gas Seal Door
GSP	Gas Seal Plug
GZ	Ground Zero

H&N	Holmes & Narver, Inc.
HAC	Hughes Aircraft Co.
HDL	Harry Diamond Laboratory
HDR	Hot Dry Run
HE	High explosives (conventional)
HEPA	High-efficiency particulate aerosol
HFR	High Fluence Recoverable
HLOS	Horizontal line-of-sight
HQ, DASA	Headquarters, Defense Atomic Support Agency
HSG	High-strength grout
IRT	Intelcom Rad Tech
ISAFAF	Indian Springs Air Force Auxiliary Field (formerly Indian Springs Air Force Base)
JAYCOR	Jaycor Corporation (derived from J.A. Young Corporation)
JCS	Joint Chiefs of Staff
KAFB	Kirtland Air Force Base
KN	Kaman Nuclear
KOA	Ken O'Brien Associates
KSC	Kaman Sciences Corp. (formerly Kaman Nuclear)
kt	Kilotons
LANL	Los Alamos National Laboratory
LASL	Los Alamos Scientific Laboratory
LEL	Lower explosive limit
LLC	Limited-life components
LLL	Lawrence Livermore Laboratory
LLNL	Lawrence Livermore National Laboratory
LMSC	Lockheed Missile and Space Corporation

LOS	Line-of-sight
LPARL	Lockheed Palo Alto Research Laboratory
LRL	Lawrence Radiation Laboratory
LVFO	Las Vegas Field Office
M&D	MAC and DAC
MAC	Mechanical Auxiliary Closure
MDAC	McDonald Douglas Aircraft Corporation
MDAC	McDonnel Douglas Astronautics Corporation
MDR	Mandatory Dry Run
MED	Manhattan Engineer District
MFP	Mandatory full-participation
MFP/FPPF	Mandatory full-participation/full-power full-frequency
MPC	Maximum permissible concentration
mR	Milliroentgen
mrad	Millirad
MRC	Mission Research Corporation
mrem/qt	Millirem per quarter
mrem/yr	Millirem per year
mR/h	Milliroentgens per hour
MSA	Mine Safety Appliances
MSD	Mandatory Signal Dry Run
MSL	Mean sea level
NAFB	Nellis Air Force Base
NOAA/ARL	National Oceanic and Atmospheric Administration's Air Resources Laboratory
NO_2	Nitrogen dioxide
$NO+NO_2$	Nitric oxide plus nitrogen dioxide

NPG	Nevada Proving Ground
NRDS	Nuclear Rocket Development station
NSC	National Security Council
NTIS	National Technical Information Service
NTS	Nevada Test Site
NTSO	Nevada Test Site Organization
NV	DOE Nevada Operations Office
NVOO	Nevada Operations Office
NWET	Nuclear weapons-effect test
OBP	Overburden Plug
OMA	Office of Military Application
Pan Am	Pan American World Airways
PDT	Pacific Daylight Time
PI	Physics International
ppm	Parts per million
PRS	Portal Recording Station
PS	Postshot
psi	Pounds per square inch
PST	Pacific Standard Time
QF	Quality factor
R&D	Research and development
rad	Radiation absorbed dose
rad/h	Radiation absorbed dose per hour
Radsafe	Environmental Sciences Department (formerly Radiological Safety Department), REECo
radsafe	Radiological safety, in general
RAMP-4	Multichannel, hard-wire linked, remote area gamma monitoring telemetry system

RAMS	Remote area monitoring system
RCG	Radioactivity concentration guide
REECo	Reynolds Electrical & Engineering Company, Inc.
rem	Roentgen equivalent man or mammal
R/h	Roentgens per hour
RMG	Rock-Matching Grout
ROSES	Recorder and Oscilloscope Sealed Environmental System
RPG	Radiation Protection Guide
SAC	Sandia Auxiliary Closure
SAI	Science Applications, Inc. (became Science Applications International Corp., SAIC on 1 August 1984)
SAMSO	Space and Missile Systems Organization
SC	Sandia Corporation
SCBA	Self-Contained Breathing Apparatus
SDR	Signal Dry Run
SFOO	Santa Fe Operations Office
SGEMP	Source Generated Electromagnetic Pulse
SGZ	Surface Ground Zero
SL	Sandia Laboratories
SLA	Sandia Laboratories, Albuquerque
SLG	Superlean Grout
SNL	Sandia National Laboratories
SOP	Standard Operating Procedures
SRD	Secret Restricted Data
SREMP	Source Region Electromagnetic Pulse
SRI	Stanford Research Institute
SRII	Stanford Research Institute International

SSPO	Strategic Systems Project Office (Navy)
SSS	Systems, Science, and Software
STARSAT	Source Generated Electromagnetic Pulse Test, Analysis and Research Satellite
STU	Special Test Unit
TAC	Tactical Air Command
TAPS	Tunnel and Pipe Seal
TC	Test Chamber
TCDASA	Test Command, Defense Atomic Support Agency
TCDNA	Test Command, Defense Nuclear Agency
TEP	Test Evaluation Panel
TGD	Test Group Director
TGS	Test Group Staff
TID	Test Instrumentation Development
TLD	Thermoluminescent dosimeter
TNT	High explosive chemical, (2,4,6-trinitrotoluene)
TOA	Time-of-Arrival
TRI	Technical Representatives, Incorporated
TSP	Thermal Shield Plug
TTR	Tonopah Test Range
UCRL	University of California Radiation Laboratory
USAF	United States Air Force
USGS	United States Geological Survey
VA	Veterans Administration
VLOS	Vertical line-of-sight
WES	Waterways Experiment Station
WETG	Weapons Effects Test Group
WP	Working Point
WSI	Wackenhut Services, Incorporated
WTD	Weapons Test Division

APPENDIX C

U.S. DEPARTMENT OF ENERGY
STANDARD OPERATING PROCEDURE
NEVADA TEST SITE

NTS-SOP-0101

CHAPTER 0101 THE NUCLEAR TEST ORGANIZATION (NTO)

0101.01 GENERAL

011 The Nevada Test Site

The Nevada Test Site (NTS) is a Department of Energy (DOE) facility managed by the Nevada Operations Office (NV). The NTS supports the field test programs of the DOE and its contractors, the Department of Defense (DoD), and others authorized to conduct programs at the NTS.

012 The Nuclear Test Organization (NTO)

The Nuclear Test Organization (NTO) includes DOE, DoD, Laboratory, contractor, agency and organizational personnel who participate in or provide support for test operations at the Nevada Test Site (NTS). The Manager, NV, heads the NTO. (See Appendix A).

0101.02 ORGANIZATIONAL CONCEPT AND POLICIES

021 Nuclear Test Organization (NTO)

The Nuclear Test Organization is a continuing task organization whose composition may be readily changed in response to the needs and technical objectives of the test program.

022 The NV staff, on behalf of the Manager, provides for the approval and coordination of program proposals, approvals for project support, funding and/or authority for financial agreement, legal counsel, contract authority and administration, engineering, accounting, classification and security policy and guidance, safety policy and guidance, environmental safety analyses, industrial relations, and public information policy to the NTO.

023 Test execution shall conform to statutory, regulatory, and other responsibilities in accordance with delegations to the Manager, NV, by the Assistant Secretary for Defense Programs.

024 Technical users are allowed maximum technical latitude in the conduct of their scientific programs and are responsible for their technical readiness.

025 The Manager, NV, has the authority to approve or disapprove the field execution of tests that have been approved by Headquarters, DOE. During the Test Execution Period, authority to proceed with or postpone the field execution of approved activities or tests is delegated to the Test Controller in accordance with his Delegation of Authority from the Manager, NV.

0101.03 RESPONSIBILITIES

031 The Manager, NV, is responsible for administering the NTS, for all preparations required for the safe execution of programs and projects at the NTS and for providing construction and logistic support services and facilities required to support the technical users.

032 NTS Users are assigned areas in which to conduct their operations and exercise technical control subject to operational site coordination and control exercised by the Manager, NV, or, the Test Controller (TC), (during a Test Execution Period).

033 The NTS Planning Board is a permanent board composed of representatives designated by the principal users of the NTS and appointed by the Manager, NV, whose principal function is to assess current and proposed NTS activities with regard to technical impact and economic implications.

034 The Threshold Treaty Review Panel (TTRP) evaluates and validates preshot yield estimates to determine if design estimates are within the limits of the Threshold Test Ban Treaty (TTBT). Postmortem analyses are also evaluated if the post-shot prompt yield measurements data indicate that a threshold breach may have occurred. Reports on these evaluations are made to the Manager, NV.

035 The Containment Evaluation Panel (CEP) evaluates, as an independent agent, the containment design of each proposed nuclear test assuring that all relevant data available for proper evaluation is considered. The Manager, NV, is advised of the findings of the evaluation in order to provide a basis on which he may request detonation authority.

036 The Nuclear Explosive Safety Study and Survey groups conduct safety analyses of all proposed operations involving nuclear explosives and prepare reports for the approval and signature of the Manager, NV, which may contain safety rules, recommendations, and/or approvals of operations.

037 The Test Controller is appointed by the Manager, NV, and is assigned full responsibility for the safe conduct of nuclear tests. The NV Master Schedule of Tests lists the individual scheduled to be Test Controller for each test. In performing his functions, the Test Controller will be supported by the Nuclear Test Organization.

038 The Scientific Advisory Panel is comprised of individuals who have combined expertise in the fields of underground testing phenomenology, meteorology, radiation medicine and other subjects pertaining to the safety of a specific activity. Members of the panel will be selected from a list of candidates which has previously been approved by the Manager, NV. The chairman of the Panel is the scientific advisor nominated by the scientific user and designated by the Manager, NV. The Panel makes recommendations to the Test Controller as to whether the test should proceed or be delayed.

039 The Test Group Directors (TGD) are assigned by the scientific sponsor to direct the fielding and technical aspects of experiments and tests. The TGD reports to the Test Controller on operational matters relating to test execution.

040 The Environmental Protection Agency, Environmental Monitoring Systems Laboratory (EPA/EMSL) provides a member to serve on the Test Controller's Advisory Panel, provides a comprehensive radiological surveillance and safety program in off-site areas surrounding the NTS and conducts a public contact and information program in the off-site area to assure residents that reasonable safeguards are being employed to protect health and property from radiation or other test hazards off-site.

041 The National Oceanic and Atmospheric Administration Weather Service Nuclear Support Office (NOAA/WSNO) provides a member to serve on the Test Controller's Advisory Panel, analyzes data obtained from weather stations and presents pre- and post-shot weather predictions to the Test Controller and his panel.

042 Test Support is provided to DOE and the user organizations by the organizations responsible for technical, construction, M&O, Security, <u>on-site safety</u> and other support as required.

043 The Health Physics Division provides a radiation safety advisor during Test Execution periods, coordinates and resolves rad-safety problems between the technical laboratories and other organizations and assures that the Test Controller is fully advised on radiological matters.

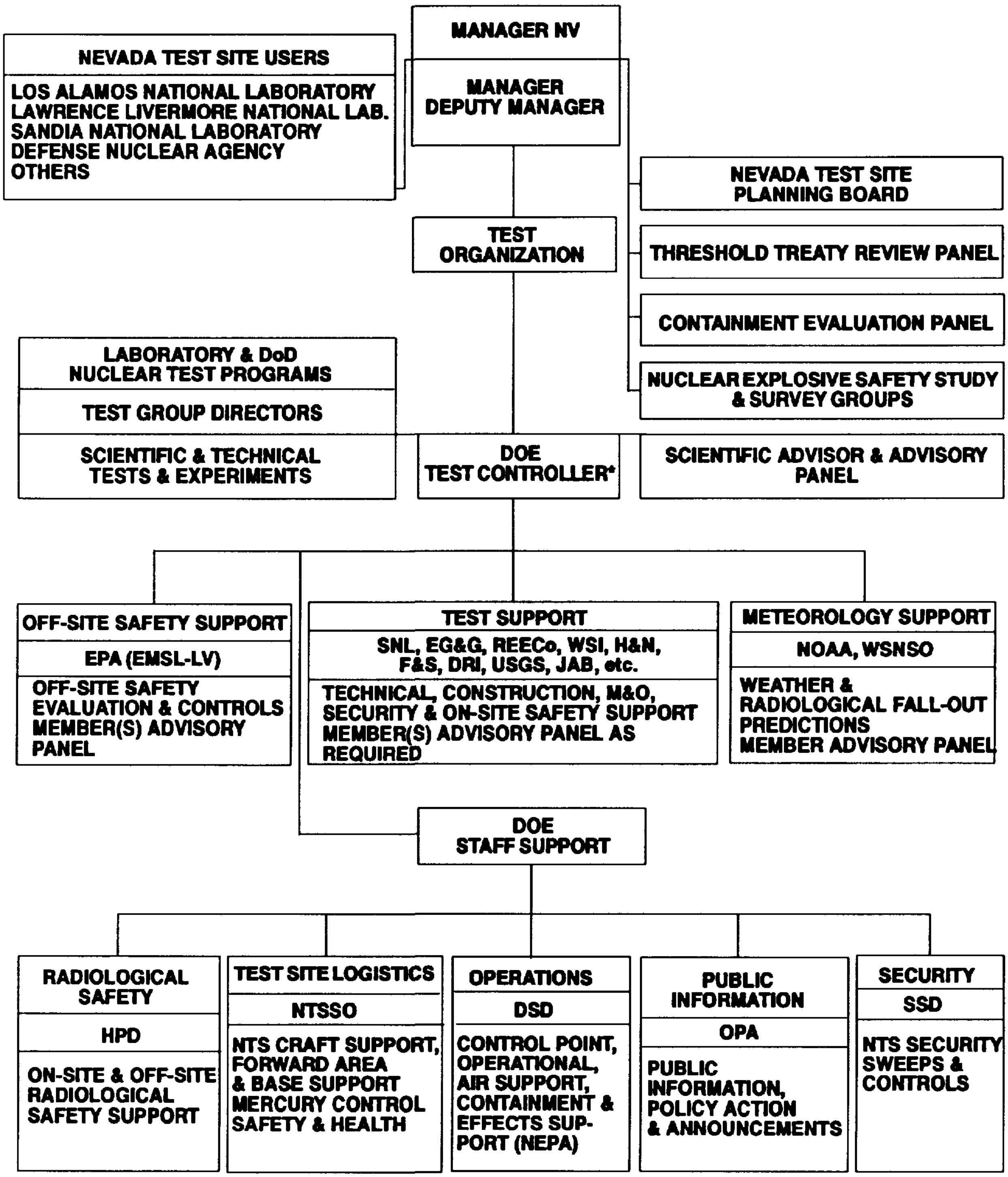
044 The Director, NTSSO, is responsible for the direction and control of construction and logistical support activities at the NTS and, during Test Execution Periods, supports the Test Controller directly in the field execution of experiments and test events.

045 The Director, Operations Support Division, provides for the manning of the Operations Coordination Center and the services of the Test Operations Officer, Test Liaison Officer, Air Operations Officer, and support in the area of containment and effects and assures compliance with the National Environmental Policy Act.

046 The Director, Office of Public Affairs, advises and assists the Test Controller with regard to informational aspects of public safety and public affairs generally, providing management of special projects as assigned.

047 The Director, Safeguards and Security Division, assigns a security advisor to the Test Controller to provide coordination and resolution of security problems between the Test Group Directors, organizations and users in compliance with security policy.

UNITED STATES DEPARTMENT OF ENERGY
NUCLEAR TEST ORGANIZATION



*DESIGNATED FOR EACH TEST OR SPECIAL EXPERIMENT. (ASSUMES OPERATIONAL CONTROL OF NTS DURING TEST OPERATIONAL PERIODS.)

Revised: August 18, 1982
P?691-5

APPENDIX D

U.S. DEPARTMENT OF ENERGY
STANDARD OPERATING PROCEDURE
NEVADA TEST SITE

NTS-SOP-0524

CHAPTER 0524 RADIOLOGICAL SAFETY

0524.01 POLICY

a. Establish radiation protection standards applicable to DOE and DOE contractor operations which are designed to protect the general public, DOE and DOE contractor and user personnel and property.

b. Conduct DOE and DOE contractor operations in such a manner that radiation exposure to individuals is limited to levels as low as reasonably achievable (ALARA).

c. Assure compliance with NVO-232 "Radiation Safety Manual for the Nevada Test Site" published in October 1981, for all NTS operations.

0524.02 OBJECTIVE

The objective of this policy is to assign and delineate radiological safety coordination responsibilities for all activities and operations at the NTS.

0524.03 RESPONSIBILITIES AND AUTHORITIES

031 The Manager, NV, has the overall responsibility for the radiological safety of personnel on the NTS and of the general public for all activities conducted at the NTS; for protection of property, both government and private; and for the application of DOE and NV codes and standards for radiological safety.

032 The Test Controller, as the Manager's representative, is responsible for overall health and safety during test execution periods as defined in NTS-SOP-Appendix 0501, Part 11, relative to the field execution of nuclear tests at the NTS. (See NTS-SOP-0103-02 for Test Controller operational control).

033 The Director, Health Physics Division (HPD), is responsible to the Test Controller during test execution periods and has direct responsibility, at other times to the Manager, NV, through the Assistant Manager for Defense, for radiological safety. The Chief, Coordination Branch, OSD, administers for HPD the delegation and return of the primary radiological safety responsibility within the GZ area to the Laboratory or other Test Group Directors when the device is in the field and during post-shot operations.

034 The Director, Office of Safety and Health (OSH) is responsible to the Manager, NV, for nuclear criticality safety and non-ionizing radiation safety.

035 Reynolds Electrical & Engineering Co., Inc. (REECo) is responsible to the Director, HPD, for radiological safety coordination at all facilities and areas, except when responsibility for such coordination for a specified area has been assigned to another contractor or to a user organization.

036 Test Group Directors and Heads of Participating Test Site User Organizations, Contractor Operations Officials, and Other Groups are responsible to the Manager, NV; to the Test Controller during test operational periods; and to their parent organizations for radiological safety of their employees.

PART I PROCEDURES AND CONTROLS

A. Procedures

Radiological safety procedures for the NTS are listed in NV0-232 "Radiation Safety Manual for the Nevada Test Site" published in October 1981. These procedures are required of all NTS users and are updated on an annual basis.

B. Controls

Assurance of compliance with NTS radiological safety requirements is accomplished by several means:

1. Quarterly contractor CPAF reviews by HPD.

2. Regular other contractor reviews by HPD.

3. Functional and Management appraisals by OSH.

4. Monitoring of laboratories under San Francisco Operations Office (SAN) and Albuquerque Operations Office (AL) Memorandums of Understanding.

PART II DEFINITIONS

A. Test Execution Period. The period of time following the completion of the D-1 Readiness Briefing through the time when initial reentry into the surface ground zero and trailer park is complete, and the Test Controller announces that all work forces may return to normal work areas or as otherwise directed by the Manager, NV.

B. Radiological Safety and Health Coordination requires managerial cognizance of all assigned activities being performed within an assigned area, and the exercise of controls to assure that these activities are conducted in a manner which will either eliminate or reduce the possibility of radiation exposure above reasonably achievable levels.

C. Radiological Safety, as used herein, pertains to ionizing radiation, including X-rays, but excluding nuclear criticality matters. It does not include non-ionizing radiation (e.g., lasers, microwaves, etc.), for which the NV OSH has responsibility.

PART III	STANDARDS
DOE Order 5480.1A	Environmental Protection, Safety and Health Protection Program for DOE operations.
DOE Order 5480.1A Chapter XI	Requirements for Radiation Protection.

PART IV POST-SHOT RADIOLOGICAL, ENVIRONMENTAL CRITERIA AND CONTROL PROCEDURES AT DRILL HOLES, PORTALS AND OTHER LOCATIONS

A. PURPOSE

1. This Appendix establishes radiological environmental criteria and control procedures to minimize radiation exposure of personnel and to preclude the establishment of any new unnecessary radioactive waste disposal areas.

2. The responsibilities and requirements for post-shot cleanup and the handling of contaminated equipment and materials are established within NTS-SOP 0524 and NTS-SOP 8800 to prevent the proliferation of radiation and contamination areas and to provide criteria for the proper posting and surveillance of such areas.

B. CRITERIA

The criteria of Exhibit I to this Appendix for cleanup of all sites have been established in order that each construction location drill hole site and/or tunnel portal will be restored to a radiologically satisfactory condition and properly documented for release of radiological safety delegation and reassignment to NV. It is recognized that some areas at NTS exceed these criteria when area responsibility is delegated. Due to the nature of nuclear testing and drilling operations at NTS, levels not to exceed ten (10) times Exhibit 1 will be permitted. In all cases, cleanup to ALARA shall be conducted.

C. PROCEDURES

1. Radiation and Contamination

Where feasible, all areas shall be cleaned up to the levels specified in Exhibit I. All contaminated muck and debris as well as any clean superficial materials or articles should be removed prior to return to NV unless ongoing programs require their retention. All contaminated materials shall be disposed of in approved waste disposal areas.

C. PROCEDURES (continued)

2. Fencing and Posting

Posting and fencing for radiological protection are unnecessary when Exhibit I criteria have been met. However, if meeting the criteria is not feasible, levels not to exceed ten (10) times Exhibit 1 shall be permitted provided properly marked equipment and materials are fenced and posted and documentation is provided to NV.

Should radiation levels exceed (10) times Exhibit 1 and cleanup to such levels is still not considered feasible, request for special exception may be approved by the Radiological Operations Branch, HPO, NV.

Fences around potential crater sites shall be at a radius 50 percent longer than the radius of the anticipated crater. Fencing around steep-sided collapsed craters will be based on analysis of potential safety hazards. Access roads will be appropriately fenced and barricaded. All fences will consist of two strands of 3/32 inch diameter, 7 x 7, wire rope covered with a high visibility polyvinyl yellow plastic coating, or the equivalent, plus reflectors at road crossings and signs to clearly indicate the status of the area.

3. Inspection

All sites to be returned to NV shall be subject to inspection by Radiological Operations Branch, NV, personnel prior to acceptance on the site by NV. Radiological Operations Branch personnel will also make periodic inspections of all returned sites and recommend the corrective actions or maintenance items required.

D. EXCEPTIONS

Exceptions to these criteria may be made by NV on a case-by-case basis. Requests for exceptions should be directed to the Radiological Operations Branch, HPD, NV.

EXHIBIT 1

CRITERIA 1/

ISOTOPE 2/	REMOVABLE 3/	TOTAL 4/ 5/
U nat, U-235, U-238 Th nat, Th-232, and associated decay products	1,000 dpm α on any 100 cm^2	10,000 dpm α on any 100 cm^2
Other isotopes which decay by alpha emissions or by spontaneous fission	100 dpm α on any 100 cm^2	1,000 dpm α on any 100 cm^2
Beta-gamma emitters (Isotopes with decay modes other than alpha emission or spontaneous fission)	1,000 dpm $\beta\gamma$ on any 100 cm^2	0.4 mrad/hour 6/ at 1 cm from the surface

1/ As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector and count rate meter, for background, efficiency and geometric factors associated with the instrumentation.

2/ Where surface contamination by both alpha and beta-gamma emitting isotopes exists, the limits established for alpha and beta-gamma emitting isotopes shall apply independently.

3/ The amount of removable radioactive material on any 100 cm^2 of surface area shall be determined by wiping the area with dry filter or soft absorbent paper and with the application of moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. In determining the removable contamination on an object of surface area less than 100 cm^2, the pertinent levels shall be reduced proportionately, and the entire surface shall be wiped.

4/ Alternatively, for total contamination one may elect to use an average level one-half of that listed in this column, provided that:

a. The average shall be taken over the total area or 10 square meters, whichever is the lesser; and

b. At no location shall the maximum exceed 2.5 times the level listed in this column. In any event, the entire area must be surveyed.

5/ It is assumed that measurements of total contamination are made with instruments having a sensitive cross-sectional area of 100 cm^2. Measurements made with instruments having more or less than 100 cm^2 of sensitive area may be related to levels proportionately adjusted, or additional measurements may be made on contiguous areas totaling 100 cm^2 and the findings added for comparison with the specified levels.

6/ Measure through not more than a total of 7 milligrams per square centimeter of absorbing material.

PART V X-RAY MACHINE SURVEILLANCE ON THE NTS

A. PURPOSE

This appendix establishes radiological safety procedures for the registration and surveillance of X-ray machines on the NTS.

B. PROCEDURES

1. Register all X-ray machines with REECo/Environmental Sciences Department (ESD) - RAMATROL, Building 180, Mercury.

2. Provide the following information to RAMATROL when registering X-ray machines:

   a. The output of useful beam in R/mA-min at 1m at maximum rated tube potential.

   b. A locking procedure for the X-ray machine to prevent unauthorized or accidental production of radiation.

   c. A program to calibrate radiation survey instruments at three-month intervals, or a program to utilize services of the radiation safety contractor during X-ray operation.

   d. A statement that a Utilization Log, including such items as location, date, radiographer, parameters of use, exposure rate at closest point to source of personnel, etc., will be used.

   e. The identity of each X-ray machine operator with accompanying statement certifying his/her competence.

   f. A description (make and model number, collimation, filtration, maximum voltage (kVp), and maximum amperage for each X-ray machine.

   g. Measurements of leakage rate (not in useful beam) when the X-ray machine is operating at maximum voltage and aximum current.

   h. A documented inspection in compliance with applicable American National Standards Institution (ANSI) standards shall be furnished RAMATROL at least annually for all machines in use at NTS over one year. This inspection shall be performed by the user or, upon request, by RAMATROL.

l. Rem. A unit of dose equivalent. It is a unit found convenient in practice to express exposures to different types of ionizing radiation in terms that combine both the magnitude of the absorbed dose and its biological effectiveness. The dose equivalent is numerically equal to the dose in rads multiplied by the appropriate modifying factors.

m. Exposure Rate or Dose Rate. The time rate at which exposure or dose is measured or administered, i.e., dose or exposure per unit time, such as R/hr, rem/min, rad/hr, R/sec, etc.

0524-04 Radiation Protection Standards

041 Coverage. These standards shall govern ionizing radiation exposure to AEC and AEC contractor personnel and to other individuals who may be exposed to ionizing radiation from operations of the AEC and AEC contractors. These standards do not apply to radiation exposures resulting from natural radiation, medical and dental procedures, nor do they apply to the general population when the activities involved are essential to national security, such as nuclear weapons testing. The latter types of activities are covered by separate criteria. Safety criteria for each Plowshare event will be considered separately until such time as over-all policy for the Plowshare program is established. No operation shall be conducted until the radiological hazard has been evaluated and it has been determined to the satisfaction of the Test Manager, or the Test Group Director (when he has been delegated the radiological safety responsibility for the operation) that radiation exposures should not exceed the radiation protection standards established in AEC Manual Chapter 0524 (repeated below). Except for emergencies, written requests to expose personnel in excess of these limits should be directed to the Test Manager.

I. RADIATION PROTECTION STANDARDS FOR INDIVIDUALS IN CONTROLLED AREAS [1]

A. Radiation from sources external to the body

Type of Exposure	Period of Time	Dose (rem)
Whole body, head and trunk, active blood-forming organs Gonads, or lens of eye.	Accumulated dose	5 (N-18) [2]
	Calendar quarter [3]	3 [4]
	Year	30
Skin of whole body and thyroid	Calendar quarter [3]	10 [4]
	Year	75 [4]
Hands, and forearms, feet and ankles	Calendar quarter [3]	25 [4]

B. Radiation from emitters internal to the body

1. Except as provided in 2. below, the radiation protection standards for airborne radioactivity specified in annex I, table I, shall be followed. The concentration standards are based upon continuous exposure to the concentrations specified for forty hours per week (a "week" being seven consecutive days). For the purpose of applying these standards, radioactivity concentrations may be averaged over periods up to 13 consecutive weeks provided work areas are appropriately monitored and exposure histories are maintained for each individual working in such areas.

2. If it is not feasible to govern exposures to internal emitters by applying airborne radioactivity concentration standards, the following radiation protection standards shall apply:

Type of Exposure	Dose rem/year	Dose rem/quarter
Whole body, active blood-forming organs, gonads.	5	3
Thyroid	30	10
Bone	Body burden of 0.1 microgram of radium-226 or its biological equivalent [5]	–
Other ograns	15	5

The calculation of organ dose shall be based on methods recommended by the Federal Radiation Council and the International Commission on Radiological Protection.

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[1] An individual under age 18 shall not be employed in or allowed to enter controlled areas in such manner that he will receive doses of radiation in amounts exceeding the standards applicable to individuals in uncontrolled areas. Exposures to individuals under age 18 may be averaged over periods not to exceed one calendar quarter.

[2] N equals the age in years at last birthday. An individual employed at age 18 or an individual beyond age 18 who had no accured unused exposure shall not be exposed during the ensuing year to doses exceeding (a) 1.25 rem for the first calendar quarter, (b) 2.5 rem total for the first two calendar quarters, (c) 3.75 rem total for the first three calendar quarters and (d) 5 rem for the year, but in no case will exposure be more than 3 rem per quarter.

[3] A calendar quarter may be taken as a predetermined period of 13 consecutive weeks or any predetermined quarter year based on the calendar.

[4] Personnel monitoring equipment shall be provided to each individual who receives or is likely to receive a dose in any calendar quarter in excess of 10% of these values.

[5] Exposure must be governed such that the individual's body burden does not exceed this value (a) when averaged over any period of 12 consecutive months and (b) after 50 years of occupational exposure.

Revised: February 9, 1968

II. RADIATION PROTECTION STANDARDS FOR INDIVIDUALS AND POPULATION GROUPS IN UNCONTROLLED AREAS

A. Radiation dose standards for external and internal exposure

	Dose (rem/year)	
Type of Exposure	Based on exposure to individuals	Based on an average exposure to a suitable population sample
Whole body, gonads or bone marrow	0.5	0.17
Thyroid or bone	1.5	0.5
Bone (alternate standard)	Body burden of 0.003µg of radium 226 or its biological equivalent.	Body burden of 0.001µg of radium 226 or its biological equivalent.

B. Radioactivity in effluents released to uncontrolled areas

1. Except as provided in 2. below, radioactivity in effluents released to uncontrolled areas shall not exceed the radiation protection standards specified in annex I, table II. The point of release of such effluents shall be considered to be the point at which the effluents pass beyond the site boundary. Where such effluents are discharged through a conduit such as a stack or pipe, the point of release may be considered to be the conduit discharge. For the purpose of applying these standards, radioactivity concentrations in effluents may be averaged over periods up to one year.

2. Radioactivity in effluents may be released to uncontrolled areas in excess of the radiation protection standards specified in annex I, table II, provided it is reasonably demonstrated that in uncontrolled areas:

   (a) individuals are not exposed in excess of the standards specified in A. above.

   (b) individuals are not exposed in excess of annes I, table II standards, or

   (c) the average exposure of a suitable sample of an exposed population group is not in excess of one-third of annex I, table II standards. Radioactivity concentrations in the environment may be averaged over periods up to one year.

3. In any situation in which the contribution to radioactivity in the environment from effluents discharged by one or more activities of the AEC or AEC contractors is likely to result in exposures in excess of the standards specified in II.A. and B. above, lower effluent concentration limits may be set for these Operations. In such cases, the manager of the field office may take the necessary corrective action if all activities concerned are within his area of responsibility. Otherwise, each case will be referred to the Director, Division of Operational Safety, for appropriate action.

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
Actinium (89)	AC 227	S	$2x10^{-12}$	$6x10^{-5}$	$8x10^{-14}$	$2x10^{-6}$
		I	$3x10^{-11}$	$9x10^{-3}$	$9x10^{-13}$	$3x10^{-4}$
	AC 228	S	$8x10^{-8}$	$3x10^{-3}$	$3x10^{-9}$	$9x10^{-5}$
		I	$2x10^{-8}$	$3x10^{-3}$	$6x10^{-10}$	$9x10^{-5}$
Americium (95)	Am 241	S	$6x10^{-12}$	$1x10^{-4}$	$2x10^{-13}$	$4x10^{-6}$
		I	$1x10^{-10}$	$8x10^{-4}$	$4x10^{-12}$	$2x10^{-5}$
	Am 243	S	$6x10^{-12}$	$1x10^{-4}$	$2x10^{-13}$	$4x10^{-6}$
		I	$1x10^{-10}$	$8x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
Antimony	Sb 122	S	$2x10^{-7}$	$8x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$8x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
	Sb 124	S	$2x10^{-7}$	$7x10^{-4}$	$5x10^{-9}$	$2x10^{-5}$
		I	$2x10^{-8}$	$7x10^{-4}$	$7x10^{-10}$	$2x10^{-5}$
	Sb 125	S	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$3x10^{-8}$	$3x10^{-3}$	$9x10^{-10}$	$1x10^{-4}$
Argon (18)	A 37	Sub[2]	$6x10^{-3}$	....	$1x10^{-4}$	....
	A 41	Sub	$2x10^{-6}$	....	$4x10^{-8}$	....
Arsenic (33)	As 73	S	$2x10^{-6}$	$1x10^{-2}$	$7x10^{-8}$	$5x10^{-4}$
		I	$4x10^{-7}$	$1x10^{-2}$	$1x10^{-8}$	$5x10^{-4}$
	As 74	S	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$5x10^{-5}$
		I	$1x10^{-7}$	$2x10^{-3}$	$4x10^{-9}$	$5x10^{-5}$
	As 76	S	$1x10^{-7}$	$6x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$1x10^{-7}$	$6x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$
	As 77	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$8x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$8x10^{-5}$
Astatine (85)	At 211	S	$7x10^{-9}$	$5x10^{-5}$	$2x10^{-10}$	$2x10^{-6}$
		I	$3x10^{-8}$	$2x10^{-3}$	$1x10^{-9}$	$7x10^{-5}$
Barium (56)	Ba 131	S	$1x10^{-6}$	$5x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$4x10^{-7}$	$5x10^{-3}$	$1x10^{-8}$	$2x10^{-4}$
	Ba 140	S	$1x10^{-7}$	$8x10^{-4}$	$4x10^{-9}$	$3x10^{-5}$
		I	$4x10^{-8}$	$7x10^{-4}$	$1x10^{-9}$	$2x10^{-5}$
Berkelium (97)	Bk 249	S	$9x10^{-10}$	$2x10^{-2}$	$3x10^{-11}$	$6x10^{-4}$
		I	$1x10^{-7}$	$2x10^{-2}$	$4x10^{-9}$	$6x10^{-4}$
Beryillium (4)	Be7	S	$6x10^{-6}$	$5x10^{-2}$	$2x10^{-7}$	$2x10^{-3}$
		I	$1x10^{-6}$	$5x10^{-2}$	$4x10^{-8}$	$2x10^{-3}$
Bismuth (83)	Bi 206	S	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
		I	$1x10^{-7}$	$1x10^{-3}$	$5x10^{-9}$	$4x10^{-5}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column 1 Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column 1 Air (μc/ml)	Table II Column 2 Water (μc/ml)
	Bi 207	S	$2x10^{-7}$	$2x10^{-3}$	$6x10^{-9}$	$6x10^{-5}$
		I	$1x10^{-8}$	$2x10^{-3}$	$5x10^{-10}$	$6x10^{-5}$
	Bi 210	S	$6x10^{-9}$	$1x10^{-3}$	$2x10^{-10}$	$4x10^{-5}$
		I	$6x10^{-9}$	$1x10^{-3}$	$2x10^{-10}$	$4x10^{-5}$
	Bi 212	S	$1x10^{-7}$	$1x10^{-2}$	$3x10^{-9}$	$4x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-2}$	$7x10^{-9}$	$4x10^{-4}$
Bromine (35)	Br 82	S	$1x10^{-6}$	$8x10^{-3}$	$4x10^{-8}$	$3x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
Cadmium (48)	Cd 109	S	$5x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
		I	$7x10^{-8}$	$5x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
	Cd 115m	S	$4x10^{-8}$	$7x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
		I	$4x10^{-8}$	$7x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
	Cd 115	S	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$3x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-3}$	$4x10^{-5}$
Calcium (20)	Ca 45	S	$3x10^{-8}$	$3x10^{-4}$	$1x10^{-9}$	$9x10^{-6}$
		I	$1x10^{-7}$	$5x10^{-3}$	$4x10^{-9}$	$2x10^{-4}$
	Ca 47	S	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$5x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$3x10^{-5}$
Californium (98)	Cf 249	S	$2x10^{-12}$	$1x10^{-4}$	$5x10^{-14}$	$4x10^{-6}$
		I	$1x10^{-10}$	$7x10^{-4}$	$3x10^{-12}$	$2x10^{-5}$
	Cf 250	S	$5x10^{-12}$	$4x10^{-4}$	$2x10^{-13}$	$1x10^{-5}$
		I	$1x10^{-10}$	$7x10^{-4}$	$3x10^{-12}$	$3x10^{-5}$
	Cf 252	S	$2x10^{-11}$	$7x10^{-4}$	$7x10^{-13}$	$2x10^{-5}$
		I	$1x10^{-10}$	$7x10^{-4}$	$4x10^{-12}$	$2x10^{-5}$
Carbon (6)	C 14	S	$4x10^{-6}$	$2x10^{-2}$	$1x10^{-7}$	$8x10^{-4}$
	(CO_2)	Sub	$5x10^{-5}$	....	$1x10^{-6}$	....
Cerium (58)	Ce 141	S	$4x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
		I	$2x10^{-7}$	$3x10^{-3}$	$5x10^{-9}$	$9x10^{-5}$
	Ce 143	S	$3x10^{-7}$	$1x10^{-3}$	$9x10^{-9}$	$4x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$7x10^{-9}$	$4x10^{-5}$
	Ce 144	S	$1x10^{-8}$	$3x10^{-4}$	$3x10^{-10}$	$1x10^{-5}$
		I	$6x10^{-9}$	$3x10^{-4}$	$2x10^{-10}$	$1x10^{-5}$
Cesium (55)	Cs 131	S	$1x10^{-5}$	$7x10^{-2}$	$4x10^{-7}$	$2x10^{-3}$
		I	$3x10^{-6}$	$3x10^{-2}$	$1x10^{-7}$	$9x10^{-4}$
	Cs 134m	S	$4x10^{-5}$	$2x10^{-1}$	$1x10^{-6}$	$6x10^{-3}$
		I	$6x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
	Cs 134	S	$4x10^{-8}$	$3x10^{-4}$	$1x10^{-9}$	$9x10^{-6}$
		I	$1x10^{-8}$	$1x10^{-3}$	$4x10^{-10}$	$4x10^{-5}$

See footnotes at end of table.

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
	Cs 135	S	5x10^{-7}	3x10^{-3}	2x10^{-8}	1x10^{-4}
		I	9x10^{-8}	7x10^{-3}	3x10^{-9}	2x10^{-4}
	Cs 136	S	4x10^{-7}	2x10^{-3}	1x10^{-8}	9x10^{-5}
		I	2x10^{-7}	2x10^{-3}	6x10^{-9}	6x10^{-5}
	Cs 137	S	6x10^{-8}	4x10^{-4}	2x10^{-9}	2x10^{-5}
		I	1x10^{-8}	1x10^{-3}	5x10^{-10}	4x10^{-5}
Chiorine (17)	Ci 36	S	4x10^{-7}	2x10^{-3}	1x10^{-8}	8x10^{-5}
		I	2x10^{-8}	2x10^{-3}	8x10^{-10}	6x10^{-5}
	Ci 38	S	3x10^{-6}	1x10^{-2}	9x10^{-8}	4x10^{-4}
		I	2x10^{-6}	1x10^{-2}	7x10^{-8}	4x10^{-4}
Chromium (24)	Cr 51	S	1x10^{-5}	5x10^{-2}	4x10^{-7}	2x10^{-3}
		I	2x10^{-6}	5x10^{-2}	8x10^{-8}	2x10^{-3}
Cobalt (27)	Co 57	S	3x10^{-6}	2x10^{-2}	1x10^{-7}	5x10^{-4}
		I	2x10^{-7}	1x10^{-2}	6x10^{-9}	4x10^{-4}
	Co 58m	S	2x10^{-5}	8x10^{-2}	6x10^{-7}	3x10^{-3}
		I	9x10^{-6}	6x10^{-2}	3x10^{-7}	2x10^{-3}
	Co 58	S	8x10^{-7}	4x10^{-3}	3x10^{-8}	1x10^{-4}
		I	5x10^{-8}	3x10^{-3}	2x10^{-9}	9x10^{-5}
	Co 60	S	3x10^{-7}	1x10^{-3}	1x10^{-8}	5x10^{-5}
		I	9x10^{-9}	1x10^{-3}	3x10^{-10}	3x10^{-5}
Copper (29)	Cu 64	S	2x10^{-6}	1x10^{-2}	7x10^{-8}	3x10^{-4}
		I	1x10^{-6}	6x10^{-3}	4x10^{-8}	2x10^{-4}
Curium (96)	Cm 242	S	1x10^{-10}	7x10^{-4}	4x10^{-12}	2x10^{-5}
		I	2x10^{-10}	7x10^{-4}	6x10^{-12}	3x10^{-5}
	Cm 243	S	6x10^{-12}	1x10^{-4}	2x10^{-13}	5x10^{-6}
		I	1x10^{-10}	7x10^{-4}	3x10^{-12}	2x10^{-5}
	Cm 244	S	9x10^{-12}	2x10^{-4}	3x10^{-13}	7x10^{-6}
		I	1x10^{-10}	8x10^{-4}	3x10^{-12}	3x10^{-5}
	Cm 245	S	5x10^{-12}	1x10^{-4}	2x10^{-13}	4x10^{-6}
		I	1x10^{-10}	8x10^{-4}	4x10^{-12}	3x10^{-5}
	Cm 246	S	5x10^{-12}	1x10^{-4}	2x10^{-13}	4x10^{-6}
		I	1x10^{-10}	8x10^{-4}	4x10^{-12}	3x10^{-5}
Dysprosium (66))	Dy 165	S	3x10^{-6}	1x10^{-2}	9x10^{-8}	4x10^{-4}
		I	2x10^{-6}	1x10^{-2}	7x10^{-8}	4x10^{-4}
	Dy 166	S	2x10^{-7}	1x10^{-3}	8x10^{-9}	4x10^{-5}
		I	2x10^{-7}	1x10^{-3}	7x10^{-9}	4x10^{-5}
Erbium (68)	Er 169	S	6x10^{-7}	3x10^{-3}	2x10^{-8}	9x10^{-5}
		I	4x10^{-7}	3x10^{-3}	1x10^{-8}	9x10^{-5}

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column 1 Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column 1 Air (μc/ml)	Table II Column 2 Water (μc/ml)
	Er 171	S	$7x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Europium (63)	Eu 152	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	(T/2.=9.2 hrs)	I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	Eu 152	S	$1x10^{-8}$	$2x10^{-3}$	$4x10^{-10}$	$8x10^{-5}$
	(T/2=13 yrs)	I	$2x10^{-8}$	$2x10^{-3}$	$6x10^{-10}$	$8x10^{-5}$
	Eu 154	S	$4x10^{-9}$	$6x10^{-4}$	$1x10^{-10}$	$2x10^{-5}$
		I	$7x10^{-9}$	$6x10^{-4}$	$2x10^{-10}$	$2x10^{-5}$
	Eu 155	S	$9x10^{-8}$	$6x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
		I	$7x10^{-8}$	$6x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
Fluorine (9)	F 18	S	$5x10^{-6}$	$2x10^{-2}$	$2x10^{-7}$	$8x10^{-4}$
		I	$3x10^{-6}$	$1x10^{-2}$	$9x10^{-8}$	$5x10^{-4}$
Gadolinium (64)	Gd 153	S	$2x10^{-7}$	$6x10^{-3}$	$8x10^{-9}$	$2x10^{-4}$
		I	$9x10^{-8}$	$6x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
	Gd 159	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$8x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$8x10^{-5}$
Gallium (31)	Ga 72	S	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$4x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
Germanium (32)	Ge 71	S	$1x10^{-5}$	$5x10^{-2}$	$4x10^{-7}$	$2x10^{-3}$
		I	$6x10^{-6}$	$5x10^{-2}$	$2x10^{-7}$	$2x10^{-3}$
Gold (79)	Au 196	S	$1x10^{-6}$	$5x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$6x10^{-7}$	$4x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
	Au 198	S	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$5x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$5x10^{-5}$
	Au 199	S	$1x10^{-6}$	$5x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
Hafnium (72)	Hf 181	S	$4x10^{-8}$	$2x10^{-3}$	$1x10^{-9}$	$7x10^{-5}$
		I	$7x10^{-8}$	$2x10^{-3}$	$3x10^{-9}$	$7x10^{-5}$
Holmium (67)	Ho 166	S	$2x10^{-7}$	$9x10^{-4}$	$7x10^{-9}$	$3x10^{-5}$
		I	$2x10^{-7}$	$9x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
Hydrogen (1)	H3	S	$5x10^{-6}$	$1x10^{-1}$	$2x10^{-7}$	$3x10^{-3}$
		Sub	$2x10^{-3}$	....	$4x10^{-5}$	....
Indium (49)	In 113m	S	$8x10^{-6}$	$4x10^{-2}$	$3x10^{-7}$	$1x10^{-3}$
		I	$7x10^{-6}$	$4x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
	In 114m	S	$1x10^{-7}$	$5x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$2x10^{-8}$	$5x10^{-4}$	$7x10^{-10}$	$2x10^{-5}$
	In 115m	S	$2x10^{-6}$	$1x10^{-2}$	$8x10^{-8}$	$4x10^{-4}$
		I	$2x10^{-6}$	$1x10^{-2}$	$6x10^{-8}$	$4x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
	In 115	S	$2x10^{-7}$	$3x10^{-3}$	$9x10^{-9}$	$9x10^{-5}$
		I	$3x10^{-8}$	$3x10^{-3}$	$1x10^{-9}$	$9x10^{-5}$
Iodine (53)	I 125	S	$5x10^{-9}$	$4x10^{-5}$	$8x10^{-11}$	$2x10^{-7}$
		I	$2x10^{-7}$	$6x10^{-3}$	$1x10^{-9}$	$3x10^{-5}$
	I 129	S	$2x10^{-9}$	$1x10^{-3}$	$2x10^{-11}$	$4x10^{-7}$
		I	$7x10^{-8}$	$6x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
	I 131	S	$9x10^{-9}$	$6x10^{-5}$	$1x10^{-10}$	$3x10^{-7}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	I 132	S	$2x10^{-7}$	$2x10^{-3}$	$3x10^{-9}$	$8x10^{-6}$
		I	$9x10^{-7}$	$5x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
	I 133	S	$3x10^{-8}$	$2x10^{-4}$	$1x10^{-10}$	$7x10^{-6}$
		I	$2x10^{-7}$	$1x10^{-3}$	$7x10^{-9}$	$4x10^{-5}$
	I 134	S	$5x10^{-7}$	$4x10^{-3}$	$2x10^{-9}$	$1x10^{-5}$
		I	$3x10^{-6}$	$2x10^{-2}$	$1x10^{-7}$	$6x10^{-4}$
	I 135	S	$1x10^{-7}$	$7x10^{-4}$	$1x10^{-9}$	$2x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$7x10^{-5}$
Iridium (77)	Ir 190	S	$1x10^{-6}$	$6x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$4x10^{-7}$	$5x10^{-3}$	$1x10^{-8}$	$2x10^{-4}$
	Ir 192	S	$1x10^{-7}$	$1x10^{-3}$	$4x10^{-9}$	$4x10^{-5}$
		I	$3x10^{-8}$	$1x10^{-3}$	$9x10^{-10}$	$4x10^{-5}$
	Ir 194	S	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$3x10^{-5}$
		I	$2x10^{-7}$	$9x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
Iron (26)	Fe 55	S	$9x10^{-7}$	$2x10^{-2}$	$3x10^{-8}$	$8x10^{-4}$
		I	$1x10^{-6}$	$7x10^{-2}$	$3x10^{-8}$	$2x10^{-3}$
	Fe 59	S	$1x10^{-7}$	$2x10^{-3}$	$5x10^{-9}$	$6x10^{-5}$
		I	$5x10^{-8}$	$2x10^{-3}$	$2x10^{-9}$	$5x10^{-5}$
Krypton (36)	Kr 85m	Sub	$6x10^{-6}$	....	$1x10^{-7}$	....
	Kr 85	Sub	$1x10^{-5}$	....	$3x10^{-7}$	....
	Kr 87	Sub	$1x10^{-6}$	....	$2x10^{-8}$	....
Lanthanum (57)	La 140	S	$2x10^{-7}$	$7x10^{-4}$	$5x10^{-9}$	$2x10^{-5}$
		I	$1x10^{-7}$	$7x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
Lead (82)	Pb 203	S	$3x10^{-6}$	$1x10^{-2}$	$9x10^{-8}$	$4x10^{-4}$
		I	$2x10^{-6}$	$1x10^{-2}$	$6x10^{-8}$	$4x10^{-4}$
	Pb 210	S	$1x10^{-10}$	$4x10^{-6}$	$4x10^{-12}$	$1x10^{-7}$
		I	$2x10^{-10}$	$5x10^{-3}$	$8x10^{-12}$	$2x10^{-4}$
	Pb 212	S	$2x10^{-8}$	$6x10^{-4}$	$6x10^{-10}$	$2x10^{-5}$
		I	$2x10^{-8}$	$5x10^{-4}$	$7x10^{-10}$	$2x10^{-5}$

See footnotes at end of table.

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column 1 Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column 1 Air (μc/ml)	Table II Column 2 Water (μc/ml)
Lutetium (71)	Lu 177	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Manganese (25)	Mn 52	S	$2x10^{-7}$	$1x10^{-3}$	$7x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$9x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
	Mn 54	S	$4x10^{-7}$	$4x10^{-3}$	$1x10^{-8}$	$1x10^{-4}$
		I	$4x10^{-8}$	$3x10^{-3}$	$1x10^{-9}$	$1x10^{-4}$
	Mn 56	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Mercury (80)	Hg 197m	S	$7x10^{-7}$	$6x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
		I	$8x10^{-7}$	$5x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
	Hg 197	S	$1x10^{-6}$	$9x10^{-3}$	$4x10^{-8}$	$3x10^{-4}$
		I	$3x10^{-6}$	$1x10^{-2}$	$9x10^{-8}$	$5x10^{-4}$
	Hg 203	S	$7x10^{-8}$	$5x10^{-4}$	$2x10^{-9}$	$2x10^{-5}$
		I	$1x10^{-7}$	$3x10^{-3}$	$4x10^{-9}$	$1x10^{-4}$
Molydbenum (42)	Mo 99	S	$7x10^{-7}$	$5x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-3}$	$7x10^{-9}$	$4x10^{-5}$
Neodymium (60)	Nd 144	S	$8x10^{-11}$	$2x10^{-3}$	$3x10^{-12}$	$7x10^{-5}$
		I	$3x10^{-10}$	$2x10^{-3}$	$1x10^{-11}$	$8x10^{-5}$
	Nd 147	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$2x10^{-7}$	$2x10^{-3}$	$8x10^{-9}$	$6x10^{-5}$
	Nd 149	S	$2x10^{-6}$	$8x10^{-3}$	$6x10^{-8}$	$3x10^{-4}$
		I	$1x10^{-6}$	$8x10^{-3}$	$5x10^{-8}$	$3x10^{-4}$
Neptunium (93)	Np 237	S	$4x10^{-12}$	$9x10^{-5}$	$1x10^{-13}$	$3x10^{-6}$
		I	$1x10^{-10}$	$9x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
	Np 239	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$7x10^{-7}$	$4x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Nickel (28)	Ni 59	S	$5x10^{-7}$	$6x10^{-3}$	$2x10^{-8}$	$2x10^{-4}$
		I	$8x10^{-7}$	$6x10^{-2}$	$3x10^{-8}$	$2x10^{-3}$
	Ni 63	S	$6x10^{-8}$	$6x10^{-4}$	$2x10^{-9}$	$3x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-2}$	$1x10^{-8}$	$7x10^{-4}$
	Ni 65	S	$9x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Nioblum (Columbium) (41)	Nb 93m	S	$1x10^{-7}$	$1x10^{-2}$	$4x10^{-9}$	$4x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-2}$	$5x10^{-9}$	$4x10^{-4}$
	Nb 95	S	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$1x10^{-7}$	$3x10^{-3}$	$3x10^{-9}$	$1x10^{-4}$
	Nb 97	S	$6x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$9x10^{-4}$
		I	$5x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$9x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
Osmium (76)	Os 185	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$7x10^{-5}$
		I	$5x10^{-8}$	$2x10^{-3}$	$2x10^{-9}$	$7x10^{-5}$
	Os 191m	S	$2x10^{-5}$	$7x10^{-2}$	$6x10^{-7}$	$3x10^{-3}$
		I	$9x10^{-6}$	$7x10^{-2}$	$3x10^{-7}$	$2x10^{-3}$
	Os 191	S	$1x10^{-6}$	$5x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$4x10^{-7}$	$5x10^{-3}$	$1x10^{-8}$	$2x10^{-4}$
	Os 193	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$9x10^{-9}$	$5x10^{-5}$
Palladium (46)	Pd 103	S	$1x10^{-6}$	$1x10^{-2}$	$5x10^{-8}$	$3x10^{-4}$
		I	$7x10^{-7}$	$8x10^{-3}$	$3x10^{-8}$	$3x10^{-4}$
	Pd 109	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$7x10^{-5}$
Phosphorus (15)	P 32	S	$7x10^{-8}$	$5x10^{-4}$	$2x10^{-9}$	$2x10^{-5}$
		I	$8x10^{-8}$	$7x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$
Platinum (78)	Pt 191	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
	Pt 193m	S	$7x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
		I	$5x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
	Pt 197m	S	$6x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$1x10^{-3}$
		I	$5x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$9x10^{-4}$
	Pt 197	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Plutonium (94)	Pu 238	S	$2x10^{-12}$	$1x10^{-4}$	$7x10^{-14}$	$5x10^{-6}$
		I	$3x10^{-11}$	$8x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
	Pu 239	S	$2x10^{-12}$	$1x10^{-4}$	$6x10^{-14}$	$5x10^{-6}$
		I	$4x10^{-11}$	$8x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
	Pu 240	S	$2x10^{-12}$	$1x10^{-4}$	$6x10^{-14}$	$5x10^{-6}$
		I	$4x10^{-11}$	$8x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
	Pu 241	S	$9x10^{-11}$	$7x10^{-3}$	$3x10^{-12}$	$2x10^{-4}$
		I	$4x10^{-8}$	$4x10^{-2}$	$1x10^{-9}$	$1x10^{-3}$
	Pu 242	S	$2x10^{-12}$	$1x10^{-4}$	$6x10^{-14}$	$5x10^{-6}$
		I	$4x10^{-11}$	$9x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
Polonium (84)	Po 210	S	$5x10^{-10}$	$2x10^{-5}$	$2x10^{-11}$	$7x10^{-7}$
		I	$2x10^{-10}$	$8x10^{-4}$	$7x10^{-12}$	$3x10^{-5}$
Potassium (19)	K 42	S	$2x10^{-6}$	$9x10^{-3}$	$7x10^{-8}$	$3x10^{-4}$
		I	$1x10^{-7}$	$6x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
Praseodymium (59)	Pr 142	S	$2x10^{-7}$	$9x10^{-4}$	$7x10^{-9}$	$3x10^{-5}$
		I	$2x10^{-7}$	$9x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
	Pr 143	S	$3x10^{-7}$	$1x10^{-3}$	$1x10^{-8}$	$5x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$5x10^{-5}$
Promethium (61)	Pm 147	S	$6x10^{-8}$	$6x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
		I	$1x10^{-7}$	$6x10^{-3}$	$3x10^{-9}$	$2x10^{-4}$
	Pm 149	S	$3x10^{-7}$	$1x10^{-3}$	$1x10^{-8}$	$4x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$4x10^{-5}$
Protoactinium (91)	Pa 230	S	$2x10^{-9}$	$7x10^{-3}$	$6x10^{-11}$	$2x10^{-4}$
		I	$8x10^{-10}$	$7x10^{-3}$	$3x10^{-11}$	$2x10^{-4}$
	Pa 231	S	$1x10^{-12}$	$3x10^{-5}$	$4x10^{-14}$	$9x10^{-7}$
		I	$1x10^{-10}$	$8x10^{-4}$	$4x10^{-12}$	$2x10^{-5}$
	Pa 233	S	$6x10^{-7}$	$4x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$2x10^{-7}$	$3x10^{-3}$	$6x10^{-9}$	$1x10^{-4}$
Radium (88)	Ra 223	S	$2x10^{-9}$	$2x10^{-5}$	$6x10^{-11}$	$7x10^{-7}$
		I	$2x10^{-10}$	$1x10^{-4}$	$8x10^{-12}$	$4x10^{-6}$
	Ra 224	S	$5x10^{-9}$	$7x10^{-5}$	$2x10^{-10}$	$2x10^{-6}$
		I	$7x10^{-10}$	$2x10^{-4}$	$2x10^{-11}$	$5x10^{-6}$
	Ra 226	S	$3x10^{-11}$	$4x10^{-7}$	$3x10^{-12}$	$3x10^{-8}$
		I	$5x10^{-11}$	$9x10^{-4}$	$2x10^{-12}$	$3x10^{-5}$
	Ra 228	S	$7x10^{-11}$	$8x10^{-7}$	$2x10^{-12}$	$3x10^{-8}$
		I	$4x10^{-11}$	$7x10^{-4}$	$1x10^{-12}$	$3x10^{-5}$
Radon (86)	Rn 220	S	$3x10^{-7}$	....	$3x10^{-8}$	....
	Rn 222		$1x10^{-7}$	....	$3x10^{-9}$	....
Rhenium (75)	Re 183	S	$3x10^{-6}$	$2x10^{-2}$	$9x10^{-8}$	$6x10^{-4}$
		I	$2x10^{-7}$	$8x10^{-3}$	$5x10^{-9}$	$3x10^{-4}$
	Re 186	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$5x10^{-5}$
	Re 187	S	$9x10^{-6}$	$7x10^{-2}$	$3x10^{-7}$	$3x10^{-3}$
		I	$5x10^{-7}$	$4x10^{-2}$	$2x10^{-8}$	$2x10^{-3}$
	Re 188	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$2x10^{-7}$	$9x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
Rhodium (45)	Rh 103m	S	$8x10^{-5}$	$4x10^{-1}$	$3x10^{-6}$	$1x10^{-2}$
		I	$6x10^{-5}$	$3x10^{-1}$	$2x10^{-6}$	$1x10^{-2}$
	Rh 105	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Rubidium (37)	Rb 86	S	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$7x10^{-5}$
		I	$7x10^{-8}$	$7x10^{-4}$	$2x10^{-9}$	$2x10^{-5}$
	Rb 87	S	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$7x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
Ruthenium (44)	Ru 97	S	$2x10^{-6}$	$1x10^{-2}$	$8x10^{-8}$	$4x10^{-4}$
		I	$2x10^{-6}$	$1x10^{-2}$	$6x10^{-8}$	$3x10^{-4}$
	Ru 103	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$8x10^{-5}$
		I	$8x10^{-8}$	$2x10^{-3}$	$3x10^{-9}$	$8x10^{-5}$
	Ru 105	S	$7x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
	Ru 106	S	$8x10^{-8}$	$4x10^{-4}$	$3x10^{-9}$	$1x10^{-5}$
		I	$6x10^{-9}$	$3x10^{-4}$	$2x10^{-10}$	$1x10^{-5}$
Samarium (62)	Sm 147	S	$7x10^{-11}$	$2x10^{-3}$	$2x10^{-12}$	$6x10^{-5}$
		I	$3x10^{-10}$	$2x10^{-3}$	$9x10^{-12}$	$7x10^{-5}$
	Sm 151	S	$6x10^{-8}$	$1x10^{-2}$	$2x10^{-9}$	$4x10^{-4}$
		I	$1x10^{-7}$	$1x10^{-2}$	$5x10^{-9}$	$4x10^{-4}$
	Sm 153	S	$5x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$8x10^{-5}$
		I	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$8x10^{-5}$
Scandium (21)	Sc 46	S	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$4x10^{-5}$
		I	$2x10^{-8}$	$1x10^{-3}$	$8x10^{-10}$	$4x10^{-5}$
	Sc 47	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
		I	$5x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$9x10^{-5}$
	Sc 48	S	$2x10^{-7}$	$8x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$8x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
Selenium (34)	Se 75	S	$1x10^{-6}$	$9x10^{-3}$	$4x10^{-8}$	$3x10^{-4}$
		I	$1x10^{-7}$	$8x10^{-3}$	$4x10^{-9}$	$3x10^{-4}$
Silicon (14)	Si 31	S	$6x10^{-6}$	$3x10^{-2}$	$2x10^{-7}$	$9x10^{-4}$
		I	$1x10^{-6}$	$6x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
Silver (47)	Ag 105	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$8x10^{-8}$	$3x10^{-3}$	$3x10^{-9}$	$1x10^{-4}$
	Ag 110m	S	$2x10^{-7}$	$9x10^{-4}$	$7x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-8}$	$9x10^{-4}$	$3x10^{-10}$	$3x10^{-5}$
	Ag 111	S	$3x10^{-7}$	$1x10^{-3}$	$1x10^{-8}$	$4x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$4x10^{-5}$
Sodium (11)	Na 22	S	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
		I	$9x10^{-9}$	$9x10^{-4}$	$3x10^{-10}$	$3x10^{-5}$
	Na 24	S	$1x10^{-6}$	$6x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
		I	$1x10^{-7}$	$8x10^{-4}$	$5x10^{-9}$	$3x10^{-5}$
Strontium (38)	Sr 85m	S	$4x10^{-5}$	$2x10^{-1}$	$1x10^{-6}$	$7x10^{-3}$
		I	$3x10^{-5}$	$2x10^{-1}$	$1x10^{-6}$	$7x10^{-3}$
	Sr 85	S	$2x10^{-7}$	$3x10^{-3}$	$8x10^{-9}$	$1x10^{-4}$
		I	$1x10^{-7}$	$5x10^{-3}$	$4x10^{-9}$	$2x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-*continued*

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column 1 Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column 1 Air (μc/ml)	Table II Column 2 Water (μc/ml)
	Sr 89	S	$3x10^{-8}$	$3x10^{-4}$	$3x10^{-10}$	$3x10^{-6}$
		I	$4x10^{-8}$	$8x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
	Sr 90	S	$3x10^{-10}$	$1x10^{-5}$	$3x10^{-11}$	$3x10^{-7}$
		I	$5x10^{-9}$	$1x10^{-3}$	$2x10^{-10}$	$4x10^{-5}$
	SR 91	S	$4x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$7x10^{-5}$
		I	$3x10^{-7}$	$1x10^{-3}$	$9x10^{-9}$	$5x10^{-5}$
	SR 92	S	$4x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$7x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
Sulfur (16)	S 35	S	$3x10^{-7}$	$2x10^{-3}$	$9x10^{-9}$	$6x10^{-5}$
		I	$3x10^{-7}$	$8x10^{-3}$	$9x10^{-9}$	$3x10^{-4}$
Tantalum (73)	Ta 182	S	$4x10^{-8}$	$1x10^{-3}$	$1x10^{-9}$	$4x10^{-5}$
		I	$2x10^{-8}$	$1x10^{-3}$	$7x10^{-10}$	$4x10^{-5}$
Technetium (43)	Tc 96m	S	$8x10^{-5}$	$4x10^{-1}$	$3x10^{-6}$	$1x10^{-3}$
		I	$3x10^{-5}$	$3x10^{-1}$	$1x10^{-6}$	$1x10^{-2}$
	Tc 96	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-3}$	$8x10^{-9}$	$5x10^{-5}$
	Tc 97m	S	$2x10^{-6}$	$1x10^{-2}$	$8x10^{-8}$	$4x10^{-4}$
		I	$2x10^{-7}$	$5x10^{-3}$	$5x10^{-9}$	$2x10^{-4}$
	Tc 97	S	$1x10^{-5}$	$5x10^{-2}$	$4x10^{-7}$	$2x10^{-3}$
		I	$3x10^{-7}$	$2x10^{-2}$	$1x10^{-8}$	$8x10^{-4}$
	Tc 99m	S	$4x10^{-5}$	$2x10^{-1}$	$1x10^{-6}$	$6x10^{-3}$
		I	$1x10^{-5}$	$8x10^{-2}$	$5x10^{-7}$	$3x10^{-3}$
	Tc 99	S	$2x10^{-6}$	$1x10^{-2}$	$7x10^{-8}$	$3x10^{-4}$
		I	$6x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
Tellurium (52)	Te 125m	S	$4x10^{-7}$	$5x10^{-3}$	$1x10^{-8}$	$2x10^{-4}$
		I	$4x10^{-8}$	$2x10^{-3}$	$1x10^{-9}$	$5x10^{-5}$
	Te 127	S	$2x10^{-6}$	$8x10^{-3}$	$6x10^{-8}$	$3x10^{-4}$
		I	$9x10^{-7}$	$5x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
	Te 129m	S	$8x10^{-8}$	$1x10^{-3}$	$3x10^{-9}$	$3x10^{-5}$
		I	$3x10^{-8}$	$6x10^{-4}$	$1x10^{-9}$	$2x10^{-5}$
	Te 129	S	$5x10^{-6}$	$2x10^{-2}$	$2x10^{-7}$	$8x10^{-4}$
		I	$4x10^{-6}$	$2x10^{-2}$	$1x10^{-7}$	$8x10^{-4}$
	Te 131m	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$2x10^{-7}$	$1x10^{-3}$	$6x10^{-9}$	$4x10^{-5}$
	Te 132	S	$2x10^{-7}$	$9x10^{-4}$	$7x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$6x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$

See footnotes at end of table.

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
Terbium (65)	Tb 160	S	$1x10^{-7}$	$1x10^{-3}$	$3x10^{-9}$	$4x10^{-5}$
		I	$3x10^{-8}$	$1x10^{-3}$	$1x10^{-9}$	$4x10^{-5}$
Thallium (81)	Tl 200	S	$3x10^{-6}$	$1x10^{-2}$	$9x10^{-8}$	$4x10^{-4}$
		I	$1x10^{-6}$	$7x10^{-3}$	$4x10^{-8}$	$2x10^{-4}$
	Tl 201	S	$2x10^{-6}$	$9x10^{-3}$	$7x10^{-8}$	$3x10^{-4}$
		I	$9x10^{-7}$	$5x10^{-3}$	$3x10^{-8}$	$2x10^{-4}$
	Tl 202	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$2x10^{-7}$	$2x10^{-3}$	$8x10^{-9}$	$7x10^{-5}$
	Tl 204	S	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$3x10^{-8}$	$2x10^{-3}$	$9x10^{-10}$	$6x10^{-5}$
Thorium (90)	Th 228	S	$9x10^{-12}$	$2x10^{-4}$	$3x10^{-13}$	$7x10^{-6}$
		I	$6x10^{-12}$	$4x10^{-4}$	$2x10^{-13}$	10^{-5}
	Th 230	S	$2x10^{-12}$	$5x10^{-5}$	$8x10^{-14}$	$2x10^{-6}$
		I	10^{-11}	$9x10^{-4}$	$3x10^{-13}$	$3x10^{-5}$
	Th 232	S	$3x10^{-11}$	$5x10^{-5}$	10^{-12}	$2x10^{-6}$
		I	$3x10^{-11}$	10^{-3}	10^{-12}	$4x10^{-5}$
	Th natural	S	$3x10^{-11}$	$6x10^{-5}$	10^{-12}	10^{-6}
		I	$3x10^{-11}$	$6x10^{-4}$	10^{-12}	10^{-5}
	Th 234	S	$6x10^{-8}$	$5x10^{-4}$	$2x10^{-9}$	$2x10^{-5}$
		I	$3x10^{-8}$	$5x10^{-4}$	10^{-9}	$3x10^{-5}$
Thulium (69)	Tm 170	S	$4x10^{-8}$	$1x10^{-3}$	$1x10^{-9}$	$5x10^{-5}$
		I	$3x10^{-8}$	$1x10^{-3}$	$1x10^{-9}$	$5x10^{-5}$
	Tm 171	S	$1x10^{-7}$	$1x10^{-2}$	$4x10^{-9}$	$5x10^{-4}$
		I	$2x10^{-7}$	$1x10^{-2}$	$8x10^{-9}$	$5x10^{-4}$
Tin (50)	Sn 113	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$9x10^{-5}$
		I	$5x10^{-8}$	$2x10^{-3}$	$2x10^{-9}$	$8x10^{-5}$
	Sn 125	S	$1x10^{-7}$	$5x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$8x10^{-8}$	$5x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$
Tungsten (Wolfram) (74)	W 181	S	$2x10^{-6}$	$1x10^{-2}$	$8x10^{-8}$	$4x10^{-4}$
		I	$1x10^{-7}$	$1x10^{-2}$	$4x10^{-9}$	$3x10^{-4}$
	W 185	S	$8x10^{-7}$	$4x10^{-3}$	$3x10^{-8}$	$1x10^{-4}$
		I	$1x10^{-7}$	$3x10^{-3}$	$4x10^{-9}$	$1x10^{-4}$
	W 187	S	$4x10^{-7}$	$2x10^{-3}$	$2x10^{-8}$	$7x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
Uranium (92)	U 230	S	$3x10^{-10}$	$1x10^{-4}$	$1x10^{-11}$	$5x10^{-6}$
		I	$1x10^{-10}$	$1x10^{-4}$	$4x10^{-12}$	$5x10^{-6}$
	U 232	S	$1x10^{-10}$	$8x10^{-4}$	$3x10^{-12}$	$3x10^{-5}$
		I	$3x10^{-11}$	$8x10^{-4}$	$9x10^{-3}$	$3x10^{-5}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-**continued**

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I		Table II	
			Column I Air (μc/ml)	Column 2 Water (μc/ml)	Column I Air (μc/ml)	Column 2 Water (μc/ml)
	U 233	S	$5x10^{-10}$	$9x10^{-4}$	$2x10^{-11}$	$3x10^{-5}$
		I	$1x10^{-10}$	$9x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
	U 234	S	$6x10^{-10}$	$9x10^{-4}$	$2x10^{-11}$	$3x10^{-5}$
		I	$1x10^{-10}$	$9x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
	U 235	S	$5x10^{-10}$	$8x10^{-4}$	$2x10^{-11}$	$3x10^{-5}$
		I	$1x10^{-10}$	$8x10^{-4}$	$4x10^{-12}$	$3x10^{-5}$
	U 236	S	$6x10^{-10}$	$1x10^{-3}$	$2x10^{-11}$	$3x10^{-5}$
		I	$1x10^{-10}$	$1x10^{-3}$	$4x10^{-12}$	$3x10^{-5}$
	U 238	S	$7x10^{-11}$	$1x10^{-3}$	$3x10^{-12}$	$4x10^{-5}$
		I	$1x10^{-10}$	$1x10^{-3}$	$5x10^{-12}$	$4x10^{-5}$
	U-natural	S	$7x10^{-10}$	$1x10^{-3}$	$3x10^{-12}$	$2x10^{-5}$
		I	$6x10^{-10}$	$1x10^{-3}$	$2x10^{-12}$	$3x10^{-5}$
Vanadium (23)	V 48	S	$2x10^{-7}$	$9x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
		I	$6x10^{-8}$	$8x10^{-4}$	$2x10^{-9}$	$3x10^{-5}$
Xenon (54)	Xe 131m	Sub	$2x10^{-5}$	....	$4x10^{-7}$	....
	Xe 133	Sub	$1x10^{-5}$	....	$3x10^{-7}$	....
	Xe 135	Sub	$4x10^{-6}$	....	$1x10^{-7}$	....
Ytterbium (70)	Yb 175	S	$7x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
		I	$6x10^{-7}$	$3x10^{-3}$	$2x10^{-8}$	$1x10^{-4}$
Yttrium (39)	Y 90	S	$1x10^{-7}$	$6x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$1x10^{-7}$	$6x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$
	Y 91m	S	$2x10^{-5}$	$1x10^{-1}$	$8x10^{-7}$	$3x10^{-3}$
		I	$2x10^{-5}$	$1x10^{-1}$	$6x10^{-7}$	$3x10^{-3}$
	Y 91	S	$4x10^{-8}$	$8x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
		I	$3x10^{-8}$	$8x10^{-4}$	$1x10^{-9}$	$3x10^{-5}$
	Y 92	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	Y 93	S	$2x10^{-7}$	$8x10^{-4}$	$6x10^{-9}$	$3x10^{-5}$
		I	$1x10^{-7}$	$8x10^{-4}$	$5x10^{-9}$	$3x10^{-4}$
Zinc (30)	Zn 65	S	$1x10^{-7}$	$3x10^{-3}$	$4x10^{-9}$	$1x10^{-4}$
		I	$6x10^{-8}$	$5x10^{-3}$	$2x10^{-9}$	$2x10^{-4}$
	Zn 69m	S	$4x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$7x10^{-5}$
		I	$3x10^{-7}$	$2x10^{-3}$	$1x10^{-8}$	$6x10^{-5}$
	Zn 69	S	$7x10^{-6}$	$5x10^{-2}$	$2x10^{-7}$	$2x10^{-3}$
		I	$9x10^{-6}$	$5x10^{-2}$	$3x10^{-7}$	$2x10^{-3}$
Zirconium (40)	Zr 93	S	$1x10^{-7}$	$2x10^{-2}$	$4x10^{-9}$	$8x10^{-4}$
		I	$3x10^{-7}$	$2x10^{-2}$	$1x10^{-8}$	$8x10^{-4}$

See footnotes at end of table.

Revised: February 9, 1968

ANNEX I

CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND-continued

(See notes at end of annex)

Element (atomic number)	Isotope[1]		Table I Column I Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column I Air (μc/ml)	Table II Column 2 Water (μc/ml)
	Zr 95	S	$1x10^{-7}$	$2x10^{-3}$	$4x10^{-9}$	$6x10^{-5}$
		I	$3x10^{-8}$	$2x10^{-3}$	$1x10^{-9}$	$6x10^{-5}$
	Zr 97	S	$1x10^{-7}$	$5x10^{-4}$	$4x10^{-9}$	$2x10^{-5}$
		I	$9x10^{-8}$	$5x10^{-4}$	$3x10^{-9}$	$2x10^{-5}$

[1] Soluble (S); Insoluble (I).
[2] "Sub" means that values given are for submersion in an infinite cloud of gaseous material.

NOTE: In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Annex should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Annex I for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity").

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable MPC's, are MPC_A, and MPC_B, and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$$\frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \frac{C_C}{MPC_C} \leq 1$$

2. If either the identity of the concentration of any radionuclide in the mixture is not know, the limiting values for purposes of Annex I shall be:

a. For purposes of Table I, Col. 1-1 x 10^{-12}
b. For purposes of Table I, Col. 2-3 x 10^{-7}
c. For purposes of Table II, Col. 1-4 x 10^{-14}
d. For purposes of Table II, Col. 2-1 x 10^{-5}

3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known, the concentration limit for the mixture is the limit specified in Annex I for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Annex I are not present in the mixture, the concentration limit for the mixture is the lowest concentration limit specified in Annex I for any radionuclide which is not known to be absent from the mixture; or

Revised: February 9, 1968

c. Element (atomic number)	Table I Column 1 Air (μc/ml)	Table I Column 2 Water (μc/ml)	Table II Column 1 Air (μc/ml)	Table II Column 2 Water (μc/ml)
If it is known that Sr 90, I 129, Pb 210, Po 210, At 211, Ra 23, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, and Th-nat, are not present	....	$9x10^{-5}$	....	$3x10^{-6}$
If it is known that Sr 90, I 129, Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Ra 231, and Th-nat, are not present . . .	....	$6x10^{-5}$	....	$2x10^{-6}$
It it is known that Sr 90, Pb 210, Ra 226, Ra 228, are not present	....	$2x10^{-5}$	....	$6x10^{-7}$
It it is known Ra 226 and Ra 228, are not present	....	$3x10^{-6}$	....	$1x10^{-7}$
It it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present	$3x10^{-9}$	....	$1x10^{-10}$	....
It it is known that alpha-emitters and Pb 210, Ac 227, Ra 228 and Pu 241, are not present	$3x10^{-10}$	....	$1x10^{-11}$	....
If it is known that alpha-emitters and Ac 227 are not present	$3x10^{-11}$	....	$1x10^{-12}$	....
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, and Cf 249, are not present	$3x10^{-12}$	....	$1x10^{-13}$	....
If Pa 231, Pu 239, Pu 240, Pu 242, and Cf 249 are not present	$2x10^{-12}$	....	$7x10^{-14}$	....

4. If the mixture of radionuclides consists of uranium and its daughter products in ore dust prior to chemical processing of the uranium ore, the values specified below may be used in lieu of those determined in accordance with paragraph 1 above or those specified in paragraphs 2 and 3 above.

a. For purposes of Table 1, Col. 1-1 x 10^{-10} μc/ml gross alpha activity; or 2.5 x $^{-11}$ μc/ml natural uranium; or 75 micrograms per cubic meter or air natural uranium.

b. For purposes of Table II, Col. 1-3 x 10^{-11} μc/ml gross alpha activity; or 8 x 10^{-13} μc/ml natural uranium; or 3 micrograms per cubic meter of air natural uranium.

5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_A) to the concentration limit for that radionuclide specified in Table II of Annex I (MPC_A) does not exceed 1/10.

i.e. $$\frac{C_A}{MPC_A} \leq \frac{1}{10}$$

and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed 1/4.

i.e. $$\frac{C_A}{MPC_A} + \frac{C_B}{MPC_B} + \cdots \leq \frac{1}{4}$$

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APPENDIX E

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GENERAL TUNNEL REENTRY PROCEDURES FOR DEFENSE NUCLEAR AGENCY AND SANDIA LABORATORIES NUCLEAR TESTS

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ABSTRACT

Underground weapons effects testing requires that personnel reenter the tunnel complex to recover data and scientific experiments for postshot evaluation. The preparation for and the handling of the hazards encountered during such reentry operations are described.

1-2

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TABLE OF CONTENTS

TABLE OF CONTENTS (cont.)

GENERAL TUNNEL REENTRY PROCEDURES FOR DEFENSE NUCLEAR AGENCY AND SANDIA LABORATORIES NUCLEAR TESTS

Introduction

Detonation of a nuclear device in an underground test facility adds many unique hazards to those existing in any underground construction. Instrumentation which can be remotely monitored can provide a general picture of conditions, but ultimately, personnel, properly protected from the hazards they might encounter, must reenter the tunnel to verify the condition of the facility.

Personnel from the Environmental Health Department of Sandia Laboratories have been participating in tunnel reentries since 1962. During this time experience, improvements in instrumentation, and changes in containment features have caused tunnel reentry procedures to be continually revised. This document describes preshot preparations and postshot procedures currently being used for safe and economical reentry and scientific recovery from a tunnel area.

Responsibilities

Manager, NVOO

The Manager, NVOO, is responsible for administering, preparing, and executing all programs and projects at NTS. He has the overall responsibility for the health and safety of both the general public and NTS personnel for all activities at the NTS. The Manager, NVOO, may delegate operational control of an approved program, project, or experiment to a Test Controller, who is responsible for field execution of that specific program.

Test Controller

The Test Controller has full responsibility during the test execution period for the safe conduct of the program to which he is assigned. By mutual agreement between the Test Controller and a scientific user, control of safety hazards within the area assigned for a particular activity may be delegated to the user's Test Group Director during times other than the test execution period.

Test Group Director

Whenever operational control is delegated to a Test Group Director, he is responsible to the Manager, NVOO, for the establishment and implementation of safety criteria within the assigned area. He will be responsible for submitting a plan for all operation to the Manager, NVOO for review and concurrence. Upon termination of need for the Test Group Director to retain control of the test complex, the Test Group Director will be relieved of safety responsibility.

SLA Environmental Health Department

During the time that the Test Group Director has operational safety responsibility, the Environmental Health Department will provide consultants who will advise the Test Group Director on tunnel reentry procedures (for Sandia and Defense Nuclear Agency sponsored events). These consultants will be familiar with the configuration of the test bed, and with possible postshot tunnel conditions and hazards. They will specify the necessary instrumentation to monitor the postshot conditions of the tunnel and will document any release of radioactive material to the environment. During postshot reentry and recovery operations, they will provide technical direction of radiation safety and industrial hygiene personnel provided by the NTS Support Contractor.

NTS Support Contractor

Reynolds Electrical & Engineering Company (REECo) is responsible for construction and mine safety for all personnel working underground. REECo will provide the personnel necessary for the support of the tunnel reentry and experiment recoveries. This includes mine-rescue-trained mining personnel, radiation safety monitors, and industrial hygiene and industrial safety personnel.

Preshot Preparations for Reentry

Containment

The stemming should contain the fireball and should thus minimize radioactivity and explosive and toxic gases in the experimental area. If the stemming fails, the overburden plug provides a secondary containment barrier. If the gases penetrate the overburden plug, the gas seal plug and/or the gas seal door should contain the gases within the tunnel complex.

Ventilation System

The tunnel ventilation system is set up so that all areas of the tunnel complex can be swept with fresh air from the portal. Valves which can be remotely operated from a manned location are installed in the ventilation and makeup lines in the gas seal door and/or gas seal plug and the overburden plug. The ventilation system utilizes a positive displacement Sutorbilt blower which is installed so that the air from the tunnel complex passes through a filter system before it is released to the atmosphere. Radiation detectors are placed on the ventilation lines to monitor the radioactive effluent released, and continuous samples are taken for isotope identification.

Environmental Instrumentation

Radiation detectors are installed in the tunnel complex to supply tunnel reentry personnel with information about radiation levels in the tunnel. Other types of instrumentation which are used to remotely monitor conditions in the tunnel include geophones and pressure and temperature gauges.

Gas Sampling System

Sampling lines for remotely taking gas samples from various points in the tunnel are installed during preparation of the facility for the test. Samples taken from these lines after test execution help to determine the concentration of explosive and toxic gases in the tunnel prior to reentry. Samples can usually be taken from inside the gas seal door and/or the gas seal plug, from both sides of the overburden plug, from the experiment drift near the stemming, and from the horizontal-line-of-sight (HLOS) pipe itself.

Reentry Communications System

The reentry communications system provides a communications link between the reentry control group in the trailer at the portal and the reentry party in the tunnel. This system consists of (1) a portable reel of WD-7 field wire and (2) a shielded cable, which is permanently installed in the tunnel. Access to this permanent cable is provided at designated locations along the reentry route. Preshot preparations for an event include installation and checkout of the shielded cable used for reentry communications.

Possible Hazards to Reentry Personnel

Radiation

Reentry teams may encounter radioactivity in the tunnel that results from any one or more of the following:

1. Gross failure of the stemming, in which case large quantities of fission products are deposited throughout the tunnel complex. When this condition exists, the team must be concerned with external radiation hazards and with control of contamination.

2. Seepage of radioactive gases or materials through fissures or fractures from ground zero. In this case, external radiation fields are not usually a significant hazard, but contamination control is of primary concern.

3. Activation of experiment samples and components of the HLOS pipe. If sample integrity is maintained after the event, contamination is only a minor problem and external radiation is the major consideration. If the sample contaminant is ruptured and the sample is dispersed throughout the test chamber, contamination control is of primary concern.

Explosive and Toxic Gases

Explosive and toxic gases may be produced as direct or secondary products of the detonation of the device. They may also be produced by the detonation of explosives used in some experimental samples or in HLOS pipe closure systems. These gases may be present in concentrations that are hazardous to personnel.

Tunnel Damage

The ground motion associated with the detonation of the device may cause structural damage to the tunnel. All reentry team members must be alert for unstable overhead conditions, such as hanging slabs and broken timber. They should also watch for broken ventilation lines and utility lines (water, compressed air, electrical cables). Physical damage to the tunnel may at times be such that rehabilitation of the drift must be accomplished before experiment recoveries can be initiated.

Explosives

Explosives are associated with pipe closure and sample protection systems, and may also be present as part of some of the experiments. These explosives, which may still be unexpended after the test, may have been sensitized by the exposure to the device radiation. If the unexpended explosives are contained in experiments in which the sample integrity has been maintained, they do not pose a significant hazard for initial reentry teams. However, team members should be aware of the possibility of unexpended high explosives lying on the bottom of the HLOS pipe.

Toxic Materials

Experiments to be exposed to radiations from the device may contain materials which have some degree of chemical toxicity. In particular, many experiments contain beryllium or have beryllium filters, a portion of which will be present in the postshot environment as finely divided dust. These materials are of concern primarily during postshot recovery of experiments when it is extremely probable that a portion of the dust will become airborne.

High-Pressure Gas Cylinders

Some experiments typically have pressurized gas as an integral part of the experimental system. The gas is usually supplied from high-pressure (2200 psi) gas cylinders which may have been damaged as a result of ground motion or high temperature. Reentry personnel must exercise caution around pressurized systems and will check them to see that the pressure has been bled off.

Reentry Party Composition and Equipment

A team for reentry into a tunnel following a nuclear test shall consist of a minimum of five personnel, one of whom shall be designated as a team chief. He will be responsible for the team during all work underground. All personnel participating as members of initial reentry parties must be certified in the use of USBM* -approved self-contained breathing apparatus. Composition of the reentry parties and their equipment is summarized in Table 1.

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*U.S. Bureau of Mines

TABLE I

Summary of Reentry Parties and Equipment

Party Name	Equipment
<u>Initial Reentry Parties</u>	Full Radex clothing
1. Team Chief	USBM-approved, 2-hour self-contained breathing apparatus
2. Radiation Safety Monitor	Radiation detectors
3. Industrial Hygiene Monitor	Explosimeter
4. Two or More Miners	Toxic gas indicators
	Oxygen detector
	Hard-wire communications
<u>Work Party</u>	Full Radex clothing
1. Team Chief	Respiratory protection (as required)
2. Radiation Safety Monitor	Radiation detectors
3. Industrial Hygiene Monitor	Explosimeter
4. Miners and Support Personnel	Toxic gas indicators
	Oxygen detector
<u>Rescue Team</u>	Full Radex clothing
1. Team Chief	USBM-approved, 2-hour self-contained breathing apparatus
2. Radiation Safety Monitor	Radiation detectors
3. Industrial Hygiene Monitor	Explosimeter
4. Two or More Mine-Rescue Trained Personnel	Toxic gas indicators
	Oxygen detector
	Wire litters
<u>Scientific Assessment Team</u>	Full Radex clothing
1. Team Chief	Respiratory protection (as required)
2. Radiation Safety Monitor	Radiation detectors
3. Industrial Hygiene Monitor	Explosimeter
4. Scientific Advisors	Toxic gas indicators
5. Mine Support Personnel	Oxygen detector

Guidelines for Initial Reentry Parties

Authorization

Initial reentry and each subsequent phase will be initiated upon authorization of the Test Group Director (TGD) with the concurrence of the Test Controller. Operational control will be retained by the TGD until all recovery and reentry mining operations are completed and tunnel access is returned to AEC control.

Activating and Monitoring Tunnel Ventilation System

Tunnel reentry will not start until after the tunnel ventilation system has been activated and samples of tunnel air have been taken and monitored at the portal. Evaluation of these samples must indicate that reentry can be made within the limitations of this procedure.

Reentry Control Group

The reentry control group will normally be composed of an SLA Environmental Health consultant, the TGD or his designated alternate, the tunnel construction engineer or some other person who has an intimate knowledge of tunnel construction details, a REECo Rad-Safe Superintendent, and a senior industrial hygienist. All activities of the reentry party in the tunnel are performed at the direction of this group, and any deviations from the guidelines presented in this procedure are by a consensus of its members. Communications between the reentry control group and the reentry party in the tunnel will be maintained whenever reentry teams are underground. All observations by team members during reentry will be communicated through the team chief to the reentry control group and will be recorded for future reference. Only one team will be in the tunnel at any one time unless otherwise directed by the reentry control group.

Team Limitations

Personnel radiation exposure limits for a reentry operation are 3 rem per calendar quarter (NTSO SOP Chapter 0524). If it is assumed that a person's exposure history would allow an accumulation of 3 rem during the operation, his exposure will be terminated when his pocket dosimeter indicates an accumulated exposure of 2 rem.

Except under extenuating circumstances and by mutual decision of the reentry control group and the team chief, reentry teams will not enter radiation fields greater than 10 R/h, nor will they enter ares in which the concentration of carbon monoxide is greater than 1000 ppm or the concentration of explosive gases is greater than 30 percent of the lower explosive limit (LEL).

Self-Contained Breathing Apparatus

Prior to entry into any potentially hazardous atmosphere, the self-contained breathing apparatus of each team member will be personally checked by the team chief and/or another certified person for proper fit and operation. Malfunctions of the breathing apparatus of any team member shall cause the reentry mission to be aborted.

Emergency Return to Portal

A reentry party will return to the portal as a result of any of the following conditions:

1. On decision of the team chief.

2. When any member of the reentry team has a McCaa oxygen supply less than 30 atmospheres or a Draeger pressure less than 450 psi.

3. On loss of communications with the reentry control group at the portal.

Rescue Team

A rescue team will be stationed near the portal or at the fresh air station underground at all times that reentry teams are in the tunnel. If located at the portal, the rescue team will have a train available for immediate departure. The rescue team will be dispatched only at the direction of the reentry control group and only after it has been determined that the rescue team can conduct its mission safely.

Medical Support

A medical technician with an ambulance and the necessary medical equipment will be available at the portal during initial reentry operations. This medical support will be released only at the direction of the reentry control group.

Summary of Initial Tunnel Reentries

This plan is written as though one team can complete the entire reentry operation. In actual practice, several teams will probably be necessary. As many teams as are needed will be used to complete the tunnel exploration.

Preparation of Tunnel for Reentry

As soon as possible after the event, and with the concurrence of the Test Controller, the tunnel ventilation system will be activated. The tunnel complex will be further prepared for reentry by securing all unnecessary power going into the tunnel. All downhole cables from the mesa trailer park will be disconnected in the cable splice shack and each cable termination will be taped. **CABLES WILL NOT BE CUT WITHOUT SPECIAL AUTHORIZATION FROM THE TEST GROUP DIRECTOR.** All electrical power to the mesa trailer park will be turned off. All instrumentation and utility power cables and telephone lines going into the tunnel from the portal will be disconnected or confirmed to be off. Cables for the tunnel ventilation system, the temperature and pressure monitors, the geophones, and the remote radiation monitoring system will be left connected.

Evaluation of Tunnel Environment

The reentry control group will review the data from the radiation system, the temperature and pressure monitors, the geophones, and the gas samples taken from the tunnel complex to assure that the reentry can be made within the limitations of this procedure. With this assurance, and when cleared by the TGD and the Test Controller, the reentry operation may begin. No changes will be made in the tunnel ventilation system or in any electrical system while reentry teams are underground.

Exploration of Tunnel

The reentry team will enter the tunnel by using a diesel locomotive for transportation and will proceed to the gas seal door. The team will monitor continuously for radioactivity and for toxic and explosive gases. These readings, as well as the progress of the team and the physical condition of the tunnel, will be reported to the reentry control group. Pressure gauges at the gas seal door will be checked, and a gas sample will be taken through the door to determine the environment on the working point side of the door. If conditions are satisfactory, the team will open the gas seal door and proceed to the gas seal plug.

The pressure gauges at the gas seal plug will be checked, and a gas sample will be taken from the working point side of the plug to determine the environment. If ventilation has not been reestablished remotely through this plug, the team will take the necessary steps to establish ventilation through the plug. If conditions permit, the team will then proceed to the overburden plug, where the same procedure will be followed.

After ventilation to the working point side of the overburden plug has been established and it has been determined that explosive and toxic gases are below the reentry guideline concentrations, the team will proceed through the overburden plug and check out the experiment drift complex. Team members will walk to the portal face of the stemming, if possible, monitoring continuously for radioactivity and for toxic and explosive gases. They will also observe the ventilation lines to assure themselves that the lines are intact, and will report this information, along with the general condition of the tunnel and the HLOS pipe, to the reentry control group. After the condition of the tunnel has been determined, the team will establish ventilation to the HLOS pipe. The doors to the test chambers will be opened and swipes will be taken from the floor of the test chambers. These swipes will be analyzed for beryllium and will also be used to identify the radionuclides present inside the HLOS pipe.

As soon as the reentry team has verified that the tunnel complex is within acceptable levels for radiation and for toxic and explosive gases and has determined the physical condition of the tunnel and HLOS pipe, the initial reentry operation is complete.

Scientific Assessment of the Experiments

Scientific Assessment Team

As soon as the initial reentry teams have verified that the tunnel and HLOS pipe are clear of hazardous amounts of radiation and of toxic and explosive gases and as soon as the physical hazards have been identified and repaired, as necessary, the scientific assessment team will enter the HLOS pipe and observe the condition of the experiments.

Photographic Documentation -- Photographic documentation of the condition of each experimental station may take place concurrently with or immediately after preliminary assessment of the experiments.

Removal of Unexpended Explosives -- Unexpended explosives which are found to be uncontained will be removed from the HLOS pipe before experiment recoveries are begun.

Recovery of Experiments From the Test Chambers

Before scientific recoveries may be begun, repair of the tunnel to the test chambers must be complete. This activity may include repairing broken lagging and removing hazardous conditions, as well as repairing railroad track and ventilation lines. Tunnel utility power will be restored before experiment recoveries (except for recovery of film) are begun.

After tunnel repairs have been completed, experiment agencies will be permitted to begin recovery of samples from the test chambers in order of priority. A radiation safety monitor will be present at the test chambers at all times to assist the experimenters and to help control contamination.

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