DNA 6018F

SHOTS
ENCORE TO CLIMAX
The Final Four Tests of the UPSHOT-KNOTHOLE Series 8 MAY - 4 JUNE 1953

United States Atmospheric Nuclear Weapons Tests
Nuclear Test Personnel Review

Prepared by the Defense Nuclear Agency as Executive Agency
for the Department of Defense

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UPSHOT-KNOTHOLE	CLIMAX	Exercise Desert Rock V	Radiation Exposure
ENCORE	AFSWC		Radiological Safety
GRABLE	Field Command	Decontamination	Ionizing Radiation
AFSWP	Military Effects Group	AEC	
HARRY		Dosimetry	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the activities of DOD personnel, both civilian and military, in Shots ENCORE, HARRY, GRABLE, and CLIMAX, the final four shots of the UPSHOT-KNOTHOLE atmospheric nuclear weapons tests series conducted between 8 May and 4 June 1953. These tests involved participants from Exercise Desert Rock V, AFSWP, AFSWC, AEC nuclear weapons design laboratories, and the Civil Effects Group. This volume also describes the radiological safety activities at each of these four shots.

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PREFACE

Between 1945 and 1962, the United States Government, through the Manhattan Engineer District and its successor agency, the Atomic Energy Commission (AEC), conducted 235 atmospheric nuclear weapons tests at sites in the southwestern United States and in the Pacific and Atlantic Oceans. In all, an estimated 220,000 Department of Defense participants, both military and civilian, were present at the tests. Of these, approximately 90,000 participated at the atmospheric nuclear weapons tests conducted at the Nevada Proving Ground (NPG),* northwest of Las Vegas, Nevada.

In 1977, 15 years after the last above-ground weapons test, the Center for Disease Control+ noted a possible leukemia cluster among a small group of soldiers at Shot SMOKY, one test of Operation PLUMBBOB, the test series conducted in 1957. Since that initial report by the Center for Disease Control, the Veterans Administration has received a number of claims for medical benefits from former military personnel who believe their health may have been affected by their participation in atmospheric nuclear weapons tests.

In late 1977, the Department of Defense (DOD) began a study which provided data to both the Center for Disease Control and the Veterans Administration on potential exposures to ionizing

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*Renamed the Nevada Test Site in 1955.

+The Center for Disease Control is an agency of the U.S. Department of Health and Human Services (formerly the U.S. Department of Health, Education, and Welfare).

radiation among its military and civilian personnel who participated in the atmospheric nuclear weapons tests. DOD organized an effort to:

- Identify DOD personnel who had taken part in the atmospheric nuclear weapons tests
- Determine the extent of the participants' exposure to ionizing radiation
- Provide public disclosure of information concerning participation by DOD personnel in the atmospheric nuclear weapons tests.

This report concerns the final four tests of UPSHOT-KNOTHOLE: Shots ENCORE, HARRY, GRABLE, and CLIMAX. It is based on the military and technical documents associated with the atmospheric nuclear weapons tests.

METHODS AND SOURCES USED TO PREPARE THIS DOCUMENT

Many of the documents pertaining specifically to DOD involvement in the final four UPSHOT-KNOTHOLE events were found in the Defense Nuclear Agency Technical Library, the Department of Energy Nevada Operations Office, the Los Alamos National Laboratory,* and the Modern Military Branch of the National Archives.

In most cases, the surviving historical documentation of activities conducted at Shots ENCORE, HARRY, GRABLE, and CLIMAX addresses test specifications and technical information, rather than the personnel data critical to the study undertaken by the Department of Defense. The available historical documentation sometimes has inconsistencies in vital facts. Efforts have been made to resolve these inconsistencies wherever possible or to bring them to the attention of the reader.

*Formerly the Los Alamos Scientific Laboratory (LASL)

To facilitate the use of references, this report uses weapons test report titles for each project. All yield information presented in this report is taken from the Department of Energy, Announced United States Nuclear Tests, July 1945 through 1979 (NVO-209). Other data on the tests, concerning fallout patterns, meteorological conditions, and cloud dimensions, are taken from DNA 1251-1, Compilation of Local Fallout Data from Test Detonations 1945-1962, volume 1, except in instances where more specific information is available elsewhere.

For several of the Exercise Desert Rock and test organization projects discussed in this volume, the only documents available are the Sixth Army Desert Rock operation orders and the Test Director's Schedule of Events from "Operation Order 1-53." These sources detail the plans developed by DOD and AEC personnel. Although some of the after-action documents, such as the weapons test reports for AFSWP, summarize the projects performed during the UPSHOT-KNOTHOLE Series, they do not always supply shot-specific information. In the absence of shot-specific after-action reports, projects are described according to the way they were planned. The references indicate whether the description of activities is based on the schedule of events, operation orders, or after-action reports.

ORGANIZATION AND CONTENT OF UPSHOT-KNOTHOLE SERIES REPORTS

This volume details participation by DOD personnel in the final four events of the Operation UPSHOT-KNOTHOLE atmospheric nuclear weapons testing series. Four other publications address DOD activities during the UPSHOT-KNOTHOLE Series:

- Series volume: Operation UPSHOT-KNOTHOLE, Atmospheric Nuclear Weapons Tests, 1953
- Multi-shot volume: Shots ANNIE to RAY, the Early UPSHOT-KNOTHOLE Tests

- Shot volume: Shot BADGER
- Shot volume: Shot SIMON.

The volumes addressing the test events of Operation UPSHOT-KNOTHOLE have been designed to complement one another. The series volume describes those dimensions of UPSHOT-KNOTHOLE which transcend specific events, such as historical background, organizational relationships, and radiological safety procedures. In addition, it discusses the overall objectives of the operation, describes the geographic layout of the NPG, and contains a bibliography of works consulted in the preparation of all five Operation UPSHOT-KNOTHOLE reports. The shot volumes and the multi-shot volumes, on the other hand, contain none of this general information on Operation UPSHOT-KNOTHOLE.

The two single-shot volumes describe DOD participation in Shots BADGER and SIMON, and the multi-shot volumes combine shot-specific descriptions of the other nuclear events in the UPSHOT-KNOTHOLE Series. Descriptions of activities at any particular shot in the UPSHOT-KNOTHOLE Series, whether the shot is addressed in a single-shot volume or in a multi-shot volume, may be supplemented by the general organizational and radiological safety information contained in the Operation UPSHOT-KNOTHOLE volume.

Chapter 1 of this volume describes the physical setting and general characteristics of the final UPSHOT-KNOTHOLE test events and briefly introduces the Desert Rock maneuvers and those JTO diagnostic and scientific activities in which DOD personnel participated. The remaining four chapters address the final UPSHOT-KNOTHOLE tests in turn. Each chapter describes the specific setting and characteristics of one detonation, details DOD personnel activities in the scientific, diagnostic, technical, and training projects sponsored by the Joint Test Organization and Exercise Desert Rock V, and discusses the steps taken to minimize exposures to ionizing radiation. Details of

the overall radiation protection program at Operation UPSHOT-KNOTHOLE are provided in the series volume.

The information in this report is supplemented by the Reference Manual: Background Materials for the CONUS Volumes. This volume summarizes basic radiation physics, radiological health concepts, exposure criteria, and measurement techniques and includes a listing of acronyms and terms used in the DOD reports documenting the events in the continental United States.

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LIST OF ABBREVIATIONS AND ACRONYMS

The following abbreviations and acronyms are used in this volume:

AEC	Atomic Energy Commission
AFB	Air Force Base
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
BCT	Battalion Combat Team
BJY	BUSTER-JANGLE "Y"
CONUS	Continental United States
DOD	Department of Defense
EG&G	Edgerton, Germeshausen, and Grier, Incorporated
FCDA	Federal Civil Defense Administration
HumRRO	Human Resources Office
IBDA	Indirect Bomb Damage Assessment
JTO	Joint Test Organization
LASL	Los Alamos Scientific Laboratory
NPG	Nevada Proving Ground
R/h	Roentgen per hour
SAC	Strategic Air Command
TAC	Tactical Air Command
UTM	Universal Transverse Mercator
2d MCPAEB	2d Marine Corps Provisional Atomic Exercise Brigade

CHAPTER 1

INTRODUCTION

Shots ENCORE, HARRY, GRABLE, and CLIMAX were tests of nuclear devices conducted from 8 May through 4 June 1953 at the Nevada Proving Ground, the U.S. Atomic Energy Commission continental nuclear test site located northwest of Las Vegas. The shots were the final four nuclear detonations of Operation UPSHOT-KNOTHOLE, the series of atmospheric nuclear weapons tests performed from 17 March through 4 June 1953.

Table 1-1 presents a summary of these four nuclear tests, including information on the dates of detonation, the UTM* coordinates of the points of detonation, the types of detonation, the heights of burst, and the explosive yields. Figure 1-1 displays a map of the NPG in 1953, showing the positions of all of the UPSHOT-KNOTHOLE tests (43; 56).+

The four nuclear devices were developed for the Atomic Energy Commission by the Los Alamos Scientific Laboratory, one of two AEC nuclear weapons development laboratories. The primary objective of the HARRY and CLIMAX shots, which were weapons development tests, was to evaluate the nuclear yield and the blast, thermal, and radiation phenomena produced by the

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*Universal Transverse Mercator (UTM) coordinates are used in this report. The first three digits refer to a point on an east-west axis, and the second three refer to a point on a north-south axis. The point so designated is the southwest corner of an area 100 meters square.

+All sources cited in the text are listed alphabetically and numbered in the Reference List, appended to this volume. The number given in the text is the number of the source document in the Reference List.

Table 1-1: SUMMARY OF THE FINAL FOUR OPERATION UPSHOT-KNOTHOLE EVENTS (1953)

Shot	ENCORE	HARRY	GRABLE	CLIMAX
Sponsor	DOD-LASL	LASL	DOD-LASL	LASL
Planned Date	7 May	2 May	21 May	31 May
Actual Date	8 May	19 May	25 May	4 June
Local Time*	0830	0505	0830	0415
NPG Location	Area 5	Area 3	Area 5	Area 7
UTM Coordinates	956726	867996	956728	872048
Type	Aircraft	Tower	280mm Gun	Aircraft
Height of Burst (feet)†	2,423	300	524	1,334
Yield (kt)	27	32	15	61

*Pacific Daylight Time

†Altitudes are measured from mean sea level, while heights are measured from the ground. All vertical distances are given in feet.

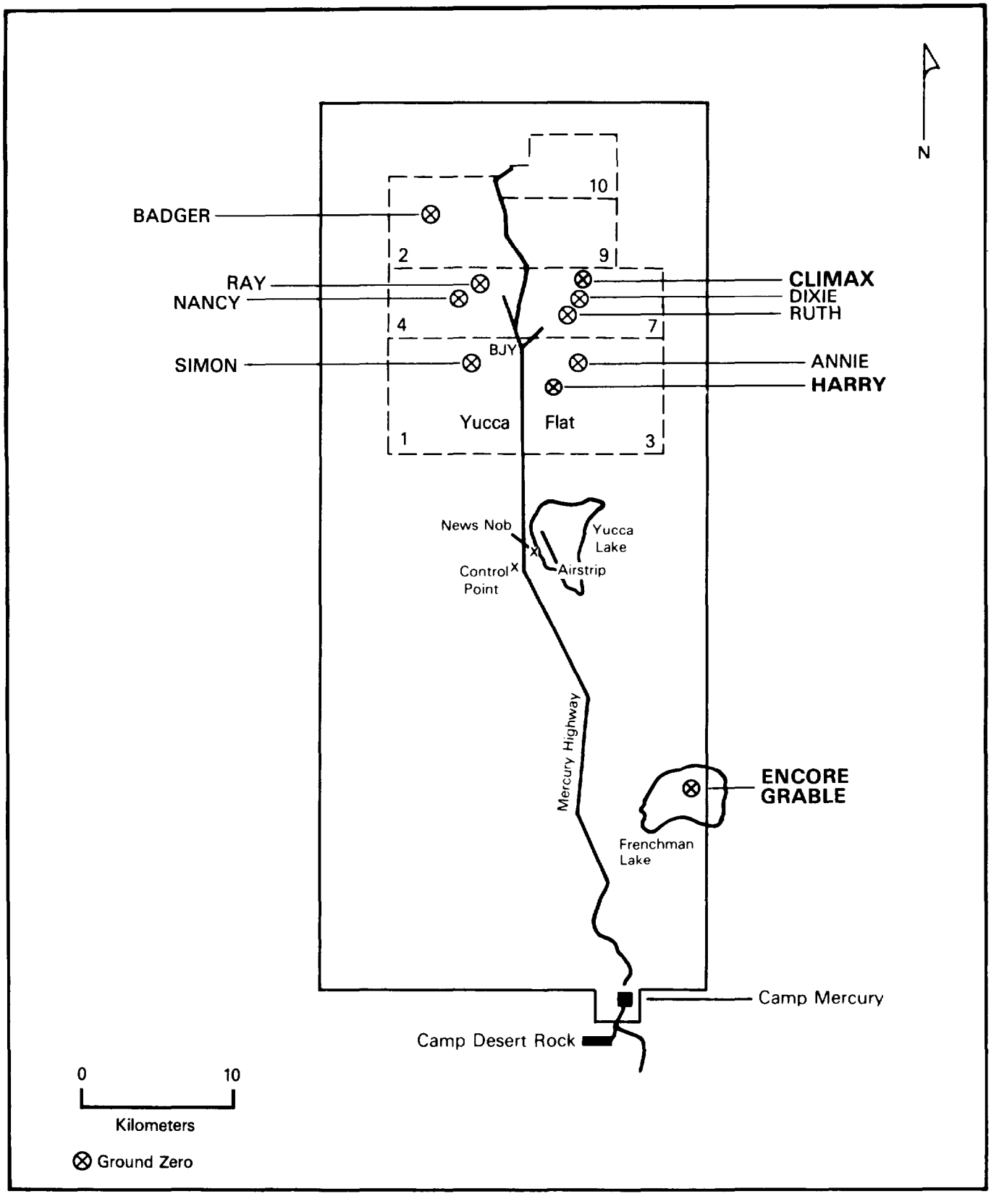

Figure 1-1: NEVADA PROVING GROUND SHOWING GROUND ZEROS FOR OPERATION UPSHOT-KNOTHOLE

devices. The ENCORE and GRABLE weapons, taken from the U.S. nuclear stockpile, were tested to provide information on weapon outputs such as blast for full-scale military effects tests. These two nuclear detonations also provided the opportunity for military personnel to participate in a variety of field exercises and training programs related to nuclear warfare (64).

1.1 DEPARTMENT OF DEFENSE PARTICIPATION AT THE FINAL FOUR UPSHOT-KNOTHOLE EVENTS

Department of Defense personnel took part in three types of activity during Shots ENCORE, HARRY, GRABLE, and CLIMAX: scientific experiments, military technical and training projects, and support services. Numerous scientific and diagnostic experiments were conducted at the last four UPSHOT-KNOTHOLE events by the Weapons Development Group, the Military Effects Group, and the Civil Effects Group. Armed services personnel on temporary assignment from stations throughout the country took part in the military training programs associated with Exercise Desert Rock V. The Test Manager reviewed and approved these activities to ensure coordination with the AEC and the test groups mentioned above.

The Weapons Development Group, comprising scientists from the Los Alamos Scientific Laboratory, the University of California Radiation Laboratory, and the Sandia Corporation, performed diagnostic tests of the nuclear devices by measuring characteristics of the detonation. The Military Effects Group of the Armed Forces Special Weapons Project (AFSWP) fielded projects to evaluate the utility of the four nuclear devices for military applications. The Federal Civil Defense Administration (FCDA) Civil Effects Group also conducted projects to assess the effects of nuclear detonations on civilian structures, products, and food supplies, and to evaluate civil emergency preparedness plans.

At the two military effects tests, Shots ENCORE and GRABLE, the AFSWP Military Effects Group conducted numerous projects. With the exception of Project 3.30, the Program 3 projects were conducted only at these two shots. Three of the projects were designed to provide instrumentation for the other projects of Program 3. Participants in these three projects placed and retrieved equipment and data for projects at Shots ENCORE and GRABLE. These personnel usually retrieved all data and equipment for all of the projects for which they provided instruments. In this way, fewer personnel were needed for recovery operations (84-85; 119).

DOD personnel also took part in Exercise Desert Rock V, part of the Armed Forces' continuing program to train personnel in the use and effects of nuclear weapons and test battlefield doctrine and tactics. The majority of DOD personnel involved in Shots ENCORE, HARRY, and GRABLE were participants in Exercise Desert Rock V. During these three shots, over 7,200 DOD personnel participated in four Desert Rock programs: orientation and indoctrination, tactical troop maneuvers at Shots ENCORE and GRABLE, operational helicopter tests at Shots ENCORE and HARRY, and damage effects tests. There were no Desert Rock activities at Shot CLIMAX (37; 45; 64).

A variety of support services were required by Desert Rock and test group personnel, as well as by the Test Manager, who was responsible for the execution of the tests. Approximately 2,000 soldiers from various Army units maintained and operated Camp Desert Rock, an installation of the U.S. Sixth Army. These individuals administered Exercise Desert Rock V activities and performed various services. Some of the support troops worked in the forward areas of the NPG to construct observer trenches, lay communication lines, provide transportation and security, and assist in other preparations for Desert Rock activities (65).

Soldiers of the 50th Chemical Service Platoon served as radiological safety monitors for Exercise Desert Rock participants following each detonation (64).

The Air Force Special Weapons Center (AFSWC) provided air support to the Test Manager and to various test group projects, in addition to conducting test activities of its own. AFSWC had operational control for all participating aircraft, performed the airdrops for Shots ENCORE and CLIMAX, and provided cloud-sampling, cloud-tracking, courier, aerial survey missions, and air transportation services (38; 51; 123).

During Operation UPSHOT-KNOTHOLE, the Joint Test Organization (JTO) coordinated all activities. Composed of personnel from the AEC, DOD, and FCDA, the JTO was administered by the Test Manager, assisted by a Test Director (37). The UPSHOT-KNOTHOLE Series volume includes a detailed description of their duties, as well as the functions of the Joint Test Organization.

1.2 RADIATION PROTECTION PROCEDURES DURING THE FINAL FOUR UPSHOT-KNOTHOLE EVENTS

In carrying out their tasks, DOD participants followed the radiation protection procedures established to minimize exposure to ionizing radiation while still allowing participants to accomplish their missions.

The AEC Division of Biology and Medicine established exposure limits for JTO participants, including test group and AFSWP personnel. Test Group participants were to receive no more than 3.9 roentgens of radiation exposure per 13-week period, or for the entire operation (39).

To help implement this criterion, radiological safety personnel controlled access to contaminated areas. Within two or

three hours before each detonation, the test area was closed to all personnel except those with special authorization to enter. These personnel included the timing and firing party at Shot HARRY, the Artillery Test Unit at GRABLE, Desert Rock personnel, and personnel who manned stations for some of the Weapons Development and Military Effects projects. Personnel manning project stations were required to be at a distance from ground zero that was deemed safe by the Test Director and to have at least two vehicles and good communications equipment. The only aircraft in the air until after the detonation were the drop aircraft at ENCORE and CLIMAX and any aircraft that were authorized to be in the area for project purposes. Immediately after each detonation, the shot areas were closed until radiological safety personnel, both on the ground and in the air, had surveyed the area and set up checkpoints. Some of the time-sensitive projects required that personnel enter the area to recover experiments or data as soon after a shot as possible. These parties were authorized to enter shot areas with the radiological safety groups. They wore anticontamination clothing and were accompanied by monitors who kept them informed of radiation conditions.

When the initial radiation intensities had been plotted on maps at the Control Point, recovery personnel were briefed on the radiological environment and given access permits. All personnel entered the shot area at designated checkpoints. Radiological safety monitors accompanied project personnel recovering test instruments from radiation areas. The monitors, who continuously monitored the radiation intensity in the recovery area, kept the participants informed of the radiological environment. The 9778th Radiological Safety Support Unit issued film badges for project personnel to wear at all times in the test area. These film badges were collected, processed, and evaluated at regular intervals, and any individual whose accumulated dose exceeded the established limits was barred from further participation in

project activities in the forward area. Although evacuation was not required during UPSHOT-KNOTHOLE, emergency evacuation procedures were prepared for all test events.

The radiation protection procedures authorized for AFSWC by the Test Manager included the same cumulative exposure limit of 3.9 roentgens of gamma radiation for air and ground crews as that established for the test group personnel. Complete decontamination, including showers and exchanges of clothing, was required of all aircrew members following each project mission, regardless of the exposure received on the flight. Aircraft were either decontaminated by washing or were isolated until radiation intensities decayed to predetermined levels.

Radiation protection procedures for Exercise Desert Rock V participants, like those of the test groups and AFSWC, were designed to minimize potential exposure to ionizing radiation. Camp Desert Rock personnel and exercise participants were limited to no more than 6.0 roentgens of whole-body gamma radiation during any six-month period.

SHOT ENCORE SYNOPSIS

AEC TEST SERIES:	UPSHOT-KNOTHOLE
DOD EXERCISE:	Desert Rock V
DATE/TIME:	8 May 1953, 0830 hours
YIELD:	27 kilotons
HEIGHT OF BURST:	2,423 feet (airdrop)

AEC Objective: To evaluate the nuclear yield, blast, thermal, and radiological phenomena produced by this weapon.

DOD Objective: To evaluate military equipment, tactics, and doctrine; to measure weapons effects characteristics and evaluate the military applications of the weapon; and to train personnel in the tactical use of a nuclear weapon.

Weather: At shot-time, the winds at surface level were from the south at five knots. Winds at 10,000 feet were from the west at 12 knots. At all levels above 10,000 feet, the winds were from the west-southwest, at 57 knots at 20,000 feet, 103 knots at 30,000 feet, and 146 knots at 40,000 feet. At the surface, the temperature was 16.7°C, the relative humidity was 19 percent, and the pressure was 900 millibars.

Radiation Data: The radiation intensity measured at ground zero 30 minutes after the detonation was 0.3 R/h.* An intensity no greater than 0.1 R/h extended about 400 meters from ground zero.

Participants: Exercise Desert Rock V, Armed Forces Special Weapons Project, Air Force Special Weapons Center, Los Alamos Scientific Laboratory, Federal Civil Defense Administration, contractors.

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*Roentgens per hour

CHAPTER 2

SHOT ENCORE

Shot ENCORE was an airdropped nuclear weapon, detonated with a yield of 27 kilotons at 0830 hours on 8 May 1953. ENCORE was originally planned as the ninth test of the series but became the eighth test when Shot HARRY was postponed. The detonation of ENCORE, scheduled for 7 May, was postponed for 24 hours because of adverse winds (13).

An AFSWC B-50 from the 4925th Test Group (Atomic), based at Kirtland Air Force Base (AFB), New Mexico, delivered the ENCORE weapon, which detonated at a height of 2,423 feet* above Frenchman Flat, UTM coordinates 956726. The B-50 flew several practice runs before beginning the actual bombing run, which it made at an altitude of 22,000 feet, at an azimuth of 245 degrees, and at a speed of 250 knots. In the last few seconds before bomb release, a mechanical linkage failure in the bombing system allowed the aircraft to drift off course. The bomb released at the instant the bombardier flipped the switch to disable the bombing system. As a result, the bomb missed the target by 250 meters.+ The time of fall to detonation was 33.6 seconds (45; 51).

While the predicted path of the cloud resulting from Shot ENCORE was due east into the northern parts of Arizona and New Mexico, the cloud actually drifted northeast into Utah. The bottom of the cloud reached 29,000 feet, and the top attained an altitude of 42,000 feet (56).

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*Vertical distances are given in feet. Altitudes are measured from mean sea level, and heights are measured from ground level.

+Throughout this report, surface distances are given in metric units. The metric conversion factors include: 1 meter = 3.28 feet; 1 meter = 1.09 yards; and 1 kilometer = 0.62 miles.

2.1 EXERCISE DESERT ROCK V OPERATIONS AT SHOT ENCORE

More than 3,000 exercise troops and observers participated in Desert Rock V programs at Shot ENCORE. An additional 300 Camp Desert Rock support troops provided radiological safety, transportation, communications, and control functions for the exercises in the forward areas. A total of 532 military personnel took part in the troop orientation and indoctrination program. The tactical troop maneuvers were conducted by 2,149 Army troops and 326 Air Force personnel. During Operation UPSHOT-KNOTHOLE, Air Force personnel participated in troop maneuvers only during ENCORE. An estimated 12 Marines took part in the operational helicopter tests (37).

Personnel from Army Field Forces Human Research Unit No. 2 from the Human Resources Research Office (HumRRO) were also present at Shot ENCORE to investigate the psychological reactions of these troops to the detonation. These research personnel conducted studies at all shots where provisional Battalion Combat Teams (BCTs) participated. At ENCORE, the HumRRO personnel studied the reactions of two companies of airborne troops before and after the shot (57; 64; 127).

Table 2-1 provides information on the Desert Rock V programs at ENCORE by indicating the number of DOD participants in each program, the nature of the activity and, when possible, the service of the units involved.

2.1.1 Support Troop Participation

The Desert Rock support troops at ENCORE provided logistical, operational, and administrative support to the exercise. While performing these duties, support troops sometimes entered the forward area. Particularly involved in shot-day operations were the Radiological Safety Section and the Control Group.

Table 2-1: EXERCISE DESERT ROCK V ACTIVITIES AT SHOT ENCORE

Program	Participating Service	Estimated DOD Personnel
Troop Orientation and Indoctrination (Observers)	Army	135
	Army (Camp Desert Rock Troops)	180
	Navy	92
	Air Force	113
	Marine Corps	12
Tactical Troop Maneuver	Army	2,149
	Air Force	326
Operational Helicopter Tests	Marine Corps	12
Damage Effects Evaluation	Army	*

* Unknown

The Radiological Safety Section, supported by the 50th Chemical Service Platoon, enforced radiological safety criteria and conducted radiological surveys. One significant function conducted after the ENCORE detonation was a survey of the shot area by two radiological safety teams. Each team generally consisted of one radiological safety monitor, one driver, and one radio operator. Other radiological safety teams, consisting of a monitor from the Radiological Safety Section, a driver from the 50th Chemical Service Platoon, and a radio operator from the 505th Signal Service Group were to accompany each of the Battalion Combat Teams during the postshot maneuver. Another radiological safety team operated on the ground zero flank. Additional radiological monitoring was provided by BCT teams, who accompanied their respective battalions (66).

The Control Group accompanied troops into the shot area to ensure that all personnel remained together and followed safety instructions. The Control Group comprised officers and enlisted men from the Operations Section (G-3), as well as the Instructor

Group, the Radiological Safety Section, and the Aviation Section (64-65). The core Instructor Group consisted of four Army officers and four enlisted men. An Air Force officer, a Navy officer, and an Army medical officer provided specialized instruction when needed (64). After the detonation, the instructors advised observers and later the maneuver units during their tour of the display area to view the damage effects of the burst. They discussed differences between the predicted and actual effects of the detonation.

Several other Desert Rock support elements were active at Shot ENCORE. Before the shot, the 412th Engineer Construction Battalion spent from seven to ten days preparing the equipment display area. The 26th Transportation Truck Battalion provided approximately 170 vehicles to carry military personnel to and from the forward area. At shot-time, these vehicles were parked about 11 kilometers south of ground zero, at the rear of the trench area.

The 505th Signal Service Group established wire and radio communications within the forward area, as well as at Camp Desert Rock. It was planned that company personnel would operate the two mobile public address systems in the display area after the shot, to assist the Instructor Group in its presentations.

The 371st Evacuation Hospital (-)* provided medical support in the forward area and at Camp Desert Rock. A doctor was scheduled to accompany the Control Group to the forward area and remain at the forward command post throughout the maneuvers. A medical detachment of one medical officer and three enlisted men was to establish an aid station in the parking area and move to the command post at the trench area after the shot. In addition, two aidmen were to accompany the observers after the shot (64-68).

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*Some subordinate units were not present.

2.1.2 Troop Orientation and Indoctrination Activities

As table 2-1 indicates, 532 personnel from the four armed services participated as official observers at Shot ENCORE. The 315 Army observers, including 180 Camp Desert Rock participants, composed the largest contingent.

All of the observers took part in the same orientation and training activities for the event. Most reported for duty between 2 and 5 May. On 5 May, the observers present rehearsed their shot-day activities, including an inspection of the display area. After spending about five hours at the test site, they returned to Camp Desert Rock (64).

On 6 May, the Instructor Group presented an eight-hour orientation for the observers, who viewed films and attended lectures on the characteristics of a nuclear detonation and the procedures to follow during a shot. When ENCORE was postponed for 24 hours, the Instructor Group presented a more detailed eight-hour orientation to the observers (64).

At 0640 hours on 8 May, the observers left Camp Desert Rock for the trench area, located 9,400 meters from the intended ground zero, at UTM coordinates 924639. After they arrived at about 0705 hours, the Instructor Group conducted a 35-minute preshot orientation. Fifteen minutes before shot-time, the observers were directed to enter the trenches to observe the shot (64).

Thirty minutes after the shot, the observers began the 40-minute trip by truck to the display area. They returned to Camp Desert Rock after their tour of the display area, having spent about five hours and 20 minutes at the test site (37; 64; 72).

2.1.3 Tactical Troop Maneuvers

During the ENCORE event, 2,475 personnel took part in the tactical maneuvers, as table 2-1 indicates. Two Battalion Combat Teams were formed of units from the First, Third, and Fourth Armies and from individual Air Force units. The following list indicates the home stations of the troops in the two BCTs (73):

First Army
- Camp Drum, New York

Third Army
- Camp Campbell, Kentucky
- Fort Benning, Georgia
- Fort Bragg, North Carolina
- Camp Rucker, Alabama

Fourth Army
- Camp Polk, Louisiana
- Camp Chaffee, Arkansas
- Fort Bliss, Texas
- Fort Hood, Texas.

Participants in the troop maneuvers arrived at Camp Desert Rock between 2 and 4 May. On 5 May, they rehearsed the exercise. The troops spent a maximum of eight hours at the test site practicing all activities scheduled for shot-day, including the observation of the shot from the trenches and the postshot inspection of the display area. Figure 2-1 depicts the trench and display areas prepared for ENCORE and shows the ground zero (64).

On 6 May, the BCTs attended four-hour classes presented by the Instructor Group, which showed films on nuclear energy and weapons. Although attendance at the films was voluntary, more than 400 BCT participants were present for the showing. At 2230 hours, the AEC announced that activities scheduled for that day had been postponed for 24 hours. On 7 May, personnel received additional orientation (64).

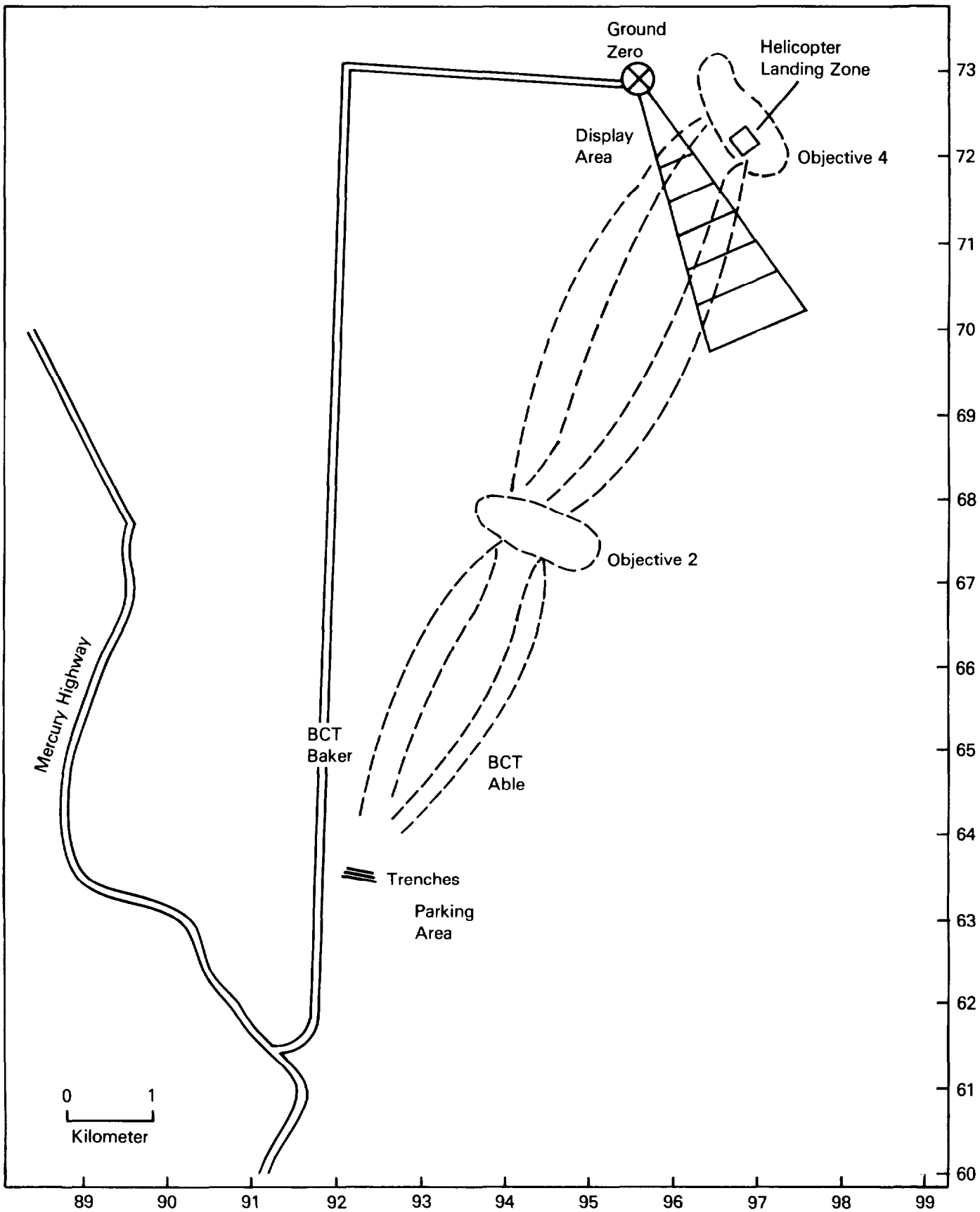


Figure 2-1. DESERT ROCK OPERATIONS ON FRENCHMAN FLAT, SHOT ENCORE

On 8 May, convoys carrying maneuver troops left Camp Desert Rock between 0550 hours and 0625 hours. The last elements arrived at the trench area by 0650 hours. After the troops had disembarked, the vehicles were moved to a parking area south of the trenches. An orientation briefing at the trench area began at 0730 hours and ended at 0800 hours. Fifteen minutes before shot-time, personnel were directed into the trenches, and two minutes before the detonation, they were told to crouch (64).

The detonation, described by veteran observers as the most picturesque ever seen at the Nevada Proving Ground, occurred 2,423 feet above Frenchman Lake. Because the trenches were 9,150 meters from the actual ground zero, personnel were permitted to stand and observe the fireball before the arrival of the shock wave, which was a change from previous policy (64).

Five minutes after the shot, the BCTs left the trenches and began their attack toward Objectives 2 and 4. Objective 2 was about 5,000 meters south-southwest of ground zero; Objective 4 was about 1,400 meters south-southeast of ground zero. The ground troops marching from the trenches secured Objective 2 by 0943 hours and reached objective 4 by 1045 hours. Figure 2-1 shows the location of the objectives and movements of the troops.

Meanwhile, at 0843 hours, seven H-19 helicopters landed at the trench area to begin the airlift phase of the maneuver. The helicopters transported one 30-man platoon from each BCT to Objective 4. The first group to arrive at Objective 4 was a pathfinder team, which included a radiological safety monitor. The helicopter airlift was complete by 0912 hours. The two platoons then spent 30 minutes moving toward ground zero (64).

After spending almost seven hours in the forward area, troops began to return to Camp Desert Rock at approximately 1230 hours. They reached the camp by 1400 hours (37; 64).

2.1.4 Operational Helicopter Tests

Four HRS helicopters, designated A, B, C, and D, participated in the operational helicopter tests at ENCORE. Each helicopter had a pilot, a co-pilot, and a monitor. Participants were part of the 2d Marine Corps Provisional Atomic Exercise Brigade (2d MCPAEB). The monitors was to wear protective clothing. None of the helicopters was to fly into areas with radiation intensities greater than 10.0 R/h, or land in areas with intensities greater than 50 R/h (63).

The activities began two hours and 30 minutes before shot-time, when the helicopters left Camp Desert Rock for the forward area. Helicopters A, B, and C headed for the northern tip of the Yucca Lake Airstrip, at UTM coordinates 850900. Helicopter D proceeded to a landing area approximately 15.5 kilometers from ground zero, at UTM coordinates 838828. Figure 2-2 traces the helicopter routes and their landing zones during the tests (63).

Five minutes before the shot, helicopters A, B, and C lifted off from Yucca Lake Airstrip and flew in a left echelon formation at a height of 400 feet. At the time of detonation, they were about 20 kilometers from ground zero, and the flight leader was looking in a 60-degree direction from the flash. The wingmen were looking about 90 degrees from the direction of the flash (63-64).

Pilots wore variable-density goggles darkened so that they could just see the flight instruments and the ground. Co-pilots were wearing either high-density goggles or variable-density goggles adjusted for maximum optical density. All pilots reported that the time during which their vision was impaired did not exceed two to three seconds (63-64).

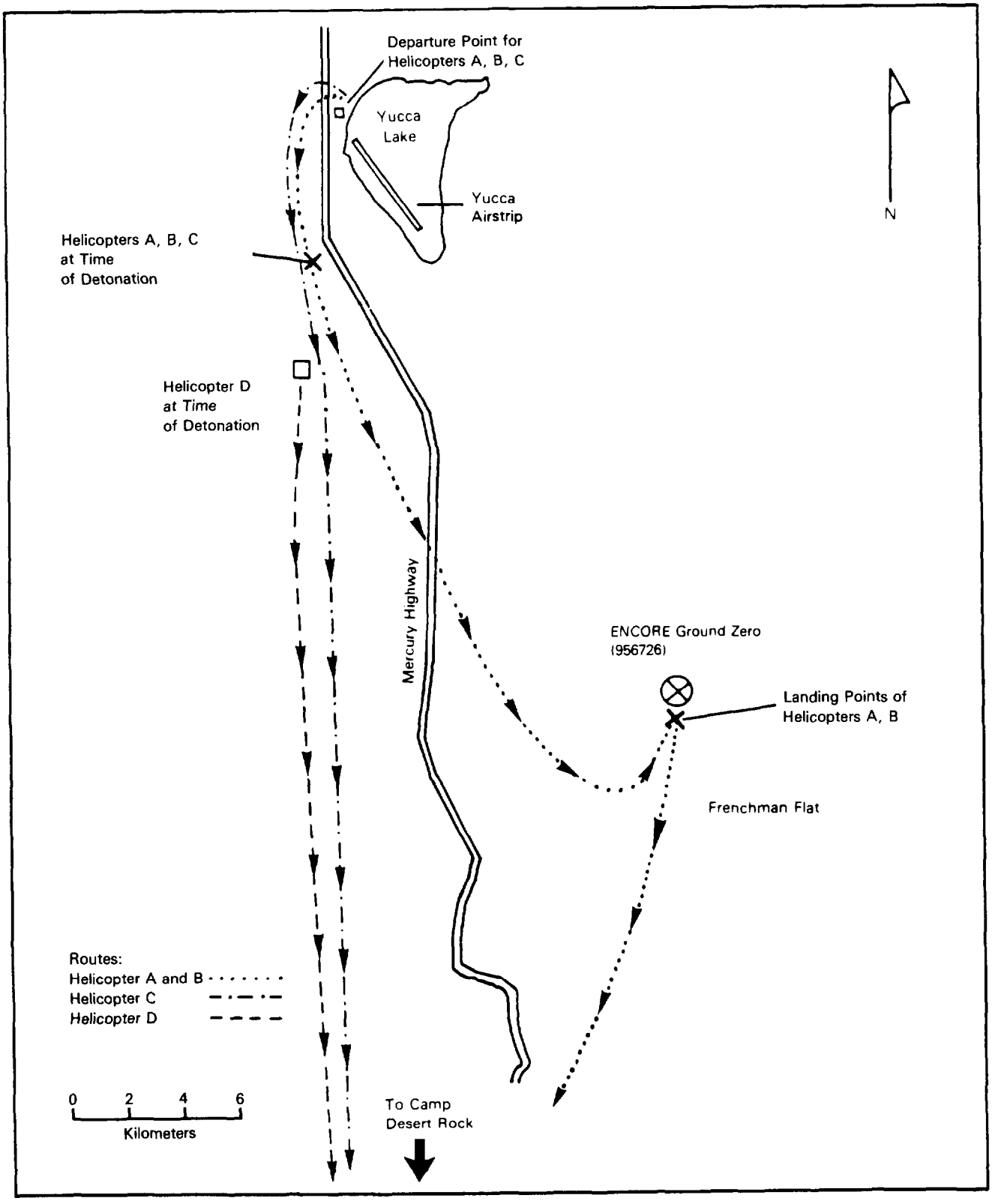


Figure 2-2: OPERATIONAL HELICOPTER TESTS AT SHOT ENCORE

After the shock wave passed, helicopters A and B continued their flight to an area about 1,000 meters south of ground zero. They arrived about 15 minutes after the shot and landed briefly to allow radiological safety monitors to survey the immediate area. They detected radiation levels of 1.4 R/h or less 20 to 30 minutes after the shot. After the monitors reboarded the aircraft, the two helicopters returned to Camp Desert Rock. Helicopter C returned to Camp Desert Rock immediately after the shock wave passed. Helicopter D hovered five to ten feet over its position, with its right side toward ground zero, until the shock wave passed. It then headed directly for Camp Desert Rock. Although part of the mission was to take airborne radiation readings, restrictions imposed by the Test Director prevented helicopter operations in the vicinity of the dust column. Consequently, no measures of airborne radiation were made for the shot (63).

2.1.5 Damage Effects Evaluation

The ENCORE display, which stretched 3,200 meters southeast of ground zero, was designed primarily to add realism to the orientation and indoctrination of troops, who viewed the display after their maneuver. Before the shot, the 412th Engineer Construction Battalion prepared the structures for the display. Their tasks included digging bunkers, trenches, and foxholes, placing stakes, and building two sections of bridging. The bridging was placed 460 meters from ground zero. Out to a distance of 460 meters, the bunkers were constructed at 90-meter intervals. Thereafter, the stakes and dugouts were at 460-meter intervals (64).

The 3623rd Ordnance Company placed equipment in the display, including a 2 1/2 ton truck at ground zero. Other equipment, placed in the display at 460-meter intervals, included machine guns, 1/4 ton trucks, a 57mm gun, carbines, rifles, mortars,

communications equipment, rocket launchers, tanks, 90mm guns, and a howitzer. After the shot, engineer and ordnance teams evaluated the damage to the emplacements and equipment in the display area.

In conjunction with the damage effects evaluation, Army personnel used the bunkers, trenches, and foxholes constructed as the location for test animals and instruments used in medical and shielding evaluations (64).

For the medical evaluation, 50 sheep were placed in the display area on the day before the shot. The sheep were placed in the bunkers, trenches, and foxholes and in the open from 90 to 2,740 meters from ground zero (64).

Immediately after the shot, the veterinary officer, a Navy monitor officer, and an enlisted man accompanied the Control Group into the forward area. These personnel moved by vehicle to the display area to evaluate the effects of the detonation on the sheep. Later that day, the sheep that had survived the shot were taken to sheep pens in Frenchman Flat, where they were kept separate for further observation (64).

To evaluate the shielding offered by the bunkers, trenches, and foxholes in the display, a chemical team (probably part of the 50th Chemical Service Platoon) placed heat-sensitive paper and film badges both inside and outside the fortifications. Sometime after the shot, the chemical team retrieved the badges and recorded their readings (64).

2.2 DEPARTMENT OF DEFENSE PARTICIPATION IN JOINT TEST ORGANIZATION OPERATIONS AT SHOT ENCORE

In addition to the Desert Rock activities described in the previous section, DOD personnel performed a variety of tasks that

required them to enter the forward area before, during, and after the shot. DOD personnel took part in projects conducted by the Military Effects Group, the Weapons Development Group, the Civil Effects Group, and in air support provided by the Air Force Special Weapons Center.

2.2.1 Military Effects Group Projects

The Military Effects Group conducted more projects at ENCORE than at any other event in Operation UPSHOT-KNOTHOLE. Table 2-2 lists the Military Effects Group projects at the shot. Many of these projects were part of Program 3, which studied structures, material, and equipment. The three sub-projects of Project 3.28 provided instrumentation support for the following Program 3 projects: 3.1, 3.1u, 3.3, 3.4, 3.5, 3.7, 3.8, 3.9, 3.13, 3.14, 3.15, 3.19, 3.21, 3.22, 3.26, and 3.29. In addition, measurements for Project 1.1a were combined and instrumented as a unit by Naval Ordnance Laboratory personnel of Project 3.28.2. All ground personnel, except those at manned stations or those authorized to enter the area early, were briefed on the radiological environment when the Test Director declared recovery hour at 0919 hours, about 49 minutes after the detonation. From that time on, project personnel with access permits could enter the test site through designated checkpoints to recover experiments. All project parties traveled with a radiological safety monitor (39; 84-85; 119).

Projects 1.1a/1.2, Air Blast Measurements, were fielded by the Naval Ordnance Laboratory. The objectives were to measure blast pressures in free air and along the ground at various distances from nuclear detonations, to study shock wave behavior, and to relate the new data to military effects. There were two parts to Project 1.1a. In the first part, pressure gauges were placed along two blast lines to measure pressure as a function of distance and time. This part of the project utilized Project

Table 2-2: MILITARY EFFECTS GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT ENCORE

Project	Title	Participants
	Military Effects Group	
1.1a/1.2	Air Blast Measurements	Naval Ordnance Laboratory
1.1a-1	Evaluation of Wiancko and Vibrotron Gauges and Development of New Circuitry for Atomic Blast Measurements	Naval Ordnance Laboratory
1.1a-2	Development of Mechanical Pressure-time and Peak Pressure Recorders for Atomic Blast Measurements	Naval Ordnance Laboratory
1.1b	Air Pressure and Ground Shock Measurements	Stanford Research Institute
1.1d	Dynamic Pressure versus Time and Supporting Air Blast Measurements	Sandia Corporation
1.3	Free-air Atomic Blast Pressure Measurements	Air Force Cambridge Research Center
1.4	Free-field Measurements of Earth Stress, Strain and Ground Motion	Sandia Corporation
2.1	Radioactive Particle Studies inside an Aircraft	Chemical and Radiological Laboratories
2.2a	Gamma Radiation Spectrum of Residual Contamination	Signal Corps Engineering Laboratories
2.2b	Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material	Naval Medical Research Institute
2.3	Neutron Flux Measurements	Naval Research Laboratory
3.1	Tests on the Loading of Building and Equipment Shapes	Air Materiel Command; Armour Research Foundation
3.1u	Shock Diffraction in the Vicinity of a Structure	Naval Ordnance Laboratory
3.3	Test on the Loading of Horizontal Cylindrical Shapes	Air Materiel Command; Armour Research Foundation
3.4	Tests on the Loading of Truss Systems Common to Open-framed Structures	Air Materiel Command; Armour Research Foundation
3.5	Tests on the Response of Wall and Roof Panels and the Transmission of Load to Supporting Structure	Air Materiel Command; Armour Research Foundation
3.7	Air Blast Effects on Entrances and Air Intakes of Underground Installations	Office, Chief of Engineers, U.S. Army; Structural Research Laboratory, University of Illinois*
3.8	Air Blast Effects on Underground Structures	Office, Chief of Engineers, U.S. Army; Structural Research Laboratory, University of Illinois
3.9	Field Fortifications	Engineer Research and Development Laboratories*
3.11-3.16	Navy Structures	Navy Bureau of Yards and Docks*
3.19	Blast Damage to Coniferous Tree Stands by Atomic Explosions	Forest Service
3.20	Blast and Thermal Effects of an Atomic Bomb on Typical Tactical Communication Systems	Signal Corps Engineering Laboratories*

*Other participating agencies are listed in the text.

Table 2-2: MILITARY EFFECTS GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT ENCORE (Continued)

Project	Title	Participants
3.21	Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts	Ballistic Research Laboratories
3.22	Effects on Engineer Bridging Equipment	Engineer Research and Development Laboratories
3.24	Effects of an Airburst Atomic Explosion on Landing Vehicles Tracked (LVT's)	Naval Radiological Defense Laboratory
3.26	Test of the Effects on POL Installations	Air Materiel Command; Office of the Quartermaster General; Marine Corps Schools
3.27	Effects of Atomic Explosions on Field Medical Installations Equipment	Brooke Army Medical Center
3.28.1	Structures Instrumentation	Ballistic Research Laboratories
3.28.2	Pressure Measurements for Various Projects of Program 3	Naval Ordnance Laboratory
3.28.3	Pressure Measurements on Structures	Stanford Research Institute
3.29	Blast Effects of Atomic Weapons upon Curtain Walls and Partitions of Masonry and Other Materials	Federal Civil Defense Administration
3.30	Air Blast Gauge Studies	Ballistic Research Laboratories
4.1	The Radiation Hazard to Personnel within an Atomic Cloud	Air Force Cambridge Research Center*
4.2	Direct Air Blast Exposure Effects in Animals	Naval Medical Research Institute
5.1	Atomic Weapon Effects on AD Type Aircraft In Flight	Navy Bureau of Aeronautics
5.2	Atomic Weapon Effects on B-50 Type Aircraft In Flight	Wright Air Development Center
5.3	Blast Effects on B-36 Type Aircraft In Flight	Wright Air Development Center; Strategic Air Command
6.2	Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques	Wright Air Development Center; Vitro Corporation
6.3	Interim IBDA Capabilities of Strategic Air Command	Strategic Air Command
6.7	Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations	Signal Corps Engineering Laboratories
6.8	Evaluation of Military Radiac Equipment	Signal Corps Engineering Laboratories; Bureau of Ships
6.8a	Initial Gamma Exposure versus Distance	Signal Corps Engineering Laboratories
6.10	Evaluation of Rapid Aerial Radiological Survey Techniques	Signal Corps Engineering Laboratories
6.11	Indoctrination of TAC Air Crews in the Delivery and Effects of Atomic Weapons	Tactical Air Command
6.12	Determination of Height of Burst and Ground Zero	Signal Corps Engineering Laboratories; Army Field Forces Board #1
6.13	Effectiveness of Fast Scan Radar for Fireball Studies and Weapons Tracking	Naval Electronics Laboratory

* Other participating agencies are listed in the text.

Table 2-2: MILITARY EFFECTS GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT ENCORE (Continued)

Project	Title	Participants
7.1	Electromagnetic Effects from Nuclear Explosions	Headquarters, Air Force*
7.3	Detection of Airborne Low Frequency Sound from Nuclear Explosions	Headquarters, Air Force*
7.4	Seismic Measurements	Headquarters, Air Force
7.5	Calibration and Analysis of Close-in A-Bomb Debris	Headquarters, Air Force; AFSWC
8.1a	Effects of Thermal and Blast Forces from Nuclear Detonations on Basic Aircraft Structures and Components	Wright Air Development Center; Division of Research, University of Dayton
8.1b	Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs	Wright Air Development Center
8.2	Measurement of Thermal Radiation with a Vacuum Microphone	Air Force Cambridge Research Center
8.4.1	Protection Afforded by Operational Smoke Screens against Thermal Radiation	Chemical and Radiological Laboratories; Naval Radiological Defense Laboratory
8.5	Thermal Radiation Protection Afforded Test Animals by Fabric Assemblies	Quartermaster Research and Development Laboratories; Walter Reed Army Medical Center; Atomic Energy Project, University of Rochester
8.6	Performance Characteristics of Clothing Materials Exposed to Thermal Radiation	Army Quartermaster Research and Development Laboratories
8.9	Effects of Thermal Radiation on Materials	Naval Material Laboratory
8.10	Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation	Naval Radiological Defense Laboratory
8.11a	Incendiary Effects on Buildings and Interior Kindling Fuels	Forest Service, Forest Products Laboratory
8.11b	Ignition and Persistent Fires Resulting from Atomic Explosions—Exterior Kindling Fuels	Forest Service, Division of Fire Research
8.12a	Sound Velocities near the Ground in the Vicinity of an Atomic Explosion	Naval Electronics Laboratory
8.12b	Supplementary Pressure Measurements	David Taylor Model Basin
8.13	Study of Fire Retardant Paints	Engineer Research and Development Laboratories; Bureau of Yards and Docks
9.1	Technical Photography	EG&G; Signal Corps Pictorial Center; Air Force Lookout Mountain Laboratory
9.6	Production Stabilization	Army Waterways Experiment Station*
9.7	Experimental Soil Stabilization	Army Waterways Experiment Station*

*Other participating agencies are listed in the text.

3.28.2 instrumentation and personnel. The personnel placed the gauges at 16 stations along the main blast line from 80 to 4,570 meters west of the intended ground zero and at eight stations along the smoke line from 150 to 1,520 meters northeast of the intended ground zero. The main blast line was used by most of the Program 1 and 3 projects and several other projects concerned with overpressure effects. The smoke line was an array of smoke pots, used by several projects studying the effect of smoke on certain characteristics of the detonation. Instruments for Project 1.1a were also placed in another area near ground zero to determine the effect of the smoke layers on overpressure. However, due to strong winds that might have blown the smoke over the ground zero target, the smoke was not used. The instruments were connected by underground cable to recording instrumentation housed in two trailers located in underground revetments 2,130 and 3,500 meters from ground zero. The stations were unmanned at shot-time. About two hours after recovery hour, three Project 3.28.2 personnel recovered the tapes. The gauges were recalibrated and left in the test area for Shot GRABLE (91).

The second part of Project 1.1a was designed to evaluate and field-test modified indenter gauges and to obtain pressure data in the free-field and in and around structures and equipment. Project personnel placed the gauges from 340 to 2,450 meters away from ground zero along and near the main blast line, in foxholes from 1,250 to 2,130 meters from ground zero, and from 150 to 1,520 meters along a blast line that extended southwest of ground zero. The gauges were probably connected to recording equipment located somewhere near the blast lines and the foxholes. Personnel probably retrieved the recordings and left the gauges in place for Shot GRABLE (91).

For Project 1.2, cameras and smoke rockets were used to determine pressure in free air and along the ground as a function of distance and time. In one part of Project 1.2, personnel

placed 15 rocket launchers at 130-meter intervals along a north-south line located east of ground zero. A high-speed camera, located 3,600 meters west of ground zero, was set to photograph the smoke rocket trail distortions. The launchers were ignited from the Control Point seconds before the detonation. The camera photographed the broken and hooked patterns in the trails to indicate motion in air produced by the shock front.

To measure the effect of the shock wave along the ground, nine high-speed cameras that functioned by remote control were located south of the main blast line. At the time of detonation, the cameras photographed the motion of the ground along the main blast line (91).

Project 1.1a-1, Evaluation of Wiancko and Vibrotron Gauges and Development of New Circuitry for Atomic Blast Measurements, tested four types of experimental blast gauges. Project 1.1a-2, Development of Mechanical Pressure-time and Peak Pressure Recorders for Atomic Blast Measurement, evaluated two different mechanical air blast gauges. There are no project descriptions concerning these two projects. The weapons test reports for Projects 1.1a-1 and 1.1a-2 indicate that Project 1.1a personnel conducted or assisted in the field and laboratory activities for the projects. The two projects probably were part of Project 1.1a, and the experimental gauges were placed in the same areas and connected to the same recording equipment as Project 1.1a gauges (96; 100).

Project 1.1b, Air Pressure and Ground Shock Measurements, was fielded to obtain data on blast phenomena resulting from ENCORE. Before the shot, project personnel placed 51 air pressure gauges, 14 acceleration gauges, and six experimental gauges along the main blast line from 160 to 2,290 meters from ground zero. At about 1120 hours, recording equipment was placed in two shelters used by Program 3. Between four and five hours

before the detonation, three men calibrated the instruments along the blast line and turned on power to the equipment at the stations. Three project personnel recovered the records two to three hours after the shot. Plans called for them to spend 30 minutes in the test area (14; 120).

Project 1.1d, Dynamic Pressure versus Time and Supporting Air Blast Measurements, was fielded to measure blast wave pressures near ground level and to evaluate several new and modified gauges. Several days before the shot, project personnel placed pressure gauges at various heights above the ground from ground zero to about 2,000 meters west of ground zero along the main blast line. Personnel placed recording equipment in shelters located along the blast line. Project 1.1d gauges were also placed on a bridge structure for Project 3.4 and in the tree stand established by Project 3.19. Two hours after recovery hour, two parties of three men each spent an estimated two hours retrieving records from the recording shelters (23).

The objective of Project 1.3, Free-air Atomic Blast Pressure Measurements, was to determine the peak overpressure for air-burst nuclear devices. The ENCORE detonation was high enough above the terrain to give a good separation of the direct and ground-reflected blast waves.

About five hours before the detonation, two personnel traveled to a beacon station about 1,520 meters southwest of ground zero to start a radar transmitter. Seconds before the shot, two B-29s flying at 8,000 and 11,000 feet dropped a total of 20 instrumented canisters. Twelve to fourteen project personnel at each of two stations near Yucca Lake recorded data that were telemetered from the canisters and transmitted by the beacon station (3; 14; 61).

Project 1.4, Free-field Measurements of Earth Stress, Strain, and Ground Motion, had two objectives:

- To measure the degree that various depths of earth cover reduced the vertical forces produced by a nuclear device
- To test instrumentation used to measure forces transmitted through the earth.

Before the shot, project personnel placed earth pressure, earth strain, and air pressure gauges along the main blast line about 430 meters west of ground zero. The gauges were attached to cables leading to shelters containing recording equipment. These shelters also housed Project 1.1d recording equipment. Two parties of three men each from Projects 1.1d and 1.4 recovered records in the shelters about two hours after recovery hour. Recovery took about two hours (99).

Project 2.1, Radioactive Particle Studies inside an Aircraft, was fielded by the Chemical and Radiological Laboratories of the Army Chemical Center. The objective was to evaluate the inhalation hazard to which aircraft crews would be exposed when flying through the cloud formed by a nuclear detonation.

Project personnel placed a sampling apparatus with an attached ionization chamber in each of the two QF-80 drones used in Project 4.1. The drones, also carrying mice and monkeys for the Project 4.1 study, were sent through the ENCORE cloud twice. Drone activities are described in greater detail in the Project 4.1 description. When the drones landed, the sampling instruments were removed, packaged, and flown to the Army Chemical Center in Maryland for analysis (28).

Project 2.2a, Gamma Radiation Spectrum of Residual Contamination, was conducted to characterize the residual gamma contamination resulting from the shot. Data gained from the project were to be used in designing radiation detection devices and in

assessing the biological significance of residual gamma radiation. Two hours after the detonation, three project participants approached ground zero from a crosswind direction in a van. They stopped when the gamma intensity reached 0.18 R/h at ground zero. Equipment was removed and placed about six meters from the van. After taking measurements, personnel loaded instruments into the van and left the area (14; 18).

Project 2.2b, Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material, evaluated the biological effects of beta and gamma radiation fields. To obtain data on initial radiation, two or three project participants placed lucite and masonite spheres containing radiation-detecting devices at stations 1,460 and 1,650 meters southeast of ground zero before the detonation. It is not known when the spheres were recovered (30).

Project 2.3, Neutron Flux Measurements, was designed to measure neutron intensities at various distances from ground zero. Before the shot, project personnel secured neutron detectors to a cable stretching 900 meters from ground zero. They also placed neutron detectors on stakes from 900 to 1,830 meters from ground zero. These detectors were attached to cables that were connected to the main cable. Soon after the detonation, four project personnel recovered the cable by pulling the end farthest from ground zero by truck until the other end passed the 900-meter point. They then detached the samples from the stakes and pulled in the remaining detectors (126).

Project 3.1, Tests of the Loading of Building and Equipment Shapes, was conducted by the Air Materiel Command, with primary contracting assistance from the Armour Research Foundation and construction assistance from the Silas Mason Company. The objective was to collect more information about blast effects on various structures, material, and equipment differing in size, shape, and orientation to the detonation.

Construction personnel assembled 15 structures along an arc 1,500 meters from the intended ground zero. Two additional models, also used in Project 1.1a, were positioned 350 and 670 meters from ground zero. Project 3.28 participants mounted about 235 gauges on the test structures. After the Test Director declared the area open for recovery operations at 0919 hours, personnel returned to the test site to inspect structural damage and recover instrument records (55).

Project 3.1u, Shock Diffraction in the Vicinity of a Structure, was conducted by the Naval Ordnance Laboratory to determine changes in the shock wave pattern as it diffracted around a structure. The instrumentation system was part of the systems used for Projects 1.1a and 3.28.2, both of which were Naval Ordnance Laboratory projects. One or two days before the shot, personnel positioned 14 pressure gauges in and around the structure used for Project 3.1 that was located 670 meters from ground zero. Signals from the gauges were transmitted and recorded on magnetic tape recorders. Personnel retrieved the records when the area was cleared for recovery operations (90).

Project 3.3, Test on the Loading of Horizontal Aluminum Cylindrical Shapes, was fielded by personnel from the Armour Research Foundation, under contract to the Air Materiel Command. The objective was to increase the knowledge of blast loadings on cylindrical structures.

Five steel cylinders with reinforced end-sections were supported above the ground at two stations located 1,460 and 1,910 meters from ground zero. Project 3.28.1 personnel mounted 30 air pressure gauges and ten strain gauges on the cylinders and calibrated them before the shot. At recovery hour, participants returned to the site to observe the results and collect the gauge data (112).

Project 3.4, Tests on the Loading of Truss Systems Common to Open-framed Structures, was fielded by Armour Research Foundation personnel for the Air Materiel Command. The objective was to determine the effects of a nuclear blast on open-framed structures, such as bridges. The information obtained was compared to wind-tunnel data and data gathered during the previous nuclear weapons testing series.

Personnel positioned five structures, each of which duplicated the center section of an open-deck, single-track railroad bridge, at distances of 670 to 710 meters from ground zero. Personnel from Project 3.28.1 mounted strain gauges on the foundations of the structures. After recovery hour was declared at 0919 hours, participants retrieved the gauge data and inspected the bridge spans (111).

Project 3.5, Tests on the Response of Wall and Roof Panels and the Transmission of Load to Supporting Structures, was performed by personnel from the Armour Research Foundation for the Air Materiel Command. The objective was to determine the load, as produced by a nuclear blast, transmitted to building frames through various common types of panel wall and roof construction.

Three reinforced concrete structures, positioned 670, 1,370, and 2,040 meters from ground zero, were fitted with wall and roof panels constructed of cinder block, brick, corrugated steel, wood, and reinforced concrete. The structure at 670 meters was also instrumented for Projects 1.1a, 3.1, 3.1u, and 3.28.2. The other two structures were built for Project 3.29. Project 3.28.1 personnel instrumented each structure with gauges measuring pressure and strain. In addition, the structures at 1,340 and 2,020 meters were photographed by high-speed, remote-control cameras provided by Project 9.1, Technical Photography. After recovery hour, project personnel recovered the gauge records and

film and evaluated the effects of the detonation on the structures (114).

Project 3.7, Air Blast Effects on Entrances and Air Intakes of Underground Installations, was conducted for the Office of the Chief of Engineers, U.S. Army, through a contract with the Structural Research Laboratory of the University of Illinois. Personnel from the Stanford Research Institute and Project 3.28 personnel from the Naval Ordnance Laboratory assisted. The objective was to obtain basic data to be used in designing underground shelters for protection from nuclear detonations.

Six hours and 30 minutes before the shot, three men were scheduled to remove the seal on filters and start the electric generators at an underground structure 290 meters southwest of ground zero. They were to spend three hours on the assignment. In addition, Project 3.28.2 personnel installed 34 air pressure gauges and two ground-surface air pressure gauges near and in the structure.

Three hours after recovery hour, ten men from Projects 3.7, 3.8, and 3.28 proceeded to this structure and then to the Project 3.8 structure to open them, turn off generators, collect data, and check for gross damage effects (14; 118).

Project 3.8, Air Blast Effects on Underground Structures, was performed by the Structural Research Laboratory of the University of Illinois for the Office of the Chief of Engineers, U.S. Army. The overall objective of this project was similar to that of Project 3.7: to collect necessary data for designing underground shelters. Three test structures, buried at depths of one, four, and eight feet, were on an arc about 280 meters west-northwest of the intended ground zero. They were built of reinforced concrete with roofs of simply supported steel-beam strips (93).

Project 3.28.1 personnel installed 26 earth-pressure gauges on the ceiling beams, floors, and walls of the structures before the shot. They placed air pressure, strain, and acceleration gauges in and around the structure. Three hours after recovery hour, project personnel with personnel from Projects 3.7 and 3.28, as described under the Project 3.7 description, checked the gauges, recovered data, and examined the structures (84).

Project 3.9, Field Fortifications, was conducted by the Engineer Research and Development Laboratories, with construction support from the 412th Engineer Construction Battalion, and instrumentation and technical assistance from the Naval Material Laboratory, the Naval Radiological Defense Laboratory, the Ballistic Research Laboratories, the Signal Corps Engineering Laboratories, and Naval Ordnance Laboratory personnel from Project 3.28.2.

The main objectives were to obtain data on the effects of blast on field fortifications and to take radiation measurements. There were four parts to this project. The first part was concerned with the general effects of a detonation on field fortifications, while the other three parts were each concerned with one effect: pressure, reflected thermal radiation, and gamma radiation. The fortifications used for all parts of Project 3.9 included command posts, machine gun emplacements, and two-man foxholes constructed with various revetments, structure frames, and overhead cover. They were located 150, 460, 1,220, 1,830, and 2,440 meters from the planned ground zero.

The 412th Engineer Construction Battalion completed the fortifications at least a week before the shot. Personnel instrumented the positions with pressure gauges, thermal gauges, and film badges. Project 9.1 personnel photographed the fortifications before and after the shot. At about 1030 hours on shot-day, four project personnel recovered the gauge data. One

man collected the film badges. The recovery mission took an estimated three hours (14; 53).

Projects 3.11 through 3.16, Navy Structures, were conducted by the Navy Bureau of Yards and Docks. Personnel from the following organizations assisted in fielding the projects: the Naval Civil Engineering Research and Evaluation Laboratory, the Stanford Research Institute, the Army Signal Corps, and the Ballistic Research Laboratories and the Naval Ordnance Laboratory from Projects 3.28.1 and 3.28.2.

The overall objective was to test the protection afforded by various structures against the effects of a nuclear blast. Each project tested a particular structure:

- 3.11, steel warehouses
- 3.12, brick buildings and precast panels
- 3.13, precast personnel shelters
- 3.14, precast warehouse
- 3.15, steel arch shelters with earth cover
- 3.16, prefabricated wood-paneled structures containing various types of window glass hardware.

Personnel positioned the structures at distances ranging from 820 to 6,100 meters from ground zero. Fifty-four gauges measuring pressure, deflection, strain, torque, and shear were interspersed among the various structures. Project 9.1 personnel photographed the test structures before the shot and again after recovery hour. Other personnel retrieved the gauge data and made surveys to detect cracks and points of stress (14; 82).

Project 3.19, Blast Damage to Coniferous Tree Stands by Atomic Explosions, was fielded by the Forest Service, Department of Agriculture. The objective was to assess the damage done to trees by the detonation and to determine the amount of cover provided by a forest.

In the days and weeks before the shot, personnel placed 145 trees in a stand about 50 meters wide and 100 meters long, about 2,000 meters from ground zero. They also positioned 16 trees at 152-meter intervals in two parallel lines 30 meters apart located 460 to 2,440 meters west-southwest of ground zero. Project 3.28.2 personnel placed instruments on one tree in the stand and on several of the trees in the lines. Project 9.1 personnel photographed the trees before the shot.

One minute after the shot, an H-19 helicopter left the Control Point pad to survey the project area. At recovery hour, 49 minutes after the burst, four men traveled to the tree stand to recover records. Two hours and 30 minutes later, two parties, one of seven men and the other of four men, went to the project site to survey the results. Project 9.1 personnel, probably traveling with these personnel, photographed the trees. They spent about three hours at the site (14; 109).

Project 3.20, Blast and Thermal Effects of an Atomic Bomb on Typical Tactical Communication Systems, was fielded by the Signal Corps Engineering Laboratories, with support from the 16th Signal Service Battalion (Corps), Detachment A, and the 412th Engineer Construction Battalion, both from Camp Desert Rock, and personnel from Coles Signal Laboratory. Lookout Mountain Laboratory personnel provided preshot and postshot photography. The Medical Corps and the Ordnance Corps from Camp Desert Rock allowed signal items to be placed in vehicles and installations. The objective was to determine the effects of a nuclear blast on signal communication electronics.

The day before the shot, enlisted men from the 16th Signal Battalion (Corps), Detachment A, under the technical supervision of Signal Corps Engineering Laboratories personnel, laid surface wires and cables, set up communications gear, and strung wire along poles from 90 to 4,570 meters from ground zero.

Five hours before the shot, two participants went to project stations to start power generators and radio receivers. They spent an estimated two hours in the area. Project participants attached field-type radio sets and film badges to dummies in foxholes at graduated distances from ground zero. At recovery hour, two project personnel and a monitor inspected the poles and lines 1,500 and 1,800 meters from ground zero. Three hours later, qualified damage analysis personnel, accompanied by photographers, went to the test area to conduct a general survey and photograph the damage (14; 48).

Project 3.21, Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts, was fielded by personnel from the Ballistic Research Laboratories to obtain data on damage to various weapons and vehicles. These data would be used to predict the percentage of equipment that would be available for combat after a nuclear blast.

Before the shot, project participants positioned tanks, trucks, jeeps, and guns at 14 sites located 270 to 2,000 meters from ground zero. Project 3.28.1 personnel attached 45 gauges to measure linear displacement of the equipment. Project 9.1 personnel photographed the equipment before the shot and placed seven cameras in four locations.

Two days after the shot, seven men in a five-ton wrecker traveled into the area to evaluate and recover 54 vehicles and two 90mm anti-aircraft guns. The five-ton wrecker was used to right all vehicles that had overturned. It took about 65 man-hours to restore the vehicles to upright positions and evaluate the damage (25).

Project 3.22, Effects on Engineer Bridging Equipment, was conducted by Engineer Research and Development Laboratories personnel. The objective was to determine the effects of a nuclear blast on prefabricated fixed bridging.

Several weeks before Shot ENCORE, personnel from the 412th Engineer Construction Battalion constructed two 30-meter Bailey bridge spans and two single-bay aluminum sections. They placed these bridges at distances of 320 to 1,340 meters from the intended ground zero. Figure 2-3 shows the Bailey bridge constructed for the project. Project 3.28 personnel instrumented one of the Bailey bridges and both of the aluminum sections with accelerometers and strain gauges. In addition, Project 9.1 personnel placed cameras in the areas to photograph the movement of the bridges during the shot. Three hours after the announcement of recovery hour, four men were scheduled to proceed into the test site to spend one hour assessing damage, retrieving gauge data, and recovering the film (14; 88).

Project 3.24, Effects of an Airburst Atomic Explosion on Landing Vehicles Tracked (LVT's), was fielded by the Naval Radiological Defense Laboratory and five Marine Corps personnel. The objective was to determine the degree of blast damage that the LVTs would sustain from a nuclear explosion and to determine the degree of protection that these vehicles would give.

Six LVTs were stationed before the shot at seven locations from 240 to 1,370 meters west to northwest of ground zero, probably by an officer and four enlisted men. About 40 dosimeters and film badges were attached to the vehicles. Project 9.1 personnel placed a motion picture camera near the landing vehicle 570 meters from ground zero to photograph thermal and blast effects. Project 9.1 personnel also photographed each LVT before and after the shot.

About an hour after recovery hour, eight personnel retrieved the film badges and dosimeters. They spent an estimated 90 minutes in the area. Other personnel entered the area later to inspect and photograph vehicle damage (14; 98).

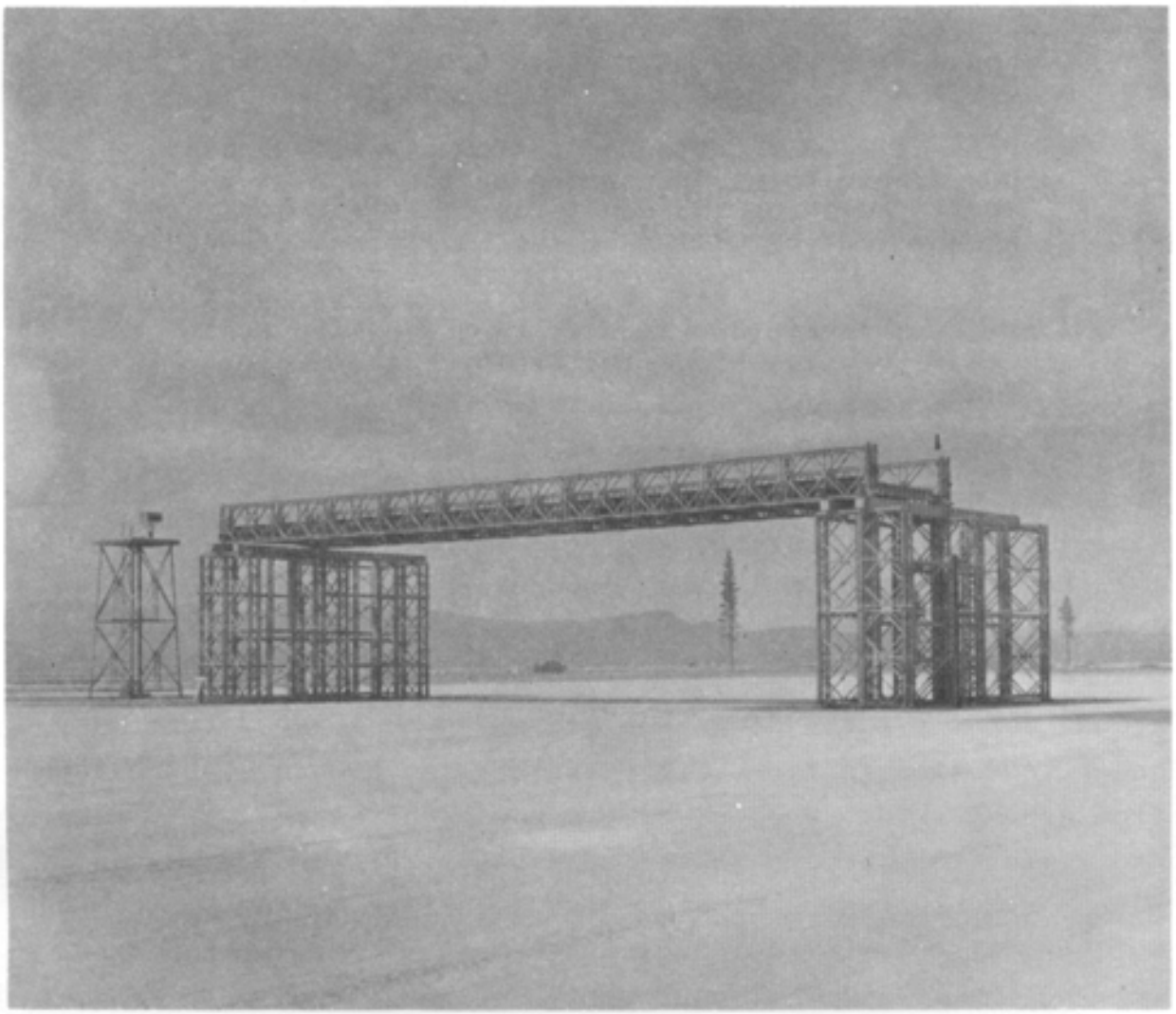


Figure 2-3: BAILEY BRIDGE CONSTRUCTED FOR PROJECT 3.22 AT SHOT ENCORE

Project 3.26, Tests of the Effects on POL* Installations, was conducted in three parts:

- Project 3.26.1, Test of the Effects on POL Installations, performed by the Armour Research Foundation under contract to the Air Materiel Command
- Project 3.26.2, Effects of Atomic Weapons on a POL Supply Point, performed by the Quartermaster Research and Development Field Evaluation Agency for the Office of the Quartermaster General
- Project 3.26.3, Effect of an Atomic Explosion upon an Amphibious Assault Fuel Handling System (Shore Phase), conducted by the Marine Corps Schools.

The objective was to determine the effects of a nuclear blast on tactical fuel supply systems and containers.

For Project 3.26.1, the Armour Research Foundation (the contractor for the Air Materiel Command), aided by Silas Mason Company, placed fuel storage tanks from 70 to 1,410 meters from ground zero, stacked 55-gallon drums 330 to 1,390 meters away, and placed storage tanks filled with water 600 to 4,580 meters from ground zero. Project 3.28.1 personnel attached air pressure and temperature gauges to the test items. Project personnel placed two high-speed cameras near each item to photograph the motion of the tanks and drums. At recovery hour, ten personnel entered the area to extinguish small fires and inspect damage. This was expected to take about one hour (14; 115).

For Project 3.26.2, personnel from the Quartermaster Research and Development Field Evaluation Agency placed gasoline cans and drums in the open and in areas protected by revetments and collapsible gas storage tanks and cleaning equipment at four stations located 800 to 3,050 meters from ground zero. Motion

*Petroleum, Oil, Lubricants

picture cameras were placed near three locations to photograph the blast effects during the shot. Several hours before the detonation, eight men traveled to the four stations to turn on gasoline engine pumps. Each station was photographed. After the detonation, probably at recovery hour, four trained observers traveled to their four assigned stations and examined each item. Photographs were again taken at each site (14; 115).

For Project 3.26.3, personnel from the Marine Corps Development Center of the Marine Corps Schools placed LVT-transported fuel tanks and shore unloading, transfer, dispensing, and storage equipment at five locations 910 to 3,110 meters from ground zero. After the detonation, at recovery hour, four project personnel and a monitor traveled to each of the sites to inspect damage. This inspection was scheduled to take about two hours (3; 14; 115).

Project 3.27, Effects of Atomic Explosions on Field Medical Installations Equipment, was performed by Medical Field Service School personnel of the Brooke Army Medical Center. The objective was to determine the effects of a nuclear blast on field medical installations and equipment and the degree of protection afforded by placing such installations partially within dug-in positions.

Before the ENCORE detonation, construction crews entered the area and partially excavated three positions 1,270, 2,750, and 4,570 meters from the intended ground zero to accommodate the field medical installations. After the excavation, construction personnel set up the field stations. Five hours before the shot, five men visited the stations and turned on several pieces of equipment. Cameras photographed the installations during the detonation (14).

When recovery hour was announced, a project officer and six enlisted men began guarding the medical material used in the tests. The guards, two of whom were posted at each site, were to be relieved in three hours, subject to radiological safety considerations. Two hours later, personnel photographed the damage. Figure 2-4 presents a photograph of field medical installations after the shot. At about 1220 hours, 17 members of a medical equipment maintenance evaluation team checked the equipment. At the same time, three project participants estimated the damage to equipment. The 20 participants were scheduled to spend about two hours at the test site. Six project personnel were to spend approximately five hours at the test site evaluating the operational capabilities of equipment and materiel beginning at about 1320 hours. At the same time, 12 project personnel, accompanied by technical observers in a bus, were to proceed to the area to observe the damage. Two groups of six men made a final visit to the three sites about five hours after the shot, spending no more than four hours in the area (14; 32).

Project 3.28.1, Structures Instrumentation, was conducted by the Ballistic Research Laboratories to obtain structural loading data for the following Program 3 projects: 3.1, 3.3, 3.4, 3.8, 3.13, 3.14, 3.15, 3.21, and 3.22. Project 3.28.1 personnel determined proper instrumentation layout, procured, installed, and operated the instruments, and reduced the field data for each of the projects. Army, Navy, and Air Force officers and enlisted men provided through AFSWP assisted the Ballistic Research Laboratories personnel. Most of the gauges and recording instruments were placed within 2,050 meters west of ground zero, along the main blast line. After they had placed the gauges and recording instruments in the field, personnel checked the gauges about eight days before the shot, conducted a complete dry run three days before the shot, and made a final check of all instruments the day before the shot. As soon after recovery hour as possible, three teams of three men each entered the recording

Figure 2-4: PROJECT 3.27, FIELD MEDICAL INSTALLATIONS AFTER SHOT ENCORE

shelters, retrieved all data tapes, and returned them to another location, probably at Camp Mercury, to play them back and make reproductions (84).

Project 3.28.2, Pressure Measurements for Various Projects of Program 3, was conducted by the Naval Ordnance Laboratory, with assistance from five military officers and six enlisted men provided by AFSWP. The objectives were to make pressure-time measurements in and around structures and installations of Projects 3.1, 3.1u, 3.7, 3.9, 3.13, and 3.19, and to present the resulting data to the agencies conducting those projects. The recording instrumentation used for those projects by Project 3.28.2 was also used for Naval Ordnance Laboratory Project 1.1a. The recording instruments were housed in two vans located 2,130 and 3,500 meters from ground zero, and the gauges were placed in the field. After the detonation, personnel retrieved the records and returned to Camp Mercury to reproduce them for the participating agencies (89).

Project 3.28.3, Pressure Measurements on Structures, was conducted by the Stanford Research Institute to measure pressure on and around Project 3.1 structures located along an arc about 1,500 meters from ground zero. Recording instrumentation was in an underground shelter behind the structures. At recovery hour, personnel recovered the records (119).

Project 3.29, Blast Effects of Atomic Weapons upon Curtain Walls and Partitions of Masonry and Other Materials, was fielded by the Federal Civil Defense Administration (FCDA) to measure the effectiveness of wall partitions commonly used in conventional, framed buildings in resisting blast pressures striking perpendicular to the surfaces. Two frame structures of reinforced concrete, which resembled long, low, narrow buildings, open in the front and back, were constructed about 1,340 and 2,020 meters from ground zero. Window openings and various partitions were

placed in the openings. These structures were also used for Project 3.5. Plans called for six men to inspect the damage four hours after recovery hour. The recovery team was to spend four hours in the field (14; 122).

Project 3.30, Air Blast Gauge Studies, was fielded by personnel from the Ballistic Research Laboratories. The objective was to test a new self-contained recording gauge for the measurement of pressure-time phenomena from a nuclear blast. Personnel placed 29 gauges on the main blast line 140 to 1,980 meters due west of ground zero and on a blast line 230 to 1,140 meters southwest of ground zero before the shot. They mounted the gauges in several different positions: on roofs, rear walls of structures, and under test vehicles. Four hours after recovery hour, three project personnel were scheduled to retrieve the gauges (14; 78).

Project 4.1, Radiation Hazards to Personnel within an Atomic Cloud, evaluated the various hazards a flight crew might encounter while flying in a modern military aircraft through the cloud formed by a detonation a few minutes after the shot. Two QF-80 drone aircraft were equipped with dosimeters, and each carried 60 mice and two monkeys enclosed in pressurized containers. The drones also carried the Project 2.1 experiment. The 3205th Drone Group from Eglin AFB, Florida, provided and maintained the drones. Four T-33 aircraft, each with an estimated crew of two, guided the drones, and four F-86 aircraft provided escort. The aircraft, based at Indian Springs AFB, did not fly through the cloud as the drone aircraft did but remained over the test site for one hour.

In addition, Project 4.1 involved a canister drop, which engaged a B-50 and a B-47 aircraft, both provided by AFSWC. These aircraft were based at Kirtland AFB. The B-50 dropped five telemetered canisters and remained over the test area for two

hours. The mission of the B-47 was terminated when its bomb-bay doors failed to open. The B-47 was over the test area for 21 minutes.

Four project personnel operated a station seven kilometers south of ground zero through shot-time to pick up telemetered data as the canisters fell to the ground (14; 51; 79).

Project 4.2, Direct Air Blast Exposure Effects in Animals, was designed to evaluate injuries received by animals exposed to 20 to 50 pounds per square inch of overpressure. The information obtained was used in estimating direct blast hazards to humans in air raid shelters or underground bunkers.

Project personnel placed rats in aluminum cylinders, which were sandbagged and covered with wet dirt to secure them and to shield them from radiation and flying debris. The ends were covered only by mesh hardware cloth to keep the rats in but allow entrance of the airblast wave. Pressure recorders were placed inside the cylinders. Project participants placed rats and instruments at stations 290, 320, 360, and 460 meters from ground zero. Four hours after the detonation, three project personnel retrieved the animals and instruments (14; 46).

Project 5.1, Atomic Weapon Effects on AD Type Aircraft in Flight, studied the blast and thermal effects of a nuclear detonation on AD aircraft in an escape configuration following the delivery of a nuclear weapon. The project involved both air and ground operations. A piloted AD2, staged from Indian Springs AFB, was over the test area for 70 minutes. The aircraft flew in formation with the drop aircraft until the time of detonation. In addition, personnel placed three groups of aircraft panels on the ground about 1,200, 1,600, and 2,200 meters from ground zero. Three hours after recovery hour, four project personnel entered the test area to photograph and recover the aircraft panels (14; 45; 51; 108).

Project 5.2, Atomic Weapon Effects on B-50 Type Aircraft in Flight, was designed to determine the minimum altitude at which a medium bomber aircraft could safely deliver a nuclear weapon. Three B-50 aircraft, each carrying eight or nine personnel and staging from Kirtland AFB, flew patterns that simulated the flight pattern of the bomb delivery aircraft. At the time of burst, they were all at an altitude of 21,800 feet. They continued on a straight and level path after the weapon was dropped. In addition, project personnel attached test aircraft panels to the T-33s flying for Project 6.11 (3; 45; 51; 81).

Project 5.3, Blast Effects on B-36 Type Aircraft in Flight, was fielded to obtain data on the blast response and delivery capabilities of a B-36D aircraft, flown near a nuclear detonation. The aircraft and crew of ten were from the Strategic Air Command (SAC). The test aircraft, which had been used for similar testing by Project 6.10 personnel during Operation IVY, staged from Kirtland AFB. The aircraft, flying 3,000 feet above and 1,490 meters ahead of the drop aircraft, was at an altitude of 25,135 feet at the time of the shot (3; 51; 102).

Project 6.2, Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques, was performed to confirm indications that a radar return could be used to determine ground zero, and to indicate gross errors in predicting the height of burst and the yield of a nuclear detonation. This project required both ground and air personnel. Three hours before shot-time, two project personnel proceeded to a radar station west of the Control Point, where they remained through the test (14).

Three B-29 aircraft, each with an estimated crew of six, left Kirtland AFB at 0325 hours on shot-day and entered the test area at about 0550 hours. One aircraft orbited south of ground zero, one orbited east of ground zero, and one orbited north of ground zero. The aircraft left the area at about 0835 hours and landed at Kirtland AFB at about 1045 hours (45; 51; 74; 86).

Project 6.3, Interim IBDA Capabilities of Strategic Air Command, like Project 6.2, evaluated IBDA systems installed in SAC bomber and fighter aircraft flying simulated strike and support missions over a target. The aircraft recorded data essential for determining the three IBDA parameters: ground zero, burst height, and yield of a nuclear detonation.

Twelve B-36 aircraft of the 57th Air Division from Fairchild AFB, Washington, and eight F-84 aircraft of the 40th Air Division from George AFB, California, reached the test area at 0750 hours at an altitude of 37,000 feet. The aircraft flew in formation for about 40 minutes over the test site to simulate strike and support activities. While over the test site, the crews tested IBDA equipment and familiarized themselves with operations pertaining to the use of nuclear weapons. A total of 212 personnel participated in the flights (3; 76).

Project 6.7, Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations, was conducted by the Signal Corps Engineering Laboratories. It consisted of two parts. Part I measured the physical characteristics of the pulse of the electromagnetic radiation. Part II detected and recorded electromagnetic signals emitted by nuclear devices before the detonation. Part II was performed at the request of AFSWP and the Office of Naval Research.

According to the schedule of events for ENCORE, three project personnel were to travel to a shelter at an unknown distance from ground zero to turn on equipment. They then were to travel to a station, the location of which is unknown, and remain there through the shot. At recovery hour, the three men were to leave the station, pick up a monitor at the Control Point, and return to the station to retrieve film (3; 14; 40).

Projects 6.8, Evaluation of Military Radiac Equipment, and 6.8a, Initial Gamma Exposure versus Distance, were performed by the Signal Corps Engineering Laboratories, assisted by Air Force and Navy personnel. The projects were designed to test dosimeters and radiac instruments in initial and residual radiation fields. Project personnel placed dosimeters before the shot at 23 stations located 740 to 2,600 meters south and 19 stations 1,070 to 2,850 meters west of ground zero. One hour after recovery hour was announced at 0919 hours, five parties, each consisting of a monitor and four participants, began retrieving the dosimeters. Two hours later, four parties, each with a monitor and five participants, traveled to an area an unknown distance from ground zero to evaluate radiac instruments by conducting radiological safety surveys. The crews observed and recorded any instrument malfunctions (14; 75).

The objective of Project 6.10, Evaluation of Rapid Aerial Radiological Survey Techniques, was to improve the procedures used during both Operations BUSTER-JANGLE and TUMBLER-SNAPPER in making radiological aerial surveys. In addition, the effect of the aircraft on radiac instrument readings taken inside the aircraft was studied.

This project used one HRS-2 helicopter, which was based at Camp Desert Rock. Before the mission, project personnel placed film badges at various locations opposite one another on the interior and exterior of the aircraft. The helicopter left Desert Rock at 0900 hours on shot-day and reached the test area at 0905 hours, about 30 minutes after the shot. Flying at a height of about 500 feet, it circled 800 meters from ground zero. The crew selected a landmark near ground zero as a reference point to determine the direction of maximum fallout. The aircraft then flew a cloverleaf pattern centered over the reference point at three different heights. The first leg of the cloverleaf pattern passed over the reference point in the direction of

maximum fallout. Airspeed, direction, and height were kept constant on each leg of the pattern.

Monitors in the aircraft obtained data by using a mechanical recording system and by writing intensity readings on a data sheet every five seconds. A notation was made on the data sheet as the aircraft passed over the reference point. The aircraft was in the test area for two hours and landed at 1105 hours at Camp Desert Rock (45; 51; 101).

Project 6.11, Indoctrination of Tactical Air Command Air Crews in the Delivery and Effects of Atomic Weapons, was conducted to teach Tactical Air Command (TAC) aircrews about blast, thermal, and nuclear radiation effects that might be encountered in the delivery of nuclear weapons. The activity also trained TAC reconnaissance pilots in the techniques of photographing areas subjected to the effects of a nuclear detonation and using the photographs for bomb damage assessment. Seven TAC T-33s and three RF-80s (crew of two each) from George AFB were used in this maneuver.

The T-33 aircraft departed from Indian Springs AFB one hour before the shot. When the bomb was released, each aircraft began a 55-degree dive at 85 percent power to a minimum altitude of 17,000 feet, where they went into a 15-degree climb directly away from the point of detonation. Fifteen seconds after the shot, normal fighter formation was resumed, and all aircraft returned directly to George AFB for decontamination and debriefing (3; 45; 51; 104).

The RF-80 aircraft took off from George AFB about one hour after the shot and began an orbit at an altitude of 30,000 feet directly over Indian Springs AFB. Two hours after the detonation, the first RF-80 made a photography run over the ground zero target array and returned to the orbit point. The second

and third aircraft also made runs over the target area and returned to the orbit point. They then flew back to George AFB for decontamination (104).

Project 6.12, Determination of Height of Burst and Ground Zero, was fielded by the Signal Corps Engineering Laboratories and Army Field Forces Board #1. The objective was to evaluate artillery sound-ranging equipment for location of ground zero, seismic wave velocity for determination of height of burst, and flash-ranging equipment for determination of ground zero and height of burst. This project required sound-ranging systems located 22 to 40 kilometers from ground zero. In addition, seismic geophones and flash-ranging cameras were positioned at the south end of Yucca Lake, 13 to 16 kilometers from ground zero. Four hours before the shot, six men in three vehicles activated the geophones and flash-ranging cameras and returned to the Control Point before shot-time (14; 124).

Project 6.13, Effectiveness of Fast Scan Radar for Fireball Studies and Weapons Tracking, was conducted to evaluate the effectiveness of a new fast scan X-band radar for phenomenology studies of nuclear detonations. Project plans called for six men to proceed to Station 6.13b, at UTM coordinates 917622, over 11 kilometers from ground zero, and remain there through the detonation (14; 77).

Project 7.1, Electromagnetic Effects from Nuclear Explosions, was designed to obtain additional information on the electromagnetic radiation produced by a nuclear detonation. Personnel from the National Bureau of Standards, the Air Force Security Service, the Air Force Cambridge Research Center, and the Air Weather Service manned one station onsite and 13 stations located throughout the United States. Two personnel manned the onsite station, about 19 kilometers from ground zero, beginning four hours before the detonation and continuing through shot-time (14; 95).

Project 7.3, Detection of Airborne Low Frequency Sound from Nuclear Explosions, was conducted to compare low frequency sounds produced by nuclear detonations at various remote field stations. These stations were located across the United States and around the world. The Signal Corps Engineering Laboratories operated stations in Alaska, Hawaii, Greenland, Japan, and Germany. The Naval Electronics Laboratory, the Signal Corps Engineering Laboratories, and the National Bureau of Standards manned the nine stations throughout the United States (97).

The purpose of Project 7.4, Seismic Measurements, was to record the seismic waves produced by the shot for comparison with those produced by shots of other series and by other shots of Operation UPSHOT-KNOTHOLE. Project personnel manned stations located in Alabama, Alaska, Arizona, Montana, South Dakota, Wyoming, and Nevada. The station closest to the shot was about 40 kilometers to the north, at UTM coordinates 843094 in Yucca Flat (14; 41).

Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris, analyzed samples of the Shot ENCORE cloud to evaluate various parameters of the nuclear device. . An F-84 aircraft took gaseous and particulate samples from the cloud. Because this project required cloud sampling, it is described in more detail in section 2.2.4 of this volume, which discusses AFSWC support at ENCORE (117).

Project 8.1a, Effects of Thermal and Blast Forces from Nuclear Detonations on Basic Aircraft Structures and Components, was developed to increase knowledge of the capabilities of weapons-delivery aircraft and to establish design criteria for future weapons-delivery aircraft. Project personnel placed aircraft structures and components such as box beams, tension ties, horizontal stabilizer and elevator assemblies, and aircraft panels from 700 to 3,960 meters from ground zero.

According to the operation order, 12 project personnel proceeded to the test area six hours before the shot to check and adjust equipment, a process requiring about two hours. Seven project participants and a monitor went to the project site at recovery hour to inspect damage and photograph the equipment area. The estimated time of this mission was four hours (14; 110).

Project 8.1b, Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs, was conducted to assess the damage of fighter aircraft parked in the vicinity of a detonation and to determine the effort required to restore the aircraft to flying condition. Four F-47s and one F-86 were parked from 520 to 1,610 meters northwest of ground zero. Personnel, probably from Project 9.1, set up remote-control cameras near each aircraft to photograph the effects of the blast. Five hours before the shot, the project officer and three personnel made a final inspection of equipment, which took about one hour. At recovery hour, six project personnel and a monitor traveled to the project area to inspect the aircraft and recover instrument recordings at distances of 700, 1,980, 2,200, and 2,690 meters from ground zero. They spent about two hours in the area. Three hours after recovery hour, 11 men inspected the aircraft. Their estimated time in the area was three hours (14; 54).

Project 8.2, Measurement of Thermal Radiation with a Vacuum Microphone, was designed to evaluate a microphone used to measure the thermal radiation produced by a nuclear detonation. Project personnel manned two vans containing recording equipment. One was located about ten kilometers from ground zero. They arrived at the vans about four hours before the shot and remained through shot-time (14; 20).

Project 8.4.1, Protection Afforded by Operational Smoke Screens against Thermal Radiation, was to be conducted by the

Chemical and Radiological Laboratories of the Army Chemical Center to evaluate the effect of smoke screens on thermal radiation resulting from a nuclear detonation. Personnel set up stations with smoke pots, thermal radiation measurement instruments and wind velocity and direction gauges from 760 to 1,980 meters along a line northwest of ground zero. More smoke pots were placed along a line to the north of these stations. Other projects had set up instrumentation along the smoke line to determine smoke effect on other detonation characteristics. The smoke was to be started just prior to shot-time. However, only a few hours before the detonation, the wind increased, and the stronger winds made it possible that the smoke would cover the ground zero target array. This would cause problems if the first bomb-run did not go as planned and the aircraft, upon a second attempt, could not determine the target area due to smoke. Therefore, the project was canceled (50).

The purpose of Project 8.5, Thermal Radiation Protection Afforded Test Animals by Fabric Assemblies, was to evaluate the protection against skin burns afforded by service and experimental clothing. Six hours before the shot, 15 project personnel transported 55 pigs to the shot area. They anesthetized the animals and placed them in field exposure holders. Forty-four pigs were dressed in experimental clothing and exposed at eight stations located 700 to 2,750 meters west-southwest of ground zero. The remaining 11 pigs were placed at three stations in cylindrical aluminum containers with fabric-covered portholes. When the area was cleared for recovery operations, 12 project personnel and a monitor spent at least one hour retrieving the pigs (14; 94).

Project 8.6, Performance Characteristics of Clothing Materials Exposed to Thermal Radiation, was closely associated with Project 8.5. The objective was to study the thermal effects of nuclear detonations on standard and experimental field

clothing. Personnel placed 15 wood panels with fabric attached at the same stations used for Project 8.5. At about 1220 hours, an estimated eight project personnel went to the test site to recover the burned textile test samples. It is not known how long they remained in the area (14; 52).

Project 8.9, Effects of Thermal Radiation on Materials, was designed to study the effects of heat from the nuclear detonation on materials, to evaluate specific methods of measuring thermal radiation, to study the protective value of fabrics and paints, and to evaluate a physical substitute for skin to be used in cloth-barrier studies. Five stations were instrumented for this experiment at distances of 1,520 to 3,350 meters from ground zero along the Project 8.4.1 smoke line. The various instruments and materials were mounted on panels which, in turn, were mounted on structures. Two hours after the announcement of recovery hour, nine men proceeded to the stations to retrieve instrument records and burned fabric samples. The estimated time of the mission was one hour (14; 87).

Project 8.10, Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation, was designed to study theoretical approaches to measuring radiation. Project personnel set up seven stations, each instrumented with different types of calorimeters, at distances of 820 to 2,990 meters from ground zero. Two of the stations were along the Project 8.4.1 smoke line, and the remaining five were on the main blast line west of ground zero. Plans called for eight men to go to the stations three hours after recovery hour to retrieve film from recorders. They were to spend one hour on this mission. In addition, the three Project 5.2 B-50 aircraft and a Project 5.3 B-36 aircraft used calorimeters and radiometers to measure thermal radiation (14; 60).

Project 8.11a, Incendiary Effects on Building and Interior Kindling Fuels, was designed to study the vulnerability of urban

structures to primary fires produced by nuclear detonations. The study focused on materials that were either part of a building or were found within a building.

Project personnel erected five demonstration houses before the shot at two locations, 1,830 and 2,430 meters from ground zero. Three of the houses were miniature two-by-two meter structures, and the other two were three-by-three meters. In addition, personnel placed 20 samples of common ground materials from 1,520 to 5,490 meters from ground zero. Five hours before the shot, seven project personnel spent about three hours removing paper coverings from the test materials.

Immediately after recovery hour was announced at 0919 hours, six personnel, including personnel from Project 8.11b, began an initial inspection of the houses and materials, a process taking about three hours. At about 1220 hours, 11 Project 8.11a and 8.11b personnel began another, more detailed inspection of the houses and materials (14; 24).

Project 8.11b, Ignition and Persistent Fires Resulting from Atomic Explosions - Exterior Kindling Fuels, was conducted in conjunction with Project 8.11a to study the vulnerability of exterior kindling fuels encountered in urban areas to primary fires produced by nuclear detonations. Before the shot, project personnel placed various flammable materials, including paper products and clothing, at the same locations as those used in Project 8.11a. In addition, they positioned 13 FCDA automobiles about 2,440 meters from ground zero and nine fence sections at unknown locations around ground zero.

A helicopter, used to observe the effects of the blast on test materials, left the helipad at the Control Point five minutes after the shot. For the next 41 minutes, it flew over the various project sites and recorded observations made of the

test materials. Project personnel later traveled with Project 8.11a personnel to inspect the test materials at 1220 hours (14; 108).

Project 8.12a, Sound Velocities near the Ground in the Vicinity of an Atomic Explosion, was designed to measure sound velocities near the surface before the arrival of the shock wave. Personnel placed acoustic velocity instruments along the Project 8.4.1 smoke line 460 to 1,180 meters from ground zero and along the main blast line 260 to 1,540 meters from ground zero. Two hours after the area was opened for recovery operations, four project personnel traveled to a recording station located at an unknown distance from ground zero to recover records and turn off equipment. They spent an estimated one hour in the field (14; 83).

Project 8.12b, Supplementary Pressure Measurements, was designed to determine whether intense thermal radiation over a surface could generate a precursor shock wave. Project personnel installed three-by-three meter test panels at distances of 460 and 920 meters from ground zero. They also constructed instrument shelters behind the panels. Two hours after the announcement of recovery hour, eight project personnel spent about one hour retrieving the records (14; 19).

The objective of Project 8.13, Study of Fire Retardant Paints, was to study the thermal effects of nuclear detonations on surfaces treated with fire retardant paints. Project personnel instrumented and placed five painted panels at three field locations. There were no recovery operations on shot-day. Some days later, the panels were monitored for possible contamination and then visually inspected for thermal damage and other effects. The panels were then removed, placed in sample cases, and returned to the Engineer Research and Development Laboratories (85).

Project 9.1, Technical Photography, was conducted by Edgerton, Germeshausen, and Grier, Incorporated (EG&G) and by personnel from the Signal Corps Pictorial Center and the Air Force Lookout Mountain Laboratory. Twenty-three Signal Corps officers and five Air Force enlisted personnel were assigned to work directly with EG&G. The objective of Project 9.1 was to provide both still photographs and motion pictures of the preshot and postshot stages of various projects. Some of the technical photographs were taken with remote-control cameras from 100 unmanned steel photo-towers six to 25 feet high. The project required 193 cameras at ENCORE.

Twelve project personnel spent two days before the shot loading film into the cameras and testing them. These same project personnel and a radiological safety monitor recovered the film on shot-day, after recovery hour. It is estimated that eight hours were required to complete the task. EG&G processed all film either in Las Vegas or Los Angeles.

In addition to Project 9.1 photographers, 17 personnel from the Air Force Lookout Mountain Laboratory were scheduled to take documentary photographs of the ENCORE burst and subsequent cloud development. These personnel manned six camera stations, from two hours and 30 minutes before the shot through shot-time. The Test Director's Schedule of Events identifies these station locations as follows (14):

STATION	LOCATION (UTM)	NUMBER OF PERSONNEL
1	955640	2
2	936626	3
3	917618	2
4	906640	2
5*	843878	4
6	928646	4

*Station 5 was at the Control Point.

Personnel were to dismantle their camera stations and return to Camp Mercury when they had completed their assignment. One hour after the test area was opened for postshot activities, three additional Lookout Mountain Laboratory personnel and a monitor were scheduled to enter Frenchman Flat and spend three hours photographing test results.

An hour before the ENCORE burst, a C-47 aircraft with Lookout Mountain Laboratory personnel left Indian Springs AFB to take aerial photographs of the ENCORE airdrop and burst. The C-47 entered the test area at about 0745 hours, established an orbiting pattern, and photographed the burst and fireball development. The aircraft left the test area by 0836 hours and landed at Indian Springs by 0845 hours (14; 51; 59).

Project 9.6, Production Stabilization, and Project 9.7, Experimental Soil Stabilization, were conducted to find a means of stabilizing the soil in the Frenchman Flat area so that dust clouds formed by blast waves would not interfere with technical photography. The Army Waterways Experiment Station coordinated these projects. The Engineer Research and Development Laboratories, which conducted laboratory heat testing of various samples of prepared soil-stabilizing agents, assisted, as well as the Ohio River Division Laboratory, which prepared samples of soil and sand-cement stabilizing agents and conducted some laboratory testing.

Project personnel entered the Frenchman Flat test area and prepared sand-cement stabilized areas 160, 280, 810, and 890 meters from ground zero. In addition, they sprayed a surface of about 1,840 square meters with sodium silicate. Still and motion pictures showed how well the soil-stabilizing test materials worked. After the shot, project personnel inspected the materials for damage (14; 47; 116).

2.2.2 Weapons Development Group Projects

The Weapons Development Group conducted 16 projects at Shot ENCORE, only five of which required DOD participation, as indicated in table 2-3.

Project 13.1, Radiochemistry Sampling, performed by the Los Alamos Scientific Laboratory, was supported by pilots from the AFSWC 4926th Test Squadron (Sampling). This project is discussed under AFSWC participation in section 2.2.4.

Table 2-3: WEAPONS DEVELOPMENT GROUP AND CIVIL EFFECTS GROUP PROJECTS WITH DOD PARTICIPATION, SHOT ENCORE

Project	Title	Participants
	Weapons Development Group	
13.1	Radiochemistry Sampling	Air Force Special Weapons Center
18.1	Total Thermal and Air Attenuation	Naval Research Laboratory
18.2	Power versus Time	Naval Research Laboratory
18.3	Spectroscopy	Naval Research Laboratory
18.6	Surface-brightness Investigations	Naval Research Laboratory
	Civil Effects Group	
23.1	Biological Effectiveness of Ionizing Radiation within Shelters	Naval Radiological Defense Laboratory; Naval Medical Research Institute
23.2	Bacteriological Studies on Animals Exposed to Neutron Radiation	Naval Radiological Defense Laboratory
23.3	Long-term Studies on Dogs Exposed to Primarily Neutron Irradiation in Shelters	Naval Radiological Defense Laboratory
23.17	Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres	Naval Radiological Defense Laboratory
29.1	Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation	Atomic Energy Project, UCLA*

*Other participating agencies are listed in the text.

Of the four Program 18 projects, detailed documentation is available only for Project 18.3, Spectroscopy, conducted by the Naval Research Laboratory. The objective was to obtain information on spectral characteristics of light emitted from nuclear detonations. This was accomplished by using two spectrometers, which recorded the wavelength of light with time. The spectrometers were located in Building 400, a permanent building situated near the Control Point at Yucca Pass and at a distance of about 19 kilometers from the ENCORE ground zero. The spectrometers were loaded with film, aligned, and checked for final operation about three hours before the shot. Project personnel remained in the building operating the spectrometers through shot-time. They turned off the equipment and removed the film for processing after the shot (27; 42).

2.2.3 Civil Effects Group Projects

The Civil Effects Group conducted 14 projects at Shot ENCORE. Five of these projects, listed in table 2-3, involved DOD participants. In general, the same personnel conducted all of the Naval Radiological Defense Laboratory Program 23 projects. No information is available for Project 23.3, Long-term Studies on Dogs Exposed to Primarily Neutron Irradiation in Shelters.

Project 23.1, Biological Effectiveness of Ionizing Radiation within Shelters, investigated neutron and gamma radiation hazards to mice placed within AEC shelters located at a slant range of 850 meters from the burst point. Personnel transported the animals to the shelters eight hours before the shot (21).

Project 23.2, Bacteriological Studies on Animals Exposed to Neutron Radiation, collected data on the role played by post-irradiation infection in deaths caused by radiation exposure. Project participants placed 153 animals, mostly mice and dogs, in shelters at a slant range of 850 meters from the burst point

(128). One hour after recovery hour, three parties, one with four members and two with three members, were scheduled to recover the animals from the shelters for both Projects 23.1 and 23.2. Recovery operations were scheduled to take 15 minutes (14).

Project 23.17, Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres, investigated neutron radiation inside and outside lead hemispheres and shelters and the neutron dose received by animals in those structures. Before the shot, personnel placed gold and sulfur neutron detectors in the open at slant ranges of 850 to 1,250 meters from the burst point. At Shot ENCORE, no lead hemispheres were used. Personnel placed animals in the same shelters used for Projects 23.1 and 23.2 and probably retrieved the animals at the same time that the Project 23.1 and 23.2 animals were recovered (125).

Project 29.1 Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation, was conducted by the Atomic Energy Project, University of California at Los Angeles, with fielding support from the Evans Signal Laboratory, part of the Signal Corps Engineering Laboratories. The project evaluated chemical and film dosimeters located in the northwest quadrant of Frenchman Flat as methods of measuring initial and residual gamma radiation. At ENCORE, only residual radiation was measured. It was planned that survey teams with an estimated 26 members would check the performance of various radiation instruments. Before the shot, these personnel traveled to five posts located at unspecified distances from ground zero. At about 1030, survey teams entered the radiation areas and measured intensities for about 30 minutes. They received about 0.05 to 0.2 roentgens of whole body radiation (34; 121).

2.2.4 Air Force Special Weapons Center Activities

AFSWC provided operational control of all air activities through the Air Participation Unit. In addition to airdropping

the ENCORE device, AFSWC personnel conducted cloud sampling and sample courier missions for the test groups, as well as cloud tracking and aerial surveys of the terrain for the Test Manager.

The following listing indicates the types and numbers of aircraft and the estimated numbers of AFSWC aircrew personnel involved in air missions at Shot ENCORE (51):

TITLE	TYPE OF AIRCRAFT	NUMBER OF AIRCRAFT	NUMBER OF PERSONNEL
Sampling			
Sampler	F-84G	8	8
Sampler Control	B-50	1	9
Snooper	F-84	1	1
Sample Courier	C-47	3	9
Missions	B-25	1	5
Cloud Tracking	B-25	1	5
	B-29	2	20
Aerial Surveys	H-5	1	2
	L-20	1	3
	C-47	1	4
Airdrop Mission	B-50	1	11

In addition to the aircraft listed, two C-47 emergency aircraft, one based at Kirtland AFB and the other at Indian Springs AFB, were available in case the delivery aircraft had problems. These aircraft were not needed at Shot ENCORE (51).

Cloud Sampling

At ENCORE, eight F-84G aircraft code-named Tiger, each with one pilot from the 4926th Test Squadron, collected particulate and gaseous samples of the ENCORE cloud for LASL Project 13.1, Radiochemistry Sampling, and AFSWP Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris. A B-50 sampler control aircraft, with a crew of nine including a LASL scientific

advisor, and one F-84G aircraft surveyed the cloud before the sampling sorties began. The first penetration of the cloud occurred one hour after shot-time. The peak intensity encountered by any sampler was 12 R/h. Each aircraft was called in succession following completion of the preceding sampler mission. The following listing details the activities of each sampler aircraft. Aircraft are listed according to the sequence in which they flew (51).

AIRCRAFT (F-84G)	NUMBER OF PENETRATIONS	TOTAL TIME IN CLOUD (seconds)	TOTAL TIME IN CLOUD AREA (minutes)
Tiger Red 1	2	5	81
Tiger Red 2	1	130	63
Tiger Red 4	2	122	75
Tiger Red 5	3	175	102
Tiger White 1	1	180	73
Tiger White 2	2	290	70
Tiger White 3	1	960	100
Tiger Blue 4	0	0	95

Upon completion of the mission, the samplers returned to Indian Springs AFB and parked in designated areas. Engines were shut down, and the canopies remained closed and sealed until the samples were removed from the aircraft. The pilots remained on full oxygen while they waited. The 4926th sample-removal team and radiological safety monitors removed the samples from each aircraft and placed them in shielded containers.

After the samples from each aircraft were removed and stored, the pilot shut down his oxygen and opened the canopy. He then stepped onto a platform held by a forklift so he would not touch the exterior of the aircraft. Then he was placed in a pickup truck and taken to the decontamination station for monitoring and decontamination, as necessary (51; 123).

Sample Courier Missions

After the sampling missions were completed, three C-47 aircraft, each with a crew of three, and one B-25 aircraft, with a crew of five, left Indian Springs AFB on shot-day to transport samples to the AEC nuclear weapons development laboratories and various airbases. The 4901st Support Wing (Atomic) from Kirtland AFB conducted these courier missions. The C-47s transported samples, animals, and experimental equipment for test group projects, including Project 7.5. The B-25 aircraft flew Project 13.1 filter papers to Kirtland AFB (45).

Cloud Tracking

Immediately after the ENCORE detonation, one B-25 aircraft from Indian Springs AFB and two B-29s from Kirtland AFB left for cloud-tracking missions over and beyond the NPG. The B-25 had a crew of five, and each B-29 had a crew of ten. The B-25 flew at 12,000 feet and the B-29s at 22,000 feet. The three trackers flew relatively short missions of one to two hours because of the low radiation intensity of the cloud and because one of the B-29s had mechanical problems (39; 51).

Radiological Safety and Aerial Surveys

After the shot, one H-5 helicopter, one L-20 aircraft, and a C-47 aircraft flew survey missions to record radiation intensities. The H-5, with a crew of two, flew at 15 feet over the shot area and completed the survey by 0928 hours, about one hour after the detonation. The L-20, with a crew of three, conducted an intermediate survey at 500 feet above ground for 90 minutes. The C-47, with a crew of four, flew an offsite survey but was unable to complete its mission because of unfavorable weather (39; 51).

2.3 RADIATION PROTECTION AT SHOT ENCORE

For Operation UPSHOT-KNOTHOLE, Exercise Desert Rock V, the test groups, and AFSWC developed radiation protection procedures

to keep individual exposure to ionizing radiation to a minimum while still allowing participants to accomplish their missions. Some of the radiological safety procedures described generally in chapter 5 of the series volume required that records be kept to evaluate the effectiveness of the radiation protection programs (12).

2.3.1 Desert Rock Radiation Protection Activities

Information concerning Desert Rock radiation protection activities has been obtained from the annex for ENCORE of the Exercise Desert Rock final report of operations (64) and from the operations order for the shot (66). Although film badge readings are not available for Desert Rock participants at ENCORE, these two documents describe specific radiological safety activities performed at the shot.

After the detonation, radiation monitors were airlifted to the objective near ground zero. Approximately two hours after the shot, the two Battalion Combat Teams, who had witnessed the detonation from trenches about nine kilometers from ground zero, also arrived at that objective. The radiation intensity was relatively low around ground zero because ENCORE was detonated at a considerable height. The low radiation level alleviated the necessity for radiological safety restrictions and permitted the free movement of troops within the maneuver and display areas (64). Readings from pocket dosimeters issued to some of the participants indicate an exposure range of 0.0 to 0.2 roentgen with an average of 0.06 roentgen (70).

Four Marine HRS helicopters participated in the Operational Helicopter Test at ENCORE. Two of the helicopters proceeded toward ground zero after the blast wave passed. These two helicopters landed about 900 meters south of ground zero, and monitors disembarked from both aircraft to measure radiation intensities. The monitors, as well as the personnel in the

helicopters, wore protective clothing. The monitors noted radiation intensities of 0.3 R/h around 30 minutes after the shot. Personnel were not permitted to enter areas with radiation intensities in excess of 10.0 R/h; thus, they were well within established safety limits (62-63).

2.3.2 Joint Test Organization Radiation Protection Activities

Records of JTO radiation protection activities conducted at ENCORE have been obtained from the radiological safety report of Operation UPSHOT-KNOTHOLE. The information available includes logistical data on film badges and protective clothing, survey records and isointensity plots, and decontamination records.

Dosimetry

During the period of 3 May to 15 May 1953, which covers the 8 May detonation of Shot ENCORE, the Dosimetry and Records Section of the JTO issued 4,500 film badges. Film badge records indicate that two Air Force personnel, one from the 4925th Test Group and the other from Bergstrom AFB, Texas, received total exposures of 14.7 and 4.3 roentgens, respectively, by 8 May. Records also indicate that an individual from the Naval Research Laboratory accumulated an exposure of 4.0 roentgens by 17 May and a member of the Radiological Safety Support Unit from Fort McClellan, Alabama, received a total exposure of 4.7 roentgens by 18 May. The dates that these two men turned in their film badges were 17 and 18 May, respectively (1b).

Logistics and Supply

For the period covering Shot ENCORE, the Supply Section issued the following items:

- 38 pairs of clear goggles
- 541 pairs of high-density goggles

- 561 respirators
- 882 protective caps
- 1,254 pairs of cotton gloves
- 1,314 pairs of sleeve covers.

In addition, the Supply Section issued 183 radiation-survey instruments (39).

The Supply Section operated a mobile supply point, located with the processing station at Frenchman Flat, in addition to its regular service in the Radiological Safety Building. The mobile supply point, which used a 2 1/2-ton cargo truck borrowed from the 412th Engineer Construction Battalion, was placed in operation at the old RANGER Control Point, located in Frenchman Flat, at 0645 hours. Immediately before the shot, the Supply Section issued about 50 sets of protective clothing and 100 pairs of high-density goggles (39).

Monitoring

The initial survey party began its survey at 0857 hours and completed its readings at 0928 hours. The party, probably consisting of eight men, detected only low levels of radiation. Thirty minutes after the detonation, the intensity at ground zero was 0.3 R/h. Four hours and 30 minutes after the shot, the intensity was 0.11 R/h. The area around ground zero registered an intensity of about 0.01 R/h the day after the shot, and radiological safety control of the entire area was canceled. As described in the AFSWC section of this chapter, the aerial terrain survey was completed by 0928 hours. Four of the 16 offsite monitors were DOD personnel (39).

An H-5 helicopter performed the onsite aerial survey and encountered a maximum radiation intensity of 0.35 R/h 15 feet above Frenchman Flat. An L-20 and a C-47 aircraft also performed aerial surveys up to 320 kilometers offsite. Because of bad weather, the C-47, which encountered negligible levels of radia-

tion, could not complete its mission. The highest intensity encountered by the L-20 was 0.01 R/h (39).

Plotting and Briefing

Figure 2-5 shows a copy of the isointensity plot resulting from the initial survey. Resurveys were not conducted of the test area since the initial survey team had found only light levels of contamination (39).

In addition to its other activities, the Plotting and Briefing Section briefed 890 parties for entry into the test area during the period of 3 May to 15 May. The majority of these personnel were construction workers in Areas 3 and 7 (39).

Decontamination

During the period of Shot ENCORE, the Vehicle and Equipment Decontamination Section decontaminated 104 vehicles (39).

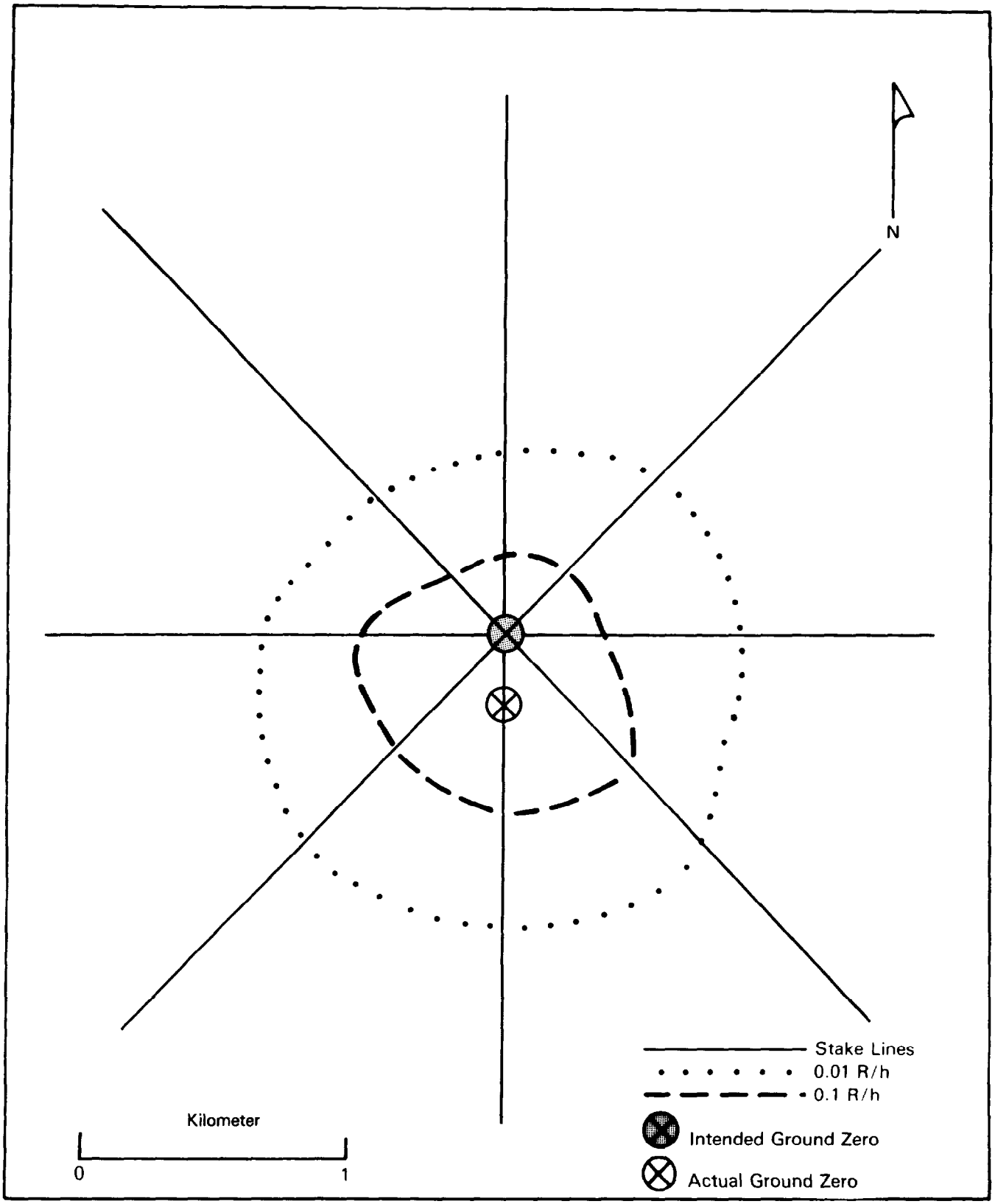


Figure 2-5: INITIAL SURVEY FOR SHOT ENCORE, 8 MAY 1953, 0857 TO 0928 HOURS

SHOT HARRY SYNOPSIS

AEC TEST SERIES:	UPSHOT-KNOTHOLE
DOD EXERCISE:	Desert Rock V
DATE/TIME:	19 May 1953, 0505 hours
YIELD:	32 kilotons
HEIGHT OF BURST:	300 feet (tower shot)

AEC Objective: To evaluate the nuclear yield, blast, thermal, and radiological phenomena produced by this device.

DOD Objective: To evaluate military equipment, tactics, and doctrine; to measure weapons effects characteristics and evaluate the military applications of the device; and to indoctrinate DOD personnel in the tactical applications of a nuclear weapon.

Weather: At shot-time, the winds at surface level were five knots from the north-northwest. Winds at 10,000 feet were from the south-southwest at 18 knots, at 20,000 feet from the west at 38 knots, and from the west-northwest at 30,000 and 40,000 feet at 60 and 67 knots, respectively. The temperature was 14.3°C, the relative humidity was 35 percent, and the pressure was 874 millibars.

Radiation Data: Onsite fallout, measured about one hour after the shot, occurred to the east and northeast of ground zero. In other directions, intensities greater than 0.01 R/h were confined to an area extending about 1.5 kilometers from ground zero.

Participants: Exercise Desert Rock V participants, Armed Forces Special Weapons Project, Air Force Special Weapons Center, Los Alamos Scientific Laboratory, contractors.

CHAPTER 3

SHOT HARRY

Shot HARRY, the ninth nuclear test of Operation UPSHOT-KNOTHOLE, was detonated at 0505 hours on 19 May 1953, in Area 3 of the Nevada Proving Ground, UTM coordinates 867996. A developmental device designed by the Los Alamos Scientific Laboratory, HARRY was fired on top of a 300-foot tower, and had a yield of 32 kilotons.

The shot was originally planned for 2 May, but was rescheduled for 16 May because of heavy fallout in the planned shot area caused by Shot SIMON, detonated on 25 April 1953. Three additional 24-hour postponements resulted from unfavorable weather conditions.

The top of the cloud resulting from Shot HARRY rose to an altitude of 42,500 feet and moved east from the point of detonation. Fallout occurred to the east and northeast, with offsite fallout heaviest to the east. The highest levels were recorded on U.S. Highway 93 between Alamo and Glendale, Nevada, and around St. George, Utah (56).

3.1 EXERCISE DESERT ROCK V OPERATIONS AT SHOT HARRY

Over 900 military personnel participated in Desert Rock V programs at Shot HARRY. About 200 additional troops provided radiological safety, transportation, communications, and control functions for the exercises in the forward area. Table 3-1 provides information on the Desert Rock V programs, indicating the number of DOD participants in each program, the nature of the activity and, when possible, the service of involved units (64).

Table 3-1: EXERCISE DESERT ROCK V ACTIVITIES AT SHOT HARRY

Program	Participating Service	Estimated DOD Personnel
Troop Orientation and Indoctrination (Observers)	Army (Camp Desert Rock Troops)	526
	Army	99
	Navy	14
	Air Force	255
	Marine Corps	2
Operational Helicopter Tests	Marine Corps	10
Damage Effects Evaluation	Army	*

* Unknown

3.1.1 Support Troop Participation

The Desert Rock support troops provided logistical, operational, and administrative support to the exercise. In performing these duties, the support troops sometimes entered the forward area. Particularly involved in shot-day operations were the Radiological Safety Section and the Control Group.

The Radiological Safety Section, supported by the 50th Chemical Service Platoon, enforced radiological safety criteria and conducted radiation surveys. One of their significant functions after the detonation was a survey of the shot area, conducted by two radiological safety teams. Each three-man team consisted of one radiological safety monitor, one driver, and one radio operator.

The Control Group accompanied troops into the shot area to ensure that all personnel remained together and followed safety procedures. The Control Group comprised officers and enlisted men from the Operations Section (G-3), as well as the Instructor Group, the Radiological Safety Section, and the Aviation Section (62; 63). The Instructor Group included four Army officers and four enlisted men. The instructors advised observers during their tour of the display area after the shot to view the effects of the burst and discussed differences between predicted and actual effects (64).

In addition to the Control Group, the Instructor Group, and the Radiological Safety Section, several other units provided support services necessary to Desert Rock troops participating in Shot HARRY. Before the shot, the 412th Engineer Construction Battalion and the 3623rd Ordnance Company spent from seven to ten days preparing the display area. The 26th Transportation Truck Battalion provided 112 vehicles to carry military personnel to and from the forward area. At shot-time, these vehicles were parked about eight kilometers south of ground zero.

The 505th Signal Service Group established wire and radio communications within the forward area, as well as at Camp Desert Rock. It was planned that 505th Signal personnel would operate the two mobile public address systems in the display area to assist the Instructor Group in its presentations (67).

The 371st Evacuation Hospital (-) provided medical support both in the forward area and at Camp Desert Rock. Plans for HARRY called for a doctor to accompany the Control Group to the forward area and remain at the forward command post throughout the maneuvers. One medical officer and four enlisted men established an aid station in the parking area and moved to the forward command post after the shot. In addition, two aidmen accompanied the observers after the shot (67).

3.1.2 Troop Orientation and Indoctrination Activities

As table 3-1 indicates, 896 observers from the four armed services took part in the troop orientation and indoctrination activities at Shot HARRY. The 526 participants from Camp Desert Rock comprised the largest contingent of observers.

All observers took part in the same orientation and training activities for the event. They attended preshot classroom presentations by the Instructor Group on such subjects as basic nuclear theory, characteristics of nuclear weapons, the tactical use of nuclear weapons, radiological protective measures, and plans for shot-day. During the various postponements of HARRY, additional orientation and briefing sessions were held (64).

At 0335 hours on shot-day, 90 minutes before the scheduled detonation, the observers arrived at the trench area located 3,660 meters from ground zero, as shown in figure 3-1. The vehicles were then driven to a parking area eight kilometers from ground zero. From 0415 hours to 0450 hours, the Instructor Group briefed observers again on nuclear detonations and safety procedures. Fifteen minutes before the shot, the observers were instructed to enter the trenches. Two minutes before the blast, they were directed to crouch in the trenches. Seconds after the passage of the shock wave, the observers were allowed to stand and view the fireball (64).

At about 0520 hours, 15 minutes after shot-time, the observers left the trenches to begin their tour through the damage effects display area, a wedge-shaped sector extending south of ground zero, as shown in figure 3-1. This tour was conducted by members of the Control Group from Camp Desert Rock and the Instructor Group, who explained the effects of the detonation on equipment, sheep, and field fortifications (64).

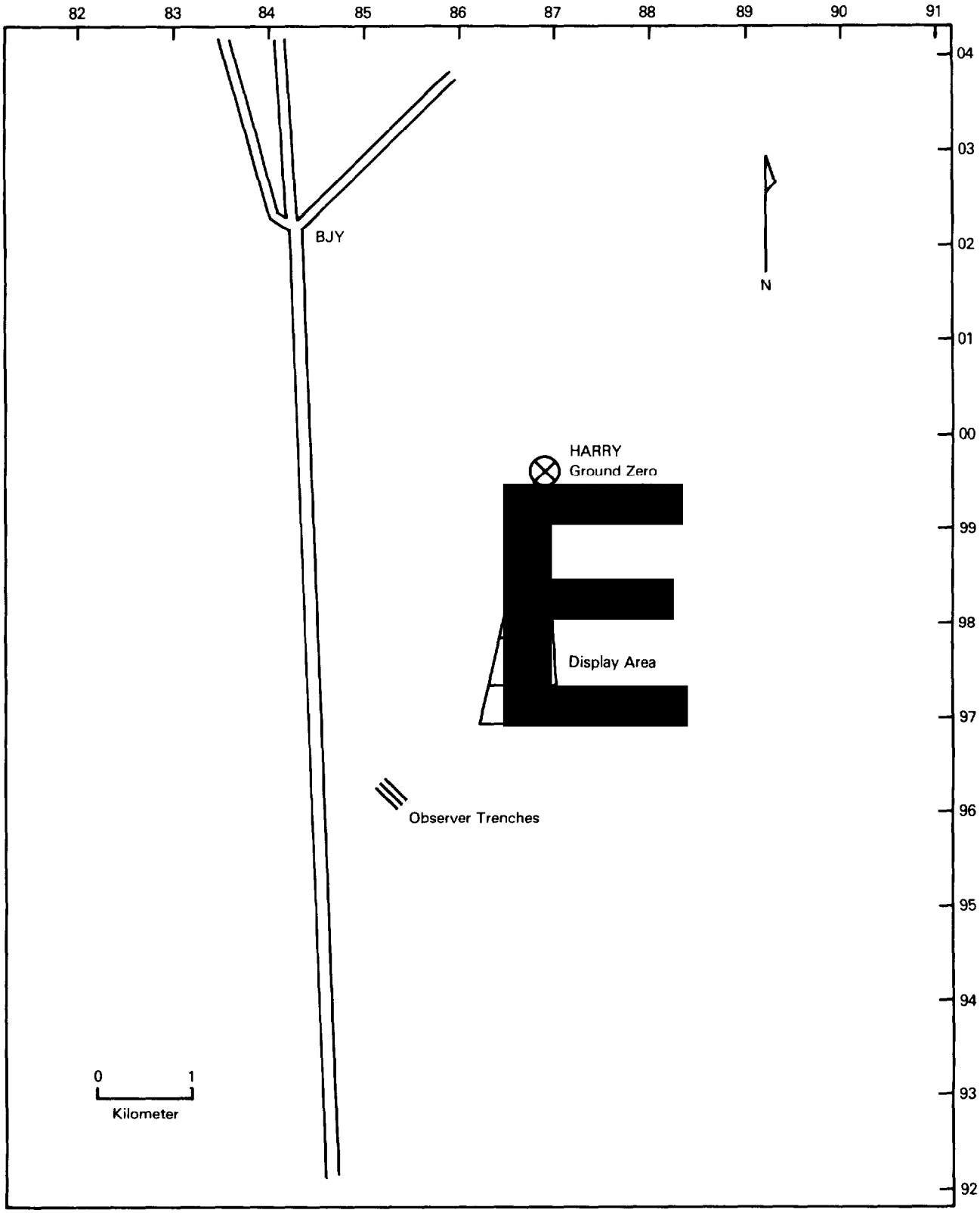


Figure 3-1: OBSERVER TRENCHES AND DISPLAY AREA, SHOT HARRY

Radiological safety monitors preceded the observers and established the location of various radiation intensity lines up to 5.0 R/h. The previous restriction barring observers from entering an area registering more than 2.5 R/h had been lifted. They could be escorted into areas of intensity higher than 5.0 R/h as long as the total personnel dose did not exceed 6.0 roentgens. Observers were allowed to proceed as close as 410 meters to ground zero (64).

At 0630 hours, observers began boarding trucks at the display area. They left for Camp Desert Rock at 0650 hours (64).

3.1.3 Operational Helicopter Tests

Four HRS helicopters, each with a pilot and a co-pilot from the 2d Marine Corps Provisional Atomic Exercise Brigade, were used to conduct the operational helicopter test at Shot HARRY. The co-pilots also functioned as monitors, measuring both ground and airborne radiation as part of the test. Participants wore protective clothing, with the monitors additionally wearing high-intensity goggles (63).

From the time of detonation until after the shock wave passed, helicopters A and B were positioned 12 kilometers south-southwest of ground zero. They were on the ground, port-side to the blast, with rotors turning. Pilots were looking about 90 degrees from the direction of the burst. These helicopters were subjected to an overpressure of 0.59 $\pm$ 0.06 pounds per square inch. Upon passage of the shock wave, the two helicopters left their position and proceeded around the west side of the shot area, as indicated in figure 3-2. Through the use of a small

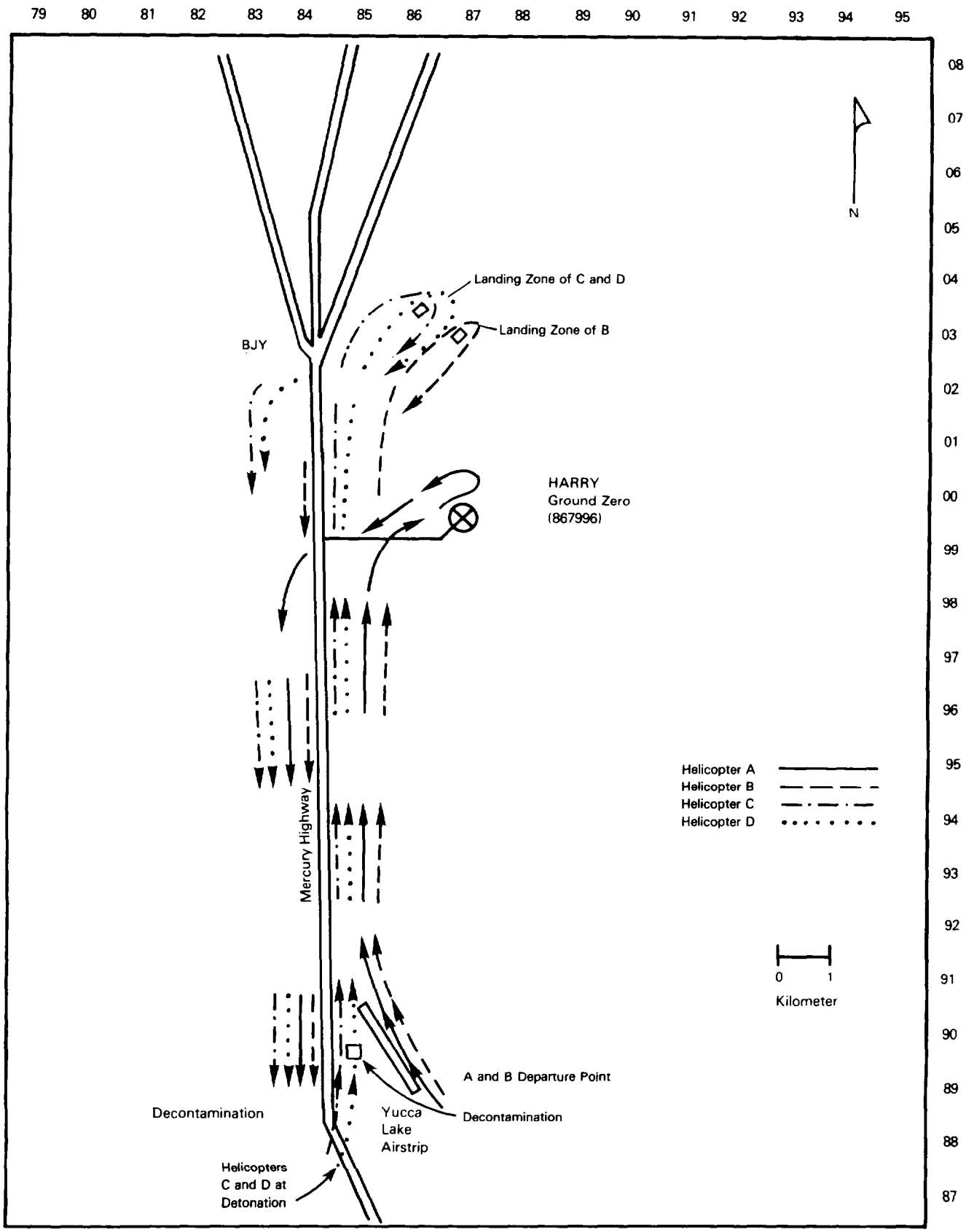


Figure 3-2: OPERATIONAL HELICOPTER TESTS, SHOT HARRY

radiac meter mounted on the instrument panel, helicopter A was able to fly as close as 230 meters from the upwind side of the dust pedestal without exceeding a reading of 10.0 R/h. In some instances, however, the meter quickly indicated that more clearance was required. Helicopter A skirted the upwind region of the dust column and recorded radiological conditions in the air before returning to the Yucca Lake airstrip. Helicopter B landed three kilometers north of ground zero, where a radiological safety monitor disembarked to record early radiation levels from the landing point toward ground zero (63).

Last-minute instructions from the Air Operations Center prevented helicopters C and D from following plans to fly up to 11 kilometers from ground zero shortly before the shot. Instead, the two aircraft were ordered to remain more than 15 kilometers from ground zero until the shock wave passed. As a result, they were partially shielded by intervening hills and were not subjected to significant overpressure. The aircraft then proceeded to a landing point about four kilometers north of ground zero to simulate troop landings.

Upon completion of their mission, all helicopters landed at Yucca Airstrip for monitoring and decontamination. They then returned to Camp Desert Rock (63).

3.1.4 Damage Effects Evaluation

The HARRY display was established south of ground zero by the 412th Engineer Construction Battalion, which constructed fortifications, and the 3623rd Ordnance Company, which placed equipment. Fortifications, including bunkers and trenches, were constructed 460 to 2,740 meters from ground zero, at 460-meter intervals. Stakes were also placed in the open every 460 meters. Equipment was placed in approximately the same areas except for one 105mm howitzer, which was placed at ground zero. Other

equipment in the display area included trucks of various sizes, howitzers, guns, tanks, machine guns, rifles, mortars, and communications equipment. After the shot, engineer, ordnance, and signal teams evaluated the damage to the fortifications and equipment in the display area (64).

In conjunction with the damage effects evaluation, Army personnel placed test animals and instruments in the bunkers and trenches constructed for the display area as part of medical and shielding evaluations (64).

For the medical evaluation, 26 sheep were placed in the display area on the day before the shot. Personnel placed the sheep in trenches, bunkers, and in the open, at 460-meter intervals out to 2,290 meters from ground zero. Immediately after the shot, the veterinary officer, a monitor, and an enlisted veterinary technician accompanied the Control Group into the forward area. These men moved forward by vehicle to the display area to evaluate the effects of the detonation on the sheep. Later that day, the sheep that had survived the shot were taken to pens in Frenchman Flat, where they were isolated and observed for further effects (64).

To evaluate the shielding offered by the fortifications, a chemical team, probably from the 50th Chemical Service Platoon, placed film badges in the bunkers and trenches and in the open. Sometime after the shot, the chemical team obtained and recorded readings from the badges (64).

3.2 DEPARTMENT OF DEFENSE PARTICIPATION IN JOINT TEST ORGANIZATION OPERATIONS AT SHOT HARRY

Department of Defense personnel took part in projects conducted by the Military Effects Group, the Weapons Development Group, and the Civil Effects Group. In addition to test group participants, DOD personnel active at Shot HARRY included Air

Force Special Weapons Center personnel who flew support missions for the test groups and the Test Manager. Table 3-2 lists the test group projects by number and title and identifies the participating groups.

3.2.1 Military Effects Group Projects

At Shot HARRY, the Military Effects Group of AFSWP Field Command conducted the projects indicated in table 3-2. The Test Director declared recovery hour at 0631 hours, about 85 minutes after the shot.

Project 1.1a-2, Development of Mechanical Pressure-time and Peak Pressure Recorders for Atomic Blast Measurement, was conducted to design, evaluate, and field test newly developed air-blast gauges. Before the shot, personnel placed 27 gauges in dirt mounds and in concrete mounts about 700 meters from ground zero. They recovered the pressure data after recovery hour (6; 96).

Project 2.2a, Gamma Radiation Spectrum of Residual Contamination, was conducted to characterize the residual gamma radiation resulting from the detonation. Data gained from the project were to be used in designing radiation detection devices. Personnel placed instruments at ranges of 520 to 610 meters from ground zero. At about 0800 hours, three project participants, accompanied by a monitor and traveling in a van, approached ground zero from a crosswind direction. Project personnel removed instruments from the van and took measurements 610 meters west of ground zero. They recorded a reading of 0.32 R/h at that location. Personnel measured radiation intensities again two days and three days after the detonation. On the second day, personnel measured an area with a radiation intensity of 0.22 R/h 520 meters from ground zero. The next day, they recorded a radiation measurement of 0.24 R/h 430 meters west of ground zero (15a-15b; 18).

Table 3-2: TEST GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT HARRY

Project	Title	Participants
	Military Effects Group	
1.1a-2	Development of Mechanical Pressure-time and Peak Pressure Recorders for Atomic Blast Measurements	Naval Ordnance Laboratory
2.2a	Gamma Radiation Spectrum of Residual Contamination	Signal Corps Engineering Laboratories
2.2b	Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material	Naval Medical Research Institute
2.3	Neutron Flux Measurements	Naval Research Laboratory
3.30	Air Blast Gauge Studies	Ballistic Research Laboratories
4.2	Direct Air Blast Exposure Effects in Animals	Naval Medical Research Institute
4.5	Ocular Effects of Thermal Radiation from Atomic Detonation	Air Force School of Aviation Medicine
4.7	Beta-gamma Skin Hazard in the Postshot Contaminated Area	Walter Reed Army Medical Center
5.1	Atomic Weapon Effects on AD Type Aircraft in Flight	Navy Bureau of Aeronautics
6.2	Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques	Wright Air Development Center; Vitro Corporation
6.3	Interim IBDA Capabilities of Strategic Air Command	Strategic Air Command
6.4	Evaluation of Chemical Dosimeters	Chemical and Radiological Laboratories
6.7	Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations	Signal Corps Engineering Laboratories
6.8	Evaluation of Military Radiac Equipment	Signal Corps Engineering Laboratories; Bureau of Ships
6.8a	Initial Gamma Exposure versus Distance	Signal Corps Engineering Laboratories
6.10	Evaluation of Rapid Aerial Radiological Survey Techniques	Signal Corps Engineering Laboratories
6.12	Determination of Height of Burst and Ground Zero	Signal Corps Engineering Laboratories; Army Field Forces Board #1
6.13	Effectiveness of Fast Scan Radiation for Fireball Studies and Weapons Tracking	Naval Electronics Laboratory
7.1	Electromagnetic Effects from Nuclear Explosions	Headquarters, Air Force *
7.3	Detection of Airborne Low Frequency Sound from Nuclear Explosions	Headquarters, Air Force *
7.4	Seismic Measurements	Headquarters, Air Force
7.5	Calibration and Analysis of Close-in A-Bomb Debris	Headquarters, Air Force; AFSWC
8.1b	Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs	Wright Air Development Center
8.2	Measurement of Thermal Radiation with a Vacuum Microphone	Air Force Cambridge Research Center
9.1	Technical Photography	EG&G; Signal Corps Pictorial Center; Air Force Lookout Mountain Laboratory

* Other participating agencies are listed in the text.

Table 3-2: TEST GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT HARRY (Continued)

Project	Title	Participants
	Weapons Development Group	
13.1	Radiochemistry Sampling	Air Force Special Weapons Center
18.1	Total Thermal and Air Attenuation	Naval Research Laboratory
18.2	Power versus Time	Naval Research Laboratory
18.3	Spectroscopy	Naval Research Laboratory
18.4	Light Absorption	Naval Research Laboratory
18.6	Surface-brightness Investigations	Naval Research Laboratory
	Civil Effects Group	
23.1	Biological Effectiveness of Ionizing Radiation within Shelters	Naval Radiological Defense Laboratory; Naval Medical Research Institute
23.2	Bacteriological Studies on Animals Exposed to Neutron Radiation	Naval Radiological Defense Laboratory
23.3	Long-term Studies on Dogs Exposed to Primarily Neutron Irradiation in Shelters	Naval Radiological Defense Laboratory
23.17	Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres	Naval Radiological Defense Laboratory
29.1	*Comparison and Evaluation of Dosimetry Methods* Applicable to Gamma Radiation	*Atomic Energy Project, UCLA* *

* Other participating agencies are listed in the text.

The objective of Project 2.2b, Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material, was to evaluate the biological effects of residual beta and gamma radiation fields. To obtain these data, six project personnel placed a masonite sphere containing dosimeters in a 1.5 R/h fallout field located on Mercury Highway about 730 meters northwest of ground zero (15b; 30).

Project 2.3, Neutron Flux Measurements, was conducted to measure neutron intensities at various distances from ground zero. Before the shot, project personnel secured neutron detectors to a cable extending 900 meters from ground zero. Beyond 900 meters, stations consisted of two steel stakes, with a steel crossbar between them. The neutron detectors were attached to the steel crossbars.

Thirty minutes after the area was opened for recovery operations, a truck pulled the cable out about 700 meters from ground zero, where a recovery team of four project personnel and a monitor removed the detectors from the cable. This same team also investigated and removed detectors from the stakes located about 1,130 and 1,830 meters from ground zero. These individuals spent about one hour in the area. All individuals wore full anti-contamination clothing, including respirators (15b; 126).

Project 3.30, Air Blast Gauge Studies, was fielded to test a new self-contained recording gauge for the measurement of pressure-time phenomena from a nuclear blast. Project personnel placed gauges at distances of 300, 640, 2,400, 3,200, 4,000, and 8,000 meters south of ground zero before the shot. They mounted the gauges in several different positions, on roofs and rear walls of structures, and under test vehicles. Four hours after recovery operations began, project personnel were scheduled to retrieve the gauges (15a-15b; 78).

Project 4.2, Direct Air Blast Exposure Effects in Animals, was designed to evaluate injuries received by animals within air raid shelters and underground bunkers. During Shot HARRY, the project was planned as an equipment test. Three or four project personnel were to spend about one hour placing empty rat cages and empty exposure cylinders with attached pressure recorders in four locations from 410 to 470 meters from ground zero. One hour after recovery hour, three project personnel and a monitor were scheduled to spend about 30 minutes recovering the pressure recorders (15a-15b; 46).

Project 4.5, Ocular Effects of Thermal Radiation from Atomic Detonation, was fielded to determine how the flash of a nuclear detonation impairs night vision. In the first part of this project, eight officers from Nellis AFB witnessed the nuclear detonation from a darkened trailer located north of the Control Point, about 10 kilometers from ground zero. They viewed the detonation through experimental filters that protected their eyes from much of the visible and infrared portion of the spectrum. Afterwards, they remained in the trailer for about an hour to perform visual tasks.

In the second part of the project, 130 rabbits were placed at four locations 15 to 60 kilometers from ground zero to determine the distance at which retinal burns could be produced. Project personnel, probably two parties of three each, positioned the animals about 12 hours before the shot. Two parties of three, accompanied by a radiological safety monitor, were authorized to recover the rabbits about 90 minutes after the shot (6; 15a-15b; 26).

For Project 4.7, Beta-gamma Skin Hazard in the Postshot Contaminated Area, the beta (and low-energy gamma) radiation exposure of a material similar to human skin was measured. This measurement was compared with the exposure routinely reported in radiological safety monitoring, which generally represented only gamma radiation exposure.

About an hour after recovery hour, project personnel traveled to the radiation area and established a station at the 0.01 R/h line. They then looked for a spot further within the area where a gamma survey meter would read about 0.8 R/h. At HARRY, the 0.8 R/h area was located 460 meters upwind of ground zero. Here, personnel placed thin-walled and thick-walled ion chambers attached to wooden racks. The thin-walled chambers were of the same thickness as the outer layer of skin and similar to skin in sensitivity to beta radiation. By placing the ion chambers in a 0.8 R/h area, personnel could obtain readings relatively quickly, about five to 30 minutes per exposure. By returning to the 0.01 R/h line after they set up the wooden racks, personnel kept their gamma exposures below the limit of 3.9 roentgens (15a-15b; 22).

The objective of Project 5.1, Atomic Weapon Effects on AD Type Aircraft in Flight, was to study the blast and thermal effects of a nuclear detonation on the AD aircraft. An AD2 drone aircraft, accompanied by two F8F aircraft and two armed AD4 aircraft, left Indian Springs AFB about 70 minutes before shot-time. At the time of the detonation, the drone was in a delivery escape maneuver at a slant range of 7,100 feet from ground zero at an altitude of 6,800 feet. At shock arrival, the aircraft was at a slant range of 8,000 feet. Visible damage to the drone was minimal.

In addition to the aircraft, a ground station was used in this project. About three hours and 30 minutes before shot-time, 23 project personnel were scheduled to begin operating station 5.1b at UTM coordinates 861877, in the southwest corner of Yucca Lake. These personnel probably assisted in controlling the drone before and after the detonation and directed the F8F control aircraft during the detonation (6; 15a-15b; 45; 51; 106).

Project 6.2, Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques, was performed to confirm indications that a radar return could be used to determine ground zero, height of burst, and the yield of a nuclear detonation. The project required both ground and air personnel.

On the night before the shot, three groups of two men each were scheduled to travel to three sites. Two groups operated radar receiver stations 6.2b and 6.2c, located on the east side of Yucca Lake. The third group went to a remote transmitter station, about eight kilometers north of ground zero to turn on generators. This group soon departed for radar station 6.2a, located 1.6 kilometers west of the Control Point. They operated the station through shot-time. Two hours after the announcement of recovery hour, a project member and a monitor went to the remote transmitter station to turn off the generators.

Three B-29 aircraft, each with an estimated crew of ten, left Kirtland AFB at 0040 hours on shot-day and entered the test area at approximately 0315 hours. One aircraft orbited eight kilometers south of ground zero, one orbited 11 kilometers east of ground zero, and one orbited eight kilometers north of ground zero. The B-29s left the area at about 0511 hours and landed at Kirtland AFB at about 0720 hours (15a-15b; 45; 51; 74; 86).

Project 6.3, Interim IBDA Capabilities of Strategic Air Command, like Project 6.2, evaluated IBDA systems installed in bomber and fighter aircraft flying simulated strike and support missions over a target. The aircraft recorded data essential for determining the three IBDA parameters: ground zero, burst height, and yield of a nuclear detonation.

Ten SAC B-50 aircraft of the 509th Bombardment Wing (Medium), Roswell AFB, New Mexico, reached the test area at 0430 hours at an altitude of 25,000 feet. The aircraft flew in

formation for about 45 minutes over the test site to simulate strike and support activities. While over the area, the crews tested IBDA equipment and familiarized themselves with operations relating to the use of nuclear weapons. Preceding the squadron was a B-50 weather reconnaissance aircraft of the 28th Tactical Reconnaissance Squadron. A total of 110 personnel participated in the flights (15a-15b; 45; 51; 76).

Project 6.4, Evaluation of Chemical Dosimeters, was fielded by the Chemical and Radiological Laboratory of the Army Chemical Center. The objective was to evaluate the E-1 Tactical Dosimeter and several other personnel dosimeters under development. Before the shot, project personnel assembled 18 tactical dosimeters at eight stations consisting of a plate covered by a thermal and shock shield affixed to a frame. The distance of the stations from ground zero is unknown. Personnel retrieved the instruments two or three hours after the detonation (15a-15b; 31).

Project 6.7, Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations, had two objectives:

- To measure amplitude, duration, and polarization of the pulse of the electromagnetic radiation
- To detect and record electromagnetic signals emitted by nuclear devices before the detonation.

Two or three hours before the shot, three project personnel went to a station located about five kilometers south of the Control Point. They checked equipment, which included antennas, oscilloscopes, and remote-controlled cameras, and turned on power. Personnel returned sometime after the detonation to turn off the equipment and collect data (40).

Projects 6.8, Evaluation of Military Radiac Equipment, and 6.8a, Initial Gamma Exposure versus Distance, were both performed by the Signal Corps Engineering Laboratories, assisted by Air

Force and Navy personnel. Project 6.8 was designed to test newly developed dosimeters and radiac instruments in initial and residual radiation fields. Project 6.8a provided reliable National Bureau of Standards film dosimeters as bases for the evaluation of other dosimeters tested by Project 6.8.

Project personnel placed experimental and standard dosimeters at an estimated 12 stations fitted with aluminum thermal and blast shields before the shot. The stations were located 820 to 2,290 meters from ground zero. Thirty minutes after the announcement of recovery hour, two parties, each consisting of a monitor and six other participants, retrieved the dosimeters. Plans called for the parties to spend three hours in recovery procedures. Two hours after recovery hour, three parties, each with a monitor and five other participants, traveled by vehicles to an area 460 to 910 meters from ground zero to evaluate radiac instruments by conducting radiological safety surveys.

Three hours after recovery hour, four men accompanied by a monitor traveled to a previously surveyed radiation area to place the experimental dosimeters in residual radiation fields. The entire mission took about 45 minutes. It is not known when the dosimeters were retrieved (15a-15b; 75; 80).

The objective of Project 6.10, Evaluation of Rapid Aerial Radiological Survey Techniques, was to improve the procedures used during both Operations BUSTER-JANGLE and TUMBLER-SNAPPER in making radiological aerial surveys. In addition, the effect of the aircraft on radiac instrument readings taken inside the aircraft was studied.

The project used one HRS-2 helicopter with an estimated crew of four, based at Camp Desert Rock. Before the mission, project personnel placed film badges at various locations opposite one another on the interior and exterior of the aircraft. The

helicopter left Desert Rock at 1430 hours on shot-day and reached the test area at 1455 hours, about ten hours after the shot. Flying at a height of 500 feet, it circled 800 meters from ground zero. The crew selected a landmark near ground zero as a reference point to determine the direction of maximum fallout. The aircraft then flew a cloverleaf pattern centered over the reference point at three different heights. The first leg of the cloverleaf pattern passed over the reference point in the direction of maximum fallout. Airspeed, direction, and height were kept constant on each leg of the pattern.

Monitors in the helicopter obtained data by using a mechanical recording system and by writing intensity readings on a data sheet every five seconds. A notation was made on the data sheet as the aircraft passed over the reference point. The helicopter was in the test area for 90 minutes and landed at Camp Desert Rock at 1640 hours (15a-15b; 101).

Project 6.12, Determination of Height of Burst and Ground Zero, was fielded by the Signal Corps Engineering Laboratories and Army Field Forces Board #1. The objective was to evaluate artillery sound-ranging equipment for location of ground zero, seismic wave velocity for determination of height of burst, and flash-ranging equipment for determination of ground zero and height of burst. The project required sound-ranging systems, located 50 to 60 kilometers from ground zero. In addition, seismic geophones and flash-ranging cameras were positioned at several stations in the southeast corner of Yucca Lake, 13 to 16 kilometers from ground zero.

Three hours before the shot, nine men activated two of the geophone and camera outpost stations. They then traveled to a third station located between the other two and remained there through shot-time (15a-15b; 124).

Project 6.13, Effectiveness of Fast Scan Radar for Fireball Studies and Weapons Tracking, was conducted to evaluate the effectiveness of a new fast scan X-band radar for phenomenology studies of nuclear detonations. The radar and two movie cameras were mounted on a van located about ten kilometers from ground zero, at UTM coordinates 840892. Project plans called for nine men to go to the van two hours before shot-time and remain there through the detonation (15a-15b; 77).

Project 7.1, Electromagnetic Effects from Nuclear Explosions, was a continuation of studies conducted during both Operations BUSTER-JANGLE and TUMBLER-SNAPPER. This project was designed to obtain additional information on the electromagnetic radiation produced by a nuclear detonation. The project had 13 locations throughout the United States and three onsite locations, though only one onsite station was used at Shot HARRY. This station was south of Yucca Lake, about 15 kilometers from ground zero. Four hours before the shot, nine men planned to go to the station to check equipment and operate the station through shot-time. Personnel from the National Bureau of Standards, the Air Force Security Service, the Air Force Cambridge Research Center, and the Air Weather Service manned the onsite and offsite stations (15a-15b; 95).

Project 7.3, Detection of Airborne Low Frequency Sound from Nuclear Explosions, was designed to compare low frequency sounds produced by nuclear detonations at various stations located across the United States and around the world. The Signal Corps Engineering Laboratories operated stations in Alaska, Hawaii, Greenland, Japan, and Germany. Personnel from the Naval Electronics Laboratory, the Signal Corps Engineering Laboratories, and the National Bureau of Standards manned the nine stations in the United States (97).

The purpose of Project 7.4, Seismic Measurements, was to record the seismic waves produced by the shot for comparison with the seismic waves produced at other shots of other series and at other shots of Operation UPSHOT-KNOTHOLE. Project personnel manned offsite stations in Alabama, Alaska, Arizona, Montana, Oklahoma, and South Dakota. One onsite station, probably unmanned, was about ten kilometers north of ground zero at UTM coordinates 843094. Personnel traveled to the station before the detonation to turn on generators and check equipment. They returned to the Control Point before the detonation. Two hours after recovery hour, one participant and a radiation monitor drove to this station and spent one or two hours turning off equipment and recovering seismic records (15a-15b; 41).

Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris, was conducted to analyze samples of the Shot HARRY cloud to evaluate various parameters of the nuclear device. Two B-29 aircraft, each with a crew of ten, took gaseous and particulate samples of the cloud. The activities of these personnel are detailed in section 3.2.4, which discusses AFSWC support at Shot HARRY (117).

Project 8.1b, Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs, was designed to determine thermal and blast effects of nuclear detonations on parked aircraft. A B-29 and a B-17 were placed about 1,360 meters from ground zero and a B-45 was positioned 1,130 meters from ground zero. The night before the shot, personnel instrumented the aircraft to determine the maximum skin temperature. An hour after the area was declared open for recovery operations, nine project members and a monitor investigated damage to the aircraft. These personnel spent about two hours in the area (15a-15b; 54).

Project 8.2, Measurement of Thermal Radiation with a Vacuum Microphone, evaluated a device used to measure the thermal radiation produced by a nuclear detonation. Thermal-sensing equipment

for HARRY was in Building 400, near the Control Point and about 12 kilometers from ground zero. Recorders were in two nearby vans. Four hours before the shot, six project members went to the vans and remained there until two hours after the detonation (15a-15b; 20).

Project 9.1, Technical Photography, was conducted by EG&G and by 23 officers from the Signal Corps Pictorial Center and five enlisted men from the Air Force assigned to work directly with EG&G. The objective of Project 9.1 was to provide both still photographs and motion pictures of the preshot and postshot stages of various projects. In addition, photographs of the burst were taken by remote-control cameras from unmanned steel photo-towers six to 25 feet high.

Project personnel loaded film into the cameras and tested them before the shot. These same project personnel and a radiological safety monitor recovered the film on shot-day, when the Test Director announced recovery hour. EG&G processed all film either in Las Vegas or in Los Angeles (59).

In addition, Air Force Lookout Mountain Laboratory personnel were scheduled to take documentary photographs of the HARRY burst and subsequent cloud development from five manned camera stations and from a C-47 aircraft. The ground stations, occupied about two hours before the shot, were located as follows (11; 15a-15b):

STATION	LOCATION (UTM)	NUMBER OF PERSONNEL
1	900920	3
2	880910	3
3	829900	4
4	781958	2
5*	843878	3

*Station 5 was at the Control Point.

Personnel dismantled their camera stations and returned to Camp Mercury when they had completed their assignments.

Meanwhile, a C-47 aircraft with Lookout Mountain Laboratory personnel departed from Indian Springs AFB at 0407 hours to take aerial photographs of the HARRY detonation. The C-47 entered the test site area at about 0423 hours, established a pattern about 16 kilometers south of ground zero, and photographed the burst and fireball development. The aircraft landed at Indian Springs AFB by 0520 hours (15a-15b; 51; 59).

3.2.2 Weapons Development Group Projects

The Weapons Development Group conducted 18 projects at Shot HARRY, only six of which had DOD participants, as indicated in table 3-2.

Project 13.1, Radiochemistry Sampling, was conducted by the Los Alamos Scientific Laboratory. Personnel from the AFSWC 4926th Test Squadron (Sampling) provided air support, as discussed in section 3.2.4.

Of the five Program 18 projects, detailed documentation is available only for Project 18.3, Spectroscopy, which was conducted by the Naval Research Laboratory. The objective was to obtain information on spectral characteristics of light emitted from nuclear detonations. This was accomplished by using spectrometers that recorded the wavelength of light with time.

Two spectrometers were located in Building 400, a permanent building about 12 kilometers from ground zero, situated on a hill near the Control Point at Yucca Pass. These spectrometers were loaded with film, aligned, and checked for final operation about three hours before the shot. Project personnel remained in the building operating the spectrometers through shot-time. After

the detonation, they turned off the equipment and removed the film for processing.

Three spectrometers were located in Station 413, a reinforced semitrailer about two kilometers from ground zero, which usually served as a mobile instrument station for Project 18.3. However, the spectrometers were used for another project during Shot HARRY (27; 42).

3.2.3 Civil Effects Group Projects

The Civil Effects Group conducted ten projects at Shot HARRY. Five of these projects, listed in table 3-2, involved DOD participants. In general, the same personnel conducted all of the Naval Radiological Defense Laboratory Program 23 projects. No information is available for Project 23.3, Long-term Studies on Dogs Exposed to Primarily Neutron Irradiation in Shelters.

Project 23.1, Biological Effectiveness of Ionizing Radiation within Shelters, investigated neutron and gamma radiation hazards to dogs and mice placed within AEC shelters about 610 meters from ground zero. Personnel transported the animals to the shelters eight hours before the shot (21).

Project 23.2, Bacteriological Studies on Animals Exposed to Neutron Radiation, collected data on the role played by post-irradiation infection in deaths caused by radiation exposure. Project participants placed 153 animals, mostly mice and dogs, in shelters about 610 meters from ground zero. Twenty-five Program 23 personnel and two monitors were scheduled to go to the shelter area and spend about 25 minutes picking up the animals (15a-15b; 128).

Project 23.17, Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres, investigated neutron radiation

inside and outside lead hemispheres and shelters. At Shot HARRY, personnel placed gold and sulfur neutron detectors in and near hemispheres 750 to 1,190 meters from ground zero (121).

Project 29.1, Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation, was fielded by the University of California at Los Angeles, with assistance from the Evans Signal Laboratory of the Signal Corps Engineering Laboratories. The project evaluated chemical and film methods for measuring initial and residual gamma radiation. To measure initial radiation, project personnel placed dosimeters in 11 stations the night before the shot. The stations were located at distances ranging from 1,200 to 2,200 meters from ground zero. When the area was declared open for recovery operations, two project personnel retrieved the dosimeters. To measure residual radiation, personnel used survey instruments to measure gamma radiation levels in areas with intensities up to 10.0 R/h (35; 121).

3.2.4 Air Force Special Weapons Center Activities

AFSWC provided operational control of all air activities through the Air Participation Unit. In addition, AFSWC personnel conducted cloud sampling, sample courier missions, cloud tracking, and aerial surveys for the Test Manager and for test group projects (58). The following listing indicates the types and numbers of aircraft and estimated numbers of AFSWC personnel involved in air missions at Shot HARRY (51):

TITLE	TYPE OF AIRCRAFT	NUMBER OF AIRCRAFT	NUMBER OF PERSONNEL
Sampling			
Sampler	F-84G	11	11
Sampler (Project 7.5)	B-29	2	20
Sampler Control	B-50	1	9
Snooper	F-84G	1	1
Sample Courier	C-47	2	6
Missions	B-25	3	18
Cloud Tracking	B-25	1	5
	B-29	1	10
Radiological Safety/			
Aerial Surveying	H-19	1	4
	L-20	1	3
	C-47	1	4

Cloud Sampling

Fifteen aircraft were involved in the collection of particulate and gaseous samples from the Shot HARRY cloud. Eleven of these were F-84G samplers, code-named Tiger, flown by pilots of the 4926th Test Squadron to collect samples for LASL Project 13.1. Of the 11 F-84G samplers, four successfully collected samples, two aborted before takeoff, one aborted before penetrating the cloud, and the remaining four made no cloud contact but were in the area from 22 to 65 minutes. The two B-29 sampling aircraft, with a crew of ten each, collected gaseous and particulate samples for Project 7.5. A B-50 sampler control aircraft with a crew of nine, including a scientific advisor from LASL, and an F-84G aircraft surveyed the cloud before the actual sampling sorties (51).

Each aircraft was called in succession, following the completion of the preceding sampler mission. Information concerning the time the B-29s spent in the cloud area is not

available. The listing below details the activities of the F-84G sampler aircraft that were in the cloud area. The peak intensity encountered by the F-84G samplers was 20 R/h.

AIRCRAFT (F-84G)	NUMBER OF PENETRATIONS	TOTAL TIME IN CLOUD (seconds)	TOTAL TIME IN CLOUD AREA (minutes)
Tiger Red 1	0	-	65
Tiger White 2	0	-	22
Tiger Red 3	3	N/R*	63
Tiger Red 4	0	-	41
Tiger White 1	0	-	43
Tiger White 3	3	275	80
Tiger Blue 2	1	N/R	51
Tiger Blue 3	1	N/R	55

The samplers returned to Indian Springs AFB and parked in designated areas when they had completed their mission. Engines were shut down, and the canopies remained closed and sealed until the samples were removed from the aircraft. The pilots remained on full oxygen while they waited. The 4926th sample-removal team and radiological safety monitors removed the samples from each aircraft and placed them in shielded containers.

After the samples from each aircraft were removed and stored, the pilot shut down his oxygen and opened the canopy. He then stepped onto a platform held by a forklift so he would not touch the exterior of the aircraft. Each B-29 crew exited through the rear side door. The F-84 pilots and B-29 crews were then taken to the decontamination station for monitoring and decontamination, as necessary (51; 123).

* N/R indicates not reported.

Sample Courier Missions

After the sampling missions were completed, two C-47 aircraft, each with a crew of three, and three B-25s left Indian Springs AFB on shot-day to transport samples to various airbases for analysis by AEC and DOD development laboratories. The 4901st Support Wing (Atomic) from Kirtland AFB conducted these courier missions for test group projects, including Projects 7.5 and 13.1 (45; 51).

Cloud Tracking

After the shot, one B-25 aircraft from Indian Springs AFB and one B-29 from Kirtland AFB flew cloud-tracking missions over and beyond the NPG. The B-25, flying at 12,000 feet, tracked the cloud for three hours. The B-29, flying at altitudes of 18,000 to 22,000 feet, tracked the cloud for two hours (39; 51). On completion of the mission, each aircraft returned to its staging base.

Aerial Surveying

After the detonation, one H-18 helicopter, one L-20 aircraft, and a C-47 aircraft flew survey missions downwind of the shot area to record radiation intensities. The H-18, which flew at heights ranging from ten to 100 feet above the ground, conducted an onsite survey. The L-20 also surveyed the NPG, spending about one hour at a height of 500 feet above the ground. The C-47 surveyed as far as 300 kilometers offsite at heights ranging from 500 to 2,500 feet above the ground. The C-47 flew again for about 90 minutes the day after the detonation (39; 51).

3.3 RADIATION PROTECTION AT SHOT HARRY

Exercise Desert Rock V, the test groups, and AFSWC each developed radiation protection procedures to keep individual exposure to ionizing radiation to a minimum while allowing

participants to accomplish their missions. Some of the radiological safety procedures described generally in chapter 5 of the series volume resulted in the production of records that enabled the organizations to evaluate the effectiveness of the radiation protection programs.

3.3.1 Desert Rock Radiation Protection Activities

Information concerning Desert Rock radiation protection activities has been obtained from the annex for HARRY of the Exercise Desert Rock V, Final Report (64) and from the operations order for the shot (67). Although film badge readings are not available for Desert Rock participants at HARRY, these two documents describe specific radiological safety activities at the shot.

There was no troop maneuver at HARRY, although observers witnessed the detonation from trenches 3,660 meters from ground zero. Members of the Instructor Group led the observers on a tour of the display area after the shot. At HARRY, however, the forward limit for individuals on foot was not the 2.5 R/h area, as at previous shots. Instead, observers were permitted into areas of higher radiation intensity, provided they remained below the 6.0 roentgen exposure limit, as indicated on their pocket dosimeters. The observers approached as close as 410 meters to ground zero. The highest exposure indicated by the observers' pocket dosimeters was 2.5 roentgens, with an average of 1.75 roentgens (64; 69).

Four HRS helicopters participated in the Marine Corps operational helicopter test. After the blast wave passed, helicopters A and B flew toward ground zero around the west side of the shot area. All personnel in these two aircraft wore protective

clothing. Helicopter A was able to fly within 230 meters of the upwind portion of the dust column without exceeding the established 10.0 R/h limit. Helicopter B landed about three kilometers north of ground zero, and a monitor disembarked to record radiation levels. The monitor walked toward ground zero, stopping when he encountered intensities of 10.0 R/h, the established safety limit. Helicopters C and D landed about four kilometers north of ground zero, where the radiation intensity was less than 0.05 R/h. Helicopters C and D were to have spent less than one minute in the area. Helicopter B, however, remained in the area for about 45 minutes (62-63).

Although the exposure report of the Radiological Safety Support Unit lists film badge data for JTO personnel, it also reports that one Desert Rock participant had received a total gamma exposure of 7.1 roentgens by 19 May (1b).

3.3.2 Joint Test Organization Radiation Protection Activities

Records describing JTO radiation protection activities conducted at HARRY have been obtained from the radiological safety report of Operation UPSHOT-KNOTHOLE. The available information includes dosimetry data, logistical data on film badges and protective clothing, radiological survey records and isointensity plots, and decontamination records.

Dosimetry

During the period of 16 May to 24 May 1953, which covers the 19 May detonation of Shot HARRY, the Dosimetry and Records Section of JTO issued 1,400 film badges (39).

Film badge readings indicate that four personnel received exposures exceeding the 3.9 roentgen limit during HARRY. One individual involved with a Military Effects Group project had a total exposure of 7.5 roentgens by 19 May. An individual from the 3398th Technical Training Squadron at Keesler AFB,

Mississippi, received a total exposure of 4.8 roentgens by 19 May. By 23 May, four days after the detonation, an individual from the Naval Research Laboratory had a total exposure of 4.4 roentgens. In addition, a radiological safety monitor from Fort McClellan, Alabama, received an exposure of 8.5 roentgens (1b).

Logistics and Supply

For the period covering Shot HARRY, the Supply Section issued the following items:

- 104 pairs of goggles
- 295 respirators
- 320 protective caps
- 536 pairs of cotton gloves
- 803 coveralls
- 924 shoe covers.

In addition, the Supply Section issued 143 radiological survey instruments (39).

Monitoring

The initial ground survey began one-half hour after detonation, with monitors completing the survey within the next hour. The monitoring teams encountered high radiation levels during their survey of the Yucca Flat area, so Plotting and Briefing Section personnel were unable to plot completely the isointensity lines for that area. Figure 3-3 shows a copy of the plot of this initial survey. Figure 3-4 presents copies of the plots resulting from the 20 May resurvey and from a survey of Yucca Flat on 31 May.

Four of the 21 offsite monitors were DOD personnel, who surveyed terrain east of the NPG, particularly in the area of St. George, Utah. The peak radiation intensity recorded at St. George was 0.35 R/h (39).

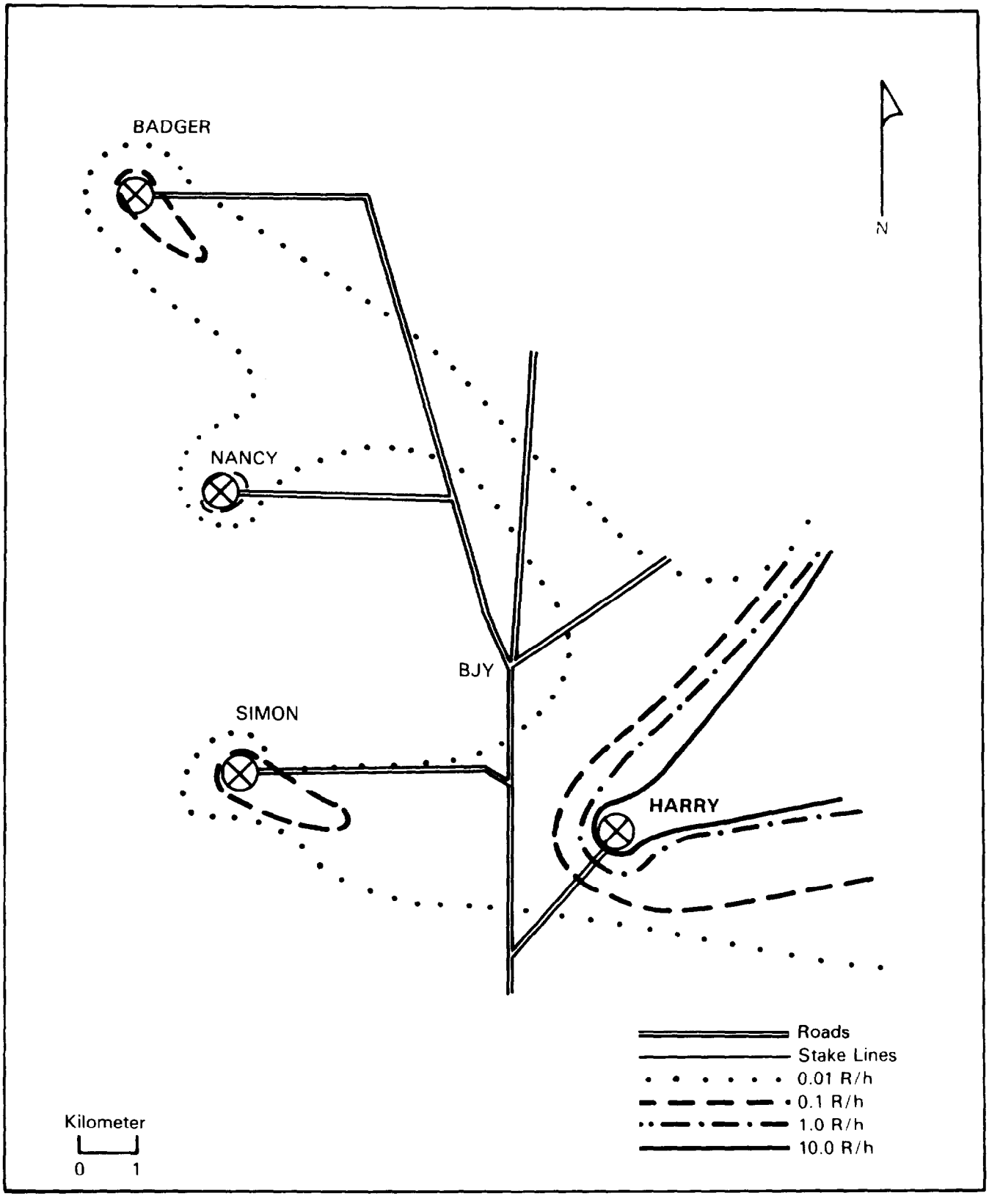
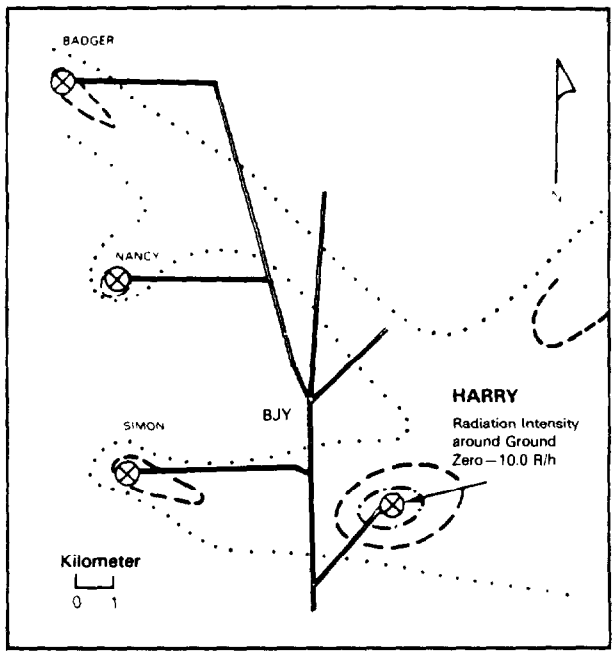
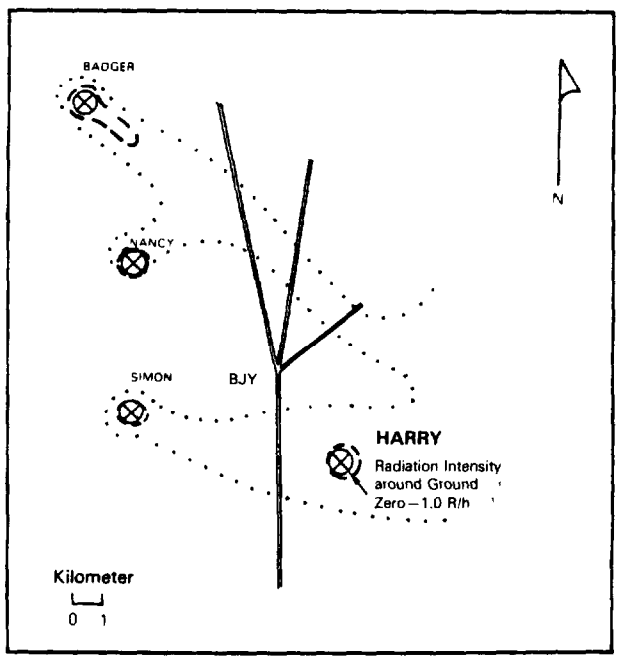


Figure 3-3: INITIAL SURVEY FOR SHOT HARRY, 19 MAY 1953, 0535 TO 0640 HOURS, WITH YUCCA FLAT RESURVEY OF 15 MAY 1953



20 May 1953, 0700 Hours



31 May 1953

Roads
0.01 R/h
0.1 R/h
1.0 R/h
10.0 R/h

Figure 3-4: SUBSEQUENT SURVEYS OF YUCCA FLAT AFTER SHOT HARRY

Decontamination

During the period of Shot HARRY, the Vehicle and Equipment Decontamination Section decontaminated 85 vehicles. In addition to the other decontamination personnel, three monitors from the Onsite Operations Section assisted with decontaminating vehicles in St. George (39).

SHOT GRABLE SYNOPSIS

AEC TEST SERIES:	UPSHOT-KNOTHOLE
DOD EXERCISE:	Desert Rock V
DATE/TIME:	25 May 1953, 0830 hours
YIELD:	15 kilotons
HEIGHT OF BURST:	524 feet (280mm cannon)

AEC Objective: To evaluate the nuclear yield, blast, thermal, and radiological phenomena produced by an atomic artillery projectile.

DOD Objective: To evaluate military equipment, tactics, and doctrine; to measure weapons effects characteristics; to evaluate the military applications of the atomic artillery projectile; and to orient DOD personnel in the tactical use of a nuclear weapon.

Weather: At shot-time, the winds at surface level were four knots from the north. Winds were 30 knots from the south-southwest at 10,000 feet, 74 knots from the southwest at 20,000 feet, and 85 knots from the southwest at 30,000 feet. The temperature was 14.8°C, the relative humidity was 32 percent, and the pressure was 901 millibars.

Radiation Data: Light fallout occurred to the north onsite. About one hour after the shot, intensities greater than 0.1 R/h were confined to an area about 0.5 kilometers from ground zero.

Participants: Exercise Desert Rock V, Armed Forces Special Weapons Project, Air Force Special Weapons Center, Los Alamos Scientific Laboratory, contractors.

CHAPTER 4

SHOT GRABLE

Shot GRABLE, the tenth test of Operation UPSHOT-KNOTHOLE, was detonated with a yield of 15 kilotons at 0830 hours on 25 May 1953. GRABLE was originally scheduled for 21 May, but because of a general change in scheduling after Shot BADGER, the event was postponed until 23 May. When Shot HARRY was postponed for three days because of unfavorable weather conditions, GRABLE was rescheduled for 25 May.

A 280mm cannon fired the atomic artillery projectile, which was detonated at a height of 524 feet above Frenchman Flat (Area 5 of the Nevada Proving Ground), at UTM coordinates 956728, which was the same ground zero intended for Shot ENCORE. The top of the cloud resulting from Shot GRABLE reached an altitude of 35,000 feet. Light fallout occurred to the north onsite and to the northeast offsite (13; 56).

The firing of GRABLE from a 280mm cannon marked the first time an atomic artillery shell was fired and detonated. Preliminary firings of the cannon, using high-explosive rounds, occurred from 15 May to 25 May. Figure 4-1 shows a preliminary firing, and figure 4-2 shows the GRABLE detonation.

The Artillery Test Unit from the Artillery Center, Fort Sill, Oklahoma, fired the GRABLE device. This unit consisted of a gun battery from the 867th Field Artillery Battalion, a communications platoon, a flash platoon, a meteorological platoon, a radar platoon, a camera team, and an ordnance detachment. Unit personnel arrived at Camp Desert Rock on 7 May. On 22 May, they participated in a full rehearsal of the shot. Although the 280mm cannon was fired by remote control, unit personnel were at the

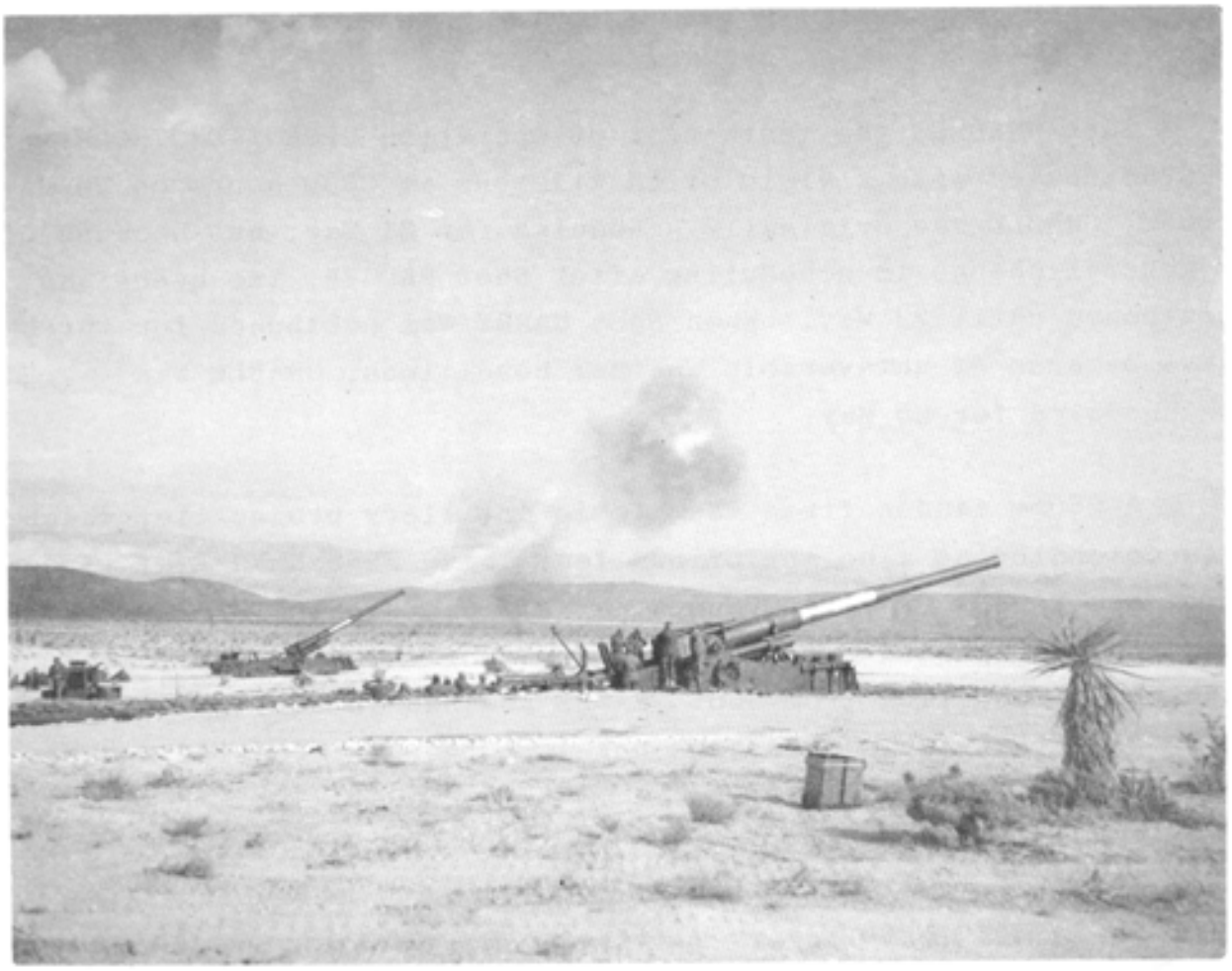


Figure 4-1: A PRELIMINARY TEST OF THE 280mm GUN USING A HIGH EXPLOSIVE SHELL

Figure 4-2: SHOT GRABLE, FIRST TEST OF THE 280mm ATOMIC GUN, 25 MAY 1953

gun position before the shot to assemble and load the round. At shot-time, these personnel were either in trenches or behind barricades for protection from blast effects and flash burns. The cannon was about ten kilometers south-southwest of ground zero (7-9; 37; 64).

The Secretary of Defense, the Secretary of the Army, the Army Chief of Staff, and several congressional observers witnessed the detonation from an area 11 kilometers north of ground zero.

4.1 EXERCISE DESERT ROCK V OPERATIONS AT SHOT GRABLE

An estimated 3,388 exercise troops and observers participated in Desert Rock V programs at Shot GRABLE. In addition, a group of 160 special observers from the 9th Ordnance Battalion viewed the detonation. Three hundred support troops, whose activities are discussed in the first part of this section, provided radiological safety, transportation, communications, and control services for the exercises in the forward area. Personnel from Army Field Forces Human Research Unit No. 2 were probably present at the shot to investigate the psychological reactions of these troops to the detonation. These research personnel were to be present for all shots attended by provisional Battalion Combat Teams. The unit probably administered a questionnaire to the troops before and after the shots. Table 4-1 provides information on the Desert Rock V programs at GRABLE by indicating the number of DOD participants in each program, thenature of the activity, and the service of involved units (64; 127).

Table 4-1: EXERCISE DESERT ROCK V ACTIVITIES AT SHOT GRABLE

Program	Participating Service	Estimated DOD Personnel
Troop Orientation and Indoctrination (Observers)	Army Navy Air Force Marine Corps	606 70 13 29
Tactical Troop Maneuvers	Army	2,670
Damage Effects Evaluation	Army	*

* Unknown

4.1.1 Support Troop Participation

The Desert Rock support troops provided logistical, operational, and administrative support to the exercise. In performing these duties, about 300 support troops sometimes entered the forward area. Particularly involved in shot-day operations were the Radiological Safety Section and the Control Group (65).

The Radiological Safety Section, supported by the 50th Chemical Service Platoon, enforced radiological safety criteria and conducted radiological surveys. One of their significant functions after the detonation was a survey of the shot area, conducted by two radiological safety teams. Each three-man team consisted of one radiological safety monitor, one driver, and one radio operator (64-65).

One of these radiological safety teams accompanied each of the BCTs into the forward area. Another radiological safety team operated on the ground zero flank of the attack line. Members of

the BCTs who accompanied their respective battalions into the shot area provided additional radiological monitoring (64-65).

The Control Group accompanied troops into the shot area to ensure that all personnel remained together and followed safety and tactical instructions. The Control Group consisted of officers and enlisted men from the Operations Section (G-3), as well as the Instructor Group, the Radiological Safety Section, and the Aviation Section (63-64). The Instructor Group consisted of an Air Force officer, a Navy officer, and a medical officer, all of whom represented AFSWP, four Army officers, and four enlisted men. After the detonation, the instructors advised observers and later the maneuver units during their tour of the display area to view the effects of the burst. They discussed differences between the predicted and actual effects (64).

In addition to the Radiological Safety Section and Control Group, several other Desert Rock support elements had duties at GRABLE.

Before the shot, the 412th Engineer Construction Battalion spent from seven to ten days preparing the display area. The 26th Transportation Truck Battalion used 184 vehicles to carry military personnel to and from the forward area. At shot-time, these vehicles were parked about ten kilometers southwest of ground zero (64-65).

The 505th Signal Service Group (Composite Company) established wire and radio communications within the forward area, as well as at Camp Desert Rock. It was planned that company personnel would operate the two mobile public address systems in the display area to assist the Instructor Group in its presentations after the shot (64-65).

The 371st Evacuation Hospital (-) provided medical support in the forward area and at Camp Desert Rock. During the maneuvers, a medical officer accompanied the Control Group to the forward area. A medical detachment of one medical officer and four enlisted men established an aid station in the parking area and moved to the forward area after the shot. In addition, two aidmen accompanied the observers after the shot (64-65; 68).

4.1.2 Troop Orientation and Indoctrination Activities

As table 4-1 indicates, 718 personnel from the four armed services participated as official observers at Shot GRABLE. All of the observers took part in the same orientation and training activities for the event. Most observers arrived at Camp Desert Rock between 18 May and 23 May. In the days preceding the shot, the Instructor Group and the Artillery Instruction Team from Fort Sill, Oklahoma, used lectures, demonstrations, and films to inform personnel about the characteristics and effects of nuclear weapons and the employment of a 280mm gun. On 23 May, the observers present rehearsed their shot-day activities, inspected the display in Area 3 of the NPG, and witnessed the 280mm gun register with high-explosive rounds (64).

On 25 May, the observers left Camp Desert Rock and arrived at the trench area by 0730 hours. The Instructor Group then conducted preshot orientation. Fifteen minutes before the shot, the observers were directed to enter the trenches, 4,570 meters west of ground zero, as shown in figure 4-3. An additional group of 160 special observers from the 9th Ordnance Battalion witnessed the detonation with the other observers (64; 68).

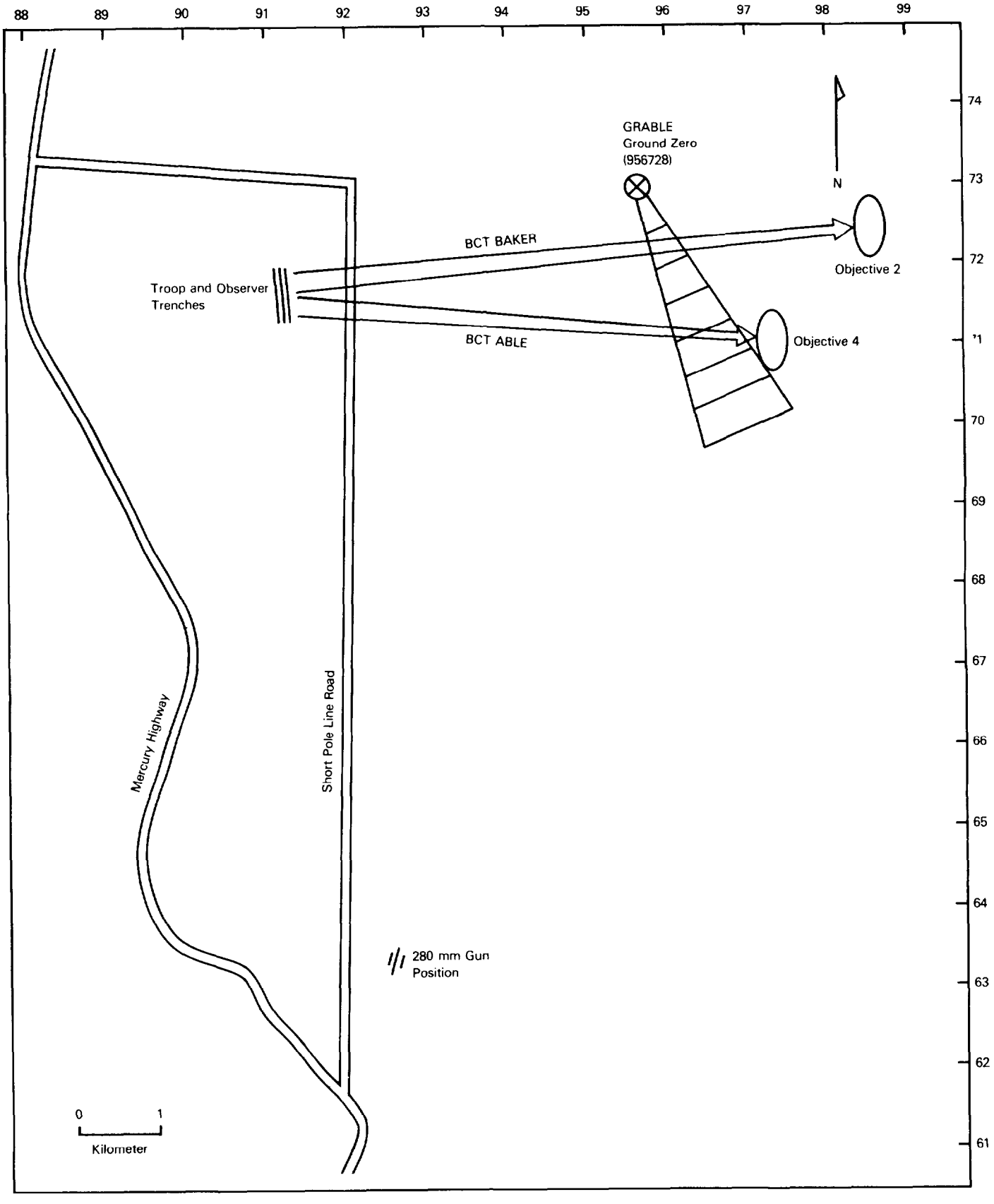


Figure 4-3: OPERATIONS ON FRENCHMAN FLAT, SHOT GRABLE

Thirty-five minutes after the shot, the observers left the trenches for the display area. They could not inspect the effects of the detonation on equipment and animals closer than 1,370 meters from ground zero, however, because of a dust storm. After spending about five hours and 15 minutes in the shot area, the observers returned to Camp Desert Rock, which they reached by 1247 hours (64).

4.1.3 Tactical Troop Maneuvers

As table 4-1 indicates, an estimated 2,670 DOD personnel took part in the tactical maneuvers at Shot GRABLE. The participants included two BCTs, composed of units from all CONUS Army areas. The following list indicates the home stations of the troops in the two BCTs (73):

First Army
- Fort Totten, New York
- Fort Jay, New York

Second Army
- Camp Pickett, Virginia
- Fort Meade, Maryland

Third Army
- Fort Jackson, South Carolina
- Fort Benning, Georgia
- Fort Bragg, North Carolina

Fourth Army
- Camp Chaffee, Arkansas
- Camp Polk, Louisiana
- Fort Bliss, Texas
- Fort Hood, Texas
- Fort Sill, Oklahoma

Fifth Army
- Camp Atterbury, Indiana
- Fort Leonard Wood, Missouri
- Camp Carson, Colorado
- Fort Sheridan, Illinois
- Fort Riley, Kansas

Sixth Army
Fort Ord, California
Fort MacArthur, California
Presidio of San Francisco, California.

Participants in the troop maneuvers began arriving at Camp Desert Rock on 18 May. The troops attended classes presented by the Instructor Group and were shown films on nuclear energy and weapons. On 23 May, the troops rehearsed the exercise. They practiced all activities scheduled for shot-day, including observation of the detonation from the trenches, the maneuver to be conducted immediately after the shot, and the inspection of the display area. The rehearsal was halted because a dust storm limited movement through the display area. At 1125 hours, the troops began their return to Camp Desert Rock, which they reached three hours later (64).

At 0452 hours on 25 May, maneuver troops left Camp Desert Rock for the trench area. After the troops had disembarked, the vehicles were driven to a parking area about ten kilometers from ground zero. All troops were at the trenches, located at UTM coordinates 911717, by approximately 0730 hours. Fifteen minutes before the shot, personnel were directed into the trenches, where they were instructed to crouch two minutes before shot-time. Three seconds after the shot and before shock arrival, the troops were allowed to stand and view the fireball (64).

At 0841 hours, 11 minutes after the shot, the BCTs began their attack toward the objectives, 2,400 meters southeast of ground zero and 2,800 meters east-southeast of ground zero. Figure 4-3 shows the locations of the objectives and movements of the troops. BCT BAKER reached 700 meters to the south of ground zero, while BCT ABLE moved 1,200 meters south of ground zero (64).

The attack was halted at 0950 hours because of high winds and dust. Elements of BCT BAKER were subsequently able to inspect a portion of the display area up to the 450-meter line. BCT ABLE could not proceed into the display area (64).

Vehicles were then driven to the display area to transport the troops back to Camp Desert Rock. They left Frenchman Flat at 1100 hours and arrived at the camp by 1200 hours. The troops left for their home stations on the following day (64).

4.1.4 Damage Effects Evaluation

The GRABLE display area was established southeast of ground zero by the 412th Engineer Construction Battalion and the 3623rd Ordnance Company, who constructed fortifications and placed equipment, respectively. Fortifications, including trenches, bunkers, and foxholes, were constructed at 460-meter intervals 460 to 3,200 meters from ground zero. In addition, stakes were placed in the open every 460 meters. As at Shot ENCORE, two sections of bridge were constructed 460 meters from ground zero. Equipment was placed in approximately the same areas, except for one 2 1/2-ton truck, placed at ground zero. Other equipment in the display area included trucks of various sizes, machine guns, mortars, 57mm guns, rifles, communications equipment, howitzers, flamethrowers, a trailer, and a rocket launcher. After the shot, engineer, ordnance, chemical, medical, and quartermaster teams evaluated damage to the equipment, animals, and fortifications in the display (64).

In conjunction with the damage effects evaluation, Army personnel placed test animals and instruments in the fortifications constructed for the display area. These specimens were used in medical and shielding evaluations (64).

For the evaluation of damage to animals, 45 sheep were placed in the display area on the day before the shot. They were placed in trenches, bunkers, foxholes, and in the open at 460-meter intervals from 460 to 2,290 meters from ground zero (64).

Immediately after the shot, the veterinary officer, a monitor, and an enlisted technician accompanied the Control Group into the forward area. These men moved forward by vehicle to the display area to evaluate the effects of the detonation on the sheep. Later that day, the sheep that survived the shot were taken to pens at Frenchmen Flat, where they were isolated and observed for further effects (64).

To evaluate the shielding offered by the fortifications, a chemical team, probably from the 50th Chemical Service Platoon, placed film badges in the bunkers, trenches, and foxholes, and in the open. Sometime after the shot, the chemical team obtained and recorded readings from the badges (64).

4.2 DEPARTMENT OF DEFENSE PARTICIPATION IN JOINT TEST ORGANIZATION OPERATIONS AT SHOT GRABLE

Department of Defense personnel took part in projects conducted by the Military Effects Group, the Weapons Development Group, and the Civil Effects Group. In addition, DOD personnel of the Air Force Special Weapons Center provided support to the test groups and the Test Manager. Table 4-2 lists the test group projects by number and title and identifies the participating groups.

4.2.1 Military Effects Group Projects

As shown in table 4-2, many of the Military Effects Group projects at Shot GRABLE were part of Program 3. Because most of

Table 4-2: TEST GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT GRABLE

Project	Title	Participants
	Military Effects Group	
1.1a/1.2	Air Blast Measurements	Naval Ordnance Laboratory
1.1a-1	Evaluation of Wiancko and Vibrotron Gauges and Development of New Circuitry for Atomic Blast Measurements	Naval Ordnance Laboratory
1.1a-2	Development of Mechanical Pressure-time and Peak Pressure Recorders for Atomic Blast Measurements	Naval Ordnance Laboratory
1.1b	Air Pressure and Ground Shock Measurements	Stanford Research Institute
1.1d	Dynamic Pressure versus Time and Supporting Air Blast Measurements	Sandia Corporation
1.4	Free-field Measurements of Earth Stress, Strain and Ground Motion	Sandia Corporation
2.2a	Gamma Radiation Spectrum of Residual Contamination	Signal Corps Engineering Laboratories
2.2b	Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material	Naval Medical Research Institute
2.3	Neutron Flux Measurements	Naval Research Laboratory
3.1	Tests on the Loading of Building and Equipment Shapes	Air Materiel Command; Armour Research Foundation
3.1u	Shock Diffraction in the Vicinity of a Structure	Naval Ordnance Laboratory ·
3.3	Test on the Loading of Horizontal Cylindrical Shapes	Air Materiel Command; Armour Research Foundation
3.4	Tests on the Loading of Truss Systems Common to Open-framed Structures	Air Materiel Command; Armour Research Foundation
3.6	Test on the Loading and Response of Railroad Equipment	Air Materiel Command; Armour Research Foundation; Army Transportation Corps
3.7	Air Blast Effects on Entrances and Air Intakes of Underground Installations	Office, Chief of Engineers, U.S. Army; Structural Research Laboratory, University of Illinois*
3.8	Air Blast Effects on Underground Structures	Office, Chief of Engineers, U.S. Army; Structural Research Laboratory, University of Illinois
3.9	Field Fortifications	Engineer Research and Development Laboratories*
3.11-3.16	Navy Structures	Bureau of Yards and Docks*
3.18	Minefield Clearance	Engineer Research and Development Laboratories; 412th Engineer Construction Battalion; 44th Infantry Division
3.19	Blast Damage to Coniferous Tree Stands by Atomic Explosions	Forest Service

* Other participating agencies are listed in the text.

Table 4-2: TEST GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT GRABLE (Continued)

Project	Title	Participants
	Military Effects Group	
3.20	Blast and Thermal Effects of an Atomic Bomb on Typical Tactical Communication Systems	Signal Corps Engineering Laboratories*
3.21	Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts	Ballistic Research Laboratories
3.22	Effects on Engineer Bridging Equipment	Engineer Research and Development Laboratories
3.24	Effects of an Airburst Atomic Explosion on Landing Vehicles Tracked (LVT's)	Naval Radiological Defense Laboratory
3.26	Test of the Effects on POL Installations	Air Materiel Command; Office of the Quartermaster General; Marine Corps Schools
3.28.1	Structures Instrumentation	Ballistic Research Laboratories
3.28.2	Pressure Measurements for Various Projects of Program 3	Naval Ordnance Laboratory
3.28.3	Pressure Measurements on Structures	Stanford Research Institute
3.30	Air Blast Gauge Studies	Ballistic Research Laboratories
4.2	Direct Air Blast Exposure Effects in Animals	Naval Medical Research Institute
4.7	Beta-gamma Skin Hazard in the Postshot Contaminated Area	Walter Reed Army Medical Center
4.8	The Biological Effects of Neutrons	Naval Radiological Defense Laboratory
6.2	Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques	Wright Air Development Center; Vitro Corporation
6.3	Interim IBDA Capabilities of Strategic Air Command	Strategic Air Command
6.7	Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations	Signal Corps Engineering Laboratories
6.8a	Initial Gamma Exposure versus Distance	Signal Corps Engineering Laboratories
6.10	Evaluation of Rapid Aerial Radiological Survey Techniques	Signal Corps Engineering Laboratories
6.12	Determination of Height of Burst and Ground Zero	Signal Corps Engineering Laboratories; Army Field Forces Board #1
6.13	Effectiveness of Fast Scan Radar for Fireball Studies and Weapons Tracking	Naval Electronics Laboratory
7.1	Electromagnetic Effects from Nuclear Explosions	Headquarters, Air Force*
7.3	Detection of Airborne Low Frequency Sound from Nuclear Explosions	Headquarters, Air Force*
7.4	Seismic Measurements	Headquarters, Air Force
7.5	Calibration and Analysis of Close-in A-Bomb Debris	Headquarters, Air Force; AFSWC

* Other participating agencies are listed in the text.

Table 4-2: TEST GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT GRABLE (Continued)

Project	Title	Participants
8.1b	Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs	Wright Air Development Center
8.2	Measurement of Thermal Radiation with a Vacuum Microphone	Air Force Cambridge Research Center
8.4.1	Protection Afforded by Operational Smoke Screens against Thermal Radiation	Chemical and Radiological Laboratories; Naval Radiological Defense Laboratory
8.4.2	Evaluation of a Thermal Absorbing Carbon Smoke Screen	Chemical and Radiological Laboratories; Naval Radiological Defense Laboratory
8.5	Thermal Radiation Protection Afforded Test Animals by Fabric Assemblies	Quartermaster Research and Development Laboratories; Walter Reed Army Medical Center; Atomic Energy Project, University of Rochester
8.6	Performance Characteristics of Clothing Materials Exposed to Thermal Radiation	Quartermaster Research and Development Laboratories
8.9	Effects of Thermal Radiation on Materials	Naval Material Laboratory
8.10	Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation	Naval Radiological Defense Laboratory
8.11a	Incendiary Effects on Building and Interior Kindling Fuels	Forest Service, Forest Products Laboratory
8.11b	Ignition and Persistent Fires Resulting from Atomic Explosions: Exterior Kindling Fuels	Forest Service—Division of Fire Research
8.12a	Sound Velocities near the Ground in the Vicinity of an Atomic Explosion	Naval Electronics Laboratory
8.12b	Supplementary Pressure Measurements	David Taylor Model Basin
9.1	Technical Photography	EG&G; Signal Corps Pictorial Center; Air Force Lookout Mountain Laboratory
9.6	Production Stabilization	Army Waterways Experiment Station*
9.7	Experimental Soil Stabilization	Army Waterways Experiment Station*
	Weapons Development Group	
13.1	Radiochemistry Sampling	Air Force Special Weapons Center
18.1	Total Thermal and Air Attenuation	Naval Research Laboratory
18.2	Power versus Time	Naval Research Laboratory
18.3	Spectroscopy	Naval Research Laboratory
18.6	Surface-brightness Investigations	Naval Research Laboratory
	Civil Effects Group	
23.17	Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres	Naval Radiological Defense Laboratory
29.1	Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation	Atomic Energy Project, UCLA*

* Other participating agencies are listed in the text.

the projects were the same as those conducted at Shot ENCORE, little preshot construction was necessary. In addition, most of the instrumentation used for projects at ENCORE remained in the field after personnel recalibrated the gauges and conducted a dry run to insure that all equipment necessary for GRABLE was working properly. An organization designated as Project 3.28 provided instrumentation for these Program 3 projects: 3.1, 3.1u, 3.3, 3.4, 3.6, 3.7, 3.8, 3.9, 3.13, 3.14, 3.15, 3.19, 3.21, and 3.22.

The Test Director declared recovery hour at 0952 hours. At this time, project personnel were briefed on the radiological environment in the areas where the experiments were placed and given access permits to enter the area through designated checkpoints.

Projects 1.1a/1.2, Air Blast Measurements, were fielded by the Naval Ordnance Laboratory to measure blast pressures at various distances from a nuclear detonation. In addition, the experiment studied the effect of different surfaces on the blast wave. Project personnel measured peak overpressure by photographing smoke rocket trail distortions. For Project 1.1a, they used three instrumented blast lines, two of which were used for this project at Shot ENCORE.

Project personnel recalibrated the blast gauges and checked the recording instruments in the field 80 to 4,570 meters along the main blast line west of ground zero and 150 to 1,520 meters along the smoke line. They placed gauges 290 to 780 meters from ground zero along a north-south blast line near the minefield area set up for Project 3.18. In another part of Project 1.1a, personnel recalibrated gauges that had been placed along the main blast line and along a blast line southwest of ground zero for ENCORE. These gauges were 200 to 1,650 meters along the main blast line and 180 to 1,094 meters along the southwest line from the actual GRABLE ground zero. Recording instruments were

probably placed along the blast lines and checked before the detonation. For the Project 1.2 smoke rocket photography, participants positioned 13 launchers east of ground zero in the same location as the launchers used at ENCORE and a camera in a station 3,680 meters west of ground zero. For another part of Project 1.2, personnel placed cameras south of the main blast line to photograph the effect of the shock wave along the ground.

At about 1200 hours, three project personnel retrieved film from the cameras, spending approximately 30 minutes in the test area. Five hours after the announcement of recovery hour, an estimated three project personnel began retrieving blast gauge records, a process requiring about one hour (16; 91).

Project 1.1a-1, Evaluation of Wiancko and Vibrotron Gauges and Development of New Circuitry for Atomic Blast Measurements, tested four types of experimental blast gauges. Project 1.1a-2, Development of Mechanical Pressure-time and Peak Pressure Recorders for Atomic Blast Measurement, evaluated two different mechanical air-blast gauges. The weapons test reports for Projects 1.1a-1 and 1.1a-2 do not describe the projects, but the reports do indicate that Project 1.1a personnel conducted or assisted in the related field and laboratory activities. Both projects were probably part of Project 1.1a, and the experimental gauges were either the same as those used for Project 1.1a or were placed in the same areas and connected to the same recording equipment (96; 100).

The objective of Project 1.1b, Air Pressure and Ground Shock Measurements, was to obtain data on blast phenomena resulting from GRABLE. The gauges and recording equipment were placed in the field before the ENCORE detonation. The gauges that had been at ground zero and above-ground out to 150 meters from the ENCORE ground zero were removed before Shot GRABLE so they would not be destroyed. Five hours before the shot, project personnel

calibrated 52 air pressure gauges, 13 acceleration gauges, and six experimental gauges 300 meters to 1,520 meters from the intended ground zero. Two hours after recovery hour, three project personnel retrieved records. Plans called for them to spend one hour in the test area (16; 120).

Project 1.1d, Dynamic Pressure versus Time and Supporting Air Blast Measurements, was designed to measure blast wave pressures near ground level and to evaluate new and modified gauges. Gauges placed along the main blast line before ENCORE were calibrated before GRABLE. The gauges were located between 150 and 1,980 meters from ground zero. Project 1.1d gauges were also placed on a bridge structure for Project 3.4 and in the tree stand established by Project 3.19. Two hours after recovery hour, two parties of three men each spent an estimated 90 minutes retrieving records (16; 23; 107).

Project 1.4, Free-field Measurements of Earth Stress, Strain, and Ground Motion, had two objectives:

- To measure the degree that various depths of earth cover reduced the vertical forces produced by a nuclear device
- To test instruments used to measure forces transmitted through the earth.

The earth stress accelerometers and air pressure gauges used during Shot ENCORE remained in the field for the GRABLE detonation. The gauges were along the main blast line 340 meters from the actual GRABLE ground zero. Project personnel calibrated the above-ground gauges before the shot. The gauges were attached to cables connected to recording equipment in the Project 1.1d shelters. After the detonation, personnel from Projects 1.1d and 1.4 recovered the records in the shelter (16; 99; 107).

Project 2.2a, Gamma Radiation Spectrum of Residual Contamination, was conducted to characterize the residual gamma contamination resulting from the detonation. Two hours after the shot,

three project personnel transported a spectrometer to a location 730 meters west of ground zero. There they removed the spectrometer from the van and took spectral measurements for two hours. They then returned the spectrometer to the van and drove out of the area.

Project members took similar measurements one day and four days after the shot. The day after the detonation, a group worked 240 meters west of ground zero, where the radiation intensity was 0.25 R/h. Four days after the shot, personnel made measurements 120 meters west of ground zero, where intensities were 0.23 R/h (18).

The objective of Project 2.2b, Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material, was to evaluate the biological effects of residual beta and gamma radiation fields. For this shot, however, measurements were made in initial as well as residual radiation areas. Before the detonation, a phantom containing radiation detection devices was placed along the main access road. The phantom was made of material simulating human tissue.

After recovery hour, six project participants placed more instrumented phantoms and lucite and masonite spheres 370 and 460 meters from ground zero, where the radiation intensities were 10.0 R/h and 3.0 R/h, respectively. They also recovered the phantom placed in the field before the detonation. They recovered the other phantoms and spheres about one hour later. The next day, project participants performed similar activities at the location 370 meters from ground zero (16; 30).

Project 2.3, Neutron Flux Measurements, measured neutron intensities at various distances from ground zero. Before the shot, project personnel attached neutron detectors to a cable extending 900 meters from ground zero. They also placed

detectors on stakes 900 to 1,830 meters from ground zero. These detectors were also attached to cables that led to the main cable. Soon after the detonation, four project personnel recovered the cable by attaching the end farthest from ground zero to a truck and driving until the other end was past the 900-meter point. They then removed the detectors as quickly as possible (126).

Project 3.1, Tests of the Loading of Building and Equipment Shapes, was conducted by the Air Materiel Command, with primary contracting assistance from the Armour Research Foundation and construction assistance from the Silas Mason Company. The objective was to collect more information about blast effects on various structures, materials, and equipment differing in size, shape, and orientation to the detonation.

Project personnel used the 15 structures that had been assembled for Shot ENCORE. These structures were on an arc 1,500 meters west of the intended ground zero. Two additional models were placed 350 and 670 meters from the actual GRABLE ground zero. Project 3.28 personnel calibrated the 235 gauges previously placed on these structures. When the area was declared open for recovery operations, personnel returned to inspect damage to structures and recover instrument records (55).

Project 3.1u, Shock Diffraction in the Vicinity of a Structure, was fielded by the Naval Ordnance Laboratory to determine changes in the shock wave pattern as it diffracted around a structure. Fourteen pressure gauges had been placed in and around a structure located 670 meters from the intended ground zero before Shot ENCORE. Before the shot, project personnel calibrated the gauges and placed recording equipment in a safe location, probably inside the shelter. Projects 1.1a and 3.28.2, conducted by the Naval Ordnance Laboratory, also used the instrumentation system. Participants returned to the test

site to retrieve the records and gauges when the area was cleared for recovery operations (90).

Project 3.3, Test on the Loading of Horizontal Cylindrical Shapes, was conducted by the Armour Research Foundation for the Air Materiel Command. The main objective was to increase the knowledge of blast loadings on cylindrical structures.

Five steel cylinders with reinforced end-sections were supported above the ground at two stations 1,460 and 1,910 meters from ground zero. Project 3.28.1 personnel recalibrated 30 air pressure gauges and ten strain gauges placed on the cylinders before Shot ENCORE. At recovery hour, participants returned to the site to observe the results and collect the gauges (112).

Project 3.4, Tests on the Loading of Truss Systems Common to Open-framed Structures, was conducted by Armour Research Foundation for the Air Materiel Command. The project was designed to determine the effects of a nuclear blast on open-framed structures, such as bridges. The data obtained were compared to wind-tunnel data and data gathered during earlier nuclear weapons testing series.

Five structures, each of which duplicated the center section of an open-deck, single-track railroad bridge, had been positioned 670 to 710 meters northwest of ground zero before Shot ENCORE. Project 3.28.1 personnel recalibrated the strain gauges on the foundations of the structures. When the test site was cleared for postshot activities, participants recovered the gauges and inspected the bridge spans (111).

Project 3.6, Tests of the Loading and Response of Railroad Equipment, was fielded by the Army Transportation Corps and the Armour Research Foundation, under contract to the Air Materiel Command. The Air Materiel Command provided 11 personnel for the

project, and the Army Transportation Corps provided 23 personnel to perform the postshot damage survey and evaluation. The objective was to study the vulnerability of various types of railroad equipment to the blast and thermal effects of a nuclear detonation.

Project personnel positioned 15 railroad cars and a locomotive at six locations 460 to 2,010 meters from ground zero on tracks constructed for the project. Project 3.28.1 personnel installed pressure gauges and accelerometers on three cars and calibrated the instruments before the shot. Project 9.1 personnel positioned cameras at each of the locations. About five hours before the shot, four project participants started the locomotive engine and otherwise prepared the vehicle for the test.

At recovery hour, two project personnel accompanied by a monitor traveled to the project site to shut down the locomotive engine and cover the intake valves. The estimated time in the area was 30 minutes. Two hours later, five project personnel accompanied by a monitor inspected the damage to the cars. They spent about one hour in the area. Sometime after recovery hour, project participants recovered gauges and film (16; 113).

Project 3.7, Air Blast Effects on Entrances and Air Intakes of Underground Installations, was conducted for the Office of the Chief of Engineers, U.S. Army, through a contract with the Structural Research Laboratory of the University of Illinois. The objective was to obtain basic data to be used in designing underground shelters for protection from nuclear detonations.

Six hours and 30 minutes before the shot, three project personnel went to the same underground structure used for Shot ENCORE, located 290 meters southwest of ground zero. There they spent about three hours removing the seal on filters and starting

the electric generators. Before the shot, Project 3.28.2 and 3.28.3 personnel recalibrated 34 air pressure gauges and two ground-surface air pressure gauges near and on the structure. Three hours after recovery hour, ten personnel from Projects 3.7, 3.8, and 3.28 returned to the test area to open this structure and the Project 3.8 structures, turn off generators, collect data, and check for gross damage effects (16; 118).

Project 3.8, Air Blast Effects on Underground Structures, was performed by the Structural Research Laboratory of the University of Illinois for the Office of the Chief of Engineers, Army. The overall objective was similar to that of Project 3.7: to obtain data for designing underground shelters. The three underground test structures, also used at Shot ENCORE, were on an arc about 280 meters west-northwest from the intended GRABLE ground zero. They were built of reinforced concrete with roofs of simply supported steel-beam strips. Project 3.28.1 personnel recalibrated the earth pressure and air pressures gauges placed in and around the structures before Shot ENCORE. Three hours after recovery hour, ten participants retrieved the gauges and examined the structures (93).

Project 3.9, Field Fortifications, was conducted by the Engineer Research and Development Laboratories, with instrumentation and technical assistance provided by the Naval Material Laboratory, the Naval Radiological Defense Laboratory, the Ballistic Research Laboratories, the Signal Corps Engineering Laboratories, and Naval Ordnance Laboratory personnel from Project 3.28.2.

The main objectives were to obtain data on the effects of the blast on field fortifications and to take radiation measurements. The fortifications included command posts, machine gun emplacements, and two-man foxholes 150, 460, 1,220, 1,830,

and 2,440 meters from the planned ground zero. The fortifications had been built and instrumented with pressure and thermal gauges and film badges before Shot ENCORE. Before GRABLE, personnel recalibrated the gauges and checked the recording instruments.

At about 1100 hours, four project personnel began recovering the gauge data, and one participant started collecting the film badges. This mission took about three hours. In addition, Project 9.1 personnel photographed the fortifications (53).

Projects 3.11 through 3.16, Navy Structures, were conducted by the Navy Bureau of Yards and Docks. Personnel from the following organizations assisted in fielding the projects: the Naval Civil Engineering Research and Evaluation Laboratory, the Stanford Research Institute, the Army Signal Corps, and Project 3.28.1 and 3.28.2 participants.

The overall objective was to study the protection afforded by various structures against the effects of a nuclear blast. Each project tested a particular structure (82):

- 3.11, steel warehouses
- 3.12, brick buildings and precast panels
- 3.13, precast personnel shelters
- 3.14, precast warehouse
- 3.15, steel arch shelter with earth cover
- 3.16, prefabricated wood paneled structures containing various types of window glass hardware.

The structures, completed in April before the ENCORE detonation, were 820 to 6,100 meters from ground zero. Fifty-four gauges measuring pressure, deflection, strain, torque, and shear were interspersed among the various structures. Project 9.1 personnel photographed the test structures before the

shot and again after recovery hour. Other personnel retrieved the gauges and made surveys to detect cracks and points of stress (16; 82).

Project 3.18, Minefield Clearance, was supervised by the Engineer Research and Development Laboratories and fielded by a company from the 412th Engineer Construction Battalion and by five personnel from the 44th Infantry Division, Fort Lewis, Washington. The project was to study the effects of a nuclear blast on pressure-activated land mines.

Before ENCORE, the company from the 412th had built a fence around the field to be mined. The area, about 820 meters from the GRABLE ground zero, was 190 meters wide and 640 meters long. The company began to lay the mines after ENCORE. Two days before Shot GRABLE, the five 44th Infantry Division personnel armed the mines.

After recovery hour, participants from the 44th Infantry Division went into the project area, where they recorded data pertaining to the live mine detonations and recovered fuses from indicator mines. They also destroyed the remaining mines by detonating a TNT charge on top of each mine. The engineer company then repaired the fence and minefield markers and replaced signs around the perimeter of the area (105).

Project 3.19, Blast Damage to Coniferous Tree Stands by Atomic Explosions, was fielded by the Forest Service, Department of Agriculture. The objective was to assess the damage done to trees by the detonation and to determine the amount of cover provided by a forest.

Before Shot ENCORE, the trees had been placed in a stand about 2,000 meters from ground zero and along two parallel lines 460 to 2,440 meters west-southwest of ground zero. After ENCORE,

trees that had been broken by the blast were removed, and Project 3.28.2 and 3.28.3 personnel recalibrated the gauges in the tree stand and on several of the trees. Project 9.1 personnel photographed the trees before GRABLE.

One hour after recovery hour, three personnel and a monitor recovered the gauge data. Two hours after recovery hour, five personnel reached the site to measure the age and diameter of fallen trees and study the remaining trees. Project 9.1 personnel again photographed the trees (16; 109).

Project 3.20, Blast and Thermal Effects of an Atomic Bomb on Typical Tactical Communication Systems, was fielded by the Signal Corps Engineering Laboratories, with support from Coles Signal Laboratory personnel. Lookout Mountain Laboratory personnel provided preshot and postshot photography. The objective was to determine the effects of a nuclear blast on signal communication-electronics.

The day before GRABLE, project personnel repaired or replaced equipment used for the experiment at ENCORE. The items used were placed along a line 90 to 2,450 meters from the GRABLE ground zero. Five hours before the shot, personnel went to project stations to start power generators and radio receivers. When the area was cleared for postshot activities, damage analysis personnel and photographers evaluated the effects of the detonation on test equipment (16; 48).

Project 3.21, Statistical Estimation of Damage to Ordnance Equipment Exposed to Nuclear Blasts, was fielded by personnel from the Ballistic Research Laboratories. The objective was to obtain data on damage to various weapons and vehicles for use in predicting the percentage of equipment that would be available for combat within a given time after exposure to a nuclear blast.

Before the shot, project participants positioned trucks and tanks at sites 110 to 1,340 meters from ground zero. Project 3.28 personnel attached gauges measuring linear displacement to the frames of the equipment. Project 9.1 personnel set up six movie cameras at three locations to record the effects of the detonation.

Seven men traveled in a five-ton wrecker into the area to evaluate and recover the vehicles two days after the shot. During the recovery phase, they used the wrecker to right all vehicles that had been overturned. About 65 man-hours were required to upright the vehicles and evaluate the damage (25).

Project 3.22, Effects on Engineer Bridging Equipment, was conducted by the Engineer Research and Development Laboratories. The objective was to determine the effects of a nuclear blast on prefabricated inflexible bridging. The particular types of structures tested were a double-truss, single-story Bailey bridge and a T-6 aluminum bridge.

Before Shot ENCORE, the 412th Engineer Construction Battalion set up two 30-meter Bailey bridge spans and two single-bay aluminum bridge sections 320 to 1,340 meters from the intended ground zeros of ENCORE and GRABLE. Project 3.28 personnel recalibrated accelerometers and strain gauges located on the structures. Project 9.1 personnel placed cameras in the area of each bridge to photograph its movement during the detonation. Three hours after the announcement of recovery hour, four men went into the test site and spent about one hour assessing damage, retrieving gauge data, and recovering the film (16; 88).

Project 3.24, Effects of an Airburst Atomic Explosion on Landing Vehicles Tracked (LVT's), was fielded by the Naval Radiological Defense Laboratory and five Marine Corps personnel. The objective was to determine the degree of blast damage the

LVTs would sustain from a nuclear explosion and to determine the degree of protection that these vehicles would give personnel. Before the shot, personnel stationed six LVTs 310 to 1,050 meters from ground zero. Dosimeters were attached to each of the vehicles, and temperature gauges were placed on two of them. Project 9.1 personnel placed a motion picture camera near one of the vehicles to record movement.

After recovery hour, a group that included at least the five Marine Corps personnel and Project 9.1 personnel went to the test site. The Marines inspected each vehicle and detailed the damage. Project 9.1 participants took still photographs and recovered the motion picture film. They spent an estimated 40 minutes in the area (16; 98).

Project 3.26, Tests of the Effects on POL* Installations, was conducted in three parts:

- Project 3.26.1, Test of the Effects on POL Installations, performed by the Armour Research Foundation under contract to the Air Materiel Command
- Project 3.26.2, Effects of Atomic Weapons on a POL Supply Point, performed by the Quartermaster Research and Development Field Evaluation Agency for the Office of the Quartermaster General
- Project 3.26.3, Effect of an Atomic Explosion upon an Amphibious Assault Fuel Handling System (Shore Phase), conducted by the Marine Corps Schools.

The objective was to determine the effects of a nuclear blast on tactical fuel supply systems and containers (115).

For Project 3.26.1, the Armour Research Foundation (the contractor for the Air Materiel Command) stacked 55-gallon drums 230 to 480 meters from ground zero and placed six empty storage tanks 500 to 4,570 meters from ground zero, with assistance from

*Petroleum, Oil, Lubricants

the Silas Mason Company. Project 3.28.1 personnel attached air pressure and temperature gauges to the test items. Project personnel placed two high-speed cameras near each item to photograph the motion of the tanks and drums. About four hours after recovery hour, ten personnel entered the area to extinguish small fires and inspect damage. This took about one hour (4; 115).

For Project 3.26.2, personnel from the Quartermaster Research and Development Field Evaluation Agency placed stacks of gasoline cans and drums in the open at four stations 230 to 660 meters from ground zero. Before the detonation, when all stations were set up, photographs were taken. After the detonation, at recovery hour, six project personnel and a monitor traveled to the stations and examined each item. Photographs were again taken at each site (4; 16; 115).

For Project 3.26.3, Marine Corps personnel placed LVT-transported fuel tanks and shore unloading, transfer, dispensing, and storage equipment at three locations 230, 330, and 490 meters from ground zero. At recovery hour, four project personnel and a monitor traveled to each of the sites to inspect damage. The inspection took about one hour (4; 16; 115).

Project 3.28.1, Structures Instrumentation, was conducted by the Ballistic Research Laboratories to obtain structural loading data for the following Program 3 projects: 3.1, 3.3, 3.4, 3.6, 3.8, 3.13, 3.14, 3.15, 3.21, and 3.22. Project 3.28.1 personnel determined proper instrumentation layout, procured, installed, and operated the instruments, and reduced the field data for each of the ten projects. Assisting Ballistic Research Laboratories personnel were Air Force, Army, and Navy officers and enlisted men provided through AFSWP. Most of the gauges and recording instruments were placed along the main blast line, extending about 2,050 meters west of ground zero. After they had placed

the gauges and recording instruments in the field, personnel checked the gauges about eight days before the shot, conducted a complete dry run three days before the shot, and made a final check of all instruments the day before the shot. As soon after recovery hour as possible, three teams of three men each entered the recording shelters, retrieved all data tapes, and returned them to another location, probably at Camp Mercury, to play them back and make reproductions (84).

Project 3.28.2, Pressure Measurements for Various Projects of Program 3, was conducted by Naval Ordnance Laboratory personnel, with assistance from five military officers and six enlisted men provided by AFSWP. The objectives were to make pressure-time measurements in and around an underground structure and above-ground structures, foxholes, in a tree stand, and in isolated trees for Projects 3.1, 3.1u, 3.7, 3.9, 3.13, and 3.19, and to present the resulting data to the agencies conducting those six projects. The recording instrumentation used for these projects by Project 3.28.2 was also used by Naval Ordnance Laboratory Project 1.1a. The recording instruments were housed in two vans 2,130 and 3,500 meters from ground zero, and the gauges were placed in the field. After the detonation, personnel retrieved the records and returned to Camp Mercury to play them back and reproduce them for the participating agencies (89).

Project 3.28.3, Pressure Measurements on Structures, was conducted by the Stanford Research Institute to measure pressure on and around Project 3.1 structures along an arc located about 1,500 meters from ground zero. Recording instrumentation was in an underground shelter behind the structures. At recovery hour, personnel retrieved the records (119).

Project 3.30, Air Blast Gauge Studies, was fielded by personnel from the Ballistic Research Laboratories. The objective was to test a new self-contained recording gauge for the

measurement of pressure-time phenomena from a nuclear blast. Before the shot, personnel placed gauges on the main blast line 140 to 1,980 meters due west of ground zero and on a blast line 230 to 1,140 meters southwest of ground zero. They mounted the gauges in several different positions, on roofs, rear walls of structures, and under test vehicles. Four hours after recovery hour, three project personnel began retrieving the gauge data. They did not complete recovery at that time because of higher than acceptable levels of radiation in the area (4; 16; 78).

Project 4.2, Direct Air Blast Exposure Effects in Animals, was conducted to evaluate injuries received by animals exposed to 20 to 50 pounds-per-square-inch of overpressure. The information obtained was used in estimating direct blast hazards to humans in air raid shelters or underground bunkers.

Project personnel exposed rats and dogs in open-ended aluminum cylinders, which were sandbagged and covered with wet dirt to secure them and to shield them from radiation and flying debris. The ends were covered with wire mesh, which allowed entrance of the airblast wave. Pressure recorders were placed in four of the cylinders. Project participants spent about an hour placing the cylinders at seven locations 290 to 460 meters from ground zero. Four hours after recovery hour, three project personnel spent 15 minutes in the test area retrieving the animals and instruments (4; 16; 46).

The objective of Project 4.7, Beta-gamma Skin Hazard in Post-shot Contaminated Area, was to measure beta (and low-energy gamma) radiation exposure to human skin. Another objective was to determine to what extent this exposure exceeded the exposure routinely reported in radiological safety monitoring, which generally measured only gamma radiation exposure.

One hour after the area was cleared for recovery operations, project personnel established a station at the 0.01 R/h line. They then looked for a spot further within the radiation area where a gamma survey meter would read about 0.8 R/h. At GRABLE, the 0.8 R/h area was located 730 meters from ground zero. Here, personnel placed thin-walled and thick-walled ion chambers attached to wooden racks and then returned to the 0.01 R/h station. The thin-walled chambers were of the same thickness as the outer layer of human skin and had a similar sensitivity to beta radiation. By placing experiments in a 0.8 R/h area, personnel could obtain readings in a reasonable amount of time, such as five to 30 minutes per exposure. By returning to the 0.01 R/h line, personnel kept their gamma exposures below the limit of 3.9 roentgens (22).

Project 4.8, Biological Effect of Neutrons, determined the biological effects of neutron radiation on animals in the open and in foxholes. Twelve hours before the detonation, personnel placed mice in cylindrical tubes. Five hours before the shot, two teams of three men each placed the mice in lead shields positioned in six foxholes and 14 surface stations 450 to 1,800 meters south-southeast of ground zero. Three hours after the detonation, three parties, each with three project personnel and a radiation monitor, recovered all of the animals except those exposed in the foxhole 450 meters from ground zero (16; 29).

Project 6.2, Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques, was conducted to confirm indications that a radar return could be used to determine ground zero, height of burst, and the yield of a nuclear detonation. This project required both ground and air personnel. Three hours before shot-time, two project personnel proceeded to a radar station west of the Control Point and remained there through the test.

Three B-29 aircraft left Kirtland AFB at 0405 hours on shot-day and entered the test area at 0657 hours. One aircraft orbited south of ground zero, one orbited east of ground zero, and one orbited north of ground zero. The aircraft left the area at about 0835 hours and landed at Kirtland AFB at about 1110 hours (45; 51; 74; 86).

Project 6.3, Interim IBDA Capabilities of Strategic Air Command, like Project 6.2, evaluated IBDA systems installed in bomber and fighter aircraft flying simulated strike and support missions over a target. The aircraft recorded data essential for determining the three IBDA parameters: ground zero, burst height, and yield of a nuclear detonation.

Twelve SAC B-36 aircraft of the 19th Air Division from Carswell AFB, Texas, and eight F-84s from George AFB, California, reached the test area at 0745 hours at an altitude of 37,000 feet. The aircraft flew in formation over the test site for about 60 minutes to simulate strike and support activities. While over the test site, the crews tested IBDA equipment and familiarized themselves with operations pertaining to the use of nuclear weapons. A total of 212 personnel participated in the flights (4; 51; 76).

Project 6.7, Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations, had a dual objective: to measure amplitude, duration, and polarization of the pulse of the electromagnetic radiation, and to detect and record electro-magnetic signals emitted by a nuclear device before the detonation.

Five hours before the shot, three project personnel went to a shelter 150 meters west of ground zero to turn on equipment. They then proceeded to a station 16 kilometers west of ground zero, where they stayed during the shot.

Once the area was cleared for recovery operations, the three participants left the station and traveled to the Control Point, where they were joined by a monitor. With the monitor, they were to proceed to the shelter to retrieve the tape recordings. Estimated time of the mission was 30 minutes (16; 40).

Project 6.8a, Initial Gamma Exposure versus Distance, was performed by the Signal Corps Engineering Laboratories to document initial gamma radiation exposure data for the 280mm cannon-fired device. Before the shot, project personnel placed dosimeters at 19 stations, fitted with aluminum thermal and blast shields, located 800 to 2,610 meters south of ground zero and at another 19 stations 810 to 2,630 meters west of ground zero. One hour after the announcement of recovery hour, five parties, each consisting of a monitor and an estimated five project personnel, were to retrieve the film. Plans called for the parties to spend three hours in recovery procedures (16; 80).

The objective of Project 6.10, Evaluation of Rapid Aerial Radiological Survey Techniques, was to improve the procedures used for radiological aerial surveys during Operations BUSTER-JANGLE and TUMBLER-SNAPPER. In addition, the effect of the aircraft on radiac instrument readings taken inside the aircraft was studied.

The project used a C-45 aircraft with an estimated crew of four, which was based at Indian Springs AFB. Before the C-45 began its mission, project personnel placed film badges at various locations opposite one another on the interior and exterior of the aircraft. The aircraft left Indian Springs AFB at 1130 hours on shot-day and reached the shot area at 1145 hours, about three hours and 15 minutes after the shot. Flying at a height of about 500 feet, it circled 800 meters from ground zero. The crew selected a landmark near ground zero as a reference point to ascertain the direction of maximum fallout. The aircraft then

flew a cloverleaf pattern centered over the landmark at three different altitudes. The first leg of the cloverleaf pattern passed over the reference point in the direction of maximum fallout. Airspeed, direction, and altitude were kept constant on each leg of the pattern.

Monitors in the aircraft obtained data by using a mechanical recording system and by writing intensity readings on a data sheet every five seconds. A notation was made on the data sheet as the aircraft passed over the reference point. The aircraft was in the test area for one hour and landed at Indian Springs AFB at 1249 hours (45; 51; 101).

Project 6.12, Determination of Height of Burst and Ground Zero, was fielded by the Signal Corps Engineering Laboratories and Army Field Forces Board #1. The objective was to evaluate artillery sound-ranging equipment for location of ground zero, seismic wave velocity for determination of height of burst, and flash-ranging equipment for determination of ground zero and height of burst. The project required sound-ranging systems, located 20 to 40 kilometers from ground zero. In addition, seismic geophones and flash-ranging cameras were positioned at various locations about 16 kilometers from ground zero.

Three hours and 30 minutes before the shot, nine men in three vehicles activated the geophone and camera outpost stations at the south end of Yucca Lake about 16 kilometers from ground zero. They remained at one of the stations through shot-time. Afterward, they probably turned off equipment at the stations and returned to the Control Point (16; 124).

Project 6.13, Effectiveness of Fast Scan Radar for Fireball Studies and Weapons Tracking, was conducted to evaluate the effectiveness of a new fast scan X-band radar for phenomenology studies of nuclear detonations. Project personnel mounted the

radar on a van and photographed the radar scope with high-speed cameras also mounted on the van. Plans called for six men to go to the van, about 11 kilometers southwest of ground zero, and remain there through shot-time (16; 77).

Project 7.1, Electromagnetic Effects from Nuclear Explosions, was a continuation of studies conducted during both Operations BUSTER-JANGLE and TUMBLER-SNAPPER. It was designed to obtain additional information on the electromagnetic radiation produced by a nuclear detonation. Personnel from the National Bureau of Standards, the Air Force Security Service, the Air Force Cambridge Research Center, and the Air Weather Service manned onsite and offsite locations for this project. Two onsite locations were used: station A, just south of Yucca Lake about 14 kilometers from the detonation, and station C, about three kilometers southwest of the Control Point and 19 kilometers from ground zero.

Two project personnel went to station A four hours before the shot to check equipment. At the same time, nine project personnel went to station C. Project participants remained at both stations through shot-time (16; 95).

Project 7.3, Detection of Airborne Low Frequency Sound from Nuclear Explosions, was designed to compare low frequency sounds produced by nuclear detonations at various remote field stations. These stations were located across the United States and around the world. The Signal Corps Engineering Laboratories operated stations in Alaska, Hawaii, Greenland, Japan, and Germany. The nine stations throughout the United States were manned by the Naval Electronics Laboratory, the Signal Corps Engineering Laboratories, and the National Bureau of Standards (97).

Project 7.4, Seismic Measurements, was performed to record the seismic waves produced by the shot for comparison with those

produced by shots of other series and by other shots of Operation UPSHOT-KNOTHOLE. Project 7.4 personnel manned ten stations in Alabama, Alaska, Arizona, Montana, South Dakota, and Wyoming. An onsite seismic station was located at UTM coordinates 843094. Two hours after the area was cleared for recovery operations, two project personnel and a radiation monitor drove to the onsite station in one vehicle and spent one or two hours turning off equipment and recovering records (16; 41).

Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris, analyzed samples of the Shot GRABLE cloud to evaluate various parameters of the nuclear device. Nine F-84G aircraft, operated by AFSWC personnel, took gaseous and particulate samples of the cloud. The activities of these personnel are detailed in section 4.2.4, which discusses AFSWC support at GRABLE (117).

Project 8.1b, Additional Data on the Vulnerability of Parked Aircraft to Atomic Bombs, was developed to assess the damage to fighter aircraft parked in the vicinity of a detonation and to determine the effort required to restore the aircraft to good condition. Four F-47s and one F-86 were parked between 470 and 700 meters northwest of ground zero. Remote-control cameras were placed around the aircraft, probably by Project 9.1 personnel.

According to the operation orders, 16 project personnel went to the test area six hours before the shot to check aircraft and cameras, a process requiring an estimated two hours. Five hours before shot-time, the project officer and three personnel spent about two hours making a final inspection.

At recovery hour, six project participants, accompanied by a monitor, went to the aircraft to note damage and photograph the aircraft. The estimated time of this mission was four hours. At the same time, six project personnel and a monitor traveled to the aircraft to recover instrument recordings. They spent about

two hours on this mission. Four hours after recovery hour, ten men made more detailed inspections of the aircraft. Their estimated time in the area was three hours (16; 54).

Project 8.2, Measurement of Thermal Radiation with a Vacuum Microphone, was conducted to evaluate a microphone used to measure the thermal radiation produced by a nuclear detonation. Personnel manned two vans containing recording equipment. The vans were about 11 kilometers from ground zero, located within view of the detonation. Four hours before the shot, six men arrived at this van, where they operated the equipment through shot-time (16; 20).

The objective of Project 8.4.1, Protection Afforded by Operational Smoke Screens against Thermal Radiation, measured the reduction in thermal radiation behind a white smoke screen. This project was canceled at Shot ENCORE at the last minute because of adverse winds, so it was rescheduled on a smaller scale at GRABLE. Project personnel placed an instrumented station 680 meters from ground zero before the shot. They positioned 175 smoke pots on arcs 30 and 45 meters from ground zero. The night before the shot, three project personnel went to the station, where they removed covers from instruments and made other final preparations for the experiment. They remained at the station until three hours before the detonation. Immediately before the shot, they set off the smoke pots by remote control (50).

Project 8.4.2, Evaluation of a Thermal Absorbing Carbon Smoke Screen, was conducted to determine changes in the blast wave as it moved over a heated air layer created by carbon black smoke from smoke pots. To generate a smoke screen, project personnel placed 451 smoke pots in a grid 150 to 1,400 meters from ground zero. The smoke pots were fired from the Control Point by means of a selective firing system of three manually operated circuits. A wind direction and velocity gauge, mounted

on a 30-foot pole and connected to recorders in the Control Point to provide remote readings, was installed 670 meters from ground zero on the smoke instrumentation line.

During the night before the shot, three project participants went into the test area to remove covers from instruments and prepare the smoke pots. They remained in the area until three hours before shot-time. After the announcement of recovery hour, six project personnel retrieved instrument recordings in the test area (49).

The purpose of Project 8.5, Thermal Radiation Protection Afforded Test Animals by Fabric Assemblies, was to evaluate the protection against skin burns afforded by service and experimental clothing. Six hours before the shot, 15 project personnel spent about three hours transporting 56 pigs to the shot area. They anesthetized the animals and placed them in field exposure holders. Forty-two pigs were clothed with fabric ensembles and exposed at eight stations. Twelve animals were placed at three stations in cylindrical aluminum containers with fabric-covered portholes. The remaining two were covered with protective cream. The animals were placed at locations 660 to 2,090 meters from ground zero. When the area was cleared for recovery operations, 12 project personnel accompanied by a monitor spent at least one hour retrieving the pigs (16; 94).

Project 8.6, Performance Characteristics of Clothing Materials Exposed to Thermal Radiation, was closely associated with Project 8.5. The objective was to characterize further the thermal effects of a nuclear detonation on standard and experimental field clothing. Personnel placed wood panels with textile samples attached at some of the same stations used for Project 8.5. Three hours after the area was opened for postshot activities, an estimated eight project personnel went to the test site to recover the burned fabric samples (16; 52).

Project 8.9, Effects of Thermal Radiation on Materials, was designed to study the effects of heat from the detonation on materials, to evaluate specific methods of measuring thermal radiation, to study the protective value of fabrics and paints, and to evaluate a substitute for skin to be used in cloth-barrier studies.

Five instrumented stations were 1,520 to 3,350 meters from ground zero along the Project 8.4.1 line of smoke pots northeast of ground zero. Personnel mounted the various instruments and materials on panels erected on structures. One hour after the announcement of recovery hour, eight men went to the stations and retrieved instrument records and burned fabric samples. The mission took about 90 minutes (16; 87).

Project 8.10, Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation, was to study theoretical approaches to calculating levels of thermal radiation. Project personnel set up seven stations, each instrumented with different types of calorimeters, at distances of 670 to 4,270 meters from ground zero. Two of the stations were along the Project 8.4.1 smoke line; the other five were on the main blast line west of ground zero. Calorimeters were also placed on the fighter aircraft positioned on the ground for Project 8.1b. Plans called for eight personnel to proceed to the stations three hours after the area was opened for recovery operations and to retrieve film from recorders (16; 60).

Project 8.11a, Incendiary Effects on Building and Interior Kindling Fuels, was designed to study the vulnerability of urban structures to primary fires produced by nuclear detonations. The study focused on building materials. Seven hours before the shot, two project personnel removed paper coverings from 136 trays of test materials at stations 610 to 6,100 meters from ground

zero. Their assignment took an estimated three hours. Immediately after the announcement of recovery hour, three project personnel began an initial inspection of the exposed materials, a process that took about three hours (16; 24).

The purpose of Project 8.11b, Ignition and Persistent Fires Resulting from Atomic Explosions: Exterior Kindling Fuels, like that of Project 8.11a, was to study the vulnerability of various materials to primary fires produced by nuclear detonations. Project 8.11b was distinctive in its investigation of exterior kindling fuels encountered in urban areas.

Before the shot, project personnel placed various flammable materials, including paper products and clothing, at several stations where it was predicted that thermal energy would be 12.2 calories per square centimeter. In addition, personnel placed fence sections in several areas. Plans called for two participants to spend no more than two hours before shot-time removing paper coverings from trays of test materials. After the announcement of recovery hour, two project personnel spent about two hours inspecting the materials and fence sections (16; 108).

Project 8.12a, Sound Velocities near the Ground in the Vicinity of an Atomic Explosion, had two objectives: to measure sound velocities near the surface before the arrival of the shock wave and to examine sound velocities produced through white and black smoke along the Project 8.4.1 and 8.4.2 smoke lines. Project personnel placed instruments 50 to 1,490 meters along the main blast line and 150 to 1,520 meters along the smoke line. Recording equipment for the gauges was located in shelters 460 and 910 meters from ground zero along the smoke line and 2,130 meters from ground zero along the main blast line.

Two hours after the area was opened for recovery operations, four project personnel went to the station on the main blast line

to recover records and turn off equipment. They spent an estimated one hour in the field. At the same time, eight project participants went to the two stations along the smoke line to recover records and turn off equipment (16; 83).

Project 8.12b, Supplementary Pressure Measurements, was designed to determine whether intense thermal radiation over a surface could enhance a blast wave. Before the shot, project personnel checked the test panels with pressure gauges attached to them and the recording instrument shelters located behind each panel. These had been used during Shot ENCORE. The panels were located 460 and 920 meters from ground zero. Two hours after recovery hour, eight project personnel spent about one hour retrieving the records (16; 19).

Project 9.1, Technical Photography, was conducted by EG&G and by personnel from the Signal Corps Pictorial Center and the Air Force. Twenty-three Signal Corps officers and at least 20 Air Force enlisted personnel were assigned to work directly with EG&G. The objective of Project 9.1 was to provide both still photographs and motion pictures of the preshot and postshot stages of various projects. Some technical photographs were taken with remote-control cameras from steel photo-towers six to 25 feet high, at distances of 310 to 3,660 meters from ground zero. The project required 94 cameras at Shot GRABLE.

Twelve project personnel spent two days before the shot loading film into the cameras and testing them. The same personnel and a radiological safety monitor recovered the film on shot-day, when the Test Director announced that recovery operations could begin. It is estimated that eight hours were required to complete the task. EG&G processed the film either in Las Vegas or in Los Angeles.

In addition to the Project 9.1 technical photography, Air Force Lookout Mountain Laboratory personnel took documentary photographs. Eighteen Lookout Mountain personnel were scheduled to photograph the GRABLE burst and subsequent cloud development from six manned camera stations, starting two hours and 30 minutes before the shot and continuing through the burst. The Test Director's Schedule of Events identifies these station locations as follows (16):

STATION	LOCATION (UTM)	NUMBER OF PERSONNEL
1	928622	5
2	916626	6
3	876736	2
4	899790	2
5*	843878	1
6	922632	2

Personnel dismantled their camera stations and returned to Camp Mercury when they had completed this assignment. One hour after the test area was opened for postshot activities, three additional Lookout Mountain Laboratory personnel and a monitor were scheduled to enter Frenchman Flat and spend three hours photographing test results.

Before the detonation, at 0732 hours, a C-47 aircraft with Lookout Mountain Laboratory personnel onboard left Indian Springs AFB to take aerial photographs of the GRABLE artillery fire and burst. The C-47 was 16 kilometers south of ground zero when the photographers recorded the burst and fireball development. The aircraft left the test area by 0836 hours and landed at Indian Springs by 0845 hours (16; 51; 59).

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*Station 5 was at the Control Point.

Project 9.6, Production Stabilization, and Project 9.7, Experimental Soil Stabilization, were conducted to find a means of stabilizing the soil in the Frenchman Flat area so that dust clouds formed by blast waves would not interfere with technical photography. The Army Waterways Experiment Station coordinated these projects. Assisting were the Engineer Research and Development Laboratories, which conducted laboratory heat testing of various samples of prepared soil-stabilizing agents, and the Ohio River Division Laboratory, which prepared samples of soil and sand-cement stabilizing agents and conducted some laboratory testing.

Project personnel entered the Frenchman Flat test area and prepared sand-cement stabilizing areas 160, 280, 810, and 890 meters from ground zero. In addition, they sprayed a surface of about 1,840 square meters with sodium silicate. Still and motion pictures showed how well the soil-stabilizing test materials worked (16; 47; 116).

4.2.2 Weapons Development Group Projects

The Weapons Development Group conducted 16 projects at Shot GRABLE. Only five of these projects had DOD participants, as shown in table 4-2.

Project 13.1, Radiochemistry Sampling, conducted by the Los Alamos Scientific Laboratory, was supported by pilots from the AFSWC 4926th Test Squadron (Sampling). Cloud sampling is discussed in section 4.2.4.

Of the four Program 18 projects, detailed documentation is available only for Project 18.3, Spectroscopy, conducted by the Naval Research Laboratory. The objective was to obtain information on spectral characteristics of light emitted from nuclear detonations. This was accomplished by using two

spectrometers, which recorded the wavelength of light with time. The spectrometers were located in Building 400, a permanent building situated near the Control Point at Yucca Pass, at a distance of about 19 kilometers from the GRABLE ground zero. The spectrometers were loaded with film, aligned, and checked for final operation about three hours before the shot. Project personnel remained in the building operating the spectrometers through shot-time. They turned off the equipment and removed the film for processing after the shot (27; 42).

4.2.3 Civil Effects Group Projects

The Civil Effects Group conducted 14 projects at Shot GRABLE. Only the two projects listed in table 4-2 involved DOD participants.

Project 23.17, Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres, was conducted by the Naval Radiological Defense Laboratory to investigate neutron radiation inside and outside lead hemispheres. Project personnel placed gold and sulfur neutron detectors in and near hemispheres at distances of 360 to 1,960 meters from ground zero (36; 125).

The Atomic Energy Project and the University of California at Los Angeles, with assistance from the Evans Signal Laboratory of the Signal Corp Engineering Laboratories, conducted Project 29.1, Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation. The project compared the accuracy of chemical and film dosimetry in measuring initial and residual gamma radiation. To measure initial radiation, project personnel placed dosimeters in the field the night before the shot. Fifteen minutes after recovery hour, two project personnel and a monitor retrieved the dosimeters located 1,170 to 1,830 meters from ground zero. Recovery operations took about 25 minutes (16).

To measure residual radiation, about 26 personnel formed survey teams to check the performance of various radiation instruments in freshly contaminated areas with residual gamma-radiation intensities up to 10.0 R/h. These personnel traveled before the shot to five posts at unspecified distances from ground zero (121).

4.2.4 Air Force Special Weapons Center Activities

AFSWC provided operational control of all air activities through the Air Participation Unit. In addition, AFSWC personnel conducted cloud sampling and sample courier missions for the test groups and cloud tracking and aerial surveys of the terrain for the Test Manager (58).

With the exception of the Air Weather Service B-29 cloud-tracking aircraft, which staged out of Kirtland AFB, AFSWC aircraft originated at Indian Springs AFB. The following listing indicates the types and numbers of aircraft and the estimated numbers of the AFSWC aircrews involved in these missions (51):

MISSION	TYPE OF AIRCRAFT	NUMBER OF AIRCRAFT	NUMBER OF PERSONNEL
Sampling			
Sampler	F-84G	9	9
Sampler Control	B-50	1	9
Sample Courier	B-25	3	15
	C-47	2	6
Cloud Tracking	B-25	1	5
	B-29	2	20
Radiological Safety/ Aerial Surveying	H-5	1	4
	L-20	1	3
	C-47	1	4

Cloud Sampling

At GRABLE, nine F-84G aircraft with Tiger code names, each with one pilot from the 4926th Test Squadron, collected particulate samples of the Shot GRABLE cloud for AFSWP Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris, and LASL Project 13.1, Radiochemistry Sampling. A B-50 sampler control aircraft, with a crew of nine and a LASL scientific advisor, and one of the F-84G aircraft surveyed the GRABLE cloud before the sampling sorties began. The sampling was confined to the lower portion of the stem, as the main part of the GRABLE cloud was hidden by cirrus clouds from 28,000 to 35,000 feet. The peak intensity encountered by any sampler was 10.0 R/h.

After the shot, the sampler control B-50 climbed through the overcast sky and determined the portion of the GRABLE cloud extending above the cirrus deck. The LASL scientific advisor then decided that samples would be taken only from the portion of the GRABLE cloud unobscured by the cirrus clouds.

During the sampling, each aircraft was called in succession, following the completion of the preceding sampling mission. The listing below provides information on each of the participating aircraft. Aircraft are listed according to the sequence in which they flew the sampling missions (51; 123):

AIRCRAFT (F-84G)	NUMBER OF PENETRATIONS	TOTAL TIME IN CLOUD (seconds)	TOTAL TIME IN CLOUD AREA (minutes)
Tiger Red 1	1	185	75
Tiger Red 2	2	192	90
Tiger Red 3	1	125	81
Tiger Red 4	1	900	97
Tiger White 1	1	220	80
Tiger White 2	1	600	95
Tiger White 3	-	-	105
Tiger Blue 2	-	-	15
Tiger Blue 5	4	-	98

Approximately two hours and 30 minutes after the detonation, the aircraft returned to Indian Springs AFB and parked in designated areas. Engines were shut down, and the canopies remained closed and sealed until the samples were removed from the aircraft. The pilots remained on full oxygen while they waited. The 4926th sample-removal team and radiological safety monitors took the samples from each aircraft and placed them in shielded boxes (51; 123).

After the samples from the aircraft were removed and stored, the pilots shut down their oxygen and opened their canopies. They stepped onto a platform held by a forklift, so they would not touch the exterior of the aircraft (123). The pilots were then taken by pickup truck to the decontamination station, where they were monitored and decontaminated as necessary.

Sample Courier Missions

After the sampling missions were completed, three B-25 aircraft, each with a crew of five, and two C-47 aircraft, each

with a crew of three, left Indian Springs AFB to transport samples and filter papers to various airbases for analysis by AEC and DOD laboratories. The B-25s transported filter papers for Project 13.1 to Kirtland AFB. The C-47s transported cloud samples for test group projects, including Project 7.5 (45; 51).

Cloud Tracking

Immediately after the detonation, one B-25 aircraft from Indian Springs AFB and two B-29s from Kirtland AFB flew a cloud-tracking mission over and beyond the NPG. The B-25 had a crew of five, and the B-29s each had a crew of ten. The B-25 flew at 12,000 feet and the B-29s at 18,000 and 22,000 feet, respectively. The B-25, which spent three hours following the cloud, encountered a maximum radiation intensity of 1.5 R/h (39; 51).

Aerial Surveying

After the detonation, one H-5 helicopter, one L-20 aircraft, and one C-47 aircraft flew survey missions to record radiation intensities. The H-5 had a crew of four, the L-20 a crew of three, and the C-47 a crew of at least four. The H-5, which flew at heights ranging from 20 to 500 feet above the ground, spent three hours completing an onsite survey. The L-20 conducted a survey beyond the shot area at a height of 500 feet for about one hour. On two separate sorties, the C-47 flew an offsite survey at heights ranging from 500 to 800 feet. Due to turbulent flying conditions, the C-47 did not complete its mission (39; 51).

4.3 RADIATION PROTECTION AT SHOT GRABLE

Exercise Desert Rock V, the test groups, and AFSWC each developed radiation protection procedures to keep individual exposure to ionizing radiation to a minimum while still allowing

participants to accomplish their mission. Some of the radiological safety procedures described generally in chapter 5 of the series volume required that records be kept to evaluate the effectiveness of the radiation protection programs. The available records for Shot GRABLE are presented below.

4.3.1 Desert Rock Radiation Protection Activities

Information concerning Desert Rock radiation protection activities has been obtained from the annex for GRABLE of the Exercise Desert Rock V, Final Report (64) and from the operations order for the shot (68). Although film badge readings are not available for Desert Rock participants at GRABLE, these two documents describe specific radiological safety activities performed at the shot.

Two Battalion Combat Teams and the observer group witnessed the shot from trenches 4,570 meters from ground zero. After the tactical portion of the maneuver was halted because of high winds and severe dust conditions, the BCTs and observers were guided by the Instructor Group on a tour of the display area. A dust storm restricted movement in the area, however. Observers and BCT BAKER were able to view part of the display, but BCT ABLE was unable to enter the display area because of the dust conditions. According to pocket dosimeters read after the maneuver, the highest exposure was 6.0 roentgens (64; 71).

Because of the large number of senior military observers, additional monitors served as display area tour guides. Desert Rock support personnel, in addition to 50th Chemical Platoon Service personnel, assisted in decontamination monitoring to expedite the departure of observers from the forward area (64).

4.3.2 Joint Test Organization Radiation Protection Activities

Records of JTO radiation protection activities conducted at GRABLE have been obtained from the radiological safety report of Operation UPSHOT-KNOTHOLE. The information includes data on film badges and protective clothing, survey records and isointensity plots, and decontamination records.

Dosimetry

During the period of 25 May to 30 May 1953, which covers the 25 May detonation of Shot GRABLE, the Dosimetry and Records Section of the JTO issued 3,000 film badges (39).

According to film badge records, ten Navy personnel received overexposures while participating at GRABLE. Eight individuals were from the Naval Medical Research Institute and had exposures ranging from 4.1 to 8.2 roentgens. Another Navy participant, affiliated with the Bureau of Medicine and Surgery, had a total exposure of 8.9 roentgens. These personnel, involved either with Project 2.2b or 4.2, may have received exposures while recovering instruments or animals from the test area. Additionally, two Navy participants whose units have not been identified received exposures of 6.1 and 6.4 roentgens while at GRABLE (1a; 1b).

Fourteen personnel from Fort McClellan who were with the Radiological Safety Support Unit received overexposures ranging from 3.9 to 8.4 roentgens. Many of these individuals received exposures while working in the shot area several days after the detonation. Dates when their final film badges were turned in included 28 and 29 May and 1 and 2 June.

Three individuals from the Ballistic Research Laboratories had total exposures of 4.7, 4.8, and 7.7 roentgens by 26 May, one day after the detonation. These personnel were involved with the recovery of instruments and recording equipment from the shot area (1b; 4; 16; 44).

Two personnel from the Directorate, Weapons Effects Tests, had total gamma exposures of 4.4 and 7.8 roentgens. Two personnel from Lookout Mountain Laboratory had total gamma exposures of 4.5 and 4.6 roentgens, recorded on film badges turned in on 26 May. These participants took documentary photographs (1b; 4; 16).

One individual from the 1090th Reporting Group had an exposure of 5.2 roentgens by 22 May. In addition, an individual from LASL and one from the 93rd Fighter Interceptor Squadron at Kirtland AFB had total exposures of 4.6 and 4.3 roentgens, respectively. These men turned in their film badges on 26 May and 2 June, respectively (1b).

Logistics and Supply

For the period covering Shot GRABLE, the Supply Section issued the following items:

- 16 pairs of goggles
- 154 respirators
- 194 protective caps
- 310 pairs of gloves
- 316 pairs of shoe covers
- 342 pairs of coveralls.

In addition, the Supply Section issued 183 radiation survey instruments (39).

Monitoring

The initial survey teams began their survey at 0846 hours and completed readings a little less than an hour later. The teams, probably totaling ten men, had difficulty completing their survey because of dust in the test area. Resurveys of the area were conducted on 25, 26, 27, and 28 May.

The onsite aerial survey, conducted by an H-5 helicopter two hours after the shot, encountered gamma intensities of 17.0 R/h 500 feet above ground zero. An L-20 performed an additional aerial survey that began three hours after the detonation, encountering intensities up to 0.4 R/h 500 feet above Frenchman Flat. The scheduled mission of a C-47 aircraft was aborted (39).

In addition to the onsite monitors, three of the 17 offsite monitors were DOD personnel. In performing radiation surveys near Lincoln Mine, Nevada, they encountered a maximum radiation intensity of 0.007 R/h (39).

Plotting and Briefing

Figure 4-4 shows a copy of the isointensity map resulting from the initial survey. Figure 4-5 presents copies of the radiological plots drawn from the resurveys.

In addition to its other activities, the Plotting and Briefing Section briefed 216 parties for entry into Frenchman Flat and 218 parties for entry into Yucca Flat during the period 25 May to 30 May (39).

Decontamination

During the period of Shot GRABLE, the Vehicle and Equipment Decontamination Section decontaminated 50 vehicles (39).

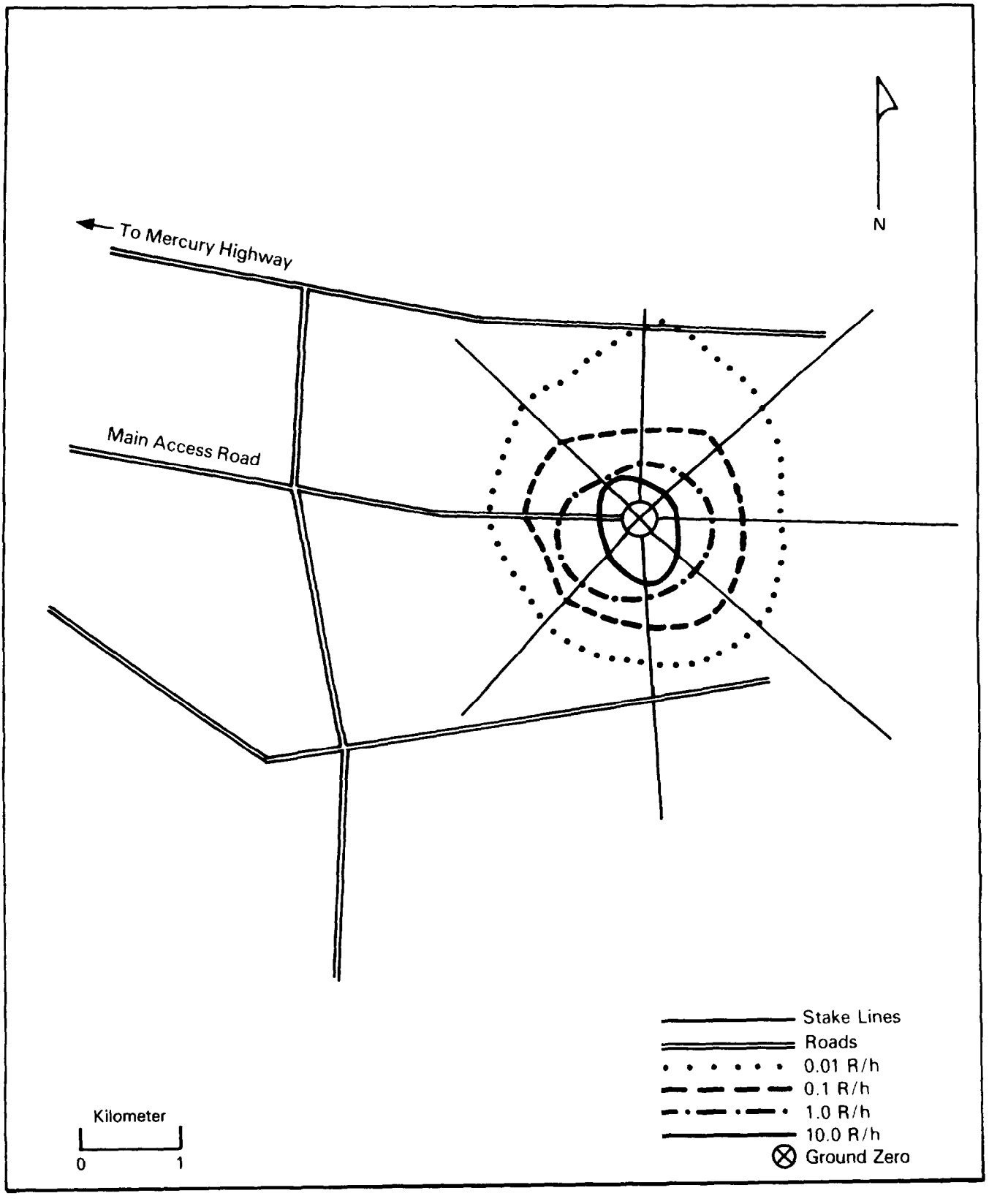
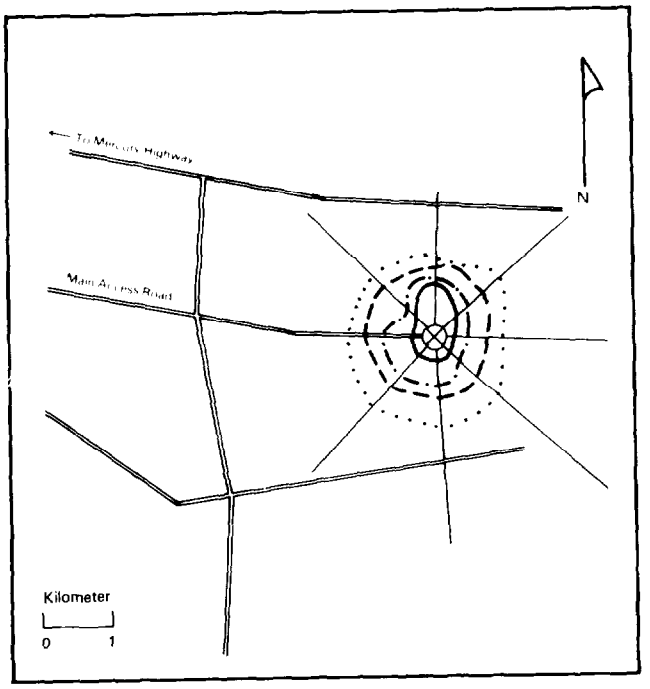
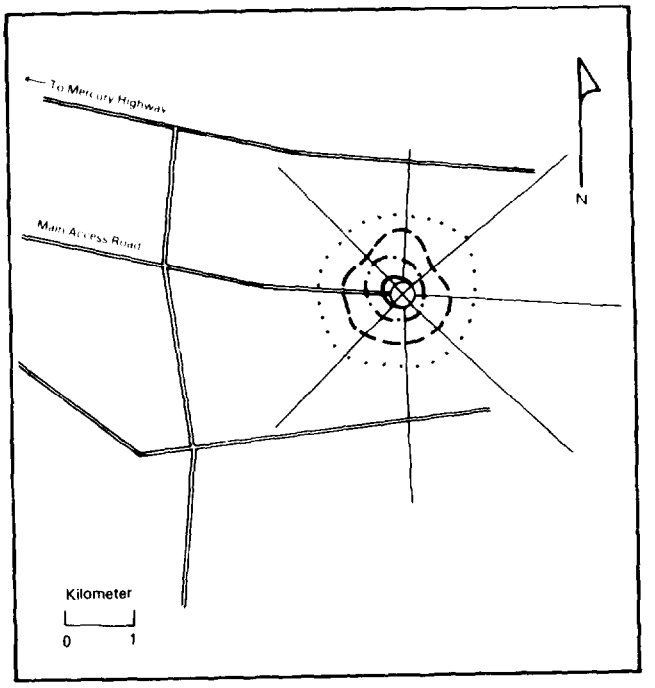


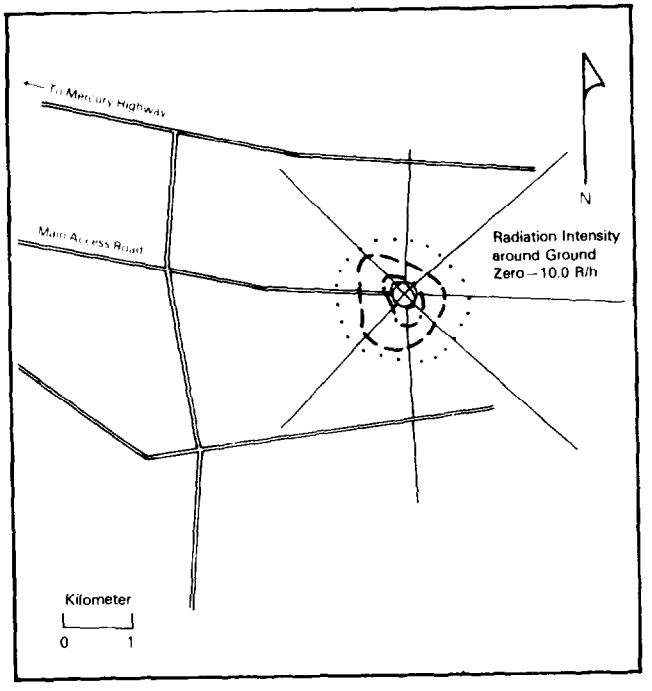
Figure 4-4: INITIAL SURVEY FOR SHOT GRABLE, 25 MAY 1953, 0846 TO 0940 HOURS



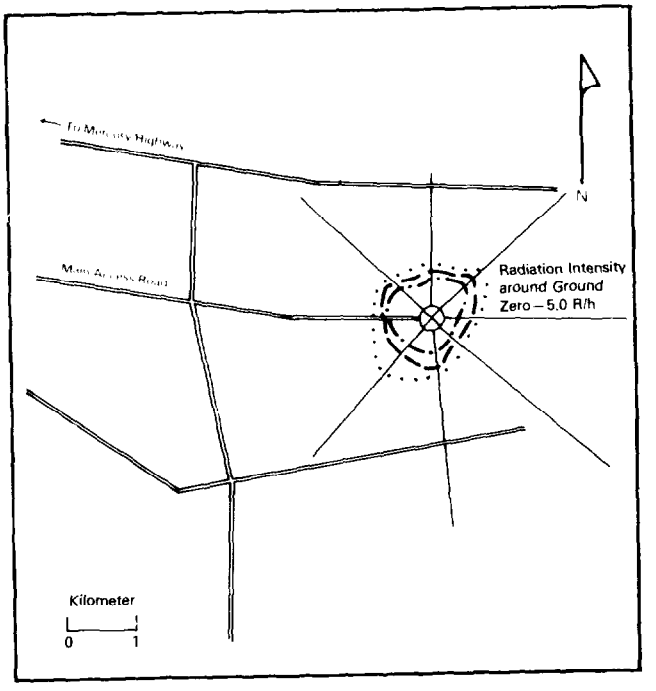
25 May 1953, 1630 Hours



26 May 1953, 0630 Hours



27 May 1953, 1330 Hours



28 May 1953, 1100 Hours

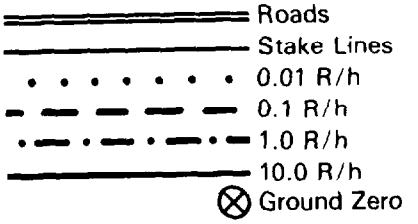


Figure 4-5: SUBSEQUENT SURVEYS FOR SHOT GRABLE

SHOT CLIMAX SYNOPSIS

AEC TEST SERIES:	UPSHOT-KNOTHOLE
DOD EXERCISE:	None
DATE/TIME:	4 June 1953, 0415 hours
YIELD:	61 kilotons
HEIGHT OF BURST:	1,334 feet (airdrop)

AEC Objective: To evaluate the nuclear yield, blast, thermal, and radiological phenomena produced by this device.

DOD Objective: To measure weapons effects characteristics and evaluate the military applications of the device.

Weather: At shot-time, the winds at surface level were three knots from the northeast. The winds were three knots from the southeast at 10,000 feet, 13 knots from the west at 20,000 feet, 28 knots from the west-northwest at 30,000 feet, and 24 knots from the west-southwest at 40,000 feet. The temperature was 13.3°C, the relative humidity was 30 percent, and the pressure was 867 millibars.

Radiation Data: Intensities of 0.1 R/h and greater reached as far as two kilometers from ground zero, with an intensity of 10.0 R/h extending about 750 meters northwest of ground zero.

Participants: Armed Forces Special Weapons Project, Air Force Special Weapons Center, Los Alamos Scientific Laboratory, contractors.

CHAPTER 5

SHOT CLIMAX

Shot CLIMAX, an airdropped nuclear device, was detonated with a yield of 61 kilotons at 0415 hours on 4 June 1953. CLIMAX, the last nuclear test of Operation UPSHOT-KNOTHOLE, was not originally planned as part of the series. On 5 May 1953, however, the Director of Los Alamos Scientific Laboratory requested permission to add CLIMAX to Operation UPSHOT-KNOTHOLE to test a device which was planned for the CASTLE Series in the Pacific Ocean.

Shot CLIMAX was initially scheduled for 31 May but was postponed until 2 June because of adverse weather. Even though the forecast for 2 June indicated remote possibilities of contaminated rain in Salt Lake City, the decision was made to proceed with the detonation. At 0245 hours, with the delivery aircraft airborne, the shot was again postponed because of an increased probability of rain at Salt Lake City, combined with a closer predicted approach of the cloud that would result from the detonation. The shot was then postponed for 48 hours (56; 92).

On 4 June, a B-36 from the 4925th Test Group (Atomic), Kirtland AFB, delivered the CLIMAX device, which detonated at a height of 1,334 feet above Area 7 of Yucca Flat, UTM coordinates 872048. The B-36 flew several practice runs before beginning the actual bombing run, which it made at an altitude of 26,000 feet, at a heading of 268 degrees, and at an air speed of 250 knots. Figure 1-1 shows the CLIMAX ground zero (56). The bottom of the cloud reached 35,000 feet, while the top of the cloud attained a height of 42,000 feet. Onsite radiation was due to neutron-induced activity. Offsite, the maximum fallout activity detected was 0.012 R/h on Highway 93, 16 kilometers west of Glendale, Nevada.

Although no Exercise Desert Rock activities were conducted at Shot CLIMAX, DOD personnel did participate in scientific and diagnostic projects conducted by the test groups and in AFSWC support missions.

5.1 DEPARTMENT OF DEFENSE PARTICIPATION IN JOINT TEST ORGANIZATION OPERATIONS AT SHOT CLIMAX

Department of Defense personnel took part in projects sponsored by the Military Effects Group, the Weapons Development Group, and the Civil Effects Group. In addition, the Air Force Special Weapons Center flew missions for the test groups and the Test Manager. Table 5-1 lists the test group projects by number and title and identifies the participating groups.

5.1.1 Military Effects Group Projects

The Military Effects Group conducted 18 projects at Shot CLIMAX, as shown in table 5-1. The Test Director declared recovery hour at 0532 hours, one hour and 17 minutes after the shot.

Projects 1.1a/1.2, Air Blast Measurements, were fielded to measure blast pressures at various distances from the nuclear detonation. Peak overpressure was measured by photographing rocket smoke trail distortions. Before the shot, project personnel positioned 15 rocket launchers at 135-meter intervals along a line that was 730 meters northwest of ground zero. A high-speed camera was placed about 12 kilometers southeast of ground zero. Immediately before the detonation, the smoke rockets were ignited from the Control Point. The camera, equipped with a timing apparatus, photographed the broken and hooked patterns in the trails to indicate motion in air produced by the shock front (2; 17; 91).

Table 5-1: TEST GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT CLIMAX

Project	Title	Participants
	Military Effects Group	
1.1a/1.2	Air Blast Measurements	Naval Ordnance Laboratory
1.1b	Air Pressure and Ground Shock Measurements	Stanford Research Institute
1.1d	Dynamic Pressure versus Time and Supporting Air Blast Measurements	Sandia Corporation
2.2a	Gamma Radiation Spectrum of Residual Contamination	Signal Corps Engineering Laboratories
3.30	Air Blast Gauge Studies	Ballistic Research Laboratories
4.5	Ocular Effects of Thermal Radiation from Atomic Detonation	Air Force School of Aviation Medicine
4.7	Beta-gamma Skin Hazard in Postshot Contaminated Area	Walter Reed Army Medical Center
6.2	Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques	Wright Air Development Center; Vitro Corporation
6.3	Interim IBDA Capabilities of Strategic Air Command	Strategic Air Command
6.7	Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations	Signal Corps Engineering Laboratories
6.12	Determination of Height of Burst and Ground Zero	Signal Corps Engineering Laboratories; Army Field Forces Board #1
7.1	Electromagnetic Effects from Nuclear Explosions	Headquarters, Air Force *
7.3	Detection of Airborne Low Frequency Sound from Nuclear Explosions	Headquarters, Air Force *
7.4	Seismic Measurements	Headquarters, Air Force
7.5	Calibration and Analysis of Close-in A-Bomb Debris	Headquarters, Air Force; AFSWC
8.9	Effects of Thermal Radiation on Materials	Naval Material Laboratory
8.10	Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation	Naval Radiological Defense Laboratory
9.1	Technical Photography	EG&G; Signal Corps Pictorial Center; Air Force Lookout Mountain Laboratory

* Other participating agencies are listed in the text.

Table 5-1: TEST GROUP PROJECTS WITH DEPARTMENT OF DEFENSE PARTICIPATION, SHOT CLIMAX (Continued)

Project	Title	Participants
	Weapons Development Group	
13.1	Radiochemistry Sampling	Air Force Special Weapons Center
18.1	Total Thermal and Air Attenuation	Naval Research Laboratory
	Civil Effects Group	
23.1	Biological Effectiveness of Ionizing Radiation within Shelters	Naval Radiological Defense Laboratory; Naval Medical Research Institute
23.17	Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres	Naval Radiological Defense Laboratory
29.1	Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation	Atomic Energy Project, UCLA *

* Other participating agencies are listed in the text.

Project 1.1b, Air Pressure and Ground Shock Measurements, was conducted generally to obtain additional data on blast phenomena and specifically to gather data on the blast phenomena resulting from CLIMAX. No ground shock measurements were taken at the shot. Project personnel placed 24 air pressure gauges along a blast line at distances between 470 and 4,080 meters northwest of ground zero before the shot. The gauges were connected to cables that led to a station about 2,440 meters from ground zero. This station contained instruments that recorded data from the gauges. One hour after the area was cleared for recovery operations, four project personnel and a radiological safety monitor retrieved the data from the instrument station. Plans called for them to spend 30 minutes in the test area (17; 120).

Project 1.1d, Dynamic Pressure versus Time and Supporting Air Blast Measurements, was designed to measure blast wave

pressures near ground level. The night before the shot, three project personnel installed one pressure gauge at a station about 1,050 meters from ground zero (17; 23).

Project 2.2a, Gamma Radiation Spectrum of Residual Contamination, collected data to be used in designing radiation detection devices and assessed the biological significance of residual gamma contamination. Three hours after the shot, three project participants and a monitor traveled in a van towards ground zero from a crosswind direction. They stopped about 910 meters west of ground zero, where the gamma intensity reached the desired magnitude of 0.24 R/h. Personnel then placed spectrometers in the field near the van. They spent two hours taking gamma-ray spectral measurements. After completing the measurements, personnel loaded instruments into the van and left the area. The same personnel took additional measurements the day after the shot at a location 460 meters west of ground zero, where the radiation intensity was 0.28 R/h (17-18).

Project 3.30, Air Blast Gauge Studies, was fielded to compare the new self-contained recording gauges with other gauges used for the measurement of pressure-time phenomena from a nuclear blast. Before the shot, project personnel placed two to six gauges at each of 11 stations located due south of ground zero, 12 gauges on a blast line 90 degrees to the main blast line, seven gauges in an air raid shelter built for a Civil Effects Group project, and one gauge on a ten-foot pole. These gauges were all 290 to 4,020 meters from ground zero. Personnel spent an estimated one hour retrieving most of the instruments after the area was opened for recovery operations. They recovered the remaining gauges after radiation levels decreased (2; 17; 78).

Project 4.5, Ocular Effects of Thermal Radiation from Atomic Detonation, was fielded to determine to what degree the flash of

a nuclear detonation impairs night vision. Only the second part of this two-part project was conducted at CLIMAX. The night before the shot, project personnel placed 80 rabbits at six locations 15 to 70 kilometers from ground zero to determine the distance at which retinal burns could be produced. Thirty minutes after the shot, three parties, each consisting of three project personnel and a monitor, spent two hours recovering the rabbits (17; 26).

Project 4.7, Beta-gamma Skin Hazard in the Postshot Contaminated Area, measured the beta (and low-energy gamma) radiation exposure of a material similar to human skin. Results were used to detemine the extent that this exposure exceeded the exposure routinely reported in radiological safety monitoring, which generally measured only gamma radiation exposure. On the day of the shot, project personnel found locations where a gamma survey meter read about 0.8 R/h. Two parties, each consisting of three project participants and a radiological safety monitor, placed wooden racks, with thin-walled and thick-walled ion chambers attached, at five locations. Two locations were 910 and 1,000 meters upwind of ground zero; the other three locations were 1,370 to 2,930 meters downwind of ground zero. The thin-walled chambers were of the same thickness as the outer layer of skin and similar to the skin in sensitivity to beta radiation. By placing the racks in the 0.8 R/h area, personnel could obtain readings relatively quickly, about five to 30 minutes per exposure. By returning to the 0.01 R/h line after the racks were placed, personnel were able to keep their gamma exposures below the limit of 3.9 roentgens (2; 17; 22).

Project 6.2, Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques, was performed to confirm indications that a radar return could be used to determine ground zero, height of burst, and the yield of a nuclear detonation. The project required both ground and air personnel. Two hours before

the shot, two project personnel went to a radar station 1.6 kilometers west of the Control Point, where they remained through the test.

Three B-29 aircraft containing IBDA equipment left Kirtland AFB at 0020 hours on shot-day and entered the test area at about 0220 hours. One aircraft orbited south of ground zero, one orbited east of ground zero, and one orbited north of ground zero. The aircraft left the area at about 0420 hours and landed at Kirtland AFB at 0634 hours (17; 45; 51; 74; 86).

Project 6.3, Interim IBDA Capabilities of Strategic Air Command, was performed by the Strategic Air Command. Like Project 6.2, this project evaluated IBDA systems installed in bomber and fighter aircraft flying simulated strike and support missions over a target. The aircraft recorded data essential for determining the three IBDA parameters: ground zero, burst height, and yield of a nuclear detonation.

Six B-36 aircraft of the 57th Air Division from Fairchild AFB, Washington, reached the test area at 0340 hours at an altitude of 33,000 feet. The aircraft flew in formation over the test site for 47 minutes to simulate strike and support activities. While over the test site, the crews tested IBDA equipment and familiarized themselves with operations pertaining to the use of nuclear weapons. Preceding the squadron was a B-36 weather reconnaissance aircraft of the 19th Air Division from Fairchild AFB. In all, 119 personnel participated in the flights (45; 51; 76).

Project 6.7, Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations, had two objectives:

- To measure the amplitude, duration, and polarization of the pulse of the electromagnetic radiation
- To detect and record electromagnetic signals emitted by nuclear devices before the detonation.

Before the shot, three project personnel turned on equipment in a shelter located 2,700 meters south of ground zero and returned to the Control Point no later than two hours before the detonation. After the announcement of recovery hour, two men and a radiological safety monitor spent about 45 minutes retrieving the film (17; 40).

Project 6.12, Determination of Height of Burst and Ground Zero, was fielded by the Signal Corps Engineering Laboratories and Army Field Forces Board #1. The objective was to evaluate seismic wave velocity for determination of height of burst.

The seismic geophones were positioned at several outposts in the southeast corner of Yucca Lake 13 to 16 kilometers from ground zero. One hour before the shot, one project participant went to the centrally located station, 4.8 kilometers south of the Control Point, and stayed there through shot-time (17; 124).

Project 7.1, Electromagnetic Effects from Nuclear Explosions, was a continuation of studies conducted during Operations BUSTER-JANGLE and TUMBLER-SNAPPER. It was designed to obtain additional information on the electromagnetic radiation produced by a nuclear detonation. Personnel from the National Bureau of Standards, the Air Force Security Service, the Air Force Cambridge Research Center, and the Air Weather Service manned stations at one location onsite and at 11 locations offsite. The onsite location was just south of Yucca Lake about 20 kilometers from the CLIMAX ground zero. Three hours before the detonation, 12 personnel traveled to the station, where they remained through shot-time (17; 95).

Project 7.3, Detection of Airborne Low Frequency Sound from Nuclear Explosions, was designed to compare low frequency sounds produced by nuclear detonations at various remote field stations located across the United States and around the world. The Signal

Corps Engineering Laboratories operated stations in Alaska, Hawaii, Greenland, Japan, and Germany. The Naval Electronics Laboratory, the Signal Corps Engineering Laboratories, and the National Bureau of Standards manned the nine stations in the United States (97).

Project 7.4, Seismic Measurements, recorded the seismic waves produced by the shot for comparison with the seismic waves produced by shots of other series and by other shots of Operation UPSHOT-KNOTHOLE. Project personnel operated ten stations in Alabama, Alaska, Arizona, Montana, Oklahoma, South Dakota, and Wyoming. Another station was located onsite, about five kilometers northwest of ground zero at UTM coordinates 843094. This station contained equipment powered by generators. Before the shot, personnel arrived to turn on power. About two hours after recovery hour, two project personnel and a radiation monitor drove in one vehicle to this station and spent one or two hours turning off equipment and recovering records (17; 41).

The objective of Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris, was to analyze samples of the Shot CLIMAX cloud to evaluate various parameters of the device. F-84 aircraft took gaseous and particulate samples of the cloud (117). The activities of project participants are detailed in section 5.1.4, which discusses AFSWC support at CLIMAX.

Project 8.9, Effects of Thermal Radiation on Materials, was designed to study the effects of heat from the detonation on materials, to evaluate specific methods of measuring thermal radiation, to study the protective value of fabrics and paints, and to evaluate a substitute for skin to be used in cloth-barrier studies.

Before the shot, three project participants placed temperature-sensing instruments and various clothing materials about 3,660

meters from ground zero. Two hours after the area was opened for recovery operations, two project members and a radiological safety monitor spent about 15 minutes recovering the instruments and materials (17; 87).

Project 8.10, Physical Characteristics of Thermal Radiation from an Atomic Bomb Detonation, was designed to study the theoretical approaches to the problem of measuring radiation. Four project personnel set up three stations, each instrumented with different types of calorimeters, about two, five, and eight kilometers south and southwest of ground zero. Plans called for four project members and a monitor to go to the stations one hour after the area was opened for recovery and spend one hour retrieving film from the instruments (17; 60).

Project 9.1, Technical Photography, was conducted by EG&G and by personnel from the Signal Corps Pictorial Center and the Air Force. Twenty-three Signal Corps officers and five Air Force enlisted personnel were assigned to work directly with EG&G. The objective of Project 9.1 at Shot CLIMAX was to photograph the shock front.

Personnel placed four remote-control cameras in photography trailers. Project personnel loaded film and tested the cameras before the shot. The same project personnel who loaded the cameras and a radiation safety monitor recovered the film on shot-day, when recovery operations were allowed to begin. EG&G processed the film either in Las Vegas or in Los Angeles.

In addition to Project 9.1 photography, Air Force Lookout Mountain Laboratory personnel took documentary photographs of the CLIMAX burst and subsequent cloud development from five manned camera stations and from a C-47 aircraft. The Test Director's

Schedule of Events identifies these station locations as follows (17):

STATION	LOCATION (UTM)	NUMBER OF PERSONNEL
1	900923	3
2	829900	2
3	793939	2
4	781958	2
5*	843878	4

Personnel dismantled their camera stations and returned to Camp Mercury when they had completed their assignment.

To take aerial photographs at CLIMAX, a C-47 aircraft, with Lookout Mountain Laboratory personnel onboard, took off from Indian Springs AFB just before the shot. The C-47 entered the test area at about 0334 hours and established an orbiting pattern, while the Lookout Mountain Laboratory personnel photographed the burst and fireball development. The aircraft left the test area by 0420 hours and landed at Indian Springs AFB by 0433 hours (17; 51; 59).

5.1.2 Weapons Development Group Projects

The Weapons Development Group performed 18 projects at Shot CLIMAX, only four of which involved DOD personnel. Table 5-1 lists DOD participation in the Weapons Development Group projects, which were all conducted onsite at the Nevada Proving Ground.

Information is available only for Project 13.1, Radiochemistry Sampling. Sampling pilots from the AFSWC 4926th Test Squadron (Sampling) performed this project, and it is discussed under AFSWC participation in section 5.1.4.

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*Station 5 was at the Control Point.

5.1.3 Civil Effects Group Projects

The Civil Effects Group conducted 11 projects at Shot CLIMAX. Only the three projects listed in table 5-1 involved DOD participants. The same personnel usually conducted all of the Naval Radiological Defense Laboratory Program 23 projects.

Project 23.1, Biological Effectiveness of Ionizing Radiation within Shelters, investigated neutron and gamma radiation hazards to dogs and mice placed within AEC shelters at a slant range of about 990 meters from the burst point. Personnel transported the animals to the shelters at 1915 hours the night before the CLIMAX detonation. Because of high radiation levels, recovery was delayed until 13 hours after the shot (21; 33).

Project 23.17, Neutron Flux Measurements in AEC Group Shelters and Lead Hemispheres, investigated neutron radiation in the open and the neutron dose received by animals in a shelter. Project participants placed gold and sulfur neutron detectors in the open at slant ranges of 650 to 1,780 meters from the burst point. They also placed animals in a shelter at a slant range of 610 meters from the burst point (33; 125).

Project 29.1, Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation, was fielded by the University of California at Los Angeles, assisted by the Evans Signal Laboratory, part of the Signal Corps Engineering Laboratories. The project compared and evaluated the accuracy and practicality of chemical and film methods for measuring initial and residual gamma radiation. At CLIMAX, personnel collected data only on residual contamination. Twenty-six project participants placed dosimeters at distances ranging from 730 to 2,290 meters from ground zero, with radiation intensities up to 10.0 R/h. Before the shot, they traveled to four posts located 900, 1,620, 1,800, and 2,250 meters from ground zero. Thirty-five minutes after recovery hour was declared, a party of three project personnel

and a radiological safety monitor entered the area to retrieve the dosimeters (33; 121).

5.1.4 Air Force Special Weapons Center Activities

AFSWC provided operational control of all air activities through the Air Participation Unit. In addition to airdropping the CLIMAX device, AFSWC personnel conducted cloud sampling, sample courier missions, cloud tracking, and aerial surveys for the Test Manager.

With the exception of the Air Weather Service B-29 cloud-tracking aircraft, which staged out of Kirtland AFB, AFSWC aircraft originated at Indian Springs AFB. The following listing indicates the type and number of aircraft and estimated number of AFSWC aircrew personnel involved in air missions at Shot CLIMAX (51).

TITLE	TYPE OF AIRCRAFT	NUMBER OF AIRCRAFT	NUMBER OF PERSONNEL
Delivery	B-36	1	16
Sampling			
Sampler	F-84G	11	11
Sampler Control	B-50	1	9
Courier Service	C-47	2	6
	B-25	2	10
Cloud Tracking	B-25	1	5
	B-29	2	20
Radiological Safety/ Aerial Surveying	L-20	1	3
	C-47	1	4

Cloud Sampling

At CLIMAX, 11 F-84G aircraft with Tiger code names, each flown by a pilot from the 4926th Test Squadron, collected

particulate samples of the cloud for AFSWP Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris, and LASL Project 13.1, Radiochemistry Sampling. A B-50 sampler control aircraft, with a crew of nine including a LASL scientific advisor, and one F-84G aircraft surveyed the cloud before the sampling sorties began. The first penetration of the cloud occurred two hours and 50 minutes after shot-time. The peak intensities encountered by the samplers ranged from 0.5 to 30 R/h. Each aircraft was called in succession, following completion of the preceding sampler mission. The following listing details the activities of each sampler aircraft. Aircraft are listed according to the sequence in which they flew the sampling missions.

AIRCRAFT (F-84G)	NUMBER OF PENETRATIONS	TOTAL TIME IN CLOUD (seconds)	TOTAL TIME IN CLOUD AREA (minutes)
Tiger Red 1	4	495	321
Tiger Red 2	2	26	58
Tiger Red 3	2	280	66
Tiger Red 4	1	1620	53
Tiger White 1	2	50	79
Tiger White 2	2	315	16
Tiger White 3	3	1200	28
Tiger Blue 1	1	1440	68
Tiger Blue 2	1	900	78
Tiger Blue 3	3	665	14
Tiger Blue 4	-	-	75

When the mission was complete, the samplers returned to Indian Springs AFB and parked in designated areas. Engines were shut down, and the canopies remained closed and sealed until the samples were removed from the aircraft. The pilots remained on

full oxygen while they waited. Personnel from the 4926th sample-removal team and radiological safety monitors removed the samples from each aircraft and placed them in shielded containers.

After the samples from each aircraft were removed and stored, the pilots shut down their oxygen and opened the canopies. They then stepped onto a platform held by a forklift, so they would not touch the exterior of the aircraft. The pilots were taken by pickup truck to the decontamination station to be monitored and decontaminated, as necessary (51; 123).

Sample Courier Missions

After the sampling missions were completed, two C-47 aircraft, each with a crew of three, and two B-25 aircraft, each with a crew of five, left Indian Springs AFB on shot-day to transport samples and filter papers to various airbases for analysis by AEC and DOD laboratories. The 4901st Support Wing (Atomic) from Kirtland AFB conducted these courier missions. The C-47s transported samples for the test group projects, including Project 7.5. The B-25s flew Project 13.1 filter papers to Kirtland AFB (45; 51).

Cloud Tracking

Immediately after the CLIMAX shot, one B-25 aircraft, with a crew of five from Indian Springs AFB, and two B-29s, each with a crew of ten from Kirtland AFB, flew cloud-tracking missions over and beyond the NPG. The B-25 flew at 12,000 feet; its mission lasted only 20 minutes. The two B-29 aircraft flew at 18,000 and 22,000 feet, and their missions lasted 199 and 379 minutes, respectively (39; 51).

Aerial Surveying

One L-20 and one C-47 aircraft flew survey missions downwind of the shot area to record radiation intensities after the shot.

The L-20, which flew at heights up to 100 feet, completed the survey after six hours and 43 minutes. The C-47, on an offsite survey, flew at heights of 500 to 800 feet on two separate sorties. An H-5 helicopter was scheduled for an onsite survey but did not participate because of mechanical problems (39; 51).

5.2 RADIATION PROTECTION AT SHOT CLIMAX

The test groups and AFSWC each developed radiation protection procedures for Operation UPSHOT-KNOTHOLE to keep individual exposure to ionizing radiation to a minimum while still allowing participants to accomplish their missions. Some of the procedures described in chapter 5 of the series volume resulted in records that enabled these organizations to evaluate the effectiveness of their radiation protection programs. Records of JTO radiation protection activities at CLIMAX are included in the radiological safety report of Operation UPSHOT-KNOTHOLE. The information includes data on film badges and protective clothing, survey records and isointensity plots, and decontamination records (39).

Dosimetry

During the period of 31 May to 5 June 1953, which covers the 4 June detonation of Shot CLIMAX, the Dosimetry and Records Section of JTO issued 1,230 film badges (39). Film badge records indicate that one individual from the Radiological Safety Support Unit, seven monitors from Fort McClellan, and one individual from the Ballistic Research Laboratories received total exposures exceeding the JTO 3.9 roentgen limit. The Radiological Safety Support Unit and Fort McClellan personnel had total exposures ranging from 3.9 to 5.5 roentgens. The individual from the Ballistic Research Laboratories had a total exposure of 4.0 roentgens (1b).

Logistics and Supply

For the period covering Shot CLIMAX, the Supply Section issued the following items (39):

- 6 pairs of goggles
- 53 respirators
- 61 protective caps
- 87 pairs of gloves
- 93 pairs of shoe covers
- 97 coveralls.

Monitoring

Four days before the detonation of CLIMAX, monitors surveyed the entire Yucca Flat area to determine residual radiation intensities from previous shots. The initial survey team began its survey 20 minutes after the detonation and completed the assignment 50 minutes later. Resurveys were conducted later on shot-day and on 5 June (39).

In addition to the onsite monitors, there were 19 offsite monitors, including four DOD personnel. They encountered a maximum radiation intensity of 0.012 R/h in surveying an area on Highway 93, 16 kilometers east of Glendale, Nevada. The L-20 and C-47 that performed on- and offsite aerial surveys encountered negligible amounts of fallout (39).

Plotting and Briefing

Figure 5-1 presents a copy of the plot generated from the initial ground survey, begun 20 minutes after shot-time. Copies of the results of the resurveys on 4 and 5 June are given in figure 5-2. In addition to its other activities, the Plotting and Briefing Section briefed 136 parties for entry into Yucca Flat during the period 31 May to 5 June (39).

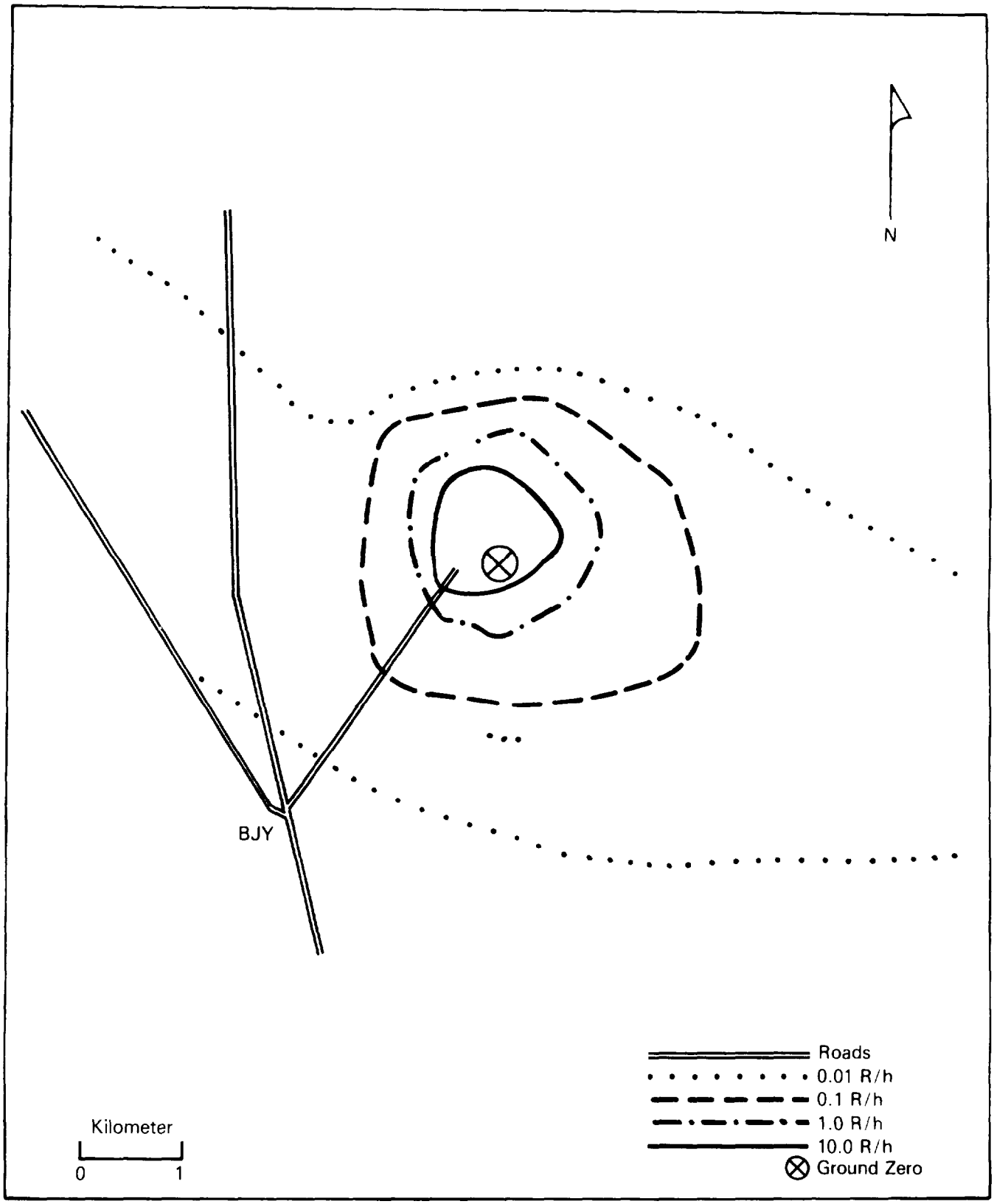
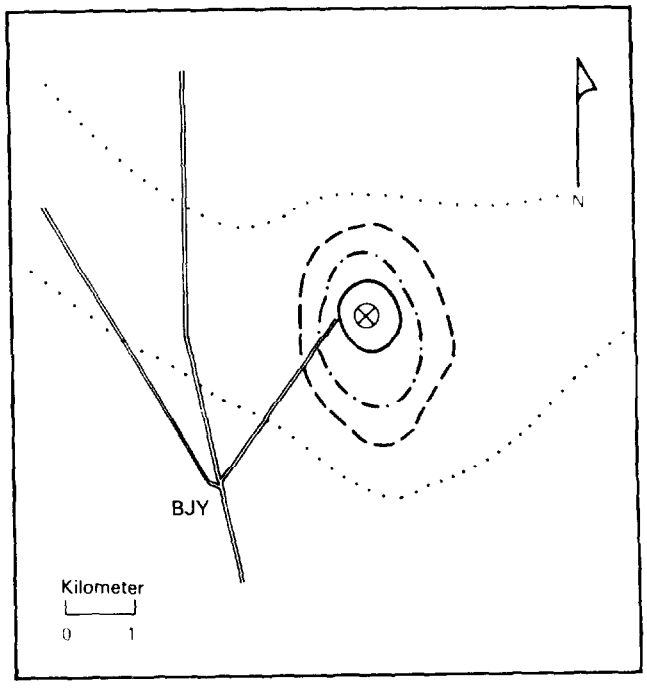
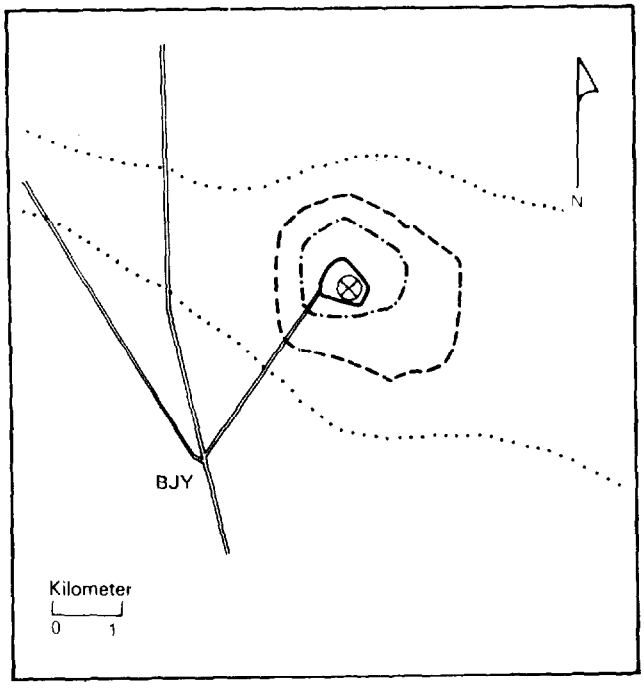


Figure 5-1: INITIAL SURVEY FOR SHOT CLIMAX, 4 JUNE 1953, 0435 TO 0525 HOURS



4 June 1953, (Time Unspecified)



5 June 1953, 0800 Hours

Roads
0.01 R/h
0.1 R/h
1.0 R/h
10.0 R/h
Ground Zero

Figure 5-2: SUBSEQUENT SURVEYS FOR SHOT CLIMAX

Decontamination

During the period of Shot CLIMAX, the Vehicle and Equipment Decontamination Section decontaminated 14 vehicles (39).

SHOTS ENCORE THROUGH CLIMAX REFERENCE LIST

The following list of references represents only those documents cited in the ENCORE through CLIMAX volume. When a DNA-WT document is followed by an EX, the latest version has been cited. A complete list of documents reviewed during the preparation of the Operation UPSHOT-KNOTHOLE volumes is contained in the Operation UPSHOT-KNOTHOLE volume Bibliography.

AVAILABILITY INFORMATION

An availability statement has been included at the end of the reference citation for those readers who wish to read or obtain copies of source documents. Availability statements were correct at the time the bibliography was prepared. It is anticipated that many of the documents marked unavailable may become available during the declassification review process. The Coordination and Information Center (CIC) and the National Technical Information Service (NTIS) will be provided future DNA-WT documents bearing an EX after the report number.

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Department of Energy
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Springfield, Virginia 22161 (Sales Office)

Additional ordering information or assistance may be obtained by writing to the NTIS, Attention: Customer Service, or by calling (703) 487-4660.

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OTHER GOVERNMENT AGENCIES (Continued)

U.S. House of Representatives
Committee on Interstate & Foreign Commerce
ATTN: Subcommittee on Health & Envir

U.S. Military Academy
ATTN: Director of Libraries

U.S. Senate
Committee on Armed Services
ATTN: Committee on Veterans Affairs

U.S. Senate
ATTN: Committee on Veterans Affairs

Veterans Administration-RO
Providence, RI
ATTN: Director

Veterans Administration-RO
Montgomery, AL
ATTN: Director

Veterans Administration-RO
Anchorage, AK
ATTN: Director

Veterans Administration-RO
Phoenix, AZ
ATTN: Director

Veterans Administration-RO
Little Rock, AR
ATTN: Director

Veterans Administration-RO
Los Angeles, CA
ATTN: Director

Veterans Administration-RO
San Francisco, CA
ATTN: Director

Veterans Administration-RO
Denver, CO
ATTN: Director

Veterans Administration-RO
Hartford, CT
ATTN: Director

Veterans Administration-RO
Wilmington, DE
ATTN: Director

Veterans Administration-OFC Central
Washington, D. C.
ATTN: Dept Veterans Benefit, Central Ofc
ATTN: Director
ATTN: Board of Veteran Appeal

Veterans Administration-RO
St. Petersburg, FL
ATTN: Director

Veterans Administration-RO
Atlanta, GA
ATTN: Director

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Honolulu, HI
ATTN: Director

Veterans Administration-RO
Chicago, IL
ATTN: Director

Veterans Administration-RO
Seattle, WA
ATTN: Director

Veterans Administration-RO
Indianapolis, IN
ATTN: Director

Veterans Administration-RO
Des Moines, IA
ATTN: Director

Veterans Administration-RO
Wichita, KS
ATTN: Director

Veterans Administration-RO
Louisville, KY
ATTN: Director

Veterans Administration-RO
New Orleans, LA
ATTN: Director

Veterans Administration-RO
Togus, ME
ATTN: Director

Veterans Administration-RO
Baltimore, MD
ATTN: Director

Veterans Administration-RO
Boston, MA
ATTN: Director

Veterans Administration-RO
St. Paul, MN
ATTN: Director

Veterans Administration-RO
Jackson, MS
ATTN: Director

Veterans Administration-RO
Huntington, WV
ATTN: Director

Veterans Administration-RO
St. Louis, MO
ATTN: Directo

Veterans Administration-RO
Ft. Harrison, MT
ATTN: Director

National Archives
ATTN: Librn

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Lincoln, NE
ATTN: Director

Veterans Administration-RO
Reno, NV
ATTN: Director

Veterans Administration-RO
Manchester, NH
ATTN: Director

Veterans Administration-RO
Newark, NJ
ATTN: Director

Veterans Administration-RO
Milwaukee, WI
ATTN: Director

Veterans Administration-RO
Albuquerque, NM
ATTN: Director

Veterans Administration-RO
Buffalo, NY
ATTN: Director

Veterans Administration-RO
New York, NY
ATTN: Director

Veterans Administration-RO
Winston-Salem, NC
ATTN: Director

Veterans Administration-RO
Fargo, ND
ATTN: Director

Veterans Administration-RO
Cleveland, OH
ATTN: Director

Veterans Administration-RO
Muskogee, OK
ATTN: Director

Veterans Administration-RO
Portland, OR
ATTN: Director

Veterans Administration-RO
Pittsburgh, PA
ATTN: Director

Veterans Administration-RO
Philadelphia, PA
ATTN: Director

Veterans Administration-RO
San Francisco, CA
ATTN: Director

Veterans Administration-RO
San Juan, Puerto Rico
ATTN: Director

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Columbia, SC
ATTN: Director

Veterans Administration-RO
Sioux Falls, SD
ATTN: Director

Veterans Administration-RO
Houston, TX
ATTN: Director

Veterans Administration-RO
Waco, TX
ATTN: Director

Veterans Administration-RO
Salt Lake City, UT
ATTN: Director

Veterans Administraiton-RO
White River Junction, VT
ATTN: Director

Veterans Administration-RO
Roanoke, VA
ATTN: Director

Veterans Administration-RO
Cheyenne, WY
ATTN: Director

Veterans Administration-RO
San Diego, CA
ATTN: Director

Veterans Administration-RO
Boise, ID
ATTN: Director

Veterans Administration-RO
Detroit, MI
ATTN: Director

Veterans Administration-RO
Nashville, TN
ATTN: Director

The White House
ATTN: Domestic Policy Staff

DEPARTMENT OF ENERGY CONTRACTORS

Lawrence Livermore National Lab
ATTN: Tech Info Dept Library

Los Alamos National Lab
ATTN: Library
ATTN: ADPA MMS 195

Sandia National Lab
ATTN: W. Hereford
ATTN: Central Library

Reynolds Electrical & Engr Co., Inc
ATTN: CIC
ATTN: W. Brady

OTHER

Adams State College
ATTN: Librn

Akron Public Library
ATTN: Librn

Alabama State Dept of Archives & History
ATTN: Military Records Div

University of Alabama
ATTN: Reference Dept/Docs

University of Alaska Library at Anchorage
ATTN: Librn

University of Alaska
ATTN: Dir of Libraries

Albany Public Library
ATTN: Librn

Alexander City State Jr College
ATTN: Librn

Allegheny College
ATTN: Librn

Allen County Public Library
ATTN: Librn

Altoona Area Public Library
ATTN: Librn

American Statistics Index
Congressional Info Service, Inc
ATTN: Cathy Jarvey

Anaheim Public Library
ATTN: Librn

College of Wooster
ATTN: Gov Docs

Angelo State University Library
ATTN: Librn

Angelo Iacoboni Public Library
ATTN: Librn

Anoka County Library
ATTN: Librn

Appalachian State University
ATTN: Library Docs

Arizona State University Library
ATTN: Librn

University of Arizona
ATTN: Gov Doc Dept/C. Bower

Arkansas College Library
ATTN: Library

Brooklyn College
ATTN: Doc Div

OTHER (Continued)

Arkansas Library Comm
ATTN: Library

Arkansas State University
ATTN: Library

University of Arkansas
ATTN: Gov Docs Div

Austin College
ATTN: Librn

Atlanta Public Library
ATTN: Ivan Allen Dept

Atlanta University
ATTN: Librn

Auburn University Library at Mongomery (Reg)
ATTN: Librn

C. W. Post Ctr Long Island University
ATTN: Librn

Bangor Public Library
ATTN: Librn

Bates College Library
ATTN: Librn

Baylor University Library
ATTN: Docs Dept

Beloit College Libraries
ATTN: Serials Docs Dept

Bemidji State College
ATTN: Library

State University College
ATTN: Gov Docs

Akron University
ATTN: Gov Docs

Boston Public Library (Reg)
ATTN: Docs Dept

Bowdoin College
ATTN: Librn

Bowling Green State University
ATTN: Lib Gov Docs Services

Bradley University
ATTN: Librn

Brandeis University Library
ATTN: Docs Section

Brigham Young University
ATTN: Librn

Brigham Young University
ATTN: Docs Collection

Brookhaven National Laboratory
ATTN: Tech Library

OTHER (Continued)

Broward County Library Sys
ATTN: Librn

Brown University
ATTN: Librn

Bucknell University
ATTN: Reference Dept

Buffalo & Erie Co Public Library
ATTN: Librn

State University Library of California at Fresno
ATTN: Library

University Library of California at Los Angeles
ATTN: Pub Affairs Serv U.S. Docs

University of California at San Diego
ATTN: Docs Dept

State College Library of California at Stanislaus
ATTN: Library

California State Polytechnic University Library
ATTN: Librn

California State University at Northridge
ATTN: Gov Doc

California State Library (Reg)
ATTN: Librn

California State University at Long Beach Library
ATTN: Librn

California State University
ATTN: Librn

California State University
ATTN: Librn

California University Library
ATTN: Gov Pub Dept

California University Library
ATTN: Librn

California University Library
ATTN: Gov Docs Dept

California University Library
ATTN: Docs Sec

University of California
ATTN: Gov Docs Dept

Calvin College Library
ATTN: Librn

Kearney State College
ATTN: Gov Docs Dept

Cambria County Library Sys
ATTN: Librn

Carleton College Library
ATTN: Librn

OTHER (Continued)

Carnegie Library of Pittsburgh
ATTN: Librn

Carnegie Mellon University
ATTN: Dir of Libraries

Carson Regional Library
ATTN: Gov Pubs Unit

Case Western Reserve University
ATTN: Librn

Casper College
ATTN: Librn

University of Central Florida
ATTN: Library Docs Dept

Central Michigan University
ATTN: Library Docs Sec

Central Missouri State Univ
ATTN: Gov Docs

Central State University
ATTN: Lib Docs Dept

Central Washington University
ATTN: Lib Docs Sec

Central Wyoming College Library
ATTN: Librn

Charleston County Library
ATTN: Librn

Charlotte & Mechlenburg County Public Library
ATTN: E. Correll

Chattanooga Hamilton County, Bicentennial Library
ATTN: Librn

Chesapeake Public Library System
ATTN: Librn

Chicago Public Library
ATTN: Gov Pubs Dept

State University of Chicago
ATTN: Librn

Chicago University Library
ATTN: Dir of Libraries
ATTN: Docs Processing

Cincinnati University Library
ATTN: Librn

Claremont Colleges Libraries
ATTN: Doc Collection

Clemson University
ATTN: Dir of Libraries

OTHER (Continued)

Cleveland Public Library
ATTN: Docs Collection

Cleveland State University Library
ATTN: Librn

Coe Library
ATTN: Docs Div

Colgate University Library
ATTN: Ref Lib

Colorado State University Libraries
ATTN: Librn

University of Colorado Libraries
ATTN: Dir of Libraries

Columbia University Library
ATTN: Docs Svc Ctr

Columbus & Franklin Cty Public Library
ATTN: Gen Rec Div

Compton Library
ATTN: Librn

Connecticut State Library (Reg)
ATTN: Librn

University of Connecticut
ATTN: Gov't of Connecticut

University of Connecticut
ATTN: Dir of Libraries

Cornell University Library
ATTN: Librn

Corpus Christi State University Library
ATTN: Librn

Culver City Library
ATTN: Librn

Curry College Library
ATTN: Librn

University of North Carolina at Asheville
ATTN: Librn

Dallas County Public Library
ATTN: Librn

Dallas Public Library
ATTN: Librn

Dalton Junior College Library
ATTN: Librn

Dartmouth College
ATTN: Librn

Davenport Public Library
ATTN: Librn

Davidson College
ATTN: Librn

OTHER (Continued)

Dayton & Montgomery City Public Library
ATTN: Librn

University of Dayton
ATTN: Librn

Decatur Public Library
ATTN: Librn

Dekalb Community College So Cpus
ATTN: Librn

Delaware Pauw University
ATTN: Librn

University of Delaware
ATTN: Librn

Delta College Library
ATTN: Librn

Delta State University
ATTN: Librn

Denison University Library
ATTN: Librn

Denver Public Library (Reg)
ATTN: Docs Div

Dept of Library & Archives (Reg)
ATTN: Librn

Detroit Public Library
ATTN: Librn

Burlington Library
ATTN: Librn

Dickinson State College
ATTN: Librn

Alabama Agricultural Mechanical University & Coll
ATTN: Librn

Drake University
ATTN: Cowles Library

Drew University
ATTN: Librn

Duke University
ATTN: Pub Docs Dept

Duluth Public Library
ATTN: Docs Sec

East Carolina University
ATTN: Lib Docs Dept

East Central University
ATTN: Librn

East Islip Public Library
ATTN: Librn

OTHER (Continued)

East Orange Public Library
ATTN: U.S. Gov't Depository

East Tennessee State University Sherrod Library
ATTN: Docs Dept

East Texas State University
ATTN: Library

Monmouth County Library Eastern Branch
ATTN: Librn

Eastern Illinois University
ATTN: Librn

Eastern Kentucky University
ATTN: Librn

Eastern Michigan University Library
ATTN: Library

Eastern Montana College Library
ATTN: Docs Dept

Eastern New Mexico University
ATTN: Librn

Eastern Oregon College Library
ATTN: Librn

Eastern Washington University
ATTN: Librn

El Paso Public Library
ATTN: Docs & Geneology Dept

Elko County Library
ATTN: Librn

Elmira College
ATTN: Librn

Elon College Library
ATTN: Librn

Enoch Pratt Free Library
ATTN: Docs Ofc

Emory University
ATTN: Librn

Evansville & Vanderburgh Cty Public Library
ATTN: Librn

Everett Public Library
ATTN: Librn

Fairleigh Dickinson University
ATTN: Depository Dept

Florida A & M University
ATTN: Librn

Florida Atlantic University Library
ATTN: Div of Pub Docs

OTHER (Continued)

Florida Institute of Technology
ATTN: Library

Florida International University Library
ATTN: Docs Sec

Florida State Library
ATTN: Docs Sec

Florida State University
ATTN: Librn

University of Florida
ATTN: Docs Dept

Fond Du Lac Public Library
ATTN: Librn

Ft Hays State University
Ft Hays Kansas State College
ATTN: Librn

Ft Worth Public Library
ATTN: Librn

Free Public Library of Elizabeth
ATTN: Librn

Free Public Library
ATTN: Librn

Freeport Public Library
ATTN: Librn

Fresno Cty Free Library
ATTN: Librn

Gadsden Public Library
ATTN: Librn

Garden Public Library
ATTN: Librn

Gardner Webb College
ATTN: Docs Library

Gary Public Library
ATTN: Librn

Geauga Cty Public Library
ATTN: Librn

Georgetown University Library
ATTN: Gov Docs Room

Georgia Institute of Technology
ATTN: Librn

Georgia Southern College
ATTN: Librn

Georgia Southwestern College
ATTN: Dir of Libraries

Georgia State University Library
ATTN: Librn

OTHER (Continued)

University of Georgia
ATTN: Dir of Libraries (Reg)

Glassboro State College
ATTN: Librn

Gleeson Library
ATTN: Librn

Graceland College
ATTN: Librn

Grand Forks Public City-County Library
ATTN: Librn

Grand Rapids Public Library
ATTN: Dir of Lib

Greenville County Library
ATTN: Librn

Guam RFK Memorial University Library
ATTN: Fed Depository Coll

University of Guam
ATTN: Librn

Gustavus Adolphus College
ATTN: Librn

South Dakota University
ATTN: Librn

Hardin-Simmons University Library
ATTN: Librn

Hartford Public Library
ATTN: Librn

Harvard College Library
ATTN: Dir of Lib

Harvard College Library
ATTN: Serials Rec Div

University of Hawaii Library
ATTN: Gov Docs Coll

Hawaii State Library
ATTN: Fed Docs Unit

University of Hawaii at Monoa
ATTN: Dir of Libraries (Reg)

University of Hawaii
Hilo Campus Library
ATTN: Librn

Haydon Burns Library
ATTN: Librn

Hennepin County Library
ATTN: Gov Docs

Henry Ford Community College Library
ATTN: Librn

OTHER (Continued)

Herbert H. Lehman College
ATTN: Lib Docs Div

Hofstra University Library
ATTN: Docs Dept

Hollins College
ATTN: Librn

Hopkinsville Community College
ATTN: Librn

Wagner College
ATTN: Librn

University of Houston Library
ATTN: Docs Div

Houston Public Library
ATTN: Librn

Tulane University
ATTN: Docs Dept

Hoyt Public Library
ATTN: Librn

Humboldt State College Library
ATTN: Docs Dept

Huntington Park Library
ATTN: Librn

Hutchinson Public Library
ATTN: Librn

Idaho Public Library & Information Center
ATTN: Librn

Idaho State Library
ATTN: Librn

Idaho State University Library
ATTN: Docs Dept

University of Idaho
ATTN: Dir of Libraries (Reg)
ATTN: Docs Sec

University of Illinois Library
ATTN: Docs Sec

Illinois State Library (Reg)
ATTN: Gov Docs Br

Illinois University at Urbana-Champaign
ATTN: P. Watson Docs Lib

Illinois Valley Community College
ATTN: Library

Illinois State University
ATTN: Librn

Indiana State Library (Reg)
ATTN: Serial Sec

Indiana State University
ATTN: Docs Library

OTHER (Continued)

Indiana University Library
ATTN: Docs Dept

Indianapolis Marion County Public Library
ATTN: Social Science Div

Iowa State University Library
ATTN: Gov Docs Dept

Iowa University Library
ATTN: Gov Docs Dept

Butler University
ATTN: Librn

Isaac Delchdo College
ATTN: Librn

James Madison University
ATTN: Librn

Jefferson County Public Library
Lakewood Regional Library
ATTN: Librn

Jersey City State College
ATTN: F. A. Irwin Library Periodicals
Doc Sec

Johns Hopkins University
ATTN: Docs Library

La Roche College
ATTN: Librn

Johnson Free Public Library
ATTN: Librn

Kalamazoo Public Library
ATTN: Librn

Kansas City Public Library
ATTN: Docs Div

Kansas State Library
ATTN: Librn

Kansas State University Library
ATTN: Docs Dept

University of Kansas
ATTN: Dir of Library (Reg)

University of Texas
ATTN: Lyndon B. Johnson School of Public
Affairs Library

Maine Maritime Academy
ATTN: Librn

University of Maine
ATTN: Librn

OTHER (Continued)

Kent State University Library
ATTN: Docs Div

Kentucky Dept of Library & Archives
ATTN: Docs Sec

University of Kentucky
ATTN: Gov Pub Dept
ATTN: Dir of Lib (Reg)

Kenyon College Library
ATTN: Librn

Lake Forest College
ATTN: Librn

Lake Sumter Community College Library
ATTN: Librn

Lakeland Public Library
ATTN: Librn

Lancaster Regional Library
ATTN: Librn

Lawrence University
ATTN: Docs Dept

Brigham Young University
ATTN: Docs & Map Sec

Lewis University Library
ATTN: Librn

Library and Statutory Dist & Svc
2 cy ATTN: Librn

Earlham College
ATTN: Librn

Little Rock Public Library
ATTN: Librn

Long Beach Public Library
ATTN: Librn

Los Angeles Public Library
ATTN: Serials Div U.S. Docs

Louisiana State University
ATTN: Gov Doc Dept
ATTN: Dir of Libraries (Reg)

Louisville Free Public Library
ATTN: Librn

Louisville University Library
ATTN: Librn

Hoover Institution
ATTN: J. Bingham

OTHER (Continued)

Manchester City Library
ATTN: Librn

Mankato State College
ATTN: Gov Pubs

University of Maine at Farmington
ATTN: Dir of Libraries

Marathon County Public Library
ATTN: Librn

Principia College
ATTN: Librn

University of Maryland
ATTN: McKeldin Library Docs Div

University of Maryland
ATTN: Librn

University of Massachusetts
ATTN: Gov Docs Coll

Maui Public Library
Kahului Branch
ATTN: Librn

McNeese State University
ATTN: Librn

Memphis & Shelby County Public Library &
Information Center
ATTN: Librn

Memphis State University
ATTN: Librn

Mercer University
ATTN: Librn

Mesa County Public Library
ATTN: Librn

Miami Dade Community College
ATTN: Librn

University of Miami Library
ATTN: Gov Pubs

Miami Public Library
ATTN: Docs Div

Miami University Library
ATTN: Docs Dept

University of Santa Clara
ATTN: Docs Div

Michigan State Library
ATTN: Librn

Michigan State University Library
ATTN: Librn

Murray State University Library
ATTN: Lib

OTHER (Continued)

Michigan Tech University
ATTN: Lib Docs Dept

University of Michigan
ATTN: Acq Sec Docs Unit

Middlebury College Library
ATTN: Librn

Millersville State College
ATTN: Librn

State University of New York
ATTN: Docs Librn

Milwaukee Public Library
ATTN: Librn

Minneapolis Public Library
ATTN: Librn

University of Minnesota
ATTN: Dir of Libraries (Reg)

Minot State College
ATTN: Librn

Mississippi State University
ATTN: Librn

University of Mississippi
ATTN: Dir of Libraries

Missouri University at Kansas City General
ATTN: Librn

University of Missouri Library
ATTN: Gov Docs

M.I.T. Libraries
ATTN: Librn

Mobile Public Library
ATTN: Gov Info Div

Midwestern University
ATTN: Librn

Montana State Library
ATTN: Librn

Montana State University Library
ATTN: Librn

University of Montana
ATTN: Dir of Libraries (Reg)

Montebello Library
ATTN: Librn

Moorhead State College
ATTN: Library

Mt Prospect Public Library
ATTN: Gov't Info Ctr

OTHER (Continued)

Nassau Library System
ATTN: Librn

Natrona County Public Library
ATTN: Librn

Nebraska Library Community
Nebraska Public Clearinghouse
ATTN: Librn

University of Nebraska at Omaha
ATTN: Univ Lib Docs

Nebraska Western College Library
ATTN: Librn

University of Nebraska
ATTN: Dir of Libraries (Reg)

University of Nebraska Library
ATTN: Acquisitions Dept

University of Nevada Library
ATTN: Gov Pubs Dept

University of Nevada at Las Vegas
ATTN: Dir of Libraries

New Hampshire University Library
ATTN: Librn

New Hanover County Public Library
ATTN: Librn

New Mexico State Library
ATTN: Librn

New Mexico State University
ATTN: Lib Docs Div

University of New Mexico
ATTN: Dir of Libraries (Reg)

University of New Orleans Library
ATTN: Gov Docs Div

New Orleans Public Library
ATTN: Librn

New York Public Library
ATTN: Librn

New York State Library
ATTN: Docs Control Cultural Ed Ctr

State University of New York at Stony Brook
ATTN: Main Lib Docs Sec

State University of New York Col Memorial Lib at Cortland
ATTN: Librn

State University of New York
ATTN: Lib Docs Sec

North Texas State University Library
ATTN: Librn

OTHER (Continued)

State University of New York
ATTN: Librn

New York State University
ATTN: Docs Ctr

State University of New York
ATTN: Docs Dept

New York University Library
ATTN: Docs Dept

Newark Free Library
ATTN: Librn

Newark Public Library
ATTN: Librn

Niagara Falls Public Library
ATTN: Librn

Nicholls State University Library
ATTN: Docs Div

Nieves M. Flores Memorial Library
ATTN: Librn

Norfolk Public Library
ATTN: R. Parker

North Carolina Agricultural & Tech State University
ATTN: Librn

University of North Carolina at Charlotte
ATTN: Atkins Lib Doc Dept

University Library of North Carolina at Greensboro
ATTN: Librn

University of North Carolina at Wilmington
ATTN: Librn

North Carolina Central University
ATTN: Librn

North Carolina State University
ATTN: Librn

University of North Carolina
ATTN: BA SS Div Docs

North Dakota State University Library
ATTN: Docs Librn

University of North Dakota
ATTN: Librn

North Georgia College
ATTN: Librn

Minnesota Div of Emergency Svcs
ATTN: Librn

OTHER (Continued)

Northeast Missouri State University
ATTN: Librn

Northeastern Oklahoma State University
ATTN: Librn

Northeastern University
ATTN: Dodge Library

Northern Arizona University Library
ATTN: Gov Docs Dept

Northern Illinois University
ATTN: Librn

Northern Michigan University
ATTN: Docs

Northern Montana College Library
ATTN: Librn

Northwestern Michigan College
ATTN: Librn

Northwestern State University
ATTN: Librn

Northwestern State University Library
ATTN: Librn

Northwestern University Library
ATTN: Gov Pubs Dept

Norwalk Public Library
ATTN: Librn

Northeastern Illinois University
ATTN: Library

University of Notre Dame
ATTN: Doc Ctr

Oakland Community College
ATTN: Librn

Oakland Public Library
ATTN: Librn

Oberlin College Library
ATTN: Librn

Ocean County College
ATTN: Librn

Ohio State Library
ATTN: Librn

Ohio State University
ATTN: Lib Docs Div

Ohio University Library
ATTN: Docs Dept

Oklahoma City University Library
ATTN: Librn

Oklahoma City University Library
ATTN: Librn

OTHER (Continued)

Oklahoma Department of Libraries
ATTN: U.S. Gov Docs

University of Oklahoma
ATTN: Docs Div

Old Dominion University
ATTN: Doc Dept Univ Lib

Olivet College Library
ATTN: Librn

Omaha Public Library Clark Branch
ATTN: Librn

Onondaga County Public Library
ATTN: Gov Docs Sec

Oregon State Library
ATTN: Librn

University of Oregon
ATTN: Docs Sec

Ouachita Baptist University
ATTN: Librn

Pan American University Library
ATTN: Librn

Passaic Public Library
ATTN: Librn

Queens College
ATTN: Docs Dept

Pennsylvania State Library
ATTN: Gov Pubs Sec

Pennsylvania State University
ATTN: Lib Doc Sec

University of Pennsylvania
ATTN: Dir of Libraries

University of Denver
ATTN: Penrose Library

Peoria Public Library
ATTN: Business, Science & Tech Dept

Free Library of Philadelphia
ATTN: Gov Pubs Dept

Philipsburg Free Public Library
ATTN: Library

Phoenix Public Library
ATTN: Librn

University of Pittsburgh
ATTN: Docs Office, G8

Plainfield Public Library
ATTN: Librn

OTHER (Continued)

Popular Creek Public Library District
ATTN: Librn

Association of Portland Library
ATTN: Librn

Portland Public Library
ATTN: Librn

Portland State University Library
ATTN: Librn

Pratt Institute Library
ATTN: Librn

Louisiana Tech University
ATTN: Librn

Princeton University Library
ATTN: Docs Div

Providence College
ATTN: Librn

Providence Public Library
ATTN: Librn

Public Library Cincinnati & Hamilton County
ATTN: Librn

Public Library of Nashville and Davidson County
ATTN: Librn

University of Puerto Rico
ATTN: Doc & Maps Room

Purdue University Library
ATTN: Librn

Quinebaug Valley Community College
ATTN: Librn

Auburn University
ATTN: Microforms & Docs Dept

Rapid City Public Library
ATTN: Librn

Reading Public Library
ATTN: Librn

Reed College Library
ATTN: Librn

Augusta College
ATTN: Librn

University of Rhode Island Library
ATTN: Gov Pubs Ofc

University of Rhode Island
ATTN: Dir of Libraries

Rice University
ATTN: Dir of Libraries

Louisiana College
ATTN: Librn

OTHER (Continued)

Richland County Public Library
ATTN: Librn

Riverside Public Library
ATTN: Librn

University of Rochester Library
ATTN: Docs Sec

University of Rutgers Camden Library
ATTN: Librn

State University of Rutgers
ATTN: Librn

Rutgers University
ATTN: Dir of Libraries (Reg)

Rutgers University Law Library
ATTN: Fed Docs Dept

Salem College Library
ATTN: Librn

Samford University
ATTN: Librn

San Antonio Public Library
ATTN: Bus Science & Tech Dept

San Diego County Library
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San Diego Public Library
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San Diego State University Library
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Seattle Public Library
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Slippery Rock State College Library
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South Carolina State Library
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University of South Carolina
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University of South Carolina
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South Dakota School of Mines & Technical Library
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University of South Dakota
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South Florida University Library
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Southeast Missouri State University
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Southeastern Massachusetts University Library
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University of Southern Alabama
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Southern California University Library
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Southern Connecticut State College
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Southern Illinois University
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Southern Illinois University
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Southern Methodist University
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University of Southern Mississippi
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OTHER (Continued)

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Southern University in New Orleans Library
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Southern Utah State College Library
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Southwest Missouri State College
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University of Southwestern Louisiana Libraries
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Southwestern University
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Spokane Public Library
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Springfield City Library
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St Bonaventure University
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St Joseph Public Library
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St Lawrence University
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St Louis Public Library
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St Paul Public Library
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Stanford University Library
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State Historical Soc Library
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State Library of Massachusetts
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State University of New York
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Stetson University
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University of Steubenville
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Stockton & San Joaquin Public Library
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Albion College
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OTHER (Continued)

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Swarthmore College Library
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Syracuse University Library
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Tacoma Public Library
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Hillsborough County Public Library at Tampa
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Temple University
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Tennessee Technological University
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University of Tennessee
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College of Idaho
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Texas A & M University Library
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University of Texas at Arlington
ATTN: Library Docs

University of Texas at San Antonio
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Texas Christian University
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Texas State Library
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Texas Tech University Library
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Texas University at Austin
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University of Toledo Library
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Toledo Public Library
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Torrance Civic Center Library
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Traverse City Public Library
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Trenton Free Public Library
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UCLA Research Library
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Uniformed Services University of the Health Sciences
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University of Maine at Oreno
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University of Northern Iowa
ATTN: Library

Upper Iowa College
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Utah State University
ATTN: Librn

University of Utah
ATTN: Special Collections

University of Utah
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ATTN: Dept of Pharmacology

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Valencia Library
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Valparaiso University
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Vanderbilt University Library
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University of Vermont
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Virginia Commonwealth University
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Virginia Military Institute
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Virginia Polytechnic Institute Library
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Virginia State Library
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University of Virginia
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Volusia County Public Library
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OTHER (Continued)

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Washington State University
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Washington University Libraries
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Wayne State University Library
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Wayne State University Law Library
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Weber State College Library
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Wesleyan University
ATTN: Docs Librn

West Chester State College
ATTN: Docs Dept

West Covina Library
ATTN: Librn

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ATTN: Librn

West Hills Community College
ATTN: Library

West Texas State University
ATTN: Library

West Virginia College of Grad Studies Library
ATTN: Librn

University of West Virginia
ATTN: Dir of Libraries (Reg)

Westerly Public Library
ATTN: Librn

Western Carolina University
ATTN: Librn

Western Illinois University Library
ATTN: Librn

Western Washington University
ATTN: Librn

Western Wyoming Community College Library
ATTN: Librn

Westmoreland City Community College
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OTHER (Continued)

Whitman College
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Wichita State University Library
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Williams & Mary College
ATTN: Docs Dept

Emporia Kansas State College
ATTN: Gov Docs Div

William College Library
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Willimantic Public Library
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Winthrop College
ATTN: Docs Dept

University of Wisconsin at Whitewater
ATTN: Gov Docs Lib

University of Wisconsin at Milwaukee
ATTN: Lib Docs

University of Wisconsin at Oshkosh
ATTN: Librn

University of Wisconsin at Platteville
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University of Wisconsin at Stevens Point
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University of Wisconsin
ATTN: Gov Pubs Dept

University of Wisconsin
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Worcester Public Library
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Wright State University Library
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Wyoming State Library
ATTN: Librn

University of Wyoming
ATTN: Docs Div

Yale University
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Yeshiva University
ATTN: Librn

Yuma City County Library
ATTN: Librn

Simon Schwob Mem Lib, Columbus Col
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