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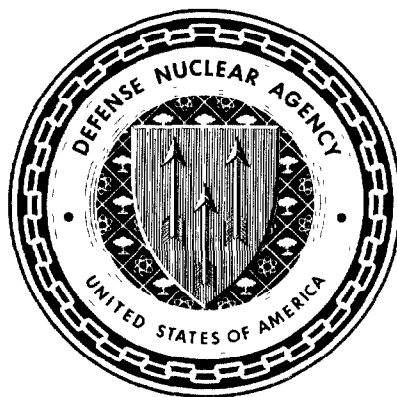
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HAROLD L. BRODE

DNA 6015F

SHOT BADGER

A Test of the UPSHOT-KNOTHOLE Series 18 APRIL 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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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DNA 6015F	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) SHOT BADGER A Test of the UPSHOT-KNOTHOLE Series 18 April 1953		5. TYPE OF REPORT & PERIOD COVERED Technical Report
7. AUTHOR(s) Jeannie Massie, Carl Maag, Stephen Rohrer, Robert Shepanek		6. PERFORMING ORG. REPORT NUMBER JRB 2-816-03-423-00
9. PERFORMING ORGANIZATION NAME AND ADDRESS JRB Associates 8400 Westpark Drive McLean, Virginia 22102		8. CONTRACT OR GRANT NUMBER(s) DNA 001-79-C-0473
11. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, D.C. 20305		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Subtask U99QAXMK506-08
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE 12 January 1982
		13. NUMBER OF PAGES 100
		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE NA Since UNCLASSIFIED
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES For sale by National Technical Information Service, Springfield, Virginia 22161. This work was sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B350079464 U99QAXMK50608 H2590D.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) BADGER Nevada Proving Ground UPSHOT-KNOTHOLE 2d Marine Corps Provisional Ionizing Radiation Atomic Exercise Brigade Exercise Desert Rock Joint Test Organization		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report describes the activities of DOD personnel in Shot BADGER, the sixth nuclear test in the UPSHOT-KNOTHOLE atmospheric nuclear weapons testing series. The test, conducted on 18 April 1953, involved military personnel in Exercise Desert Rock V, AFSWP, AFSWC, and AEC test activities. The largest activity was the 2d Marine Corps Provisional Atomic Exercise Brigade maneuver involving 2,167 Marines.		

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18. SUPPLEMENTARY NOTES (continued)

The Defense Nuclear Agency Action Officer, Lt. Col. H. L. Reese, USAF, under whom this work was done, wishes to acknowledge the research and editing contribution of numerous reviewers in the Military Services and other organizations in addition to those listed in block 7.

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PREFACE

Between 1945 and 1962, the U.S. 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 (DOD) participants, both military and civilian, were present at the tests. Of these, approximately 90,000 were present 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 present at Shot SMOKY, one test of Operation PLUMBBOB, the series of atmospheric nuclear weapons tests conducted in 1957. Since the 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 the atmospheric nuclear weapons tests.

In late 1977, DOD began a study to provide data to both the Center for Disease Control and the Veterans Administration on potential exposures to ionizing 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

*Renamed the Nevada Test Site in 1955.

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

- 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 on Shot BADGER is based on the military and technical documents associated with the atmospheric nuclear weapons test event.

METHODS AND SOURCES USED TO PREPARE THIS VOLUME

Many of the documents pertaining specifically to DOD involvement during Shot BADGER, the sixth event of the UPSHOT-KNOTHOLE Series, were found in the Defense Nuclear Agency Technical Library, the National Federal Archives Record Center, 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 Shot BADGER addresses test specifications and technical information, rather than personnel data. The available historical documentation sometimes has inconsistencies in vital facts. Efforts have been made to resolve the inconsistencies wherever possible, or otherwise to bring them to the attention of the reader.

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 prior to the UPSHOT-KNOTHOLE Series. It is not known if all of

*Formerly Los Alamos Scientific Laboratory (LASL)

the projects addressed in these planning documents were conducted exactly as planned. Although some of the after-action documents, such as the Armed Forces Special Weapons Project weapons test reports, 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.

To facilitate use of references, this volume 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 test, 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.

ORGANIZATION AND CONTENT OF UPSHOT-KNOTHOLE SERIES REPORTS

This volume details participation by DOD personnel in Shot BADGER, the sixth detonation 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
- Shot Volume: Shots ANNIE to RAY, the First Five UPSHOT-KNOTHOLE Tests
- Shot Volume: Shot SIMON
- Shot Volume: Shots ENCORE to CLIMAX, the Final Four UPSHOT-KNOTHOLE Tests.

The volumes addressing the test events of Operation UPPHOT-KNOTHOLE have been designed to complement one another. The series volume describes those dimensions of Operation UPPHOT-KNOTHOLE that apply to the series as a whole, such as historical background, organizational relationships, and radiological safety procedures. In addition, that volume 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 UPPHOT-KNOTHOLE reports.

The single-shot volumes describe DOD participation in Shots BADGER and SIMON, and each multi-shot volume combines shot-specific descriptions for the other nuclear events of the UPPHOT-KNOTHOLE Series. The shot and multi-shot volumes list only the sources referenced in each text. Descriptions of activities concerning any particular shot in the UPPHOT-KNOTHOLE Series, whether the shot is addressed in a single-shot volume or in a multi-shot volume, should be supplemented by the general organizational and radiological safety information contained in the UPPHOT-KNOTHOLE Series volume.

This volume is divided into four chapters: an introduction, two chapters on DOD activities, and a final chapter on radiation protection. It examines the activities of DOD personnel before, during, and after the BADGER event, focusing on their movements relative to the radiological environment. The procedures designed to ensure personnel safety, including exposure records indicating the effectiveness of those procedures, are included in chapter 4 whenever that information is available.

The information in this report is supplemented by the Reference Manual: Background Materials for the CONUS Volumes. The Reference Manual summarizes the basics of radiation physics, radiation health concepts, exposure criteria, and measurement techniques, as well as listing acronyms and terms used in the reports documenting nuclear test 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
BJY	BUSTER-JANGLE Y
DOD	Department of Defense
EG&G	Edgerton, Germeshausen, and Grier, Incorporated
FCDA	Federal Civil Defense Administration
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
UTM	Universal Transverse Mercator
2d MCPAEB	2d Marine Corps Provisional Atomic Exercise Brigade

BADGER

SHOT SYNOPSIS

AEC TEST SERIES: UPSHOT-KNOTHOLE
DOD EXERCISE: Desert Rock V
DATE/TIME: 18 April 1953, 0435 hours
YIELD: 23 kilotons
HEIGHT OF BURST: 300 feet (tower shot)

AEC Objective: To investigate the possibility of increasing yield of a standard fission-type weapon by varying the composition; to evaluate blast, thermal, and radiation phenomena produced by this device.

DOD Objective: To evaluate troop maneuvers, military equipment, and tactics.

Weather: At shot-time, recorded temperature at ground zero was 7.7° C. The relative humidity was 40 percent, and the air pressure was 862 millibars. Surface winds were from the north at nine knots. At 10,000 feet, the winds were 17 knots from the west; at 40,000 feet, the winds were 68 knots from the northwest.

Radiation Data: Onsite fallout occurred mostly to the southeast of ground zero. During the initial survey, which was completed at 0730 hours, radiation intensities greater than 0.1 R/h were measured within three kilometers north, east, and west of ground zero.

Participants: 2d Marine Provisional Atomic Exercise Brigade, Armed Forces Special Weapons Project, Los Alamos Scientific Laboratory, Federal Civil Defense Administration, Air Force Special Weapons Center, University of California Radiation Laboratory, contractors.

CHAPTER 1

INTRODUCTION

Shot BADGER was conducted at 0435 hours Pacific Standard Time on 18 April 1953 at the Nevada Proving Ground, the Atomic Energy Commission continental nuclear test site located northwest of Las Vegas. BADGER was the sixth nuclear test of Operation UPSHOT-KNOTHOLE, a series of 11 atmospheric nuclear weapons tests performed at the NPG from 17 March through 4 June 1953. The detonation was originally scheduled for 11 April, but residual radioactivity from the second shot of the series, NANCY, delayed preparations. To ensure careful preparation and the success of the shot, the dates for Shots BADGER and RAY were reversed (10; 20).*

The BADGER device was fired on a 300-foot steel tower in Area 2 of Yucca Flat, UTM coordinates 784104.⁺ Figure 1-1 shows the location of the detonation in relation to the other ten detonations of Operation UPSHOT-KNOTHOLE. Although the BADGER device was expected to yield 40 kilotons of energy, its yield was only 23 kilotons. Nevertheless, the blast illuminated Las Vegas like daylight and was evident 500 kilometers** to the southwest in Los Angeles (20).

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

⁺ 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.

**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.

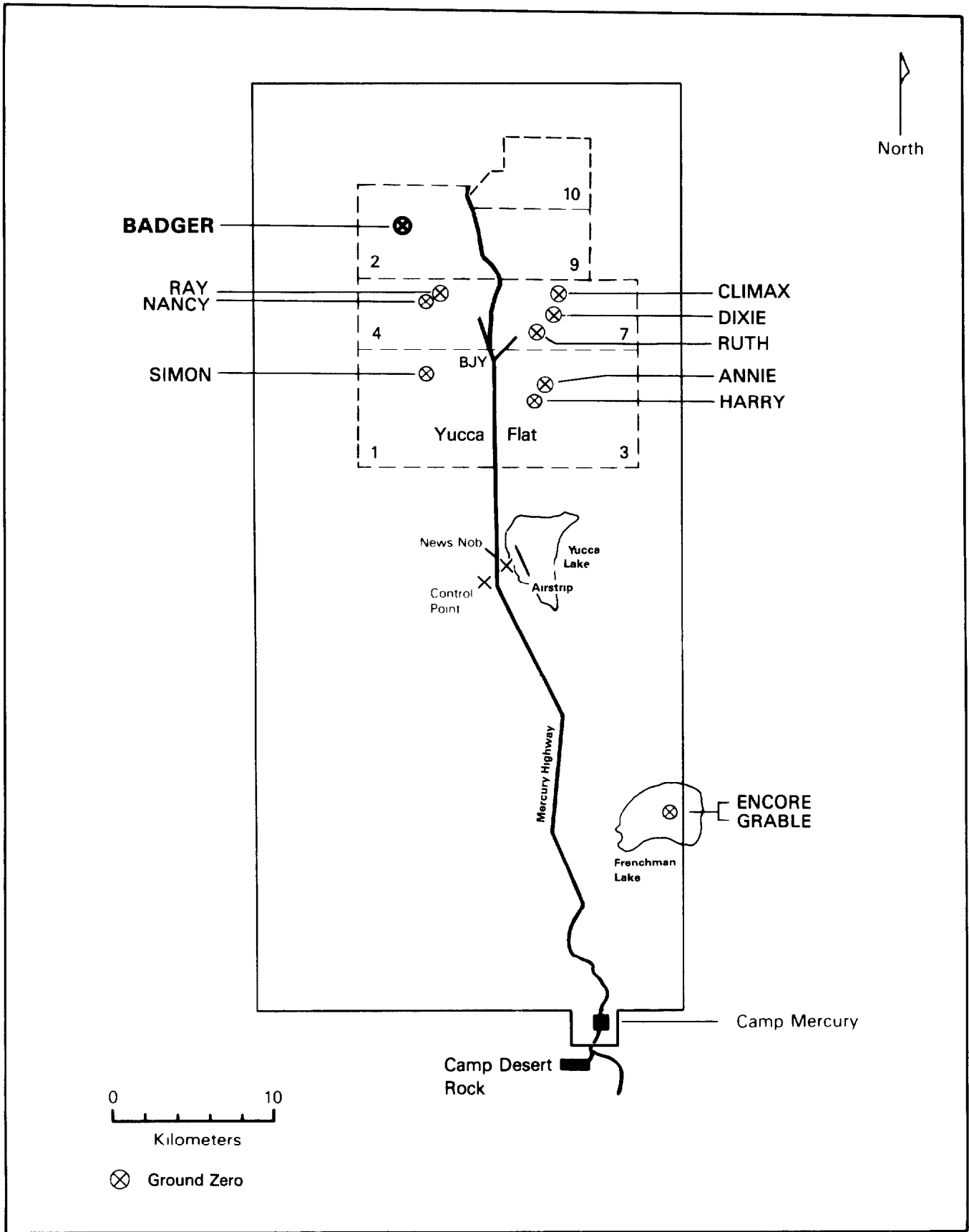


Figure 1-1: LOCATION OF SHOT BADGER IN THE NEVADA PROVING GROUND

The top of the cloud formed by Shot BADGER rose to an altitude of 36,000 feet and the bottom reached 23,000 feet.* Winds blew the BADGER cloud to the southeast. Onsite fallout was in Areas 2, 3, and 7. The main access road was contaminated, causing delays in various projects. Within the Desert Rock area, significant fallout occurred in the southeastern portion of the equipment displays, as well as near ground zero (20).

The BADGER device was designed and built for the Atomic Energy Commission by the Los Alamos Scientific Laboratory, one of two AEC nuclear weapons development laboratories. The primary objective of the event was to investigate the possibility of increasing the yield of a standard fission-type weapon by varying the composition of the device. Other important objectives included evaluating the blast, thermal, and radiation phenomena produced by this nuclear detonation and conducting a simulated air and amphibious assault under nuclear battlefield conditions (10; 24).

1.1 DEPARTMENT OF DEFENSE PARTICIPATION

Department of Defense personnel took part in three types of activity at Shot BADGER, as at other shots in the UPSHOT-KNOTHOLE Series: scientific experiments, military technical and training projects, and support services. The Weapons Development Group, the Military Effects Group, and the Civil Effects Group conducted the scientific experiments. Various armed services personnel on temporary assignment from stations throughout the country conducted the military technical and training projects, known as Exercise Desert Rock V. Camp Desert Rock troops, elements of the Joint Test Organization (JTO), and Air Force Special Weapons Center (AFSWC) personnel provided support services.

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

In the area of scientific experimentation, the two AEC weapons development laboratories, the Los Alamos Scientific Laboratory and the University of California Radiation Laboratory, teamed up to form the Weapons Development Group. This test group studied the characteristics of the various UPSHOT-KNOTHOLE detonations in an effort to develop more sophisticated nuclear weapons. At Shot BADGER, the Weapons Development Group conducted 18 experiments to study the effects of the detonation. DOD personnel assisted in five of these experiments. The Military Effects Group, sponsored by Field Command, Armed Forces Special Weapons Project (AFSWP), conducted military effects experiments during Shot BADGER. DOD personnel conducted 19 experiments to determine specific applications of the nuclear devices against a variety of targets (15). The Federal Civil Defense Administration (FCDA) also conducted experiments at the shot. The FCDA Civil Effects Group conducted six experiments that dealt with civil defense shelter durability and the effects of radiation on living organisms and drugs. DOD personnel assisted in two of these experiments. Participants in test group projects generally fielded data-collection instruments at various distances around ground zero in the days and weeks preceding the scheduled detonation. They returned and recovered the equipment some time after the detonation, when the Test Director had determined that the radiological environment in the test area would permit limited access.

Exercise Desert Rock V technical and training projects at Shot BADGER included orientation, a volunteer officer observer program, damage effects tests, operational helicopter tests, and a large Marine Corps maneuver. Exercise Desert Rock V programs generally accounted for the largest numbers of DOD participants during UPSHOT-KNOTHOLE tests, and Shot BADGER was no exception. In contrast to the various scientific experiments, which probably involved no more than 500 DOD personnel, the number of Exercise Desert Rock V participants is estimated at about 2,800 personnel.

Most of these individuals participated in BADGER only, unlike members of the test groups, who may have been active at the test site throughout Operation UPSHOT-KNOTHOLE.

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 personnel administered Exercise Desert Rock V activities and performed various services. 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. Soldiers of the 50th Chemical Service Platoon served as radiological safety monitors for Exercise Desert Rock participants during the nuclear tests (28).

JTO support elements included AEC construction contractors and radiological safety personnel. The construction contractors assisted test group personnel in building structures used in the projects. The radiological safety unit conducted an initial radiological survey of the project instrumentation areas immediately after the detonation, briefed personnel on radiological conditions, issued access permits to recovery personnel, established checkpoints for personnel entering the areas, provided extra monitors to recovery parties, and monitored and, if necessary, decontaminated personnel and vehicles as they left the forward area.

Lookout Mountain Laboratory personnel were available to provide documentary photography for various projects.

The Air Force Special Weapons Center also performed a number of support tasks. Based at Kirtland Air Force Base (AFB) in

Albuquerque, New Mexico, AFSWC personnel performed cloud-sampling missions for two test group projects, as well as aerial surveys and cloud-tracking missions for the Test Manager.

At Shot BADGER, as at all shots in Operation UPSHOT-KNOTHOLE, the Joint Test Organization coordinated all activities. Consisting of personnel from the AEC, DOD, and FCDA, the JTO was administered by the Test Manager, assisted by a Test Director. The series volume contains a detailed description of their duties and the functions of the JTO.

1.2 RADIATION PROTECTION PROCEDURES

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. Test Group participants were to receive no more than 3.9 roentgens of radiation exposure per 13-week period, or for the entire operation. To help implement this criterion, radiological safety personnel controlled access to contaminated areas. In addition, radiological safety monitors accompanied project personnel recovering test instruments from highly radioactive areas. The monitors kept the participants informed of the radiological environment in the recovery area. 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, developed, 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 (13).

The radiation protection procedures authorized for AFSWC by the Test Manager included the same 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, with the exception of the 12 volunteer officer observers, were limited to no more than 6.0 roentgens of whole-body gamma radiation during any six-month period. The volunteer officer observers were limited to 10.0 roentgens per test, with no more than 25 roentgens for the series. With the approval of the AEC, the Office, Chief of Army Field Forces, established these limits (13; 27).

CHAPTER 2

EXERCISE DESERT ROCK V OPERATIONS AT SHOT BADGER

Department of Defense personnel participated in five Exercise Desert Rock V programs at Shot BADGER. In all, about 2,800 individuals took part in the Desert Rock exercises at BADGER. Approximately three-fourths of these participated in a single project, the maneuvers of the 2d Marine Corps Provisional Atomic Exercise Brigade (2d MCPAEB). Table 2-1 lists the Desert Rock programs and includes the estimated number of DOD participants in each program.

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

Program	Participating Service	Estimated DOD Personnel
Volunteer Officer Observers	Army Marine Corps	6 6
Troop Orientation and Indoctrination	Army Navy Marine Corps Air Force	260 122 106 101
Tactical Troop Maneuvers	Marine Corps	2,167
Damage Effects Evaluation	Army Marines	* *
Operational Helicopter Tests	Marine Corps	11

*Unknown

2.1 CAMP DESERT ROCK PERSONNEL

Camp Desert Rock personnel played an active role at Shot BADGER by providing support services for the exercise troops.

The Control Group accompanied Desert Rock personnel, with the exception of Marines, into the shot area to ensure that all personnel remained together and followed safety and tactical instructions. This group comprised officers and enlisted men from the Operations Section (G-3) and included the Instructor Group, the Radiological Safety Section, and the Aviation Section (27). In addition, the following units were represented at BADGER:

- Company C, 505th Military Police Battalion, provided direction and control of military vehicles.
- The 505th Signal Service Group (Composite Company) operated the public address system in the trench and parking areas and the mobile system, composed of two jeeps outfitted with speakers. They also were responsible for the radio system used by the radiological safety monitors and Control Group.
- The 371st Evacuation Hospital (-) established an aid station in Parking Area B (UTM coordinates 755031) before the shot. After the shot, they relocated forward to the vicinity of the Command Post. They also provided an aid team for the observers.
- The 26th Transportation Truck Battalion (-) transported exercise troops from Camp Desert Rock to the forward area and back to Camp Desert Rock.
- The 50th Chemical Service Platoon was responsible for all radiological safety operations.
- The 412th Engineer Construction Battalion constructed the display area, a wedge-shaped sector ranging about 460 meters to 3,200 meters from ground zero (27).

2.2 ORIENTATION AND INDOCTRINATION

The military observers who witnessed BADGER included 260 from the Army, 122 from the Navy, 106 from the Marine Corps, and

101 from the Air Force. Sixty of the Army observers had witnessed a previous nuclear detonation (10; 18; 27).

The observers participated in the 16 April field rehearsal, which included all Desert Rock participants. An officer of the Instructor Group from Camp Desert Rock conducted a preshot orientation for the observers and other personnel taking part in the exercise. The orientation was given in the trench area, 3,660 meters from ground zero. This 25-minute orientation described the terrain surrounding the shot, procedures to be followed, safety precautions, the phenomena associated with the burst, and Air Force activity in the shot area, such as cloud sampling and air photography. The troop orientation also included a rehearsal of the countdown to shot-time by the instructor and a simulation of the passage of the shock wave over the trench. After the orientation and countdown, the instructor escorted members of the observer group through the display area. In addition to military equipment, the display area included 37 sheep placed at various distances from ground zero by participants in the Desert Rock damage effects project (see section 2.6.). During this tour, the instructor pointed out the expected conditions of the equipment and sheep after the detonation. After the rehearsal, instructors escorted the observers through the Shot NANCY display area, allowing them to examine the effects of blast and heat on the material from a previous shot (27).

A full eight-hour orientation for observers was conducted on 17 April. The course covered the doctrine and employment of nuclear weapons, medical aspects of nuclear detonations, individual and collective protective measures, and the use of radiac instruments. The observers also viewed films of previous Desert Rock activities (31).

Observers who arrived too late on 17 April to attend the eight-hour orientation were briefed at 1930 hours by a Marine

Corps officer assisted by a member of the Camp Desert Rock Instructor Group. This instructor provided technical aid to the briefing officer and answered questions not specifically related to the field maneuver of the Marine units (27).

On shot-day, the observers were in the trenches ten minutes before shot-time to observe the detonation. After the shot, observers remained in the trenches while the Marines began their maneuver. The observers then moved forward on foot and inspected the equipment and animals at 910 to 1,000 meters, 1,550 to 1,580 meters, and 2,380 meters from ground zero. The observers were escorted through the display area by two Camp Desert Rock instructors using sound trucks for voice amplification (27; 38).

2.3 VOLUNTEER OFFICER OBSERVERS

Twelve officers had volunteered to occupy a trench forward of the main trench area at Shot BADGER. Each participant calculated the minimum distance from ground zero at which he would receive no more than 5.0 roentgens of prompt whole-body radiation exposure, eight pounds per square inch maximum overpressure, and one calorie per square centimeter of thermal radiation. To assist in their calculations, they used data from TM 23-200, Capabilities of Atomic Weapons, published in October 1952. Trenches were prepared for the volunteers 1,370, 1,830, and 2,060 meters from ground zero. The officers agreed to occupy the trench 1,830 meters from ground zero. The trench, which was six feet deep and nearly four feet (1.2 meters) wide, was dug in soil consisting of rocks and fine silt. The participants decided not to have the trench reinforced, but two rows of sandbags were placed on the forward ridge of the trench (26-27).

The volunteer officer observers probably left Camp Desert Rock just before midnight for the forward area. They arrived at the trench area about 0300 on the morning of 18 April (22). Each

of the volunteers wore a utility uniform and helmet. As they awaited the detonation, they wore protective masks and crouched at the bottom of the trench.

What happened immediately after detonation is best described by one of the participants:

...I was leaning against the forward wall of the trench holding an AN/PDR 32 dose rate meter with both hands for the purpose of observing the intensity of initial radiation. The white light was so intense that I was blinded by absolute whiteness. This apparently lasted for several seconds. There was a vague recollection of a slight crackling sound at this time. It is believed that this sound may have been the result of intense ionization which takes place in the atmosphere. I felt no rise in temperature nor any thermal effects, but it is noted that the only part of my body not covered was my hands.

The next sensation was that of earth shock which was very pronounced. The earth seemed to shift back and forth very strongly a number of times...

Again regaining my sight, estimated to be about three to four seconds after the detonation, I noticed that the indicator of my meter was off the dial on the high side which read to 500 R/hr.*

The blast wave then hit with a high-pitched crack and general increase in the ambient pressure was noticed. I was enveloped in dust and had the sensation of a heavy windstorm blowing over my head. I was not tossed about in the trench. The wind subsided and I climbed from the trench to observe the atomic cloud. This was not seen due to the very heavy dust which enveloped the position... (38).

A reading of 500 R/h from the initial radiation was registered for 15 to 20 seconds in the trench. Because of this

*Roentgens per hour

high intensity, the officers decided to evacuate the trench. About seven minutes later, they started walking toward a road about 180 meters west of the trenches. By this time, gamma intensities had decreased to about 30 to 50 R/h. The radiation intensity continued to drop as the men walked toward the road, decreasing to 1.0 R/h when they reached the road two minutes later (22; 24; 38).

The observers waited at this road for a few minutes until transportation arrived to take them to the main trench area, about 1,830 meters to the south. Between 20 and 35 minutes later, the men reached the main trenches, where they were interviewed by Army Field Forces Human Research Unit No. 2 from the Human Resources Research Office. They were then transported to the decontamination station (21-22; 24; 38; 51).

Chapter 4 contains more information about the radiation intensities, dosimeter readings, and exposures for the volunteer officer observers.

2.4 MARINE MANEUVERS

Developments in tactical warfare in the early 1950s included the use of nuclear weapons and the growing importance of the helicopter. The development of the helicopter as a troop carrier presented the ideal device to exploit and expand a break in enemy lines produced by nuclear weapons. The tactic of rapidly deploying troops via air transport is known as vertical envelopment. The concept involved the joint deployment of ground and airborne troops (24).

Exercise Desert Rock V provided the Marine Corps with an opportunity to develop and test vertical envelopment tactics in conjunction with the use of nuclear weapons. Basic objectives were to (24):

- Familiarize personnel with the effects of nuclear weapons

- Test and further develop tactics and techniques for getting helicopter-borne forces to objectives immediately after a nuclear detonation
- Give commanders and staffs realistic training in planning and conducting operations supported by nuclear weapons
- Provide field training in radiological survey operations
- Familiarize personnel with individual and collective protection against nuclear weapon effects.

The 2d Marine Corps Provisional Atomic Exercise Brigade, which conducted the largest DOD activity at Shot BADGER, was activated on 2 March 1953 at Camp Pendleton, California. The 2d MCPAEB consisted of four major units (24):

- Brigade Headquarters - 152 personnel
- 1st Battalion (-) (Reinforced), 8th Marine Regiment, 2d Marine Division (hereafter referred to as the 1st Battalion, 8th Marines) - 862 personnel
- 2d Battalion (-) (Reinforced), 3d Marine Regiment, 3d Marine Division (hereafter referred to as the 2d Battalion, 3d Marines) - 907 personnel
- Marine Helicopter Transport Group 16 (MAG (HR) 16) (Reinforced), Aircraft Fleet Marine Force, Pacific - 220 personnel.

The two battalions were reinforced by personnel from the following unidentified units (24):

- A 105mm howitzer battery
- A tank platoon
- An engineer platoon
- An ordnance maintenance platoon
- A regimental tactical air control party
- A battalion tactical air control party

- A battalion naval gunfire liaison party
- An aviation detachment.

The equipment of these units was not used in the maneuvers.

The Brigade Headquarters included representatives from the Marine Corps Public Information Office and special and technical advisors from Headquarters, Marine Corps, Washington, D.C. (24).

The 2d Battalion, 3d Marines, was from Fleet Marine Force, Pacific, based at Camp Pendleton, California. At Desert Rock V, the 2d Battalion included:

- Headquarters and Service Company
- Company D
- Company E (airborne assault troops)
- Company F.

The 200 E Company personnel were airlifted in the airborne assault part of the maneuver.

The 1st Battalion, 8th Marines, was from Fleet Marine Force, Atlantic, based at Camp Lejeune, North Carolina. The battalion included the following companies:

- Headquarters and Service Company
- Company A
- Company B
- Company C.

Headquarters and Service Company included personnel from the Headquarters Company Force Troops and from the 2d Marine Aircraft Wing, Headquarters 2d Engineer Company.

MAG (HR) 16, from the Aircraft Fleet Marine Force, Pacific, consisted of personnel from Marine Helicopter Transport Squadrons 162, 163, 361, 362, and 363. The MAG (HR) 16 unit was based at Santa Ana, California (24).

Preliminary planning for the exercise was initiated immediately upon activation of the 2d MCPAEB on 2 March 1953. On 4 March, the 2d MCPAEB commanding general and key staff officers visited Camp Desert Rock for briefing and joint planning conferences with the Exercise Director (24).

Before proceeding to Camp Desert Rock, the 2d MCPAEB drilled, studied films of previous Desert Rock exercises, and attended lectures on a variety of subjects, including atomic weapons effects, nuclear radiation and detection instruments, individual protection measures, and decontamination. On 30 March 1953, a rehearsal for the air assault phase was conducted in the San Mateo Canyon Maneuver Area at Camp Pendleton. The MAG (HR) 16 and the 2d Battalion, 3d Marines, participated in this rehearsal (24).

By 14 April, the entire brigade had arrived at Camp Desert Rock. On 16 April, a full dress rehearsal was conducted at the actual site of the test. The rehearsal included the orientation described earlier in the discussion of observer activities (27).

After the orientation and rehearsal countdown, the Marines practiced the maneuver, attacking north of their trenches. After advancing 180 meters, they moved through the display area, as shown in figure 2-1. Meanwhile, E Company boarded MAG (HR) 16 HRS helicopters that had landed immediately to the rear of the trenches and headed for an objective located 1,830 meters southwest of ground zero, as shown in figure 2-2. From there, they joined the ground forces to tour the display area. The Marines returned to Camp Desert Rock by truck upon completing the walk-through (24).

On the day before the shot, 17 April, final preparations for the exercise were made. Two film badges were issued per platoon and two pocket dosimeters per company (24).



**Figure 2-1: MARINES MOVE THROUGH DISPLAY AREA DURING
BADGER REHEARSAL, 16 APRIL 1953**

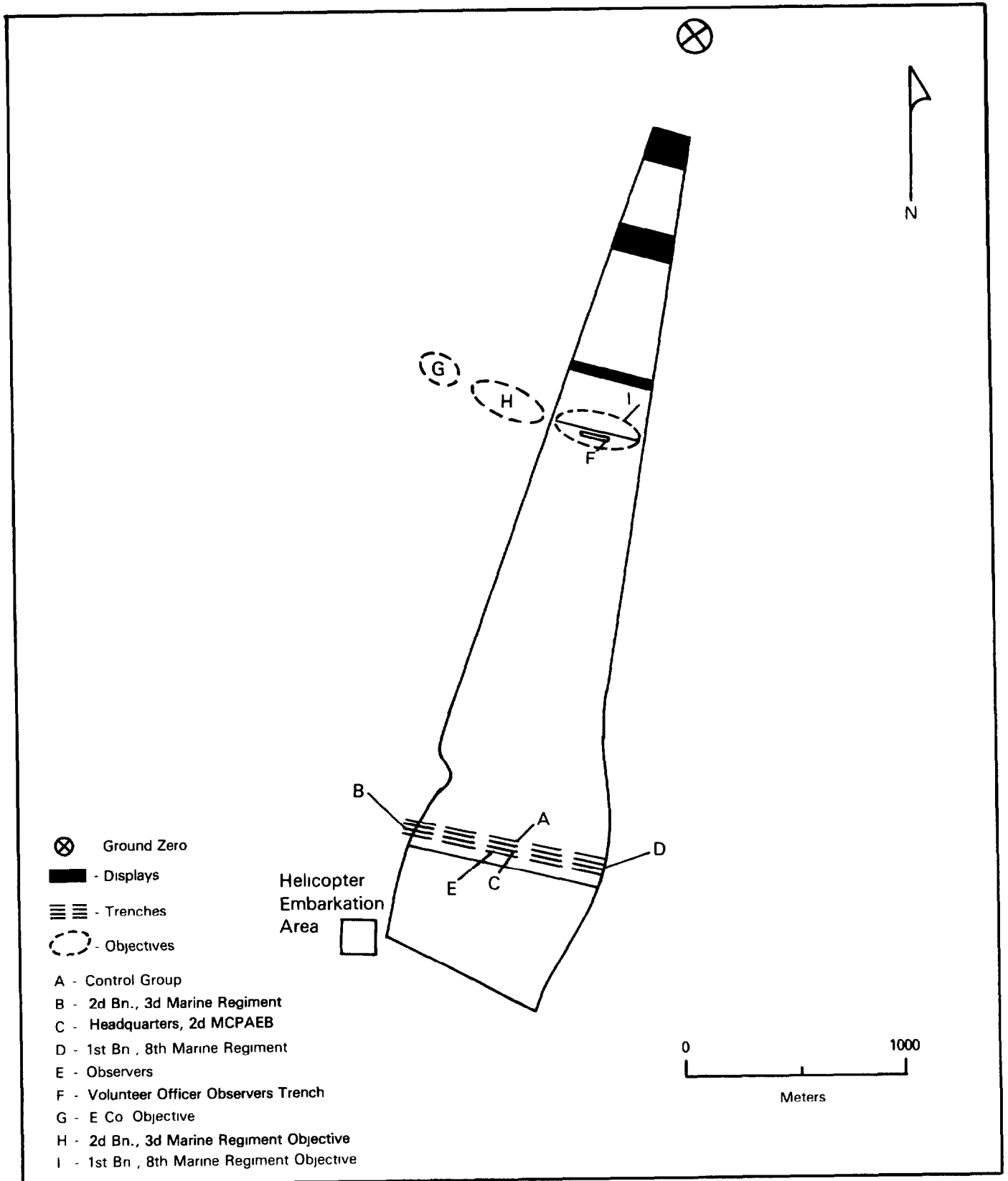


Figure 2-2: POSITION OF EXERCISE DESERT ROCK PARTICIPANTS AT SHOT-TIME, SHOT BADGER

The actual exercise began at 1700 hours on 17 April, when MAG (HR) 16 flew its 39 HRS helicopters from Camp Desert Rock to the staging area at Yucca Airstrip, 20 kilometers from ground zero. The crews remained there overnight (24).

At 2317 hours on 17 April, the 2d MCPAEB, including the ground echelon of MAG (HR) 16, began leaving Camp Desert Rock by truck. The first elements arrived at the trenches by 0135 hours on 18 April, with the last arriving at about 0225. The Test Manager and the Exercise Director required this early arrival to allow ample time for mustering and final instructions by unit commanders before shot-time. In addition, personnel were briefed further on instrumentation, thermal and other effects of the detonation, and aircraft participation. Officers accompanying the Camp Desert Rock staff presented the briefing over a public address system (24; 29).

Ten minutes before the detonation, all personnel were ordered into their trenches. Figure 2-2 shows the various unit positions before the shot. Two minutes before the detonation, the Marines knelt and braced themselves against the ground zero side of the trench, as shown in figure 2-3 (24; 37).

The detonation occurred at 0435 hours. After the shock wave passed, the Marines left the trenches, formed up, and moved out in attack formation toward the objectives to the north. Though the dust raised by the shock wave was thick, the cloud formed by BADGER was visible to the Marines as they moved forward to their objectives. They were preceded by a 2d MCPAEB Radiological Safety Officer in a jeep who assessed radiation conditions before the participants entered the area. Despite this precaution, however, a northeasterly surface wind of about ten to 15 knots, blowing across the right flank of the Marines and from the direction of ground zero, exposed the 1st Battalion, 8th Marines, "to an unprecedented and unanticipated radiation fallout



Figure 2-3: MARINE CORPS TROOPS AT 16 APRIL 1953 REHEARSAL FOR THE BADGER DETONATION

immediately after H-hour" (24). After proceeding less than 460 meters, the battalion had dosimeter readings exceeding 3.0 roentgens and was required to move out of contaminated areas. Unable to proceed toward the assigned objective, the battalion withdrew to the trench area and was not permitted to continue the maneuver or to tour the display area. During the withdrawal from the trench area, some elements of the battalion exceeded the allowable dose of 6.0 roentgens, with film badge readings as high as 7.1 roentgens (22; 24).

Meanwhile, 11 minutes after the detonation, two pathfinder helicopters from the Yucca Airstrip arrived at an embarkation area immediately behind the trenches. At that point, radiological monitoring teams boarded. Four minutes later, the two helicopters landed at the E Company objective. The remaining 37 helicopters arrived at the embarkation area, where they loaded half of E Company. Upon receiving clearance from the pathfinder teams, the helicopters flew to the objective, about two kilometers from ground zero, and landed 50 minutes after the detonation. After the troops disembarked, the helicopters returned to the embarkation area to load the remainder of E Company. Figure 2-4 shows the helicopters transporting the second wave of Marines as the first wave stands by. After the second trip, the helicopters returned to the embarkation area and were shut down. The pilots and crews then toured the display area by bus (24).

The 2d Battalion, 3d Marines, advanced to its objective without incident about 90 minutes after the shot. Headquarters, 2d MCPAEB, were probably at the forward part of the 2d Battalion, 3d Marines, and walked to the display area with E Company, which had joined them at the objective. The 2d Battalion, 3d Marines, viewed the displays as far forward as the 910-meter display, as did the observers (see section 2.2). Because participants in the maneuver were allowed exposure to the higher radiation intensity of 5.0 R/h, as opposed to the observers' limit of 2.5 R/h, it is possible that the Marines viewed the display located 460 to 600



Figure 2-4: E COMPANY BEING AIRLIFTED TO ITS OBJECTIVE AFTER THE BADGER DETONATION

meters from ground zero. They traveled up the west side of the display area toward ground zero and then south, away from ground zero. At 2,000 to 2,500 meters south of ground zero, they would have moved to the west because of radiation levels encountered, before again turning to the south to reach the embarkation area behind the trenches (24). By 0850 hours, all participants in the maneuver had left the forward area and by 1103 hours had arrived at Camp Desert Rock (24).

2.5 OPERATIONAL HELICOPTER TEST PROGRAM

Personnel from the Provisional Helicopter Atomic Test Unit, 2d Marine Corps Provisional Atomic Exercise Brigade, conducted a program to observe the effects of a nuclear blast on four helicopters in flight. Radiological safety monitors were on board three of the helicopters (A, B, and C) to check early radiation levels at designated landing points to determine the feasibility of troop entry. The crews, consisting of one pilot and co-pilot in each helicopter, were instructed not to fly into areas where the radiation intensity exceeded 10.0 R/h and not to land in areas where the radiation intensity was greater than .05 R/h (27). Figure 2-5 traces the routes taken by the four helicopters.

The helicopters were to leave the Camp Desert Rock Airstrip for the forward area about one hour and 20 minutes before the shot. The helicopters proceeded in pairs. Helicopters A and B landed at Yucca Airstrip, 20 kilometers south-southeast of ground zero. Helicopters C and D landed at a point 13 kilometers southeast of ground zero at UTM coordinates 854995 (25).

Four minutes before the detonation, helicopters A and B left Yucca Airstrip. They proceeded toward the shot area at a height of 400 feet and a speed of 60 knots and arrived at a point 14 kilometers southeast of ground zero at the time of the detonation. When the shock wave passed, helicopters A and B were about

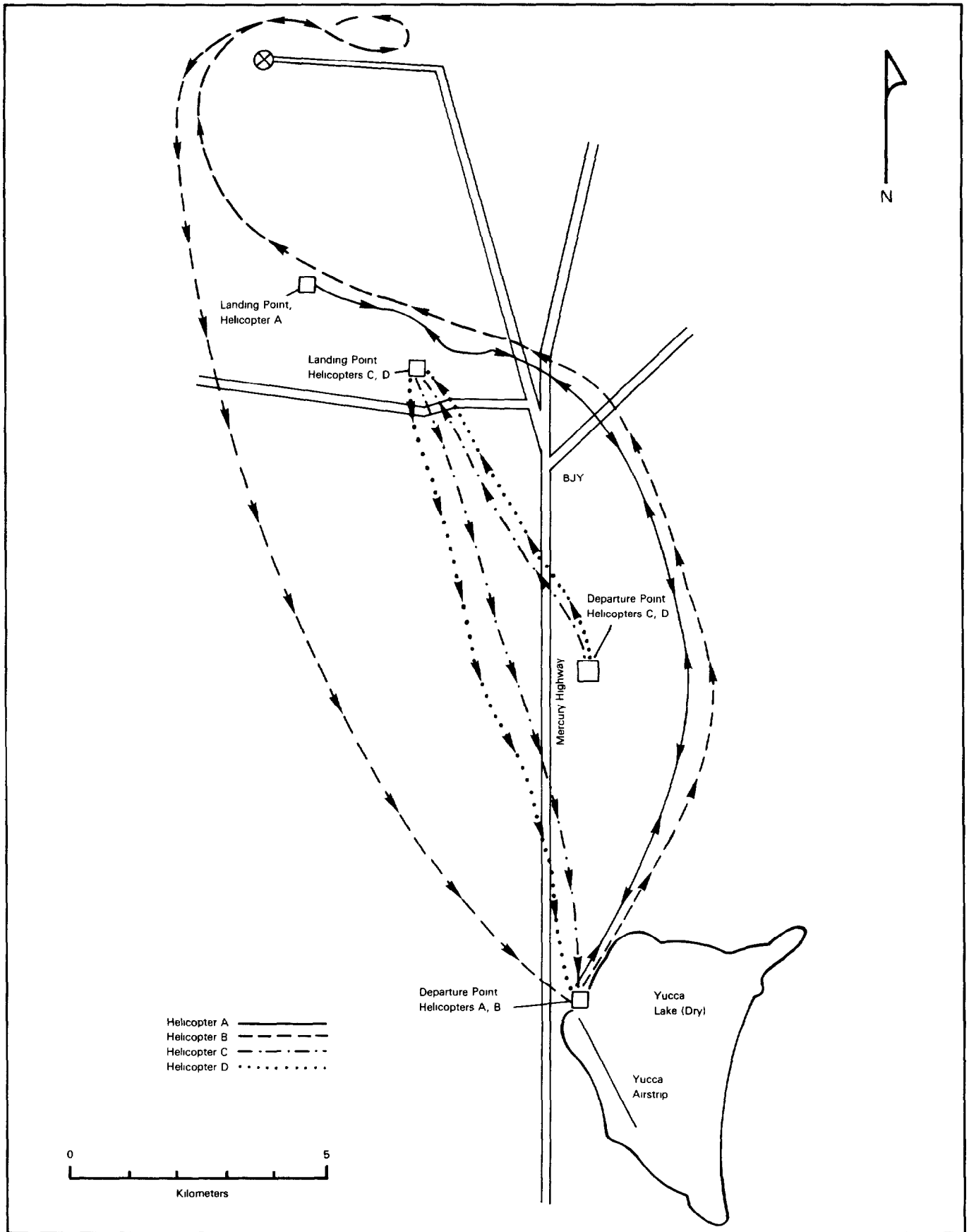


Figure 2-5: OPERATIONAL HELICOPTER TEST PROJECT AT SHOT BADGER

13 kilometers from ground zero. They continued toward ground zero. Because of the contaminated dust cloud drifting southward and the operational restrictions presented by the helicopters associated with the 2d MCPAEB exercise, helicopter A landed about six kilometers southeast of ground zero.*

Helicopter B, which was to accompany helicopter A, lost visual contact with that helicopter and could not continue its mission. It flew around the north side of ground zero to a clear area northeast of ground zero (25). Since the general wind direction was from the northwest, the entire area directly north of ground zero was clear. Helicopter B proceeded into this clear area and encountered minimal radiation. It headed east of ground zero until it encountered radiation from fallout. The helicopter turned back and retraced its route north of ground zero and then to the west of ground zero where the radiation level was considerably lower than it was east of ground zero. Helicopter B proceeded from there to Yucca Airstrip and landed (25; 27).

Unlike helicopters A and B, helicopters C and D stayed at their initial landing point, 13 kilometers southeast of ground zero during the detonation. Fifteen minutes before the shot, the pilots of helicopters C and D started the engines and brought the aircraft ten feet off the ground. They hovered facing the direction of the expected blast until the shock wave passed and then proceeded toward the shot area. They were forced to land approximately seven kilometers southeast of ground zero instead of the planned two kilometers north of ground zero because of the approach of the cloud stem, which increased radiation intensities above the 10.0 R/h maximum level permitted for the helicopters (25).

*The Exercise Desert Rock Final Report places the landing point for helicopter A at 6,000 yards, or about 5.4 kilometers, from ground zero (26).

Probably about 20 to 30 minutes after the shot, the helicopters encountered levels greater than 50 R/h and possibly as high as 200 R/h before landing.

Safety precautions for the project called for the pilots in all four helicopters to look at their instrument panels at the time of detonation. The pilots were also to pull the visors of their caps down to block their view of the initial direct light from the fireball. All pilots reported that their loss of vision did not last more than two or three seconds after the fireball was at its brightest. They also reported that their control of the aircraft was not adversely affected. The co-pilots wore high-density protective goggles at the time of detonation and were prepared to take the controls in case the pilot was incapacitated. Other personnel not equipped with protective goggles were instructed to face away from the blast (27).

2.6 DAMAGE EFFECTS EVALUATION

Before the shot, Sixth Army and Marine Corps personnel established displays at various distances from ground zero to study the blast and radiation effects of the detonation. The Sixth Army display consisted of animals and various emplacements, and the Marine Corps display consisted of field equipment and uniformed mannequins (27). The displays were designed primarily to add realism to the orientation and indoctrination of troops, who were to view the displays before and after the shot.

Before the shot, Sixth Army personnel placed stakes and constructed bunkers, trenches, and foxholes at 460-meter intervals extending 460 to 3,200 meters from ground zero. After the shot, one engineer team evaluated the displays visually to compare predicted with actual damage (27). In conjunction with the damage effects evaluation, Sixth Army personnel conducted medical

and shielding evaluations using the bunkers, trenches, and foxholes as the locations for test animals and film badges (27).

For the medical evaluation, 37 sheep were positioned in bunkers and in the open, beginning 90 to 460 meters from ground zero at 90-meter intervals and extending 3,200 meters from ground zero at 460-meter intervals. After the shot, a medical technician, accompanied by a monitor, moved forward by truck to observe the sheep. Sheep were also placed in two of the trenches that had been prepared for the volunteer officer observers. These trenches were 1,370 and 2,060 meters from ground zero. Later in the morning of shot-day, the veterinary officer accompanied the loading party to begin evaluation of the blast and radiation effects incurred by the sheep. The sheep not seriously injured or killed were moved as soon as possible to an area where they could be observed for delayed radiation effects (27).

To evaluate the shielding afforded by the various fortifications in the display, a chemical team took radiation measurements by placing film badges inside and outside the trenches and other dugouts. Film badges were also placed on the collars of the sheep and in six-foot-deep trenches 1,370, 1,830, and 2,060 meters from ground zero. The volunteer officer observers occupied the trench 1,830 meters from ground zero (27; 31).

The Marine Corps display area was established southwest of ground zero before shot-day to study the effects of a nuclear detonation and to demonstrate those effects to the participants at Shot BADGER. The display consisted of Marine Corps equipment and clothing placed in various attitudes with respect to ground zero and with various types of protection in the form of foxholes and emplacements. The items were arrayed in three main positions, as shown in figure 2-2. To facilitate examination of the

display by observers and maneuver participants, items in these positions were split so that about half the items were on either side of the display sector. In general, and as far as equipment available would allow, similar items, in similar dispositions, were displayed in all positions to contrast the effects on equipment placed at different distances (27).

The three positions were Position #1, 460 to 600 meters from ground zero; Position #2, 910 to 1,000 meters from ground zero; and Position #3, 1,550 to 1,580 meters from ground zero. Equipment placed at these positions included howitzers, tanks, rifles and carbines, machine guns, mortars, landing vehicles, trucks, radar vans, communications equipment, gasoline supply dumps, rocket launchers, flame throwers, and stacked cases of "C" rations. In addition to the three primary positions, two special positions were situated 1,530 and 2,380 meters from ground zero. Each of these positions contained three mannequins, two standing and one prone, clad in different combat uniforms (27).

After the shot, observers and elements of the 2d MCPAEB viewed the display area, as described in section 2.4. Sometime thereafter, Marine Corps damage effects evaluation personnel went into the area to assess the effects of the blast on the display items. At Position #1, they found that all items were severely damaged or totally destroyed. Vehicles that were dug in were in noticeably better condition, although they too were heavily damaged. At Position #2, the damage was considerably lighter. Heavy vehicles, such as the tank, the M7 motor carriage, and the landing vehicle, suffered comparatively little damage at this position. Small, light equipment, such as radios and switchboards, suffered moderate to severe damage if exposed, but little to no damage if dug in. At Position #3, about 1.6 kilometers from ground zero, all items except the trucks and the exposed mannequin received slight damage. The truck was damaged by both blast and thermal radiation, and the mannequin was burned. It

was estimated that, had the mannequin been in even a shallow foxhole, it would have escaped all effects of the weapon. At the two special mannequin positions, all standing mannequins were burned to some extent, while those in the prone position were relatively unharmed (24; 27).

CHAPTER 3

TEST ORGANIZATION OPERATIONS AT SHOT BADGER

AT Shot BADGER, Department of Defense personnel participated in a variety of diagnostic and military effects projects, as well as in support activities. The Armed Forces Special Weapons Project Field Command Military Effects Group sponsored 19 projects during the BADGER event. DOD personnel were also involved in five of the 18 projects performed by the Weapons Development Group and two of the six projects conducted by the Federal Civil Defense Administration Civil Effects Group. These activities required DOD personnel to enter the forward areas before, during, and after the shot. The Test Manager declared the area safe for recovery operations at 0710 hours, two hours and 35 minutes after the shot. In addition to the test group activities, the Air Force Special Weapons Center flew cloud-sampling missions for two projects, courier missions for four projects, and cloud-tracking and aerial survey missions for the Test Manager.

3.1 MILITARY EFFECTS GROUP PROJECTS

The Military Effects Group of AFSWP Field Command performed 19 projects at Shot BADGER, as shown in table 3-1.

Project 2.2a, Gamma Radiation Spectrum of Residual Contamination, was fielded to characterize the residual radiation resulting from the shot. Three men and a monitor spent three hours taking spectral measurements in the radiation field of the shot area. They had been instructed to limit their time in areas with radiation intensities greater than 0.1 R/h. Personnel took more spectral measurements two days after the shot at 300 and 400 meters from ground zero, where intensities were 0.2 R/h and

Table 3-1: AFSWP FIELD COMMAND MILITARY EFFECTS GROUP PROJECTS, SHOT BADGER

Project	Title	Participants
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
4 5	Ocular Effects of Thermal Radiation from Atomic Detonation	Air Force School of Aviation Medicine
5 1	Atomic Weapons Effects on AD Type Aircraft in Flight	Navy Bureau of Aeronautics
6 2	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
6.9	Evaluation of Naval Airborne Radiac Equipment	Navy Bureau of Aeronautics
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
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 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

0.08 R/h, respectively. Four days after the shot, personnel made the final spectral measurements at ground zero, where the radiation intensity was 0.09 R/h (3-4).

Project 2.2b, Residual Ionizing Radiation Depth Dose Measurements in Unit-density Material, evaluated the biological effects of residual beta and gamma radiation fields. At recovery hour, six men in three vehicles were scheduled to begin placing test chambers in various radiation fields on Mercury Highway about 5.6 kilometers from ground zero. They were to spend 90 minutes in the field. These personnel worked in areas with radiation intensities ranging from 10 R/h to 2.5 R/h. The day after the shot, they returned to the same areas to gather more data (3; 8).

Project 4.5, Ocular Effects of Thermal Radiation from Atomic Detonation, was to determine to what degree the flash of a nuclear detonation impairs night vision. In the first part of this project, 12 officers from Nellis AFB witnessed the nuclear detonation in a trailer located about 23 kilometers from ground zero, just north of the Control Point. They peered through experimental filters that selectively obscured much of the visible and infrared portion of the spectrum. Afterward, the officers performed a number of visual tasks.

In the second part of the project, rabbits were placed at various distances from ground zero to determine the distance at which retinal burns could be produced. Two five-man parties placed 130 rabbits 4.8 to 27.4 kilometers from ground zero. They were to begin this activity at 2200 hours on the night before the shot and to leave the area three hours and 15 minutes before the shot. Beginning 20 minutes after the shot, two parties, each consisting of six project personnel and a monitor, were to spend one hour retrieving the rabbits. Seven hours after the detonation, two B-25 aircraft transported project personnel and the rabbits from Indian Springs AFB to Randolph AFB, Texas (3; 6).

Project 5.1, Atomic Weapon Effects on AD Type Aircraft in Flight, was designed to study blast and thermal effects of a nuclear detonation on AD-type aircraft in a simulated escape configuration after a bombing mission. An AD-2 drone aircraft was scheduled to be tested. However, due to control difficulties in both the drone and the back-up drone, the flight was canceled. Since the F8F drone control, the F8F drone control back-up, and three AD-2 fighter escort aircraft were already in the air when the mission was aborted, the five aircraft were assigned an orbit position and altitude for timing practices during actual shot conditions. They remained in the area from 20 minutes before until seven minutes after shot-time. They landed at Indian Springs AFB at about 0500 (19; 44).

In addition to the Project 5.1 air operations, 23 project personnel manned a ground station on the west side of Yucca Flat, at UTM coordinates 861877. They went to the station three hours and 30 minutes before the detonation and stayed there through shot-time (2-3).

Project 6.2, Indirect Bomb Damage Assessment (IBDA) Phenomena and Techniques, was intended to confirm indications that a radar return obtained from a nuclear detonation could be used to determine ground zero and to indicate gross errors in estimating height of burst and yield. This project involved both air and ground operations.

Two B-29 aircraft took off from Kirtland AFB at 0150 and 0200 hours on shot-day. One entered the test area at approximately 0350 hours, but the other had to turn back because of mechanical difficulties. The remaining aircraft, with an estimated nine crew members, flew a holding pattern about eight kilometers south of ground zero. The aircraft left the area around 0445 hours and landed at Kirtland AFB around 0640 hours (19; 32).

Two hours before the detonation, two project personnel went to Station 6.2a, located west of the Control Point, and manned the station through shot-time. At the same time, two project personnel went to Station 6.2b, located northwest of the first station, and stayed through shot-time. The two stations were about 20 kilometers south of ground zero in Yucca Flat (3; 19; 32; 36; 39).

Project 6.3, Interim IBDA Capabilities of Strategic Air Command, was a corollary to Project 6.2. An interim IBDA system, installed in operational Strategic Air Command (SAC) aircraft, was evaluated under field conditions. SAC aircraft, equipped with the latest available IBDA systems, flew simulated strike and support formations over a target. These aircraft recorded data essential for determination of the three IBDA parameters: yield, burst height, and ground zero.

Twelve B-50 aircraft of the 93rd Medium Bomber Wing from Castle AFB, California, reached the test area at 0414 hours at an altitude of 25,000 feet. From 0414 hours until about five minutes after the shot, the aircraft flew in formation over the test site to simulate strike and support activities. At the time of detonation, the aircraft were short of the assigned position by about 800 meters. While over the test site, the crews tested IBDA equipment and familiarized themselves with operations pertaining to nuclear warfare. Approximately 132 personnel were involved.

Preceding the bomber formation was a B-50 weather reconnaissance aircraft from the 5th Tactical Reconnaissance Squadron. About ten personnel were aboard the aircraft. The crew radioed weather and cloud conditions to the trailing bombers (18-19; 34).

Project 6.7, Measurements and Analysis of Electromagnetic Radiation from Nuclear Detonations, consisted of two parts. Part

I measured amplitude, duration, and polarization of the pulse of the electromagnetic radiation. Part II detected and recorded electromagnetic signals emitted by nuclear devices before the nuclear detonation. The stations used for this project were located close to ground zero and were unmanned during the shot.

At 2300 hours the night before the shot, three project personnel and a monitor traveled in two vehicles to two stations 2,740 meters south of ground zero to turn on equipment. They then traveled to Station 6.7a, near the Control Point, where they remained through shot-time. One hour after recovery activities were permitted, the three men and the monitor returned to the equipment stations and recovered film. Estimated time in the area was 30 minutes (2-3; 14).

Project 6.8, Evaluation of Military Radiac Equipment, and Project 6.8a, Initial Gamma Exposure versus Distance, were coordinated and fielded by the Signal Corps Engineering Laboratories and the Bureau of Ships. Air Force students and Navy personnel assisted. Project 6.8 was designed to test dosimeters and radiac instruments in initial and residual radiation fields produced by a nuclear detonation. Project 6.8a provided reliable National Bureau of Standards dosimeters as a basis for evaluating the newer dosimeters tested in Project 6.8.

Personnel placed experimental dosimeters and reliable National Bureau of Standards film dosimeters at 21 stations located from 825 to 2,650 meters from ground zero. These portable stations were protected with aluminum thermal and blast shields.

One minute after the detonation, two project personnel and a monitor were scheduled to travel to the 5.0 R/h line to evaluate portable air-sampling equipment. Two to three hours after recovery hour, two parties of six men each and a monitor

recovered the dosimeters. They spent about three hours in the field. The experimental dosimeters were later compared to the film exposed in the National Bureau of Standards film holders (3; 33; 35).

At least three hours after recovery hour, four parties, each with six project personnel, traveled to the shot area to conduct radiological safety surveys with experimental radiac instruments. The personnel observed and reported the performance of the instruments. Participants included project personnel, Air Force students, and Navy personnel. Estimated time for this part of the experiment was three hours (3; 33).

Project 6.9, Evaluation of Naval Airborne Radiac Equipment, was designed to evaluate airborne radiac equipment, such as aerial ground survey equipment, automatic recording dosimeters, and telemetering and flare units. Equipment was evaluated to compare its accuracy at various altitudes with its accuracy at ground level. The equipment was designed for ultimate use by special carrier-based aircraft to warn assault troops that they might be entering contaminated areas.

A P2V-2 aircraft, carrying the test equipment and a crew of three, took off from Kirtland AFB three to four hours before the shot. At shot-time, the aircraft was in a holding pattern about 19 kilometers southwest of the shot area at an altitude of about 12,000 feet. The radiac equipment was turned on shortly before shot-time to allow for a one-hour warm-up period before the aircraft entered the radiation area.

Soon after the shot, the aircraft approached the area and orbited within several kilometers while it waited for the dust cloud over the area to dissipate. About one hour after the detonation, the Aircraft Participation Unit cleared the aircraft to enter the test area. It then began runs over the radiation

area in the form of a cloverleaf. The patterns were initially flown at a height of some 6,000 feet above the ground, with subsequent patterns flown at heights decreasing by 500 feet each run. The lowest height was 1,000 feet. Project personnel had placed six prototype flashing units on the ground, and the crew attempted to detect them from the aircraft. The aircraft was over the area for three hours and landed at Indian Springs AFB at about 0848 hours. The P2V-2 conducted similar missions on the evening of shot-day and at sunrise the following day (19; 49).

Also for Project 6.9, three men and a monitor were scheduled to photograph the telemetering units dropped by the P2V-2. They were to spend about an hour on this task, beginning ten hours after shot-time (3).

Project 6.10, Evaluation of Rapid Aerial Radiological Survey Techniques, was fielded to improve the aerial radiological survey procedures used during Operations BUSTER-JANGLE and TUMBLER-SNAPPER and to determine the effect of the aircraft on radiac instrument readings taken inside. Before takeoff, film badges were placed at various locations opposite one another on the interior and exterior of the HRS-2 helicopter used in the project.

The helicopter took off from Yucca Airstrip at 0655 hours on shot-day and reached the test area at 0700 hours. Flying at a height of about 500 feet, the HRS-2 circled ground zero at a distance of roughly one kilometer. The crew selected a landmark at or near ground zero as a reference point to ascertain the direction of maximum fallout. The crew determined approximate radiation levels and decided on the altitude of operation.

The helicopter then flew a cloverleaf pattern centered over the reference point 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 the 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 area for 30 minutes and landed by 0800 hours (18-19; 42).

Project 6.12, Determination of Height of Burst and Ground Zero, was fielded by the Signal Corps Engineering Laboratories, with assistance from Army Field Forces Board Number 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 location of ground zero and determination of height of burst.

Sound-ranging stations were located up to 60 kilometers from ground zero. The system comprised three separate microphone arrays several kilometers apart along a line perpendicular to the line from the center of the array to the burst point. Seismic geophones and flash-ranging cameras were located on a line roughly perpendicular to the lines of sight to ground zero at a range of 13 to 17 kilometers (50).

Three hours before the shot, ten men in three vehicles were scheduled to turn on power in seven outpost stations within two kilometers of Station 6.12b in the southeast corner of Yucca Lake. After completing that mission, the men manned Station 6.12b at UTM coordinates 885875 through shot-time (3).

Project 7.1, Electromagnetic Effects from Nuclear Explosions, was intended to obtain additional information on the electromagnetic radiation produced by nuclear detonations. Headquarters, Air Force, with assistance from the National Bureau of Standards, the Air Force Security Service, Air Force Cambridge Research Center, and the Air Weather Service, conducted this

project. Personnel manned monitoring stations onsite and offsite. Four hours before the shot, 16 persons went to Station 7.1a, at UTM coordinates 885875, on high ground in the southeast corner of Yucca Lake (3; 40).

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. Personnel from the following organizations manned the remote field stations (41):

<u>ORGANIZATION MANNING THE STATION</u>	<u>STATION LOCATION</u>
Naval Electronics Laboratory	Los Angeles
	San Diego
	Arizona #1
	Arizona #2
Signal Corps Engineering Laboratories	Washington State
	Texas
	Louisiana
	New Jersey
	Alaska
	Hawaii
	Greenland
	Japan
National Bureau of Standards	Germany
	Washington, D.C.

Project 7.4, Seismic Measurements, recorded the seismic waves produced by the shot for comparison with those produced by other shots of Operation UPSHOT-KNOTHOLE and earlier operations. For this project, ten offsite stations were manned throughout the midwestern and western United States. These seismic stations were in Arizona, Montana, South Dakota, Oklahoma, Alabama, Alaska, Wyoming, and Nevada. Wyoming had three stations. Two of

the stations were temporary: the Homestake Mine Station near Lead, South Dakota, and the station at Mercury, Nevada. One onsite station was located at UTM coordinates 843094.

Two hours after recovery hour, two project personnel and a radiation monitor in one vehicle went to the onsite seismic station for one to two hours to turn off the equipment and recover the records (3; 15).

Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris, involved the analysis of samples of the Shot BADGER cloud to evaluate various parameters of the nuclear device. A B-29 aircraft with a crew of six took gaseous and particulate samples of the cloud. This project was similar to Project 13.1, Radio-chemistry Sampling. AFSWC support of both projects is discussed in section 3.4 (46).

Project 8.1a, Effects of Thermal and Blast Forces from Nuclear Detonations on Basic Aircraft Structures and Components, was fielded to obtain data on the response of aircraft components to the thermal and blast effects of nuclear detonations. Project personnel placed aircraft structures and components at various distances from ground zero. A major effort was directed toward obtaining the time-history temperature and strain responses of these specimens.

About seven hours and 30 minutes after the detonation, four project personnel accompanied by a monitor inspected blast panels at three stations located 330 meters to 670 meters from ground zero. The estimated time of the mission was one hour (3; 45).

Project 8.2, Measurement of Thermal Radiation with a Vacuum Microphone, was conducted by the Air Force Cambridge Research Center. The objective was to evaluate a device used to measure thermal radiation produced by a nuclear detonation. Project

personnel placed the microphones 3,220 meters from ground zero several days before the detonation. Signals from the microphones were electronically transmitted to recording equipment located in two vans north of the Control Point. Four hours before the detonation, six project personnel traveled to these vans to man equipment through shot-time (3; 5).

Project 9.1, Technical Photography, was conducted by personnel from Edgerton, Germeshausen, and Grier, Incorporated (EG&G), and photographers from the Army Signal Corps Pictorial Center and the Air Force Lookout Mountain Laboratory. Twenty-three Signal Corps personnel and five Air Force enlisted personnel were assigned to work directly with EG&G, a civilian contractor.

Two types of technical photography were required for this project: blast and shock photography and effects photography. Some technical photography was done by remote control from steel towers located between 350 and 4,570 meters from ground zero. The cameras were mounted on top of these steel photo towers, which ranged in height from six to 25 feet.

After all camera stations were installed for the shot, a complete dry run was held. Once installed, all cameras were covered with plastic bags to keep dust from the camera. Before the shot, the plastic bags were removed and all cameras were loaded with film. After the declaration of recovery hour, the same project personnel who loaded the cameras recovered the film. EG&G processed all film at Las Vegas or Los Angeles (23).

In addition to the Project 9.1 technical photography, Air Force Lookout Mountain Laboratory personnel photographed the detonation and test group activities for historical purposes.

Two hours before shot-time, ten Lookout Mountain Laboratory personnel were scheduled to occupy the following stations:

<u>STATION</u>	<u>UTM COORDINATES</u>	<u>NUMBER OF PERSONNEL</u>	<u>DISTANCE FROM GROUND ZERO (kilometers)</u>
1	894982	2	17
2	900928	2	21
3	804988	2	12
4	781958	2	15
5*	843878	2	23

The photographers remained at these stations to photograph the BADGER detonation. After the shot, they removed film from cameras and dismantled equipment before returning to Camp Mercury.

Lookout Mountain Laboratory personnel also conducted an aerial photography mission. A C-47 aircraft with three crew members and Lookout Mountain Laboratory personnel onboard left Indian Springs AFB at 0337 hours to be in the BADGER test area by shot-time. The C-47 entered the test area by 0350 hours and established a holding pattern 16 kilometers south of ground zero at an altitude of 10,000 feet. At shot-time, the crew photographed the burst and resulting cloud development and left the area by 0440 hours. The C-47 landed at Indian Springs at 0456 hours (3; 19).

3.2 WEAPONS DEVELOPMENT GROUP PROJECTS

The Weapons Development Group performed 18 projects at Shot BADGER. Of these, only the five listed in table 3-2 involved DOD participants. Project 13.1, Radiochemistry Sampling, which was performed by sampling pilots from AFSWC, 4926th Test Squadron (Sampling), is discussed under AFSWC participation in section 3.4 of this chapter. Little is known about Project 18.1, Total

*Station 5 was at the Control Point.

Thermal and Air Attenuation, Project 18.2, Power versus Time, and Project 18.6, Surface-brightness Investigation, except that they were conducted by personnel from the Naval Research Laboratory.

Table 3-2: WEAPONS DEVELOPMENT GROUP PROJECTS AND CIVIL EFFECTS GROUP PROJECTS WITH DOD PERSONNEL INVOLVEMENT, SHOT BADGER

Project	Title	Participating Agency
13.1	Radiochemistry Sampling	4926th Test Squadron,
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
27.1	Distribution and Characteristics of Fallout at Distances Greater than Ten Miles, March and April 1953	School of Medicine, UCLA, Navy
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 18.3, Spectroscopy, was also conducted by personnel from the Naval Research Laboratory. The objective was to obtain information on spectral characteristics of light emitted from nuclear detonations. Spectrometers were used to record on film the wavelength of light with time. Two spectrometers were located in Building 400, a permanent building located on a hill near the Control Point at Yucca Pass. Project personnel operated these instruments on shot-day. Three other spectrometers were located in station 413, a reinforced semitrailer which served as a mobile instrument station. The trailer was located about three kilometers from the BADGER ground zero. Five people occupied

station 413 from the day before the scheduled test until four hours before shot-time. Project personnel loaded film into the spectrometers and put the instruments into remote-control operation. They then secured the trailer and left the area. Four personnel plus a monitor from the radiological safety unit entered the BADGER test area about 15 minutes after recovery hour to retrieve film and recorder charts from station 413 for processing and analysis. The estimated working time in this area was 15 minutes (3; 7; 16).

3.3 CIVIL EFFECTS GROUP PROJECTS

The Federal Civil Defense Administration Civil Effects Group performed six separate projects at Shot BADGER, with DOD participants in two (9). Table 3-2 lists the Civil Effects Group projects that had DOD participants.

Project 27.1, Distribution and Characteristics of Fallout at Distances Greater than Ten Miles from Ground Zero, March and April 1953, was to study the fallout from a nuclear detonation and the possible associated hazards. The field group had 32 Navy enlisted men. This group, organized into 13 teams, was responsible for placing and collecting samples, monitoring, and making field observations.

The operational plan involved setting up various experiments along roads and trails chosen on the basis of the predicted fallout patterns. The field group remained at previously assigned rendezvous points until after a final weather briefing was given at 2100 hours on the day before the shot. After learning the predicted fallout pattern, the teams established 12 stations onsite and offsite from about 16 to 140 kilometers from ground zero in a pattern that covered 30 degrees on each side of the estimated midline of the fallout. They were allowed four hours to complete the job and return to their respective

rendezvous points before the shot. The teams recovered the samples on 19 April, one day after the shot (43).

Approximately ten hours after the detonation, the teams collected samples and continued to work at the stations until 24 hours after shot-time. At that time, the group dismantled the stations and returned to Camp Mercury. The highest concentrations of radioactivity were found at (43):

- Nye Canyon, 32 kilometers from ground zero: 1.3 R/h
- Indian Springs Valley, 50 kilometers from ground zero: 0.7 R/h
- Sheep Canyon, 85 kilometers from ground zero: 0.4 R/h
- South of Glendale, 145 kilometers from ground zero: 0.1 R/h.

Project 29.1, Comparison and Evaluation of Dosimetry Methods Applicable to Gamma Radiation, dealt with the accuracy and practicality of chemical versus film and other methods of gamma dosimetry. Radiation-detecting instruments were to be tested under several types of radiation conditions:

- Either prompt- or residual-gamma exposures or mixtures of both
- Only residual-gamma radiations, either neutron-induced or from fission-product fallout
- Mixed neutron-gamma radiation plus correlation with biological effects.

Twenty-six members of the Evans Signal Laboratory, part of the Signal Corps Engineering Laboratories, made up survey teams to check the performance of various radiation instruments in fresh fallout areas. One duty was to calibrate film using an 88-curie cobalt-60 source.

The Evans Signal Laboratory personnel also arranged 4,200 chemical dosimeters and 250 film badges at 13 posts prior to shot-day. The posts were located 690 to 2,400 meters from ground zero. These dosimeters and film badges were probably recovered the day after shot-day (47).

Beginning 15 minutes after recovery hour, one project participant and a monitor were scheduled to place dosimeters in areas with intensities ranging from 25 to 50 R/h. These men had instructions not to stay in the areas longer than three minutes. Personnel were to retrieve the dosimeters 12, 24, and 36 hours after recovery hour (3).

Another party, made up of six project participants and a monitor, were to begin placing radiation-recording devices about 730 meters from ground zero 15 minutes after recovery hour. They were scheduled to spend 15 minutes in this activity (3).

3.4 AIR FORCE SPECIAL WEAPONS CENTER ACTIVITIES

AFSWC support to the test groups and to the Test Manager during Shot BADGER consisted of aircraft operational control, cloud sampling, sample courier missions, cloud tracking, security sweeps, and aerial surveys. Cloud sampling was conducted for LASL Project 13.1, Radiochemistry Sampling, and AFSWP Project 7.5, Calibration and Analysis of Close-in A-Bomb Debris. Table 3-3 details DOD participation in AFSWC projects, including the number and type of aircraft used (19).

3.4.1 Cloud Sampling

Ten aircraft collected particulate and gaseous samples of the Shot BADGER cloud for LASL Project 13.1 and AFSWP Project 7.5. Nine of the aircraft were F-84G samplers, code-named "Tiger," each flown by one pilot of the 4926th Test Squadron.

The other aircraft was a B-29 sampler, with a crew of ten, that collected samples for Project 7.5. A B-50 sampler control aircraft, which carried an AFSWC crew of nine including a scientific advisor from LASL, and one of the F-84G sampler aircraft, surveved the cloud before the actual sampling sorties. The F-84G, called a snoopier, remained in the cloud area for 18 minutes to report the top and base altitude of the cloud. It landed at Indian Springs AFB at 0506, and took off again three hours and 20 minutes later to replace one of the sampler aircraft that could not fly the mission because of engine failure (19; 48).

Table 3-3: AFSWC AIR MISSION SUPPORT, SHOT BADGER

Mission	Type of Aircraft	Number of Aircraft	Estimated DOD Personnel
Cloud Sampling			
Sampler Control	B-50	1	9
Sampler	F-84G	9	9
Sampler	B-29	1	10
Sample Courier	B-25	11	55
	C-47	2	8
Cloud Tracking	B-29	2	20
	B-25	1	5
Aerial Surveys	H-5	1	3
	L-20	1	3
	C-47	1	4

The first cloud penetration occurred at 0542 hours, 67 minutes after the detonation. The following listing details the activities of each sampler aircraft:

AIRCRAFT	NUMBER OF PENETRATIONS	TOTAL TIME IN CLOUD (seconds)	TOTAL TIME IN CLOUD AREA (minutes)
Tiger Red 1	3	480	70
Tiger Red 3	1	-	112
Tiger Red 4	4	464	60
Tiger White 1	3	405	80
Tiger White 2	5	535	56
Tiger White 3	2	205	34
Tiger White 4	2	145	78
Tiger Blue 1	1	70	13
Tiger Blue 3	4	220	58
Catnip 1 (B-29)	-	-	183

The highest intensity recorded during the sampling missions was 100 R/h, and the highest pilot exposure was 1.42 roentgens (19).

After the sampling missions were completed, the aircraft landed at 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 F-84G 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 boxes. For the B-29 aircraft, the crew remained aboard while the sample-removal team removed the sample from the polyethylene bag and transferred it to a steel cylinder using a diaphragm-type pump (48).

After the samples from each aircraft were removed and stored, the pilots of the F-84G aircraft shut down their oxygen and opened their canopies. The pilots stepped onto a platform held by a forklift, so they would not touch the exterior of the aircraft. The B-29 crew exited through the rear side door. The pilots and crew of all aircraft were taken by pickup truck to the decontamination station, where they were monitored and decontaminated as necessary (48).

3.4.2 Sample Courier Missions

Within 24 hours after Shot BADGER, two C-47s and 11 B-25s flown by AFSWC crews took film, filter and gas samples, and threshold detectors to laboratories for analysis for the test group projects, including Projects 7.5 and 13.1. The air routes taken by the courier aircraft precluded flying over the NPG (18).

3.4.3 Cloud Tracking

Immediately after the BADGER detonation, two B-29s from Kirtland AFB, each with a crew of ten, and one B-25 from Indian Springs AFB, with a crew of five, flew cloud-tracking missions over and beyond the NPG. The purpose of this mission was to determine the direction in which the cloud was traveling so that the Test Manager could keep the airways clear of any private or commercial aircraft that might encounter the cloud. One B-29 tracked the cloud at 22,000 feet and was in the air for four hours and 54 minutes. The other B-29 followed the cloud at 18,000 feet for four hours. The B-25, flying at 12,000 feet, tracked the cloud for three hours and eight minutes. On completing this mission, the three aircraft returned to their staging bases (13; 19).

3.4.4 Aerial Surveys

As directed by the Test Manager and Test Director, one H-5, one H-18, one C-47, and one L-20 flew radiological safety and aerial surveys after the BADGER detonation to assess detonation damage and record radiation intensities.

The H-5 helicopter flew the initial onsite radiological safety survey. It began 12 minutes after the detonation and continued for one hour at heights ranging from ten to 100 feet above the ground. Three hours after the detonation, the H-18 surveyed 30 feet above the ground for about 15 minutes. The L-20 aircraft surveyed offsite and onsite for two hours and 23 minutes, beginning about two hours after the shot, at a height of 500 feet. Three hours after the shot, the C-47 began surveying and continued for about three hours as far as 320 kilometers offsite, at heights ranging from 500 to 800 feet. The C-47 flew the day after the shot for one hour and 15 minutes at 400 to 2,000 feet above the ground (13; 19).

CHAPTER 4

RADIATION PROTECTION AT SHOT BADGER

Exercise Desert Rock V, the Joint Test Organization, and the Air Force Special Weapons Center each developed procedures to protect participants from the radiation resulting from the nuclear detonation. The JTO and AFSWC based their procedures on criteria developed by the AEC Division of Biology and Medicine. The Office, Chief of Army Field Forces, established the radiological safety criteria and procedures for Desert Rock participants. The safety criteria and procedures, as well as the organizations developed to implement them, are described in chapter 5 of the Operation UPSHOT-KNOTHOLE volume.

The primary purpose of the radiation protection procedures established at Operation UPSHOT-KNOTHOLE was to avoid unnecessary exposure to ionizing radiation while still allowing participants to accomplish their missions. Records of some of the procedures described in the Operation UPSHOT-KNOTHOLE volume enabled Exercise Desert Rock V, the JTO test groups, or AFSWC to evaluate the effectiveness of the radiation protection programs. Complete records of the radiation protection programs at Shot BADGER were found only for the test groups. Although Desert Rock film badge records are incomplete, some information is available in final operations reports.

Data that indicate the results of the test groups' radiation protection activities are available from two sources: the onsite radiological safety report and the final dose report. The onsite report summarizes the activities that took place at each shot during Operation UPSHOT-KNOTHOLE, including monitoring, plotting and briefing, personnel dosimetry, issue of protective equipment,

and decontamination. The final exposure report contains a listing of total gamma doses for all DOD personnel in the JTO who received film badges at Operation UPSHOT-KNOTHOLE. Although this report contains individual names, units, total doses, and dates of exposure, some of the exposure periods cover more than one shot. The final exposure report cannot, therefore, be used to determine all personnel exposures that occurred at Shot BADGER. A more detailed description of these sources is contained in the series volume.

The after-action report for the Marine Corps maneuver at Shot BADGER contains some details of the radiation protection activities (24). In addition, the operation orders for Shot BADGER and for the Marine Corps maneuver list planned activities (29-30).

4.1 DESERT ROCK RADIATION PROTECTION PROCEDURES

The project that distinguished Shot BADGER from the rest of the shots in Operation UPSHOT-KNOTHOLE was the comprehensive exercise performed by the 2d Marine Corps Provisional Atomic Exercise Brigade. This section describes the radiation protection procedures at this exercise and at two other Desert Rock programs, the volunteer observer program and the operational helicopter test. In cases where additional information was available, this section discusses radiation protection procedures for the other Desert Rock participants.

4.1.1 Radiation Protection for Troop Maneuvers

Representative Marine Corps personnel involved in the 2d MCPAEB at Shot BADGER were issued film badges and pocket dosimeters before 1800 hours on the day before the shot. Although it had been planned that each participant would receive a film badge, film badges and pocket dosimeters were actually

issued on the basis of two badges per platoon and two pocket dosimeters per company. The 2d MCPAEB Radiological Safety Officer and the Desert Rock Radiological Safety Section supervised the issue of film badges and recording of film badge information. Individuals carried protective masks, to be worn to avoid inhalation of radioactive particles if the test area were evacuated. After the detonation, Marines returned their film badges either before 1800 hours on shot-day or immediately upon return to Camp Desert Rock (24).

The Marines witnessed the detonation from trenches about 3,660 meters from ground zero. Immediately after the shock wave passed, the Marines left the trenches and moved out in attack formations. An experienced 2d MCPAEB Radiological Safety Officer preceded the Marines via jeep to measure radiation intensities as the Marines moved closer to ground zero. In addition, two Marine Corps monitors accompanied each platoon. One monitor preceded each maneuvering platoon, checking and recording radiation intensities with an AN/PDR-39 survey meter. Readings were taken with the instruments held at waist height. The other monitor, carrying an AN/PDR-27C meter, remained with the platoon. The data recorded by the monitors were not reported to the Marine units but were recorded for later study (24).

As reported in chapter 2, personnel of the 1st Battalion, 8th Marines, were exposed to radiation exceeding the 6.0 roentgen limit during their maneuver. Readings of up to 7.5 roentgens were registered on the pocket dosimeters 36 minutes after the detonation, so the maneuver was terminated, and the troops were not permitted to tour the display area. It was later determined from pocket dosimeter readings that the average total exposure of the 1st Battalion was 4.8 roentgens. Film badge records are available for 24 personnel of the 1st Battalion, 8th Marines. These film badges represent about half of the badges issued to the 1st Battalion. The exposure range was from less than 0.1 up

to 7.5 roentgens, with an average film badge exposure of 3.0 roentgens. Only two of these readings, 6.2 and 7.1 roentgens, were greater than the 6.0 roentgen limit. The Marines were probably on the right flank of the maneuver, where the radiation was most intense (17; 24).

The 2d Battalion, 3d Marines, and Brigade Headquarters advanced as planned and were able to tour the display area. According to exposures registered on pocket dosimeters, the 2d Battalion received an average exposure of 2.3 roentgens, and Brigade Headquarters personnel received about a 2.0 roentgen exposure (24).

Film badge records are available for 44 personnel from the 2d Battalion, 3d Marines, and four personnel from Headquarters, 2d Marine Corp Provisional Atomic Exercise Brigade, who had film badge data specific to Shot BADGER. The 44 film badge records of the 2d Battalion probably represent the majority of film badges issued. The total number of badges issued to the Headquarters Brigade is not known. For the 2d Battalion, the range of gamma exposures was from less than 0.1 to 5.2 roentgens, with an average film badge exposure of 3.0 roentgens. For Headquarters Brigade, the range of exposures was from 3.42 to 5.7 roentgens, with an average of 4.1 roentgens. The highest may have been for personnel who also evaluated the Marine equipment displays (17).

Eleven minutes after the shot, two pathfinder helicopters from MAG-16 arrived behind the entrenchments to carry the Marine radiological monitor teams to the maneuver area, where they assessed the radiological situation. The radiological monitor teams reached the area 15 minutes after detonation. No film badge data are available for the MAG-16 personnel. However, pocket dosimetry indicated 0.5 roentgen for those who were bused through the display area (24).

4.1.2 Radiation Protection for Volunteer Observers

Twelve volunteer officers, six Marine Corps and six Army officers, observed Shot BADGER from a trench 1,830 meters from ground zero. These volunteers were outfitted with the following dosimetric devices (24):

- One film badge each, provided by the JTO
- One pocket dosimeter each, provided by the Army
- Three film badges each, also furnished by the Army, one in the top of the helmet liner, one in the breast pocket, and one taped to the back of the jacket
- Six film badges each, provided by the Marine Corps and located in the top of the helmet liner, in the breast pocket, in the left hip pocket, in the right front pocket, and in the top of each boot.

The JTO provided 12 additional film badge packs for the project. Two were placed on top of the trench, two in the middle of the trench, and two in the bottom of the trench. Selected individuals carried the others (24).

As described in chapter 2, the observers evacuated the trenches when the instruments indicated an initial radiation reading of 500 R/h. As the officers left the trenches, the radiation level dropped to between 30 to 50 R/h. As they walked to the road west of the trenches, the radiation levels decreased to about 1.0 R/h (27). Upon reaching the junction of the 1,830-meter road and the display area access road, the officers obtained an intensity reading of 0.95 R/h. As they moved away from ground zero, the officers obtained readings of 0.5 R/h and less on the access road.

The film badges furnished by the AEC Radiological Safety Officer indicated exposures of from 5.2 to 9.5 roentgens. A set furnished by the Army ranged from 6.8 to 14.9 roentgens. Pocket

dosimeters recorded readings from 5.25 to 9.5, which agreed with the film badges furnished by the JTO. The higher readings indicated on the Army film badges were judged to have resulted from inaccurate response of the film in the range of 5 to 25 roentgens (27).

The volunteer officer observers were also exposed to prompt neutron radiation. Film badges worn by the observers did not measure neutron radiation, but dose reconstruction indicates that the volunteers received a neutron dose of about 2.5 roentgens. In addition, the dose reconstruction estimates the average total gamma dose for the volunteers to be about 7.2 roentgens (22).

4.1.3 Radiation Protection for the Operational Helicopter Test

The objectives and description of the helicopter test mission are presented in chapter 2. During this mission, pilots were instructed to avoid areas where the radiation intensity was greater than 10.0 R/h. They were not to land their aircraft in areas where the radiation intensity at ground level was greater than 0.05 R/h. Radiological safety monitors were scheduled to be aboard three of the four helicopters (25). Information is available regarding radiation levels encountered by these monitors. Such film badge data that have been found for the helicopter personnel cannot be related specifically to BADGER.

4.1.4 Radiation Protection for Observers in Orientation and Indoctrination

The observers left the trench area about 35 minutes after the shot. They toured the display areas as close as 910 meters to ground zero and returned to the trenches within about three hours. Although no film badge records have been located for these observers at BADGER, a dose reconstruction indicates that these troops received a gamma dose of 1.3 roentgens and that

their neutron dose was negligible (less than 0.001 roentgen). The gamma dose was higher than for most observers at other shots because of the amount of time that the observers spent near the forward radiological safety limit of 2.5 R/h (22).

4.2 RESULTS OF THE AEC-DOD JOINT TEST ORGANIZATION RADIATION PROTECTION ACTIVITIES

The initial onsite radiation survey at Shot BADGER began 15 minutes after the shot, at 0450 hours, and was completed at 0730 hours. The survey took longer than usual because some teams had difficulty in traveling over the rough terrain west of ground zero. Normal access routes to the north and northeast of ground zero were blocked by radiation fields in excess of 50 R/h crossing Mercury Highway. Recovery hour was not declared until 0710 hours (13).

Twelve JTO participants at Shot BADGER received exposures greater than 3.9 roentgens. Nine monitors from Fort McClellan, Alabama, assigned to the Radiological Safety Support Unit had total exposures ranging from 4.3 to 7.1 roentgens. These personnel performed a variety of monitoring and surveying activities. An Air Force participant from the Wright Air Development Center was assigned to Project 8.1a and received a total exposure of 7.4 roentgens. In other BADGER activities, a civilian employee of the Naval Research Laboratory assigned to Program 18 received an exposure of 4.5 roentgens. Also, an AFSWC monitor from Walker AFB, New Mexico, turned in a film badge that indicated an exposure of 17.5 roentgens (1a; 1b).

4.2.1 Onsite Operations

Because fallout occurred to the southeast of ground zero, across Mercury Highway, survey teams had to enter the shot area from the west in order to survey the northern areas. Figure 4-1

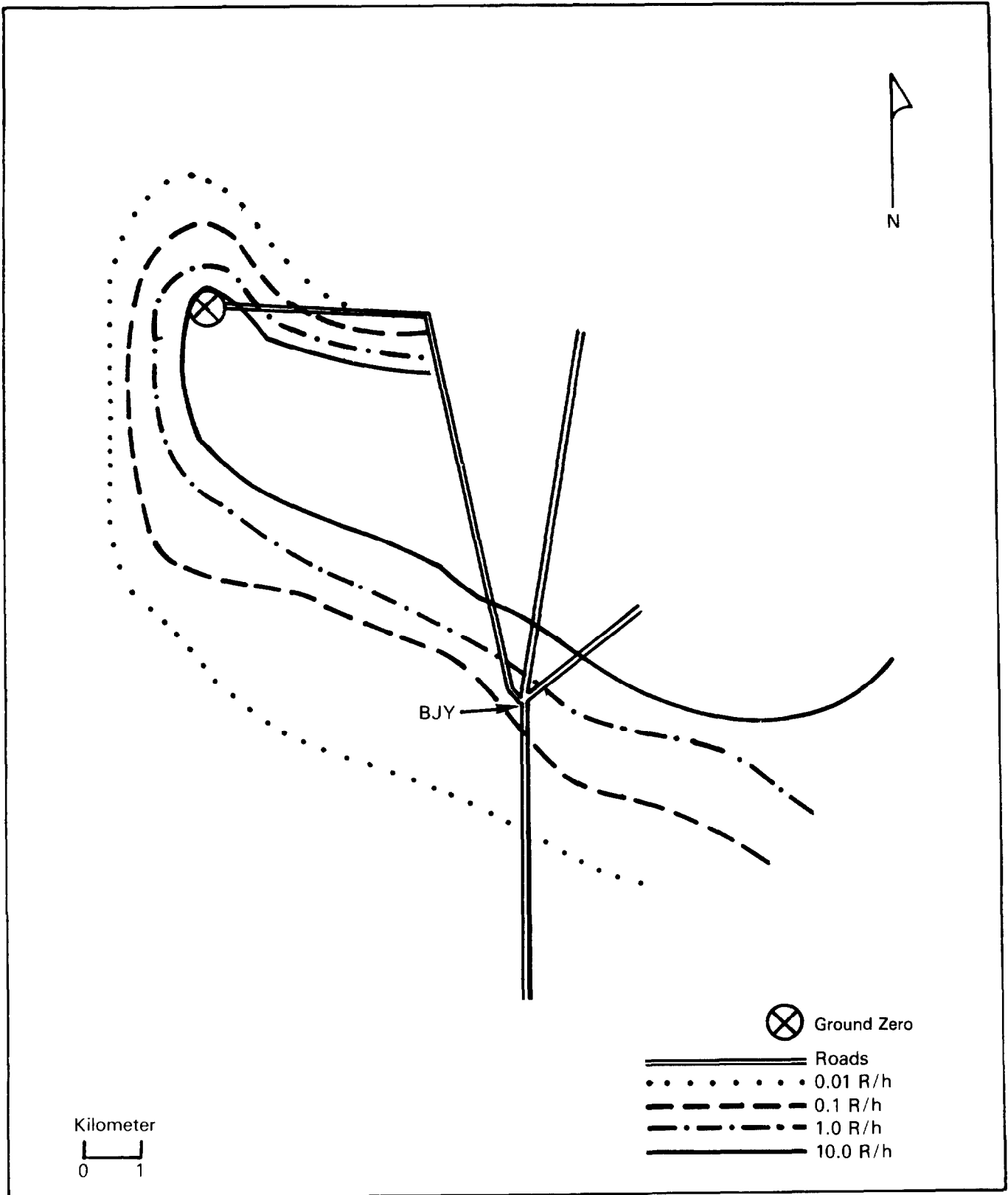


Figure 4-1: INITIAL SURVEY FOR SHOT BADGER, 18 APRIL 1953, 0730 HOURS

shows the plot resulting from the initial survey. Resurveys were conducted on 19 April, 20 April, and 23 April. Figures 4-2 and 4-3 present the results of the 19 and 20 April resurveys (13).

Generally, recovery parties were not permitted to enter areas with radiation levels of 10.0 R/h. For this shot, however, the Test Director permitted some parties in vehicles to use Mercury Highway to reach recovery areas, even though fallout in some areas along the highway measured greater than 50 R/h. This exception led some parties to believe that they could also recover test data in areas with radiation levels greater than 10.0 R/h without the specific permission of the Test Director. An unknown number of overexposures resulted from this misunderstanding. Because of these overexposures, the Onsite Radiological Safety Operations Officer initiated a special training program for monitors.

During the period 17 to 23 April, 133 recovery parties, consisting of 396 people, were briefed and processed for entry into radiation areas. Approximately 1,600 film badges were issued, and 92 vehicles were decontaminated. From 17 through 23 April 1953, including the 18 April detonation of BADGER, the Supply Section issued 238 protective caps, 274 pairs of shoe covers, 261 pairs of coveralls, 117 respirators, 133 pairs of cotton gloves, and 527 pairs of high-density goggles (13).

4.2.2 Offsite Operations

Areas east-southeast of the Nevada Proving Ground received some fallout from Shot BADGER. A wide path ranging from Kingman, Arizona, in the south, to north of Lake Mead, Nevada, had radiation intensities of at least 0.0002 R/h about ten hours after the detonation. Within that range was a narrow band of intensity up to 0.30 R/h that extended to the northern shores of Lake Mead. Radiation from BADGER was detected as far east as

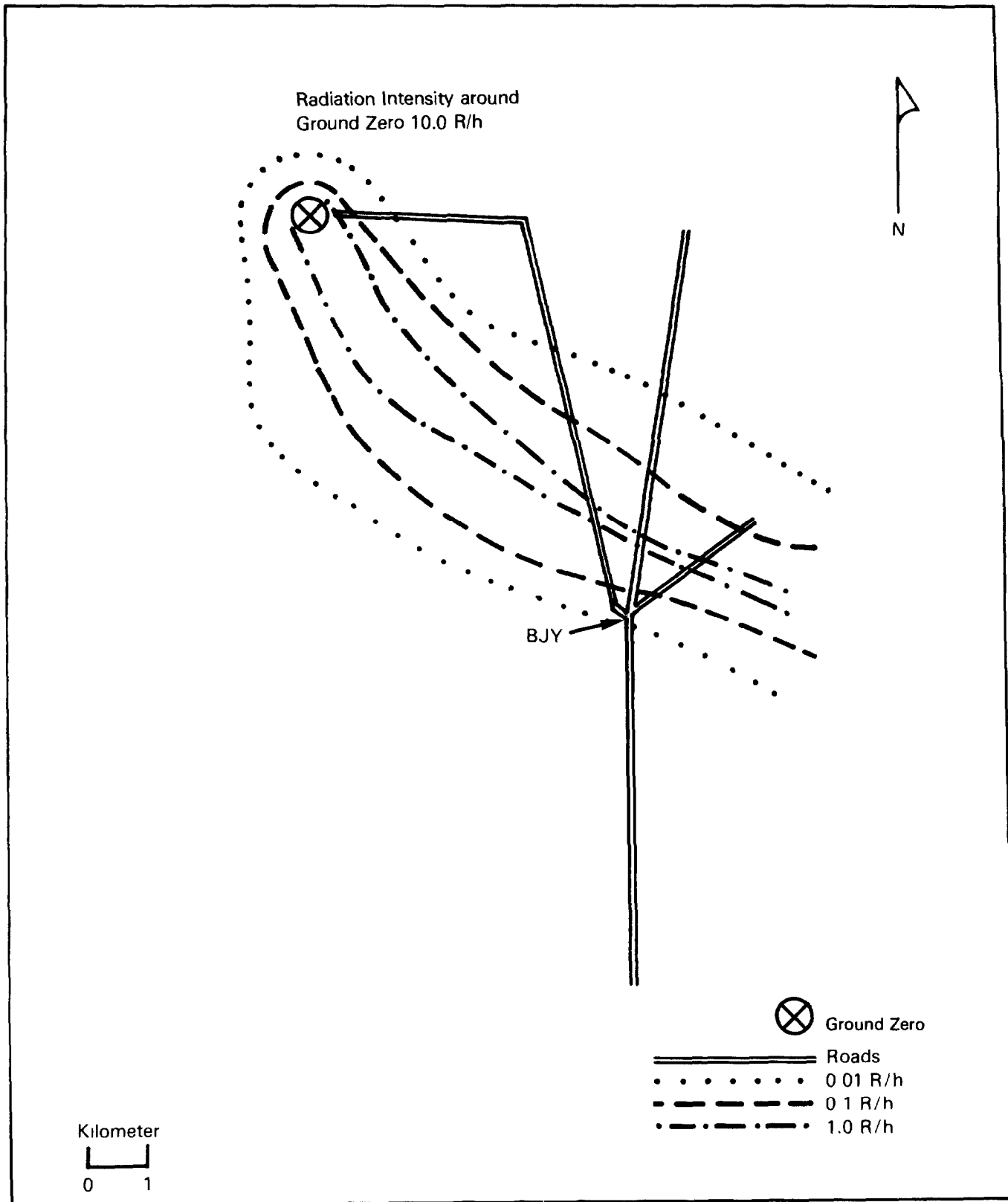


Figure 4-2: RESURVEY FOR SHOT BADGER, 19 APRIL 1953, 0630 HOURS

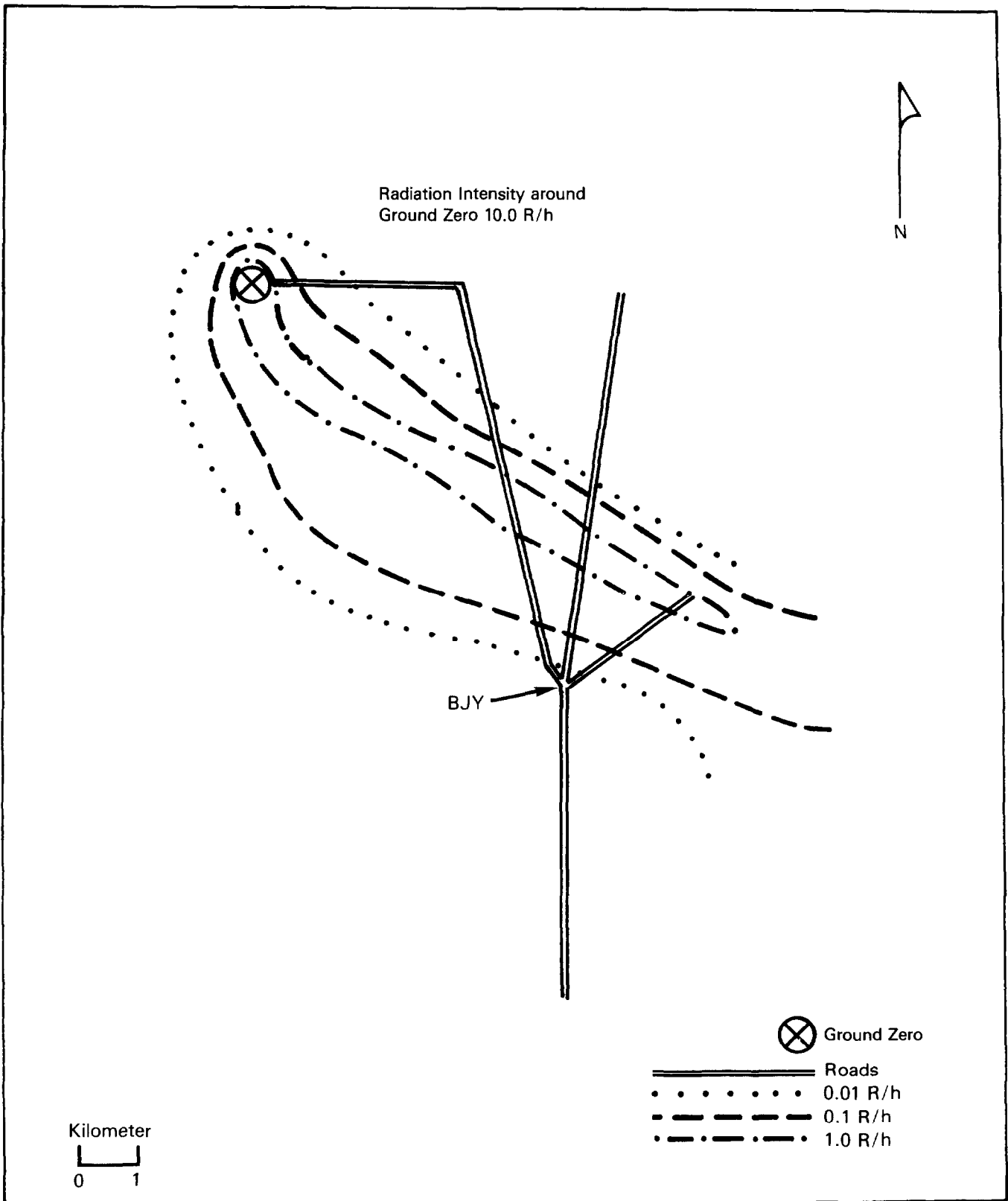


Figure 4-3: RESURVEY FOR SHOT BADGER, 20 APRIL 1953, 0730 HOURS

Arizona Highway 64 between Williams, Arizona, and the southern rim of the Grand Canyon (13).

Twelve monitors, four of whom were DOD personnel, performed offsite radiological surveys. Two DOD monitors surveyed extensively around Glendale Junction, Nevada, and Arizona Highway 40, two areas that received fallout from BADGER. The highest radiation intensity encountered by the DOD monitors was 0.2 R/h (13).

4.2.3 Air Participation

Four aircraft flown by AFSWC personnel conducted aerial surveys after the shot: two helicopters, a C-47, and an L-20. Section 3.4.4 has more information on this mission. The helicopters surveyed the terrain close to ground zero. Both the pilots and the monitors received exposures in excess of 3.9 roentgens due to the monitors' decision to enter areas with gamma intensities exceeding 10.0 R/h. The helicopters returned to the landing pad east of Control Point Building 2. The helicopters and crews were monitored and decontaminated (13).

The L-20 and C-47 performed the offsite aerial survey. Because communications were never established with the L-20, a late change in pattern, necessary because the cloud was not following the path predicted, was never effected. The C-47, however, did fly the alternate patterns ordered by the Test Director. The C-47 also surveyed on the day after detonation (19).

4.3 RADIOLOGICAL SAFETY FOR AFSWC UNITS BASED AT KIRTLAND AFB

The Radiological Warfare Defense Unit, as part of the 4910th Air Base Group, handled radiological activities at Kirtland AFB for AFSWC personnel. Two monitoring teams were required for the

BADGER test and were on duty from 0700 to 2400 hours, 18 April. No contamination was found on Kirtland-based aircraft participating in the BADGER test (11-12). Additional information regarding AFSWC radiological safety procedures and results at BADGER is not available.

SHOT BADGER REFERENCE LIST

The following list of references represents only those documents cited in the BADGER 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 UPHOT-KNOTHOLE volumes is contained in the Operation UPHOT-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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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 & Mecklenburg 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
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Monmouth County Library Eastern Branch
ATTN: Librn

Eastern Illinois University
ATTN: Librn

Eastern Kentucky University
ATTN: Librn

Eastern Michigan University Library
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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
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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
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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
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OTHER (Continued)

Indiana University Library
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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
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Kentucky Dept of Library & Archives
ATTN: Docs Sec

University of Kentucky
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Kenyon College Library
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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
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ATTN: Dir of Libraries (Reg)

Louisville Free Public Library
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Louisville University Library
ATTN: Librn

Hoover Institution
ATTN: J. Bingham

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Manchester City Library
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Mankato State College
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University of Maine at Farmington
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Marathon County Public Library
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Principia College
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University of Maryland
ATTN: McKeldin Library Docs Div

University of Maryland
ATTN: Librn

University of Massachusetts
ATTN: Gov Docs Coll

Mauı Public Library
Kahului Branch
ATTN: Librn

McNeese State University
ATTN: Librn

Memphis & Shelby County Public Library &
Information Center
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Memphis State University
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Mercer University
ATTN: Librn

Mesa County Public Library
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Miami Dade Community College
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University of Miami Library
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Miami Public Library
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Miami University Library
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University of Santa Clara
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Michigan State Library
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Michigan State University Library
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Murray State University Library
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University of Michigan
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Millersville State College
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State University of New York
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Milwaukee Public Library
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Minneapolis Public Library
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University of Minnesota
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Minot State College
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Mississippi State University
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University of Mississippi
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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
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Moorhead State College
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Mt Prospect Public Library
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OTHER (Continued)

Nassau Library System
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Natrona County Public Library
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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
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OTHER (Continued)

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New York State University
ATTN: Docs Ctr

State University of New York
ATTN: Docs Dept

New York University Library
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Newark Free Library
ATTN: Librn

Newark Public Library
ATTN: Librn

Niagara Falls Public Library
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Nicholls State University Library
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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
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North Georgia College
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Minnesota Div of Emergency Svcs
ATTN: Librn

OTHER (Continued)

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Northeastern Oklahoma State University
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Northeastern University
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Northern Arizona University Library
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Northern Illinois University
ATTN: Librn

Northern Michigan University
ATTN: Docs

Northern Montana College Library
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Northwestern Michigan College
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Northwestern State University
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Northwestern State University Library
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Northwestern University Library
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Norwalk Public Library
ATTN: Librn

Northeastern Illinois University
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University of Notre Dame
ATTN: Doc Ctr

Oakland Community College
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Oakland Public Library
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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
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Oklahoma City University Library
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OTHER (Continued)

Oklahoma Department of Libraries
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University of Oklahoma
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Olivet College Library
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Omaha Public Library Clark Branch
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Onondaga County Public Library
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Oregon State Library
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University of Oregon
ATTN: Docs Sec

Ouachita Baptist University
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Pan American University Library
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Passaic Public Library
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Queens College
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Pennsylvania State Library
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Pennsylvania State University
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University of Pennsylvania
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University of Denver
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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
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Association of Portland Library
ATTN: Librn

Portland Public Library
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Portland State University Library
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Pratt Institute Library
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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
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Quinebaug Valley Community College
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Auburn University
ATTN: Microforms & Docs Dept

Rapid City Public Library
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Reading Public Library
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Reed College Library
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Augusta College
ATTN: Librn

University of Rhode Island Library
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University of Rhode Island
ATTN: Dir of Libraries

Rice University
ATTN: Dir of Libraries

Louisiana College
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OTHER (Continued)

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University of Rutgers Camden Library
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State University of Rutgers
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Rutgers University
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Rutgers University Law Library
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Salem College Library
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Samford University
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San Antonio Public Library
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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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San Francisco Public Library
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San Francisco State College
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San Jose State College Library
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San Luis Obispo City-County Library
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Savannah Public & Effingham Liberty Regional
Library
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Scottsbluff Public Library
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Scranton Public Library
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Seattle Public Library
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OTHER (Continued)

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Shawnee Library System
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Shreve Memorial Library
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Silas Bronson Public Library
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Sioux City Public Library
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Skidmore College
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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
ATTN: Gov Docs

South Dakota School of Mines & Technical Library
ATTN: Librn

South Dakota State Library
ATTN: Fed Docs Dept

University of South Dakota
ATTN: Docs Librn

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
ATTN: Docs Ctr

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
ATTN: Docs Dept

Southwest Missouri State College
ATTN: Library

University of Southwestern Louisiana Libraries
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Southwestern University
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Spokane Public Library
ATTN: Ref Dept

Springfield City Library
ATTN: Docs Sec

St Bonaventure University
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St Joseph Public Library
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St Lawrence University
ATTN: Librn

St Louis Public Library
ATTN: Librn

St Paul Public Library
ATTN: Librn

Stanford University Library
ATTN: Gov Docs Dept

State Historical Soc Library
ATTN: Docs Serials Sec

State Library of Massachusetts
ATTN: Librn

State University of New York
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Stetson University
ATTN: Librn

University of Steubenville
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Stockton & San Joaquin Public Library
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Stockton State College Library
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Albion College
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OTHER (Continued)

Superior Public Library
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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
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University of Texas at San Antonio
ATTN: Library

Texas Christian University
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Texas State Library
ATTN: U.S. Docs Sec

Texas Tech University Library
ATTN: Gov Docs Dept

Texas University at Austin
ATTN: Docs Coll

University of Toledo Library
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Toledo Public Library
ATTN: Social Science Dept

Torrance Civic Center Library
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Traverse City Public Library
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Trenton Free Public Library
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Trinity College Library
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Trinity University Library
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OTHER (Continued)

Tufts University Library
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University of Tulsa
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UCLA Research Library
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Uniformed Services University of the Health Sciences
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University Libraries
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University of Maine at Orono
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University of Northern Iowa
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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

Utica Public Library
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Valencia Library
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Valparaiso University
ATTN: Librn

Vanderbilt University Library
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University of Vermont
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Virginia Commonwealth University
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Virginia Military Institute
ATTN: Librn

Virginia Polytechnic Institute Library
ATTN: Docs Dept

Virginia State Library
ATTN: Serials Sec

University of Virginia
ATTN: Pub Docs

Volusia County Public Library
ATTN: Librn

OTHER (Continued)

Washington State Library
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Washington State University
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Washington University Libraries
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University of Washington
ATTN: Docs Div

Wayne State University Library
ATTN: Librn

Wayne State University Law Library
ATTN: Docs Dept

Weber State College Library
ATTN: Librn

Wesleyan University
ATTN: Docs Librn

West Chester State College
ATTN: Docs Dept

West Covina Library
ATTN: Librn

University of West Florida
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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
ATTN: Learning Resource Ctr

OTHER (Continued)

Whitman College
ATTN: Librn

Wichita State University Library
ATTN: Librn

Williams & Mary College
ATTN: Docs Dept

Emporia Kansas State College
ATTN: Gov Docs Div

William College Library
ATTN: Librn

Willimantic Public Library
ATTN: Librn

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
ATTN: Doc Unit Lib

University of Wisconsin at Stevens Point
ATTN: Docs Sec

University of Wisconsin
ATTN: Gov Pubs Dept

University of Wisconsin
ATTN: Acquisitions Dept

Worcester Public Library
ATTN: Librn

Wright State University Library
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Wyoming State Library
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University of Wyoming
ATTN: Docs Div

Yale University
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Yeshiva University
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Simon Schwob Mem Lib, Columbus Col
ATTN: Librn

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