24

DNA 6005F

LEVEL II

AD A107317

PLUMBBOB SERIES 1957

United States Atmospheric Nuclear Weapons Tests

Nuclear Test Personnel Review

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

81 11 17002

Destroy this report when it is no longer needed. Do not return to sender.

PLEASE NOTIFY THE DEFENSE NUCLEAR AGENCY, ATTN: STTI, WASHINGTON, D.C. 20305, IF YOUR ADDRESS IS INCORRECT, IF YOU WISH TO BE DELETED FROM THE DISTRIBUTION LIST, OR IF THE ADDRESSEE IS NO LONGER EMPLOYED BY YOUR ORGANIZATION.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: DNA 6005F	2. GOVT ACCESSION NO.: AD-A107317
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): PLUMBBOB SERIES, 1957	5. TYPE OF REPORT & PERIOD COVERED: Technical Report
	6. PERFORMING ORG. REPORT NUMBER: 2087-79-02
7. AUTHOR(s): P.S. Harris, C. Lowery, A. Nelson, S. Obermiller, W.J. Ozeroff, S.E. Weary	8. CONTRACT OR GRANT NUMBER(s): DNA 001-78-C-0311
9. PERFORMING ORGANIZATION NAME AND ADDRESS: JAYCOR, 205 South Whiting Street, Alexandria, Virginia 22304	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Subtask U99QAXMK506-04
11. CONTROLLING OFFICE NAME AND ADDRESS: Director, Defense Nuclear Agency, Washington, D.C. 20305	12. REPORT DATE: 15 Sep[redacted]981
	13. NUMBER OF PAGES: 312
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A

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

This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B350078464 U99QAXMK50604 H2590D. For sale by the National Technical Information Service, Springfield, Virginia 22161. (Continued)

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

AEC	Desert Rock	NTPR	SMOKY
AFSWC	Fallout	PLUMBBOB	
AFSWP	GALILEO	PRISCILLA	
Atmospheric Nuclear Tests	HOOD	Radiation Exposure	
Decontamination	Ionizing Radiation	Radioactivity	

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

This report describes the activities of DOD participants in the atmospheric nuclear test series, Operation PLUMBBOB. The various levels at which DOD personnel participated with the Nevada Test Organization are identified. DOD participants in Desert Rock Exercise Projects are described. The AEC and DOD criteria and procedures for Rad-safe are included. Those projects related to DOD mission activities are described as to purpose, agency, operations, and Rad-safe aspects.

DD FORM 1473, 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

394532

18. SUPPLEMENTARY NOTES (Cont.)
The Defense Nuclear Agency Action Officer, Major 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 writers listed in block 7.

Accession For	
NTIS GRA&I	X
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A	

Fact Sheet

Defense Nuclear Agency
Public Affairs Office
Washington, D.C. 20305

Subject: PLUMBBOB Series

Operation PLUMBBOB, the sixth series of atmospheric nuclear weapons tests conducted within the continental United States, consisted of 24 nuclear detonations and six safety experiments. The PLUMBBOB series lasted from April 24, to October 7, 1957, and involved about 18,000 DOD personnel participating in observer programs, tactical maneuvers, and scientific and diagnostic studies. The series tested nuclear weapons for possible inclusion in the defense arsenal. The tests were also used to improve military tactics, equipment, and training. The safety experiments were conducted to ensure that no nuclear reaction would occur if the high explosive components of the device were accidentally detonated during storage or transport.

Department of Defense Involvement

During Operation PLUMBBOB, the activity with the largest DOD participation was Exercise Desert Rock VII and VIII, a program involving members of all armed services. Exercise Desert Rock VII and VIII included training programs, tactical maneuvers, and technical service projects. Training programs generally included lectures and briefings on the effects of nuclear weapons, observation of a nuclear detonation, and a subsequent visit to a display of military equipment exposed to the detonation. At shots HOOD, SMOKY, and GALILEO, maneuvers were conducted to develop tactics applicable to the nuclear battlefield. At HOOD, the Marine Corps conducted a maneuver involving the use of a helicopter airlift and tactical air support. At shot SMOKY, Army troops conducted an airlift assault, and at shot GALILEO, Army troops were tested to determine their psychological reactions to witnessing a nuclear detonation. Technical service projects were designed to test equipment and techniques.

In addition to Desert Rock activities, scientific experiments to assess the effects of each nuclear detonation were conducted by four test groups of the Nevada Test Organization (NTO). The Weapons Effects Test Group was sponsored by Field Command, Armed Forces Special Weapons Project (AFSWP). The two AEC weapons development laboratories sponsored the Los Alamos Scientific Laboratory (LASL) and the University of California Radiation Laboratory (UCRL) Test Groups. Finally, the Federal Civil Defense Administration sponsored the Civil Effects Test Group (CETG), which evaluated the effectiveness of civil defense measures. Although the Weapons Effects Test Group was the only DOD-sponsored test group, DOD personnel took part in the experiments of the other three groups.

Individuals participating in scientific experiments placed data-collection instruments around the point of detonation in the days and weeks preceding the scheduled nuclear test. They returned to the test area to recover equipment and gather data after the detonation, when the Test Manager had determined that the area was safe for limited access.

Support services for both Exercise Desert Rock VII and VIII and the Nevada Test Organization included radiological safety, security, transportation, communications, engineering, and logistics. The Air Force Special Weapons Center (AFSWC) at Kirtland Air Force Base, New Mexico, provided aircraft and pilots for preshot security sweeps, cloud sampling, cloud tracking, and aerial radiological surveys conducted for the NTO. During PLUMBBOB, AFSWC also conducted cloud penetration studies for the Weapons Effects Test Group to determine Air Force needs in monitoring the accumulation of radioactive contaminants on aircraft.

Safety Standards and Procedures

Exercise Desert Rock VII and VIII, the test groups, and AFSWC each developed its own organization and procedures for ensuring the radiological safety of its members based on the established criteria of the Atomic Energy Commission. The radiological safety plans were developed to minimize operational exposures to ionizing radiation.

The safety of Desert Rock VII and VIII participants was the responsibility of the Desert Rock Exercise Director. A maximum radiation exposure limit of 5.0 roentgens in any six-month period was established for Desert Rock troops. Of this exposure, no more than 2.0 roentgens was to be from prompt radiation.

Exposure limits for blast pressure and thermal radiation were also established. Based on exposure limits and mode of delivery, minimum distance criteria for positioning Desert Rock troops and observers were established. For a tower shot with a predicted maximum yield of about 10 kilotons, troops in the open were positioned at least 4,000 yards from ground zero. Troops in trenches at such a shot were positioned no closer than 2,600 yards from ground zero. Troops in armored vehicles were positioned no closer than 2,800 yards from ground zero.

The Desert Rock Radiological Safety Section implemented procedures for Exercise Desert Rock during PLUMBBOB. The 50th Chemical Platoon supported the Radiological Safety Section by providing materials, equipment, and personnel.

The Test Manager was responsible for the safety of all test group personnel at the Nevada Test Site during the operation. The radiological safety criteria for test group personnel was 3.0 roentgens for any 13-week period, and 5.0 roentgens for one calendar year. AFSWC pilots were subject to the same exposure limits as the test groups. Onsite radiological safety operations were performed for the Test Manager by AEC personnel. The Air Force Special Weapons Center implemented its own radiological safety procedures.

Although the missions of Exercise Desert Rock, NTO, and AFSWC required different types of activities and separate radiation protection plans and staffs, many of the procedures were similar and were performed by two or more of the three radiological safety groups. These procedures included:

- Orientation and training - preparing radiological monitors for their work and familiarizing participants with radiological safety procedures

- Personnel dosimetry - issuing, processing, developing film badges for participants, and determinming gamma radiation exposures recorded on film badges

- Use of protective equipment - providing anti-contamination equipment, including clothing and respirators

- Monitoring - performing radiological surveys and controlling access to all contaminated areas

- Briefing - informing observers and project personnel of radiological hazards and the current status of contamination in the test area

- Decontamination - detecting and removing contaminated material from personnel and equipment.

Radiation Exposures at PLUMBBOB

The following table indicates the findings of the military Services as of April 23, 1981.

	Army	Navy	Marines	Air Force	DOD Civilians
# Participants	7,226	466	2,417	2,505	2,266
# With Film Badge	7,226	442	540	1,446	2,222
# With less than 0.1 rem	3,194	371	241	893	1,558
Greater than 5 rem	27	3	1	19	0

Summaries of PLUMBBOB Nuclear Events

The 24 PLUMBBOB nuclear shots and the safety experiments are summarized in the accompanying table, and their locations are shown on the accompanying map. Shots PRISCILLA, HOOD, SMOKY, and GALILEO are described in the following paragraphs. PRISCILLA is significant due to the large number of participants involved and the extensive military effects program. HOOD and SMOKY involved large troop tests. GALILEO is significant because some personnel had been at the test site for an extended period of time awaiting a decision as to whether they would be able to participate at SMOKY. For a number of reasons including delays in the scheduling of SMOKY, the Army troop test was conducted at GALILEO instead of SMOKY.

Shot PRISCILLA, a 37-kiloton shot, was detonated from a balloon 700 feet above Frenchman Flat at 0630 hours on June 24, 1957. While there was no troop maneuver at PRISCILLA, more than 1,700 individuals took part in Exercise Desert Rock activities. Most of these individuals were involved in the troop observer indoctrination program. The closest troops witnessed the detonation from trenches 3,500 meters southwest of ground zero. After the detonation, troops toured the extensive equipment display area, located directly south of ground zero. At the time of the first survey, residual radiation greater than 1 R/h* was confined to a circular area within 550 meters of ground zero. Troops were able to view equipment up to the 5 R/h intensity line located 500 meters from ground zero.

The primary objective of the PRISCILLA event was to correlate the yield and characteristics of the device with its effects on military equipment, materiel, structures, and ordnance. To fulfill this objective, about 300 Armed Forces Special Weapons Project personnel conducted 34 scientific projects at shot PRISCILLA, making this shot one of the largest military effects tests ever conducted at the Nevada Test Site. In addition, AFSWC aircrew personnel provided such services to the Test Manager as cloud sampling, cloud tracking, and security sweeps. The principal AFSWC unit involved in the PRISCILLA shot, as at other shots in the PLUMBBOB series, was the 4950th Test Group (Nuclear), with support from the 4900th Air Base Group. During shot PRISCILLA, AFSWC also conducted the cloud penetration study.

Shot HOOD, a 1,500-foot balloon shot with a yield of 74 kilotons, was fired at 0440 hours on July 5, 1957 in Yucca Flat. HOOD was the largest atmospneric detonation to occur at the NTS. Residual radiation greater than 1 R/h at the time of the first survey was confined to a circular area 1,000 meters from ground zero.

Exercise Desert Rock programs included troop observer and indoctrination projects, a troop test, radiological training projects and technical service projects. Over 3,000 DOD personnel participated in these projects, the largest being the Marine Brigade Exercise, which involved 2,100 to 2,200 Marines from the Fourth Marine Corps Provisional Atomic Exercise Brigade. The principal participating units were from the First Marine Divison of Camp Pendleton, California, and the Third Air Wing from the Marine Corps Air Station at El Toro, California.

Originally scheduled to take place during shot DIABLO, the exercise was rescheduled for shot HOOD when DIABLO misfired. The Marine exercise had several objectives, including the training of personnel in the effects and employment of nuclear weapons, the formulation of tactics and techniques relative to nuclear war, and the training of personnel in passive defense measures against the effects of nuclear weapons. The postshot troop maneuver involved a coordinated air-ground assault by a reinforced Marine battalion against a military objective. After observing the shot, the Marines were transported by helicopters to landing zones near the attack objective. A ground assault on the objective, supported by tactical aircraft, was to follow the airlift. When the objective was obtained at 1100 hours, more than six hours after the shot, some of the troops viewed an equipment display area, located from 240 to 2,170 meters from ground zero.

---

*R/h = roentgens per hour

Another 100 project participants took part in 24 scientific experiments and six operational training projects at shot HOOD. AFSWC activities included the cloud penetration study, as well as such standard support missions as cloud sampling, courier missions, cloud tracking, and security sweeps. About 80 AFSWC aircrew took part in these activities at shot HOOD.

Shot SMOKY was fired from a 700-foot tower in Yucca Flat at 0530 hours on August 31, 1957. The shot had a yield of 44 kilotons. At the time of the first survey, the 1 R/h line extended more than 6 kilometers to the southeast of ground zero. Exercise Desert Rock troops observed the detonation from a location 13 kilometers southwest of ground zero. The closest approach was 4,100 meters west of ground zero. Exercise Desert Rock activities at shot SMOKY included a troop test, the troop observer program, technical service projects, and radiological monitoring training. The most significant of these activities, an attack and resupply maneuver, involved an estimated 1,144 troops. The initial phase of the project was conducted two weeks before the shot. Troops prepared defensive positions north and west of SMOKY ground zero for inspection after the shot. The troops, a reinforced Infantry Company named Task Force WARRIOR, were part of the 1st Battle Group, 12th Infantry Regiment, 4th Infantry Division, Fort Lewis, Washington. They observed the shot assembly areas some 13 kilometers from ground zero. Fifteen minutes after the shot, a Pathfinder unit, accompanied by radiological monitors, flew into the objective area northwest of ground zero and determined it radiologically safe to occupy. At 0550 hours, assault elements of the task force had been brought into the objective area. The exercise ended at 0945 hours on August 31, 1957.

About 200 additional participants took part in the scientific experiments at shot SMOKY. Another 22 Navy and Air Force crewmen participated in operational training projects designed to indoctrinate personnel, practice photographic reconnaissance, and test indirect bomb damage assessment equipment and techniques. In addition to performing cloud sampling, sample courier returns, security sweeps, and cloud tracking missions, AFSWC pilots provided support to Desert Rock, AFSWP, UCRL, and CETG projects. More than 200 AFSWC aircrew personnel were involved in these activities.

Shot GALILEO, with a yield of 11 kilotons of explosive energy, was detonated from a 500-foot tower at 0540 hours on September 2, 1957. At the time of the first survey, fallout of 1 R/h was detected as far as 2,750 meters northwest of ground zero. Exercise Desert Rock activities at GALILEO, which involved 295 individuals, included a troop test and two technical service projects. The troop test, conducted by the Human Resources Research Office (HumRRO), was to monitor the performance of persons who had witnessed a nuclear detonation for the first time.

Immediately after witnessing GALILEO, troops performed a rifle disassembly/assembly to test their reactions. They then went to the SMOKY trench area, where they performed the infiltration course test. Film badge records suggest that only 110 of the 167 servicemen scheduled to participate actually took part in the troop test. Eighty-six of these were test troops, and seven were troop monitors who were to supplement the HumRRO monitors who had left early. The remaining 17 probably also assisted in the HumRRO team as monitors.

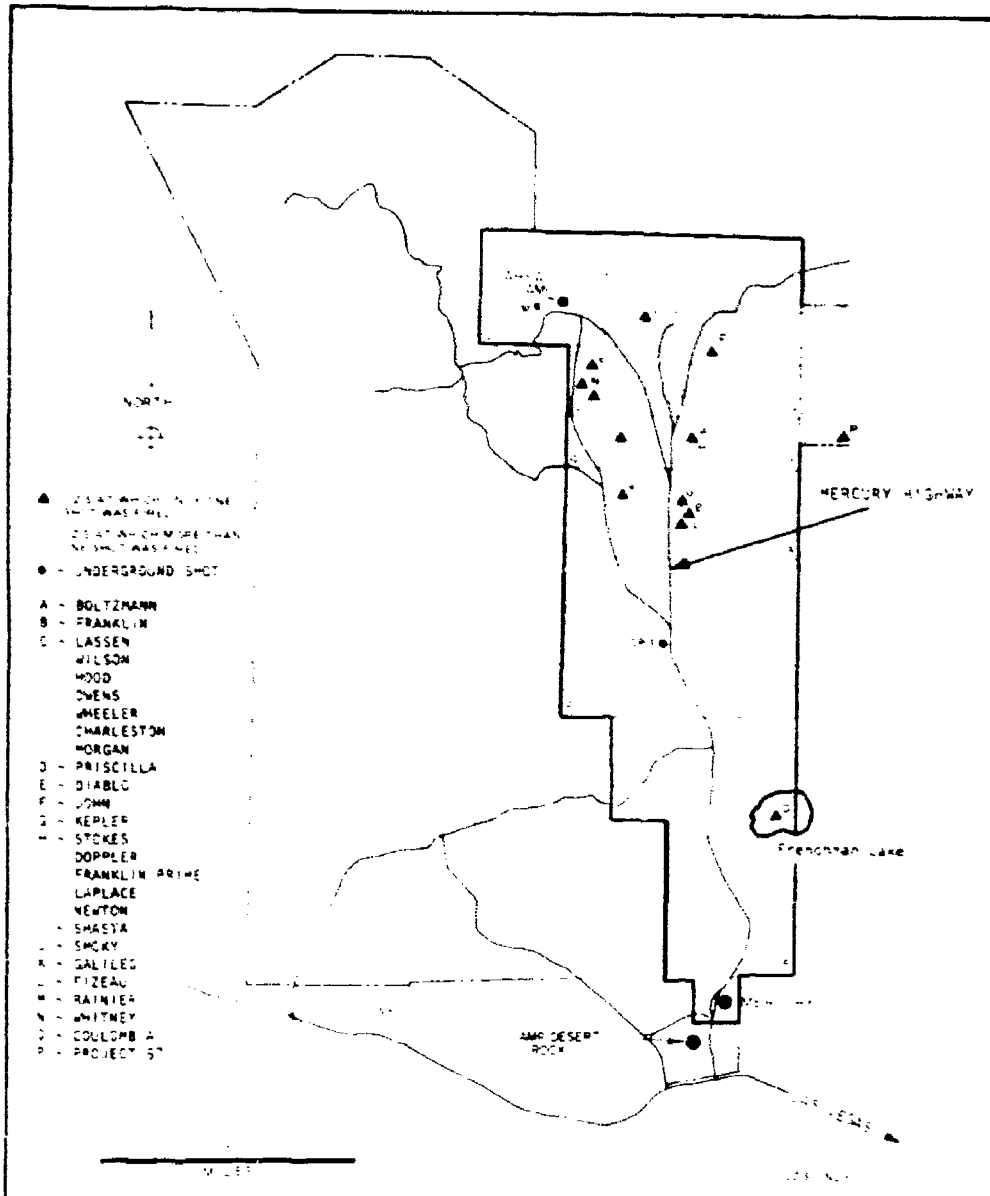
SUMMARY OF OPERATION PLUMBBOB EVENTS (1957)*

Shot	Sponsor	Date	Local Time	Type	Height of Burst (ft)	Actual Yield
PROJECT 57	AEC	April 24	0627 PST	Surface	0	0
BOLTZMANN	LASL	May 28	0455 PDT	Tower	500	12KT
FRANKLIN	LASL	June 2	0455 PDT	Tower	300	140 tons
LASSEN	UCRL	June 5	0445 PDT	Balloon	500	0.5 tons
WILSON	UCRL	June 18	0455 PDT	Balloon	500	10KT
PRISCILLA	LASL DOD	June 24	0630 PDT	Balloon	700	37KT
COULOMB A (Safety Experiment)	LASL	July 1	1030 PDT	Surface	0	0
HOOD	UCRL	July 5	0440 PDT	Balloon	1500	74KT
DIABLO	UCRL	July 15	0430 PDT	Tower	500	17KT
JOHN	DOD	July 19	0700 PDT	Air to Air Missile	18 500	< 2KT
KEPLER	LASL	July 24	0450 PDT	Tower	500	10KT
OWENS	UCRL	July 25	0630 PDT	Balloon	500	9.7KT
PASCAL A (Safety Experiment)	LASL	July 26	0100 PDT	Shaft	500	slight
STOKES	LASL	Aug 7	0525 PDT	Balloon	1500	19KT
SATURN (Safety Experiment)	UCRL	Aug 9	1800 PDT	Tunnel	100	0

*Four safety experiments (PASCAL C, COULOMB C, VENUS, and URANUS) were conducted at NTS for Project 58 between the end of PLUMBBOB testing in October 1957 and the start of HARDTACK II in September 1958.

SUMMARY OF OPERATION PLUMBBOB EVENTS (1957) (Continued)

Shot	Sponsor	Date	Local Time	Type	Height of Burst (ft)	Actual Yield
SHASTA	UCRL	Aug 18	0500 PDT	Tower	500	17KT
DOPPLER	LASL	Aug 23	0530 PDT	Balloon	1500	11KT
PASCAL B Safety Experiment	LASL	Aug 27	1535 PDT	Shaft	500	0.3KT
FRANKLIN PRIME	LASL	Aug 30	0540 PDT	Balloon	750	4.7KT
SMOKY	UCRL	Aug 31	0530 PDT	Tower	700	44KT
GALILEO	LASL	Sept 2	0540 PDT	Tower	500	11KT
WHEELER	UCRL	Sept 6	0545 PDT	Balloon	500	197 tons
COULOMB B Safety Experiment	LASL	Sept 6	1305 PDT	Surface	0	300 tons
LAPLACE	LASL	Sept 8	0600 PDT	Balloon	750	1KT
FIZEAU	LASL	Sept 14	0945 PDT	Tower	500	11KT
NEWTON	LASL	Sept 16	0550 PDT	Balloon	1500	12KT
RAINIER	UCRL	Sept 19	1000 PDT	Tunnel	880	1.7KT
WHITNEY	UCRL	Sept 23	0530 PDT	Tower	500	19KT
CHARLESTON	UCRL	Sept 28	0600 PDT	Balloon	1500	12KT
MORGAN	UCRL	Oct 7	0500 PST	Balloon	500	8KT



NEVADA TEST SITE

NOTE THE BOUNDARY BETWEEN AREAS 1 & 3 AND AREAS 4 & 7 IS MERCURY HIGHWAY, THE NORTH-SOUTH ROAD SHOWN TRAVERSING THOSE AREAS. THE BOUNDARY BETWEEN AREA 2 AND AREA 9 LIES ALONG THE CENTER OF THE THREE ROADS SHOWN.

PREFACE

Between 1945 and 1962 the Atomic Energy Commission (AEC) carried out some 235 atmospheric nuclear tests, principally in Nevada and in the Pacific. An estimated 220,000 Department of Defense (DOD) personnel, military and civilian, participated in this testing.

Until 1977 there was no indication that former test participants were experiencing any adverse health effects which might be attributable to exposure to ionizing radiation at the tests. In 1977 the Center for Disease Control (CDC)* discovered a possible leukemia cluster among participants in shot SMOKY, Nevada, 1957. By late 1977 a DOD ad hoc committee, working together with CDC, had reconstructed a list of those present at SMOKY and identified nine leukemia cases from among the 3200-odd DOD participants. CDC calculations showed that the expected incidence of leukemia should be three to four cases. CDC undertook an epidemiological study to investigate the cause of these leukemias. On a broader scale, the CDC data show that among SMOKY participants, the total number of deaths from all causes is about that which would be normally expected.

Responding to this initial indication of a possible health problem, DOD in December 1977 began a program of wide-ranging actions on behalf of the atmospheric nuclear test participants. The Defense Nuclear Agency (DNA) was appointed DOD's executive agent for this effort. The program established by DNA to carry out these responsibilities is termed the Nuclear Test Personnel Review (NTPR) program.

NUCLEAR TEST PERSONNEL REVIEW PROGRAM

First, the NTPR program conducts extensive research to retrieve every bit of data about personnel participation and radiation exposure that can be recovered from records, archives, repositories, files, etc., throughout the U.S. and piece it together into a coherent, personnel-oriented history of the atmospheric test program. The result is a bookshelf of volumes, organized by

---

*The CDC is a part of the Department of Health and Human Services.

series and shot, showing who was there, what they were doing, what radiological safety precautions were taken, what radiation doses individuals received, etc.

Second, in the process of this research, the NTPR program declassified documents which formerly bore a security classification, and reprinted, catalogued, and assembled these historical documents for easy reference by former participants, the Veterans Administration (VA), and others.

Third, the NTPR program calculated or estimated atmospheric test radiation exposures, both as a check on film badge readings and as a substitute for those cases where badges were not worn or readings were not recorded or are not retrievable.

Fourth, the NTPR program established personal contact with as many test participants as possible through a nationwide public information program, toll-free telephone lines, return letters, interaction with the VA, and development of a permanent, computerized data base.

Fifth, the NTPR program identified individuals who received doses higher than today's Federal guidelines, notified them of their exposure level, and offered them free medical examinations at Government hospitals.

Sixth, the NTPR program, in conjunction with the Department of Energy (DOE), funded an extensive morbidity/mortality study by the National Academy of Sciences (NAS) of about 40,000 test participants selected by the NAS. The purpose of this study was to determine whether there was an increased incidence of disease among these individuals. It should be noted that even 20-35 years after some 220,000 DOD personnel participated in the atmospheric test program, the only indication that there might have been an increased health risk associated with test participation was CDC's identification of nine leukemia cases among participants in shot SMOKY, where the normal incidence would have been between three and four. (And, as stated above, CDC did not attribute this leukemia to exposure to ionizing radiation.)

Finally, the NTPR program provided assistance to veterans, the VA, and other organizations by doing individual research and providing as complete data as possible on individual participation and radiation doses.

Thus, the overall NTPR effort served a major function of assisting test participants and other interested parties to ascertain, in as much depth as possible, the details of their participation. This report is the history for testing programs executed during the Operation PLUMBBOB test series. Radiation control policies, procedures, and requirements are discussed as implemented across the series of tests. Also included are references to those individual shot volumes which illustrate particular activities.

METHODS AND SOURCES USED TO PREPARE THIS VOLUME

The Defense Nuclear Agency compiled information for this volume by examining available documents which record the military operations and scientific activities performed during Operation PLUMBBOB, the atmospheric nuclear weapons tests conducted in 1957. These records, most of which were developed by individuals and organizations participating in the tests, are kept in over three dozen document repositories throughout the United States.

In compiling information for this report, teams of historians, health physicists, radiation specialists, and information analysts canvassed document repositories known to contain materials on atmospheric nuclear weapons tests conducted in the southwestern U.S. These repositories include armed services libraries, Government agency archives and libraries, Federal repositories, and libraries of scientific technical laboratories. The teams examined large amounts of both classified and unclassified documents containing information on DOD participation in Operation PLUMBBOB. Researchers recorded relevant information concerning the activities of DOD personnel during PLUMBBOB, and catalogued the data sources in an automated database for easy cross-referencing and retrieval. The following document repositories held the most information on Operation PLUMBBOB.

- Defense Nuclear Agency Technical Library, Alexandria, Virginia
- Los Alamos Scientific Laboratory, Los Alamos, New Mexico
- Department of Energy, Nevada Operations Office, Las Vegas, Nevada
- U.S. Air Force Weapons Laboratory Archives, Kirtland AFB, Albuquerque, New Mexico
- U.S. Air Force Special Weapons Center (AFSWC) - Air Force Weapons Laboratory Technical Library, Kirtland AFB, Albuquerque, New Mexico
- Modern Military Branch, National Archives, Washington, D.C.
- Defense Atomic Support Agency Information Center, Santa Barbara, California.

Most documents pertaining specifically to DOD involvement during PLUMBBOB were found in the Defense Nuclear Agency's Technical Library, the Department of Energy's Nevada Operations Office, the Los Alamos Scientific Laboratory, and the Modern Military Branch of the National Archives. The significant documents (all cited in the Reference List) used in the development of this report included:

- Final Report of Operations for Exercise Desert Rock VII and VIII.
- Report of the Test Director, PLUMBBOB
- Report of the Test Manager, PLUMBBOB
- Test Director's Operation Plan and schedule of events for PLUMBBOB
- Exercise Desert Rock VII and VIII operation orders and After-action Reports
- Analysis of Radiation Exposure for Troop Observers, Exercise Desert Rock VII and VIII, Operation PLUMBBOB, prepared by the Defense Nuclear Agency

- Air Force Special Weapons Center Report of the 4925th Test Group (Atomic) at PLUMBBOB
- Air Mission Summary Reports
- Radiological Safety Report, prepared for the Nevada Test Organization by Reynolds Electrical and Engineering Company, Inc.
- PLUMBBOB AFSWP Operation Summary Report
- Weapons Test Reports for the Armed Forces Special Weapons Project
- Compilation of Local Fallout Data from Test Detonations 1945-1962.

Gathering data for this study presented a variety of challenges. Many different military and civilian organizations were involved in developing and storing records related to Operation PLUMBBOB. Each branch of the armed services and each civilian organization had its own system of recording information. Much material was never preserved, probably because it was not considered important at the time. Other records have been transferred from one repository to another, and accounts of the transfer of documents are not always available.

Frequently, the surviving historical documentation of activities conducted during Operation PLUMBBOB addresses test specifications and technical information rather than the personnel data critical to the study undertaken by the Nuclear Test Personnel Review. Moreover, instances have arisen in which available historical documentation has revealed inconsistencies in factual data, such as the number of DOD participants in a certain project at a given shot or their locations and assignments at a given time. These inconsistencies in data usually occur between two or more documents, but occasionally appear within the same document. Efforts have been made to resolve these data inconsistencies wherever possible, or to otherwise bring them to the attention of the reader.

ORGANIZATION OF THE PLUMBBOB SERIES REPORTS

This volume details participation by DOD personnel in Operation PLUMBBOB, the sixth atmospheric nuclear weapons testing series conducted at the Atomic Energy Commission's Nevada Test Site. Seven other shot volumes address DOD activities during the various detonations of the PLUMBBOB series:

- First Four Tests, BOLTZMANN - WILSON
- PRISCILLA
- HOOD
- Mid-Series Tests, DIABLO - FRANKLIN
- SMOKY
- GALILEO
- Final Eight Tests, WHEELER - MORGAN

All volumes addressing the test events of Operation PLUMBBOB have been designed for use with one another. This series volume, for example, includes a description of the historical context of the atmospheric nuclear weapons test program in general and the 1957 PLUMBBOB series in particular, a discussion of the operation's overall objectives, a description of the geographic layout of the Nevada Test Site, organizational relationships, general radiation safety procedures, and an appendix listing of all test programs. It contains information which applies to those dimensions of the operation which transcend specific events. The shot volumes, on the other hand, contain little of this general information on PLUMBBOB, since such matters apply to all events of the series rather than to any single shot. Similarly, this volume contains a bibliography of all works consulted in the preparation of the eight Operation PLUMBBOB reports, while the shot volumes and multi-shot volumes contain a bibliography only of the sources referenced in each of these texts.

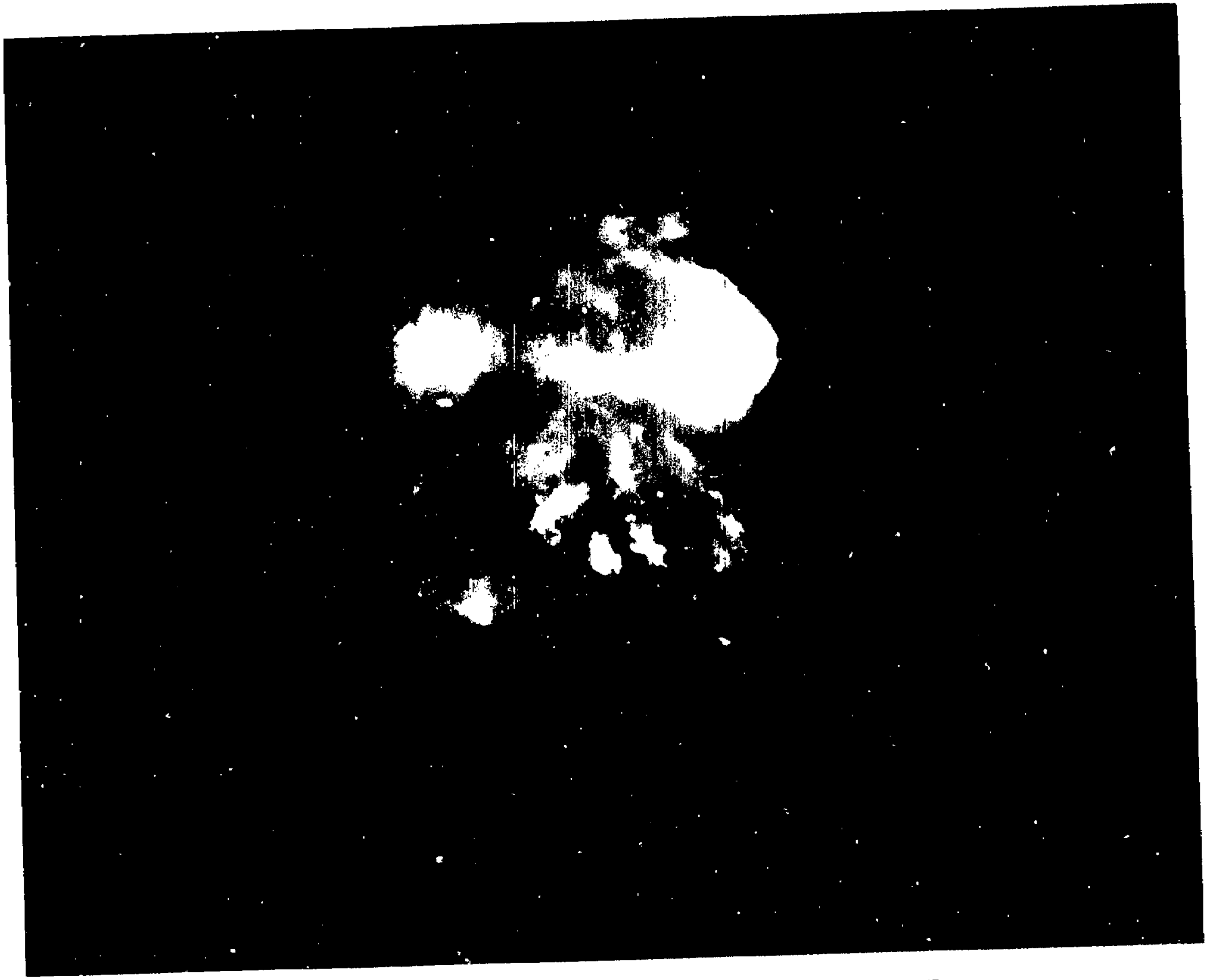


Figure 1. SHOT WILSON, 18 JUNE 1957.

Figure 2. SHOT PRISCILLA, 24 JUNE 1957.

U.S. ARMY PHOTO.

Figure 3. SHOT HOOD, 5 JULY 1957.

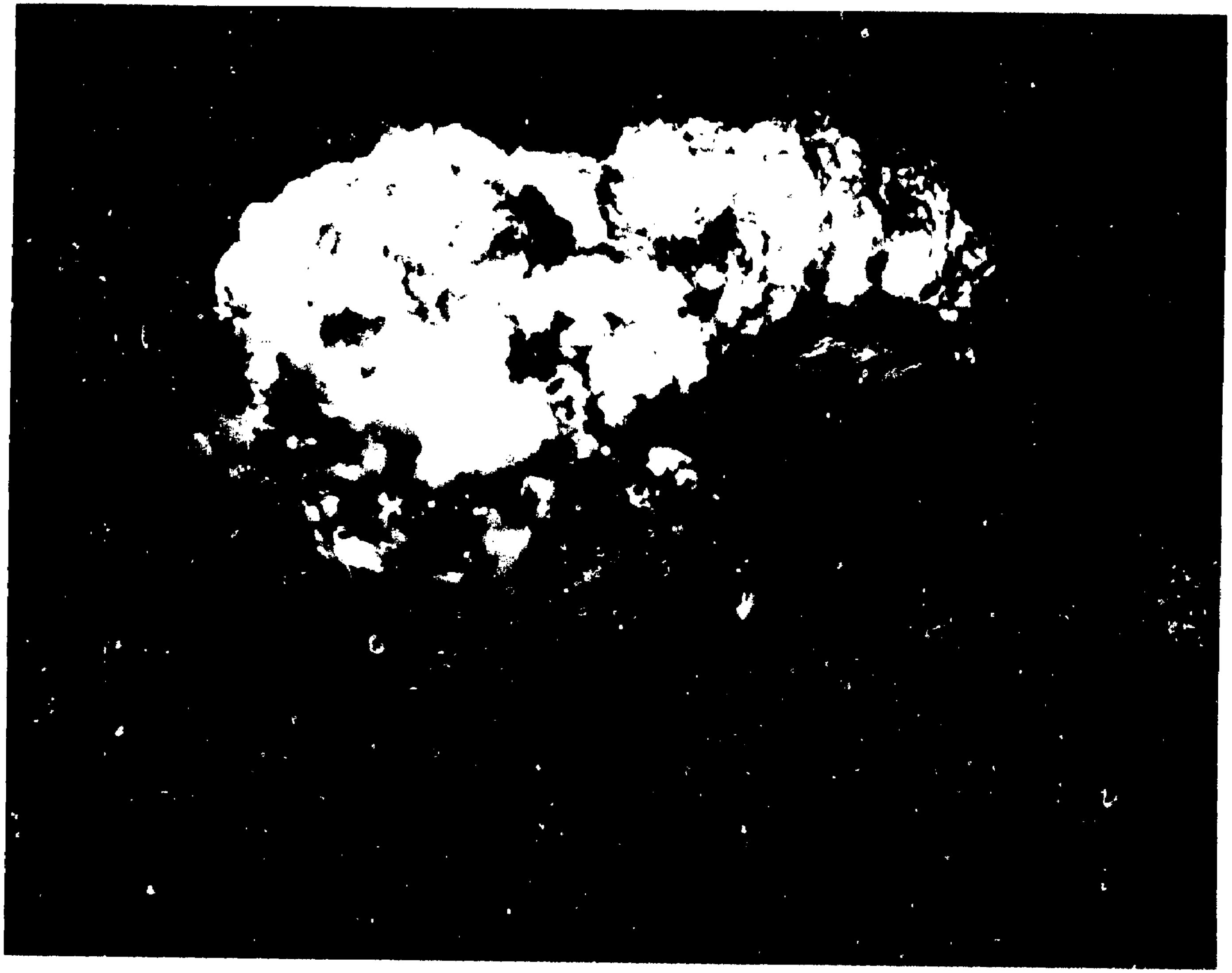


Figure 4. SHOT KEPLER, 24 JULY 1957.

Figure 5. SHOT OWENS, 25 JULY 1957.

TABLE OF CONTENTS

PAGE

PAGE

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(Continued)

LIST OF ILLUSTRATIONS
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

ACRONYMS AND ABBREVIATIONS

The following is a list of the acronyms and abbreviations frequently cited in this volume:

AEC	Atomic Energy Commission
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
CDR	Camp Desert Rock
CETG	Civil Effects Test Group
DASA	Defense Atomic Support Agency
DNA	Defense Nuclear Agency
DOD	Department of Defense
DOE	Department of Energy
EDR	Exercise Desert Rock
EG&G	Edgerton, Germeshausen, and Grier
FCDA	Federal Civil Defense Administration
FCSU	Field Command Support Unit
FCWT	Field Command Weapons Test
GZ	Ground Zero
HumRRO	Human Resources Research Office
LASL	Los Alamos Scientific Laboratory
NASWF	U.S. Naval Air Special Weapon Facility
NTO	Nevada Test Organization
NTPR	Nuclear Test Personnel Review
NTS	Nevada Test Site (formerly Nevada Proving Ground)
Radex	Radiological exclusion
Rad-safe	Radiological safety
REECo	Reynolds Electrical and Engineering Company
UCRL	University of California Radiation Laboratory
USAF	United States Air Force

Measurements

Ci	Curie
cps	cycles per second
D-day	day of detonation
D-1 day	day before detonation
D+1 day	day after detonation
H-hour	hour of detonation
H-1 hour	hour before detonation
H+1 hour	hour after detonation
kt	kilotons (lower case = weight)
KT	kilotons (upper case = yield)
Mc	megacycles
MCi	megacuries
mR	milliroentgen
mR/h	milliroentgen/hour
mrem	millirem
R	roentgen
R/h	roentgen/hour
rem	roentgen-equivalent-mammal
μg	micrograms

CHAPTER 1
INTRODUCTION

1.1 PURPOSE OF THIS REPORT

This report is about Department of Defense (DOD) personnel involvement in the atmospheric nuclear weapons test series, Operation PLUMBBOB, which took place at the Nevada Test Site in 1957. This volume deals with why the testing took place, the activities and safety measures, the procedures used to limit or control exposure of personnel to ionizing radiation, the activities that may or may not have resulted in personnel exposure to radiation, and an analysis and summary of the ionizing radiation exposures received by various military units. This report serves to assist test participants and other interested parties in ascertaining, to as much depth as possible, details of individual participation. Additionally, it is an instrument to assist scientific research, the Veterans Administration, and the public as a historical account of the PLUMBBOB series of atmospheric nuclear weapons tests.

1.2 HISTORICAL BACKGROUND

From 1945 to 1962, the United States conducted a number of nuclear weapons series in the continental United States. The sixth series was Operation PLUMBBOB, the first test conducted on 24 April 1957 and the last on 7 October 1957.

Progression of the U.S. nuclear test program had a direct link with United States defense policy, aimed at keeping the United States competitive in the nuclear arena and secure in its place as a world leader. With emergence of the USSR as a nuclear rival in 1949, the U.S. had strong motivation for continuing, and even intensifying, its test program.

Despite this impetus, however, a counter-movement was emerging. It began in 1954, after some of the inhabitants of the Marshall Islands were accidentally exposed to fallout. At that time, Prime Minister Nehru of India proposed a cessation of tests (130).* The call for a "test ban" figured repeatedly

*All sources cited in the text are listed alphabetically by author in the Reference List, appended at the back of this volume. The number given within the citation in the text is the number of the source document in the Reference List.

in disarmament discussions, most importantly, those of the Disarmament Subcommittee of the U.N. Disarmament Commission. The Disarmament Commission was in session from 18 March to 6 September 1957 at the same time that PLUMBBOB was being conducted--May to October 1957. Thus, as the PLUMBBOB series went forward, the international effort was turning toward cessation of future testing.

However, the test ban did not take place in 1957 because of the seemingly irreconcilable differences between the U.S. and the Soviet positions. The Subcommittee's discussions ended in September 1957 with no significant movement from either side. As background for test program decisions, however, it is important to note that 1957 was a year charged with controversy over the future of nuclear testing.

1.3 PURPOSE OF OPERATION PLUMBBOB

On 21 December 1956, after a year of AEC, DOD and FCDA* planning, Lewis Strauss, Chairman of the AEC, requested Presidential approval for Operation PLUMBBOB, then termed PILGRIM (Figure 1-1). The letter requesting approval listed the primary objectives of PLUMBBOB. (299) In view of the scientific and political situation described above, the letter thus indicates how PLUMBBOB might advance the U.S. position. The primary objectives were as follows:

- To proof test a weapon for desired military characteristics before it enters the national stockpile.
- To provide a firm basis for undertaking the extensive engineering and fabrication efforts which must be expended to carry a "breadboard" model to a version satisfactory for stockpile purposes.
- To demonstrate the adequacy, inadequacy, or limitations of current theoretical approaches.
- To explore phenomena which can vitally affect the efficiency and performance of weapons but which are not susceptible to prior theoretical analysis of sufficient certainty.

*Atomic Energy Commission, Department of Defense, and Federal Civil Defense Administration, respectively.

December 21, 1956

Dear Mr. President:

A number of nuclear devices for early entry into our defense stockpile, or important to the most rapid advancement of later weapons designs, will require testing in calendar year 1957. Such tests would include:

a. The proof-firing of certain air defense and anti-submarine warheads scheduled for early production....

b. Development tests of components and mockups which provide design information for thermonuclear devices, which we plan to test in the Eniwetok Proving Ground in 1958. These include...devices directed toward a higher yield-to-weight ratio.

c. Exploratory and development tests directed toward achieving more efficient use of active material and warheads of smaller size and weight.

d. A deep underground test designed to explore this manner of testing. This testing technique would guarantee no off-site fallout and would furnish information of importance to several new possible applications of atomic weapons.

In addition, the Department of Defense and the Federal Civil Defense Administration have indicated a need to secure from any test series in 1957 certain effects data important to the protection of our people and military forces. A portion of this data can be secured from diagnostic shots. However, two special shots designed specifically to secure such effects information may be required, one of which would be a Department of Defense test involving an air-burst of the nuclear warhead in the new USAF air-to-air rocket following its launching from an interceptor aircraft.

Finally, it will be necessary during the year to conduct certain safety tests--tests wherein the high explosive is detonated in an asymmetrical manner to prove that no nuclear reaction will occur if the weapon, while safed, is subjected to fire or accident, and to determine the extent of local contamination which might result from the spread of nuclear material from weapons involved in fire or accident.

Approximately 25 nuclear shots, together with five or more safety tests, may be required during the year. The first nuclear device would be detonated on or about May 1, 1957, and it is estimated that all nuclear shots would be fired in a period of the order of five months. The safety tests, from which no nuclear reaction is expected, would be fired on an "as needed" basis throughout the year.

The operation would be designated PILGRIM. So as to avoid hazard to participants or the public, shots will be limited in yield, will be fired only under favorable weather conditions and will be implaced so as to minimize local fallout. Larger shots of the series will be detonated generally at higher altitudes than those for past shots of comparable yield. The expected local fallout from such shots should be reduced materially thereby.

It is not possible at the present moment to specify exactly what shots are to be fired. This information is now being developed by the laboratories which are studying intensively the detailed results from REDWING and laying their plans for PILGRIM. It is our intention, however, to finalize a schedule as early as possible and immediately thereafter to request your approval for the expenditure of the necessary special nuclear material.

In the meantime, it is necessary that major preparations proceed. These include the mobilizing of forces at the proving ground and the inauguration of necessary construction. Importantly, too, it should involve the informing of the public in the area and others possibly affected, such as the photographic industry, of the timing of our series.

We request your approval, therefore, for the conduct of the tests on the scale and in a manner as we have described above. As soon as practical after receipt of your approval, it is our intent to issue a brief public announcement as to our plan for the conduct of tests at the Nevada Test Site during calendar year 1957.

Respectfully yours,

Chairman

The President
The White House

I approve the conduct of Operation PILGRIM on the scale and in the manner outlined above, and authorize the issuance of a suitable public announcement of plans for tests at the Nevada Test Site during calendar year 1957.

Dwight D. Eisenhower Dec 23 1956

Figure 1-1. LETTER TO PRESIDENT EISENHOWER FROM CHAIRMAN OF AEC, WITH PRESIDENTIAL APPROVAL FOR PLUMBBOB.

Operation PLUMBBOB was to be an integral part of the continuing national program for developing the means to conduct nuclear warfare in defense of the nation. Largely a joint AEC/DOD operation, the program had objectives which ranged beyond those listed in the letter. The AEC needed to test a number of nuclear devices scheduled for early production for the defense stockpile or those important to the design of improved weapons. One test (RAINIER) was conducted underground to contain the radioactive material resulting from the detonation; in this way, detonation of the device--and the instrumentation involved with it--would be freed from the constraints of weather. (Weather caused a number of delays in shots conducted above ground due to concern over the extent of fallout.)

One special program should be noted here: the AEC's safety tests, which arose from the military's need to handle large numbers of nuclear weapons in the field. These tests were planned to ensure that no nuclear reaction will occur if the high explosive components in a weapon are accidentally detonated, as in a fire or accident. Another part of the program was to determine what contamination might result from the spread of nuclear materials from such an accident.

DOD used the test series to continue its study of military weapons effects and its training of personnel in nuclear operations. The DOD also planned a military weapons effects program involving blast and shock measurements, protection of underground structures such as missile launchers, nuclear radiation effects, and tests of service equipment. In addition, the various military services participated in Exercise Desert Rock to develop operational doctrine for use on a nuclear battlefield, provide training in essential physical protective measures, observe psychological effects of atomic explosions on individuals, and to indoctrinate participating troops and troop observers in the effects of an atomic explosion on equipment, material, and emplacements.

In addition to the AEC and DOD programs, the FCDA (Federal Civil Defense Administration) participated in PLUMBBOB as part of its mission to protect the civilian population in the event of nuclear warfare. This program included tests of civilian shelters, studies of fallout, biological effects of blast, and other related studies.

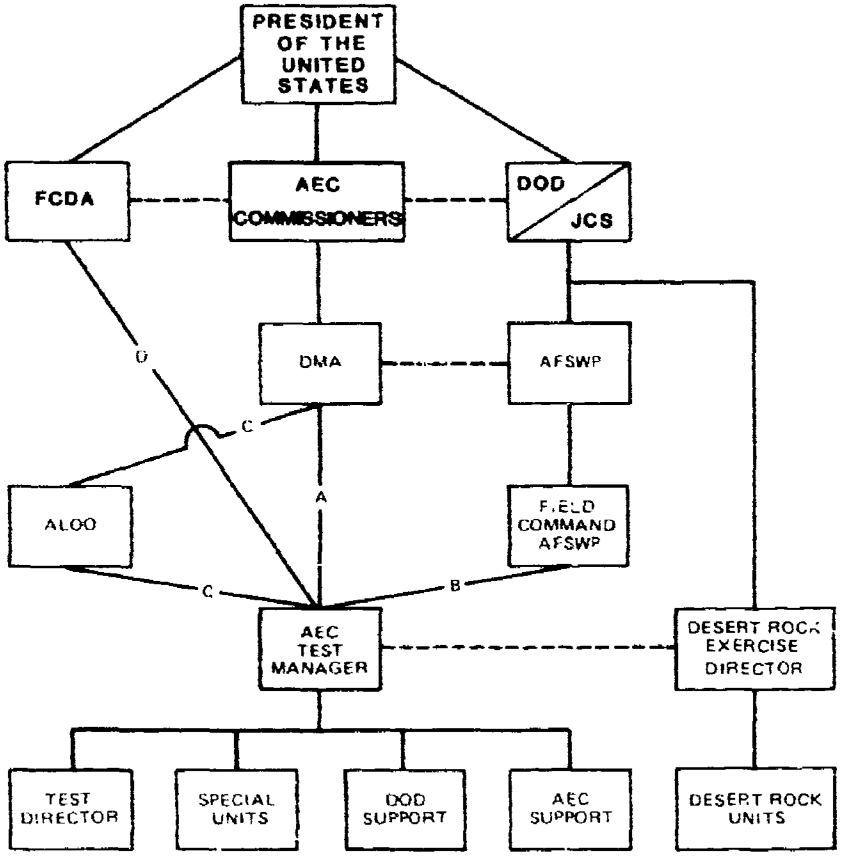
1.4 AUTHORITY

On December 28, 1956, President Eisenhower approved Operation PLUMBBOB (See Figure 1-1). Subsequently, agreements had to be formalized on the following issues:

- Use of the Nellis Bombing and Gunnery Range
- Authorization for the expenditure of nuclear materials
- Designation of the Test Manager.

AEC Staff Paper 944/8, dated February 8, 1957, cited a memo of agreement between the AEC and DOD (139). This February 1953 memo authorized use of the Nellis Bombing and Gunnery Range, one of the largest tactical fighter training areas in the world (some 7.5 million acres). On February 23, 1957, the President authorized expenditure of the special nuclear materials necessary to conduct the test series. This step was essential in order for the testing to proceed. The Test Manager for Operation PLUMBBOB was designated in a March 13, 1957 letter directive from the Albuquerque Operations Office (ALOO) (202). This letter was generated by the AEC staff paper cited above.

To control and guide the actual conduct of the joint operation, the AEC and DOD had the organizational relationship shown in Figure 1-2. As this figure and its explanatory notes show, the Division of Military Application (DMA) and the Armed Forces Special Weapons Project (AFSWP) were the executive agents for the AEC and DOD, respectively, which established the Nevada Test Site (NTS) as a joint AEC/DOD operation. The AEC General Manager directed ALOO to appoint a Test Manager and instruct him to conduct the operation. Overall directions to the Test Manager came from the AEC/DMA through ALOO. In similar fashion, the Chief of AFSWP instructed the Commander, Field Command, AFSWP, to carry out the DOD mission and appointed the Deputy Chief of Staff, Weapons Effects Tests, AFSWP, to execute the Field Command functions at the NTS. Chapter 2 will explain both taskings in detail.



---- LIAISON AND COORDINATION
A GENERAL CONDUCT AND EXECUTION OF THE ATOMIC TESTS
B EXECUTION OF DOD PROGRAMS
C AEC ADMINISTRATIVE AND CONTRACTUAL CONTROL
D EXECUTION OF FCDA PROGRAMS

NOTE THE DESERT ROCK EXERCISE DIRECTOR, WHO WAS RESPONSIBLE FOR ALL ACTIVITIES AT CAMP DESERT ROCK, WAS NOT RESPONSIBLE TO THE TEST MANAGER. INSTEAD, HE WAS RESPONSIBLE TO DOD. HIS CONNECTION WITH THE TEST MANAGER WAS ONE OF LIAISON AND COORDINATION IN ORDER TO ENSURE THAT DESERT ROCK ACTIVITIES DID NOT INTERFERE WITH THE EXECUTION OF THE NUCLEAR EVENT

Figure 1-2. ORGANIZATIONAL CHART, OPERATION PLUMBBOB.

1.5 SETTING

Nevada was chosen as the site for nuclear weapons testing because it was one of the least populated, largest, and most arid regions within the continental United States. The Nevada Test Site* was located on tableland 4-5,000 feet above sea level. It contained mountain ranges extending several thousand feet above the plateau as well as dry alkalai flats. Vegetation consisted mainly of sagebrush and other small shrubs. The climate was desertlike and inhospitable: hot during the day and cold at night with generally clear skies and slight rainfall or snow.

The site itself (Figures 1-3 and 1-4), if distinguished from the larger military reservation later known as the Nellis Air Force Range and Nuclear Testing Site, is a rectangular area toward the center of southern Nevada. Its southeast extremity is about 65 miles* northwest of Las Vegas (Figure 1-5). This map shows two settlements at the site: Mercury and Desert Rock, which housed the NTO and EDR personnel, respectively. The peak population at Camp Mercury (in Area 23) during PLUMBBOB was 3,500. The living area is a permanent installation, registered with the U.S. Post Office as Mercury, Nevada. It was built by the Atomic Energy Commission after Operation RANGER in 1951, the first use of the Nevada Test Site. By 1957 sixteen dormitories, including two for women, and many other buildings had been added.

A few miles to the southwest was Camp Desert Rock, a temporary base of the U.S. Sixth Army out of Camp Irwin, California. Desert Rock was established to accommodate troops during tests. The peak population of the camp during PLUMBBOB was almost 5,000.

Weapons tests were staged considerably to the north of these living areas. As listed in Table 1-1, there were 24 nuclear tests and six safety experiments. The black triangles and circles on Figure 1-5 represent ground zero (GZ)

---

*Until 1955 the Nevada Test Site (NTS) was called the Nevada Proving Ground. It covered about 900 square miles of the Nellis Bombing and Gunnery Range and was located in Nye County, northwest of Las Vegas. The site was operated by the Atomic Energy Commission for the specific purpose of testing nuclear weapons. The nuclear weapons test functions of the AEC have been incorporated into the Department of Energy.

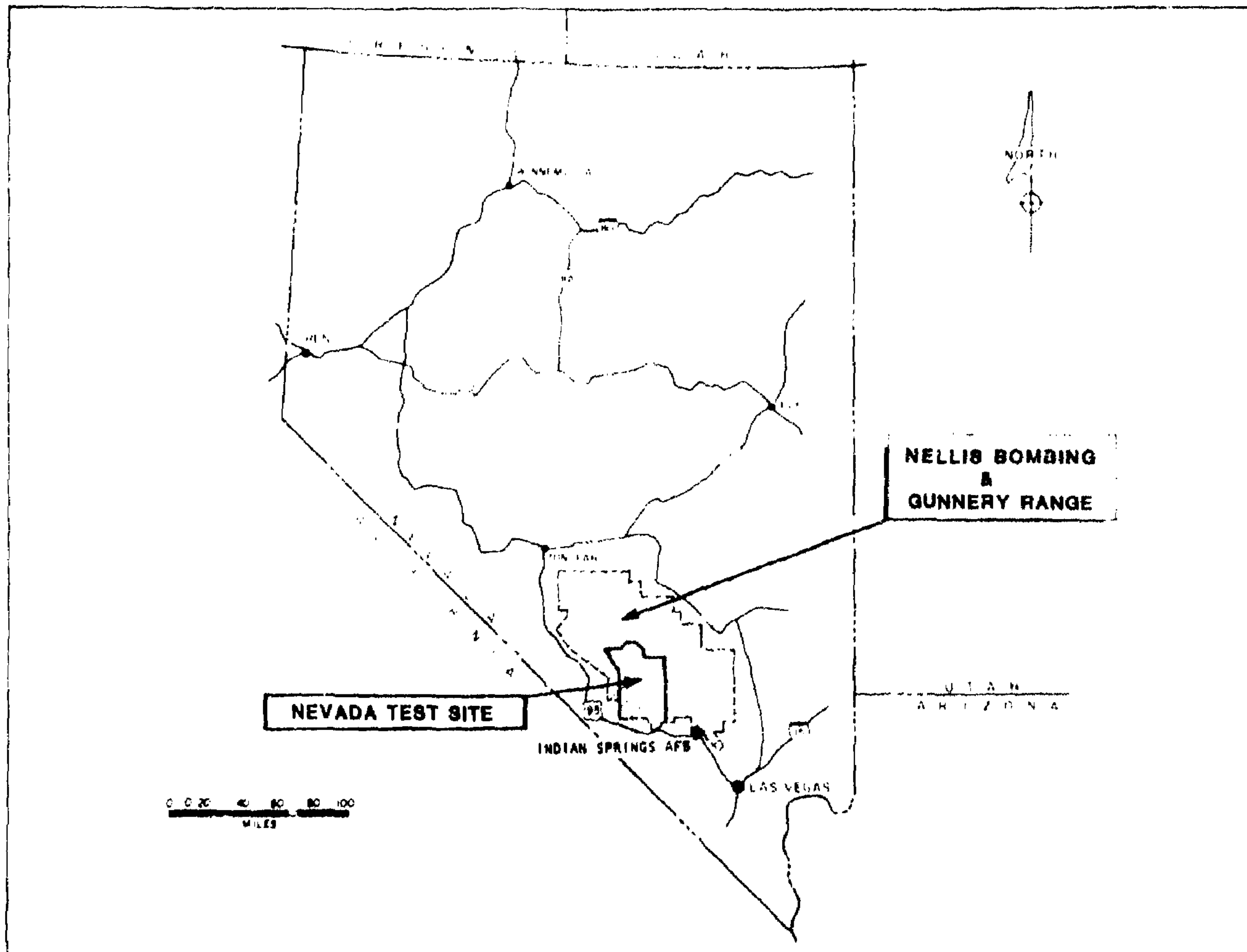


Figure 1-3. STATE OF NEVADA, SHOWING NUCLEAR TESTING AREA.

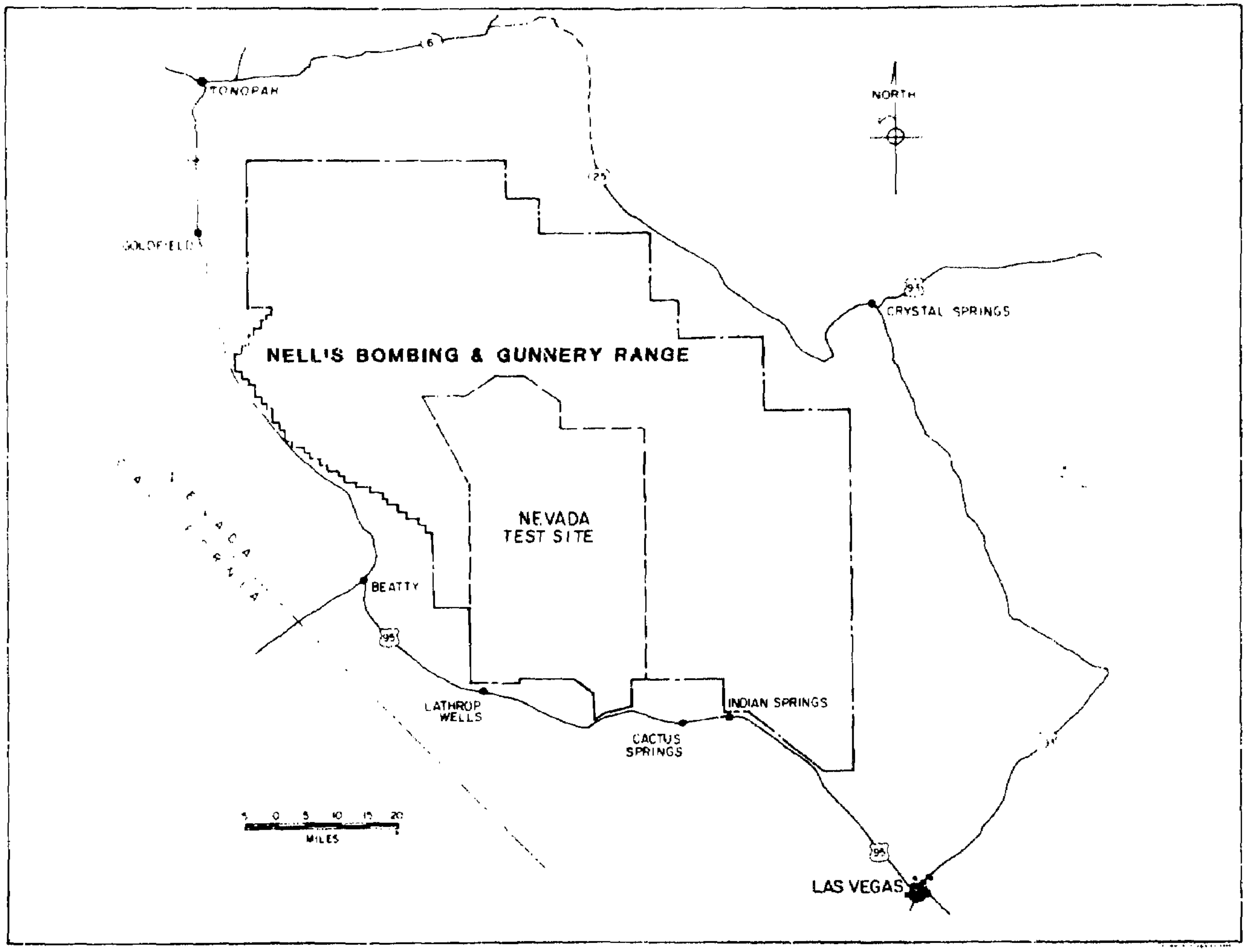
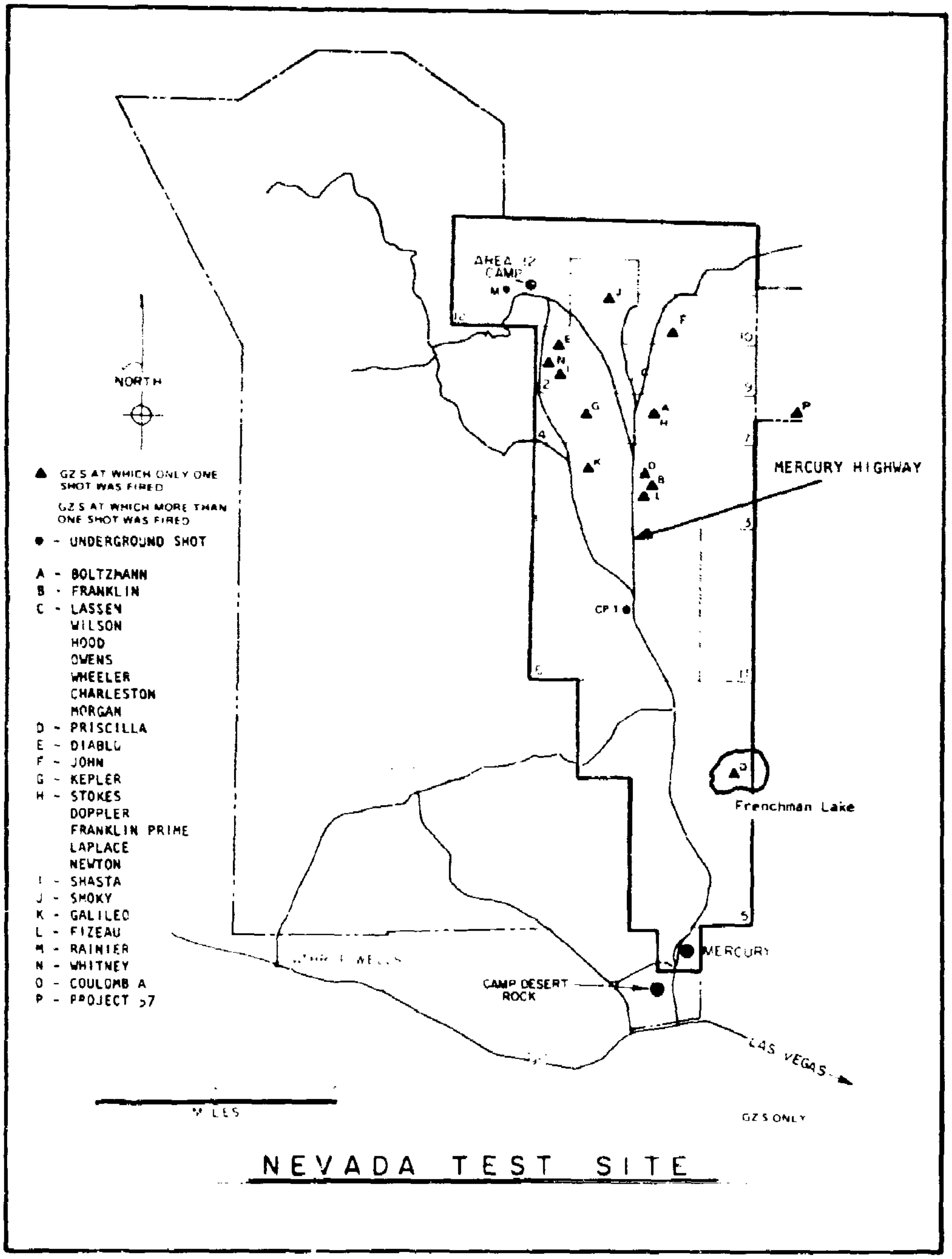


Figure 1-4. NUCLEAR TEST FACILITIES IN NEVADA.



NOTE: THE BOUNDARY BETWEEN AREAS 1 & 3 AND AREAS 4 & 7 IS MERCURY HIGHWAY, THE NORTH-SOUTH ROAD SHOWN TRAVERSING THOSE AREAS. THE BOUNDARY BETWEEN AREA 2 AND AREA 9 LIES ALONG THE CENTER OF THE THREE ROADS SHOWN.

Figure 1-5. NEVADA TEST SITE.

Table 1-1. SUMMARY OF OPERATION PLUMBBOB EVENTS (1957)*

Shot	Sponsor	Planned Date	Actual Date	Local Time	NTS Location	GZ Position (Nevada State Grid)	Type	Height of Burst (ft)	Actual Yield
PROJECT 57	AEC	April 24	April 24	0627 PST	Area 13		Surface	0	0
BOLTZMANN	LASL	May 15	May 28	0455 PDT	Area 7c	N - 854,123.9 E - 687,540.2	Tower	500	12KT
FRANKLIN	LASL	May 24	June 2	0455 PDT	Area 3 (T-3)	N - 837,026 E - 688,416	Tower	300	140 tons
LASSEN	UCRL	June 3	June 5	0445 PDT	Area B9a (B-9a)	N - 868,633 E - 682,418	Balloon	500	0.5 tons
WILSON	UCRL	June 10	June 18	0455 PDT	Area B9a	N - 868,633 E - 682,418	Balloon	500	10KT
PRISCILLA	LASL/DOD	June 23	June 24	0630 PDT	Area F	N - 746,250 E - 716,000	Balloon	700	37KT
COULOMB A Safety Experiment	LASL	July 1	July 1	1030 PDT	Area 3 (S-3h)		Surface	0	0
HOOD	UCRL	July 3	July 5	0440 PDT	Area 9 (B-9a)	N - 868,633 E - 682,418	Balloon	1500	74KT
DIABLO	UCRL	June 26	July 15	0430 PDT	Area 2 (T-2b)	N - 874,146 E - 662,634	Tower	500	17KT
JOHN	DOD	July 19	July 19	0700 PDT	Area 10	N - 877,939 E - 678,838	Air to Air Missile	18,500	< 2KT
KEPLER	LASL	July 18	July 24	0450 PDT	Area 4	N - 854,234 E - 664,464	Tower	500	10KT
OWENS	UCRL	July 17	July 25	0630 PDT	Area 9 (B-9a)	N - 868,633 E - 682,418	Balloon	500	9.7KT
PASCAL A Safety Experiment	LASL	July 26	July 26	0100 PDT	Area 3	N - 838,428 E - 684,790	Shaft	-500	slight
STOKES	LASL	July 30	Aug 7	0525 PDT	Area 7 (B-7b)	N - 851,125 E - 687,533	Balloon	1500	19KT
SATURN Safety Experiment	UCRL	Aug 9	Aug 9	1800 PDT	Area U12c		Tunnel	-100	0

*Four safety experiments (PASCAL C, COULOMB C, VENUS, and URANUS) were conducted at NTS for Project 58 between the end of PLUMBBOB testing in October 1957 and the start of HARDTACK II in September 1958.

Table 1-1. SUMMARY OF OPERATION PLUMBBOB EVENTS (1957) (Continued)

Shot	Sponsor	Planned Date	Actual Date	Local Time	NTS Location	GZ Position (Nevada State Grid)	Type	Height of Burst (ft)	Actual Yield
SHASTA	UCRL	July 30	Aug 18	0500 PDT	Area 2 (2a)	N - 866,030 E - 663,322	Tower	500	17KT
DOPPLER	LASL	Aug 19	Aug 23	0530 PDT	Area 7 (B-7b)	N - 851,125 E - 687,533	Balloon	1500	11KT
PASCAL B Safety Experiment	LASL	Aug 27	Aug 27	1535 PDT	Area 3 (U-3d)	N - 837,440 E - 684,640	Shaft	-500	0.3KT
FRANKLIN PRIME	LASL	Aug 14	Aug 30	0540 PDT	Area 7 (B-7b)	N - 851,125 E - 687,533	Balloon	750	4.7KT
SMOKY	UCRL	Aug 28	Aug 31	0530 PDT	Area 8 (T-2c)	N - 887,690 E - 674,450	Tower	700	44KT
GALILEO	LASL	Sept 2	Sept 2	0540 PDT	Area 1 (T-1)	N - 838,780 E - 644,589	Tower	500	11KT
WHEELER	UCRL	Sept 6	Sept 6	0545 PDT	Area 9 (B-9a)	N - 868,633 E - 682,418	Balloon	500	197 tons
COULOMB B Safety Experiment	LASL	Sept 6	Sept 6	1305 PDT	Area 3a (S-3g)	N - 835,204 E - 686,639	Surface	0	300 tons
LAPLACE	LASL	Sept 8	Sept 8	0600 PDT	Area 7 (B-7b)	N - 851,125 E - 687,533	Balloon	750	1KT
FIZEAU	LASL	Sept 11	Sept 14	0945 PDT	Area 3 (T-3b)	N - 831,773 E - 685,427	Tower	500	11KT
NEWTON	LASL	Sept 16	Sept 16	0550 PDT	Area 7 (B-7a)	N - 851,125 E - 687,540	Balloon	1500	12KT
RAINIER	UCRL	Sept 19	Sept 19	1000 PDT	Area 12 (U-12b)	N - 890,571 E - 635,003	Tunnel	-880	1.7KT
WHITNEY	UCRL	Sept 11	Sept 23	0530 PDT	Area 2 (T-2)	N - 869,283 E 660,103	Tower	500	19KT
CHARLESTON	UCRL	Sept 23	Sept 28	0600 PDT	Area 9 (B-9a)	N - 868,634 E - 682,418	Balloon	1500	12KT
MORGAN	UCRL	Oct 3	Oct 7	0500 PST	Area 9 (B-9a)	N 868,634 E - 682,418	Balloon	500	8KT

locations used during Operation PLUMBBOB. All were in the northern operational areas except for shot PRISCILLA on Frenchman Flat in Area 5. The single shot in Area 12 was RAINIER, an underground test. Safety tests are reported in a separate volume.

*No single, standardized set of linear dimensions is used in this report. While altitudes are generally given in feet, other distances may be in yards, meters, or variations of either. This is because the test data is taken from original sources and used exactly as researched. For those who desire different measures, the following are conversion factors:

1 foot = 0.3048 meters	1 meter = 3.2808 feet
1 yard = 0.9144 meters	1 meter = 1.0936 yards
1 mile = 1.609 kilometers	1 kilometer = 0.621 miles

CHAPTER 2

RESPONSIBILITIES OF ADMINISTRATIVE ORGANIZATIONS

The Atomic Energy Commission and the Department of Defense shared responsibility for planning and implementing the U.S. atmospheric nuclear weapons test program. The AEC was responsible for exploring and developing new areas of nuclear weapons technology, while the DOD was subsequently to incorporate the weapons into the U.S. military defense program.

The Nevada Test Organization under AEC, and Exercise Desert Rock VII and VIII under DOD, were both organized to manage the many activities associated with some 30 nuclear tests of Operation PLUMBBOB. In addition to those personnel from the DOD, participants included employees of other Federal agencies, research laboratories, and private firms under contract to the Government. Department of Defense personnel participated in most of the activities conducted during this test series. Chapter 6 of this report lists the chief organized military units participating in the Nevada Test Organization and Desert Rock exercises during Operation PLUMBBOB. However, appreciable numbers of military personnel came as individuals or in small groups from a cross-section of U.S. military installations and organizations. Overall, about twenty thousand Department of Defense personnel participated in Operation PLUMBBOB.

2.1 INTRODUCTION

The three main participating agencies in PLUMBBOB were the AEC, Federal Civil Defense Administration (FCDA), and the DOD, which was represented primarily by the Armed Forces Special Weapons Project (AFSWP). Table 2-1 summarizes the scientific programs conducted by these agencies at PLUMBBOB. Their responsibilities were:

- AEC had direct authority to conduct nuclear development tests and provided the staff for detonating all the shots.
- The FCDA measured weapons effects important to the safety of civilians in the United States during nuclear war.
- DOD, in cooperation with the AEC, measured weapons effects of military importance and conducted military training maneuvers.

Table 2-1. SUMMARY OF SCIENTIFIC PROGRAMS AT PLUMBBOB*

SPONSORING AGENCY	PROGRAM NUMBER	PERFORMING AGENCY	PURPOSE
AEC	10-19	Los Alamos Scientific Lab	Weapons Development
	21-26	Univ. of Cal. Radiation Lab.	Weapons Development
	41 & 64	Sandia Corporation	Weapons Development
	71-74	Project 57 (Sandia)	Weapons Development (Safety)
DOD	1-9	Field Command Weapons Test Group (FCWT), AFSWP †	Weapons Effects
	50	U.S. Army	Weapons Effects; Training; Operations; and Observations
	51	U.S. Navy	Weapons Effects; Training; Operations; and Observations
	52	U.S. Marine Corps	Weapons Effects; Training; Operations; and Observations
	53	U.S. Air Force	Weapons Effects; Training; Operations; and Observations
FCDA	30-39	Civil Effects Test Group (CETG)†	Weapons Effects relative to Civil Defense

*For details see Appendix A.
†The U.S. Air Force was also involved in Projects 4.1, 39.5, and 39.6.

Although AFSWP represented a major Department of Defense effort during Operation PLUMBBOB, two other DOD agencies were prominent at PLUMBBOB: the Air Force Special Weapons Center (AFSWC) and Exercise Desert Rock (EDR). Their participation is summarized as follows:

- AFSWC provided all air support for both AEC and DOD projects at the tests. In addition, AFSWC flew cloud tracking and sampling missions, security sweeps, and aerial surveys. AFSWC also provided courier and sample return service, as well as conducting air operational training projects.

- Camp Desert Rock, under the command of the Commanding General, U.S. Sixth Army, provided the support troop and garrison quarters for units participating in the Desert Rock Exercises. These exercises consisted of military troop maneuvers, technical service projects, training, and indoctrination programs; such DOD activities were performed in conjunction with the nuclear tests

Consistent with the operational directive from the AEC, the Test Manager set up the Nevada Test Organization (NTO) at Camp Mercury as a "mutually satisfactory joint organization" in collaboration with the DOD as represented by AFSWP (Figure 2-1 and see Figure 1-2). The NTO contained elements from the AEC laboratories, from DOD laboratories, the Services, and DOD agencies, and from FCDA representatives. Nearby at Camp Desert Rock, the U.S. Army set up Exercise Desert Rock VII and VIII. This was a program of troop participation and observers in Operation PLUMBBOB. Participation of this operating group in NTO activities at the test site, which was coordinated through the NTO Test Manager's Deputy for Military Matters, was to be conducted during many of the weapons tests, but on a non-interference basis. Except for this coordination, the two operating groups, NTO and EDR (Exercise Desert Rock), were essentially independent of each other. In the following sections, the AEC and DOD components of the Nevada Test Organization will be described together. The organization of Exercise Desert Rock, because it functioned so separately, is discussed thereafter.

Operational Directive

1.9 The Manager, ALOO, by memorandum dated March 13, 1957, subject: "Directive for Operation Plumbbob", designated the Assistant Manager for Test Operations, Albuquerque Operations, as Test Manager for Operation Plumbbob, with further direction as follows.

Under authority delegated to me by the Director of Military Application, in a letter dated March 1, 1957, you are hereby designated as Test Manager for Operation Plumbbob.

As Test Manager you are directed to:

a. Execute Operation Plumbbob in accordance with the general plan approved by the Commission, and including the detonation of devices incorporated in the detailed shot schedule contained in AEC 944/8. Deviation from this schedule involving the addition of shots, or the modification of shots which would increase the probability of local fallout, must be approved by the Commission.

b. Submit to the Commission for approval the Operation Plan for Plumbbob.

c. Assume over-all responsibility personally for the conduct of Operation Plumbbob, in a manner similar to that done for Operation Teapot.

d. Report to the Chief, Armed Forces Special Weapons Project, for the conduct of the programs sponsored by the Department of Defense.

e. Coordinate with the Commander, Field Command, Armed Forces Special Weapons Project, for the conduct of the programs sponsored by the Department of Defense.

f. Execute the Department of Defense sponsored programs.

g. Provide maximum assistance to the Department of Defense in carrying out their programs.

h. Coordinate the Federal Civil Defense Administration programs and render such technical and other assistance as may be required by that agency to efficiently execute its programs in Plumbbob.

i. Prepare in conjunction with the Commander, Field Command, Armed Forces Special Weapons Project, the details of a mutually satisfactory joint organization for Plumbbob and submit them to the Director, Division of Military Application and the Chief, Armed Forces Special Weapons Project for final approval.

j. Control the issuance of public information by members of the Joint Test Organization with respect to the tests in compliance with the Information Plan to be approved by the Commission for Plumbbob. Release of public information regarding Operation Desert Rock and Military Training and Observer Programs will be in general accordance with the Information Plan to be approved by the Commission.

k. Conduct Operation Plumbbob in accordance with:

(1) The approved Operational Safety Criteria and shot schedule as contained in AEC 944/8, and

(2) A Radiological Safety Criteria of 3.9 roentgens for the series for exposures of populations around the Nevada Test Site to gamma radiation from fallout, and

(3) A Radiological Safety Criteria of 3 roentgens within any consecutive 13 weeks and 5 roentgens within a period of one year, for exposures of personnel on-site at NTS to whole body gamma radiation.

l. Utilize the instructions contained in the AEC Pamphlet "Radiological Safety Criteria and Procedures for Protecting the Public During Weapons Testing at the Nevada Test Site", dated February 1955, which is currently undergoing minor revision, in developing operational measures to be taken to protect the public in fallout areas.

m. Institute an expanded off-site monitoring program as directed in memorandum from the Director, DMA, to Manager, ALOO, dated December 25, 1956.

n. Assume responsibility for supervising the implementation of the Test Manager's operational safety directives. With respect to such directives, the Test Manager may delegate to the appropriate Department of Defense representatives responsibility for implementing his general safety directives within the Nevada Test Site insofar as DOD Operation and Training Program personnel and Desert Rock personnel are concerned. Responsibility for safety of troops, troop observers and Department of Defense sponsored personnel within the area assigned by the area manager to Operation Desert Rock VII and VIII will be assumed by the Exercise Director, Desert Rock VII and VIII. Should participation by the Department of Defense in any of the above programs appear to the Test Manager to jeopardize unduly participating personnel, the Test Manager will forward the appropriate exercise plan or program with his comments to the Division of Military Application for such action as is deemed necessary and advise the appropriate Department of Defense representative of such action.

o. Execute tests pertaining to the Atomic Energy Commission's weapons development program within cost ceiling approved for the weapons program. All weapons effects projects of the Department of Defense and all Federal Civil Defense Administration projects will be funded by those agencies.

p. Obtain military support necessary to the conduct of Plumbbob through, or from, the Commander, Field Command, AFSWP.

q. Arrange a mutually satisfactory agreement with the Commander, Field Command, AFSWP, for briefing of the official observers. (The Observer Program is presently under consideration, and it is anticipated that it will be similar to the Operation Teapot Observer Program.)

r. Provide such assistance as may be required to make available facilities and equipment for the establishment of the Office of Test Information and to accommodate the on-site news media representatives who may be authorized by the Commission in their action on the Information Plan staff paper. The Office of Test Information will be headed by an Atomic Energy Commission representative designated by the Test Manager.

s. Inform the Director, Division of Military Application, by an initial report shortly after each scheduled detonation of a test device stating the device has or has not been detonated and containing any additional information available. This report should be made within 30 minutes of shot time if practicable. Forward a second report to reach the Division of Military Application by 1600 EST on shot day. This report should contain information pertaining to fallout, any unusual circumstances caused by the shot, yield information if available, and such other information as would be useful to the Commission. Submit a third report about 15 hours after the shot containing the best yield information available, radioactive fallout and off-site radioactivity information, and information regarding any unusual public reaction to the shot.

t. Designate March 15, 1957, as the effective date for the commencement of the operational period for Operation Plumbbob.

u. Designate a classification officer and establish procedures to insure that all classification of information connected with the test will be in accordance with appropriate official Classification Guides.

v. Provide necessary support for a representative of the Division of Military Application and a representative of the Division of Biology & Medicine at the NTS throughout the operation. Make arrangements to keep the DBM representative currently informed on all off-site and on-site radiological information.

w. Take every precaution, including postponement of any shot as necessary, to reduce to the minimum the hazards to the public.

Commencing March 15, 1957, the Test Manager for Operation Plumbbob will report directly to the Director of the Division of Military Application for all matters pertaining to the Operation. The long-range aspects of the administrative and fiscal functions pertaining to the Nevada Test Site will be retained by the Manager, Albuquerque Operations Office.

Figure 2-1. TEST MANAGER'S FUNCTIONS AND DUTIES.(260)

2.2 AEC AND DOD COMPONENTS IN THE NEVADA TEST ORGANIZATION

The Test Manager appointed by the Albuquerque Operations Office of the Atomic Energy Commission was responsible for the overall direction of the PLUMBBOB series. Because of their importance, his duties are listed in detail in Figure 2-1. In summary, his major taskings included planning for and execution of the test shots and associated test programs, supervision of support efforts such as radiological safety and communications, handling of public affairs (including briefing of official observers and press releases).

The NTO contained elements from both the AEC and the DOD. Thus, AEC and DOD personnel conbined to constitute the NTO's planning and advisory panels, several staff and operations groups, and large functional components. Approximately a thousand Department of Defense personnel were integrated into the NTO. The relationship between the various components of the NTO are illustrated in the organization chart of Figure 2-2. Because Desert Rock functioned separately from the NTO and its interactions were restricted to those not interfering with the tests, it is not shown on Figure 2-2 nor is it discussed in this section. It must be stressed, however, that Exercise Desert Rock was a DOD organization and was responsible to DOD authority.

To fulfill his wide range of responsibilities, the Test Manager had a variety of staff support.

- The Planning Board consisted of the Test Director, who was a scientist, and representatives from the primary organizations involved these testing programs: Los Alamos Scientific Laboratory, University of California Radiation Laboratory, Civil Effects Test Group, DOD, and the Sandia Corporation. The purpose of the board was to consider proposed nuclear tests, firing schedules, and the assignment of firing areas to the participants.

- The Advisory Panel, comprised of individuals with extensive weapons test experience, advised the Test Manager, especially with regard to the issues of safety and ramifications of executing or delaying scheduled detonations. The panel evaluated forecasts presented by the representatives of the Blast, Fallout, and Weather Pre-

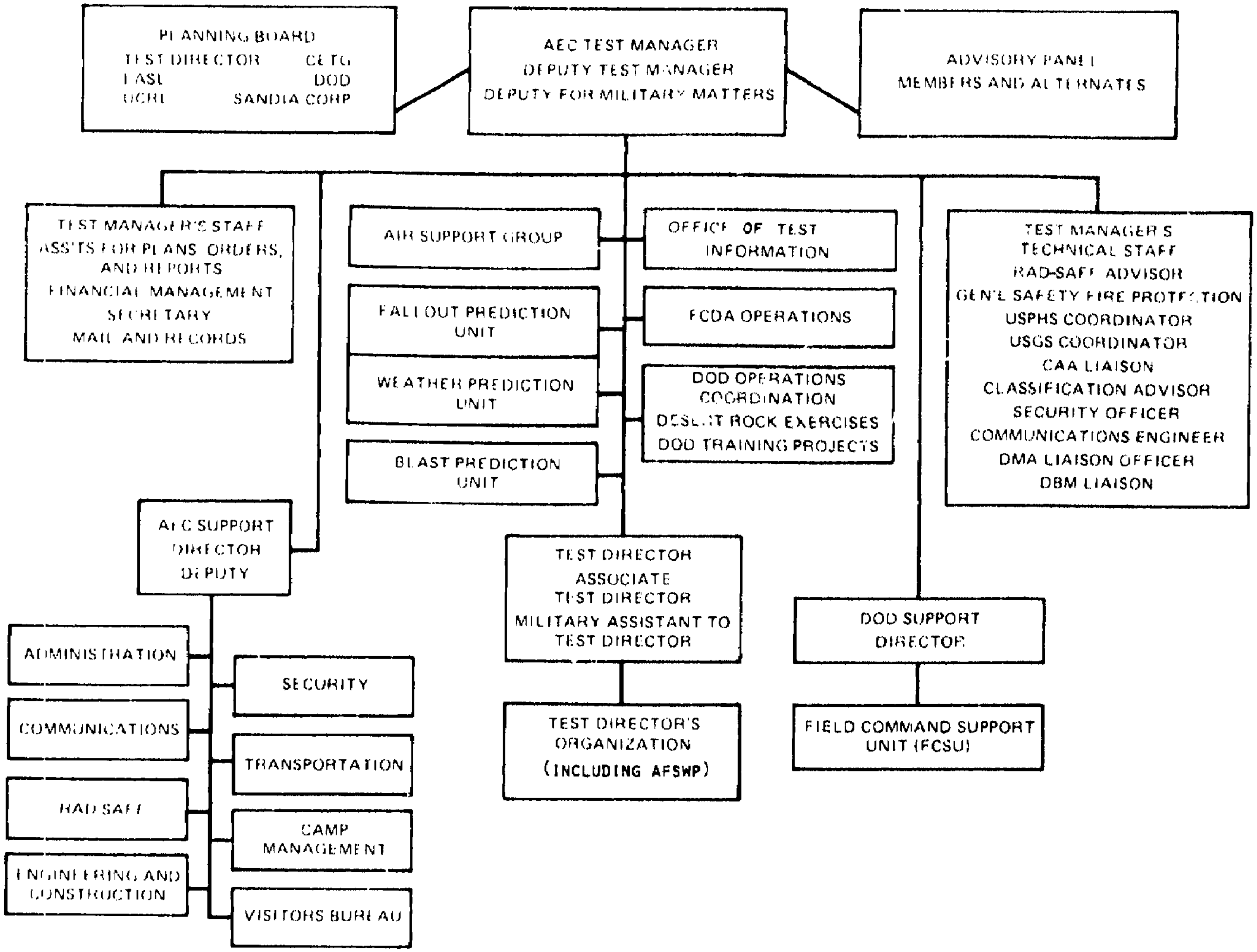


Figure 2-2. TEST MANAGER'S ORGANIZATION.

diction units. The panel also ascertained the readiness of participating scientific, technical, and support personnel for a specific detonation.

- The Test Manager's administrative staff included assistants who worked on the development of plans, orders, and reports. This staff also had financial management and secretarial functions, as well as control of mail and records.

- The Test Manager's technical staff consisted of a number of individuals with special qualifications who had advisory, coordination, liaison, and functional responsibilities in relation to the Test Manager. Included on the staff were individuals with responsibilities in the areas of Rad-safe advice, general safety and fire protection, United States Public Health Service coordination, United States Geodetic Survey coordination. Civil Aeronautics Administration liaison, classification, security, communications, and representatives of the AEC's Division of Military Applications and Division of Biology and Medicine.

Several special operational units were included in the NTO: air support, three prediction units, the Office of Test Information, FCDA Operations, and DOD Operations Coordination.

- The Air Support Group in the NTO was part of the 4950th Test Group (Nuclear) of AFSWC, Kirtland AFB. It was augmented by personnel and aircraft from several commands in the Air Force. This group served as the focal point for all air activity at PLUMBBOB. Its functions for the NTO were to collect cloud samples for later analysis following nuclear detonations, track radioactive clouds as they drifted with the wind, provide air shuttle service, and maintain air security. In addition, the Air Support group assisted the Test Director in Rad-safe surveys, aerial probe surveys, rapid return of radioactive samples to distant laboratories, photography, and other special airborne missions. The 4935th Air Base Squadron and Test Aircraft Unit were based at Indian Springs (the principal forward base about 23 miles east southeast from Camp Mercury). The Test Aircraft Unit included the 4926th Sampling Squadron plus elements from Wright Air Development Center, Naval Air Special

Weapons Facility, a cloud tracker unit, Air National Guard elements, and the tactical helicopter element which supported troop maneuvers.

- The three Prediction Units (for fallout, weather, and blast) provided technical support to the Test Manager and his Advisory Panel. These prediction units developed detailed, current information on possible effects of the shot up to the last minutes before shot time. This information allowed the Test Manager and the Advisory Panel to assess possible onsite and offsite hazards before each shot.

- The Office of Test Information conducted a program of public information for the tests by reporting on the activities at PLUMBBOB and inviting observers from the press.

- The Federal Civil Defense Administration Operations Unit oversaw execution of the Civil Effects Test Group test programs, assisted the public information program, and conducted an extensive observer program.

- The DOD Operations Coordination Group maintained official liaison between DOD personnel and the Test Manager in order to ensure that all DOD training and observer programs, including those of the Desert Rock Organization (described in Chapter 4) could be fitted into the overall program of the operation without interfering with the technical tests. It coordinated the operational training programs, military observers, and other DOD onsite activities with AEC's Test Manager.

One major administrative entity was the AEC Support Group. This provided radiological safety (Rad-safe) services at the Nevada Test Site through a contractor and was responsible for such functions as communications, engineering and construction, security, transportation, management of Camp Mercury, and control of the Visitors' Bureau. Its head, the AEC Support Director, also had the responsibility for providing Rad-safe support and for ensuring radiological safety off the Nevada Test Site. Since it coordinated contractor support, the group had its own administrative section. Additionally, the DOD Support Director had control of the Field Command Support Unit, whose mission was to provide administrative, logistical, and general support to the Field Command Weapons Test personnel who conducted the Armed Forces Special Weapons Project programs.

The Test Director handled day-to-day operations. He was head of the organization which actually fired the shots and executed the programs and tests associated with the shots. His organization is illustrated in Figure 2-3. Six test groups were included within the organization. The DOD sponsored the Field Command Weapons Test Group. The AEC sponsored the LASL, UCRL, Sandia Corporation and Project 57 programs. The FCDA sponsored the CETG programs. The Staff Coordinator, Administrative Services, Planning and Air Operations, Construction, Radiological Safety, Safety, and Classification (i.e., security) groups had functions mirrored by their designations. Because of its importance to the NTPR program, the Rad-safe group, including its organizational relationships, is described and amplified separately in Chapter 3.

The three technical support groups in the Test Director's organization were:

- The Assembly and Arming Group directly responsible for the arming of the nuclear device, and (in event of delay or misfire) the disarming of the device. Operations began with pre-dry run tests with each step highly standardized up to the final arming.
- A contract group from the Edgerton, Germeshausen, and Grier, Inc. (EG&G) Support Group provided precise timing and firing signals to the experimenters.
- The Sandia Support Group provided the balloons and facilities for the balloon shots and other technical support functions. The Sandia Corporation was responsible for suspending nuclear test devices from balloons for 13 of the PLUMBBOB tests. Balloons were used instead of towers for some tests where air bursts at a particular height of burst were desired without the perturbation of outputs associated with the use of the steel tower. This organization also conducted fireball and nuclear environmental studies.

The Atomic Energy Commission programs were executed by the two AEC design laboratories (LASL and UCRL) and by Sandia Corporation (an AEC laboratory concerned principally with development of the firing signal components for nuclear devices). During the PLUMBBOB series, 16 of the devices detonated (including safety shots) were of LASL design, while 13 were the product of UCRL. A

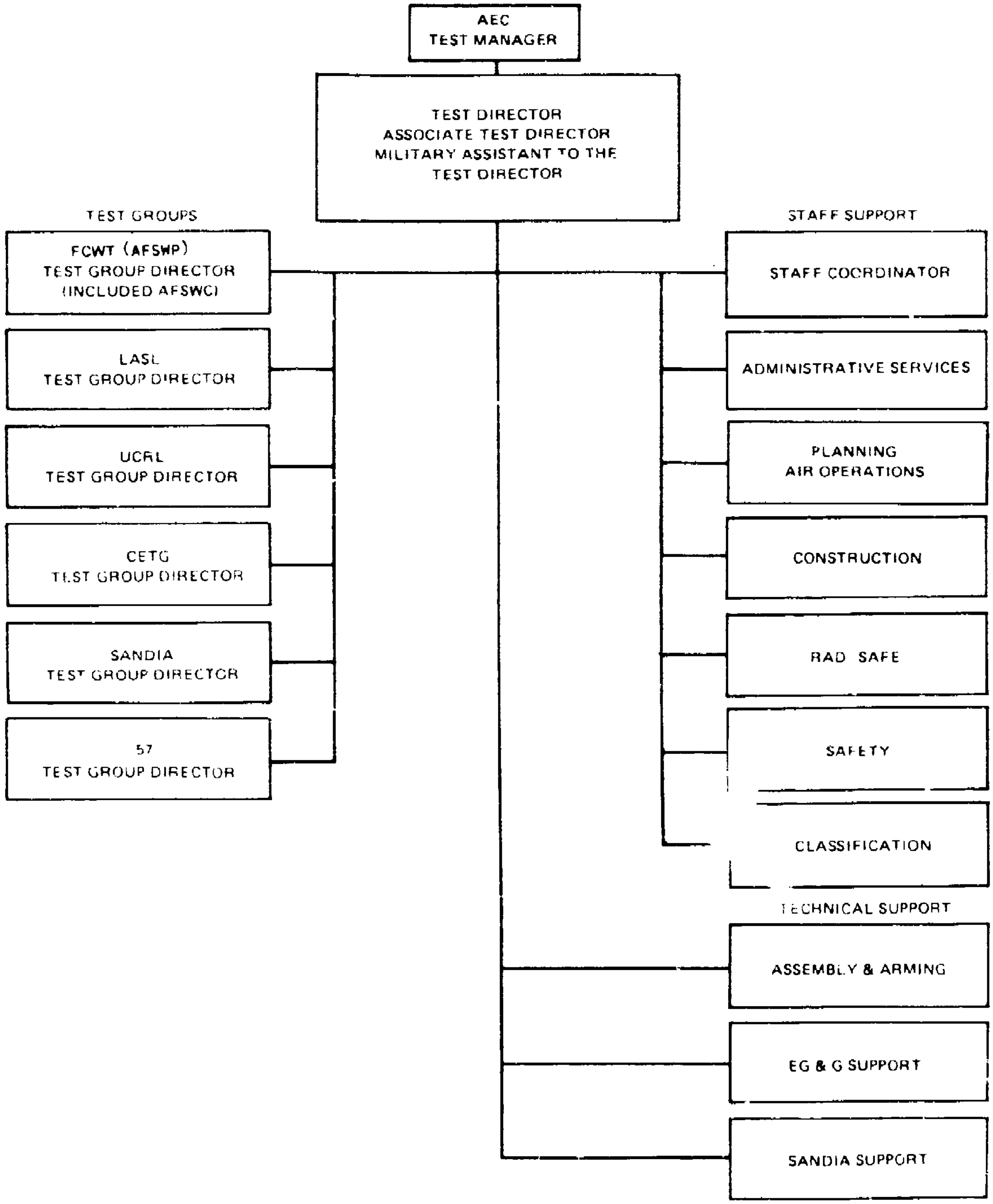


Figure 2-3. TEST DIRECTOR'S ORGANIZATION.

Sandia-led task group conducted one plutonium-scattering test using part of a LASL-designed warhead. Disarming procedures were necessary for shots CHARLESTON and WHITNEY. Each design laboratory was responsible for diagnostic projects within the programs described in Chapter 5. These included the necessary hydrodynamics, radiochemistry, and measurements of the temperature, electromagnetic spectrum, neutron and gamma spectrum, and thermal spectrum necessary to quantify the nuclear reaction of each device. It must be stressed that the primary purpose of the PLUMBBOB tests was to conduct scientific and diagnostic tests which would evaluate and subsequently improve this nation's nuclear arsenal.

Federal Civil Defense Administration studies were conducted by the Civil Effects Test group (CETG), also a part of the Test Director's organization. CETG projects involving DOD participation included fallout studies; biomedical aspects of gamma and neutron radiation; blast effects on structures; biomedical effects of blast; radiological contamination, decontamination and training; and instrumentation and support services.

Finally, the Armed Forces Special Weapons Project was responsible for execution of technical projects through the Field Command Weapons Test group. This was the primary DOD involvement at PLUMBBOB and some 45 AFSWP- sponsored projects were pursued during the various PLUMBBOB tests (see Chapter 5). AFSWP was supported by the Field Command Support Unit (FCSU); this provided general and technical support to the AFSWP activities and participating personnel during Operation PLUMBBOB. Specific FCSU support functions included communications, transportation, maintenance, supply and procurement, housing, and commercial transportation.

2.3 DESERT ROCK ORGANIZATION

The Exercise Desert Rock troops--some six thousand in all--were present at Operation PLUMBBOB, through the invitation of the AEC. Desert Rock activities were always contingent upon prior approval by the Test Manager. The Test Manager had final control over the planning and scheduling of nuclear events at Operation PLUMBBOB. This included review and approval authority over all associated program activities at the Nevada Test Site. Therefore, in effect, he influenced Exercise

Desert Rock activities as well. Operationally, however, Exercise Desert Rock VII and VIII had their own administrative structure as described later.

Exercise Desert Rock VII and VIII, sponsored by the Department of the Army, involved an estimated sixteen thousand DOD participants in the orientation activities, tactical troop maneuvers, and training tests conducted at Operation PLUMBBOB. In addition, about two thousand DOD personnel were required to administer Camp Desert Rock and support the exercises. For these Desert Rock exercises, the overall responsibility for supervising Army, Navy, and Air Force participants belonged to the Desert Rock Exercise Director. The Commanding General, Sixth U.S. Army, was designated to fill this role. His chief aide, the Deputy Exercise Director and Commander of Camp Desert Rock, was directly responsible for conducting the exercise. This position was filled by Commanding General, Camp Irwin, California. Although Exercise Desert Rock functioned separately from the NTO -- indeed, it provided its own Radiological Safety program -- operations of both EDR and NTO personnel depended completely upon the NTO Test Manager's shoot/no shoot decisions.

The Department of Defense was permitted to conduct adjunctive exercises on a non-interference basis at 24 of the PLUMBBOB events. These Service-oriented projects were done by personnel stationed at Camp Desert Rock and consisted of Exercises Desert Rock VII and VIII. These provided military maneuvers, troop orientation and training; technical service projects conducted by the Army's technical branches; and air and ground operational training projects conducted by each of the military services. Also included was the orientation, training and maneuver participation by elements of the Canadian Army and Air Force. Troop involvements of primary interest included a U.S. Marine Corps maneuver at shot HOOD and Army maneuvers at shots SMOKY and GALILEO; these are reported in individual shot volumes.

As shown in Figure 2-4, the Director for Desert Rock exercises VII and VIII was the Commanding General, Sixth Army. He was responsible for supervising and coordinating the Services participation in the Desert Rock Exercise. He also provided operational control as well as administrative and logistical support for Exercise Desert Rock troops and observers. As noted in item "n" of the directive to the Test Manager (Figure 2-1), the Desert Rock Exercise Director was

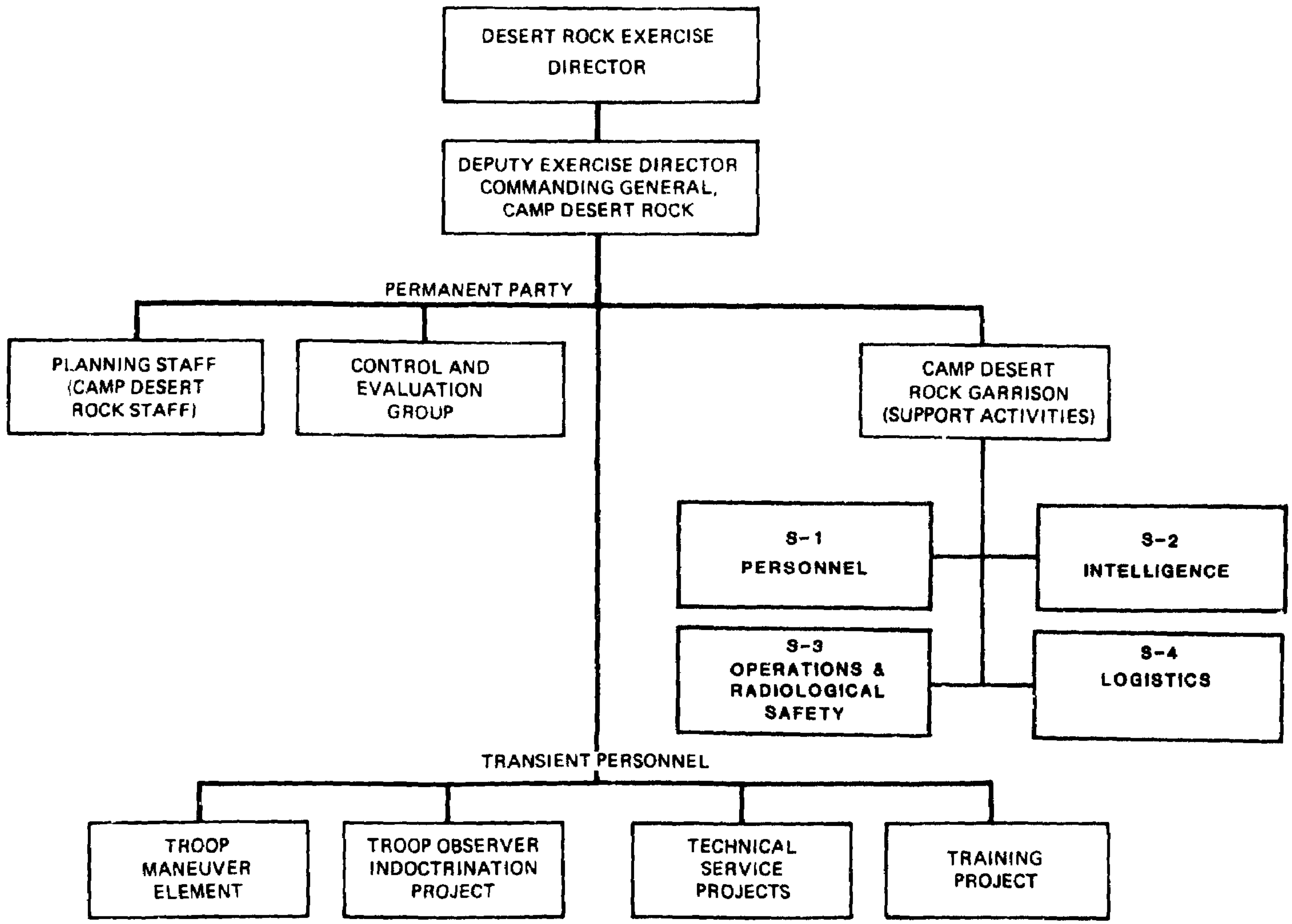


Figure 2-4. EXERCISE DESERT ROCK ORGANIZATION.

responsible for the safety (including radiological safety) of all troops, troop observers, and DOD personnel within areas assigned to him. This responsibility did not extend to the DOD personnel attached to the AEC or AFSWP nor did it include Air Force personnel supporting the AEC and DOD projects since those personnel operated under the Test Manager.

Directly under the Exercise Director was the Deputy Exercise Director, who was the Commanding General of Camp Desert Rock (CDR)*. He was responsible for coordinating and managing the activities of both the permanent party and the transient personnel at Camp Desert Rock. Together, the permanent party and transients accounted for about ten percent of Desert Rock personnel at the test site during Operation PLUMBBOB.

Elements of the permanent party were those usually present to plan, conduct, and evaluate tactical maneuvers. (See Figure 2-4 for the planning staff and the control and evaluation group). In addition, all the Camp Desert Rock garrison units were included as part of the permanent party. Chapter 6 lists the chief units garrisoned at Desert Rock in support of the transient personnel. Throughout Operation PLUMBBOB, the support troops resided at Camp Desert Rock, located just south of the Nevada Test Site. These personnel provided a number of services to the exercise troops including security and law enforcement, radiological safety, medical care, communications, transportation, engineering, mess, mail, and laundry. (Conversely, exercise troops, who were assigned to Camp Desert Rock for periods of a few days or a few weeks to participate in a particular program, left when their participation was complete.)

There was a shortage of support troops. At no time during the activities did the actual strength of these troops reach the authorized level. Some of the troops had only 30 days or less of military service remaining upon arrival at Camp Desert Rock. This situation created a continual flow of individuals being returned to their stations for release from the service. This turnover in personnel resulted in long hours and work weeks for some support troops, degraded efficiency of operations and created a shortage of enlisted specialists.

---

*EDR or Exercise Desert Rock refers to the operational command. CDR or Camp Desert Rock refers to the garrison location.

Transient personnel generally fell into one of four groupings: troop maneuver elements, troop observers (as part of the indoctrination program), those working on technical service projects, and those involved in training projects.

The exercise troops for the Troop Maneuver Element included:

- A reinforced Infantry Company from the 1st Battle Group, 12th Infantry Regiment, 4th Infantry Division, Fort Lewis, Washington (Task Force Warrior), which participated in Project 50.1, Army Troop Exercise
- The 4th Marine Corps Provisional Atomic Exercise Brigade, which participated in Project 52.1, USMC Troop Exercise
- Provisional Company, 82nd Airborne Infantry Division, which was tested to determine soldiers' psychological reactions to nuclear warfare
- The 3rd Transportation Battalion, which provided helicopter support
- The 506th Pathfinder Unit, which was attached to the 3rd Transportation Battalion, provided air-landed reconnaissance and Rad-safe monitoring.

Personnel selected to participate in the Troop Observer Indoctrination Project (Project 50.2) included the following:

- Troop, aircraft, and ship commanders
- Staff officers whose duties would require familiarity with the employment of nuclear weapons
- Members of fire support units who would plan the employment of nuclear weapons.

Technical Service Projects (Projects 50.3 through 50.8) were manned by Technical Service Project Personnel provided by the Department of the Army.

The Training Project involved the training of chemical, biological, and radiological (CBR) defense teams. Training was provided to the following major elements:

- Permanent party
- Sixth U.S. Army CBR Survey Teams
- 4th Marine Provisional Brigade
- 2nd Battalion, 5th Marine Division
- Infantry Battle Group
- Canadian Infantry (Queens Own Rifles)
- XVIII Airborne Corps Pathfinders
- Atomic Energy Commission personnel.

CHAPTER 3
RADIOLOGICAL SAFETY AT OPERATION PLUMBBOB

3.1 INTRODUCTION

This chapter describes the radiological safety (Rad-safe) operations carried out at PLUMBBOB. For a complete understanding of this chapter, the reader must be familiar with the concepts involved in protecting personnel against the hazards of nuclear radiation. While this chapter gives an overall description of Rad-safe for the AEC and DOD, details of how Rad-safe procedures were implemented, as well as how exposure may have occurred are given for each program in the chapters which follow.

The AEC was responsible for radiological safety at the NTS. As part of these duties, the AEC defined permissible radiation exposure levels and instructed the NTO Test Manager to implement the Rad-safe program necessary to comply with these levels. Some 30 shots involving nuclear devices were planned for Operation PLUMBBOB. Each shot with significant nuclear yield could produce one or more radiological environments: initial nuclear radiations from the burst, neutron induced soil activity surrounding GZ, and fallout of radioactive weapon debris.

The radiological safety mission, simply stated, was to ensure that no individual on site or off site, received radiological exposure from the test in excess of the defined safe levels. Authorized exceptions were to be the very minimum that might be needed to achieve the objectives of Operation PLUMBBOB.

The general plan for Rad-safe operations consisted of four main elements. First, an education and training program was implemented to inform all participants of potential radiological hazards and of the means available to avoid them. Second, all sources of contamination were to be identified and clearly marked to be easily recognizable. Access to them was to be controlled by physical means such as checkpoints, monitors, etc. As part of this latter activity, routine surveys of living and working areas at the NTS were to be made to ensure that contamination was not spread to these areas. Third, all personnel movements on site were to be monitored and controlled as to the proximity to and time spent in radiation areas. This personnel movement control was critical at shot times for other than Rad-safe reasons, namely, to avoid other weapon effects such as blast and heat. Fourth, the integral dose received by onsite participants (and a representative fraction of the offsite population) was measured by film badges and the results routinely monitored by responsible supervisors to ensure that the cumulative total dose of each individual did not exceed the permissible level as the operation progressed.

It is important to note that, as described in Chapter 1, DOD personnel participated heavily in both NTO and EDR operations. In the NTO, under AFSWP sponsorship, they performed many tests as the DOD Test Group (FCWT) and the DOD Test Support Group (FCSU). Under AFSWC, which was also under the NTO, they carried out airborne test operations. The radiological safety for all these personnel was the responsibility of the NTO. In addition, DOD personnel were assigned to other NTO units as participants in test groups, such as that of the Los Alamos Scientific Laboratory (LASL), CETG, etc., and to support groups, such as the Weather Prediction Unit. In Exercise Desert Rock, on the other hand, DOD personnel took part in training maneuvers and rehearsals and as observers. For these activities, EDR provided Rad-safe services.

Throughout the years of testing, the NTO Rad-safe program had been developing to cover the variety of activities involved in nuclear testing (i.e., recovery operations, offsite surveys, air flights, etc.). The EDR program originated concurrently with and was modeled very closely on the NTO program. The similarities will be clear in the program descriptions which follow; some differences, which arose from specific needs, will be noted.

The preceding remarks apply to onsite Rad-safe. Offsite Rad-safe was the sole responsibility of the NTO.* DOD programs involving offsite activity were minor, as was the involvement of DOD personnel.

---

*"Onsite" was considered to be the total Nevada Test Site; "offsite" was the area outside the Nevada Test Site and within a 250-300 mile radius of the site: this also included Camp Desert Rock itself. [3;255]

3.2 AEC/NTO RADIOLOGICAL SAFETY AT OPERATION PLUMBBOB

3.2.1 Radiological Safety Standards

The Rad-safe criteria used on site during PLUMBBOB were recommended by the AEC's Division of Biology and Medicine (DBM). The criteria, as quoted in the Test Manager's Report (260), were as follows:

- Gamma: a maximum of 3.0 roentgens (R) for any consecutive 13-week period, and 5.0 R for one calendar year.
- Alpha: a maximum of 10,000 units for any consecutive 13-week period. ("Units" are computed by multiplying the average air concentration, excluding natural background, in the area of exposure, in units of alpha disintegrations per minute per cubic meter, by the hours of exposure when no protective respiratory equipment is worn.)

These criteria, in essence, were the same as those recommended by international and national committees (ICRP, NCRP*) at the time.

3.2.2 Organization of NTO Radiological Safety Programs

The responsibility for Rad-safe programs during Operation PLUMBBOB was defined in the 13 March 1957 memorandum designating the Test Manager (260) (Figure 2-1). Articles k,l,m,n,s,v, and w of the memorandum are specifically concerned with radiation contamination and safety.

The Test Manager had both onsite and offsite radiation safety responsibilities. On site, the Test Manager was required to implement Rad-safe directives for all personnel, excluding Desert Rock troops, troop observers, and other Desert Rock personnel who were within the area that the Test Manager assigned to Exercises Desert VII and VIII. With regard to the Desert Rock personnel, the Test Manager was responsible for the issue of NTS security and film

---

*International Commission on Radiological Protection and National Council on Radiation Protection and Measurements, respectively.

badges to Desert Rock personnel during times they were not participating in Desert Rock exercises. Figure 3-1 is a chart illustrating his organization for radiological safety.

Off site, the Test Manager was responsible for protecting the public in fallout areas and for keeping the AEC Division of Military Application (DMA) and Biology and Medicine (DBM) current on all radiological information. The Test Manager delegated offsite radiological safety operations to the AEC Support Director, who was supported in this task by the Public Health Service, Reynolds Electrical and Engineering Co., Inc. (REECo), and other agencies.

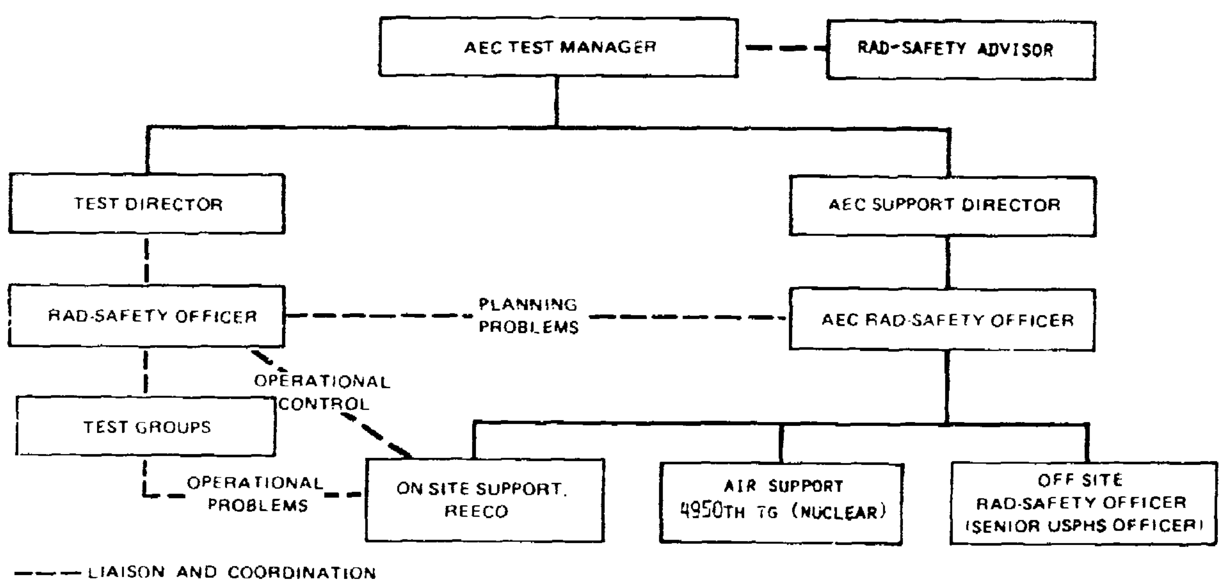


Figure 3-1. NTO RADIOLOGICAL SAFETY ORGANIZATION.

In matters regarding radiological safety, the Test Manager's key man was his Rad-safe advisor who was responsible for executing all radiological safety policies on the test site. During operational periods of PLUMBBOB, such as the preparation for executing the tests, Rad-safe responsibilities in the testing areas of NTS were delegated to the Test Director. The Test Director assigned Rad-safe responsibility for each of the six test groups to the directors of those groups. Each of these, in turn, appointed a Rad-safe officer for their group and these later worked with the Test Director's Rad-safe Officer. The Test Director's Rad-safe Officer was thus directly responsible for the operational control of radiological safety.

AEC's Support Director was responsible for providing the Rad-safe support services such as monitoring and air sampling. These were provided through a contract with REECo. The AEC Rad-safe Officer coordinated all Rad-safe support services for the Support Director. In addition, this Rad-safe officer was responsible for a downwind, low-level terrain sweep of the predicted fallout area prior to each detonation. He was also responsible for the personnel of both the Support Director and the contractor.

The 4950th Test Group (Nuclear), AFSWC, organized its radiological safety operations as part of the NTO, but most of this group's activities were based off the test site. Therefore, in addition to providing and processing film badges, REECo provided considerable support, including Rad-safe support for helicopters. REECo Rad-safe also provided training at Indian Springs Air Force Base, in observer areas, and during Rad-safe courses at the NTS. The 4950th Test Group itself provided the remaining functions (monitoring, decontamination, etc.). Figure 3-2 shows how these functions were organized (also see reference 3).

3.2.3 Onsite Radiological Safety Procedures and Operations

This section describes how the essential onsite Rad-safe functions were conducted: personnel education, identification of contamination sources, control of personnel movements, and dose control by film badge (260; 334). Except for control of personnel movement, AFSWC Rad-safe procedures were included in those described in this section. A special discussion of AFSWC is contained later in this section to explain that difference.

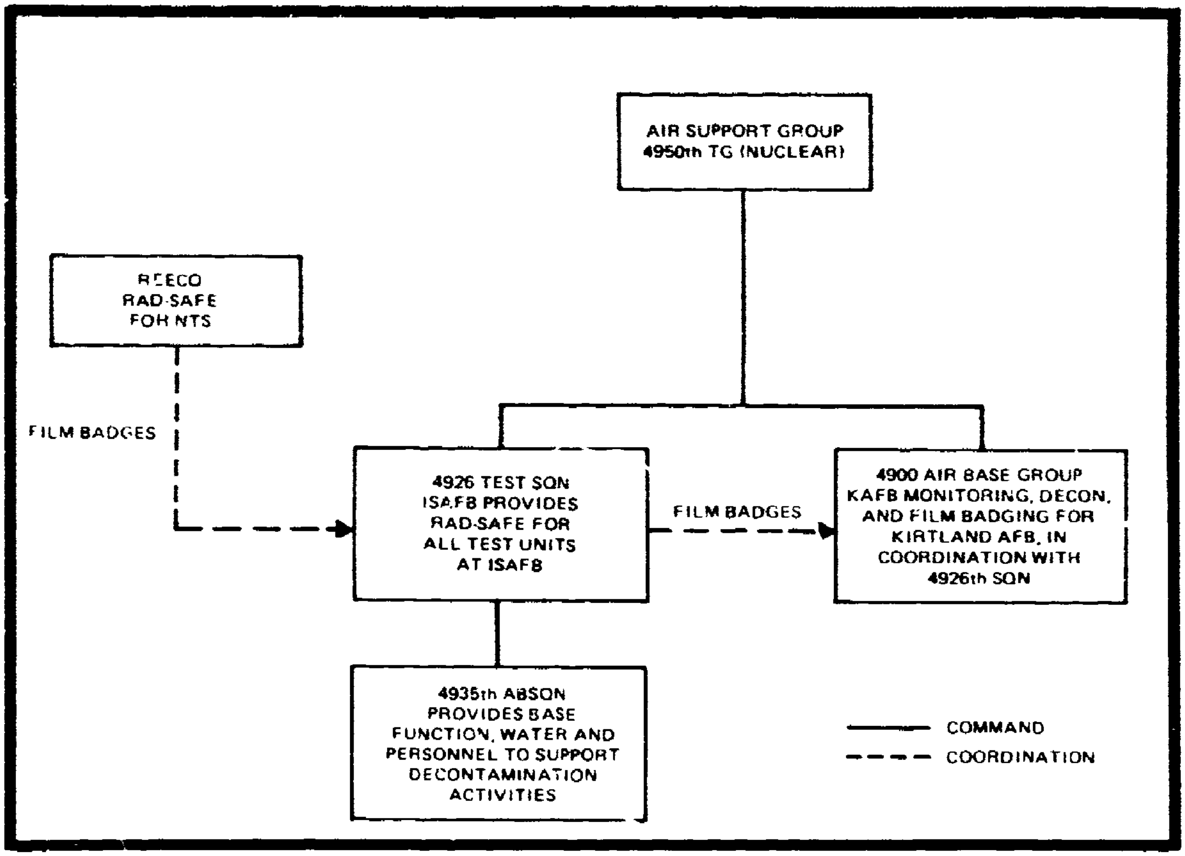


Figure 3-2. AFSWC RADIOLOGICAL SAFETY ORGANIZATION.

Education and Training. Although many of the NTO personnel, particularly in the test groups, were technically trained and well-informed on radiation hazards, others were not. Thus, new employees, touring groups, and official observers received Rad-safe training and indoctrination in courses lasting up to two weeks. In addition, three-day monitoring courses were given, and a training manual was distributed. A total of 3,300 NTS personnel attended these lectures during PLUMBBOB.

Radiation Areas. Radiological exclusion (Radex) areas were defined as follows (334):

- Full Radex: An area with radiation greater than 100 mR/h* gamma
- Limited Radex: An area with radiation intensity between 10 and 100 mR/h gamma
- Non Radex: An area with a radiation level of less than 10 mR/h in which no alpha contamination hazard exists

Full and limited radiological exclusion areas were determined through surveys of the forward areas of NTS. These surveys were accomplished as follows. Prior to Operation PLUMBBOB, shot areas were re-surveyed and re-mapped to show existing roads. Radial roads at or near ground zero were used to determine radiation dose rate contours in each test area. New roads were added in those areas where suitable roads did not exist. The 5,000-foot Nevada Grid Coordinate System was used to locate survey stakes in the test area prior to the operation. These stakes were used as reference points for preparing Rad-safe maps of the entire test area. Stakes were placed on the radial roads at half-mile intervals from each ground zero. Plotting facilities were established at CP-1 and CP-2† for simultaneous plotting of dose rate contours after each detonation. Prior to each detonation, the monitoring branch leader briefed Rad-safe initial ground survey teams on the expected fallout pattern. Four two-man teams were responsible for

*mR/h = milliroentgen per hour.

†CP-1 and CP-2 were the NTS shot control point and Rad-safety buildings located just off Mercury Highway near Yucca Pass.

obtaining the information necessary to plot the dose rate contours after each shot.

The Rad-safe initial ground survey teams entered the test areas as early as safely possible after each detonation. They used both radio-equipped vehicles and helicopters to determine how far the reference stakes were from the 10, 100, and 1,000 mR/h lines. The information was transmitted by radio to CP-1 and CP-2 where the dose rate contours were plotted on plastic overlay maps. Special readings above 1,000 mR/h or at specific locations were obtained as requested by the Test Director or by experiment recovery parties. A roving team monitored radio transmissions, maintained contact with each survey team, and if a vehicle failed, transported survey personnel from radiation areas. (Dose rate contours prepared after each shot in PLUMBBOB are given in the pertinent shot volumes.)

In general, all personnel were permitted to enter and to work in non-Radex areas (i.e., less than 10 mR/h) at all times without monitors as long as film badges were worn. Individuals who worked for long periods in such areas accumulated some whole body gamma dose, but this was measured by their film badges.

Air samples and fallout trays were used to measure the levels of air borne radioactivity and the amount of fallout deposition, respectively. The results of these measurements, particularly for alpha radiation, are given in the individual shot reports. (The extensive air sampling and fallout tray measurements of Project 57 will be discussed in Chapter 5.)

In addition to these controls of weapon-produced contamination, the Rad-safe organization maintained a radioactive source registry for all other sources brought on the test site. The same radiological safety procedures controlled possible exposure of personnel to these sources.

Control of Personnel Movement Onsite. Forty-eight hours before a firing, the shot area was cleared and closed. Check stations were set up on roads leading into the area where persons required to make final preparations for the shot were mustered in and out by use of specially logged badges. These persons included, for example, the assembly and arming team and the security guards. This procedure was used to ensure that no one was left in the test area at shot time.

After the shot, entry into contaminated areas was controlled for the Test Director by REECo Rad-safe (called the Rad-safe Division during PLUMBBOB). No individual was permitted beyond the Rad-safe checkpoint without a proper access permit stating the purpose of entry and the precise location for activities related to entry. Continuing limited Radex area cards were issued to individuals who required frequent entry into limited Radex areas. The cards were valid until the individual exceeded an exposure of 2 R. All groups entering full Radex areas were accompanied by a certified monitor. Projects were generally required to provide their own monitors; however, if project monitors were unavailable, REECo supplied them.

After being issued access permits, personnel were briefed on the radiological conditions in those work or observation areas that they intended to enter. They were also advised on the anticontamination clothing and equipment required.

Anyone entering a full Radex area was required to wear complete anticontamination clothing. REECo determined the clothing to be worn in a limited Radex area on the basis of the particular demands of a mission. All necessary equipment (i.e., instruments, clothing, respirators, film badges, and dosimeters) were obtained from the Rad-safe building (CP-2) located at the control point. Despite these precautions, problems did occur during post-shot surveillance of contaminated areas, primarily because clearance of a party by a specified route did not always ensure the movement of the party. For example, individuals cleared for entry might be curious and might not always fully appreciate the potential radiation hazards. Consequently, a roving monitor assigned to each area observed the activities of all persons within his area to ensure that no one strayed from the specified route. These monitors also made sure that radiation warning and dose rate signs were posted properly by replacing stake-type signs with sawhorse-type signs and moving the sawhorse signs daily as radioactivity decreased (due to decay) or increased because of new contamination.

Rad-safe monitors conducted resurveys of shot areas several days after the shot and periodically thereafter. The isodose rate contours determined in this way are reproduced in the individual shot reports.

In addition to the Rad-safe facilities at CP-2, temporary facilities were maintained in Area 13 and at Frenchman Flat as a matter of convenience while these areas were under Rad-safe control. Hence, test personnel working in these areas could enter the areas without first traveling CP-2 to pick up their protective clothing and equipment.

Post-shot regulation of areas were conducted in the following manner: entry was not permitted until such time following the burst when it was determined that controlled access to the shot could be re-established except in specific cases determined ahead of time. Contaminated area control stations were established on the main access roads to the test areas outside the 10mR/h lines to control personnel movement in and out of the area. The primary check stations were mobile house trailers equipped with radios, radiation detection instruments, and other Rad-safe equipment. Signs were posted on frequently used back roads directing personnel to enter and exit through the check stations. "Contaminated Material" stickers, attached to all vehicles entering the Radex areas, were removed only after monitoring checks showed that the vehicles were not contaminated. All materials taken from radiological exclusion areas were monitored. If they were found to be contaminated (i.e., greater than 7 mR/h reading), "Contaminated Material" stickers were attached to them. Personnel then took the materials to the CP-2 area for decontamination. Personnel returning from Radex areas were routinely monitored and decontaminated when necessary at CP-2.

Table 3-1. AEC and Desert Rock Decontamination Criteria.

Vehicles:	7 mR/h (gamma) outer surface 7 mR/h (beta + gamma) inner surface
Personnel:	7 mR/h (beta + gamma) on protective clothing 1 mR/h (gamma) on surface of skin or underclothing

Vehicles leaving contaminated areas were monitored and decontaminated if the radiation levels were greater than 7 mR/h (gamma) on the outside of 7 mR/h (gamma plus beta) on the inside. (Decontamination facilities were located east of

CP-2.) Vehicles and equipment were decontaminated with vacuum cleaners, high pressure water, and detergent mixtures. Those unsuccessfully decontaminated were placed in a "hot park" next to the facilities until normal decay reduced their contamination to the required level.

Personnel leaving contaminated areas were monitored and decontaminated by showering when radiation exceeded 7 mR/h (beta plus gamma) on protective clothing or 1 mR/h (gamma) on the skin surface or underclothing. Contaminated clothing was washed at the CP-2 laundry facilities. Clothing highly contaminated with alpha-emitting material was sealed in plastic bags and buried in the contaminated waste area.

Control of Personnel Movement, AFSWC. Because AFSWC activities by their nature differed from activities on the ground, AFSWC Rad-safe procedures and operations differed from the norm for control of personnel movement. AFSWC (the 4950th Test Group) personnel were subject to the NTO radiological safety criteria and procedures. However, because AFSWC air activities were based off site for the most part, their administrative procedures differed in some details. In addition to providing film badges* and reporting film badge readings, REECo also provided advisory support and normal reentry support in the NTS forward areas for helicopters on official reentry missions. AFSWC procedures are described in reference 3; relevant extracts are given below.

- The arrival or proposed use of radioactive sources in any 4950th controlled area was reported to the Nuclear Research Officer (NRO), 4950th TG (Nuclear).

- Contaminated containers for radioactive materials and equipment leaving Indian Springs Air Force Base (ISAFB) (other than those escorted by courier) were decontaminated, packaged, monitored, and properly labeled.

- All radioactive samples and materials removed from ISAFB by courier aircraft were packaged and loaded to minimize the radiation intensity. The

*Although most film badges provided by REECo were for gamma only, neutron film badges were used for air delivery crew on shot JOHN. Subsequent to this use, REECo provided neutron badges for the air crews in the effects projects (Program 5). These badges were processed and interpreted by UCRL.

loads were cleared from a Rad-safe viewpoint by competent authority. The following criteria determined the loading requirements:

- Anticipated future exposure of aircraft personnel

- Length of exposure during flight

- In no case were the crew or passengers to be exposed to a dosage rate of more than 20 mR/h during flight

- To minimize internal hazards, all personnel handling radioactive samples or contaminated equipment in an enclosed space, or under other conditions producing heavily contaminated air, were to wear respirators.

- Eating, drinking, smoking, or chewing gum in a contaminated area, or when working with contaminated materials, was forbidden.

- The total permissible integrated gamma radiation dose for personnel involved in the operation was 3.0 R for any given 13-week period and no more than 5 R per year, unless otherwise specified by proper authority.

In addition to providing for operational procedures, the operation plan included the following training requirements:

- Personnel designated as radiological monitors were to be trained in compliance with existing Air Force technical orders and regulations. Personnel, such as Air Force participants in Project 39.5 and 39.6 who had been trained in an approved course prior to operations were considered qualified, subject to review and approval by the NRO, 4950th TG (N). All other individuals designated as monitors were trained in the Rad-safe monitor's course presented by the 4926th Test Squadron.

- Each project officer or test aircraft unit was responsible to ensure that all participating personnel were briefed, prior to the test, on the general and specific radiological problems involved in their operations. They also ensured that their personnel were kept abreast of any changes in the radiological situation that might have occurred during the test series.

Specific procedures for handling radioactive contamination plus recovering and returning radioactive samples were provided for in the 4950th TG (N) Operation Plan 1-57. Because of its importance, the plan's special procedures for contaminated aircraft are quoted in their entirety (Figure 3-3). Special procedures were also developed in the event of accidental radiological contamination of Indian Springs Air Force Base (3).

Dose Control by Film Badge. All NTO personnel and some official observer groups, with the exception of Desert Rock personnel, were provided with a charge-a-plate* and a film badge. The film badge was attached to the security badge which was to be worn at all times. Different colored tape was attached to the film badge each month to allow for easy and rapid determination of valid film badges. Badges were exchanged on a monthly basis or upon return from a mission in a contaminated area. Federal Services Incorporated (FSI)† guards assisted in the film badge program by checking all personnel prior to entry into forward areas for possession of a valid film badge. ADP cards corresponding to numbered film badges were stamped (using the individual charge-a-plates), at the time of film badge issue. The cards were used to tabulate all individual dosages and to prepare the following reports:

- Daily dosage
- Weekly summary
- Quarterly summary
- Daily over 2 R
- Weekly over 2 R

The various dose reports were used by NTO supervision to control each individual accumulated dose. The weekly summary reports at the end of the operation listed the accumulated exposures of more than 9,000 personnel. Records of all NTO-PLUMBBOB film badges and running totals for each participant are presently available at the NTS office of REECo, Las Vegas, Nevada.

---

*A "charge-a-plate" is a metal tag bearing a person's name and other identifying information.

†Federal Services Inc. was an AEC contractor providing security guard services.

(APPENDIX 4 TO ANNEX F OF OPERATIONS PLAN 1-57) (3)

1. GENERAL.

This Appendix presents special instructions for the regulation of contaminated aircraft.

2. PROCEDURES.

a. All aircraft participating in the test array and staging from other than ISAFB or KAFB will be monitored at their home stations and allowed to decay and/or will be decontaminated in accordance with the policies of their parent commands. Sound principles of radiological health should be followed to insure that air and ground crews are not exposed to unnecessary dosages of ionizing radiation, in no case to more than 3.0 r, unless specifically authorized to exceed this level.

b. Aircraft staging from ISAFB will be allowed to decay and/or will be decontaminated in accordance with the procedures established by the Commander, Test Aircraft Unit. (Reference F, paragraph 6[1] [a].)

c. Aircraft staging from KAFB:

(1) Will be monitored upon landing by the Base Passive Defense Unit in accordance with pertinent regulations.

(2) Except as otherwise required by operational contingencies, aircraft contaminated in excess of 50 mr/hour gamma measured at six inches from exterior surfaces of the aircraft, engine nacelles, jet intakes, dive brakes, etc., or so contaminated that the gamma radiation intensity inside the cockpit or any crew compartment is in excess of 20 mr/hour, will be allowed to decay until these allowable criteria are met and will be marked with standard radiation warning signs until they have decayed to 7 mr/hr or less at six inches from the surface.

(3) If the monitor on board the cloud tracker aircraft determines that the gamma background in the crew compartment is in excess of 50 mr/hour after the cloud tracking is concluded (i.e. he determines that the aircraft is in fact contaminated such that the crew is being exposed to 50 mr/hour or greater), he will so inform the pilot and the pilot will proceed to ISAFB for landing. The aircraft will then be allowed to decay and/or will be decontaminated as required.

d. In all cases, flights and ground maintenance of contaminated aircraft will be programmed so that aircrews and ground personnel are not exposed to dosages in excess of 300 mr per week (exclusive of dosages which may be received in future missions). In no case will an individual be permitted to accumulate more than 3.0 r in any given 13-week period or more than 5 r in any year while participating in or in support of Operation PLUMBBOB unless special permission has been obtained through proper Air Force and Test Organization channels.

3. REFERENCES.

a. Air Force Technical Orders in the 00-110A Series.

Figure 3-3. SPECIAL PROCEDURES FOR CONTAMINATED AIRCRAFT.

3.3 DESERT ROCK RADIOLOGICAL SAFETY AT OPERATION PLUMBBOB

3.3.1 Radiological Safety Standards

The DOD radiation safety criteria were (200):

- Whole body gamma exposure is limited to 5 roentgens at any one test, of which no more than 2 R would be from prompt radiation.
- No individual is to receive more than 5 R in any 6-month period.
- Limits on other forms of radiation, alpha, beta, neutron, will be included at such time as the AEC prescribes these. (The AEC did prescribe a limit on alpha radiation, as noted in Section 3.2.1. Reference 200 does not specifically mention this limit on alpha radiation.)

These criteria, while similar to those of the AEC, are not the same. For example, while the AEC limit is 5 R in any calendar year, the DOD limit was 5 R in any six-month period. The relationship of AEC and DOD limits had been discussed in the final report of an earlier exercise, Desert Rock IV (1952). In that exercise, Rad-safe for Desert Rock troops was the responsibility of the AEC and the limit was 3 R in any 13-week period. The final report recommended that the limit for Desert Rock troops be increased in future exercises. The reason given was that the short period of time spent by Desert Rock troops at the test site relative to time spent by other test participants such as AEC or AFSWP personnel would, in effect, limit Desert Rock troops to a lower total of radiation than that received by other test participants, and unduly hamper Desert Rock operations. Consequently, the DOD limit was changed to 5 R in any six-month period for Desert Rock VII and VIII. Because Desert Rock troops participated in only one operation during 1957, this limit did not constitute an increase in the annual allowable dose accepted by the AEC; the troops were not expected to remain at NTS more than six months and were not usually engaged in activities where they could be exposed after their Desert Rock assignments. However, it permitted accumulation of this dose over a shorter period and permitted greater flexibility in the employment of maneuver forces.

3.3.2 Organization of Desert Rock Radiological Safety

The Director of Exercise Desert Rock was responsible for the radiological safety of participants in the exercise projects and maneuvers and for those support personnel stationed at Camp Desert Rock. This responsibility was clarified in the memorandum of instructions to the AEC Test Manager (Figure 2-1). Article "n" of this memorandum states the Exercise Director's responsibility and, in addition, requires the Test Manager to report to the AEC's Division of Military Application any Desert Rock programs that "appear to the Test Manager to jeopardize unduly participating personnel."

The following procedure was used at the NTS for Desert Rock onsite activities. The Exercise Director's Chief of Operations submitted plans for a given Desert Rock project to the AEC Test Director for review. After review and resolution of any conflicts, the Chief of Operations prepared a detailed operating plan and submitted it to the Test Manager for approval. If approved, the operation plan would become the Desert Rock Operation Order and its execution would be monitored by the Test Manager's DOD Coordination Group. Thus, the operating plans and orders contained detailed Rad-safe plans. In this way the two organizations tended to coordinate their Rad-safe activities.

While onsite radiological safety was implemented as described above, no evidence yet shows that Desert Rock Rad-safe personnel performed appreciable monitoring or survey duties, other than for training purposes, during nonoperational periods between shots. Thus, the principal difference between the NTO and the Desert Rock radiological safety programs was that the NTO's program operated continuously while the Desert Rock program (except for film badging) only covered activities associated with a planned exercise.

The organizational chart for Exercise Desert Rock (Figure 2-4) shows the Radiological Safety Section for Camp Desert Rock under the S-3 (Operations Office). In the Army, radiological safety is a function normally performed by the chemical staff element of the headquarters. Camp Desert Rock was not an exception since the Chemical Officer was in charge of the Radiological Safety Section. This section conducted the radiological safety program for all Camp Desert Rock operations, trained project and support personnel as radiological monitors, and provided radiological survey training for Chemical, Biological, and Radiological (CBR) survey teams.

3.3.3 Onsite Radiological Safety Procedures and Operations (200; 169)

Criteria for Positioning Troops and Observers. This was carefully determined well ahead of time. Standards developed for continental atomic tests were (200):

- Overpressure: three (3) pounds per square inch.
- Nuclear radiation: five (5) roentgen equivalent mammal (rem) at any one test of which no more than two (2) rem is prompt, whole body radiation provided further that no individual will receive more than five (5) rem in any six month period. (Exposure refers to gamma only. As long as limit of 5 roentgens gamma is observed, alpha, beta, and neutron radiation will not be included until such time as AEC may prescribe safety criteria for one or more of these last three.)
- Thermal radiation: two-thirds the calories per square centimeter (2/3 Q) necessary for a first degree burn on bare skin.

For tower or balloon shots, the criteria were (from intended GZ):

Max Predicted Yield (KT)	Troops in Open (Yds)	Troops in Trenches (Yds)	Troops in Armored Vehicles (Yds)
0.1	1700	1400	1600
0.5	2100	1700	2000
1	2300	1900	2200
2	2500	2100	2300
5	3000	2300	2600
10	4000	2600	2800
20	5200	3100	3100
30	6200	3500	3500
40	7000	3900	3900
50	7600	4200	4200
60	8200	4400	4400
70	8700	4700	4700
80	9200	4900	4900
90	9600	5100	5100
100	10,200	5300	5300

Other important criteria were:

- For aircraft-delivered devices (excluding air-launched rocket) it was necessary to add three (3) times the circular error probable (CEP) for the aircraft delivery system to the positioning criteria above.
- Troop positions would be located so that an aircraft-delivered device is delivered along a line in front of and parallel to the positions.
- Trenches provided for troops and observers were to be at least six (6) feet deep and all participants were to be instructed to keep below a point at least two (2) feet below ground level.

Education and Training. Three radiological training projects were established under the supervision of the Rad-safe Section.

- The Camp Desert Rock Rad-safe school trained a total of 417 personnel as Rad-safe monitors.
- The U.S. Navy Rad-safe project trained approximately 120 individuals as monitors.
- The U.S. Air Force, using instructors from its Radiological Defense School, conducted classes for students from CONUS Air Bases in radiological monitoring. This project trained 370 personnel.

In addition to these formal training projects, Rad-safe briefings and pre-maneuver rehearsals were conducted.

Radiation Area Control. Radiological exclusion areas were defined in the same way as the NTO (See Section 3.2.3). The specific procedures were, in many cases, the same as those used by the AEC. However, some applications were tailored to the needs of the Desert Rock Rad-safe Program. For example, like the AEC, the Rad-safe Section maintained radiological situation maps showing isodose rate lines of 10 mR/h, 100 mR/h and 1 R/h. Information plotted was provided by Desert Rock monitors and by AEC radiological safety personnel. For Desert Rock, however, the maps were located in both the Rad-safe building at Camp Desert Rock and the 50th Chemical Platoon orderly room at Camp Desert Rock (the 50th Chemical Platoon also had a training decontamination station with maps at Yucca Pass). For observers reviewing equipment displays in the forward area, Rad-safe monitors also marked the 20 mR/h line as a limit for buses and personnel vehicles and the 5 R/h line as a warning of a high radiation area. The 5 R/h line was identified with red cones and white engineer tape; the 20 mR/h line for vehicles was identified by yellow cones. At various locations in the display area, localized high radiation areas were also identified for the guidance of observer personnel. Whenever trenches or open observation areas were used, radiological monitors watched the radiological situation at that point and recommended moving if necessary to ensure the safety of participants.

Control of Personnel Movements On Site. Rad-safe personnel controlled entry of EDR personnel into the forward area after shot time. A permit was required for any entry into a full Radex area. Checkpoints were established on the access roads to the areas and were moved as the radioactivity within the areas diminished. A monitor was required to accompany personnel entering full radiological exclusion areas. Although personnel entering limited Radex areas required clearance by the Rad-safe office, they required no monitor unless display equipment or contaminated material was to be removed. Military police traffic control teams were posted to ensure that no buses or other ground vehicles passed beyond the 20 mR/h line.

Desert Rock personnel wore specific uniforms during the exercises, but no specialized protective clothing was issued. Each man wore a field uniform and his film badge and carried a protective mask. Some observers had dust respirators rather than an issue protective mask, while news media personnel were provided helmets, dust masks, and canteens.

Decontamination of personnel and equipment was a major portion of the Desert Rock Rad-safe program. At the conclusion of each shot or exercise and before loading trucks or buses, individuals were monitored to determine if external contamination was present. If contamination over 7 mR/h (gross count) was observed, decontamination was required. Ground vehicles, helicopters, and equipment were monitored in the same fashion prior to their return to the base camp. Decontamination was achieved by physical removal of the contaminant. Normally, decontamination proceeded from the easiest approach to the most complex, with monitoring after each step. Brushing or shaking of clothing or brushing of equipment or vehicles with brooms was adequate in some cases. However, washing with water and brushes was required for some vehicles and aircraft. Those personnel showing dose rates in excess of 7 mR/h were taken to the 50th Chemical Platoon decontamination station in the vicinity of News Nob at Yucca Pass. Individuals requiring further decontamination showered and received an issue of clean clothing.

After decontamination, each individual, vehicle, or item of equipment was again monitored to ensure that radioactivity had been reduced to below the allowable limits. After clearance by the monitor, personnel and vehicles were allowed to return to base camp.

During Desert Rock Exercises VII and VIII, 6,218 personnel were screened at the Desert Rock decontamination center. Of these, seven individuals required complete decontamination. In terms of equipment decontamination, the monitors processed 838 vehicles, of which 303 required complete washing. In addition, 48 helicopters required decontamination, of which two required complete washing (200).

Dose Control by Film Badge. Each person was issued a film badge upon arrival at Camp Desert Rock. The film badges issued during 1957 Desert Rock tests contained Dupont dosimeter film packets Type 559; these contained Type 502 and Type 606 component films. An Eberline model FD3 densitometer was used to read the optical density of film components. The accuracy was as good as $\pm$ 10 percent in the low-density range for each film component; in the crossover vicinity (about 10 roentgens) between the sensitive and less sensitive film components, however, accuracy was $\pm$ 50 percent (192).

The film packet holder itself was designed with an open window and a cluster of three metal filters - one aluminum, one copper, and one laminated tin/lead. The area covered by the foil cluster gave a flat blackened response to gamma rays above the Compton edge ($\sim$70,000 electron volts). The open window area of the badge responded to beta rays and gamma rays of all energies. Thus, if the photoelectric component of the gamma source is small, the difference between the density change in the open window and the filtered area give a crude estimate of the beta dose.

Dosimetry teams from the Nucleonics Branch, Lexington Signal Depot, Lexington, Kentucky, processed and developed the badges at Camp Desert Rock in two specially equipped vans. The Radiological Safety Section, Camp Desert Rock, maintained dosimetry records, which were forwarded to Lexington Signal Depot, Lexington, Kentucky, and were later provided to the Army Staff. The references do not specify a definite turn-in time for film badges. The issue and accession dates* shown in the Lexington records span varying time periods so a single-shot dosage cannot always be determined. Approximately 33,000 film badges were developed during Desert Rock VII and VIII (200).

DD Form 1141, "Record of Exposure to Ionizing Radiation," was to be forwarded to the home stations of permanent party personnel for inclusion in their medical records. Records of exposure for observers were to be forwarded to their home stations through administrative rather than medical channels since these were often in the form of lists of names (200).

---

*"Accession date" refers to the date on which the film badge dose was recorded.

CHAPTER 4

EXERCISE DESERT ROCK VII AND VIII PROGRAMS

4.1 INTRODUCTION

Desert Rock Exercises VII and VIII were involved in 24 of the 30 events during Operation PLUMBBOB. Service-related projects involved are shown in Table 4-1. Participation of personnel in these projects by test shot is shown in Table 4-2. (Unless otherwise indicated, references 3 and 7 are the principal sources for the following sections.)

The projects fall into five general categories: technical service projects, troop-observer indoctrination programs, troop maneuvers and tests, operational training projects, and training projects. Also the support troops at Camp Desert Rock, although not specifically identified with any single project, must be examined with regard to their general activities through Operation PLUMBBOB.

4.2 TECHNICAL SERVICE PROJECTS

During Desert Rock VI in 1955, some technical projects had been placed under supervision of the Desert Rock Exercise Director, who was responsible for the overall supervision, coordination, general administration, and logistical support of such tests. This was continued in PLUMBBOB. The chief of the respective technical service or agency was responsible for planning and supervising the test and for evaluating the test results. Project officers appointed by the technical services directed the actual conduct of the tests, which included the following:

- Evaluation of Medium Range Detonation-Detection and Cloud Tracking Systems (Project 50.3) - Sponsor: Chief Signal Officer, U.S. Army

- Evaluation of Water Decontamination Methods (Project 50.4) - Sponsor: Office of Chief Engineer, U.S. Army

Table 4-1. SERVICE-RELATED PROJECTS AT PLUMBBOB.

PROGRAM	PROJECT NO.	TITLE
U.S. Army Program 50	50.1	Combat Team Exercise
	50.2	Troop Observers
	50.3	Technical Service Project
	50.4	Technical Service Project
	50.5	Technical Service Project
	50.6	Technical Service Project
	50.7	Technical Service Project
	50.8	Technical Service Project
	----	Rad-safe Training
U.S. Navy Program 51	51.1	Rad-safe Monitoring Training
	51.3	Operational Training Project
U.S. Marine Corps Program 52	52.1	Marine Brigade Exercise
	52.2	Troop Observers
	52.3	Operational Training Project
U.S. Air Force Program 53	53.2	Operational Training Project
	53.3	ADC Air Crew Operations
	53.4	Radiological Defense Training
	53.5	Operational Training Project
	53.7	Operational Training Project
	53.8	Operational Training Project
	53.9	Operational Training Project
	53.10	Operational Training Project
Royal Canadian Army and Air Force	N/A	Operation BOBCAT I-III
		Operation BOBCAT IV
		Radiological Teams

Table 4-2. PERSONNEL PARTICIPATION IN EXERCISE DESERT ROCK VII AND VIII.

OBSERVER PARTICIPATION

Shot	Date	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Total
[illegible]	[illegible]		4				[illegible]
[illegible]	[illegible]						
[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]					[illegible]
[illegible]	[illegible]	[illegible]				[illegible]	[illegible]
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]					[illegible]
[illegible]	[illegible]	[illegible]			[illegible]		[illegible]
[illegible]	[illegible]				[illegible]		60
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	446
[illegible]	[illegible]	[illegible]			[illegible]	24	102
[illegible]	[illegible]	[illegible]					[illegible]
[illegible]	[illegible]						
[illegible]	[illegible]	[illegible]					[illegible]
[illegible]	[illegible]	284					284
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	454
[illegible]	[illegible]						
[illegible]	[illegible]						
[illegible]	[illegible]						
[illegible]	[illegible]						[illegible]
[illegible]	16 SEPT						
[illegible]	[illegible]						
[illegible]	[illegible]						
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						
[illegible]			[illegible]	314	246	[illegible]	[illegible]

TROOP UNITS

Shot	[illegible]	Army	Navy	Air Force	Marines	[illegible]	Total
[illegible]	[illegible]						[illegible]
[illegible]							[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]				[illegible]		416
[illegible]	[illegible]				[illegible]		[illegible]
[illegible]	[illegible]				[illegible]		[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						[illegible]
[illegible]	[illegible]						21
[illegible]	[illegible]	495				40	614
[illegible]	[illegible]	11					[illegible]
[illegible]	60	492					[illegible]
[illegible]	40	121				[illegible]	[illegible]
[illegible]	[illegible]	1,104				40	[illegible]
[illegible]		[illegible]					95
[illegible]	[illegible]						[illegible]
[illegible]							[illegible]
[illegible]	[illegible]						[illegible]
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]							
[illegible]	[illegible]	2,404			[illegible]	[illegible]	[illegible]

PROJECTS

Shot	[illegible]	50.4	50.5	50.6	50.7	50.8	51.4	PROJECT TOTAL	GRAND TOTAL
[illegible]	25		4	2	[illegible]			34	[illegible]
[illegible]	26							28	28
[illegible]	25	5	4		1			37	242
[illegible]	25	5	4	2	1	557	21	610	866
[illegible]	25	5	4	2	3	557		596	[illegible]
[illegible]	25	5	4	2	3	557	36	632	2,680
[illegible]	25	5	4	2	2	557	36	631	2,761
[illegible]	25	5	2	2	2	557	46	639	1,333
[illegible]	25	5	2	1	2	557		592	689
[illegible]	25	5	2	1	2	557	30	622	1,556
[illegible]	25	5	1	1	2	557		592	715
[illegible]	25	5	[illegible]		3	557	35	676	1,359
[illegible]	25	5	1		3	557		591	611
[illegible]	25				[illegible]	557	56	[illegible]	1,206
[illegible]	25				1	557	48	631	1,088
[illegible]	25				1	557		583	2,232
[illegible]	23					105		128	323
[illegible]	23					105		128	140
[illegible]	23					105		128	135
[illegible]	28					105		133	143
[illegible]	28					50		78	78
[illegible]	28							28	28
[illegible]	28							28	28
[illegible]	28							28	28
[illegible]									
[illegible]	[illegible]	55	34	15	37	[illegible]	311	[illegible]	20,339

*REFERENCE 280. [illegible] PARTICIPATE IN [illegible] SHOTS [illegible] COULOMB A, PASCAL A, [illegible], PASCAL B, COULOMB B

THIS REPRESENTS DATA OBTAINED AT THE TIME AND THE NUMBERS EXCEED THOSE RECOVERED LATER AND INCLUDED IN CHAPTER 8.

- Evaluation of Shielding for Engineer Heavy Equipment (Project 50.5) - Sponsor: Office of Chief Engineer, U.S. Army

- Protection Afforded by Field Fortifications (Project 50.6) - Sponsor: Office of Chief Engineer, U.S. Army

- Test of Ordnance Material (Project 50.7) - Sponsor: Chief of Ordnance, U.S. Army

- Detection of Atomic Burst and Radioactive Fallout (Project 50.8) Sponsor: U.S. Army Artillery and Guided Missile School.

4.2.1 Project 50.3 (Evaluation of Medium Range Detonation-Detection and Cloud Tracking System)

The U.S. Army Signal Engineering Laboratory conducted this project, which had two purposes: to test the Army's capability of evaluating atomic detonations and tracking radioactive clouds, and to test fallout prediction methods and instruments developed by the United States Army Signal Engineering Laboratory. Table 4-3 indicates shot participation during Operation PLUMBBOB for Project 50.3 personnel. Participants in Project 50.3 included a radar section and a fallout team.

The radar section used AN/PRC-9, AN/MPG-1, and AN/TPS-1D, initially located southeast of Yucca Lake. All radars operated from that site for the first ten shots, but were later moved to other locations (see Table 4-3). Radar distances from ground zero were large. The closest radars were remotely operated so that no operating personnel were closer than eight miles to ground zero. Thus, radar personnel were generally not exposed to initial radiation. However, moving radars from site-to-site and operating sets located at the Nevada Test Site required multiple entries into forward areas. Although EDR issued film badges to project personnel, EDR did not really function as a Rad-safe organization between and during shots. It was responsible only for Rad-safe activities within its own sector of interest. The radar sites were generally outside the Desert Rock sectors and so were subject to the AEC radiological safety procedures.

A fallout prediction technique developed at the Signal Engineer Laboratory was tested under actual conditions and efforts were made to improve the

Table 4-3. PARTICIPATION IN PROJECT 50.3.

SHOT	DATE 1957	DISTANCE, RADAR TO GZ (MILES)	NO. OF PROJECT PERSONNEL
BOLTZMANN	28 May	11.8	25
FRANKLIN	2 Jun	8.5	25
LASSEN	5 Jun	14.6	25
WILSON	18 Jun	15.0	25
PRISCILLA	24 Jun	4.5	25
HOOD	5 Jul	15.0	25
DIABLO	15 Jul	19.5	25
JOHN	18 Jul	16.5	25
KEPLER	24 Jul	13.2	25
OWENS	25 Jul	14.6	25
STOKES	7 Aug	11.0 and 3.5	25
SHASTA	17 Aug	Not operative	25
DOPPLER	23 Aug	14.0 and 3.5	25
FRANKLIN PRIME	30 Aug	39.0, 30.0 and 3.0	25
SMOKY	31 Aug	41.0 and 30.0	25
GALILEO	2 Sep	50.0 and 30.0	23
WHEELER	6 Sep	100.0 and 8.0	23
LAPLACE	8 Sep	100.0, 30.0 and 8.0	23
FIZEAU	14 Sep	97.0, 30.0, 8.0 and 7.5	28
NEWTON	16 Sep	90.0, 19.0, and 15.0	28
WHITNEY	23 Sep	99.0, 30.0, and 15.0	28
RAINIER	19 Sep	--	28*
CHARLESTON	28 Sep	--	28*

*Both Desert Rock VII and VIII Final Report and the Operation PLUMBBOB Test Manager's Report list 28 participants for Project 50.3 at Shots RAINIER and CHARLESTON. However, the project report (87) does not provide any discussion for these shots (260:200).

model. The fallout team operated in an M-109 mobile van located at Camp Mercury next to the weather station. Initially, the team used weather data from Camp Mercury. After 15 June 1957 the team used a meteorological section team located near Alamo, Nevada, to supplement the Camp Mercury data. EDR provided film badge service for the fallout team personnel. Activities at Camp Mercury were subject to the AEC Rad-safe procedures. The following conclusions were reached as a result of Project 50.3:

- The radar section proved that radar could detect and track atomic detonations at ranges up to and beyond 100 miles under atmospheric conditions like those encountered during Operation PLUMBBOB.
- The standard military radar equipment could both locate ground zero and determine nuclear cloud rise rate.
- The fallout prediction method tested could be used for tactical situations.

4.2.2 Project 50.4 (Evaluation of Water Decontamination Methods)

The purpose of this project was to study water solubility characteristics of radioactive bomb debris and to evaluate a number of procedures for removing these contaminants from water. It was conducted by the U.S. Army Engineer Research and Development Laboratory. Approximately five personnel were involved. A more detailed discussion of this project is included in the PRISCILLA shot volume.

4.2.3 Project 50.5 (Evaluation of Shielding for Engineer Heavy Equipment)

The purpose of this project was twofold: first, to determine the attenuation of residual gamma radiation (from fallout and neutron-induced activity) by shielding heavy equipment operating in a large, uniformly contaminated field, and second, to evaluate the effective uses of this equipment in clearing (decontaminating) land areas. Although project personnel were present for shots LASSEN through SHASTA, the tests were conducted only in relation to shots BOLTZMANN and WILSON. The Army Corps of Engineers provided the project personnel. At shot BOLTZMANN, areas 100' X 100' and 30' X 100' were decontaminated on D+8 and D+9 days, respectively. At shot WILSON, radiation protection readings were taken at H+9 hours and on D+1, areas 100' X 100' and 30' X 100' were decontaminated. The preliminary results (200) are shown in Table 4-4. These results indicate the degree of protection provided and extent of decontamination. It is obvious from the exposures indicated that both operations involved entry into full radiological exclusion areas requiring full anti-contamination clothing, respiratory protection, and monitoring. Although no documentation has been located, the vehicle must have been contaminated and would have required washdown or isolation until activity reduced below 7 mR/h.

4.2.4 Project 50.6 (Protection Afforded by Field Fortifications)

Army Engineer personnel dug the fortifications. Although only shot PRISCILLA was involved, project personnel were present for shots WILSON through OWENS. Twenty-seven unmanned emplacements were provided as follows:

Machine Gun Emplacement	5
Two-man Foxhole	10
Modified Two-man Foxhole	2
Offset Foxhole (covered)	5
Offset Foxhole (open)	3
Hasty Shelter	2

The Army's Ballistic Research Laboratories installed pressure-time gauges in the machine gun and offset foxholes. AFSWP Project 2.4 instrumented all the emplacements for nuclear radiation. The radiation readings were time-sensitive so that entry to the experimental area soon after the shot would be required. Additional details are provided in the PRISCILLA shot volume.

4.2.5 Project 50.7 (Test of Ordnance Material)

This was conducted to test items of ordnance equipment under the blast, thermal, and radioactive effects of nuclear explosions. Throughout PLUMBBOB, this project served to investigate the following specific areas. Table 4-5 shows personnel participation:

Table 4-4. PRELIMINARY RESULTS OF PROJECT 50.5.

OPERATION	BOLTZMANN	WILSON
GZ Region traversal:		
Maximum indicated intensity (outside vehicle)	-	90 R/h
Maximum indicated intensity (inside vehicle)	-	10 R/h
Average operator exposure rate	-	1.4 R/h
20 Hour exposure to 500 mR free-field:		
Outside free field dosage	-	970 R
Outside dosage on tractor	-	840 R
Inside dosage at operator's position	-	80 R
Decontamination		
Average intensity in 100' X 100' area before decontamination	1.5	0.336 R/h
Average intensity in 100' X 100' area after decontamination	0.44	0.306 R/h
Average intensity in 30' X 100' area before decontamination	2.6	0.416 R/h
Average intensity in 30' X 100' area after decontamination	1.35	0.374 R/h
Direct measurement		
Free-field intensity	-	0.42 R/h
Intensity inside cab	-	0.023 R/h
Intensity on hood	-	0.23 R/h

Preliminary analysis of the data yielded the following tentative results:

PROTECTION FACTOR*	BOLTZMANN (PF)*	WILSON (PF)*
GZ region traversal - near GZ	-	13
2500' out	-	16
20 hour exposure to 500mR Free-field	-	12
Decontamination operations	-	14.5
Direct measurements	-	18

DECONTAMINATION FACTOR	(DF)	(DF)
100' X 100' area	0.29	0.91
30' X 100' area	0.52	0.91

*PF equals outside dose rate/inside dose rates.

DF equals average dose rate after/average dose rate before.

Table 4-5. PROJECT 50.7 PARTICIPATION IN PLUMBBOB.

SHOT	ARMOR RADIATION TESTS	FOXHOLE TESTS	VEHICLE DAMAGE TESTS	FUZE TESTS	NUMBER OF PROJECT PERSONNEL
FRANKLIN	X		X		3
LASSEN	X		X		3
WILSON	X	X	X		3
PRISCILLA				X	3
DIABLO I*					3
HOOD	X	X	X		2
DIABLO II*					2
JOHN*					2
KEPLER*					2
OWENS*					2
STOKES*					3
SHASTA*					3
DOPPLER*					1
FRANKLIN PRIME*					1
SMOKY			X		1

*These shots are included since the Desert Rock VII and VIII Final Report (200) lists personnel as participating. However, no mention of these shots was made in the narrative of that reference. Since this project is related to AFSWP Projects 1.8 and 2.4, the personnel shown may have participated with AFSWP on those shots.

- Radiation tests - the shielding effects of armored vehicles and armor materials against gamma and neutron radiation. This effort was related to AFSWP Project 2.4, which used some of the same vehicles. The U.S. Army Ballistics Research Laboratory (BRL) conducted this phase of the project.

- Foxhole tests - The protective value of armored vehicles placed over revetted and unrevetted foxholes. This effort was related to AFSWP Project 1.8, which used the same vehicles. Continental Army Command (CONARC, now Training and Doctrine Command, TRADOC) conducted this phase of the project.

- Vehicle damage tests - The effects of blast on five Ontos (light armored vehicles). This effort was related to AFSWP project 1.8. Detroit Arsenal (now Tank and Automotive Research and Development Command) conducted this phase of the project.

- Fuze tests - The effects of neutron radiation on component parts of rocket and shell fuzes. This effort was conducted by Diamond Ordnance Fuze Laboratories (DOFL, now Harry Diamond Laboratory, HDL).

Radiation tests evaluated the protective effect of armor at shots FRANKLIN, LASSEN, WILSON, and HOOD. For each test, an array of equipment was used consisting of three tanks, three Ontos vehicles, two solid armor hemispheres, and two hemispheres of laminated armor. At each test, every item was placed at the same radial distance from ground zero. The radial distance was 1800 feet for FRANKLIN, LASSEN, and WILSON, and 3000 feet for shot HOOD. Personnel from AFSWP Project 2.4 provided and installed the instrumentation for this project. Gamma ray detectors, low, medium, and high energy neutron detectors, gamma-sensitive film badges, and gamma-neutron dosimeters were placed inside hemispheres and within the vehicles in locations corresponding to crew positions. The tests resulted in the determination of a transmission factor for gamma and neutrons for each vehicle or hemisphere. The more technical results are reported under AFSWP Project 2.4.

Foxhole tests were conducted at shots WILSON and HOOD. Although the project was intended to study both revetted and unrevetted foxholes, only the unrevetted were used at PLUMBBOB. Two-man foxholes were dug both end-on and side-on to ground zero. The foxholes were then covered with Ontos vehicles and tanks in side-on and face-on configurations. Some foxholes were left uncovered to serve as standards for comparison. The effects of blast, thermal radiation, and ionizing radiation were then noted. In some cases, the vehicles were dragged across foxholes, by the blast wave, caving them in and thus damaging them. In those cases where vehicles remained in position, thermal and ionizing radiation had a lesser effect than on unprotected foxholes.

Vehicle damage tests were also conducted. Ontos vehicles were positioned at varying distances from ground zero at shots FRANKLIN, LASSEN, WILSON, and HOOD. Jeeps were also placed at these shots, but the jeeps were part of AFSWP Project 1.8. At FRANKLIN and LASSEN, no vehicle was damaged even though severe damage was predicted for vehicles close to GZ. At WILSON and HOOD, on the other hand, damage varied from light to severe, depending on distance from GZ. M-48 tanks were used at shots WILSON, HOOD and SMOKY. These were the same vehicles used in AFSWP Project 2.4. No blast damage was experienced by the tanks in WILSON and HOOD. However, at SMOKY one unmanned tank, placed at 1,231 feet from GZ, was rolled on its top and severely burned. The tank was not economically repairable. Also at SMOKY another tank, placed 2,840 feet from GZ, was undamaged.

Fuzes for bombs, rockets, artillery shells, and hand grenades were tested on Frenchman Flat during shot PRISCILLA. The test items were buried in shallow trenches dug at distances of 1,200, 2,400, and 3,500 feet from GZ and located close to the neutron detector line described in AFSWP Project 2.3. The project was to ascertain the effects of neutron radiation on grenade initiators and fuze electronic components. The activities described above show the following:

- Entry to forward areas was required prior to the shots involved in order to construct foxholes and to place vehicles, instruments, and fuzes.
- Photographs available (200) indicate that entry was made into the blast zone surrounding the shot subsequent to detonation.

- The use of vehicles on more than one shot indicates that personnel entered the shot area after the shots to recover vehicles and move them to other test areas.

- Entry into the shot area after the burst to read dosimeters and instruments and to collect film badges was also required. These activities would provide multiple occasions for exposure to ionizing radiation. Participants would be subject to both Desert Rock and AEC Rad-safe procedures. Desert Rock provided film badging and radiological monitoring support.

4.2.6 Project 50.8 (Detection of Atomic Burst and Radioactive Fallout)

This project had purposes which were related either to fallout prediction procedures or to equipment testing:

- To test the capability of Army units to predict and monitor fallout using standard Army instruments or research items available for testing

- To determine specific requirements for weather data necessary to predict radiological fallout patterns

- To determine the suitability of standard equipment and research items available to the U.S. Army for detecting the horizontal location of surface ground zero, determining the height of the burst, and estimating the yield of atomic detonations

- To determine the organization and equipment required at Army, Corps, and Division levels to predict and monitor radiological fallout

- To determine the capability available of radar equipment to acquire and track targets and guided missiles through an atomic cloud and fireball.

Shot participation for Project 50.8 is shown in Table 4-6. The following organizations provided guidance and troops for the projects:

Table 4-6. PROJECT 50.8 PARTICIPATION IN PLUMBBOB.

SHOT	DATE	PARTICIPATING AGENCY	NUMBER OF PERSONNEL ASSIGNED
WILSON	18 JUN 1957	AIR DEFENSE BOARD; ARTILLERY BOARD	557
PRISCILLA	24 JUN 1957	ALL ORGANIZATIONS LISTED IN TEXT	557
COULOMB A	1 JUL 1957	ARTILLERY BOARD (optical instruments only)	557
HOOD	5 JUL 1957	ALL	557
DIABLO	15 JUL 1957	ALL	557
JOHN	19 JUL 1957	AIR DEFENSE BOARD; ARTILLERY BOARD	557
KEPLER	24 JUL 1957	ALL	557
OWENS	25 JUL 1957	ALL EXCEPT CHEMICAL CORPS	557
PASCAL	26 JUL 1957	ARTILLERY BOARD (sound ranging only)	557
STOKES	7 AUG 1957	ALL	557
SHASTA	18 AUG 1957	ALL	557
DOPPLER	23 AUG 1957	AIR DEFENSE BOARD	557
SMOKY	31 AUG 1957	ALL	557
GALILEO	2 SEP 1957	ALL	105
WHEELER	6 SEP 1957	ARTILLERY BOARD	105
LAPLACE	8 SEP 1957	ARTILLERY BOARD	105
FIZEAU	14 SEP 1957	ARTILLERY BOARD	105
NEWTON	16 SEP 1957	ARTILLERY BOARD	50

- The U.S. Army Air Defense Board and Artillery Board* provided one Air Defense Board test and evaluation unit, one Artillery Board test and evaluation unit, and one Test Director detachment.

- The U.S. Army Chemical Corps provided both ground and aerial radiological monitoring parties

- The Air Weather Service Provided one Air Weather Service detachment.

*Within the Army combat arms and branches, boards were appointed to evaluate and test new and proposed items of equipment, as well as doctrinal techniques and concepts appropriate to that arm or branch.

- The U.S. Army Artillery and Missile Center provided one field artillery observation battalion consisting of communications, survey, sound, flash, and radar personnel; three field artillery meteorological sections, one tactical support center detachment, one fire support coordination center detachment, and one Army aviation detachment.

The following fallout prediction procedures, as devised by various military services and agencies, were tested during Project 50.8:

- The Navy Radiological Defense Laboratory method used fall rates and the path of various size particles to predict a "hot line" of expected contamination.

- The Air Weather Service method plotted 10,000-foot wind vectors from GZ and enclosed an area between GZ and the end of the vector to estimate arrival time of fallout. Results were fair for area coverage. After the first few hours, arrival times were inaccurate.

- A method outlined in Technical Manual 23-200 (Capabilities of Atomic Weapons) used ellipses from GZ based on one scaled wind vector from the surface to the top of the cloud. Results were poor, both quantitatively and qualitatively.

- The Chemical Corps method assumed uniform cloud distribution and plotted separate ellipses for each 5000-foot wind level. Qualitative results were good but quantitative results were only fair.

- The Army Command and General Staff College method scaled predetermined density contours on the wind hodograph. Direction and area coverage results were good.

- The U.S. Weather Bureau method plotted wind vectors in increments of 10,000 feet, and used the area enclosed by vectors as the fallout area. Qualitative results were fair.

The various agencies involved tested fire control center optical and plotting equipment; an experimental camera (AN/TVS-1); an infrared, photo-electric, light detecting device (AN/GAS-1); the AN/ASH-4 Bhangmeter (pressure-measuring device); the sound ranging set GR-8; radars AN/MPQ-10, AN/MPQ-21, AN/FCS-33, AN/FPS-36; and an experimental fire adjustment radar. The following results at the time are listed to indicate the scope of experimentation achieved:

- Horizontal locations of atomic detonations were made by flash and sound equipment. Horizontal location could have been made by radar in the special case of radar tracking of atomic projectiles.

- Height of burst was determined by the AN/TVS-1 camera when line-of-sight was maintained. Range capability was estimated at under 25 miles.

- It was decided that yield could be determined by the AN/ASH-4 Bhangmeter, but this item required considerable development.

- The radar set AN/MPQ-21 displayed some technical capability to detect and track atomic clouds. However, no corrections with yield or fallout were reliable.

- A suitable tactical method existed to provide a qualitative fallout pattern for small yield weapons (below 40 KT).

- None of the methods tested were suitable to provide quantitative fallout isodose patterns.

- A quantitative system of the fallout prediction must consider time and space of variation of the wind and large scale vertical motions of the atmosphere.

- Air burst atomic clouds did not cause too much difficulty with regard to attenuation of, or interference with, radar signals.

- Ground survey provided more detailed results than aerial survey but was severely limited in the area that could have been monitored in given time.

- Aerial surveys were required to provide rapid determination of fallout direction and contamination.

- The then standard military instruments were unsatisfactory for use in aerial survey due to the slow response time in a rapidly changing intensity area.

4.3 TROOP OBSERVER INDOCTRINATION PROGRAM

The troop observer indoctrination program enabled observer personnel to witness the effects of nuclear weapons during and following a nuclear detonation. The troop observer program consisted of two parts: official observers, and troop packet units from six continental armies plus the Air Force. This was an important phase of the exercise since these personnel later disseminated first hand information acquired at these tests. In view of this fact, a very detailed program of orientation was established, including lectures, films, pre-shot tours of the Desert Rock display area, and post-shot tours of the same area. All troop observers not previously trained in the area of special weapons were required to participate in this orientation program. Other observers at the exercise were from three programs sponsored by the Operation Coordination Visitor Program and coordinated with the joint AEC/DOD Visitor's Bureau. Though the success of the observer program was affected by unfavorable weather and other factors which often delayed firing, most observers (via completed questionnaires) recommended continuation of the troop observer program.

4.3.1 Projects 50.2, 52.2, 53.3, and BOBCAT

These observer projects operated to acquaint representatives from the Armed Forces with the effects of nuclear weapons and to allow them to observe a nuclear detonation. Personnel selected to participate in these projects normally included troop, aircraft, and ship commanders, staff officers whose duties would require familiarity with such weapons, and members of fire support units who would plan the employment of nuclear weapons, i.e., American civilian and Canadian military observers also participated. The Canadians (BOBCAT I through III) did not possess security clearances for all of the information presented and were briefed separately. For PLUMBBOB, the following Desert Rock observers are listed (200):

Army	2849
Navy	93
Air Force	246
Marine Corps	106
Civilian	56
Canadian	316
TOTAL	3666*

The program for observers consisted of an 8-hour orientation in special weapons and follow-on classes in special advanced subjects. The orientation was mandatory for those people who had not previously received similar training. Subjects of instruction included the AEC testing program, security, and radiological safety, as well as technical service project participation. Visits to equipment displays before and after the shots were included, as were visits to the areas of earlier shots. During Desert Rock VII and VIII, 1,435 observers attended the mandatory 8-hour pre-exercise orientation class and 1,613 attended the voluntary special weapons classes.

To experience the close effects of a nuclear detonation, some volunteer observers occupied trenches at least six feet deep, located far enough from ground zero to meet the safety criteria for overpressure, nuclear radiation, and thermal radiation. Most other observers watched shots from the vicinity of News Nob. After the shots, some observers were conducted to the equipment display areas. In addition, standard observer grouping, rostering, and convoy procedures for Camp Desert Rock were followed (see Figure 4-1).

4.3.2 Operation Coordination Visitors' Program

The Operation Coordination Visitor Program had three subdivisions during Operation PLUMBBOB: The Foreign Observer Program, AFSWP Visitor Program, and an observer program whereby personnel from the local bases (Indian Springs, Nellis, and Lake Mead) could witness shots. This visitor program was coordinated and augmented with the Joint AEC-DOD Visitor's Bureau personnel when required. Likewise Operation Coordination personnel augmented he Joint AEC-DOD Visitor's Bureau

*The totals shown reflect more than the number of individuals observing the test because observers were sometimes present for several shots and were counted as observers for each shot.

ROSTERING

Staff supervision of grouping and rostering observers was considered a dual responsibility of S-2 and S-3. S-2 was responsible that all rostered observers had the proper security clearance. S-3 was responsible that all properly cleared observers were grouped and rostered to see a shot.

The following procedure was found to be the most effective: Prior to arrival of observers, S-3 estimated the number of briefing groups required and the anticipated vehicle requirements for each shot, provided S-2 with a break-out of convoy serials to include respective vehicle numbers and capacities. The size of the briefing or orientation groups was dictated by the seating capacity (600) of the auditorium and the size of training aids being used. From this information, S-2 prepared security identification cards with space for observer's signature, briefing group number and vehicle number. Cards were filed in vehicle order. As observers reported, they were initially processed through Visitors Bureau and into S-2 office. Each observer gave S-2 an official copy of his orders and signed his identification card with grouping and vehicle numbers. The orders were filed in vehicle bundles, from which stenciled rosters were prepared with escort officer's name added. Stencils were proofed and certified by S-2 to insure proper clearance. Approximately eight copies of each roster were needed for each convoy movement into the Nevada Test Site. In the event it was necessary to re-roster for special situations, observers were re-routed through S-2.

CONVOY PROCEDURES

A physical check of personnel in each convoy moving into and out of the Nevada Test Site was accomplished by the Camp Mercury security personnel.

To save time and avoid congestion at the entrance to the Test Site, DoD personnel adopted the practice of checking the convoys at Camp Desert Rock and escorting them through gates 1 and 2 at Camp Mercury.

The following procedures were found to be most effective in controlling convoys to the forward area: Five copies of all rosters were required to be turned in to DoD Security a minimum of six hours prior to the departure of the convoy. Vehicles were spotted in convoy order with ten by ten-inch signs A-1, A-2, etc., taped on the right front windshield of each vehicle. Designated escort officers for each vehicle were briefed thirty minutes prior to loading time and given two copies of the vehicle roster. As observers loaded, each Escort Officer checked off individual names. At the announced time, Escort Officers read lined names of absentees on both copies of the rosters. Since no changes could be made on the rosters, anyone arriving after this time could not go with the convoy. Escort Officers added names of drivers (who were all badged) and entered the total number present on the two rosters. As the DoD Security representative came by to check the bus, one copy of the roster was presented to him, and the other copy was retained by the Escort Officer until his return from the forward area and then turned over to S-3 as a permanent record. In case of vehicle breakdowns, personnel could be loaded into a spare vehicle by merely exchanging vehicle numbers. Vehicle loads could also be consolidated by grouping rosters and vehicle numbers on the one vehicle being used for consolidation.

Figure 4-1. STANDARD OBSERVER GROUPING, ROSTERING, AND CONVOY PROCEDURES FOR CAMP DESERT ROCK (200).

at times when official observers were present at the Nevada Test Site. Foreign observer visitors sponsored by the Department of Defense witnessed four atomic detonations during PLUMBBOB: the BOLTZMANN, JOHN, PRISCILLA, and SMOKY shots. Observers from local military bases (Indian Springs Air Force Base, Nellis Air Force Base, and Lake Mead Base) witnessed shots throughout the series. These observers were not badged, but entered the test site on a roster basis, were escorted as a group to the observation point, and returned to their bases immediately after witnessing the shot. This program was highly successful and afforded many of the troops, directly and indirectly supporting PLUMBBOB, an opportunity to witness a shot. A total of 342 local military observers, not including Desert Rock, witnessed shots.

4.3.3 Shot JOHN Observer Program.

"The Commander, Army Air Defense Command, accepting the responsibility, requested and received permission to place six [volunteer] observers at ground zero at H-hour for Shot JOHN . . . Prior to the shot, all observers attended a combined technical briefing at Indian Springs Air Force Base. No adverse effects to the observers were noted." (200) Since this 2 KT explosion was at 18,500 feet altitude, these individuals did not receive any appreciable ionizing radiation.

4.4 TROOP MANEUVERS AND TESTS

The military services took advantage of the nuclear test series to exercise their units in actual nuclear environments. During shot HOOD, the Fourth Marine Corps Provisional Atomic Exercise Brigade observed the detonation from trenches and then conducted a planned maneuver (Project 52.1) involving the use of helicopter airlift and tactical air support. Detailed troop activities are discussed in the shot volume for HOOD.

A unit from the 1st Infantry Regiment, 4th Infantry Division (Fort Lewis, Washington) was formed to conduct a military maneuver at shot SMOKY. Members of this unit observed shot DOPPLER from trenches, prepared defensive positions northwest of the SMOKY GZ, and then, after the SMOKY firing, conducted the air-lifted assault. This troop exercise (Project 50.1) is described and analyzed in detail in the shot volume for SMOKY.

Members of a provisional company from the 82nd Infantry Division (Airborne) were assembled to participate in a test of troop reactions to nuclear blasts. These troops were initially scheduled to observe the SMOKY detonation and then perform the test. However, the radiological fallout situation predicted for SMOKY led to postponement of the testing phase until shot GALILEO. Troops observed shot SMOKY from News Nob. A more detailed discussion of this is included in the GALILEO shot volume.

4.5 TRAINING PROJECTS

In conjunction with the nuclear testing at the Nevada Test Site, three radiological training projects were established under the supervision of the assistant Rad-safe Officer. These training projects were designed to familiarize the participants with radiological monitoring techniques under the realistic conditions available at the test site. The largest of the three projects was the establishment of the Camp Desert Rock Rad-safe School, which trained 417 personnel as radiological monitors.

UNITS	PERSONNEL
Permanent Party	84
Sixth U.S. Army CBR Survey Teams	89
4th Marine Provisional Brigade	180
2nd Bn, 5th Marine Division	16
Infantry Battle Group	30
Canadian Infantry (Queens Own Rifles)	3
XVIII Airborne Corps Pathfinders	14
AEC	1
TOTAL	417

This training course consisted of 18 hours of formal instruction followed by several days of practicing monitoring techniques in contaminated areas of the Nevada Test Site. Nine U.S. Sixth Army chemical, biological, radiological (CBR) survey teams received field experience in conducting radiological surveys in contaminated target areas subsequent to shot days. These exercises were conducted from 25 May 1957 to 18 August 1957. The average length of stay for an individual was 11 days.

Another training program run during this period was the Navy's radiological safety monitoring program (Project 51.1), sponsored by the Bureau of Yards and Docks. Approximately 120 individuals from all parts of the world were brought to the Nevada Test Site for training planned to coincide with shot BOLTZMANN. This shot was delayed, however, and the training exercises had to be held in an area of low contamination containing debris from the 1955 test series (TEAPOT). All participants in this project, except for three, had to depart without witnessing a shot.

The Air Force also had a radiological survey project (USAF Radiological Defense Training, Project 53.4) which was sponsored by the Radiological Defense School located at Lowry Air Force Base, Denver, Colorado. Instructors from the school were stationed at Nellis AFB where they conducted classes in radiological survey monitoring. Students from continental air bases attended the classes at Nellis AFB, after which they viewed a shot at the NTS. The students then conducted radiological survey monitoring in the target area of the shot where they were participating. Areas to be surveyed were first marked with stakes. Monitors then proceeded down the staked sectors toward ground zero, reporting dose rates encountered at mileages indicated on vehicle odometers. The dose rate readings were radioed to control stations where they were integrated into isodose rate maps. Desert Rock Rad-safe monitors were present to enforce the radiological safety criteria and provide technical assistance if necessary.

4.6 DESERT ROCK SUPPORT ACTIVITIES

The command organization for Camp Desert Rock was shown in Figure 2-4. The troops assigned to the Camp Desert Rock organization were called permanent party personnel although, with the exception of a small caretaker crew, they were only present at Desert Rock during the operational period of a Desert Rock exercise. The Camp Desert Rock staff activities included all those functions necessary for administration, finance, security, and logistics, and for planning the Desert Rock activities to be conducted in the forward area of NTS as an adjunct to nuclear tests. The staff also provided supervision for all the various related special activities necessary to operate the garrison and support the field activities.

These personnel frequently entered the NTS forward areas--before, during, and after the nuclear tests--in support of troop maneuvers, troop tests, training projects, and technical service projects. Any occasion for entry into the test site posed the same problems in varying degree: Rad-safe support, transportation, communications, medical support, and mess facilities. These problems existed whether the entry was made by a monitoring team or by an engineer construction battalion. This section illustrates some of the more important activities.

Radiological safety personnel had numerous occasions for providing support to operations or for being in the forward area. The Rad-safe section provided monitors for any entry into Radex or limited Radex areas. In addition, they provided film badges to all Desert Rock personnel entering NTS. In exercises, they would be among the first to enter a contaminated area to determine, by means of monitoring or radiological survey, the extent of contamination. In line with these duties, they were often among the last to leave the maneuver or display area to ensure that all other participants had left. They also monitored personnel and equipment leaving the areas to determine the need for decontamination. Monitors were provided by the 50th Chemical Platoon, which also provided the personnel to operate a field decontamination station near News Nob.

The 84th Engineer Construction Battalion was required to support troop maneuvers, tests, and the observer indoctrination program. They constructed trenches for observers and project personnel at many of the shots. For example, Figure 4-2 shows the trenches located in the northern portion of the test site. (The insert shows the trench area for PRISCILLA in Frenchman Flat.) Display areas required some engineer construction. Test areas were prepared for troop tests such as the HumRRO test as described in SMOKY and GALILEO shot volumes, which required an infiltration course (crawl under barbed wire) and a dummy mine field. Although construction sometimes occurred in areas exposed to radioactive contamination from earlier tests, the nuclear activity had decayed or had either

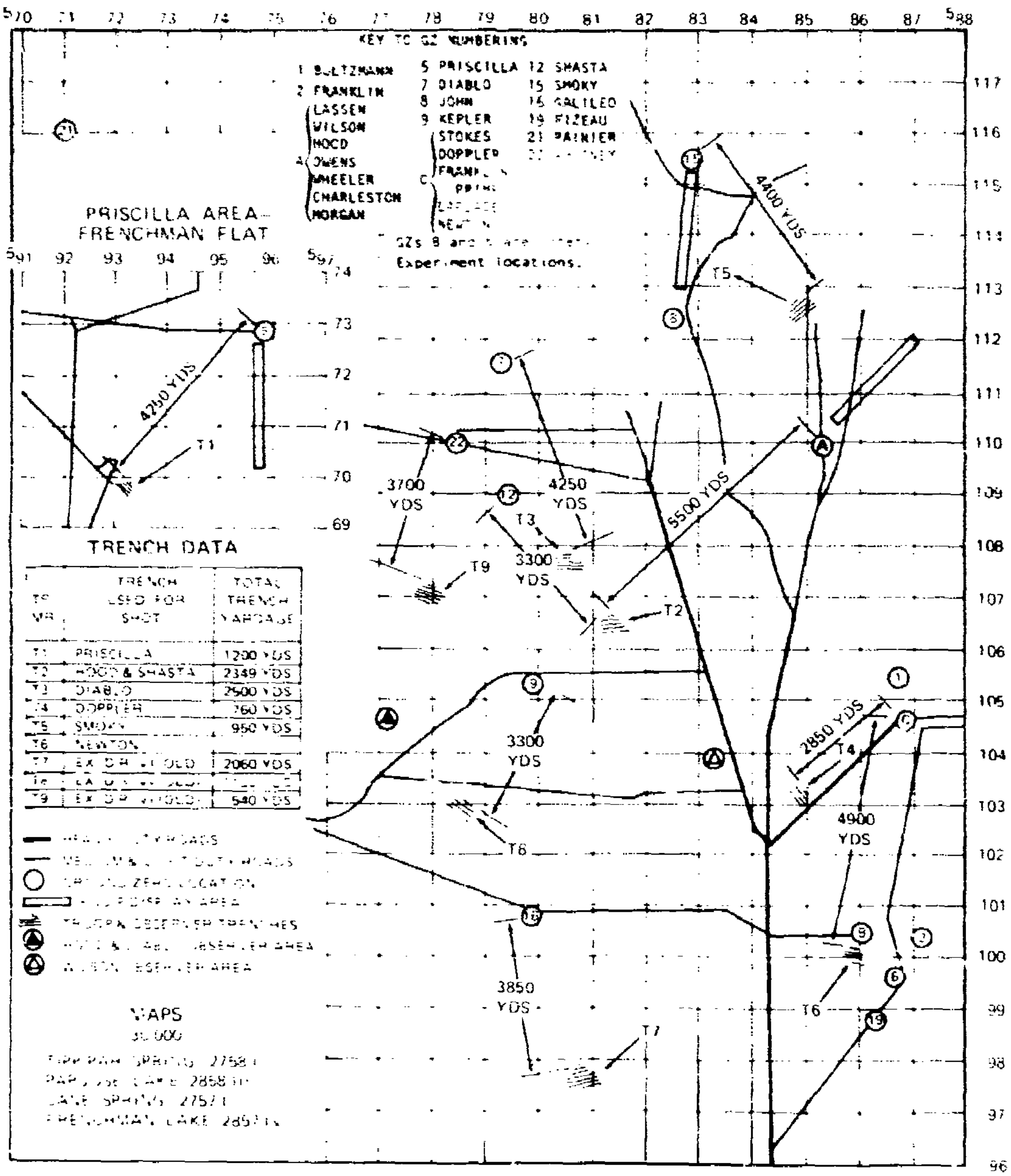


Figure 4-2. TRENCHES IN OPERATIONAL AREA, NTS.

been scraped away or covered to the point that these areas were no longer designated Radex or limited Radex areas. However, the potential for some degree of both external and internal exposure would still exist. The engineer construction activities also involved Rad-safe, communications, transportation, and medical support.

Desert Rock communications support in the forward area was provided by the 232nd Signal Company and some attached signal units. Support included essential fixed and mobile tactical communications, pictorial and photo-dosimetry services, plus necessary maintenance and supply of signal items of equipment such as radiac meters for Exercise Desert Rock VII and VIII. Some of the dose received by signal equipment repair technicians can be attributed to the radiological calibration sources used in conjunction with their equipment. The extensive wire communications to numerous points in the NTS forward area required installation of more than 1,200 miles of wire during PLUMBBOB. Installing of this wire required entry into the NTS forward area before and after nuclear tests, as well as troubleshooting and maintenance during shots and their related Desert Rock operations (troop maneuvers, inspection of display areas). In addition to wire communications, several radio nets supported each shot. These included a Rad-safe net, a road guard net, and an ambulance and emergency net.

Signal units also planned for television coverage of one shot, SMOKY. Equipment was installed and calibrated to allow the military maneuver activities to be viewed and relayed. A late decision to switch to an alternate maneuver area, however, rendered the pre-sited equipment ineffective so that no television coverage was obtained. The 2nd Signal Platoon did provide black and white photo coverage of activities throughout the various activities in Desert Rock VII and VIII.

Military Police personnel were required to enter the NTS forward area frequently throughout Desert Rock VII and VIII. This was to augment the traffic control provided by the AEC checkpoints at the main gate and at Yucca Pass. In addition, Desert Rock military police were used to man traffic control points on entry roads, at maneuver areas, and at motor-park and pick-up points which supported troop maneuvers and projects. The traffic control teams accompanied monitoring teams into shot areas after the detonation to establish a checkpoint at the 20 mR/h point on the access roads. No vehicular traffic was permitted beyond this point.

Another permanent party activity requiring frequent NTS entry was the public information program. Personnel from this activity were often present during reconnaissance, rehearsals, and photographic sorties. They also accompanied troop maneuvers, observed shots, and visited trench and equipment display areas.

Transportation Battalion personnel had an opportunity for exposure before, during, and after the shots since they were the prime source for personnel movement to and from the test areas (See Figure 4-1).

The 526th Ordnance Company personnel were frequently in the test area. Their duties included movement of tanks and other vehicles to the demonstration locations before the firings, and some post-shot recovery.

Quartermaster detachment personnel were responsible for providing field rations, gasoline, and water to troops throughout the test site. Consequently the forward echelons could be expected to receive some radiation dose.

The Eighth Field Hospital provided on-scene doctors, first aid personnel, and ambulance services. For those who worked with the Desert Rock was equivalent to those of the maneuver personnel they were safeguarding. The exposure opportunity for those who worked with the Desert Rock troops in the forward area was equivalent to that of the maneuver personnel they were safeguarding.

The 21st Helicopter Squadron aviators and crew members were often in the test areas to shuttle troops, high priority cargo, and dignitaries.

Finally, all Desert Rock personnel, even if their duties did not normally require leaving the camp area, probably had an opportunity to witness at least one shot since it was customary to offer personnel not assigned onsite duties (e.g., finance) the opportunity to watch a shot in the test series which they supported.

CHAPTER 5

DOD PARTICIPATION IN NTO OPERATIONS

5.1 INTRODUCTION

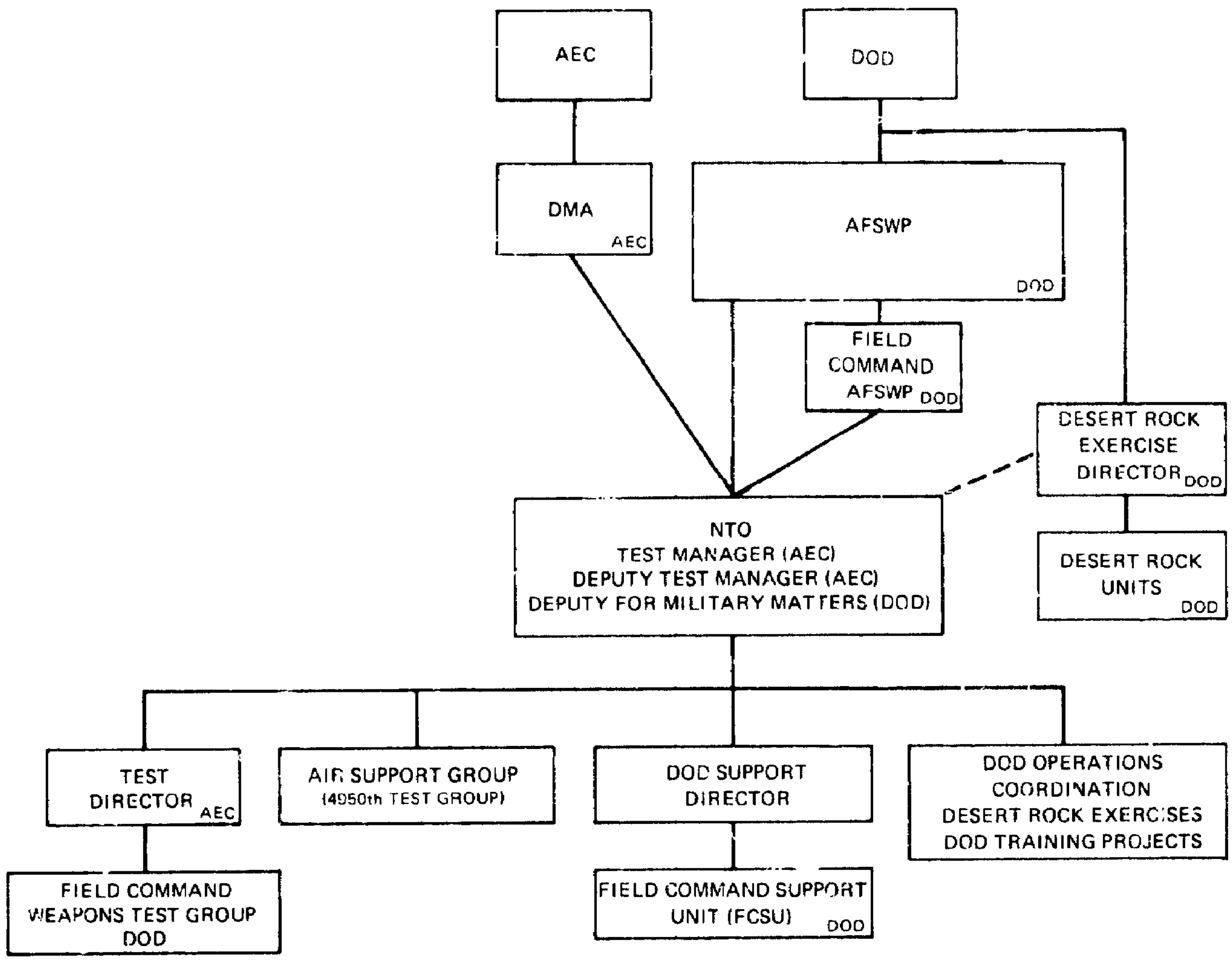
The Atomic Energy Commission developed new weapons of requisite yield, variety, military utility and deliverability, and manufactured weapons for storage in the defense stockpile or for delivery to the Armed Forces. In 1957, to advance this effort, the AEC continued to test its designs of nuclear devices in Operation PLUMBBOB. Also included were five safety experiments to verify design safeguards against accidental nuclear detonations and one non-nuclear detonation to study plutonium contamination. Although these AEC programs as such were carried out mainly by AEC and AEC contractor personnel, DOD personnel assisted in many of them, and in addition, carried out many programs of their own within the NTO. These latter, sponsored by AFSWP, concentrated on the military effects of nuclear weapons such as blast damage to military equipment and the like.

5.2 DEPARTMENT OF DEFENSE OPERATIONS WITHIN THE NTO

The DOD was interested in AEC's conduct of full-scale tests of the output characteristics of nuclear weapons (such as blast and nuclear radiation) and their effects on various military targets under varying conditions. Such tests were essential for planning the use of weapons, preparing military defenses against nuclear weapons, and searching for desired characteristics of new weapons. The DOD military effects programs and projects at Operation PLUMBBOB were planned and coordinated by the Armed Forces Special Weapons Project (AFSWP) (Figure 5-1). At Operation PLUMBBOB, AFSWP had several responsibilities:

- Directing the field conduct of the experiments
- Coordinating all military participation in the tests
- Providing logistical support to the AEC and the Armed Forces.

The Field Command Weapons Test (FCWT) group under AFSWP performed nine programs which considered the effects of radiation on military personnel, equipment, and structures. AFSWP was represented by the Deputy Test Manager for Military Matters



— — — LIAISON AND COORDINATION

Figure 5-1. DOD OPERATIONS, PLUMBBOB.

within the joint AEC/DOD test organization. This Deputy for Military Matters served under the Test Manager. He represented the Commander, Field Command, AFSWP, and provided staff assistance to the Test Manager on subjects involving DOD participation and support. He also performed liaison between AEC and DOD agencies on policy and operational matters, and was responsible for military administration such as management of military property and funds. The Field Command Support Unit (FCSU), which came under DOD direction, provided general and technical support to the agencies, activities, and participating personnel at Operation PLUMBBOB. The Air Force Special Weapons Center (AFSWC), the air support group under the Test Manager, provided all aviation support. The DOD Coordination Group, acting as a staff agency for DOD, coordinated training and observer programs.

5.2.1 Armed Forces Special Weapons Project (AFSWP) Military Effects Programs

The Chief, AFSWP (now the Defense Nuclear Agency) planned an integrated program of military-effects tests based on the continuing study of the needs of the Armed Forces for data on the effects of nuclear weapons. In September 1956 the Chief, AFSWP directed the Commander, Field Command, AFSWP to do the following (260):

- Execute the military effects test phases as a joint AEC/DOD endeavor
- Coordinate military assistance and participation in support of the AEC
- Coordinate operational, training, and troop observer participation
- Coordinate Federal Civil Defense Administration participation in the military effects program.

Table 5-1 lists the PLUMBBOB shots on which each project actually participated. There were 43 projects in the weapons-effects test program and they participated in 24 of the operational shots. Participation was not always as planned because of such factors as instrumentation difficulties and changes in yield or firing schedules (127).

Table 5-1. DOD TEST GROUP PROGRAMS AT PLUMBBOB INDICATING PROJECTS AT EACH SHOT (1957)

SHOT \ Program	Program 1 Blast and Shock Effects	Program 2 Nuclear Radiation Effects	Program 3 Effects on Structures and Equipment	Program 4 Biomedical Effects	Program 5 Effects on Aircraft Structures	Program 6 Electro-magnetic Effects, Service Equipment, and Material	Program 8 Thermal Radiation Effects	Program 9 Support Photography
PROJECT 57								
BOLTZMANN		2.5,2.7, 2.10		4.2	5.1,5.3, 5.4,5.5	6.4,6.5		9.1
FRANKLIN	1.1	2.1,2.3, 2.4,2.5, 2.6		4.1	5.1,5.2, 5.5	6.3,6.4, 6.5		9.1
LASSEN		2.1,2.3, 2.4,2.5, 2.6,2.7, 2.10				6.2,6.3, 6.4,6.5	8.2,8.3a	9.1
WILSON	1.1	2.1,2.2, 2.3,2.4, 2.5,2.6, 2.7,2.8, 2.10		4.1,4.2	5.1,5.5	6.2,6.3, 6.4,6.5	8.2,8.3a	9.1
PRISCILLA	1.1,1.3, 1.4,1.5, 1.7	2.1,2.3, 2.4,2.6, 2.7,2.8	3.1,3.2, 3.3,3.4, 3.5,3.6, 3.7,3.8	4.1,4.2, 4.3	5.1,5.4, 5.5	6.1,6.2, 6.3,6.4	8.1,8.2, 8.3a, 8.3b	9.1
COULOMB A Safety Experiment								
HOOD	1.1	2.2,2.3, 2.4,2.5, 2.6,2.7, 2.8,2.10		4.2	5.3,5.4, 5.5	6.2,6.4, 6.5	8.2	9.1
DIABLO		2.7,2.8, 2.10		4.2	5.1,5.3, 5.4,5.5	6.2,6.4, 6.5	8.3a	9.1
JOHN	1.1	2.3,2.5, 2.9,2.10			5.5	6.4	8.3a	9.1
KEPLER	1.1,1.2	2.7,2.10			5.1,5.3, 5.5	6.4,6.5	8.3a	9.1
OWENS	1.1,1.2	2.1,2.2, 2.3,2.4, 2.5,2.7, 2.10			5.1,5.5	6.2,6.4, 6.5		9.1
PASCAL A Safety Experiment								
STOKES	1.1,1.9				5.1,5.2, 5.5	6.4		9.1
SATURN Safety Experiment								

Table 5-1. DOD TEST GROUP PROGRAMS AT PLUMBBOB INDICATING PROJECTS AT EACH SHOT (1957) (Continued)

SHOT \ Program	Program 1 Blast and Shock Effects	Program 2 Nuclear Radiation Effects	Program 3 Effects on Structures and Equipment	Program 4 Biomedical Effects	Program 5 Effects on Aircraft Structures	Program 6 Electromagnetic Effects, Service Equipment, and Material	Program 8 Thermal Radiation Effects	Program 9 Support Photography
SHASTA	1.1				5.3,5.4, 5.5			9.1
DOPPLER					5.3,5.4, 5.5	6.4		9.1
PASCAL B Safety Experiment								
FRANKLIN PRIME					5.5	6.4		9.1
SMOKY	1.8,1.9	2.3		4.3	5.3,5.4, 5.5	6.4	8.3b	9.1
GALILEO	1.1,1.9			4.3		6.4		9.1
WHEELER						6.4		9.1
COULOMB B Safety Experiment								
LAPLACE		2.0,2.2, 2.3,2.10				6.4		9.1
FIZEAU						6.4,6.5		9.1
NEWTON	1.9					6.4		9.1
RAINIER						6.4		9.1
WHITNEY	1.1,1.9							9.1
CHARLESTON	1.1,1.9					6.4		9.1
MORGAN	1.1					6.5		9.1

Program 1 - Blast and Shock Effects

Blast and shock measurements were made on 13 events. Eight projects dealt with phenomenology, ground motions, loading of structures, and effects of terrain. They were fielded by the Ballistic Research Laboratories, the Naval Ordnance Laboratory, Stanford Research Institute, Sandia Corporation, the Air Force Special Weapons Center, and the Air Force Ballistic Missile Division of the Air Research and Development Command.

The blast and shock program for Operation PLUMBBOB had the following objectives:

- Thoroughly document the time history of overpressure in the ground range between 50 psi overpressure and ground zero on a typical nuclear detonation.
- Extend that data out to the lower pressure regions (about 6 psi), in order to have continuity for a complete pressure-distance curve.
- Obtain records of overpressure and dynamic pressure versus time throughout the precursor region on a number of shots.
- Measure the variation with time, depth, and ground range of underground effects resulting from overpressures higher than 50 psi incident on the ground surface.
- Measure air-induced underground pressures on large, buried objects of different flexibilities in the high-pressure region as a function of depth and ground range.
- Obtain data on overpressure and dynamic pressure versus time in the region of precursor formation over a variety of terrain.
- Obtain measurements of the influence of gullies, washes, mounds, etc., and of gross terrain features on damage to military equipment.

Ballistic Research Laboratories (BRL) measured overpressure and dynamic pressures during 12 shots of Operation PLUMBBOB (98). In these experiments, 233 overpressure-time measurements were made on self-recording P_t-gauges (as shown in Figure 5-2) and 57 dynamic self-recording dynamic pressure time q-gauges were used. All the q-gauges were essentially the same used during previous operations except for five experimental models. Figure 5-3 shows a typical gauge installation. Instrumentation was placed at different locations on the blast lines. For each of these locations, accurate surveys were made, holes were dug, cement foundations were poured to hold the gauges, the gauges were installed, and the calibration checked. Eleven shots were instrumented for precursor waveform information. One hundred twenty-seven P_t-gauges were fielded on nine shots to record pressure-time and peak pressures. Thirty-one dynamic pressure gauges were fielded to record pressure-time data.

Naval Ordnance Laboratory (NOL) measured airblast phenomena by means of a prototype system consisting of parachute-supported canisters containing a self-recording mechanical pressure and timing system as shown in Figure 5-4 (166). The systems were deployed on shot OWENS by means of rockets and on shot KEPLER by means of a balloon. An account of the activities required for fielding the system will be given in the individual shot volumes.

Air Force Ballistic Missile Division (AFBMD) of the Air Research and Development Command (ARDC) fielded twelve self-contained shock gauges and protective canisters to study the spectra of ground shocks on five PLUMBBOB events (165). After surveying, the following sequence of events took place to install the shock gauges:

- Excavation of a 27-inch to 36-inch cubical hole at the desired pressure range
- Placement of a protective canister (400 pounds total weight) (as shown in Figure 5-5)
- Placement of backfill around the canister
- Placement of the gauge, (130 pounds) (as shown in Figure 5-6), in the canister
- Placement of the polished record plates (two per gauge)

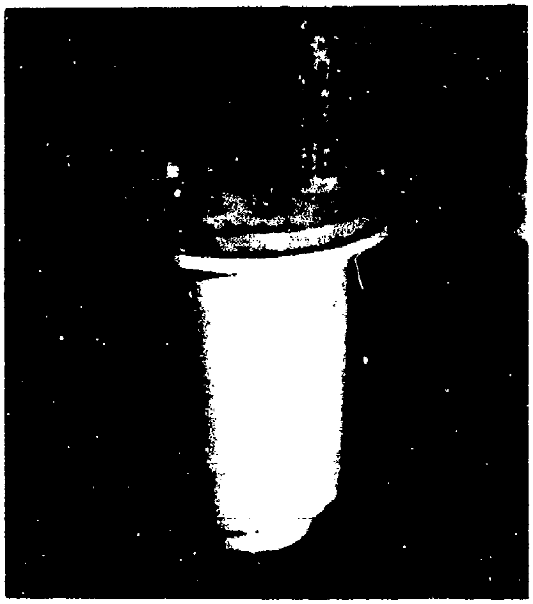


Figure 5-2. SELF RECORDING P_t GAUGE.

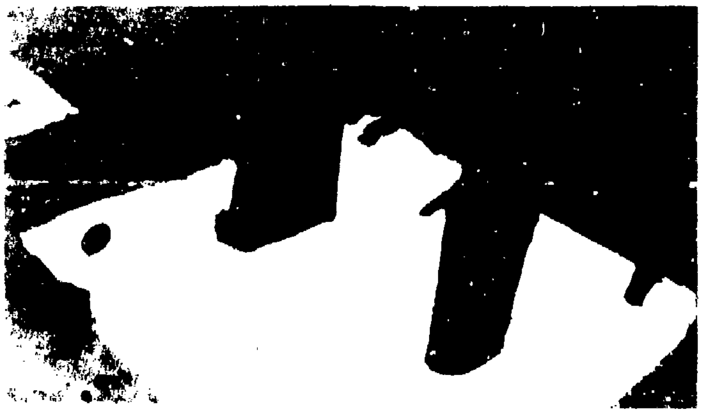


Figure 5-3. CONTRACTOR-INSTALLED TOWERS FOR OLD AND NEW MODEL Q-GAUGES.

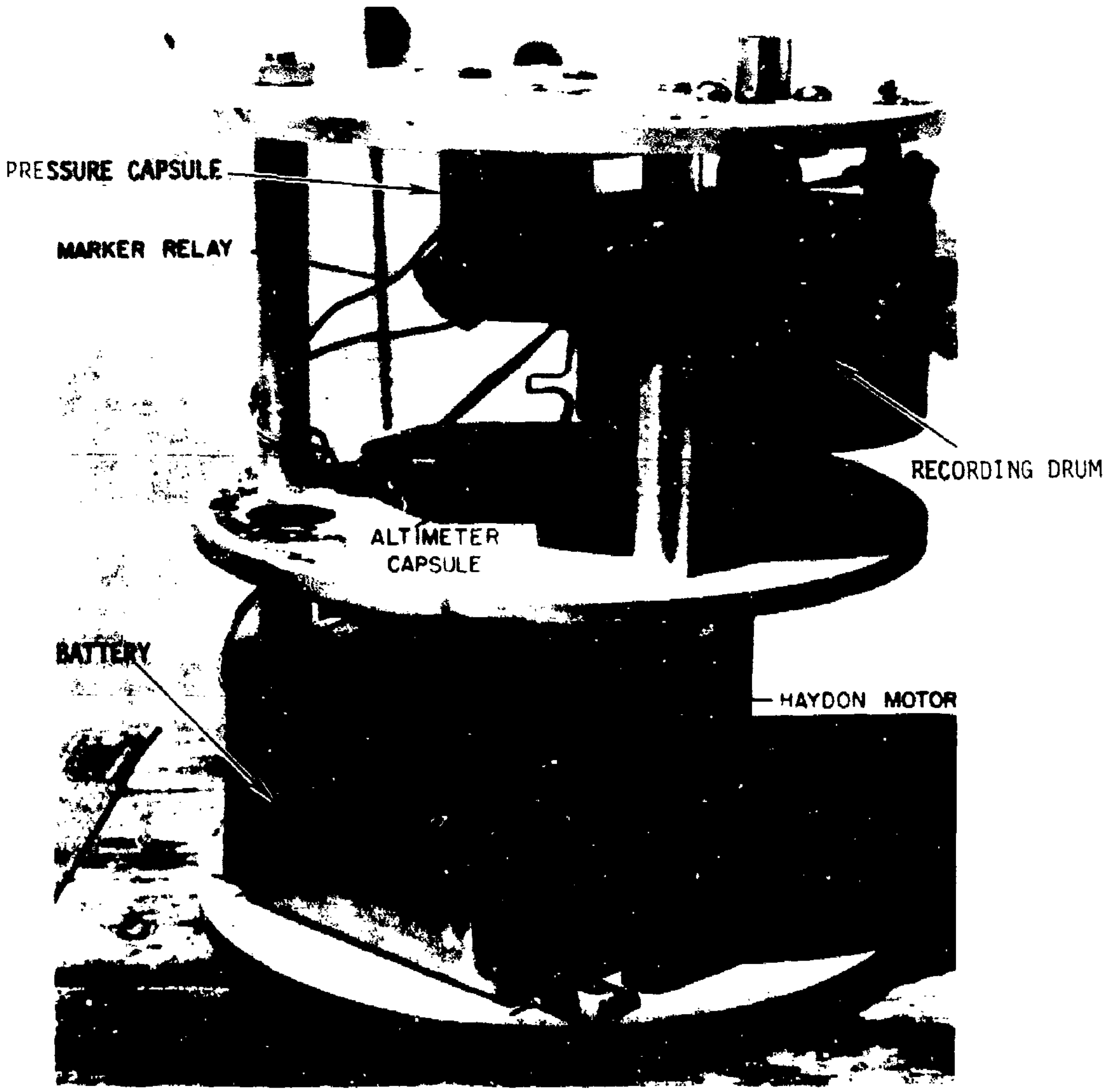


Figure 5-4. PRESSURE AND TIMING SYSTEM.

Figure 5-5. TYPICAL PLACEMENT OF PROTECTIVE CANISTER.

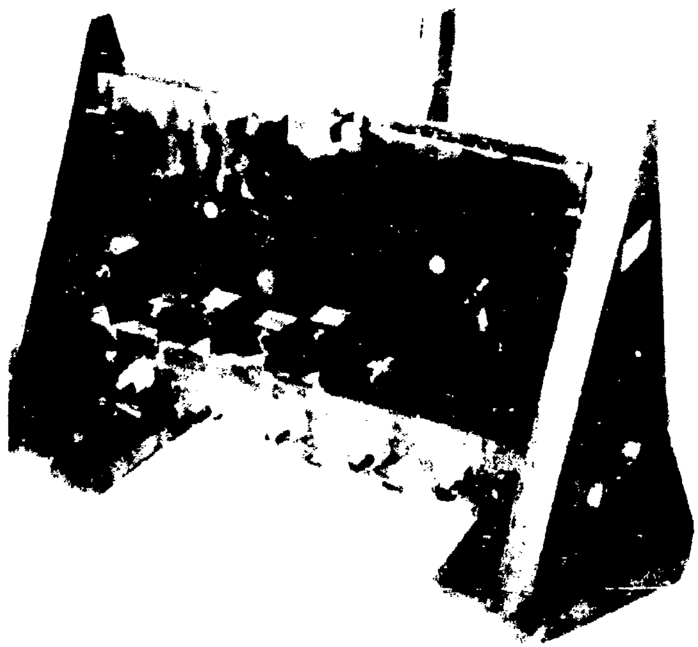


Figure 5-6. PROJECT 1.9 SHOCK SPECTRA GAUGE.

- Careful placement and bolting of the canister lid (rough handling might have excited the gauges)

- Placement of three layers of sandbags over the lid for thermal and nuclear radiation protection.

Recovery of the records was accomplished by moving or sweeping sandbag debris from the cover, unbolting and removing the lid, removing wing-nuts from the gauge, and slipping out the polished record plates.

At shot PRISCILLA, airblast measurement, ground acceleration, stress, and strain measurements were made in the high pressure region, while 68 buried structures (drums) were fielded to study the factors affecting the transmission of air-induced ground pressures and loading (303;302). An account of the activities required for fielding these measurements is given in the PRISCILLA shot volume.

On shot SMOKY, measurements were made to determine the effects of rolling, steep slopes, and rough terrain (99;98). A summary of the field activities is contained in the SMOKY shot volume.

Program 1 personnel from AFSWC (102) and Sandia (252) participated only at shot PRISCILLA; SRI personnel participated on shot PRISCILLA and SMOKY; NOL personnel participated only on shots KEPLER and OWENS; AFBMD personnel participated on five shots; and BRL personnel were on 11 shots. Going from one shot to another, project personnel and supervisory AFSWP staff personnel worked at various tasks throughout the Nevada Test Site. In doing their work--layout, construction, installation, dry run operation, and recovery of data or instruments--personnel could have passed through or worked in areas with measurable low-level radiation from previous events which had only incidental relationship to their participation in individual shots.

Program 2 - Nuclear Radiation Effects

Nuclear radiation effects experiments were installed on twelve of the PLUMBBOB events. The program comprised ten projects in the following five areas:

(1) Neutron-Induced Radiation. New weapons of major tactical importance introduced amplified nuclear radiation effects. One such amplified effect, which is of particular importance to land forces, was the generation of neutron-induced radiation fields of such intensities as to have a direct influence on tactical ground operations. Military planning for the tactical employment of nuclear weapons in land warfare created the need for a reliable method of predicting the neutron-induced field from low air burst tactical weapons. As a result, a major effort for study of this problem was scheduled for Operation PLUMBBOB to obtain experimental data needed for the development of satisfactory prediction methods. Objectives of the neutron-induced soil activity studies on Projects 2.1, 2.2, 2.3, and 2.5 were to determine the following:

- The neutron-induced gamma activity in three types of American soils and in constituent soil elements was a significant contributor to induced soil activity.
- The neutron flux and spectra gave rise to the induced soil activities both as a function of distance from ground zero and as a function of depth beneath the surface.

(2) Initial Nuclear Radiation. This was studied by projects 2.3, 2.5, 2.9, and 2.10 to measure the following:

- The neutron flux, spectra and total neutron dose for weapons of potential tactical interest
- The initial gamma dose rate as a function of time and distance for several events
- The variation of neutron and gamma dose and gamma dose rate with time as a function of altitude and distance to determine the effect of the air-earth interface
- The nuclear radiation dose sustained by the aircraft crew in the delivery of an MB-1 air-to-air missile.

(3) Radio Wave Attenuation. Studies of the radio wave attenuation caused by the ionized volume generated about the burst point of a nuclear

detonation were conducted by Project 2.7 to:

- Proof test the proposed system for Operation HARDTACK nuclear-radiation-data telemeter (HARDTACK was conducted the next year).
- Obtain basic information on the radio wave attenuation problem under nuclear burst conditions to permit a more complete understanding of this phenomenon.

(4) Nuclear-Radiation Shielding. Determination of the shielding effectiveness of the Program 3 structures was part of the overall program to determine the suitability of these structures as shelters in atomic warfare. Similarly, the measurement of the shielding afforded by foxholes, machine gun emplacements, and personnel shelters was part of the continuing Army program to develop improved field fortifications. Nuclear-radiation shielding was studied by Project 2.4 through determination of the gamma and neutron shielding characteristics.

(5) Instrument Evaluation. As the neutron hazard from newly developed weapons increased, the need for a neutron personnel dosimeter became more evident. Instrumentation proposed for use in making nuclear radiation measurements at very high altitudes during Operation HARDTACK was proof tested. The problem of telemetering this data from these altitudes was studied as well. Instrument evaluation was performed by PLUMBBOB Projects 2.6 and 2.8 to evaluate the performance of:

- The IM-93 beta-gamma radiation-survey meter under nuclear test field conditions
- Specially shielded DT-60/PD and IM-107/PD dosimeters and standard AN/PDR-43 and AN/PDR-44 survey meters in the measurement of equivalent body dose and dose rate.

U.S. Army Chemical Warfare Laboratories (ACWL) fielded the experiments necessary for the investigation of the induction of gamma-emitting radioisotopes in the soil caused by five different PLUMBBOB nuclear detonations (252).

The following three test soils were used on Project 2.1:

- Dade fine sandy loam, which has a high silicon content and low mineral content
- Chester loam, which has a strong aluminum concentration and a fairly high manganese content
- Nevada Test Site soil, which has a large sodium component, significant aluminum and manganese content, and is the natural terrain over which the detonations at Operation PLUMBBOB took place.

To evaluate the effect of the water in these soils, the moisture content was carefully controlled in all specimens. The soils exposed were one cubic yard specimens. The exposure station is illustrated in Figure 5-7.

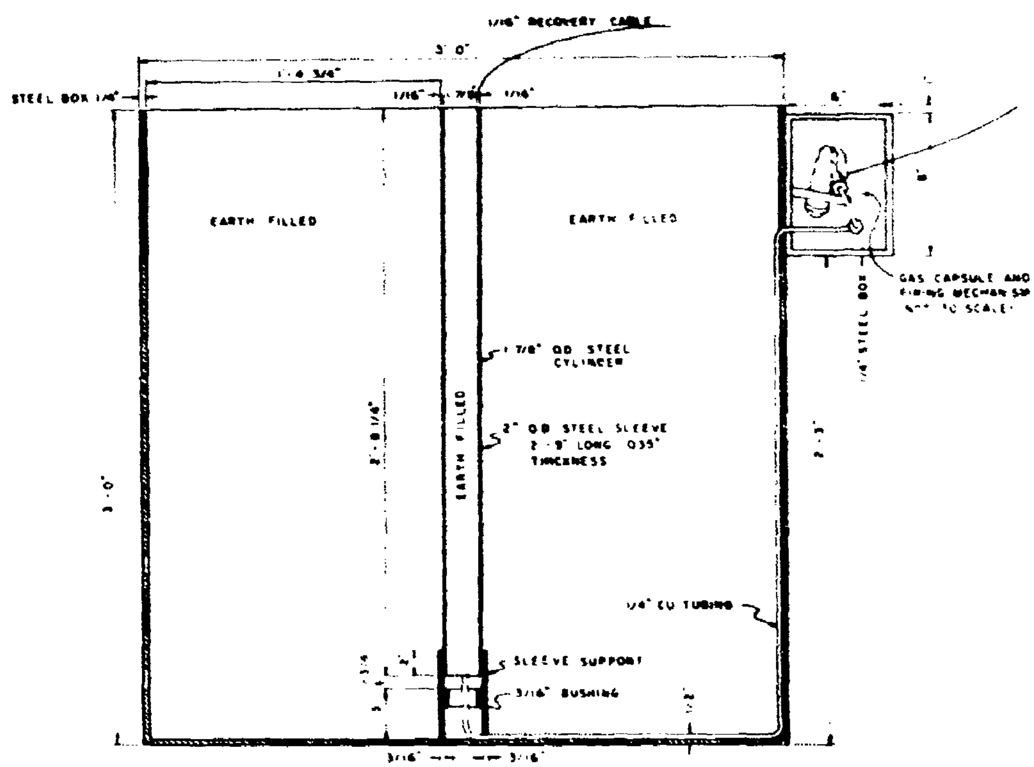


Figure 5-7. CROSS-SECTIONAL DIAGRAM OF AN EXPOSED SOIL SAMPLE.

The cylindrical column in the center of the sample was so constructed that, following the detonation, the soil sample could be ejected from its tubular container and recovered by means of a cable leading out of the exposure area (Figure 5-8).

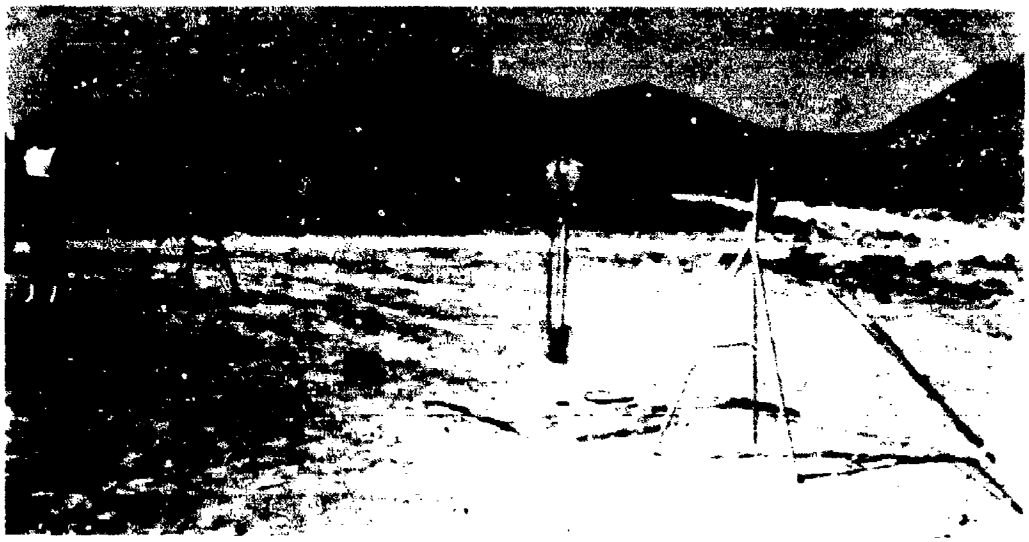


Figure 5-8. OVERALL VIEW OF MONITORING RIG.

For Project 2.3 ACWL measured the neutron flux and spectra for the devices used in nine events (287). ACWL personnel also performed the Project 2.4 neutron- and gamma-shielding tests on structures, shelters, fortifications, and M-48 tanks (Figures 5-9 and 5-10) for six shots (308).

U.S. Navy Radiological Defense Laboratory (NRDL) fielded Project 2.2 on four shots (118). This project studied the nature of radioactivity, especially the problems associated with induced radioactivity in soils near ground zero. Figure 5-11 shows a cutaway drawing of a typical sample container. Figure 5-12 shows a photograph of a typical station with three of the containers with hoops that were used for helicopter pickup. In addition, they measured the induced radioactivity in an M-48 tank on shot HOOD.

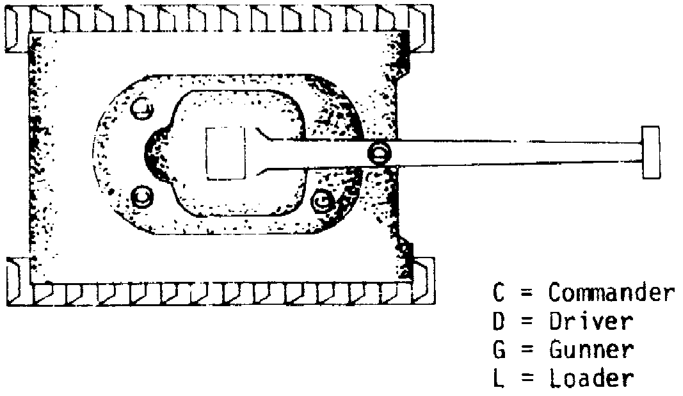


Figure 5-9. M-48 TANK.

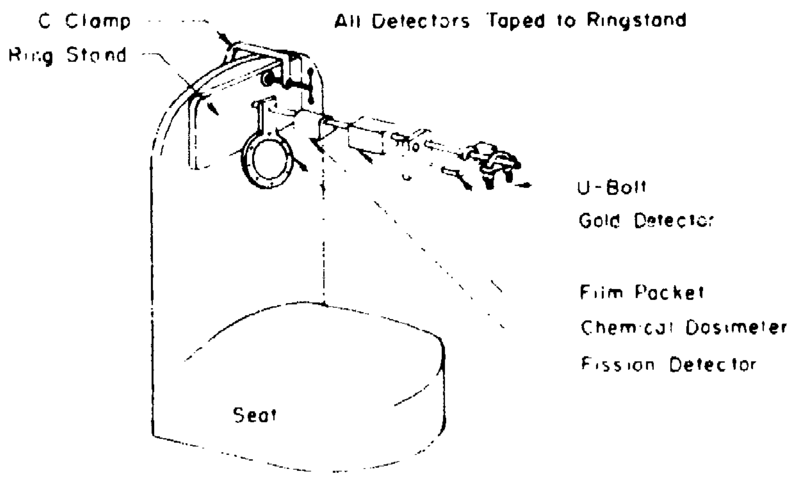


Figure 5-10. MOUNTING OF DETECTORS IN M-48 TANK.

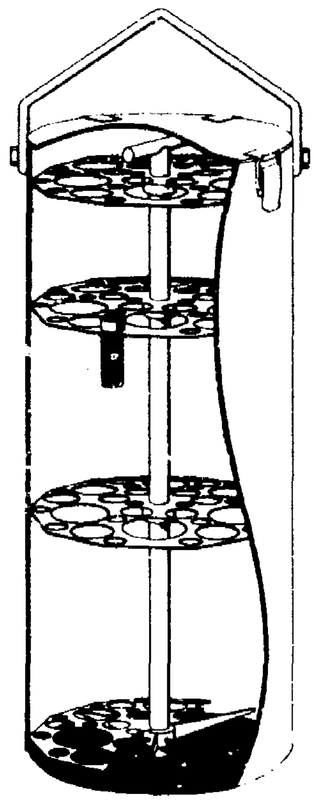


Figure 5-11. CROSS-SECTIONAL DIAGRAM OF ALUMINUM SAMPLE CONTAINER.

U.S. Army Signal Research and Development Laboratory determined the initial-gamma intensity versus time and distance on the ground and in the air for Project 2.5 on seven shots (109). A second part of this project measured the neutron-induced gamma activity from shot OWENS. Tissue-equivalent tactical neutron dosimeters as well as a standard radiac meter (IM-93) were fielded on five events by the Army Signal R&D Laboratory in Project 2.6 (115).

Figure 5-12. THE 500-YARD STATION AT SHOT WILSON LOOKING TOWARD GROUND ZERO.

U.S. Naval Research Laboratory (NRL) fie'd-d Project 2.7 on eight events (167). Transmitters in the frequency range of 16o to 9,850 mc were located in shielded bunkers (Figure 5-13) to transmit radially outward from GZ, such that the transmission path went through the fireball. Receivers were installed in Building 400, about 12 miles from the various ground zeros (Figure 5-14).

U.S. Navy Material Laboratory, for Project 2.8, participated in four events (138). Between H+45 minutes and H+2 hours, masonite phantoms were loaded with DT-60/PD and IM-107/PD dosimeters (Figure 5-15) and AN/PDR-43 (XN-1) and AN/PDR-44 (XN-1) rate meters (Figure 5-16). After the dosimeters were exposed to H+6 1/2 hours on shot DIABLO to H+56 hours on shot HOOD, they were recovered and the data interpreted.

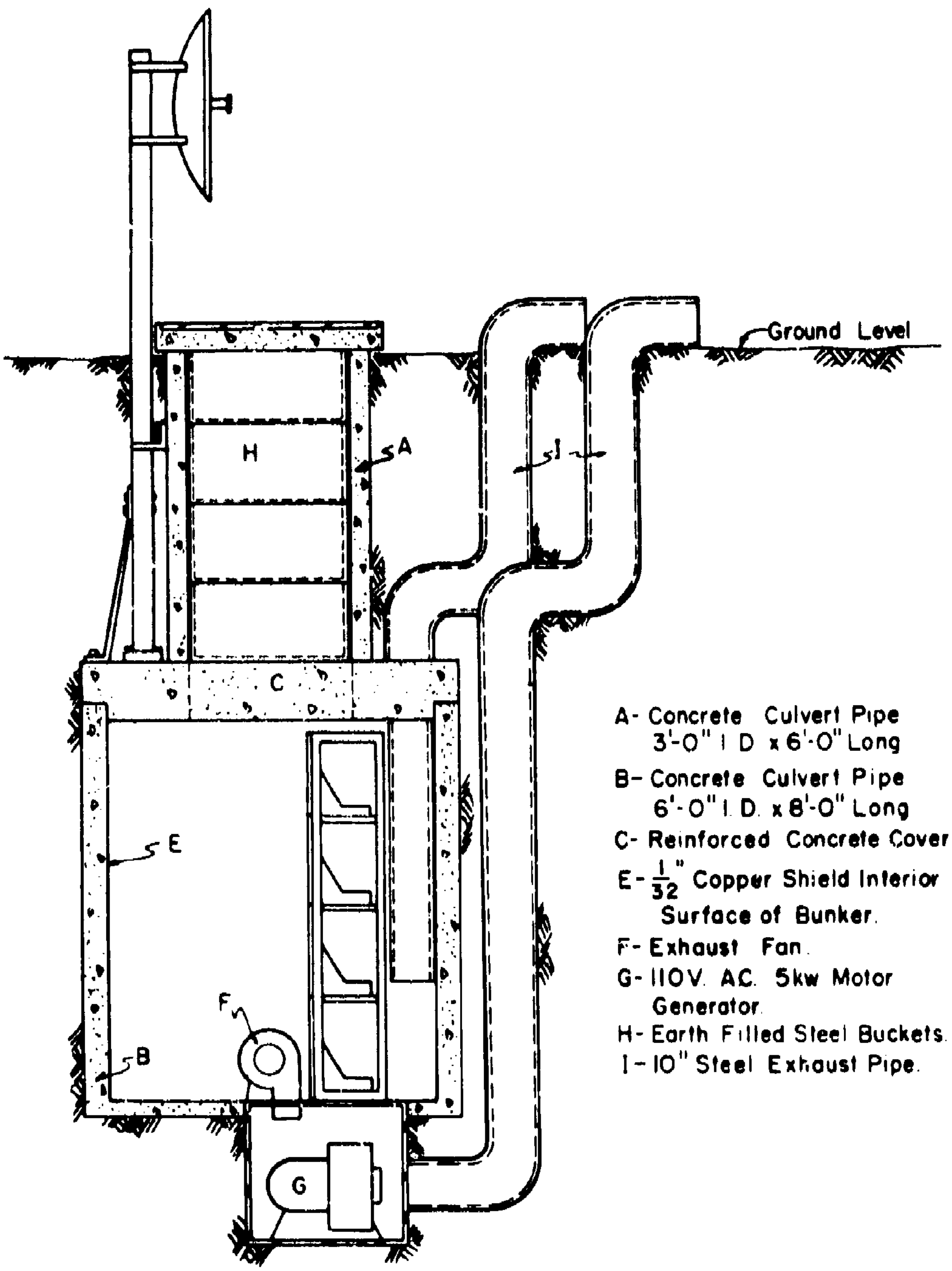


Figure 5-13. TYPICAL BUNKER INSTALLATION.

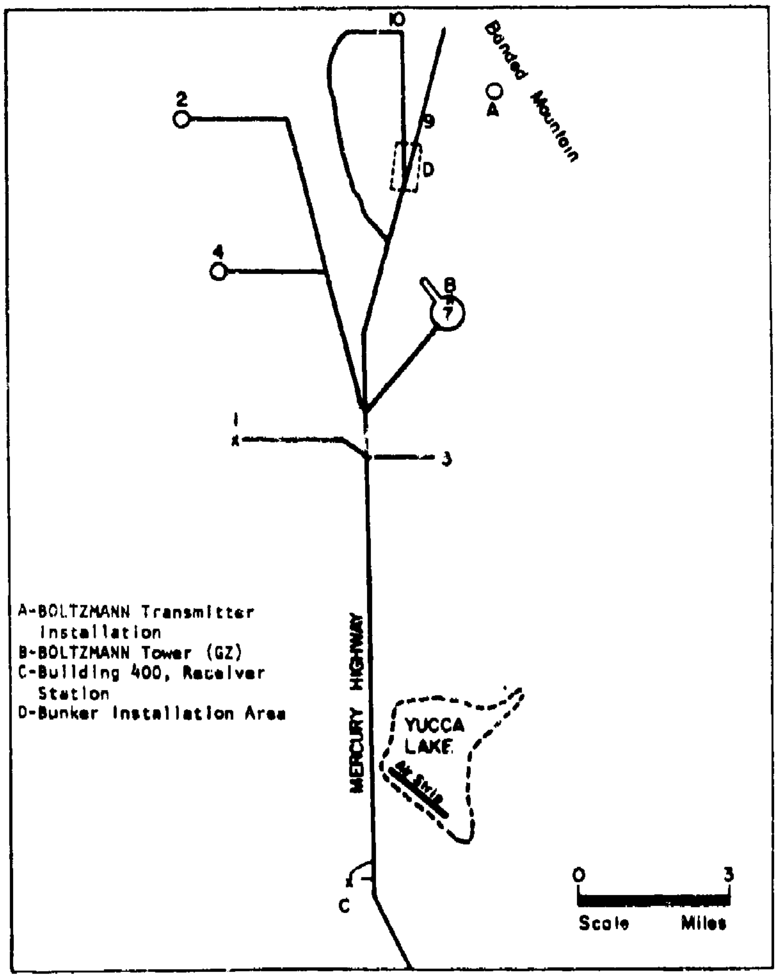


Figure 5-14. RELATIVE POSITIONS FOR TRANSMITTERS AND RECEIVERS FOR SHOT BOLTZMANN.

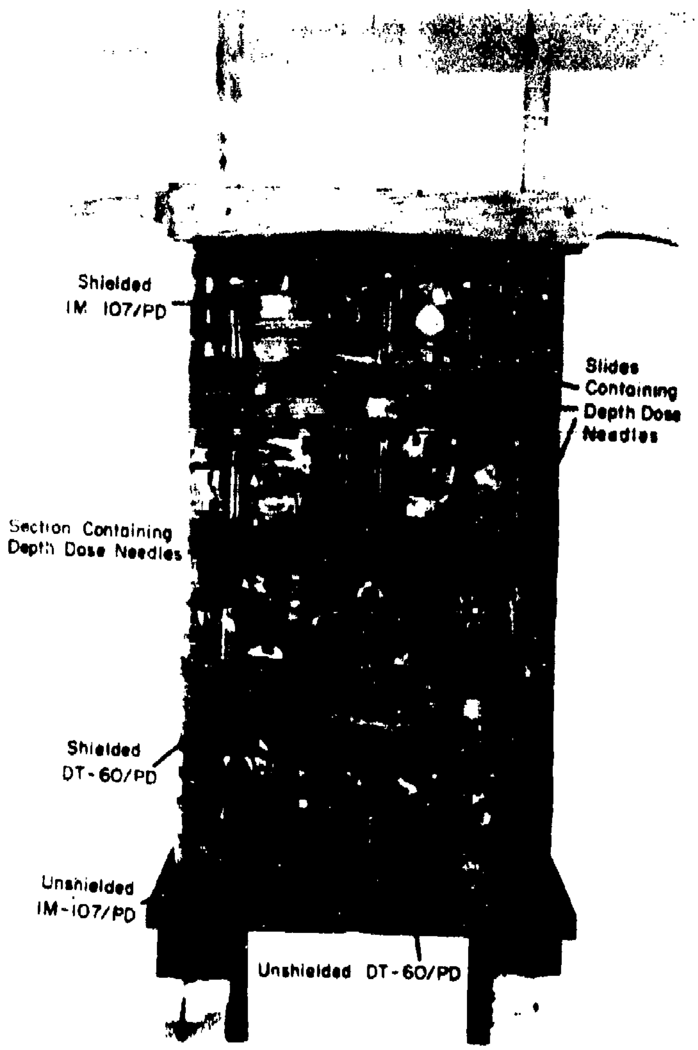


Figure 5-15. MASONITE PHANTOM, SHOWING DOSIMETER ARRAY.

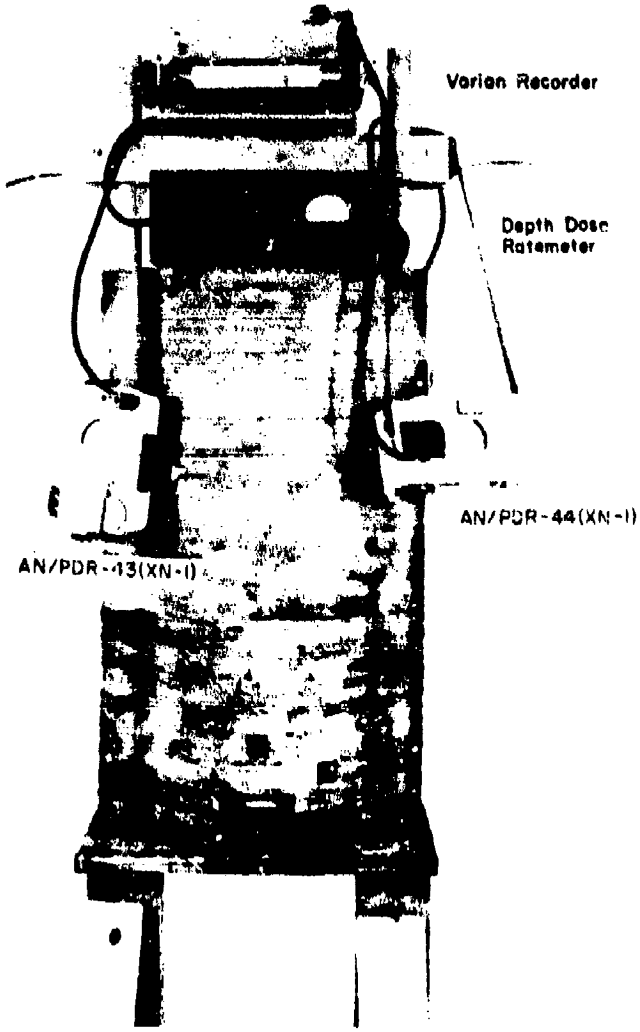


Figure 5-16. MASONITE PHANTOM LOADED WITH STANDARD DEPTH-DOSE RATEMETER AND HOLDING RATEMETER TYPES AN/PDR-43 (XN-1) AND AN/PDR-44 (XN-1).

Air Force Special Weapons Center (AFSWC) participated in Project 2.9 with three F-89 all weather interceptor aircraft and successfully delivered a live MB-1 air-to-air rocket on the JOHN event (214). The JOHN event volume contains details of this project. AFSWC also participated in nine events with Project 2.10 to measure total gamma dose, gamma dose rate, neutron flux, and neutron doses at the surface and at heights up to 950 feet to determine the effect of the air-ground interface on initial nuclear radiation (339).

Program 3 - Effects on Structures

The effects on structures were studied only on shot PRISCILLA. Eight unmanned structures were instrumented to obtain loading and response data. This program had the following objectives (127):

- To obtain loading and response data on various types of above- and below-ground structures in regions of moderately high overpressures (above 50 psi) (This was the primary objective)
- To proof-test various underground structures on a go/no-go basis
- To determine the structures' capacity to provide Class I (100-psi) and Class II (50-psi) protection as prescribed in the then current DOD Protection Construction Policy
- To obtain loading and response information from existing structures, constructed for past tests in the Frenchman Flat area, that could be recorded and subsequently analyzed.

Program 4 - Biomedical Effects

Biomedical effects were measured on eight events. Three projects were fielded by the Walter Reed Army Institute of Research, the Aero Space Medical Research Laboratories, and the Lovelace Foundation for Medical Education and Research. The purposes of Program 4 were:

- To furnish information on the effects of nuclear weapons on large biological specimens (swine)
- To evaluate the eye protection afforded by an electromechanical shutter

- To evaluate the casualty effect of missiles translated by a nuclear detonation.

Walter Reed Army Institute of Research fielded Project 4.1 (Effects of Nuclear Detonations on a Large Biological Specimen (swine)) on shots FRANKLIN, WILSON, and PRISCILLA (234). Objectives of this project were:

- To determine the effectiveness of field medical procedures in a mass casualty situation
- To investigate the effects of combined injuries from supralethal to nonlethal ranges
- To derive the LD_{50-30} (midlethal dose in 30 days) for a large biological specimen
- To obtain information on blast injuries in a large biological specimen
- To obtain information on thermal injuries in a large biological specimen.

The swine had been determined to be a suitable animal for the project due to size, skin and ionizing radiation response similarity to humans. Thermal, pressure, and radiation measurement as required were made in support of the project. After exposure and as soon as the radiation conditions permitted, the animals were recovered and returned to the animal hospital area. Surgical and medical treatment was administered and documentary records kept on each animal.

Aero Space Medical Research Laboratories fielded Project 4.2 (Evaluation of Eye Protection Afforded by an Electromechanical Shutter) on five shots. The purpose of this project was to evaluate the effectiveness of a high-speed electromechanical anti-glare shutter that was coupled with a flash detector and a power supply (See Figure 5-17).

Service personnel volunteers (mostly from the Tactical Air Command) viewed the detonations from a C-47 aircraft and from a trailer exposure station with protective shutters. Control rabbits, both with and without protection, were subjected to the bomb light. All exposure stations were located at slant ranges where the total energy was expected to be between 0.04 and 0.1 cal/cm^2 so that, in case of shutter failure, the eye would not be exposed to more than the safe

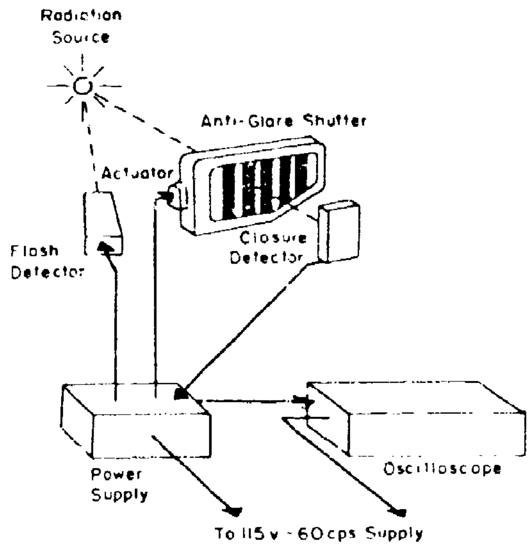


Figure 5-17. ANTI-GLARE SHUTTER SYSTEM.

chorioretinal burn threshold. The critical threshold adopted for this project was 0.004 cal/cm^2 over the first 0.1 second.

Immediately after exposure, the subject turned to a visual-testing device located slightly to the side of his position. Visual recovery was tested on either the stereocamptometer, or nyctometer, or a combination thereof. Time to recover useful vision was measured by ability to read aircraft instruments. The time of return to mesopic visual acuity was determined and recorded. Upon completion of visual recovery testing, all human subjects went to Nellis AFB for complete opthalmological evaluation.

Lovelace Foundation for Medical Educational and Research jointly fielded Project 4.3 for the Department of Defense and Project 33.2 for the Civil Effects Test Group (CETG) on three shots. The objectives were:

- To determine, for various dynamic pressures, the velocities attained by planted missiles, consisting of military debris at different ranges from a nuclear detonation

- To determine the mass and velocities of natural missiles

- To analyze all data in a manner that would aid the assessment of secondary blast casualties.

The DOD test group furnished part of the required funds and minor logistical support. One hundred fifty-five traps (See Figure 5-18), having a total missile-collecting area of about 486 ft^2 were employed in open regions, shelters, and houses. In addition, approximately 234 ft^2 of missile-absorbing material cemented to walls was used to study missile behavior in a shelter and in open areas. Secondary missiles were studied in open regions where peak overpressures ranged from about 4 to 15 psi. The effects of hill-and-dale terrain upon missile production were investigated during shot SMOKY. Missiles used in the three shots were window glass mounted in frames, marked military debris, marked gravel, marked spheres, and native stone. Displacement distances were measured for stones (weighing up to 19 kg), which were placed at various ranges from ground zero. For shot PRISCILLA, 25 stones were placed at each of seven ranges varying from 2,030 to 6,120 feet from ground zero. Each group of 25 stones was divided into five subgroups, whose average masses ranged from 0.249 to 12,442 kg.

Program 5 - Effects on Aircraft Structures

The effects on aircraft structures were studied on 13 events. The program consisted of five projects: the HSS-1 helicopter, model ZSG-3 airships, FJ-4, A4D-1, and the F-89D aircraft. The overall objective of the PLUMBBOB aircraft-effect studies was to extend the scope of available data in line with service requirements by:

- Obtaining a better definition of aircraft safe-delivery criteria for nuclear weapons

- Obtaining a better definition of thermal inputs and dynamic gust loadings resulting from nuclear blasts

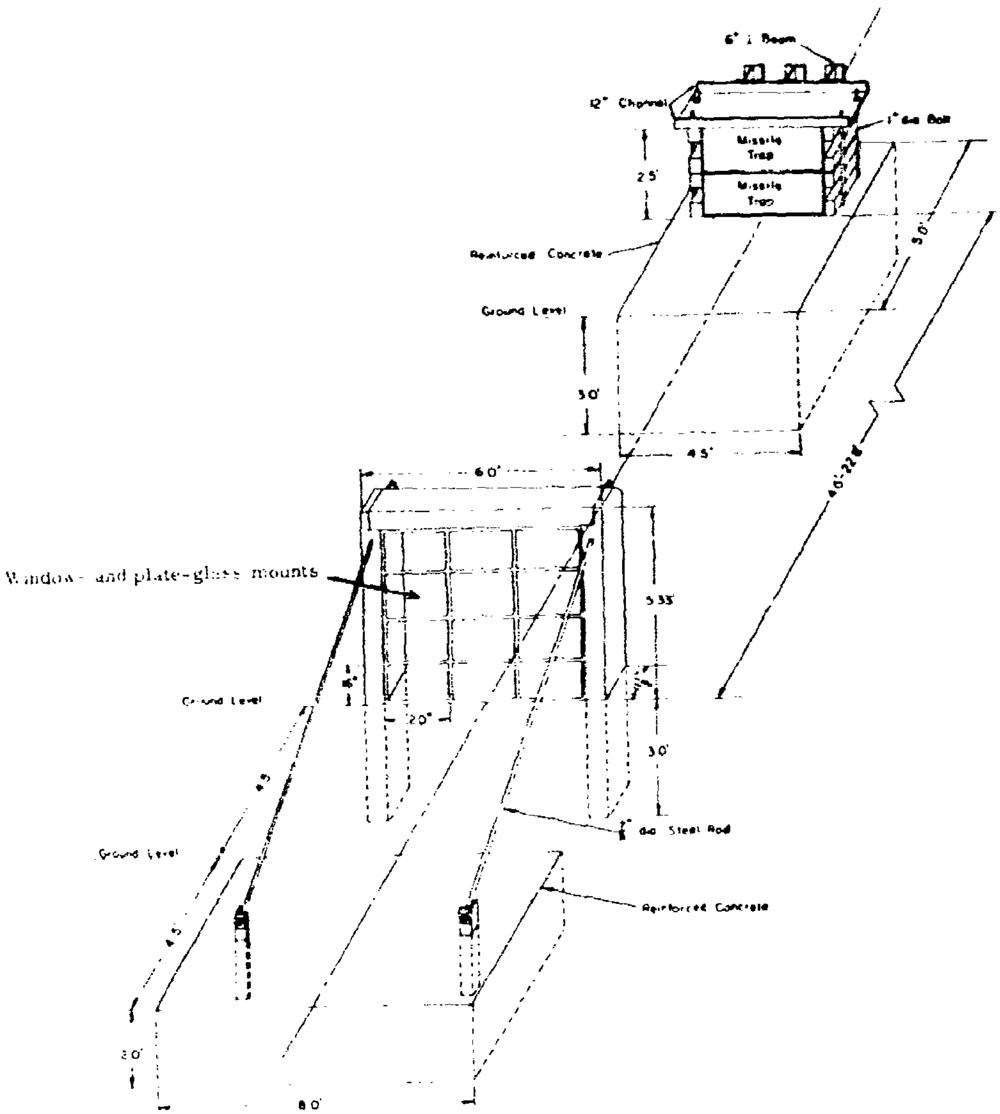


Figure 5-18. MISSILE-COLLECTING TRAP SYSTEM.

- Obtaining response data from a nuclear blast for a HSS-1 helicopter and a ZSG-3 airship.

Project 5.1 (In-flight Structural Response of the HSS-1 Helicopter to a Nuclear Detonation) was under the supervision of the Navy Bureau of Aeronautics and Sikorsky Aircraft Division of the United Aircraft Corporation (317). The HSS-1 participated in eight PLUMBBOB events. Objectives of this project were:

- To measure the overpressure and gust response of the HSS-1 helicopter
- To determine the delivery capabilities of the HSS-1 helicopter for antisubmarine warfare weapons as limited by blast effects
- To obtain experimental data for the Departments of the Army and Navy related to helicopter response to nuclear blast for correlation with analytical techniques.

The flight conditions, aircraft positions, and results of each test are reported in the appropriate shot volume.

Project 5.2 (Structural Response and Gas Dynamics of an Airship Exposed to a Nuclear Detonation) was under the supervision of the Navy Bureau of Aeronautics and the Aeronautical Structures Laboratory of the Naval Air Material Center (151). Four model ZSG-3 airships (Figure 5-19) participated in two events (FRANKLIN and STOKES). The basic objective of Project 5.2 was to determine the response characteristics of the model ZSG-3 airship when subjected to a nuclear detonation in order to establish criteria for safe escape distances after airship delivery of antisubmarine warfare special weapons. Specifically, the test program was arranged to secure data in the following major categories:

- Dynamic response of the entire airship and its structural members to various energy input levels
- Temperature rise and distribution in the airship envelope as a result of thermal radiation
- Shock wave propagation in the airship envelope

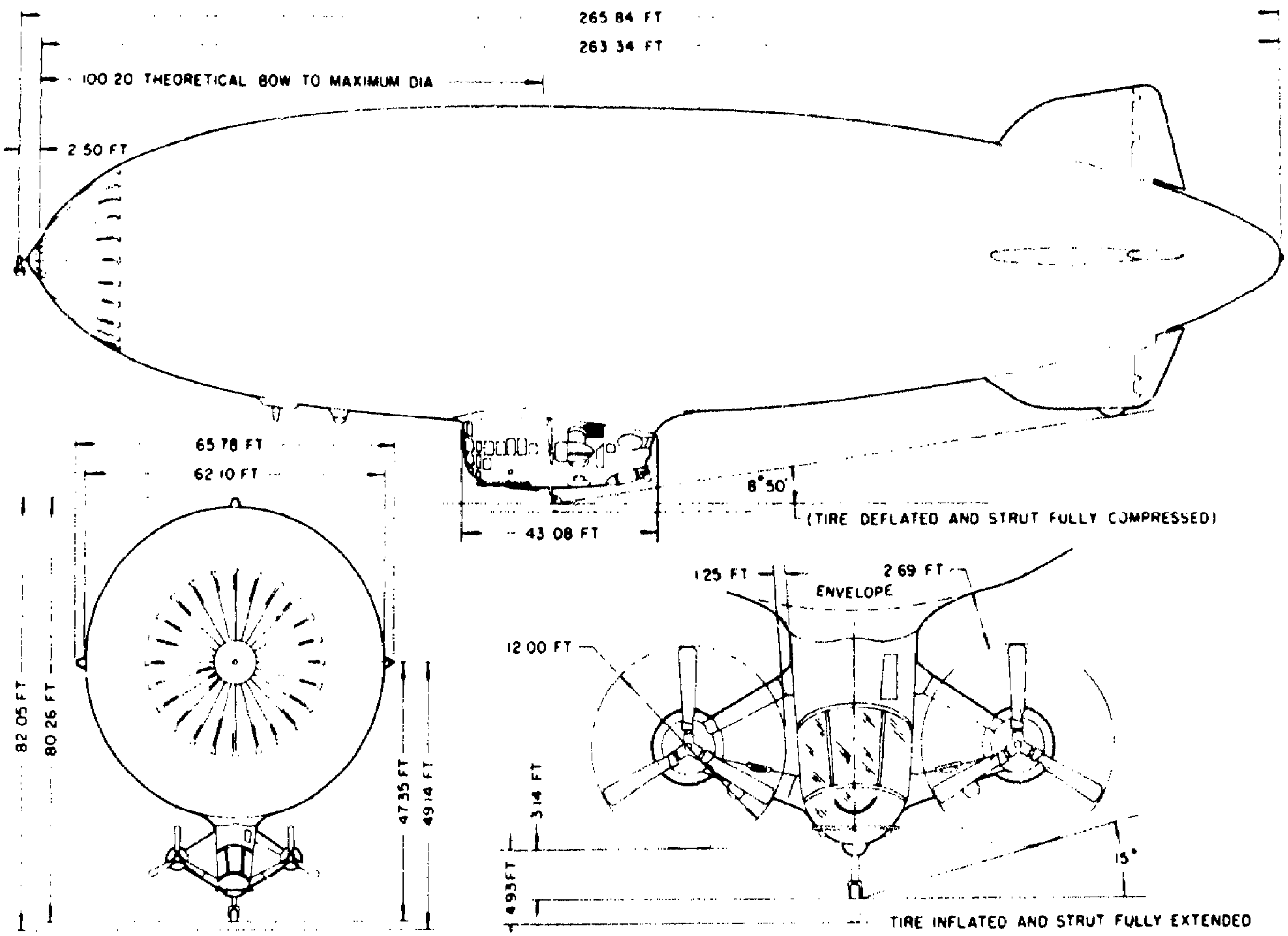


Figure 5-19. PRINCIPAL DIMENSIONS OF MODEL ZSG-3 AIRSHIP.

- Vulnerability of structural components that would restrict the weapon-delivery capabilities of the weapon system.

Airship operations were conducted with extreme difficulty. Airship K-46 was destroyed when it was torn from its mooring mast on Yucca Lake bed by a violent windstorm. Ship K-77 was lost after it became detached from the mast due to the failure of the mooring cone following the passage of the FRANKLIN shock wave. Airship K-92 was destroyed when it was torn from its mooring mast at Yucca Lake by a sudden wind. The mooring lines holding airship K-40 were released about 20 seconds before the STOKES shock arrival to obtain free-body response data. Immediately following shock arrival, the envelope ruptured forward of the car, and the airship crashed but did not burn. In spite of the operational difficulties, data were obtained and are reported in the FRANKLIN and STOKES shot volumes.

Project 5.3 (In-flight Structural Response of the FJ-4 Aircraft to a Nuclear Detonation) was under the supervision of the Bureau of Aeronautics and North American Aviation, Inc. (213). Two FJ-4 aircraft (Figure 5-20) participated on seven PLUMBBOB events. The project had the following three objectives:

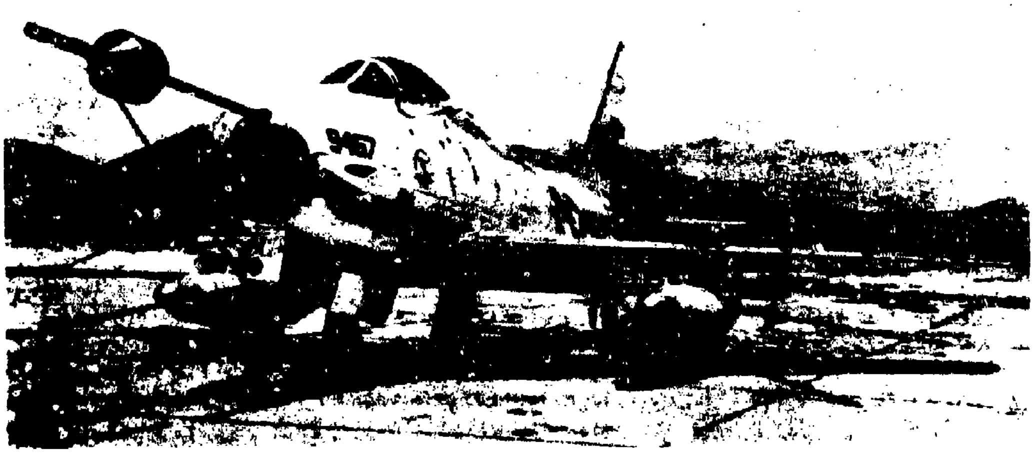


Figure 5-20. FJ-4 AIRPLANE INSTRUMENTED FOR OPERATION PLUMBBOB.

- Measuring thermal and blast response of the FJ-4 aircraft to the effects of a nuclear explosion
- Correlating the experimental response data with analytic predictions in order to confirm the delivery capability of the FJ-4 aircraft
- Obtaining data to help improve methods for predicting the blast response of swept wing aircraft.

The atmospheric conditions, flight parameters, flight conditions at the time of burst and shock arrival, and the radiation data for each event are in the appropriate shot volumes.

Project 5.4 (In-flight Structural Response of the A4D-1 Aircraft to a Nuclear Detonation) was under the supervision of the Douglas Aircraft Company (316). The A4D-1 aircraft participated on seven events. Objectives of this project were the following:

- To measure thermal and blast gust response of the A4D-1 aircraft to nuclear explosion effects
- To obtain data to improve the methods of predicting blast gust response of aircraft with wings of triangular platform
- To correlate experimental response data for the A4D-1 with analytical methods for use in determining its nuclear weapon delivery capability.

The flight parameters, flight conditions at the time of burst and shock arrival, and the radiation data pertaining to each event are given in the appropriate shot volume.

Project 5.5 (In-flight Structural Response of the F-89D Aircraft to a Nuclear Detonation) was jointly fielded by the Wright Air Development Center (WADC) and the Northrop Aircraft, Inc. (297). The F-89D aircraft participated in 14 events. The primary purpose of Project 5.5 was to determine the structural response of the F-89D aircraft in-flight to the blast and thermal effects of a nuclear detonation. An Air Force F-89D was concerned with the critical air-to-air delivery problem and the capability of aircraft to deliver weapons with nuclear warheads under varying conditions of weapon yield, altitude, and aircraft characteristics. In addition, the project provided basic research data for design of future USA ' aircraft.

Program 6 - Electromagnetic Effects and Tests of Service Equipment

This program consisting of five projects, was conducted in 22 of the 24 primary PLUMBBOB events. Program 6 was not involved on shots SHASTA and WHITNEY. Objectives of the five projects were to study the following:

- The behavior of pressure-actuated antitank mines under airblast loading from a nuclear detonation
- The vulnerability of three types of antitank influence-mine fuzes to a nuclear detonation
- The ground contamination pattern of a chemical land mine detonated by a nuclear blast
- The magnetic component of the electromagnetic (EM) energy radiated from a nuclear detonation as measured in the near-field region as a function of time and distance
- The effect of radiation from nuclear detonations on semi-conductor devices
- The attenuation of EM energy propagated through the cloud of a nuclear detonation
- The accuracy and reliability of a short-baseline NAROL system by using it to locate ground zero positions at ranges from 500 to 1,000 miles
- The characteristics peculiar to these pulses that might distinguish them from bomb pulses
- The nuclear radiation effects produced by a nuclear detonation on the operational and structural characteristics of components and materials in the guidance package of the Nike Hercules guided missile
- The effects of a nuclear detonation on the propagation of signals from the Nike Hercules radar system.

Project 6.1 (Minefield Clearance by Nuclear Weapons) was fielded by the U.S. Army Engineer Research and Development Laboratories and the Midwest Research Institute. Its objective was to investigate the behavior of pressure-activated antitank mines under airblast loading from a nuclear detonation. This project was done only during PRISCILLA.

Project 6.2 (Measurement of the Magnetic Component of the Electromagnetic Field Near a Nuclear Detonation) was fielded by the Diamond Ordnance Fuze Laboratories on six events. The objective of this project was to provide a record of the magneticfield component of the electromagnetic field from a nuclear detonation as a function of time and distance, including the near-field region (164). Two to five instrument stations were established for each participation at ranges of 650 to 14,400 feet from ground zero. The stations consisted of concrete-lined holes 6 to 12 feet deep in which the instrumentation sets were protected from radiation, blast, and thermal effects by burial under sandbags.

Project 6.2a (Measurement of the Effects of Nuclear Radiation on Semiconductor Devices). The major effort for this project was on shot PRISCILLA and details are contained in that shot volume.

Project 6.3 (Attenuation of Electromagnetic Radiation Through an Ionized Medium) was fielded by the U.S. Naval Air Development Center on four events (225). Objectives of Project 6.3 were to measure the attenuation of electromagnetic radiation of various frequencies due to propagation through an ionized cloud from a nuclear detonation, and to compute the rate of removal of electrons by recombination and attachment from the attenuation measurements. An A4D-1 aircraft carried the airborne pod used to house the electronic equipment on shots FRANKLIN, LASSEN, and WILSON. An FJ-4 aircraft was used for the PRISCILLA event. The aircraft were based at Indian Springs Air Force Base.

Project 6.4 (Accuracy and Reliability of the Short-Baseline NAROL System) was fielded by the Air Force Cambridge Research Center on 21 of the 24 primary PLUMBBOB events and had the following three objectives (203):

- Determining the position and yield of a nuclear burst as a function of distance from ground zero
- Investigating methods for isolating the electromagnetic pulse of a nuclear burst from lightning transients
- Collecting data on the nature of bomb pulse distortion which results from overland propagation.

Since the distances of personnel from Ground Zero were several hundred miles (see Figures 5-21 and 5-22) there was no exposure to ionizing radiation by participants.

Project 6.5 (Effects of Nuclear Detonation on Nike Hercules) was done by White Sands Missile Range personnel on nine PLUMBBOB events (143). The principal objective was to investigate effects of radiation produced by nuclear-warhead detonation on the operational and structural characteristics of components, materials, and systems of the Nike Hercules guided-missile system. The specific requirements were to:

- Ascertain the radiation susceptibility of the electronic devices, circuits, and allied materials which are employed or are to be employed in the circuitry of the missile-borne guidance system
- Establish the minimum radius from the center of burst, as a function of yield for reliable operations of existing systems
- Establish the maximum radius from the center of burst, as a function of yield, for positive failure of essential components, the reliability of which cannot be feasibly improved by employing less-vulnerable materials or components
- Ascertain the effect versus time of induced radioactivity for both immediate and permanent damage
- Provide data to establish operational criteria for the tactical employment of guided-missile systems
- Validate the extrapolation of laboratory results to the magnitude of field-encountered radiation levels.

Another objective was to investigate the effects of nuclear-warhead detonation on the propagation of radar signals. In this area, it was specifically desired to:

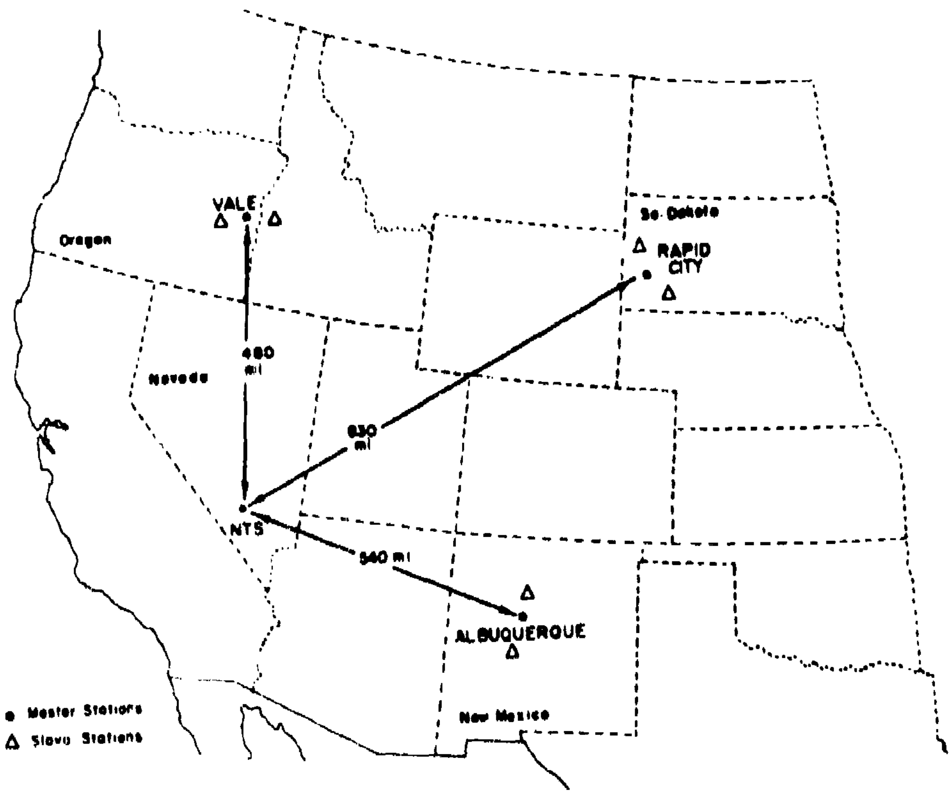


Figure 5-21. RELATIVE DISPOSITION OF NAROL NETS.

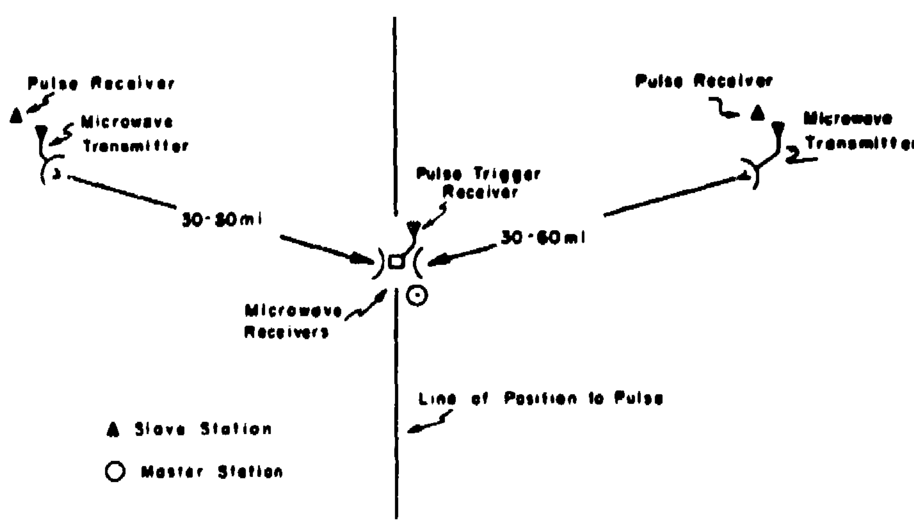


Figure 5-22. TYPICAL NAROL NET LAYOUT.

- Determine if attenuation effects exist at X-band frequencies about and through the fireball and convection cloud

- Evaluate the magnitude and duration of these attenuation effects

- Determine the degree of reflectivity of the radar signal from the cloud

- Obtain preliminary and planning information for more comprehensive laboratory and field tests

- Provide data to establish operation criteria for the tactical employment of guided-missile radar systems

- Provide design criteria for radar systems.

Program 8 - Thermal Radiation Effects

This program consisted of three projects that participated in eight events. Its objectives were:

- To investigate thermal protection for the individual soldier

- To determine the effects of thermal radiation on a standard reference material

- To evaluate laboratory methods for determining the protection afforded by uniform systems

- To test instrumentation systems.

Project 8.1 (Thermal Protection of the Individual Soldier) was fielded by the U.S. Army Quartermaster Research and Engineering Command. The major effort of this project on the PRISCILLA event and the details are contained in that shot volume.

Project 8.2 (Prediction of Thermal Protection of Uniforms, and Thermal Effects on Standard Materials) was fielded by the Naval Material Laboratory (NML) on four events (136). Its purpose was to determine the adequacy of the laboratory methods employed in the study of the effects of intense thermal radiation on materials. The primary objectives were to determine the adequacy of physical methods for studying thermal damage to materials, and to evaluate by means of a physical skin simulant, the protection afforded by clothing to personnel against intense thermal radiation. A secondary objective of the project was to compare the burns predicted from the temperatures of the skin simulant behind an irradiated fabric assembly, and the burns obtained on animals under identical exposure configurations. Project 8.2 made basic thermal radiation measurements for the use of Projects 4.1, 8.1, and 8.2.

Project 8.3a (Performance of a High-Speed Spectrographic System) was fielded by the U.S. Naval Radiological Defense Laboratory (NRDL) in six events (256). Its objective was to field-test a high-speed spectrographic system being designed for subsequent use during Operation HARDTACK for very-high-altitude detonations. NRDL and Naval Research Laboratory (NRL) high-speed spectrographs were tested. Project 8.3b (Instrumentation for Measuring Effects Phenomena Inside the Fireball) was conducted by three groups, Wright Air Development Center, University of Dayton Research Institute, and Allied Research Associates, Inc. This project had five objectives (120):

- Instrumenting tests for future use in making measurements within the fireballs resulting from nuclear detonations
- Increasing the information available regarding the thermonuclear effects of a nuclear detonation
- Measuring the time history of the pressure, acceleration, and temperature of a nuclear burst
- Determining peak velocities by means of mechanical velocity--distance impact gauges
- Supplementing ablation data obtained in previous tests.

Because Project 8.3b was active only during shot PRISCILLA and shot SMOKY, this project is described in more detail in those volumes.

Program 9 - Support Photography

This program was primarily of a support nature and consisted of a single project which was concerned with:

- Technical photographic support of the military-effects programs

- The documentation of the overall military-effects program and production of an effects motion picture

- The documentation of the detonations for release through the Joint Office of Test Information, and for historical purposes

- The general photographic support of DOD projects.

The Lookout Mountain Laboratory Group from Hollywood, California, staffed by the 1352nd Motion Picture Squadron, Air Photographic and Charting Service, provided motion picture and still photography coverage. This group involved about two dozen participants during Operation PLUMBBOB. Program 9 provided camera instrumentation on ten shots of the test series as shown in Table 5-2. Approximately 75,000 feet of color motion picture film was taken at the test site for the purposes of documentation of the weapons effects program and the production of a military effects motion picture report. This footage was planned and accomplished to cover the significant features of participation of each DOD project. From this footage, a military effects motion picture was produced. To document the detonations for historical purposes and for release to the press through the Joint Office of Test Information, both color and black-and-white coverage of each detonation was done from an airborne camera station and a forward area manned camera station. This coverage consisted of both still and motion picture photography. Laboratory facilities established at the test site made it possible to process, classify, and release coverage to the press within two hours after each detonation. In general support of the participating DOD projects, approximately 5,000 still photographs were made at the test site. Immediate prints were produced for the use of project analysis.

5.2.2 DOD Support Group/Field Command Support Unit (FCSU)

The Field Command Support Unit was an organizational element under the Test Manager. The Deputy for Military Matters had operational supervision over the FCSU through the Officer-in-Charge, Field Command Support Unit. The mission of the FCSU was to provide administrative, logistical, and general support to

Table 5-2. PHOTOGRAPHIC SUPPORT.

SHOT	PROJECT	PURPOSE
FRANKLIN	5.2	Blimp effects
	6.3	Cloud tracking
LASSEN	2.10	Kytoon position and effects
WILSON	2.10	Kytoon position and effects
	6.3	Cloud tracking
PRISCILLA	6.3	Cloud tracking
	1.3	Shock-wave photography
	3.6	Dome deflection
	4.1	Biomedical photography
	8.1	Thermal effects
	8.2	Skin-simulant effects
HOOD	2.1	Cloud tracking
	8.2	Skin-simulant effects

SHOT	PROJECT	PURPOSE
PASCAL A	9.1	Gross-effect views
OWENS	6.3	Cloud tracking
	2.10	Kytoon positions
	1.2	Rocket launcher and canister positions
JOHN	9.1	Fireball photography
	9.1	Cloud tracking
SMOKY	6.3	Cloud tracking
	1.8	Shock-wave photography
	1.8	Tank-model photography
STOKES	5.2	Blimp effects

DOCUMENTARY PHOTO ELEMENT STATISTICAL SUMMARY

RC-47 (1)	April	May	June	July	August	September	Total
Total Time	8:00	24:50	30:50	22:35	47:00	33:40	166:55
Mission Time		5:25	18:20	7:45	4:10	16:50	52:30
Take-offs & Ldgs	----	----	----	----	----	----	47

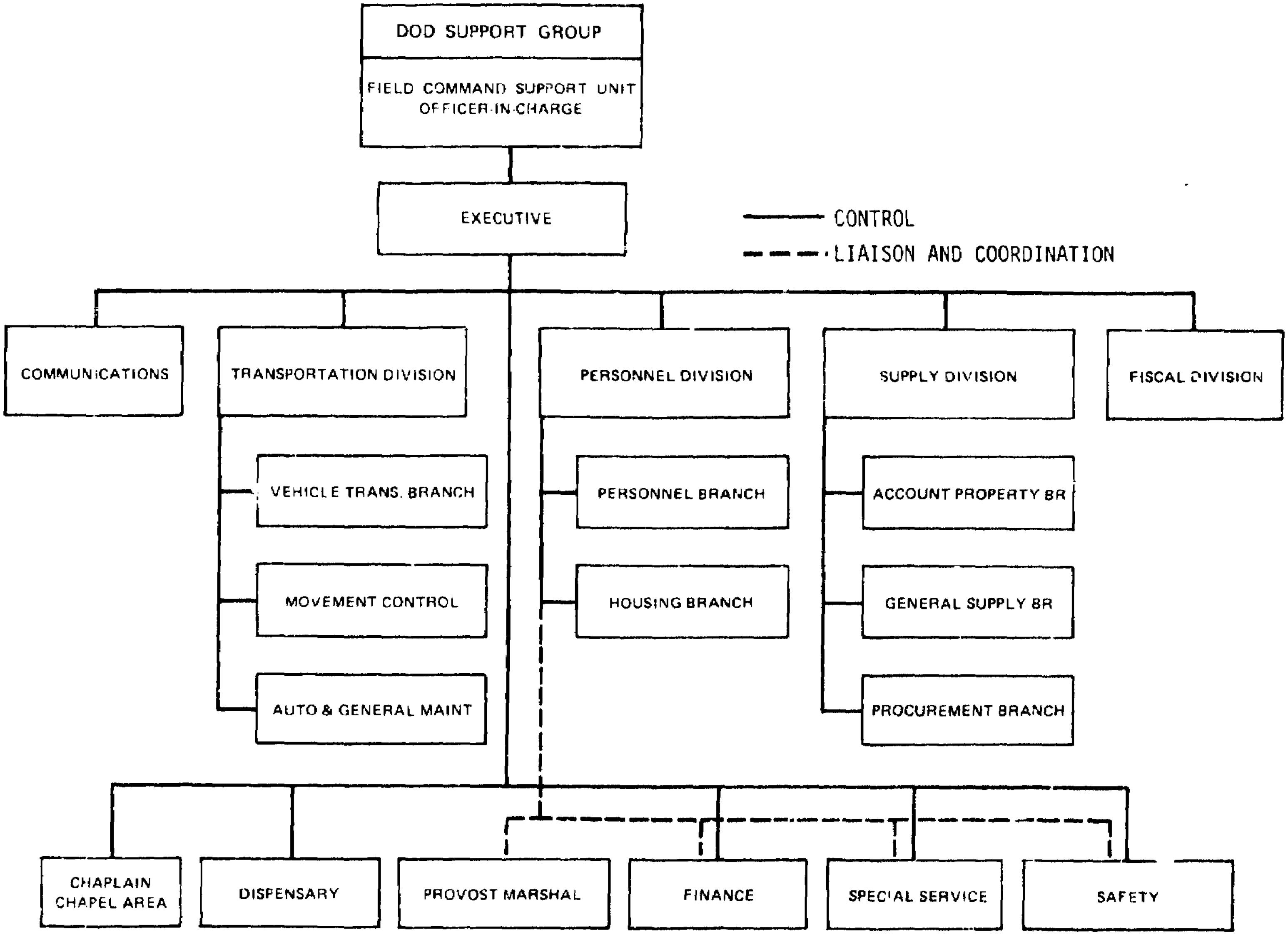
DOD/AFSWP project agencies, activities, and personnel participating in continental tests at the Nevada Test Site. The unit was organized as shown in Figure 5-23. Limited logistical support was also furnished to the AEC based on the authority contained in instructions for implementing Operation PLUMBBOB to the Commander, Field Command, AFSWP (260). Assistance to the AEC primarily consisted of lending special items of supply and equipment from available AFSWP material at the site. Because most of the support requirements referred to DOD projects, the FCSU performed its mission principally by direct telephone and personal contact with the Director of the DOD Test Group, the DOD Program Directors, and the Project Officers.

The principal elements and activities of the Field Command Support Unit were:

- The Communications Officer was responsible for arranging telephone and other signal services for the DOD elements participating in PLUMBBOB. The primary mission of the Communications Division was to support the test projects for and under the supervision of the Director, DOD Test Group.

- The DOD motor pool was activated on 1 April 1957 and was responsible for operational control, dispatching, and servicing all DOD-owned vehicles at NTS. Dispatch and other administrative functions were accomplished in the manner normally prescribed for any military motor pool, except that weekly issue of vehicles was made to some users on a continuing basis when justified. Motor pool vehicles were dispatched daily and provided a source of vehicles when permanently allocated vehicles were in maintenance. The vehicles were also extensively used in support of the AEC.

- The FCSU vehicle maintenance shop provided both maintenance service and repair for all DOD administrative vehicles and electric generators supplied to the Nevada Test Site. Maintenance activities included removal of vehicles from long term storage at the beginning of the operation and placement of vehicles in long term storage at the conclusion of the operation. A total of 86 generators, ranging in capacity from 1.5 to 75 kilowatts, were on hand for assignment. During peak periods of operation, a total of 38 generators were assigned. Parts support for the maintenance activities were provided by



ALL OFFICES LOCATED IN BUILDING 200, NTS, UNLESS OTHERWISE INDICATED

Figure 5-23. ORGANIZATIONAL CHART, DOD SUPPORT GROUP.

normal issues and local procurement. The maintenance shop was manned by one officer and 44 enlisted men.

- The General Supply Branch, Supply Division, FCSU, began operations at the NTS on 18 February 1957; it was charged with providing depot-, post-, camp-, and station-type supply support to DOD/AFSWP-participating agencies and activities, including 50 test projects. Supplies were requisitioned from military technical service supply sources, the General Services Administration, and REECo. A purchasing office for an AFSWP account was located in Las Vegas.

- The DOD Housing Office assigned accommodations to DOD/AFSWP military and civilian participants in the operation. All assignments, terminations, and related activities were under the general supervision of the Director, Personnel Division, FCSU. Continuous coordination was maintained with the REECo housing office. Housing was assigned to the personnel of the FCSU and Headquarters, DOD Test Group, on a semi-permanent basis. Since they were generally on duty at the site during the entire operational period, project personnel were provided housing as required in coordination with the commander of the DOD Test Group. Personnel were housed at Mercury, Nevada, in dormitories, huts, and trailers.

- The Commercial Traffic Branch was organized and operated in conformity with a military base or post traffic section. The branch provided courier services to the Las Vegas Municipal Airport, DOD Las Vegas Procurement Officer, and Nellis Air Force Base; made commercial carrier reservations for DOD personnel; handled packing, crating, and shipping of DOD material; received and processed incoming and outgoing shipments, and traced and expedited cargo movements.

- The Public Information Officer, Field Command, AFSWP, was placed on temporary duty at the Las Vegas Branch Office, AEC, so that he could carry out the public information mission of AFSWP in coordination with the AEC Public Information Office.

- The Deputy Surgeon, Field Command, AFSWP, directed and monitored the orientation and training program for medical officers from the

Armed Services. A total of 28 medical officers participated in this program on the basis of 14 days temporary duty at the site for each officer.

- In addition to the various groups previously mentioned, other elements provided services to base personnel. The Military Police Unit enforced military directives and civil laws on the Nevada Test Site. The unit consisted of one Army military police officer and three enlisted men. The Special Services Unit provided recreational support to all DOD military and civilian personnel, and managed facilities both on and off the test site for sports and educational activities. The Finance Unit provided travel and per diem allowances for all DOD and military personnel at NTS, although regular monthly pay was not handled by this unit.

The Field Commander, AFSWP, was able to augment manpower in the FCSU with Army, Navy, and Air Force personnel. A total of 13 officers and 147 enlisted men filled specific positions. The Commanding Officer, Sandia Base, provided military as well as civilian personnel to perform specialized services. In particular, the Finance Office at NTS received six enlisted men and one civilian (during the peak operational period) and one typewriter repairman (during the closing phase of PLUMBBOB). Four enlisted men reported for duty with the DOD Medical Dispensary.

Based on the responsibilities of the FCSU, few individuals other than the military police would be expected to enter areas containing radioactivity.

5.2.3 Air Force Special Weapons Center

As field headquarters for Air Force nuclear research and development, AFSWC provided air support for the PLUMBBOB test series. This support was headed by the 4950th Test Group (Nuclear), organized at Kirtland AFB, NM, on 1 September 1956, to plan for and accomplish those portions of the nuclear test programs at the Nevada Test Site and the Enewetak Proving Ground for which AFSWC was responsible. This group participated heavily in the series (see Table 5-3):

Table 5-3. AIRCRAFT PARTICIPATION. (2)

EVENT	FIRING DATE	PROJ 4.2 C-47	PROJ 5.1 HSS-1	PROJ 5.2 ZSG-3	PROJ 5.3 FJ-4	PROJ 5.3 TY-2	PROJ 5.4 A4D	PROJ 5.5 F-89D	PROJ 6.3 FJ-4	PROJ 6.3 A4D	PROJ 50.1 "COPTERS"	PROJ 50.8 L-20	PROJ 50.8 "COPTERS"	PROJ 50.8A B-26	PROJ 51.3 A3D	PROJ 51.3 F9F3	PROJ 52.1 "COPTERS"	PROJ 52.1 F9F	PROJ 52.3 R5D	PROJ 52.3 A4D	PROJ 53.1 T-33 SAMPLERS
BOLT[illegible]NN	28 MAY 57	1	1	PROJECT ABORTED OR CANCELLED EACH SCHEDULED E[illegible]	1		1	1													
FRANKLIN	2 JU[illegible]		1					1	1	1											
LASSEN	5 [illegible]									1											
WILSON	18 [illegible] 57							1		1				1							4
PRISCILLA	[illegible]NE 57	1	1		1		1	1		1	2				2						2
COULOMB A	[illegible] JUL 57																				
HOOD	5 JUL 57	1	1		2	1	1	1					3	1			30	45	1	3	2
DIABLO	15 JUL 57		1		1	1	1	1					3	1							4
JOHN	19 JUL 57							1				1									
KEPLER	24 JUL 57		1		2	1		1				1	3	1							4
OWENS	25 JUL 57		1		1	1		1						1							3
PASCAL A	26 JUL 57				NO AIRCRAFT PARTICIPATION																
STOKES	7 AUG 57		1			1	1	1						1							
SATURN	9 AUG 57				NO AIRCRAFT PARTICIPATION																
SHASTA	18 AUG 57				2		1	1				1	4								2
DOPPLER	23 AUG 57				1	1	2	1						1							
PASCAL B	27 AUG 57				NO AIRCRAFT PARTICIPATION																
FRANKLIN PRIME	30 AUG 57							1				1		1							5
SMOKEY	31 AUG 57				1		2	1			44	1	4	1		3					4
GALILEO	2 SEPT 57																				
WHEELER	6 SEPT 57																				2
COULOMB B	6 SEPT 57																				
LAPLACE	8 SEPT 57																				
FIZEAU	14 SEPT 57																				
NEWTON	16 SEPT 57													1	2						2
RAINIER	19 SEPT 57																				
WHITNEY	23 SEPT 57																				
CHARLESTON	28 SEPT 57																				
MORGAN	7 OCT 57																				
TOTAL NUMBER OF AIRCRAFT PARTICIPATING		5	9	0	12	6	10	14	1	4	16	5	17	9	4	3	30	45	1	J	34

EVENT	PROJ 53.5 T-33	PROJ 53.5 F-102	PROJ 53.5 R6D	PROJ 53.7 F-89D	PROJ 53.8 B-47	PROJ 53.9 RF-84F	PROJ 9 C-47	PROJ 37 C-47	AFSWC F-89J	SAMPLERS B-57	SAMPLERS F-84	CLOUD TRACKERS	CLOUD TRACKERS B-50, B-29	SECURITY TRACKERS B-25	SWEEP LIAISON	SURVEY H-21	SAMPLE RETURN C-47	SPECIAL PHOTO AIRCRAFT	AFSWC PENETRATION T-33 / MISCELLANEOUS O&I	TOTAL NUMBER OF AIRCRAFT	ABORT & CANCELLED	TOTAL NO. AIRCRAFT PLANNED
BOLT[illegible]NN			5	1		2	1	1		3	6	2	1	1	3	3				34	0	34
FRANKLIN				1		2	1			1	5	2	1	2	5	3				27	0	27
LASSEN				1		2	1			1	5		2	2	4	3				23	4	27
WILSON		2		1		2	1	1		4	4	2	2	2	3	3				35	4	39
PRISCILLA	2			1		2	1	1		4	2	2	2	2	4	3	1	1		40	5	45
COULOMB A				1							2				2	2				7	2	9
HOOD	4			1		2	1	1		5	2	2	2	2	6	3		1		24	6	30
DIABLO				1		2	1	1		4	5	2	2	2	6	3		1		42	7	49
JOHN			4	1					2	5		1			2	3	2		4	26	0	25
KEPLER	5			1		2	1	1		3	4	2	1	1	2	3		1		41	1	41
OWENS				1		2	1			2	4	2	1	1	2	3		1		28	0	28
PASCAL A																				0	0	0
STOKES						2	1			3	5	1	2	2	5	3				29	4	33
SATURN																				0	0	0
SHASTA				1				1		3	4	2	1	1	3	3				30	12	42
DOPPLER				1		2				3	4	1	1	1	4	3				[illegible]	12	30
PASCAL B																				0	0	0
FRANKLIN PRIME				1		2				1	3		2	1	1	3				22	1	23
SMOKEY				1	2	2	1	1		5	2	1	1	2	2	3				34	3	87
GALILEO						2	1	1		3	4	1	1	1	5	3				22	0	22
WHEELER										1	6		2	1	1	2				15	0	21
COULOMB B											4		1			2				7	0	7
LAPLACE	1									1	5	1	1	1	1	3				14	7	21
FIZEAU	6						1			2	4	2	1	2	2	3				23	2	25
NEWTON					2		1	1		5			1	1	1	5	1			21	8	29
RAINIER							1				3			1	2				1	8	0	8
WHITNEY					2		1	1		3	4	1	2	1	2	3				20	1	20
CHARLESTON							1			3	4	1	1	1	2	3	1		2	19	5	24
MORGAN							1			1	8		2						2	18	3	21
TOTAL NUMBER OF AIRCRAFT PARTICIPATING	18	2	9	15	6	28	19	11	2	66	96	28	33	32	70	59	5	5	9	786	87	875

- Exercising operational control over aircraft participating in or supporting atmospheric nuclear testing programs
- Collecting particulate and gaseous samples
- Providing support for aircraft of participating organizations through the 4935th Air Base Squadron, Indian Springs Air Force Base (ISAFB), NV
- Satisfying air support requirements of the AEC's test organization at the Nevada Test Site.

The 4950th Test Group was composed of a headquarters and four squadrons. The group headquarters (4900th Air Base Group, Kirtland AFB, NM) supported PLUMBBOB by providing daily shuttle service between Kirtland AFB and Indian Springs AFB. The four squadrons were:

- The 4926th Test Squadron, stationed at Kirtland AFB. The squadron, in support of the AEC, collected gaseous and particulate cloud samples following nuclear detonations. As noted in Chapter 6, members of this group received an appreciable radiation dose.
- The 4935th Air Base Squadron, located at Indian Springs AFB, operated the air base and furnished the test support aircraft. It provided housing, messing, air base operations, security, flying time for DOD personnel at the NTS, and limited air support missions. Personnel augmentation from AFSWC was provided so that the squadron could accomplish these services. The normal number of personnel (257) was increased to 410 for PLUMBBOB.
- The 4951st Support Squadron (Test) at Enewetak Atoll may have furnished some support to the tests. There is, however, no sure indication that this squadron participated in PLUMBBOB.
- The 4952nd Support Squadron, essentially an augmentation squadron, provided personnel to the buildup for the operational and rollup phases of the tests.

Test participants were required to submit air support requirements through an Air Force officer assigned to the Test Director's staff. By this means, any conflicts which arose in the use of the limited number of support aircraft were resolved by an individual in the best position to determine relative priority. The system also provided a means to ensure that civilian test participants were properly authorized to fly in military aircraft. The effectiveness of the planning, the operational procedures, and the flying safety measures resulted in 90 percent of the scheduled test missions being flown as planned (2).

TABLE 5-4
TEST AIRCRAFT UNIT TOTALS FOR OPERATION PLUMBBOB (2)

	T.O. & Landings	Total Flying Time
4926th Test Squadron	1932	2669:45
NASWF	729	963:00
Documentary Photo	47	166:55
MB-1 Project	62	85:00
WADC Element	134	125:10

Since certain units were based at Kirtland Air Force Base, the limited resources available at Indian Springs Air Force Base could be applied to the needs of those units which had priority assignment for operational reasons. All units participating on an operational and training basis were requested to provide the 4950th Test Group with copies of their operational plans and the aircrew briefings to be used during the test (see Table 5-5).

Most test and support aircraft operated from Indian Springs AFB. Command supervision of the organizations operating from this base was exercised by a Deputy Commander of the 4950th Test Group responsible for supervising the activities of the 4935th Air Base Squadron and the Test Aircraft Unit (Figure 5-24).

Table 5-5. BRIEF DESCRIPTION OF AIR OPERATIONS.(3)

1. Location

   a. Indian Springs AFB all helicopters, B-57 sampling aircraft, L-20s, jet fighter types.

   b. Kirtland AFB multi-engine prop-driven aircraft, B-50s, 29s, 36s, etc.

2. Security sweep aircraft and certain helicopters were not expected to penetrate contaminated airspace and no special procedures taken other than pilots, passengers, and observer types wore film badges.

3. Multi-engine aircraft operating from Kirtland; trackers, long range cloud trackers drop aircraft, etc. also had no special procedures for pre-shot operations except as in number 2 above.

4. Sampling aircraft (B-57s) procedures

   a. Pre-test
      1) Load filter papers
      2) Final mechanical checks
      3) Pilot briefings (2 per plane) as to orbit levels pre-shot, expected cloud height, penetration times, other aircraft, etc.
      4) Take off for pre-shot, air set up etc., to be in position at H-1 hour.

   b. Penetration phase. Underground control for time altitude and number of passes before returning to base. Determination of adequacy of sample for radiochemistry was based on integrating dosimeter location in the aircraft on basis of previous experience. All pilots were on full internal oxygen prior to, during, and after penetration. Cockpits were pressurized as normally done with no added special filters on air intakes pre- or post-compressor.

   c. Landing phase. Aircraft landed as usual. After landing, aircraft taxied to east taxi strip (Indian Springs AFB) which is farthest strip from operations area, and parked on the east edge of pad in pre-located area. Engines were shut down, but pilots remained on full oxygen (internal) and canopies remained closed and latched.

   d. Forklift and pickup truck with sample removal team and R/S monitors proceed to aircraft.

   e. Sample removal team removes filter papers (via forklift) and places same in sample boxes. After removal and placing in sample boxes (shielded) in pickup, forklift proceeds to aircraft cockpit.

   f. Oxygen shutdown, canopy opened, and pilots evacuate aircraft via forklift without climbing on outside of aircraft and transfer to pickup.

   g. Pickup proceeds to decontamination area where pilots off-load, then proceeds to sample return aircraft which then departs to UCRL and/or LASL with courier and samples.

   h. Pilots monitored at decontamination facility were the to proceed through full decontamination (strip down, shower, etc.), even though no contamination may have been present. Clothing (normal flight suit) handled as necessary.

   i. Aircraft decontamination proceeds at aforementioned parking location. Decontamination crew washes down aircraft externally with water (fire-hose type) (canopy closed). Engines started and water (firehose) allowed to enter engines; waste water soaks into desert off taxi strip. Engines shut down; and wipe down of cockpit internally necessary done. Aircraft returned to flight line for necessary maintenance, preparation for next flight, etc. Decontamination levels same as in Rad-Safe operation order for vehicles, etc.

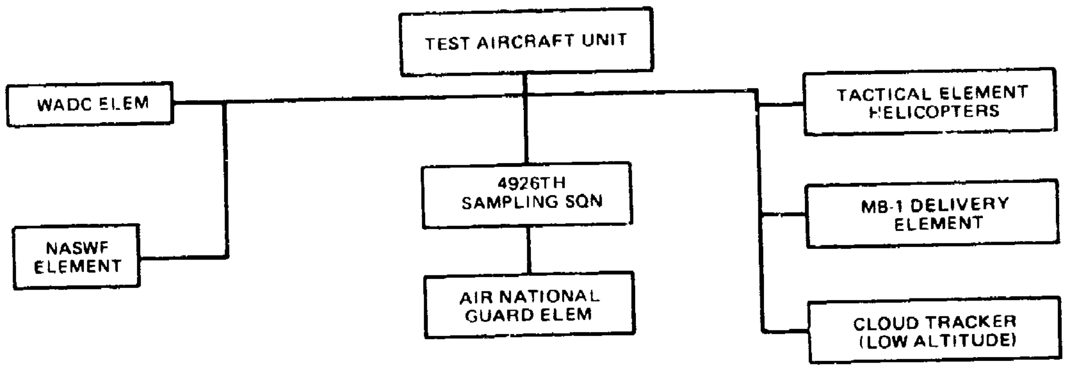
   j. Helicopter procedures for helicopters expected to be used in areas of either contaminated airspace or contaminated ground space.

      1) Pre-test interior of helicopter lined with strippable paper - this takes 2 days.

      2) Test use phase - Passengers equipped with anti-contamination clothing and respirators. Pilots in usual flying attire. Monitor on board. Proceeds on mission and returns to chopper area. Persons on board dismount, go to decontamination area. Proceed through decontamination if necessary.

      3) Chopper checked for contamination - external washdown if necessary. Internal area stripped of paper if necessary.

      4) Decontamination levels same as for all vehicles.



WADC - WRIGHT AIR DEVELOPMENT CENTER
NASWF - NAVAL AIR SPECIAL WEAPONS FACILITY

Figure 5-24. TEST AIRCRAFT UNIT ORGANIZATION.

The Test Aircraft Unit headquarters, manned by personnel of the 4926th Test Squadron (Sampling), was responsible for the operational control of all organizations and aircraft not permanently assigned at Indian Springs. Control of these units was effected by conducting aircrew briefings, publishing mission execution charts, scheduling flying activities, monitoring personnel radiation exposures, operating fixed and mobile ground UHF radio equipment, and maintaining a 24-hour operations section which kept all Test Aircraft Unit elements informed of pertinent shot schedules. The 4926th Test Squadron (Sampling) deployed the majority of their personnel to Indian Springs AFB to accomplish the required cloud sampling, personnel dosimetry, and aircraft decontamination. During Operation PLUMBBOB, pilots from the Strategic Air Command and the Air National Guard were indoctrinated in cloud sampling techniques. A rear echelon of the 4926th Test Squadron accomplished major maintenance and inspections of the Squadron's aircraft at Kirtland Air Force Base.

4926th Test Squadron (Sampling)

The 4926th Test Squadron (Sampling) was formed in April 1953 to fulfill the AEC requirements for collecting gaseous and particulate cloud samples after nuclear detonations (See Table 5-6). This unit handled all such sampling work from Operation CASTLE at Enewetak in 1954 through the PLUMBBOB Series.

The unique mission of the 4926th Test Squadron (Sampling) is reflected in its organization. In addition to executing the normal functions of a squadron operating several different types of mission aircraft, the 4926th maintained a Nuclear Applications section, whose primary function was to instrument and prepare aircraft for nuclear cloud sampling. This section was also responsible for removing the cloud samples from aircraft and preparing them for shipment to the appropriate laboratories for analysis. In addition, the Nuclear Applications Section operated decontamination and personnel dosimetry facilities.

During Operation PLUMBBOB, all periodic inspections and controlled major maintenance of F-84G and B-57B aircraft were performed at Kirtland Air Force Base. The average strength of the Kirtland Air Force Base detachment was one officer and 40 airmen. The strength of the forward element at Indian Springs Air Force Base averaged 26 officers and 130 airmen.

During Operation PLUMBBOB, the following flight times applied (2):

Aircraft	Flight Time (Hours: Min)
B-57B	796:05
F-84G	1,331:55
T-33A	541:45
Total Time	2,669:45

Of the total flying time, 175:45 hours were logged during test mission sorties. Total number of sorties flown was 1,821, which included 161 test mission sorties. A total of 1,932 take-offs and landings were recorded. There were seven aborts due to reasons other than shot cancellation. During the entire time of Operation PLUMBBOB, the 4926th Test Squadron (Sampling) had no accidents or incidents. Table 5-7 is a statistical summary of this squadron's operations at PLUMBBOB.

Table 5-6. SAMPLE RECOVERY AND SAMPLE RETURN OPERATIONS. (This information is a copy of Appendix 5 to Annex F of Operations Plan 1-57) (3)

1. GENERAL.

This Appendix outlines the sample recovery and sample return operations to be performed by the 4950th Test Group (Nuclear) during the operation.

2. RESPONSIBILITIES. (C)

a. All cloud sample recovery operations will be the responsibility of the Commander, 4950th Test Group (Nuclear) and will be performed as follows:

(1) The 4926th Test Squadron (Sampling) will:

(a) Designate a sample Recovery Officer to supervise all sample recovery operations and control the entrance of personnel to the sample recovery area.

(b) Isolate the sample recovery area.

(c) Park and secure aircraft.

(d) Assist pilot from aircraft and remove all film badges.

(e) Provide Rad-Safe monitors for sample recovery operations.

(f) Provide personnel for the recovery operation. These personnel will:

1. Mark the cloud sample pigs by aircraft number and designate whether samples were taken from right or left tanks.

2. Roll films and insert them in pigs.

3. Read and record dose rates from pigs.

4. Package pigs in wooden crates as provided by UCRL and LASL.

5. Recover, mark, and crate AFOAT-1 sample bottles.

b. In the sample return operation, the Commander, 4950th Test Group (Nuclear) will provide to the Test Director through its subordinate units as follows:

(1) The 4926th Test Squadron (Sampling) will:

(a) Provide facilities to transport samples from the sample processing compound to the sample return aircraft.

(b) Load samples on return aircraft.

(2) The 4900th ABG Support Operations Officer at Indian Springs AFB, in conjunction with the Test Director's Sample Return Coordinator, will:

(a) Brief sample return aircraft crews.

(b) Insure that top priority is given for the departure of the sample return aircraft when released by the Sample Return Coordinator.

(c) Insure that aircraft commanders understand their responsibilities for:

1. Placement of samples, tie-down, etc.

2. The expeditious return of samples to destinations, consistent with flight safety.

3. Observing radio security.

3. PROCEDURES.

Special detailed operating procedures for the implementation of the above will be prepared by the responsible unit. Copies of these SOP's will be forwarded to the Commander, 4950th Test Group (Nuclear), ATTN: Nuclear Research Officer, prior to 15 April 1957.

Table 5-7. STATISTICAL SUMMARY 4926th TEST SQUADRON (SAMPLING).(2)

	TOTAL SORTIES	MISSION SORTIES	TOTAL TIME	AV TIME PER ACFT	MISSION TIME	OTHER SORTIES	T.O. AND LANDINGS
May							
(11) JF-84G	168	5	191:30	17.5	6:25	163	168
(6) B-57B	76	4	136:45	22.7	7:35	72	76
(2) T-33	69	1	115:15	57.6	1:15	68	76
TOTAL	313	10	443:30	97.8	15:15	303	320
June							
JF-84G	254	15	335:15	31.9	16:20	239	254
B-57B	99	11	198:30	33.1	18:45	88	99
T-33	94	1	154:35	77.3	1:10	93	136
TOTAL	447	27	688:20	142.3	36.15	420	489
July							
JF-84G	210	12	282:45	25.7	10:30	198	210
B-57B	84	16	156:30	26.1	30:25	68	84
T-33	42	3	70:50	35.4	3:20	39	59
TOTAL	336	31	510:05	87.2	44:15	305	353
August							
JF-84G	237	19	299:25	27.2	16:50	218	237
B-57B	92	16	173:00	28.8	28:20	76	92
T-33	67	1	121:30	60.7	1:50	66	92
TOTAL	396	36	593:55	116.7	47:00	360	421
September							
JF-84G	169	30	212:25	19.3	10:40	139	169
B-57B	94	17	122:55	20.5	5:55	77	94
T-33	54	2	79:35	38.7	2:20	52	74
TOTAL	317	49	414:55	78.5	18:55	268	337
to Oct 7							
JF-84G	8	6	10:35		8:05	2	8
B-57B	4	2	8:25		6:10	2	4
T-33	0	0	0		0	0	0
TOTAL	12	8	19:00	—	11:15	4	12
4926th TS Totals for Test	1821	161	2669:45	522.5	175:55	1660	1932

At the request of Headquarters, U.S. Air Force, each of fourteen* Air National Guard squadrons having secondary sampling missions was given special training. Four officers and six airmen from each squadron were ordered on active duty for two weeks and were integrated into the operations, maintenance, and nuclear applications sections of the 4926th Test Squadron (Sampling). Orientation and familiarization lectures were given and an on-the-job training program conducted to provide practical experience in aircraft instrumentation, particulate sampling, sample recovery, aircraft decontamination, and personnel dosimetry.

In the course of normal sampling mission operations, orientation, indoctrination, familiarization, and special studies were conducted for various U.S. Air Force and Royal Canadian Air Force personnel:

- Personnel from the 4935th Air Base Squadron and from the Test Aircraft Unit were trained in personnel dosimetry and precautionary measures.
- Strategic Air Command pilots from Laughlin Air Force Base, Texas, were given lectures on nuclear cloud sampling techniques and radiological safety. Twelve pilots participated on actual cloud sampling missions as observers.
- Royal Canadian Air Force (RCAF) personnel, in three groups of 25 each, were indoctrinated in radiological procedures pertaining to the sampling mission. They observed the various phases of the operation and actually participated in aircraft decontamination operations.

Wright Air Development Center (WADC) (Projects 5.5 and 53.7)

The mission of the WADC element was to determine the structural response of in-flight F-89D aircraft to the blast and thermal effects of a nuclear detonation. This information was required primarily for the purposes of correcting or verifying the weapons delivery handbook for the aircraft and for defining its delivery capability. The WADC Element was composed of two F-89D aircraft, six pilots (two of which were at the Nevada Test Site at a given time), one enlisted man (supply sergeant), and seven civilian maintenance men.

---

*Montana, New Hampshire, Illinois, New York, Ohio, Texas, Nebraska, Oregon, Idaho, California, Arizona, Oklahoma, Delaware, Wisconsin.

Both aircraft participated in most of the shots up to and including shot SMOKY (31 August 1957). The following flying times apply for the period from 12 April 1957 to 31 August 1957 (2):

	Flying Time (Hours)	Sorties
Total Missions	125:10	134
Actual Shot Missions	30:30	29

There was only one abort during the entire period; it occurred on the STOKES event (7 August 1957). No accidents or incidents occurred during the operation.

TABLE 5-8

WRIGHT AIR DEVELOPMENT CENTER STATISTICAL SUMMARY (2)

(2) JF-89D	Total Time	Mission Time	Av Time/Acft	Mission Sorties	T.O. & Landing
April	15:25		7:42	17	
May	26.10	2:00	13:05	2	24
June	28:20	8:30	14:10	9	31
July	29:35	12:00	14:50	11	37
August	25:40	8:00	12:50	7	25
TOTALS	125:10	30:30	62:37	29	134

Naval Air Special Weapons Facility (NASWF) (Projects 5.3, 5.4 and 6.3)

The mission of the NASWF detachment was to obtain data on aircraft response to nuclear blast and thermal inputs for the A4D, FJ-4, and HSS-1 aircraft. Since these aircraft represent three general types not previously investigated (FJ-4, extremely thin swept wing aircraft; A4D, very low aspect ratio; and HSS-1, rotary wing), basic effects data was obtained in addition to specific data on these aircraft types. Generally, the effects prediction systems proved reliable. Data was obtained to establish the delivery capabilities of the A4D and FJ-4 aircraft for low yield weapons.

The NASWF detachment consisted of two A4-D aircraft, two FJ-4 aircraft, one AD-5, one HSS-1, one TV-2 (thirteen officers, 45 enlisted men, and 43 civilian contractor personnel). It accomplished its mission without any accidents or incidents. An average of 214 hours were flown each month from 15 April 1957 to 31 August 1957. Of this total, 118 hours per month (average) were logged during mission or practice mission flights. There were seven aborts during the test period; one A4-D standby mission due to aircraft control difficulties; and three A4-D and three FJ-4 missions due to radar malfunction or interference from other radar stations (2).

TABLE 5-9
U.S. NAVY SPECIAL WEAPONS FACILITY STATISTICAL SUMMARY (2)

	Average Monthly Flying Time Hours	Total Time For Test
(2) A4D	35	157:30
(2) FJ4	45	202:30
(1) HSS-1	38	171
(1) AD5	58	261
(1) TV2	38	171
	TOTAL	963
Average Mission and Practice Time Per Month		118
Total Mission and Practice Time for Test		531
Average Total Time per Month		214
Average T.O. and Landings per Month		162
Total T.O. and Landings for Test		729
Average Sorties per Month		143
Total Sorties for Test		644
Average Mission or Mission Practice Sorties per Month		94
Total Mission or Mission Practice Sorties for Test		423

MB-1 Element (Genie) (Shot JOHN)

The mission of the MB-1 Element was to test--scientifically--a "live" air-to-air nuclear rocket and to collect radiation data for operational and scientific planning. The MB-1 Element consisted of two F-89J aircraft, permanent project personnel (eight officers, four airmen, and ten civilians from Northrop) plus temporary personnel who were on site two weeks or less (two officers, two airmen, and four civilians from Douglas, Hughes, and Northrop). The first fighter delivery of a live nuclear rocket in U.S. history was achieved on 19 July 1957. From 28 May 1957 to 26 July 1957, the two F-89J aircraft assigned to the project flew a total of 170 hours. From 14 June to 26 July, each aircraft crew flew two sorties per day. A 99.25 percent aircraft-in-commission rate for scheduled missions was achieved. One practice mission was aborted. No accidents or incidents occurred during the period of the project.

TABLE 5-10 (2)
MB-1 PROJECT STATISTICAL SUMMARY

	28 May to 26 July 1957
(2) F-89J	
Total Flying Time	85:00
Total Mission Time	2:30
Pro-rated Average Monthly Time/Aircraft	22:00
Total Sorties	62
Mission Sorties	2
Practice Sorties	60
Total Take-offs and Landings	62

21st Helicopter Squadron (Detachment #1)

The mission of this unit was to conduct radiation surveys at the test site; recover rockets in remote and otherwise inaccessible areas; provide taxi service in support of nuclear tests, handle search and rescue service, and do any other necessary, special helicopter flights within operational capabilities. The 21st Helicopter Squadron was a unit of the 314th Troop Carrier Wing, Medium, Sewart Air Force Base, Tennessee. The squadron consisted of an average of seven H-21 helicopters, eleven officers, seventeen airmen, and one civilian. Squadron aircraft and crews flew a total of 737:40 hours, of which 695:05 hours were logged during mission sorties. A total of 745 mission sorties were flown. Aircraft flying time on a 30-day average was 143:35 hours. There were only two aborts during the operation. No accidents or incidents occurred (2).

4935th Air Base Squadron

This squadron furnished normal air base operations services to aircraft participating in or supporting the test. In addition, flying time was furnished to attached rated personnel, while aircraft and crews were furnished for security sweeps, rocket nose cone searches, sampler controls, sample returns, cloud trackers, and photo missions. The Base Communications section (which was a part of operations) provided long distance, Kirtland hotline, teletype, Western Union, commercial TWX, and cryptographic facilities for test and test support units.

5.3 AEC OPERATIONS WITH DOD INVOLVEMENT

The AEC's test programs measured the intrinsic aspects of nuclear devices. Their diagnostic measurements were directly related to the problems of weapon development. Generally, weapon (or device) diagnostics are considered in totality. Of primary importance is, of course, yield. Yield is, in final analysis, a measure of the efficiency of the system. During Operation PLUMBBOB, there were four main test groups active with AEC test programs (Figure 5-25): Los Alamos Scientific Laboratory, University of California Radiation Laboratory, Livermore (UCRL), Sandia Laboratory, and Project 57.

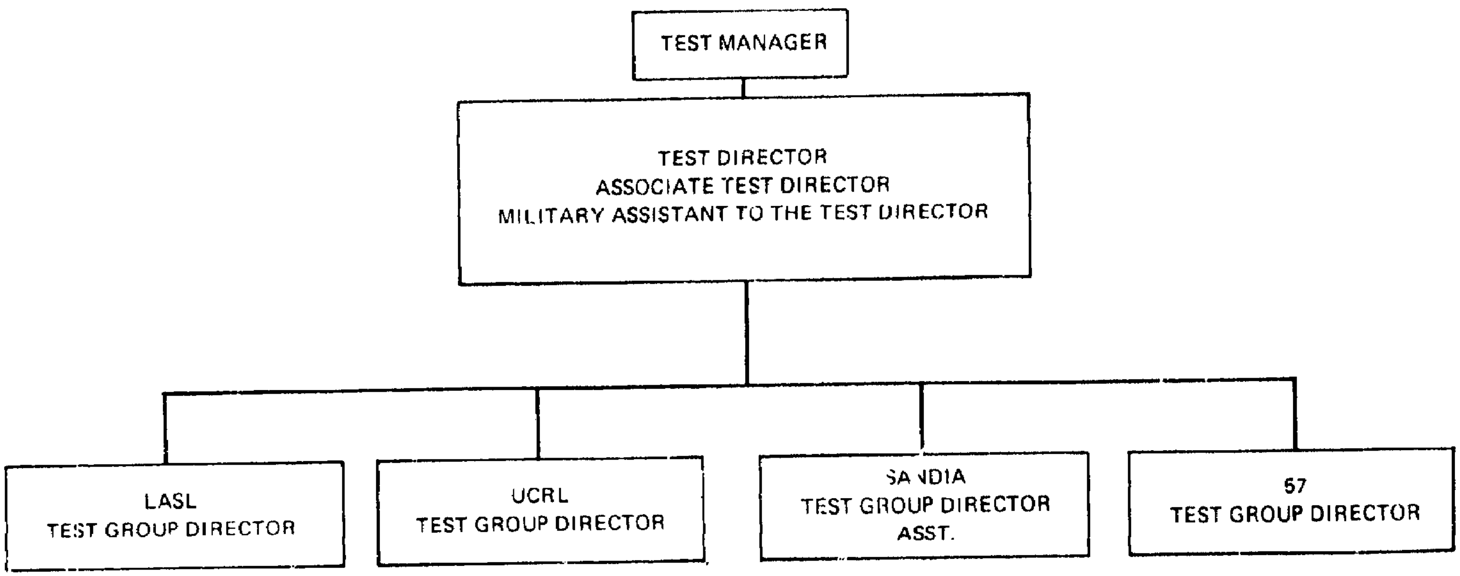


Figure 5-25. **FUNCTIONAL TEST GROUPS, AEC OPERATIONS, PLUMBBOB.**

The AEC weapons laboratories, LASL and UCRL,* utilized the test site for field testing nuclear devices, nuclear weapon proof-testing, and special tests of nuclear materials regarding theory and safety. These laboratories primarily developed nuclear weaponry for incorporation into militarily useful systems. To develop systems for nuclear weapons it is necessary to consider the functional aspects of the weapon itself. Within their various programs, LASL and UCRL measured and analyzed their nuclear devices or weapons. Both LASL and UCRL measured yield with proven methods, including fireball photography, bhangmeter measurements, alpha measurements, and radiochemistry.

In addition to the usual measurements made for yield determination, each laboratory had specific experiments tailored to a specific detonation. In general, these experiments involved the nuclear reaction history. The laboratories utilized both their own personnel as well as those of subcontractors and other organizations. For example, LASL used the Naval Research Laboratory in one group of studies. Similarly, the UCRL effort was concerned with the same investigations. The final analysis of the experimental results was a function of the laboratory itself using the measurements made internally or by a laboratory contractor. The overall list of AEC projects for PLUMBBOB is given in Appendix A.

Many of these projects required onsite recovery operations. These were usually conducted by laboratory and associated personnel under the control of the Test Director's Rad-safe organization. Most were non-DOD civilian laboratory personnel whose recorded exposures are not a part of this document. Some DOD personnel, on assignment to the laboratories, were involved in these recovery operations. In general the only measurement (other than radiochemistry) that required prompt entry into radioactive areas was the pickup of films for estimation of alpha radiation. In cases where radiation dose rates were too high, the films could not be recovered immediately.

*LASL and UCRL were both operated for the AEC by the University of California. UCRL is now Lawrence Livermore National Laboratories. Both are operated for DOE by the University of California at Berkeley.

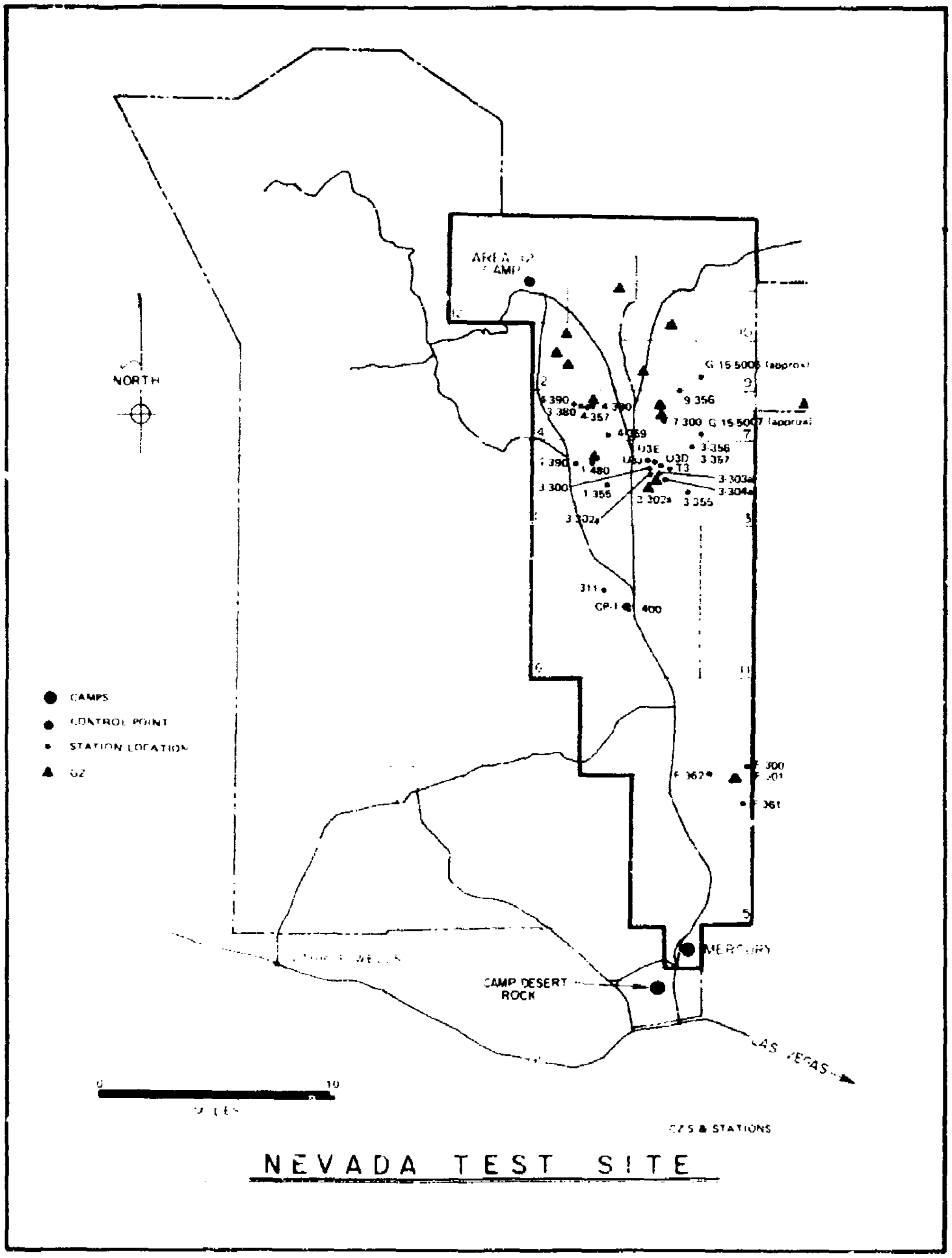
After a weaponry system has been conceived, there must be a merger of the nuclear device and system components to produce an efficient and practical weapon. Building this system into a practical weapon is the primary concern of the Sandia Laboratory at Albuquerque* which concentrated on the non-nuclear components of weapons. Through the use of fireball studies and weapons vulnerability tests, Sandia tested the reliability and adequacy of the design of weapon components.

The first concern with the development of nuclear weapons and weaponry systems is safety. During Operation PLUMBBOB, LASL and UCRL sponsored certain safety tests to verify the weapons' reliability with respect to safety.

In December of 1956, the AEC Albuquerque Operations Office, with the sanction of the Division of Military Application (DMA), asked Sandia Corporation to arrange an extensive experimental program to evaluate plutonium contamination from a non-nuclear one-point detonation--a test where a particular nuclear device is detonated at one warhead location rather than at multiple locations. Plutonium is a serious radiological hazard when deposited internally in much smaller amounts than would cause chemical damage to tissues as a "heavy metal poison." Sandia accepted and set up Project 57 to perform the experiment. Sandia also appointed the Test Director; he called together representatives of participating organizations to rule on a choice for the test site and to formulate the first experimental plans for this Project 57.

An area adjacent to and northeast of NTS, (just northeast of Area 10, Figure 5-26), was borrowed from the Air Force for a 200-day period and designated as Area 13. Seventy square miles of the valley area and 100 square miles total were surveyed for instrument and fallout collector locations. Radiochemical analysis of earth samples confirmed the belief that there was an insignificant plutonium background from previous test operations. The one-point detonation was made at 0627 on 24 April 1957 in Area 13. A non-nuclear device was detonated to create conditions for conducting studies in Plutonium (Pu) contamination, biological effects, and alpha decontamination procedures. The device had no

*Sandia was operated for the AEC by the Sandia Corporation, a unit of the Bell System.



NOTE THE BOUNDARY BETWEEN AREAS 1 & 3 AND AREAS 4 AND 7 IS MERCURY HIGHWAY, THE NORTH-SOUTH ROAD SHOWN TRAVERSING THOSE AREAS. THE BOUNDARY BETWEEN AREA 2 AND AREA 9 LIES ALONG THE CENTER OF THE THREE ROADS SHOWN.

Figure 5-26. NEVADA TEST SITE WITH STATION LOCATIONS.

nuclear yield. Sandia Corporation provided direct operational support to Project 57 before and after detonation, as well as normal Rad-safe support to all test personnel, until completion of the experiment. REECo provided all Rad-safe support to Project 57 in Area 13 (and considerable operational support to Sandia). Project 57 performed four safety programs, 71 (Particulate Physics), 72 (Biomedical Field Study of Plutonium Inhalation), 73 (Plutonium Monitoring), and 74 (Surface Alpha Monitoring).

5.3.1 Los Alamos Scientific Laboratory (LASL) Programs

The following list summarizes the LASL programs that were active during Operation PLUMBBOB (see Table 5-11). A more detailed description is precluded by the classified nature of these projects. Most of the station locations mentioned are shown in Figure 5-26.

- Program 10 - Hydrodynamics. This program consisted of two projects: 10.1 (Fireball Analysis) and 10.2 (Time of Arrival). It consisted of fireball studies in which photographic techniques were used to determine yield. EG&G carried out this work for LASL. Stations were fixed and used as necessary for a particular event. Recovery was required and may have taken place in radiological exclusion areas, depending on post-shot survey results. Program 10 was active for the following shots and at the following stations.

BOLTZMANN	Sta 9-356 372; G-15-5006
FRANKLIN	G-15-5007; 3-356; 372
LASSEN	372
WILSON	372
PRISCILLA	F 361; F 362; 372
HOOD	372
DIABLO	372
KEPLER	4-357; 7-357; 372
OWENS	372
STOKES	9-356; 7-357; 372
SHASTA	372
DOPPLER	70357; 9-356; 372
FRANKLIN PRIME	7-357: 9;356; 372

Table 5-11. LASL TEST GROUP PROJECTS CONDUCTED AT OPERATION PLUMBBOB SHOTS (1957)*

PROGRAM / SHOT	Program 10 Hydrodynamics	Program 11 Radiochemistry	Program 12 Diagnostic Neutron Measurements	Program 13 Gamma Ray Measurements	Program 14 New Instrument Development	Program 15 Photophysics	Program 16 Bhangmeter Measurements	Program 17 Electromagnetic Measurements	Program 18 Thermal Spectroscopy	Program 19 Vulnerability Studies
PROJECT 57										
BOLTZMANN	10.1 10.2	11.1 **11.2**	12.1 12.2 12.4	13.1 13.2 13.3	14	15.1 15.2	**16.2**	17.1	**18.1** **18.2** **18.3** 18.4	
FRANKLIN	10.1 10.2	11.1 **11.2**	12.2 12.4	13.1 13.2	14	15.1 15.2	**16.2**	17.1	**18.1** **18.2** **18.3** 18.4	
LASSEN	10.1 10.2						**16.2**	17.1		
WILSON	10.1 10.2				14		**16.2**	17.1		
PRISCILLA	10.1 10.2	11.1 **11.2**	12.2 12.4	13.1 13.2		15.1 15.2	**16.2**	17.1	**18.1** **18.2** **18.3** 18.4	19.1
COULOMB A Safety Experiment		11.1 11.2	12.3	13.1 13.2		15.1 15.2		17.1		
HOOD	10.1 10.2	11.1 **11.2**		13.1 13.2			**16.2**	17.1		
DIABLO	10.1 10.2	11.1 **11.2**		13.1 13.2	14		**16.2**	17.1		
JOHN		11.1 **11.2**					**16.2**	17.1		
KEPLER	10.1 10.2	11.1 **11.2**	12.1 12.2 12.4	13.1 13.2 13.3	14	15.1 **15.2**	**16.2** 16.4	17.1	**18.1** **18.2** **18.3** 18.4	
OWENS	10.1 10.2						**16.2**	17.1		
PASCAL A Safety Experiment			12.3	13.1 13.2				17.1		
STOKES	10.1 10.2	11.1 **11.2**	12.2 12.4	13.1 13.2		15.1 15.2	**16.2**	17.1	**18.1** **18.2** **18.3** 18.4	
SATURN Safety Experiment										

*Bold print indicates projects with DOD participation

Table 5-11. LASL TEST GROUP PROJECTS CONDUCTED AT OPERATION PLUMBBOB SHOTS (1957) (Continued)

PROGRAM / SHOT	Program 10 Hydro-dynamics	Program 11 Radio-chemistry	Program 12 Diagnostic Neutron Measurements	Program 13 Gamma-Ray Measurements	Program 14 New Instrument Development	Program 15 Photophysics	Program 16 Bhangmeter Measurements	Program 17 Electro-magnetic Measurements	Program 18 Thermal Spectroscopy	Program 19 Vulnerability Studies
SHASTA	10.1 10.2	11.1 **11.2**			14		**16.2**	17.1		
DOPPLER	10.1 10.2	11.1 **11.2**	12.2 12.4	13.1 13.2		15.1 15.2	**16.2**	17.1		
PASCAL B Safety Experiment			12.3	13.1 13.2				17.1		
FRANKLIN PRIME	10.1 10.2	11.1 **11.2**	12.2 12.4	13.1 13.2		15.1 15.2	**16.2**	17.1		
SMOKY	10.1 10.2	11.1 **11.2**					**16.2**	17.1		
GALILEO	10.1 10.2	11.1 **11.2**	12.2 12.4	13.1 13.2	14	15.1 15.2	16.1 **16.2**	17.1		
WHEELER				13.1 13.2				17.1		
COULOMB B Safety Experiment	10.1 10.2	11.1 **11.2**	12.3	13.1 13.2		15.1 15.2				
LAPLACE	10.1 10.2	11.1 **11.2**	12.4	13.1 13.2		15.1 15.2	**16.2**	17.1		
FIZEAU	10.1 10.2	11.1 **11.2**	12.2 12.4	13.1 13.2		15.1 15.2	**16.2**	17.1		
NEWTON	10.1 10.2	11.1 **11.2**	12.2 12.4	13.1 13.2 13.3		15.1 15.2	**16.2**	17.1		
RAINIER										
WHITNEY					14		**16.2**			
CHARLESTON							**16.2**			
MORGAN	10.1 10.2						**16.2**			

SMOKY	372
GALILEO	1-355; 1-356; 372
COULOMB B	3-357
LAPLACE	7-357; 9-356; 372
FIZEAU	3-356; 3-357; 372
NEWTON	1-355; 3-355; 372
MORGAN	372

- Program 11* - Radiochemistry: This program consisted of Project 11.1 (Radiochemistry Analysis) and 11.2 (Radiochemistry Sampling). AFSWC performed the sampling and LASL performed the analysis, which resulted in the final determination of yield. The AFSWC portion of this PLUMBBOB report describes the Air Force sampling efforts which supported this program. Program 11 was active at 17 shots.

- Program 12† - Diagnostic Neutron Measurements - consisted for four projects. Project 12.1 and 12.2 were reaction studies which required personnel to enter contaminated areas to recover the experiments. Special measurements were required on BOLTZMANN and KEPLER. In these cases, a special cable extended 2,000 yards from ground zero. The cable was pulled from the 2,000-yard point to an area of sufficiently low radiation intensity so that retrieval was possible. Project 12.3, a special study performed at safety shots only, gave some estimate of yield. Project 12.4 was another reaction study but, unlike Projects 12.1 and 12.2, it presented no recovery problems. Program 12 was active for 15 shots.

- Program 13§ - Gamma Ray Measurements - provided basic early yield estimates and reaction history. Project 13.1 (Alpha Yield Estimates and Reaction History) was supported by EG&G and required personnel to enter contaminated areas to recover experiments. Neither Projects 13.2 (Telemetry) nor 13.3 (J-13 Explorations), both supported by Sandia, required recovery efforts in contaminated areas.

*Reference LASL J-11 letter reports.

†Reference LASL J-12 letter reports.

§"Diagnostic Measurements on Operation PLUMBBOB," LAMS 2772.

The stations used by EG&G consisted of detector locations, which were serviced both before and after events, and blockhouses permanently installed from which post-shot recoveries were required. Station identification was:

1-300	
4-300	
7-300	Blockhouses
F-300	
3-300	
1-480	Collimated blockhouses
4-480	
7-300	
F-301	Detector locations
3-301	
T-3	Tower detector location
U-3d	Underground detector location
U-3j	
3A-302	
3A-303	Surface detector locations
3A-304	

All telemetry information obtained from Sandia measurements of reaction history was received at Station 311. In addition, there were other experiments that fell under Program 13; certain LASL experiments were placed in Program 13 even though in specific cases they involved neutron diagnostics. Of interest in this respect are the special gamma ray studies by LASL at BOLTZMANN and DOPPLER. Program 13 was active at 18 shots.

- Program 14 was involved with new instrument development by LASL which had to do with radiological monitoring. This did not require entry into contaminated areas. Program 14 was active at eight shots.

- Program 15 - Photophysics - analyzed the nuclear reactions using photographic techniques and required no recovery efforts in contaminated areas. It consisted of Project 15.1 (EG&G Photophysics) and Project 15.2 (LASL Photophysics). Photos were made from existing stations and bunkers. This involved recovery of film. These stations were:

BOLTZMANN	Station 7-15-5006
FRANKLIN	Station 3-15-5011
KEPLER	Station 7-15-5005
KEPLER	Station 4-380
KEPLER	Station 4-390
DOPPLER	Station 1-390
GALILEO	Station 1-390
LAPLACE	Station 1-355
NEWTON	Station 1-355

Naval Research Laboratory personnel participated in this program for shot KEPLER. Program 15 was active for 13 shots.

- Program 16 - Bhangmeter Measurements - produced yield measurements and required no recovery operations. Project 16.1 involved Area 1 Measurements; Project 16.2 involved Portable recorders;* and Project 16.3 involved Area 4 Measurements. Information was obtained from the EG&G bhangmeter station at the CP, which operated at all events. Additionally, station locations varied from the CP to Kingman, Arizona; Los Alamos, New Mexico; and other remote areas. Personnel participating and operating the telemetry equipment were military. This program was active for all shots with the exception of Project 57, COULOMB A, PASCAL A, SATURN, PASCAL B, COULOMB B, WHEELER, and RAINIER.

- Program 17 - Electromagnetic Measurements - concerned the long-range effects of electromagnetic pulses (EMP) and consisted of one project, 17.1. Experimentation was conducted at long distances and required no recovery efforts in contaminated areas. Program 17 was active at all shots except Project 57, SATURN, COULOMB B, RAINIER, WHITNEY, CHARLESTON, and MORGAN.

- Program 18 - Thermal Radiation and Spectroscopy consisted of four projects. Project 18.1, 18.2, and 18.3 were performed by NRL for LASL. Project 18.4 was performed by LASL personnel. Recording for this program was done at Station

---

*Reference LASL J-16 letter reports.

311 and at a second (unknown) station. This program was accomplished at some distance from the contaminated areas, and so required no recovery efforts in contaminated areas. Program 18 was active for five shots.

- Program 19 - Vulnerability - entailed a specific experiment on the proximity of one weapon to another. It presented no recovery problems. This program was active for shot PRISCILLA only.

5.3.2 University of California Radiation Laboratory (UCRL) Programs

The following list summarizes the UCRL programs during Operation PLUMBBOB (see Table 5-12). A more detailed description is precluded by the classified nature of these projects. The station locations mentioned are shown in Figure 5-26.

- Program 21 - Radiochemistry - had the same objectives as the LASL Program 11--to determine the yield of the device. It consisted of Projects 21.1 (Analysis), 21.2 (Sample Collection, and 21.3 (Rocket Sampling). The procedures were exactly the same as for LASL except that sample measurement was done at UCRL rather than at LASL. In addition, UCRL used rocketry to collect samples from the JOHN event. Program 21 required no ground recovery near GZ. It was active for 14 shots.

- Program 22 - Reaction History/Electronic - was divided into four projects: 22.1 (Nuclear Radiation Measurements); 22.2 (Remote Technique Development); 22.3 (Telemetry); and 22.4 (Development Experiments). This program required personnel to enter contaminated areas in order to recover experiments. UCRL methods were somewhat different from LASL methods. The only station identified is the CP bhangmeter station. Program 22 was active for 12 shots.

- Program 23 - Reaction History/Photo - required personnel to enter contaminated ›as to recover experiments. It consisted of three projects 23.1 (Flow and Capacity), 23.3 (Ball and Fire, Bhangmeter, EG&G), and 23.4 (Cloud Photography, EG&G). UCRL methods were somewhat different than LASL methods. The fireball results were obtained at station 372 and possibly other locations. Program 23 was active for 12 shots.

Table 5-12. UCRL TEST GROUP PROJECTS CONDUCTED AT OPERATION PLUMBBOB SHOTS (1957)*

SHOT \ PROGRAM	Program 21 Radiochemistry	Program 22 Reaction History, Electronic	Program 23 Reaction History, Photo	Program 25/26 Underground Yield/Effects
PROJECT 57				
BOLTZMANN				
FRANKLIN				
LASSEN	21.1 **21.2**	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
WILSON	21.1 **21.2**	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
PRISCILLA		22.1 22.2 22.3 22.4	23.1 23.3 23.4	
COULOMB A Safety Experiment				
HOOD	21.1 **21.2** 21.3	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
DIABLO	21.1 **21.2**	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
JOHN	21.1 **21.2** 21.3			
KEPLER				
OWENS	21.1 **21.2**	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
PASCAL A Safety Experiment				
STOKES				
SATURN Safety Experiment				**26.1** **26.4**
SHASTA	21.1 **21.2** 21.3	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
DOPPLER	21.1 **21.2**			
PASCAL B Safety Experiment				
FRANKLIN PRIME	21.1 **21.2**			
SMOKY	21.1 **21.2** **21.3**	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
GALILEO	21.1 **21.2**			
WHEELER	21.1 **21.2**	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
COULOMB B Safety Experiment				
LAPLACE				
FIZEAU				
NEWTON				
RAINIER		22.1 22.2 22.3 22.4		**25/26**
WHITNEY	21.1 **21.2** 21.3	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
CHARLESTON	21.1 **21.2** 21.3	22.1 22.2 22.3 22.4	23.1 23.3 23.4	
MORGAN	21.1 **21.2** 21.3	22.1 22.2 22.3 22.4	23.1 23.3 23.4	

*Bold print indicates projects with DOD participation.

- Program 25/Program 26 - Underground Yield/Underground Effects - measured yield and effects of underground shots. These programs involved only the RAINIER event. They were UCRL programs but were performed primarily by Sandia Corporation and were the Armour Research Foundation under the auspices of UCRL. Recovery was on a delayed basis depending on the radiological situation. (Some recovery work took months to perform.) The following civilian agencies participated in Program 26: U.S. Geological Survey, Broadview Research Corporation, Sandia Corporation, Stanford Research Institute, and U.S. Coast and Geodetic Survey. The following military agencies participated in Program 26: U.S. Army Engineer Research and Development Laboratories and Ballistics Research Laboratory. (Methodology checks for Projects 26.1 and 26.4 were performed on shot SATURN).

5.3.3 Sandia Programs

During Operation PLUMBBOB, both functional and support programs were sponsored and performed by Sandia Corporation (Table 5-13). Those functional projects performed by Sandia were grouped under Program 41 which consisted of three projects: 41.1 (Fireball Studies), 41.2 (Weapons Vulnerability), and 41.3 (Neutrons versus Altitude). Those projects for which Sandia provided a support function were grouped under Program 64 (discussed later).

Project 41.1 - Fireball Studies (209;97)

Project 41.1, which was active for shots BOLTZMANN, SHASTA, and FIZEAU, had the following objectives: to explore material properties in the vicinity of a fireball, to explore weapon component properties in the vicinity of a fireball, and to advance the basic understanding of fireball physics. Recovery operations were not required.

Project 41.2 - Weapons Vulnerability (209)

The objectives of Project 41.2 were to increase the general knowledge of the possible vulnerability of nuclear weapons to nuclear bursts and to demonstrate the ability of Sandia Corporation to build a tough nuclear device as similar as

Table 5-13. SANDIA PROJECTS AT OPERATION PLUMBBOB*

SHOT \ TITLE	Project 41 Fireball Studies	Project 41.2 – Weapon Vulnerability	Project 41.3 – Neutrons vs Altitude	Project 64.1 – Balloon Suspension Systems	Project 64.2 – High Time Resolution Telemetry	Project 64.3 – Neutron Sources	Project 64.4 – Device Support Structures	Program 71 – Particulate Physics	Program 72 – Plutonium Inhalation	Program 73 – Plutonium Inhalation	Program 74 – Plutonium Decontamination
PROJECT 57								71	72	73	74
BOLTZMANN	41.1				64.2	64.3					
FRANKLIN					64.2	64.3					
LASSEN				64.1	64.2	64.3	64.4				
WILSON			41.3	64.1	64.2	64.3	64.4				
PRISCILLA				64.1	64.2	64.3	64.4				
COULOMB A Safety Experiment					64.2	64.3					
HOOD				64.1	64.2	64.3	64.4				
DIABLO					64.2	64.3					
JOHN											
KEPLER					64.2	64.3					
OWENS				64.1	64.2	64.3	64.4				
PASCAL A Safety Experiment					64.2	64.3					
STOKES				64.1	64.2	64.3	64.4				
SATURN Safety Experiment						64.3					
SHASTA	41.1	41.2			64.2	64.3					
DOPPLER				64.1	64.2	64.3	64.4				
PASCAL B Safety Experiment					64.2	64.3					
FRANKLIN PRIME				64.1	64.2	64.3	64.4				
SMOKY					64.2	64.3					
GALILEO					64.2	64.3					
WHEELER				64.1	64.2	64.3	64.4				
COULOMB B Safety Experiment					64.2	64.3					
LAPLACE				64.1		64.3	64.4				
FIZEAU	41.1	41.2			64.2	64.3					
NEWTON				64.1	64.2	64.3	64.4				
RAINIER						64.3					
WHITNEY					64.2	64.3					
CHARLESTON				64.1	64.2	64.3	64.4				
MORGAN				64.1	64.2	64.3	64.4				

*Bold print indicates projects with DOD participation possible to an operational nuclear device. Project 41.2 was active for shots SHASTA and FIZEAU and was intimately connected with Project 41.1. For FIZEAU, the toughened devices were located atop television towers within several hundred feet of the FIZEAU device. For this project, the recording station was located on Red Rock butte.

Project 41.3 - Neutrons versus Altitude (209; 141)

The objective of Project 41.3 was to determine the effect of ground terrain on the measurements of free-field neutron flux during the WILSON event. The experiment was conducted by attaching foil detectors on the ground and on the vertical mooring cables of polyethylene balloons. This project required post-shot recovery of foils suspended from balloon cables at the following locations:

900 feet from ground zero to a 700-foot altitude
1,800 feet from ground zero to a 1200-foot altitude
2,700 feet from ground zero to a 1500-foot altitude
3,600 feet from ground zero to a 1500-foot altitude.

5.3.4 Project 57 Programs

Project 57 performed one non-nuclear special shot during Operation PLUMBBOB (139). It had four programs: 71 (Particulate Physics), 72 (Biomedical Field Study of Plutonium Inhalation), 73 (Plutonium Monitoring), and 74 (Surface Alpha Monitoring). DOD personnel were deeply involved in Project 57 activities.

- AFSWP, through REECo, supplied Rad-safe monitors (334).
- Military supplied veterinarians for Program 72 (336).
- AFSWC conducted Program 73 (137), while Desert Rock Rad-safe personnel participated in Program 73 (286).
- Military organized Program 74 personnel (106).

These DOD personnel entered areas contaminated by the Project 57 detonation while performing program-related activities. A review of the special Rad-safe procedures for Project 57 follows the program descriptions.

Program 71 - Particulate Physics (260;121)

This program was intended to:

- Measure the levels of plutonium on the surface and in the air as a function of time after detonation

- Construct a fallout pattern/model for the particular nuclear device used so that it might be used for any wind pattern

- Check and compare fractionation characteristics of plutonium fallout with uranium fallout

- Consider the physical nature of the fallout particulate--size, shape, and distribution.

The experimental approach used was the distribution of more than 4,000 sticky pans over an area of about 43 square miles. Air samplers, balloon-borne precipitators, soil samples, and photographic methods were used to satisfy the objectives. As a result of Program 71, isoconcentration contours of alpha contamination were inferred. The sticky pan contours were deemed of sufficient quality to permit planning for accidental situations. The maximum air concentration levels of alpha contaminants were at 5,000 feet from the detonation. The nature of the measurements suggested that the spatial width of the region of high air concentration was small and that only a very narrow spike-like region could have received significant airborne contamination beyond 5000 feet.

Program 72 - Biomedical Field Study of Plutonium Inhalation (260;336)

This program studied environmental short-term and chronic rates and persistency of plutonium debris resulting from subcritical bursts. It also studied the rate of environmental decay of plutonium in selected areas of contamination. This program required the exposure of a group of aninals to the radioactive cloud to test the effects of acute exposure. To examine the effects of chronic exposure, a larger group of 70 to 80 animals was placed in the contaminated zone. Autopsies of the animals suggested that acute exposure is a much more significant factor than chronic exposure, at least for dusty desert areas. This conclusion was suspect, however, since the air samples and wind data taken had not been analyzed.

Program 73 - Plutonium Monitoring (260;137)

This program studied and developed methods and techniques for decontamination of large surface areas contaminated with Plutonium as a result of a one-point detonation. In particular, decontamination techniques were investigated with regard to plutonium removal from large land surface areas in the test areas, concrete and asphalt pads of reasonable size, and materials used in equipment and building construction such as concrete, wood, stucco, brick, aluminum, and steel. Several decontamination techniques were used such as washing, vacuuming and steam cleaning, plowing, leaching with water, and fixation with subsequent removal of land surface areas. The results of the program suggested that natural factors caused rapid decreases in contamination levels. Repeated surface monitorings suggested that the contamination level of smooth surfaces decreased by a factor of 10 by D+7 days. Soil contamination decreased by a factor of 15 by D+7 days and 40 by D+24 days. Sampling stations north of ground zero indicated an average concentration of 35,000 disintegrations per minute per cubic meter at H+3 hours. Samples taken at H+7 hours suggested that the airborne contamination was reduced by as much as a factor of 100 by H+7 hours. The numerous decontamination techniques used had varying degrees of success.

Program 74 - Surface Alpha Monitoring (260;106)

This program correlated alpha monitoring data from sticky pan experiments with field survey data from broom-finished concrete slabs placed throughout Area 13 adjacent to the sticky pan collectors. The sticky pan collectors were used as uniform monitoring surfaces and principal survey references. Measurements were made on the soil and brush as well.

Rad-safe Procedures for Project 57

A precise estimate of degree of hazard likely to exist in the detonation area was unknown, but it was recognized that this could be severe, particularly at locations close to the detonation point and at times shortly after the detonation. Of particular concern was the possibility of breathing airborne weapon material which posed an internal alpha radiation hazard. In addition, it was expected that a great deal of physical labor would be required to accomplish the tasks of the

Test Group. Consequently, the radiation safety requirements specified that the minimum degree of personnel protection necessary until the levels of hazard decreased, would be:

- Full protective clothing
- All openings in the clothing taped to the skin
- Full-face respirators with high efficiency filters.

A problem with the heavy respiratory protection was the difficulty in breathing during hard physical labor. Consequently, it was decided that field crews would receive supplied-air respirators for Program 72. Air supplied to the crews had a higher pressure than the ambient atmosphere. Therefore, any leaks in the protective garb would be outwards and would prevent breathing of contaminated air. After information was accumulated regarding the extent of hazard in the target area, it was decided that use of supplied-air respirators was no longer required. Field personnel were given the option of supplied-air respirators or full-face filter respirators. Most personnel chose the latter. As restrictions were further reduced, half-face respirators with high efficiency filters were considered acceptable except for areas in which the plutonium contamination exceeded 100 micrograms per square meter. The supplied-air respirators were the sole responsibility of Program 72, but REECo allowed full use of facilities to the extent of supplying air and equipment decontamination. In all other aspects of radiation safety control, Program 72 made complete use of full protective clothing, monitoring, and decontamination facilities.

REECo provided direct operational Rad-safe support to Project 57. Prior to D-Day for the safety shot, a temporary personnel decontamination building was erected beside the access road into the test area. The basic facilities of the building duplicated those of CP-2. Supplies of radiation detection instruments, protective clothing, and equipment were stocked. The building also contained an issue room, shower stalls, and a dressing room with benches and clothes hangers. All personnel entering or leaving the area were required to pass through the building. A diagram of the decontamination building is shown in the REECo Radiological Safety Reports (334). A two-foot wide wooden approach walk was constructed and covered with Kraft paper. Containers were provided for the disposal of protective clothing. Parking lots for contaminated vehicles were established inside the area northwest of the building. A parking space for uncontaminated vehicles was available south of the building. West of the building on the contaminated side of the barbed wire fence, three tables were installed for packaging fallout trays and soil samples for shipment off site. A 350-gallon hot water supply was installed to provide the necessary hot water for the personnel decontamination facility.

Area surveys by REECo were performed with the following portable instruments: Beckman MX-5, AN/PDR 34, Eberline PAC 1-A, and Nuclear Chicago Model 2111 (Pee Wee). Sampling equipment consisted of air samplers, impactors, and fallout trays. The problem of possible cross-contamination and contamination of personnel who collected the steel fallout trays was solved by using magnetic pickup devices with long handles. These pickup devices were actuated by six-volt storage batteries.

REECo provided a major support function through the placement of trays coated with fresh adhesive and the replacement of aged trays in order to provide maximum particle collection efficiencies. Approximately 15,000 trays were sprayed and set out. These trays were unflanged nine-inch squares of sheet steel coated with an adhesive. The area covered by the tray placement teams measured approximately 8 by 13 miles. Trays were placed and recovered during a period of 22 days from D-20 to D+2 days. The area covered by the map was divided into four zones (A, B, C, and D). A fallout tray stake and platform was established at each intersection of grid lines in all four zones. In Zone A, the zone of ground zero, the tray platforms were installed at 25-foot intervals; in Zone B at 250-foot intervals; in Zone C at 500-foot intervals, and in Zone D at 1000-foot intervals. Teams of two men were used in the placement and replacement of trays. The extremely dusty conditions and shot delays led to the requirement of tray replacement with freshly sprayed trays. In the two-week period prior to D-Day, old trays were replaced with freshly sprayed trays. An average 50 percent replacement was necessary each day. The tray recovery after the one-point detonation was begun at H+2 hours. The fallout tray collection procedure consisted of picking up a clean tray with the magnetic device and placing it over the contaminated tray. The two trays were then lifted up together, placed in a container, and covered with a cardboard separator. The collection of the fallout trays in Zones A and B was accomplished by personnel from Sandia Corporation. REECo personnel collected the trays from Zone C immediately after the detonation. Only those Zone D trays which were in the projected fallout path were collected. The Zone D collection process was completed by the end of D+1 day. The percentage of desired trays recovered was 100 percent in Zone A, 90 percent in Zones B and C, and 80 percent in Zone D. Incomplete recovery was also affected by loss of trays in high wind. All the fallout trays recovered between April 24 and April 26 were packaged for shipment to Sandia Corporation.

REECo assisted Sandia Corporation in the placement and setting of timers and batteries at 46 impactor stations. Impactors were collected by REECo for Sandia on D-Day. Recovery of the batteries and pumps from the impactor stations was completed on D+2 days. Along with air filter and fallout trays, impactor pads and approximately 126 soil samples were packaged and shipped to Sandia Corporation.

A mobile rest station for personnel working in Zones C and D was manned by REECo personnel. A monitor with first aid training was a member of the operating crew. Clean clothing, washing and drinking water, soap, towels, and nose swipes were carried. Nasal swabs were taken of all personnel leaving the contaminated area and analyzed by REECo personnel. Urine samples were packaged and shipped off site for analysis. This rest station operated through D+3 days. Daily radiological surveys were made inside the decontamination building and in surrounding "clean" areas using alpha survey instruments, filter paper swipes, and air samplers. Air samples collected on the north side of the decontamination building indicated activity of less than 32 decays per minute per cubic meter from April 24 to April 30. Surveys inside the building indicated no significant alpha contamination.

Surveys of the ground zero area after the shot indicated extensive alpha contamination, but no significant beta or gamma activity. Full anti-contamination clothing was worn by all Project 57 personnel along with the following respiratory devices:

Area Designation	Device
A	Air-supplied or full-face mask with dust, fume, and mist canister
B	Full-face mask with dust, fume and mist canister
C and D	Ultra-filter respirator

Personnel contamination was maintained as low as possible. All personnel participating in Project 57 received bioassay tests. These were primarily nasal swabs, although some individuals had urinalysis done also. Decontamination was deemed necessary when any positive indication of alpha contamination was measured on skin. (One hundred alpha counts per minute per 55 square centimeters of probe area was the average background instrument reading-- any reading above this was considered positive.) Vehicles above 500 counts per minute per probe area were decontaminated to this level or less. Equipment and devices were buried at a specified location if decontamination was not successful.

5.4 OPERATIONAL TRAINING PROJECTS

The primary aims of the operational training projects were to test service tactics and operational equipment and to train and indoctrinate aviation personnel. These projects were planned and conducted so as not to interfere with the AEC diagnostic and AFSWP military effects tests. Table 5-14 summarizes the planned and actual participation, by events, for the air projects. These projects are described in the following paragraphs (Project 53.6, SAC Aircrew Training, is not described. This provided for orientation of crews who were allowed to observe shots while flying a corridor located 30 nautical miles northwest of NTS. Additional details are included in shot volumes).

5.4.1 Project 51.3 (Navy Heavy Attack Indoctrination - AJ/A3D)

This project was established to provide an opportunity for AJ and A3D combat crews to observe an atomic detonation in the near vicinity of a burst. These aircraft came from naval air stations at San Diego, California and Whidby Island, Washington. The aircrews were scheduled to participate in four events. Due to radio trouble, however, the aircraft aborted on the PRISCILLA and HOOD shots before reaching the test area. (The Test Manager's report at SMOKY indicates that three F9F-3 aircraft were substituted for that event; however, analysis of conflicting evidence indicates that these aircraft were not used.) The aircraft were to fly on a simulated bomb run on a target offset from the ground zero position. They were to execute a 135° escape maneuver to arrive at H-hour at a position five miles from ground zero on a 180° True heading.

Table 5-14. AIR OPERATION TRAINING PROJECTS (PROGRAMMED VS. ACTUAL). (200) *

[illegible]	[illegible]	MISSION	TYPE AIRCRAFT	BOLTZMANN	PRISCILLA	WILSON	LASSEN	FRANKLIN	COULOMB A	HOOD	DIABLO	JOHN	KEPLER	OWENS	STOKES	SHASTA	DOPPLER	FRANKLIN PRIME	SMOKY	GALILEO	LAPLACE	FIZEAU	NEWTON	WHITNEY	CHARLESTON
[illegible]	[illegible]	CREW TRAINING																							
		FLY BY	A1 A4D		2.0					2.0													2/2		
		FLY BY	F9F																3.0						
[illegible]	[illegible]	CREW TRAINING																							
		FLY BY	A4D							2.1															
		FLY BY	F4D							2.2															
		FLY BY	H4D H5D							1.1															
[illegible]	USAF ADC	CREW TRAINING																							
		CLOUD PENETRATION	F86D	6.5																					
		CLOUD PENETRATION	F89H								6.0												2/0		
		CLOUD PENETRATION	F102			6.2																			
		CLOUD PENETRATION	T 33		6.2					6.4			5.5			5.0	5.0		5.0	5.0	1/1	2/6		3/6	
		FLY BY	T 33									3.4													
		FLY BY	C 131									1.1													
		FLY BY	C 54									0.1													
[illegible]	USAF WADC	BDA	F89D	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1/1	1.1	1.1	0/1	1/1	1.1	1.1	1.1	1.0	1/0	1/0	1/0		
[illegible]	USAF SAC	CREW TRAINING																							
		BDA	B47																2.2				2/2	2/2	
[illegible]	USAF TAC (ANG)	CREW TRAINING																							
		FLY BY PHOTO MISSION	RF84F	2.2	2.2	2.2	2.2	2.2		2.2	2.2		2/2	2/2	0/2	2/0	2.2	2.2	2.2	2.2	2/0	2/0	2/0	2/2	2/2

* THIS DATA WAS OBTAINED ALMOST ENTIRELY FROM NUMBERS REPORTED AT THE TIME OF PLUMBBOB AND IS NOT COMPLETELY IN AGREEMENT WITH THE STATISTICS LATER DEVELOPED FOR CHAPTER 6.

5.4.2 Project 52.3 (Marine Fly-by Indoctrination - A4D/F4D)

This project was established to provide an opportunity for Marine Corps combat aircrews to observe an atomic detonation in the near vicinity of an atomic burst. The crews were to participate in the HOOD event with A4D aircraft at 21,000 to 24,000 feet and at 11,000 feet. The aircraft came from El Toro Marine Air Station, Santa Ana, California. The A4D aircraft aborted before entering the test area because of communication failure. The R4D/R5D aircraft successfully participated. They were to be in a left-hand race track between Lathrop Wells and Desert Rock, 31 nautical miles from GZ, bearing 178° True at H-hour.

5.4.3 Project 53.2 (Ground Motion Studies)

The purpose of this project was to collect strong-motion data concerning the amount of energy introduced into the ground from the detonation of nuclear devices. This was accomplished using aerial photography.

5.4.4 Project 53.5 (Air Crew Indoctrination-Early Cloud Penetration)

This project was established to provide an opportunity for Air Defense Command (ADC) aircrew members and commanders to witness an atomic detonation in the near vicinity of the burst and to penetrate an atomic cloud. These aircraft were staged out of Indian Springs and Nellis Air Force Base and originated at the various installations throughout the Air Defense Command (ADC). Aircraft participating in the various events included F-86-H, F-102, T-33, and C-131 aircraft. The principal ADC participation was in the JOHN shot where four T-33 type aircraft flew in formation with the delivery aircraft. Interested ADC commanders watched the detonation from a C-131 aircraft positioned 15 nautical miles south of ground zero in an east-west orbit at 14,500 feet MSL. In the other events, aircraft orbited over the Las Vegas Visual Omni Range (VOR) at an altitude of 35,000 feet in a left orbit until the sample controller ordered them to proceed into the atomic cloud. After cloud penetration, the aircraft proceeded to recovery bases.

5.4.5 Project 53.7 (Indirect Bomb Damage Assessment [IBDA] B-58 Evaluation)

The objective of this project was to evaluate B-58 IBDA equipment. The equipment was installed on an F-89 test aircraft staged at Indian Springs Air Force Base. Several different flight patterns were flown for each event. For each event, however, data was obtained by the instrumentation as the aircraft flew approximately 67 statute miles, horizontal range, from ground zero at an altitude of 35,000 feet.

5.4.6 Project 53.8 (Indirect Bomb Damage Assessment)

This project was established to test, as far as possible, the suitability of indirect bomb damage assessment (IBDA) equipment and techniques under simulated bomb drop and actual burst conditions. The aircraft were to operate between 10,000 and 16,000 feet MSL and start their orbit at Indian Springs, using a right-hand race track pattern oriented east and west, 35 nautical miles short of ground zero. They were to be on a heading of 360° at H-hour and execute a standard breakaway maneuver. This project was to determine the effectiveness of the P-2 camera, A-5 control, and the 0-15 scope cameras.

5.4.7 Project 53.9 (Photographic Reconnaissance Training)

This project was established to provide an opportunity for Air National Guard tactical crews to observe an atomic detonation in the near vicinity of a burst and make a damage assessment photo run over the target. Air National Guard units from 14 states participated during PLUMBBOB (see footnote page 162). These units (two RF-84F aircraft for each shot) participated on a rotational basis, staging out of George Air Force Base, California. Prior to the detonation, the aircraft flew from George AFB to a holding point where they orbited in a race-track-shaped pattern at 31,000 feet from Beatty to Lathrop Wells. About 10 minutes after the detonation, the aircraft were cleared to make a photo-reconnaissance run over ground zero at an altitude of approximately 10,000 feet.

5.4.8 Project 53.10 (Passive Defense)

The purpose of this Air Force project was to develop a passive means of detecting large scale disturbances in the upper atmosphere, such as might be caused by detonation of fission or fusion bombs or by passage of supersonic or hypersonic vehicles or missiles.

5.5 SUPPORT PROGRAMS

There were eight main support groups:

- Air Support Group
- Fallout Prediction Unit
- Weather Prediction Unit
- Blast Prediction Unit
- DOD Operations Coordination Group
- Assembly and Arming
- Sandia Support
- AEC Support Group.

(Figure 5-27 illustrates the organizational breakdown of these support groups under the Test Manager and Test Director.) The Air Support Group and the three prediction units (concerned with the shot-environment interface) came under the direction of the Test Manager. Both the Assembly and Arming as well as Sandia Support Groups were involved with the firing of the device based on its location (e.g., balloon). These came under the direction of the Test Director. The AEC Support Group, which provided back-up support and various services for the test series, was answerable immediately to the AEC Support Director and ultimately to the Test Manager.

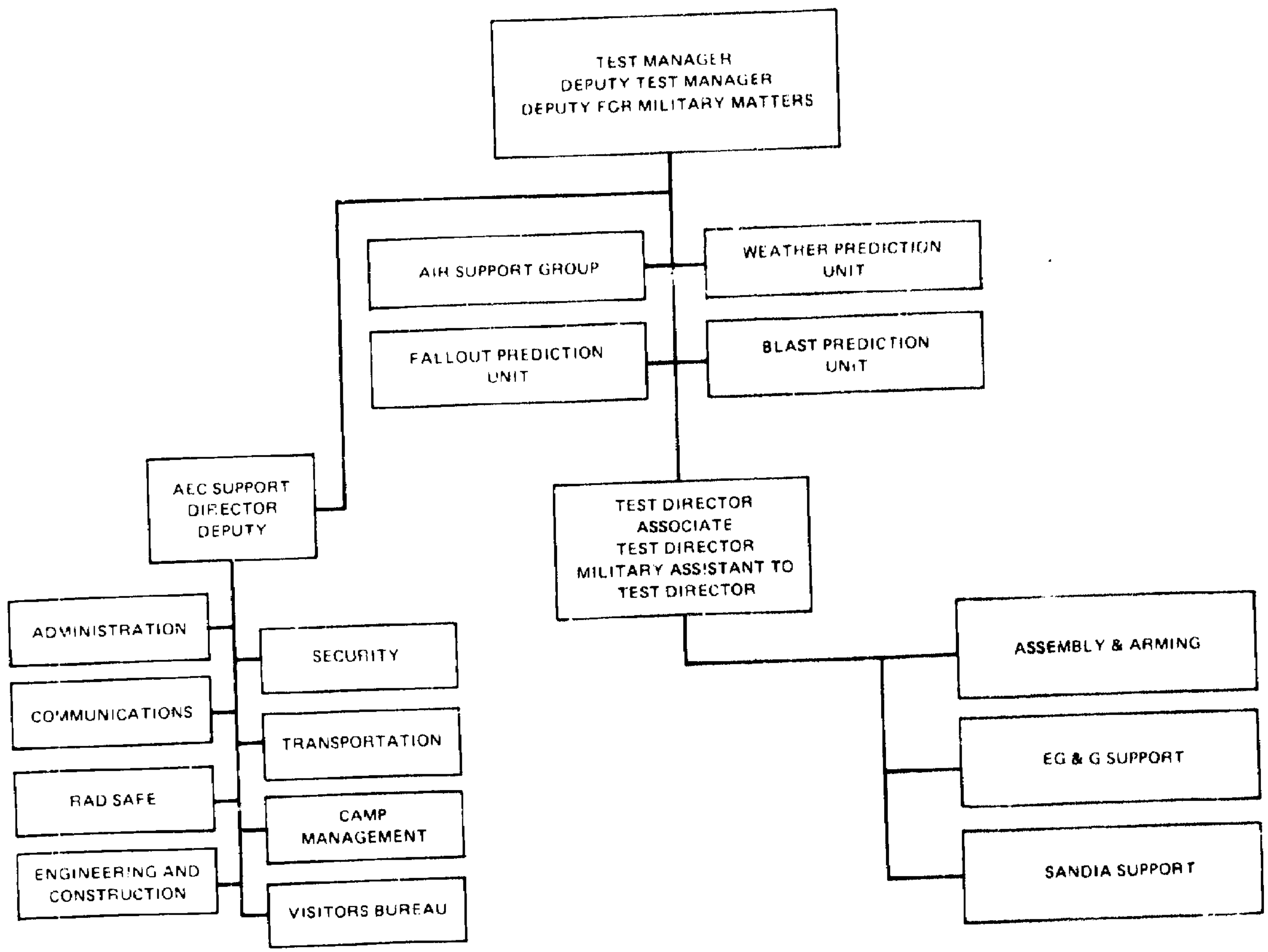


Figure 5-27. SUPPORT GROUPS, AEC OPERATIONS, PLUMBBOB.

5.5.1 Air Support Group Programs for the NTO

The Air Support Group, a portion of the 4950th Test Group (Nuclear) was responsible for coordinating all aviation activities required by the AEC, DOD, and FCDA projects during PLUMBBOB. See Section 5.2.3 and associated tables.

5.5.2 Fallout Prediction Unit (260)

The Fallout Prediction Unit (FOPU) served on the Test Manager's staff to brief the Test Manager, his Scientific Advisor, the Advisory Panel, and any other interested groups on the predicted fallout locations and intensities for each shot. (The FOPU did not directly participate in Project 57 but was on the advisory panel primarily to help restrict the amount of plutonium reaching various areas on the Nevada Test Site.) Forecasts of cloud height and, to a limited extent, air concentration were also furnished. Forecasts of air concentration were used to evaluate possible hazards to aircraft. Before and after a shot, the FOPU coordinated as closely as possible with onsite and offsite Rad-safe and CETG, Program 37. The FOPU also collected post-shot fallout data for use in the evaluation of the prediction. The FOPU was composed of either four or five individuals at any one time from Sandia, LASL, UCRL, and the United States Weather Bureau (USWB). Most of the FOPU members had performed the same function during previous operations.

At each formal meeting, a member of the FOPU presented the predicted fallout pattern and cloud height, and commented on the effect of possible wind shifts away from the predicted or observed situation. The briefer was available during the last two hours before a shot to evaluate the effect of the observed winds on fallout. Any change in the forecast wind direction or velocity could result in a postponement. The formulae for predicting the intensity and location of significant fallout, on site and off site, were matched to the varying weather forecasts throughout the night. The Atomic Energy Commission's guide for public radiation exposure--3.9 roentgens per series--was a determining factor in evaluating offsite fallout forecasts. The shot would be postponed if radiation exposure caused by fallout from the present shot or present fallout, plus fallout from a previous shot, approached 3.9 roentgens. As a series progressed, the direction and velocity of acceptable wind may have become more restricted. Based on the techniques used by the FOPU to predict fallout (260), its personnel had no need to enter the radioactive areas.

5.5.3 Weather Prediction Unit (260)

The U.S. Air Force Weather Service established a weather unit at NTS, which included personnel of the U.S. Weather Bureau. Organization of the Weather Prediction Unit (WPU) (also called the Air Weather Service Unit) is shown in Figure 5-28. Operational control over all weather activities and personnel was handled by the commander of the Air Weather Service Unit. He not only assisted the chief of the Weather Prediction Unit and the weather prediction team chiefs with the various aspects of the forecasts (e.g., precipitation, cloud cover, temperature, temperature inversions, and wind directions and velocities) but he also served as the member of the Advisory Panel to the Test Manager and occasionally gave the weather briefing. Although he maintained close liaison with

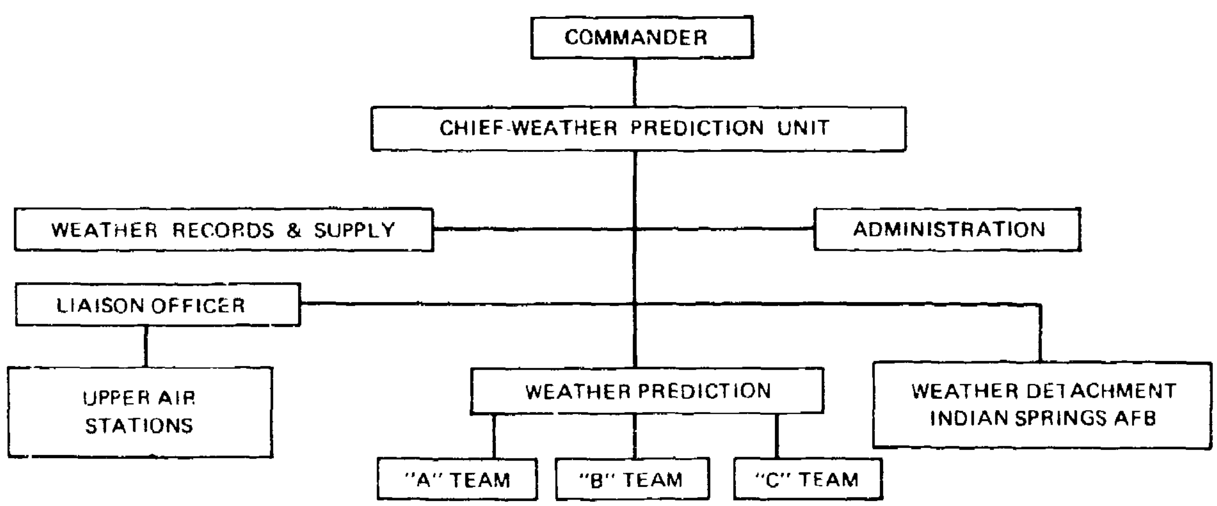


Figure 5-28. NTO AIR WEATHER SERVICE UNIT.

the Test Manager on requirements and schedules, the Chief of the Weather Prediction Unit primarily handled specific weather requirements and coordination for the Test Director. Forecasters and observing personnel furnished a forecaster for each of the three forecasting shifts, and conducted observational studies of both surface and low-level wind conditions in the vicinity of the underground shot.

The average strength of the forecast team, with the exception of the last two shots, consisted of four forecasters and six observers. The average strength of the rawinsonde* group was seven observers, two technicians, and three additional personnel at Mercury for use in checking records. A PIBAL† team consisted of three observers. All offsite observing sections supplemented the liaison officer of the Sixth Weather Squadron, Mobile, Tinker Air Force Base, Oklahoma.

The Mercury weather station began normal forecasting functions on 15 May 1957; however, station observers and forecasting personnel were present for duty by 16 April 1957. Personnel and equipment provided by the Sixth Weather Squadron were in place and operating by 12 April 1957. The locations and types of stations and the methods of communication were as follows:

PIBAL Stations	Method of Communication
Kingman, Arizona	Long Distance Telephone
Beatty, Nevada	Long Distance Telephone
Overton, Nevada	Long Distance Telephone
Caliente, Nevada	Long Distance Telephone
Indian Springs, Nevada	Direct Telephone
Lincoln Mine, Nevada	Rad-safe Radio Net
Austin, Nevada (later relocated to Shoshone, California)	Long Distance Telephone

*Rawinsonde is an electronic balloon-borne device tracked by a direction-finding device to determine velocity and direction of winds aloft, in this case primarily winds at high altitude.

†PIBAL is a system for determining low-level (altitude) wind information.

Rawinsonde Stations

Yucca, Nevada	Direct Telephone and Pony Teletype Circuit
St. George, Utah	Long Distance Telephone
Baker, California	Long Distance Telephone
Stead AFB, Nevada	Weather Teletype Net

Additional stations were manned by the U.S. Weather Bureau and consisted of:

PIBAL Stations

Milford, Utah	Long Distance Telephone
Bishop, California	Long Distance Telephone

Rawinsonde Stations

Tonopah, Nevada	Pony Teletype Circuit
Las Vegas, Nevada	Pony Teletype Circuit

Besides the specifically designed supporting stations, the following U.S. Weather Bureau stations supplied weather information: Arizona (Phoenix and Winslow), California (Fresno, Oakland, San Diego, Santa Maria, and Santa Monica), Colorado (Grand Junction), Nevada (Ely and Winnemucca), Oregon (Medford), Utah (Salt Lake City).

Weather briefings consisted of a formal presentation of the forecast by the forecasting shift on duty. Responsibility for the preparation of the forecast and the necessary briefing aids was delegated to the individual shift chiefs. Formal weather briefings were scheduled at 1600 hours Pacific Daylight Time (PDT) on D-1. The winds and temperature forecasts were prepared and disseminated to the Fallout Prediction and Blast Prediction Units by 1430 Pacific Daylight Time on D-1 in order that this information might be incorporated in their briefings.

Weather affects aircraft operations, the direction and intensity of radioactive fallout and blast, scientific data gathering, and the successful conduct of an entire technical operation. If the weather was satisfactory for both technical experiments as well as onsite and offsite safety, the shot remained scheduled and the WPU continued to make checks on the weather. If the forecast was unfavorable, shot preparations were discontinued and the shot was rescheduled. Thus, the weather conditions were of paramount importance in determining whether the test was fired.

Military personnel actively participated ˈ the Weather Prediction Unit. Based on the description of the unit in the Test Manager's Report, it is not apparent that entry into radiologically contaminated areas was required of WPU members other than certain PIBAL teams.

5.5.4 Blast Prediction Unit (260)

Personnel from Sandia Corporation Weapons Effects Department manned the Blast Prediction Unit (BPU), a part of the Test Manager's staff. Both the Blast and Fallout Prediction Units were project units in the Sandia Test Organization for administration purposes. Microbarograph equipment, operated by REECo under the technical direction provided by the BPU, recorded the offsite blast pressure. Sandia's field test organization loaned microbarograph equipment and maintenance assistance to the BPU.

The BPU staff consisted of the unit chief and an engineering assistant for computer maintenance who remained at NTS for the entire operation. Two assistants used for prediction and briefings rotated on shorter tours at NTS. Seven other Sandia Corporation personnel were attached to the Sandia Corporation project unit at various times to work with FOPU. The microbarograph program utilized ten station operators and two high explosive experts from REECo.

The microbarograph equipment was used to record the blast noise off site. Eight stations were regularly operated at the CP: California (Bishop and Inyokern), Nevada (Boulder City, Las Vegas, Lund, and Tonopah), Utah (St. George). Four mobile stations were on call and operated at various times at the following locations: California (Daggett and Red Mountain), Nevada (Camp Mercury, Coaldale, Indian Springs, Lincoln Mine, Sodaville, Yucca Flat). The operating locations with distances and bearings from NTS are shown in Figure 5-29.

Offsite blast prediction was mainly concerned with the possible transmission of pressure waves through the jet streams to communities at distances greater than 20 miles from the burst. The range and intensity of the blast waves that were predicted required detailed knowledge of atmospheric conditions well into the ionosphere. High-explosive shots were made at various times (H-1, H-2, or H-3 hours) and the results were checked with predictions. Both shots CHARLESTON and MORGAN were delayed twice because of predicted offsite blast effects.

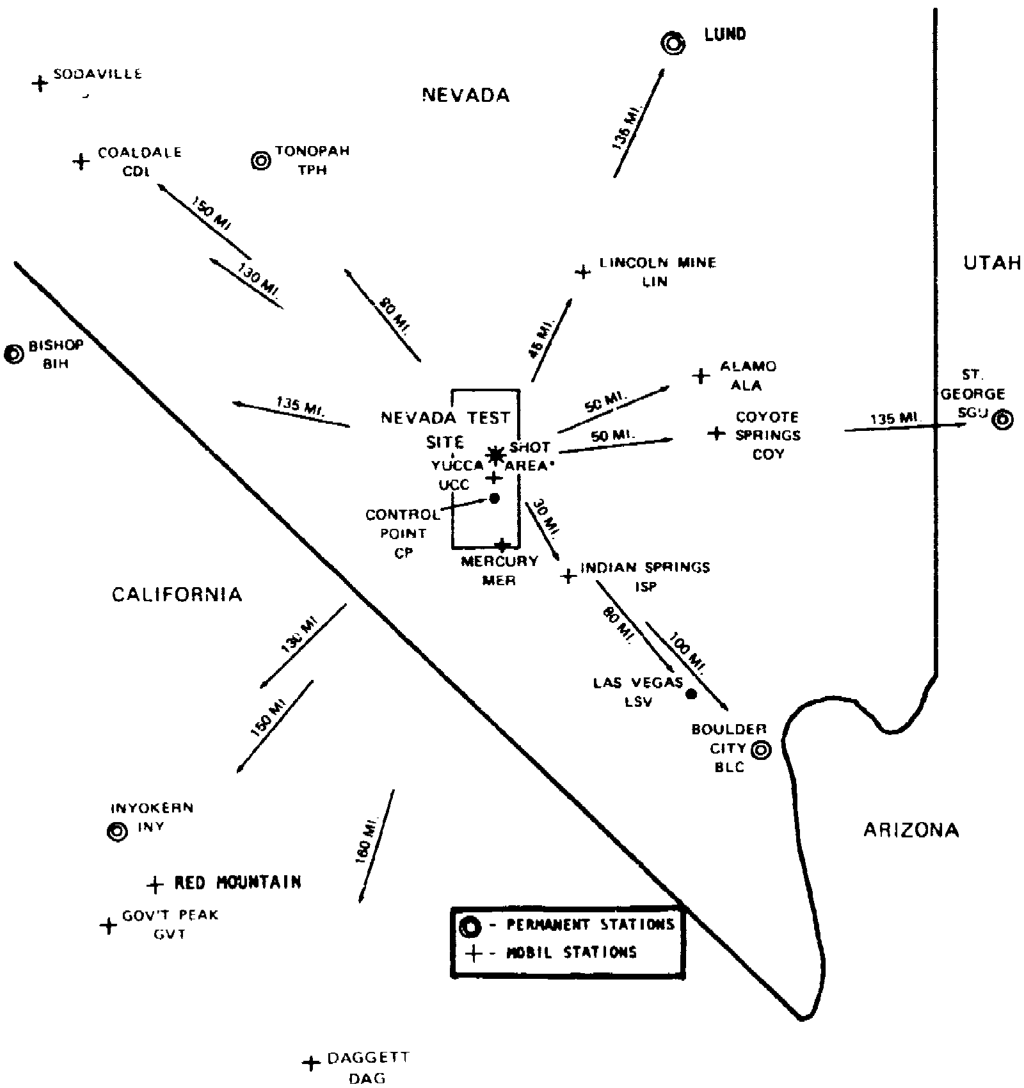


Figure 5-29. MICROBAROGRAPH RECORDING LOCATIONS (1957).

On site, the blast prediction was dependent on the atmospheric structure to about 2,000 feet above ground level. Often on site, various agencies requested locations for pressures ranging between 0.1 and 2 pounds per square inch. These predictions were used in tower construction, balloon, blimp, helicopter, and radar trailer operations.

It is uncertain whether any military personnel were involved in the Blast Prediction Unit.

5.5.5 DOD Operations Coordination Group

Prior to Operation PLUMBBOB, the DOD Operations Coordination Group functioned as a staff agency under the direction of the Deputy Chief of Staff, Weapons Effects Test Group, Field Command, AFSWP. During PLUMBBOB, it became part of the Test Manager's staff and was responsible for coordinating all DOD training activities as the single official liaison point for the Desert Rock activities. The group also supervised and planned the troop observer program and maintained liaison between the DOD personnel and the Test Manager in order to ensure that all training and observer programs could be fitted into the overall program of the operation without interfering with the technical tests. The DOD Operations Coordination Group contained about a hundred DOD personnel. Normal staff activities would not require these personnel to enter NTS forward operational areas. However, activities related to coordination of Desert Rock exercises, observer programs, and training projects could have required reconnaissance or operational review during actual exercises which would have required entry into forward areas of NTS. Thus, although not specifically documented, some potential for exposure to ionizing radiation existed for these individuals.

5.5.6 Assembly and Arming (260)

The Assembly and Arming Organization was responsible for assembly, arming, and disarming the nuclear devices. Other associated responsibilities were to ensure the overall reliability of the components required for arming and firing and to prevent the accidental firing of nuclear devices after their installation at the burst site. Duties of the Assembly and Arming Organization required close liaison with LASL, UCRL, Sandia, EG&G, and DOD.

Work of the Assembly and Arming Organization was divided into several parts: pre dry run tests, zero area installation, dry runs, interlock checks, monitor checks, arming operations, and disarming operations. Pre dry run tests, conducted at Sandia security compound with a representative of each concerned organization, were compatibility checks of equipment. At their conclusion, the equipment was ready for installation at the zero area. Installation involved placement of arming and firing components at the burst site by the responsible organizations. Upon completion of the installation, the arming and firing personnel operated the equipment locally (if required) for test purposes prior to the regular dry runs. Dry runs were conducted to ensure that equipment would operate properly while connected in the same manner as at shot time. During all dry runs, both the arming and firing components as well as the interlock and monitoring indicators at the control point were carefully observed by a representative of the Assembly and Arming Organization in order to ensure proper operation. Interlock checks involved personnel who individually checked interlocks in the gas, arming, or firing signal lines; these checks were made after a number of dry runs proved that all equipment was operating properly. Personnel had to be present at the timing distribution station, the signal pit, and the zero area in order for the interlocks to be checked properly. Monitor checks were carefully made on the monitoring devices associated with the arming and firing equipment. If the monitors were found to be malfunctioning, the shot would be delayed until the monitors were functioning correctly. Arming operations, which involved an arming party and salvage party, made final checks and connections to the nuclear device and associated equipment in preparation for the firing. Final arming connections were made as close to H-hour as possible and only with the permission of the Test Director or the Associate Test Director. Timing of the final arming connections permitted experimenters maximum time to secure stations and vacate the forward areas. Timing of the final connections also permitted the weather panel to analyze data nearer to shot time in order to evaluate weather conditions.

The arming party was composed of personnel from several organizations, each having specific responsibilities in relation to the arming component, the nuclear device, or associated experiments. The arming party assembled at the control point (where the monitoring devices were carefully checked) to verify that the arming and firing equipment was in safe condition. From the control point, the arming party proceeded to the timing distribution station where the monitors were again checked for proper indications. The Test Director was called for permission to complete the final connections for arming and firing. Final connections were never made until the Test Director was sure the forward area was clear of people not required during or following the arming.

Following arming operations at the device, the salvage party removed both the elevator hoist and the power transformer for tower shots. The party removed an AC power generator and a crane for balloon shots. Upon completion of these salvage operations, both arming and salvage parties, along with security inspectors, evacuated the area and proceeded toward the control point. The arming party stopped at the timing distribution station enroute to the control point and prepared it for the shot. At the control point, the arming party made final monitor checks to ensure that the device was ready to be fired and they reported back to the Test Director.

Disarming operations were essentially the reverse of arming operations but without the exhaustive checks required for arming. Routine disarming was accomplished during Operation PLUMBBOB because of adverse weather conditions, technical difficulties, and a possible misfire. The normal or routine disarming function was accomplished at least once for most tower shots and several times for those delayed for long periods after their first ready date. At one balloon shot (CHARLESTON) routine disarming was necessary because of weather delay. The disarming of CHARLESTON was accomplished essentially the same way as the disarmament of tower shots except that the salvaged equipment did not have to be replaced before disarming could proceed. Disarming as a result of technical difficulties was also performed for shot WHITNEY. The type of disarming procedure was very similar to that used for routine disarmament, but careful consideration had to be given to the probable cause of failure and its possible consequences. Disarming due to a "misfire" was accomplished once when DIABLO failed to fire at the completion of the timing sequence. For shot JOHN, the nuclear device was assembled and checked at Indian Springs Air Force Base under the scrutiny of an arming representative of the Test Director. Only a few DOD personnel were involved in the Arming Organization. If these DOD personnel were in close proximity to the nuclear devices and if they entered radioactive contaminated areas, they could have been subjected to radioactive exposure.

5.5.7 Sandia Support

Project 64.1 (Balloon Suspension Systems)

Sandia Corporation was assigned responsibility for suspending nuclear test devices from balloons. Project 64.1 personnel were responsible for the balloon suspension system. This system was active in 13 shots. Balloon installations were constructed in Areas 7, 9, and F (See map, Figure 5-26). Each installation consisted of three guy winches 3,000 feet from ground zero. These winches were housed in concrete shelters covered with earth in order to prevent blast damage. A main winch was housed with a guy winch in one of the shelters. The main cable ran along the ground to GZ, through a sheave, and then to the balloon cab. The guy cables ran directly from each winch shelter to the balloon cab. All winches were capable of being run remotely as well as from ground zero. Two television cameras were mounted at ground zero and pointed upward. All remote controls were combined into one operational console located in the control room at the control point (CP-1). Here a console operator could run the winches, observe cable footages, observe cable tensions, and monitor the balloon's position by television. All balloon areas could be monitored from the one console.

Project 64.2 (High Time Resolution Telemetry)

Project 64.2 made high time resolution measurements on every test event of Operation PLUMBBOB except LAPLACE, JOHN, SATURN, and RAINIER. In addition, project personnel supplied, installed, and operated release time equipment for the JOHN shot. During some UCRL events, a fiducial time marker system was also installed and operated on some UCRL events. The largest project effort was to monitor certain neutron sources used to initiate a fission-type weapon.

Project 64.3 (Neutron Sources)

Project 64.3 personnel were responsible for supplying certain neutron sources to the LASL and UCRL weapon assembly groups. This project was active for all shots except JOHN, and had special test equipment mounted on racks in an H-trailer and in an adjacent tent. The test equipment was used in preparing the sources prior to their installation in the vicinity of ground zero.

Project 64.4 (Balloon Cabs)

Project 64.4 personnel supported the balloon suspension system by constructing a device support structure. A Project 64.4 representative at Albuquerque coordinated the assembly for LASL cabs while Sandia representatives at Livermore coordinated the assembly for UCRL cabs. A plywood shelter was used to house the device cab in the vicinity of ground zero. This shelter was usually ready four days before the event; at that time, the device was moved to the zero area. Dry runs and checkouts were conducted prior to the shot. Approximately three hours before zero time, the device cab was transferred to the balloon, and arming began. One member of the balloon crew stayed at GZ as a member of the arming party. When arming was completed, all personnel returned to the control point and the balloon, remotely started, began to gain altitude.

5.5.8 AEC Support Group

This section describes the AEC Support Director's responsibilities in the Nevada Test Organization, including those in security, communications, engineering and construction, transportation, camp management, and the Visitor's Bureau. (The Support Director's responsibilities concerning radiological safety were described earlier in Chapter 2).

Security

The security staff under the Office of Assistant Manager for Test Operations, ALOO, handled the pre-operational planning for security operations. Among the activities preceding PLUMBBOB was the development of an instruction manual, "Joint AEC/DOD Security Instructions for Arrivals at Nevada Test Site," which was normally furnished to each test participant upon arrival at NTS. These instructions emphasized basic security rules and regulations and provided information concerning NTS security ground rules. A contractor, Federal Services, Inc. (FSI), was responsible for physical security at the site. The hiring techniques used by FSI (260) suggest that DOD personnel were probably not involved in FSI operations. In addition to their PLUMBBOB activities at the Nevada Test Site, FSI personnel provided security for the JOHN device at Indian Springs Air Force Base. Security was maintained by AEC and FSI security personnel even when the JOHN device was transferred to the aircraft. An L-20 aircraft from Indian

Springs Air Force Base participated in security ground sweeps and air sweeps of the NTS perimeter on D-1 days.

Communications

The communication service was sponsored by the Atomic Energy Commission's Communications Division, and provided by the support contractor, Reynolds Electrical and Engineering Company, Inc. (REECo). DOD provided some of the mobile and fixed stations used in the communications networks. (There were 29 mobile and 24 fixed stations, for a total of 53.) Among the various stations, a U.S. Air Force communication trailer was located at Smoky Mountain, Jr., and a microwave site was located on Smoky Mountain, Sr. The microwave site was used by the Air Operations Center at CP-1 for communications with Lookout Mountain Air Force radar personnel located eight miles to the west. A Sixth Army repeating station was also in operation at this location with maintenance performed by site technicians. Due to interference problems, this station was eventually relocated to Smoky Mountain, Jr. Off site, a U.S. Air Force Air Weather Operations station was located at Lincoln Mine. In addition to the 53 DOD stations, DOD personnel may have been involved in the communication efforts of other groups (e.g., CETG, Project 57, REECo, etc.).

Engineering and Construction

This activity provided for the design, fabrication, and installation of special support facilities in addition to those already available as part of the NTS complex. Major scientific stations designed by the AEC contractor, Holmes & Narver, included balloon launching facilities, seven towers (300 to 700 feet), line-of-sight, open and closed detector stations, coaxial cable connection pits, special purpose detector pits, and effects conduits. The construction of these facilities was accomplished mainly through contracts with Holmes & Narver, Reynolds Electrical and Engineering Company, Inc., and Silas-Mason*. Construction of the tower presented the most significant problem. The phases for each

*Silas Mason Company, an AEC contracting firm, provided construction services for the Weapons Development Test Group and Civil Effects Test Group projects at the NTS. These services included constructing shot towers and building bunkers to house AEC diagnostic instruments.

tower included the following steps: foundation, steel erection, platform fabrication and erection, coaxial cable installation, cab installation, vacuum pipe installation, check-out period, and user occupancy period.

Transportation

The transportation group rented 804 vehicles in addition to using 469 AEC-owned vehicles. All requests for vehicles were made through and approved by the Las Vegas Branch Office, Atomic Energy Commission.

Camp Management

The AEC Support Group managed Camp Mercury which included housing, messing, medical, and other facilities to accommodate the personal needs of participants. In addition, the AEC Support Group provided office facilities, motor and equipment pools for security, engineering, and other support operations. During PLUMBBOB, peak population at Camp Mercury for the shot execution period (May-October 1957) fluctuated between 2,400 and 3,007. The peak was reached on 23 June 1957, and tapered off to between 1000-2000 for the last month of that period. At maximum population, the Test Director's organization comprised about 34 percent of the Mercury population, the Test Manager's staff was nine percent, and the contractors' was 47 percent, with the remaining 10 percent comprised of the more transient personnel, such as visitors and VIPs.

Visitor's Bureau

The Visitor's Bureau was organized as a joint AEC/DOD activity reporting to the Support Director. The NTO, AEC, and DOD mutually agreed upon the staffing, which consisted of each organization's personnel plus their contractors. As the activity in charge of conducting the observer program and coordinating it with the other test activities, the Visitor's Bureau was responsible for the reception, security, messing, billeting, and radiological safety of all official observers. Briefings, tours, and transportation to the forward area were also provided to employee observers, FCDA observers, and the news media.

The Visitor's Bureau organization, illustrated in Figure 5-30, was mutually agreed upon by the AEC and AFSWP Field Command. Reynolds Electrical and Engineering Company, Inc., and Federal Services, Inc. handled the administrative workload and the security liaison work. The Special Weapons Training Group, Sandia Base, assigned escort officers to the Visitor's Bureau on temporary duty status to help handle large official observer groups. The following list shows personnel used in the Visitors Bureau:

<u>Mercury</u>

AEC - 1 civilian
DOD - 3 officers, 2 enlisted men
REECo - 3 civilians
FSI - 1 inspector

<u>Indian Springs Air Force Base</u>

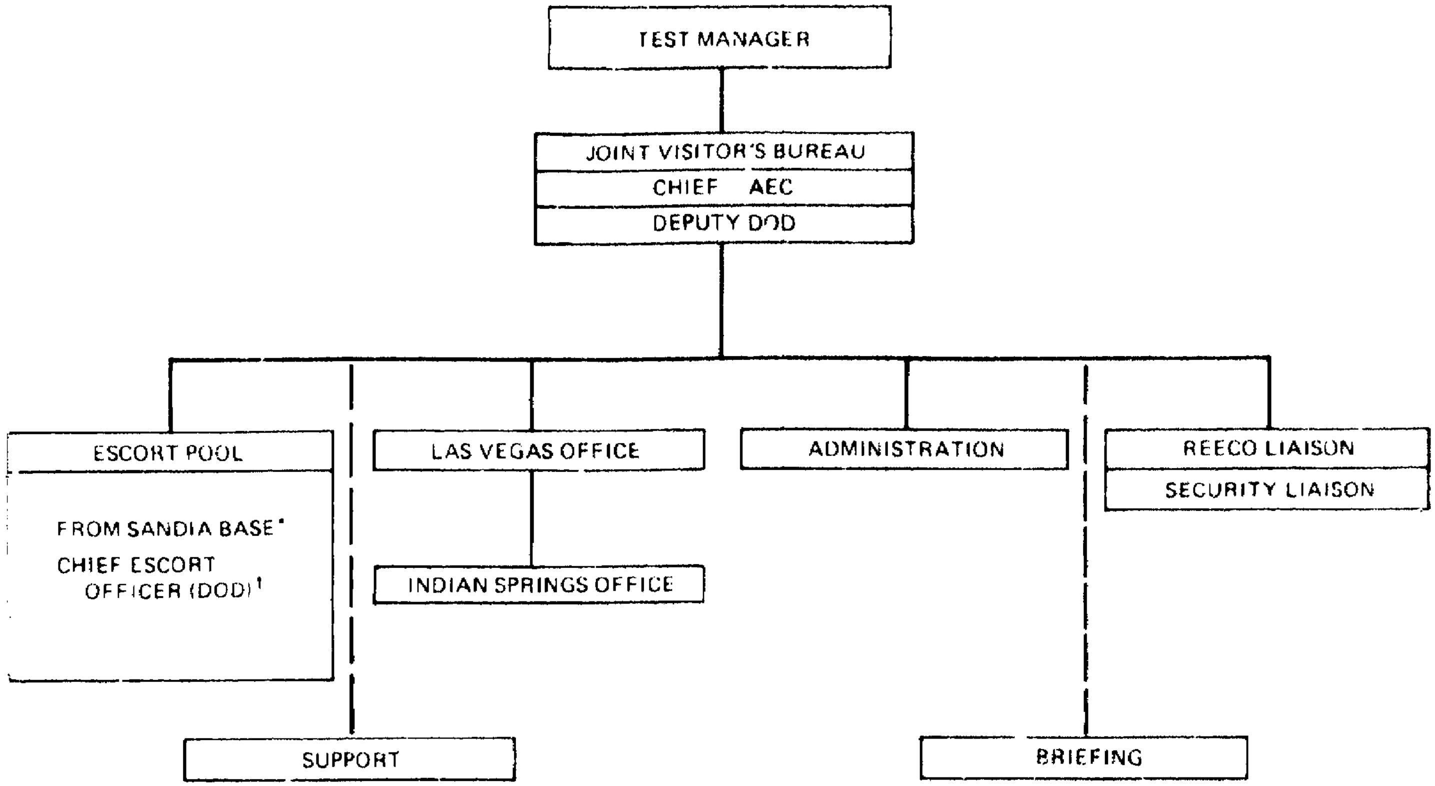
DOD - 1 officer, 1 enlisted man

<u>Las Vegas AEC Office</u>

DOD - 1 officer, 1 enlisted man
REECo - 2 civilians

With the Visitor's Bureau activation at the Nevada Test Site on 1 April 1957, planning and forward area construction began. Work consisted of the selection and construction (or rehabilitation) of observer areas in both Yucca Flat and Frenchman Flat. This involved painting benches, constructing telephone and power systems, and building snack bar shacks, etc.

Several visitor's programs were extremely active during PLUMBBOB. The official observer program was made up of personnel from the Army, Navy, Air Force, AEC, and representatives of Congress. These observers were usually housed at Indian Springs Air Force Base and were transported from the base to briefings, forward area tours, and the scheduled shots. Details of the official observer program, such as transportation, clearances, and rosters, were coordinated by AFSWP Headquarters. The number of official observers attending the various shots, as administered and billeted by the Visitor's Bureau of Indian Springs Air Force Base, were:



*THESE OFFICERS WERE SECURED TEMPORARILY AS NEEDED THEY WERE REQUESTED 10 DAYS BEFORE THEY WERE NEEDED AND WERE TO REPORT 2 DAYS BEFORE THE TEST.

†INCLUDED MERCURY PERSONNEL

Figure 5-30. VISITORS' BUREAU ORGANIZATION.

SHOT	DATE	NO. FORECAST	NO. WITNESSING SHOT
PRISCILLA	6/24/57	77	68
DIABLO	7/15/57	86	48
JOHN	7/19/57	100	93
STOKES	8/07/57	66	44
SMOKY	8/31/57	75	59
GALILEO	9/02/57	(Late arrivals for SMOKY)	2
FIZEAU	9/14/57	(Bonus shot for early NEWTON arrivals)	48
NEWTON	9/16/57	86	32

Foreign observers included 130 representatives invited by DOD from all foreign countries with whom the U.S. had any formal defense agreements at that time. These witnessed BOLTZMANN, SMOKY, and NEWTON.

The Federal Civil Defense Administration (FCDA) observer program consisted of three different types, the first group (VIPs, headquarters personnel) received some classified information related to PRISCILLA, the military effects test shot at Frenchman Flat in which FCDA had several foreign test projects. The second group in the FCDA program consisted of members of the NATO Civil Defense Committee and the Swedish Civil Defense Director. French and German shelter designers were given the opportunity to observe the structures before and after a shot in which the structures were to be tested. The third group was composed of national, state, and local civil defense personnel whose attendance was considered beneficial to the civil defense program.

U.S. public news representatives and some foreign news representatives were permitted to attend those shots in which uncleared observer groups participated. Some of the AEC operations offices established an employee observer program for personnel connected with the weapons program. The AEC also invited certain individuals from related industries to attend events at NTS. DOD invited a hundred senior USAF personnel to attend the JOHN air rocket shot, while DOD invited Field Command and Headquarters personnel from AFSWP.

The Visitor's Bureau arranged programs which included appropriate briefings for official groups and for some special employee observer groups. The Department of Defense was normally represented by a colonel in these briefings.

Pre-shot tours of the Nevada Test Site were arranged for all observers. Tours included visits to the military effects test area and the FCDA test area plus inspection of a typical tower and some instrumentation staff. Post-shot tours were arranged as necessary and depended upon both Radex conditions and visitor schedules.

Transportation for observers was furnished jointly by AEC and DOD. The AEC furnished bureau vehicles, while occasionally DOD provided drivers and additional sedans. Both the AEC and DOD furnished buses and drivers.

DOD personnel were clearly involved in Visitor's Bureau activities and so had the opportunity for exposure to radioactivity related to entry into NTS forward operational areas.

5.6 FEDERAL CIVIL DEFENSE ADMINISTRATION OPERATIONS

The PLUMBBOB FCDA studies were conducted through the FCDA Operations Office at the test site by the Civil Effects Test Group, which was formed for that purpose. The CETG projects were organized under Programs 30-39 (see Table 5-15). Approximately 60 projects were conducted under these programs in support of the principal FCDA objective, to protect the civilian population of the United States from the effects of nuclear weapons. Most such studies fell under one of six major categories: fallout studies; biomedical and physical aspects of prompt gamma and neutron radiation; blast effects on structures; biomedical effects of blast; radiological contamination, decontamination, and training; and instrumentation and support services. DOD participation for these is summarized in Table 5-16.

Fallout Studies

The CETG fallout studies were conducted by means of aerial monitoring and ground survey methods. Fallout patterns were surveyed and mapped in detail up to 600 miles from ground zero. The gamma measurements made by aerial survey agree with those made by ground survey to within 25 percent. These fallout maps assisted in refining the deposition activity forecast by the Fallout Prediction Unit during pre-detonation briefings. For each shot studied, 200 to 300 fallout

Table 5-15. CETG PROJECTS CONDUCTED AT OPERATION PLUMBBOB*

SHOT \ PROGRAM	Program 30 Shelters for Civil Population	Program 31 Structures, Equipment, Devices, and Components	Program 32 Radiological Counter-measures	Program 33 Biological Assessment of Blast Effects	Program 34 Physical Response to Blast Loading	Program 35 Radiological Defense Technologies	Program 36 Radiological Defense Operations	Program 37 Radio-Ecological Aspects of Nuclear Fallout	Program 38 Effects of Radioactive Fallout on Foodstuffs	Program 39 Instrumentation and Dosimetry
PROJECT 57										
BOLTZMANN								**37.2** **37.2a** **37.6**	38.3	**39.1** **39.7a**
FRANKLIN										**39.1** **39.5** **39.6** **39.7** **39.7a** **39.8**
LASSEN										**39.5**
WILSON								**37.2** **37.2a** **37.6**		**39.1** **39.5** **39.6** **39.7a** **39.8**
PRISCILLA	30.1 30.2 30.3 30.4 30.5 30.5a	31.1 31.2 31.4 31.5	**32.4**	**33.2** **33.3** **33.4**	**34.1**		**36.1** **36.2**	**37.2** **37.2a**	38.1 38.2 38.3	
COULOMB A Safety Experiment										
HOOD		31.1						**37.2** **37.2a**		**39.1** **39.5** **39.9**
DIABLO			**32.1** **32.3** **32.4**					**37.2** **37.2a** **37.6**		**39.1b** **39.5**
JOHN										
KEPLER		31.1	**32.3**	33.1				**37.2** **37.2a** **37.6**		39.1 **39.5**
OWENS		31.1	**32.4**							39.1
PASCAL A Safety Experiment										
STOKES										39.1 39.5
SATURN Safety Experiment										

*Bold print indicates projects with DOD participation.

Table 5-15. CETG PROJECTS CONDUCTED AT OPERATION PLUMBBOB (Continued)

PROGRAM / SHOT	Program 30 Shelters for Civil Population	Program 31 Structures, Equipment, Devices, and Components	Program 32 Radiological Countermeasures	Program 33 Biological Assessment of Blast Effects	Program 34 Physical Response to Blast Loading	Program 35 Radiological Defense Technologies	Program 36 Radiological Defense Operations	Program 37 Radio-Ecological Aspects of Nuclear Fallout	Program 38 Effects of Radioactive Fallout on Foodstuffs	Program 39 Instrumentation and Dosimetry
SHASTA		31.1	32.1 32.3 32.4					37.2 37.2a 37.6		39.1
DOPPLER								37.5		39.1 39.5
PASCAL B Safety Experiment										
FRANKLIN PRIME								37.5		39.1 39.5
SMOKY	30.5 30.6 30.7	31.1		33.2 33.3	34.2 34.3	35.2 35.3	36.1	37.1 37.2 37.2a 37.4 37.5 37.6		39.1 39.1a 39.1b 39.5 39.9
GALILEO			32.4a	33.1 33.2 33.4	34.3 34.4	35.2 35.3		37.1 37.2 37.2a 37.3 37.4 37.5 37.6		39.1a 39.3
WHEELER										
COULOMB B Safety Experiment										
LAPLACE										39.1 39.1a
FIZEAU			32.1							39.1 39.5 39.6
NEWTON								37.2 37.2a		
RAINIER										
WHITNEY			32.1					37.2 37.2a		
CHARLESTON										39.1 39.5 39.8
MORGAN										39.8

TABLE 5-16

DOD PARTICIPATION IN CETG PROJECTS
BY PROGRAM (119)

Program	No. DOD Personnel Involved	No. DOD Personnel w/Non-zero Exposure	Non-zero DOD Exposures (m/R) Min	Max	Mean
30	0	0	0	0	0
31	0	0	0	0	0
32	39	22	75	2595	998
33	0	0	0	0	0
34	1	1	1670	1670	1670
35	0	0	0	0	0
36	3	2	370	385	378
37	8	7	20	830	452
38	1	1	940	940	940
39	26	13	35	1910	453
TOTALS	77	46			

collecting trays were exposed and later processed in the laboratory. The following data were obtained from these studies:

- Beta and gamma energy spectra and decay properties of debris calculated by particle size and fallout time
- Radioactivity per particle relation as a function of particle size and time
- Certain physical and chemical characteristics relative to particle size and time of fallout.

Biomedical and Physical Aspects of Prompt Gamma and Neutron Radiation

Associated with these fallout studies were biomedical experiments to determine the persistence of fission products in the tissues of native rodents. One balloon detonation and one tower detonation of approximately the same yield were utilized for this purpose. In addition, measurement of the directional distribution of radiations at various distances from the hypocenter resulted in valuable data for determining the amount of shielding afforded by any type of structure against prompt bomb radiations. In conjunction with making precise measurements of radiation dosages, a number of large and small animal species were exposed to prompt radiations. Mice, monkeys, swine, and burros were used to develop inter-species relationships showing reactions to prompt radiations. The data obtained was also correlated with the results of tests prior to PLUMBBOB.

Blast Effects on Structures

The CETG structures tests were largely FCDA-sponsored projects. The resulting data made important contributions to the development of designs for reinforced concrete dome shelters, a dual-purpose garage shelter, a family shelter, and a modular reinforced brick unit. Generally, the results of tests on structural environments were used to develop shelters which would be safer and more habitable in a nuclear target area. An array of fourteen French- and German-designed and financed shelters was also tested. Overpressures ranging from 75 psi to 200 psi were measured during these tests. More elaborately designed than comparable U.S. structures, these shelters were exposed to higher overpressures than the U.S. structures had been exposed to previously.

Biomedical Effects of Blast

Along with the structures test, a study was made of the biological environment produced inside shelters by blast effects. Data gathered concerning this study also included the biological response to different patterns of overpressure; the characteristics of blast-induced missiles (how objects are thrown against personnel), and the possible physical displacement of personnel by blast-induced winds (how personnel would be thrown by the blast).

Radiological Contamination, Decontamination and Training

CETG personnel conducted a radiological defense experiment in which they occupied a protective region in an area of heavy fallout. The experiments effectively demonstrated the magnitude of the radiation field and procedures for leaving the shelter and recovering a working area. The CETG also sponsored a series of training exercises for radiological defense leaders selected from state and local civil defense organizations.

Instrumentation and Supporting Services

A system of remote gamma radiation monitoring was conducted at stations from 30 to 300 miles away. Personnel could determine offsite radiation intensities resulting from fallout simply by dialing the station through the telephone network. The station would automatically reply with a coded signal giving the radiation level. This experiment showed that early data on close-in radiation levels could be obtained without exposing personnel to contamination.

The CETG studies involved both onsite and offsite activities. Many studies required that equipment be recovered as early as practicable after a nuclear detonation. This needed a means of minimizing the danger to personnel tasked with the recoveries. One of the CETG studies (Project 39.9) was directed to this purpose. It provided continuous, remote monitoring of radiation levels at various points of interest on shots in which CETG projects were active. Onsite locations were selected on the basis of early recovery requirements and the data obtained was utilized to determine safe recovery routes. Project 39.9 thus supplemented the normal Rad-safe procedures employed during PLUMBBOB.

DOD participation in CETG projects was generally light as indicated in Table 5-16. The exceptions were Programs 32 and 39 where certain projects were conducted by military organizations, and Program 37 where the activities of the military participants are uncertain but may have occurred through participation in a training program.

The program and project descriptions which follow will describe the activities and movement of DOD personnel when known. When this information is not available, then the intent is to describe the activities required of project participants if a significant number of DOD personnel were involved. If DOD participation was not appreciable, then only general objectives are mentioned.

Programs 30, 31, and 34 were primarily concerned with the mechanical response of various structures, materials and devices to nuclear blast effects. Tests involving several different civilian shelters including some elaborate French (114) and German (113) designs were conducted in Program 30. Programs 31 and 34 were concerned with the performance of various structures, structural elements, and devices in response to nuclear blasts. Program 34 was generally interested in the performance of higher strength materials and structural elements in the higher overpressure regions than Program 31. Among the devices tested in these two programs were cameras, filters, and antiblast valves. The data resulting from these studies made important contributions to the development of design for reinforced concrete dome shelters, a dual-purpose garage-shelter, a family shelter, and a modular reinforced brick unit.

Program 32. Four projects were conducted. The performing agency for Projects 32.3 and 32.4 was NRDL, and DOD personnel involvement was correspondingly heavy. Program 32 was primarily concerned with radiological countermeasures in terms of protection offered by shelters, simple structures, distance from the point of detonation (vertical and horizontal), and the effect of terrain attenuation. Due to the involvement of military personnel (See Table 5-15), the projects are described individually.

In Project 32.1 (90) a reinforced building was exposed to fallout from two shots and the resulting dose rates and fallout deposition inside and outside the structure were measured with various instruments and techniques. Participation was scheduled for a third shot, but was cancelled because of heavy fallout in an area the recovery team would have had to pass through. Protection factors and roof and ground contributions to the total dose rates at points within the structure were determined from the measurements. Comparisons were made with the results of theoretical and experimental studies. The equipment utilized for obtaining this data included remote monitoring systems affording continuous time measurements, film packs to provide integrated dose measurements, portable survey instruments, and sequential air samplers. These devices were mounted inside and outside the building prior to the shots. There were periodic recoveries in which film packs were exchanged, portable survey meters were read, and filters in the air samplers were changed.

The first recovery for shot DIABLO apparently occurred at H+12 and for shot SHASTA at H+14.5. These times are deduced from the data rather than being explicitly stated. No special Rad-safe considerations are mentioned, but it seems likely they were required. DOD participation is not evident.

The objective of Project 32.2 was to test the calibration and utility of a high-level aerial survey system designed for civil defense applications (119).

Aircraft flew in orbits over areas of known activity (levels of interest start at 20 to 100 mR/h). Two types of scintillation detectors were used in the aircraft. Ground and aircraft readings were compared to allow correlation of the two monitoring systems.

Project 32.3 (System Operation Exercise and Evaluation) was performed in and around an underground radiological shelter located within the fallout zone beyond the region of significant blast damage (300). The first phase involved evaluation of shelter performance and the ability of simple devices to predict the radiological environment outside the shelter. It was performed from within the shelter. The second phase involved precise determination of the exterior radiological environment by personnel outside the shelter. Personnel from NRDL were involved in both phases of this project. Phase II activities began 45 minutes after the detonation. Those active in Phase II are known to have worn special clothing and respirators.

The objectives of Project 32.4 were to provide documentary support for Project 32.3 and to study the following (290):

- The attenuation of gamma radiation emitted from a fallout field due to surface roughness of the terrain
- Comparison of fallout material from tower- and balloon-supported shots of equal-scaled height
- The use of small balloons as instrument platforms, and the stability of a new fallout collector.

The terrain attenuation study required both ground and aerial surveys to obtain measurements of radiation intensity vs. height. A helicopter was utilized for shot SHASTA. For shot DIABLO, a 60-ton crane was utilized because a helicopter was not available. These measurements began on D+2 for shot SHASTA and on D+5 for shot DIABLO. Radiation levels were generally less than 300 mR/h.

The remaining objectives involved collection of fallout. Recovery (by helicopter) as early as H+20 minutes is documented. The extent of DOD participation is unknown, but NRDL is known to have analyzed the fallout samples, and was listed as the performing agency.

Program 33 was conducted to assess biomedical effects from nuclear blasts. Included were studies to determine the biological environment produced within shelters by blast effects, biological response to different patterns of overpressure, characteristics of blast-induced missiles, and displacement of personnel due to blast-induced winds. Involvement by the DOD in Program 33 was on a funding basis to the Lovelace Foundation.

Programs 35 and 36 were primarily concerned with civilian radiological defense operations and technologies. Program 35 was concerned with advancing the state of the art while Program 36 was involved in providing personnel with background and experience in field operations. General activities included monitoring radiation fields, evaluation and testing of radiological instruments, and study of aerial and ground recovery methods. A study of gamma intensity as a function of shielding geometry was also conducted to provide data on attenuation and build-up factors for thick shields.

Program 37. Five of the seven projects conducted studies to assess the biological hazards associated with radioactive fallout from nuclear detonations. These studies (119) were divided into three primary areas:

- The delineation and characterization of fallout patterns
- The radiological, physical, and chemical properties of the fallout debris within these patterns
- The evaluation of biological availability and accumulation of radionuclides in plants and animals.

The delineation and characterization of fallout patterns was the primary responsibility of Projects 37.2 (Laboratory Analysis) and 37.2a (Field Surveys). Laboratory analysis was conducted by approximately 30 personnel at Mercury. In addition, certain specific fission-product analyses were conducted by the Chemical Analysis Group at AEP/UCLA and data reduction required a five-man group. The field survey group of Project 37.2a consisted of as many as 15 two-man teams who were responsible for installation, operation, and recovery of sampling and monitoring equipment.

Four teams of four men each conducted field persistence studies as part of Project 37.1, which was concerned with the longer term aspects of biological accumulation of the fission products on and in plants and native rodents. Project 37.3 utilized a single two-man team to obtain data on biological accumulation in agricultural environments.

Project 37.6 was a training program. Personnel from various scientific disciplines were trained in the techniques of environmental assessment with practical application under fallout conditions. Rotating project assignments were an integral part of their training. Among the mentioned participants in the training program were USAF veterinarians.

A description of pre-shot activities follows (222):

> The program's activities for fallout studies for a detonation routinely began at 1500 hours on each scheduled D-1 day and consisted of a review of the weather forecast, of the possible uncertainties in the forecast, and of their probable influence on the predicted direction of the fallout pattern. This information was prepared by the NTS Weather Group and the Fallout Prediction Unit (FOPU) for the formal weather briefings of the Test Manager's Advisory Panel usually scheduled at 1600 hours, D-1 day. If the Advisory Panel's recommendations were to proceed with the detonation, Project 37.2a teams were assigned rendezvous (standby) locations along the predicted pattern and were dispatched from NTS.
>
> In general, five to ten field teams were assigned standby locations near the 20-, 50-, 80-, and 120-mile sampling arcs along the fallout patterns predicted by FOPU. Communications with these teams were maintained by telephone and radio. Specific station assignments were transmitted between H-3.5 hours and H+4 hours, depending on the wind speed forecast (fallout time-of-arrival). Each team required 2.5 to 5 hours for the placement of twenty sampling stations and safe retirement from the area of potential contamination to a standby location.

Post-shot activities for these teams and for a U.S. Geodetic Survey team that conducted aerial surveys began on D+1. The Project 37.2a field teams conducted road surveys and recovered samples. Laboratory processing usually began at approximately H+30 hours. If hot spots were indicated by the initial surveys, they were investigated and documented by two aerial teams from the Raw Materials Division of the AEC on D+2. On two shots, special teams recovered samples at H+5 hours and immediately returned them to Mercury for processing.

Project 37.1 recovery teams did not enter the field until D+3 (data for earlier times were provided by Project 37.2a recovery teams). Data from Project 37.2a teams were also utilized to direct Project 37.3 recovery teams to offsite farms exhibiting a dose rate of at least 2 mR/h at H+12 hours.

In Project 37.4 laboratory and field tests were conducted on germanium dosimeters to determine whether better knowledge of the characteristics of these devices could be utilized to improve accuracy and sensitivity of fast-neutron dosage measurements obtained near nuclear detonations (110). The expected improvements were not realized. DOD participation was not evident.

Chemical dosimetry studies to estimate human exposures to prompt and residual radiations from nuclear detonations were performed in Project 37.5. On and offsite activities were required (304). Offsite fallout measurements were made in conjunction with Project 37.2a. Close cooperation with the dosimetry studies conducted by Projects 39.1 and 39.16 is indicated.

<u>Program 38</u> consisted of four projects concerned with possible contamination of foodstuffs by radioactive fallout. One project (223) studied the ability of glass containers to withstand the effects of nuclear blasts. Another (227) was concerned with the effectiveness of various packaging materials and subsequent decontamination procedures. A similar study (226) of contamination of raw agricultural products considered post-harvest contamination of produce in bulk storage or processing situations, practical methods of decontamination, and the possible influence of processing operations on removal of contamination. The fourth (233) was a field training course.

<u>Program 39</u>. Several of the projects involved outside instrumentation and support services for the various CETG programs. The other projects were

oriented toward assessing the biological effects of radiation on various animals for the ultimate purpose of extrapolation to man. DOD participation was heavy as suggested in Table 5-15. Most DOD personnel were from various military medical organizations.

The objective of Project 39.1 was to utilize film dosimetry techniques to measure gamma radiation from nuclear detonations. Two types of chemical dosimeters were utilized (295). Pre- and post-exposure measurements were taken at NTS by USAF School of Aviation Medicine personnel. Installation and recovery of the dosimeters were apparently accomplished by personnel of the projects which required the dosimetry measurements. This included Projects 2.3, 2.4, 2.5, 4.1, 30.1, 30.2, 30.3, 30.4, 39.1, 39.6, 39.6a, 39.7, 39.7a, and 39.8.

In Project 39.1a a film-taping technique designed and used by EG&G was utilized to measure integrated gamma dose at points along the ground and in selected structures for 15 shots (142). The data was taken primarily in support of CETG projects from Programs 30, 35, 37, and 39, but some fallout measurements and other special data were supplied to other projects (2.1, for example). The objective of Project 39.1b was to furnish neutron-dose measurements for other CETG projects. Personnel involved in this effort were the same as those involved in Project 39.5.

Project 39.2 provided instrumentation for measuring static and dynamic pressures in support of CETG Projects 32.1, 33.1, 33.2, and 34.4. Most of the instrumentation was self-recording (237). The remainder was apparently electronic recording. Three methods of remote actuation of these devices were discussed. Details of location, mounting, and installation during pre-shot periods were given. Recovery procedures are not discussed.

The objective of Part I of Project 39.3 was to measure transient air temperature at selected locations in the blast-biology underground shelter in Area 1 during shot GALILEO (161). Due to problems with the recorders, this objective was not met. The objective of Part II (conducted by the University of Rochester) was to evaluate thermal burns from a nuclear explosion on biological receivers. Pigs were used for the test. The original intent was to correlate the results from Parts I and II, but this could not be accomplished because of the recording problems. Recovery of one recorder at H+3.5 hours was indicated. High levels of radiation limited exposure time to six or seven minutes, and the second recorder was recovered later. The instrumentation was provided by NRDL.

Project 39.4 was scheduled but later cancelled.

The objective of Project 39.5 was to gain information on the characteristics of neutron and gamma radiation at various distances from selected nuclear devices as a step in evaluating the doses received by the survivors of the bombings of Hiroshima and Nagasaki (204). The project complemented Projects 39.6, 39.6a, and 39.7, which involved animal exposure to irradiation. The ultimate goal of these projects was to provide reasonable estimates of the chronic effects of radiation on man. The experiments required placing detection devices as near as 500 yards from ground zero and recovering them soon after the detonations. Care was taken in mounting these devices to allow rapid recovery. DOD involvement included several members of the U.S. Air Force School of Aviation Medicine; they provided instrumentation for measuring gamma irradiation.

The main objective of Project 39.6 was to correlate neutron and gamma measurements with biological response. The program was conducted by the USAF School of Aviation Medicine (254;346). It involved exposing monkeys to neutron and gamma radiation such that a range of radiation doses was received by the different groups. All animals were monitored for short-term, acute radiation effects, and where mortality did not occur, they were monitored for long-term effects. Considerable data was obtained relating to symptoms shown during post-irradiation periods vs. radiation dose. The data was considered especially important due to similiarities of the monkey to man in certain physiological responses.

The objective of Project 39.6a was to expose a large animal (burro) to a nuclear detonation under conditions identical to the exposure of a smaller laboratory animal (monkey) (219). It was hoped these comparisons could eventually be extrapolated to man for use in estimating the response of humans to whole body irradiation. Considerable data was made available and, to this extent, the experiment was successful. There was substantial military involvement in this program. Many participants are known. The project interfaced with Projects 39.6, 39.1, and 39.1b. It utilized the animal facilities provided for Project 4.1 and the laboratory facilities of Project 57. The study continued at the shot site for two months prior to moving to the University of Tennessee.

Long-term study of the delayed effects of acutely delivered nuclear radiation on small animals (mice) was the original objective of Project 39.7. A chronic infection in the animal colony caused this objective to be abandoned. The objective of Project 39.7a was to collect and evaluate information on the neutron effects on several species and sizes of mammals in internally controlled fields. This involved cooperation with Projects 39.5, 39.6, 39.7, and 39.8.

Project 39.8 was conducted by the Naval Medical Research Institute (208). Its objectives were to determine (in tissue-equivalent phantoms approximating the size of man) the relation of the air exposure or the incident dose to the absorbed dose in tissue-equivalent material, and the distribution of absorbed dose through the tissue-equivalent material. Both studies were made for initial neutron and gamma radiation from an atomic detonation. Several members of the military services were involved, and one served as Field Supervisor.

Project 39.9 utilized telemetering techniques for recording radiation data to supplement onsite and offsite Rad-safe. The offsite monitoring provided data in areas not otherwise covered, while the onsite monitoring provided information needed for early recovery parties. Offsite locations were usually unmanned and were accessed by telephone to automatic equipment. Onsite locations were unmanned, but those in high-radiation, early recovery areas utilized direct coupling to provide continuous readings to the control area. The onsite stations were housed in blast-protected units and were located in or adjacent to structures being studied by various CETG projects. Locations were selected on the basis of early recovery requirements of these projects. Data were utilized to ascertain Rad-safe routes for early recovery in hot areas, to determine time of recoveries, and to determine the necessity for countermeasures.

CHAPTER 6

RADIATION ANALYSIS OF DOD PERSONNEL

6.1 INTRODUCTION

This chapter addresses data available on recorded exposures to ionizing radiation for approximately 18,000 DOD participants at Operation PLUMBBOB. It reflects information available as of 23 April 1981.

6.2 CHARACTERISTICS OF EXPOSURE DATA FOR PLUMBBOB PERSONNEL

During this test series, the principal device for recording and monitoring individual radiation exposures was the DuPont Type 559 film badge. This had both low and high range components. The low range component measured intensities of 0.02 to 10 roentgens, and the high range component recorded radiation levels of 10 to 300 roentgens. This packet of films, which had a lead shield covering both sides, was enclosed in a waterproof plastic covering, which comprised the film badge itself. Each film badge had an alligator clip for fastening it to clothing. In addition to film badges, self-reading pocket dosimeters were also used as exposure indicators for some personnel working in radiation areas. Film badges were processed by the Army's Lexington Blue Grass facility for Desert Rock personnel; other participants were serviced by REECo. Individuals were issued a numbered film badge; record was kept of his name and his film badge number. After badges were worn in contaminated areas, participants returned the badges for processing to determine their radiation exposure received. Each film badge reading was then recorded on a form for later transcription onto the individual's cumulative exposure card; this provided a permanent record of the his total radiation exposure.

6.3 DATA SOU CES

The military services developed the information pertaining to both identification of the individuals as well as the ionizing radiation dose they received. This data was obtained from a variety of sources:

- Reynolds Electrical and Engineering Company (REECo) was the principal source of dosimetry data. REECo is the DOE contractor charged with radiological safety support at the Nevada Test Site and has maintained a master file of dosimetry data for the Department of Energy since 1955. Most data is either on microfiche, microfilm, or summarized computer tapes indexed for retrieval. REECo has on file the original processed film badges for activities at NTS and has been provided supplementary material from various other repositories of dosimetry information. REECo also has microfilm records of a variety of source documents, such as contaminated area entry logs.

- Lexington-Blue Grass Signal Facility (located in Lexington, Kentucky), is an important source of dosimetry information for military personnel who participated in Exercise Desert Rock VII and VIII during Operation PLUMBBOB. This information is on microfilm but only covers the year 1957, when Lexington provided dosimetry services for Desert Rock. The Lexington films also provide identification of personnel by military unit.

- Information from the general public contributed to the identification of participants. In February 1978, the public was invited via mass media to call in by toll-free telephone to the Defense Nuclear Agency describing their participation in nuclear tests. Over 50,000 responses were received for further checking by the military services. The public provided identification and other helpful information for further research and verification.

- The General Services Administration (GSA) has been involved in both the identification of individuals and dose information. GSA operates the National Personnel Records Center (NPRC), located in St. Louis, Missouri. This is the main repository for medical and personnel records of individuals separated from the Armed Services. The determination of dose information from Army medical records was hampered by the fire that, in July 1973, destroyed 13-17 million Army records for personnel discharged between 1 November 1912 and 31 December 1959, and for members of the Army Air Corps/Air Force discharged between 31 December 1947 and 31 December 1963. The GSA also operates records storage facilities which provided some operational data, principally supporting identification information with only limited dose information. The most useful of these were at Laguna Niguel, CA; San Bruno, CA; and Suitland, MD.

- The Veteran's Administration (VA) is a source of some dose information in that it maintains file copies or originals of medical or personnel records for personnel separated from the Services. These records are required to substantiate an individual's eligibility for medical or dental care, as well as any disability compensation, claims, and other authorized veteran benefits. The VA obtains files from the NPRC in St. Louis and usually only retains an individual's file while a case is under consideration. However, the VA does maintain a master computer file (BIRLS) which can provide some information on cases previously considered.

- DOD Nuclear Information and Analysis Center (DASIAC, formerly Defense Atomic Support Information and Analysis Center) provided information relative to identification of individuals and military units by identifying and reviewing a large body of reports available or listed in this bibliographic data base.

Some personnel identification and dose information is contained in official reports written relative to Operation PLUMBBOB. These include:

- AEC Test Manager's Report (260) provided some generalized dose information and total numbers of participants, but no specific data relative to individuals by name.

- AEC Test Director's Report (209) provided some individual identification data, but no dose data.

- The REECo Onsite Rad-Safety Report (334) provided some data on exposures, but no individual identification on dose data. This source also included radiation exclusion contours, residual radiation measurements, and some non-specific decontamination data.

- Technical after-action reports were written by project or program leaders. Some of these name individuals or list participants, but provide no other identification information and no dose data. These reports also provide prompt, neutron-induced and fallout radiation information for those projects concerned with such measurements.

- The Desert Rock VII and VIII Final Report (200) provides numbers of personnel participating in projects and total numbers. However, this report contains no identification data.

- The AFSWC PLUMBBOB Final Report (2) provides some dose data on pilots in the sampling program and some total numbers for project participation.

- Operation orders and schedules of events furnish some names and numbers of participants.

The above sources provided information of general applicability to the DOD participants in Operation PLUMBBOB. In addition, the Armed Forces have Service-unique sources:

- Morning reports, unit diaries, muster rolls, and ships' deck logs provide identification data on personnel assigned to participating units, absent from their home unit, or in transient status for the purpose of participating in a nuclear weapons test.

- Official travel or reassignment orders provide further identification information relative to transient or assigned personnel participating in the nuclear weapons tests.

- Discharge records are maintained by all Services and aid in identification.

- Military personnel records for individuals still on active duty provide information relative to that individual's assignment to participating units or attendance in transient status at the nuclear weapons test.

- Medical records for participating DOD personnel provide dose information in some cases (about 25%).

- Each Service also has an Adjutant General (or similar) concerned not only with the administration of its Service but also with the maintenance of records and the preservation of unit histories.

- After-action reports, security rosters, and vehicle loading rosters related to the military exercises provide identification information on participants.

- The Services' Reserve personnel activities provide both identification information on participants who may still be carried on active or inactive reserve roles, and dose information in medical records of some individuals.

Table 6-1 summarizes NTPR data sources which relate to the identification of personnel and the determination of dose.

6.4 GENERAL PERSONNEL GROUPINGS

Regardless of the organization to which an individual was administratively assigned, his possible exposure depended on the capacity in which he was physically operating at the time. There were three general groupings:

- Scientific project personnel. This group includes personnel concerned with the placement, recovery and evaluation of experimentation conducted at the shots. Personnel involved were generally assigned to the AEC design laboratories (UCRL, LASL, and Sandia), AFSWP personnel, and those Desert Rock personnel who were involved in the technical service and air operational training projects.

- Maneuver elements. This group includes units conducting planned troop maneuver activities and their transportation; the requisite field support elements such as communications, military police, etc., to accompany the maneuver troops; and whatever observers, controllers, evaluators and Rad-safe personnel were required during maneuver activities in the NTS operational areas.

Table 6-1. DATA SOURCES IN NTPR ROSTER OF DOD PARTICIPANTS.

SOURCE	IDENTIFICATION DATA	DOSE DATA
REECo	X	X
Lexington Microfilm	X	X
GSA Repositories		
- Personnel Records (Separated)	X	
- Medical Records (Separated)	X	X
Veterans Administration	X	X
DASIAC	X	
Defense Nuclear Agency	X	
Armed Services		
- Morning Reports, Diaries, Muster Rolls, Deck Logs	X	
- Orders	X	
- Discharge Records	X	
- Personnel Records (Active Duty)	X	
- Medical Records (Active Duty)		X
- Administrative Service	X	
- After-Action Reports, Rosters	X	
- Reserve Affairs	X	X
Other Sources		
- Internal Revenue Service	X	
- Defense Documentation Center	X	
- Department of Energy	X	

- Support elements. This group includes all other personnel who were necessary to support the test, but were not usually required to go into the operational areas with the project personnel or maneuver elements.

6.4.1 Before the Detonation

- Scientific project personnel were involved in the layout, construction, equipment placement, installation and dry runs for the scientific projects and could have been exposed to ionizing radiation prior to the shots. Areas of the NTS were already contaminated by prior nuclear detonations and by earlier PLUMBBOB shots. Although entry into Radex areas was controlled, residual radiation in non-Radex areas (less than 10 mR/h) could have contributed to exposure over a period of time.

- Maneuvers by troops required entry into operational areas at NTS for orientation, training and rehearsal purposes. Although these activities did not involve entry into any Radex area, there was an opportunity for exposure to low-level radiation from previous nuclear tests. Rehearsals also provided the opportunity for exposure prior to the shots. It should be noted that the troops needed to support the maneuver units during rehearsals included some personnel who were not a part of the actual maneuver itself, such as those necessary to help dig the defensive positions.

6.4.2 Detonation Time

- Scientific project personnel on the ground were usually located well distant from surface ground zero, and few were exposed to initial radiation from the burst. Aircraft involved in air operational training and AFSWP projects were closer to the burst. None of the cloud sampler, cloud tracker or National Guard crews were exposed to appreciable initial radiation from the burst.

- Maneuver elements were located safely distant from surface ground zero. None were exposed to appreciable initial radiation from the burst. Helicopter support aircraft were in this category.

- Support elements at Camp Desert Rock or Indian Springs were all far distant from surface ground zero. None were exposed to initial radiation from the burst.

6.4.3 After the Detonation

All the numbered operational areas around ground zero were closed until initial surveys of the area were completed. At that time controlled access to all areas were established. This time was delineated as R-hour.

- Scientific project personnel. There was specific, pre-programmed entry into contaminated areas prior to R-hour for retrieval of time-sensitive data, although most entries did not occur until after R-hour. Subsequent to D-Day, the scientific project personnel had recurrent opportunities for exposure to ionizing radiation depending on the number of entries required to gather data or to recover equipment.

- Maneuver elements. Troop maneuvers were not controlled by R-hour. In this case the Radex monitors accompanying the troops established the limits of troop penetration into contaminated areas. When the Rad-safe monitors with the troops determined that each maneuver element had advanced to a safe limit, the exercises were terminated. Troops from maneuver elements were also involved in subsequent entries into the area to recover equipment, inspect defensive positions, and visit the display areas; these entries provided recurrent opportunity for exposure.

- Support elements. These personnel did not normally enter the contaminated areas on D-Day although activities associated with the maneuver elements and scientific project personnel did require some exposure of some of the support elements in other operational areas. One example was the ground transportation required to remove maneuver elements following the exercise. After D-Day, such support elements as decontamination teams, construction engineers and signal personnel had recurring opportunity for exposures when they entered the Nevada Test Site areas to recover or to service the support equipment.

6.5 SUMMARIES OF PERSONNEL DOSE DATA

The personnel dose data available as of 23 April 1981 have been analyzed to address the following topics:

- Total person-rem.
- The personnel present at each series, subdivided by Service, organization and unit (if known).
- Who, among DOD participants at the nuclear tests, were film badged.
- The ionizing radiation dose as measured by film badges.
- The distribution of dose subdivided by service, organization and unit.

Table 6-2 gives the number of participants by shot for PLUMBBOB based on historical reports. For comparison, dose distribution is provided for those participants whose names have been matched with dose records: Figure 6-1 provides an overall look at dose distribution; Table 6-3 examines known participants by military service; the total number of known participants for PLUMBBOB is divided by major organizations in Table 6-4; in similar fashion this number of known participants is subdivided by unit in Table 6-5. There will be some differences in personnel numbers among the shot volumes, this series volume, and the census volume because their contents are based on successively later studies and data. However, the differences are not considered statistically significant.

The total number of personnel in Table 6-2 is obviously larger than those in the subsequent tables. There are several reasons for this difference:

- Many personnel who participated at a project in one shot were the same ones who conducted that project at another shot.
- Some of the participants were not badged. Thus any numbers taken from the dosimetry records will automatically be lower than those from other sources.
- Identification of participants is not absolute.

Table 6-2. PLUMBBOB DOD PERSONNEL PARTICIPATION BY SHOT *
(Estimated Totals)

SHOT	NTO TEST GROUP PROJECTS†	DESERT ROCK PROJECTS (200)§	AFSWC (3)**
PROJECT 57	NO NUMBERS AVAILABLE		
BOLTZMANN	60	350	80
FRANKLIN	300	30	70
LASSEN	50	240	60
WILSON	170	870	70
PRISCILLA	300	1720	90
COULOMB A	0	0	10
HOOD	100	2760	280
DIABLO	40	1340	100
JOHN	50	690	60
KEPLER	70	1560	100
OWENS	90	720	70
PASCAL A	0	560	0
STOKES	40	1360	70
SATURN	0	590	0
SHASTA	30	610	80
DOPPLER	35	1210	70
PASCAL B	0	0	0
FRANKLIN PRIME	20	1080	50
SMOKY	320	2230	190
GALILEO	120	320	60
WHEELER	20	140	50
COULOMB B	0	0	15
LAPLACE	30	130	50
FIZEAU	60	140	60
NEWTON	15	80	60
RAINIER	10	30	20
WHITNEY	150	30	60
CHARLESTON	60	30	60
MORGAN	40	0	50
TOTALS	**2180**	**18820**	**1935**

†760 Support Personnel for Series

§1000 Support Personnel for Series

**900 Support Personnel for Series

* If one eliminates the obvious duplications from shot to shot, the estimated total number of DOD personnel participating in the PLUMBBOB series reduces from a total of 25,600 to about 18,000.

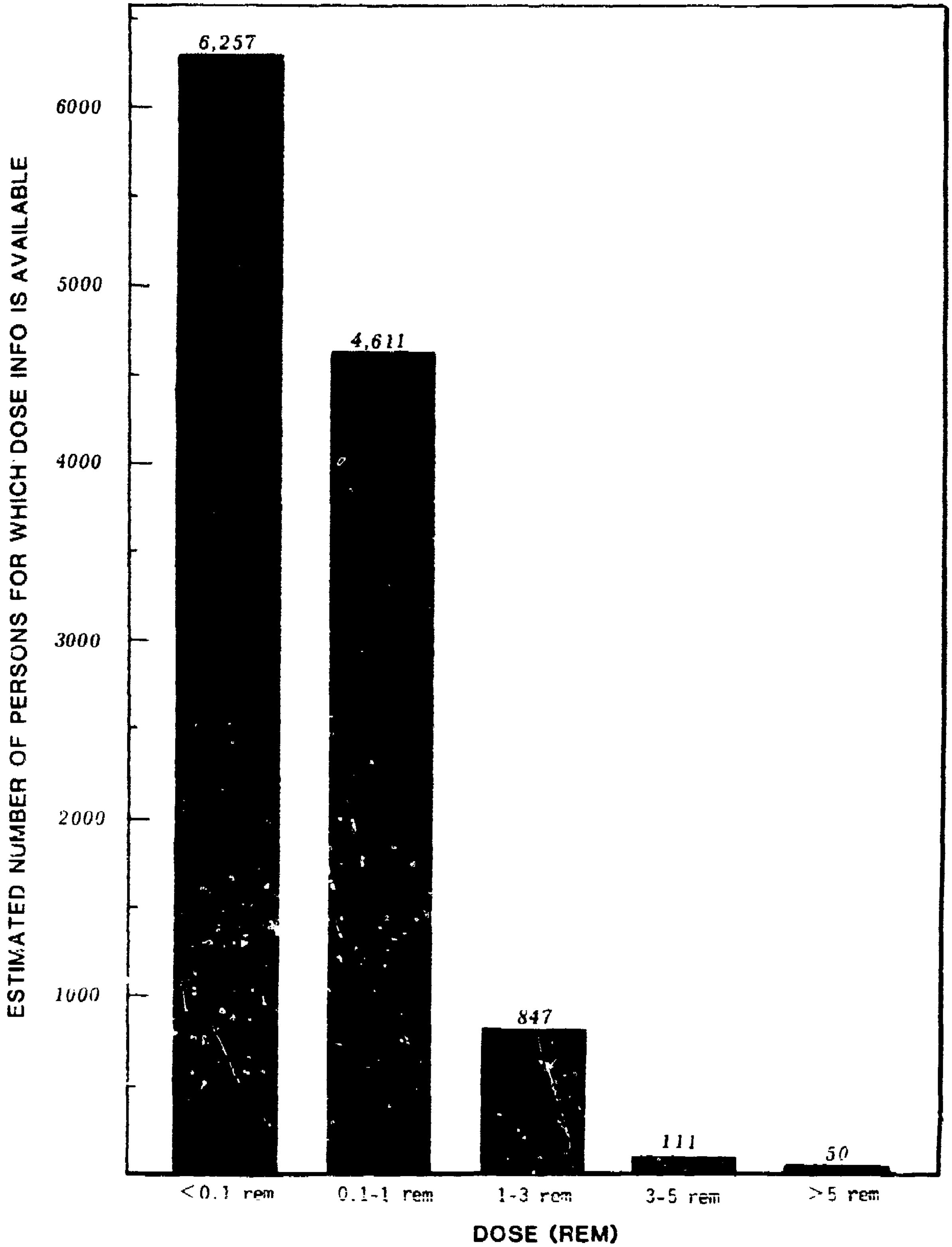


Figure 6-1. DOSE DISTRIBUTION, PLUMBBOB SERIES.

Table 6-3. PLUMBBOB PERSONNEL PARTICIPATION (MILITARY OR CIVILIAN)

PARTICIPANTS:	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE *				
			Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
ARMY	7,226	7,226	3,194	3,401	542	62	27
NAVY	466	442	371	52	14	2	3
AIR FORCE	2,505	1,446	893	411	100	23	19
MARINES	2,417	540	241	214	81	3	1
CIVILIANS	2,266	2,222	1,558	533	110	21	
TOTAL	14,880	11,876	6,257	4,611	847	111	50

*In recording doses, only doses greater than 0.1 rem have been considered to be significant. This definition of a "significant recorded dose" as being above 0.1 rem is somewhat arbitrary. It is intended to exclude badge data which indicate either no exposure or minimal exposure. In addition, there are uncertainties regarding exposure to natural and other sources of radiation not related to weapons testing, uncertainties in film response, and the like.

TROOP UNIT ABBREVIATIONS

The following is a list of the abbreviations used for PLUMBBOB troop units in Tables 6-4 and 6-5. (Names in brackets indicate home stations of participating units.)

ABBREVIATION	UNIT
1st MARINE DIV	1st Marine Division [Camp Pendleton, CA]
1st RSSU	1st Rad-safe Support Unit [Ft. McClellan, AL]
2 SIG PLT (PHOTO)	2nd Signal Platoon (Photo) [Ft. Huachuca, AZ]
2 TR CO (TRUCK) 26 TR BN	2nd Transportation Company (Truck) 26th Transportation Battalion [Ft. Ord, CA]
3 MAW HQ	3rd Marine Air Wing Headquarters [El Toro, CA]
3rd LT SUPPORT CO 1st SERVICE BN	3rd Light Support Company, 1st Service Battalion, 1st Marine Division [Camp Pendleton, CA]
8 FIELD HOSP	8th Field Hospital [Ft. Lewis, WA]
8 TRANS CO	8th Transportation Company [Ft. Benning, GA]
21st HELO SQDN	21st Helicopter Squadron [Ft. Benning, GA]
26 TRANS BN (HQ & HQ CO)	26th Transportation Battalion (Headquarters and Headquarters Company) [Ft. Ord, CA]
31 TRANS CO	31st Transportation Company, 3rd Transportation Battalion [Ft. Benning, GA]
38 TR CO (HV)	38th Transportation Company (Heavy) [Ft. Ord, CA]
50 CHEM PLT	50th Chemical Platoon [Ft. Ord, CA]
53 QM SUB/SUP CO	53rd Quartermaster Detachment [Ft. Ord, CA]
82nd AIRBORNE	82nd Airborne Division [Ft. Bragg, NC]
84th ENG BN	84th Engineer Battalion (Company B) [Ft. Ord, CA]
138 TRANS DET	138th Transportation Detachment, 3rd Transportation Battalion [Ft. Benning, GA]

ABBREVIATION	UNIT
140 TRANS DET	140th Transportation Detachment, 3rd Transportation Battalion [Ft. Bragg, NC]
163 QM (LAUNDRY)	163rd Quartermaster Detachment [Ft. Lewis, WA]
232 SIGNAL CO	232nd Signal Company [Ft. Huachuca, AZ]
293 MP CO	293rd Military Police Company [Ft. Ord, CA]
526 ORD CO (HAM)	526th Ordnance Company (Helicopter and Maintenance)
531 TR CO (MED)	531st Transportation Company (Medium)
656 QM (PET SUP CO)	656th Quartermaster Detachment (Petroleum Supply Company) [Ft. Lee, VA]
802nd AIR DIV	802nd Air Division
3395th C/C TRNG	3395th Combat Crew Training Support Squadron
4925th TG	4925th Test Group (Atomic) [Kirtland AFB, NM]
4926th T SQDN	4926th Test Squadron [Kirtland AFB, NM]
4927th T SQDN	4927th Test Squadron [Kirtland AFB, NM]
4935th AIR BASE GP	4935th Air Base Group [Indian Springs AFB, NV]
4950th TG (N)	4950th Test Group (Nuclear) [Kirtland AFB, NM]
4952nd SUPP SQDN	4952nd Support Squadron [Kirtland AFB, NM]
AFSWC (HQ)	Air Force Special Weapons Center (Headquarters) [Kirtland AFB, NM]
AFSWP (HQ)	Armed Forces Special Weapons Project (Headquarters) [Washington, DC]
AFSWP (FC)	Armed Forces Special Weapons Project (Field Command) [Sandia Base, Albuquerque, NM]
AF HQ	Air Force Headquarters
AG SECT	Adjutant General Section, U.S. Army

ABBREVIATION	UNIT
ARMY ENG R&D	Army Engineer Research and Development Laboratory [Ft. Belvoir, VA]
AVIATION SECT	Aviation Section [Camp Desert Rock]
CDR HQ	Camp Desert Rock (headquarters)
CDR STAFF	Camp Desert Rock (staff)
CETG	Civil Effects Test Group
CO A	Company A, 1st Anti-tank Battalion, 1st Marine Division [Camp Pendleton, CA]
CO B	Company B, 1st Motor Transportation Battalion, 1st Marine Division [Camp Pendleton, CA]
CO C	Company C, 3rd Armoured Transportation Battalion, 1st Marine Division [Camp Pendleton, CA]
CO E	Company E, 2nd Battalion, 5th Marine Regiment, 1st Marine Division [Camp Pendleton, CA]
CO F	Company F, 2nd Battalion, 5th Marine Regiment, 1st Marine Division [Camp Pendleton, CA]
CO G	Company G, 2nd Battalion, 5th Marine Regiment, 1st Marine Division [Camp Pendleton, CA]
CO H	Company H, 2nd Battalion, 5th Marine Regiment, 1st Marine Division [Camp Pendleton, CA]
CWL	Chemical Warfare Laboratory [Ft. McClellan, AL]
DOFL	Diamond Ordnance Fuze Laboratory [Maryland]
ENGINEER SECT	Engineer Section [Camp Desert Rock]
ESL	Evans Signal Laboratory [Ft. Monmouth, NJ]
EVALUATION GP	Evaluation Group, Task Force WARRIOR
FINANCE SECT	Finance Section [Camp Desert Rock]

ABBREVIATION	UNIT
FOPU	Fallout Prediction Unit
HQ & HQ CO 3rd TRANS BN	Headquarters and Headquarters Company, 3rd Transportation Battalion [Ft. Benning, GA]
H&S CO 2nd BN 5th M	Headquarters and Support Company, 2nd Battalion, 5th Marine Regiment, 1st Marine Division [Camp Pendleton, CA]
HUMRRO GP	Human Resources Research Office [Department of the Army]
INSTRUCTOR GP	Instructor Group
ISAFB	Indian Springs Air Force Base [Indian Springs, NV]
LEX SIG DEPOT	Lexington Signal Depot [Lexington, KY]
MAG 15	Marine Attack Squadron 223, Marine Aircraft Group 15, 3rd Marine Aircraft Wing, (El Toro, CA]
MAG 33	Marine Air Group 33 [El Toro, CA]
MAG 36	Marine Air Group 36 [El Toro, CA]
MISC GARRISON CDR	Miscellaneous U.S. Army Garrison, Camp Desert Rock [Camp Irwin, CA]
NAU (Sandia)	Naval Administrative Unit (Sandia) [Sandia Base, Albuquerque, NM]
NASWF	Naval Air Special Weapons Facility [Sandia Base, Albuquerque, NM]
NASWP	Naval Air Special Weapons Project [Sandia Base, Albuquerque, NM]
NML	Naval Material Laboratory (Naval Shipyard, Brooklyn, NY]
NOL	Naval Ordnance Laboratory [Washington, DC]
NRDL	Navy Radiological Defense Laboratory (San Francisco, CA]
NRL	Naval Research Laboratory [Washington, DC]
PATHFINDERS	506th Pathfinder team for Task Force WARRIOR [Ft. Bragg, NC]

ABBREVIATION	UNIT
PIO	Public information Office
QM/R&D	Quartermaster Research and Development [Natick, MA]
QM/SECTION	Quartermaster Section [Camp Desert Rock]
RAD-SAFE SECT	Radiological Safety Section [Camp Desert Rock]
SAM USAF	School of Aero Space Medicine, U.S. Air Force [Brooks AFB, TX]
SIG SECT	Signal Section [Camp Desert Rock]
SGO/ARMY	Office of Surgeon General [Washington, DC]
SRI	Stanford Research Institute [Menlo Park, CA]
UNK REECo CDR	Unknown REECo Badged at Camp Desert Rock
USWB	United States Weather Bureau [Greensboro, NC]
USA/BRL	Army Ballistics Research Laboratory [Aberdeen Proving Ground, MD]
WADC	Wright Air Development Center [Wright-Patterson AFB, OH]
WSPG	White Sands Proving Ground [New Mexico]

Table 6-4. PLUMBBOB PERSONNEL PARTICIPATION FOR MAJOR ORGANIZATIONS

MAJOR ORGANIZATION:	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE				
			Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
AFSWP	1240	1211	767	283	133	28	
DESERT ROCK	2101	2101	997	935	134	22	13
AFSWC	2140	1189	800	256	89	22	22
NTO/MILITARY	192	192	123	60	8	1	
OBSERVERS	3150	3126	1698	1348	80		
USMC TROOPS	2101	289	65	153	66	4	1
ARMY TR. TEST	1202	1202	345	669	180	5	3
TECHNICAL AND TRAINING PROGRAMS:							
50.8	598	598	213	287	72	18	8
CBR	109	109	1	50	46	10	2
OTHERS*	864	723	519	204			

*Denotes small groups of nine persons or less.

Table 6-5. PLUMBBOB PERSONNEL PARTICIPATION BY UNIT.

AFSWP UNITS	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE				
			Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
AFSWP (HQ)	19	19	13	4	2		
AFSWP (FC)	407	407	336	63	8		
NAU (Sandia)	59	59	46	10	3		
1st RSSU	47	47	14	14	12	7	
USA/BRL	66	61	18	10	26	7	
SGO/ARMY	179	179	100	77	2		
CWL	50	49	14	11	18	6	
ESL	27	27	10	8	8	1	
NRDL	91	89	49	15	21	4	
DOFL	28	24	15	7	2		
NML	44	38	26	2	10		
NRL	59	56	37	18	1		
QM/R&D	21	21	19	2			
WSPG	36	36	9	22	5		
SRI	26	26	12	2	12		
ARMY ENG R&D	39	39	21	14	1	3	
NOL	15	15	13	1	1		
SAM USAF	13	11	8	2	1		

Table 6-5. PLUMBBOB PERSONNEL PARTICIPATION BY UNIT (Continued)

DESERT ROCK UNITS	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE: Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
POSTAL UNIT	4	4		4			
163 QM (LAUNDRY)	27	27	27				
232 SIGNAL CO	373	373	144	202	24	1	2
26 TRANS BN (HQ & HQ CO)	88	88	57	21	10		
293 MP CO	113	113	33	75	3		2
2 SIG PLT (PHOTO)	34	34	19	8	6	1	
2 TR CO (TRUCK) 26 TR BN	94	94	22	69	2	1	
38 TR CO (HV) 26 TR BN	92	92	16	67	9		
50 CHEM PLT	88	88	10	41	24	9	4
526 ORD CO (HAM)	153	153	113	22	14	4	
531 TR CO (MED) 26 TR BN	110	110	51	55	4		
53 QM SUB/SUP CO	59	59	45	14			
656 QM(PET SUP CO)	21	21	14	7			
8 FIELD HOSP	67	67	36	25	6		
AG SECT	27	27	11	16			
AVIATION SECT	37	37	18	19			
CDR STAFF	70	70	36	26	7	1	

Table 6-5. PLUMBBOB PERSONNEL PARTICIPATION BY UNIT (Continued)

DESERT ROCK UNITS (Cont.)	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE: Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
DOSIMETRY TEAM	5	5	1	1	3		
ENGINEER SECT	21	21	16	5			
FINANCE SECT	14	14	13	1			
INSTRUCTOR GP	9	9	4	2	1	1	1
LEX SIG DEPOT	1	1			1		
PIO	18	18	11	7			
QM SECTION	14	14	8	6			
RAD-SAFE SECT	13	13	2	3	3	2	3
SIG SECT	13	13	11	2			
UNK REECo CO.	13	13	8	5			
MISC GARRISON CDR	83	83	45	38			
84th ENG BN	312	312	148	152	11		1
CDR HQ	128	128	78	42	6	2	

Table 6-5. PLUMBBOB PERSONNEL PARTICIPATION BY UNIT (Continued)

ARMY TROOP TEST PROJECT 50.1 UNITS	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE				
			Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
TASK FORCE WARRIOR	555	555	28	473	53	1	
PATHFINDERS	15	15	1	1	13		
EVALUATION GP HQ & HQ CO	20	20	4	16			
3rd TRANS BN	39	39	22	16	1		
138 TRANS DET	54	54	51	3			
140 TRANS DET	47	47	44	3			
31 TRANS CO	148	148	95	45	8		
8 TRANS CO	136	136	62	71	2		1
82nd AIRBORNE	176	176	31	39	102	2	2
HUMRRO GP	12	12	7	2	2	1	

Table 6-5. PLUMBBOB PERSONNEL PARTICIPATION BY UNIT
(Continued)

MARINE TROOP TEST PROJECT 52.1 UNITS	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE				
			Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
1st MARINE DIV	515	155	32	61	59	2	1
H & S CO 2nd BN 5th M	300	10		9	1		
3rd LT SUPPORT CO 1st SERVICE BN	66	3	2	1			
CO A	10	1		1			
CO B	24	1				1	
CO C	43	0					
CO E	140	11	3	6	2		
CO F	186	23	2	20	1		
CO G	195	16	2	14			
CO H	192	14		13	1		
MAG 36	226	44	21	21	2		
MAG 33	16	0					
3 MAW HQ	26	2		1		1	
MAG 15	162	9	3	6			

Table 6-5. PLUMBBOB PERSONNEL PARTICIPATION BY UNIT (Continued)

AFSWC UNITS	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE: Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
OPERATIONS GROUPS:							
4925th TG	159	3	2	1			
AFSWC (HQ)	57	57	38	19			
4950th TG (N)	126	51	23	14	6	5	3
4926th T SQDN	252	192	54	78	34	11	14
4927th T SQDN	217	5	4	1			
4935th AIR BASE GP	311	67	64	3			
ISAFB	448	448	343	66	32	5	2
21st HELO SQDN	6	6		3	3		
4952nd SUPP SQDN	214	44	32	12			
TECHNICAL PROGRAMS AND TRAINING:							
NASWF	95	95	91		1		3
NASWP	27	27	26	1			
WADC	62	62	48	12	2		
AF HQ	20	20	18	2			
802nd AIR DIV	14	4	3			1	
AIR NAT. GUARD	59	43	18	18	7		
3395th C/C TRNG	73	65	36	26	33		

Table 6-5. PLUMBBOB PERSONNEL PARTICIPATION BY UNIT (Continued)

NTO/MILITARY UNITS	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE				
			Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
CETG	138	138	85	44	8	1	
FOPU & USWB	54	54	38	16			

OBSERVER UNITS	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME	NUMBER OF PARTICIPANTS IDENTIFIED BY NAME & FILM BADGE	NUMBER IN DOSE RANGE				
			Less than 0.1 rem	0.1 rem to 1 rem	1 rem to 3 rem	3 rem to 5 rem	Greater than 5 rem
ARMY	2284	2284	972	1242	70		
OFFICIAL OBSERVER	383	383	347	36			
VISITING GENERAL OFFICER & PARTY	68	68	40	18	10		
OBSERVER (UNCLASS)	58	34	22	12			
OBSERVER(UNIT UNK)	357	357	317	40			

6.6 SUMMARY OF RADIOLOGICAL SAFETY AT PLUMBBOB

This analysis of the PLUMBBOB radiation safety program considers only the Department of Defense personnel (including those assigned to the AEC and its laboratories). As a result of the safety measures instituted at the time

- The total person rem was approximately 5,200. Assuming some 14,880 badged participants, this results in a mean dose of 0.35 rem.
- Out of 14,880 dose records, only 111 individuals (0.7% of all participants) exceeded 3R for the 13-week limit; of these 50 exceeded 5 R for the yearly limit.

6.6.1 Overall Results of the EDR Radiological Safety Program

The final report of Exercise Desert Rock VII and VIII contains no overall assessment of the Rad-safe program except to say that a total of 33,000 film badges were processed. Some additional results are quoted in the "After Action Reports" written by the responsible officers (8). The 50th Chemical Platoon, which provided Rad-safe monitors and decontamination services, reported the following results:

Personnel monitored	5,725
Personnel requiring decontamination	7
Vehicles monitored	867
Vehicles requiring decontamination	166

This platoon (which could expect higher than average doses because of its employment during the exercises) also reported on its cumulative dose for each man in the platoon: only two persons received "5 R or greater." The Signal Officer, whose personnel processed and read the film badges, reported that "this operation was highly successful and the statistics accumulated will provide adequate basis upon which to render scientific data for study.

For the period encompassed by shots BOLTZMANN, FRANKLIN, LASSEN and WILSON (7 May to 20 June 1957), one member of the 84th Engineer Battalion

(Company B) showed a reading of 4.9 roentgens. Other troops received "warning-level" exposures, but because of the regulations regarding film badge issue and turn-in, a period of one week could elapse before report of the film badge reading was made. Thus it is difficult to assign a reading to a particular shot. (291)

The equipment display officer at shot HOOD, who made several return trips to the display area in the days following the shot, received 7.2 roentgens. This is the only reading detected so far among Project 52.1 participants at shot HOOD in excess of the established Exercise Desert Rock criterion of five roentgens.

From 8 July to 30 July 1957, the period encompassing shots DIABLO, JOHN, KEPLER, and OWENS, available film badge readings for Project 50.8 participants indicate that five cases exceeded the five roentgens-per-year exposure limit; three in the survey platoon, one in the 495th AAA Missile Battalion (Nike), and one in the air section. A member of the Radiological Safety Section showed a reading of 5.7 roentgens from 19 July to 24 July 1957, the period encompassing shots JOHN and KEPLER. The troops received "warning-level" exposures, but because of the usual one-week reporting delay, it is difficult to assign a reading to a particular shot.

One member of the 50th Chemical Platoon showed a reading of 5.5 roentgens from 15 July to 25 July 1957, the period for shots DIABLO to OWENS. Other troops received "warning-level" exposure, but because of the usual one-week reporting delay, it is difficult to assign a reading to a particular shot.

6.6.2 Overall Results of the NTO Radiological Safety Program

The results of the NTO onsite Rad-safe program are best described in the words of the Test Manager's Report (extracted on the following page, pp. 73 and 74, reference 260; note that this does not differentiate between DOD and AEC personnel):

> <u>Onsite Personnel Gamma Overexposure</u>
>
> Of the total of 9,000 individual radiation dosage records maintained by the Support Contractor, Nevada Test Organization, there were 22 individuals that exceeded the 3 R for the 13-week

guide with only 2 exceeding the 5 R yearly limit. These over-exposures can be summarized as follows:

Three men received their dosage in small portions over the 13-week period and were over the 3 R guide by only a few milliroentgens.

Four men performed recovery operations in about a 10 R/h field and failed to provide proper shielding for their samples while returning to the CP.

Two men on separate recovery operations miscalculated their stay time.

Three men violated Rad-safety regulations and entered a radiation field in excess of 10 R/h without permission of the Test Director.

Three men on initial helicopter radiological survey became overexposed when the pilot failed to pull out of the radiation field on instruction from the monitor.

Seven helicopter pilots received over 3 R for 13 weeks performing initial radiation surveys and recovery missions. Two of these exposures were over 5 R for the operation.*

There were some 17 personnel from the 4950th Test Group (Nuclear) performing cloud sampling missions that received over 3 R for 13 weeks or 5 R for the operation. These had previously bee authorized to receive 7.5 R for the operation.

There were 3 men from the U.S. Naval Special Weapon Facility, Kirtland Air Force Base, who received over 3 R for 13 weeks and 5 R for the operation. These men had previously been authorized to receive 15 R for the operation.

For Project 5.5 at shot JOHN, dosimeters in the pilot's cockpit of an F-89D aircraft measured 3.55 roentgens of gamma radiation. Those in the observer's cockpit recorded 2.44 roentgens of gamma radiation. (297)

---

*This item on seven helicopter pilots was apparently placed in the Internal Exposure section of the reference in error. These seven cases when placed in "the Gamma Overexposure" category, bring the total up to 22, as previously mentioned.

Onsite Personnel Internal Exposure

Several incidents occurred during the series which could have led to internal exposures. Laboratory analysis of body fluid indicated that no significant exposures occurred. These exposures can be summarized as follows:

- During the Project 57 experiment one person removed his respiratory protective device while in the area of surface plutonium contamination.
- Twelve personnel were exposed to radioactive gas in a tower cab.
- Several personnel were exposed while removing and cutting a piece of plutonium-contaminated cable.
- Four personnel without respiratory protection entered a plutonium-contaminated tunnel. They left immediately after detecting the plutonium contamination.

REFERENCE LIST

The following list of references represents all the documents consulted during the preparation of the PLUMBBOB volumes. All documents used in writing this volume are cited in the text. The reference lists in the shot volumes contain only documents cited in those volumes.

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. The following addresses are being provided for that purpose.

Source documents, bearing an availability statement of DOE CIC, may be reviewed at the following address:

Department of Energy
Coordination and Information Center
(Operated by Reynolds Electrical & Engineering Co., Inc.)
ATTN: Mr. Richard V. Nutley
2753 S. Highland
P.O. Box 14100
Las Vegas, Nevada 89114

Phone: (702) 734-3194
FTS: 598-3194

Source documents, bearing an availability statement of NTIS, may be purchased from the National Technical Information Service. When ordering by mail or phone please include both the price code and the NTIS number.

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Phone: (703) 487-4650
(Sales Office)

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

REFERENCES

1. 21st Helicopter Squadron. "Special Orders Number 48." Donaldson AFB, SC: USAF. 06/20/57. 1 page.***

2. 4950th Test Group (Nuclear). "Final Report: Operation PLUMBBOB." Kirtland AFB, NM: AFSWC. 10/21/57. 167 pages. AD/A 995 104.*

3. 4950th Test Group (Nuclear). "Operation Plan 1-57, Operation PLUMBBOB." Kirtland AFB, NM: AFSWC. April 1957. 200 pages. AD/A 995 031.*

4. 4950th Test Group (Nuclear). [Film Badge Requirements.] Kirtland AFB, NM: AFSWC. 02/25/57. 2 pages.**

5. 4950th Test Group (Nuclear). [T-33 Contamination Study.] Kirtland AFB, NM: AFSWC. 10/07/57. 7 pages.**

6. 4th Marine Corps Provisional Atomic Exercise BDE. "Administrative Plan 1-57." Desert Rock VIII. Camp Pendleton, CA: 4th MCPAE BDE. 05/29/57. 80 pages.**

7. 4th Marine Corps Provisional Atomic Exercise BDE. "Administrative Plan 1-57," Desert Rock VII, Marine Corps, Annex G: Equipment Demonstration. Camp Pendleton, CA: 4th MCPAE BDE. 06/05/57. 20 pages.**

8. 79th Congress of the United States, 2nd Session. Public Law 585: Atomic Energy Act of 1946. Washington, DC: GPO. 08/01/46. 24 pages.

9. 83rd Congress of the United States, 2nd Session, Public Law 703: Atomic Energy Act of 1954. Washington, DC: GPO. 08/30/54. 16 pages.

10. AFSWP Field Command Training Division. "Principals of Radiation Detectors." Albuquerque, NM: AFSWP. 02/15/56. 36 pages.***

11. AFSWP Field Command. "Operation PILGRIM, Operational Planning Guide." Albuquerque, NM: AFSWP. January 1957. 23 pages.***

12. AFSWP Field Command, ODCS/WET. "Operational Summary: Operation PLUMBBOB." Albuquerque, NM: Field Command, DASA. 02/23/60. 73 pages. WT-1444. AD/B 951 751.*

13. AFSWP. [Participation of Military Personnel Assigned to Nevada Test Organization in Exercise Desert Rock.] Mercury, NV: AFSWP. 07/10/57. 2 pages.**

---

* Available from NTIS; order number appears before the asterisk.
** Available at DOE CIC.
*** Not Available.

REFERENCES
(Continued)

14. Air Force NTPR Program/SGPR. [Lists of Air Force Personnel at PLUMBBOB, Their Job Titles, Present Whereabouts; and Dose Rates."] Washington, DC: USAF, SGPR. 1978. 200 pages.***

15. Air Force Special Weapons Center, ASG. "Air Mission Summary for Shot FRANKLIN." Mercury, NV: AFSWC, Air Support Group. 06/10/57. 5 pages.***

16. Air Force Special Weapons Center, ASG. "Air Mission Summary for GALILEO Event." Mercury, NV: AFSWC, Air Support Group. 09/03/57. 3 pages.**

17. Air Force Special Weapons Center, ASG. "Air Mission Summary for LAPLACE Event." Mercury, NV: AFSWC, Air Support Group. 09/09/57. 5 pages.***

18. Air Force Special Weapons Center, ASG. "Air Mission Summary Report for CHARLESTON Event." Mercury, NV: AFSWC, Air Support Group. 09/29/57. 3 pages.***

19. Air Force Special Weapons Center, ASG. "Air Mission Summary Report for HOOD Event." Mercury, NV: AFSWC, Air Support Group. 07/06/57. 6 pages.**

20. Air Force Special Weapons Center, ASG. "Air Mission Summary Report for MORGAN Event." Mercury, NV: AFSWC, Air Support Group. 10/07/57. 2 pages.***

21. Air Force Special Weapons Center, ASG. "Air Mission Summary Report for NEWTON Event." Mercury, NV: AFSWC, Air Support Group. 09/17/57. 3 pages.***

22. Air Force Special Weapons Center, ASG. "Air Mission Summary Report for RAINIER Event." Mercury, NV: AFSWC, Air Support Group. 09/20/57. 2 pages.***

23. Air Force Special Weapons Center, ASG. "Air Mission Summary Report for WHEELER Event." Mercury, NV: AFSWC, Air Support Group. 09/07/57. 6 pages.***

24. Air Force Special Weapons Center, ASG. "Air Mission Summary Report for WHITNEY Event." Mercury, NV: AFSWC, Air Support Group. 09/22/57. 3 pages.***

25. Air Force Special Weapons Center, ASG. "Air Mission Summary Report." Mercury, NV: AFSWC, Air Support Group. 06/25/57. 4 pages.**

26. Air Force Special Weapons Center, ASG. "Air Mission Summary COULOMB A." Mercury, NV: AFSWC, Air Support Group. 07/02/57. 2 pages.***

27. Air Force Special Weapons Center, ASG. "Air Mission Summary, COULOMB B." Mercury, NV: AFSWC, Air Support Group. 09/07/57. 2 pages.***

REFERENCES
(Continued)

28. Air Force Special Weapons Center, ASG. "Air Mission Summary, PASCAL A." Mercury, NV: AFSWC, Air Support Group. 09/28/57. 2 pages.***

29. Air Force Special Weapons Center, ASG. "Air Mission Summary, SATURN." Mercury, NV: AFSWC, Air Support Group. 08/10/57. 2 pages.***

30. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot BOLTZMANN." Mercury, NV: AFSWC, Air Support Group. 05/28/57. 11 pages.***

31. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot DIABLO." Mercury, NV: AFSWC, Air Support Group. 06/10/57. 4 pages.***

32. Air Force Special Weapons Center, ASG. "Air Mission Summary. Shot DOPPLER." Mercury, NV: AFSWC, Air Support Group. October 1957. 4 pages.***

33. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot FRANKLIN PRIME." Mercury, NV: AFSWC, Air Support Group. October 1957. 4 pages.***

34. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot JOHN." Mercury, NV: AFSWC, Air Support Group. 06/10/57. 4 pages.***

35. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot KEPLER." Mercury, NV: AFSWC, Air Support Group. 06/10/57. 4 pages.***

36. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot LASSEN." Mercury, NV: AFSWC, Air Support Group. 06/10/57. 2 pages.***

37. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot OWENS." Mercury, NV: AFSWC, Air Support Group. 06/10/57. 4 pages.***

38. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot SHASTA." Mercury, NV: AFSWC, Air Support Group. October 1957. 4 pages.***

39. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot STOKES." Mercury, NV: AFSWC, Air Support Group. 06/10/57. 4 pages.***

40. Air Force Special Weapons Center, ASG. "Air Mission Summary, Shot WILSON." Mercury, NV: AFSWC, Air Support Group. 06/21/57. 4 pages.***

41. Air Force Special Weapons Center, "Air Mission Summary Report for FIZEAU Event." Mercury, NV: AFSWC, Air Support Group. 09/16/57. 4 pages.***

42. Air Operations Center. Air Operations Center - History for the Month of August 1957. Kirtland AFB, NM: USAF. 1957. 5 pages.***

43. Albright, G; Beck, E; Ledoux, J; et al. "Evaluation of Buried Corrugated-Steel Arch Structures and Associated Components." Project 3.3. Albuquerque, NM: Field Command, DASA. 02/28/61. 112 pages WT-1422. AD 615 737.*

REFERENCES
(Continued)

44. Albright, G; Ledoux, J; Mitchell, R. "Evaluation of Buried Conduits as Personnel Structures, Project 3.2" Albuquerque, NM: Field Command, DASA. 07/14/60. WT-1421. AD 691 406.*

45. Allardice, C.; Trapnell, E. The Atomic Energy Commission. New York: Praeger Publishers. 1974. 236 pages.

46. Anonymous. "25 Seconds of Atomic Explosion on the Nevada Desert," Milwaukee Sentinel. Milwaukee, WI: 07/06/57. 1 page.

47. Anonymous. "Biggest A-Blast in U.S. Jolts California Areas." San Diego Union. San Diego, CA: 07/06/57. 2 pages.

48. Anonymous. "Fourth Marine Corps Provisional Exercise Brigade Holds Maneuvers After Biggest 'A' Bomb." Camp Desert Rock: July 1957. 1 page.

49. Anonymous. "Gigantic Atomic Blast is Set Off in the Desert." (Unknown Newspaper). Nevada Test Site, NV: July, 1957. 1 page.

50. Anonymous. "Tired After 500-Foot Climb" and "HOOD Shot Set for July 3rd with Marine Brigade." Las Vegas Sun. Las Vegas, NV: 06/29/57. 3 pages.

51. Anonymous. [Collection of Newspaper Articles on the PLUMBBOB Weapons Test Series.] 1957. 230 pages.

52. Anonymous. [List of AF Unit Participation in CONUS and OCEANIC Series 1945-1962.] San Antonio, TX: Air Force NTPR. 12/01/79. 12 pages.***

53. Armed Forces Radiobiology Research Institute. The Medical Effects of Nuclear Weapons. Washington, DC: AFRRI. October, 1977. 300 pages.***

54. Armed Forces Special Weapons Project. [First] History of AFSWP 1947-1954, Volume VI; 1953 Chapter 3: Headquarters AFSWP: 1960. 900 pages.***

55. Army Artillery and Guided Missile School. Detection of Atomic Burst and Radioactive Fallout, Plan of Troop Test. Fort Sill, OK: U.S. Army. 04/15/57. 132 pages.***

56. Army Artillery and Missile School. Detection of Atomic Burst and Radioactive Fallout, Final Report. Fort Sill, OK: U.S. Army. 12/13/57. 364 pages.***

57. Atomic Energy Commission, "Status of Nuclear Test Reports." Oak Ridge, TN: AEC. 01/31/71. 107 pages. TID-9534.***

58. Atomic Energy Commission, Division of Military Application. [Participation of Navy Test Aircraft.] AEC, DMA. (Undated) 5 pages. MR & A7, Vol. 2.**

REFERENCES
(Continued)

59. Atomic Energy Commission. "Continental Atomic Tests: Background Information For Observers: Operation PLUMBBOB." Mercury, NV:AEC.June 1957. 52 pages. AD/A 080 273.*

60. Atomic Energy Commission. "Draft Press Release on National Academy of Sciences Radiation Study." Washington, DC: AEC, Secretariat. 06/11/56. 17 pages. 604/18.***

61. Atomic Energy Commission. "Outline Test Manager's Report; Operation PLUMBBOB." Mercury, NV: AEC. 09/11/57. 6 pages.**

62. Atomic Energy Commission. "PLUMBBOB CTDN-22, Test Director's Operation Plan." Mercury, NV: AEC, 1957. (undated). AD/A 995 053.*

63. Atomic Energy Commission. "Annex G to Test Director's Operation Plan CTDN-22; Special Instructions, PRISCILLA." Mercury, NV: AEC. 06/20/57. (undated) CTDN-121,122.**

64. Atomic Energy Commission. "Annex J to Test Director's Operation Plan CTDN-22; Special Instructions, HOOD." Mercury, NV: AEC 06/29/57. CTDN-140,141.**

65. Atomic Energy Commission. "Annex M to Test Director's Operation Plan No. CTDN-22: Special Instructions, JOHN." Mercury, NV: AEC. 07/15/57. 4 pages.***

66. Atomic Energy Commission. "Annex P to Test Director's Operation Plan No. CTDN-22: Special Instructions, SHASTA." Mercury, NV: AEC. 07/23/57. 4 pages.***

67. Atomic Energy Commission. "Annex V to Test Director's Operation Plan No. CTDN-22: Special Instructions, WHEELER." Mercury, NV: AEC. 08/29/57. 4 pages. CTDN-233.**

68. Atomic Energy Commission. "Annex W to Test Director's Operation Plan CTDN-22; Special Instructions, GALILEO." Mercury, NV: AEC. 09/01/57. CTDN-250,251.**

69. Atomic Energy Commission. [Joint AEC/DOD Security Instructions for Arrivals at Nevada Test Site.] Mercury, NV: AEC 1957. 8 pages.***

70. Atomic Energy Commission. "Schedule of Events for PRISCILLA." Mercury, NV: AEC, OTD. 06/24/57. 10 pages.**

71. Atomic Energy Commission. "The Effects of Nevada Atomic Tests." [Washington, DC]: AEC. March 1957. 46 pages.**

72. Atomic Energy Commission. [Four Maps of Radiological Safety Activities, 1958 to 1960.] Las Vegas, NV: AEC 1960. 4 pages.***

73. Atomic Energy Commission. [General Correspondence.] Atomic Energy Commission. 1957. 6 pages.**

REFERENCES
(Continued)

74. Atomic Energy Commission. [Program and Project Participation in Operation PLUMBBOB.] Washington, DC: AEC. 04/01/57. 13 pages. CTDN-22.**

75. Atomic Energy Commission. [Schedule of Events, D-Day, FRANKLIN.] Mercury, NV: AEC, OTD. 05/21/57. 1 page. CTDN-78.**

76. Atomic Energy Commission. [Test PLUMBBOB MH and S.] Las Vegas, NV: AEC. 1957. 0302-0C-11.**

77. Atomic Energy Commission. [Test PLUMBBOB; MR and A 7.] Las Vegas, NV: AEC. 1957.**

78. Atomic Energy Commission. [Test-NTS-MR and A 7; Project 58.] Las Vegas, NV: AEC. 1958.**

79. Atomic Energy Commission. [Test-PLUMBBOB I&P July 1957 through June 1958.] Las Vegas, NV: AEC. (undated) 0302-0C-17.**

80. Atomic Energy Commission. [Test-PLUMBBOB MH & Radiation No. 1956 through June 1958.] Las Vegas, NV: AEC. 50 pages. 0302-0C-14.**

81. Atomic Energy Commission; Department of Defense. "Joint Public Education and Information Plan for Operation PLUMBBOB." AEC. (undated) 10 pages.**

82. Babers, F. [Personal Journal Account of Project 8.1]. Natick, M.A.: U.S. Army Quartermaster's Research and Development Branch. 1957. 200 pages.***

83. Babers, F.; McQuade, A. "Thermal Protection of the Individual Soldier, Project 8.1." Albuquerque, NM: Field Command, DASA. 06/10/59. 48 pages. WT-1440. AD 460 309.*

84. Baldwin, R. "Experiences at Desert Rock VII and VIII." Washington, DC: HumRRO. March 1958. AD/A 044 440, AD 995 069.*

85. Ballard, G. [Notes from SAI Interview with Lt.Col. George Ballard, USMC (Ret.), Subject: Shots HOOD and PRISCILLA.] Houston, TX: U.S. Marine Corps. 10/04/80. 4 pages.***

86. Ballistic Research Laboratories. "Army Ordnance Test, Exercise VII and VIII, Project 50.7." Aberdeen, MD: BRL. 04/02/57. 35 pages. AD/A 995 040.*

87. Bastian, C.; Robbiani, R. "Radar Detection and Observation of Nuclear Clouds, Part II." Desert Rock VII and VIII, Operation PLUMBBOB, Project 50.3. Fort Monmouth, NJ. 11/02/59. 50 pages. AD 344 156.*

88. Becquerel, H.; Curie, P. Compte Rendu Hebdomadaire des Seances de L'Academie des Sciences. Paris, France: 1901. 1 page.***

REFERENCES
(Continued)

89. Bowen, I.; Franklin, M; Fletcher, E; et al. "Secondary Missiles Generated by Nuclear-Produced Blast Waves, Project 33.2." Albuquerque, NM: LFMER. 10/28/63. 480 pages. WT-1468. AD 436 391.*

90. Breslin, A.; Loysen, P.; Weinstein, M. "Protection Against Fallout Radiation in a Simple Structure, Project 32.1." Washington, DC: FCDA. 08/12/63. 63 pages. WT-1462. AD 611 231.*

91. Bridgman, L., Ed. Jane's All the World's Aircraft, 1955-1956. New York: McGraw-Hill. (1956.)

92. Bridgman, L., Ed. Jane's All the World's Aircraft, 1956-1957. New York: McGraw-Hill. (1956.)

93. Bridgman, L., Ed. Jane's All the World's Aircraft, 1951-1952. New York: McGraw-Hill. (1951.)

94. Bridgman, L., Ed. Jane's All the World's Aircraft, 1952-1953. New York: McGraw-Hill. (1952.)

95. Bridgman, L., Ed. Jane's All the World's Aircraft, 1953-1954. New York: McGraw-Hill. (1953.)

96. Bridgman, L., Ed. Jane's All the World's Aircraft, 1957-1958. New York: McGraw-Hill. (1957).

97. Broyles, C.D., et al., "Fireball Studies, Operation PLUMBBOB, Project 41.1a." Albuquerque, NM: Field Command AFSWP. April, 1959. 82 pages. WT-1517. AD/B 951 753.*

98. Bryant, E.J.; Day, J.D. "Effects of Rough Terrain on Drag-Sensitive Targets, Operation PLUMBBOB, Project 1.8b." Ballistic Research Laboratories 11/09/59. 28 pages. WT-1408. AD 344 937.*

99. Bryant, E.J.; Keefer, J.H.; Swift, L.M.; et al. "Effects of Rough and Sloping Terrain on Airblast Phenomena, Operation PLUMBBOB," Projects 1.8a and 1.8c. Ballistic Research Laboratories; Stanford Research Institute. 07/05/62. 230 pages. WT-1407. AD 452 637.*

100. Bryant, E.; Keefer, J.H. "Basic Airblast Phenomena, Project 1.1." Albuquerque, NM: Field Command, DASA. 06/25/62. 202 pages. WT-1401. AD 344 935.*

101. Bultmann, E.; Morrison, T.; Johnson, M.R. "Full-Scale Field Tests of Dome and Arch Structures, Project 3.6." Albuquerque, NM: Field Command, DASA. 08/31/60. 168 pages. WT-1425. AD 355 561.*

102. Bultmann, E; McDonough, G.; Sinnamon, G. "Loading on Simulated Buried Structures at High Incident Overpressures, Project 1.7." Albuquerque, NM: Field Command, DASA. 04/18/60. 108 pages. WT-1406. AD 356 399.*

REFERENCES
(Continued)

103. Bultmann, E.; Sevin, E.; Schiffman, T. "Blast Effects on Existing UPSHOT-KNOTHOLE and TEAPOT Structures, Project 3.4." Albuquerque, NM: Field Command, DASA. 05/06/60. 130 pages. WT-1423. AD 460 283.*

104. Butera, S. [Letter of Inquiry to Shot HOOD Participants.] Washington, DC: Marine Nuclear Test Personnel Review. 1978. 2 pages.***

105. Butera, S. [Letter of Response to Participants, Subject: Inquiry About Desert Rock VII at Shot HOOD.] Washington, DC: Marine Corps Nuclear Test Personnel Review. 05/23/78. 2 pages.***

106. Butler, R.E.; Miller, H.M. "Surface Alpha Monitoring as a Method of Measuring Plutonium Fallout." Albuquerque, NM: Field Command, DASA. January, 1961. 39 pages. WT-1513. AD 611 240.*

107. Brady, B. [Notes from SAI Interview with Lt.Col. Byron Brady, USMC, Subject: Shots HOOD and PRISCILLA.] 09/25/80. 5 pages.***

108. Canterbury, W.M., Brig. Gen., USAF. [Radiation Dosage Limitations for Atomic Cloud Samplers.] Kirtland AFB, NM: AFSWC. 01/14/57. 4 pages.**

109. Carp, G.; Johnson, O.; Baldwin, T.; et al. "Initial-Gamma Radiation Intensity and Neutron-Induced Gamma Radiation of NTS Soil, Operation PLUMBBOB, Project 2.5." Fort Monmouth, NJ: Field Command DASA. 04/11/61. WT-1414. AD/A 995 036.*

110. Cassen, B.; Gass, H.C. "Measurement and Permanent Recording of Fast Neutrons by Effects on Germanium Dosimeters, Project 37.4." University of California, Atomic Energy Project. 18 Pages. ITR-1492. AD/A 078 543.*

111. Chatham Electronics. Instruction Book and Maintenance Manual for Radiological Survey Meter FCDA Item No. CD V-F20. Livingston, N.J: Chatham Electronics. (Undated.) 15 pages.***

112. Chiment, J.; Goetz, J.; Facer, G.C. "Neutron and Gamma Radiation From Shot LAPLACE, Operation PLUMBBOB, Program 2." 11/20/59. 9 pages. WT-1541.***

113. Cohen, E.; Boettenhofer, A. "Test of German Underground Personnel Shelters," Project 30.7. Ammann and Whitney. July, 1960. 295 pages. WT-1454. AD 691 407.*

114. Cohen, E.; Dobbs, N. "Test of French Underground Personnel Shelters," Project 30.6. Ammann and Whitney. June, 1960. 295 pages. WT-1453. AD 611 259.*

REFERENCES
(Continued)

115. Cohen, A.; Jachter, M.H.; Koehler, D.K.; et al. "Evaluation of New Types of Radiac Instruments, Project 2.6." Albuquerque, NM: Field Command, DNA. 01/10/79. 75 pages. WT-1415-Ex. AD/B 951 766.*

116. Considine, B. "A-Blast Seen 1,000 Miles Away." Yucca Flat, NV: 07/05/57. 1 page.***

117. Coogan, J. SATURN Shot Report. Mercury NV: REECo. 08/10/57. 25 pages.**

118. Cook, C.; Thompson, W.E.,; Tomnover, F.M.; et al. "Neutron-Induced Activities in Soil Elements, Operation PLUMBBOB, Project 2.2." Albuquerque, NM: Field Command, DNA. 01/02/80. 82 pages. WT-1411-Ex. AD/A 995 019.*

119. Corsbie, R. "Operation PLUMBBOB, Civil Effects Test Group Project Summaries," Mercury, NV: FCDA. May 1957. 114 pages. AD/B 951 587.*

120. Cosenza, C.; Coy, R.; Kahle, D.; et al. "Instrumentation for Measuring Effects Phenomena Inside the Fireball, Project 8.3b." Albuquerque, NM: Field Command, DNA. 6/23/61. 224 pages. WT-1443-Ex. AD/A 995 020.*

121. Cowan, M. "Plutonium Contamination from One-Point Detonation of an XW-25." Albuquerque, NM: Field Command, DASA. 11/06/60. 138 pages. WT-1510.***

122. Cramer, J.W., CWO, USA, Ass't Adjutant Gen. [Form Letter, AMCML 201, Subject: Exposure to Ionizing Radiation with Hdqrs., Camp Desert Rock Memos 9 and 10.] Presidio, San Francisco: Sixth U.S. Army. (Undated.) 10 pages.***

123. Cruise, R.; Shipman, T.; Johnson, G. [General Correspondence Concerning Radiological Safety.] Los Alamos, NM: Los Alamos Scientific Laboratory. 1957. 4 pages.***

124. Davis, N.J. "Protection Afforded by Field Fortifications Against Nuclear Weapons Effects, Project 50.6." Fort Belvoir, VA: ERDL. 12/08/58. 61 pages. 1557-TR. AD 860 811.*

125. Deeds, F.; Fleming, F.; Stump, R. "Mine-Field Clearance by Nuclear Weapons, Project 6.1." Albuquerque, NM: Field Command, DASA. 08/16/60. 112 pages. WT-1435. AD 358 121.*

126. DELETED

127. Defense Atomic Support Agency, Field Command. "Technical Summary of Military Effects, Programs 1-9," Operation PLUMBBOB. Albuquerque, NM: Field Command, DASA. 08/15/62. 230 pages. WT-1445. AD 995 075.*

REFERENCES
(Continued)

128. DELETED

129. Denton, C. "Reporter Near Site Likens A-Blast to Raging Tornado." Yucca Flat, NV: 07/05/57. 1 page.***

130. Department of State, Bureau of Public Affairs, "Documents on Disarmament (1945-1959)." Washington, DC: GPO. August 1960. #7008.

131. Department of the Air Force. "PLUMBBOB Correspondence." U.S. Air Force. 1956. 150 pages.***

132. Department of the Army. "Atomic Energy Indoctrination." Washington, DC: AGO. 09/01/50. 145 pages. PAM 20-110.***

133. Department of the Army. Radiac Set AN/PDR-27. Washington, DC: AGO. August 1952. 116 pages. TM11-5543.***

134. Department of the Army. Radiac Set AN/PDR-39. Washington, DC: AGO. July 1956. 54 pages. TM11-5514A.***

135. Department of the Army. "Supplement to TM11-5514, Radiac Training Sets AN/PDR-T1A and AN/PDR-T1B, and Radiac Set AN/PDR-39." Washington, DC: AGO. 08/05/55. 84 pages.***

136. Derksen, W.; Monahan, T.; Bracciaventi, J.; et al. "Prediction of Thermal Protection of Uniforms, and Thermal Effects on a Standard Reference Material, Project 8.2." Albuquerque, NM: Field Command, DASA. 05/02/60. 50 pages. WT-1441. AD 360 876.*

137. Dick, J.L., Maj., USAF; Baker, T. "Monitoring and Decontamination Techniques for Plutonium Fallout on Large Area Surfaces." Albuquerque, NM: AFSWC. 03/03/67. 61 pages. WT-1512. AD 810 310.*

138. Diianni, E.; Riggin, F.C. "Evaluation of Military Radiac, Project 2.8." Albuquerque, NM: Field Command, DASA. 11/09/59. 58 pages. WT-1417. AD 360 872.*

139. Director of Military Application. [Atomic Energy Commission Proposed Test Plans for CY 1957, Report to the General Manager by the DMA.] AEC. 02/08/57. 19 pages. AEC 944/8.**

140. Distenfel, D.; Weaver, C.; Goeke, R. "Final Report Unit 260 Mobile Off-site Radiation Data Collection." Santa Fe, NM: AEC, OTM. October 1957. 10 pages.***

141. Dolen, W.K.; et al. "Effects on Materials Exposed to a Nuclear Detonation, Operation PLUMBBOB, Project 41.1c." Albuquerque, NM: Field Command DASA. November 1964. 142 pages. WT-1519. AD 369 966.*

REFERENCES
(Continued)

142. Edgerton, Germeshausen & Grier, Inc. "Gamma Dosimetry by Film-Badge Techniques, Project 39.1a." Albuquerque, NM: Field Command, DASA. 07/17/59. 103 pages. WT-1466. AD 339 487L.*

143. Elder, G. "Effects of Nuclear Detonations on Nike Hercules, Operation PLUMBBOB, Project 6.5." 1960. ***

144. Elmgren, J. [Letter to the Office of Test Director, Subject: Recovery Crews for WHITNEY, with Layout Sketches and Records. Mercury, NV: Reynolds Electrical and Engineering Company, Inc. 09/10/57. 14 pages.**

145. Essington, E.; Forslow, E. "Distribution of Radioactivity in and near the RAINIER Rubble Chimney." Las Vegas, NV: Teledgne Isotopes. September, 1971. 81 pages. NV01229180. AD/A 076 360.*

146. Evans, R.D. The Atomic Nucleus. New York, NY: McGraw-Hill Publishing Co. 10/03/55. 972 pages.

147. Evans, W.A. "History of 4950th Test Group (Nuclear) in Operation PLUMBBOB." Kirtland AFB, NM: AFSWC. 01/06/58. 128 pages. SWC8S21045-1/3.***

148. Flathau, W.; Breckenridge, R.; Wiehle, C. "Blast Loading and Response of Underground Concrete-Arch Protective Structures, Project 3.1." Albuquerque, NM: Field Command, DASA. 06/05/59. 144 pages. WT-1420. AD/B 001 855.*

149. General Electric Company - TEMPO. "Compilation of Local Fallout Data from Test Detonations, 1945-1962." Vol. I: Continental U.S. Tests, Extracted from DASA 12. Washington, DC: Defense Nuclear Agency. 1979. 600 pages. DNA1251-1[Ex].**

150. Gerster, M. "The Special Weapons Center and Atomic Testing." Kirtland, NM: AFSWC. 305 pages. K242.01-K242.04. January, 1957.***

151. Gilstad, D.; Weeber, C.G.; Kviljord, A.; et al. "Structural Response and Gas Dynamics of an Airship Exposed to a Nuclear Detonation, Operation PLUMBBOB, Project 5.2." Albuquerque, NM: Field Command, DASA. 04/25/60. 99 pages. WT-1431. AD 360 874.*

152. Gise, L. [Memorandum for Test Manager, Subject: AEC Unofficial Observers, with Attachment.] Washington, DC: AEC, Division of Military Application. 08/27/57. 4 pages.**

153. Gise, L.P., Ass't Director, DMA. [Memo to: R.F. Hertford, Manager, ALOO, Subject: USAF-AEC Agreement on Use of Lookout Mountain Lab at (29-2)-383, w/encl.] Washington, DC: Atomic Energy Commission, DMA. 04/30/57. 29 pages. AT292383.**

154. Glasstone, S.D.; Dolan, P.H. The Effects of Nuclear Weapons. Washington, DC: GPO. 1977. 653 pages.

REFERENCES
(Continued)

155. Goetz, J.; Kaul, D.; et al. "Analysis of Radiation Exposure for Task Force Warrior, Shot SMOKY," Washington, DC: Defense Nuclear Agency. 05/31/79. 112 pages. DNA-4747F. AD/A 070 239.*

156. Goetz, J.; Kaul, D.; Klemm, J.; et al. "Analysis of Radiation Exposure for Task Force BIG BANG, Shot GALILEO, Exercise Desert Rock VII-VIII, Operation PLUMBBOB." Washington, DC: Defense Nuclear Agency. 12/07/79. 97 pages. DNA-4772F. AD/A 085 801.*

157. Goetz, J. [Calculations on Scaling DIABLO Equipment Display Area for HOOD.] McLean, VA: Science Applications, Inc. 06/02/80. 2 pages.***

158. Goldizen. V.C., et al. "Missile Studies with a Biological Target," Project 33.4." Albuquerque, NM: Lovelace Foundation; CETG. April 1960. 64 pages. DTL019-848. AD/A 077 510.*

159. Goode, T.; Shockley, W.; Cunny, R.; et al. "Soil Survey and Backfill Control in Frenchman Flat, Project 3.8." Albuquerque, NM: Field Command, DASA. 10/23/59. 174 pages. WT-1427. AD 460 289.*

160. Greene, W.; Minge, W.; Yost, M. "History of the AFSWC for 1 July-31 December 1957," Volume 1: Narrative; and Volume 2: Appendix. Kirtland AFB, NM: AFSWC. June, 1958. 212 pages. K242-01 K2823.***

161. Greig, A.; Pearse, H. "Thermal Radiation Measurements (Parts I and II), Project 39.3." [Washington, DC]: AEC. January, 1958. 38 pages. ITR-1502. AD/A 078 822.*

162. Gulley, W.; Metcalf, R.; Wilson, M; et al. "Evaluation of Eye Protection Afforded by an Electromechanical Shutter, Project 4.2." Albuquerque, NM: Field Command. DASA. 04/29/60. 54 pages. WT-1429. AD 615 738.*

163. Haas, P.; Shaull, J.; Behrens, W. "Effect of Nuclear Radiation on Semiconducter Devices, Project 6.2a." Albuquerque, NM: Field Command, DASA. 10/07/60. 22 pages. WT-1489. AD 339 501.*

164. Haas, P.; Wimenitz, F.; Hoadley, J.; et al. "Measurement of the Magnetic Component of the Electromagnetic Field Near a Nuclear Detonation, Project 6.2." Albuquerque, NM: Field Command, DASA. 05/08/82. 68 pages. WT-1436. AD/B 951 750.*

165. Halsey, J.; Barton, M. "Spectra of Ground Shocks Produced by Nuclear Detonations, Operation PLUMBBOB, Project 1.9." Albuquerque, NM: Field Command, DASA. 08/17/59. 99 pages. WT-1487. AD 491 311.*

166. Hanlon, P.; Cooper, S.E.; Ives, J.S.; et al. "Field Test of a System for Measuring Blast Phenomena by Airborne Gauges, Operation PLUMBBOB, Project 1.2." White Oak, MD: Naval Ordnance Lab. 10/11/57. 20 pages. ITR-1402. AD/B 951 745.*

REFERENCES
(Continued)

167. Hanscome, T.; Caldwell, P.; Gorbics, S.; et al. "Investigation of Effects of Nuclear Detonations on Electromagnetic Wave Propagation and Nuclear Radiation Detector Design, Project 2.7." Albuquerque, NM: Field Command, DNA. 01/09/80. 102 pages. WT-1416-Ex. AD/A 995 057.*

168. Harner, E.L. "Summary of Technical Experiments to Determine Effects of Atmospheric Nuclear Test Series on Military Targets," Washington, DC: DNA. May, 1976. 114 pages. DASIAC SR-156.***

169. Headquarters, Camp Desert Rock. "After Action Reports by Technical Services Chiefs, Operation PLUMBBOB, Camp Desert Rock VII and VIII. Camp Desert Rock, NV: Hdqrs. Camp Desert Rock. 1957. 100 pages. AD 080 236.*

170. Headquarters, Camp Desert Rock. [Memoranda, #1-33, May-June 1957.] Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 07/05/57. 107 pages. AD 080 257.*

171. Headquarters, Exercise Desert Rock VII & VIII. Operation Order Number 7, Exercise Desert Rock VII and VIII, Shot HOOD. Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 06/28/57. 39 pages.**

172. Headquarters, Exercise Desert Rock VII and VIII. "Report of Test, Infantry Troop Test, Exercise Desert Rock VII and VIII." Camp Irwin, CA: Hdqrs., Ex. Desert Rock. 12/11/57. 90 pages. AD/A 075 358.*

173. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order 17; Desert Rock VII and VIII; SMOKY." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 08/23/57. 60 pages. AD/A 995 039.*

174. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 1, Desert Rock VII, BOLTZMANN." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 05/11/57. 23 pages. AD/A 080 266.*

175. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 10, Desert Rock VII and VIII, PASCAL A." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 07/10/57. 11 pages. AD 080 252.*

176. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 11, Desert Rock VII and VIII, JOHN." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 07/13/57. 23 pages. AD/A 080 253.*

177. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 12, Desert Rock VII and VIII, KEPLER," Camp Desert Rock, NV: Camp Desert Rock. 07/18/57. 25 pages. AD 080 254.*

178. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 13, Desert Rock VII and VIII, SHASTA." Camp Desert Rock. 07/02/57. 31 pages.***

REFERENCES
(Continued)

179. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 14, Desert Rock VII and VIII, STOKES." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 07/30/57. 22 pages.***

180. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 15, Desert Rock VII and VIII, SATURN." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 08/21/57. 11 pages.***

181. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 16, Desert Rock VII and VIII, FRANKLIN PRIME." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 08/12/57. 15 pages.***

182. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 18, Desert Rock VII and VIII, DOPPLER." Camp Desert Rock, NV: Camp Desert Rock. 08/15/57. 25 pages.***

183. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 2, Desert Rock VII and VIII, FRANKLIN." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 05/15/57. 23 pages. AD/A 080 267.*

184. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 20 and 21, Desert Rock VII and VIII; WHEELER and LAPLACE." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 08/28/57. 30 pages.***

185. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 3, Desert Rock VII, LASSEN." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 05/21/57. 8 pages. AD/A 080 268.*

186. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 4, Desert Rock VII and VIII, WILSON." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 05/29/57. 26 pages. AD/A 080 259.*

187. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 5, Desert Rock VII and VIII, PRISCILLA." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 06/11/57. 40 pages. AD/A 080 260.*

188. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 6, Desert Rock VII and VIII, DIABLO." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 06/23/57. 55 pages. AD/A 080 250.*

189. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 8, Desert Rock VII and VIII, OWENS." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 07/01/57. 55 pages.**

190. Headquarters, Exercise Desert Rock VII and VIII. "Operation Order Number 9, Desert Rock VII and VIII, DIABLO." Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 07/08/57. 16 Pages. AD/A 080 251.*

191. Headquarters, Exercise Desert Rock VII and VIII. Annex C: Rad-safety Plan for Opn. 07 [Desert Rock VII.] Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 06/28/57. 4 pages.***

REFERENCES
(Continued)

192. Headquarters, Lexington Blue Grass. Letter to: S.E. Weary (JAYCOR); Subject: Film Badge Information. Lexington, KY: SDSRR-LQCP, Army Depot. 06/16/78. 2 pages.**

193. Headquarters, Sharpe General Depot. [Correspondence File, Subject: Monthly Cost Reports.] Lathrop, CA. 1957. 7 pages.***

194. Headquarters, Sharpe General Depot. [Memorandum, Subject: Request and Authorization for Civilian Travel at Government Expense.] Lathrop, CA. 1957. 3 pages.***

195. Headquarters, Sharpe General Depot. [Miscellaneous Telegrams 1957]. Lathrop, CA. 1957. 12 pages.***

196. Headquarters, Sharpe General Depot. [Special Orders, March-August, 1957]. Lathrop, CA. 1957. 25 pages.***

197. Headquarters, Sixth Army, OCG. "Camp Desert Rock Information Book, U.S. Army, 1957." Presidio, San Francisco: Sixth U.S. Army. (Undated) 14 pages.***

198. Headquarters, Sixth Army. "Directive for Exercise Desert Rock VII and VIII." Presidio, San Francisco: Sixth U.S. Army. 03/27/57. 35 pages. AD/A 995 041.*

199. Headquarters, Sixth Army. Change 1 to Directive for Exercise Desert Rock VII and VIII. Presidio, San Francisco: Hdqrs., Sixth Army. 05/15/57. 30 pages. AMGCT-4-354-21.***

200. Headquarters, Sixth Army. Exercise Desert Rock VII and VIII: Final Report of Operations. Presidio, San Francisco: Sixth U.S. Army. 11/25/57. 107 pages. AG-S-9531. AD/A 077 515.*

201. Headquarters, Sixth Army. Letter of Instruction, Subject: Use of Camp Desert Rock, Nevada, to Support Special Field Exercises, with 1 encl. Presidio, San Francisco: Sixth U.S. Army. 02/20/57. 4 pages. AD/A 080 256.*

202. Hertford, K., Manager, Albuquerque Operations. [Memorandum to Test Manager, Subject: Directive for Operation PLUMBBOB.] Albuquerque, NM: Atomic Energy Commission. ETP: CLL-3492. 03/13/57. 5 pages.***

203. Houghten, R.; Harvey, R. "Accuracy and Reliability of a Short-Baseline NAROL System, Project 6.4." Albuquerque, NM: Field Command, AFSWP. 03/03/58. 81 pages. ITR-1438. AD/A 995 005.*

204. Hunter, W.A., Col., USAF. [Letter to J.E. Reeves, Director, Test Division, Subject: Future Cloud Sampling Requirements.] Kirtland AFB, NM: AFSWC, Operations Division 05/09/57. 1 page.***

REFERENCES
(Continued)

205. Hurst, G.S.; Ritchie, R.H. "Radiation Dosimetry for Human Exposures, Project 39.5." Oak Ridge, Tennessee: ORNL. March 1958. 147 pages. WT-1504. AD/B 951 581.*

206. DELETED (See Reference 205)

207. Hynes, R.J., Lt. Col., USAF. [Letter to Test Manager, Subject: Film Badge Requirements.] Kirtland AFB, NM: Air Force Special Weapons Center. 02/25/57. 3 pages.***

208. Imirie, G.W.; et al. "Depth Dose Studies in Phantoms with Initial Bomb and Neutron Radiation." Naval Medical School; Brookhaven National Laboratory. October 1958. 61 pages. WT-1508. AD/B 951 725.*

209. Johnson, Gerald "Test Director's Report on Operation PLUMBBOB." Livermore, CA: University of California Radiation Laboratory. 11/15/57. 90 pages. UCRL 5166. AD/A 995 021.*

210. Johnson, G. [Memo to J.E. Reeves, Test Manager, Subject: Retention of F84-G Aircraft.] Mercury, NV: Atomic Energy Commission, NTO. 07/11/57. 1 page.***

211. Joint Board on Future Storage of Atomic Weapons. "Safety Criteria for Storage Handling of Plutonium Bearing Weapons." Washington, DC: Defense Atomic Support Agency. 1959. 25 pages.***

212. Jones, T.H. "A Prediction System for the Neutron-Induced Activity Contribution to Fallout Exposure Rates." San Francisco, CA: Naval Radiological Defense Laboratory. October 1956. 50 pages. NRDL-TR-1056. AD 639 446.*

213. Julian, A. "In-flight Structural Response of FJ-4 Aircraft to Nuclear Detonations, Operation PLUMBBOB, Project 5.3." Washington, DC: Bureau of Aeronautics. 02/10/60. WT-1432. AD 360 875.*

214. Kaericher, K.C.; Martin, T.P.; Banks, J.E. "Nuclear Radiation Received by Aircrews Firing the MB-I Rocket, Operation PLUMBBOB, Project 2.9." Albuquerque, NM: Field Command, DASA. 05/27/59. 18 pages. WT-1418. AD/B 951 740.*

215. Kennedy, E. "Documents to be Released at Senate Health Subcommittee Hearing Held in Salt Lake City on Health Effects of Nuclear Tests." Washington, DC: U.S. Senate. 04/17/79. 80 pages.

216. Kennedy, E. "Statements on Introduced Bills and Joint Resolutions." Washington, DC: U.S. Senate. 10/09/79. 5 pages. Vol. 125, No. 135.

217. Killian, B.; Emmons, A. "Field Radiological Defense Technical Operations," Washington, DC: Department of Commerce, OTS. 09/09/59. 32 pages. WT-1482. AD 611 235.*

REFERENCES
(Continued)

218. Krey, P.; Wilsey, E., McNeilly, J.; et al. "Soil Activation by Neutrons, Project 2.1." Albuquerque, NM: Field Command, DASA. 05/16/60. 116 pages. WT-1410. AD/A 995 006.*

219. Kuhn, U.; Kyner, R. "Large-Animal Neutron-Gamma Irradiation Experiment," Project 39.6a." Oak Ridge, Tennessee: AEC. May 1958. 55 pages. ITR-1476. AD/A 077 512.*

220. Lapp, Ralph E.; Andrews, H.L. Nuclear Radiation Physics. 2nd Edition. New York, NY: Prentice-Hall, Inc. 1954. 532 pages.

221. Lariviere, P.D.; Brown, S.L; Sartor, J.D.; et al. "Local Fallout from Nuclear Test Detonations," in Transport and Distribution of Local (Early) Fallout From Nuclear Weapon Tests (U)." Edgewood Arsenal, MD: Army Nuclear Defense Laboratory May, 1965. 579 pages. DASA 1251. Vol. V.***

222. Larson, K.H. "Distribution, Characteristics, and Biotic Availability of Fallout, Operation PLUMBBOB, Projects 37.1, 37.2, 37.3, and 37.6." University of California. 07/26/66. 276 pages. WT-1488. AD/A 077 509.*

223. Laug, E.; Leininger, H. "Blast Effects on Glass Vacuum Containers, Project 38.1-11." Battle Creek, MI.: FCDA. March 1958. 14 pages. WT-1461. AD 611 236.*

224. Laursen, H. " The Use of Balloons to Suspend Nuclear Test Devices, Project 63.1." Albuquerque, NM: Sandia Corporation. 06/12/58. 71 pages. WT-1522. AD/A 995 078.*

225. Lee, W.; Krumboltz, H.; Glimber, G. "Attenuation of Electromagnetic Radiation Through an Ionized Medium, Project 6.3." Albuquerque, NM: Field Command, DASA. 06/13/60. 60 pages. WT-1437. AD 311 158.*

226. Leininger, H.; Laug, E.; Chapman, R.; et al. "Effect of Fallout Contamination on Raw Agricultural Products, Project 38.1" Battle Creek, MI: FCDA. March 1958. 18 pages. WT-1497. AD 607 647.*

227. Leininger, H.; Laug, E.; McConnell, H.; et al. "Effect of Fallout Contamination on Processed Foods, Containers and Packaging, Project 38-1.I." Battle Creek, MI: FCDA. March 1958. 19 pages. WT-1496. AD 611 237.*

228. Leya, Charles, J., Jr. [Notes From SAI Interview with Former 1st Lt. Charles Leya, USMC, on Shot HOOD and Project 52.1, and Shot PRISCILLA and HOOD.] Newbury, NY: 09/27/80. 4 pages.***

229. Lobdell, M. "Radiological Defense Operations Photography, Project 36.3." Washington, DC: FCDA. 11/11/57. 42 pages. WT-1484. AD/A 995 067.*

REFERENCES
(Continued)

230. Lock, H. "HOOD Shot" [One Marine's Personal Recollection.] Washington, D.C.: Marine Nuclear Test Personnel Review. 1979. 2 pages.***

231. Marine Corps Nuclear Test Personnel Review. Operation PLUMBBOB: List of Participation Units. Washington, DC: Marine Nuclear Test Personnel Review. 1979. 1 page.**

232. Mather, R.L. "Chance Observations of Fallout Cloud Transit Radiation at Operation PLUMBBOB." San Francisco: NRDL. 01/30/59. 16 pages. NRDLTR344(Rev.). AD 239 961.*

233. McConnell, H.; Chapman, R.; Spiher, A.; et al. "Measuring and Monitoring Training Exercise: Foodstuffs," Project 38.3. Battle Creek, MI: FCDA. December, 1959. 28 pages. WT-1498. AD 611 238.*

234. McDonnell, G.; Crosby, W.; Tessmer, C. "Effects of Nuclear Detonations on a Large Biological Specimen (Swine), Project 4.1." Albuquerque, NM: Field Command, DASA. 08/11/61. 200 pages. WT-1428. AD 460 308.*

235. McNeilly, J.H.; et al. "External Neutron Measurements, 1952 through 1958." Edgewood Arsenal, MD: U.S. Chemical Warfare Laboratories. March, 1968. 135 pages. CWLR-2377.***

236. Meszaros, J.; Burden, H.; Day, J. "Instrumentation of Structures for Airblast and Ground-Shock Effects, Project 3.7." Albuquerque, NM: Field Command, AFSWP. 12/06/57. 62 pages. ITR-1426. AD/B 951 598, AD 611 230.*

237. Meszaros, J.; Keefer, J.; Day, J. "Blast Measurements for CETG Projects, Project 39.2." Washington, DC: OTS. April 1960. 96 pages. WT-1501. AD 350 279.*

238. Metzger, H. The Atomic Establishment. Simon and Schuster: New York. 1972. 318 pages.

239. Miller, C.F. "Analysis of Radiological Decontamination Data Obtained from Field Tests." San Francisco, CA: NRDL. 04/03/59. 80 pages. TR-321. AD 219 720.*

240. Miller, C.F. "Some Properties of Radioactive Fallout: Balloon-Mounted Shot PRISCILLA." San Mateo, CA: URS Research Co. September 1969. 16 pages. URS7574.***

241. Miller, C.F. "Some Properties of Radioactive Fallout: Surface Detonation COULOMB C: Final Report." San Mateo, CA: URS Research Co. September 1969. 23 pages.***

242. Milligan, M.; Salop, J.; Weaver, C. [Letters to AEC and NRL, Subject: Results of Radiation Exposure.] Los Alamos, NM: Los Alamos Scientific Laboratory. 07/15/57. 3 pages.**

REFERENCES
(Continued)

243. Morgan, K.Z. "Cancer and Low Level Ionizing Radiation." Bulletin of the Atomic Scientists. Chicago, Illinois: September 1978. 12 pages. Vol. 34, #7.***

244. Morgan, K.Z.; Turner, J.E. Principles of Radiation Protection: A Textbook of Health Physics. New York, NY: R.E. Krieger Publishing Co. 1973. 622 pages.

245. Morgenthau, M.; Meieram, H.B.; Showers, R.; et al. "Vol II: Compilation of Fallout Patterns and Related Data. Part 2: PLUMBBOB Through HARDTACK (U)." Edgewood Arsenal MD: Army Nuclear Defense Laboratory. August 1963. 456 pages. DASA1251 Vol. II.***

246. National Bureau of Standards. "Maximum Permissible Radiation Exposures to Man" (Addendum to National Bureau of Standards Handbook #59.) Washington, DC: NBS. 04/15/58. 7 pages. Handbook #59.**

247. Negron, R.; Murphy, H. [Notes of Telephone Interviews to Reconstruct Marine Activities at Shot HOOD.] Washington, DC: Marine NTPR. April 1978. 21 pages.***

248. Obermiller, S.; Lowery, C.; Jordan, C; et al. "Atmospheric Nuclear Weapons Tests (1945-1962): Exposure Criteria, Film Badge, and Decontamination Summary." Washington, DC: Defense Nuclear Agency. 10/23/79. 65 pages.***

249. Office of Test Information. "Background Information of Nevada Nuclear Tests." Las Vegas, NV: AEC. 07/15/57. 75 pages.***

250. Office of the Deputy Director. "Plan for the U.S. Army Infantry Battle Group Test, for Exercise Desert Rock VII and VIII." Camp Desert Rock, NV: Hqdrs., Camp Desert Rock. 1957. 125 pages. Ex Memo 1.***

251. Pearce, G. [Notes from SAI Interview with Lt. Col. Gary Pearce, USMC (Ret.), Equipment Officer, 4th MCPAEB.] McLean, VA. 04/22/80. 1 page.***

252. Perret, W. "Ground Motion Studies at High Incident Overpressure, Project 1.5." Albuquerque, NM: Field Command, DASA. 06/20/60. 85 pages. WT-1405. AD 611 229.*

253. Pickering, J. [Memo to AMD/RDR, Subject: USAF School of Aero Space Medicine Involvement in Atmospheric Nuclear Weapons Tests.] Brooks AFB, TX: US Air Force School of Aerospace Medicine. 06/08/78. 4 pages.***

254. Pickering, J.; Williams, D.; Melville, G. "Biological Effects of Nuclear Radiation on the Monkey: Two-Year Evaluation, Project 39.6," (Supplement 1). Oak Ridge, TN: ORNL. June, 1959. 51 pages. WT-1542. AD 611 247.*

REFERENCES
(Continued)

255. Placak, O., Carter, M.; Gilmore, R; et al. "Operation PLUMBBOB Offsite Radiological Safety Report." Mercury, NV: REECo. 1957. 194 pages. AD/A 075 357.*

256. Plum, W. "Performance of a High-Speed Spectrographic System, Project 8.3a." San Francisco, CA: NRDL. 09/20/57. 200 pages. ITR-1442. AD/A 077 501.*

257. Reed, J. "Operation PLUMBBOB: Blast and Prediction Units." Albuquerque, NM: Sandia Laboratory. 05/01/57. 12 pages. SCTM-186-57-51.***

258. Reeves, J. [Letter to Col. P.R. Wignall, CMDR, 4950th Test Group (Nuclear), Subject: Crew Dosage, MG-1 Shot.] Albuquerque, NM: Atomic Energy Commission. 03/05/57. 2 pages.***

259. Reeves, J. [Memo to Test Director, Subject: Participation of Military Personnel Assigned to the Nevada Test Organization in Desert Rock Exercises] Mercury, NV: w/encl. 07/17/57. 2 pages.***

260. Reeves, J. [Selected Extracts From: Report of the Test Manager, Operation PLUMBBOB.] Nevada Test Site. [AEC.] AD/A 995 083.*

261. Reeves, J. [Telex Concerning Shots SMOKY and GALILEO.] Mercury, NV: Nevada Test Organization. 1957. 6 pages.**

262. Reeves, J. [Telex to Distribution, Subject: Shots JOHN and OWENS.] Mercury, NV: Atomic Energy Commission. 07/13/57. 3 pages.***

263. Reeves, J. [Telexes from Test Manager to Division of Military Applications Following Detonations.] Mercury, NV: Atomic Energy Commission. 1957. 20 pages.**

264. Reinhardt, G.C., Col., USA; Kintner, W.R., Lt. Col. USA. "Atomic Weapons in Land Combat." Harrisburg, PA: Military Service Publishing Co. August 1954. 243 pages.***

265. Reynolds Electrical and Engineering Company, Inc. "Onsite Rad-safe Support, Shot MORGAN." Mercury, NV: REECo. 1957. 12 pages.**

266. Reynolds Electrical and Engineering Company, Inc. "Onsite Rad-safe Support, Shot PRISCILLA." Las Vegas, NV: REECo. 1957.**

267. Reynolds Electrical and Engineering Company, Inc. "Onsite Rad-safe Support, Shot HOOD." Mercury, NV: REECo. 1957. 7 pages.**

268. Reynolds Electrical and Engineering Company, Inc. "Onsite Rad-safe Support: Shots DIABLO through FRANKLIN PRIME". Mercury, NV: REECo. 1957.**

269. Reynolds Electrical and Engineering Company, Inc. "Onsite Rad-safe Support, COULOMB A." Mercury, NV: REECo. 07/01/57. 10 pages.**

REFERENCES
(Continued)

270. Reynolds Electrical and Engineering Company, Inc. "Onsite Rad-safe Support, Shot FRANKLIN." Mercury, NV: REECo. 06/03/57. 10 pages.**

271. Reynolds Electrical and Engineering Company, Inc. "Onsite Rad-safe Support, Shot LASSEN." Mercury, NV: REECo. 06/19/57. 10 pages.**

272. Reynolds Electrical and Engineering Company, Inc. "Onsite Rad-safe Support, Shot WILSON." Mercury, NV: REECo. 06/22/57. 10 pages.**

273. Reynolds Electrical and Engineering Company, Inc. "Photographic Dosimetry, Third Supplemental Evaluation." Mercury, NV: REECo. 10/17/57. 7 pages.**

274. Reynolds Electrical and Engineering Company, Inc. [Access Permits, PASCAL A.] Mercury, NV: REECo. 07/14/57. 6 pages.**

275. Reynolds Electrical and Engineering Company, Inc. [FIZEAU Radiological Survey and Recovery Operations Access Permits.] Mercury, NV: REECo. 1957. 20 pages.**

276. Reynolds Electrical and Engineering Company, Inc. [Rad-safe Division Files, Subject: Radiological Safety Division Monitoring and Recovery Parties Access Plans.] Mercury, NV: Reynolds Electrical and Engineering Company, Inc. 09/25/57. 9 pages.**

277. Reynolds Electrical and Engineering Company, Inc. [Recovery Operations, PASCAL B.] Mercury, NV: REECo. 1957. 3 pages.**

278. Reynolds Electrical and Engineering Company, Inc. [REECo Dosimetry Records, 31 August 1957 and 1 August - 31 August 1957.] Mercury, NV: REECo. 1957.**

279. Reynolds Electrical and Engineering Company. "Monitor's Maze and Information Bulletins." Mercury, NV: REECo. (Undated.) 300 pages.**

280. Reynolds Electrical and Engineering Company. "Onsite Rad-safe Support, Shot GALILEO." Las Vegas, NV: REECo. 1957.**

281. Reynolds Electrical and Engineering Company. Radiological Safety Handbook for Nevada Test Site 1957. Mercury, NV: REECo. 1957. 29 pages.**

282. Reynolds Electrical and Engineering Company. [Access Permits for LAPLACE Recovery Operations.] Mercury, NV: REECo. 1957. 16 pages.**

283. Reynolds Electrical and Engineering Company, Inc. [Rad-safe Division Files, Subject: NEWTON Radiological Survey Access Permits and Isodose Maps.] Mercury, NV: Reynolds Electrical and Engineering Company. 1957. 11 pages.**

284. Richards, W.; Watson, B. "Operations of the Fallout Group of Project 50.3." Fort Monmouth, NJ: U.S. Army. 08/15/60. 77 pages. AD 252 267.*

REFERENCES
(Continued)

285. Richmond, D.R.; et al. "Blast Biology - A Study of the Primary and Tertiary Effects of Blast in Open Underground Protective Shelters." Oak Ridge, TN: ORNL. February, 1959. 68 pages. WT-1467. AD/A 077 511.*

286. Richmond, D.; White, C.; Sanchez, R. "The Internal Environment of Underground Structures Subjected to Nuclear Blast. II Effects of Mice Located in Heavy Concrete." Oak Ridge, TN.: ORNL. 05/31/60. 48 pages. WT-1507. AD 611 264.*

287. Rigotti, D.; Kinch, H.; Funsten, H.; et al. "Neutron Flux From Selected Nuclear Devices, Project 2.3." Albuquerque, NM: Field Command, DASA. 04/28/60. 63 pages. WT-1412. AD/A 995 074.*

288. Roebeck, G.G.; Woodward, R.L.; Muschler, W.K. "Water Contamination in Fallout Areas." Cincinnati, OH: Robert A. Taft Engineering Center. May, 1958. 50 pages.***

289. Saunders, David I., MAJ., USA. "Final Report, Radiological Safety Section, Exercise Desert Rock VII and VIII," with 6 encls. Camp Desert Rock, NV: Hdqrs., Camp Desert Rock. 1957. 20 pages.***

290. Schuert, E.A. "Fallout Studies and Assessment of Radiological Phenomena, Project 32.4." Washington, DC: DNA. October 1979. 112 pages. WT-1465 (Ex.). AD/A 995 003.*

291. Science Applications, Inc. Film Badge Dosimetry Analysis: Exercise Desert VII-VIII. McLean, VA: SAI. 06/18/79. 345 pages.***

292. Sherwood, A.M., Maj., USAF. [Letter to J.E. Reeves, Test Manager, Subject: Air Photographic and Charting Service United States Air Force.] Los Angeles, CA: 1352nd Motion Picture Sqdn., USAF. 10/01/57. 2 pages.**

293. Sigoloff, S. "Remote Radiological Monitoring, Project 39.0." Mercury, NV: Civil Effects Test Group. 1960. 50 pages. WT-1509. AD/A 077 508.*

294. Sigoloff, S.; Logie, L.; Borella, H.; et al. "Radiation Measurements Utilizing the USAF Chemical Dosimeters, Project 39.1." Albuquerque, NM: Field Command, AFSWP. 1958. 66 pages. WT-1500. AD 339 464.*

295. Smith, R.J.; et al. "Initial Gamma Data from Nuclear Weapons Tests 1940-1962." Edgewood Arsenal, MD: U.S. Army Nuclear Defense Laboratory. July 1965. NDL-TR-53.***

296. Sobsey, C. "Biggest Blast of Series Damages Control House," Los Angeles Examiner. Los Angeles, CA: 06/25/57. 2 pages.

297. Stalk, G.; Gee, R.; Bednar, J.; et al. "In-flight Structural Response of an F-89D Aircraft to a Nuclear Detonation, Project 5.5." Albuquerque, NM: Field Command, DASA. 03/22/60. 56 pages. WT-1434. AD 357 975.*

REFERENCES
(Continued)

298. Starbird, A. [Memo to: J.E. Reeves, Test Manager, Subject: Classified Film Report for Operation PLUMBBOB. W/encl.] Washington, DC: Atomic Energy Commission. 04/24/57. 5 pages.**

299. Strauss, Lewis. "Letter to President Eisenhower from Chairman of the AEC." AEC. 12/21/56. 2 pages.**

300. Strope, W. "Project 32.3: Evaluation of Countermeasure System Components and Operational Procedures." San Francisco, CA: Civil Effects Test Group. 08/14/58. 159 pages. WT-1464. AD 611 260.*

301. Suhosky, R. "Biggest Shot." Marine Corps, DOD. September 1957. 6 pages.***

302. Swift, L. "Project 1.4: Stress and Strain at High Incident Overpressures." Albuquerque, NM: Field Command, DASA. 05/10/60. 136 pages. WT-1404. AD 491 310.*

303. Swift, L.; Sachs, D.; Kriebel, A. "Air-blast Phenomena in the High-Pressure Region, Project 1.3." Albuquerque, NM: Field Command, DASA. 12/15/60. 134 pages. WT-1403. AD 611 257.*

304. Taplin, G.; Malin, K.; Griswold, M.; et al. "Chemical Dosimetry of Prompt and Residual Radiations from Nuclear Detonations, Project 37.5." Oak Ridge, TN: ORNL. July 1960. 34 pages. WT-1493. AD 611 249.*

305. Taylor, L.B. History of the Air Force Atomic Cloud Sampling Volume 1 Narrative and Volume 2, Appendix. Kirtland AFB, NM: AFSWC. January 1963. 330 pages. K242.04-8.***

306. Taylor, L. "Radiation Protection Standards." Cleveland, OH: CRC Press. May 1977. 110 pages.***

307. Tomnovec, F.M. "Review of Neutron-Induced Activity Studies." ST: The Fields of Calculated Neutron-Induced Radiation Fields (U). San Francisco, CA: Naval Research Defense Lab. October, 1965. 76 pages. NRDL TR 860.***

308. Tompkins, R.; Weaver, C.; Peterson, G. "Neutron and Initial-Gamma Shielding, Project 2.4." Albuquerque, NM: Field Command, DASA. 01/23/61. 120 pages. WT-1413. AD/A 995 035.*

309. Tschirgi, H. [Statement by Brig. Gen. Harvey Tschirgi, USMC (Ret.), former C.G., 4th MCPAEB, to Capt. James McNabb, MNTPR]. Washington, DC: Marine Corps NTPR. 1979. 1 page.***

310. United States Department of Commerce. "Local Climatological Data." [Readings Taken at McCarran Field, Las Vegas, from March to October, 1957.] Washington, DC: USGPO. 1957. 24 pages.***

REFERENCES
(Continued)

311. U.S. Army, Office of the Chief of Military History. "Chapter 26: The Army and the New Look." (In: American Military History.) Washington, DC: Department of the Army. 1969. 18 pages.

312. USAF, NTPR Brooks AFB. [Historical Files, PLUMBBOB Reading File, Nevada Test Site, 8V-3-15, Subject: Air Force Personnel in Operation PLUMBBOB Brooks AFB, TX:] U.S. Air Force. 1978. 5 pages.***

313. Vaile, R. "Isolation of Structures from Ground Shock, Project 3.5a." Albuquerque, NM: Field Command, DASA. 04/23/62. 68 pages. WT-1424-1.***

314. Van Horn, W.H. "Protection of Engineer Heavy Equipment Operators in Radiologically Contaminated Areas." Fort Belvoir, VA: Army, ERDL. 02/03/59. 69 pages. 1565-TR.

315. Walker, E.; Wignall, P. [Correspondence from USAF Commands to AEC, Subject: Sampler Crew Dosage.] United States Air Force. 1957. 4 pages.**

316. Walls, J. "In-flight Structural Response of the Model A4D-1 Aircraft to a Nuclear Explosion, Project 5.4." Albuquerque, NM: Field Command, DASA. 03/31/60. 186 pages. WT-1433. AD 355 562.*

317. Walls, J.; Heslin, N. "In-flight Structural Response of an HSS-1 Helicopter to a Nuclear Detonation, Project 5.1." Albuquerque, NM: Field Command, DASA. 07/25/60. 88 pages. WT-1430. AD 360 873.*

318. DELETED

319. Weary, S.; Ozeroff, W.; Nelson, A.; et al. Shot SMOKY, A Test of the PLUMBBOB Series, 31 August 1957. Washington, DC: Defense Nuclear Agency. 05/31/81. DNA Report: 6004F. 154 pages.*

320. Werdig, G. "Public Health Offsite Activities Conducted by the Public Health Service." USPHS. June, 1964. 24 pages.***

321. Wignall, P.R., Col., USAF. [Letter to G.W. Johnson, OTD, Subject: Contamination Build-up Study, with encl.] Camp Mercury, NV: U.S. Air Force, Air Support Group. 06/04/57. 7 pages.***

322. Wignall, P.R., Col., USAF. [Letter to J.E. Reeves, Test Manager, Subject: Operating Procedures for Cloud Tracking with Attachments.] Camp Mercury, NV: USAF, Air Support Group. 06/04/57. 7 pages.**

323. Wignall, P.R., Col., USAF. [Memorandum to Test Manager, Subject: Crew Dosage, MB-1 Shot.] Kirtland AFB, NM: 4950th Test Group (Nuclear). 02/26/57. 4 pages.***

REFERENCES
(Continued)

324. Wilcox, F. "Onsite Rad-safe Support, Shot COULOMB C." Mercury, NV: REECo. 12/12/57. 46 pages.**

325. Wilcox, F. "Onsite Rad-safe Support, Shot PASCAL C." Mercury, NV: REECo. 12/09/57. 45 pages.**

326. Wilcox, F. "Qualified Monitors." Mercury, NV: REECo. 05/13/57. 3 pages. NTS1263M.**

327. Wilcox, F. "Radiological Safety Training: Instructor's Handbook." Mercury, NV: REECo. January 1961. 145 pages.**

328. Wilcox, F.; et al. [REECo File, Subject: URANUS Event, 3/14/58, March 1958.] AEC, Office of the Test Manager. Mercury, NV. March 1958. 19 pages.**

329. Wilcox, F.; et al. [REECo File, Subject: VENUS Event, 2/22/58, and February - June 1958.] AEC, Office of the Test Manager. Mercury, NV. 37 pages.***

330. Wilcox, F. [Memos: Radiological Data, Shot BOLTZMANN.] Mercury, NV: REECo. 05/28/57. 24 pages.**

331. Wilcox, F. [Memos: Radiological Data, Shot COULOMB B.[Mercury, NV: REECo. 09/09/57. 25 pages.**

332. Wilcox, F. [Notes and Records, Subject: Radiological Data, Shot WHEELER.] Mercury, NV: REECo. 1957. 20 pages.**

333. Wilcox, F. [Post-shot Activity Plans and Access Permits.] Mercury, NV: REECo. 02/24/58. 6 pages.**

334. Wilcox, F.; Goeke, R.; Weaver, C. "Operation PLUMBBOB Onsite Radiological Safety Support Report." Albuquerque, NM: REECo. 1957. 250 pages. OTO-57-2.**

335. Wilcox, F.; [Ed.] "Emergency Radiation Monitoring Team Training Manual, 1959. Mercury, NV: REECo. November 1959. 67 pages.***

336. Wilson, R.H.; Thomas, R.G.; Stannard, J.N. "Biomedical and Aerosol Studies Associated with a Field Release of Plutonium." University of Rochester Atomic Energy Project. November 1960. 70 pages. WT-1511. AD/A 077 507.*

337. Winograd, Berton. "G. in Information in the Desert Rock A-Bomb Maneuvers." Washington, DC: HumRRO. March, 1954. 19 pages.***

338. York, Herbert F. (Compiler). Arms Control: Readings from Scientific American. San Francisco, CA: W.H. Freeman & Co. 1973. 427 pages.

REFERENCES
(Continued)

339. York, E.; Boyd, R.; Blaylock, J. "Initial Neutron and Gamma Air-Earth Interface Measurements, Operation PLUMBBOB, Project 2.10." Albuquerque, NM: Field Command, DASA. 02/23/60. WT-1419. AD 464 381.*

340. [Continent and Pacific Historical Records, 1957], rolls 16, 17, and 19 (Boxes 40-44 and 47) Microfilmed Records. Nevada Test Site, NV: Reynolds Electrical and Engineering Co., Inc. 1957.***

341. [List of SMOKY Participants], (Undated). Department of Army.***

342. Military Participation in PLUMBBOB, Department of Defense OTI-57-3 through OTI-57-114. Washington, DC: Office of Public Information. May 1957.***

343. "Rules and Regulations." Federal Register. 01/13/77. 4 pages.

344. [Department of the Army. NTPR.] "Final Report of Army Review." Washington, DC: 1979. 17 pages.***

345. Marine Nuclear Test Personnel Review. [Dosimetry Data for Exercise Desert Rock VII and VIII.] Washington, DC: 1979. 2 pages.***

346. Pickering, J.E.; et al. "Biological Effects of Nuclear Radiation on the Monkey (Macaca Mulatta), Project 39.6." Washington, DC: DNA. 10/01/79. 50 pages. WT-1505. AD/B 951 752.*

APPENDIX A

INDEX TO PROJECTS AT PLUMBBOB

PRECEDING PAGE BLANK-NOT FILMED

APPENDIX A

Index to Projects at PLUMBBOB

APPENDIX A

Index to Projects at PLUMBBOB (Continued)

DOD Program/Project	Title	Sponsor	Page
PROGRAM 2	**Nuclear Radiation Effects**		116
Project 2.0	Neutron and Gamma Radiation	NRDL and U.S. Army Chemical Warfare Laboratories	117
Project 2.1	Soil Activation by Neutrons	U.S. Army Chemical Warfare Laboratories, Evans Signal Laboratory	118
Project 2.2	Neutron Induced Activity in Soil Elements	U.S. Naval Radiological Laboratory	120
Project 2.3	Neutron Flux from Selected Nuclear	U.S. Army Chemical Warfare Laboratories	120
Project 2.4	Nuclear Radiation Shielding Studies	U.S. Army Chemical Warfare Laboratories; Evans Signal Laboratory	120
Project 2.5	Initial Gamma Radiation Intensity and Neutron Induced Gamma Radiation of NTS Soils	Evans Signal Laboratory	122
Project 2.6	Evaluation of New Radiac Instrument (IM-93)	U.S. Army Signal Research and Development Laboratory	122
Project 2.7	Radiowave Attenuation Studies	U.S. Naval Research Laboratory	123
Project 2.8	Evaluation of Military Dosimeters and Radiac Instruments	U.S. Naval Material Laboratory	123
Project 2.9	The Nuclear Radiation Dose Received by Aircrews Firing the MB-1 Missile	AFSWC	128
Project 2.10	Initial Neutron and Gamma Air-Earth Interface Measurements	Air Defense Command (AFSWC); General Mills Company	128

APPENDIX A

Index to Projects at PLUMBBOB
(Continued)

APPENDIX A

Index to Projects at PLUMBBOB (Continued)

APPENDIX A

Index to Projects at PLUMBBOB (Continued)

DOD Program/Project	Title	Sponsor	Page
Project 5.3	In-flight Structural Response of the FJ-4 Aircraft to a Nuclear Detonation	U.S. Navy Bureau of Aeronautics and North American Aviation, Inc.; Naval Air Special Weapons Facility	158
Project 5.4	In-flight Structural Response of the A4D-1 Aircraft to a Nuclear Detonation	Douglas Aircraft Co.; AFSWC; and Naval Air Special Weapons Facility	158
Project 5.5	In-flight Structural Response of the F-89D Aircraft to a Nuclear Detonation	Wright Air Development Center; Northrop Aircraft, Inc.	136
PROGRAM 6	**Electromagnetic Effects, Service Equipment, and Material**		137
Project 6.1	Minefield Clearance by Nuclear Weapons	U.S. Army Engineer Research and Development Laboratory; 91st Engineer Battalion Fort Belvoir Picatinny Arsenal; Diamond Ordnance Fuze Laboratory; U.S. Army Chemical Warfare Laboratories; United Kingdom	137
Project 6.2	Measurement of the Magnetic Component of the Electromagnetic Field near a Nuclear Detonation	Diamond Ordnance Fuze Laboratories	138
Project 6.2a	Measurement of the Effects of Nuclear Radiation on Semiconductor Devices	Diamond Ordnance Fuze Laboratories	138
Project 6.3	Attenuation of Electromagnetic Radiation Through an Ionized Medium	U.S. Naval Air Development Center; AFSWC	158
Project 6.4	Accuracy and Reliability of the Short-Baseline NAROL System	Air Force Cambridge Research Center	138

APPENDIX A

Index to Projects at PLUMBBOB
(Continued)

APPENDIX A

Index to Projects at PLUMBBOB
(Continued)

APPENDIX A

Index to Projects at PLUMBBOB (Continued)

APPENDIX A

Index to Projects at PLUMBBOB
(Continued)

APPENDIX A

Index to Projects at PLUMBBOB
(Continued)

APPENDIX A

Index to Projects at PLUMBBOB
(Continued)

APPENDIX A

Index to Projects at PLUMBBOB
(Continued)

APPENDIX A

Index to Projects at PLUMBBOB
(Continued)

APPENDIX A

Index to Projects at PLUMBBOB (Continued)

APPENDIX A

Index to Projects at PLUMBBOB (Continued)

APPENDIX A

Index to Projects at PLUMBBOB (Continued)

APPENDIX A

Index to Projects at PLUMBBOB (Continued)

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Armed Forces Staff College
ATTN: Library

Assistant Secretary of Defense, Public Affairs
ATTN: PAO

Defense Nuclear Agency
ATTN: PAO
ATTN: GC
ATTN: BA
ATTN: TISI
5 cy ATTN: NTPR
25 cy ATTN: TITL

Defense Technical Information Center
12 cy ATTN: DD

Field Command
Defense Nuclear Agency
ATTN: FCLS
ATTN: FCTMO

Interservice Nuclear Weapons School
ATTN: TTV

National Defense University
ATTN: ICAF Tech Library

DEPARTMENT OF THE ARMY

Army Library
ATTN: Military Doc Sec

Army Nuclear Test Personnel Review
ATTN: DAAG-AMR-R TAGO

U.S. Army Center of Military History
ATTN: DAMH

U.S. Army Chemical School
ATTN: ATZN-CM-CS
ATTN: ATZN-CM-AL

U.S. Army Comd & General Staff College
ATTN: Library

U.S. Army Nuclear & Chemical Agency
ATTN: Library

U.S. Army War College
ATTN: Library

DEPARTMENT OF THE NAVY

Aviation History Unit
Department of the Navy
ATTN: Library

Bureau of Medicine and Surgery
Department of the Navy
ATTN: Asst for Med Surgery

Engineering Duty Officer School
Department of the Navy
ATTN: Library

DEPARTMENT OF THE NAVY (Continued)

James Carson Breckinridge Library
Department of the Navy
ATTN: Library Div

Marine Corps Nuclear Test Personnel Review
ATTN: Code MSRB-60

Merchant Marine Academy
ATTN: Director of Libraries

Naval Aviation School Command
ATTN: Library

Naval Hospital Corps School
ATTN: Library

Naval Ocean Systems Center
ATTN: Library

Naval Oceanographic Office
ATTN: Code 025, Historian

Naval Postgraduate School
ATTN: Code 1424, Library

Naval Research Laboratory
ATTN: Library

Naval School
Naval Construction Battalion Center
ATTN: Commanding Officer

Naval School of Health Sciences
ATTN: Library

Naval Sea Systems Command
ATTN: Nuclear Technology Div

Naval Surface Weapons Center
ATTN: Library

Naval War College
ATTN: Professor 8 Libraries

Naval Weapons Center
ATTN: Code 233

Naval Weapons Evaluation Facility
ATTN: Library

Navy Dept Library
ATTN: Librn

Navy Nuclear Power School
ATTN: Library

Navy Nuclear Test Personnel Review
2 cy ATTN: W. Loeffler

U.S. Naval Academy
Nimitz Library
ATTN: Documents & Reports Dept

DEPARTMENT OF THE NAVY (Continued)

Office of the Judge Adv Gen
Department of the Navy
ATTN: Code [illegible]

U.S. Marine Corps Cmd & Staff College
ATTN: Library

U.S. Merchant Marine Academy
ATTN: Librn

U.S. Naval Air Station Library
Department of the Navy
ATTN: Library

DEPARTMENT OF THE AIR FORCE

Academy Library [illegible]
U.S. Air Force Academy
ATTN: Library

Aerospace Defense Command
ATTN: Historian

Air Force Communications Service
ATTN: Historian

Air Force Institute of Technology
ATTN: Library

Air Force Logistics Command
ATTN: Historian

Air Force Nuclear Test Personnel Review
ATTN: HQ [illegible]SAF/SGES

Air Force School of Aerospace Medicine
ATTN: Strughold Library

Air Force Systems Command
ATTN: Historian

Air Force Technical Applications Center
ATTN: Historian

Air Force Weapons Laboratory
Air Force Systems Command
ATTN: Tech Library

Air National Guard
ATTN: Historian

Air Training Command
ATTN: Historian

Air University Library
Department of the Air Force
ATTN: [illegible]

Military Air Lift Command
ATTN: Historian

Commander-in-Chief
Pacific Air Forces
ATTN: Historian

Strategic Air Command
Department of the Air Force
ATTN: NRI-STINFO Library
ATTN: Historian

DEPARTMENT OF THE AIR FORCE (Continued)

Tactical Air Command
Department of the Air Force
ATTN: Historian

U.S. Air Force Occupational & Env Health Lab
ATTN: NTPR

DEPARTMENT OF ENERGY

Department of Energy
ATTN: OMA

Department of Energy
Nevada Operations Office
ATTN: Health Physics Div
2 cy ATTN: R. Nutley

Department of Energy
Human Health & Assessments Division
ATTN: [illegible]-31

OTHER GOVERNMENT AGENCIES

Centers for Disease Control
U.S. Public Health Service
ATTN: G. Caldwell

Central Intelligence Agency
ATTN: Office of Medical Services

Department of Health & Human Svcs
ATTN: Office of General Counsel

Exec Ofc of The President
Management & Budget Off Lib
ATTN: Librn

Library of Congress
ATTN: Library Service Division
ATTN: Science & Technology Div
ATTN: Serial & Govt Publication

National Atomic Museum
ATTN: Historian

Department of Commerce
National Bureau of Standards
ATTN: Librn

National Technical Information Service
12 cy ATTN: Customer Services

Occupational Safety & Health Admin
ATTN: C. Wright

Office of Health & Disability (ASPER)
ATTN: R. Copeland

Ofc of Workers Compensation Program
Department of Labor
ATTN: R. Larson

U.S. Coast Guard Academy Library
ATTN: Librn

U.S. House of Representatives
ATTN: Committee on Armed Svcs

OTHER GOVERNMENT AGENCIES (Continued)

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

U.S. Military Academy
ATTN: Director of Libraries

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

U.S. Senate
ATTN: Committee on Veterans Affairs

Veterans Administration-RO
Providence, RI
ATTN: Director

Veterans Administration-RO
Montgomery, AL
ATTN: Director

Veterans Administration-RO
Juneau, AK
ATTN: Director

Veterans Administration-RO
Anchorage, AK
ATTN: Director

Veterans Administration-RO
Phoenix, AZ
ATTN: Director

Veterans Administration-RO
Little Rock, AR
ATTN: Director

Veterans Administration-RO
Los Angeles, CA
ATTN: Director

Veterans Administration-RO
San Francisco, CA
ATTN: Director

Veterans Administration-RO
Denver, CO
ATTN: Director

Veterans Administration-RO
Hartford, CT
ATTN: Director

Veterans Administration-RO
Wilmington, DE
ATTN: Director

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

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

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Atlanta, GA
ATTN: Director

Veterans Administration-RO
Honolulu, HI
ATTN: Director

Veterans Administration-RO
Chicago, IL
ATTN: Director

Veterans Administration-RO
Seattle, WA
ATTN: Director

Veterans Administration-RO
Indianapolis, IN
ATTN: Director

Veterans Administration-RO
Des Moines, IA
ATTN: Director

Veterans Administration-RO
Wichita, KS
ATTN: Director

Veterans Administration-RO
Louisville, KY
ATTN: Director

Veterans Administration-RO
New Orleans, LA
ATTN: Director

Veterans Administration-RO
Togus, ME
ATTN: Director

Veterans Administration-RO
Baltimore, MD
ATTN: Director

Veterans Administration-RO
Boston, MA
ATTN: Director

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

Veterans Administration-RO
Jackson, MS
ATTN: Director

Veterans Administration-RO
Huntington, WV
ATTN: Director

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

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

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Lincoln, NE
ATTN: Director

Veterans Administration-RO
Reno, NV
ATTN: Director

Veterans Administration-RO
Manchester, NH
ATTN: Director

Veterans Administration-RO
Newark, NJ
ATTN: Director

Veterans Administration-RO
Milwaukee, WI
ATTN: Director

Veterans Administration-RO
Albuquerque, NM
ATTN: Director

Veterans Administration-RO
Buffalo, NY
ATTN: Director

Veterans Administration-RO
New York, NY
ATTN: Director

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

Veterans Administration-RO
Fargo, ND
ATTN: Director

Veterans Administration-RO
Cleveland, OH
ATTN: Director

Veterans Administration-RO
Muskogee, OK
ATTN: Director

Veterans Administration-RO
Portland, OR
ATTN: Director

Veterans Administration-RO
Pittsburgh, PA
ATTN: Director

Veterans Administration-RO
Philadelphia, PA
ATTN: Director

Veterans Administration-RO
San Francisco, CA
ATTN: Director

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

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration-RO
Columbia, SC
ATTN: Director

Veterans Administration-RO
Sioux Falls, SD
ATTN: Director

Veterans Administration-RO
Houston, TX
ATTN: Director

Veterans Administration-RO
Waco, TX
ATTN: Director

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

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

Veterans Administration-RO
Roanoke, VA
ATTN: Director

Veterans Administration-RO
Cheyenne, WY
ATTN: Director

Veterans Administration-RO
San Diego, CA
ATTN: Director

Veterans Administration-RO
Boise, ID
ATTN: Director

Veterans Administration-RO
Detroit, MI
ATTN: Director

Veterans Administration-RO
Nashville, TN
ATTN: Director

The White House
ATTN: Domestic Policy Staff

DEPARTMENT OF ENERGY CONTRACTORS

Lawrence Livermore National Lab
ATTN: Tech Info Dept Library

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

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

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

OTHER

Adams State College
ATTN: Librn

Akron Public Library
ATTN: Librn

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

University of Alabama
ATTN: Reference Dept, Dralier 3
ATTN: Director of Libraries (Reg)

University of Alaska Library at Anchorage
ATTN: Librn

University of Alaska
ATTN: Director of Libraries

Albany Public Library
ATTN: Librn

Alexander City State Jr College
ATTN: Librn

Allegheny College
ATTN: Librn

Allen County Public Library
ATTN: Librn

Altoona Area Public Library
ATTN: Librn

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

Anaheim Public Library
ATTN: Librn

College of Wooster
ATTN: Gov Docs

Angelo State University Library
ATTN: Librn

Angelo Iacoboni Public Library
ATTN: Librn

Anoka County Library
ATTN: Librn

Appalachian State University
ATTN: Library Docs

Arizona State University Library
ATTN: Librn

University of Arizona
ATTN: Dir of Libraries (Reg)

Arkansas College Library
ATTN: Library

Brooklyn College
ATTN: Doc Div

OTHER (Continued)

Arkansas Library Comm
ATTN: Library

Arkansas State University
ATTN: Library

University of Arkansas
ATTN: Gov Docs Div

Austin College
ATTN: Librn

Atlanta Public Library
ATTN: Ivan Allen Dept

Atlanta University
ATTN: Librn

Auburn University Library at Mongomery (Reg)
ATTN: Librn

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

Bangor Public Library
ATTN: Librn

Bates College Library
ATTN: Librn

Baylor University Library
ATTN: Docs Dept

Beloit College Libraries
ATTN: Serials Docs Dept

Bemidji State College
ATTN: Library

State University College, B. F. Feinberg Lib
ATTN: Gov Docs

Akron University
ATTN: Gov Docs

Boston Public Library (Reg)
ATTN: Docs Dept

Bowdoin College
ATTN: Librn

Bowling Green State University
ATTN: Lib Gov Docs Services

Bradley University
ATTN: Librn

Brandeis University Library
ATTN: Docs Section

Brigham Young University
ATTN: Librn

Brigham Young University
ATTN: Docs Collection

Brookhaven National Laboratory
ATTN: Tech Library

OTHER (Continued)

Broward County Library Sys
ATTN: Librn

Brown University
ATTN: Librn

Bucknell University
ATTN: Reference Dept

Buffalo & Erie Co Public Library
ATTN: Librn

State University Library of California at Fresno
ATTN: Library

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

University of California at San Diego
ATTN: Docs Dept

State College Library of California at Stanislaus
ATTN: Library

California State Polytechnic University Library
ATTN: Librn

California State University at Northridge
ATTN: Gov Doc

California State Library (Reg)
ATTN: Librn

California State University at Long Beach Library
ATTN: Librn

California State University
ATTN: Librn

California State University
ATTN: Librn

California University Library
ATTN: Gov Pub Dept

California University Library
ATTN: Librn

California University Library
ATTN: Gov Docs Dept

California University Library
ATTN: Docs Sec

University of California
ATTN: Gov Docs Dept

Calvin College Library
ATTN: Librn

Kearney State College
ATTN: Gov Docs Dept

Cambria County Library Sys
ATTN: Librn

Carleton College Library
ATTN: Librn

OTHER (Continued)

Carnegie Library of Pittsburgh
ATTN: Librn

Carnegie Mellon University
ATTN: Dir of Libraries

Carson Regional Library
ATTN: Gov Pubs Unit

Case Western Reserve University
ATTN: Librn

Casper College
ATTN: Librn

University of Central Florida
ATTN: Library Docs Dept

Central Michigan University
ATTN: Library Docs Sec

Central Montana State College
ATTN: Gov Docs

Central State University
ATTN: Lib Docs Dept

Central Washington University
ATTN: Lib Docs Sec

Central Wyoming College Library
ATTN: Librn

Charleston County Library
ATTN: Librn

Charlotte & Mechlenburg County Public Library
ATTN: E. Correll

Chattanooga Hamilton County, Bicentennial Library
ATTN: Librn

Chesapeake Public Library System
ATTN: Librn

Chicago Public Library
ATTN: Gov Pubs Dept

State University of Chicago
ATTN: Librn

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

Cincinnati University Library
ATTN: Librn

Citadel, Daniel 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

Dickinson College Library
ATTN: Librn

Dickinson State College
ATTN: Librn

Alabama Agricultural Mechanical University & Coll
ATTN: Librn

Drake University
ATTN: Cowles Library

Drew University
ATTN: Librn

Duke University
ATTN: Pub Docs Dept

Duluth Public Library
ATTN: Docs Sec

East Carolina University
ATTN: Lib Docs Dept

East Central University
ATTN: Librn

East Islip Public Library
ATTN: Librn

OTHER (Continued)

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

East Tennessee State University Sherrod Library
ATTN: Docs Dept

East Texas State University
ATTN: Library

Monmouth County Library Eastern Branch
ATTN: Librn

Eastern Illinois University
ATTN: Librn

Eastern Kentucky University
ATTN: Librn

Eastern Michigan University Library
ATTN: Library

Eastern Montana College Library
ATTN: Docs Dept

Eastern New Mexico University
ATTN: Librn

Eastern Oregon College Library
ATTN: Librn

Eastern Washington University
ATTN: Librn

El Paso Public Library
ATTN: Docs & Genealogy Dept

Elko County Library
ATTN: Librn

Elmire College
ATTN: Librn

Elon College Library
ATTN: Librn

Enoch Pratt Free Library
ATTN: Docs Ofc

Enory 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: Dir of Library (Reg)
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

Gardena Public Library
ATTN: Librn

Gardner Webb College
ATTN: Docs Library

Gary Public Library
ATTN: Librn

Geauga Cty Public Library
ATTN: Librn

Georgetown University Library
ATTN: Gov Docs Room

Georgia Institute of Technology
ATTN: Librn

Georgia Southern College
ATTN: Librn

Georgia Southwestern College
ATTN: Dir of Libraries

Georgia State University Library
ATTN: Librn

OTHER (Continued)

University of Georgia
ATTN: Dir of Libraries (Reg)

Glassboro State College
ATTN: Librn

Gleeson Library
ATTN: Librn

Graceland College
ATTN: Librn

Grand Forks Public City-County Library
ATTN: Librn

Grand Rapids Public Library
ATTN: Dir of Lib

Greenville County Library
ATTN: Librn

Grinnell College 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: Dif of Libraries (Reg)

University of Hawaii
Hilo Campus Library
ATTN: Librn

Haydon Burns Library
ATTN: Librn

Hennepin County Library
ATTN: Gov Docs

Henry Ford Community College Library
ATTN: Librn

OTHER (Continued)

Herbert H. Lehman College
ATTN: Lib Docs Div

Hofstra University Library
ATTN: Docs Dept

Hollins College
ATTN: Librn

Hopkinsville Community College
ATTN: Librn

Wagner College
ATTN: Librn

University of Houston Library
ATTN: Docs Div

Houston Public Library
ATTN: Librn

Tulane University
ATTN: Docs Dept

Hoyt Public Library
ATTN: Librn

Humboldt State College Library
ATTN: Docs Dept

Huntington Park Library
ATTN: Librn

Hutchinson Public Library
ATTN: Librn

Idaho Public Library & Information Center
ATTN: Librn

Idaho State Library
ATTN: Librn

Idaho State University Library
ATTN: Docs Dept

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

University of Illinois Library
ATTN: Docs Sec

Illinois State Library (Reg)
ATTN: Gov Docs Br

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

Illinois Valley Community College
ATTN: Library

Illinois State University
ATTN: Librn

Indiana State Library (Reg)
ATTN: Serial Sec

Indiana State University
ATTN: Docs Library

OTHER (Continued)

Indiana University Library
ATTN: Docs Dept

Indianapolis Marion County Public Library
ATTN: Social Science Div

Iowa State University Library
ATTN: Gov Docs Dept

Iowa University Library
ATTN: Gov Docs Dept

Butler University
ATTN: Librn

Isaac Delchdo College
ATTN: Librn

James Madison University
ATTN: Librn

Jefferson County Public Library
Lakewood Regional Library
ATTN: Librn

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

John Hopkins University
ATTN: Docs Library

La Roche College
ATTN: Librn

Johnson Free Public Library
ATTN: Librn

Kalamazoo Public Library
ATTN: Librn

Kansas City Public Library
ATTN: Docs Div

Kansas State Library
ATTN: Librn

Kansas State University Library
ATTN: Docs Dept

University of Kansas
ATTN: Dir of Library (Reg)

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

Maine Maritime Academy
ATTN: Librn

University of Maine
ATTN: Librn

OTHER (Continued)

Kent State University Library
ATTN: Docs Div

Kentucky Dept of Library & Archives
ATTN: Docs Sec

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

Kenyon College Library
ATTN: Librn

Lake Forest College
ATTN: Librn

Lake Sumter Community College Library
ATTN. Librn

Lakeland Public Library
ATTN: Librn

Lancaster Regional Library
ATTN: Librn

Lawrence University
ATTN: Docs Dept

Brigham Young University
ATTN: Docs & Map Sec

Lewis University Library
ATTN: Librn

Library and Statutory Dist & Svc
2 cy ATTN: Librn

Earlham College
ATTN: Librn

Little Rock Public Library
ATTN: Librn

Long Beach Public Library
ATTN: Librn

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

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

Louisville Free Public Library
ATTN: Librn

Louisville University Library
ATTN: Librn

OTHER (Continued)

Manchester City Library
ATTN: Librn

Mankato State College
ATTN: Gov Pubs

University of Maine at Farmington
ATTN: Dir of Libraries

Marathon County Public Library
ATTN: Librn

Principia College
ATTN: Librn

University of Maryland
ATTN: McKeldin Library Docs Div

University of Maryland
ATTN: Librn

University of Massachusetts
ATTN: Gov Docs Coll

Maui Public Library
Kahului Branch
ATTN: Librn

McNeese State University
ATTN: Librn

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

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

Memphis State University
ATTN: Librn

Mercer University
ATTN: Librn

Mesa County Public Library
ATTN: Librn

Miami Dade Community College
ATTN: Librn

University of Miami Library
ATTN: Gov Pubs

Miami Public Library
ATTN: Docs Div

Miami University Library
ATTN: Docs Dept

University of Santa Clara
ATTN: Docs Div

Michigan State Library
ATTN: Librn

Michigan State University Library
ATTN: Librn

OTHER (Continued)

Michigan Tech University
ATTN: Lib Docs Dept

University of Michigan
ATTN: Acq Sec Docs Unit

Middlebury College Library
ATTN: Librn

Millersville State College
ATTN: Librn

State University of New York
ATTN: Docs Librn

Milwaukee Public Library
ATTN: Librn

Minneapolis Public Library
ATTN: Librn

University of Minnesota
ATTN: Dir of Libraries (Reg)

Minot State College
ATTN: Librn

Mississippi State University
ATTN: Librn

University of Mississippi
ATTN: Dir of Libraries

Missouri University at Kansas City General
ATTN: Librn

University of Missouri Library
ATTN: Gov Docs

M.I.T. Libraries
ATTN: Librn

Mobile Public Library
ATTN Gov Info Div

Midwestern University
ATTN: Librn

Montana State Library
ATTN: Librn

Montana State University Library
ATTN: Librn

University of Montana
ATTN: Dir of Libraries (Reg)

Montebello Library
ATTN: Librn

Morhead State College
ATTN: Library

Mt Prospect Public Library
ATTN: Gov't Info Ctr

Murray State University Library
ATTN: Lib

OTHER (Continued)

Nassau Library System
ATTN: Librn

Natrona County Public Library
ATTN: Librn

Nebraska Library Community
Nebraska Public Clearinghouse
ATTN: Librn

University of Nebraska at Omaha
ATTN: Univ Lib Docs

Nebraska Western College Library
ATTN: Librn

University of Nebraska
ATTN: Dir of Libraries (Reg)

University of Nebraska Library
ATTN: Acquisitions Dept

University of Nevada Library
ATTN: Gov Pubs Dept

University of Nevada at Las Vegas
ATTN: Dir of Libraries

New Hampshire University Library
ATTN: Librn

New Hanover County Public Library
ATTN: Librn

New Mexico State Library
ATTN: Librn

New Mexico State University
ATTN: Lib Docs Div

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

University of New Orleans Library
ATTN: Gov Docs Div

New Orleans Public Library
ATTN: Librn

New York Public Library
ATTN: Librn

New York State Library
ATTN: Docs Control Cultural Ed Ctr

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

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

State University of New York
ATTN: Lib Docs Sec

North Texas State University Library
ATTN: Librn

OTHER (Continued)

State University of New York
ATTN: Librn

New York State University
ATTN: Docs Ctr

State University of New York
ATTN: Docs Dept

New York University Library
ATTN: Docs Dept

Newark Free Library
ATTN: Librn

Newark Public Library
ATTN: Librn

Niagara Falls Public Library
ATTN: Librn

Nicholls State University Library
ATTN: Docs Div

Nieves M. Flores Memorial Library
ATTN: Librn

Norfolk Public Library
ATTN: R. Parker

North Carolina Agricultural & Tech State University
ATTN: Librn

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

University Library of North Carolina at Greensboro
ATTN: Librn

University of North Carolina at Wilmington
ATTN: Librn

North Carolina Central University
ATTN: Librn

North Carolina State University
ATTN: Librn

University of North Carolina at Wilmington
ATTN: Librn

University of North Carolina
ATTN: BA SS Div Docs

North Dakota State University Library
ATTN: Docs Librn

University of North Dakota
ATTN: Librn

University of North Dakota
ATTN: Dir of Libraries

North Georgia College
ATTN: Librn

OTHER (Continued)

Northeast Missouri State Univeristy
ATTN: Librn

Northeastern Oklahoma State University
ATTN: Librn

Northeastern University
ATTN: Dodge Library

Northern Arizona University Library
ATTN: Gov Docs Dept

Northern Illinois University
ATTN: Librn

Northern Michigan University
ATTN: Docs

Northern Montana College Library
ATTN: Librn

Northwestern Michigan College
ATTN: Librn

Northwestern State University
ATTN: Librn

Northwestern State University Library
ATTN: Librn

Northwestern University Library
ATTN: Gov Pubs Dept

Norwalk Public Library
ATTN: Librn

Northeastern Illinois University
ATTN: Library

University of Notre Dame
ATTN: Doc Ctr

Oakland Community College
ATTN: Librn

Oakland Public Library
ATTN: Librn

Oberlin College Library
ATTN: Librn

Ocean County College
ATTN: Librn

Ohio State Library
ATTN: Librn

Ohio State University
ATTN: Lib Docs Div

Ohio University Library
ATTN: Docs Dept

Oklahoma City University Library
ATTN: Librn

Oklahoma City University Library
ATTN: Librn

OTHER (Continued)

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

University of Oklahoma
ATTN: Docs Div

Old Dominion University
ATTN: Doc Dept Univ Lib

Olivet College Library
ATTN: Librn

Omaha Public Library Clark Branch
ATTN: Librn

Onondaga County Public Library
ATTN: Gov Docs Sec

Oregon State Library
ATTN: Librn

University of Oregon
ATTN: Docs Sec

Ouachita Baptist University
ATTN: Librn

Pan American University Library
ATTN: Librn

Passaic Public Library
ATTN: Librn

Queens College
ATTN: Docs Dept

Pennsylvania State Library
ATTN: Gov Pubs Sec

Pennsylvania State University
ATTN: Lib Doc Sec

University of Pennsylvania
ATTN: Dir of Libraries

University of Denver
ATTN: Penrose Library

Peoria Public Library
ATTN: Business, Science & Tech Dept

Free Library of Philadelphia
ATTN: Gov Pubs Dept

Philipsburg Free Public Library
ATTN: Library

Phoenix Public Library
ATTN: Librn

University of Pittsburgh
ATTN: Docs Office, G8

Plainfield Public Library
ATTN: Librn

OTHER (Continued)

Popular Creek Public Library District
ATTN: Librn

Association of Portland Library
ATTN: Librn

Portland Public Library
ATTN: Librn

Portland State University Library
ATTN: Librn

Pratt Institute Library
ATTN: Librn

Louisiana Tech University
ATTN: Librn

Princeton University Library
ATTN: Docs Div

Providence College
ATTN: Librn

Providence Public Library
ATTN: Librn

Public Library Cincinnati & Hamilton County
ATTN: Librn

Publi… …brary of Nashville and Davidson County
…: Librn

University of Puerto Rico
ATTN: Doc & Maps Room

Purdue University Library
ATTN: Librn

Quinebaug Valley Community College
ATTN: Librn

Auburn University
ATTN: Microforms & Docs Dept

Rapid City Public Library
ATTN: Librn

Reading Public Library
ATTN: Librn

Reed College Library
ATTN: Librn

Augusta College
ATTN: Librn

University of Rhode Island Library
ATTN: Gov Pubs Ofc

University of Rhode Island
ATTN: Dir of Libraries

Rice University
ATTN: Dir of Libraries

Louisiana College
ATTN: Librn

OTHER (Continued)

Richland County Public Library
ATTN: Librn

Riverside Public Library
ATTN: Librn

University of Rochester Library
ATTN: Docs Sec

University of Rutgers Camden Library
ATTN: Librn

State University of Rutgers
ATTN: Librn

Rutgers University
ATTN: Dir of Libraries (Reg)

Rutgers University Law Library
ATTN: Fed Docs Dept

Salem College Library
ATTN: Librn

Samford University
ATTN: Librn

San Antonio Public Library
ATTN: Bus Science & Tech Dept

San Diego County Library
ATTN: C. Jones, Acquisitions

San Diego Public Library
ATTN: Librn

San Diego State University Library
ATTN: Gov Pubs Dept

San Francisco Public Library
ATTN: Gov Docs Dept

San Francisco State College
ATTN: Gov Pubs Coll

San Jose State College Library
ATTN: Docs Dept

San Luis Obispo City-County Library
ATTN: Librn

Savannah Public & Effingham Liberty Regional Library
ATTN: Librn

Scottsbluff Public Library
ATTN: Librn

Scranton Public Library
ATTN: Librn

Seattle Public Library
ATTN: Ref Docs Asst

OTHER (Continued)

Selby Public Library
ATTN: Librn

Shawnee Library System
ATTN: Librn

Shreve Memorial Library
ATTN: Librn

Silas Bronson Public Library
ATTN: Librn

Sioux City Public Library
ATTN: Librn

Skidmore College
ATTN: Librn

Slippery Rock State College Library
ATTN: Librn

South Carolina State Library
ATTN: Librn

University of South Carolina
ATTN: Librn

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
ATTN: Librn

Southeast Missouri State University
ATTN: Librn

Southeastern Massachusetts University Library
ATTN: Docs Sec

University of Southern Alabama
ATTN: Librn

Southern California University Library
ATTN: Docs Dept

Southern Connecticut State College
ATTN: Library

Southern Illinois University
ATTN: Librn

Southern Illinois University
ATTN: Docs Ctr

Southern Methodist University
ATTN: Librn

University of Southern Mississippi
ATTN: Library

OTHER (Continued)

Southern Oregon College
ATTN: Library

Southern University in New Orleans Library
ATTN: Librn

Southern Utah State College Library
ATTN: Docs Dept

Southwest Missouri State College
ATTN: Library

University of Southwestern Louisiana Libraries
ATTN: Librn

Southwestern University
ATTN: Librn

Spokane Public Library
ATTN: Ref Dept

Springfield City Library
ATTN: Docs Sec

St Bonaventure University
ATTN: Librn

St Johns River Junior College
ATTN: Library

St Joseph Public Library
ATTN: Librn

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
ATTN: Librn

Stetson University
ATTN: Librn

University of Steubenville
ATTN: Librn

Stockton & San Joaquin Public Library
ATTN: Librn

Stockton State College Library
ATTN: Librn

Albion College
ATTN: Gov Docs Librn

OTHER (Continued)

Superior Public Library
ATTN: Librn

Swarthmore College Library
ATTN: Ref Dept

Syracuse University Library
ATTN: Docs Div

Tacoma Public Library
ATTN: Librn

Hillsborough County Public Library at Tampa
ATTN: Librn

Temple University
ATTN: Librn

Tennessee Technological University
ATTN: Librn

University of Tennessee
ATTN: Dir of Libraries

College of Idaho
ATTN: Librn

Texas A & M University Library
ATTN: Librn

University of Texas at Arlington
ATTN: Library Docs

University of Texas at San Antonio
ATTN: Library

Texas Christian University
ATTN: Librn

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
ATTN: Librn

Toledo Public Library
ATTN: Social Science Dept

Torrance Civic Center Library
ATTN: Librn

Traverse City Public Library
ATTN: Librn

Trenton Free Public Library
ATTN: Librn

Trinity College Library
ATTN: Librn

Trinity University Library
ATTN: Docs Coll

OTHER (Continued)

Tufts University Library
ATTN: Docs Dept

University of Tulsa
ATTN: Librn

UCLA Research Library
ATTN: Pub Affairs Svc/U.S. Docs

Uniformed Services University of the Health Sciences
ATTN: LRC Library

University Libraries
ATTN: Dir of Lib

University of Maine at Oreno
ATTN: Librn

University of Northern Iowa
ATTN: Library

Upper Iowa College
ATTN: Docs Coll

Utah State University
ATTN: Librn

University of Utah
ATTN: Special Collections

University of Utah
ATTN: Dir of Library

Utica Public Library
ATTN: Librn

Valencia Library
ATTN: Librn

Valparaiso University
ATTN: Librn

Vanderbilt University Library
ATTN: Gov Docs Sec

University of Vermont
ATTN: Dir of Libraries

Virginia Commonwealth University
ATTN: Librn

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
ATTN: Docs Sec

Washington State University
ATTN: Lib Docs Sec

Washington University Libraries
ATTN: Dir of Lib

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

Univeristy of West Florida
ATTN: Librn

West Georgia College
ATTN: Librn

West Hills Community College
ATTN: Library

West Texas State University
ATTN: Library

West Virginia College of Grad Studies Library
ATTN: Librn

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

Westerly Public Library
ATTN: Librn

Western Carolina University
ATTN: Librn

Western Illinois University Library
ATTN: Librn

Western Washington University
ATTN: Librn

Western Wyoming Community College Library
ATTN: Librn

Westmoreland City Community College
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

Williamantic 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
ATTN: Gov Docs Librn

Wyoming State Library
ATTN: Librn

University of Wyoming
ATTN: Docs Div

Yale University
ATTN: Dir of Libraries

Yeshiva University
ATTN: Librn

Yuma City County Library
ATTN: Librn

Simon Schwob Mem Lib, Columbus Col
ATTN: Librn

DEPARTMENT OF DEFENSE CONTRACTORS

Advanced Research & Applications Corp
      ATTN: H. Lee

JAYCOR
      ATTN: A. Nelson
5 cy ATTN: C. Lowery
10 cy ATTN: Health & Environment Div

JRB Associates
10 cy ATTN: L. Novotney

Kaman Tempo
      ATTN: DASIAC
      ATTN: E. Martin

Kaman Tempo
      ATTN: R. Miller

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Kaman Tempo
      ATTN: C. Jones

National Academy of Sciences
      ATTN: C. Robinette
      ATTN: Med Follow-up Agency
      ATTN: Natl Mat Advisory Bd

Pacific-Sierra Research Corp
      ATTN: H. Brode

R & D Associates
      ATTN: P. Haas

Science Applications, Inc
      ATTN: Tech Lib