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For the Record—A History of the Nuclear Test Personnel Review Program, 1978 - 1993

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13. ABSTRACT (*Maximum 200 words*) This volume is a history of the Nuclear Test Personnel Review (NTPR) program from 1978 through September 30, 1993. It identifies the origins, missions, and historical evolution of the effort, focusing on the contributions of the Defense Nuclear Agency, the NTPR teams, the Veterans Administration, and the Department of Energy. In addition, the narrative describes U.S. nuclear operations, including weapons testing and the atomic bombing of Hiroshima and Nagasaki, Japan, personnel participation in those operations, and radiation safety measures. The report also discusses radiation dose determination and medical studies of potential dose effects.			
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PREFACE

The Defense Nuclear Agency (DNA) established the Nuclear Test Personnel Review (NTPR) Program in 1978. This report For the Record - A History of the Nuclear Test Personnel Review Program, 1978-1993 has two purposes: (1) to provide the public with information concerning personnel participation in U.S. atmospheric nuclear testing and the postwar U.S. occupation of Hiroshima and Nagasaki, Japan, and (2) to provide a public accounting of the NTPR effort, which has involved a series of actions on behalf of the nuclear test participants and veterans of the Hiroshima and Nagasaki occupation. This edition is an update of the original For the Record - A History of the Nuclear Test Personnel Review Program, 1978-1986, published as DNA 6041F in 1986.

For the Record synthesizes information from a substantial number of published sources, including the 41-volume, 9,082-page history of the atmospheric nuclear testing program published by DNA. It also presents data elicited from unpublished sources, such as letters, memoranda and speeches, and from interviews with involved personnel. Readers desiring additional information should consult the original sources, which are identified in Appendix F and general references identified in Appendices G and H.

The text is divided into three basic parts. Sections 1 through 4 introduce the NTPR program and highlight organizational contributions. Sections 5 through 7 concentrate on the nuclear operations, describing the detonations, personnel participation, and radiation safety measures. Sections 8 and 9 focus on radiation dose, the former on radiation dose determination and the latter on medical studies of potential radiation effects.

Section 1, "Introduction to the Defense Nuclear Agency and the NTPR Program," identifies the origins, scope, and accomplishments of the program and presents summary tables of radiation doses for veterans of the nuclear tests.

Section 2, "Work of the NTPR Teams," highlights the NTPR efforts of the four military service teams and a separate team at DNA's Field Command in Albuquerque, New Mexico, from 1978 to 1988. While DNA directed the NTPR program, the five teams executed the assigned tasks. This chapter identifies the resources that were available to each team, in terms of both personnel and funds, and itemizes the results, including statistics on the assignment of doses and the notification of personnel concerning available medical examination programs.

Section 3, "The Consolidated NTPR Program Under DNA," describes the progress of the NTPR program since the elimination of the Service teams and the consolidation of work under DNA's direct supervision in 1987 and 1988. It points out the impact of Congressional legislation passed since consolidation, especially that of Public Law 100-321, which as interpreted by the Department of Veterans Affairs (VA), allows claims by several new groups of veterans, the largest being those who participated in the occupation of Hiroshima and Nagasaki, Japan, after World War II. It also looks at some likely trends in the future.

Section 4, "Other Interactions in the NTPR Program," discusses the efforts of the Department of Energy (DOE) and Department of Veterans Affairs (VA) which make important contributions to the program, although neither has an NTPR organization. It also describes the legislation that brought the Department of Justice (DOJ) into the administration of radiation compensation. Finally, it briefly summarizes contractor support of NTPR activities.

Section 5 focuses on the U.S. postwar occupation of Japan. Entitled "The Atomic Bombings and U.S. Occupation of Hiroshima and Nagasaki," the section describes the detonations, the residual radiation, and the participation and radiation doses of U.S. occupation troops. DNA expanded the NTPR program in 1979 to incorporate research and assistance efforts on behalf of the former occupation troops. The program was expanded still further following passage of Public Law 100-321.

With 21 subsections, Section 6, "U.S. Nuclear Testing from Project TRINITY to the PLOWSHARE Program," is the most extensive part of the volume. It summarizes the test series from 1945 to the end of U.S. atmospheric nuclear testing, which came with the last Pacific test on 3 November 1962. The narrative delineates the background, purpose, and operations for each series, and provides a summary of doses according to Service participation. This history is current as of 30 September 1993, with the exception of yield information for a number of U.S. atmospheric nuclear tests in the Pacific. Declassified by DOE, these yields were announced on 7 December 1993.

Section 7, "Radiation Safety at U.S. Atmospheric Nuclear Tests," is a companion to Section 6. It discusses radiation safety at the nuclear tests, concentrating primarily on protective measures against exposure to initial and residual radiation and personnel contamination. The chapter identifies radiation detection/measurement instruments used for survey and/or personnel monitoring. It also describes protective measures taken to prevent internal radiation exposure from the inhalation or ingestion of radioactive material.

Section 8, "Radiation Dose Determination," focuses on dose determination for the veterans of both nuclear testing and the Hiroshima/Nagasaki occupation. It discusses the use of film badge data from badged personnel to estimate individual doses for unbadged personnel. In addition, it presents the methods for dose reconstruction employed when film badge data were unavailable or unrepresentative of individual or group activities.

Section 9, "Health Effects of Ionizing Radiation and Medical Follow-up Studies of Veterans," addresses two topics. It first discusses the health effects of ionizing radiation as generally understood by both national and international experts. The chapter then summarizes the epidemiological studies of the veterans of the nuclear tests and the Hiroshima/Nagasaki occupation. The studies have been conducted by the Centers for Disease Control (CDC), the Argonne National Laboratory, the National Research Council (NRC) of the National Academy of Sciences (NAS), and the Office of Technology Assessment (OTA), a support organization of Congress.

The six appendices are designed to assist the reader in using this volume and in conducting additional research. Appendix A, "Chronology of Selected Events Relevant to the NTPR Program," highlights key information presented in the text. Appendix B, "Glossary," defines technical and organizational terms pertinent to the commentary; Appendix C lists abbreviations and acronyms. Appendix D, "Public Resources for Documents on U.S. Atmospheric Nuclear Weapons Testing," discusses the availability of documents for purchase at the National Technical Information Service (NTIS) and at the DOE Coordination and Information Center (CIC), Las Vegas, Nevada, and for research at CIC or the DNA reading room. Appendix E identifies the DNA personnel-oriented histories of atmospheric nuclear testing, all of which are for sale at NTIS and available for review at CIC, VA Regional Offices and numerous public libraries nationwide. Appendix F identifies the source documents used for preparing this report. Appendix G lists selected references concerning radiological conditions at Hiroshima and Nagasaki, Japan. The volume ends with Appendix H, "Selected Bibliography," which specifies selected resources for further information that should be available through major public and university libraries.

This volume quantifies program results in several places, particularly in Section 1.4, "NTPR Program Accomplishments;" Section 1.5, "Summary of Radiation Doses;" and in the "Results" sections of Sections 2, 3, 4 and 6. These statistics are current as of 30 September 1993, when research for this book was completed.

To facilitate the reading of this volume, the most current and commonly accepted names of locations and organizations are generally used throughout the text. Hence, the continental test site, which was called the Nevada Proving Ground from 1952 to 1955, is consistently referred to as the Nevada Test Site (NTS). Pacific Proving Ground (PPG) is used as the designation of the primary oceanic test site, which was also sometimes termed the Enewetak Proving Ground or Bikini Proving Ground. Furthermore, local times and dates are used throughout this volume, rather than Greenwich Mean Time. In addition, the weapons development laboratories are cited by their present designations: Los Alamos National Laboratory (LANL), instead of Los Alamos Scientific Laboratory (LASL), as it was known earlier; and Lawrence Livermore National Laboratory (LLNL), rather than previous names, such as University of California Radiation Laboratory (UCRL).

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SECTION 1

INTRODUCTION TO THE DEFENSE NUCLEAR AGENCY AND THE NTPR PROGRAM

The United States Government, primarily through the Manhattan Engineer District (MED) and its successor agency, the Atomic Energy Commission (AEC), conducted some 235 nuclear weapons tests from 1945 to 1962, during the atmospheric nuclear testing program. The testing was principally conducted in Nevada and the Pacific. An estimated 205,000 Department of Defense (DoD) personnel, military and civilian, took part in the tests.

In March 1977, 15 years after the last above-ground nuclear test, the VA Regional Office in Boise, Idaho, received a claim for disability benefits from retired Army Sergeant Paul R. Cooper. A patient at the VA hospital in Salt Lake City, Utah, Cooper attributed his acute myelocytic leukemia to the radiation exposure he had received as a participant in Shot SMOKY, conducted on 31 August 1957 as part of the 1957 series of nuclear tests, Operation PLUMBBOB. The VA initially denied Cooper's claim but later reversed its decision. The appeals board noted that sufficient signs of the disease had been present when Cooper was on active duty to support the claim as Service connected. The board did not comment, however, on Cooper's assertion that his leukemia resulted directly from radiation exposure he had received at Shot SMOKY.

The VA's decision on the Cooper claim initiated a series of events that ultimately involved the military services, DNA, DOE, NAS, the Department of Health and Human Services and the White House. Questions fueling that involvement concerned, among other issues, the possible radiation doses received by test participants and the possible long-term health effects resulting from those doses.

1.1 ORIGINS OF THE NTPR PROGRAM.

Through a series of meetings held in 1977, representatives of DoD, DOE, VA, and CDC, among other agencies, concluded that research should be conducted concerning personnel participation in the U.S. atmospheric nuclear weapons test program. DoD, including DNA representatives, made commitments to establish an effort that would coordinate this research during hearings held by the Subcommittee on Health and Environment of the House Committee on Interstate and Foreign Commerce during 24-26 January and 14 February 1978. Their statements, along with decisions made during the 1977 meetings, laid a basis for the official establishment of NTPR in 1978.

An initial step was taken by the physician assigned in February 1977 to the Paul Cooper case at the Salt Lake City, Utah, VA hospital. Concerned over the possibility of a connection between his patient's illness and his earlier participation in Shot SMOKY, the physician contacted Dr. Glyn G. Caldwell, Chief of the Cancer Branch of CDC in Atlanta, Georgia. Dr. Caldwell, an epidemiologist who had an interest in leukemia studies, then contacted Colonel LaWayne R.

Stromberg, MC, USA, Director of the Armed Forces Radiobiology Research Institute (AFRRI)*. Dr. Caldwell informed Colonel Stromberg that he wanted to investigate the question of a possible relationship between participation in a nuclear test and later development of cancer. Colonel Stromberg agreed to support the effort by attempting to retrieve dosimetry readings for the names of DoD personnel forwarded to him by Dr. Caldwell.

Shortly thereafter, the VA decided against Paul Cooper's claim. Sergeant Cooper then took his case to the media, which accorded him considerable attention. "Almost immediately the subject became a part of the public consciousness," to quote from a document tracing NTPR origins that was drafted by Paul H. Carew, DNA Comptroller. According to Carew, CDC received correspondence within a few days from "several dozen people" who claimed to have participated in the nuclear weapons tests. The number of letters increased to approximately 2,000 within four months.

During March and April 1977, against the backdrop of increasing media attention, representatives from CDC, AFRRI, and the Office of the Surgeon General, U.S. Army, discussed the research effort proposed by Dr. Caldwell and the need for a mechanism to address relevant issues and process inquiries. With the support of the DNA Director, the Surgeon General of the Army appointed an ad hoc committee to coordinate a detailed review of troop participation in the U.S. atmospheric nuclear test program. Headed by Dr. Stromberg, the committee included representatives from various Army organizations, such as the Office of the Surgeon General, Office of the Deputy Chief of Staff for Operations and Plans, and Office of the Chief of Public Affairs. The committee convened on 6 May 1977 to formulate its goals and agenda.

On 13 May 1977, an AFRRI representative met with Dr. Caldwell at CDC in Atlanta to discuss the information CDC had and needed and to assess progress on the work undertaken. In reviewing his efforts, Dr. Caldwell noted that he had identified three confirmed cases of leukemia among the personnel who had written to CDC and indicated their participation in Shot SMOKY. This number was of interest to CDC because it appeared to be higher than expected for a group of that size. Dr. Caldwell had accordingly received CDC approval to conduct an epidemiological study of the entire SMOKY population. He required, however, a list of SMOKY participants complete with radiation exposure histories from DoD. Upon conclusion of the meeting, the AFRRI representative recommended that DoD provide the requested roster and data.

It soon became clear that the requisite data were incomplete and scattered in repositories across the country. To discuss data needs, as well as other concerns, a meeting of the ad hoc committee was scheduled for June 1977 at the DOE Nevada Operations Office in Las Vegas. DOE Nevada Operations Office was the center for testing activities at NTS and a central archive for DOE information on the atmospheric nuclear test program.

Convened on 3 June 1977, the meeting involved 24 participants representing the military services, DNA, DOE, LANL, and Reynolds Electrical & Engineering Co., Inc. (REECo), a DOE contractor based in Las Vegas, Nevada. The discussion focused on the availability of information,

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*AFRRI is a DoD activity responsible for studying the biological effects of ionizing radiation.

particularly from the REECo records indicating personnel exposures to ionizing radiation during the U.S. atmospheric nuclear tests. These records provided useful information on personnel who had worn film badges. There were no entries, though, for the participants who did not wear film badges. The committee concluded that information would be needed to supplement the data made available by the REECo files and that cooperation would be required between the participants in the testing and CDC. The Army representatives supported this conclusion but announced they would proceed with a unilateral investigation of Army personnel at Shot SMOKY. They accordingly requested access to information on Army personnel exposures and related data as they were identified.

During the next two weeks, Major Alan L. Skerker, USA, Office of the Deputy Chief of Staff for Operations and Plans, developed a roster for one of the Army contingents that had been at Shot SMOKY: the Provisional Company, 82nd Airborne Division. He recovered names from such sources as yearbooks housed at Fort Bragg, North Carolina. Individual dosimetry information came from records kept at the Lexington Blue-Grass Signal Depot, Lexington, Kentucky. These data were sent on 15 June 1977 to Dr. Caldwell after the dose information had been removed according to constraints believed to be imposed by Public Law 93-579 of 1974, commonly known as the Privacy Act of 1974. It was later learned that the dose information could be provided to CDC.

By mid-August 1977, the ad hoc committee, which had been restructured to include the Surgeon General of the Air Force, the Surgeon General of the Navy, and DOE, had summarized its findings. The committee agreed to the following:

- That the concerned Federal agencies support Dr. Glyn Caldwell in his attempt to identify, locate, and obtain the necessary medical data on SMOKY participants;

- That the ad hoc committee be established formally as an interagency committee with DoD, DOE, VA, and the U.S. Public Health Service as members;

- That the review of DoD personnel exposure records associated with the nuclear weapons testing be continued.

On 3 November 1977, the interagency committee held a preliminary meeting to discuss the possible long-term health effects resulting from participation in U.S. atmospheric nuclear weapons testing. The attendees recommended that a major epidemiological study of test participants be undertaken under the direction of an independent scientific organization, such as NRC of the NAS, and that this effort be funded jointly by DoD and DOE. They suggested, moreover, that a central administrative unit be established within DoD to coordinate all related activities. The final recommendation was for a meeting of senior officials of the concerned agencies, to be held as soon as possible, to organize the effort (Carew, 3 May 1979).

On 1 December 1977, the Assistant Secretary of Defense for Health Affairs convened a meeting to address the U.S. atmospheric nuclear weapons testing program and the possible relationship between participation in the program and an increased incidence of disease attributable to radiation exposure. Participants included representatives from the military services, DNA, DOE, VA, CDC, and NRC/NAS, as well as epidemiological consultants from Walter Reed Army Medical Center. The meeting resulted in a decision to solicit a formal proposal for a study from NRC of the U.S. atmospheric nuclear test participants. It also resulted in the unofficial agreement that DNA would function as DoD executive agency for all matters pertaining to DoD personnel participation in the U.S. atmospheric nuclear test program (Carew, 3 May 1979; McIndoe, 23 January 1978).

The Subcommittee on Health and Environment of the House Committee on Interstate and Foreign Commerce held hearings during 24-26 January and 14 February 1978 on DoD actions to collect data on DoD personnel who participated in U.S. atmospheric nuclear weapons testing. These hearings functioned as a catalyst for official establishment of the NTPR Program in late January 1978. In their testimony, DoD, DOE, and DNA representatives not only highlighted the research initiated by concerned Federal agencies in 1977, but made commitments to establish an effort that would develop histories of the U.S. atmospheric nuclear weapons tests, describe radiation safety policies and procedures in effect during the tests, identify participation and radiation doses for DoD military and civilian personnel who took part in the tests, and make the resulting information available for review by scientific organizations. These commitments emerged as the primary NTPR tasks (Johnson, 13 June 1986).

1.2 FOCUSING THE NTPR PROGRAM.

The early history of the NTPR program can be traced through memoranda drafted during the initial months of the effort. Most of the initial documents discussed in this section were written by or to Vice Admiral Robert R. Monroe, USN, Director of DNA from March 1977 to August 1980 and principal architect of the NTPR.

DNA responsibility for the NTPR officially started with two memoranda dated 28 January 1978 and signed by John P. White, Assistant Secretary of Defense for Manpower, Reserve Affairs, and Logistics. One of the documents, addressed to the Director of DNA, made the agency responsible for the following tasks and "for any others that may develop" (White, 28 January 1978, a):

- Develop a history of every U.S. atmospheric nuclear event that involved DoD personnel;
- Identify the radiation monitoring control policies, procedures, and requirements that were in effect;
- Assemble a census of personnel at each event. Identify their location, movements, protection, and radiation dose exposure;
- Make this information available for scientific review and appraisal;
- Handle public affairs matters in cooperation with the Office of the Assistant Secretary of Defense (Public Affairs); and

- Handle congressional affairs matters in coordination with the Office of the Assistant to the Secretary of Defense for Legislative Affairs.

These tasks evolved over time, as indicated in section 1.3, and were the basis of the NTPR effort.

The other 28 January 1978 memorandum was important because it gave the DNA Director "authority to task the Military Departments and other DoD elements and components" in responding to the assignments. This document was sent to the Secretaries of the Military Departments, the Chairman of the Joint Chiefs of Staff, and the Under Secretaries of Defense, among others (White, 28 January 1978, b).

Using his given authority, Vice Admiral Robert R. Monroe, Director, DNA, delineated the respective responsibilities of DNA and the military services in a 13 February 1978 memorandum directed to the Secretary of the Army, the Secretary of the Navy, and the Secretary of the Air Force. DNA, he emphasized, would "organize and direct the overall effort," while each military service would be responsible for NTPR research pertinent to that Service and for follow-up communications with Service personnel (Monroe, 13 February 1978).

DNA coordinated its approach with DOE and CDC in meetings held during March and April 1978. Representatives from DNA explained the NTPR program to DOE Nevada Operations Office and its contractors at a 9 March 1978 meeting. DOE hosted a meeting on 4 April 1978 that was attended by representatives of the DoD NTPR, National Archives, REECo, LANL, NRC/NAS, and each DNA contractor organization. The discussion focused on methods for identifying and obtaining records on U.S. atmospheric nuclear weapons testing (Brady, 10 April 1986).

An 8 June 1978 memorandum by Vice Admiral Monroe directed the NTPR teams toward consistency in research. It asked them to collect the following information on test participants: 1) full name (no initials); 2) branch of service (if civilian, Service/contractor/laboratory affiliation); 3) unit or ship (at time of test); 4) grade, rank, or rating (at time of test); 5) service serial number(s); 6) social security number; 7) date of birth; 8) shots participated in; 9) radiation exposure data, in as much detail as possible (e.g., total atmospheric test exposure; exposure by radiation type; exposure by shot, series, or time period; badge issue and turn-in dates; bioassay data; etc.); 10) sources of above data elements. The memorandum also required the teams to research individual medical records, which would be a major effort involving considerable time. The rationale for this records search was as follows:

> First, the NTPR effort could scarcely be considered thorough, searching, or even competent if this basic source is not explored. Second, radiation exposure data is so central to the purpose of NTPR, and recorded information elsewhere is known to have such limitations, that no potential source can be overlooked. Third, since future research efforts (epidemiological, claims, etc.) will, in many cases, retrace this same ground, knowledge even of absence of information in medical records will be of considerable value. Finally, an understanding of the Services' past success or failure in recording exposures will be important in devising new systems (Monroe, 8 June 1978).

With a memorandum dated 3 October 1979, DNA expanded the NTPR effort to include U.S. service personnel who had participated in the postwar occupation of Hiroshima and Nagasaki. Vice Admiral Monroe noted that the original NTPR charter had not included these personnel because the effort had been "limited to test participants" and the "wartime bombings were not tests." Nevertheless, he added, they had "the same need for DoD research and assistance" as did the former test participants. "Unless otherwise directed," he concluded, the NTPR program "is being expanded to include those U.S. servicemen who might have been exposed to low-level ionizing radiation as a result of the Hiroshima and Nagasaki bombings" (Monroe, 3 October 1979). Vice Admiral Monroe was "so confident this step was right," he later explained, that he did not preface his statement to his superiors with "I recommend" (Monroe, 8 July 1985).

The central management decisions that emerged from the memoranda cited above and the other documents drafted in the early months of the NTPR effort were:

- To undertake the NTPR program as a major, multi-year, multi-million dollar effort;
- To organize the NTPR program with DNA exercising centralized guidance and the military services having responsibility for the execution of Service research and follow-up with their own Service personnel;
- To pursue the NTPR program as a scientific and historical inquiry, producing factual results without regard to preconceptions or political acceptability; and
- To remain alert to any possible new requirement or any additional action that might seem needed and to modify the NTPR program accordingly (Monroe, 8 July 1985).

1.3 SCOPE OF THE NTPR PROGRAM.

During the early years of the program, the specific tasks of NTPR became more detailed and numerous. The 28 January 1978 memorandum cited in the preceding section itemized six tasks. Nine tasks eventually emerged, as listed below (Defense Nuclear Agency, April 1984):

1. To compile a roster of the DoD personnel involved in the U.S. atmospheric nuclear tests;
2. To develop a history of each atmospheric nuclear event that involved DoD personnel;
3. To declassify all possible nuclear test related source documents that bore a security classification;
4. To provide estimates of radiation doses--both as a check on film badge readings and as a substitute for them in those cases where badges were not worn or readings were either not recorded or retrievable--and to submit the methodology for the estimates to the NAS for peer review;

5. To establish personal contact with as many test participants as possible;

6. To identify those individuals who received a higher radiation dose than those doses recommended under current Federal guideline for radiation workers, to notify those individuals of their dose, and to offer veterans free medical examinations at Government hospitals;

7. To sponsor, in conjunction with the DOE, independent mortality studies by NAS of selected test participants;

8. To carry out a detailed research program, in conjunction with the ongoing NTPR program, to recover all data pertaining to possible radiation exposure of U.S. postwar occupation troops at Hiroshima and Nagasaki, Japan; and

9. To provide assistance to veterans, the VA, and interested organizations by researching and providing as complete data as possible on individual participation and radiation doses.

As NTPR was originally organized, an NTPR team in each military service and a separate team at the DNA Field Command worked with DNA in meeting these tasks, as explained in Section 2. By late 1986, DNA's leadership came to believe that elimination of the Service teams and consolidation of NTPR under DNA's direct control was the best approach in a time of reduced funding. The progress of the NTPR program under consolidation is described in Section 3. During the entire NTPR effort, DNA has employed contractors to provide specialized support services. **Figure 1-1** shows the basic organization of NTPR until 1986. The five NTPR teams and the contractors reported to the NTPR Program Manager, who was responsible to the Director of DNA. **Figure 1-2** shows the consolidated arrangement since 1987. Succeeding Vice Admiral Robert R. Monroe as DNA Director were Lieutenant General Harry A. Griffith, USA, August 1980 to August 1983; Lieutenant General Richard K. Saxer, USAF, August 1983 to June 1985; Lieutenant General John L. Pickett, USAF, June 1985 to May 1987; Rear Admiral John T. Parker, USN, September 1987 to August 1989; Major General Gerald G. Watson, USA, August 1989 to April 1992, and Major General Kenneth L. Hagemann, USAF, April 1992 to the present.

1.4 NTPR PROGRAM ACCOMPLISHMENTS.

The NTPR program has been pursued on a high-priority basis. **Table 1-1** shows NTPR government and contractor person years from 1978 to 30 September 1993. **Table 1-2** itemizes DNA and DoD annual NTPR funding for the same period (Johnson, 20 December 1985; Johnson, 6 June 1986; Defense Nuclear Agency, 3 September 1986). This section presents the results achieved from these expenditures.

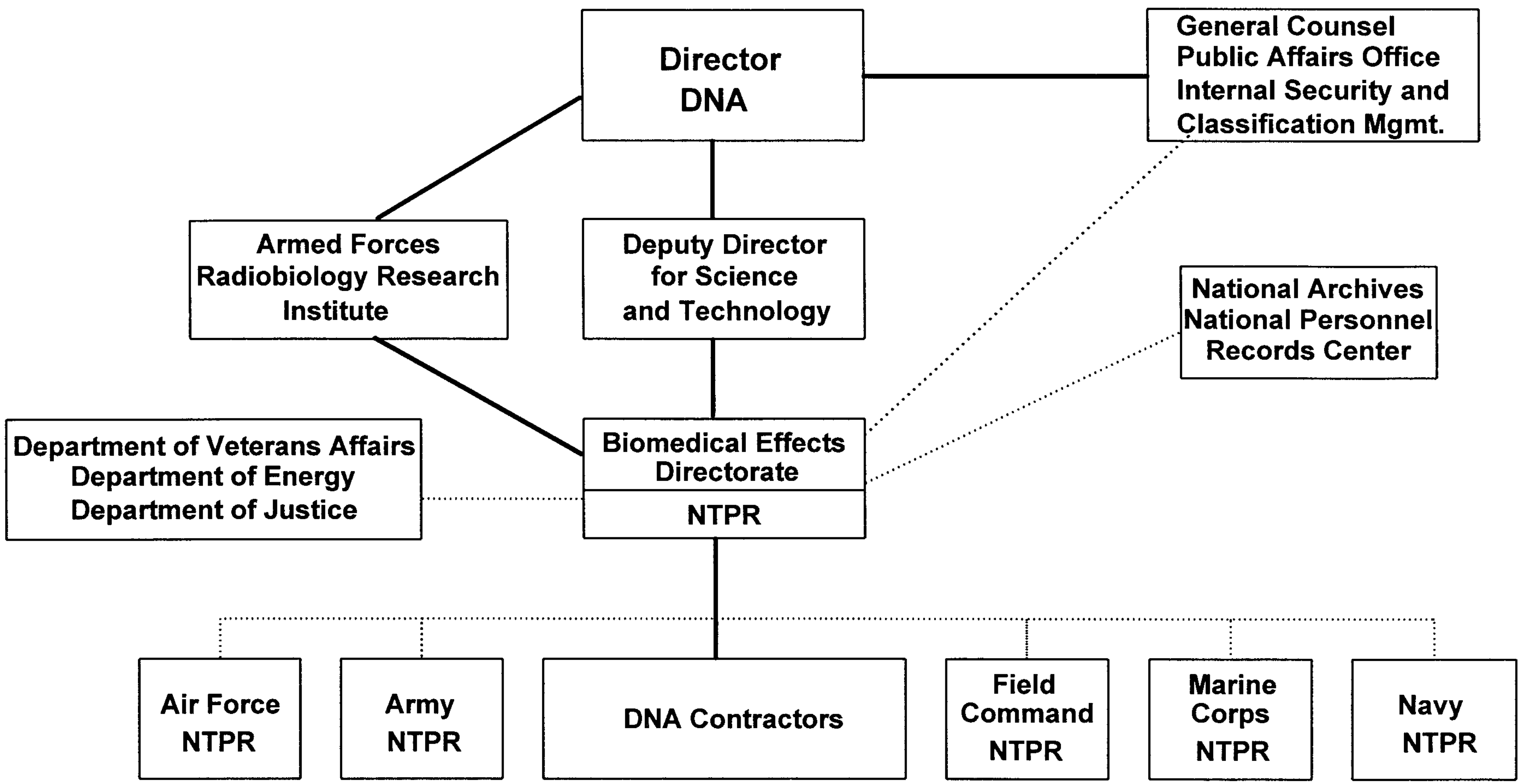

Figure 1-1. Organization of NTPR until 1986.

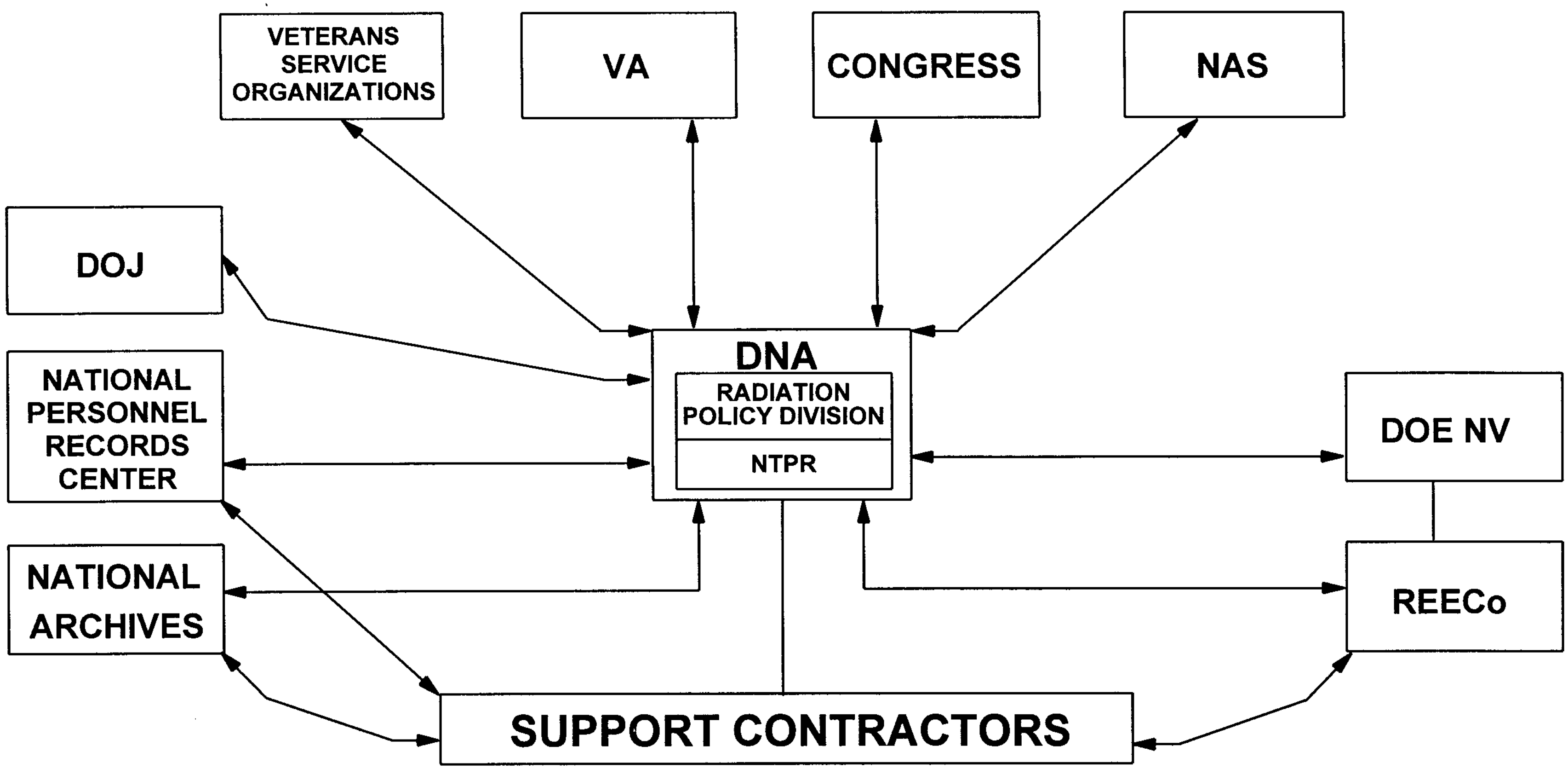

Figure 1-2. Organization of NTPR under consolidated operation.

Table 1-1. NTPR government and contractor person years from 1978 through 30 September 1993.

	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	TOTAL
DNA*	6	10	7	6	6	4	4	3	3	2	4	4	4	5	5	4	77
DoD**	74	160	197	201	186	140	60	54	60	68	73	75	73	64	62	63	1610

*In-house
**In-house and contractors combined

Table 1-2. NTPR funding in millions of dollars from 1978 through 30 September 1993.

	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	TOTAL
DNA Contract Costs	1.91	4.75	6.91	6.66	6.31	3.03	1.60	1.94	1.75	2.36	2.75	3.42	3.70	4.15	3.88	4.50	59.62
Other DoD Contract Costs	1.59	1.70	2.31	1.80	1.59	1.55	1.53	1.03	0.90	1.12	0.39	0.41	0.33	0	0	0	16.25
DoD Total Manpower Costs	0.39	1.15	1.46	1.52	1.63	1.26	0.79	0.62	0.59	0.32	0.19	0.19	0.19	0.30	0.30	0.30	11.2
DoD Total Contract & Manpower Costs	3.89	7.60	10.68	9.98	9.53	5.84	3.92	3.59	3.24	3.80	3.33	4.02	4.22	4.45	4.18	4.80	87.07

TASK 1

In mid-1986 it was believed that the first NTPR task, the development of a roster of DoD participants in the nuclear tests, was nearly complete. However, the passage of Public Law 100-321, "Radiation-Exposed Veterans Compensation Act of 1988," resulted in the VA (and therefore, NTPR) identifying several new categories of participants (see Section 3.3.2).

Consequently, the NTPR data base of participants more than doubled since 1986 and new participants continue to be discovered. As of 30 September 1993, the NTPR data base of participants had 415,392 records (JAYCOR, 6 October 1993).

TASK 2

The personnel-oriented history of the U.S. atmospheric nuclear test program has been completed. This 9,086-page history comprises 41 volumes. The reports, organized by series and shots, identify the participating organizations and their activities, and discuss radiological safety procedures and exposure data. The reports have been distributed to over 700 locations, including many public and college libraries and all VA Regional Offices throughout the United States. The distribution list is included at the back of each volume and is available upon request from DNA.

TASK 3

DNA has declassified over 1,000 publications containing information pertinent to the personnel aspects of the U.S. atmospheric nuclear tests. These documents are catalogued for easy reference and placed for ready availability at NTIS in Springfield, Virginia, and CIC in Las Vegas, Nevada. DNA has also declassified hundreds of relatively brief documents, such as memoranda and letters, and placed them at CIC. Appendix D explains NTIS and CIC holdings and procedures.

TASK 4

The NTPR dose reconstruction program emerged from this task, to provide estimates of radiation doses. This program has been used where film badge readings were not available or incomplete for personnel in participating units and to reconstruct individual doses in specific cases, as in support of veterans claims. Part of this effort is a separate analysis of possible internal dose due to inhalation and ingestion of radioactive materials. This process was submitted for peer review to NAS. On 7 February 1986, NAS released its report, and found that:

> ...the procedures used to estimate external radiation doses were reasonably sound. The NTPR has developed procedures that permit satisfactory estimates to be made of the external doses received by these participants. There are uncertainties in the dose estimates, but it appears that 99 percent of the personnel received doses of less than 5 rem, which is approximately the average dose received by the general population during the last 30 years from exposure to natural radiation and the use of ionizing radiation during medical procedures. [The committee] found no

evidence that the NTPR teams had been remiss in carrying out their mandate. If any bias exists in the estimates, it is probably a tendency to overestimate the most likely dose, especially for internal emitters or when the statistical procedure for assigning dose is used. (National Research Council, 1985)

TASK 5

DNA and NTPR personnel have taken various actions to establish personal contact with as many test participants as possible. On 9 February 1978, DNA initiated its nationwide toll-free call-in program for participants to report their involvement in U.S. atmospheric nuclear tests. The agency then issued multiple news releases that identified the purpose of the NTPR program, the toll-free number, and the DNA address. Releases were disseminated in part through the U.S. Army Home Town News Center in Kansas City, Missouri, which mailed information to 8,066 daily and weekly newspapers, as well as 720 television and 6,394 radio stations. DNA sent letters to news directors and editors asking them to issue an enclosed press release as a service to members of their audiences who participated in atmospheric nuclear testing (Department of the Army, 24 September 1987, p. 8).

The response to the initial nationwide news release was overwhelming. During the first two weeks after the toll-free lines were established, almost 13,000 persons called to report or inquire about their test participation. DNA progressively increased the toll-free lines from two to 20 (Monroe, 28 April 1980). The calls have continued to the present, although in diminishing numbers. By 1984, DNA was averaging 150-200 calls a week and by 1985, about 65 a week (Loeffler, 1 May 1984; Zillig, 16 April 1985). The highest monthly total since consolidation was 934 calls in September 1989 (the results of an August 1989 DNA mailout apprising previous callers of program developments). As of 30 September 1993, a total of approximately 76,000 individuals had called or written to the agency requesting participation information*. The information extracted from the telephone calls and letters comprises what has come to be known as the File A database. (JAYCOR, 6 October 1993, p. 5).

DNA has also conducted four major mailings to all veterans of the atmospheric nuclear tests and the Hiroshima/Nagasaki occupation for whom it had current addresses (Johnson, 6 June 1986):

- In June 1983, DNA and the Navy mailed copies of an NTPR fact sheet and VA Circular 10-83-61 to about 40,000 veterans. VA Circular 10-83-61 authorized treatment of test participant veterans for any ailments except those that clearly are not radiogenic in origin.

- In July 1983, DoD mailed copies of the 1983 NAS study "Multiple Myeloma Among Hiroshima/Nagasaki Veterans," discussed in Section 9, to the approximately 1,000 callers who had reported participation in Hiroshima/Nagasaki.

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*The toll-free number is 1-800-462-3683. The collect number is (703) 285-5610. The mailing address is: Defense Nuclear Agency, ESN/NTPR, 6801 Telegraph Road, Alexandria, VA 22310-3398.

- In June 1985, DNA mailed to about 45,000 veterans a packet of information containing the following:

  - Results of the CDC study "Mortality and Cancer Frequency Among Military Nuclear Test (Smoky) Participants, 1957 through 1979," published in the Journal of the American Medical Association on 5 August 1983 (see Section 9).

  - Results of the 1985 mortality study, entitled Mortality of Nuclear Weapons Test Participants.

  - NTPR program developments.

  - Information on free medical benefits available through the VA.

  - Request for comments on the proposed rules for responding to VA/NTPR inquiries (see Chapter 4).

- In August 1989, DNA mailed to about 42,000 veterans a packet of information containing the following:

  - Four fact sheets describing the NTPR program which included current NTPR call-in numbers.

  - A copy of Public Law 100-321, "Radiation-Exposed Veterans Compensation Act of 1988."

  - An excerpt from the Federal Register dated 21 June 1989, implementing PL 100-321.

As the DoD executive agent for the NTPR program, DNA has responded to requests for information from Congress, medical and scientific communities, veterans groups, lawyers, and citizens with special interests in NTPR. It has sent approximately 1,450 letters to the offices of U.S. senators and representatives, governors, and the White House, in response to requests for information on the program or on behalf of constituents (Johnson and others, 1 August 1986; Defense Nuclear Agency, no date; JAYCOR, 4 September 1991 through 6 October 1993). In addition, DNA representatives have testified at Congressional hearings from the very start of NTPR. The Director of DNA, along with other agency and DoD personnel, made statements at the hearings identified in **Table 1-3** (U.S. Congress, House, January and February 1978; U.S. Congress, House, April and July 1978; U.S. Congress, Senate, May 1979; U.S. Congress, Senate, June 1979; U.S. Congress, Senate, July 1979; U.S. Congress, Senate, October 1981; U.S. Congress, Senate, April 1983; U.S. Congress, House, May 1983; U.S. Congress, Senate, November and December 1985; U.S. Congress, House, November 1991). The last time DNA officials testified on NTPR was November 13, 1991.

Table 1-3. Congressional hearings at which DNA representatives have given testimony.

Committee	Date of Testimony
Subcommittee on Health and Environment of the House Committee on Interstate and Foreign Commerce -- Emphasis on actions then underway in DoD to collect data on DoD personnel who participated in U.S. atmospheric nuclear weapons testing.	25 January and 14 February 1978
Subcommittee on Environment, Energy, and Natural Resources of the House Committee on Government Operations -- Emphasis on DoD research to identify participants in U.S. atmospheric nuclear weapons testing and possible exposures to ionizing radiation resulting from their participation.	13 July 1978
Subcommittee on Energy, Nuclear Poliferation, and Federal Services of the Senate Committee on Governmental Affairs -- Emphasis on health effects of low-level ionizing radiation; radiation safety; identification of personnel involved in testing; and fallout from tests.	7 March 1979
Subcommittee on Energy, Nuclear Proliferation and Federal Services of the Senate Committee on Governmental Affairs -- Emphasis on progress made by DNA and the Service teams to identify participants in U.S. atmospheric nuclear weapons testing and possible exposures to ionizing radiation resulting from their participation.	8 May 1979
Senate Committee on Veterans' Affairs -- Emphasis on declassification of documents relevant to U.S. atmospheric nuclear weapons testing and on dose reconstruction for test participants with no or incomplete dose records.	20 June 1979
Senate Committee on Labor and Human Resources with incomplete dose records -- Emphasis on proposed Bill S. 1483, which would make the U.S. liable in incidents related to fallout from U.S. atmospheric nuclear tests.	27 October 1981

Table 1-3. **Congressional hearings at which DNA representatives have given testimony. (Cont'd)**

Committee	Date of Testimony
Senate Committee on Veterans' Affairs -- Emphasis on the status of the NTPR program and VA's adjudication process.	6 April 1983
Subcommittee on Oversight and Investigations of the House Committee on Veterans' Affairs -- Emphasis on the NTPR program, Operation CROSSROADS, and the Stafford Warren papers.	24 May 1983
Senate Committee on Veterans' Affairs -- Emphasis on issues resulting from a General Accounting Office (GAO) report on radiation exposures received by participants in Operation CROSSROADS, the first postwar nuclear test series, conducted in 1946 at Bikini Atoll.	11 December 1985
Compensation, Pension, and Insurance Subcommittee of the House Committee on Veterans' Affairs -- Emphasis on the extension of the list of presumptive Service-connected diseases and the requirement that DoD and VA study additional radiation exposure activities.	13 November 1991

DNA has also responded to requests for information from U.S. and foreign print and electronic media. It has provided data on NTPR to both national and local television programs and publications, including "60 Minutes," "20/20," "Good Morning, Washington," National Geographic, People magazine, The Washington Post, and the Los Angeles Times.

TASK 6

NTPR's sixth task was to identify and notify individuals whose radiation doses exceeded the current federal exposure guideline for radiation workers and to offer veterans free medical examinations at VA hospitals. Notification and medical examination programs exist for three categories of DoD test participants: over-25-rem* participants, Desert Rock officer volunteer observers, and over-5-rem participants. In addition, free VA medical examinations are available upon request to all veterans of atmospheric nuclear testing. See Section 4 for a discussion of the VA examination process.

*See Appendix B, Glossary, for definitions of rem and other technical terms.

In March 1979, the notification and veterans medical examination program was initiated for all test participants with cumulative doses from U.S. atmospheric nuclear testing in excess of 25 rem. The threshold of 25 rem was selected because it was the recommended national guideline for a one-time, planned exposure under emergency conditions.

As of 1986, NTPR had identified 39 DoD personnel who received doses over 25 rem. Most of these exposures resulted from a wind shift at Shot BRAVO, detonated on 1 March 1954 at Bikini as part of Operation CASTLE (see Section 6.10). Of the 37 participants who had identifiable addresses and could be contacted, 19 wanted examinations, five did not; 12 veterans took the examinations (Johnson, 6 June 1986).

In May 1979, the DoD notification and VA examination program was expanded to include officer volunteer observers who took part in the Desert Rock troop exercises during the testing. These volunteers were closer to ground zero than any other participants at shot-time. The officer volunteer observers at Shots NANCY (24 March 1953), BADGER (18 April 1953), SIMON (25 April 1953), and APPLE 2 (5 May 1955) also received measureable neutron radiation doses (Defense Nuclear Agency, April 1984). The first three of these shots were part of Operation UPSHOT-KNOTHOLE and are discussed in Section 6.9. The fourth, Shot APPLE 2, was part of Operation TEAPOT and is discussed in Section 6.11. As of 1986, NTPR personnel had located current addresses and written 40 of the officer volunteer observers, as noted in Sections 2.2.2, 2.3.3, 2.4.2, and 2.5.2 (Johnson, 6 June 1986).

In June 1979, the DoD notification and VA medical examination program was expanded to include all veterans with doses over 5 rem in 12 consecutive months. Five rem per calendar year is the current Federal guideline for allowable annual dose to radiation workers. As of 1986 this program included 1,430 personnel, and NTPR had contacted about 70 percent of them, using records 25 to 40 years old in their effort to find current addresses.

TASK 7

Work continues on this NTPR task, to sponsor independent NAS studies of the mortality of test participants. Sections 9.4.1 and 9.5.1 discuss these studies.

TASK 8

Early in the NTPR Program it appeared that DNA and the NTPR teams had completed this task, research on the U.S. occupation of Hiroshima and Nagasaki. DNA issued a detailed fact sheet about the occupation forces on 6 August 1980 and has since provided this data to all occupation personnel who have called or written DNA. A detailed dose reconstruction, using assumptions chosen to give an estimate of the maximum possible dose, has also been completed. The conclusion, reported in Section 5, is that the radiation doses received by members of the occupation forces were very low (Defense Nuclear Agency, 6 August 1980). After the passage of Public Law 100-321, which resulted in the VA defining the term "occupation of Hiroshima or Nagasaki, Japan, by United States forces," DNA made a concerted effort to identify these participants. As of 30 September 1993, DNA had identified 195,814 personnel. (Personnel who were at both Hiroshima and Nagasaki are counted twice in this total.)

TASK 9

NTPR personnel research individual participation and radiation exposure data in response to inquiries from veterans and their families, the VA, Congress, and other interested parties. This is an ongoing effort.

1.5 SUMMARY OF RADIATION DOSES.

Doses to participants in the U.S. atmospheric nuclear tests are determined through several means. Film badge dosimetry, when available, provides a measure of the external gamma radiation doses to persons wearing film badges. The primary source of recorded film badge dose data is the file maintained by REECo, the official DOE master repository of dose records for U.S. nuclear weapons tests.

Using contractor support, DNA also provides reconstructed doses for those personnel who were not issued film badges and/or whose dose records are missing or incomplete. These dose determinations, described in Section 8, are based on specific unit activities and actual radiological conditions. Doses so determined correlate well with film badge readings when the circumstances of exposure are generally known.

Findings to date indicate that most external gamma doses to personnel at the tests were quite low--averaging about 0.63 rem. (The 1986 edition of *For the Record* notes that this average was 0.5 rem. The increase is primarily due to the discovery of additional information concerning the completeness of recorded dosimetry data and the application of reconstructed doses from available radiological information to cover unbadged periods.) Many participants received no dose at all, and less than one percent exceeded 5 rem, the current annual whole body dose limit recommended by the National Council on Radiation Protection and Measurements. **Table 1-4** presents data provided by NTPR that show the breakdown of all external gamma doses, both recorded and reconstructed.

The dose totals given in Table 1-4 do not precisely match the estimated numbers of participants for the specific test series given in Section 6 or the estimated number of DoD participants in the U.S. atmospheric nuclear tests. This is because some individuals were in more than one test series. Consequently, the table of dose totals contains some double counting. However, while the numbers in Table 1-4 will be adjusted with further research and analysis, the overall results are not expected to change appreciably--the preponderance of doses are expected to remain in the level below 0.63 rem. DoD participants in this table and the tables summarizing external doses for each test series in Section 6 represent military personnel, civilian employees of the military services and their contractors.

Table 1-4. Summary of external doses for DoD atmospheric nuclear test participants as of 30 September 1993.*

Operation		Dose (rem)						
	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0	Totals
TRINITY	385	154	65	112	73	18	3	810
CROSSROADS	9319	24714	7595	4047	11	1	2	45689
SANDSTONE	363	11234	57	43	6	2	0	11705
RANGER	24	104	5	3	3	1	0	140
GREENHOUSE	1222	1220	882	2590	1624	173	9	7720
BUSTER-JANGLE	2420	4420	596	621	336	5	0	8398
TUMBLER-SNAPPER	413	8061	604	262	50	11	1	9402
IVY	407	9756	78	126	9	6	14	10396
UPSHOT-KNOTHOLE	724	5101	1497	6601	2986	114	17	17040
CASTLE	737	5676	2464	3803	843	386	46	13955
TEAPOT	950	3659	2688	1199	715	66	11	9288
WIGWAM	6313	493	1	2	0	0	0	6809
REDWING**	1080	3728	3111	3773	1624	162	14	13492
PLUMBBOB	2880	6757	2131	990	84	39	5	12886
HARDTACK I	2473	4584	4242	4379	270	75	8	16031
ARGUS	4525	0	0	0	0	0	0	4525
HARDTACK II	971	512	81	58	9	5	2	1638
DOMINIC I**	11269	10368	238	362	17	9	9	22272
DOMINIC II	2490	567	126	182	7	1	0	3373
Total	48965	101108	26461	29153	8667	1074	141	215569

* The figures in each dose column show the number of DoD participants at a given U.S. atmospheric nuclear test series who received an external dose in the indicated range. For any individual, the total dose may have been measured by one or more film badges, may have been reconstructed, or may be the sum of both film badge data and reconstruction, if the film badge dosimetry did not cover the person's full exposure potential. Because some personnel participated in more than one test series, the total of external doses in any column may include some double counting.

** Many of the REDWING and DOMINIC I doses are possibly overstated due to environmentally damaged film badges.

Consequently, civilians do not form a distinct category in some tables as was the case in the 1986 edition of this history.

During Operations UPSHOT-KNOTHOLE (1953), TEAPOT (1955), and PLUMBBOB (1957), all at the NTS, about 10,000 military observers and maneuver troops were exposed to neutron radiation while observing nuclear tests from forward locations in the shot areas. Of these, 44 were volunteers positioned closer to ground zero than the other troops. Through reconstruction methods described in Section 8, neutron doses for the volunteers were determined to be as high as 28 rem, while the highest neutron dose received by regular troops was 1.4 rem for the 500 observers at Shot TESLA, Operation TEAPOT. Neutron doses to all other troops were calculated to be less than 0.5 rem.

At some operations, the circumstances of radiation exposure were such that some participants may have ingested or inhaled radioactive materials. Another aspect of the NTPR dose reconstruction program is the estimation of such internal doses, where applicable. A "dose screen" methodology is applied to each internal exposure situation investigated to determine the possibility that the 50-year committed dose to the bone could exceed 0.15 rem. The internal dose assessment for over 85% of the participants falls below that level. (See Section 7.2.3.)

SECTION 2

WORK OF THE NTPR TEAMS

Since January 1978, DNA has been the executive agent for the NTPR program; however, the military service teams and a separate team at DNA's Field Command in Albuquerque, New Mexico, performed the tasks assigned the Agency from 1978 until the program was consolidated under DNA in late 1987 and early 1988. These five teams expended considerable time, personnel effort, and funds meeting their responsibilities. This section sketches their common challenges and traces the efforts and accomplishments of each team.

2.1 COMMON CHALLENGES.

Each NTPR team was responsible for a different constituency and had a distinctive history. At the same time, the teams shared a number of experiences. They all, for example, had certain problems with inadequate documentation from the testing period, although some teams had more difficulties in this area than others. These problems posed challenges to the teams in fulfilling their responsibilities, such as determining a veteran's role in a nuclear test.

2.1.1 Documentation from the Testing Period.

Inadequate documentation was a significant problem, even though many of the source materials are detailed and useful. The sources, written some 30 to 50 years ago, are housed in some 194 private, public, and government repositories scattered nationwide. In addition, the extant DoD records of the U.S. atmospheric nuclear test program do not emphasize personnel participation and exposure data, as Vice Admiral Robert R. Monroe explained in testimony given on 20 June 1979 before the Senate Committee on Veterans' Affairs (U.S. Congress, Senate, June 1979):

> The reason that DoD records do not meet today's needs in this specific area derives from the views of medical science in the 1940s and 1950s concerning the hazards of ionizing radiation. Both national and international authorities at that time were more certain than they are today that there is negligible health risk from exposure to low-levels of ionizing radiation (e.g., a few rem). Thus the DoD-allowed exposure limits per test or series (typically 3 to 5 rem) were regarded primarily as operational safety guides, and once doses had been kept within these limits, their recording was not, in all cases, accomplished with an eye on permanency.

A major fire at the National Personnel Records Center (NPRC) in St. Louis, Missouri, compounded the difficulties. Beginning on 12 July 1973, the fire burned for four days. It damaged 17.5 million records of Army personnel discharged between 1912 and 1959, 2,000 records of Army personnel discharged in 1973, and one million records of Air Force personnel whose last names began with the letters I through Z and who had been discharged between 1947 and 1963. Many other records were water damaged. Only 10 to 15 percent of the 1912 to 1959 Army records were recovered, while about 40 percent of the Air Force records were salvaged (General Service Administration, April 1977, pp. 31, 36, 60). The destruction of these documents created problems particularly for the Army, as is discussed in Section 2.3.

2.1.2 Responses to File A Personnel.

The NTPR program evolved into a much more extensive effort than had originally been envisioned by Congress, government organizations, and the NTPR teams. The demanding and lengthy procedure required to respond to File A personnel provides one example of this effort.

According to established guidelines, the NTPR interviewer requested the following information from each caller on the toll-free DNA telephone lines: participant's name, social security number, telephone number, date of birth, address, caller's name, caller's relationship to participant, test series, test event, test location, date of test, participant's receipt of dosimeter, participant's use of dosimeter, armed service rank, service number, unit during test, place of birth, cause of death if participant was deceased, year of death, and remarks. DNA proceeded with a follow-up letter to the caller providing information on the program. The responsible NTPR team then conducted research to secure accurate participation and dose data, which were sent in a final letter to the caller. Each service NTPR team responded to its own File A personnel.

The teams did not formulate any set approach for processing File A inquiries at the beginning of the task. They did, however, generally use the procedures identified below.

- Collected information
  - Requested specified data from each caller on the DNA toll-free lines
  - Accumulated records from over 100 repositories
  - Gathered data from individuals knowledgeable about the U.S. atmospheric nuclear weapons tests and personnel participation
- Established data base
  - Entered participants' personal and participation data
  - Incorporated relevant dosimetry information from medical records, REECo files, Lexington Blue-Grass Signal Depot records, as well as some 80 other sources
- Provided missing dosimetry information
  - Reviewed assembled data for gaps
  - Incorporated reconstructed dose information into the data base
- Developed final response
  - Determined participation and dosimetry information
  - Sent a letter to each caller.

The final File A letters were the conclusion of a lengthy procedure. The drafting and processing of these letters was a considerable effort in itself, although not as demanding as the preceding research. In 1984 the Navy NTPR (NNTPR) team estimated the average time spent on this correspondence as shown in **Table 2-1** (Buckley, 29 August 1979):

Table 2-1. Average File A letter processing requirements.

Function	Number of People	Time Per Record (minutes)	NTPR Work Hours Daily (for 30 records)
Draw Records	1	3	1.5
Process Dose Data	1	10	5
Research/Draft Letter	3	45	22.5
Type Letter	1	15	7.5
Quality Control	1	10	5
Signature	1	2	1
Mail, Refile, Log	1	3	1.5
Supervision	1	8	4
Total	**10**	**1 Hr. 36 Min.**	**48 Hrs.**

The next five sections summarize the work of the individual service NTPR teams. The commentary focuses on key efforts, including responses to File A inquiries from veterans or family members, assignment of doses, notification of medical examination programs, and investigations for VA claims.

2.2 NAVY NTPR EFFORTS.

The NNTPR was responsible for tracking the largest group of test participants, 52 percent of the total number reported by the military services as of mid-1986 (Baciocco, 11 July 1984). NNTPR identified 106,942 Navy personnel, believed to be virtually all of its participants (Bell, 20 May 1986). In addition, the Navy claimed about one-third of the approximately 50,000 File A inquiries made by that time (Johnson, 2 May 1985).

The NNTPR had distinct advantages over the other teams in locating its personnel. Most of the Navy participants, for example, were in ships during the tests, and their exact locations could be identified through the use of ship logs and daily diaries. The NNTPR had access, too, to the personnel records system maintained by the Navy. Making good use of these advantages, the NNTPR made the best initial progress of the Service teams on the tasks DNA assigned it.

The NNTPR concentrated on quality control in the handling and processing of data and assembled information that will be useful for years to come. With these data, the NNTPR prepared a number of tables, a sample of which is given below, that summarized its efforts and the participation of Navy personnel in the nuclear tests.

2.2.1 Resources.

The NNTPR office was established at the Pentagon on 21 February 1978. The Project Managers, from the beginning of the effort until April 1987, were Captain Thomas H. Sherman, February to April 1978; Captain Andrew G. Nelson, May 1978 to June 1979; Captain James R. Buckley, June 1979 to April 1981; Commander R. Thomas Bell, May 1981 (Acting Project Manager); Captain William H. Loeffler, June 1981 to September 1984; Commander R. Thomas Bell, October 1984 to September 1986; and Commander Karl G. Mendenhall, September 1986 to April 1987, when DNA took over NNTPR's work. As of 1 May 1986, the NNTPR had used 195 person years and spent $9,256,000 (Johnson, 8 July 1986). **Tables 2-2** and **2-3** itemize the annual expenditures (Bell, 20 May 1986):

Table 2-2. NNTPR personnel effort.
(in person years)

	FY78*	FY79	FY80	FY81	FY82	FY83	FY84	FY85**	FY86
Military Officer Enlisted	 2.08 0.75	 4 2.17	 3.75 1.71	 2.92 2.06	 3 1.25	 3 1	 3 1	 2 1	 2 1
Civil Service	0.83	3.42	3.62	3	2	2	2	1	1
Contractor	1.67	29.67	35.07	21.11	15	14	14	4	4
Total	5.33	39.26	44.15	29.09	21.25	20	20	8	8

* FY78-FY84: Research and program development phase.
** FY85-on: Maintenance office phase.

Table 2-3. NNTPR costs.
(in thousands of dollars)

	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86
Separately identifiable costs *	205	1,524	1,748.1	1,032.7	839	953	801	300	300
Salaries and benefits **	71.6	173.6	177.7	191.7	220.6	208	210	150	150
Total	276.6	1,697.6	1,925.8	1,224.4	1,059.6	1,161	1,011	450	450

* Contracts, services, travel, materials, equipment rental, etc. less items in**.
** Uniformed military and civil service personnel only.

2.2.2 Results.

The NNTPR identified and assigned external gamma doses to virtually all of the Navy test participants. The summaries in this section detail the team's fulfillment of its assigned responsibilities.

Response to File A Personnel. As of 1 May 1986, the NNTPR had mailed nearly 20,000 File A letters containing information on participation and dosimetry data to Navy personnel who had contacted DNA (Bell, 20 May 1986). Approximately 300 follow-up letters were sent as dose reconstructions were completed. The NNTPR also mailed more than 1,500 final letters to callers who reported participation in the occupation of Hiroshima/Nagasaki as well as to callers found to be non-participants in either the occupation or U.S. atmospheric nuclear testing.

Assignment of Doses. The NNTPR had recorded and/or calculated radiation doses for nearly 99 percent of all Navy test participants. The team and its contractors assembled this information by searching through medical and historical records, by using film badge information, and by reconstructing doses when film badges were not available, or complete.

The NNTPR reviewed over 99 percent of the participants' medical records (more than 105,000 records). Researchers accomplished most of this work during a one-year period, when they examined about 1,700 records a week (Johnson, 2 May 1985).

Doses had to be reconstructed for more than half the Navy participants since only about 45 percent of these personnel had recorded exposure data. The effort was even greater for Operation CROSSROADS, conducted in 1946 at Bikini as the first postwar nuclear test series. Because no participants were badged for the entire operation and many were not badged at all, reconstructed doses covering at least a portion of the operation were needed for all of the then estimated 38,000 Navy participants in this operation. The NNTPR spent more time determining the doses for CROSSROADS personnel than it did for Navy participants in all the other series combined. Commander R. T. Bell, acknowledged the challenge of CROSSROADS when he referred in an interview to the "massive effort" expended by the NNTPR and DNA contractors on dose reconstruction (Johnson, 2 May 1985).

Notification of VA Medical Examination Programs. The NNTPR had a total of three personnel in the Over-25-rem Program, five in the Volunteer Observer Program, and 503 in the Over-5-rem Program, as shown in the table below. Approximately 65 percent of those in the Over-5-rem Program participated in Shot BRAVO of Operation CASTLE (Bell, 20 May 1986).

The NNTPR sent notification letters to all personnel in these programs having identifiable addresses, a number totaling 464. Of this group, 150 participants stated that they wanted the medical examination being provided by the VA. Only 108, or 23 percent of the personnel notified, actually took the examination (Bell, 20 May 1986).

Table 2-4 provides a breakdown of the NNTPR medical examination programs.

Table 2-4. NNTPR personnel eligible for medical examination programs (Bell, 20 May 1986).

		Number
1.	Over-25-rem Program	
	Total	3
	Notifications sent	3
	Replies received	2
	Number deceased	1
	Number desiring examinations	0
	Number not desiring examinations	0
	Number not making preference clear	2
	Examinations administered	0
2.	Officer Volunteer Observer Program	
	Total	5
	Notifications sent	5
	Replies received	5
	Number deceased	0
	Number desiring examinations	2
	Number not desiring examinations	3
	Examinations administered	2
3.	Over-5-rem Program	
	Total	503
	Notifications sent	456
	Replies received	285*
	Number deceased	58
	Number desiring examinations	148
	Number not desiring examinations	95
	Examinations administered	106

Investigations for VA Claims. The NNTPR provided information on participation and dose data to the VA for 1,045 claims filed for compensation benefits by Navy personnel who believed their diseases or disabilities were caused by their exposure to ionizing radiation from U.S. atmospheric nuclear weapons testing (Bell, 20 May 1986).

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*The memorandum of 20 May 1986 gives the number of replies received as 285, but it accounts for only 243, indicating that 148 Navy personnel replied who desired exmainations and 95 replied who did not desire examinations.

In compiling data for the VA, the NNTPR developed over 360 unit histories, usually from one to three pages long, for the ships, squadrons, and staffs associated with the oceanic atmospheric nuclear tests. These histories provided unit locations and activities during the test series, unit dosimetry data, and, when available, the radiological conditions present (Bell, May 1986).

Correspondence Summary. In fulfilling its obligations, the NNTPR processed considerable amounts of correspondence. **Table 2-5** summarizes both the type and volume of correspondence for selected years (Bell, May 1986):

Table 2-5. NNTPR outgoing correspondence totals.

Type	1978	1980	1982	1984	1985	1986
Personal Inquiry	11	1,226	217	218	107	47
VA Request	14	325	132	212	223	62
Congressional	8	46	42	17	20	8
Request from Family	1	25	13	9	18	1
Request from Employer	0	12	8	2	2	0
Miscellaneous	291	58	262	227	164	30
Memorandum for the Record	33	114	58	59	16	1
FOIA	0	2	35	16	24	2
Attorney's Request	0	13	7	6	4	2
Special Medical Letter	0	586	0	0	0	0
Over-5-rem Letter	0	163	13	0	4	0
Medical Records Request	0	483	21	0	2	2
Form Letter	0	552	89	124	135	127
Final File "A" Letter	0	0	5,170	6,632	182	170
Non-Participant Letter	0	0	523	271	9	4
Total	358	3,605	6,590	7,793	910	456

2.3 ARMY NTPR EFFORTS.

The Army NTPR (ANTPR) had 50,989 participants, the second largest group, about 25 percent of the total. Of these, about 77 percent took part in continental United States (CONUS) tests and 23 percent in the Pacific tests.

The ANTPR presented these figures, along with others, in its History of the Army Nuclear Test Personnel Review (1978-1987), the only such summary developed by an NTPR Service team (Department of the Army, 24 September 1987). Unless otherwise documented, the following sections are drawn from this text.

2.3.1 Objectives.

In 1978, the ANTPR began pursuing its assigned tasks by researching Army documents, developing a data base, and corresponding with individual participants (Johnson, 25 June 1985). It concentrated first on personnel identification and records retrieval for the operations involving Desert Rock exercises performed to train troops in tactics for possible use on a nuclear battlefield. The operations incorporating these exercises were BUSTER-JANGLE (1951), TUMBLER-SNAPPER (1952), UPSHOT-KNOTHOLE (1953), TEAPOT (1955), PLUMBBOB (1957), and DOMINIC II (1962). This particular focus was selected because of the continuing CDC epidemiological investigation of Shot SMOKY, which was one of the PLUMBBOB tests, and because of Congressional requests for information. After completing this phase of the research, the ANTPR team turned its attention to Army participants in the oceanic series of atmospheric nuclear tests.

ANTPR researched available Service and medical records for participants and reviewed the morning reports of Army units. The effort was challenging because of inadequate documentation of Army personnel participation:

- The 1973 fire at NPRC had destroyed about 85 percent of the Army personnel records for veterans who had left the Service from 1912 to 1959;
- About 50 percent of the Army participants had been assigned to provisional Desert Rock units which did not require permanent recordkeeping; and
- The extant records did not provide sufficient information on personnel activities and locations at the test sites.

To gain the needed information, ANTPR researchers had to check virtually every morning report for every unit identified as having participated in or having sent members to participate in U.S. atmospheric nuclear weapons tests. The sheer volume of morning reports made the task extremely time-consuming.

The ANTPR approach, like that of the other NTPR teams, evolved in response to DNA directives, along with Congressional and public needs. By August 1979, the ANTPR team had shifted its primary emphasis from research on individuals to responses to specific groups, such as the Over-25-rem and Over-5-rem participants, officer volunteer observers, and VA claimants. Section 2.3.3 presents statistics on these efforts.

In late 1982, the ANTPR data entry staff decreased in number, as personnel and financial resources were redirected to handle new priorities within the Army, such as the Agent Orange Task Force. At about the same time, programming and data entry errors created problems in the ANTPR computer system. In early 1983, the ANTPR Program Manager sent a memorandum to the DNA NTPR Program Manager indicating that these problems, along with the decrease in staff, had resulted in considerable curtailment of data entry within the past quarter. DNA and the Army worked together in the latter half of 1983 to identify the difficulties and prescribe solutions.

In a meeting with DNA on 31 January 1984, the Army agreed to provide funds to contract for technical support, especially for purifying the ANTPR data base. The contract was awarded in September 1984, and work commenced immediately toward accomplishment of the five major ANTPR tasks, beginning with the data base purification. Subsequent tasks involved identifying personnel and units, determining radiation exposure and entering information into the ANTPR data base, notifying test participants of their exposure, and responding to requests for information from veterans, the VA, and Congress. With the assistance of its contractor, the ANTPR's progress toward its objectives was much more rapid.

2.3.2 Resources.

The ANTPR had five chief administrators: Colonel Victor J. Hugo, February 1978 to September 1978; Colonel David P. Lucke, September 1978 to October 1979; Lieutenant Colonel Darwin M. Way, 17 October 1979 to June 1980; Mr. Waldemar A. Anderson, June 1980 to March 1981; and Mr. Richard S. Christian, March 1981 to September 1987.

As of 24 September 1987, the ANTPR had used 265 person years and spent over $5,600,000. **Table 2-6** and **2-7** itemize these expenditures on an annual basis. As shown in the table on costs, the expenditures for such items as contracts, services, and equipment increased in fiscal year 1984, when the ANTPR engaged a contractor to purify its data base and provide other technical support (Department of the Army, 24 September 1987).

Table 2-6. ANTPR personnel effort.*
(in person years)*

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87
10	41	41	37	37	33	15	17	17	17

* Some of the numbers shown differ from the ones provided in the 1986 edition of this history. They are based on a later Department of the Army report (dated 24 September 1987).

Table 2-7. ANTPR costs.*
(in thousands of dollars)

	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87
Separately identifiable costs**	23	25	36	40	160	110	720	730	730	730
Salaries and benefits***	168	448	552	507	50	60	66	150	150	150
Total	191	473	588	547	210	170	786	880	880	880

* Some of the numbers shown differ from the ones provided in the 1986 edition of this history. They are based on a later Department of the Army report (dated 24 September 1987).

** Contracts, services, travel, materials, equipment rental, etc. less items in***.

*** Uniformed military and civil service personnel only.

2.3.3 Results.

The numbers given below were current as of 24 September 1987.

Response to File A Personnel. By September 1987, when ANTPR was disestablished and its work taken over by the consolidated effort at DNA, the team had sent final letters to 11,494 participants after work was completed on dose information and reconstruction (Department of the Army, 24 September 1987).

Notification of VA Medical Examination Programs. Among the NTPR teams, ANTPR had the largest number of individuals, a total of 24, in the Volunteer Observer Program. **Table 2-8** below shows statistics of this program, as well as the Over-25-rem and Over-5-rem Programs. The ANTPR notified all personnel in these programs who had identifiable addresses.

Table 2-8. ANTPR personnel eligible for medical examination programs.

		Number
1.	Over-25-rem-Program (Samiljan, 8 July 1987)	
	Total	4
	Notifications sent	4
	Replies received	2
	Number deceased	1
	Number desiring examinations	1
	Number not desiring examinations	1
	Examinations administered	1
2.	Volunteer Observer Program (Samiljan, 8 July 1987)	
	Total	24
	Notifications sent	24
	Replies received	11
	Number deceased	2
	Number desiring examinations	5
	Number not desiring examinations	6
	Examinations administered	1
3.	Over-5-rem-Program (Nelson, 5 October 1987)	
	Total	558

Table 2-8. ANTPR personnel eligible for medical examination programs. (Cont'd)

Personnel notified	301
Desiring physicals	90
Not desiring physicals	54
No responses	157
Personnel not notified	257
Insufficient information* (no address/no SSN)	153
Addresses (known)	1
SSN (no addresses)*	38
Deceased	65

* Includes those returned for incorrect/unknown address.

Investigations for VA Claims. The ANTPR provided participation, unit histories, and dose data for about 1,200 VA inquiries received concerning Army veterans (Samiljan, 8 July 1987). Because of the inadequate documentation of Army personnel participation as discussed earlier, ANTPR researchers had to scrutinize individual unit morning reports and secondary sources to verify claimants' participation in the atmospheric nuclear tests.

2.4 AIR FORCE NTPR EFFORTS.

The Air Force NTPR (AFNTPR) team was responsible for about 25,000 participants, which is approximately 12 percent of the total number of U.S. nuclear test participants. It was tasked with assembling participant and dose information for its personnel in those series after 1947, when the Air Force was established as a separate military service. The Army Air Force personnel who took part in the two preceding operations, TRINITY (1945) and CROSSROADS (1946), were the responsibility of the ANTPR. The exception involved Army Air Force participants who later entered the Air Force and took part in subsequent atmospheric nuclear test series. DNA assigned responsibility to AFNTPR for compiling Army and Air Force records on these personnel in response to claims filed with the VA (Johnson, 23 May 1985).

2.4.1 Resources.

The AFNTPR Team Chief, part of the Air Force Surgeon General's office, oversaw the effort, which was conducted at the Occupational and Environmental Health Laboratory (OEHL), Brooks Air Force Base (AFB), Texas. OEHL had a radiation services division and was a logical organization for involvement.

AFNTPR was officially established in March 1979. During 1978, when a basis was being laid for the AFNTPR, Lieutenant Colonel George S. Kush, USAF, attended NTPR meetings. The first AFNTPR Team Chief was Colonel Paul F. Fallon, who held the position from March 1979 to February 1984. His successor was Colonel William D. Gibbons, February 1984 to June 1988. The following Project Officers managed the AFNTPR office at OEHL: Captain John L. Ricci, September 1978 to September 1979; Captain Robert J. Berger, September 1979 to May 1981;

Captain David S. Pitts, May 1981 to June 1985; Mr. John A. Herman, June 1985 to January 1986; and Mr. William D. Holland, January 1986 to June 1988.

As of 1 May 1986, the team chiefs and project officers had overseen a total AFNTPR expenditure of 175 person years and $3,924,000. The numbers were largest in the early 1980s, as with the other Service teams. **Tables 2-9** and **2-10** indicate the annual expenditures (Gibbons, 30 May 1986; Pitts, 23 May 1985):

Table 2-9. AFNTPR personnel effort.
(in person years)*

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86
0.18	7.65	33.7	44.30	38.30	25.5	16.0	7.0	2.0

* Does not include Air Staff time.

Table 2-10. AFNTPR costs.
(in thousands of dollars)

	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86
Separately identifiable costs**	1.5	148	525	722	590	486	7	2.5	1.5
Salaries and benefits***	4.1	100	187	285	315	231	236	58	24
Total	5.6	248	712	1007	905	717	243	60.5	25.5

** Contracts, services, travel, materials, equipment rental, etc., less items in ***.
*** Uniformed military and civil service personnel, but does not include salaries for Air Staff.

Inquiries at the Air Force Office of the Surgeon General, Bolling AFB, Washington, D.C., and at Brooks AFB, did not reveal records documenting the AFNTPR personnel effort or costs after 1 October 1986.

2.4.2 Results.

By 1985, the AFNTPR believed it had successfully completed most of its tasks. Team project officers attributed much of the success to a solid research effort, conducted at such sites as Brooks AFB, Kirtland AFB, Maxwell AFB, Randolph AFB, Scott AFB, Tinker AFB, LANL, and REECo (Johnson, 23 May 1985).

Response to File A Personnel. The AFNTPR finished sending letters to participants who called DNA on the toll-free number. As of 1 May 1986, the team had completed 8,047 File A cases, which comprised 100 percent of the then known Air Force cases (Gibbons, 30 May 1986).

The AFNTPR was responsible for a lesser number of File A personnel than the NNTPR and the ANTPR. The task for the AFNTPR was compounded, however, because many Air Force participants attended more than one series and thus required comparatively more research.

Moreover, some Air Force personnel were crewmembers aboard aircraft that staged from air bases outside the immediate area of NTS and returned to those bases after participation without landing near NTS. These men, numbering perhaps several hundred, have proved very difficult to identify.

<u>Assignment of Doses</u>. As of 1 May 1986, compilation of dose information for then-known Air Force test participants neared completion. The AFNTPR had identified 23,403 of the estimated 205,660 total participants (Gibbons, 30 May 1986). This data base became an integral part of the Air Force Master Radiation History Repository at OEHL.

<u>Notification of VA Medical Examination Programs</u>. The Air Force had 32 individuals in the Over-25-rem Program, the largest number of participants for this program among the NTPR teams. Twenty-five Air Force participants were stationed on Rongerik Island where an unexpected high level of fallout from Shot BRAVO of Operation CASTLE (1954) occurred. (See Section 6.10.)

Cloud-sampling pilots and crews often received higher doses than did other test participants because their missions required them to fly near and through the clouds resulting from the nuclear detonations. The cloud-sampling teams were commonly authorized special exposure limits so they could accomplish their assigned tasks. As noted in Section 6, these limits ranged from 3.9 rem at such series as BUSTER-JANGLE, TUMBLER-SNAPPER, IVY, UPSHOT-KNOTHOLE, and TEAPOT, among others, to 10 rem at Operation HARDTACK II and 20 rem at Operation DOMINIC I.

Table 2-11 presents statistics on the Volunteer Observer Program, the Over-25-rem Program, and the Over-5-rem Program. The AFNTPR notified all personnel in these categories that had identifiable addresses.

Table 2-11. AFNTPR personnel eligible for medical examination programs.

		Number
1.	Over-25-rem Program (AFNTPR, 1 Oct 1986)	
	Total	32
	Notifications sent	30
	Replies received	22
	Number deceased	2
	Number desiring examinations	18

Table 2-11. AFNTPR personnel eligible for medical examination programs. (Cont'd)

	Number not desiring examinations	4
	Number not making preference clear	8
	Examinations administered	11
2.	Officer Volunteer Observer Program (Gibbons, 30 May 1986)	
	Total	6
	Notifications sent	5
	Replies received	3
	Number deceased	1
	Number desiring examinations	0
	Number not desiring examinations	3
	Examinations administered	0
3.	Over-5-rem Program (AFNTPR, 1 October 1986)	
	Total	508
	Notifications sent	334
	Replies received	185
	Number deceased	61
	Number desiring examinations	138
	Number not desiring examinations	47
	Examinations administered	53

Investigations for VA and Department of Labor (DoL) Claims. The AFNTPR provided participation and dose information for 266 VA claims filed by Air Force test participants (Gibbons, 30 May 1986). It gave the same kinds of data to the DoL for the one DoL claim filed by a civilian working under contract to the Air Force during nuclear testing (Herman, June 1985).

2.5 MARINE CORPS NTPR EFFORTS.

As of 30 September 1986, the Marine Corps NTPR (MCNTPR) was responsible for an estimated 11,100 participants in the atmospheric nuclear weapons tests (Martinez, 1 October 1986). To provide participation and dose information for these personnel, the MCNTPR developed and pursued a vigorous outreach program, which was one of the most distinctive characteristics of its efforts. The MCNTPR completed most of its assigned tasks, as noted below.

2.5.1 Resources.

From its inception in early 1978 to May 1986, the MCNTPR engaged a total of 26 Marine Corps personnel, including four project coordinators: Major Rafael Negron, January 1978 to April 1979; Captain James W. McNabb, May 1979 to June 1982; Major Michael J. Shinabeck, July 1982 to May 1983; and Major Daniel G. Martinez, May 1983 to April 1987.

As of 1 April 1987, the MCNTPR effort cost approximately 40 person years and $848,250. The largest expenditures were during 1980-82, as shown in **Tables 2-12** and **2-13** the following tables (Martinez, March 1985; Johnson, 10 July 1986; Gladeck, 16 August 1993):

Table 2-12. MCNTPR effort.
(in person years)

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87
1.5	4.8	6.8	6.5	6.5	4.0	3.0	3.0	3.0	0.75

Table 2-13. MCNTPR costs.
(in thousands of dollars)*

FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87
22	77	168	160	160	70	50	60	65	16.25

* To 1 April 1987 when MCNTPR was disestablished.

The dollar costs are for salaries and benefits. Specific data are not available for contracts, services, travel, materials, and equipment rental during FY78 through FY87, although the expenditures were minimal.

2.5.2 Results.

The personnel effort and dollar costs brought some "positive results," to quote Major Daniel Martinez, the last MCNTPR Project Coordinator (Johnson, 14 May 1985). This section discusses accomplishments beginning with an outreach program, which included commentary on the MCNTPR response to File A personnel.

<u>Outreach Program</u>. One of the specific NTPR tasks, as noted in NTPR fact sheets of the early and mid-80's, was to "establish personal contact with as many test participants as possible" (Defense Nuclear Agency, April 1984). The MCNTPR developed an active outreach program, making this effort its highest priority in 1985 and 1986. The emphasis resulted in a considerable amount of additional information from participants who had not yet contacted DNA.

As of 1 May 1986, the MCNTPR had sent letters with information on participation and dosimetry data to 3,600 of the 4,500 Marine Corps personnel who used the toll-free DNA telephone number or wrote to the Agency. The correspondence went to all participants having identifiable addresses. Because addresses had changed and return addresses were not provided, 325 letters were returned (Martinez, 1 July 1986).

The MCNTPR used several strategies to locate additional personnel. One of the first involved a computer comparison between known participants in the nuclear tests and retired Marines. Personnel who had not yet contacted DNA were sent questionnaires filled in with available information. They were asked to check the incorporated data, complete, and then return the forms in the stamped and self-addressed envelopes that had been enclosed (Johnson, 16 May 1985). The last of these questionnaires were mailed in August 1985.

The MCNTPR had good results from the placement of advertisements in periodicals, such as Leatherneck Magazine and the Marine Corps Gazette, and from letters sent to Marine Corps associations celebrating reunions. Among the groups contacted were the 1st, 2nd, 3rd, 4th, 5th, and 6th Marine Division Associations; the Marine Corps League; and the Woman Marines Association. The MCNTPR sent 3,000 copies of the circular shown in **Figure 2-1** to the 2nd Marine Division. This circular alone drew 500 responses (Johnson, 16 May 1985). Through the outreach program, the MCNTPR team, to quote from the letter sent to the 2nd Marine Division Association, collected "useful information that normally cannot be obtained from service records."

Assignment of Doses. As of 30 September 1986, the MCNTPR verified the participation of 11,067 of the estimated 11,100 Marine Corps test participants. It had dose information for 10,767, or approximately 97 percent, of these participants (Martinez, 30 September 1986).

Notification of VA Medical Examination Programs. The MCNTPR and the Field Command NTPR (FCNTPR) (see Section 2.6) were the only NTPR teams having no personnel in the Over-25-rem Program. Six Marine Corps personnel were in the Officer Volunteer Observer Program and 29 in the Over-5-rem Program, as shown in **Table 2-14**. The MCNTPR notified all of the participants, 27, who had identifiable addresses (Martinez, 30 September 1986).

Table 2-14. MCNTPR personnel eligible for medical examination programs.

1. Officer Volunteer Observer Program	Number
Total	6
Notifications sent	6
Replies received	6
Number deceased	0
Number desiring examination	4
Number not desiring examinations	1
Number undecided or unspecified	1
Examinations administered	3

DEPARTMENT OF THE NAVY
HEADQUARTERS UNITED STATES MARINE CORPS
WASHINGTON, D.C. 20380

May 1984

Second Marine Division Association Members

Dear Fellow Marine:

Please excuse the informality of this letter, but this is the best way for me to get in touch with you.

Since 1978, the Marine Corps Nuclear Test Personnel Review (NTPR) has been trying to identify every Marine who participated in at least one nuclear weapon event. The purpose of the NTPR is to compile data on Marines who could have been exposed to weapon-induced ionizing radiation. NTPR data will be studied in an effort to elucidate the health effects of exposure to low-level ionizing radiation. The Defense Nuclear Agency (DNA) is the NTPR executive agency for the Department of Defense.

Marines of the Second Marine Division have taken an active role in America's use and development of nuclear weapons. Nagasaki, Japan, was destroyed by a nuclear weapon on August 9, 1945, and Second Division Marines occupied that area some six weeks later. Between 1945 and 1962, the United States conducted 235 atmospheric nuclear weapon detonations and tests in which many Second Division Marines participated.

If you participated in the post World War II occupation of Nagasaki or in at least one nuclear weapon test, I urge you to call DNA's toll-free NTPR telephone number. Call 800-336-3068 to provide some basic information about your role in nuclear weapon-related events. If you know other Marines whom we might be interested in hearing from, please pass this information on to them.

It has been our experience that Marines are able to provide for the NTPR much useful information that normally cannot be obtained from service records. To contact the Marine Corps NTPR, write to Commandant of the Corps (Code MMRB-60), Washington, D.C. 20380. If you already have contacted DNA, please keep your mailing address current by calling the toll-free number.

Best wishes to you, and I hope that your reunion will be a great success.

Sincerely,

D. G. MARTINEZ
Captain, U.S. Marine Corps Reserve
Project Coordinator
Marine Corps Nuclear Test Personnel Review
By direction of the Commandant of the Marine Corps

Figure 2-1. Letter sent to the Second Marine Division Association as part of the MCNTPR Outreach Program.

Table 2-14. MCNTPR personnel eligible for medical examination programs. (Cont'd)

2. Over-5-rem Program	Number
Total	29
Notifications sent	21
Replies received	13
Number deceased	3
Number desiring examinations	11
Number not desiring examinations	1
Number undecided or unspecified	1
Examinations administered	4

Investigations for VA Claims. The MCNTPR provided participation and dose information for 217 VA claims filed by Marine Corps personnel (Martinez, 30 September 1986).

2.6 FIELD COMMAND NTPR EFFORTS.

On 1 May 1951, the organization that became Field Command, DNA, was established as part of the Armed Forces Special Weapons Project (AFSWP). AFSWP was redesignated the Defense Atomic Support Agency (DASA) in 1959 and then DNA in 1971. On 7 June 1978, DNA sent a tasking letter to Field Command DNA requiring it to function generally "in the same manner as the four military services to provide an input to the NTPR covering the personnel of AFSWP and their contractors and laboratories for all atmospheric tests" (Isengard, 6 June 1978).

William S. Isengard, the first FCNTPR Project Officer, noted that FCNTPR was starting "several months downstream" of the other NTPR teams and that the delay was both bad and good. The disadvantage was that FCNTPR would have "less time" for research on Shot SMOKY and the other nuclear tests. The advantage was that FCNTPR could learn from the experience of the other teams (Isengard, 6 June 1978).

Although the initial tasking to FCNTPR seemed straightforward enough, the development of the NTPR program led the team to cope with the group of nuclear test participants most difficult to track and quantify. Included were:

1. Civilian employees of DoD organizations at the Secretary of Defense level, such as AFSWP, and their contractors.

2. Civilian employees of agencies other than DoD and DOE and their contractors.

3. U.S. civilian observers, such as members of Congress and corporation executives, and

4. Foreign observers, military and civilian.

In practice, FCNTPR functioned as a holding area into which unidentified participants were put for further screening (Gladeck, 19 August 1993). The team identified about 11,900 personnel as participants (Nelson, 12 June 1989). However, most turned out not to fall within the scope of the NTPR program because no DoD connection could be established.

2.6.1 Resources.

Field Command recognized the challenge of the NTPR tasking and acknowledged that "some of our best people" would be required. The personnel needed would include at least two researchers and a computer systems analyst/programmer (Isengard, 8 June 1978). From its inception in 1979, the FCNTPR team usually consisted of three persons, military and civilian. The following Project Officers coordinated the team: Mr. William S. Isengard, 1978; Major James E. Thomas and Major David E. Hanson, 1979; Captain Mark L. Davis, 1980 to August 1982; Joe A. Stinson, August 1982 to February 1988. As of 1 May 1986, the FCNTPR effort had cost 24 person years and $240,000 (Stinson, 3 March 1986; Johnson, June 1986). The annual FCNTPR budget, excluding military pay, was about $29,000 and included salaries and benefits for civilian personnel, transportation, equipment, supplies and materials, and contracted services (Johnson, 11 July 1985). FCNTPR was disestablished on 2 February 1988. Exact figures for total expenditures and person years during the team's existence are not available, but estimates of $288,000 and 28 person years seem reasonable based on the record up to May 1986.

2.6.2 Results.

Compared to the other NTPR teams, FCNTPR had a greater challenge identifying its personnel, their participation, and their doses. The FCNTPR lacked good source documents. Unlike their counterparts on the other teams, FCNTPR researchers were unable to use ship logs, morning reports, or the records generated by military retirement pay centers. Moreover, they experienced difficulties finding information on certain DoD contracting organizations, many of which no longer existed. To assist research on these organizations, Major Stinson developed and published a reference book listing the contracting organizations that had been identified (Stinson, May 1986).

Response to File A Personnel. The FCNTPR contacted over 500 participants who used the DNA toll-free lines. Many of these participants, however, were transferred to the other NTPR teams. As of 1 May 1986, the FCNTPR File A consisted of 297 participants who had been identified as employees of DoD joint-service organizations and their contractor. The team sent final letters on participation and dose to 119 of these personnel for whom it had addresses. FCNTPR researchers also identified approximately 500 Canadian observers of the CONUS tests and believed there may have been as many as 500 more. FCNTPR received permission from DNA to contact the Canadian government concerning these personnel.

Notification of VA Medical Examination Programs. The FCNTPR obtained dose information, primarily from film badges, for almost all of its personnel. Unlike most of the other NTPR teams, it had no participants in the Volunteer Observer Program or Over-25-rem Program. The team had only one participant in the over-5-rem program. Researchers did not succeed in finding a current address for this individual.

Investigations for Department of Labor Claims. None of the Field Command personnel had filed a claim with the DoL (Johnson, 11 July 1985).

SECTION 3

THE CONSOLIDATED NTPR PROGRAM UNDER DNA

From its beginning in 1978, NTPR made considerable progress in collecting, organizing, and disseminating information on veterans who participated in U.S. atmospheric nuclear testing and the occupation of Hiroshima and Nagasaki, Japan, following World War II. By 1986, however, shortcomings of the five-team approach became apparent. Moreover, it was believed that activity in the program would decrease, and enter a maintenance phase. DNA's leadership decided that these problems called for phasing out the Service teams and consolidating the work under DNA's direct control.

3.1 REASONS FOR CONSOLIDATION.

In a memorandum dated 29 September 1986, distributed to each of the Service secretaries, Lieutenant General John L. Pickett, USAF, Director, DNA, proposed the consolidation of all NTPR functions under DNA (Pickett, 29 September 1989). He pointed out that NTPR had accomplished almost all of the original goals set forth in February 1978 by Vice Admiral R. R. Monroe, USN, then Director, DNA (Monroe, 13 February 1978). The program's major accomplishments included:

- Publishing a 41-volume history of the U.S. atmospheric nuclear tests from 1945 to 1962;
- Identifying 198,000 of the approximately 200,000 participants;
- Compiling dose information for 190,000 participants;
- Sponsoring NAS studies; and
- Corresponding with over 50,000 veterans to provide them with relevant information.

General Pickett explained that the original research assignment was no longer appropriate. Original planning had called for each NTPR Service team to complete its research and shift to a maintenance program. This, however, would lead to duplication of effort among the teams and unnecessary use of resources in a time of reduced funding.

The proposed reorganization would save DoD approximately $900,000 and open up nine personnel slots over the next four fiscal years. To fund the consolidated operations at first, each Service would transfer money to DNA in proportion to the number of that Service's personnel involved in atmospheric nuclear testing. After fiscal year 1990, DNA would assume all NTPR financial burdens. General Pickett recommended that because both the Air Force and Navy had completed their research and moved into a maintenance phase; their NTPR work would be consolidated with DNA in fiscal year 1987. ANTPR still had one year left in its research phase, so General Pickett suggested that the Army delay transferring functions until fiscal year 1988 or when the research was complete. After fiscal year 1987, DNA would provide all the manpower needed for the Army portion of NTPR. FCDNA and MCNTPR were not mentioned in General Pickett's memorandum.

3.2 MECHANICS OF CONSOLIDATION.

The Services agreed to consolidation and began turning over their functions and records to DNA. MCNTPR and NNTPR closed in April 1987 and ANTPR in September 1987. FCNTPR closed in February 1988, and AFNTPR closed in June of that year (JAYCOR, no date).

Consolidation required considerable work. For example, records filling 130 boxes were packed and trucked from AFNTPR headquarters at Brooks AFB, San Antonio, Texas, to the Washington, D.C., area, to be unpacked and installed in the NTPR facility. Each Service team had maintained its own computer data base of information on veterans, generally referred to as File B. Each team's File B was housed on a different model computer and each had similar but not matching data fields. In mid-1988 after considerable effort, the data bases were merged to form the NTPR data base.

3.3 NTPR WORK UNDER THE CONSOLIDATED SYSTEM.

Contrary to expectations, the program did not enter a maintenance phase. No major new tasks arose, but the work pace in established channels was brisk, and much new information was uncovered and had to be assimilated. Moreover, Congress passed new legislation allowing many more veterans to make claims for radiation injury.

3.3.1 Work in Established Channels.

By the time consolidation was complete, NTPR work had settled into two major categories: (1) Responding to mail and telephone inquiries, and (2) research. These are not isolated from each other. Responding to inquiries often requires research beyond checking a data base or folder in a filing cabinet.

Despite all the work by program personnel in NTPR's early days, troublesome gaps exist in the program's information. This is true for both information about the activities of personnel and units and about individual exposure to radiation. Although some of this information is lost forever, some can still be retrieved and program personnel are continuing to search for data.

3.3.1.1 **Responding to Inquiries.** Word of NTPR continues to spread, and veterans who have not previously contacted the program call or write. Their unverified data is entered in the File A data base. Then research is conducted to determine whether their participation in U.S. atmospheric nuclear testing can be verified. Available substantiating data is subsequently entered in the NTPR data base. Correspondents are then provided with a written response.

Claims continue to arrive from the VA. As with File A inquiries, research is conducted to verify participation and when required, dosimetry data is provided. For many cases that effort is fairly straightforward, but some require intense dosimetry records research. In a case where dosimetry has gaps or does not exist, the veteran's dose must be reconstructed, an often labor-intensive, time-consuming process.

Less numerous than File A contacts and VA claims are personal letters from veterans who have already contacted the program, letters from members of Congress seeking information for constituents, and Freedom of Information Act (FOIA) requests. File A and VA responses often follow established patterns that help speed the process. Personal and Congressional inquiries and FOIA requests are very diverse and often require unique research and non-standardized replies.

3.3.1.2 Research. Several categories of research continue.

1. Research required to meet short-term requirements.

   For example, a veteran contacting NTPR for the first time may have belonged to a unit not previously identified as having members that participated in U.S. atmospheric nuclear testing. In these cases, recorded dosimetry is often lacking. Therefore, considerable effort is often required to verify the veteran's participation and to assess radiation exposure.

2. Research required to improve the dosimetry data base.

   Originally each NTPR Service team was responsible for collecting and maintaining dosimetry data for identified participants. Disparities occurred in the way key terms, such as participant, test site, and operational period, were defined and applied.

   Moreover, each Service team had established its own criteria for:

   - assigning reconstructed doses,
   - responding to inquiries,
   - entering attach and detach dates,
   - reporting doses,
   - applying "benefit of the doubt," and
   - maintaining an audit trail of dose data

   With consolidation and the creation of a unified data base, these differences became apparent. Research, programming, and data entry continue to identify and resolve these disparities.

   In addition, the dosimetry records of several test series pose major research challenges.

For example: During Operation CROSSROADS in 1946, relatively few personnel were issued film badges, so NNTPR undertook a massive dose reconstruction effort. As experience with dose reconstructions matured and new data became available, the dose reconstructions of significant numbers of CROSSROADS participants required modification.

During Operation GREENHOUSE in 1951, many participants were not badged, and after the operation, fallout doses were added to some participants' medical records or to the 5x8 inch cards on which their badge readings were recorded. The details of the methods used to calculate these fallout doses are unknown. NTPR's program managers decided to recalculate the fallout doses by the same method used for other NTPR reconstructions.

The 1954 dosimetry records from Operation CASTLE (1954) are especially hard to interpret. Badges were generally issued to a representative number of people and dates of issue and/or return were often not recorded. Also, many gaps exist in the badging data. CASTLE dosimetry data is therefore undergoing extensive review and analysis. This CASTLE data reevaluation will take several more years to complete.

3. Archival Research.

In the early years of NTPR, the Service teams and those writing the series histories undertook a major effort to locate relevant documents in government archives and repositories nationwide. Improved understanding of NTPR's requirements and of the federal record system have resulted in the discovery of promising records not previously reviewed. Since NTPR consolidation, DNA personnel have often visited records centers to review these materials. These research trips continue, as needed.

3.3.2 Impact of Recent Legislation.

On 20 May 1988, Public Law 100-321, "Radiation-Exposed Veterans Compensation Act of 1988," was enacted (see Section 4.2.1). The VA, in its implementing regulations of this law, defined as participants, not only veterans who had been at test sites during the period of testing, but also veterans who:

- Had been at a test site or test staging area and had performed official military duties in connection with completing test projects or decontaminating test equipment during a six-month period after the end of a testing period, or

- Had served as a member of the garrison or maintenance forces on Enewetak Atoll for a defined period after Operations GREENHOUSE, REDWING, or HARDTACK I, or

> Were assigned duties involving decontamination at Navy shipyards of ships involved in CROSSROADS.

Additionally, the VA defined the occupation of Hiroshima and Nagasaki, Japan, as:

> ...official military duties within 10 miles of the city limits of either Hiroshima or Nagasaki, Japan, which were required to perform or support military occupation functions such as occupation of territory, control of the population, stabilization of the government, demilitarization of the Japanese military, rehabilitation of the infrastructure or deactivation and conversion of war plants or materials.

Former prisoners of war who were interned within 75 and 150 miles of Hiroshima or Nagasaki city limits, respectively, or were repatriated through Nagasaki, were also considered eligible participants by the VA. (Department of Veterans Affairs, 3 March 1989)

As of 30 September 1993, 195,814 Hiroshima and Nagasaki participants had been identified since February 1989, when research required by PL 100-321 began. The list of participating units includes over 500 Army company-size units, more than 80 Marine Corps company-size units, and over 700 vessels. The total for ships includes not only those that anchored or docked at Hiroshima and Nagasaki, but also those that passed through the waters within 10 miles of each city.

Personnel now verified as participants by virtue of service at test sites or staging areas in the six-month post-operation periods, as members of the Enewetak garrison or maintenance forces, or at shipyards after CROSSROADS number 14,146.

3.3.3 Resources.

In April 1987, when consolidation began, first-line supervision of the NTPR effort was already vested in DNA's Radiation Policy Division (RARP). Dr. David L. Auton headed the effort with Commander R. Thomas Bell, MSC, USN, as NTPR program manager. On 31 August 1988, Commander Bell retired from the Navy, and Carlton T. Chapman became acting program manager. On 5 October 1988 Captain W. J. Flor, MSC, USN, became program manager. Mr. D. M. Schaeffer succeeded him on 21 April 1993.

From 1987 through 30 September 1993, RARP oversaw total NTPR expenditures of 506 person years and $28 million. See Tables 1-1 and 1-2.

3.3.4 Results.

NTPR's program of aid to veterans consists of File A activities; processing VA, personal, Congressional and Freedom of Information Act (FOIA) correspondence; and doing the research, including dose reconstruction and data base building, to support the entire effort. **Table 3-1** summarizes File A activities from 1 September 1988 to 30 September 1993. (September 1988 is the first month of the consolidated NTPR effort for which full statistics are available.)

Table 3-1. File A activities.
(Defense Nuclear Agency, no date; JAYCOR 4 September 1991 through 6 October 1993)

Incoming information	
Telephone calls	13,869
Letters	1,716
Returned questionnaires	2,671
Action taken	
Letters with questionnaires mailed	5,698
Other (previous contact, non-participant)	3,516

Table 3-2 summarizes the processing of other correspondence from 1 September 1988 to 30 September 1993.

Table 3-2. Other correspondence.
(Defense Nuclear Agency, no date; JAYCOR 4 September 1991 through 6 October 1993)

Incoming correspondence	
Congressional	294
FOIA	56
VA claims	4,729
Other (includes VA Medical Center, White House, personal, 5-rem and DOJ)	2,218
Outgoing Correspondence	
VA claims	5,126

Table 3-2. Other correspondence. (Cont'd)

Outgoing Correspondence	
Other (includes Congressional, White House, FOIA, personal follow-up, 5-rem, VA Medical Center, and DOJ)	2,823

3.4 PROGRAM TRENDS.

Although figures for the NTPR Program are incomplete for 1988, the level of activity appears to have been low compared to both earlier and later years. The busiest year since consolidation was 1989. The pace of activity in the NTPR Veterans' Assistance Program decreased significantly in 1990 and 1991. Incoming veterans' claims increased slightly in 1992, but the downward trend continued in incoming File A calls, letters, and returned questionnaires. However, as of 30 September 1993, the 1993 total for incoming File A calls, letters, and returned questionnaires was already greater than for all of 1992, while the 1993 total for incoming VA claims makes it appear that the total for the year will exceed that for 1992 by about 10 percent. **Table 3-3** summarizes calls and correspondence activity from 1989 through 1993.

Table 3-3. Trends in the Veterans' Assistance Program.

	1989	**1990**	**1991**	**1992**	**1993***
Incoming File A calls, letters and returned questionnaires	7,391	4,514	2,626	1,446	1,536
Incoming VA claims	1,356	941	686	702	587

* Projection based on figures up to 30 September 1993.

SECTION 4

OTHER INTERACTIONS IN THE NTPR PROGRAM

DOE and VA interact significantly with the NTPR program. Furthermore, as a result of recent legislation, DOJ has established the Office of Radiation Programs which also interacts with NTPR.

4.1 INTERACTIONS BETWEEN DOE AND THE NTPR PROGRAM.

DOE, through its contractor, REECo, maintains the official master file of dose records for nuclear weapons testing from 1945 to the present. A subset of those data for the period of U.S. atmospheric nuclear testing from 1945 to 1962 was the basis from which the NTPR master table was developed. NTPR dosimetry research and dose reconstructions are added to the master file as they become available. DOE/NV also has key responsibilities for the Coordination and Information Center (CIC). A public archives housed in Las Vegas, Nevada, CIC contains unclassified and declassified historical documentation relevant to U.S. atmospheric nuclear weapons testing.

4.1.1 The Master File of Dose Records.

REECo was a prime support contractor of the DOE (originally the AEC) throughout most of the U.S. atmospheric nuclear weapons testing. It supports DoD and the military Services through agreements between DOE and DoD (Reynolds Electrical Engineering Co., Inc., no date).

In 1943, REECo was selected to construct electrical facilities at Los Alamos, New Mexico, the site where the atomic bomb was developed. The company began construction at the NTS for the AEC in December 1950. In July 1955, the company assumed responsibility for radiological safety services at the test site. It maintained this responsibility throughout the remaining period of U.S. atmospheric nuclear weapons testing (Reynolds Electrical Engineering Co., Inc., no date).

As early as 1957, REECo began receiving requests for dosimetry information, and it started collecting all records indicating personnel exposures to ionizing radiation during the U.S. atmospheric nuclear tests. This quickly developed into a major effort, resulting in a substantial number of records concerning individual film badge issues, accumulations of badges for an individual for a given series, contemporaneous summations of the badge data, some of the badges themselves, and a collection of other documents pertinent to personnel dosimetry.

In 1966, DNA funded REECo to automate the information on radiation doses. From 1967 to 1969, five keypunch operators transferred approximately 400,000 records to 80-column punched cards, organized by continental and oceanic nuclear testing, by year. Of these records, more than 232,000 were for the U.S. atmospheric nuclear testing period. By 1971, the records had been transferred to 35-millimeter microfilm, and by 1974 to 16-millimeter microfilm cassettes and microfiche. In addition, REECo microfilmed 400 boxes of source documents for the dosimetry records. These documents, like the dose records, were organized chronologically, according to continental and oceanic nuclear test series, and were placed on 16-millimeter microfilm cassettes. In 1978, DOE and DNA began funding REECo for a dosimetry project to establish a database of all U.S. atmospheric nuclear testing records. The total REECo database now comprises about 5.14 million dose records, including those from underground nuclear tests. Of these, 1,422,394 are dose records for DoD and AEC participants in U.S. atmospheric nuclear testing (Johnson, 9-10 July 1985; Reynolds Electrical Engineering Co., Inc., 23 November 1992).

To check the accuracy of the dose data and complete participants' radiation exposure history, the NTPR program conducted:

- Research into the historical documentation of numerous individual shots and test series;
- Verifications of radiation dose records obtained from 7,900 medical records of Navy personnel;
- Dose reconstructions for participants in several shots and series, including Shot SMOKY of the 1957 Operation PLUMBBOB; and
- Sample selection of film badge readings for members of units that maneuvered in proximity to each other and thus should have received comparable exposures.

The NTPR program has always been supported by the REECo dose data. REECo has provided dose data and accompanying source documents on request to U.S. government organizations and individuals. The DOE managers of the dosimetry research project have been John D. Moroney, 1978-1980, and Michael A. Marelli, 1980 to the present. REECo's efforts were directed primarily by W. Jay Brady until his retirement in August 1991, when C. Thomas Bastian assumed those duties.

4.1.2 The Coordination and Information Center (CIC).

In March 1979, DOE established the CIC, which is a public archive for unclassified documents relating to U.S. atmospheric nuclear weapons testing and offsite fallout. Administered by the DOE Nevada Operations Office, Las Vegas, CIC is operated by REECo.

CIC began document collection in the fall of 1979. Since then, CIC staff have indexed about 260,000 documents. Some of them were originally classified. The classified documents were declassified or sanitized; all are now unclassified. Collection activities continue, and it is anticipated the CIC will ultimately contain about 390,000 documents (Department of Energy, 4 March 1991; Gladeck, 2 September 1993).

DOE is responsible for data collection. One of its contractors, History Associates Incorporated (HAI), is collecting pertinent information under the direction of the Historian's Office, DOE Headquarters. The effort initially focused on sources concerned with offsite radioactive fallout from U.S. atmospheric nuclear weapons testing at the NTS. It was later broadened to include documents relevant to onsite fallout, oceanic nuclear testing and military participation.

HAI has reviewed and sent to CIC selections from some major collections, including materials from DOE Headquarters and LANL. The collection at DOE Headquarters provided minutes from meetings of the AEC, the General Advisory Committee established by AEC to advise on the testing, and the AEC/Military Liaison Committee, as well as staff papers and records of the Division of Military Application and the Division of Biology and Medicine. The LANL archives made documents available concerning the Test Organization, which was responsible for conducting a number of the atmospheric nuclear test series; scientific studies performed as part of the tests; and fallout resulting from the detonations. In addition, some significant collections were located at such sites as the Navy Bureau of Ships, the Naval Radiological Defense Laboratory, and the Oak Ridge Center for Atomic Research (Johnson, 29 May 1985).

CIC is a valuable public resource on U.S. atmospheric nuclear weapons testing. A substantial number of the documents have been selected by professional historians according to established screening criteria, some of which are highlighted in **Figure 4-1**. These researchers have identified the materials by location, collection, and folder title. Such identifiers make it possible to trace the documentation to its original source (Johnson, 29 May 1985; Department of Energy, May 1985).

Appendix D provides further information on the scope of the CIC collection and on facility policies and procedures.

4.2 COOPERATION BETWEEN THE VA AND THE NTPR PROGRAM.

On 15 June 1979, Vice Admiral Robert R. Monroe, USN, DNA Director, and Dorothy L. Starbuck, Chief Benefits Director at VA, signed a "Memorandum of Understanding on behalf of the Department of Defense and the Veterans Administration" (later the Department of Veterans Affairs). The understanding was "to formalize and improve existing procedures to ensure the most complete investigation of veterans' ionizing radiation claims." DoD and VA representatives had cooperated closely regarding these claims during the preceding year, but thought they were "in a position to do more, particularly in cases for which no recorded radiation dosage is available." As stated in the document, VA would "determine the critical elements of information necessary to support each case" and DoD would "thoroughly research each case to develop as much as possible the information needed" (Monroe and Starbuck, 15 June 1979). This general procedure has remained intact, despite the fact that the memorandum was subsequently superseded by various pieces of legislation. Through its Service teams, the NTPR program gave the VA information useful for its determination of eligibility for medical care, compensation programs, and service connected benefits (Johnson, 25 July 1985). The same sort of information has been provided since consolidation.

DOE SCREENING CRITERIA FOR DOCUMENT COLLECTION (6)

GENERAL CRITERIA

All pertinent policy, program, correspondence, and public relations documents of the Atomic Energy Commission and other Government agencies and organizations relating to 1) radiological fallout onsite and offsite from atmospheric and underground nuclear testing between 1945 and 1972 and the technology of predicting and measuring that fallout; 2) the biological and environmental effects of radiation; 3) the organizational structure and responsibilities, planning, and conduct of nuclear testing; 4) the development of radiation safety standards, and 5) safety issues and operations in nuclear testing.

SELECTED SPECIFIC CRITERIA

- All pertinent documents relating to specific military or civilian personnel at the Nevada or Pacific Test Sites, including units, locations, assignments during atmospheric testing, any radiation dosage received, organization responsibilities, job position descriptions, delegations of authority, and test series histories as they relate to test organization.
- All pertinent documents relating to both on-site and off-site fallout, including atmospheric nuclear test exposure or dose predictions, exposure/dose data, and monitoring policy, technology, instrumentation, training, personnel and field team notes.
- All pertinent documents relating to atmospheric nuclear test safety, the development of radiation safety standards, and reports of and requirements for decontamination and evacuation either offsite or onsite.
- All pertinent "after action" reports concerning atmospheric nuclear tests.
- All aerial and ground monitoring records, including air sampling, air crew, or cloud tracking.
- All pertinent documents relating to cleanup activities, including efforts to decontaminate tracking aircraft and ships.

Figure 4-1. Selected DOE screening criteria for CIC document collection.

4.2.1 VA Service-Connected Disability Program.

Public Law 98-542, enacted 24 October 1984 as the "Veterans' Dioxin and Radiation Exposure Compensation Standards Act," required the VA to conduct rulemaking regarding its guidelines for the adjudication of compensation claims. The VA procedures formalized in response to this act were published in the Federal Register on 26 August 1985 and became effective on 25 September 1985. Amendments were published in the Federal Register on 18 October 1989 and 26 March 1993. According to these procedures, the VA Chief of Benefits Director reviews claims based on U.S. atmospheric nuclear test participation only if the following criteria are met: (1) the veteran was exposed to ionizing radiation as a result of participation in U.S. atmospheric nuclear weapons testing or the postwar occupation of Hiroshima or Nagasaki, Japan; (2) the veteran subsequently developed one of several specified illnesses; and (3) the illness became manifest during the specified time (Department of Veterans Affairs, 26 August 1985; Department of Veterans Affairs, 18 October 1989; Department of Veterans Affairs, 26 March 1993).

Public Law 98-542 also mentioned DNA specifically for the first time, thereby formally bringing the Agency into the VA claims process. The law directed the Secretary of Defense to promulgate regulations for the reporting of radiation dose estimates used by the VA in its adjudication of claims. On 21 October 1985, as executive agency for the DoD NTPR program, DNA published its final rules, establishing minimum standards for reporting nuclear radiation doses for DoD participants in the U.S. atmospheric nuclear test program (Defense Nuclear Agency, 21 October 1985).

In reviewing a claim brought under Public Law 98-542, the VA Chief Benefits Director considers such factors as the most probable dose, the relative sensitivity of the involved tissue to induction of the specified condition by ionizing radiation, the veteran's gender and pertinent family history, the veteran's age at time of exposure, the time elapsed between exposure and onset of the disease, and possible contributions to the disease made by exposures to radiation or other carcinogens that were not Service connected. The Chief Benefits Director may request an advisory medical opinion from the VA Chief Medical Director or from an outside consultant selected according to the provisions of its final rules. The Chief Benefits Director then submits his decision on the claim to the Regional Office of jurisdiction, which makes the final determination (Department of Veterans Affairs, 26 August 1985).

Under Public Law 100-321, "Radiation-Exposed Veterans Compensation Act of 1988," enacted 20 May 1988, no dose determination is required for veterans with one of the diseases specified in the law. A connection between participation in U.S. atmospheric nuclear testing and the disease is presumed by the statute. Therefore, the veteran's disease, its time of manifestation, and documentation of participation in U.S. atmospheric nuclear testing are the relevant issues (Department of Veterans Affairs, 21 June 1989). Except for leukemia, the illnesses identified in the law had to be manifested within 40 years beginning on the last date on which the veteran participated in a radiation-risk activity; the presumptive period for leukemia was 30 years (Department of Veterans Affairs, 21 June 1989). The VA published its implementing regulations for Public Law 100-321 on 21 June 1989 in the Federal Register.

Public Law 102-86, "Veterans' Benefits Program Improvement Act of 1991," enacted 14 August 1991, amended Public Law 100-321 by making the presumptive period for all illnesses listed 40 years. It also expanded coverage of Public Law 100-321 to members of the Reserves and National Guard who participated in U.S. atmospheric nuclear testing.

Public Law 102-578, "Veterans' Radiation Exposure Amendments of 1992," enacted 30 October 1992, further amended Public Law 100-321 by entirely eliminating the 40-year presumptive period and by adding salivary gland and urinary tract cancers to the list of illnesses. Public Law 102-578 also amended Public Law 98-542 by requiring the identification and review of other possible radiation-risk activities performed by military personnel prior to 1970 and to review scientific evidence on whether bronchio-alveolar cancer was caused by ionizing radiation.

The diseases covered by Public Laws 98-542, 100-321, 102-86, and 102-578 are listed in **Table 4-1**. Also shown in the table are the illnesses covered under Public Laws 101-426 and 101-510 (see Section 4.3).

If a veteran or eligible family member believes a veteran's disease or disability resulted from radiation exposure incurred during U.S. atmospheric nuclear testing or the Hiroshima/Nagasaki occupation, they may file for benefits with the nearest VA Regional Office. The VA then requests DNA verify a veteran's participation and determine the radiation dose (when applicable). NTPR personnel research all claims from the VA that have as a basis participation in the U.S. atmospheric nuclear tests or the occupation of Hiroshima and Nagasaki.

Up to mid-1986, the Service teams had provided VA with information for 2,302 claims. Section 2 gives these statistics for each Service team. From January 1988, when consolidation was in progress, through September 1993, NTPR responded to 5,431 VA claims (Defense Nuclear Agency, no date; JAYCOR, 4 September 1991 through 6 October 1993). Claims statistics for the period from mid-1986 to January 1988 are not available.

On 18 November 1988, Public Law 100-687, "Veterans' Judicial Review Act of 1988," was enacted. The law established a new Court of Veterans' Appeals for the review of claims denied by the VA Board of Veterans' Appeals. This law has had minimal impact on the NTPR program.

4.2.2 VA Medical Examinations and Health Care Services.

Since the beginning of the NTPR effort, VA has provided, upon request, a complete physical examination, including all requisite tests, to any veteran exposed to ionizing radiation during the U.S. atmospheric nuclear tests or the Hiroshima and Nagasaki, Japan, occupation. When the veteran requests the physical, VA writes DNA, which attempts to verify participation and responds with the research results. The NTPR teams sent special notifications concerning the availability of these examinations to personnel whose radiation doses exceeded the Federal guideline of 5 rem per year for whom it had addresses.

Table 4-1. Diseases covered by Public Laws 98-542, 100-321, 102-86, 102-578, 101-426, and 101-510.

PL 98-542 (38CFR 3.311b) (All diseases must be manifested 5 years or more after exposure except where noted differently)	**PL 100-321/PL 102-86/PL 102-578** (38CFR 3.309d) (No manifestation period)	**PL 101-426/101-510** (Manifestation period and age of exposure varies)
Leukemia (except Chronic Lymphatic Leukemia) (any time after exposure)	Leukemia (except Chronic Lymphocytic Leukemia)	Leukemia (except Chronic Lymphocytic Leukemia)
Thyroid Cancer	Thyroid Cancer	Primary Thyroid Cancer
Breast Cancer	Breast Cancer	Female Breast Cancer
Liver Cancer	Primary Liver Cancer (except if cirrhosis or hepatitis B is indicated)	Liver Cancer (except if cirrhosis or hepatitis B is indicated)
Esophageal Cancer	Esophageal Cancer	Esophageal Cancer
Stomach Cancer	Stomach Cancer	Stomach Cancer
Pancreatic Cancer	Pancreatic Cancer	Pancreatic Cancer
Multiple Myeloma	Multiple Myeloma	Multiple Myeloma
Lung Cancer	Cancer of Pharynx	Cancer of Pharynx
Bone Cancer (within 30 years)	Cancer of the Small Intestine	Cancer of the Small Intestine
Skin Cancer	Cancer of the Bile Ducts	Cancer of the Bile Ducts
Colon Cancer	Cancer of Gallbladder	Cancer of Gallbladder
Kidney Cancer	Lymphomas (except Hodgkins Disease)	Lymphomas (except Hodgkins Disease)
Urinary Bladder Cancer	Urinary Tract Cancer	
Salivary Gland Cancer	Salivary Gland Cancer	
Posterior Subcapsular Cataracts (six months or more after exposure)		
Non-Malignant Thyroid Nodular Disease		
Ovarian Cancer		
Parathyroid Adenoma		

The "Veterans' Health Care, Training, and Small Business Loan Act of 1981," enacted on 3 November 1981 as Public Law 97-72, authorized the VA to provide hospital and nursing home care and limited outpatient services to veterans who may have been exposed to ionizing radiation while in service at a U.S. atmospheric nuclear test or during the Hiroshima/Nagasaki, Japan, occupation. This care is not, however, available for disorders determined to be the result of causes other than exposure to ionizing radiation. These exceptions are:

1. Congenital or developmental conditions (conditions the veteran was born with or which are hereditary);

2. Conditions the veteran had before military service;

3. Conditions resulting from injury;

4. Conditions having a specific and well-established cause, such as tuberculosis and gout; and

5. Common, well-understood conditions, such as inguinal hernia and acute appendicitis (Department of Veterans Affairs, no date).

To receive VA health care, a veteran must have been at the site of U.S. atmospheric nuclear testing or in occupied Hiroshima or Nagasaki, Japan. The veteran is asked to supply information to a VA official, who then transmits the data for confirmation to NTPR. The required information is:

- name,
- branch of service,
- service number,
- social security number,
- name of test series,
- date of test series, and
- assigned unit during test series (Smith, May 1985)

A medical history, complete physical examination, and diagnostic studies are done for each veteran requesting VA medical care under the provisions of Public Law 97-72. The examining physician is directed to pay particular attention to parts of the body most sensitive to ionizing radiation: the blood, thyroid, salivary glands, lung, bone marrow, and skin (Smith, May 1985).

4.2.3 Ionizing Radiation Registry.

Public Law 99-576, "Veterans' Benefits Improvement and Health Care Authorization Act of 1986," signed 28 October 1986, required VA to establish an Ionizing Radiation Registry. It is to contain the names of veterans who participated in atmospheric nuclear testing or the occupation of Hiroshima and Nagasaki, Japan and who:

- Apply for hospital or nursing home care;

- File a claim for compensation on the basis of a disability that may be associated with exposure to ionizing radiation; or

- Die and are survived by a spouse, child, or parent who files a claim for dependency and indemnity compensation on the basis of exposure of the veteran to ionizing radiation.

DNA has been requested to provide available doses for these veterans and gives the VA computer tapes of the NTPR database upon request.

4.3 NTPR COOPERATION WITH DOJ.

Public Law 101-426, "Radiation Exposure Compensation Act," enacted 15 October 1990, established the Radiation Exposure Trust Fund and authorizes payments from it to:

1. Individuals who were exposed to radiation and contracted specified cancers and other diseases because they were in designated affected areas downwind from NTS, and

2. Employees in uranium mines in specified states who were exposed to designated amounts of radiation and developed lung cancer and non-malignant respiratory diseases.

Public Law 101-510, "1991 DoD Authorization Act," signed into law 5 November 1990, expanded coverage to government employees and others who were onsite during U.S. atmospheric nuclear tests (18). The law required the Attorney General to develop regulations for the submission and resolution of claims. It directed him to consult with the Secretary of Defense and the Secretary of Energy to establish guidelines for determining what constitutes documentation that an individual participated onsite during an atmospheric nuclear test and what constitutes participation. On behalf of DoD, Captain W. J. Flor, MSC, USN, NTPR Program Manager, advised the DOJ group drafting the implementing regulations.

Final rules establishing criteria and procedures for dealing with claims allowed by that legislation were published in the Federal Register on 10 April 1992 (Department of Justice, 10 April 1992). DOJ created the Office of Radiation Programs (OoRP) to administer the program. The final rules require that it forward to DNA for verification claims made by any employee of DoD or its contractors. DNA began receiving DOJ claims in September 1992. By 30 September 1993, it had received 221 claims, an average of 17 per month.

4.4 CONTRACTORS.

Throughout the NTPR program, DNA has had contractor support. Basically, this has been of two types: labor-intensive operations and highly technical matters involving detailed research. Three major contractors have been involved.

4.4.1 JAYCOR.

In 1978 JAYCOR was tasked to set up DNA's call-in program and continues to perform that function. JAYCOR personnel wrote the first two histories of the U.S. atmospheric nuclear test series. The company also provided assistance to the Navy, Army, Air Force, and Coast Guard NTPR eforts. Since the consolidation of NTPR under DNA, JAYCOR personnel have unified the Service team databases into the single NTPR database, now also including Hiroshima and Nagasaki participants; performed most of the research required to support the program; and drafted for review and signature by DNA personnel responses to queries from the VA, veterans, Congress, and other interested parties. In addition, JAYCOR personnel have monitored Congressional hearings, provided litigation support, reorganized DNA's library of NTPR documents, and updated this history.

4.4.2 Science Applications International Corporation (SAIC).

In 1978, when there was concern over an apparent cluster of leukemia cases among military personnel at Shot SMOKY of Operation PLUMBBOB (1957), DNA asked SAIC to assess the doses received by troop units who maneuvered at SMOKY and to compare the findings with attendant film badge dosimetry. SAIC has been continuously engaged in dose reconstructions for the NTPR from that time forward. It has produced two-dozen published reports of radiation exposure assessments covering major troop organizations, which have formed a basis for individualized assessments for more than 1,300 participants. It has also produced (via a subsidiary, JRB) DoD-oriented historical reports of most CONUS atmospheric nuclear tests and (with JRB) the original "For the Record." SAIC's ongoing mission is summarized as follows:

- Evaluate technologies and develop methodologies relevant to ionizing radiation dose reconstruction,
- Collect and evaluate data relevant to the radiation exposure potential of U.S. atmospheric nuclear test participants,
- Reconstruct external and internal radiation doses to generic and individual DoD atmospheric nuclear test participants, and
- Report for open scrutiny the above radiological assessments and respond to official and public feedback.

In the latter capacity, SAIC has supported the NTPR before organizations including NAS, the General Accounting Office (GAO), OTA, and the Federal District Court, as well as contributing to Congressional responses.

4.4.3 GE/Kaman Tempo.

GE/Kaman Tempo, originally part of General Electric and later part of Kaman Sciences Corporation, produced all of the histories of the oceanic U.S. atmospheric nuclear tests series except WIGWAM. During the first part of that effort, it had R. F. Cross Associates as a sub-contractor. Moreover, it operates the DoD Nuclear Weapons Information Analysis Center (DASIAC) at Santa Barbara, California, a major repository for both classified and unclassified reports and data on atmospheric nuclear testing. Especially in the early stages of NTPR, before extensive archival research had been done, DASIAC was an important source of information for the program.

SECTION 5

THE ATOMIC BOMBINGS AND U.S. OCCUPATION OF HIROSHIMA AND NAGASAKI

The United States had two atomic bombs ready for use in early August 1945. They were both dropped on Japan, the first over Hiroshima on 6 August 1945 and the second over Nagasaki on 9 August. The Hiroshima weapon was smaller, with a yield of about 15 kilotons compared to the 21 kilotons for the Nagasaki detonation. They were both air bursts, detonated at about 1,670 and 1,640 feet, respectively. These burst heights were chosen to maximize blast damage and to minimize residual radiological contamination.

The objective of the bombings was to bring World War II to a quick end, thereby avoiding the death and destruction that would inevitably result from the planned invasion of the Japanese home islands. During the U.S. invasion of Okinawa, 1 April through 21 June 1945, the U.S. casualties included about 12,000 killed, and the Japanese losses approached 100,000 killed. On 26 July 1945, President Harry Truman urged the Japanese to surrender unconditionally or face "prompt and utter destruction." The Japanese ignored the warnings, having heard similar predictions before fire raids. Subsequently, they lost more than 75,000 people in Hiroshima and more than 35,000 in Nagasaki. On 2 September 1945, Japan officially surrendered to Allied forces. The early radiation surveys and the American occupation of Hiroshima and Nagasaki followed shortly thereafter.

5.1 EARLY RADIATION SURVEYS.

In the months immediately following the detonations, U.S. scientists conducted a number of onsite surveys to be sure that any residual radiation in Hiroshima and Nagasaki would not present a health hazard to occupation troops or to the Japanese remaining in the cities. General Marshall, U.S. Army Chief of Staff in Washington, addressed the first concern in a message sent to General MacArthur, the Theater Commander. General Marshall emphasized the importance of early radiation surveys so that the occupation troops "shall not be subjected to any possible toxic effects, although we have no reason to believe that any such effects actually exist." Three series of early radiation surveys followed:

- Scientists from the Manhattan Engineer District (MED), the organization that had developed the bombs, made rapid radiation surveys of Hiroshima on 8 and 9 September 1945 (one month before occupation troops arrived in that area) and of Nagasaki on 13 and 14 September (10 days before the occupation troops arrived).
  - They reported negligible levels of radioactivity in the areas surveyed (Farrell, 1977).

- The Manhattan Project Atomic Bomb Investigating Group made more extensive surveys in Nagasaki from 20 September to 6 October and in Hiroshima from 3 to 7 October 1945.

  -- Their measurements, showed the levels of residual radioactivity to be extremely low (Tybout, 6 April 1946).

- The Naval Technical Mission to Japan surveyed Nagasaki during 15 to 27 October 1945 and Hiroshima on 1 to 2 November 1945 (Pace and Smith, 16 April 1946).

  -- Their findings of negligible levels of radioactivity corroborated the earlier measurements.

In addition to these surveys, the U.S. investigation teams used data from numerous separate radiation monitoring surveys, soil and debris sampling programs, and other analyses conducted by Japanese scientists after the bombings.

The initial and rapid measurements taken by the MED served the critically important purpose of allowing the American occupation of Hiroshima and Nagasaki to proceed as scheduled. The more extensive surveys by the Manhattan Project Atomic Bomb Investigating Group and the Naval Mission to Japan resulted in reports since regarded as basic source documents and listed in Appendix G.

5.2 RESIDUAL RADIATION IN HIROSHIMA AND NAGASAKI.

After the bombings, two areas of low-level residual radioactivity remained in each city: An area of induced radioactivity around ground zero and a downwind area contaminated by rainout/fallout.

5.2.1 Induced Radioactivity at the Hypocenters.

Roughly circular patterns of residual radiation were created at the times of detonation, when the high-intensity burst of neutrons from the bomb encountered elements in the soil and building materials, such as concrete, metal, and tile, in the area beneath the detonation and caused them to become radioactive. (Examples of elements in which radioactivity can be induced are aluminum, sodium, manganese, cobalt, scandium, and cesium.) The induced radioactivity decreased rapidly since many of the radionuclides produced in this manner had short half-lives (the time required for the radiation intensity to be reduced from any given value to one-half that value). For example, aluminum-28 has a half-life of about 2.3 minutes, and manganese-56 has a half-life of about 2.6 hours.

Figures 5.1 and **5.2** clearly illustrate the area of neutron-induced radioactivity around the hypocenter (ground zero [GZ]) in each city as of the radiological survey dates indicated. By the time of occupation force arrival (23 September 1945 at Nagasaki; 7 October 1945 near Hiroshima) the radiation intensity at the hypocenter had decayed to very low levels (0.1 milliroentgens* per hour or less) and the area of measurable radioactivity had diminished to within about one mile from GZ. It should also be noted that the radioactivity was well within the area of almost total destruction.

5.2.2 Radioactivity Downwind of the Cities.

As the radioactive cloud moved downwind from the center of each city, rainshowers within the hour after the detonation caused some of the fission products and unfissioned residue of the bomb to be carried to earth in a manner similar to fallout. This "rainout" produced a small pattern of radioactivity on the west side of Hiroshima, near Takasu; and a somewhat larger area east of Nagasaki, with peak levels in the vicinity of the Nishiyama Reservoir.

Figures 5-1 and 5-2 show the areas and intensities of residual radioactivity caused by the rainout/fallout. Of the four patterns of measurable residual radioactivity remaining in and around the two cities upon the arrival of the occupation troops, the most significant was in the vicinity of the Nishiyama Reservoir outside Nagasaki, indicated in Figure 5-2. A peak intensity of about one milliroentgen per hour was measured near the reservoir about the time of the troop arrival. The terrain in the area was rugged, characterized by steep slopes and heavy vegetation, with few trails or roads and even fewer buildings. The Japanese population was sparse, and there was little need for occupation force presence in the area.

The small rainout pattern west of Hiroshima, had a peak intensity of about 0.05 milliroentgen per hour when the occupation troops reached this part of Japan.

By the time of the occupation, the intensity of the radioactivity (mixed fission products) caused by rainout had dropped to less than a thousandth of the intensity one hour after the detonation. The main reason for this was the rapid overall decay of fission products. In general, the radioactivity one hour after a detonation (H+1) will decay to one-tenth its former level within the next seven hours. Two days after the detonation, the radiation intensity would have dropped to about one-hundredth of its H+1 value. Two weeks after the detonation, the intensity would have decayed to about one-thousandth of its H+1 value.

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*A milliroentgen equals one-thousandth of a roentgen.

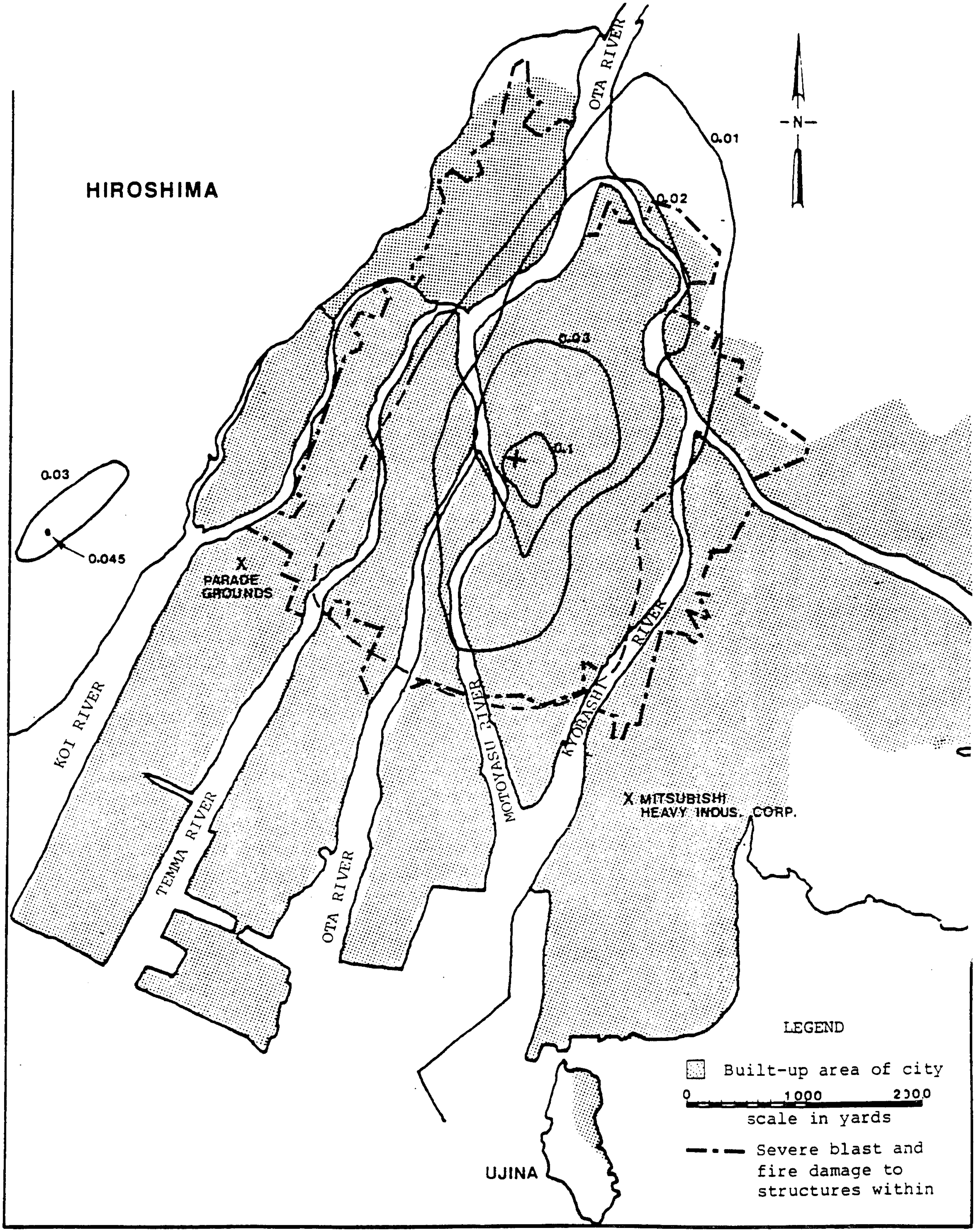

Figure 5-1. Manhattan Engineer District Survey of Hiroshima, Japan, 3-7 October 1945.

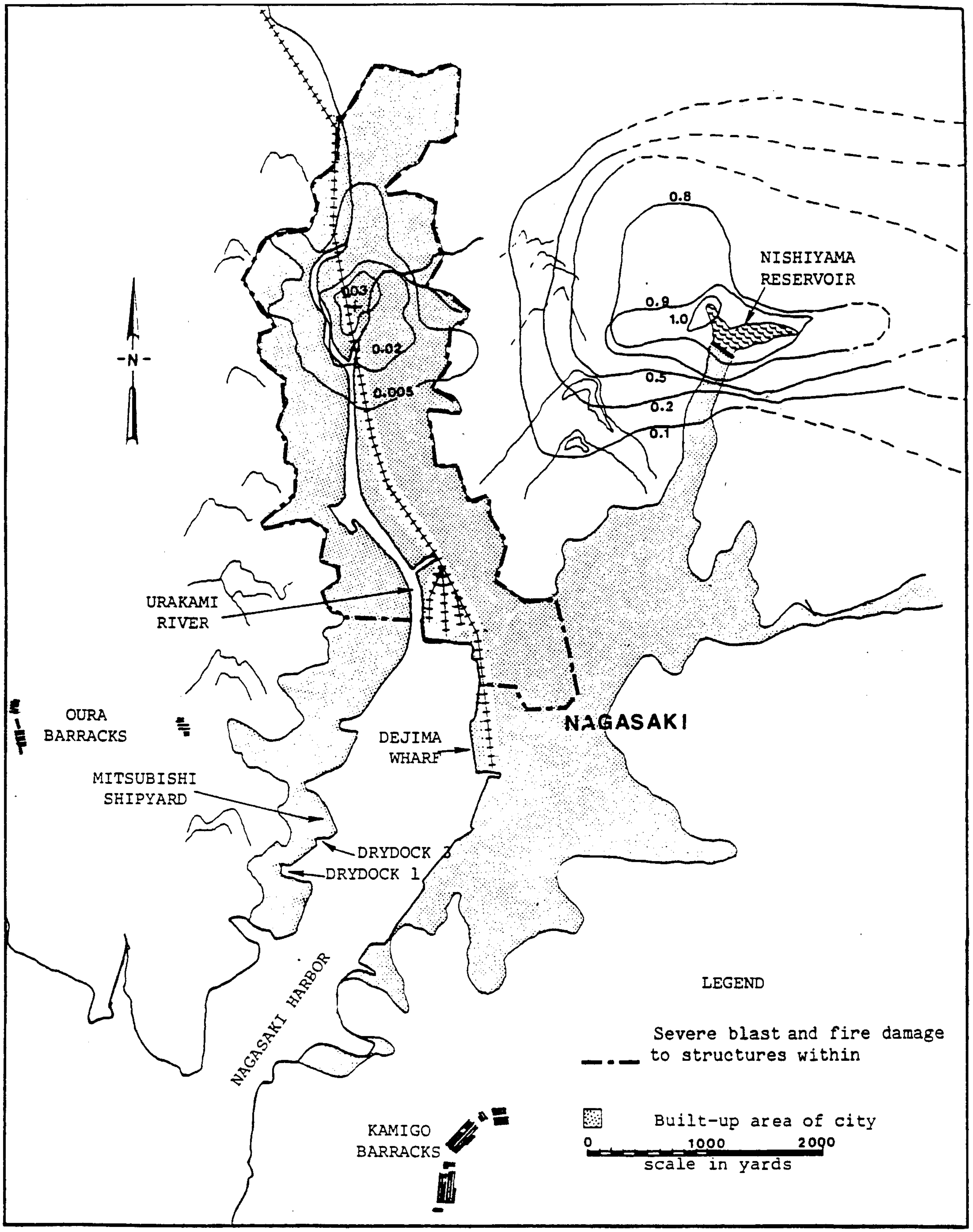

Figure 5-2. Manhattan Engineer District Survey of Nagasaki, Japan, 21 September - 4 October 1945.

The reduction of radioactivity was aided by heavy rains during autumn 1945 that washed away some of the residual radiation. Between the bombings and the start of the occupation, approximately 62 centimeters (24 inches) of rain fell in Hiroshima and 82 centimeters (32 inches) in Nagasaki. The heavy rainfall continued during the occupation, and by 1 November the cumulative total since the bombing was 91 centimeters (36 inches) in Hiroshima and 122 centimeters (48 inches) in Nagasaki.

5.3 OCCUPATION OF JAPAN.

The occupation of the western portion of Honshu Island (which contains Hiroshima), the southern Japanese islands of Kyushu (where Nagasaki is located), and Shikoku was the responsibility of the Sixth U.S. Army, consisting of the I and X Army Corps and the V Amphibious Corps (Marines). Each Corps had three divisions and supporting units. The occupation force for this portion of Japan totaled some 240,000 troops. The Army had primary responsibility for the occupation of Hiroshima and the Marine Corps had primary responsibility for the occupation of Nagasaki.

The mission of the occupation troops was to establish control of the home islands of Japan, ensure compliance with the surrender terms, and demilitarize the Japanese war machine. The duties did not include the "cleanup" of Hiroshima, Nagasaki, or any other areas, nor the rebuilding of Japan.

5.3.1 Hiroshima Occupation.

Two divisions, both part of X Corps of the Sixth Army, accomplished the occupation of the area in the immediate vicinity of Hiroshima:

- 41st Division, 7 October 1945 to December 1945
- 24th Division, December 1945 to 6 March 1946, when the U.S. occupation of Hiroshima came to an end.

The occupation troops landed at Kure, about nine miles southeast of Hiroshima. One of the first actions carried out by the 186th Infantry Regiment, 41st Division was to set up a roadblock in the vicinity of Kaidaichi to prevent entry into Hiroshima by military personnel. Units of the two divisions were billeted in barracks, rehabilitated buildings, hotels, and private residences in Kure, Hiro, Ujina, Tenno, Eta Jima, Koyaura and Kaidaichi (all within 10 miles of the city limits of Hiroshima). With the possible exception of a few troops supporting scientific groups, none of the occupation forces were billeted within the city limits of Hiroshima.

Units of the 186th Infantry Regiment, 41st Division, conducted reconnaissance patrols and other specific daily assignments throughout their area of responsibility, which included the city of Hiroshima. It is assumed that individuals of the regiment made occasional patrols into the destroyed area of the city and that individuals from nearby units of the 41st Division may have made brief sightseeing trips into the area. Radiation doses received by these participants and the other occupation troops are summarized in Section 5.4.

5.3.2 Nagasaki Occupation.

While the Hiroshima occupation primarily involved Army troops, the occupation of Nagasaki consisted mostly of Marine Corps units, with small supporting Navy and Army elements.

Responsibility for the Nagasaki area was assigned to the 2nd Marine Division, a unit of the V Amphibious Corps. During the first three months of the occupation, Division strength in Nagasaki is estimated at approximately 10,000 troops. Division strength averaged about 5,000 to 7,000 for the next three months, through February 1946, and 3,000 to 4,000 for the last four months of the occupation, through 30 June 1946.

Three units of the 2nd Marine Division had key roles during various periods of the occupation, as indicated below:

- 2nd Regimental Combat Team (RCT-2), 23 September to early November 1945. The zone of occupation included the east side of the Nagasaki Harbor and most of the nearby county east of the Urakami River.

- RCT-6, 23 September to December 1945. The zone of occupation included the west side of the Nagasaki Harbor and most of the nearby county west of the Urakami River.

- 10th Marine Regiment, November 1945 to June 1946, when the Marine Corps occupation of Nagasaki came to an end. The Regiment assumed the responsibilities of RCT-2 and RCT-6 upon their departure from Japan.

Specific billet locations have not been identified for all division units, which also included the 8th RCT, a Headquarters Battalion, Service Troops, an Engineer Group, a Tank Battalion, an Observation Squadron, and some smaller organizations. It is known, however, that RCT-2 was billeted in the Kamigo barracks and RCT-6 in the Oura barracks, both shown in Figure 5-2. The other troops also were billeted in areas well clear of the hypocenter, which was cordoned off.

Five companies of the Army's 34th Infantry Regiment moved to Nagasaki and Omura during the last 10 days of June 1946. Approximately 25,000 Marines and 2,000 Army personnel participated in the occupation of Nagasaki.

Section 5.4 summarizes doses for Nagasaki participating personnel.

5.4 RADIATION DOSES.

Few world events have been as thoroughly documented at the time, and as intensively and continuously studied since, by as many different groups of scientists as the atomic bombings and related radiation exposures at Hiroshima and Nagasaki. Thus, the patterns of residual radiation are well understood. This understanding, with other information, provides a solid basis for radiation dose determination.

The extensive radiation measurements and soil sample analyses taken by numerous Japanese and U.S. scientists in the weeks following the bombings are still available. These results and subsequent radiation measurements and sampling have formed the basis for intensive research over the past 48 years by Japanese and U.S. scientists of every aspect of the bombings and the radiation after-effects. The Japanese Government and the American NAS have stimulated, supported, and advanced this research.

Documentation of the U.S. occupation of Japan is voluminous in Army, Navy, and Marine Corps archives. Unfortunately, however, no central listing of participating units exists. Consequently, to meet the requirements of Public Law 100-321 (see Section 3.3.2), extensive research has been required to determine which units were present, when they arrived, where they were stationed, what their missions were, and when they left.

In spite of the still-existing gaps in unit data, detailed technical dose reconstructions have determined the maximum possible radiation doses that might have been received by any participant. Section 8, Radiation Dose Determination, addresses this process, explaining the "worst case" analysis used to identify the highest possible dose. Using all possible "worst case" assumptions, the maximum possible dose any occupation force member might have received from external radiation, inhalation, and ingestion is less than one rem. This does not mean that any individual approached this exposure level. In fact, it is probable that the great majority of personnel assigned to the Hiroshima and Nagasaki occupation forces received low radiation exposures and that the highest dose received by anyone was a few tens of millirem.

SECTION 6

U.S. NUCLEAR TESTING FROM PROJECT TRINITY TO THE PLOWSHARE PROGRAM

The United States conducted Project TRINITY, the world's first nuclear detonation, in 1945. From 1946 to 1963, when the limited nuclear test ban treaty was signed, the U.S. conducted 19 atmospheric nuclear test series, identified below as operations, and a program of testing called PLOWSHARE. In addition, the U.S. staged safety experiments to determine the weapons' susceptibility to fission due to accidents in storage and transport. This chapter provides historical summaries of the tests, as shown in **Table 6-1**.

Table 6-1. Chronological list of U.S. atmospheric nuclear test series.

Project TRINITY, 1945 (CONUS)	Operation WIGWAM, 1955 (Oceanic)
Operation CROSSROADS, 1946 (Oceanic)	Operation REDWING, 1956 (Oceanic)
Operation SANDSTONE, 1948 (Oceanic)	Operation PLUMBBOB, 1957 (CONUS)
Operation RANGER, 1951 (CONUS)	Operation HARDTACK I, 1958 (Oceanic)
Operation GREENHOUSE, 1951 (Oceanic)	Operation ARGUS, 1958 (Oceanic)
Operation BUSTER-JANGLE, 1951 (CONUS)	Operation HARDTACK II, 1958 (CONUS)
Operation TUMBLER-SNAPPER, 1952 (CONUS)	Safety Experiments, 1955-1958 (CONUS)
Operation IVY, 1952 (Oceanic)	Operation DOMINIC I, 1962 (Oceanic)
Operation UPSHOT-KNOTHOLE, 1953 (CONUS)	Operation DOMINIC II, 1962 (CONUS)
Operation CASTLE, 1954 (Oceanic)	PLOWSHARE Program, 1961-1962 (CONUS)
Operation TEAPOT, 1955 (CONUS)	

Most of the oceanic tests were conducted at the PPG, which consisted principally of the Enewetak and Bikini Atolls in the northwestern Marshall Islands of the Pacific Ocean. The Marshall Islands are in the easternmost part of Micronesia. The Marshalls spread over about 2 million square kilometers of the earth's surface, but the total land area is only about 180 km^{2*}. Two parallel chains form the islands: Ratak (or Sunrise) to the east, and Ralik (or Sunset) to the west; both Enewetak and Bikini are in the Ralik chain at its northern extreme. **Figure 6-1** shows these islands in the central Pacific. It also indicates the locations of Christmas and Johnston Islands, the sites for most of the DOMINIC I tests.

Most of the CONUS atmospheric tests were conducted at NTS. Established by the AEC in December 1950, the NTS is in the southeastern part of Nevada, 100 kilometers northwest of Las Vegas. **Figure 6-2** shows the current NTS, an area of high desert and mountain terrain now encompassing approximately 3,500 square kilometers in Nye County. On its eastern, northern, and western boundaries, the NTS adjoins the Nellis Air Force Range.

Below are short histories of each U.S. atmospheric nuclear test operation. Each history includes a table summarizing external dosimetry information contained in the NTPR data base as of 30 September 1993. In these tables the roentgen equivalent in man (rem) is used. It is a modern unit of dose and is considered equal to the roentgen (R), the unit of radiation exposure in use during U.S. atmospheric nuclear testing. If readers compare these tables with those in the 1986 edition of this history or with other reports generated by the NTPR effort, they will see that these numbers have changed over time. There are many reasons for these changes. New participants have been identified and personnel previously considered participants have been found to be non-participants. Reconstructed doses have been added for some personnel whose previous dose data was based solely on film badges. Reconstructed doses have been recalculated based on new information. Dosimetry records, such as issue sheets have been reviewed, revealing new information. Film badges themselves have been reexamined yielding new interpretations. The numbers in the tables will continue to change as new information is still being found even though the NTPR program has been in operation since 1978.

6.1 PROJECT TRINITY.

Project TRINITY was the first detonation of a nuclear weapon. The plutonium-fueled implosion device was detonated on a 100-foot tower at 0530 hours, 16 July 1945. The test, which occurred on the Alamogordo Bombing Range in south-central New Mexico, had a nuclear yield equivalent to the energy released by exploding 21 kilotons of TNT. **Figure 6-3** shows the location of the bombing range. It left a depression in the desert 9.5 feet deep and 335 meters wide (Maag and Rohrer, 15 December 1982, pp. 1, 23).

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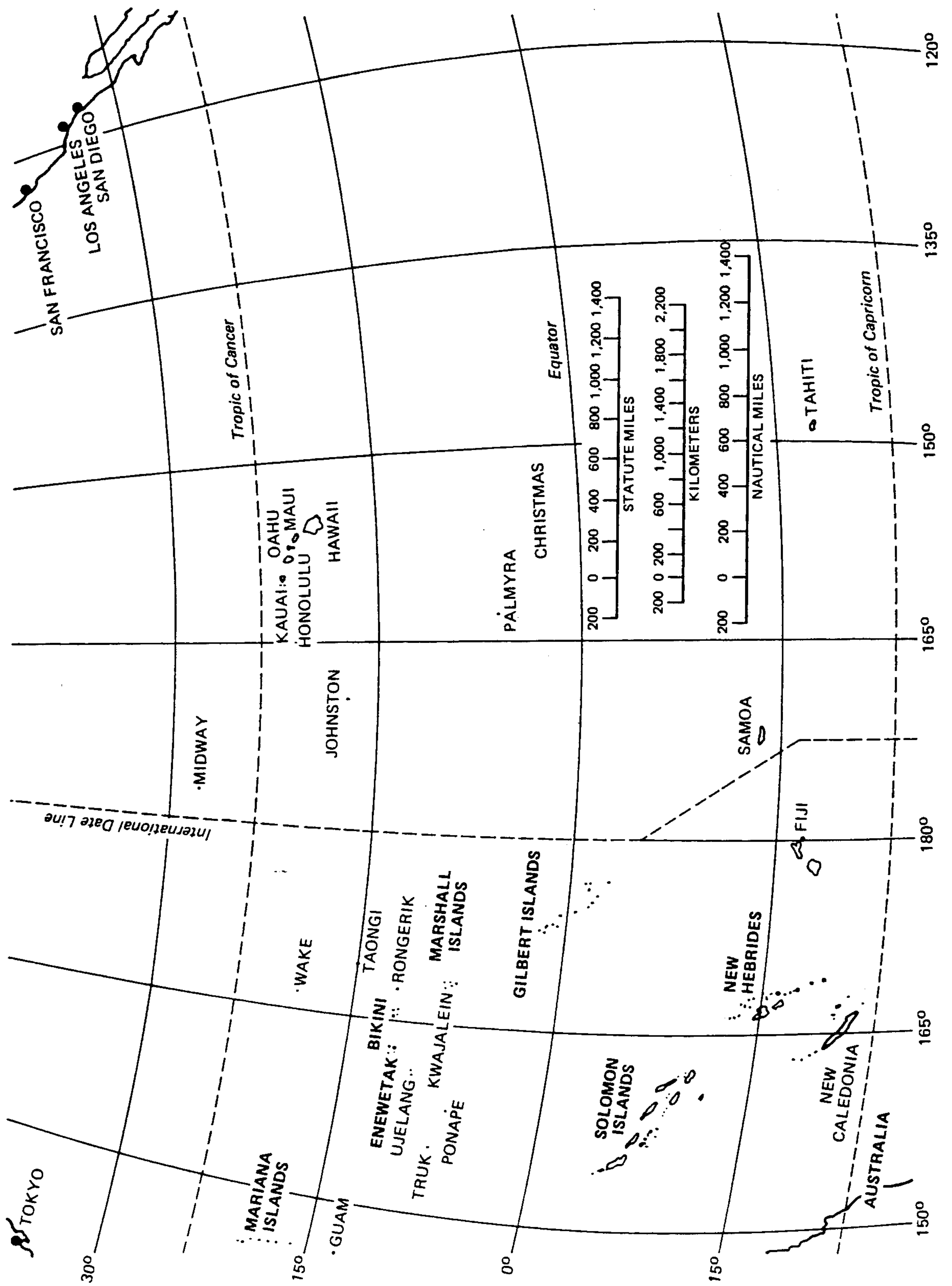
*Throughout this section, surface distances are given in metric units. The metric conversion factors include: 1 meter = 3.28 feet; 1meter = 1.09 yards; and 1 kilometer = 0.62 miles. Vertical distances are given in feet; altitudes are measured from mean sea level, while heights are measured from surface level, unless otherwise noted.


TOKYO
MARIANA ISLANDS
GUAM
TRUK
PONAPE
UJELANG
ENEWETAK
KWAJALEIN
BIKINI
RONGERIK
TAONGI
MARSHALL ISLANDS
WAKE
MIDWAY
International Date Line
JOHNSTON
KAUAI
OAHU
HONOLULU
MAUI
HAWAII
Tropic of Cancer
PALMYRA
CHRISTMAS
Equator
SAN FRANCISCO
LOS ANGELES
SAN DIEGO
GILBERT ISLANDS
SOLOMON ISLANDS
NEW HEBRIDES
NEW CALEDONIA
AUSTRALIA
FIJI
SAMOA
TAHITI
Tropic of Capricorn
200 0 200 400 600 800 1,000 1,200 1,400
STATUTE MILES
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150°
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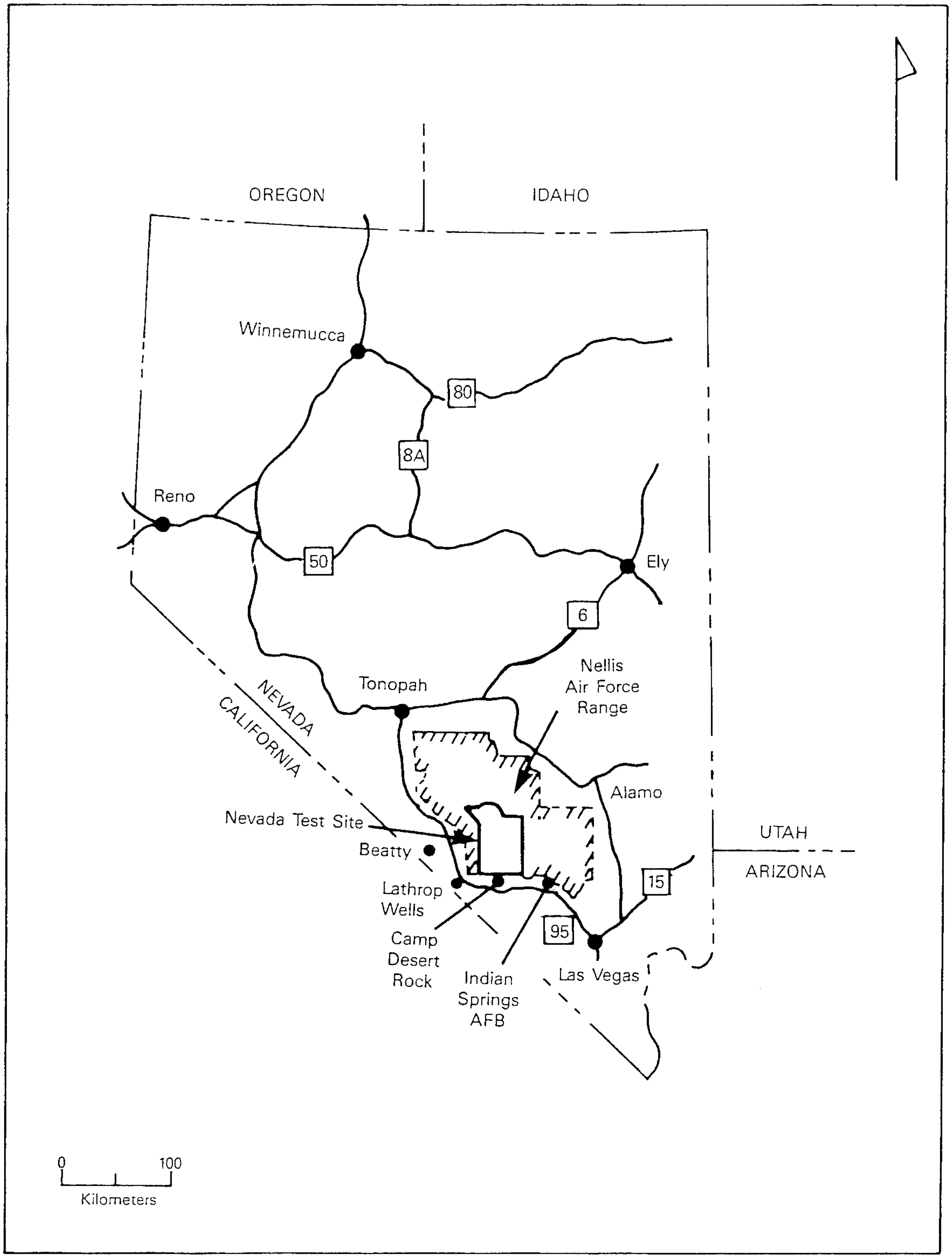

Figure 6-2. The Nevada Test Site.

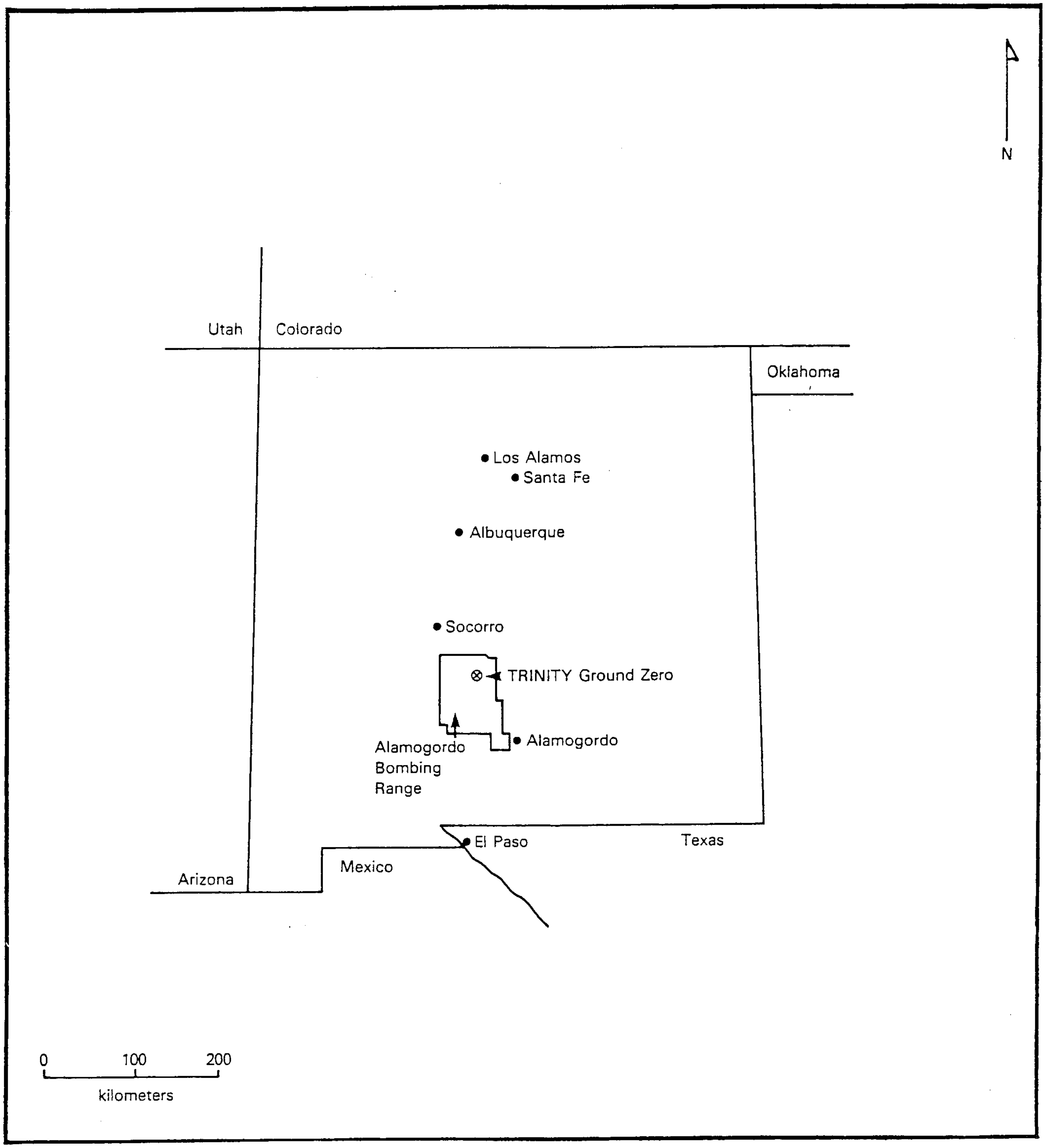

Figure 6-3. Location of Alamogordo Bombing Range.

People as far away as Santa Fe, New Mexico, and El Paso, Texas, saw the brilliant light of the detonation. Windows rattled in the areas immediately surrounding the test site, waking sleeping ranchers and townspeople. To dispel any rumors that might compromise the security of this first nuclear test, the Government announced that an Army munitions dump had exploded. However, immediately after the bombing of Hiroshima, Japan, on 6 August 1945, the Government revealed to the public what had actually occurred in the New Mexico desert (Maag and Rohrer, 15 December 1982, p. 33).

6.1.1 Background and Objectives of Project TRINITY.

The United States' effort to develop a nuclear weapon came during World War II in response to the potential threat of a German nuclear weapon. On 6 December 1941, President Roosevelt appointed a committee to determine if the United States could construct a nuclear weapon. Six months later, the committee gave the President its report, recommending a fast-paced program that would cost up to $100 million and that might produce the weapon by July 1944 (Maag and Rohrer, 15 December 1982, p. 33).

The President accepted the committee's recommendation. The effort to construct the weapon was turned over to the War Department, which assigned the task to the Army Corps of Engineers. In September 1942, the Corps of Engineers established the MED, under the command of Major General Leslie Groves, to oversee the development of a nuclear weapon. This effort was code named the "Manhattan Project" (Maag and Rohrer, 15 December 1982, p. 13).

During the first two years of the Manhattan Project, work proceeded at a slow but steady pace. Significant technical problems had to be solved, and difficulties in the concentration of uranium-235 and production of plutonium, particularly the inability to process large amounts, often frustrated the scientists. Nonetheless, by 1944 sufficient progress had been made to persuade the scientists that their efforts might succeed. A test of the plutonium implosion device was necessary to determine if it would work and what its effects would be. Led by Dr. J. Robert Oppenheimer, Manhattan Project scientists at LANL were "to make preparations for a field test in which blast, earth shock, neutron and gamma radiation would be studied and complete photographic records made of the explosion and any atmospheric phenomena connected with the explosion" (Maag and Rohrer, 15 December 1982, pp. 13-14).

The planned firing date for the TRINITY device was originally 4 July 1945. On 14 June 1945, Dr. Oppenheimer changed the test date to no earlier than 13 July and no later than 23 July. On 30 June, the earliest firing date was moved to 16 July, even though better weather was forecast for 18 and 19 July. The TRINITY test organization adjusted the schedule because the Allied conference in Potsdam, Germany, was about to begin and the President needed the results of the test as soon as possible (Maag and Rohrer, 15 December 1982, p. 26).

6.1.2 TRINITY Test Operations.

About 850 military and civilian personnel are verified as having participated in Project TRINITY or having visited the test site from 16 July 1945 through 1946 (JAYCOR, 6 October 1993). All participants, civilian as well as military, were under the authority of the MED. Project activities included scientific studies. Military exercises were not conducted at TRINITY (Maag and Rohrer, 15 December 1982, p. 1).

LANL, which was staffed and administered by the University of California (under contract to the MED), conducted diagnostic experiments. Before the detonation, civilian and military scientists and technicians, assisted by other military personnel, placed gauges, detectors, and other instruments around ground zero. An evacuation detachment consisting of 144 to 160 enlisted men and officers was established in case protective measures or evacuation of civilians living offsite became necessary. Such action was not deemed necessary, however, and the evacuation detachment was dismissed late on the day of the detonation for return to Los Alamos (Maag and Rohrer, 15 December 1982, p. 1).

For the detonation, at least 263 DoD participants were at the test site. Among this group were 99 personnel divided among three shelters approximately 9,175 meters north, south, and west of ground zero. No one was closer to ground zero at shot-time (Maag and Rohrer, 15 December 1982, p. 31).

To determine the extent of the radiation resulting from the detonation, a network of detectors with remote read-out was installed along routes between ground zero and each shelter. In addition, trained monitors with portable radiation survey instruments were assigned to each shelter. No radiation was detected at the south and west shelters. The remote detectors north of ground zero indicated that the radioactive cloud was moving in that direction, and a monitor in the north shelter observed a sharp increase in the radiation level. The shelter was consequently evacuated shortly after the detonation. It was learned later that the monitor had inadvertently changed an adjustment on his instrument, which resulted in a false reading. Very little contamination occurred at the north shelter (Maag and Rohrer, 15 December 1982, pp. 1-2).

To measure offsite fallout, four two-man teams were organized. They established monitoring posts in towns north of the test area. These towns were Socorro, Nogal, Roswell, and Fort Sumner, all in New Mexico. Following the detonation, offsite teams surveyed areas beyond the test area by car (Maag and Rohrer, 15 December 1982, p. 47).

The radioactive cloud the explosion produced moved toward the northeast at an elevation of between 45,000 and 55,000 feet. Radioactive fallout did not reach the ground in significant amounts for the first 16 to 24 kilometers of the cloud's path. Once fallout began, it created a swath of fairly high radioactivity in a northeasterly direction on the ground covering an area about 160 kilometers long and 48 kilometers wide (Weisskopf and others, 5 September 1945).

Offsite monitoring teams surveying northeast of ground zero encountered gamma readings ranging from 1.5 to 15 R/h two to four hours after the detonation. Three hours after the detonation, surveys taken in Bingham, New Mexico (located 30 kilometers northeast of ground zero), found gamma intensities of about 1.5 R/h. Radiation readings at the town of White, nine kilometers southeast of Bingham, were 6.5 R/h three hours after the detonation and 2.5 R/h two hours later. Another team monitoring in a canyon 11 kilometers east of Bingham found a gamma intensity of about 15 R/h. Five hours later, the intensity had decreased to 3.8 R/h. It was estimated that peak intensities of gamma radiation from fallout on shot-day were about 7 R/h at an occupied ranch house in this canyon area (Maag and Rohrer, 15 December 1982, p. 47).

A substantial amount of activity took place at the test site during the first three days following the detonation, as scientists entered the ground zero area to retrieve instruments or perform experiments. Their entry into, activities at, and exit from the test site were carefully controlled. When the itinerary indicated operations in regions of known radiation intensity, a limit was set on the time spent in the area. Radiation detectors were provided, when possible, to permit continuous monitoring of the exposure. Film badges were also provided to each person for subsequent determination and recording of the doses received. The number of personnel at the TRINITY test site diminished rapidly after 19 July, as the emphasis shifted to preparing the devices that were to be used over Japan (Maag and Rohrer, 15 December 1982, p. 38). In late August a fence was built around the site to help keep out unauthorized personnel.

6.1.3 Dose Summary for Project TRINITY.

The dose limit for TRINITY participants was 5.0 R (rem) of gamma radiation during a two-month period (Abersold, January 1947, p. 29). **Table 6-2** summarizes the available dosimetry information:

Table 6-2. Summary of external doses for Project TRINITY as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army *	377	143	64	110	73	17	3
Navy	8	11	1	2	0	1	0
Total for Each Column	385	154	65	112	73	18	3
Cumulative total							810

* At the time of TRINITY, the Air Force was part of the Army and no Marines were present.

6.2 OPERATION CROSSROADS.

Conducted in 1946 at Bikini, CROSSROADS involved approximately 250 ships and 160 aircraft. Verified DoD participants number about 47,400 (JAYCOR, 6 October 1993). The series consisted of an airdrop detonated at a height of 520 feet and an underwater shot conducted at a depth of 90 feet, as shown in **Table 6-3**.

Table 6-3. CROSSROADS shots.

Shot	Date (1946)	Type	Yield (kilotons)
ABLE	1 July	Airdrop	21
BAKER	25 July	Underwater	21

The nuclear devices were similar to the TRINITY device and to the weapon detonated over Nagasaki, Japan (Berkhouse and others, 1 May 1984, p. 17).

Among the numerous observers of these two detonations was First Lieutenant David J. Bradley, an Army doctor trained as a radiological safety monitor. He made the following observations of ABLE and BAKER from a Navy aircraft approximately 20 nautical miles from each detonation:

ABLE: At twenty miles [it] gave us no sound or flash or shock wave. . . . Then, suddenly we saw it -- a huge column of clouds, dense, white, boiling up through the strata-cumulus, looking much like any other thunderhead but climbing as no storm cloud ever could. The evil mushrooming head soon began to blossom out. It climbed rapidly to 30,000 or 40,000 feet, growing a tawny-pink from oxides of nitrogen, and seemed to be reaching out in an expanding umbrella overhead.... For minutes the cloud stood solid and impressive, like some gigantic monument, over Bikini. Then finally the shearing of the winds at different altitudes began to tear it up into a weird zigzag pattern (Bradley, 1948, p. 55).

BAKER: This shot in broad day, at fifteen miles, seemed to spring from all parts of the target fleet at once. A gigantic flash -- then it was gone. And where it had been now stood a white chimney of water reaching up and up. Then a huge hemispheric mushroom of vapor appeared like a parachute suddenly opening.... By this time the great geyser had climbed to several thousand feet. It stood there as if solidifying for many seconds, its head enshrouded in a tumult of steam. Then slowly the pillar began to fall and break up. At its base a tidal wave of spray and steam arose, to smother the fleet and move on toward the islands. All this took only a few seconds, but the phenomenon was so astounding as to seem to last much longer (Bradley, 1948, p. 93).

Figure 6-4 shows the BAKER detonation.

6.2.1 Background and Objectives of CROSSROADS.

After the strategic atomic bomb attacks on Japan had abruptly ended World War II, many military leaders felt that military science was at a crossroads. Vice Admiral W. H. P. Blandy, who directed CROSSROADS declared that "warfare, perhaps civilization itself, had been brought to a

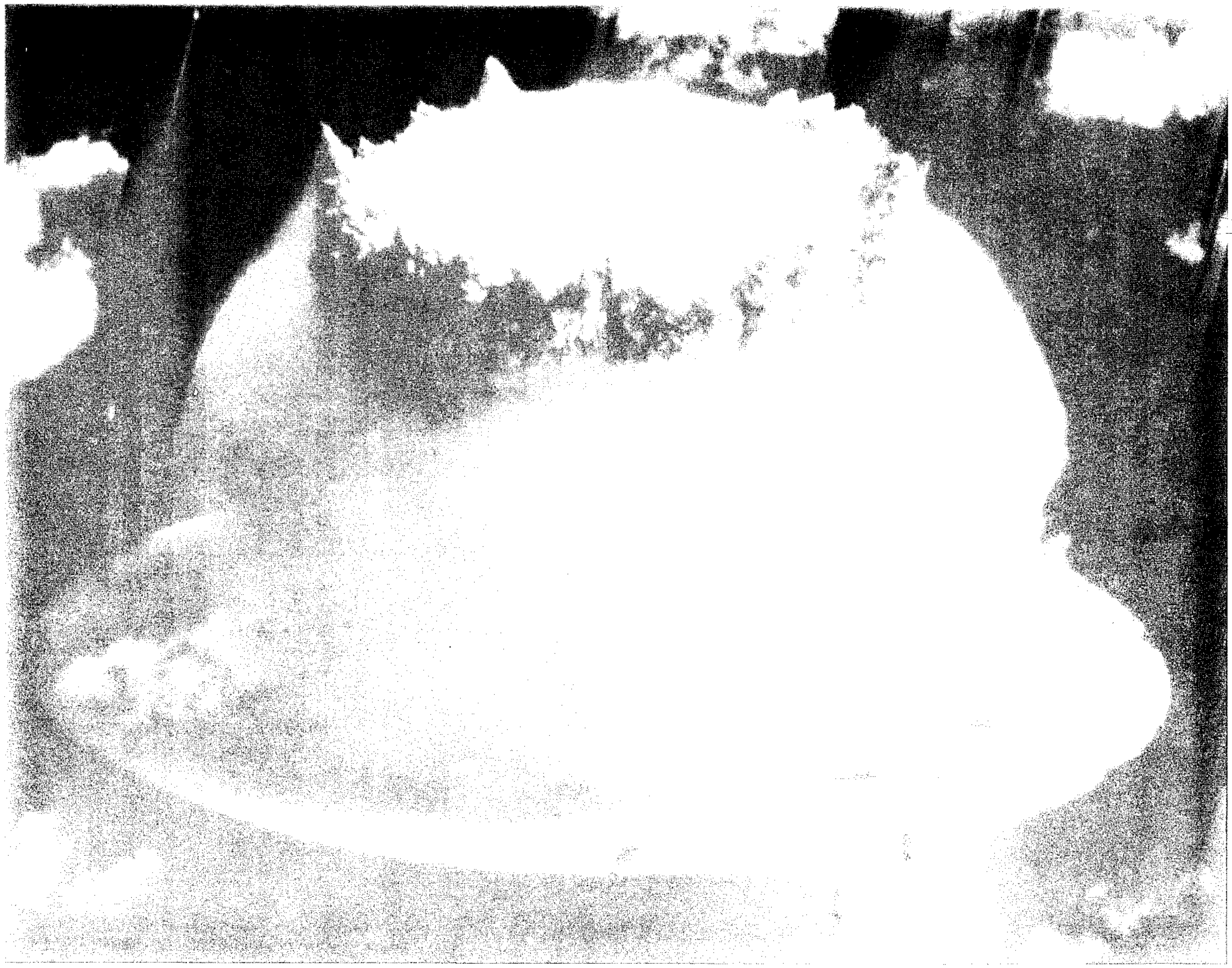

Figure 6-4. Shot BAKER emerging amidst the unmanned target fleet, 25 July 1946.
(Joint Task Force One, 18 BAKER #3, 1946.)

to a turning point by this revolutionary weapon." With this thought in mind, he named the initial postwar test series (National Geographic Magazine, April 1947, p. 529).

As early as August 1945, the Chairman of the Senate's Special Committee on Atomic Energy proposed that the effectiveness of atomic bombs be demonstrated on captured Japanese ships. In September, the General of the Army, H. H. Arnold, Commander of the Army Air Forces, put the question of such a test before the Joint Chiefs of Staff (JCS). The ensuing discussion and recommendations led President Harry Truman to announce, on 10 December 1945, that the U.S. would further explore the capabilities of atomic energy in the form of scientific atomic bomb tests under JCS jurisdiction (Berkhouse and others, 1 May 1984, p. 18).

CROSSROADS was designed to produce information not available from the TRINITY test or the Hiroshima and Nagasaki bombings. The primary purpose was to determine the effects of atomic bombs on naval vessels. The secondary purposes were to provide training for aircrews in attack techniques using atomic bombs against ships and to determine atomic bomb effects upon other military equipment and installations (Berkhouse and others, 1 May 1984, p. 18).

6.2.2 CROSSROADS Test Operations.

A fleet of more than 90 target vessels was assembled in Bikini Lagoon for CROSSROADS. The target fleet consisted of older U.S. ships, such as the aircraft carriers USS SARATOGA (CV 3) and USS INDEPENDENCE (CVL 22), the battleships USS NEVADA (BB 36), USS ARKANSAS (BB 33), USS PENNSYLVANIA (BB 38), and USS NEW YORK (BB 34), surplus U.S. cruisers, destroyers, submarines, and a large number of auxiliary and amphibious vessels. The German cruiser PRINZ EUGEN and two major captured Japanese ships, the battleship NAGATO and the cruiser SAKAWA, also were targets. The support fleet comprised more than 150 ships that provided quarters, experimental stations, and workshops for most of the approximately 43,000 participants, more than 39,000 of whom were Navy personnel (Berkhouse and others, 1 May 1984, pp. 1, 84).

In contrast to all other U.S. atmospheric nuclear test series, a large media contingent was present for both CROSSROADS detonations. Quartered aboard USS APPALACHIAN (AGC 1), the correspondents numbered 131 and were from newspapers, magazines, and the radio networks (Anonymous, no date). Included were correspondents from Australia, Canada, France, the Republic of China, the Soviet Union, and the United Kingdom. All Hands, a Navy magazine of the period, reported that:

> The press will be allowed to cover the test atomic bomb explosions at Bikini with sufficient thoroughness to satisfy the public as to the fairness and general results of the experiment, but not so completely that military information of value to the enemy will be disclosed (Bureau of Naval Personnel, 1 July 1946).

ABLE operations went smoothly. The radioactivity created by the airburst had only a transient effect. Within a day, radiation intensities in the lagoon had decayed to less than 0.1 R/24 hours, and nearly all the surviving target ships had been safely reboarded. The ship inspections, instrument recoveries, and remooring necessary for the BAKER test proceeded on schedule (Berkhouse and others, 1 May 1984, pp. 1, 217).

BAKER, on the other hand, presented difficulties. The underwater detonation caused most of the target fleet to be bathed in radioactive water spray and debris. With the exception of 12 target vessels in the lagoon and the landing craft beached on Bikini Island, the surviving target fleet was too radiologically contaminated for many days for more than brief on-board activities. During the first week of August, attempts were made to decontaminate the vessels. By 10 August, upon the advice of Colonel Stafford Warren, the Chief of the Radiological Safety Division, the Task Force Commander decided to terminate these efforts and tow most of the remaining target fleet to Kwajalein Atoll for possible decontamination (Berkhouse and others, 1 May 1984, pp. 178-187).

In the latter half of August 1946, the surviving target ships were towed or sailed to Kwajalein Atoll. Eight of the major ships and two submarines were towed back to the U.S. for radiological inspection. Twelve target ships were so lightly contaminated that their crews remanned them and sailed them back to the United States. The remaining target ships were destroyed by sinking off Kwajalein Atoll, near the Hawaiian Islands or off the California coast during 1946 to 1948. The support ships were decontaminated as necessary at various Navy shipyards, primarily in San Francisco and Long Beach, California (Berkhouse and others, 1 May 1984, pp. 178-187).

6.2.3 Dose Summary for CROSSROADS.

CROSSROADS operations were undertaken under radiological supervision intended to keep personnel doses below 0.1 R (rem) of gamma radiation per day. About 15 percent of the participants were issued film badges. Personnel anticipated to have the most potential for exposure were badged, and a percentage of each group working in less radioactive areas were badged (Berkhouse and others, 1 May 1984, pp. 2-3). Thus, because radiation dose data are not complete, reconstructions have been made of personnel doses for unbadged crewmembers of the ships involved. The calculations rely upon the radiation measurements recorded by radiation safety personnel in 1946 and use the types of methods discussed in Section 8.

In the fall of 1983, the papers of Colonel Stafford Warren, the chief of radiological safety at CROSSROADS, were released. His papers revealed certain data that had not been found in previous archival searches. When introduced into the reconstruction model, the data had the effect of reducing the reconstructed doses of many CROSSROADS personnel. **Table 6-4** summarizes the presently available dosimetry information:

Table 6-4. Summary of external doses for Operation CROSSROADS as of 30 September 1993.

Gamma dose R (rem)

	0	**>0-0.5**	**>0.5-1.0**	**>1.0-3.0**	**>3.0-5.0**	**>5.0-10.0**	**>10.0**
Army *	2,290	1,070	147	9	1	0	0
Navy	6,917	23,258	7,448	4,038	11	0	0
Marines	211	378	0	0	0	0	0
Coast Guard **	1	5	1	0	0	0	0
Foreign Military Observers	0	3	0	0	0	0	0
Total for each column	9,319	24,714	7,596	4,047	12	0	0
Cumulative total							45,689

* At the time of CROSSROADS the Air Force was part of the Army.
** Coast Guard personnel were present at some oceanic test series.

6.3 OPERATION SANDSTONE.

Conducted at Enewetak Atoll in 1948, Operation SANDSTONE consisted of three tower shots, all detonated at a height of 200 feet, as shown in **Table 6-5** (Berkhouse and others, 19 December 1983, p. 1).

Table 6-5. SANDSTONE shots.

Shot	**Date (1948)**	**Type**	**Yield (kilotons)**
X-RAY	15 April	Tower	37
YOKE	1 May	Tower	49
ZEBRA	15 May	Tower	18

6.3.1 Background and Objectives of Operation SANDSTONE.

Operation SANDSTONE was the second test series carried out in the Marshall Islands. It differed from the first, CROSSROADS, in that it was primarily a scientific series conducted by the AEC. The AEC was activated on 1 January 1947 to assume the responsibilities formerly held by the MED, dissolved at the end of 1946. The Armed Forces had a supporting role in SANDSTONE, whereas they had assumed a lead role in CROSSROADS (Berkhouse and others, 19 December 1983, p. 1).

SANDSTONE was a proof-test of second-generation nuclear devices. The two weapons detonated at CROSSROADS were the same type of weapon dropped on Nagasaki. On 3 April 1947, the General Advisory Committee to the AEC recommended development and testing of new weapons. When the President approved the preliminary SANDSTONE test program on 27 June 1947, the U.S. apparently had only 13 nuclear weapons in its stockpile. One year later, despite heavy emphasis on increased production of fissionable material, the number of weapons was only about 50, far short of the number that military planners calculated would be required in a war with the Soviet Union. The great expansion in the U.S. stockpile evident by the end of 1949 was the direct result of the higher production rates of fissionable material and the more efficient weapons proof-tested at SANDSTONE (Berkhouse and others, 19 December 1983, pp. 17-18).

Meetings were held on 9 July 1947 at Los Alamos, New Mexico, to define test responsibilities for SANDSTONE. LANL, the organization that had developed the wartime atomic weapons and that did research and laboratory development of new nuclear weapons designs, was to provide technical leadership and the military services were to provide supplies and support (Berkhouse and others, 19 December 1983, p. 18).

6.3.2 SANDSTONE Test Operations.

Numerous technical experiments were conducted in conjunction with each of the three detonations. These experiments measured the yield and efficiency of the devices and attempted to gauge the military effects of the events. The studies were similar at each of the shots but were carried out more precisely with YOKE and ZEBRA as collective experience grew (Berkhouse and others, 19 December 1983, pp. 2, 102).

Operation SANDSTONE has approximately 14,200 verified participants, most of whom were military personnel (JAYCOR, 6 October 1993). The DoD personnel had support roles and some had duty stations at the AEC weapons design and development laboratories or were part of units performing separate experiments (Berkhouse and others, 19 December 1983, pp. 1-2).

6.3.3 Dose Summary for Operation SANDSTONE.

The dose limit for SANDSTONE participants was 0.1 R (rem) of gamma radiation per 24-hour period and a maximum 3.0 R (rem) for certain approved and specific missions (Berkhouse and others, 19 December 1983, p. 2). **Table 6-6** summarizes the available dosimetry information:

Table 6-6. Summary of external doses for Operation SANDSTONE as of 30 September 1993.

	Gamma dose R (rem)						
	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	28	1,603	11	16	3	2	0
Navy	285	7,233	17	9	2	0	0
Marines	3	259	1	1	0	0	0
Air Force	30	2,130	28	16	1	0	0
Field Command	17	9	0	1	0	0	0
Total for Each Column	363	11,234	57	43	6	2	0
Cumulative total							11,705

6.4 OPERATION RANGER.

Operation RANGER was the first atmospheric nuclear weapons test series conducted by the AEC at the NTS. This 1951 series consisted of five nuclear events, all of which were airdrops detonated at heights of about 1,000-1,400 feet. In addition, RANGER included one nonnuclear high-explosive test detonated two days before the first nuclear event. **Table 6-7** provides specifics on the nuclear shots (Maag and others, 26 February 1982, pp. 1, 4).

Table 6-7. RANGER shots.

Shot	Date (1951)	Type	Yield (kilotons)
ABLE	27 January	Airdrop	1
BAKER	28 January	Airdrop	8
EASY	1 February	Airdrop	1
BAKER-2	2 February	Airdrop	8
FOX	6 February	Airdrop	22

6.4.1 Background and Objectives of Operation RANGER.

In November 1950, LANL discovered that insufficient data were available to determine satisfactory design criteria for nuclear devices to be tested in Operation GREENHOUSE, a series of AEC nuclear tests scheduled for the Pacific from 7 April through 24 May 1951. The LANL scientists believed that variations in the compression of the fissionable material could affect the yields of the GREENHOUSE devices. To confirm this hypothesis, LANL held conferences on 6 and 11 December 1950 and concluded that a series of small nuclear tests should be conducted to improve the GREENHOUSE design criteria. On 22 December 1950, LANL requested approval for a continental series from the AEC Division of Military Application (DMA). DMA approved the request and asked for Presidential approval to expend the fissionable material required for the series and to use part of the Las Vegas Bombing and Gunnery Range in Nevada for the tests. The White House responded affirmatively to both requests on 11 January 1951, formally creating Operation RANGER.

The same day that Operation RANGER was approved by the President, the AEC distributed its only announcements of the coming tests. Handbills were circulated in the area of the test site, stating that from 11 January 1951 the Government would be conducting nuclear tests at the Las Vegas Bombing and Gunnery Range. **Figure 6-5** shows this handbill (Maag and others, 26 February 1982, pp. 18-20).

6.4.2 Establishment of the Nevada Test Site.

Nearly six years passed between the detonation of TRINITY at Alamogordo, New Mexico, on 16 July 1945, and the next CONUS nuclear test, ABLE of the RANGER series. The AEC had considered establishing a continental test site in 1948 after SANDSTONE, as a way to reduce construction and logistic costs, but rejected the idea after concluding that the physical problems and domestic political concerns would be too complicated. When the Korean War began in the summer of 1950, however, the AEC doubted that the Pacific could be used for nuclear weapons testing because of the possibility of the Korean War expanding throughout the Far East, thus endangering shipping lanes. On 13 July 1950, the AEC Chairman wrote the Chairman of the Military Liaison Committee that the possibility of a national emergency required a joint effort by the AEC and DoD to find a continental test site. The DoD agreed, and the search began for a suitable site.

The AEC and DoD surveyed six sites within the continental United States before choosing the Frenchman Flat area of the Las Vegas Bombing and Gunnery Range, renamed the Nellis Air Force Range in 1956. The Government picked this site because it best suited AEC criteria for favorable meteorological conditions, distance from population areas, and proximity to operational facilities (Maag and others, 26 February 1982, pp. 19-20). Known first as the NTS, then as the Nevada Proving Ground (NPG) beginning in early 1952, the site since 1955 has again been called the NTS, the designation used throughout this volume.

6.4.3 RANGER Test Operations.

Only about 320 DoD personnel have been verified as participants in RANGER, which was primarily an AEC activity (JAYCOR, 6 October 1993). They were engaged in support services, scientific experiments, weather support, communications security, and observer activities. The majority participated in the air support services conducted primarily by Air Force personnel from the Special Weapons Command (SWC) and Headquarters, Air Force. At each event, air support activities included the airdrop of the nuclear device, cloud sampling, cloud tracking, aerial surveys

WARNING

January 11, 1951

From this day forward the U.S. Atomic Energy Commission has been authorized to use part of the Las Vegas Bombing and Gunnery Range for test work necessary to the atomic weapons development program.

Test activities will include experimental nuclear detonations for the development of atomic bombs - so-called "A-Bombs" - carried out under controlled conditions.

Tests will be conducted on a routine basis for an indefinite period.

NO PUBLIC ANNOUNCEMENT OF THE TIME OF ANY TEST WILL BE MADE

Unauthorized persons who pass inside the limits of the Las Vegas Bombing and Gunnery Range may be subject to injury from or as result of the AEC test activities.

Health and safety authorities have determined that no danger from or as a result of AEC test activities may be expected outside the limits of the Las Vegas Bombing and Gunnery Range. All necessary precautions, including radiological surveys and patrolling of the surrounding territory, will be undertaken to insure that safety conditions are maintained.

Full security restrictions of the Atomic Energy Act will apply to the work in this area.

RALPH P. JOHNSON, Project Manager
Las Vegas Project Office
U.S. Atomic Energy Commission

Figure 6-5. AEC handbill announcing the beginning of the RANGER tests.

of the terrain, and courier service. Air Force personnel also provided meteorological services and communications security and monitored worldwide radioactivity from the RANGER test for the Atomic Energy Detection System. Since RANGER was only a 13-day operation, the same units and participants performed the same duties throughout the series (Maag and others, 26 February 1982, p. 1).

6.4.4 Dose Summary for Operation RANGER.

Table 6-8 summarizes the available dosimetry information. Four doses exceeded the 3.0 R (rem) limit of gamma radiation per 13-week period (Maag and others, 26 February 1982, p. 3):

Table 6-8. Summary of external doses for Operation RANGER as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	15	9	3	3	2	0	0
Navy	0	3	1	0	1	1	0
Marines	0	0	1	0	0	0	0
Air Force	9	92	0	0	0	0	0
Total for Each Column	24	104	5	3	3	1	0
Cumulative total							140

6.5 OPERATION GREENHOUSE.

GREENHOUSE was the fourth postwar atmospheric nuclear weapons test series. Conducted in 1951 on the northeastern islands of the Enewetak Atoll, the series consisted of four tower shots as shown in **Table 6-9**. Two shots were detonated at 200 feet and two at 300 feet (Berkhouse and others, 15 June 1983, p. 1).

Table 6-9. GREENHOUSE shots.

Shot	Date (1951)	Type	Yield (kilotons)
DOG	8 April	Tower	81
EASY	21 April	Tower	47
GEORGE	9 May	Tower	225
ITEM	25 May	Tower	45.5

6.5.1 Background and Objectives of Operation GREENHOUSE.

The purpose of the four GREENHOUSE tests was to continue development of nuclear weapons for defense. More specifically, work was proceeding at this time on developing thermonuclear weapons, and the GREENHOUSE tests were part of this process (Berkhouse and others, 15 June 1983, p. 1).

In 1949, the Soviet Union detonated its first atomic bomb, providing the impetus for the United States to proceed with development of a bomb whose energy would come from the fusion, or joining, of light elements. Such a weapon is also called a thermonuclear, or hydrogen, bomb. The AEC received presidential approval for work in this area in January 1950 after lengthy debate in high defense circles over the feasibility and advisability of such weapons.

Although the GREENHOUSE nuclear devices were not thermonuclear devices, two of them involved thermonuclear experiments, and one test, GEORGE, was an important step toward thermonuclear devices. GEORGE demonstrated the initiation of a sustained thermonuclear reaction by use of a fission reaction. This led directly to the first successful thermonuclear test, MIKE (Operation IVY), some 16 months later. In addition, ITEM, the fourth test of the series, involved boosting the efficiency of fission explosions. Development of this experiment had been planned before the Soviet test in 1949 (Berkhouse and others, 15 June 1983, p. 21; JAYCOR, 6 October 1993).

6.5.2 GREENHOUSE Test Operations.

The Navy had provided most of the DoD personnel for the earlier Pacific nuclear test series. It contributed the largest number to GREENHOUSE, too, but the Army and Air Force were also well represented in the testing area. Approximately 9,570 DoD participants supported the eight GREENHOUSE scientific programs, which consisted of projects recommended by the Army, Navy, Air Force, AFSWP, and the AEC (JAYCOR, 6 October 1993). The programs were of three types: those dealing with the chemistry and physics of atomic explosions; those dealing with the effects of such explosions on the natural environment, on man-made objects, and on various plants and animals; and those designed to help develop means to detect nuclear detonations at great distances so that U.S. authorities could monitor nuclear developments in other countries (Berkhouse and others, 15 June 1983, p. 130).

6.5.3 Dose Summary for Operation GREENHOUSE.

The maximum permissible dose for Operation GREENHOUSE participants was 0.1 R (rem) of gamma radiation per day (0.7 R (rem) per week), not to exceed a total of 3.9 R (rem) for 13 weeks. A total of up to 3.0 R (rem) on any one day could be authorized in specific cases. When this authorization was made, however, individuals were not to exceed 0.1 R (rem) per day during the remainder of the operation (Berkhouse and others, 15 June 1983, p. 64).

Film badges were issued to individuals who might be exposed to radiation while performing their duties. In addition, over 75 film badges for each test were distributed among the six participating ships, to be worn from the day of the test to seven days thereafter. Among the men in the test area during all or part of the testing operations, approximately 4,000 were badged one or more times (Berkhouse and others, 15 June 1983, p. 2; JAYCOR, 1 October 1993).

Fallout occurred on the inhabited islands of Enewetak, Parry, and Japtan, and on the six task force ships after three of the four shots in the series. Fallout from Shot DOG was approximately twice as great on Parry and Japtan than it was on Enewetak, where the majority of the island-based participants were located. Shot EASY fallout was insignificant and affected all residence islands equally. Shot ITEM fallout, on the other hand, was approximately twice as great on Enewetak as it was on Japtan (Berkhouse and others, 15 June 1983, p. 3). Overall, calculated fallout doses for personnel remaining on the residence islands until the end of May, when the rollup phase was virtually complete, were nearly equal on all three of the islands: Enewetak, 2.93 R (rem); Parry, 3.10 R (rem); and Japtan, 2.57 R (rem).

The amount of fallout received by the six ships varied with their locations and decontamination procedures. The fallout exposure was lower aboard ship than on the islands due to water washdown, shielding, and decontamination of external surfaces (Berkhouse and others, 15 June 1983, p. 3). **Table 6-10** summarizes available dosimetry data.

Table 6-10. Summary of external doses for Operation GREENHOUSE as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	7	162	31	885	711	27	0
Navy	744	673	479	1,199	79	16	4
Marines	2	2	2	40	2	0	0
Air Force	469	378	367	458	831	130	5
Field Command	0	5	2	8	0	0	0
Coast Guard	0	0	1	0	1	0	0
Total for Each Column	1,222	1,220	882	2,590	1,624	173	9
Cumulative total							7,720

6.6 OPERATION BUSTER-JANGLE.

Conducted in 1951, Operation BUSTER-JANGLE was the second series of atmospheric nuclear weapons tests at the NTS. The series consisted of seven nuclear detonations, as shown in **Table 6-11**.

Table 6-11. BUSTER-JANGLE shots.

Shot	Date (1951)	Type	Yield (kilotons)
ABLE	22 October	Tower	<0.1
BAKER	28 October	Airdrop	3.5
CHARLIE	30 October	Airdrop	14
DOG	1 November	Airdrop	21
EASY	5 November	Airdrop	31
SUGAR	19 November	Surface	1.2
UNCLE	29 November	Underground	1.2

Up to this point in the U.S. atmospheric nuclear testing program, all detonations had been from towers or by air drops, except for the shallow underwater Shot BAKER of Operation CROSSROADS. BUSTER-JANGLE included the first surface detonation (SUGAR) and the first shallow underground (-17 feet) detonation (UNCLE) of the testing program (Ponton and others, 21 June 1982, pp. 1, 6)

6.6.1 Background and Objectives of Operation BUSTER-JANGLE.

This series was originally planned as two separate weapons testing programs: Operation BUSTER and Operation JANGLE. BUSTER, the plans for which began in late 1950, was to evaluate new devices developed by LANL and to obtain data on the basic phenomena associated with these devices. Plans for JANGLE originated with Operation CROSSROADS, conducted at Bikini in 1946. Scientific studies of the underwater CROSSROADS detonation led to inquiries concerning the effects and possible military value of an underground nuclear detonation. The JCS accordingly obtained AEC agreement to conduct tests involving an underground and a surface nuclear detonation. The general objectives of the tests were to determine the effects of these detonations and to study the devices for inclusion in the nuclear arsenal.

In 1950, AEC and DoD representatives selected Amchitka Island, one of the Aleutian Islands, as the site for the underground and surface tests, to be called Operation WINDSTORM and to be conducted from 15 September to 15 November 1951. During March 1951, they decided that the tests should be conducted at the NTS and should be coordinated by the Air Force. The two nuclear events were subsequently renamed Operation JANGLE.

Because BUSTER and JANGLE were both scheduled for the fall of 1951 at the NTS, AFSWP recommended that the two series be conducted as consecutive phases of one series, Operation BUSTER-JANGLE. On 19 June 1951, the AEC approved the AFSWP recommendation (Ponton and others, 21 June 1982, pp. 20-22)

6.6.2 BUSTER-JANGLE Test Operations.

Verified DoD participants in Operation BUSTER-JANGLE number about 9,700, serving in observer programs, tactical maneuvers, damage effects tests, scientific and diagnostic studies, and support activities (JAYCOR, 6 October 1993). Approximately 6,500 of these participants took part in Exercises Desert Rock I, II, and III, Army programs involving members from all four armed services. The remaining DoD personnel provided support for the Desert Rock exercises or participated in scientific activities.

Exercise Desert Rock I was conducted at Shot DOG, and Exercises Desert Rock II and III at Shots SUGAR and UNCLE, respectively. The troop exercises were the first staged by the Armed Forces during U.S. continental atmospheric nuclear weapons testing. The Desert Rock exercises included observer programs, tactical maneuvers, and damage effects tests. Observer programs, conducted at DOG, SUGAR, and UNCLE, generally involved briefings on nuclear weapons effects, observation of the nuclear detonation, and a subsequent tour of a display of military equipment exposed to the detonation. Tactical maneuvers, conducted after DOG, were designed both to train troops and to test military tactics. Damage effects tests, at DOG, SUGAR, and UNCLE, were performed to determine the effects of a nuclear detonation on military equipment and field fortifications (Ponton and others, 21 June 1982, pp. 1)

6.6.3 Dose Summary for Operation BUSTER-JANGLE.

The AEC established a dose limit of 1.0 R (rem) of gamma radiation for participants in Exercise Desert Rock I and a limit of 3.0 R (rem) for the following: participants in Exercises Desert Rock II and III; the test organization, which coordinated BUSTER-JANGLE; and SWC, which provided weather and air support, among other functions, for the test organization. SWC sampling pilots and crews were authorized to receive up to 3.9 R (rem) because their mission required them to penetrate the clouds resulting from the detonations (Ponton and others, 21 June 1982, p. 4). **Table 6-12** summarizes the available dosimetry information:

Table 6-12. Summary of external doses for Operation BUSTER-JANGLE as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	2,025	3,904	476	451	287	5	0
Navy	48	111	72	105	26	0	0
Marines	177	15	1	2	0	0	0
Air Force	168	367	44	53	21	0	0
Field Command	2	23	3	10	2	0	0
Total for Each Column	2,420	4,420	596	621	336	5	0
Cumulative total							8,398

6.7 OPERATION TUMBLER-SNAPPER.

Operation TUMBLER-SNAPPER, conducted in 1952, was the third series of nuclear weapons tests at the NTS. The operation consisted of eight nuclear detonations as shown in **Table 6-13**.

Table 6-13. TUMBLER-SNAPPER shots.

Shot	Date (1962)	Type	Yield (kilotons)
ABLE	1 April	Airdrop	1
BAKER	15 April	Airdrop	1
CHARLIE	22 April	Airdrop	31
DOG	1 May	Airdrop	19
EASY	7 May	Tower	12
FOX	25 May	Tower	11
GEORGE	1 June	Tower	15
HOW	5 June	Tower	14

6.7.1 Background and Objectives of Operation TUMBLER-SNAPPER.

As the defense policy evolved in the early 1950s, two particular factors challenged the ability of U.S. Armed Forces to defend American interests and to protect its allies during limited hostilities:

- The commitment of U.S. ground forces to the Korean peninsula, and
- The inability of European allies of the U.S. to develop effective military capabilities.

In both cases, the United States experienced difficulties because of limitations in military manpower, which emphasized the need for a new U.S. policy based not on large standing armies, but on new technological advances, particularly in nuclear weapons.

In 1951, the Chairman of the AEC strongly advocated the development of nuclear weapons for tactical purposes. "We could," he asserted, "use an atomic bomb today in a tactical war against enemy troops in the field, against military concentrations near battle areas and against other vital military targets without risk to our own troops." TUMBLER-SNAPPER was accordingly designed both to advance the development of effective nuclear weapons and to train troops in tactical nuclear warfare (Ponton and others, 14 June 1982, p. 25).

The series, like BUSTER-JANGLE, was originally planned as two separate testing programs: Operation TUMBLER, to be conducted at the NTS before 1 May 1952; and Operation SNAPPER, scheduled to begin at the NTS on 1 May 1952. Because the programs planned for the two series sometimes overlapped, they were combined into one operation, TUMBLER-SNAPPER (Ponton and others, 14 June 1982, pp. 26-28).

The series consisted of two phases. The TUMBLER phase, of primary concern to the DoD, featured four weapons effects tests: ABLE, BAKER, CHARLIE, and DOG. These airdropped devices were detonated to collect information on the effect of the height of burst on overpressure. Shots CHARLIE and DOG were also part of the SNAPPER phase, of primary concern to the AEC and LANL. The other weapons development tests in the SNAPPER phase were EASY, FOX, GEORGE, and HOW. The primary purpose of these four tower shots was to gather information on nuclear phenomena and to improve the design of nuclear weapons (Ponton and others, 14 June 1982, p. 1).

6.7.2 TUMBLER-SNAPPER Test Operations.

Approximately 7,350 of the about 10,400 verified DoD participants in Operation TUMBLER- SNAPPER took part in Exercise Desert Rock IV (JAYCOR, 6 October 1993). The remaining DoD personnel assisted in scientific experiments, air support activities, or administrative and support activities at the NTS (9: 1) (Ponton and others, 14 June 1982, p. 1).

Exercise Desert Rock IV, a training program sponsored by the Army but involving personnel from all the armed forces, included observer programs at Shots CHARLIE, DOG, FOX, and GEORGE and tactical maneuvers after Shots CHARLIE, DOG, and GEORGE. The tactical maneuvers were designed in part to provide realistic training for ground units when supported by tactical atomic weapons and to determine the psychological reactions of troops participating in the exercise. The DOG tactical maneuver was the first Marine Corps maneuver of the CONUS tests. In addition to these activities, Exercise Desert Rock IV involved psychological tests at CHARLIE, FOX, and GEORGE to gauge the troops' reactions to witnessing a nuclear detonation (Ponton and others, 14 June 1982, pp. 1, 5).

6.7.3 Dose Summary for Operation TUMBLER-SNAPPER.

A dose limit of 3.0 R (rem) of gamma radiation per 13-week period was established for participants in Exercise Desert Rock IV, the joint AEC-DoD organization (coordinator of the series), and most of the Air Force Special Weapons Center (AFSWC) activities (Ponton and others, 14 June 1982, p. 7). **Table 6-14** presents the available dosimetry information:

Table 6-14. Summary of external doses for Operation TUMBLER-SNAPPER as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	83	4,437	493	124	18	7	1
Navy	55	427	44	57	3	0	0
Marines	5	2,043	1	1	0	0	0
Air Force	173	1,000	41	47	22	4	0
Field Command	97	154	25	33	7	0	0
Total for Each Column	413	8,061	604	262	50	11	1
Cumulative total							9,402

6.8 OPERATION IVY.

IVY, conducted at Enewetak Atoll during the autumn of 1952, consisted of two detonations. These two detonations, identified in **Table 6-15**, were the largest nuclear explosions up to that time:

Table 6-15. IVY shots.

Shot	Date (1962)	Type	Yield
MIKE	1 November	Surface	10.4 megatons
KING	16 November	Airdrop	500 kilotons

The description of the MIKE detonation by the author of History--Task Group 132.1 and reproduced in History of Operation IVY bears repeating (Gladeck and others, 1 December 1982, pp. 1, 187):

> The Shot, as witnessed aboard the various vessels at sea, is not easily described. Accompanied by a brilliant light, the heat wave was felt immediately at distances of thirty to thirty-five miles. The tremendous fireball, appearing on the horizon like the sun when half-risen, quickly expanded after a momentary hover time and appeared to be approximately a mile in diameter before the cloud-chamber effect and scud clouds partially obscured it from view. A very large cloud chamber effect was visible shortly after the detonation and a tremendous conventional mushroom-shaped cloud soon appeared, seemingly balanced on a wide dirty stem. Apparently, the dirty stem was due to the coral particles, debris, and water which were sucked high into the air. Around the base of the stem, there appeared to be a curtain of water which soon dropped back around the area where the island of Elugelab [Eluklab] had been.

Figure 6-6 is a photograph of the MIKE cloud.

6.8.1 Background and Objectives of Operation IVY.

President Truman made the decision to pursue the development of thermonuclear weapons in 1950. Operation GREENHOUSE was an initial step toward this end, as Section 6.5 explains. Operation IVY considerably extended the GREENHOUSE advances. MIKE, an experimental device, produced the first thermonuclear detonation, which means that a substantial portion of its energy was generated by the fusion, or joining, of hydrogen and other light atoms. KING was a stockpile weapon, modified to produce a large yield. The energy from KING was generated by the fission, or splitting, of plutonium atoms (Gladeck and others, 1 December 1982, p. 1).

The IVY test program was the result not only of scientific and technical considerations, but also of an intense controversy within elements of the U.S. Government concerned with foreign policy and defense matters. During the early 1950s, various plans rapidly evolved to meet the challenge posed by the initial Soviet detonation of 1949. Most plans called for increased development and production of fission weapons and the required delivery systems. One plan called for the development of fusion, or thermonuclear, weapons with vastly greater explosive power. Opponents of fusion weapons argued that the Soviets could be persuaded not to develop these weapons if the United States would refrain. A further argument, among others, was that such weapons were not much more effective than high-yield fission weapons.

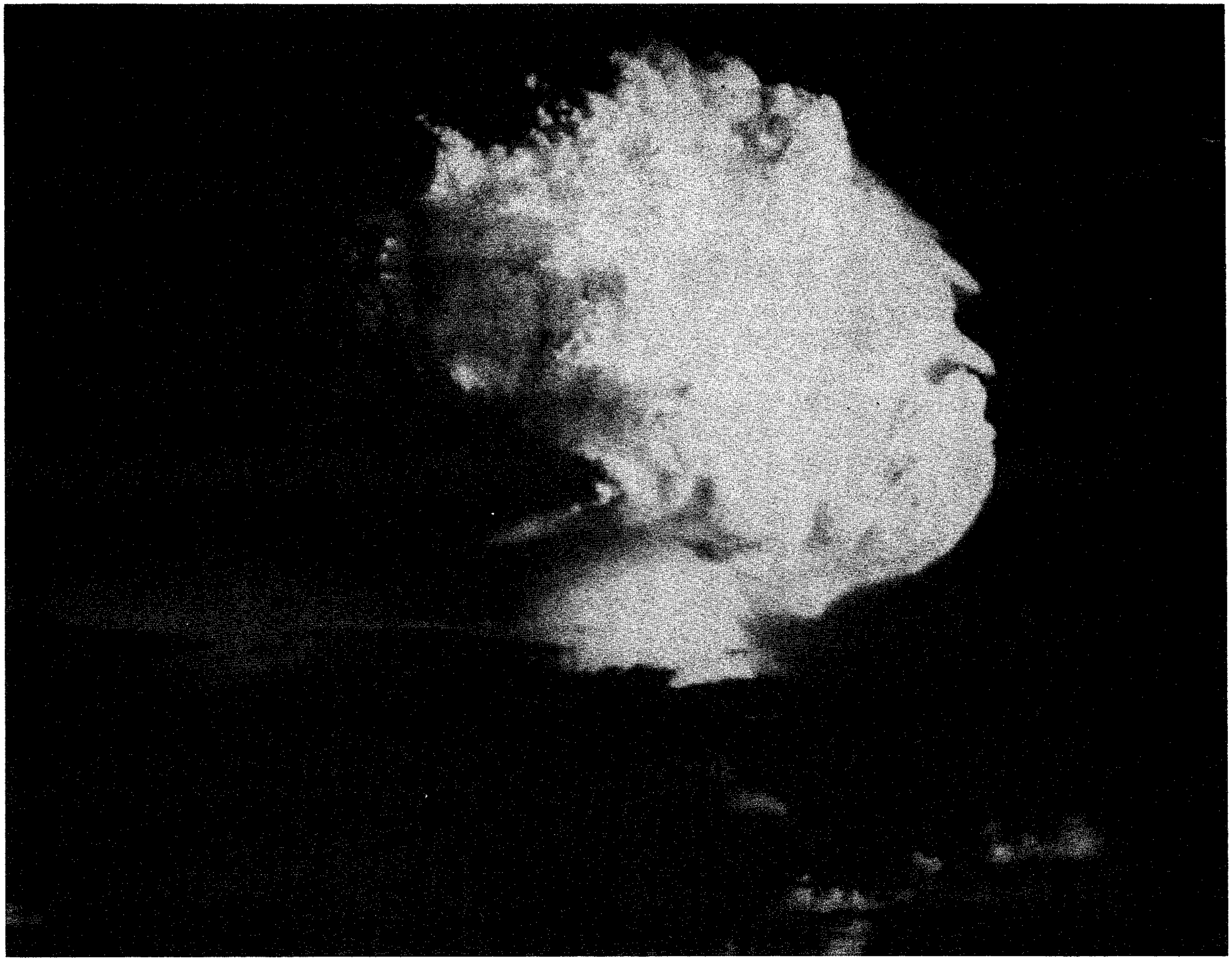

Figure 6-6. Shot MIKE, 1 November 1952.
(Air Force Lookout Mountain Laboratory Photograph, 21-APB-37-26, MIKE. 1952.)

The advocates of fusion weapons prevailed, and MIKE became the centerpiece of Operation IVY and the proof-test of the new technology. KING, however, represented a test of the kind of high-yield fission weapon some of the fusion opponents had in mind. To a degree, the KING device also offered a backup to help ease the national sense of vulnerability in the event that the initial attempt at a fusion reaction detonation was unsuccessful (Gladeck and others, 1 December 1982, pp. 18-19).

6.8.2 IVY Test Operations.

Operation IVY has approximately 10,600 verified DoD participants (JAYCOR, 6 October 1993). Most military personnel and civilians, either DoD or otherwise, were on Enewetak Atoll or on task force ships based at the Atoll (JAYCOR, 1 October 1993). These personnel were removed to evacuation ships before the detonation of MIKE. Most of the additional military were Air Force personnel who were based at Kwajalein, approximately 300 nautical miles southeast of Enewetak (Gladeck and others, 1 December 1982, pp. 178-181).

The experimental program for IVY focused primarily on the MIKE experiment and secondarily on KING. The effort, subdivided into 11 specific programs, was heavily oriented to weapons development experiments and focused to a lesser extent on effects experiments (Gladeck and others, 1 December 1982, pp. 118).

6.8.3 Dose Summary for Operation IVY.

The generally smooth MIKE operations were marred by an accident when a cloud-sampling pilot was lost at sea after his aircraft ran out of fuel. A seven-man rescue crew flew their aircraft through a fallout zone to reach the area of the downed airplane as soon as possible. In the process, the crewmembers received radiation doses ranging from 10 to 17.8 R (rem). These levels considerably exceeded the maximum permissible limit of 3.9 R (rem) of gamma radiation established for Operation IVY participants.

A crew of 12 in a second aircraft was overexposed when caught in fallout debris while on a photographic mission just after the MIKE shot. The highest dose for a member of this crew was 11.6 R (rem) (Gladeck and others, 1 December 1982, pp. 18-19). **Table 6-16** summarizes available IVY dosimetry data.

Table 6-16. Summary of external doses for Operation IVY as of 30 September 1993.

	Gamma dose R (rem)						
	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	47	1,225	15	30	3	1	0
Navy	17	5,762	23	42	3	0	0
Marines	32	167	1	8	0	0	0

Table 6-16. Summary of external doses for Operation IVY as of 30 September 1993. (Cont'd)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Air Force	109	2,590	39	43	3	5	14
Field Command	202	10	0	3	0	0	0
Coast Guard	0	2	0	0	0	0	0
Total for Each Column	407	9,756	78	126	9	6	14
Cumulative total							10,396

6.9 OPERATION UPSHOT-KNOTHOLE.

Conducted at the NTS in 1953, Operation UPSHOT-KNOTHOLE consisted of 11 nuclear tests, a number exceeding that of any previous nuclear test series. **Table 6-17** summarizes these shots.

Table 6-17. UPSHOT-KNOTHOLE shots.

Shot	Date (1953)	Type	Yield (kilotons)
ANNIE	17 March	Tower	16
NANCY	24 March	Tower	24
RUTH	31 March	Tower	0.2
DIXIE	6 April	Airdrop	11
RAY	11 April	Tower	0.2
BADGER	18 April	Tower	23
SIMON	25 April	Tower	43
ENCORE	8 May	Airdrop	27
HARRY	19 May	Tower	32
GRABLE	25 May	Airburst	15
CLIMAX	4 June	Airdrop	61

ANNIE, the first device tested, was an "open shot," meaning that reporters were allowed to view the detonation from News Nob, 11 kilometers south of the shot-tower. The Government wanted to show the American public that nuclear weapons could be used defensively, without destroying large urban centers and populations (Ponton and others, 11 January 1982, pp. 1, 3, 30-31). Among the experiments conducted during ANNIE was Operation DOORSTEP, which investigated the effect of a nuclear explosion on two typical two-story frame houses.

The firing of GRABLE from a 280 mm cannon, shown in **Figure 6-7** marked the first time an atomic artillery shell was fired and detonated. The Secretary of Defense, the Secretary of the Army, and the Army Chief of Staff, along with 96 Congressional observers, viewed the detonation from an area 11 kilometers west of ground zero (Massie and others, 15 January 1982, p. 120).

6.9.1 Background and Objectives of Operation UPSHOT-KNOTHOLE.

UPSHOT-KNOTHOLE went a step further than the previous CONUS series, TUMBLER-SNAPPER, which had explored the use of nuclear weapons for tactical purposes. Designed to address both the tactical and strategic considerations of the U.S. defense policy, UPSHOT-KNOTHOLE was designed to accomplish the following (Ponton and others, 11 January 1982, p. 33):

- Establish military doctrine for the tactical use of nuclear weapons, and
- Improve the nuclear weapons used for strategic bomber delivery and those used for tactical battlefield situations.

Like the earlier BUSTER-JANGLE and TUMBLER-SNAPPER series, UPSHOT-KNOTHOLE was initially envisioned as two separate weapons testing programs: Operation UPSHOT and Operation KNOTHOLE. Plans began in late 1951 for a large military effects test, later called Operation KNOTHOLE, to be conducted during the spring of 1953 at the NTS. The objective was to obtain general weapons effects information to supplement the data obtained from Operation GREENHOUSE, conducted at the Pacific during the spring of 1951.

Meanwhile, the AEC was planning Operation UPSHOT, with the earliest test date set for spring 1953. The DoD consequently accelerated its planning for Operation KNOTHOLE so that arrangements for the AEC and DoD tests could be coordinated. In June 1952, the DoD and AEC agreed to conduct the spring of 1953 tests as a combined operation, designated UPSHOT-KNOTHOLE (Ponton and others, 11 January 1982, p. 32).

6.9.2 UPSHOT-KNOTHOLE Test Operations.

Verified DoD participants in UPSHOT-KNOTHOLE number about 18,900 in observer programs, tactical maneuvers, scientific studies, and support activities (JAYCOR, 6 October 1993). The largest DoD participation was in Exercise Desert Rock V, which involved members of all four armed services. Exercise Desert Rock V included troop orientation and training, a volunteer officer observer program, tactical troop maneuvers, operational helicopter tests, and damage effects

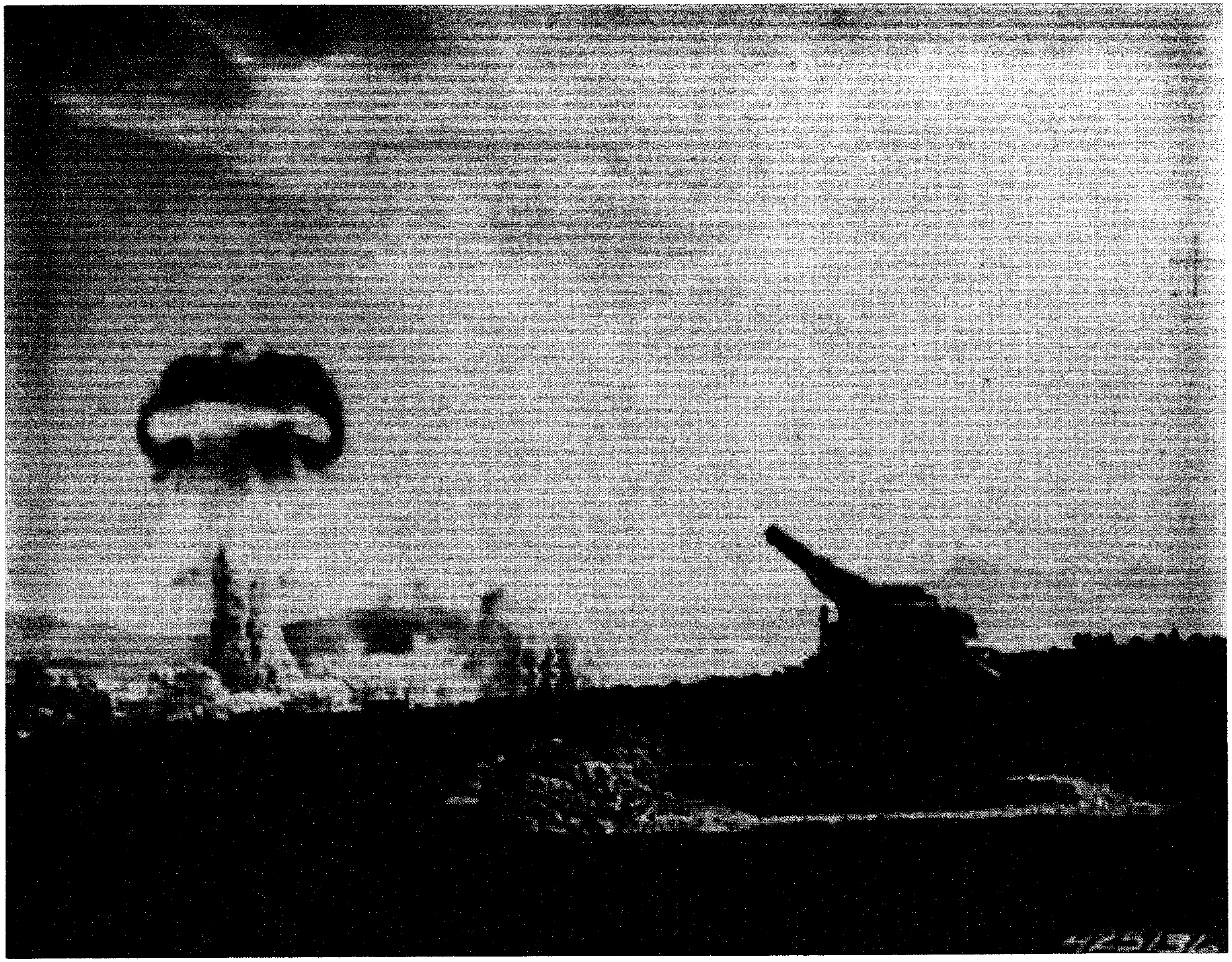

Figure 6-7. Shot GRABLE, only test of the 280 mm atomic artillery shell, 25 May 1953. (Army, Signal Corps Photograph, SC 425136. 25 May 1953.)

evaluation. The troop orientation and training included briefings before the detonation on nuclear weapons characteristics and effects and on personal protection. Troop orientation and training also involved observation of a nuclear detonation, as did the volunteer officer observer program. For the latter, trained staff officers calculated the effects of a nuclear detonation to determine a minimum safe distance for observing the blast; they later watched the detonation from the calculated position. Among the other activities, the operational helicopter tests performed by the Marine Corps were designed to investigate the capability of helicopters and their crews to withstand a nuclear burst and its effects (Ponton and others, 11 January 1982, p. 1).

6.9.3 Dose Summary for Operation UPSHOT-KNOTHOLE.

The maximum permissible dose for participants in the Joint Test Organization (JTO), which coordinated UPSHOT-KNOTHOLE, and AFSWC was 3.9 R (rem) of gamma radiation for the series. The limits were higher for Desert Rock V participants, according to the requirements of their missions. Desert Rock V troops were restricted to a maximum of 6.0 R (rem) of gamma radiation for the series, with no more than 3.0 R (rem) of prompt radiation. The volunteer officer observers were limited to 10.0 R (rem) of gamma radiation, with no more than 5.0 R (rem) of prompt radiation per test, and a total of no more than 25.0 R (rem) for the exercise.

The calculated mean gamma and neutron doses for the volunteer observers have been reconstructed as 0.64 rem gamma and 0.63 rem neutron for Shot NANCY; 7.2 rem gamma and 2.4 rem neutron for Shot BADGER; and 13.6 rem gamma and 28 rem neutron for Shot SIMON (Goetz and others 28, April 1981, p. 95). **Table 6-18** summarizes available UPSHOT-KNOTHOLE dosimetry.

Table 6-18. Summary of external doses for Operation UPSHOT-KNOTHOLE as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	147	3,736	1,028	5,208	1,848	60	11
Navy	109	300	191	202	88	17	1
Marines	92	214	5	911	1,006	20	1
Air Force	370	838	269	278	44	17	4
Field Command	6	13	4	2	0	0	0
Total for Each Column	724	5,101	1,497	6,601	2,986	114	17
Cumulative total							17,040

6.10 OPERATION CASTLE.

CASTLE was conducted at Enewetak and Bikini Atolls during the spring of 1954. The first event of this series, Shot BRAVO, had a yield of 15 megatons and was the largest device ever detonated by the U.S. Government as part of atmospheric nuclear weapons testing. **Table 6-19** provides specifics on this detonation, shown in **Figure 6-8**, as well as the other five in the series (Martin and Rowland, 1 April 1982, p. 1):

Table 6-19. CASTLE shots.

Shot	Date (1954)	Type	Yield
BRAVO	1 March	Surface	15 megatons
ROMEO	27 March	Barge	11 megatons
KOON	7 April	Surface	110 kilotons
UNION	26 April	Barge	6.9 megatons
YANKEE	5 May	Barge	13.5 megatons
NECTAR	14 May	Barge	1.69 megatons

6.10.1 Background and Objectives of Operation CASTLE.

CASTLE was the culmination in the development of the hydrogen bomb that began in 1950. Shot GEORGE, a test in the 1951 GREENHOUSE series, had demonstrated the initiation of a sustained thermonuclear reaction by use of a fission reaction. Fusion, or thermonuclear, reactions had been used in 1952 to generate the very powerful detonation of the MIKE device in Operation IVY, but MIKE was not a deliverable nuclear weapon. In BRAVO, the first CASTLE test, a device more powerful than MIKE was exploded that, although not a weapon, was capable of delivery by an aircraft.

CASTLE also was the first Pacific series in which LLNL provided a nuclear device for testing, detonated as Shot KOON. All previous nuclear test devices had been designed at LANL (Martin and Rowland, 1 April 1982, p. 26).

6.10.2 CASTLE Test Operations.

Numerous technical experiments were carried out in conjunction with each of the six detonations. These experiments measured the yield and efficiency of the devices and attempted to gauge the military effects of the explosions. The approximately 18,500 verified DoD participants in this series had duty stations at the AEC design laboratories or were members of units performing separate experiments or various support roles (JAYCOR, 6 October 1993). Almost all of the Navy support personnel were at Bikini, where Navy ships provided living quarters for participants who

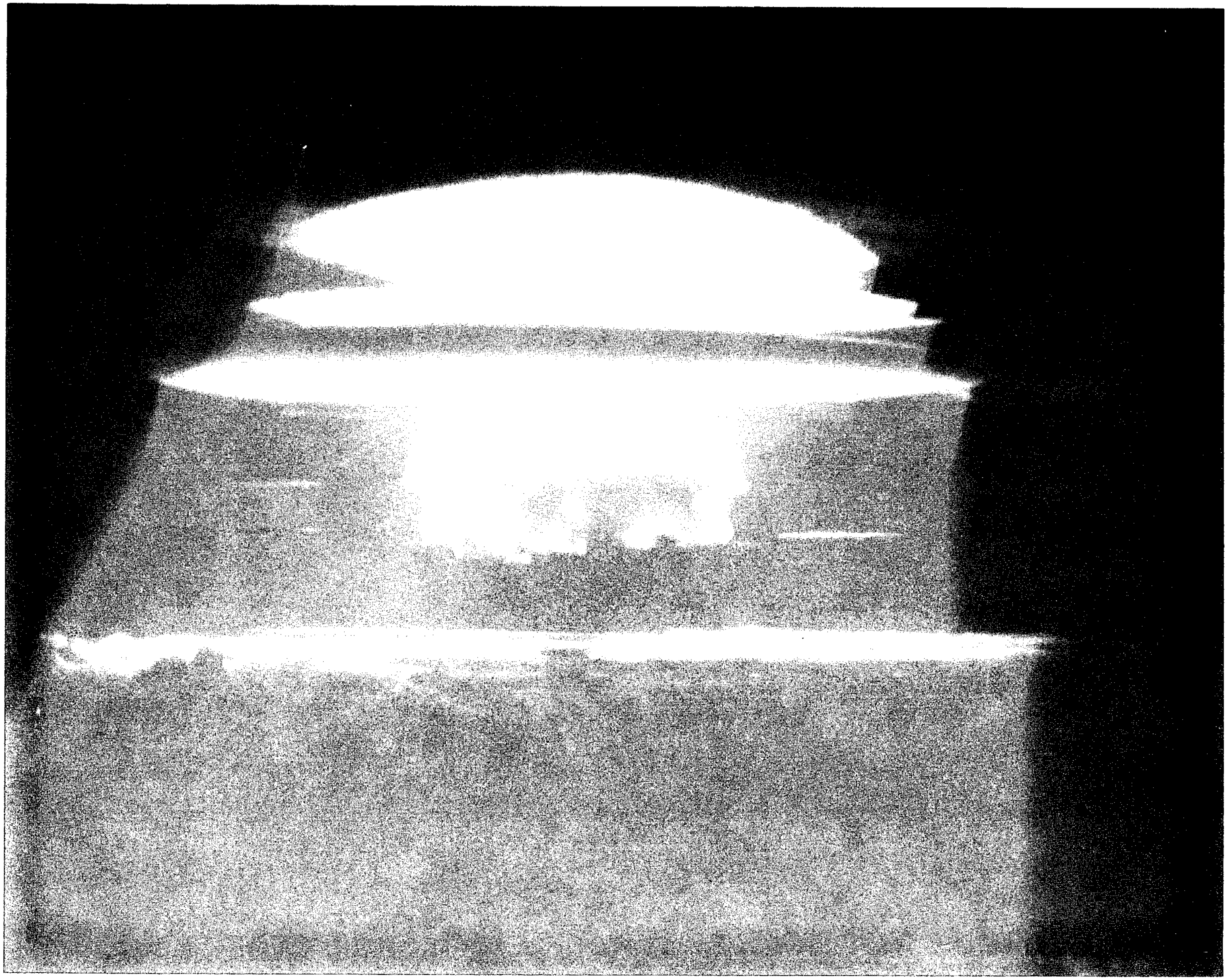

Figure 6-8. Shot BRAVO, 1 March 1954.
(Air Force, Lookout Mountain Laboratory Photograph, 22-AQB-1-13, BRAVO. 1954.)

were evacuated from the islands for the first test and then could not return to live there because of the potential for radiation exposure from BRAVO fallout (Martin and Rowland, 1 April 1982, p. 2).

6.10.3 Dose Summary for Operation CASTLE.

Among the CASTLE detonations, only BRAVO produced significant, unexpected personnel radiation exposures. This first shot of the series, which significantly exceeded its expected yield, released unprecedented quantities of radioactive materials into the atmosphere. Ambient winds dispersed the radioactive particles over a much larger area than had been anticipated. This resulted in contamination and exposure of Marshall Island residents, Japanese fishermen, and U.S. personnel on distant atolls or aboard various vessels. Acute radiation effects were observed among some of these people.

Some DoD personnel exceeded the maximum permissible limit of 3.9 R (rem) of gamma radiation within any 13-week period of the operation. BRAVO fallout on some Navy ships resulted in personnel who had doses approaching or exceeding this limit. To allow for completion of the CASTLE tests, it became necessary to issue a number of waiver authorizations permitting doses of as much as 7.8 R (rem) to specific individuals. In a limited number of shipboard cases, even this level was exceeded. Substantial overdoses from BRAVO, the highest for any test series, were accrued by the 28 Air Force and Army personnel on Rongerik Atoll. Film badge readings suggest that three members of the U.S. Navy Bikini Boat Pool also may have received substantial doses in excess of the series limits; however, a thorough investigation at the time failed to indicate reasons for these readings (Martin and Rowland, 1 April 1982, pp. 243-244). As a result of BRAVO, 21 individuals on USS PHILIP (DDE 498) and 16 on USS BAIROKO (CVE 115) sustained lesions that were classified as beta burns, all of which healed without complications (Martin and Rowland, 1 April 1982, pp. 243-244). **Table 6-20** summarizes available dosimetry data.

Table 6-20. Summary of external doses for Operation CASTLE as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	27	338	795	344	65	13	2
Navy	417	4,359	1,457	2,385	686	336	12
Marines	3	169	8	99	29	5	0
Air Force	286	807	201	967	63	32	32
Field Command	4	3	3	8	0	0	0
Total for Each Column	737	5,676	2,464	3,803	843	386	46
Cumulative total							13,955

6.11 OPERATION TEAPOT.

Conducted in 1955, Operation TEAPOT was the fifth series of CONUS tests. Two of the 14 nuclear detonations in the series, APPLE 1 and WASP PRIME, occurred on the same day, although in different parts of the NTS. ESS, the only TEAPOT subsurface detonation (-67 feet), forced tons of earth upward, thereby creating a crater 88 meters wide and 96 feet deep. APPLE 2 was an "open shot," that is, press coverage was allowed.

The TEAPOT schedule was continually revised as the AEC waited for appropriate weather conditions for firing the test shots. The delay in one shot often resulted in postponing subsequent shots, regardless of the weather. The many schedule changes, affecting all but the first two shots, caused a six-week extension of TEAPOT from 1 April to 15 May. **Table 6-21** provides data on the TEAPOT tests (Ponton and others, 23 November 1981, pp. 1-9, 29).

Table 6-21. TEAPOT shots.

Shot	Date (1955)	Type	Yield (kilotons)
WASP	18 February	Airdrop	1
MOTH	22 February	Tower	2
TESLA	1 March	Tower	7
TURK	7 March	Tower	43
HORNET	12 March	Tower	4
BEE	22 March	Tower	8
ESS	23 March	Crater	1
APPLE 1	29 March	Tower	14
WASP PRIME	29 March	Airdrop	3
HA	6 April	Airdrop	3
POST	9 April	Tower	2
MET	15 April	Tower	22
APPLE 2	5 May	Tower	29
ZUCCHINI	15 May	Tower	28

6.11.1 Background and Objectives of Operation TEAPOT.

Operation TEAPOT furthered the efforts of a previous CONUS series, Operation UPSHOT-KNOTHOLE (1953), which had studied both the tactical and strategic uses of nuclear weapons (see Section 6.9). Authorized by President Eisenhower on 30 August 1954, TEAPOT had two primary objectives:

- To establish military doctrine and tactics for the use of ground forces on a nuclear battlefield, and

- To improve the nuclear weapons used for strategic bomber delivery and missile delivery and those used for tactical battlefield situations.

The DoD conducted Exercise Desert Rock VI to achieve the first objective, and the AEC fielded scientific experiments to achieve the second (Ponton and others, 23 November 1981, pp. 27-28).

6.11.2 TEAPOT Test Operations.

Observer programs, tactical maneuvers, scientific studies, and support activities involved the approximately 10,300 verified DoD participants (JAYCOR, 6 October 1993). The largest number, about 8,000, took part in Exercise Desert Rock VI, which included observer programs at Shots WASP, MOTH, TESLA, TURK, BEE, ESS, APPLE 1, and APPLE 2 and troop tests at Shots BEE and APPLE 2. The largest single TEAPOT activity was the Marine Brigade Exercise at BEE, which involved about 300 officers and 1,950 enlisted men. The objective of the exercise was to train personnel and to test the tactics and techniques employed if a nuclear detonation were used to support an air-ground task force. The troop test at APPLE 2, involving about 1,000 troops, was designed to demonstrate the capability of a reinforced tank battalion to seize an objective immediately after a nuclear detonation. APPLE 2 also included Operation CUE conducted by the Federal Civil Defense Administration (FCDA). The FCDA conducted 40 separate projects for Operation CUE. All projects were designed to evaluate the effects of a nuclear detonation on a civilian community and to test the capabilities of local civil defense organizations to respond to such an emergency with prompt rescue and recovery operations. In addition to these activities, technical studies were conducted at 10 of the shots (Ponton and others, 23 November 1981, pp. 1-7, 51-52).

6.11.3 Dose Summary for Operation TEAPOT.

The maximum dose limit for personnel of the JTO, which coordinated Operation TEAPOT, and AFSWC was 3.9 R (rem) of gamma radiation during the series. The limit for Desert Rock troops was 6.0 R (rem) of gamma radiation during the series, with no more than 3.0 R (rem) of prompt radiation. The Desert Rock troops had this higher limit because they, unlike JTO and some AFSWC technical personnel, were not likely to be exposed to radiation after the tests (Ponton and others, 23 November 1981, pp. 2-3)

The 10 Desert Rock volunteer officer observers at APPLE 2 were authorized a special limit of 10.0 R (rem) of gamma radiation. Their calculated mean gamma and neutron dose are 1.6 rem gamma and 4.5 rem neutron (Goetz and others, 15 July 1980, p 77). **Table 6-22** summarizes available dosimetry data.

Table 6-22. Summary of external doses for Operation TEAPOT as of 30 September 1993.

	Gamma dose R (rem)						
	0	**>0-0.5**	**>0.5-1.0**	**>1.0-3.0**	**>3.0-5.0**	**>5.0-10.0**	**>10.0**
Army	284	2,471	1,117	878	636	62	3
Navy	134	204	47	202	24	0	4
Marines	58	437	1,446	4	0	0	0
Air Force	467	537	75	105	55	4	4
Field Command	7	10	3	10	0	0	0
Total for Each Column	950	3,659	2,688	1,199	715	66	11
Cumulative total							9,288

6.12 OPERATION WIGWAM.

Operation WIGWAM consisted of only one nuclear detonation, a deep underwater test conducted in the Pacific Ocean approximately 500 miles southwest of San Diego, California. The device was suspended by cable from an unmanned barge and detonated at a depth of 2,000 feet in water 16,000 feet deep. The test, which had a yield of 30 kilotons, occurred on 14 May 1955 at 1300 hours Pacific time (Weary and others, 1 September 1981, p. 9).

The test site was chosen after careful deliberation. At DoD request, Scripps Institution of Oceanography surveyed various locations in the Pacific, the Caribbean, and the Atlantic. The site had to be deep enough to contain the detonation, yet away from undersea or sea bottom perturbations, such as sea mounts, ridges, and islands. Migratory fishing areas were to be avoided. In addition, the site was to have fairly well-known currents and thermal gradients, a predominance of good weather, and isolation from shipping lanes. The area selected was judged the best to fulfill the requirements (Weary and others, 1 September 1981, p. 1-11).

6.12.1 Background and Objectives of Operation WIGWAM.

Prior to WIGWAM, nuclear weapons had been tested in the atmosphere, on the surface of the earth or water, or at a shallow depth either underwater or on land. Considerable interest developed, particularly within the Navy, in investigating deep underwater effects by detonating a weapon at sufficient depth to contain all the initial energy of the nuclear explosion in the water (Weary and others, 1 September 1981, p. 1-3).

The Navy needed to know how a deep underwater shot would affect naval forces and, specifically, the answers to two leading questions: (1) What are the characteristics and lethal ranges of the resulting underwater shock wave; and (2) What are the effects of the radioactivity, following the explosion, on naval tactical operations? For example, could a surface vessel use a nuclear depth charge to destroy submerged enemy submarines without endangering itself? Specific answers to these questions were required to plan possible naval use of these weapons (Weary and others, 1 September 1981, pp. 1-3, 1-5).

6.12.2 WIGWAM Test Operations.

Operation WIGWAM has about 6,810 verified participants, aboard 30 ships and supporting land-based aircraft (JAYCOR, 6 October 1993). They conducted or supported the four scientific programs designed to collect the desired data (Weary and others, 1 September 1981, pp. 9, 1-3).

A six-mile towline connected the fleet tug, USS TAWASA (ATF 92), and the barge from which the nuclear device was suspended. Located along this towline were a variety of pressure-measuring instruments, unmanned and specially prepared submerged submarine-like hulls (called squaws), as well as unmanned and instrumented surface vessels (Weary and others, 1 September 1981, p. 1-12).

The ships and personnel conducting the test were positioned five miles upwind from the barge that suspended the nuclear device. The only exceptions were for USS GEORGE EASTMAN (YAG 39) and USS GRANVILLE S. HALL (YAG 40). These two extensively reconfigured ships, equipped with special shielding to prevent radiological exposure, were stationed five miles downwind from the barge. Recovery parties later reentered the test area with radiological safety monitors after aerial surveys showed the general location and size of the contaminated water area and the radiation levels (Weary and others, 1 September 1981, pp. 1-14, 2-7).

6.12.3 Dose Summary for Operation WIGWAM.

The maximum dose limit established for WIGWAM was 3.9 R (rem) of gamma radiation for the duration of the operation. The two vessels (YAG 39 and YAG 40) stationed downwind of the detonation were subjected to contamination by water droplets of the base surge. Because of the special shielding, however, none of the YAG personnel exceeded the radiation limit. All doses were low because most of the radioactivity was confined deep under the surface of the water (Weary and others, 1 September 1981, pp. 10-11).

WIGWAM was the first series in which nearly all participants were issued film badges. Personnel whose duties were such that exposure to radiation was possible (such as sampling radioactive water, recovering equipment or instruments) were issued additional film badges on a daily basis. One of the vessels, the USS WRIGHT (CVL 49), contained a film processing center where badges were read and personnel exposures were recorded. **Table 6-23** summarizes available dosimetry data.

Table 6-23. Summary of external doses for Operation WIGWAM as of 30 September 1993.

Gamma dose R (rem)

	0	**>0-0.5**	**>0.5-1.0**	**>1.0-3.0**	**>3.0-5.0**	**>5.0-10.0**	**>10.0**
Army	8	2	0	0	0	0	0
Navy	6,151	452	1	1	0	0	0
Marines	118	13	0	1	0	0	0
Air Force	36	26	0	0	0	0	0
Total for Each Column	6,313	493	1	2	0	0	0
Cumulative total							6,809

6.13 OPERATION REDWING.

REDWING was conducted in 1956 as the sixth nuclear test series at the Marshall Islands, specifically at Enewetak and Bikini Atolls. The series consisted of 17 detonations as shown in **Table 6-24**. **Figure 6-9** presents a photograph taken during the ERIE detonation, the fifth shot of the series. It shows a group on Enewetak facing away from the detonation as it breaks the predawn darkness.

Table 6-24. REDWING shots.

Shot	Date (1956)	Type	Yield
LACROSSE	5 May	Surface	40 kilotons
CHEROKEE	21 May	Airdrop	3.8 megatons
ZUNI	28 May	Surface	3.5 megatons
YUMA	28 May	Tower	0.19 kilotons
ERIE	31 May	Tower	14.9 kilotons
SEMINOLE	6 June	Surface	13.7 kilotons
FLATHEAD	12 June	Barge	365 kilotons
BLACKFOOT	12 June	Tower	8 kilotons
KICKAPOO	14 June	Tower	1.49 kilotons

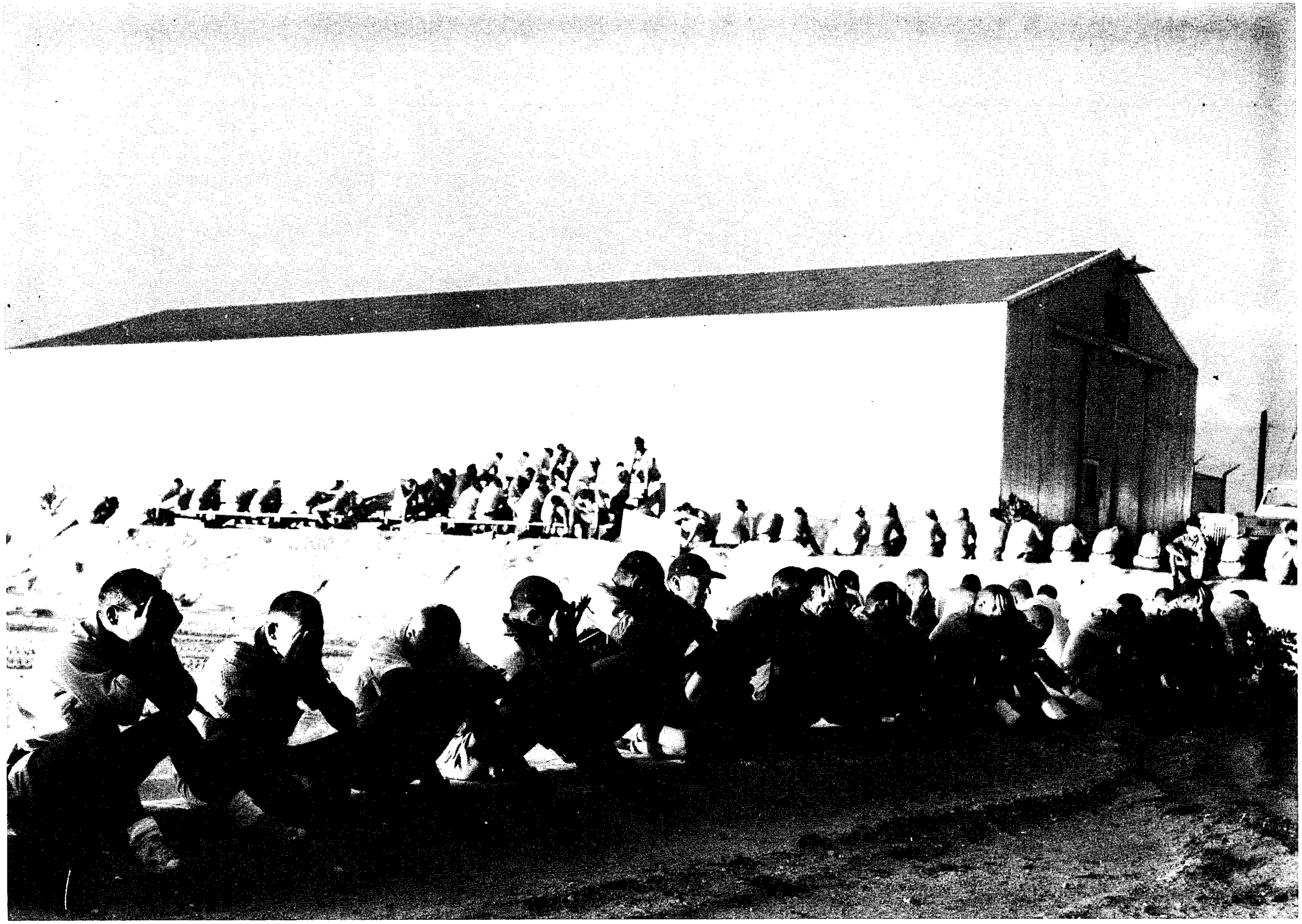

Figure 6-9. Observers facing away from the detonation of ERIE, 31 May 1956.
(Air Force, Lookout Mountain Laboratory Photograph, 23-PLK-124-11, ERIE. 1596.)

Table 6-24. REDWING shots. (Cont'd)

Shot	Date (1956)	Type	Yield
OSAGE	16 June	Airdrop	1.7 kilotons
INCA	22 June	Tower	15.2 kilotons
DAKOTA	26 June	Barge	1.1 megatons
MOHAWK	3 July	Tower	360 kilotons
APACHE	9 July	Barge	1.85 megatons
NAVAJO	11 July	Barge	4.5 megatons
TEWA	21 July	Barge	5 megatons
HURON	22 July	Barge	250 kilotons

6.13.1 Background and Objectives of Operation REDWING.

The main purpose of Operation REDWING was to test high-yield thermonuclear devices that could not be tested in Nevada. The only shot of the series not expressly for weapons development was CHEROKEE, which was airdropped from a B-52 bomber. Its primary purpose was to demonstrate the ability of the U.S. to deliver large-yield nuclear devices. The event was viewed by 15 press observers, the first such group invited to view a Pacific nuclear test since the CROSSROADS detonations of 1946. Seventeen invited Civil Defense officials also observed the shot (Bruce-Henderson and others, 1 August 1982, pp. 2-23, 177).

During CASTLE, the fifth nuclear test series conducted in the Marshall Islands, a serious fallout contamination incident from Shot BRAVO had affected not only U.S. personnel but Marshall Island residents and Japanese fishermen as well. On 27 April, eight days before the first REDWING detonation, a joint DoD-AEC press release identified the safety precautions in effect for the series. It described the improved fallout prediction capability available and the extensive monitoring that was to be done both at the PPG and beyond. It also described programs for surveying marine life in the Pacific. Moreover, the release stated that the yields of the devices to be tested were expected to be lower than the largest of those detonated as part of Operation CASTLE (Bruce-Henderson and others, 1 August 1982, pp. 21-22).

6.13.2 REDWING Test Operations.

Numerous technical experiments were carried out in conjunction with each of the 17 detonations. These experiments measured the yield and efficiency of the devices and attempted to gauge the military effects of the explosions. Operation REDWING has about 14,700 verified DoD participants (JAYCOR, 6 October 1993). Also present at the tests were several thousand personnel from the AEC and its contractors, a few from other Government agencies, and some foreign observers as well (Bruce-Henderson and others, 1 August 1982, p. 2).

Most of the Navy and Marine Corps personnel were on ships operating around Bikini providing supply, evacuation capability, and other support to the tests there. Most of the Army and Air Force personnel were on Enewetak. All the Services had personnel assigned to laboratory organizations whose operations were conducted on both atolls as well as other locations in the Pacific (Bruce-Henderson and others, 1 August 1982, p. 3).

6.13.3 Dose Summary for Operation REDWING.

TEWA, the last REDWING event fired at Bikini, led to an increase in personnel doses. The edge of the TEWA cloud passed over Enewetak causing fallout on the Enewetak base camp. Because the incident occurred toward the end of the series, some personnel had already returned to the United States. The remaining Enewetak personnel, however, received additional doses calculated at 2.0 to 3.3 R (rem) from this incident.

The personnel limit was set at 3.9 R (rem) of gamma radiation for the series. The highest doses were received by Air Force flight officers whose missions required them to penetrate the clouds resulting from the nuclear detonations (Bruce-Henderson and others, 1 August 1982, pp. 3-4). **Table 6-25** summarizes available dosimetry data.

Table 6-25. Summary of external doses for Operation REDWING as of 30 September 1993.*

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	15	294	689	876	657	57	1
Navy	816	2,512	1,837	1,630	242	18	0
Marines	13	76	65	123	7	0	0
Air Force	230	810	519	1,104	714	87	13
Field Command	6	31	2	32	0	0	0
Coast Guard	0	5	0	8	4	0	0
Total for Each Column	1,080	3,728	3,112	3,773	1,624	162	14
Cumulative total							13,492

* Many of the REDWING doses are possibly overstated due to environmentally damaged film badges.

6.14 OPERATION PLUMBBOB.

Conducted at the NTS in 1957, Operation PLUMBBOB included the 24 nuclear detonations summarized in **Table 6-26**. The series also included six safety experiments, conducted to ensure that no nuclear reaction would occur if the high explosive components of the device were accidentally detonated during storage or transport (Harris and others, 15 September 1981, pp. 1, 6, 7). These tests are discussed with the subsequent safety experiments in Section 6.18.

Table 6-26. PLUMBBOB shots.

Shot	Date (1957)	Type	Yield
BOLTZMANN	28 May	Tower	12 kilotons
FRANKLIN	2 June	Tower	140 tons
LASSEN	5 June	Balloon	0.5 tons
WILSON	18 June	Balloon	10 kilotons
PRISCILLA	24 June	Balloon	37 kilotons
HOOD	5 July	Balloon	74 kilotons
DIABLO	15 July	Tower	17 kilotons
JOHN	19 July	Air to air missile	about 2 kilotons
KEPLER	24 July	Tower	10 kilotons
OWENS	25 July	Balloon	9.7 kilotons
STOKES	7 August	Balloon	19 kilotons
SHASTA	18 August	Tower	17 kilotons
DOPPLER	23 August	Balloon	11 kilotons
FRANKLIN PRIME	30 August	Balloon	4.7 kilotons
SMOKY	31 August	Tower	44 kilotons
GALILEO	2 September	Tower	11 kilotons
WHEELER	6 September	Balloon	197 tons
LAPLACE	8 September	Balloon	1 kiloton
FIZEAU	14 September	Tower	11 kilotons
NEWTON	16 September	Balloon	12 kilotons
RAINIER	19 September	Tunnel	1.7 kilotons

Table 6-26. PLUMBBOB shots. (Cont'd)

Shot	Date (1957)	Type	Yield
WHITNEY	23 September	Tower	19 kilotons
CHARLESTON	28 September	Balloon	12 kilotons
MORGAN	7 October	Balloon	8 kilotons

6.14.1 Background and Objectives of Operation PLUMBBOB.

Largely a joint AEC/DoD effort, Operation PLUMBBOB was planned as an integral part of the continuing U.S. program for developing the means to conduct nuclear warfare in defense of the nation. The AEC wanted to test a number of nuclear devices scheduled for production for the defense stockpile or to test improvements in weapons design. Shot RANIER was exploded in a tunnel and no radioactive release was detected. Consequently, it was the first U.S. nuclear test contained underground. The DoD used the series to continue its study of military weapons effects and, with Exercises Desert Rock VII and VIII, its training of personnel in nuclear operations (Harris and others, 15 September 1981, p. 34).

6.14.2 PLUMBBOB Test Operations.

About 13,200 DoD personnel are verified PLUMBBOB participants in observer programs, tactical maneuvers, weapons development effects experiments and support activities during Operation PLUMBBOB (JAYCOR, 6 October 1993). Exercises Desert Rock VII and VIII, consisting of training programs, tactical maneuvers, and technical service projects, engaged the largest DoD participation. At Shot HOOD, approximately 2,150 Marines took part in a maneuver involving the use of a helicopter airlift and tactical air support. An estimated 1,144 Army troops (Task Force WARRIOR) participated in an airlift assault at Shot SMOKY, and about 110 Army troops (Task Force BIG BANG) were interviewed at Shot GALILEO to determine their psychological reaction to witnessing a detonation (Harris and others, 15 September 1981, pp. 1, 4-5).

6.14.3 Dose Summary for Operation PLUMBBOB.

The maximum dose limit established for Desert Rock troops was 5.0 R (rem) of gamma radiation in any six-month period, with no more than 2.0 R (rem) to be from prompt radiation. Participants in activities of the AEC Nevada Test Organization and AFSWC were limited to 3.0 R (rem) for any 13-week period and 5.0 rem for one calendar year (Harris and others, 15 October 1981, pp. 2-3). **Table 6-27** summarizes available dosimetry data.

Table 6-27. Summary of external doses for Operation PLUMBBOB as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	969	4,992	707	543	56	18	1
Navy	375	202	36	133	4	2	1
Marines	216	523	1,232	180	2	1	0
Air Force	961	790	120	104	22	18	3
Field Command	359	250	36	30	0	0	0
Total for each column	2,880	6,757	2,131	990	84	39	5
Total personnel with external doses							12,886

6.15 OPERATION HARDTACK I.

HARDTACK was the designation for U.S. atmospheric nuclear testing in both the Pacific and Nevada during 1958. Phase I, discussed in this section, consisted of 34 Pacific nuclear detonations. The series encompassed a wide variety of events, as indicated in **Table 6-28** (Gladeck and others, 1 December 1982, pp. 23-24).

All but two of the detonations were at Enewetak and Bikini Atolls in the Marshall Islands. TEAK and ORANGE, high-altitude detonations, occurred 77 and 43 kilometers over Johnston Island, which lies about 700 nautical miles west-southwest of the Hawaiian Islands. A Honolulu resident described the TEAK burst, which took place ten minutes before midnight, in a front-page story for the 1 August Honolulu Star-Bulletin (Gladeck and others, 1 December 1982, pp. 1, 266).

> I stepped out on the lanai and saw what must have been the reflection of the fireball. It turned from light yellow to dark yellow and from orange to red.
>
> The red spread in a semi-circular manner until it seemed to engulf a large part of the horizon.
>
> A cloud rose in the center of the circle. It was quite large and clearly visible. It remained visible for about a half hour.
>
> It looked much closer than Johnston Island. The elevation of the circle was perhaps 20° above the horizon.

Table 6-28. HARDTACK I shots.

Shot	Date (1958)	Type	Yield
YUCCA	28 April	High Altitude (Balloon)	1.7 kiloton
CACTUS	6 May	Surface	18 kilotons
FIR	12 May	Barge	1.36 megatons
BUTTERNUT	12 May	Barge	81 kilotons
KOA	13 May	Surface	1.37 megatons
WAHOO	16 May	Underwater	9 kilotons
HOLLY	21 May	Barge	5.9 kilotons
NUTMEG	22 May	Barge	25.1 kilotons
YELLOWWOOD	26 May	Barge	330 kilotons
MAGNOLIA	27 May	Barge	57 kilotons
TOBACCO	30 May	Barge	11.6 kilotons
SYCAMORE	31 May	Barge	92 kilotons
ROSE	3 June	Barge	15 kilotons
UMBRELLA	9 June	Underwater	8 kilotons
MAPLE	11 June	Barge	213 kilotons
ASPEN	15 June	Barge	319 kilotons
WALNUT	15 June	Barge	1.45 megatons
LINDEN	18 June	Barge	11 kilotons
REDWOOD	28 June	Barge	412 kilotons
ELDER	28 June	Barge	880 kilotons
OAK	29 June	Barge	8.9 megatons
HICKORY	29 June	Barge	14 kilotons
SEQUOIA	2 July	Barge	5.2 kilotons
CEDAR	3 July	Barge	220 kilotons
DOGWOOD	6 July	Barge	397 kilotons
POPLAR	12 July	Barge	9.3 megatons

Table 6-28. HARDTACK I shots. (Cont'd)

Shot	Date (1958)	Type	Yield
PISONIA	18 July	Barge	225 kilotons
JUNIPER	22 July	Barge	65 kilotons
OLIVE	23 July	Barge	202 kilotons
PINE	27 July	Barge	2 megatons
TEAK	31 July	High Altitude (Rocket)	3.8 megatons
QUINCE	6 August	Surface	Zero
ORANGE	11 August	High Altitude (Rocket)	3.8 megatons
FIG	18 August	Surface	0.02 kilotons

6.15.1 Background and Objectives of Operation HARDTACK I.

HARDTACK I consisted of three parts. The first, aimed at the development of nuclear weapons, continued the type of device design testing that had been conducted at Enewetak and Bikini during the early and mid-1950s. The AEC weapon development laboratories (LANL and LLNL) detonated experimental devices, with the DoD providing support and conducting military effects experiments that did not interfere with AEC activities.

The second part, sponsored by DoD, consisted of two underwater tests: Shot WAHOO, which was detonated in the open ocean about four miles south of the barrier reef that surrounds Enewetak Lagoon and Shot UMBRELLA, which was detonated in the lagoon. These tests, which furthered efforts undertaken with the 1946 CROSSROADS and the 1955 WIGWAM series, were designed to gain additional data on the effects of underwater explosions on Navy ships and material (Gladeck and others, 1 December 1982, p. 1).

The third part, sponsored by DoD, addressed a military problem that was newer: nuclear weapons in air and ballistic missile defense. Shots YUCCA, TEAK, and ORANGE, also called Operation NEWSREEL by DoD, were directed to this concern (Gladeck and others, 1 December 1982, p. 3).

6.15.2 HARDTACK I Test Operations.

The HARDTACK experimental program incorporated two aspects: the development of the weapons and the measurement of the explosive and radiation effects. The AEC was primarily interested in weapons development, and the DoD focused on weapons effects, specifically concerning the military application of the weapons (Gladeck and others, 1 December 1982, p. 3).

Verified DoD participants in HARDTACK I number approximately 17,800 (JAYCOR, 6 October 1993). They took part in the weapons development experiments by providing cloud-sampling aircraft and crews, along with ship patrols, instrument placement and recovery, and radioactive sample return. Their primary participation, however, was in the effects experiments associated with the underwater and high-altitude shots (Gladeck and others, 1 December 1982, p. 105).

6.15.3 Dose Summary for Operation HARDTACK I.

The maximum permissible dose for HARDTACK I personnel was set at 3.75 R (rem) of gamma radiation per consecutive 13-week period, with a maximum of 5.0 R (rem) for the operation. The crew of air-sampling aircraft were authorized a special limit of 10.0 R (rem). In case of operational error or emergency, an additional dose of 10.0 R (rem) would be accepted (Gladeck and others, 1 December 1982, pp. 3-4).

During the series, one incident involved the unplanned exposure of participants to significantly elevated radiation levels. On 14 May, the base islands of Enewetak and Parry at Enewetak Atoll received fallout from a test shot detonated at Bikini the day before (Gladeck and others, 1 December 1982, pp. 4-5). According to current calculations, the period of fallout, which lasted about 60 hours, could have contributed 1.64 R (rem) through 31 May 1958, 2.2 R (rem) through 30 June 1958, and 2.53 R (rem) through 31 July 1958 to personnel on the residence islands of Enewetak Atoll. **Table 6-29** summarizes available dosimetry data.

Table 6-29. Summary of external doses for Operation HARDTACK I as of 30 September 1993.

	Gamma dose R (rem)						
	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	101	220	266	1,047	64	2	0
Navy	1,680	3,384	3,369	1,424	21	1	0
Marines	5	60	109	48	3	0	0
Air Force	670	899	476	1,818	181	72	8
Field Command	14	21	22	42	1	0	0
Coast Guard	3	0	0	0	0	0	0
Total for each column	2,473	4,584	4,242	4,379	270	75	8
Cumulative total							16,031

6.16 OPERATION ARGUS.

ARGUS, the code name for the only U.S. atmospheric nuclear test operation in the Atlantic Ocean, consisted of the three high-altitude, low-yield detonations identified in **Table 6-30**. The nuclear devices were lifted to an altitude of 300 miles by rockets fired from the missile trials ship USS NORTON SOUND (AVM 1), one of the nine ships participating in the series (Jones and others, 30 April 1982, p. 1).

The operation was conducted in the South Atlantic at about 45° south longitude. The location placed the task force outside regular shipping lanes but kept the launch well within the range of U.S. military forces required for support of ARGUS scientific projects (Jones and others, 30 April 1982, p. 19).

Table 6-30. ARGUS shots.

Shot	Date (1958)	Type	Yield (kilotons)
ARGUS I	27 August	Rocket	1-2
ARGUS II	30 August	Rocket	1-2
ARGUS III	6 September	Rocket	1-2

6.16.1 Background and Objectives of Operation ARGUS.

ARGUS was unique among U.S. atmospheric nuclear test operations in a number of respects. It was one of the most expeditiously planned and executed of all U.S. nuclear tests, requiring just five months from inception to execution, in contrast to the normal period of one or more years. Besides TRINITY, it consisted of the only clandestine tests conducted during the 18-year period of U.S. atmospheric nuclear testing. The intentions of all phases of the ARGUS operation were concealed not only from other nations but also from the majority of DoD participants in the tests. In addition, ARGUS was the first shipboard launch of a ballistic missile with a nuclear warhead (Jones and others, 30 April 1982, pp. 11, 18).

Most significant of all, the purpose of ARGUS did not fit the usual categories: the ARGUS shots, strictly speaking, involved neither diagnostic tests of a weapon design nor effects tests on military systems. The objective was to establish the practicality of a theory, postulated by Nicholas Christofilos, a physicist at LLNL, that a very-high-altitude nuclear detonation of proper yield would produce phenomena of potentially significant military importance by interfering with communications and weapon performance. When the Eisenhower Administration officially announced the occurrence of the tests on 19 March 1959, the New York Times headlined ARGUS as the "Greatest Scientific Experiment Ever Conducted" (Jones and others, 30 April 1982, pp. 11-12).

The operation proved the validity of the Christofilos theory. It not only provided data on military considerations, but also produced a great mass of geophysical information (Jones and others, 30 April 1982, p. 2).

6.16.2 ARGUS Test Operations.

The series was conducted by Task Force 88, a naval organization consisting of nine ships and about 4,520 verified DoD participants (JAYCOR, 6 October 1993). Coordinated measurement programs using satellite, rocket, aircraft, and surface stations were carried out by the Services and other government agencies and contractors throughout the world.

6.16.3 Dose Summary for Operation ARGUS.

The ARGUS operation plan was silent about maximum permissible levels of radiation exposure, and the detonation occurred at such distances above the earth that the possibility of personnel exposures to ionizing radiation was considered remote (Jones and others, 30 April 1982, p. 50). The highest level recorded by the 264 film badges distributed to the task force personnel was 0.010 R (rem). The highest level recorded, 0.025 R (rem), was by a control film badge, which was not issued to personnel but remained in storage in a radiation-free area within a ship. Another control badge read 0.020 R (rem). These readings were so low that they probably were spurious and the result of environmental effects on film emulsions (Jones and others, 30 April 1982, p. 2).

6.17 OPERATION HARDTACK II.

HARDTACK II was the continental phase of Operation HARDTACK, also conducted in 1958. HARDTACK II consisted of 19 nuclear weapons tests and 18 safety experiments (Ponton and others, 3 December 1982, p. 1). The next section, 6.18, discusses the safety experiments. This section concentrates on the weapons related tests, identified in **Table 6-31**.

Table 6-31. HARDTACK II shots.

Shot	Date (1958)	Type	Yield (kilotons)
EDDY	19 September	Balloon	0.083
MORA	29 September	Balloon	2
TAMALPAIS	8 October	Tunnel	0.072
QUAY	10 October	Tower	0.079
LEA	13 October	Balloon	1.4
HAMILTON	15 October	Tower	0.0012
LOGAN	16 October	Tunnel	5
DONA ANA	16 October	Balloon	0.037

Table 6-31. HARDTACK II shots. (Cont'd)

Shot	Date (1958)	Type	Yield (kilotons)
RIO ARRIBA	18 October	Tower	0.090
SOCORRO	22 October	Balloon	6
WRANGELL	22 October	Balloon	0.115
RUSHMORE	22 October	Balloon	0.188
SANFORD	26 October	Balloon	4.9
DE BACA	26 October	Balloon	2.2
EVANS	29 October	Tunnel	0.055
MAZAMA	29 October	Tower	Zero
HUMBOLDT	29 October	Tower	0.0078
SANTA FE	30 October	Balloon	1.3
BLANCA	30 October	Tunnel	22

6.17.1 Background and Objectives of Operation HARDTACK II.

HARDTACK II was the last nuclear test series before the United States adopted a nuclear test moratorium, which had originally been intended to last one year but continued until 1961. The HARDTACK II tests were conducted to evaluate the yield and efficiency of newly developed nuclear devices (Ponton and others, 3 December 1982, pp. 1, 7).

Concern about nuclear weapon proliferation intensified throughout the 1950s, particularly after the BRAVO test of Operation CASTLE and the heavy fallout resulting from this shot. At that time, Prime Minister Nehru of India proposed a cessation of tests. The call for a test ban figured repeatedly in disarmament discussions, most importantly, those of the Disarmament Subcommittee of the United Nations Disarmament Commission, in session from 18 March to 6 September 1957. Continuing pressure on the nuclear powers to reach an agreement on limiting testing resulted in the Conference on Discontinuance of Nuclear Weapons Tests, which began in Geneva on 31 October 1958 and was attended by U.S., British, and Soviet delegates. The next day the United States began a unilateral test moratorium, declaring it would not test if the Soviet Union also refrained.

Because the testing and improvement of various nuclear weapons was crucial to American defense policy, a number of tests needed to be conducted before the moratorium began. On 28 August 1958, President Eisenhower approved an accelerated series of nuclear tests code named Operation MILLRACE to be completed at the NTS before the start of the moratorium. On 29 August 1958, by AEC directive, the name of the series was changed to Operation HARDTACK, Phase II (Ponton and others, 3 December 1982, pp. 28-29).

6.17.2 HARDTACK II Test Operations.

HARDTACK II has approximately 1,660 verified DoD participants (JAYCOR, 6 October 1993). This number is relatively small compared with previous nuclear weapons testing series because of the weapons development emphasis of the program and because of the substantial DoD involvement (about 16,000 personnel) in HARDTACK I. The primary DoD involvement in HARDTACK II was at Shots HAMILTON and HUMBOLDT, the two weapons effects tests cosponsored by the DoD and LLNL. Projects at these tests were planned to develop delivery systems for small nuclear devices, to design military equipment that could withstand the effects of a nuclear detonation, and to determine the military requirements for future nuclear device designs. In addition to participation in these projects, DoD personnel at HARDTACK II provided air and ground support, including radiological safety monitoring, and administrative staff support (Ponton and others, 3 December 1982, pp. 1-2, 29).

6.17.3 Dose Summary for Operation HARDTACK II.

HARDTACK II participants, with the exception of AFSWC personnel on cloud-sampling missions, were limited to a gamma plus neutron dose of 3.0 R (rem) per calendar quarter or a total of 5.0 R (rem) per year. The AFSWC personnel involved in cloud-sampling were permitted to receive up to 10.0 R (rem) during the series. Individuals who participated in cloud-sampling at HARDTACK II who were also at HARDTACK I were authorized to receive 15 R (rem) for the total operation (Ponton and others, 3 December 1982, pp. 5, 74). **Table 6-32** summarizes doses for both the weapons-related events and the safety experiments.

Table 6-32. Summary of external doses for Operation HARDTACK II as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	304	161	41	14	2	3	2
Navy	46	28	1	5	1	0	0
Marines	7	0	0	0	0	0	0
Air Force	217	123	30	31	6	2	0
Field Command	397	200	9	8	0	0	0
Total for each column	971	512	81	58	9	5	2
Cumulative total							1,638

6.18 SAFETY EXPERIMENTS.

The nuclear weapons testing program included 33 safety experiments, conducted at the NTS and PPG from 1955 to 1958 (Massie and Gravitis, 2 August 1982, pp. 8-9, 11-12):

- Four experiments called PROJECT 56 and conducted in November 1955 and January 1956, after Operation TEAPOT;
- Six experiments conducted by Test Group 57 in April, July, August, and September 1957 before and during Operation PLUMBBOB;
- Four experiments identified as PROJECT 58 and conducted in December 1957 and February and March 1958, after Operation PLUMBBOB; and
- Nineteen experiments conducted from July to October 1958 during Operations HARDTACK I and II.

Eleven of the tests were surface detonations, while nine occurred in shafts, six in tunnels, and one on a barge. Of the remaining safety experiments, five were tower detonations and one was a balloon test. Ten of the experiments had no measurable yield while one, COULOMB C, had 0.5 kiloton, which was the highest yield of any safety experiment. **Table 6-33** shows the safety experiments.

Table 6-33. Safety experiments, 1956-1958
Project 56 (1955-1956).

Event	Date	Location	Type	Yield (Tons)
Project 56 #1	1 November 55	NTS	Surface	Zero
Project 56 #2	3 November 55	NTS	Surface	Zero
Project 56 #3	5 November 55	NTS	Surface	Virtually No Yield
Project 56 #4	18 January 56	NTS	Surface	Very Slight
Project 57	24 April 57	NTS	Surface	Zero
Coulomb A	1 July 57	NTS	Surface	Zero
Pascal A	26 July 57	NTS	Shaft	Slight
Saturn	9 August 57	NTS	Tunnel	Zero
Pascal B	27 August 57	NTS	Shaft	Slight
Coulomb B	6 September 57	NTS	Surface	300

Project 58 (1957-1958)

Event	Date	Location	Type	Yield (Tons)
Pascal C	6 December 57	NTS	Shaft	Slight
Coulomb C	9 December 57	NTS	Surface	500
Venus	22 February 58	NTS	Tunnel	Less than 1
Uranus	14 March 58	NTS	Tunnel	Less than 1

Safety Experiments during Operations HARDTACK I and II (1958)

Event	Date	Location	Type	Yield (Tons)
SCAEVOLA	14 July 58	Enewetak	Barge	Zero
OTERO	12 September 58	NTS	Shaft	38
BERNALILLO	17 September 58	NTS	Shaft	15
LUNA	21 September 58	NTS	Shaft	1.5
MERCURY	23 September 58	NTS	Tunnel	Slight
VALENCIA	26 September 58	NTS	Shaft	2
MARS	28 September 58	NTS	Tunnel	13
HIDALGO	5 October 58	NTS	Balloon	77
COLFAX	5 October 58	NTS	Shaft	5.5
NEPTUNE	14 October 58	NTS	Tunnel	115
VESTA	17 October 58	NTS	Surface	24
SAN JUAN	20 October 58	NTS	Shaft	Zero
OBERON	22 October 58	NTS	Tower	Zero
CATRON	24 October 58	NTS	Tower	21
JUNO	24 October 58	NTS	Surface	1.7
CERES	26 October 58	NTS	Tower	0.7
CHAVEZ	27 October 58	NTS	Tower	0.6
GANYMEDE	30 October 58	NTS	Surface	Zero
TITANIA	30 October 58	NTS	Tower	0.2

6.18.1 Objectives of the Safety Experiments.

Except for PROJECT 57, the safety experiments Test Group 57 conducted were for the same purpose: to determine the weapons' susceptibility to nuclear detonation during accidents in storage and transportation. High-explosive portions of these devices were fired to simulate accidental detonation and to determine the potential for such firings to result in a significant nuclear yield. The test results were used to develop devices that could withstand shock, blast, fire, and accidents without initiating a nuclear chain reaction and producing a nuclear detonation. The PROJECT 57 test was conducted to spread alpha-emitting material (plutonium) in a defined area to study the biological effects of alpha radiation and to test monitoring and decontamination procedures (Massie and Gravitis, 2 August 1982, pp. 8, 23).

6.18.2 Test Operations at the Safety Experiments.

DoD personnel participation during these experiments is difficult to determine. Although most of the employees of LANL and LLNL were civilians, some DoD personnel also were assigned to these organizations. Some of the project activities engaged DoD participation and a DoD effects project was conducted at four of the safety experiments. Other DoD participation involved cloud-tracking and cloud-sampling missions (Massie and Gravitis, 2 August 1982, p. 12).

6.18.3 Dose Summary for the Safety Experiments.

Dosimetry for personnel who worked on SCAEVOLA, the safety experiment during HARDTACK I, is included with that operation's dosimetry in Section 6.15.3. Dosimetry for personnel who worked on the HARDTACK II safety experiments is included with that operation's dosimetry in Section 6.17.3.

The dosimetry for PROJECT 56, for the safety experiments conducted before and during PLUMBBOB, and for PROJECT 58 has not been fully studied to determine the extent of military involvement in these activities.

The first three experiments of PROJECT 56 were conducted at NTS from 1 October 1955, to 1 January 1956. An AEC memorandum dated 5 January 1956, lists cumulative exposure at NTS for 197 personnel from a number of organizations during that time. It is assumed that these men participated in Experiments 1 though 3 of PROJECT 56 because no other tests were in progress. Military rank for 24 personnel is given in the memorandum. Their dose distribution is shown in **Table 6-34**.

Table 6-34. Summary of external doses for Project 56 Experiments 1 through 3.

Gamma dose R (rem)

0-0.5	0.501-1	1.001-3
16	6	2

The highest dose was 2.2 rem gamma, which did not exceed the 3.9 rem limit (Sanders, 6 January 1956).

However, four doses exceeding the 3.9 R (rem) limit were recorded during Experiment 4 of PROJECT 56 conducted on 18 January 1956. The readings, which may have resulted from the participants' handling a hot instrumentation cable, were 28, 18.5, 13.7, and 4.3 rem (Massie and Gravitis, 2 August 1982, p. 21) These men were civilians. One worked for LANL, and the other three, including the man with the highest dose, worked for REECo. Only one military man appears to have participated in Experiment 4, and his dose was 0.045 rem (Sanders, 30 January 1956).

At least 63 DoD personnel participated in PROJECT 57, the first of the safety experiments conducted by Test Group 57 before and during Operation PLUMBBOB (Sanders, 6 January 1956; Wilson and others, 6 February 1961, p. 3; Dick and Baker, 3 March 1967, pp. 5-6; Butler and Miller, 31 January 1962, pp. 7-8, 37). Additional research would be needed to determine the exact total and how many were military. In order to determine if any personnel were exposed to inhalation or ingestion of radioactive particles released by the experiment, nose swipes were taken from men who visited Area 13, the experiment location for post-detonation activities. The highest reading appears to have been 8 disintegrations per minute. Most readings were 0 (Los Alamos Scientific Laboratory, no date).

The other safety experiments, Test Group 57, conducted were COULOMB A, PASCAL A, SATURN, PASCAL B, and COULOMB B. These shots occurred during the PLUMBBOB operational period. Badges issued for the safety experiments cannot be distinguished from those issued for regular PLUMBBOB activities because period-coverage badging applied concurrently to both. For all of these safety experiments except SATURN, some radiological safety statistics are available, such as number of film badges issued, amounts of protective clothing issued, and number of vehicles and personnel decontaminated. These numbers tell nothing, however, about the exposure of individual military personnel or of military personnel as a group (Massie and Gravitis, 2 August 1982, pp. 31-32, 36, 38). Data is absent for SATURN because it was a tunnel shot without a nuclear yield.

The radiological safety statistics are much the same for PASCAL C and COULOMB C of PROJECT 58. The limited historical record gives the impression that no military personnel participated in VENUS and URANUS (Massie and Gravitis, 2 August 1982, pp. 43, 46, 50-51).

6.19 OPERATION DOMINIC I.

Operation DOMINIC, like Operation HARDTACK, consisted of two phases: DOMINIC I, the oceanic nuclear tests discussed in this section; and DOMINIC II, the continental tests considered in Section 6.20. Shot TIGHTROPE of DOMINIC I, detonated 3 November 1962 over Johnston Island, was the last U.S. atmospheric nuclear test (Berkhouse and others, 1 February 1983, pp. 1, 2).

DOMINIC I consisted of the 36 nuclear tests identified in **Table 6-35**. Most of the shots were detonated in the air after having been dropped from B-52 bombers. Twenty-four of the airdrops took place from 25 April through 11 July 1962 over the ocean just south of Christmas Island, United Kingdom territory, 1,200 nautical miles south of Honolulu. Five more airdrops were detonated in October over the open ocean in the vicinity of Johnston Island, U.S. territory, 780 nautical miles west-southwest of Honolulu. The five rocket shots, designated FISHBOWL events, were launched from Johnston Island and detonated at high altitudes, up to 400 kilometers. The Navy conducted the other two shots: FRIGATE BIRD, launched by a Polaris missile from the submarine USS ETHAN ALLEN (SSBN 608) and detonated east of Christmas Island; and SWORDFISH, a rocket-launched antisubmarine nuclear depth charge detonated 400 miles west of San Diego (Berkhouse and others, 1 February 1983, pp. 1-2). **Figure 6-10** shows the SWORDFISH spray dome and USS AGERHOLM (DD-286), from which the rocket was fired.

Table 6-35. DOMINIC I shots.

Shot	Date (1962)	Type	Yield*
ADOBE	25 April	Airdrop	Intermediate
AZTEC	27 April	Airdrop	Intermediate
ARKANSAS	2 May	Airdrop	Low megaton range
QUESTA	4 May	Airdrop	Intermediate
FRIGATE BIRD	6 May	Rocket	**
YUKON	8 May	Airdrop	Intermediate
MESILLA	9 May	Airdrop	Intermediate
MUSKEGON	11 May	Airdrop	Intermediate
SWORDFISH	11 May	Underwater	Low
ENCINO	12 May	Airdrop	Intermediate
SWANEE	14 May	Airdrop	Intermediate
CHETCO	19 May	Airdrop	Intermediate
TANANA	25 May	Airdrop	Low
NAMBE	27 May	Airdrop	Intermediate
ALMA	8 June	Airdrop	Intermediate
TRUCKEE	9 June	Airdrop	Intermediate
YESO	10 June	Airdrop	Low megaton range
HARLEM	12 June	Airdrop	Intermediate

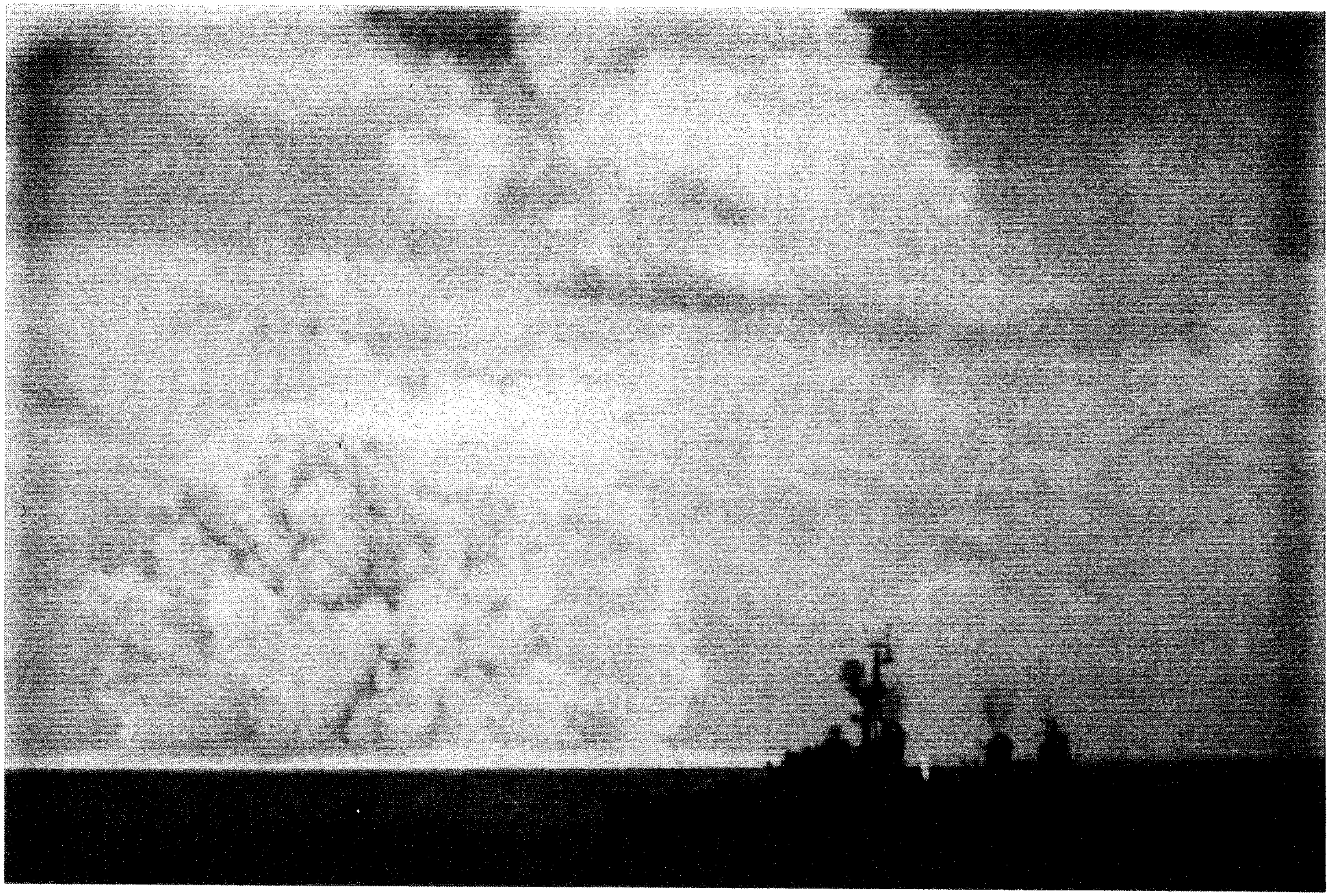

Figure 6-10. SWORDFISH spray dome with USS AGERHOLM (DD 826) in the foreground, 11 May 1962. (Joint Task Group 8, Fig. 80 DOMINIC, "Spray Dome." 1962.)

Table 6-35. DOMINIC I shots. (Cont'd)

Shot	Date (1962)	Type	Yield*
RINCONADA	15 June	Airdrop	Intermediate
DULCE	17 June	Airdrop	Intermediate
PETIT	19 June	Airdrop	Low
OTOWI	22 June	Airdrop	Intermediate
BIGHORN	27 June	Airdrop	Megaton range
BLUESTONE	30 June	Airdrop	Low megaton range
STARFISH PRIME	8 July	Rocket	1.4 megatons
SUNSET	10 July	Airdrop	Intermediate
PAMLICO	11 July	Airdrop	Low megaton range
ANDROSCOGGIN	2 October	Airdrop	Intermediate
BUMPING	6 October	Airdrop	Low
CHAMA	18 October	Airdrop	Low megaton range
CHECKMATE	19 October	Rocket	Low
BLUEGILL 3 PRIME	25 October	Rocket	Submegaton
CALAMITY	27 October	Airdrop	Intermediate
HOUSATONIC	30 October	Airdrop	Megaton range
KINGFISH	1 November	Rocket	Submegaton
TIGHTROPE	3 November	Rocket	Low

* Low yield is less than 20 kilotons and intermediate yield is 20-1,000 kilotons.
** Not announced.

6.19.1 Background and Objectives of Operation DOMINIC I.

On 1 November 1958, at the conclusion of Operation HARDTACK II, the U.S. initiated a one-year suspension of nuclear testing, which was later extended throughout 1959. On 29 December 1959, the U.S. announced an end to its moratorium, effective 31 December, but with a promise not to resume testing without advance public notice.

On 3 January 1960, the Soviet Premier pledged that the Soviet Union would not conduct nuclear tests unless the Western nations resumed their testing. On 31 August 1961, however, the

U.S.S.R. abruptly announced plans to resume atmospheric testing and then detonated a nuclear device at the Semipalatinsk test range in Central Asia the next day. This began an extensive Soviet series that continued into November 1961 and included more than 30 nuclear shots, among which were a 58-megaton detonation (the largest ever) and high-altitude tests.

On 15 September 1961, the U.S. resumed nuclear testing with a tunnel shot at NTS, followed by a series of underground tests. The President approved planning for resumption of atmospheric tests on 10 October 1961 but did not approve DOMINIC until 2 March 1962 (Berkhouse and others, 1 February 1983, p. 25).

Operation DOMINIC I was conducted with four primary objectives: to develop nuclear weapons (the 29 airdrops); to study the effects of nuclear detonations (the five high-altitude bursts); to test the Polaris weapon system (the FRIGATE BIRD event); and to test the Navy nuclear antisubmarine rocket (Shot SWORDFISH) (Berkhouse and others, 1 February 1985, p. 1).

6.19.2 DOMINIC I Test Operations.

DOMINIC I has approximately 22,500 verified DoD participants as well as personnel from AEC, contractors and various other federal agencies (JAYCOR, 6 October 1993). The DoD participation was extensive in all parts of the DOMINIC I experimental program: weapons development, weapons effects, and operational tests. Even the experimental program for the weapon development shots at Christmas Island and later at Johnston Island, conducted by AEC laboratories, involved DoD personnel and units for device placement, cloud-sampling, operation of airborne data recording stations, and general support. The weapons effects and operational tests were DoD programs, the former involving a number of experimental projects (Berkhouse and others, 1 February 1983, p. 11).

6.19.3 Dose Summary for Operation DOMINIC I.

With exceptions for specified Navy and Air Force participants, the maximum permissible dose for Operation DOMINIC I personnel was established at 3.0 rem of gamma radiation for the series. Navy personnel who were to collect samples of weapon debris from the radioactive pool of water created by SWORDFISH were authorized a maximum limit of 7.0 rem. Air Force personnel associated with cloud-sampling (crew, maintenance, sample removal, or decontamination) could receive up to 20 rem of gamma radiation (Berkhouse and others, 1 February 1983, p. 3).

Table 6-36 summarizes available dosimetry information for DOMINIC I participants. Existing evidence indicates that some of the film badges had been defectively sealed or damaged by the environment and that they gave higher readings than the dose actually received by the wearer.

According to the National Research Council:

> DOMINIC I film badge exposures should be related to known activities of the wearers. If an individual was not a cloud-sampling and crew unit, not on the ship (USS Sioux) that sampled water from the radioactive pool, not involved in

recovering instrument pods, nosecones, or other contaminated or activated material, or not a Rad-Safe monitor, then any indicated film badge exposure was likely to have been caused by environmental damage. (Masse and Lalos, 1989, p. 180.)

Table 6-36. Summary of external doses for Operation DOMINIC I as of 30 September 1993.

Gamma dose (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	344	365	10	14	1	0	0
Navy	9,185	8,054	162	268	7	0	0
Marines	342	499	1	5	0	0	0
Air Force	1,297	1,373	63	74	9	9	9
Field Command	101	77	2	1	0	0	0
Total for Each Column	11,269	10,368	238	362	17	9	9
Cumulative total							22,272

6.20 OPERATION DOMINIC II.

Also known by the DoD code name of Operation SUNBEAM, DOMINIC II was the continental phase of the DOMINIC nuclear tests. The four shots of this series were conducted at the NTS from 7 July through 17 July 1962, during the period of DOMINIC I, the nuclear test series conducted at the PPG from 25 April through 3 November 1962.

DOMINIC II consisted of the four low-yield shots as shown in **Table 6-37**. LITTLE FELLER I, one of the surface shots, was part of Exercise IVY FLATS, the only military training exercise conducted at DOMINIC II (Ponton and others, 31 January 1983, pp. 1, 5).

Table 6-37. DOMINIC II shots.

Shot	Date (1962)	Type	Yield (kilotons)
LITTLE FELLER II	7 July	Surface	Low*
JOHNNIE BOY	11 July	Crater	0.5
SMALL BOY	14 July	Tower	Low
LITTLE FELLER I	17 July	Surface	Low

* Less than 20 kilotons

6.20.1 Background and Objectives of Operation DOMINIC II.

The United States resumed nuclear weapons testing on 15 September 1961 with a series of underground tests conducted at the NTS: Operation NOUGAT, from 15 September 1961 to 30 June 1962; and Operation STORAX, from 6 July 1962 to 25 June 1963. Operation DOMINIC II was conducted during the period of Operation STORAX but was not a part of STORAX (Ponton and others, 31 January 1983, pp. 19, 20).

Operation DOMINIC II, designed to provide information on weapons effects, originally consisted only of Shot SMALL BOY, to be detonated on a 10-foot tower. Subsequent planning added three Little Feller shots, but in the end only LITTLE FELLER I and II were part of the series. LITTLE FELLER II was detonated first, using a warhead suspended three feet above the ground. For LITTLE FELLER I, Army personnel launched a weapon that exploded near the surface about 3,100 yards from the launch point as part of Exercise IVY FLATS, a troop maneuver and observer program (Ponton and others, 31 January 1983, pp. 1, 73, 114).

Plans for JOHNNIE BOY, the last shot added to the series, were not made until May 1962. Detonated two months later, JOHNNIE BOY was designed to explore the cratering effects of a subkiloton nuclear device fired in a shallow emplacement (Ponton and others, 31 January 1983, p. 94).

6.20.2 DOMINIC II Test Operations.

There are about 3,500 verified DoD military and civilian personnel participants in Operation DOMINIC II in Exercise IVY FLATS (Shot LITTLE FELLER I), scientific and diagnostic tests, and air support or administrative support activities (JAYCOR, 6 October 1993). Approximately 1,000 of these were Sixth Army military personnel who took part in Exercise IVY FLATS, which consisted of an observer program and a troop maneuver. The observers, who wore protective goggles, witnessed the detonation from bleachers about 3.5 kilometers southwest of ground zero. Five participants from the IVY FLATS maneuver task force launched the weapon from a rocket launcher mounted on an armored personnel carrier. After the initial radiological surveys were completed, the IVY FLATS troops entered their vehicles and moved into the shot area, where they spent about 50 minutes conducting maneuvers (Ponton and others, 31 January 1983, pp. 1, 3).

6.20.3 Dose Summary for Operation DOMINIC II.

DOMINIC II participants were subject to a quarterly dose limit of 3.0 R (rem) and an annual limit of 5 R (rem) (Atomic Energy Commission, February 1964, p. 25). Cloud-sampling pilots were authorized to receive a 12 R (rem) annual limit (Air Force Special Weapons Directorate, 13 June 1962, p. B-3-1).

Table 6-38 summarizes the dosimetry data available for DOMINIC II.

Table 6-38. Summary of external doses for Operation DOMINIC II as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	1,797	333	52	110	4	0	0
Navy	36	22	19	32	0	1	0
Marines	42	26	11	18	2	0	0
Air Force	103	120	23	15	1	0	0
Field Command	512	66	21	7	0	0	0
Total for Each Column	2,490	567	126	182	7	1	0
Cumulative total							3,373

6.21 PLOWSHARE PROGRAM.

Conducted from 1961 to 1973, the PLOWSHARE Program consisted of 27 nuclear detonations, four of which occurred before the signing of the 1963 limited test ban treaty. The detonations, all of which had yields of no more than 200 kilotons, were staged at the NTS and other sites in Colorado and New Mexico. The tests were all subsurface, being either shaft or cratering shots.

As indicated by **Table 6-39**, this section discusses only Projects GNOME and SEDAN, the first two PLOWSHARE events. These two experiments were selected for consideration because they were conducted during the period of U.S. atmospheric testing and they had documented, although limited, DoD participation. In addition, the extant sources were sufficient in number and detail to enable a summation of the events (Gravitis and others, 18 March 1983, p. 1). There are about 340 DoD verified participants in these two projects (JAYCOR, 6 October 1993).

Table 6-39. Projects GNOME and SEDAN.

Event	Date	Type	Yield (kilotons)
GNOME	10 December 1961	Shaft	3
SEDAN	6 July 1962	Crater	104

6.21.1 Background and Objectives of the PLOWSHARE Program.

From the earliest days of nuclear research and nuclear weapons testing, scientists were aware of the potential for peaceful applications of nuclear energy, including nuclear detonations. This recognition became U.S. policy in the Atomic Energy Act of 1946, which stated that "atomic energy is capable of application for peaceful as well as military purposes." The opportunity for American scientists to apply nuclear detonations to peaceful ends was delayed, however, by several factors, including the greater priority of developing efficient weapons applications, concern over radioactive contamination, and international suspicion of the intent of the research. Nevertheless, the AEC ultimately succeeded in initiating the PLOWSHARE Program, which had been planned in the late 1950s (Gravitis and others, 18 March 1983, pp. 17-19).

The PLOWSHARE detonations were designed to determine nonmilitary applications of nuclear explosives. The primary potential use envisioned was in large-scale geographic engineering, in such projects as canal, harbor, and dam construction, the stimulation of oil and gas wells, and mining. GNOME was planned in part to provide information on the characteristics of an underground nuclear detonation in a salt medium, while SEDAN was to extend knowledge on cratering effects from detonations with yields of 100 to 200 kilotons. Considering the peaceful objectives of PLOWSHARE, the AEC took the name of the program from the Bible: "And they shall beat their swords into plowshares" (Isaiah 2:4) (Gravitis and others, 18 March 1983, pp. 1-3).

The ultimate goal of PLOWSHARE, the peaceful applications of nuclear explosives, was never realized. The limited test ban treaty, signed on 5 August 1963 in Moscow, ended nuclear testing in the atmosphere, on land, and underwater, although not underground. Hence, a number of the PLOWSHARE experiments had to be canceled. Other contributing factors were changes in national priorities, Government and industry disinterest in the program, public concern over the health and safety aspects of using nuclear detonations for civil applications, and shortages of funding (Gravitis and others, 18 March 1983, p. 26).

6.21.2 PLOWSHARE Test Operations.

LLNL, which provided technical direction for the PLOWSHARE Program, conducted an extensive series of scientific projects at GNOME and SEDAN. Given the objectives of PLOWSHARE, the DoD did not stage military exercises during the program and had limited involvement in the shots. The primary role of the military was to provide logistical support. DoD personnel did, however, participate at GNOME and SEDAN in the VELA UNIFORM program, conducted by the DoD to develop U.S. capabilities in detecting and identifying underground nuclear detonations. In addition, the AFSWC performed cloud-sampling, cloud-tracking, and support missions at the shots (Gravitis and others, 18 March 1983, p. 3).

6.21.3 Dose Summary for the PLOWSHARE Program.

PLOWSHARE participants were limited to 3.0 R (rem) of gamma and neutron radiation per calendar year and not more than 5.0 R (rem) annually (Grevitis and others, 18 March 1983, p. 3).

The dosimetry information available for GNOME and SEDAN participants is included in **Table 6-40**.

Table 6-40. Summary of external doses for the PLOWSHARE Program as of 30 September 1993.

Gamma dose R (rem)

	0	>0-0.5	>0.5-1.0	>1.0-3.0	>3.0-5.0	>5.0-10.0	>10.0
Army	13	0	0	0	0	0	0
Navy	8	2	0	0	0	0	0
Marines	29	1	0	0	0	0	0
Air Force	55	19	1	2	0	0	0
Field Command	199	6	0	0	0	0	0
Total for Each Column	304	28	1	2	0	0	0
Cumulative total							335

SECTION 7

RADIATION SAFETY AT U.S. ATMOSPHERIC NUCLEAR TESTS

The possible hazards associated with exposure to ionizing radiation were a major concern to the planners of the nuclear tests. Consequently, many of the nation's leading experts on the subject were consulted and often served as staff members for each operation. A Health Group consisting of 35 personnel was established for Shot TRINITY, detonated on 16 July 1945 as the first test of a nuclear weapon. The group was headed by Dr. Louis Hempelmann, Medical Director of LANL; he reported to the test director, Dr. Kenneth T. Bainbridge. Colonel Stafford Warren, medical advisor to the Commanding General of the Manhattan Project, served as a special consultant. The primary function of the group was to provide for the safety of project personnel, as well as offsite citizens.

Some nuclear test participants were exposed to initial radiation (neutron and gamma rays) emitted from the fireball and the cloud column during the first minute after the detonation. Others were exposed to residual radiation, which is emitted primarily by radioactive fission products and other bomb debris in fallout, and to neutron-induced radioactivity in the soil and structures in proximity to the detonation.

7.1 PROTECTION AGAINST INITIAL RADIATION.

Protection from initial radiation was provided by ensuring that test participants were positioned at a safe distance from the detonation. The safe distance was usually calculated from empirically or theoretically derived equations that considered such factors as the type or design of the nuclear device, the expected yield of the device, environmental conditions including humidity, and any shielding between the detonation and the participant. For several of the CONUS tests, for example, military maneuver and observer troops were situated in trenches that were 3.2 to 4.6 kilometers from ground zero and that provided considerable shielding. Unshielded participants were customarily positioned much farther away from ground zero.

7.2 PROTECTION AGAINST RESIDUAL RADIATION.

Procedures for protection against residual radiation were more complex because operations in a contaminated environment involved potential exposure to radiation sources both external to and inside the body, the latter resulting primarily from inhalation or ingestion of radioactive material. The next sections address these protective measures.

7.2.1 Identification and Control of Radiation Areas.

The fundamental approach for protection against residual radiation was to control access to contaminated areas. The first step was the identification of the radiation areas and measurement of the associated radiation levels. Authorized entry into a radiation area was made through a control point and preceded by some form of survey by trained radiation monitors using state-of-the-art radiation detection and measurement equipment for that time. In a military maneuver, radiation monitors preceded the advancing troops to steer them away from radiation areas contaminated above preestablished limits. Re-entry into the shot area by scientific project personnel or military troops visiting a display area normally was delayed until a "Recovery Hour" was declared after completion of an initial radiation survey of the area. The initial survey team used radiation detectors to locate and mark various radiation intensities approaching the detonation site. In some cases, early entry was authorized for certain scientific project personnel; however, these personnel were accompanied by their own radiation monitors.

The radiation levels measured by these monitors were used to determine the amount of time the participants could remain in the area. "Stay times" were calculated and observed to ensure that external gamma radiation exposure limits were not exceeded. Only gamma radiation was considered for this purpose since normal clothing provided adequate protection against external alpha and beta radiation exposure.

The possible spread of contamination to clean areas was controlled by requiring personnel who entered a contaminated area to exit through a check point where they could be monitored and decontaminated as necessary. Most scientific project or other personnel whose activities required entry into highly radioactive areas were issued anti-contamination clothing (including coveralls, booties, and gloves) that could be easily removed, if needed, at the check station decontamination point. Such clothing did not provide any more protection against external radiation (alpha, beta, or gamma) than did ordinary clothing or military fatigues. This disposable clothing was provided simply as a convenience for contamination control and laundry purposes. Ordinary clothing and fatigues that could not be decontaminated also had to be replaced at the check station decontamination point.

7.2.2 Use of Radiation Detection and Measurement Instruments.

Monitors used several types of radiation survey instruments. The majority were gas-filled detectors, specifically ionization chambers, Geiger-Mueller counters, and gas-flow proportional counters. These detectors determined the intensity of the incident radiation by the effects of ionization produced by the radiation in a gas-filled "sensitive volume." Some of the other instruments took advantage of the fact that certain materials emit light when struck by radiation. These instruments, called scintillation detectors, simply derive the intensity of the incident radiation from the amount of light produced in the detection medium. Both gas-filled and scintillation detectors were used, depending on the basic design of the instrument, to detect and measure alpha, beta, and/or gamma radiation.

The survey instruments mentioned above portray the radiation intensity in terms of rate (e.g., milliroentgens or roentgens per hour or counts per minute). In some cases, test participants were issued pocket dosimeters that provided information on cumulative exposure. These dosimeters, about the size and shape of a writing pen, consisted of a small ionization chamber coupled to a miniature electroscope. One type of pocket dosimeter (self-reading) included an optical system that allowed the wearer to determine his cumulative exposure while in the field. Other types required a separate charger-reader.

The primary device used to determine the wearer's cumulative radiation exposure was the film badge. A film badge consisted of one or more small pieces of photographic-type film wrapped in an opaque paper packet and enclosed in a plastic envelope or other special metal or plastic holder that could be clipped or otherwise attached to the wearer's outer clothing. Film badges incorporated one or more special metal filters to improve performance. When processed, a film exhibited a darkening (net optical density) that is proportional to the cumulative radiation exposure. Optical density is measured with a densitometer and compared with a calibrated standard to determine total exposure. Film badges worn during the period of nuclear testing were primarily used to measure gamma radiation exposures. Some attempts (most unsuccessful) were made to obtain quantitative measurements of beta radiation exposures, and special neutron film badges were employed during the later stages of the test program.

Some veterans have questioned the accuracy and reliability of the film badges used during atmospheric nuclear testing between 1945 and 1962. To provide an independent assessment of the issue, DNA commissioned the NRC on 28 September 1987 to organize a Committee on Film Badge Dosimetry in Atmospheric Nuclear Tests. Committee members included recognized experts in photographic film processing, development, and interpretation; film badge dosimetry and applications; statistical treatment of uncertainties; radiation characteristics of nuclear weapons; and legal implications of study results. One committee member had continuous involvement with nuclear testing for many years (Masse and Lalos, 1989, pp. vii-viii).

The committee's mandate was to:

- Evaluate the reliability of film badge results from atmospheric nuclear testing;
- Recommend procedures for deriving the best dose estimates from these badges; and
- Quantify the uncertainty of these estimates.

After an 18-month investigation, the committee found that:

- Film badges were adequate and reliable from the beginning of testing, particularly for measurement of exposures above 0.1r;
- The reliability and precision generally improved throughout the period of testing; and
- While uncertainty increases with lower exposures, the overall uncertainty was small enough to make the data useful for consideration of potential biological effects in individual participants (Masse and Lalos, 1989, p. 2).

Moreover, the committee quantified the uncertainties in film badge readings for specific operations and dose ranges.

The NTPR program has located a considerable number of film badge dosimetry records, which have been entered into the master repository of dose records from U.S. nuclear testing maintained by REECo. As indicated by Table 1-3, presented in Section 1.4 of this report, the vast majority of doses were well below established radiation protection standards. The records attest to the effectiveness of the radiation protection efforts made during atmospheric nuclear testing.

Figure 7-1 shows a radiation monitor wearing protective clothing and using radiological safety equipment. **Table 7-1** provides a list of radiation detection and measurement instruments used for survey and personnel monitoring purposes. The list is not all-inclusive but identifies the instruments most commonly used. It is apparent that some instruments employed during an operation were replaced by improved equipment during subsequent operations. Other instruments, such as the MX-5, the T1B(AN/PDR-39), and the AN/PDR-27, were used (modified as necessary) for several years.

7.2.3 Protection Against Internal Doses.

As mentioned earlier, procedures for protection against residual radiation had to consider internal doses resulting from inhalation and ingestion of radioactive material. Respiratory protection (respirators) normally was provided for scientific project personnel involved in operations where inhalation of radioactive material was considered a potential problem. Military maneuver troops carried standard gas masks for use in dusty, possibly radioactive environments.

The degree of internal exposure resulting from inhalation or ingestion of radioactive material by DoD test participants was not **routinely** monitored. Other than a considerable number of urine and blood samples analyzed during Operation CROSSROADS, bioassays were rare among military personnel. To fill this gap, a methodology has been developed to calculate internal doses from reconstructed exposure scenarios and radiological environments, as noted in Section 8. Using a comprehensive screening methodology, the dose commitment due to internal emitters has been determined to be less than 0.15 rem to the bone for more than 185,000 test participants; and research and subsequent screening of additional personnel is continuing. The 0.15 rem level is one percent of the dose limit recommended by the National Council on Radiation Protection and Measurements in effect in 1986. This level is also less than one percent of the annual dose limit set by the U.S. Nuclear Regulatory Commission for occupational exposure to radiation in Title 10, Code of Federal Regulations, Part 20.

The choice of bone dose as a screening factor is useful because the ratio of other-organ dose to bone dose has a relatively predictable maximum for nuclear device debris, whereas the converse is not true. Certain actinide radionuclides, which have a highly shot-specific abundance relative to fission product radionuclides, increase the dose to bone (including its constituent red marrow and bone surface tissues) in greater proportion to other organs.

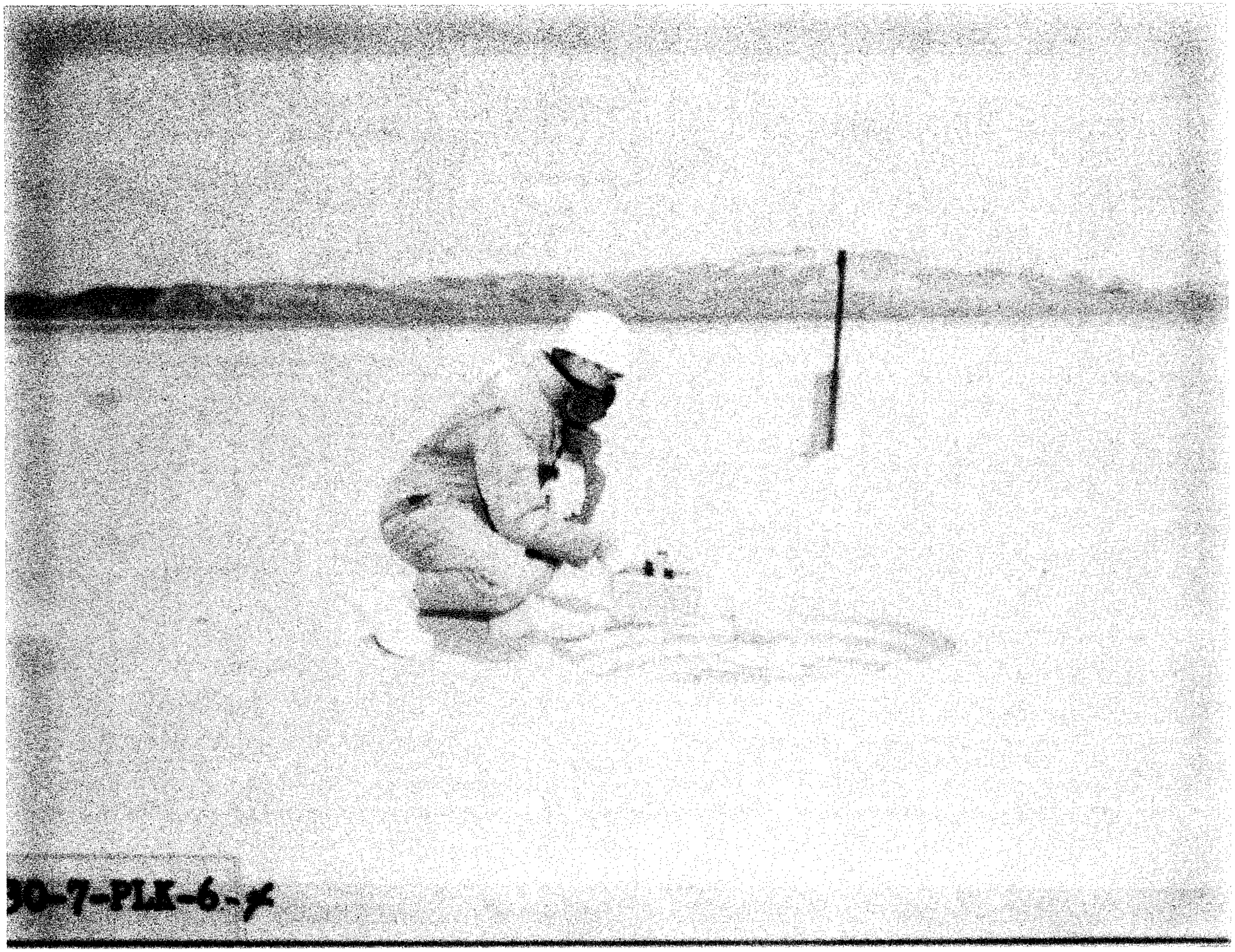

Figure 7-1. Radiation monitor wearing protective clothing and using radiological safety equipment. (DASIAC 30-7-PLK-6-4, 1 April 1952.)

Table 7-1. Radiation survey instruments used during nuclear tests.

Instrument Identification	Type	Radiation Detected/ Measured	Range (Scales)	TRINITY	CROSSROADS	SANDSTONE	RANGER	GREENHOUSE	BUSTER-JANGLE	TUMBLER-SNAPPER	IVY	UPSHOT-KNOTHOLE	CASTLE	TEAPOT	WIGWAM	REDWING	PLUMBBOB	HARDTACK I	HARDTACK II	DOMINIC I	DOMINIC II	PLOWSHARE
Unknown	Proportional Counter	A		●																		
Victoreen Model 247, Numerous Models	Ion Chamber	G	0-10R/HR (3)	●	●	●	●	●														
Hallicrafter Model 5	Geiger-Mueller	B, G	0-0.02 R/8HR (2)	●																		
Watts Meter	Ion Chamber	G		●	●	●	●															
Victoreen Model 263; AN/PDR-5	GM	B, G	0-20 MR/HR (3)		●	●	●	●														
Cutie-Pie, Various Makes and Models	Ion Chamber	B, G	0-100 R/HR (Varies)		●	●	●	●	●	●	●	●	●	●	●	●						
Victoreen - 356 "Zeuto"	Ion Chamber	A, B, G	0-40 MR/HR (2)		●	●																
Instrument Development Lab Model 2610	GM	B, G	0-20 MR/HR (3)			●	●	●	●	●	●	●	●	●	●							
National Technical Lab NTL/Beckman Model MX-5	GM	B, G	0.2-20 MR/HR (3)			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
National Technical Lab Model MX-2	Ion Chamber	B, G	0-2000-MR/HR (5)			●																
National Technical Lab Model MX-6	Ion Chamber	B, G	0-5000 MR/HR (4)			●	●															
AN/PDR-8	GM	B, G	0-500 MR/HR (4)			●	●	●														
Pee Wee, Various Makes and Models	Proportional Counter	A	0-20K CPM (2) 0-2000K CPM (2)			●	●	●	●	●	●	●	●	●	●	●	●					
TIB, AN/PDR-39, SU-10 (Navy), Various Models	Ion Chamber	G	0-50K MR/HR (5) 0-500K (Some Models)				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Juno	Ion Chamber	A, B, G	0-1M DPM Alpha 0-50K MR/HR (3) Gamma				●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
El Tronics SGM - 18A	GM	B, G						●														
AN/PDR-27 Series, Numerous Models	GM	G	0-500 MR/HR (4)					●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Victoreen 389 THYAC	GM	B, G	0-20 MR/HR (3)									●	●	●	●	●	●	●	●			
AN/PDR-10 A, Poppy	Proportional Counter	A	0-10,000 CPM (2)									●										
AN/PDR-18	Scintillation	G	0-500 R/HR (4)										●	●	●	●	●	●				
Eberline PAC-1	Proportional Counter	A	0-100K CPM (3)														●					
Eberline PAC-1A	Proportional Counter	A	0-1M CPM (3)														●					
AN/PDR-43	GM	B, G	0-500 R/HR														●					
Eberline PAC 2G, 3G	Proportional Counter	A	0-100K CPM (3)															●	●	●	●	●
CDV-700	GM	B, G	0-50 MR/HR (3)															●				
Eberline E-500 B	GM	B, G G	0-200 MR/HR (4) 0-2000 MR/HR (4)																	●	●	●
1M 108	Ion Chamber	G	0-500 R/HR																	●		
Eberline - 112 B	GM Scintillation	B, G A	0-20 MR/HR																	●	●	
Victoreen/Jordan ABG "RAD-Gun"	Ion Chamber	B, G	0-10K R/HR (Log)																		●	●
Victoreen/Jordan Radector	Ion Chamber	G	0-500R/HR (2)																		●	●

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SECTION 8

RADIATION DOSE DETERMINATION

This chapter focuses on radiation dose determination for DoD personnel exposed to ionizing radiation as a result of their participation in atmospheric nuclear weapons testing or the postwar occupation of Hiroshima and Nagasaki, Japan. The narrative outlines general procedures, the identification of unit locations and activities, the use of film badge doses, statistical methods for dose determination, and the reconstruction of radiation doses.

8.1 PROCEDURE.

The primary way researchers determine personnel radiation exposure data is by reviewing film badge records. Film badges were generally issued to scientific personnel, both military and civilian, to personnel expected to be exposed to significant amounts of radiation, and to representative personnel, if not all personnel, in troop and naval units with common activities and relationships to the radiological environment.

Before using a film badge reading for dose determination, researchers must ascertain that the badged period covers the entire period of exposure. Second, if representative badging was used, they must determine that the activities--locations, times, protection--of the badged personnel adequately represent the activities of the group as a whole, so all personnel in the group can be judged to have received the dose(s) of the representative badge(s).

If a large number of personnel in an exposed group were badged, a statistical examination of film badge doses can be used to determine the mean dose, the variance, and the confidence limits. An estimated dose, equal to a high (usually 95 percent) probability that the actual exposure did not exceed the estimate, can then be assigned to unbadged personnel. NRC evaluated this procedure and concluded it had the effect of increasing the dose estimates for most veterans whose doses are assessed in this way (National Research Council, 1985, p. 2).

When dose data from film badges are either not available or incomplete (for example badges were lost, damaged or data not recorded), or when there is reason to believe that the data does not adequately characterize actual exposure, alternative approaches are used as circumstances warrant. All approaches have in common the investigation of individual or group activities and their relationship to the radiological environment. First, if it is apparent that personnel were not present in the radiological environment and had no other potential for exposure, the assigned dose is zero. Second, if sufficient members of a group had film badge readings and others did not--and if all members had a common relationship with the radiological environment--doses for small numbers of unbadged personnel can be statistically calculated. Third, where sufficient badge readings or a common relationship to the radiological environment did not exist, a dose reconstruction is performed by correlating a unit's or individual's activities with the quantitatively determined radiological environment.

The three approaches are summarized as follows:

1. Activities of an individual or his unit are researched for the period of participation in an atmospheric nuclear test. Unit locations and movements are related to areas of radiation. If personnel were far from the nuclear detonation(s), did not experience fallout or enter a fallout area, and did not come in contact with radioactive samples or contaminated objects, they are judged to have received no dose.

2. Film badge data from badged personnel may be used to estimate individual doses for unbadged personnel, provided that the group of badged participants is sufficiently large and had common characteristics and potential similar to the unbadged personnel for radiation exposure. Then, using proven statistical methods, an estimated dose equal to 95 percent probability that the actual exposure did not exceed such estimate is assigned to unbadged personnel. This practice ensures that unbadged personnel are assigned doses that are considerably higher than the average or mean dose of the group.

3. Dose reconstruction is performed if film badge data are unavailable for all or part of the period of radiation exposure, if film badge data are partially available but cannot be used statistically for calculations, if atypical activities are indicated for specific individuals, or if other types of radiation exposures are indicated. In dose reconstruction, the conditions of exposure are reconstructed analytically to determine the radiation dose. Such reconstruction is standard scientific practice used by health physicists when the circumstances of a radiation exposure require investigation. The underlying method is the same in each case. The radiation environment is characterized in time and space, as are the activities and geometrical position of the individual. The rate at which radiation was accrued is determined throughout the time of exposure, from which the total dose is integrated.

   An uncertainty analysis of the reconstruction provides a calculated mean dose with confidence limits. The specific method used in a dose reconstruction depend on what type of data are available to provide the required characterizations, as well as the nature of the radiation environment. The radiation environment was not limited to the gamma radiation that would have been measured by a film badge, but also included neutron radiation for personnel sufficiently close to a nuclear detonation, as well as alpha and beta radiation (internally) for personnel whose activities indicated the possibility of the inhalation or ingestion of radioactive particles.

Section 8.5, Reconstruction of Radiation Doses, discusses the third approach in detail.

8.2 UNIT LOCATIONS AND ACTIVITIES.

To determine the precise locations and activities of units and individuals that could have been exposed to the radiological environment, extensive use is made of historical records and reports, augmented by personal interviews where necessary to fill gaps in the archival material. The result is a profile of activities for each definable group or individual. The locations and activities of military units, whose operations were closely monitored and controlled by radiological safety personnel, are usually well defined. The same is true for observers, who were restricted to specific locations both during and after the nuclear bursts (as described in Reference 1, for example). Ships' locations and courses, with times, are usually known with a high degree of precision from deck logs. Aircraft tracks and altitudes are also usually well defined. Personnel engaged in scientific experiments often kept logs of their activities, noting times, locations, members of the party or crew, and unusual circumstances. Moreover, the locations of their experiments are almost always a matter of record, and the schedules of their early reentry times are often documented.

Where the records are insufficiently complete for the degree of precision required to determine radiation exposure, participant comments are used and reasonable judgments are made to further the analysis. In every case, both the distance from the detonation and the movement of the unit or individual with respect to the radiological hazards are determined. Careful consideration is given to possible or potential contact with contaminated objects. Activities are described in sufficient detail to permit assessment of the dose due to inhalation or ingestion of contaminated material, such as dust, debris, or food. For example, maneuver troops who crawled in radioactive areas, or who conducted helicopter operations in such areas, are afforded extensive analysis of their potential for inhaling radioactive dust that, when metabolized in the body, could have resulted in doses to internal organs over periods of several years. When there is a reasonable possibility that a given activity or set of circumstances could have existed for the unit, the benefit of the doubt is given. Possible variations in the activities, as well as possible and reasonable individual deviations from group activities, with respect to both time and location, are considered in the uncertainty analysis of the radiation dose calculations.

8.3 FILM BADGE DOSES.

Before film badge readings can be used to characterize the radiation dose to a group or to an individual, it is first determined, primarily through analysis of the available film badge record(s) and the activities involved, that the badge readings represent the entire period of exposure. If they do not, or there is reason to believe that the badge(s) did not fully represent the entire conditions of exposure, alternative methods, such as statistical assignment or dose reconstruction, are pursued. This is obviously required in cases of exposure to initial radiation where neutrons were emitted from the burst, or in instances where inhalation or ingestion or radioactive particles is an issue. Neither of these types of exposure would have been recorded on a film badge.

8.4 STATISTICAL METHODS OF DOSE DETERMINATION.

To use badge readings to estimate the radiation doses to unbadged personnel, a group of participants is first identified that had common activity characteristics and a similar potential for exposure to radiation; that is, individuals must have been doing the same kind of work or activity and all members of the group must have had a common relationship to the radiological environment in terms of time after burst, location, duration of exposure, and behavior. Identification of these groups is based upon research of historical records, technical reports, or correspondence. For this purpose, a military or naval unit may, therefore, have consisted of several groups, or several units may have comprised a single group. This method is useful for personnel whose activities were confined to a ship or in situations where such activities could be assigned to the entire group under consideration.

Using proven statistical methods, the badge data for each group are examined to determine if they adequately reflect the entire group and are therefore valid for use in statistical calculations, or if the badge data indicated, by such characteristics as a bimodal distribution, that the group should have been subdivided into smaller groups where the distribution of readings was more normal. Only when the group data meets the above tests can the mean dose, variance, and confidence limits be used for assigning doses to unbadged personnel. When using this method, an estimated dose equal to 95 percent probability that the actual exposure did not exceed the estimate is then assigned to unbadged personnel. This high-sided, but statistically sound, procedure ensures that the assigned doses are much higher than the average or mean for the badged group.

8.5 RECONSTRUCTION OF RADIATION DOSES.

The general methodology for dose reconstruction consists of characterizing the radiation environments to which participants, through all relevant activities, were exposed. The environments, both initial and residual radiation, are correlated with the activities of participants to determine accrued doses due to initial radiation, residual radiation, and/or inhaled/ ingested radioactive material (Goetz and others, 31 May 1979; Goetz and others, 9 April 1980). Because of the variety of activities, times, geometries, shielding, and weapon characteristics, as well as the normal spread in the available data pertaining to the radiation environment, an uncertainty analysis is performed. This analysis quantifies the uncertainties due to time and space variations, group size and available data. An automated (computer-assisted) procedure is often used to facilitate handling the large amounts of data and the dose integration, and to investigate the sensitivity to variations in the values of parameters used. The results of the calculations are then compared with film badge data as they apply to the specific period of the film badges and to the comparable activities of the exposed personnel, to validate the procedure and to identify personnel activities that could have led to atypical doses.

Radiation dose from neutrons and dose commitments due to inhaled or ingested radioactive material were not detected by film badges (Goetz and others, 31 May 1979; Goetz and others, 9 April 1980). Where required, these values are calculated and recorded separately.

8.5.1 Characterization of the Radiological Environment.

This process describes and defines the radiological conditions as a function of time and space for all locations of concern, that is, where personnel were positioned or where their activities took place. The radiation environment is divided into the two standard categories: initial radiation and residual radiation.

The initial radiation environment resulted from several types of gamma and neutron emissions. Prompt neutrons and gamma radiation were emitted at the time of detonation, while delayed neutrons and fission-product gamma from the decay of radioactive products in the fireball continued to be emitted as the fireball rose. In contrast to these essentially point sources of radiation, there was gamma radiation from neutron interactions with air and soil, generated within a fraction of a second (Glasstone and Dolan, 1977). Because of the complexity of these radiation sources and their varied interaction properties with air and soil, it is necessary to obtain solutions of the Boltzmann radiation transport equation (Huang, 1963). The radiation environment thus derived includes the effects of shot-specific parameters, such as weapon design and yield, neutron and gamma output, source and target geometry, and atmospheric conditions. The calculated neutron and gamma radiation environments are checked for consistency with existing measured data. In those few cases displaying significant discrepancies that cannot be resolved, an environment based on extrapolation of the data is used if it leads to a larger calculated dose.

The residual radiation environment is divided into two general components: the neutron-activated material that emitted, over a period of time, beta and gamma radiation; and radioactive debris from the fission reaction or from unfissioned materials that emitted alpha, beta, and gamma radiation (Glasstone and Dolan, 1977). Because residual radiation decayed or diminished, the characterization of the residual environment is defined by the radiation intensity as a function of type, time, and space. Radiological survey data is used to determine specific intensities at times of personnel exposure. Interpolation and extrapolation of the existing survey and exposure data are based on known decay characteristics of the individual materials that comprised the residual contamination (Goetz and others, 15 July 1980; Goetz and others, 31 May 1979). In those rare cases where insufficient radiation data exists to define the residual environment adequately, source data is obtained from the appropriate weapon design laboratory and applied using standard radiation transport codes to determine the initial radiation at specific distances from the burst (Oak Ridge National Laboratory, September 1978; Union Carbide Corporation, 1967; Defense Nuclear Agency, January 1976). This radiation, together with material composition and characteristics, leads to a description of the neutron-activated field for each location and time of interest. In all cases, observed data, as obtained at the time of the operation, is used to normalize the calculations.

8.5.2 Activities of Participants.

This part of the process is precisely the same as that described in Section 8.2. It is important that this step be carefully accomplished to define unique groups for which the radiation exposure was essentially common. Possible and reasonable variations in group activities, as well as individual deviations from those of the group as a whole, with respect to both time and location, are considered in each uncertainty analysis, described in Section 8.5.4.

8.5.3 Calculation of Radiation Dose.

The initial radiation doses to close-in personnel (normally positioned in trenches at the time of the detonation) are calculated from the above-ground environment by simulating the radiation transport into the trenches. Various calculational approaches, standard in health physics, are employed to relate in-trench to above-trench doses for each source of radiation (Oak Ridge National Laboratory, September 1973; Oak Ridge National Laboratory, February 1975). Detailed modeling of the human body in appropriate postures in the trench is performed to calculate not only the gamma dose that would have been recorded on a film badge, but also the maximum neutron dose (National

Council on Radiation Protection and Measurements, January 1971). The neutron, neutron-generated gamma, and prompt gamma doses were accrued during such a short interval that the posture in a trench could not have been altered significantly during this exposure. The fission-product gamma dose, however, was delivered over a period of many seconds (Glasstone and Dolan, 1977). Therefore, the possibility of individual reorientation (e.g., standing up to observe the rising fireball) in the trench is considered (Goetz and others, 15 July 1980; Goetz and others, 28 April 1981).

The calculation of the dose from residual radiation follows from the characterized radiation environments and personnel activities. Because radiation intensities are calculated for a field (i.e., in two spatial dimensions) and in time, the radiation intensity is determinable for each increment of personnel activity regardless of direction or at what time (Goetz and others, 15 July 1980; Goetz and others, 31 May 1979). The dose from exposure to a radiation field is obtained by summing the contribution (product of intensity and time) to dose at each step. The dose calculated from the radiation field does not reflect the shielding of the film badge afforded by the human body. This shielding is determined for appropriate body positions by the solution of radiation transport equations as applied to a radiation field (Goetz and others, 31 May 1979). Conversion factors are used to arrive at a calculated film badge equivalent dose, which not only facilitates comparison with actual film badge data, but also serves as a substitute for any unavailable film badge reading.

The calculation of the dose from inhaled or ingested radioactivity primarily involves the determination of what shot-specific radioisotopes could have entered the body in what quantity. Published conversion factors are then applied to these data to arrive at the radiation dose and future dose commitments to selected internal organs, such as bone marrow, lungs, and thyroid (Nuclear Regulatory Commission, November 1977; Oak Ridge National Laboratory, June 1978 and November 1979). Inhalation or ingestion of radioactive material is calculated from the radioactive environment and the processes of making these materials inhalable or ingestible. In addition to direct descent of fallout, activities and processes that would have caused material to become airborne (such as wind, traffic, or decontamination) are used with empirical data (Stewart, June 1964; Arspaugh, October 1975) on particle lofting to determine airborne concentrations under specific circumstances. Volumetric breathing rates and durations of exposure are used to calculate the total material intake. Data on time-dependent weapon debris isotopic composition, and the above-mentioned conversion factors, are used to calculate the dose commitment to the body and to specific body organs (Goetz and others, 9 April 1980; Defense Nuclear Agency, 1985).

8.5.4 Uncertainty Analysis.

Because of the uncertainties associated with the radiological data or the calculations used in the absence of data, as well as the uncertainties with respect to personnel activities, confidence limits are determined where possible for group dose calculations. The uncertainty analysis quantifies the errors in available data or in the model used in the absence of data. Confidence limits are based on the uncertainty of all relevant input parameters; thus, the range of uncertainty varies with the quality of the input data. The possible range of doses due to the size of the exposure group being examined is also considered. Typical sources of error include orientation of the weapons, specific weapon yields, inherent instrument error, fallout intensity data, time(s) at which data were obtained, fallout decay rate, route of personnel movements, and arrival/stay times for specific activities. Goetz and others, 28 April 1981, and Goetz and others, 31 May 1979, discuss these in detail.

8.5.5 Comparison with Film Badge Records.

When this reconstruction methodology was first developed in 1978 and 1979, the calculations of gamma dose were compared with film badge records for two military units at Exercise Desert Rock VIII, Task Force WARRIOR and Task Force BIG BANG, both of which were involved, either directly or indirectly, in Shot SMOKY, Operation PLUMBBOB. Where all parameters relating to exposure were identified, direct comparison of gamma dose calculations with actual film badge readings was possible. The comparisons of actual and calculated doses were remarkably good, and the resultant correlations provided high confidence in the reconstruction methodology. References 3 and 4 illustrate these comparisons.

Film badge data may have been, in some cases, unrepresentative of the total exposure of a given individual or group. For example, there may have been additional unbadged opportunities for radiation exposure, as well as possible damaged film badges. Nevertheless, such information has proven extremely useful for direct comparison of incremental doses for specific periods, e.g., validating the calculations for the remaining, unbadged periods of exposure. Moreover, a wide distribution of film badge data has often led to more definitive personnel or activity groupings for dose calculations and to further investigation of the reason(s) for such distribution. Goetz and others 31 May 1979, describes such distribution and subsequent investigation.

In no cases, however, were film badge data used in the dose calculations; rather, they have been and continue to be used solely for comparison with and validation of the calculations. In virtually all cases, comparison has been favorable and within the confidence limits established by the uncertainty analysis of each calculation.

8.6 RESULTS OF DOSE RECONSTRUCTIONS.

Dose reconstructions have been completed for all operations for which there is no film badge dosimetry and there was a reasonably high potential for significant radiation exposure to large groups or units, such as ship crews or maneuver troop units. These reconstructed doses provide, in the absence of dosimetry, the readings of what probably would have been recorded on film badges, had they been worn. Because film badges did not record neutron doses or doses from inhaled or ingested radioactive contaminants, doses for these types of exposures, must be reconstructed separately.

8.7 REVIEW OF RECONSTRUCTION METHODOLOGY.

The dose reconstruction methodology and processes have been reviewed, in whole and in part, by several independent authorities throughout the NTPR program. The first NTPR report dealing with dose reconstruction, Task Force WARRIOR at Shot SMOKY (Goetz and others, 31 May 1979), was critically reviewed in 1979 by nationally recognized radiation experts from scientific laboratories, as well as by the OTA (at the request of Senator Alan Cranston, Senate

Committee on Veterans' Affairs), and the Medical Follow-up Agency of the NAS/NRC. These reviews provided the confidence to finalize the methodology and to adapt it to many other exposure scenarios. Other dose reconstructions were subsequently reviewed by committees appointed by the NAS. One such review was conducted in 1980-81 of the Hiroshima-Nagasaki dose reconstructions (National Academy of Sciences, 21 August 1981), and another review, that of the entire dose reconstruction effort, was conducted in 1984-85 (National Research Council, 1985). No major deficiencies were noted that would reflect unfavorably on the technical aspects of the external dose reconstruction methodology or on the radiation doses calculated therefrom.

Of the work on internal dose, the reviewers wrote:

> Methods used to assign internal doses associated with inhalation or ingestion of radioactive material were in general based on unsupported assumptions. The methods often attempted to relate internal dose to the magnitude of external radiation and tended to overestimate possible internal doses. There is considerable evidence that, with the exception of doses to the thyroid, doses to any organ from internal emitters were far smaller than the external dose. The Committee came to this conclusion from follow up data obtained from Bikini natives, Japanese fisherman, and veterans who had been exposed to fallout from Shot Smoky. From these groups, modern methods of radiochemical analysis of urine and whole-body counting make it possible 20 or 30 years after exposure to set upper limits of dose commitments as low as 500 mrems from exposure to strontium-90 and plutonium-239 (National Research Council, 1985, pp.2-3).

As a result of concerns over the doses received by participants at CROSSROADS, Senator Cranston asked the GAO to investigate alleged improprieties or deficiencies associated with CROSSROADS records, dosimetry, and dose reconstructions. The investigation, completed in 1985, did not assess the methodology used to calculate radiation doses, but nonetheless concluded that film badge dosimetry, personnel decontamination procedures, and contaminant ingestion could have led in some instances to higher doses than were reported (General Accounting Office, November 1985). Even if doses were higher, as suggested by the GAO study, they would not have exceeded the established Federal guideline for occupational radiation exposure.

SECTION 9

HEALTH EFFECTS OF IONIZING RADIATION AND MEDICAL FOLLOW-UP STUDIES OF VETERANS

This chapter outlines what is known about the health effects of ionizing radiation. It then summarizes the studies conducted by several agencies to ascertain if such effects exist among veterans who participated in U.S. atmospheric nuclear weapons tests and in the postwar occupation of Hiroshima and Nagasaki, Japan.

9.1 HEALTH EFFECTS OF IONIZING RADIATION.

The biological effects resulting from exposure to ionizing radiation can be grouped into two general categories, **acute** (quickly observed) and **delayed**.

Examples of acute effects are erythema or reddening of the skin, blood changes, vomiting, loss of hair (epilation), and even death in the extreme case. Before such effects can be observed, a certain minimum radiation dose, or threshold, must be exceeded. The magnitude of the effect and normally the speed at which it occurs increase with the size of the radiation dose. In cases where the radiation dose is above the threshold level, where acute effects are observed, and below the level that produces fatalities, the observed acute effects usually disappear after a period of time. For example, blood will return to normal, hair will grow back, and skin burns will heal, although some scarring and pigmentation loss may occur.

Acute effects and their threshold doses are well known. **Table 9-1** below indicates the acute effects of whole-body exposure to various levels of ionizing radiation (Cember, 1983). Observable acute effects do not occur at radiation doses below approximately 25 rem, as noted in the table. Better than 99 percent of all doses received by nuclear test participants were well below this threshold; therefore, such effects were not evident.

Table 9-1. Acute effects of exposure to ionizing radiation.

Dose (rem)	Effect
25-50	Blood changes. For example, white blood cells are reduced in number. Temporary sterility in men.
75	Vomiting in 10 percent of those exposed.
200	Depression or ablation of bone marrow. Nausea and vomiting within hours. Epilation (loss of hair) within two or three weeks.
300	Erythema (reddening of the skin).
450	Lethal dose for 50 percent of those exposed. Death within 30 days.
1000	Loss of intestinal wall. Death within one or two weeks.
2000	Unconscious within minutes, death within a few hours.

Examples of delayed effects include cataracts, several forms of cancer, and genetic disorders in offspring. Cataracts appear after a latency period of several years and require a threshold dose of at least 200 rem. Genetic effects have been demonstrated only in animal studies; they have not been observed in humans. For example, data collected on more than 30,000 children conceived after their parents were exposed at Hiroshima and Nagasaki did not reveal statistically significant increases in stillbirths, neonatal deaths, birth weight, or congenital malformations (Neel, 1963; Schull and others, 11 September 1981).

According to current medical opinion, no threshold dose is required for cancer induction. Since cancer occurs naturally in the general population and cannot be distinguished from radiation-induced disease, the problem of risk assessment, especially at low doses, is complex. The only way to determine the magnitude of the cancer risk is to study large groups of exposed personnel and compare their cancer incidence with that of a similar, unexposed group.

Numerous national and international authorities have conducted such studies. It is beyond the scope of this history to discuss these studies in any detail; however, some relevant findings are summarized in **Table 9-2** (Cember, 1983; Upton, August 1991).

Table 9-2. Lifetime risk of excess cancer mortality from gamma radiation.

Source*	Deaths per 100,000 per single dose of 10 rem
BEIR I (1972)	115-621
ICRP (1977)	125
UNSCEAR (1977)	100
BEIR III (1980)	67-226**
UNSCEAR (1988)	710
BEIR V (1990)	800

* The BEIR reports were prepared by the NAS Committee on the Biological Effects of Ionizing Radiation. ICRP is the International Commission on Radiological Protection, and UNSCEAR is the United Nations Scientific Committee on the Effects of Atomic Radiation.

** The number cited is the majority opinion. One dissenting member estimated cancer deaths as 158-501 per million person rem, and another dissenting member estimated 10-28 deaths per million person rem.

The risk estimates presented above are in terms of cancer deaths among a population of 100,000 exposed to a one-time dose of 10 rem. They are not the same, but they are similar. The differences in risk estimates result from differences in data and methodology and show the difficulty of answering the risk question except approximately. Research indicates that the veterans who participated in U.S. atmospheric nuclear tests received an average dose of 0.63 rem (see Section 1.5). About 1,700 of these men had one-year doses over 5.0 rem, the present Federal guideline for exposure of nuclear plant workers. Scientists face two basic problems of analysis. First, without good understanding of the biological mechanisms through which small doses of radiation may cause cancer, they estimate the risks of cancer from low level radiation by extrapolating from the effects of larger doses. Second, at the radiation dose levels encountered by nuclear test veterans, the number of predicted excess cancer cases is at most very small. These few possible excess cancers would be extremely hard to identify among the cancer cases that naturally occur in human populations. The mortality estimate of 800 deaths per 100,000 people exposed to 10 rem given in the above table converts to 800 fatal cancers in a population of one million exposed to 1 rem. According to current cancer statistics, approximately 180,000 fatal cancers will occur naturally in a population of one million persons. In smaller groups with only slightly elevated exposure, any increase in cancer incidence is easily obscured by the statistical variation in the naturally occurring cancer cases.

The report Health Effects of Exposure to Low Levels of Ionizing Radiation, usually referred to as BEIR V (Biological Effects of Ionizing Radiation), has generated considerable controversy because some believe it says that the risk values are three times larger for solid cancers and four times larger for leukemia than those given in The Effects on Populations of Exposure to Low Levels of Ionizing Radiation, BEIR III.

To understand the situation, one must understand how the BEIR III and BEIR V reports are alike and how they differ in data and methodology. BEIR V uses essentially the same data and study populations as BEIR III but with updated mortality statistics covering the intervening 10 years and incorporation of the most recent estimates of the radiation outputs of the nuclear weapons dropped on Hiroshima and Nagasaki, Japan. Most important, the authors of BEIR V make several important assumptions that are different from those used in BEIR III. They are described below:

1. The mathematical model used in BEIR V to extrapolate risk values into the low-dose region where there is no observed data is more conservative by a factor of about 2.

2. BEIR V ignores the fact that a threshold effect has been observed for some cancers and that some data is equally well-fitted by the previous, less conservative assumptions.

3. The extrapolated risk values used in BEIR V do not include a risk reduction factor (Dose Rate Effectiveness Factor [DREF]) to account for the observed lessening of radiation effects as dose and dose rate decrease. When applied as recommended by the authors of BEIR V, this factor would lower risk values by a factor of between 2 and 10. The authors of BEIR III included a DREF of 2.5 directly in the risk values they presented.

4. Data for doses greater than 400 rad were excluded from BEIR V, tending to increase the risk values by about 25 per cent for solid tumors.

5. Data for the youngest groups of those exposed still must be extrapolated from that of older exposed individuals because the youngest groups have not attained the age at which the full expression of their potential cancers, either naturally occurring or

excess, has occurred. Because the authors of BEIR V used more conservative assumptions to make these projections, the assumed risk values are higher than in BEIR III.

As the result of the differences listed above, the numbers in BEIR V appear to indicate higher risk; but when all the modifying factors are taken into account, the increase is modest at most.

The following statement is from BEIR V:

> Finally, it must be recognized that derivation of risk estimates for low doses and dose rates through the use of any type of risk model involves assumptions that remain to be validated. At low doses, a model dependent interpolation is involved between the spontaneous incidence and the incidence at the lowest doses for which data are available. Since the committee's preferred risk models are a linear function of dose, little uncertainty should be introduced on this account, but departure from linearity cannot be excluded at low doses below the range of observation. Such departures could be in the direction of either an increased or decreased risk. Moreover, epidemiologic data cannot rigorously exclude the existence of a threshold in the millisievert dose range. Thus the possibility that there may be no risks from exposures comparable to external natural background radiation cannot be ruled out. At such low doses and dose rates, it must be acknowledged at the lower limit of the range of uncertainty in the risk estimates extends to zero (National Research Council, 1990, p. 181).

Several studies have been conducted to determine whether there is an increased incidence of certain cancers among various groups of veterans who participated in nuclear tests. The following sections briefly summarize these efforts.

9.2 CENTERS FOR DISEASE CONTROL STUDIES.

The CDC was the first organization to study military participants in the atmospheric nuclear weapons tests from a health point of view. In 1977, CDC learned of a veteran who claimed his acute myelocytic leukemia resulted from radiation exposure allegedly received during participation at Shot SMOKY, a 44-kiloton detonation that took place on 31 August 1957 as part of Operation PLUMBBOB. Extensive publicity regarding this case prompted the CDC to initiate a study to determine if there was an excess incidence of leukemia among the nuclear test participants that might be attributable to radiation exposure. Plans were to focus on the military participants at Shot SMOKY.

The identification of a SMOKY cohort proved more difficult than expected. The index case was a member of Task Force BIG BANG, an Army unit selected to study how well military personnel who had never witnessed a nuclear explosion would perform various military tasks after such an experience. Because of an unexpected shift in wind direction, the exercise planned for Task Force BIG BANG had to be postponed. As a result, the unit observed Shot SMOKY from the press area approximately 30 kilometers away. After observing Shot GALILEO, detonated on 2 September 1957, the unit conducted its exercise in an area contaminated by two-day-old SMOKY fallout in addition to fallout from at least three previous PLUMBBOB shots. Another military maneuver was conducted in conjunction with Shot SMOKY. Task Force WARRIOR, a reinforced infantry company from the 1st Battle Group, 12th Infantry, 4th Infantry Division, performed exercises upwind of the SMOKY ground zero shortly after the shot. The area was essentially free of SMOKY fallout but was contaminated by fallout from previous PLUMBBOB shots.

To complicate matters further, there was no central listing of participants by name. A study cohort was finally identified from research by AFRRI. The list named 3,153 military personnel* who had been issued film badges at the NTS for the period that included 31 August 1957, the date of Shot SMOKY. Seventy-one names were added from other sources, thereby making a total cohort of 3,224 individuals. This number of individuals was used in the study.

Several sources were explored to identify cases of leukemia and other cancers among this cohort. Four leukemia cases were identified from a list of more than 3,000 individuals who made inquiries resulting from the publicity surrounding the index case. Of these personnel, 447 had been at the NTS on 31 August 1957. The AFRRI list was also compared with various clinical files, including those of the Armed Forces Institute of Pathology (AFIP), the VA death benefit file, and personnel records at NPRC. Four more cases were identified from these records, which made a total of nine (including the index case).

Each case was confirmed by CDC, and the total exceeded the statistically expected incidence of 3.5 leukemia cases in this cohort. The expected incidence was calculated by applying age- and sex-specific incidence rates published by the National Cancer Institute to the person-years accumulated by the SMOKY cohort from 1957 through mid-1977. Eight of the nine cases had died by the time of the study. This exceeded the expected mortality of 2.9 calculated from U.S. rates for the 1970s. Both comparisons were considered statistically significant, even if two of the cases that could be questioned with regard to inclusion in the cohort were dropped.

Radiation exposure was considered as a possible cause of this increased incidence. The available dosimetry (film badge results) and radiological analyses of tissue from two patients did not, however, support this hypothesis. Therefore, CDC tentatively concluded that, if the apparent excess of leukemia was not a chance occurrence, the SMOKY participants may have received higher radiation doses than supposed (perhaps from neutrons or inhaled radioactive material not detected by film badges) or radiation was more carcinogenic at low doses than previously assumed.

The CDC published a preliminary report of these findings in the 3 October 1980 issue of the Journal of the American Medical Association (Caldwell and others, 3 October 1980). The CDC continued to study the incidence of all forms of cancer as well as causes of death among the cohort,

*Primarily U.S. Army personnel who were assigned to Exercise Desert Rock and wore film badges provided by the U.S. Army Signal Depot, Lexington, Kentucky.

which was eventually refined to 3,217 veterans. Disease incidence and mortality data were collected through 1979 on over 95 percent of the cohort.

The follow-up study identified a total of 112 cancer cases, which is below the expected number of 117.5 cases in this study cohort. The incidence of some specific cancer types was slightly higher than expected, but the increase was not considered statistically significant with the exception of leukemia (one additional case was identified). Cancers of the digestive system, respiratory, genital, and urinary systems occurred less often than expected. No cancers of the bone/joints, soft tissue, endocrine system, or multiple myeloma were found.

With regard to mortality, the cohort had considerably fewer total deaths than expected. The number of deaths increased in only three categories: infectious and parasitic diseases, accidents, and killed in action. Deaths from individual types of cancer exceeded the norm in five categories: - leukemia, brain and nervous system, eye and orbit, genital system, and skin melanoma. Again, only the increased incidence of leukemia deaths was found statistically significant.

An analysis of the film badge dosimetry available for the cohort showed that, in general, radiation doses were well within current occupational exposure standards. The analysis also showed that the mean dose received by participants engaged in the military maneuver was higher than the mean dose received by support units. However, the frequency of cancer was higher among the participants assigned to support units. Assuming that the dosimetry is correct, at least in a relative sense, the opposite would be expected if radiation were the cause.

The findings, published in the 5 August 1983 issue of the Journal of the American Medical Association, indicated several biases that affected the study. The authors noted, for example, that the index case was included in the sample and that one of the leukemia cases was for a deceased Air National Guard pilot whose presence at SMOKY was questionable.

In summary, the CDC 1983 study revealed an increase in the incidence of leukemia and resulting deaths among a group of nuclear test participants issued film badges at the NTS for the period covering the date of Shot SMOKY. The incidence of other forms of cancer, other selected diseases, and the overall mortality among the cohort was typical of that for the general population. The conclusion was as follows: "Although uncertainty remains about the exact amount of radiation exposure, the lack of a significant increase after 22 years in either the incidence of or the mortality from any other cancer and the apparent lack of a dose effect by units lead to the consideration that the leukemia findings may be attributable either to chance, to factors other than radiation, or to some combination of risk factors possibly including radiation" (Caldwell, 5 August 1983).

9.3 ARGONNE NATIONAL LABORATORY STUDY.

The CDC study discussed above concluded that the increased incidence of leukemia among the "SMOKY" cohort may be attributable to chance or the result of an unknown combination of factors. A possible factor was that the radiation doses might have been higher than reported, since only external gamma radiation exposures were considered. One hypothesis was that significant internal doses resulted from inhalation or ingestion of radioactive material.

As a check, a group of 19 veterans was selected from the SMOKY cohort by the CDC to be sent to the Argonne National Laboratory (ANL) for special testing. The group was chosen on the basis of high film badge readings and/or potential for internal exposure. None of the group exhibited any clinical signs of radiogenic malady. Three members of the group, however, chose not to participate in the study.

The remaining 16 veterans visited ANL during 1979, where they were interviewed regarding their participation (exposure scenario) and checked for evidence of residual internal radioactivity that might be attributable to such participation. Whole-body and thorax gamma-ray counts were made looking specifically for cesium-137, a fairly long-lived fission product that distributes throughout the body after intake. Using different instruments, similar measurements were made for plutonium-239 in the thorax and skull. While at ANL, the veterans also provided 24-hour urine specimens that were analyzed for plutonium-239 and strontium-90.

None of the tests revealed internal radioactivity in excess of that found in the general population. Thus, the authors concluded that they had "no evidence that these subjects received any significant internal dose from their participation in the SMOKY weapon test" (Tookey, 14 August 1981).

9.4 NATIONAL RESEARCH COUNCIL STUDIES.

The NRC/NAS concluded two medical studies pertinent to this report: Mortality of Nuclear Weapons Test Participants (1985), referred to as the Five-Series Mortality Study, and "Multiple Myeloma among Hiroshima/Nagasaki Veterans" (1983). In addition, a follow-on to the Five-Series Mortality Study and a mortality study of CROSSROADS participants are planned. This section discusses these studies.

9.4.1 The Five-Series Mortality Study.

Preliminary reports by the CDC in 1979 that a statistically significant increase in leukemia incidence was occurring in the "SMOKY cohort" caused considerable concern. DNA requested the Medical Follow-up Agency of the NRC/NAS, an independent non-Government agency, to undertake a study of this issue. The details of the study were left to the NRC. Funded by both DNA and DOE, the effort was to determine whether participants at nuclear tests other than SMOKY were also experiencing an increased incidence of leukemia, other cancers, or any other fatal disease. The Medical Follow-up Agency chose a study cohort made up of the participants in the five series identified in **Table 9-3**. These personnel comprised about one-fourth of the total participants in U.S. atmospheric nuclear testing.

Table 9-3. Five series in the NAS study.

Series	Year	Location	No. of detonations
GREENHOUSE	1951	PPG	4
UPSHOT-KNOTHOLE	1953	NTS	11
CASTLE	1954	PPG	6
REDWING	1956	PPG	17
PLUMBBOB	1957	NTS	24

As for the CDC study of Shot SMOKY, complete rosters of participants in these series did not exist. The NTPR teams, using such sources as ship deck logs, unit morning reports, special orders, after-action reports, and film badge dosimetry logs, identified by name a total of 49,148 participants by March 1983. This list was selected as the cohort for the NRC study. Only persons identified from valid records were included in the study; self-reported participants were not accepted by NAS.

Because of the large number of participants, tracing each individual's health status, in particular for incidence of disease, was considered impractical for both technical and financial reasons. It was decided, therefore, to limit the study to mortality and to use records maintained by the VA. A mortality study would indicate any unusual incidence and would tell if a morbidity study was warranted.

Names and other identification, such as social security numbers, were submitted to the VA Beneficiary Identification Records Locator Subsystem (BIRLS) to ascertain who had died through 1982 and the location of their VA records. Death certificates for those confirmed dead by the BIRLS were ordered from the VA Regional Offices. No record existed in the BIRLS for many of the names submitted. These names were directed to the NPRC in St. Louis, Missouri, for further research using such files as the VA Master Index.

The records search confirmed a total of 5,113 deaths from all causes. This number represents 11.1 percent of the study cohort, and is 83.5 percent of the number of deaths that normally would be expected among the U.S. general population.

Mortality in this cohort from accidents, acts of war, and other external causes was six percent higher than the expected, rate compared with the general U.S. population. On the other hand, the 1,046 cancer (including leukemia) deaths were only 84 percent of the number expected, and the 2,579 deaths from other diseases were only 69 percent of expectation. Similar results emerged when each test series was examined separately. However, a statistically significant excess number of deaths from prostate cancer (not thought susceptible to causation by radiation) was found among the Operation REDWING participants.

As a check on the methodology used in the study, the SMOKY participants at Operation PLUMBBOB were subjected to the same mortality ascertainment procedures used for participants at other shots and test series. The size of the cohort increased to 3,554 participants, slightly higher than that of the CDC study, and 10 leukemia deaths were found. This incidence, 2.5 times the expected number (3.97), is considered statistically significant. No cancers other than leukemia were found in excess, and the total number of cancer deaths (67) was less than the number expected (83.8) using U.S. population rates. These results parallel those reported earlier by CDC and lend credence to the methodology pursued in the NRC study.

The following conclusions, quoted from the published findings, resulted from the study (Robinette and others, May 1985):

1. The finding by Caldwell et al. that an excessive number of cases of leukemia has occurred among former participants at Shot SMOKY of the PLUMBBOB series was confirmed.

2. No evidence was found that leukemia mortality was increased among participants at PLUMBBOB tests other than SMOKY or among participants at UPSHOT-KNOTHOLE, GREENHOUSE, CASTLE or REDWING.

3. Generally accepted estimates of the rate of excess leukemia induction per rem when applied to estimates made by DNA of the radiation doses to participants result in an expected increase of leukemias among SMOKY participants of less than 0.2 case. The observed excess mortality from leukemia among these men, then, either was a chance aberration or argues that the mean radiation doses at SMOKY (but not at the other test series) were several times the doses recorded by the film badges that were used.

4. No evidence was found that any cancer other than leukemia occurred excessively among former SMOKY participants.

5. Mortality from cancer in all groups of participants was, in general, found to be less than the number expected at population death rates, and mortality from other disease was much less than expected, a consequence of selection for good health by the physical screening employed for active duty servicemen.

6. Although there were significant excesses of leukemia among SMOKY participants and of prostate cancer among REDWING participants, no form of cancer was found to be increased in more than one test series. Since many independent comparisons of cancer rates were made, the two "significant" excesses may well have resulted from chance.

7. The total body of evidence reviewed does not convincingly either affirm or deny that the higher than statistically expected incidence of leukemia among SMOKY participants (or of prostate cancer among REDWING participants) is the result of

radiation exposure incident to the tests. However, when the data from all the tests are considered, there is no consistent or statistically significant evidence for an increase in leukemia or other malignant disease in nuclear test participants.

Because limitations in the original study have become evident, a follow-up study was initiated in September 1992 with the NAS to address such questions as (Defense Nuclear Agency, 16 September 1992):

- The first study compared cancer mortality data of test participants to like incidence data for the general U.S. population. The follow-on study will use comparable Service personnel who were not participants at the time of testing as the comparison population. It is known that personnel selected for military service were healthier than the general population.

- A 1989 comparison of purified participant data to the 1981 data used in the original study revealed that there were some names which could not be matched to those in the study population and others which had been excluded. The follow-on study will concentrate on a more accurate and thorough review of military records, participant names, and Service numbers to determine the correct assignment of personnel from the current data base to the test participant group.

- Since 1981, the cutoff year for collecting data for the first study, over 10 years of additional mortality data has accumulated for the participant group. In studies of Japanese survivors from Hiroshima/Nagasaki, leukemia is the earliest appearing cancer following radiation exposure. For other cancer types, it may take 30 years or more for them to appear under similar exposure conditions. It is important to see if there are excess incidences of cancers emerging among the test participants, especially leukemias, which should have become completely apparent in the participant groups if they are related to radiation exposure.

- Dose records used in the first study did not fully reflect all periods in which some participants were exposed to radiation at these test series. Also, monitoring devices worn at that time by participants registered most, but not all of their dose from external radiation exposure. Since then, reconstructed radiation doses have been calculated from historical data. These reconstructed doses account for periods when participants were exposed, but monitoring devices were not worn or were lost during the test series. Dose reconstructions have also been performed to account for unregistered external doses and for doses from inhaled or ingested particles of fallout. These calculated doses, which have already been added to the participants' recorded doses, will be used in the follow-on study.

The results of the follow-on study are expected to provide a current assessment of mortality due to cancer occurrence in U.S. atmospheric nuclear test participants. Comparison of results from the two studies will indicate the influence of the key issues on the new study's conclusions. The study report is expected to be completed in fall 1997.

9.4.2 Study of Multiple Myeloma Among Hiroshima/Nagasaki Veterans.

The DNA Director requested the NRC undertake the multiple myeloma study in response to allegations by various veteran groups that the disease was occurring with increased frequency among participants in the U.S. postwar occupation of Hiroshima and Nagasaki, Japan. The effort began with formation of a panel of experts from various medical and scientific disciplines. On 13 and 14 May 1981, a workshop was held at the NAS to review the available data to advise DNA concerning the feasibility and desirability of performing epidemiologic studies of the Hiroshima and Nagasaki occupation forces.

While invitations to participate were sent to a number of veteran organizations, only representatives of the Committee for U.S. Veterans of Hiroshima and Nagasaki and the National Veterans Law Center accepted. Representatives of the American Veterans Committee and the Disabled American Veterans were present as observers.

DNA representatives briefed the panel on the details of the occupation, such as the units involved, troop arrivals and departures, billet locations, and mission and assignments. SAIC, a DNA contractor, then provided a worst-case estimate of the radiation doses received by the occupation forces based on historical reports of occupation troop activities and radiological data taken directly from journals and technical reports available to the panel. Staff members of the Radiation Effects Research Foundation and the National Cancer Institute also provided expert testimony. Representatives of the veterans group took part in the discussions following these presentations.

Based on the data presented at this workshop, the panel concluded the following, quoted from the report summarizing their meeting (National Academy of Sciences, 21 August 1981):

1. Scientifically sound studies of morbidity among military personnel who entered Hiroshima or Nagasaki soon after the bombings are impractical. Records of morbidity in this population are just not available, nor could they be assembled in any objective or systemic fashion.

2. Studies of mortality among these men are feasible. However, from a strictly scientific point of view, such studies appear to carry inordinate cost in relation to the potential benefit.

3. No study of the population in question could detect effects that would be predictable from existing knowledge of health hazards associated with radiation exposure.

4. The possibility that multiple myeloma is occurring in excess in these veterans, as has been alleged, should be explored. This should not at first involve a full-scale epidemiologic study. The number of confirmed cases of the disease in this population should first be determined, and an evaluation made as to whether this is excessive before any further studies are recommended . . . Even if an excess number of cases of multiple myeloma is present in this population, it is unlikely to be attributable to ionizing radiation.

DNA requested that conclusion 4 be pursued. The NAS accordingly appointed a new panel tasked to investigate all alleged cases of multiple myeloma among the occupation troops, verify the diagnosis, and compare the number of verified cases with the number of cases that would be expected in a similar (unexposed) population.

Twenty-eight possible cases of multiple myeloma were identified from two lists of veterans who said they had served in Hiroshima or Nagasaki. DNA compiled one of the lists as part of its NTPR program. The other list was provided by the National Association of Atomic Veterans (NAAV), which had polled its membership of about 2,000. The DNA list contained 687 names, and the NAAV list approximately 500 names.

The NTPR Service teams and participating NAS staff members screened military records of the 28 veterans possibly having multiple myeloma. They eliminated nine of the veterans because their records did not confirm military assignments to either Hiroshima or Nagasaki.

Clinical records were sought from the 19 remaining cases. The veteran or, if deceased, his next-of-kin was asked for permission to obtain his medical records (including X-rays and microscope slides) from the appropriate medical authority. Six more cases were eliminated, five of them because the veterans or next-of-kin did not respond to NAS inquiries and one because a physician did not respond to the request for medical records. Four cases were eliminated from the remaining 13 when further military record searches revealed that two of the personnel had not been assigned to either Hiroshima or Nagasaki and the medical records of the other two made no reference to multiple myeloma.

The panel confirmed nine cases of multiple myeloma among the Hiroshima/Nagasaki veterans. Five of the cases had been assigned to the Nagasaki occupation; the other four were associated with Hiroshima. All cases were diagnosed between the ages of 51 and 61, the time when the disease normally appears.

On the basis of multiple myeloma incidence rates reported by the National Cancer Institute and assuming that at least 20,000 men were assigned to occupation duty at Nagasaki, the panel calculated that 9.5 cases of the disease would be expected by 1980 if all of the troops had been between the ages of 15 to 19 years at the time of the occupation. At least 18.2 cases would be expected if the ages had been between 20 and 24, and 29.2 cases would be expected if the ages had been between 25 and 29 in 1945. Similar figures were not calculated for Hiroshima since it is not possible to estimate the number of Service personnel who may have visited the city. (Occupation forces for the area were not billeted in Hiroshima proper.)

Since only nine cases were confirmed among the Hiroshima and Nagasaki occupation forces, the panel concluded that the incidence of multiple myeloma was no greater than that in the U.S. population. Their conclusion was qualified by the admission that it is quite possible that not every case had been identified (National Research Council, June 1983).

9.5 PROPOSAL FOR A VA STUDY.

The Veteran's Health Care Amendments of 1983 (Public Law 98-160) tasked the VA Administrator, in consultation with the Director of OTA, to:

> Provide for the conduct of epidemiological study of the long-term adverse health effects of exposure to ionizing radiation from the detonation of nuclear devices in connection with the test of such devices or in connection with the American occupation of Hiroshima and Nagasaki, Japan, during the period beginning on September 11, 1945, and ending on July 1, 1946, in persons who, while serving in the Armed Forces of the United States, were exposed to such radiation. Such study shall include, but not necessarily be limited to, a study of identifiable prevalent illnesses, including malignancies, in the persons exposed.

The law further states that the requirement to carry out the study will "cease to have effect as if repealed by law" if the VA Administrator, in consultation with the OTA Director, finds that such a study is not feasible.

In December 1984, the VA completed its proposed study plan, "VA Assessment of Veterans with Military Service at Sites of Temporarily Augmented Ionizing Radiation." A two-phase health assessment was proposed.

The first phase called for a questionnaire to be mailed to all veterans who participated in the Hiroshima/Nagasaki occupation or any of the U.S. continental or oceanic atmospheric nuclear tests. The questionnaire would be designed primarily to collect information on physical health, particularly regarding cancer and other chronic disease, but it would also seek information on mental health and lifestyle factors. The same questionnaire would also be sent to a similar number of veterans who had no history of such participation. Results from the two groups, adjusted for age, occupation, smoking habits, and other influences, would be compared.

The second phase would include medical and physiological examinations of an unspecified number of veterans and the collection of data regarding possible congenital or genetic abnormalities in their children. The methodology for the analysis of this information was not addressed.

The VA plan was first reviewed by a panel of Government scientists, headed by Dr. Glyn Caldwell, who had authored the SMOKY study at CDC. The Caldwell review was then submitted to the Committee on Interagency Radiation Research and Policy Coordination (CIRRPC). Both the Caldwell committee and CIRRPC concluded that the VA plan did not describe a feasible study since it would be impossible to detect the small excess of disease expected in a group of approximately 200,000 personnel exposed to the reported low levels of radiation.

The VA plan and the Caldwell/CIRRPC review were submitted to the Director of OTA for review in January 1985. OTA examined these documents and conducted its own independent review of the feasibility of the epidemiological study. The independent OTA study analyzed two strategies for assessing the health of these veterans. The first was similar to that proposed by the VA, that was to study approximately 200,000 participants in the U.S. atmospheric nuclear tests. (The Hiroshima/Nagasaki occupation troops were excluded since the doses were so low that their inclusion would weaken rather than strengthen the power of the study.) The second strategy was to study approximately 1,400 veterans with measured or estimated doses greater than 5.0 rem. The power of each strategy to detect the expected excess of radiogenic cancers was calculated based on the radiation dose information available. These calculations were repeated for doses several times higher to account for possible understatement of reported dose.

The OTA concluded, as had the Caldwell committee and CIRRPC, that such "global" studies concerning the health of nuclear test veterans are not feasible. The agency did, however, suggest two more specific studies that could provide useful information (Office of Technology Assessment, July 1985):

1. Continue to follow the "SMOKY" cohort previously studied by the CDC/NRC. If the excess leukemia detected was simply a matter of chance, no excess of other radiogenic cancers would be expected.

2. Conduct a mortality study of the veterans who participated in Operation CROSSROADS pending the results of a GAO review of the radiation dose estimates.

In determining the feasibility and desirability of an epidemiological study or studies, the VA Advisory Board considered the recommendations of the Caldwell committee, CIRRPC, and OTA. It also reviewed commentary given in the following: the GAO report Operation CROSSROADS: Personnel Radiation Exposure Estimates Should Be Improved (8 November 1985), discussed in Section 8.7; the NAS report Review of the Methods Used to Assign Radiation Doses to Service Personnel at Nuclear Weapons Tests (7 February 1986), discussed in Section 8.7; and the hearing held by the Senate Committee on Veterans Affairs on 11 December 1985 regarding issues pertinent to possible radiation exposures received by CROSSROADS participants.

During February 1986, the VA Advisory Board listened to presentations by DNA, GAO, and NAS on dose determination for CROSSROADS participants. As a result of Board recommendations, the VA decided that it would not participate in a mortality study of CROSSROADS veterans but that it would continue the follow-up of SMOKY personnel. The VA Administrator informed OTA of these decisions in April 1986.

OTA reviewed the VA decisions and considered a NAS proposal to conduct a mortality study of CROSSROADS personnel. In March 1986, DNA had indicated to the Senate Committee on Veterans Affairs that it would be willing to provide part of the funding if OTA considered the study feasible and if Congress decided against appropriating funds specifically for the effort. DNA's offer was accepted; the decision was made that the NAS Medical Follow-up Agency would conduct the study, and DNA would provide NAS with data from the NTPR files concerning CROSSROADS participants. NAS is developing protocols for the study. The study report is expected to be completed in spring 1996.

* * * * *

The NTPR effort and related activities continue. Further medical follow-up studies may be conducted of the participants in the U.S. atmospheric nuclear weapons testing program. Veterans and other interested parties continue to use the DNA toll-free line, request information concerning participation and dose, and file claims with the VA. Anniversaries of the Hiroshima and Nagasaki bombings periodically refocus national attention on veterans of the occupation, as well as on the atmospheric nuclear weapons tests.

DNA responds to continuing requests for data. With the support from DOE and the VA, the NTPR program has assembled and organized a body of information that should be useful for years to come.

APPENDIX A

CHRONOLOGY OF SELECTED EVENTS RELEVANT TO THE NTPR PROGRAM

Early 1977	CDC identified a former participant in U.S. atmospheric nuclear weapons testing who had leukemia. CDC suspected an abnormal incidence of leukemia among participants in Shot SMOKY, conducted on 31 August 1957 as part of Operation PLUMBBOB.
6 May 1977	Ad hoc DoD committee met to formulate goals and an agenda for conducting a detailed review of troop participation in the atmospheric nuclear test program. The committee was chaired by the Director of the DNA's AFRRI and included representatives from various Army organizations, such as the Office of the Surgeon General, Office of the Deputy Chief of Staff for Operations and Plans, and Office of the Chief of Public Affairs.
3 June 1977	DoD, DOE, REECo, and LANL representatives met at the DOE Nevada Operations Office in Las Vegas to determine the availability of information on personnel exposures to ionizing radiation during the atmospheric nuclear tests.
15 June 1977	Army provided initial participant information to CDC concerning the Provisional Company, 82nd Airborne Division, which was one of the Army contingents that had been at Shot SMOKY.
3 November 1977	Interagency committee, involving DoD, DOE, VA, and the U.S. Public Health Service, met to discuss the possible long-term health effects resulting from participation in atmospheric nuclear weapons testing. The attendees recommended that a major epidemiological study of test participants be undertaken under the direction of an independent scientific organization and that a central administrative unit be established within DoD to coordinate all related activities.
1 December 1977	Meeting convened by the Assistant Secretary of Defense for Health Affairs to address the atmospheric nuclear weapons testing program and the possible relationship between participation in the program and an increased incidence of disease attributable to radiation exposure. Participants included representatives from the military services, DNA, DOE, VA, CDC, and NRC/NAS, as well as epidemiological consultants from Walter Reed Army Medical Center. Results of the meeting were decisions to solicit a formal proposal for a study of the atmospheric nuclear test participants from NRC and the unofficial assignment of DNA as the DoD executive agency for all matters pertaining to DoD personnel participation in the atmospheric nuclear test program.

January 1978	DOE began its research on the nuclear test participants with specific emphasis on identifying military personnel.
25 January and 14 February 1978	DNA representatives testified at a hearing held by the Subcommittee on Health and Environment of the House Committee on Interstate and Foreign Commerce. They summarized DNA efforts to develop data on DoD participants in atmospheric nuclear weapons testing. DOE also testified regarding DoD participants and exposures.
28 January 1978	Assistant Secretary of Defense, Manpower, Reserve Affairs, and Logistics, officially designated DNA as DoD executive agent to develop information on DoD personnel participation in the U.S. atmospheric nuclear weapons tests.
9 February 1978	DNA initiated its nationwide toll-free call-in program for veterans of the atmospheric nuclear tests to report their participation.
13 February 1978	DNA initiated the NTPR program by a memorandum to the Secretaries of the Military Departments that established basic relationships and procedures. The Services were to identify their respective personnel and individual exposures.
4 April 1978	DOE hosted a meeting attended by representatives of the DoD NTPR, National Archives, REECo, LANL, NAS/NRC, and each DNA contractor organization. The agenda focused on methods for identifying and obtaining records pertaining to atmospheric nuclear weapons testing.
7 April 1978	VA issued Circular 10-78-69 authorizing physical examinations for nuclear test participants.
9 May 1978	The White House directed the Department of Health, Education, and Welfare (HEW) to coordinate a task force investigation concerning the health effects of exposure to ionizing radiation.
8 June 1978	DNA established the data elements to be developed by the military services for each test participant.
23 June 1978	DNA accepted NAS protocol for study of the participants in the atmospheric nuclear tests.
13 July 1978	DNA representatives testified at a hearing held by the Subcommittee on Environment, Energy, and Natural Resources of the House Committee on Government Operations. They discussed DoD research to identify participants in the atmospheric nuclear weapons tests and possible exposures to ionizing radiation resulting from their participation.

7 March 1979	DNA representatives testified at a hearing held by the Senate Committee on Governmental Affairs. Issues discussed included health effects of low-level ionizing radiation; radiation safety; identification of personnel involved in testing; and fallout from tests.
March 1979	DNA initiated a notification and medical examination program for all DoD test participants with cumulative doses from atmospheric nuclear testing in excess of 25 rem.
April, May, and August 1979	Subcommittee on Oversight and Investigations, House Committee on Interstate and Foreign Commerce, conducted four hearings to consider health and safety issues related to the atmospheric nuclear testing program. The hearings, directed to civilian residents downwind of the tests, were on 19 April 1979 in Salt Lake City, Utah; 23 April 1979 in Las Vegas, Nevada; and 24 May and 1 August 1979 in Washington, D.C.
May 1979	DNA expanded the notification and medical examination program to include the Desert Rock volunteer observers.
8 May 1979	DNA representatives testified at a hearing held by the Subcommittee on Energy, Nuclear Proliferation and Federal Services of the Senate Committee on Governmental Affairs. They identified the progress made by DNA and the Service teams to collect data on DoD participants in atmospheric nuclear weapons testing.
June 1979	The DoD notification and VA medical examination program was expanded to include all veterans with doses in excess of 5.0 rem during any 12-month period.
15 June 1979	DoD and VA representatives signed a formal Memorandum of Understanding concerning the investigation of ionizing radiation injury claims from veteran atmospheric nuclear test participants.
20 June 1979	DNA representatives testified at a hearing held by the Senate Committee on Veterans' Affairs. They discussed the declassification of documents relevant to atmospheric nuclear weapons testing and dose reconstruction for test participants with no or incomplete dose records.
3 October 1979	DNA expanded the NTPR effort to include U.S. Service personnel who had participated in the postwar occupation of Hiroshima and Nagasaki, Japan.
August 1980	DNA issued a detailed fact sheet on the U.S. postwar occupation of Hiroshima and Nagasaki.
28 September 1980	The CBS television program "60 Minutes" aired a segment on the NTPR program.

3 October 1980	Preliminary findings of the CDC study concerning the incidence of leukemia among SMOKY participants appeared in the Journal of the American Medical Association.
5 March 1981	The ABC television program "20/20" reported on Operation WIGWAM, conducted in the Pacific on 14 May 1955. The report was based on an article on WIGWAM in the January 1981 edition of New West magazine.
13-14 May 1981	At the request of DNA, NRC convened a panel to review available data concerning personnel participation in the occupation of Hiroshima and Nagasaki, Japan. The panel subsequently advised DNA that the incidence of multiple myeloma among the occupation forces should be explored.
4 June 1981	VA issued Circular 10-81-99, updating procedures for physical examinations of atmospheric nuclear test participants.
July 1981	DOE opened CIC, a public archive in Las Vegas, Nevada, housing documents pertinent to U.S. nuclear weapons testing and NTPR.
1 September 1981	DNA published Operation WIGWAM, the first of the DNA histories on a U.S. atmospheric nuclear test series.
27 October 1981	DNA representatives testified at a hearing held by the Senate Committee on Labor and Human Resources. They commented on proposed Bill S. 1483, which would have made the U.S. liable in incidents related to fallout from the atmospheric nuclear weapons tests.
3 November 1981	Congress enacted Public Law 97-72, "Veterans' Health Care, Training, and Small Business Loan Act of 1981" which authorizes the VA to provide hospital and nursing home care and limited outpatient services to veterans exposed to ionizing radiation while participating in U.S. atmospheric nuclear testing or the Hiroshima/Nagasaki occupation. This law does not, however, provide for the care of conditions resulting from causes other than exposure to ionizing radiation.
April 1983	VA Circular 10-83-61 authorized treatment of test participant veterans for any ailment except those that are clearly not radiogenic in origin (e.g., appendicitis and traumatic injury).
6 April 1983	DNA representatives testified at a hearing held by the Senate Committee on Veterans' Affairs. They reported on the status of the NTPR program and related matters.

24 May 1983	DNA representatives testified at a hearing held by the Subcommittee on Oversight and Investigations of the House Committee on Veterans' Affairs. They outlined the scope and accomplishments of the NTPR program and discussed the Stafford Warren papers and Operation CROSSROADS.
June 1983	NRC completed its "Multiple Myeloma Among Hiroshima/Nagasaki Veterans," a study concluding that "the reported incidence of nine verified cases of multiple myeloma among U.S. veterans of the occupation forces stationed in or near Hiroshima and Nagasaki constitutes an incidence no greater than that in the general U.S. population." This report was mailed to all Hiroshima/Nagasaki veterans for whom DNA had a current address.
June 1983	DNA and the Navy NTPR mailed information to about 40,000 veterans of atmospheric nuclear weapons testing identifying free medical benefits available to them through VA.
5 August 1983	The results of the updated CDC study of Shot SMOKY participants appeared in the Journal of American Medical Association. The conclusions were that participant deaths due to cancer and total numbers of cancer cases were slightly less than the statistical norm. The only abnormal finding was a larger number than expected of leukemia cases. This number was attributed primarily to chance.
1 May 1984	DNA published Operation CROSSROADS 1946, the last of the DNA histories on a U.S. atmospheric nuclear test series.
24 October 1984	Congress enacted Public Law 98-542, "Veterans' Dioxin and Radiation Exposure Compensation Standards Act," which defined rules for adjudicating VA claims and established a panel of experts for addressing scientific issues.
1 May 1985	NRC published Mortality of Nuclear Weapons Test Participants, which discussed the results of its study by cause of death of 46,186 participants in the nuclear tests. However, limitations in the study have led to plans for a follow-on study for which protocols are being developed.
28 May 1985	VA issued Circular 10-85-83, which replaced VA Circular 10-83-61 and provided free medical care for participants in the atmospheric nuclear tests.
7 June 1985	DNA mailed information to about 45,000 veterans of atmospheric nuclear weapons testing outlining the NRC and CDC studies, the efforts of NTPR, and the free medical benefits available to them through VA. DNA also requested comments on its proposed rules for responding to VA claims.

July 1985	OTA issued its report entitled <u>An Evaluation of the Feasibility of Studying Long-Term Health Effects in Atomic Veterans</u>. OTA concluded that global studies concerning the health of nuclear test participants were not feasible. It suggested, however, that the SMOKY cohort previously studied by the CDC/NRC be researched at five-year intervals and that a mortality study be conducted of the participants in Operation CROSSROADS.
26 August 1985	VA published its final rules on "Adjudication of Claims Based on Exposure to Dioxin or Ionizing Radiation," in the <u>Federal Register</u>, Vol. 50, No. 165, pp. 34452-34461.
21 October 1985	DNA published its final rules on "Guidance for the Determination and Reporting of Nuclear Radiation Dose for DoD Participants in the Atmospheric Nuclear Test Program" in the <u>Federal Register</u>, Vol. 50, No. 203, pp. 42520-42525.
8 November 1985	GAO published its report <u>Operation CROSSROADS: Personnel Radiation Exposure Estimates Should Be Improved</u>. Regarding the CROSSROADS participants, GAO stated that (1) allowances had not been made for film badge inaccuracies, (2) personnel decontamination procedures were inadequate, and (3) DNA did not adequately evaluate internal radiation exposure.
3 December 1985	President Reagan signed Public Law 99-166, "Veterans Administration Health-Care Amendments of 1985." This law extended certain portions of Public Law 97-72, which provided health care benefits for eligible veterans.
11 December 1985	DNA representatives testified at a hearing held by the Senate Committee on Veterans' Affairs. They commented on issues pertaining to the possible radiation exposures received by participants in Operation CROSSROADS, conducted in 1946 at Bikini as the first postwar atmospheric nuclear test series.
7 February 1986	NAS made public its report entitled <u>Review of the Methods Used to Assign Radiation Doses to Service Personnel at Nuclear Weapons Tests</u>. This report reviewed the entire dose reconstruction effort and judged the methodology and processes to have sound scientific merit: "Although the committee concentrated only on methods, it found no evidence that the NTPR teams had been remiss in carrying out their mandate. If any bias exists in the estimates, it is the tendency to overestimate the most likely dose."

7 April 1986	The President signed Public Law 99-272, "Consolidated Omnibus Budget Reconciliation Act of 1985," which included a provision for VA inpatient care with no disability or means restrictions for all atmospheric nuclear test participants.
1 August 1986	DNA published For the Record - A History of the Nuclear Test Personnel Review Program, 1978-1986 (DNA 6041F). It described the origins, missions, and evolution of the effort, focusing on the contributions of the DNA, the NTPR teams, the VA, and the DOE. In addition, the narrative described U.S. nuclear operations, including weapons testing and the atomic bombing of Hiroshima and Nagasaki, personnel participation in those operations, and radiation safety measures. The report also discussed radiation dose determination and medical studies of potential dose effects.
29 September 1986	LTG John L. Pickett, Director, DNA, sent letters to each of the Service secretaries proposing consolidation of the NTPR effort under DNA's control.
28 October 1986	President Reagan signed Public Law 99-576, "Veterans' Benefits Improvement and Health Care Authorization Act of 1986," which required VA to establish an Ionizing Radiation Registry. Under the law, DNA is required to provide the relevant information to VA.
January-February 1987	A DOJ contractor began duplication of NTPR records for the NARS v. Turnage suit in the Northern District of California. A major portion of the program's paper records were copied as part of the effort with some disruption of regular activities.
20 February 1987	DNA supplied Senator Cranston with a listing of the high doses for each test series, to include: badge doses, reconstructed doses, and total doses.
March 1987	Each of the Service teams transferred tapes of its data base to the VA for the Ionizing Radiation Registry.
1 April 1987	MCNTPR disestablished.
8 April 1987	MCNTPR files transferred to DNA.
9 April 1987	NNTPR files transferred to DNA.
29 May 1987	DNA delivered tapes containing CROSSROADS data from Army, Navy, and Marine Corps File B data bases to NAS for CROSSROADS mortality study.

29 September 1987	GAO published Nuclear Health and Safety: Radiation Exposures of Some Cloud-Sampling Personnel Need to Be Reexamined (GAO/RCED-87-134). GAO concluded that for some Air Force personnel at Operations REDWING and DOMINIC I external radiation exposure was understated. Moreover, ground personnel during Operations TUMBLER-SNAPPER and REDWING did not consistently wear protective breathing devices when working around contaminated aircraft. Consequently, the amount of internal radiation they received needed to be evaluated.
1 October 1987	The Army, Navy, and Marine Corps NTPR teams were formally consolidated under DNA.
23-25 November 1987	Commander R. Thomas Bell, DNA, testified at NARS suit in Northern District of California.
28 January 1988	DNA and its NTPR contractors briefed the NAS committee investigating accuracy of film badges used at atmospheric nuclear tests.
22 February 1988	DNA took over the work of the Field Command NTPR team.
24 February 1988	Commander R. Thomas Bell and Carlton Chapman of DNA briefed an American Legion group - some 60 service officers and 15 Washington office staffers.
8 April 1988	DNA's Radiation Policy Division relocated from the agency's main building to the nearby Telegraph Village shopping center where it set up a public reading room for veterans and other interested parties.
20 May 1988	President Reagan signed Public Law 100-321, "The Radiation-Exposed Veterans Compensation Act of 1988," which provided a presumption of Service connection to veterans who participated in atmospheric nuclear tests and the occupation of Hiroshima and Nagasaki, Japan, after World War Two. The bill identified 13 radiogenic diseases for compensation.
8 June 1988	Air Force NTPR work and records consolidated at DNA.
18 November 1988	President Reagan signed Public Law 100-687, "Veterans Judicial Review Act," which established procedures for the adjudication of veterans' benefits claims. Although the procedures apply to all veterans' claims, the legislation resulted largely from pressure brought through lobbying by atomic veterans' organizations. The legislation created the Court of Veterans Appeals to consider appeals from denials of claims.
26 May 1989	Director, DNA, met with representatives from the American Legion, VFW, DAV, NAAV, and NARS.

14 June 1989	NTPR informational material was sent to Retired Officers Association, Fleet Reserve Association, Retired Enlisted Association, Shift Colors, Army Echoes, and Afterburner.
21 June 1989	VA published its final implementing regulations for Public Law 100-321, in the Federal Register, Vol. 54, No. 118, pp. 26027-26030.
August 1989	DNA began mailing information on Public Law 100-321 to all veterans with current addresses on the File A data base, a group of about 42,000 at the time.
1 August 1989	DNA provided training to adjudication officers from VA Regional Offices.
12 and 26 September 1989	DNA provided training about NTPR to staff from VA Regional Offices.
2 October 1989	VA published an amendment to its final rule on "Evaluation of Studies Relating to Health Effects of Dioxin and Radiation Exposure," in the Federal Register, Vol. 54, No. 189, pp. 40388-40392.
2 October 1989	DNA provided training to VFW National Service Officers in Minneapolis, Minnesota.
16 October 1989	Court of Veterans' Appeals convened and began work.
18 October 1989	VA promulgated (in the Federal Register, Vol. 54, No. 200, pp. 42802-42803) an amendment to its final regulations on "Claims Based on Exposure to Ionizing Radiation," which added posterior subcapsular cataracts and non-malignant thyroid nodular disease to the list of diseases adjudicated in accordance with Public Law 98-542.
7 February 1990	The Court of Veterans' Appeals heard its first case, that of Ernest Erspamer, a participant in Operation CROSSROADS.
23 February 1990	The Court of Veterans' Appeals instructed the VA to resolve the Erspamer case within six months.
April and May 1990	DNA provided NTPR dosimetry tapes to VA for the Ionizing Radiation Registry as called for in Public Law 99-576.
15 October 1990	President Bush signed Public Law 101-426, "The Radiation Exposure Compensation Act," which provided compensation for certain person who lived downwind from the nuclear weapons tests in Nevada and to certain uranium miners.

5 November 1990	President Bush signed Public Law 101-510, "1991 DoD Authorization Act," which amended Public Law 101-426 to include among the eligible beneficiaries those who participated onsite in atmospheric nuclear testing. This expansion included veterans.
August 1991	VA established a toll-free National Radiation Help Line to assist veterans and their families with radiation disability claims.
14 August 1991	President Bush signed Public Law 102-86, "Veterans' Benefits Program Improvement Act of 1991," which amended PL 100-321 to extend the presumptive period for leukemia from 30 years to 40 years and to extend eligibility for presumptions to members of the Reserves and National Guard who participated in U.S. atmospheric nuclear testing.
13 November 1991	DNA representative testified before the Compensation, Pension, and Insurance Subcommittee of the House Committee on Veterans' Affairs during hearings on the extension of the list of presumptive Service-connected diseases and the requirement that DoD and VA study additional radiation exposure activities.
26 March 1992	The United States District Court for the Northern District of California entered judgment in the NARS lawsuit. The Court found the $10.00 attorney fee limitation unconstitutional and required the VA to notify potential eligible class members of their right to have prior claims readjudicated if they retain an attorney.
10 April 1992	DOJ published final rules for Public Law 101-462, "Claims Under the Radiation Exposure Compensation Act," as amended by Public Law 101-510, "DoD Authorization Act," in the Federal Register, Vol. 57, No. 70, pp. 12428-12461.
11 June 1992	VA published Circular 21-92-5 regarding the readjudication of ionizing radiation claims as a result of the NARS case.
August 1992	OTA issued a background paper titled "A Discussion of Questions about the 1985 NAS Report Mortality of Nuclear Test Participants." OTA found that the inaccuracies reported by DNA to NAS in 1989 concerning the number of veterans misidentified as participants as well as the number not included in the study were overstated. However, OTA found that even the lower numbers were substantial and the resulting inaccuracies could have affected the results of the study. Moreover, the dose information on the participants had been updated and those changes could also affect analyses of cancer risks. OTA concluded that the study should be redone, although it remained an open question whether an explicit internal control group was needed.

10 August 1992	GAO published Nuclear Health and Safety: Mortality Study of Atmospheric Nuclear Test is Flawed (GAO/RCED-92-182). GAO concluded that there were inaccuracies in the list of participants and exposure data used by NAS in preparing the report Mortality of Nuclear Weapons Test Participants.
30 October 1992	President Bush signed Public Law 102-578, "Veterans' Radiation Exposure Amendments of 1992." It amends Public Law 100-321 by eliminating the latency period for the diseases listed in that legislation and by adding salivary gland and urinary tract cancers to the list of diseases that are presumed to be service-connected. It also amends Public Law 98-542 in two ways. It requires (1) a review of information on other activities military personnel performed before 1 January 1970 that may have exposed them to ionizing radiation to determine whether there were adverse health effects in a significant number of these veterans, and (2) a review of information on bronchio-alveolar cancer to see whether it should be considered radiogenic.
26 March 1993	VA promulgated (in the Federal Register, Vol. 58, No. 57, pp. 16358-16359) an amendment to its final regulations on "Claims Based on Exposure to Ionizing Radiation," which added ovarian cancer and parathyroid adenoma to the list of diseases adjudicated in accordance with Public Law 98-542.

APPENDIX B

GLOSSARY

The following technical and organizational terms are used in this volume.

ABSORBED DOSE	The amount of energy absorbed per unit mass of irradiated material. Absorbed dose is measured in rads.
AIR BURST	The explosion of a nuclear weapon at such a height that the expanding fireball does not touch the earth's surface.
AIR SAMPLING for RADIOACTIVITY	The process of collecting certain volumes of air to determine the level of radioactivity in the air.
ALPHA PARTICLE	A form of particulate radiation emitted from the nuclei of certain radioactive elements. An alpha particle is composed of two neutrons and two protons and is identical to the nucleus of a helium atom, having a double positive charge. An alpha particle cannot penetrate clothing or the outer layer of skin, so it is not an external exposure hazard. Such a particle can be extremely hazardous, however, if exposure occurs internally.
ATOM	The smallest particle of an element that still retains the characteristics of that element. Every atom consists of a positively charged central nucleus, which carries nearly all the mass of the atom. The nucleus is generally composed of uncharged neutrons and positively charged protons. It is surrounded by electrons that carry a negative charge.
ATOMIC ENERGY	Energy released by various nuclear reactions, such as fission, fusion, or radioactive decay. Great amounts of energy are released during fission and fusion processes. The release of this energy in a very short time makes nuclear weapons far more powerful than conventional explosives. Nuclear energy is another and a more appropriate label for this energy.
BETA BURNS	Skin lesions caused by deposition of beta-emitting fallout particles onto bare skin.
BETA PARTICLE	A particle with a single negative charge and very small mass emitted spontaneously from the nuclei of certain radioactive elements. Physically, the beta particle is identical to an electron moving at high speed.

BIOASSAY	The determination of the concentration of materials, including radioactive materials, within the body by sampling and analyzing tissue or body fluids.
BURST	An explosion or detonation.
CHAIN REACTION	A reaction that stimulates its own repetition, usually referring to fission or fusion reactions.
CLOUD-SAMPLING	The process of collecting samples of the cloud resulting from a nuclear detonation to determine the amount of airborne radioactivity, both particulate and gaseous, contained in the cloud. This was usually conducted by specially equipped aircraft.
CLOUD STEM	The visible column of debris (and possibly dust and water droplets) extending upward from the point of burst of a nuclear device.
CLOUD TRACKING	The process of using either radar or aircraft to monitor the drift of a cloud resulting from a nuclear detonation.
CONTAMINATION, RADIOACTIVE	The presence of unwanted radioactive material on or within areas, objects, or persons.
CUMULATIVE DOSE	The total dose resulting from repeated or continued exposure to radiation.
DECAY, RADIOACTIVE	The spontaneous emission of radiation, in the form of alpha or beta particles or by gamma rays. The radiation is emitted by an unstable isotope. As a result of the emission, the radioactive isotope is converted into a different element that may or may not be radioactive.
DECONTAMINA-TION	The reduction in the effect of contaminating radioactive material or the removal of contaminating radioactive material from a structure, area, object, or person.
DEVICE, NUCLEAR	An explosive device deriving the energy of its explosion from either a fission reaction or a combination of a fission and a fusion reaction. Devices using fission only are usually referred to as atomic or nuclear weapons. Those using the combination of fission and fusion reactions are often termed hydrogen weapons. A device's yield is determined by the details of its construction.
DOSE	See ABSORBED DOSE or DOSE EQUIVALENT.

DOSE EQUIVALENT	The absorbed dose expressed in terms of its biological effect. It is the product of the absorbed dose in rads multiplied by a quality factor and any modifying factors. The dose equivalent is expressed in rem.
DOSIMETER	A device for measuring and recording the total accumulated dose of (or exposure to) ionizing radiation. Devices worn or carried by individuals are called personnel dosimeters.
DOSIMETRY	The theories about and applications of the techniques involved in measuring and recording radiation doses and dose rates. Its practical application includes the use of various types of radiation detection instruments and devices to measure radiation.
EXPOSURE, X or GAMMA RADIATION	A measure of the ionization produced by gamma (or X) rays in air. The exposure rate, exposure per unit of time, is commonly used to indicate the gamma radiation intensity of a source. The unit of exposure is the roentgen (R).
FALLOUT	The descent to the earth's surface of particles contaminated with radioactive material as a result of a nuclear detonation. The term also applies to the contaminated particulate matter itself.
FILE A	The NTPR data base consisting of information extracted from telephone calls to the DNA toll-free lines and from letters sent by participants in the atmospheric nuclear weapons tests and in the postwar occupation of Hiroshima and Nagasaki.
FILE B	The NTPR data base that has been created with verified information on individual veterans gathered by NTPR researchers since the program began in 1978. Originally, each Service team had its own, but these were combined after consolidation. Each record has space for, among other things: the veteran's name, serial number, social security number, address, whether he has filed a VA claim, date of birth and death, cause of death, participation data, and dose data. Currently it is more often referred to as the NTPR data base rather than File B. As of 30 September 1993, it contained about 401,000 records.
FILM BADGE	A personnel dosimeter which uses photographic film to measure the radiation dose of the wearer. The badge is usually clipped to an outer garment above waist level. The dose is calculated from the degree of film darkening that results from exposure to radiation.
FIREBALL	The luminous sphere of hot gases that forms a few thousandths of a second after a nuclear detonation.

FISSION	The splitting of a heavy nucleus into two or more radioactive nuclei, accompanied by the release of a large amount of energy and generally one or more neutrons and one or more gamma rays.
FUSION	The formation of a heavier nucleus from two lighter nuclei, accompanied by the release of a large amount of energy.
GAMMA RAYS	A form of electromagnetic radiation emitted spontaneously from the nuclei of certain radioactive elements, often in conjunction with the emission of alpha or beta particles. Gamma rays also result from other nuclear reactions, such as fission and neutron capture. Gamma rays are identical to X-rays, except that they originate within the nucleus. Gamma rays travel great distances in the air and can easily penetrate most substances.
GROUND ZERO (GZ) or SURFACE ZERO (SZ)	The point on the ground vertically below or above the center of a nuclear burst; frequently abbreviated GZ. This is also referred to as surface zero, especially for underwater or overwater bursts.
HALF-LIFE, RADIOLOGICAL	The time required for a radioactive substance to lose one-half of its activity by radioactive decay.
HEALTH PHYSICS	The branch of radiological science dealing with the protection of personnel from exposure to ionizing radiation.
HEIGHT OF BURST	The height above the earth's surface at which a device is detonated.
HIGH-ALTITUDE BURST	A detonation at an altitude over 100,000 feet.
INDUCED RADIOACTIVITY	Radioactivity produced in certain materials as a result of the capture of neutrons. In a nuclear detonation, neutrons induce radioactivity in the weapon debris as well as in the surroundings.
INITIAL NUCLEAR RADIATION	Nuclear radiation (essentially neutrons and gamma rays) emitted from the fireball and the cloud during the first minute after a nuclear explosion. One minute is the time required for the source of part of the radiations (such as fission products in the cloud) to attain such a height that only insignificant amounts of radiation from the cloud reach the earth's surface.
INTENSITY, NUCLEAR RADIATION	The amount of energy of any radiation incident on an area. This term, usually applied to gamma radiation, expresses the exposure rate (in R/hour) at a given location.

IONIZATION	The removal of an electron from an atom, leaving a positively charged ion. The detached electron and the remaining ion are referred to as an ion pair.
IONIZING RADIATION	Electromagnetic radiation (gamma rays or X-rays) or particulate radiation (alpha particles, beta particles, or neutrons) capable of producing ions during its passage through matter.
KILO-	A prefix denoting 1,000. For example, one kiloton means 1,000 tons.
MANHATTAN ENGINEER DISTRICT	The district of the U.S. Army Corps of Engineers, organized in 1942, that developed the atomic bomb.
MEGA-	A prefix denoting 1,000,000. For example, one megaton means 1,000,000 tons.
MONITORING	The procedure or operation of locating and measuring radiation and radioactive contamination by means of survey instruments. Persons engaged in this activity are referred to as radiological monitors.
NEUTRON	One of the elementary particles of an atom. Neutrons are uncharged and have a mass number of one. They are necessary to initiate the fission process, and large numbers of them are produced in fission and fusion processes. They constitute a significant portion of the prompt radiation from both fission and fusion detonations. Neutrons travel great distances in the air and can readily penetrate most substances.
NEVADA TEST SITE (NTS)	The region in southeast Nevada set aside for the continental atmospheric nuclear weapons testing program. Known first as the Nevada Test Site, then as the Nevada Proving Ground (NPG) beginning in early 1952, the site since 1955 has again been called the NTS.
NUCLEAR DETONATION	A general name given to any explosion in which the energy released results from reactions involving atomic nuclei, either fission or fusion or both.
NUCLEAR RADIATION	Radiation emitted from unstable nuclei. Important nuclear radiations are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true. X-rays, for instance, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atomic nuclei.

NUCLEAR TEST PERSONNEL REVIEW (NTPR)	A program established by the DNA to conduct a series of wide- ranging actions on behalf of U.S. atmospheric nuclear test participants and veterans of the postwar U.S. occupation of Hiroshima and Nagasaki, Japan.
OFFSITE	The area outside the boundaries of the NTS.
ONSITE	The total area encompassed by the NTS, including Camp Mercury, Frenchman Flat, Yucca Pass, and Yucca Flat. For oceanic testing, the various test sites and the official zone around each from which ships not affiliated with the tests were excluded for security and safety reasons.
PHOTON	A very small parcel of radiant energy.
PROMPT RADIATION	Radiation emitted from a nuclear detonation within a microsecond of detonation. It consists mainly of neutron and gamma radiation.
RAD	For contaminated testing, the unit of absorbed radiation dose that represents the absorption of 100 ergs of ionizing radiation per gram of absorbing material, such as body tissue.
RADIATION	Energy radiated in the form of waves or particles. In the case of nuclear explosions and the radioactive material created by them, the waves of concern are electromagnetic waves with wave lengths from 10^{-11} to 10^{-3} centimeters, especially gamma rays, and the photons associated with them. The particles of concern are alpha and beta particles and neutrons.
RADIOACTIVITY	The spontaneous emission of alpha or beta particles, neutrons, or gamma rays from the nuclei of unstable atoms. As a result of this emission, the radioactive atom decays into another atom that may or may not also be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) end product is formed.
REM	The unit of dose equivalent, which is the amount of any ionizing radiation that produces the same biological effect as one rad of gamma or X-radiation. The rem is the product of the absorbed dose (rads) times a quality factor and any other modifying factor. For gamma and x-rays, the 1 rad equals 1 rem and both are approximately equal to 1 roentgen.
RESIDUAL RADIATION	Nuclear radiation, chiefly beta particles and gamma rays, that persists after the first minute following a nuclear detonation. The radiation is emitted mainly by fission products and materials in which radioactivity has been induced by the capture of neutrons.
RESPIRATOR	A device worn over the mouth and nose to prevent the inhalation of hazardous material.

ROENTGEN	A unit of exposure to gamma radiation or X-radiation. It is the quantity of gamma rays or X-rays that produces 2.08×10^9 ion pairs in a cubic centimeter of air at standard temperature and pressure. An exposure of one roentgen is approximately equal to an absorbed dose of one rad in soft tissue.
SHIELDING	Any material or obstruction that absorbs or attenuates radiation and thus tends to reduce exposure of personnel on the side away from the radiation source. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed to provide shielding from gamma rays.
SURFACE BURST	The explosion of a nuclear device at a height above the surface less than the radius of the fireball. An explosion in which the device is detonated on the surface itself is called a contact surface burst or a true surface burst.
THERMONUCLEAR	An adjective referring to the process in which very high temperatures are used to bring about the fusion of hydrogen nuclei with the accompanying liberation of energy. A thermonuclear device is one in which part of the explosive energy results from thermonuclear fusion reactions. The high temperatures required are obtained by means of a fission explosion.
X-RAYS	Penetrating electromagnetic radiation similar to gamma rays but of non-nuclear origin and generally of lower energy.
YIELD	The total effective energy released in a nuclear detonation. It is usually expressed in terms of the TNT equivalent required to produce the same energy release in an explosion. Nuclear detonation yields are commonly expressed in kilotons or megatons (thousands or millions of tons) of TNT equivalent.

Many of the definitions cited above have been adapted from Glasstone and Dolan; Atomic Energy Commission, Nuclear Terms; and Bureau of Radiological Health Publication Number 2016.

APPENDIX C

LIST OF ABBREVIATIONS AND ACRONYMS

This volume uses the following abbreviations.

AEC	Atomic Energy Commission
AFB	Air Force Base
AFIP	Armed Forces Institute of Pathology
AFNTPR	Air Force Nuclear Test Personnel Review Team
AFRRI	Armed Forces Radiobiology Research Institute
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
ANL	Argonne National Laboratory
ANTPR	Army Nuclear Test Personnel Review Team
BEIR	Biological Effects of Ionizing Radiation
BIRLS	Beneficiary Identification and Records Locator Subsystem (VA)
CDC	Centers for Disease Control
CIC	Coordination and Information Center
CIRRPC	Committee on Interagency Radiation Research and Policy Coordination
CONUS	Continental United States
DASA	Defense Atomic Support Agency
DMA	Division of Military Application
DNA	Defense Nuclear Agency
DoD	Department of Defense
DOE	Department of Energy
DOJ	Department of Justice
DoL	Department of Labor
DREF	Dose Rate Effectiveness Factor
EG&G	Edgerton, Germeshausen, & Grier, Inc. (former name)
FCDA	Federal Civil Defense Administration
FCNTPR	Field Command Nuclear Test Personnel Review
GAO	General Accounting Office
HAI	History Associates Incorporated
HEW	Health, Education, and Welfare
ICRP	International Commission on Radiological Protection
JCS	Joint Chiefs of Staff
JTO	Joint Test Organization
LANL	Los Alamos National Laboratory, previously the Los Alamos Scientific Laboratory (LASL)
LASL	Los Alamos Scientific Laboratory
LLNL	Lawrence Livermore National Laboratory, previously the University of California Radiation Laboratory (UCRL)
MED	Manhattan Engineer District
MCNTPR	Marine Corps Nuclear Test Personnel Review Team
NAAV	National Association of Atomic Veterans

NARS	National Association of Radiation Survivors
NAS	National Academy of Sciences
NNTPR	Navy Nuclear Test Personnel Review Team
NPG	Nevada Proving Ground
NPRC	National Personnel Records Center
NRC	National Research Council of the National Academy of Sciences
NTIS	National Technical Information Service
NTPR	Nuclear Test Personnel Review
NTS	Nevada Test Site, known as the Nevada Proving Ground (NPG) from 1952 to 1955
NV	Nevada Operations Office
OEHL	Occupational and Environmental Health Laboratory
OoRP	Office of Radiation Programs
OTA	Office of Technology Assessment
PHS	Public Health Service
PPG	Pacific Proving Ground, sometimes called the Enewetak Proving Ground or Bikini Proving Ground
RARP	Radiation Policy Division
RAEM	Environments and Modeling Division
REECo	Reynolds Electrical & Engineering Company, Incorporated
SAIC	Science Applications International Corporation
SWC	Special Weapons Command
UCRL	University of California Radiation Laboratory
UNSCEAR	United National Scientific Commission on the Effects of Atomic Radiation
VA	Veterans Administration; on 26 March 1989 became the Department of Veterans Affairs
VARO	Department of Veterans Affairs Regional Office

APPENDIX D

PUBLIC RESOURCES FOR DOCUMENTS ON U.S. ATMOSPHERIC NUCLEAR WEAPONS TESTING

Documents pertinent to the continental and oceanic series of atmospheric nuclear tests can be located at the NTIS and at CIC, introduced in Section 3.1.2. This appendix provides detail on both of these resources.

D.1 NATIONAL TECHNICAL INFORMATION SERVICE.

The NTIS, an agency of the Department of Commerce, is the central source for the public sale of Government-sponsored research reports and analyses. The NTIS Bibliographic Data Base consists of documents from a number of Government agencies but primarily from the DOE, DoD, and the National Aeronautics and Space Administration. The agency supplies its customers with about 23,000 information products daily and approximately four million documents and microforms annually.

The NTIS information collection comprises over one million titles, all of which can be purchased under the provisions of Title 15 U.S. Code 1151-7. This law established NTIS as a clearinghouse for scientific, technical, and engineering information and directed the agency to recover its costs through the sale of information and services.

Documents available for purchase at NTIS include the 41-volume history of atmospheric nuclear weapons testing developed by DNA as part of the NTPR program. Appendix E lists these volumes according to title, DNA number, date of publication, number of pages, NTIS price code, and NTIS order number. Other NTIS materials relevant to the nuclear testing program are over 1000 documents declassified by DNA in partial fulfillment of NTPR tasking.

The address is: National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161. The telephone number (703) 487-4650 should be used when the caller has the NTIS order number and the price code. The caller should dial (703) 487-4780 when he or she does not have this information for a document.

NTIS standard prices for documents and microfiche are identified below. For billing purposes, NTIS accepts the American Express Card, Master Card and VISA accounts, as well as personal checks. There is a $3 handling charge per order.

NTIS DOMESTIC PRICE SCHEDULES EFFECTIVE AS OF 1 OCTOBER 1992

Price Codes and Prices for Documents
Microfiche and Paper Copy Reports

Price Code	Price
A01	$ 9.00
A02	12.50
A03	17.50
A04 and A05	19.50
A06 through A09	27.00
A10 through A13	36.50
A14 through A17	44.50
A18 through A21	52.00
A22 through 25	61.00

D.2 COORDINATION AND INFORMATION CENTER.

Most of the unclassified documents available at the NTIS are also accessible at CIC. This section presents information from a DOE fact sheet (dated 4 March 1991) detailing the CIC purposes, scope, and procedures, including the current fee schedule.

DEPARTMENT OF ENERGY
COORDINATION AND INFORMATION CENTER

Purpose

The purpose of CIC is to:

- Collect and consolidate, for long term preservation, all historical documents, records, and data dealing with offsite radioactive fallout from all U.S. testing of nuclear devices;

- Provide resources and methods for identification and retrieval of documents based on subject and content; and

- Allow access to the collected documents by all interested parties, including the general public.

Scope

The CIC, as a publicly accessible facility, contains only unclassified documents. Many formerly classified documents have been declassified or sanitized and are included in the CIC collection. There are **no** classified documents available at or through the CIC.

The scope of the collection includes:

- Data and documentation on the detection and measurement of radioactive fallout and related factors resulting from nuclear device test activities at the NTS, the TRINITY event, the PPG, and other on-continent test locations;

- Policy documents dealing with procedures and conduct of tests and with public safety considerations and actions;

- Published and primary sources describing the development and state-of-knowledge of the health effects of radiation;

- Documents dealing with public information as disseminated through such media as pamphlets, news releases, and news publications; and

- Related studies and reports produced by the scientific and technical field.

Sources and Types of Information

The CIC began document collection in the fall of 1979. Since then it has indexed an estimated 260,000 documents. Collection activities are continuing, and it is anticipated that approximately 390,000 documents will ultimately be included in the collection.

To date, documents have been received from over 80 individual and agency contributors. The major source of documents have been the DOE Headquarters; the DOE/NV; the Las Vegas and Washington, D.C., offices of the Environmental Protection Agency; the DoD's DNA and Defense Technical Information Center; the DOE Technical Information Center in Oak Ridge; the DOE Environmental Measurement Laboratory in New York City; the LANL; the University of California Project 37 Files; the Utah State Archives in Salt Lake City; the Nevada State Archives in Carson City; the Weather Service Nuclear Support Office; and the Technical Library of REECo, at Mercury, Nevada.

The following describes, in general, the content of some of the most significant collections:

- Documents collected from the archives in the Historian's Office of the DOE Headquarters focus primarily on the policy and decision making activities of the AEC. These include the minutes of the AEC, the General Advisory Committee, and the Advisory Committee for the Division of Biology and Medicine, executive correspondence, secretariat papers, staff papers, and special reports for the AEC, the Division of Biology and Medicine, and Division of Military Applications.

- The DOE Nevada Operations files yielded a wide variety of documentation, including operational and administrative orders, reports, procedures, and correspondence regarding conduct of nuclear testing.

- The files of the Las Vegas Environmental Protection Agency (successor to the Public Health Service) contains monitoring, sampling, and surveillance data and reports of the monitoring program in the offsite area out to 250 miles from the NTS from 1954 to the present.

- DOE's Environmental Measurements Laboratory collection contains monitoring, sampling, and surveillance data and reports from the area beyond 250 miles from the NTS.

- The files of Project 37 of the University of California deal with soil sampling, monitoring, and the persistence of fallout from select test events within the 250 mile radius of the NTS.

- By request of the HEW Department, a review of the records from the Washington, D.C., offices of the old Public Health Service was conducted in 1979. This review produced a three volume report, "Effects of Nuclear Weapons Testing on Health Report of the Panel of Experts on the Archives of PHS Documents," which lists approximately 12,000 documents. The three volume report and microfilm copy of all documents listed are in the CIC collection.

- The NTPR program produced a series of summary reports on the Pacific and continental atmospheric weapons tests in which DoD and military personnel participated. The CIC is a repository for the summary reports and for many of the reference documents used as sources.

- In January 1979, at the request of Governor Scott M. Matheson, all Utah State offices surveyed their records and files and produced a collection of documents dealing with fallout, the health effects of ionizing radiation, and related topics. Microfilm copy of this collection is resident in the CIC.

- The initial group of documents obtained from LANL contains copies of the original offsite monitoring logs for Operation UPSHOT-KNOTHOLE in 1953. The logs contain original recordings and summation of radiation measurements, sampling collections and related data. A second more extensive collection of the LANL documents contains reports, correspondence, and data related to LANL involvement in nuclear testing.

- The University of Washington and the Scripps Institution of Oceanography collections include data and reports covering their projects to document the ocean and oceanic ecosystems during the Pacific atmospheric testing era.

- The CIC collection includes press releases issued by DOE and predecessor offices as well as an extensive collection of newspaper articles which reflect the concern for public information and the public attitude and knowledge about the testing program in Nevada.

CIC Facilities and Services

The CIC facility provides accommodations for:

- A public reading room where documents of general public interest are available for review,
- A research area where requested documents may be used for more in-depth study,
- Computer terminals for staff-assisted research of the data base and files,
- Printed and microfiche indices to the collection,
- Microform reader/printers for review and copy of documents contained only on microform, and
- Document duplication equipment.

A staff of technical and clerical personnel is available to provide research assistance and access to documents.

CIC is open for visitors from 9:00 a.m. to 4:00 p.m., Monday through Friday. Requests for services should be made to Coordination and Information Center, Reynolds Electrical and Engineering Co., Inc., Post Office Box 98521, Las Vegas, Nevada 89193 or by calling commercial (702) 295-0731 or FTS 575-0731.

D.3 DNA NTPR LIBRARY.

DNA maintains a library of unclassified material on U.S. atmospheric nuclear testing for the use of veterans and the public. The library's holdings include a full set of the NTPR histories, a full set of the dose reconstruction publications, and a modest number of declassified documents on nuclear testing from the 1945 to 1962 period. Microfilm and microfiche readers are available to read material in those forms. The library is open from 8 a.m. to 4:30 p.m. Monday through Friday. Appointments can be made by calling (703) 325-7744 or writing:

Defense Nuclear Agency
ATTN: RAEM/NTPR
6801 Telegraph Road
Alexandria, Virginia 22310-3398

APPENDIX E

DNA NTPR PUBLICATIONS ON THE CONUS AND OCEANIC ATMOSPHERIC NUCLEAR TESTS AS OF 30 SEPTEMBER 1993

AVAILABILITY INFORMATION

An availability statement is included at the end of the reference citation for those readers who wish to read or obtain copies of source documents.

Source documents bearing an availability statement of NTIS may be purchased from the National Technical Information Service. When ordering by mail or phone, both the price code and NTIS number should be included. The price code appears in parentheses before the NTIS order number.

National Technical Information Service		
5285 Port Royal Road	Phone:	(703) 487-4650 (Sales Office)
Springfield, Virginia 22161		(703) 487-4780 (Identification)

Source documents bearing an availability statement of CIC may be ordered or reviewed at the following address:

Department of Energy		
Coordination and Information Center		
(Operated by Reynolds Electrical & Engineering Co., Inc.)		
3084 South Highland		
P.O. Box 98521, Mail Stop 548	Phone:	(702) 295-0731
Las Vegas, Nevada 89193	FTS:	(702) 575-0731

NTPR PUBLICATIONS ON THE CONUS AND OCEANIC ATMOSPHERIC NUCLEAR TESTS AS OF 30 SEPTEMBER 1993

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See Availability Information page.
*Available from NTIS; price code and order number appear before the asterisk.
Also available at CIC.

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