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OPERATION HARDTACK I

1958

United States Atmospheric Nuclear Weapons Tests
Nuclear Test Personnel Review

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

DARE#
24675

HARDTACK, UMBRELLA with <u>SS Michael Moran</u> (EC-2) in foreground.

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Nuclear Test Personnel Review (NTPR)	WAHOO	CACTUS
HARDTACK Phase I	UMBRELLA	FIR
Johnston Island	YUCCA	BUTTERNUT
Enewetak, Bikini	TEAK	KOA

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

HARDTACK I was an atmospheric nuclear weapon test series held at Johnston Island and in the Marshal Islands at Enewetak and Bikini atolls in 1958. This is a report of DOD personnel in HARDTACK with an emphasis on operations and radiological safety.

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7. AUTHORS (Continued)

S.E.Davis, M.K. Doyle, C.B. Jones, J. Yurechko

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HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, MAPLE, ASPEN, WALNUT, LINDEN, REDWOOD, ELDER, OAK, HICKORY, SEQUOIA, CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, PINE, QUINCE, FIG, NEWSREEL.

FACT SHEET

HARDTACK was the designation given to the atmospheric nuclear weapon tests conducted by the United States in the Pacific Ocean and in Nevada in 1958. Operation HARDTACK I was a series of 35 tests, all but two of which were detonated at Enewetak* and Bikini atolls in the Marshall Islands, the Atomic Energy Commission's (AEC) "Eniwetok Proving Ground" (EPG). The other two were detonations at 42 and 76 km above Johnston Island, which lies about 700 nmi (1,296 km) west-southwest of the Hawaiian Islands.

The tests were conducted by a joint military and civilian organization, designated Joint Task Force 7 (JTF 7). JTF 7 was a military organization in form but was made up of military personnel, Federal civilian employees, and contractors of the Department of Defense (DOD) and the AEC. The commander of this force was the appointed representative of the AEC and reported also to the Joint Chiefs of Staff (JCS) and the Commander in Chief, Pacific (CINCPAC).

TEST OPERATIONS

During HARDTACK the United States fired as many nuclear devices (35) as had been fired in all prior Pacific Ocean tests. Not only was the total number of shots in HARDTACK large, but the variety of types was great; land- and water-surface events, underwater detonations, and balloon- and rocket-borne high-altitude tests were conducted. The following page of this fact sheet lists the names, dates, and locations of the shots.

In a sense, HARDTACK was divided into three parts. The first was aimed at the development of nuclear weapons, continuing the type of testing that had taken place at Enewetak and Bikini during the early and mid-1950s. In these tests, the AEC weapon development laboratories (Los Alamos Scientific Laboratory and the University of California Radiation Laboratory) detonated their experimental devices, with the DOD providing support and conducting experiments that did not interfere with the AEC activities.

The second part, sponsored by DOD, consisted of the underwater test shots, WAHOO and UMBRELLA, the first in the open ocean and the second within the lagoon at Enewetak. The purpose of these tests was to improve the understanding of the effects of underwater explosions on Navy ships and material. These tests could be considered as a continuation of BAKER test of the CROSSROADS series at Bikini in 1946 and the WIGWAM test 500 nmi (927 km) off the U.S. west coast in 1955.

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* Formerly Eniwetok. The spelling of Marshall Island place names has changed in recent years in order to more accurately render the sounds of the Marshall Island names using English spelling.

HARDTACK I detonations, 1958.

Local Date	Assigned Name	Location	Type Burst
28 April	YUCCA	Between Enewetak and Bikini	High Altitude (balloon)
6 May	CACTUS[a]	Enewetak	Surface
12 May	FIR	Bikini	Barge
12 May	BUTTERNUT	Enewetak	Barge
13 May	KOA[b]	Enewetak	Surface
16 May	WAHOO	Enewetak, in ocean	Underwater
21 May	HOLLY	Enewetak	Barge
22 May	NUTMEG	Bikini	Barge
26 May	YELLOWWOOD	Enewetak	Barge
27 May	MAGNOLIA	Enewetak	Barge
30 May	TOBACCO	Enewetak	Barge
31 May	SYCAMORE	Bikini	Barge
3 June	ROSE	Enewetak	Barge
9 June	UMBRELLA	Enewetak, lagoon	Underwater
11 June	MAPLE	Bikini	Barge
15 June	ASPEN	Bikini	Barge
15 June	WALNUT	Enewetak	Barge
18 June	LINDEN	Enewetak	Barge
28 June	REDWOOD	Bikini	Barge
28 June	ELDER	Enewetak	Barge
29 June	OAK[c]	Enewetak	Barge
29 June	HICKORY	Bikini	Barge
2 July	SEQUOIA	Enewetak	Barge
3 July	CEDAR	Bikini	Barge
6 July	DOGWOOD	Enewetak	Barge
12 July	POPLAR	Bikini	Barge
14 July	SCAEVOLA[d]	Enewetak	Barge
18 July	PISONIA	Enewetak	Barge
22 July	JUNIPER	Bikini	Barge
23 July	OLIVE	Enewetak	Barge
27 July	PINE	Enewetak	Barge
31 July	TEAK[e]	Johnston Island area	High Altitude (rocket)
6 August	QUINCE	Enewetak	Surface
11 August	ORANGE[e]	Johnston Island area	High Altitude (rocket)
18 August	FIG	Enewetak	Surface

Notes: Yields have not been announced except as noted below.

[a] 18 KT.

[b] 1.37 MT.

[c] 8.9 MT.

[d] Low.

[e] Megaton range.

The third part, also sponsored by DOD, addressed a military problem that was newer: nuclear weapons in air and ballistic missile defense. The HARDTACK tests directed toward this problem consisted of three high-altitude shots, two of which (TEAK and ORANGE) were rocket borne and were conducted at Johnston Island. The third of these high-altitude tests, YUCCA, was carried aloft by a balloon over the ocean between Enewetak and Bikini. These high-altitude tests used device placement techniques and data-recording operations that were new to nuclear weapons testing.

Central to the test series was the experimental program. This program and its requirements dictated the form of the test organization and the detail of personnel participation. HARDTACK's experimental program incorporated two aspects, the first of which was the development of the weapons themselves, and the second involved the measurement of the explosive and radiation effects. Unlike earlier nuclear test series, the HARDTACK test operations supporting each aspect were in large part separate.

These two aspects can serve as a rough measure of differentiation of interest between the major participants; the AEC interest in weapon development, and the DOD interest in the military application of the effects of the explosions. The several parts of the weapon development and effects studies each had particular features that led to the possibility of radiation exposure.

RADIOLOGICAL SAFETY

For Operation HARDTACK, CJTF 7 was directed to "assume overall responsibility for the radiological safety of Task Force personnel and of populated islands." To carry out this responsibilty, the JTF 7 Operation Plan further directed that a Fallout Plotting Center be set up and that the capability be established to keep the task force and CINCPAC informed of the fallout situation at all times, including the announcement of safe reentry times. Fallout stations were to be set up and technical assistance given to personnel in the Trust Territory of the Pacific Islands. Monitors and couriers were to be provided for radioactive sample centers.

In addition, the Operation Plan specified that task group commanders establish radiation safety (radsafe) units within the task groups with adequate special clothing and radiac instrumentation. Task groups were also to provide a roster of their personnel for film badge preparation.

The radsafe program for Operation HARDTACK was divided into two parts: onsite and offsite. Onsite radsafe activities were conducted by the various task groups, with the scientific task group given the responsibility for all radsafe functions associated with diagnostic experimental programs and for dosimetry and other technical services to the entire task force. The operation of the offsite program and the coordination of the onsite activities were conducted by the Radsafe Office of Hq JTF 7.

RADIATION SAFETY STANDARDS

A maximum permissible exposure (MPE) for personnel was set at 3.75 roentgens (R) (gamma only) per consecutive 13-week period with a maximum of 5 R for the operation. Exceptions were made for emergency and other tactical situations. The operation was defined as the period from 15 days before the first ready date to 15 days after the last shot. A special MPE of 10 R was authorized for crewmembers of air-sampling aircraft. In the event of operational error or emergency, an additional exposure of 10 R would be accepted. Any exposure in excess of 20 R total would be considered as an overexposure for aircrew samplers.

The limit of 3.75 R per 13-week period was slightly greater than the National Council on Radiation Protection and Measurements and the International Commission on Radiation Protection limit of 3 R per 13-week period in effect at that time. The limit of 5 R for the operation is equivalent to the exposure currently permitted per year by Federal guidelines for radiation workers. Appropriate remarks were to be included in the medical records of personnel who exceeded the 3.75 and 5 R limits. Military personnel were to be advised that they should not be exposed to further radiation until sufficient time elapsed to bring their average radiation exposure down to 0.3 R/week. Civilian personnel in this category were to be informed that limitations on further radiation exposure were to be determined by the laboratory or agency having administrative jurisdiction over such personnel.

A film badge program provided an exposure-indicating device to all JTF 7 personnel to maintain complete exposure information on everyone entering the EPG during the operation. The commander of the scientific task group assigned overall badging responsibility to a special task unit. Beginning 1 April 1958, film badges were issued to all individuals upon their arrival at the EPG with instructions that the badge be worn at all times and turned in on recall, upon exit from any contaminated area, or upon departure from the EPG.

SUMMARY OF TASK FORCE EXPOSURES

The table on the following page documents the numbers and percent of task force personnel who received exposures in various categories. These data are based on the latest data available and may be added to as research is completed. Of the some 19,600 individuals badged at HARDTACK, 99 percent had exposures that did not exceed the current Federal guidelines of 5 R per year. The highest recorded exposure for the series was 12.41 R. The overall joint task force mean exposure was 0.87 R.

During the conduct of the series only one incident occurred of an exposure of a large group of JTF 7 personnel to significantly elevated radiation levels. This happened on 14 May when the base islands (Enewetak and Parry) at Enewetak Atoll received fallout from a test shot that had been detonated at Bikini two days before. This fallout episode, which lasted about 60 hours, could have contributed as much as 1.2 to 1.5 R total dose to personnel on Enewetak Atoll depending upon the island on which they lived and their work activities. However, since nearly all personnel wore film badges, this fallout exposure is reflected in the film badge doses.

There was one known incident of offsite fallout. Two Japanese research vessels operating outside the danger area set up around the EPG detected an increase in radiation after shot POPLAR. An investigation by the JTF 7 Staff

Summary of HARDTACK I Exposures

	No. of Persons Badged	Exposure Ranges (roentgens) 0	0.001-0.999	1.000-2.999	3.000-4.999	5.000-9.999	Over 10	High Recorded (R)
Army	1,574	136	371	1,011	54	2	0	6.63
% of Total		9	24	64	3	<1	0	
Navy	8,704	1,024	6,637	1,029	12	2	0	5.96
% of Total		12	76	12	<1	<1	0	
Air Force	3,795	598	1,281	1,730	106	73	7	12.41
% of Total		16	34	45	3	2	<1	
Marine Corps	219	24	151	43	1	0	0	3.23
% of Total		11	69	20	<1	0	0	
Other Military	179	33	49	95	2	0	0	3.59
% of Total		19	27	53	1	0	0	
DOD Contractors	113	10	59	41	3	0	0	4.05
% of Total		9	52	36	3	0	0	
Other Participants	5,067	1,050	1,623	2,266	126	2	0	5.26
% of Total		21	32	45	2	<1	0	
Total Participants	19,651	2,875	10,171	6,215	304	79	7	12.41
% of Total		15	52	31	1	<1	<1	

Surgeon revealed that this exposure was small, amounting to, at most, 0.085 R for the crew, and even this figure did not reflect the decontamination procedures that were used to lower the contamination.

The detonations during HARDTACK I, including those at Johnston Island, did not expose the Hawaiian Islands to fallout.

PREFACE

Between 1945 and 1962, the U.S. Atomic Energy Commission (AEC) conducted 235 atmospheric nuclear weapon tests at sites in the United States and in the Pacific and Atlantic oceans. In all, about 220,000 Department of Defense (DOD) participants, both military and civilian, were present at the tests. Of these, approximately 142,000 participated in the Pacific test series and approximately another 4,000 in the single Atlantic test series.

In 1977, 15 years after the last aboveground nuclear weapon test, the Center for Disease Control (CDC) of the U.S. Department of Health and Human Services noted more leukemia cases than would normally be expected among about 3,200 soldiers who had been present at shot SMOKY, a test of the 1957 PLUMBBOB series. Since that initial report by the CDC, the Veterans Administration (VA) has received a number of claims for medical benefits from former military personnel who believe their health may have been affected by their participation in the weapon testing program.

In late 1977, the DOD began a study that provided data to both the CDC and the VA on potential exposures to ionizing radiation among the military and civilian personnel who participated in the atmospheric testing 15 to 32 years earlier. In early 1978, the DOD also organized a Nuclear Test Personnel Review (NTPR) to:

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

This report on Operation HARDTACK Phase I is one of many volumes that are the product of the NTPR. The DOD Defense Nuclear Agency (DNA), whose Director is the executive agent of the NTPR program, prepared the reports, which are based on military and technical documents reporting various aspects of each of the tests. Reports of the NTPR provide a public record of the activities and associated radiation exposures of DOD personnel for interested former participants and for use in public health research and Federal policy studies.

Information from which this report was compiled was primarily extracted from planning and after-action reports of Joint Task Force 7 (JTF 7) and its subordinate organizations. Documents that accurately placed personnel at the test sites were desired so that their degree of exposure to the ionizing radiation resulting from the tests could be assessed. The search for this information was undertaken in archives and libraries of the Federal Government, in special collections supported by the Federal Government, and, where reasonable, by discussion or review with participants.

For HARDTACK, the most important archival source is the Washington National Records Center (WNRC) in Suitland, Maryland. The Naval Archives at the Washington Navy Yard also were helpful, as was the collection of documents assembled by the Air Force Weapons Laboratory (AFWL) Historian, the collection now being housed in the AFWL Technical Library at Kirtland Air Force Base, Albuquerque, New Mexico. Other archives searched were the Department of Energy (DOE) archives at Germantown, Maryland, its Nevada Operations Office (DOE/NV) archives at Las Vegas, and archives of the Test Division of the Los Alamos National Laboratory.

JTF 7 exposure records were retrieved from the WNRC, and an additional file of exposure-related documents that had been microfilmed by the Reynolds Electrical and Engineering Company, Inc., support contractor for DOE/NV was also useful.

Primary documentation of personnel movement in areas of potential radiation exposure is sparse. This has been compensated for, where possible, with inferences drawn from secondary sources and the exposure records themselves.

The work was performed under RDT&E RMSS B350079464 U99 QMXMK 506-09 H2590D for the Defense Nuclear Agency by personnel from Kaman Tempo and R.F. Cross Associates as subcontractor. Guidance was provided by Mr. Kenneth W. Kaye of the Defense Nuclear Agency Biomedical Effects Directorate.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

Frontispiece: HARDTACK, UMBRELLA with SS Michael Moran (EC-2) in foreground.

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

LIST OF TABLES

LIST OF TABLES (continued)

CHAPTER 1

OVERVIEW

INTRODUCTION

Purpose

HARDTACK was the operation designation for U.S. nuclear testing in both the Pacific and in Nevada in 1958. Phase I was an atmospheric test series in which 35 nuclear devices were detonated at the Atomic Energy Commission's (AEC) Eniwetok Proving Ground (EPG)* at Enewetak† and Bikini atolls in the spring and summer of 1958. HARDTACK Phase II was conducted in Nevada. HARDTACK Phase I is the subject of this report, and Table 1 lists the detonations. Phase I is subsequently referred to simply as HARDTACK throughout this report.

This report documents the participation of Department of Defense (DOD) personnel who were active in this test series. The report's purpose is to bring together the available information about this atmospheric nuclear test series pertinent to the exposure of DOD personnel, both uniformed and civilian employees. The report explains the reasons why DOD personnel were present at these tests, lists the DOD organizations represented, and describes their activities. It discusses the potential radiation exposure involved in these activities and the measures taken for the protection of DOD personnel. It presents the exposures recorded by the participating DOD units.

Historical Perspective

During HARDTACK the United States fired 35 nuclear devices, which was as many as had been fired in all prior Pacific Ocean tests. Not only was the total number of shots in HARDTACK large, but the variety of types was great; land- and water-surface events, underwater detonations, and balloon- and rocket-borne high-altitude tests were conducted.

With each nuclear explosion there was a release of some radioactive material into the atmosphere and, as a result of the increasing number of nuclear tests, concern was growing about the health effects of radioactive fallout. In some cases this concern became direct opposition to the conduct of the tests. Concern and opposition to nuclear weapon testing was also growing on purely political grounds.

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* Before 1958, the EPG was called the Pacific Proving Ground (PPG).

† A better understanding of the Marshall Islands language has permitted a more accurate transliteration of Marshall Island names into English language spelling. These newer transliterations are used in this report with few exceptions. Appendix C lists the names and their variant spelling.

Table 1. HARDTACK Phase I detonations, 1958.

Local Date	Assigned Name	Location	Type Burst
28 April	YUCCA	Between Enewetak and Bikini	High Altitude
6 May	CACTUS[a]	Enewetak	Surface
12 May	FIR	Bikini	Barge
12 May	BUTTERNUT	Enewetak	Barge
13 May	KOA[b]	Enewetak	Surface
16 May	WAHOO	Enewetak	Underwater
21 May	HOLLY	Enewetak	Barge
22 May	NUTMEG	Bikini	Barge
26 May	YELLOWWOOD	Enewetak	Barge
27 May	MAGNOLIA	Enewetak	Barge
30 May	TOBACCO	Enewetak	Barge
31 May	SYCAMORE	Bikini	Barge
3 June	ROSE	Enewetak	Barge
9 June	UMBRELLA	Enewetak	Underwater
11 June	MAPLE	Bikini	Barge
15 June	ASPEN	Bikini	Barge
15 June	WALNUT	Enewetak	Barge
18 June	LINDEN	Enewetak	Barge
28 June	REDWOOD	Bikini	Barge
28 June	ELDER	Enewetak	Barge
29 June	OAK[c]	Enewetak	Barge
29 June	HICKORY	Bikini	Barge
2 July	SEQUOIA	Enewetak	Barge
3 July	CEDAR	Bikini	Barge
6 July	DOGWOOD	Enewetak	Barge
12 July	POPLAR	Bikini	Barge
14 July	SCAEVOLA[d]	Enewetak	Barge
18 July	PISONIA	Enewetak	Barge
22 July	JUNIPER	Bikini	Barge
23 July	OLIVE	Enewetak	Barge
27 July	PINE	Enewetak	Barge
31 July	TEAK[e]	Johnston Island area	High Altitude
6 August	QUINCE	Enewetak	Surface
11 August	ORANGE[e]	Johnston Island area	High Altitude
18 August	FIG	Enewetak	Surface

Notes: Yields have not been announced except as noted below.

[a]18 KT.

[b]1.37 MT.

[c]8.9 MT.

[d]Low.

[e]Megaton range.

By 1958 the U.S.-U.S.S.R. antagonism had lessened somewhat from its peak during the earlier "cold-war" years, and there was a political sentiment that nuclear weapon tests were in large part a variety of saber-rattling that tended to enhance the international tensions that could lead to nuclear war. There was also sentiment that the ending of the tests by the United States with, or even without, a compensating and expected cessation of testing by the U.S.S.R. could be a first step on the way to general disarmament.

On the other hand, the predominant opinion in the United States was that the weapons being developed were vital to its interests and were the only counterweight the United States possessed to offset the superior manpower of the U.S.S.R. This opinion considered the low probability of adverse health effects resulting from the tests as a small, almost inconsequential, price to pay for national or, indeed, international survival. Some felt that without the deterrence provided by the massive retaliatory power of the United States in the form of nuclear weapons, the U.S.S.R. would perceive the Western world as weak and would surely attack, initiating a nuclear war in which neither side could expect victory in any conventional sense.

A drive to continue testing also resided within the testing community itself. The development of nuclear weapons up to this time had been primarily of large-yield, strategic weapons that fit with the established U.S. policy of "massive retaliation." In 1958, some weapon designers felt that with more testing, smaller and more efficient and radiologically "clean" weapons could be developed. This development would enhance flexibility in the military support of U.S. foreign policy, and the "cleanness" of the test explosions would also make testing operations themselves less contaminating and thus more acceptable to world opinion.

The debate over testing was conducted at the highest levels within the U.S. Government. The U.S.S.R. had just completed an atmospheric test series in the spring of 1958 and it was clear that the Russians, having already had their turn, were likely now to make some propaganda ploy by renouncing nuclear testing, knowing that the United States was about to begin the HARDTACK series.

Arguments for the continuation of the planning and execution of HARDTACK prevailed but with what was, perhaps, a concession to world opinion -- the addition of a shot to demonstrate the radiological cleanness of the U.S. weapons being tested. In April, an invitation was extended to the member nations of the United Nations Scientific Committee on the Effects of Atomic Radiation to observe this demonstration. The shot was basically intended to demonstrate that a low proportion of the total yield was developed by the fission process; its proof, however, required the use and understanding of scientific instruments that determine both the total yield and fission contribution. Therefore, the invitation was for each member nation to send one scientist and one press representative. The activities planned are discussed in somewhat more detail subsequently (see "Task Unit 7.1.7," page 55).

The United States cancelled this event on 26 July since the earliest the test could have been conducted was 25 August and it could have been delayed even more. This late date would have interfered with the observer scientists attending the "Second Atoms for Peace" conference on September 1 in Geneva.

The United States offered to substitute "laboratory devices" at some indefinite future date for the cancelled test. At the time of the cancellation only three (Belgium, Sweden and France) of fourteen nations had agreed to send representatives. The "Eastern bloc" nations (U.S.S.R. and Czechoslovakia) and India had declined, and eight had not replied.

Report Organization

Subsequent sections of this overview chapter discuss the form of experimental nuclear weapon test programs with emphasis on the potential radiation exposure of participating DOD personnel. The experimental activities are considered first without particular reference to the geographic location of the testing, and are then related to the geographic limitations on such activities at the EPG and Johnston Island. The portion of the experimental program in which DOD participated most heavily is emphasized.

The chapter concludes with a description of Joint Task Force 7 (JTF 7), the organization that conducted Operation HARDTACK, and indicates how the DOD elements within JTF 7 functioned.

Chapter 2 is concerned with the radiological safety (radsafe) aspects of the tests. This chapter documents the procedures, training, and equipment used to protect participants from the radiation exposure potential inherent in the test operations.

Chapter 3 focuses on the role of the DOD in the experimental program of HARDTACK in general, leading to a discussion of the DOD operations for the test events in particular in Chapters 4 and 5. Chapter 4 discusses the weapon development phase, and Chapter 5 presents the DOD phases of HARDTACK, first the underwater tests, followed by the high-altitude shots.

Chapters 6 through 9 report participation by the Army, Navy, Air Force, and Marine Corps, respectively. Chapter 10 summarizes the participation of other government agencies and contractors. A listing of participating units and a statistical characterization of their personnel exposures are included in these chapters. The personnel exposures are discussed in Chapter 11.

NUCLEAR TESTS AND RADIATION EXPOSURES

Nuclear testing before 1961 usually consisted of the unconfined detonation of nuclear devices (usually not weapons) in the atmosphere. The devices might be placed on a platform or a barge on the surface, placed atop a tower, supported by a balloon, dropped from an airplane, or flown on a rocket. On occasion, devices were detonated underwater or buried in the earth or in underground tunnels and shafts.

In theory, personnel could be exposed either by the radiation emitted at the time of explosion and for about 1 minute thereafter -- usually referred to as initial radiation -- or the radiation emitted later (residual radiation). Initial radiation is part of the violent nuclear explosion process itself; to be close enough for initial radiation exposure would place an observer within the area swept by lethal blast and thermal effects.

The neutron component of initial radiation did indirectly contribute to the possibility of personnel exposure. Neutrons are emitted in large numbers by nuclear weapon explosions. They have the property of altering certain non-radioactive materials so that they become radioactive. This process, called activation, works on some isotopes of sodium, silicon, calcium, manganese, and iron, as well as other common materials. Activation products thus formed are added to the inventory of the radioactive products formed in the explosion process. The radiation emitted by this inventory more than 1 minute after detonation is referred to as residual radiation.

The potential for personnel exposure to residual radiation was much greater than the potential for exposure to initial radiation. In the nuclear explosion process, fissioning atoms of the heavy elements, uranium and plutonium, split into lighter elements, releasing energy. These lighter atoms are themselves radioactive and decay, forming another generation of descendants from the original fission products. This process is rapid immediately after the explosion but slows later and continues for years at very low levels of radioactivity.

Overall radioactivity of all the fission products formed decays at a rate that is closely approximated by a rule that states that for each sevenfold increase in time the intensity of the radiation will decrease by a factor of ten. Thus, a radiation rate of 1 roentgen per hour (R/hr) at 1 hour after detonation would be expected to be 0.1 R/hr after 7 hours and 0.01 R/hr after 49 hours. This rule seems to be valid for about 6 months following an explosion, after which the observed decay rate is somewhat faster than that predicted by this relationship. Activation products, in general, decay at a faster rate than the fission products.

Fission products and the activation products, along with unfissioned uranium or plutonium from the device, are the components of the radioactive material in the debris cloud, and this cloud and its fallout are the primary sources of the potential exposure to radiation.

In a nuclear airburst in which the central core of intensely hot material, or fireball, does not touch the surface, the bomb residues (including the fission products, the activation products resulting from neutron interaction with device materials, and unfissioned uranium and/or plutonium) are vaporized. These vapors condense as the fireball rises and cools, and the particles formed by the condensation are small and smoke-like. They are carried up with the cloud to the altitude at which its rise stops, usually called the cloud stabilization altitude. Spread of this material then depends on the winds and weather. If the detonation is small, the cloud stabilization altitude will be in the lower atmosphere and the material will act like dust and return to the Earth's surface in a matter of weeks. Essentially all debris from detonations with yields equivalent to kilotons of TNT will be down within 2 months (Reference A.1). Areas in which this fallout material will be deposited will appear on maps as bands following the wind's direction. Larger detonations (yields equivalent to megatons of TNT) will have cloud stabilization altitudes in the stratosphere (above about 10 miles [16 km] in the tropics); the radioactive material from such altitudes will not return to Earth for many months and its distribution will be much wider. Thus, airbursts contribute little potential for radiation exposure to personnel at the testing area, although there may be some residual and short-lived radiation coming from activated surface materials under the burst if the burst altitude is sufficiently low for neutrons to reach the surface.

Surface and near-surface bursts pose larger potential radiation exposure problems. These detonations create more radioactive debris because more material is available for activation within range of the neutrons generated by the explosion. In such explosions, the extreme heat vaporizes device materials and activated earth materials as well. These materials cool in the presence of additional material gouged out of the burst crater. This extra material causes the particles formed as the fireball cools to be larger in size, with radioactivity embedded in them or coating their surfaces. The rising cloud will lift these particles to altitudes that will depend on the particle size and shape and the power of the rising air currents in the cloud, which in turn depend on the yield of the detonation. The largest particles will fall back into the crater or very near the burst area with the next largest falling nearby. It has been estimated that as much as 80 percent of the radioactive debris from a land-surface burst falls out within the first day following the burst (Reference A.1).

Bursts on the surface of seawater generate particles consisting mainly of salt and water drops that are smaller and lighter than the fallout particles from a land-surface burst. As a consequence, water-surface bursts produce less early fallout than similar weapons detonated on land. Large-yield surface bursts in the EPG over relatively shallow lagoon waters or on the very little truly dry land probably formed a complex combination of land-surface- and water-surface-burst particle-size characteristics.

Several surface detonations at the EPG were of such a large size that they formed underwater craters. These craters retained a fraction of the devices' radioactive debris and activated materials. Water that overlay these craters shielded surface operations from the radiation from this residual material, but it also moved material from the craters into the general circulation system of the lagoon waters. Craters were subject to washing and silt plumes were observed to come from them for long periods after the shots; it is reported that plumes from the MIKE crater (the first shot of the IVY Series, 1952) were visible a year after the detonation (Reference A.7).

Detonations on towers may be considered as low airbursts or ground bursts, depending upon whether the fireball touches the ground. A larger burst will create more fallout than a smaller burst on equal-height towers, not only because of the additional fission products and weapon debris, but also because it will pull up more earth materials, or even form a crater. In addition, the materials of the tower itself provide a source of easily activated materials. Particles of the tower material may also act as centers for the debris vapors to condense on to form the larger particles that lead to heavier early fallout. Devices that fission uranium or plutonium inefficiently will cause more of these radioactive components of the device residue to be dispersed.

Underwater nuclear detonations are muffled by the great mass of water that surrounds them. Initial nuclear radiation is absorbed by the water surrounding the device and the intense heat vaporizes the water near the burst, forming a bubble beneath the surface of the water that expands as the energy released in the explosion works against the mass of water. This expansion continues until the energy is expended, at which point the bubble begins to collapse as it rises toward the surface. Depending upon the depth of the burst and the size of the bubble (which in turn depends on the yield, or total energy released, of the explosion), the bubble may break the surface of the water near its fully expanded size or smaller. Some radioactive products are vented into the air as the bubble breaks the surface, but most of the device debris remains trapped in the volume of water that collapses on the bubble. This volume of water is usually referred to as the radioactive pool and was the primary source of potential radiation exposure for individuals participating in the tests. When the burst is close enough to the bottom, an underwater crater may be formed, and the material excavated from it will be radioactive and contribute to the residual radiation inventory.

When a detonation takes place high above the Earth's surface, the very thin air absorbs the initial radiation only slightly. Thus, radiation can travel great distances at very high altitudes. Downward toward the Earth's surface, however, the air becomes progressively more dense and the initial radiation from a high-altitude burst is attenuated and absorbed long before it reaches the surface of the Earth. For a burst above the atmosphere, the altitudes at which the radiations are virtually stopped are: 35 to 55 miles (56 to 88 km) for X-rays; 15 miles (24 km) for neutrons and gammas; and 35 miles (56 km) for beta particles.

The possibility of exposure from early fallout during a high-altitude burst is also virtually nonexistent. In a high-altitude detonation, the device debris is dispersed into the stratosphere or higher. This is above the height where weather, which might bring the radioactive device debris to Earth, is formed. Consequently, there is no likelihood that the suspended material will descend quickly enough to expose personnel in the vicinity of the surface zero. Such device material remains in the upper atmosphere about 6 months. During this period, and by the time they descend to Earth, most of the radionuclides produced by the detonation will have decayed to low levels, with two notable exceptions. Isotopes of strontium and cesium, ^{90}Sr and ^{137}Cs, take longer to decay than the time required for their deposition. The major radiological concern about a high-altitude burst arises from the radiation from these isotopes in the delayed fallout.

EXPERIMENTAL PROGRAM

Central to the test series was the experimental program. This program and its requirements dictated the form of the test organization and the detail of personnel participation. HARDTACK's experimental program incorporated two aspects, the first of which was the development of the weapons themselves, and the second involved measurement of the explosive and radiation effects. Unlike earlier nuclear test series, the HARDTACK test operations supporting each aspect were in large part separate.

These two aspects can serve as a rough measure of differentiation of interest between the major participants: the AEC interest in weapon development, and the DOD interest in the military application of the effects of the explosions.

The several parts of the weapon development and the effects studies each had particular features that led to the possibility of radiation exposure.

Weapon Development

In testing devices, weapon designers are interested in two classes of measurements: the total energy release of the device, and the rate of release. Total energy release measurements are called yield measurements, and the rate of release measurements are called diagnostic measurements.

YIELD MEASUREMENTS. Device yield is usually determined by several methods, two of which involve photo-optical techniques. Growth of the intensely hot and radiating mass of device debris and air that constitutes the nuclear fireball varies with its yield. Very-high-speed cameras were therefore used to record this growth, and film records subsequently analyzed to infer yield. Duration and intensity of the energy pulse in the optical-thermal spectral region also vary with yield; thus, light detectors coupled to recorders were also used to derive yield.

In addition, yield may be determined by collecting and analyzing a representative sample of the device debris. Inferences are then drawn regarding the yield, based on knowledge of the materials in the device.

Construction, instrumentation placement, and data recovery for the photo-optical yield determinations did not usually require personnel to be in areas with a potential for exposure to radiation. Cameras and light detectors need only a clear field of view of the burst point and enough breadth of view to encompass the fireball. Camera placement did not involve personnel activities at times and places of high radiation levels. Film recovery generally did not involve high exposure potential, as the photo stations were usually at ranges and in directions not heavily contaminated by fallout.

Sampling of device debris, however, necessitated much closer contact with higher levels of radioactivity. The technique used in HARDTACK and most atmospheric tests was to fly aircraft with collectors directly through portions of the radioactive (or mushroom) cloud, although on some HARDTACK shots rockets were used in an attempt to collect samples. About 90 percent of the fission debris was usually considered to be in the upper portion of the mushroom cloud (Reference A.1). Several aircraft were used to obtain a representative sample. Aircrews were exposed to the radiation emitted by the radioactive particles in the cloud as they flew through. Aircraft flying these sampling missions picked up significant amounts of radioactive material on their surfaces, posing additional and continuing radiation exposures to the aircrews as they returned to base, as well as to decontamination ground crews. Samples collected were radiologically "hot" and required special handling as they were taken from the aircraft and prepared for shipment to laboratories in the United States for analysis.

DIAGNOSTIC MEASUREMENTS. The explosion of a nuclear device is a progressive release of increasing amounts of nuclear radiation, some of which directly escapes the device. The rest of the radiant energy interacts with the associated material of the device itself and is converted into differing forms of radiation and into the kinetic energy of the remaining materials in a small fraction of a second. The intensely hot core then reradiates, heating the surrounding air and creating a shock wave that propagates outward from the burst point.

Weapon diagnosticians used sophisticated techniques to follow the processes that occurred during the device explosion. Detectors and collectors were run up to, and sometimes inside, the device case so that the radiation being sampled could be directly channeled some distance away and there be recorded by instrumentation designed to survive the ensuing blast. To enhance its transport, radiation was conducted through pipes (often evacuated or filled with special gases) from the device to stations where recording instrumentation was located or where the information could be retransmitted to a survivable recording station.

Radiation measurements are based upon the effects that result from the interaction of the radiation with matter. Fluorescence is one such effect. Materials that fluoresce with radiation exposure were placed in view of cameras or light detectors to provide a record of the variation of fluorescent intensity with time, thereby providing an indirect measurement of the radiation environment.

Other methods of detecting radiation involve the shielding (attenuation) properties of earth materials, water, and other substances. These materials are also used to baffle or collimate radiation to ensure that radiation is directed toward the detecting instrument.

Radiofrequency energy produced by the explosion can be detected by radio receivers and, with the addition of filtering and processing circuitry, can also provide information about the energy flow from the explosion. Such measurements permit remote placement of receiving and recording instruments.

Preshot preparation included the hazards normally associated with heavy construction, and some exposures of workers to residual radiation remaining from previous tests.

The potential for radiation exposure of personnel associated with weapon diagnostic experiments depended upon the proximity of the measurement or data recovery point to surface zero and the time lapse between the detonation and the data collection.

The primary radiation exposure potential is from fission* products and materials made radioactive by neutron activation of device and earth materials in the vicinity of surface zero. Thus, the distance from surface zero is a principal factor in assessing exposure to persons engaged in the experimental program.

Since radioactive material decays with time, the time lapse between the explosion and exposure is a critical factor in dose assessment. Primary recording media for these experiments were photographic films from oscilloscope,

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* Although the HARDTACK devices were mainly thermonuclear, or fusion, devices, a significant portion of their energy release resulted from fission processes.

streak, or framing cameras located in survivable bunkers near the detonation point. Because radiation fogs film in time, these films and other time-sensitive data were removed from the bunkers by helicopter-borne personnel within hours of the detonation to minimize damage by fogging. This recovery constituted the main potential for exposure of weapon diagnostics participants.

Effects Experiments

Effects experiments were intended to acquire urgently needed military data that could not be obtained from the smaller yield tests at the Nevada Test Site. These experiments may be classed into two general kinds. The first class of measurements was made to document the hostile environment created by the nuclear detonation. The second class of effects experiments documented the response of systems to the hostile environment; these measurements are termed systems response experiments.

ENVIRONMENTAL MEASUREMENTS. The purpose of environmental measurements was to gain a comprehensive view of the hostile environment created by a nuclear detonation to allow military planners to design survivable military hardware and systems and train personnel to survive. Examples of environmental measurements include static (crushing) and dynamic (blast wind) air pressures in the blast wave, heat generated by the detonation, and fallout radiation. Measurement techniques employed for HARDTACK varied with the effect being measured, but usually measuring devices or gauges were placed at a variety of ranges from surface zero and their measurement recorded in some way. A wide variety of gauges and data-recording techniques was used. In some cases, measurements were similar to those being made by the weapon designers, but at greater distances or longer after the detonation, which simplified the recording of the data, although the recovery problems were by no means trivial.

HARDTACK, with test shots conducted both deep underwater and well above the stratosphere, required a variety of techniques to document the environment affected by the bursts.

Rugged, self-recording gauges had been developed for blast and thermal radiation measurements by 1958 so that complete loss of data from a project would not occur if instrument recovery were delayed, for example, by heavy fallout. For nuclear radiation measurements, however, prompt data recovery was still desirable as the gauges used might be thin foils of some material that would be made radioactive by the burst-time neutrons; hence early observation was necessary before the information contained in the induced radiation pattern decayed away.

The potential for radiation exposure of personnel responsible for environmental measurements in general depended on the proximity of the instruments to the device and the time that elapsed between detonation and instrument recovery, as was the case for weapon development experimentation: the nearer in space or time to the detonation, the greater the potential for exposure.

SYSTEMS RESPONSE EXPERIMENTS. To document the response of systems to the hostile environment, military hardware (such as aircraft or naval mines) was exposed to the effects of nuclear detonations.

Techniques used for the systems response experiments were conceptually simple: exposure of the system of interest and observation of its response. Actual conduct of the experiments was far more complex. The level of the threat to which the system was exposed almost always required documentation so that the response could be properly understood, necessitating an environmental experiment along with the systems response experiment. It was often not enough to know whether the system survived, but rather the response of the component parts and their interactions was required, entailing the placement of sophisticated instrumentation and recording devices.

While the potential radiological exposure for these systems response experiments was governed primarily by the closeness of personnel in space or time, an additional problem arose. Often, when the subject of the exposure itself was recovered for closer examination, it could be contaminated by device debris or even be radioactive because of the activating effects of the device's neutron output.

OCEANIC TESTING OPERATIONS

Implications of oceanic testing have only incidentally been remarked upon. These are now discussed, especially as they relate to DOD operations during HARDTACK.

Marshall Islands Setting

The Marshall Islands are in the easternmost part of the area known as Micronesia ("tiny islands"). The Marshalls are spread over 770 thousand mi^2 (2 million km^2) of the Earth's surface but the total land area is only about 70 mi^2 (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 1 shows these islands in the Central Pacific, Figure 2 is a map of Enewetak Atoll, and Figure 3 is a map of Bikini Atoll.

Typical atolls, Enewetak and Bikini are coral caps set on truncated, submerged volcanic peaks that rise to considerable heights from the ocean floor. Coral and sand have gradually built up narrow islands into a ring-like formation with open ocean on the outside and a relatively sheltered lagoon on the inside. Both atolls have two passages, a wide one and a deep one, that permit access to their lagoons from the sea. Enewetak also has a third. All the islands are low-lying, with elevations seldom over 20 feet (6 meters) above high tide.

During nuclear testing, the more populated, support-oriented sections were the south and southeast areas of the atolls where the larger islands exist. Devices were detonated on the northern islands and over the northern reefs. The western sections of the atolls were not involved in test activities except for limited use as instrumentation sites.

Elliptically shaped, Enewetak is approximately 550 nmi (1,020 km) southwest of Wake Island and 2,380 nmi (4,410 km) southwest of Honolulu. It encloses a lagoon 23 miles (37 km) in diameter and has a total land area of 2.75 mi^2

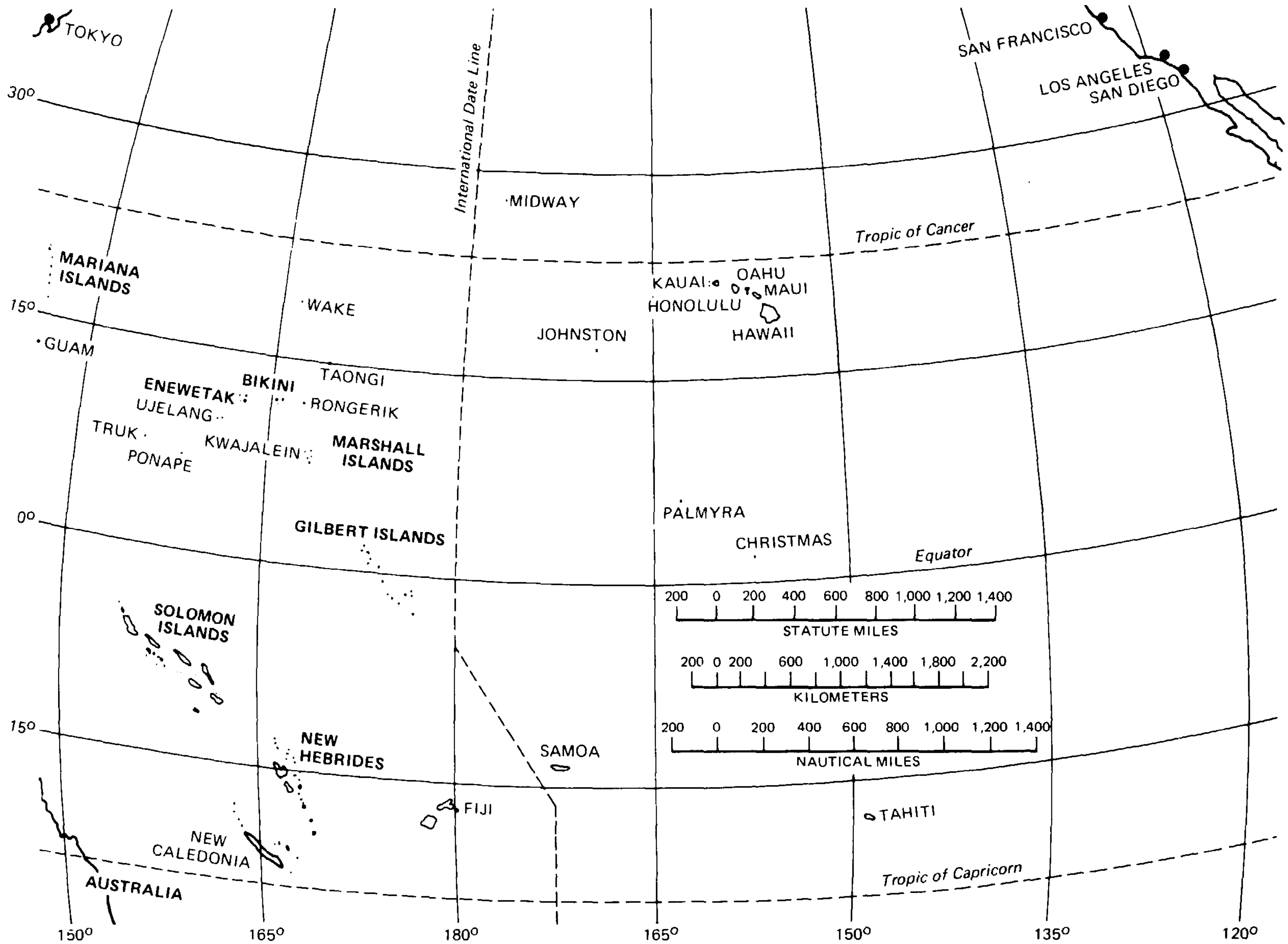

Figure 1. The Central Pacific.

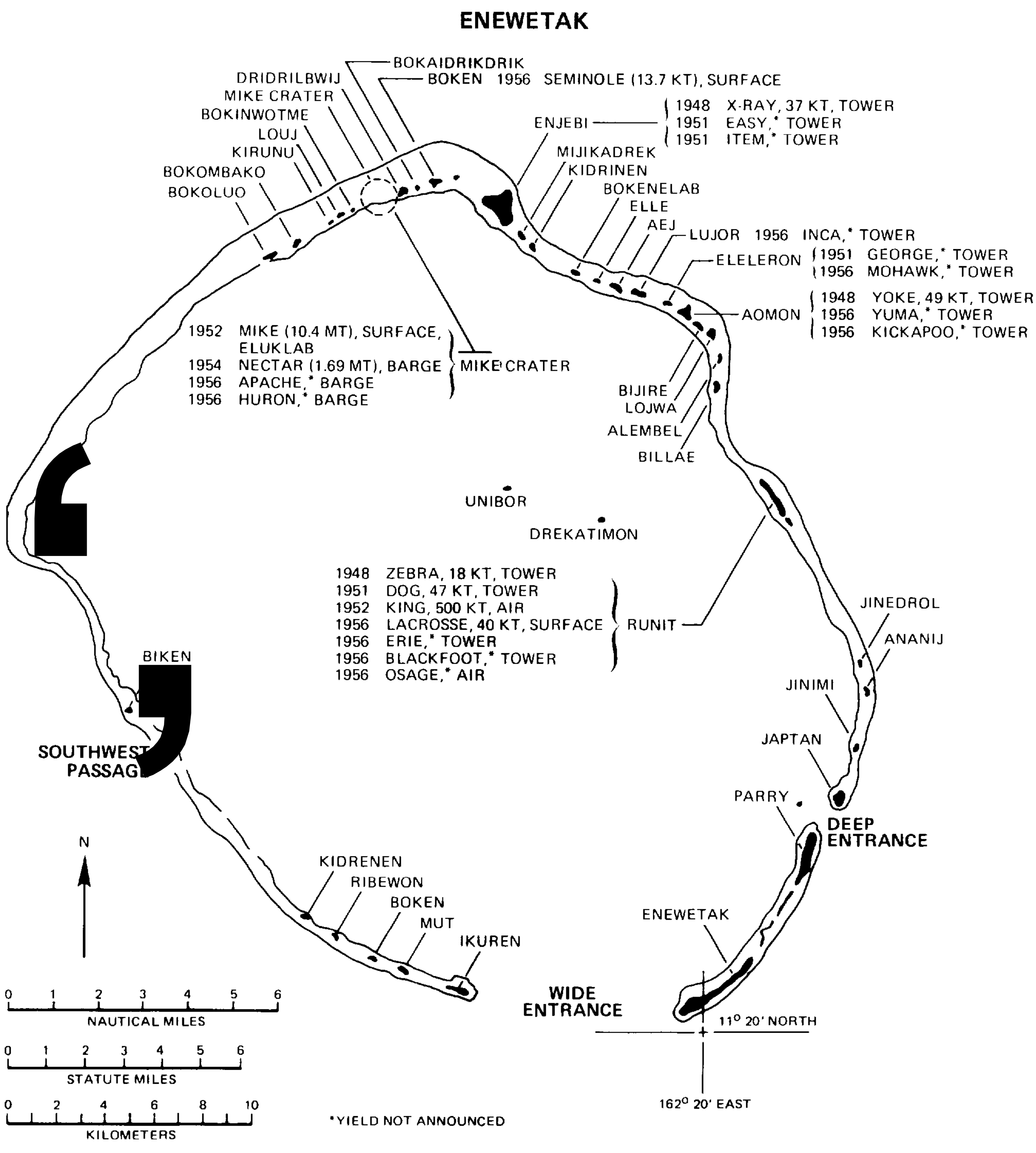

Figure 2. Enewetak Atoll, 1958, showing pre-HARDTACK detonation sites.

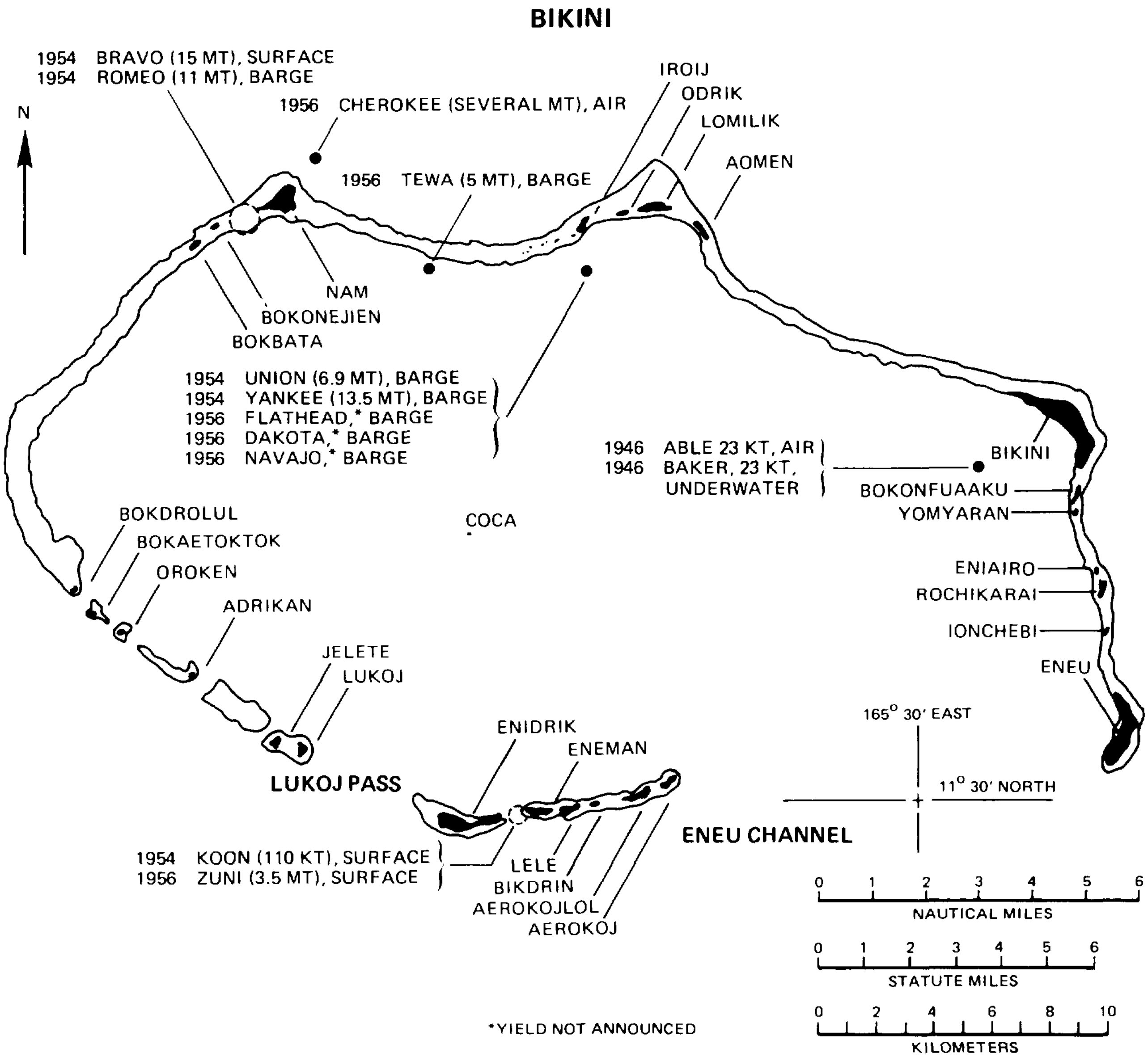

Figure 3. Bikini Atoll, 1958, showing pre-HARDTACK detonation sites.

(7.12 km^2), with elevations averaging 10 feet (3 meters) above mean sea level. The support section of Enewetak (Enewetak, Parry, and Japtan islands) constitutes about 34 percent of the atoll's land surface. The string of islands from Runit to Bokoluo, the detonation area, constitutes about 32 percent. The various names used for the islands of the atoll are listed in Appendix C, "Island Synonyms."

Bikini is 189 nmi (350 km) east of Enewetak. Its islands consist of about 2.7 mi^2 (7 km^2) of surface area and encircle a lagoon that is 25 miles (40.2 km) long and 15 miles (24.1 km) wide, with a maximum depth of about 200 feet (61 meters). The land area is concentrated in the eastern islands, from Bikini to Eneu islands, which form about 53 percent of the land total, with 24 percent taken up by the southern section of Enidrik to Aerokoj. The detonation area in the north occupies about 19 percent of the land area.

The climate of Enewetak and Bikini is tropical marine, generally warm and humid. Temperature changes are slight, ranging from 70° to 90°F (21° to 32°C). Rainfall is moderate, and prolonged droughts may occur. North of both atolls is open ocean for a thousand miles, with the only inhabited island being Wake. Storms are infrequent, although typhoons occur; nevertheless, both wind and sea are continuous erosional agents. Although possible at any time, most tropical storms occur from September to December. Cumulus clouds are abundant in the area.

The Enewetak-Bikini region incorporates three basic wind systems. Northeast trade winds extend from the surface to 25,000 to 30,000 feet (7.6 to 9.1 km), the upper westerlies from the top of the trades to the base of the tropopause at 55,000 to 60,000 feet (16.8 to 18.3 km), and the Krakatoa easterlies from the tropopause up into the stratosphere. These systems are all basically east-to-west or west-to-east currents. Day-to-day changes reflect the relatively small north-south components, which are markedly variable. Greatest variation occurs in the upper westerlies, particularly during late summer and fall.

The steady northeast trade winds in the lower levels cause the water at the surface of the lagoons to flow from northeast to southwest, where it sinks to the bottom and returns along the lower levels of the lagoons, rises to the surface along the eastern arc of the reefs and islands, and is moved by the winds to the southwest again. Lagoon waters moving in this closed loop also mix with those of the open ocean, resulting in a flushing action.

At Bikini, ocean water flows in over the northern and eastern reefs and flows out through the western portion of Eneu Channel. The water exchanges over the western reefs with the tides, ocean water flowing in and mixing with flood and lagoon water flowing out with the lows. The net rate of flushing of Bikini waters is such that half of the lagoon waters are replaced by ocean water in 22 days and the original volume will account for only 10 percent of the lagoon volume after 2-1/2 months.

At Enewetak, the flushing is more rapid and has two major routes. The first is directly through the eastern reefs to the western reefs; the second is through Deep Entrance between Japtan and Parry and out Wide Entrance west of Enewetak. These two routes also function to keep the waters of the northern part of the lagoon separate from the southern waters.

The land areas of Enewetak and Bikini atolls, their lagoons, and the waters within 3 miles (4.8 km) of their seaward sides constituted the EPG. These islands are part of the Trust Territory of the Pacific Islands, a strategic area trusteeship of the United Nations, administered by the United States. The U.S. agency in charge of the EPG itself was the AEC.

The Test Division of the AEC Division of Military Applications, Albuquerque Operations Office, administered the test site through its Enewetak Branch Office, which supervised engineering, construction, maintenance, operation, and management activities performed by its contractor, Holmes & Narver, Inc. (H&N).

PHYSICAL CONDITIONS IN 1958. Enewetak had been the site of nuclear testing since 1948: the islands in the southeast quadrant served as the base for the task forces, and the islands from north through east-northeast were used for the tests themselves. The principal base islands were Enewetak, which bordered Wide Entrance, and Parry, northeast of Enewetak, which bordered Deep Entrance. These two islands, accounting for about 30 percent of the atoll's land area, had been densely populated periodically during prior testing periods, serving as the home and working facilities for JTF 7 and its predecessors.

During the decade that nuclear testing had been conducted, the base islands had become increasingly built up, with permanent buildings replacing tents and more sophisticated structures replacing simple ones.

Parry Island was used as the joint task force headquarters as well as the headquarters and living area for the scientific groups. A compound had been set aside for device assembly work on its southern end with sheltered and secure work areas and access to a barge slip so that final assembly of test devices could take place on the test barges themselves. Parry also had a pier extending into deep water to directly offload ocean-going vessels.

Enewetak Island was primarily covered with an airfield and its support buildings and equipment. This airfield was large enough to support B-52 operations. Shops, warehouses, and barracks occupied most of the rest of the island's area. Figures 4 through 7 show the base islands as they were in 1958.

Japtan, the third major island in the base area, lay just across Deep Entrance from Parry and still contained a considerable stand of coconut palms, pandanus, scaevola, and other tropical vegetation. It was the site of a radio-receiver station and was used as a recreational area. The islands on the western side of the atoll had been less disturbed and were also covered with vegetation. Figure 8 illustrates the typical growth.

The northern and northeastern arc of the islands had been used as the location of the tests themselves and had been extensively graded. They had also been connected by causeways constructed of fill borrowed from the islands or dredged from the shallow reefs that surrounded them. This fill material was held in place by timber and sheet-steel bulkheads. In 1951, the islands from Eleleron to Lojwa had been linked by causeway, and by 1952 causeways had been built between Eluklab, Dridrilbwij, Bokaidrikdrik, and Boken.

By 1958, the test activities had changed the surface features of these shot islands. Eluklab had been completely eliminated in the MIKE test in 1952 and most of Eleleron was removed in 1956 by the MOHAWK test (Reference A.8). Figure 9 suggests the appearance of these northern islands. Specific preparations for HARDTACK included the replacement of the causeway between Bokaidrikdrik and Boken that had been destroyed by the cratering action of the SEMINOLE test in 1956, which also carried away a portion of Boken. These causeways were built to provide support for long pipe runs and subsurface conduits used in weapon development tests and dry-land access to shot points from advance camps.

In October 1952, H&N, acting as the resident contractor for the AEC, began construction of a camp on Eneman Island on the southern perimeter of Bikini.

Figure 4. Enewetak Island airfield occupying the western end and most of the rest of the island, 1958.

Figure 5. Radar vans on Enewetak Island, 1958.

Figure 6. Enewetak Island living quarters, 1958.

Figure 7. Three-hundred-foot photo tower on north end of Parry Island with equipment yard in foreground, 1958.

Figure 8. Small photo tower being built on Mut Island, Enewetak Atoll, in heavily vegetated area, 1958.

Figure 9. Aerial view of Enjebi Island, showing the general featurelessness of the shot islands, except for the test structures, and lack of substantial plant cover, 1958.

This was a base camp for the necessary construction work required to begin the reuse of Bikini as a site for nuclear weapon testing. An airstrip to serve Bikini-Enewetak traffic was also begun on the neighboring islands of Aerokojlol and Aerokoj and on the causeway that was built to link them. The islands of Eneman, Lele, and Bikdrin were also linked with the airstrip islands to form a complex 3 miles (4.8 km) long, traversable by wheeled vehicles. Additional causeways were constructed in 1953 that joined Iroij, Odrik, Lomilik, and Aomen in the northeastern arc of the Bikini islands. Figure 10 shows one of the islands in the test area at Bikini in 1958.

For the 1954 tests, Eneman was the base island for Bikini test activities; but in 1956 Eneu, at the very southeast extreme of the atoll, served this purpose. Construction at Bikini Atoll was always considered expendable as Bikini was to be an advance camp for Enewetak. However, by 1958 considerable construction was done on Eneu to facilitate the HARDTACK tests including an administration building, a device assembly area, a communications building, and a barge slip. Eneu also had an airfield. Temporary camps had also been built on Nam, Lomilik, and Aomen to house workers building the test-related structures on or near those islands.

RADIOLOGICAL CONDITIONS IN 1958. The shot islands of both atolls had been the site of many detonations, whose locations are shown in Figures 2 and 3, and the detonation sites and surrounding land areas were sources of potential

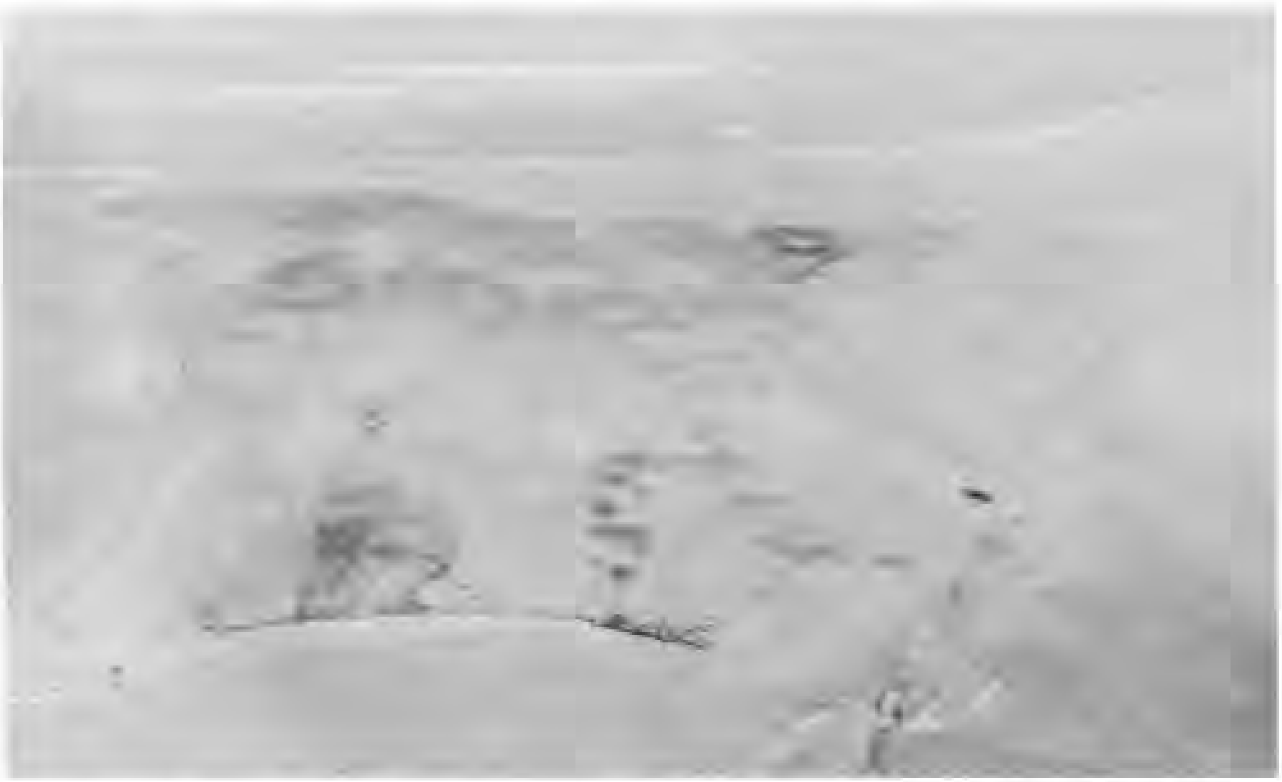

Figure 10. Aerial view northeast of Nam Island at Bikini Atoll, 1958.

radiation exposure to personnel. The degree of the potential exposure depended on the time that had elapsed since the test and the nature and size of the test itself. From the previous discussion concerning the types of detonations it can be inferred that the closer the burst point is to the surface, the greater the radiological problem posed for personnel on the surface. As the burst height increases there is less opportunity for the device debris to mix with the surface material and be deposited there. In the case of the large surface bursts at the EPG, which formed craters that filled with water, however, the surface was shielded by the blanket of seawater from the crater's radioactivity. Even in these cases, some of the crater's radioactivity left the crater through underwater currents that carried out radioactive silt.

Cleanup of the shot sites and the surrounding areas is not well documented. Generally speaking, the policy regarding these "hot" areas was to leave them alone and control personnel access. However, as the island areas were quite small, such a conservative approach had limits. Positive cleanup activities in the form of grading and covering "hot" areas are mentioned in preparation for GREENHOUSE (1951) and CASTLE (1954) at Enewetak in the base support contractor's report (Reference D.2).

Apparently, some collection and burial of concrete contaminated with alpha-emitting materials had also begun before HARDTACK, although it is not mentioned in the base support contractor's report for HARDTACK. Investigators for a defense-related program at Enewetak report (Reference D.3) that in 1972 they found five 20- x 20-foot (6.1- x 6.1-meter) concrete slabs covering 4-foot (1.2-meter) deep crypts on Aomon bearing the following notice and date:

ALPHA RADIATION

DO NOT EXCAVATE

THIS 3 INCH THICK CONCRETE SLAB COVERS

PLUTONIUM CONTAMINATED CONCRETE DEBRIS

AEC APR 11 1957

The KICKAPOO test in 1956 was held at Aomon and did spread alpha-emitting contamination. Whether these crypts contained only material from Aomon, or from other islands as well, is not stated in the source.

Results of a radiological survey of the islands of Enewetak Atoll, conducted in March 1958 by H&N, are shown in Table 2. For reference, comparable information following the HARDTACK tests is also shown in the table.

Bikini was the location of the first postwar nuclear detonation. In July 1946, the CROSSROADS tests were conducted in the lagoon. Two 23-KT devices were detonated: one airburst over a target fleet, and the second burst underwater in the lagoon about 2 nmi (3.7 km) west of Bikini Island.

When testing returned to Bikini in 1954, the use of barges as the shot point was begun and thus, with one notable exception, no radioactive surface zero areas were developed. Two large underwater craters were formed in 1954 and these were used as subsequent surface zeros for detonations fired from barges.

Table 2. Enewetak Atoll gamma backgrounds (R/hr), 1958.

Island	Preoperational (31 March)		Postoperational (31 August)	
	High	Average	High	Average
Bokoluo	0.0004	0.0002	0.105	0.040
Bokombako	0.0006	0.0003	0.090	0.060
Kirunu	0.0004	0.0003	0.120	0.040
Louj	0.0003	0.0002	0.100	0.040
Bokinwotme	0.0006	0.0002	0.030	0.012
Bokaidrikdrik	0.004	0.003	0.030	0.014
Boken	0.008	0.004	0.008	0.004
Enjebi	0.0002	0.0001	0.010	0.002
Mijikadrek	0.0002	0.0002	0.002	0.002
Kidrinen	0.0002	0.0001	0.002	0.002
Bokenelab	0.0002	0.0001	0.002	0.002
Dridrilbwij	0.007	0.003	a	a
Aej	0.0005	0.0002	0.002	0.002
Lujor	0.110[b]	0.005	0.002	0.002
Eleleron	0.400[b]	0.003	0.100[b]	0.002
Aomon	0.0012	0.0002	0.0002	0.0002
Bijire	0.0001	0.0001	0.0002	0.0002
Lojwa	0.0001	0.0001	0.0002	0.0002
Alembel	0.0002	0.0001	0.001	0.001
Billae	0.0001	0.0001	0.001	0.001
Runit	0.002	0.0007	0.800	0.005
Munjor	0	0	0.0002	0.0002
Inedral	0	0	0.0002	0.0002
Jinedrol	0	0	0.0002	0.0002
Ananij	0	0	0.0002	0.0002
Japtan	0	0	0.0002	0.0002
Parry	0	0	0.0002	0.0001
Enewetak	0	0	0.0001	0.0001
Ikuren	0	0	0.0001	0.0001
Mut	0	0	0.0001	0.0001
Ribewon	0	0	0.0001	0.0001
Biken	0	0	0.016	0.012
Unibor	0	0	0.080[c]	0.030[d]
Drekatimon	0	0	0.150[c]	0.150[c]

Notes:

[a] Dridrilbwij was destroyed by KOA detonation.

[b] Metal.

[c] Alpha contamination also present (50,000 counts per minute).

[d] Alpha contamination also present (10,000 counts per minute).

Source: Reference C.5.3.

The exception was the site of the KOON test in 1954 on the western end of Eneman Island. This device did not develop its expected yield and thus may have deposited fissionable alpha-emitting material near the shot point. In 1956, the ZUNI test was conducted on the surface at about the same place. ZUNI destroyed the western end of Eneman, distributing the remains over the lagoon waters and the northern islands. Figure 11 is an aerial view of this area. The ZUNI crater lip also contained device debris and in 1958 the JTF 7 radsafe officer observed that the radiation readings on Eneman varied with the tides. At low tide, when more of the lip was exposed, the reading was higher than during high tide when the seawater covered more of the lip (Reference C.1.1685). Figure 12 shows this crater lip in 1958.

The results of radiological surveys of Bikini in 1958 are shown in Table 3.

Johnston Island

Johnston Island is about 1,500 nmi (2,778 km) east and 350 nmi (648 km) north of Enewetak. Johnston Island is about 3,000 feet (915 meters) long and 600 feet (183 meters) wide; the smaller Sand Island lies nearby. Both are surrounded by a reef that forms a half-circle with a 7.5-mile (12-km) diameter. The islands lie within a mile of each other on the northern, semicircular portion of the reef. Figure 13 is a map showing both islands and the surrounding reef. An inset shows the Johnston Island facilities. The collective area of Johnston and Sand islands in 1958 was only 320 acres (129 hectares), most of which was Johnston Island. Almost all of the Johnston Island surface area was covered with runway, taxi strip, and buildings and other structures directly supporting the airfield operation. Figure 14 shows Johnston Island in 1958.

Johnston Island has been a possession of the United States since the acquisition of Hawaii in the 19th century. It was used as a base during World War II. In 1958 it was an Air Force base, but was only used for an emergency landing field and as a base for the operation of navigation aids. Earlier in the decade it had been a regular stop for Military Air Transport Service (MATS) trans-Pacific flights. It was manned by about 100 men in 1958.

The weather at Johnston Island is similar to that of the Marshalls except it is somewhat drier and has less frequent cloud cover. The wind system there is also similar, with trade winds from the east from the surface to about 20,000 feet (6.1 km) altitude, winds from the west from 20,000 to 50,000 feet (6.1 to 15.2 km) altitude, and winds from the east up to the stratosphere.

Special Problems in Oceanic Testing

The Marshalls offered a large uninhabited area for test activities and for the favorable disposition of the test debris if the winds were in the right direction. However, the area was almost all water, offering little dry space to place shot towers, instrumentation shelters, test structures, or places to live. At Enewetak Atoll the total land area is only about 1,800 acres (about 730 hectares), and the prime acreage in the southeastern quadrant (about one-third of the total) housed that part of the task force not based on ships. The land area of Enewetak Island, the largest of the atoll, is only about 320 acres (about 130 hectares), and about half of this was occupied by an airstrip and

Figure 11. Aerial view to east from over ZUNI crater at Eneman Island, Bikini Atoll, 1958.

Figure 12. Revetment being built at west end of Eneman Island, Bikini Atoll (lip of ZUNI crater), 1958.

Table 3. Bikini Atoll gamma backgrounds (R/hr), 1958.

Island	Preoperational (31 March)		Postoperational (31 August)	
	High	Average	High	Average
Bokbata	0.004	0.003	3.500	2.000
Nam	0.0028	0.002	0.180	0.100
Iroij	0.015	0.001	0.036	0.030
Odrik	0.001	0.0004	0.100	0.020
Lomilik	0.001	0.0005	1.000	1.000
Aomen	0.0006	0.0004	0.015	0.010
Bikini	0.0004	0.0002	0.0005	0.0003
Bokonfuaaku	0.0002	0.0002	0.0005	0.0003
Jedrol	0.0001	0.0000	0.00025	0.00025
Eniairo	0.0002	0.0002	0.00025	0.00025
Rochikarai	0	0	0.00025	0.00025
Ionchebi	0.0001	0.0001	0.00025	0.00025
Eneu	0	0	0.00025	0.00025
Aerokoj	0.0002	0.0002	0.0005	0.0005
Aerokojlol	0.0002	0.0002	0.0005	0.0005
Bikdrin	0.0002	0.0002	0.0005	0.0005
Lele	0.0002	0.0002	0.0005	0.0005
Eneman	0.0005	0.0002	1.000	0.250
Enidrik	0.0003	0.0002	0.140	0.080
Lukoj	0.0002	0.0002	0.800	0.600
Jelete	0.0006	0.0004	1.000	0.600
Adrikan	0.0006	0.0005	0.360	0.300
Oroken	0.0008	0.0004	0.300	0.260
Bokaetoktok	0.0008	0.0003	0.300	0.250
Bokdrolul	0.0008	0.0006	0.280	0.240

Source: Reference C.5.3.

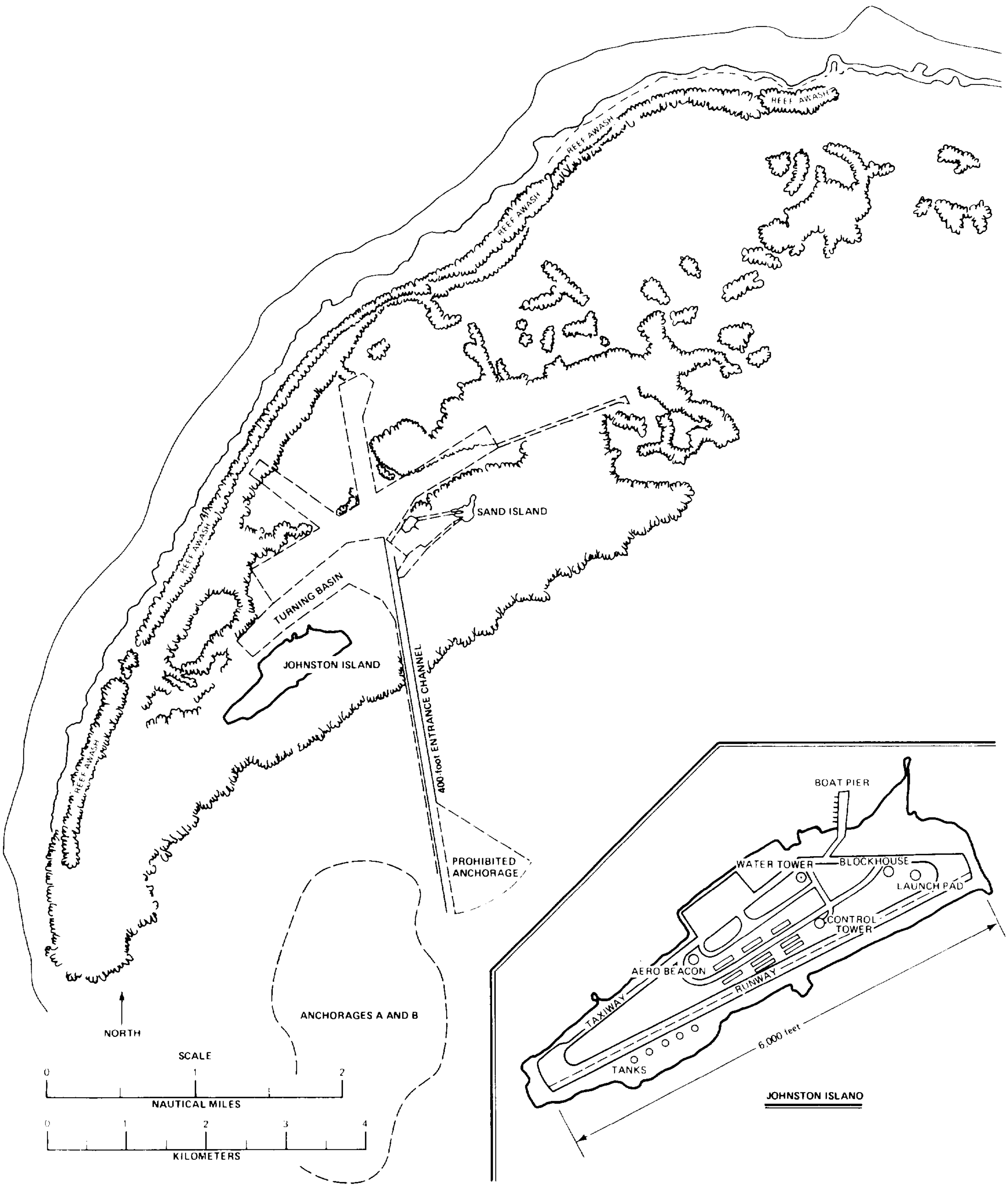

Figure 13. Johnston Island, 1958.

Figure 14. Aerial view of nearly all of Johnston Island, 1958.

associated activities. Furthermore, the land suitable for testing was not necessarily distributed in the appropriate directions and sizes for instrument placement. Lack of land area was one of the factors necessitating use of both Bikini and Enewetak atolls starting in 1954. The addition of Bikini also precluded damage to the Enewetak facilities by very-large-yield devices.

The lack of land was compensated for in part by civil engineering projects. Causeways were constructed that linked strings of islands to support the long pipe runs of some experiments over thousands of feet. These also permitted land transportation from construction camps to proposed zero points, thus allowing more time during the workday to be expended on the job rather than in commuting by water from base islands. Some artificial islands were created as shot points and instrument locations.

Floating data-collection stations also compensated for the lack of land area. These were used extensively in the nuclear radiation program. Anchored rafts and buoys, serving as fallout-collection stations, were placed in the lagoon and in the open sea.

Barge-mounted test devices, a technique first used in 1954, also compensated for the lack of land at the EPG. This allowed the available land area to be used for the placement of measurement instrumentation and reuse of the same burst point without the long delays required for radiological cooling by natural decay or expensive and long decontamination procedures. A typical shot barge is shown in Figure 15.

Figure 15. HARDTACK, ELDER shot barge at Enewetak Atoll with small landing craft alongside.

Reuse of zero points also allowed reuse of instrument locations and recording shelters for several tests, saving construction costs and time and increasing test-scheduling flexibility. In HARDTACK the 26 barge events used only five detonation areas.

Use of shot barges, however, precluded the acquisition of some weapon development data that required a precise line of sight between the test device and the recording instrumentation. Barge movement by lagoon currents was minimized by special mooring techniques, but not to the degree necessary for some measurements. Figure 16 shows a surface shot ground zero and the diagnostic pipe runs. The barges also precluded use of the long overland pipe runs required for some other diagnostic measurements. In HARDTACK, use was made of shorter pipes that collimated radiation and directed it at an angle through the bottom of the barges to instrumentation on the bottom of the lagoon at a sufficient distance to survive the blast. Placement and recovery of such instrumentation required diving operations.

JOINT TASK FORCE 7

JTF 7 was the successor to JTF 132, which had conducted the IVY test series in 1952. JTF 7 was established as a permanent organization in 1953 to conduct nuclear weapon testing in the Pacific. It existed through the end of the 1950s and was dissolved during the moratorium on nuclear weapon testing.

The joint task force incorporated into its organization elements of the four services, other government agencies including the AEC, and civilian organizations under contract. The AEC, charged with responsibility for nuclear

Figure 16. The HARDTACK, CACTUS device cab at zero point on Runit Island, 1958.

energy development by the Atomic Energy Acts of 1946 and 1954, designated Commander JTF 7 (CJTF 7) as its representative for nuclear weapon testing in the Pacific. JTF 7 was also a subordinate command of the Commander in Chief, Pacific (CINCPAC), who provided overall security and logistic support. The Chief of the Armed Forces Special Weapons Project (AFSWP) exercised technical direction of the weapon effects tests of primary concern to the Armed Forces. The complexity of these relationships is illustrated in Figure 17.

The resulting organization, though complex, worked well enough, as it conformed with the realities of the situation. The realities were that the tests were being conducted to develop nuclear weapons, an activity limited by law to a civilian agency, the AEC. The tests were mainly being conducted in an area that came under the jurisdiction of the AEC (in the sense that the AEC was the U.S. government agency primarily responsible for the islands that were included in the EPG). The United States, however, did not actually own the territory being used, but rather it was held in trust. Furthermore, the territory was remote from the United States and required special supply and security arrangements appropriate to military operations. Finally, the organization for which the weapons were being developed was the U.S. military establishment.

The special location of the EPG required a miltary operation to conduct the tests. The JTF 7 Scientific Director actually directed the tests and CJTF 7 enforced his decisions. The joint task force was divided into functional and

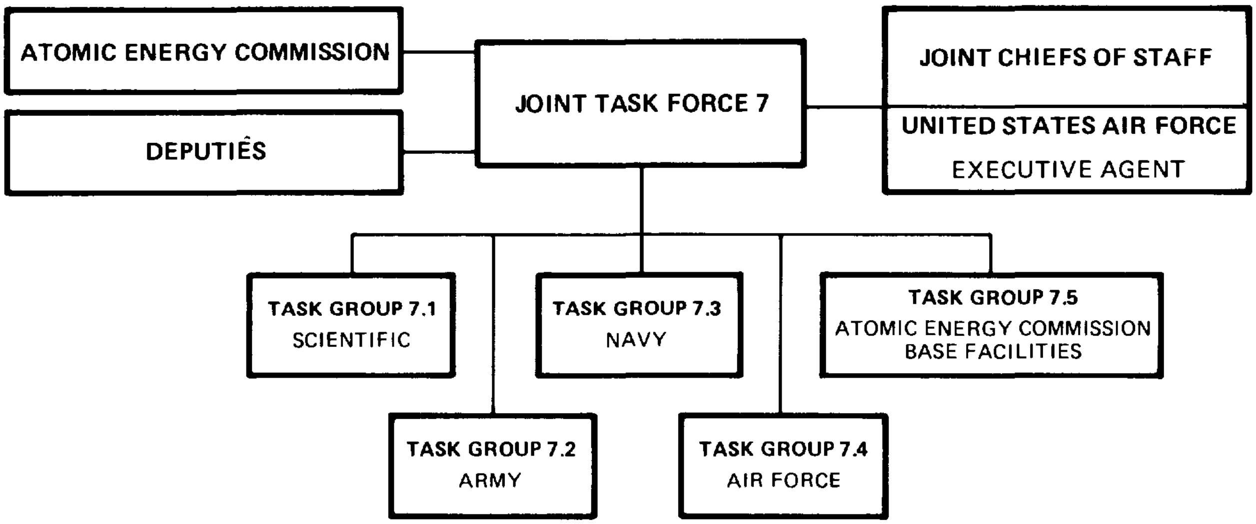

Figure 17. Organization of Joint Task Force 7.

service-branch oriented units, each of which reported to CJTF 7 through their separate task group commanders.

Task Group 7.1 (Scientific)

Functions of the scientific task group were to (Reference C.1.1682):

1. Position, arm, and detonate the nuclear test devices
2. Conduct for each explosion the experiments needed to meet the technical requirements determined by appropriate authority within the AEC and DOD.

With this charter, the scientific task group was the center of the operational effort, as it had been in all previous test series held at the EPG. The organization included seven task units (see Figure 18) with personnel from the AEC laboratories that provided the nuclear devices, from the DOD organizations interested in weapon effects, and from various contractors. All components of the joint task force functioned to support TG 7.1 work in one way or another.

Most TG 7.1 personnel were stationed on Enewetak Atoll, with Bikini Atoll and Johnston Island used as forward working areas for units participating in shots fired at these locations. A few project personnel for Task Unit 7.1.3 (TU 7.1.3) and TU 7.1.4 were stationed at Rongelap, Kwajalein, and Wotho atolls, and Kusaie and Wake islands. Peak population of TG 7.1 in the EPG was 1,333, reached on 24 April 1958 when 946 men were at Enewetak Atoll and 387 were at Bikini Atoll, although because of personnel movements both atolls had higher numbers of personnel at different dates. Peak task group population at Enewetak was 1,038, reached 8 May, and at Bikini was 490, reached on 14 April. The peak population at Johnston Island was 378 on 31 July. A total of 2,171 men were badged as members of TG 7.1, but the report of CTG 7.1 stated that a total of 2,665 individuals "participated in the operation" (Reference C.1.1682, pp. 71-72).

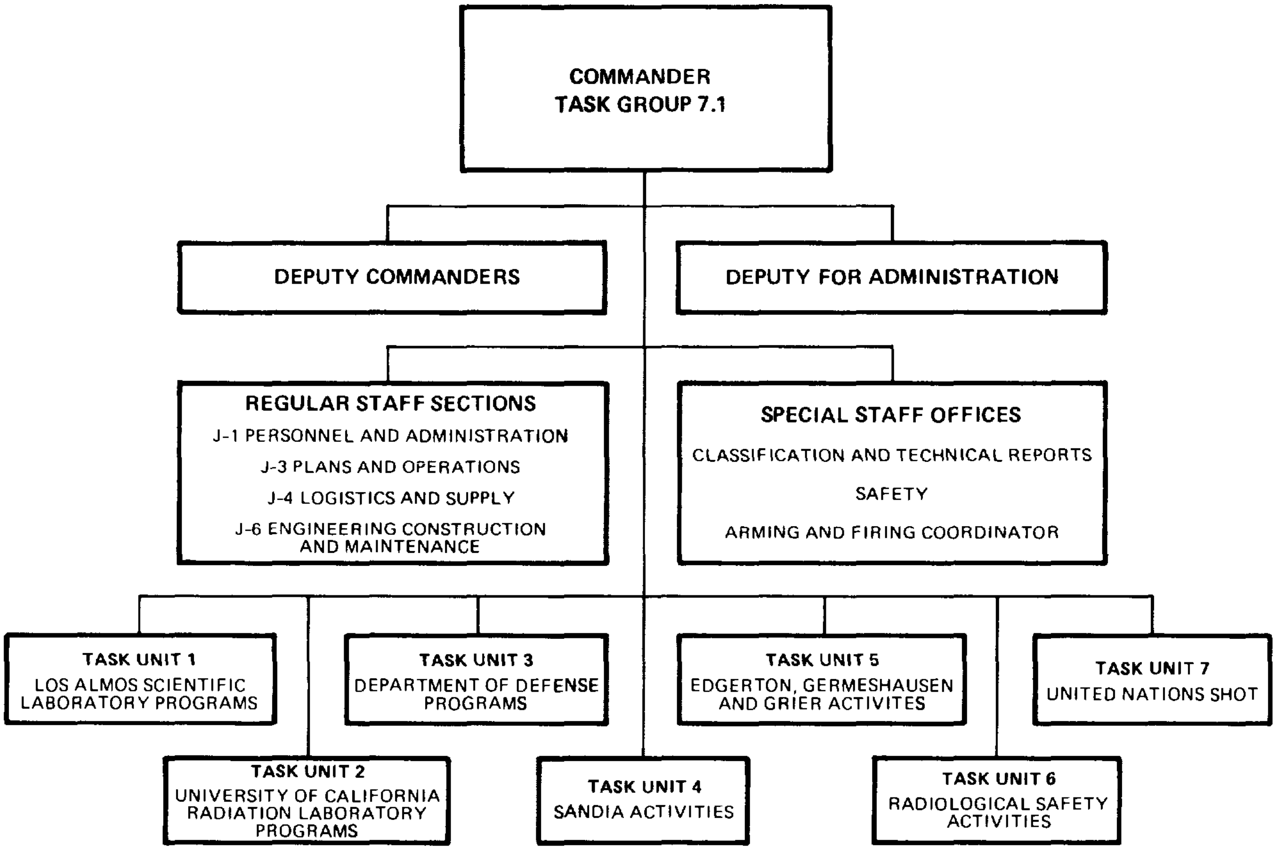

Figure 18. Organization of Task Group 7.1, HARDTACK.

TASK UNIT 7.1.1 -- LASL PROGRAMS. This unit conducted the diagnostic measurements on the LASL-developed nuclear devices. All the LASL devices were detonated on Enewetak Atoll and TU 7.1.1 was based on Parry Island (Reference B.0.1, Annex O, p. O-2). The Consolidated List of Exposures (Reference C.1.6.3), a compilation of film badge readings for HARDTACK participants, shows 264 men badged as part of the task unit, 235 from LASL, and 29 from the Naval Research Laboratory (NRL).

TASK UNIT 7.1.2 -- UCRL PROGRAMS. TU 7.1.2 was organized to make diagnostic measurements for the tests of the UCRL-developed nuclear devices. Originally, all the UCRL shots were to be conducted on Bikini Atoll; however, bad weather slowed the pace of testing at Bikini, and five of the fifteen UCRL shots were transferred to Enewetak Atoll. The Consolidated List shows men from the following organizations badged as members of this task unit:

UCRL	386
Sandia Corp	7
Unidentified	2
	395

Plans called for three military to be included, but apparently they were not unless the "Unidentified" were military.

TASK UNIT 7.1.3 -- DOD PROGRAMS. The mission of TU 7.1.3 was to conduct weapon effects experiments. Its most concentrated efforts were on shots YUCCA, UMBRELLA, WAHOO, TEAK, and ORANGE. Many projects were also active on the surface HARDTACK shots, CACTUS, KOA, QUINCE, and FIG. One or more of the project teams participated on 18 other shots.

The organization was divided into three major components. One component, including the task unit headquarters, was on Parry Island, and forward area commands were located at Bikini Atoll and Johnston Island. Until 30 June, most TU 7.1.3 personnel were based at Enewetak Atoll. The contingent at Bikini Atoll was reduced to one officer and one enlisted man after YUCCA because only one project was active there following the mid-April decision to move the launch site for the TEAK and ORANGE missile shots to Johnston Island. Most of the TU 7.1.3 personnel from Bikini were sent to Johnston Island, where, augmented by some men from the Enewetak contingent, they carried out task unit projects for TEAK and ORANGE. After 1 July, Johnston Island was the major focus of DOD HARDTACK activities.

The Consolidated List shows 841 men badged as members of TU 7.1.3 from some 40 organizations, representing both government and private industry. Strength of the task unit at the EPG peaked at 665 men on 12 April. After 1 July, staff and project personnel were sharply reduced in the EPG, leaving only those participating in the QUINCE and FIG shots. Task unit staff began arriving at Johnston Island on 1 June, with the largest buildup of personnel in early July. A task unit staff of 31 and about 230 project personnel helped support the two Johnston Island tests (Reference C.1.1682, p. 120). The task unit also had a small number of men on Wotho, Kwajalein, and Rongelap atolls, and Kusaie and Wake islands.

TASK UNIT 7.1.4 -- SANDIA ACTIVITIES. Manned entirely by Sandia Corporation personnel, TU 7.1.4 conducted Programs 32 and 34. In Program 32, instrumented rockets were used to measure various phenomena and effects resulting from the TEAK and ORANGE explosions. Project personnel photographed the two detonations. Sandia also provided the missile warheads and helped evaluate the fuzing and firing systems.

Sandia provided assorted services through Program 34, mostly to elements of TG 7.1, including (1) diagnostic telemetry for many shots, (2) the nuclear devices and various supporting systems for YUCCA, UMBRELLA, and WAHOO, (3) microbarographic measurements of blast waves on most shots, (4) measurements of radiation effects on nuclear weapon components, and (5) measurement of radiation during the QUINCE and FIG shots (Reference C.1.1682, pp. 13, 20-21).

One hundred seventy-seven Sandia employees were badged as members of TU 7.1.4. During January and February 1958, task unit staff elements arrived at the EPG. Personnel working on Program 32 arrived in March. By April most of the personnel working on Project 34 had arrived. The task unit's first personnel peak was reached in April, when 111 men were at the EPG. The second peak occurred in July with 123 personnel on hand (Reference C.1.1682, p. 121). Task force planning also called for small contingents to be stationed on Kwajalein and Rongelap (Reference B.0.1, Annex O, p. O-2).

TASK UNIT 7.1.5 -- EDGERTON, GERMESHAUSEN & GRIER (EG&G) ACTIVITIES. This task unit provided systems for arming, monitoring, and firing the nuclear devices and timing signals for the experimental programs; performed technical photography of all detonations; and measured reaction histories of 19 shots. EG&G installed a total of seven firing systems: three each on Eneu and Parry, and one on USS Boxer (CVS-21). One of the systems on Eneu Island was moved to Johnston Island when the TEAK and ORANGE missile launches were transferred there from Bikini Island.

The CTG 7.1 report states that 320 EG&G men served with TU 7.1.5 in the forward area (Reference C.1.1682, p. 124). The Consolidated List, however, shows only 229 badged personnel. One man from an unidentified organization also served with TU 7.1.5. EG&G technicians began installing equipment in early February, and a peak force of 149 was working in the field on about 1 May.

TASK UNIT 7.1.6 -- RADIATION SAFETY. This task unit was the major radsafe organization for the joint task force. Because intensive testing was conducted at both Bikini and Enewetak atolls, the task unit had to maintain extensive radsafe services at both locations. When shots TEAK and ORANGE were moved to Johnston Island, the task unit performed radsafe services there also. Chapter 2 treats the activities of TU 7.1.6 in detail.

The armed forces supplied most of the task unit personnel. The planned strengths were Army, 95; Navy, 8; and Air Force, 12. Most service personnel were members of the Army 1st Radiological Safety Support Unit (1st RSSU) stationed at Fort McClellan, Alabama. Four LASL men and three UCRL men were attached as advisors (Reference C.1.1682, p. 127). Totals of personnel for TU 7.1.6 as derived from issued film badges vary somewhat from this. According to the Consolidated List, 94 men were drawn from the 1st RSSU, 20 from LASL, and 1 from an unidentified organization.

TASK UNIT 7.1.7 -- UNITED NATIONS SHOT. CTG 7.1 reported that this unit "bore little resemblance to the other task units" (Reference C.1.1682, p. 124). Its function was to conduct a shot for observers invited by the United States to demonstrate that the United States could design nuclear weapons that were radiologically "clean;" that is, weapons in which a low proportion of their yields were generated by fission. Such weapons would therefore spread less radiologically active fission products than devices fired during prior testing.

To be convincing, the demonstration required that the observers be given access to the data on the total yield and the fission yield of the device. Further, the ways in which these yields were measured or derived also had to be demonstrated, which required scientifically trained observers in order to understand the methods and the measurements.

Observers were to be a scientist and a press representative from each of the 14 member nations of the UN Committee to Study the Effects of Atomic Radiation. The plan called for a week's orientation at the University of California in Berkeley, during which the nature of the measurements to be taken would be discussed and presumably understood by the scientific observers. The group would then proceed to the EPG to observe test preparations, the shot, and the debris sampling. The group would then return to Berkeley for another week devoted to the analysis of the data collected leading to the proof of cleanness.

Although the demonstration was cancelled on 26 July, preparations had been made at Enewetak for the test, which was to have been called PINYON. A barge and a backup had been prepared by H&N. These barges were modifications of the usual kind used, having, among other additions, periscopes so that observers on the deck of the barge could inspect the bottoms of the barges, undoubtedly to convince them that no substitutions were being made underwater. The test device and its backup were flown from Kirtland AFB to EPG on 4 July. These were returned on 5 August, a few days after the announcement of the test cancellation.

Task Group 7.2 (Army)

TG 7.2 was the permanent garrison force in the EPG; its lineage dated back to the inception of nuclear weapon tests at Enewetak in 1948.

TG 7.2 was the representative of CINCPAC at Enewetak between test operations and was responsible for internal military security and ground defense for the atoll. The HARDTACK tasks were as follows (Reference C.2):

1. Provide for the ground security of Enewetak and Bikini atolls
2. Prevent unauthorized entry into the exclusion area
3. Provide for the general surveillance of Enewetak and Bikini atolls to prevent removal of significant samples from shot islands by unauthorized persons and unauthorized photography and trespassing
4. Deny entry of uncleared personnel into Enewetak and Bikini atolls
5. Provide and operate the overall military communications system for handling all forward area task force interatoll and long-haul traffic (exclusive of air operations, air weather, internal naval communications, and the TG 7.1 interatoll radio circuit)
6. Operate all base facilities at Enewetak Island, except those specifically allocated to CTG 7.4 and CTG 7.5
7. Provide monitoring and decontamination services
8. Conduct emergency postshot evacuation of all personnel based on Enewetak Atoll on order of CJTF 7
9. Provide logistic support for those elements of JTF 7 based on Enewetak Island augmented by TG 7.4
10. Provide hospital facilities for all shore-based military personnel and emergency medical treatment for civilian personnel on Enewetak Island.

The task group was organized into three detachments, as shown in Figure 19.

ADMINISTRATIVE DETACHMENT. Personnel of this detachment supported the Chaplain, the Provost Marshal, and the Finance, Information, and Postal Section. Its scheduled strength was 50 officers and 482 enlisted men during the operational period. The detachment headquarters scheduled strength was 2 officers and 7 enlisted men during the operational period.

OPERATIONS DETACHMENT. Duties of this detachment were administrative and logistic support for assigned personnel, including laundry, medical, dental, commissary, engineering, depot, gear loft, truck motor pool, and maintenance support. Its scheduled strength was 25 officers and 379 enlisted men and its headquarters strength was 2 officers and 7 enlisted men.

1st PROVISIONAL MILITARY POLICE COMPANY. This detachment consisted of 8 officers and 133 enlisted men during the operational period who began arriving in increments during February 1958. This unit was responsible for maintaining security at all sites at Enewetak and Bikini atolls. JTF 7 maintained operational control of this unit; however, for administrative and logistic support the unit was attached to TG 7.2.

Three additional groups, otherwise unconnected with HARDTACK, reported to TG 7.2. The U.S. Coast Guard (USCG) operated a Loran Station on Enewetak, with a 10- man contingent, as a navigational aid for trans-Pacific commerce. One

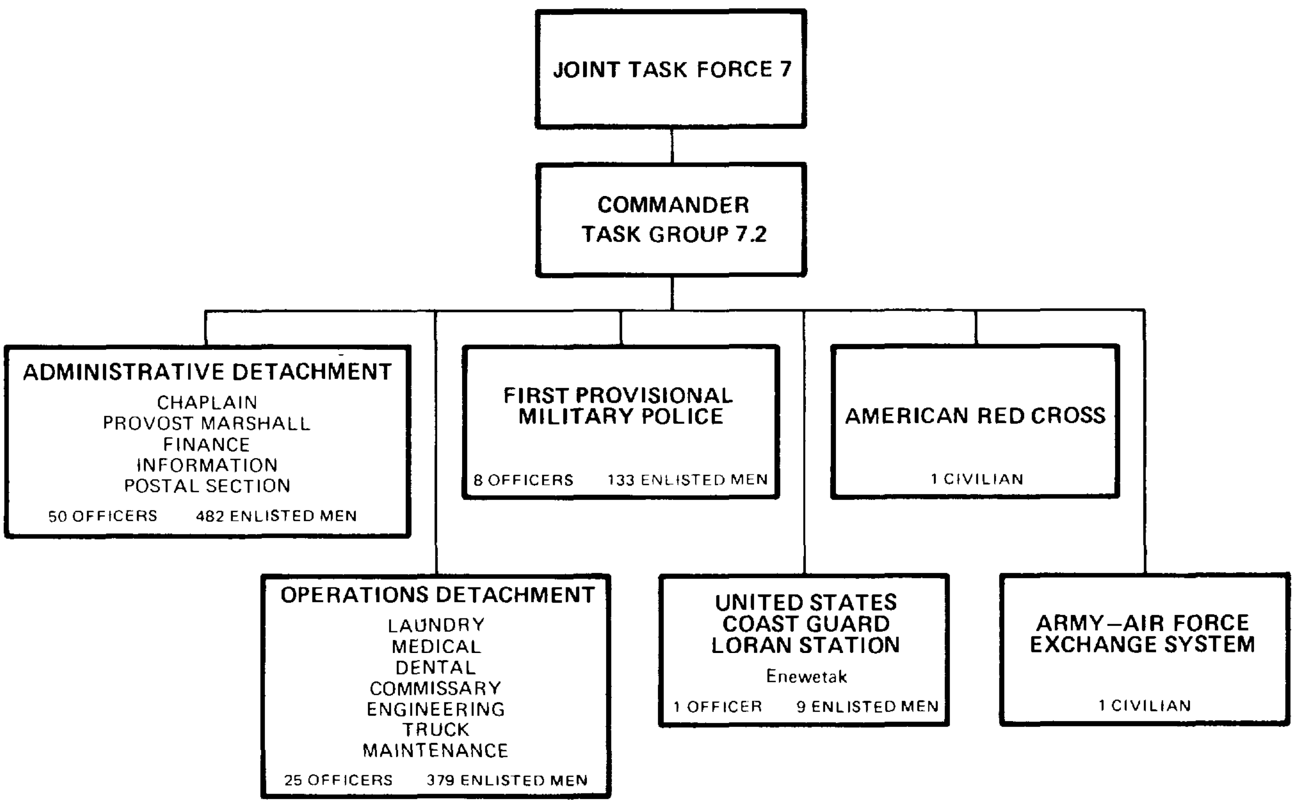

Figure 19. Organization of Task Group 7.2, HARDTACK.

civilian from the American Red Cross was assigned as field director to TG 7.2. The Army-Air Force Exchanges System had a representative who was also assigned to TG 7.2 (Reference B.0.1).

The operations plan had called upon TG 7.2 to operate a boat pool for support of Enewetak operations. However, no other evidence of TG 7.2 operating such a pool has been discovered, and it is likely that small boat support at Enewetak was provided by TG 7.5 or possibly TG 7.3.

The locations of the personnel of TG 7.2 are given in Table 4.

Table 4. Task Group 7.2 scheduled population at Eniwetok Proving Ground, HARDTACK, 1958.

Unit	Operational Strength			Operational Location
	Officers	Enlisted Men	Civilians	
Administrative Detachment	50	482	0	Enewetak
Operations Detachment	25	379	0	Enewetak
1st Provisional MP Company, 720th MP Battalion	2	39	0	Eneu
	1	13	0	Aerokojlol, Eneman, Aerokoj
	0	14	0	Bikini
	3	49	0	Parry
	1	9	0	Enjebi
	1	9	0	Runit
USCG Loran Station	1	9	0	Enewetak
American Red Cross	0	0	1	Enewetak
Army-Air Force Exchanges System	0	0	1	Enewetak
Total	84	1,003	2	

Source: Reference B.0.1.

Task Group 7.3 (Navy)

TG 7.3's major mission, according to TG 7.3 Op Plan 1-58 (Reference B.3.1), was naval support of JTF 7, including an evacuation capability. This broad assignment encompassed the ocean transportation of JTF 7 personnel, equipment, supplies, and nuclear devices. In addition, TG 7.3 was responsible for ensuring the security of the EPG and protecting it from foreign intrusion, as well as assistance with search and rescue (SAR) missions. In effect, any task or job that involved interatoll, intra-atoll, and deep-sea operations also involved TG 7.3. The intra-atoll marine transport responsibility was shared with TG 7.5.

The broad support mission of TG 7.3 included more than 30 distinct tasks. Among these, the major tasks were:

1. Maintain security of the danger area
2. Provide air support for radsafe reconnaissance and barrier patrols
3. Maintain a shipboard capability for emergency evacuation of Enewetak Atoll and off-atoll stations
4. Assist CTG 7.4 in SAR missions
5. Provide shipboard facilities at Bikini for preshot evacuation of personnel, boats, and other craft and helicopters
6. Provide an afloat air operations center (AOC) at Bikini
7. Furnish interatoll water transportation for special weapons, devices, shot barges, and other craft
8. Provide intra-atoll helicopter transportation at Bikini
9. Provide ship-to-shore transportation at both atolls
10. Provide weather information and data to JTF 7 Weather Central at designated times
11. Furnish Marine Corps security guards for weapons and devices
12. Conduct all diving operations in the EPG
13. Furnish platforms afloat for scientific projects
14. Conduct postshot recovery operations to retrieve objects from the water for diagnostic and effects measurements
15. Conduct marine salvage operations.

The units assigned to TG 7.3 by March 1958 totalled 52 ships, 33 fixed-wing aircraft, 15 helicopters, 38 small craft, and 13 service craft. Available records on the number of participating Navy personnel conflict. The final report of CJTF 7 (Reference C.0.1) gave the peak Navy personnel strength as 6,487 (599 officers and 5,888 enlisted men) out of a total of 10,233 military personnel and 4,239 civilians. The final report of CTG 7.3 (Reference C.3.1) set the Navy peak strength at 6,822, and the number of participating Navy personnel present throughout the operational phase totaled 9,178.

CTG 7.3, during the actual test phase of HARDTACK, organized his staff into seven divisions, two of which (the Technical Director [N-6] and the Special Projects Division) were primarily responsible for activities connected with shots WAHOO and UMBRELLA. Ship movement and harbor control at Bikini and Enewetak were exercised by the Senior Officer Present Afloat (Administration) (SOPA [Admin]) at each atoll.

Figure 20 shows the planned nine operational task units and one preoperational testing unit of the TG 7.3 organization (Reference C.3.1). Because of the complexity of operations, however, and the hectic pace of events, the figure does not reflect how it was actually organized during the operational phase. TG 7.3 organization varied from shot to shot, depending on the requirements for the individual shots and the ships present.

TG 7.3 task units and their supporting task elements were established to conduct all of the Navy's important missions during HARDTACK, including support for scientific projects, helicopter lift, surface and air security, radiological reconnaissance flights following shots, and both interatoll and intra-atoll surface transportation. As in past operations, Navy ships were also assigned to evacuate personnel during high-yield detonations.

Most TG 7.3 personnel and ships were concentrated in three task units at Enewetak: TU 7.3.1, the Technical Coordinating Unit; TU 7.3.2, the Enewetak Operating Unit; and TU 7.3.3, the Surface Weather Reconnaissance and Security Unit. Ships at Enewetak were: six fleet ocean tugs, two salvage ships, one submarine rescue ship, all target ships, one repair ship, three destroyers, one dock landing ship (LSD), and an attack transport. Fuel requirements at Enewetak were largely handled by the oil storage barge, YOS-32. The large number of naval vessels grew out of the demand for mooring the target arrays for the underwater shots. The repair ship was stationed at Enewetak to make it available to the greatest number of ships. The attack transport was for emergency evacuation from Enewetak Atoll, as well as sea-based decontamination facilities.

For most of the time, the forces at Bikini were Boxer, USS Cacapon (AO-52), one assigned destroyer, and USNS Fred C. Ainsworth (T-AP-181). Plans were also made that one dock landing ship, USS Belle Grove (LSD-2), be stationed at Bikini, but the requirements for preparing the site at Johnston Island for TEAK and ORANGE necessitated reassignment of Belle Grove to support the buildup of that location. TU 7.3.9, the Bikini Evacuation Unit, absorbed all ships that happened to be at Bikini when a shot was detonated. TU 7.3.5 (whose official composition was "As Assigned") served as the organizational component activated for special operations, such as required for shots YUCCA, WAHOO, UMBRELLA, TEAK, and ORANGE. Some of the task units were composed of several task elements that had specific operational responsibilities (Reference C.3.1).

Although this organizational scheme originally was designed to cover all of the Navy's responsibilities during HARDTACK, actual naval operations during the test series were conducted quite differently. The changing nature of HARDTACK, caused by the addition and deletion of several shots and projects, tended to erode this organizational structure. As a result, "there was a more or less natural division of forces" (Reference C.3.1) and the task group organization during the operation was quite fluid, with the composition and duties

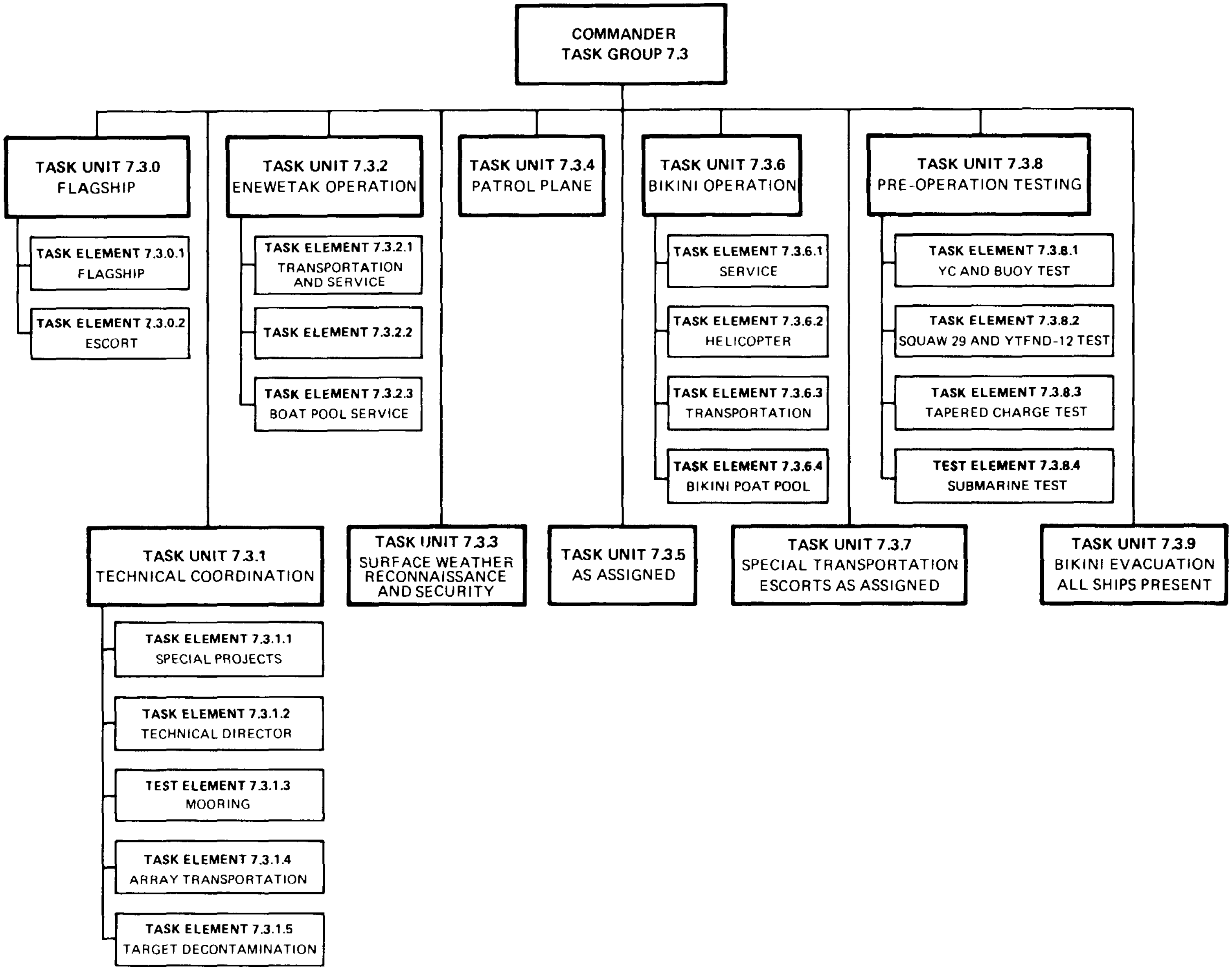

Figure 20. Organization of Task Group 7.3, HARDTACK.

of task units and elements changing frequently. An example of the changing organizational structure is TU 7.3.5, which began the operation designated as "Naval Station Unit, Kwajalein," then evolved into a miscellaneous unit that operated "As Assigned," and finished its participation in HARDTACK as the "Johnston Island Unit." CTG 7.3 recognized the changes in his staff's plans for HARDTACK when the actual operations got underway. He wrote in his final report that organization would have been greatly simplified by having task units based upon location; that is, Enewetak, Bikini, and Kwajalein, with an added unit to handle the test preparations for the underwater shots.

Table 5 lists the naval elements involved and their functions.

Task Group 7.4 (Air Force)

The Air Force support group was made up of three subordinate units: the Test Aircraft Unit (TAU), the Test Base Unit (TBU), and the Test Services Unit (TSU) (see Figure 21). The primary mission of TG 7.4 was to support and control the aircraft necessary to collect and record data required by the test program and as directed by CJTF 7. CTG 7.4 exercised operational control of all aircraft airborne in the Enewetak Air Control Area. The missions of the task group included the following:

1. Provide airbase facilities at Enewetak and Bikini
2. Provide an interatoll air transportation facility
3. Provide a helicopter and liaison aircraft interisland air transportation facility at Enewetak and Bikini atolls (Marine Helicopter Transport Squadron [Light] 361, HMR[L]-361, took over the Bikini functions as the series began)
4. Provide weather reconnaissance and forecasting service
5. Provide SAR facilities within the Air Control Area of the EPG
6. Augment tactical and administrative communications
7. Operate aircraft control system on Enewetak Island
8. Provide aircraft for resupply of weather and project islands
9. Supervise operation of a field maintenance system and supply activities on Enewetak.

In addition to the primary missions of TG 7.4, its subordinate units also had specific tasks assigned to them.

TEST AIRCRAFT UNIT. The Commander, TAU, exercised control over all TAU aircraft and administered personnel assigned or attached to the TAU. The tasks of the TAU included:

1. Supervise the general and specialized crew briefings for aircraft crews involved in the test operation
2. Prepare takeoff schedules and position times for all aircraft flying on shot and rehearsal days

Table 5. Task Group 7.3 component functions and complements, Operation HARDTACK, April to August 1958.

Unit	Number of Men[a]	Function/Comments
USS De Haven (DD-727)	244	Weather, SAR; scientific projects
USS Elkhorn (AOG-7)	93	Supplied petroleum, oil and lubricants (POL)
USS Epperson (DDE-719)	244	Johnston Island scientific projects
Fullam (DD-474)[b]		Target ship for shots WAHOO and UMBRELLA
USS Grasp (ARS-24)	81	Positioned, moored, decontaminated, salvaged target ships; scientific projects
USS Hitchiti (ATF-103)[c]	85	Scientific project 4.1, shot TEAK only.
USS Hooper Island (ARG-17)	400	Special services to target ships, evacuation ship, decontaminated Bonita (SSK-3)
Howorth (DD-592)[b]		Target ship for shots WAHOO and UMBRELLA
USS Joyce (DER-317)	160	SAR, scientific project
USS Karin (AF-33)	93	Transportation, logistic support
Killen (DD-543)[b]		Target ship for shot WAHOO and UMBRELLA
USS Lansing (DER-388)	191	SAR; scientific projects
USS Lawrence County (LST-887)	135	Provided diesel fuel, berthed and messed JTF 7 personnel, scientific project
USS Magoffin (APA-199)	341	Transportation of personnel, decontamination center
USS Mansfield (DD-728)	256	Weather observations, SAR assignments, flagship Commander Destroyer Squadron Nine
USS Merapi (AF-38)	90	Transportation and logistic support
USS Moctobi (ATF-105)	68	Positioned, moored, and salvaged target arrays; water collection
USS Monticello (LSD-35)	301	Transport of LCUs, shot devices; operational support to Boat Pool Detachment; nosecone recovery
SS Michael Moran (EC-2)[b]		Target ship for shots WAHOO and UMBRELLA
USS Munsee (ATF-107)	64	Moored scientific project vessels
USS Navarro (APA-215)	315	Transportation, evacuation capability, decontamination center
USS Nemasket (AOG-10)	82	Fuel carrier

Notes:

[a]Number of men is the greatest of CTG 7.3 Final Report (Reference C.3.1) or Ship Roster, or number badged on Consolidated List (Reference C.1.6.3).

[b]Fullam, Howorth, and Killen were not in commission status, hence are not identified as United States Ships (USS). They had been withdrawn from the Reserve Fleet Group, Long Beach, California, for HARDTACK. Michael Moran was a moth-balled Liberty ship until removed from the Maritime Administration Reserve Fleet at Suisun Bay, California, for use in HARDTACK.

[c]Ship's complement figure from Dictonary of American Naval Fighting Ships.

(continued)

Table 5. Task Group 7.3 component functions and complements, Operation HARDTACK, April to August 1958 (continued).

Unit	Number of Men[a]	Function/Comments
Commander, Destroyer Squadron One	13	Weather observations, assigned destroyers' tasks, administrative functions
Commander, Destroyer Squadron Nine	14	Relieved Commander Destroyer Squadron One on 16 May
CTG 7.3 and staff	88	Handled surface ships, submarines, and Navy aircraft
USNS Fred C. Ainsworth (T-AP-181)	195	Hotel ship, command post TG 7.5, floating administration and communications center
USS Arikara (ATF-98)	70	Positioned, moored, decontaminated, and salvaged target arrays; collected water samples
USS Belle Grove (LSD-2)	286	Transported LCUs between Pearl Harbor, Johnston Island, Enewetak, Bikini
USS Benner (DDR-807)	268	Weather observation; search and rescue (SAR); nosecone recovery, Air Operations Center, Bikini; acted as Senior Officer Present Afloat (Administration) Bikini
USS Bolster (ARS-38)	85	Moored, positioned and salvaged target arrays, recovered instruments for scientific project
Bonita (SSK-3)[b]	51	Target vessel for scientific projects
USS Boxer (CVS-21)	1,100	Command ship, CJTF 7, CTG 7.3, CTG 7.1, CTG 7.4, and Air Operations Center; involved in scientific projects; launched YUCCA balloon; carried nuclear devices
	57	U.S. Marine Corps detachment; nuclear device security
Marine Helicopter Transport Squadron (Light) 361	168	Ship-to-shore helicopter service
USS Cacapon (AO-52)	220	Supplied fuel and aviation gasoline at Bikini, Enewetak, Johnston Island
USS Chanticleer (ASR-7)	101	Mooring and diving activities
USS Chowanoc (ATF-100)	68	Positioned, retrieved target ships; moored YCs; involved in scientific projects
USS Cogswell (DD-651)	237	Johnston Island scientific projects
USS Collett (DD-730)	263	Security patrols, weather, SAR, oceanographic observations
USS Comstock (LSD-19)	233	Preoperational phase: ferried LCUs between Bikini and Enewetak
USS John R. Craig (DD-885)	241	Surface security, weather, SAR; scientific project
USS Cree (ATF-84)	62	Moored, salvaged target arrays

Note:

[a]Number of men is the greatest of CTG 7.3 Final Report (Reference C.3.1) or Ship Roster, or number badged on Consolidated List (Reference 1.6.3).

[b]Bonita's Navy status was "out of commission, in service;" hence, it is not identified as a United States Ship (USS).

(continued)

Table 5. Task Group 7.3 component functions and complements, Operation HARDTACK, April to August 1958 (continued).

Unit	Number of Men[a]	Function/Comments
USS Orleck (DD-886)	245	Weather, SAR, antisubmarine watches, nosecone recovery
USS Floyd B. Parks (DD-884)	237	Surface security patrols, weather observations, SAR
USS Perkins (DDR-877)	235	Weather observations, surface security patrols, SAR, escort for YUCCA balloon launch ship
USS Rehoboth (AGS-50)	164	Oceanographic surveys, scientific projects
USS Renville (APA-227)	330	Floating radsafe decontamination center
USS Safeguard (ARS-25)	72	Recovered radioactive nosecones from TEAK, ORANGE shots
USS Silverstein (DE-534)[b]	222	Postoperational: collected water samples to measure radioactivity
USS Sterlet (SS-392)	83	Target submarine for shot WAHOO
USNS T-LST-618	52	Moved heavy construction equipment and material; emergency evacuation ship; rollup of weather islands
USNS T-LST-664	47	Transported heavy construction equipment; emergency evacuation ship; rollup of weather islands
USS Takelma (ATF-113)	81	Positioned, recovered, decontaminated target arrays; laid moors; scientific projects
USS Tillamook (ATA-192)	38	Towed YOGN-115 and YB-11 to Pearl Harbor from Johnston Island
USS Tombigbee (AOG-11)	78	Supplied various fuels
USS Tortuga (LSD-26)[b]	326	Preoperational: shuttled men, material between Enewetak, Bikini
Bikini Boat Pool Element	227	Boat Pool support at Bikini, interatoll lifts
TG 7.3 Boat Pool Detachment	209	Supported movement of project personnel and equipment to and from underwater target arrays
Special Projects Unit	164	Prepared target vessels, brought ships to EPG, moored target vessels
Explosive Ordnance Disposal Unit 1	6	Laid four mine fields for scientific project 6.7, conducted diving operations
Mine Detail Augmenting Unit 0302	15	Support for mine project in UMBRELLA, recovered mines
Patrol Squadron 22	154	Detected, warned, and escorted unauthorized craft out of the danger area; collected scientific data; radiological surveys; SAR; nosecone recovery
Patrol Squadron 28	378	
Kwajalein Naval Air Station	22	Transported VIP observers to the EPG
VA-10, Detachment A	20	Supported Air Force operations at Johnston Island recovering nosecones
VM-3, Detachment A	13	
VW-1, Detachment A	13	

Notes:

[a] Number of men is the greatest of CTG 7.3 Final Report (Reference C.3.1) or Ship Roster, or number badged on Consolidated List (Reference C.1.6.3).

[b] Ships's complement figure from Dictonary of American Naval Fighting Ships.

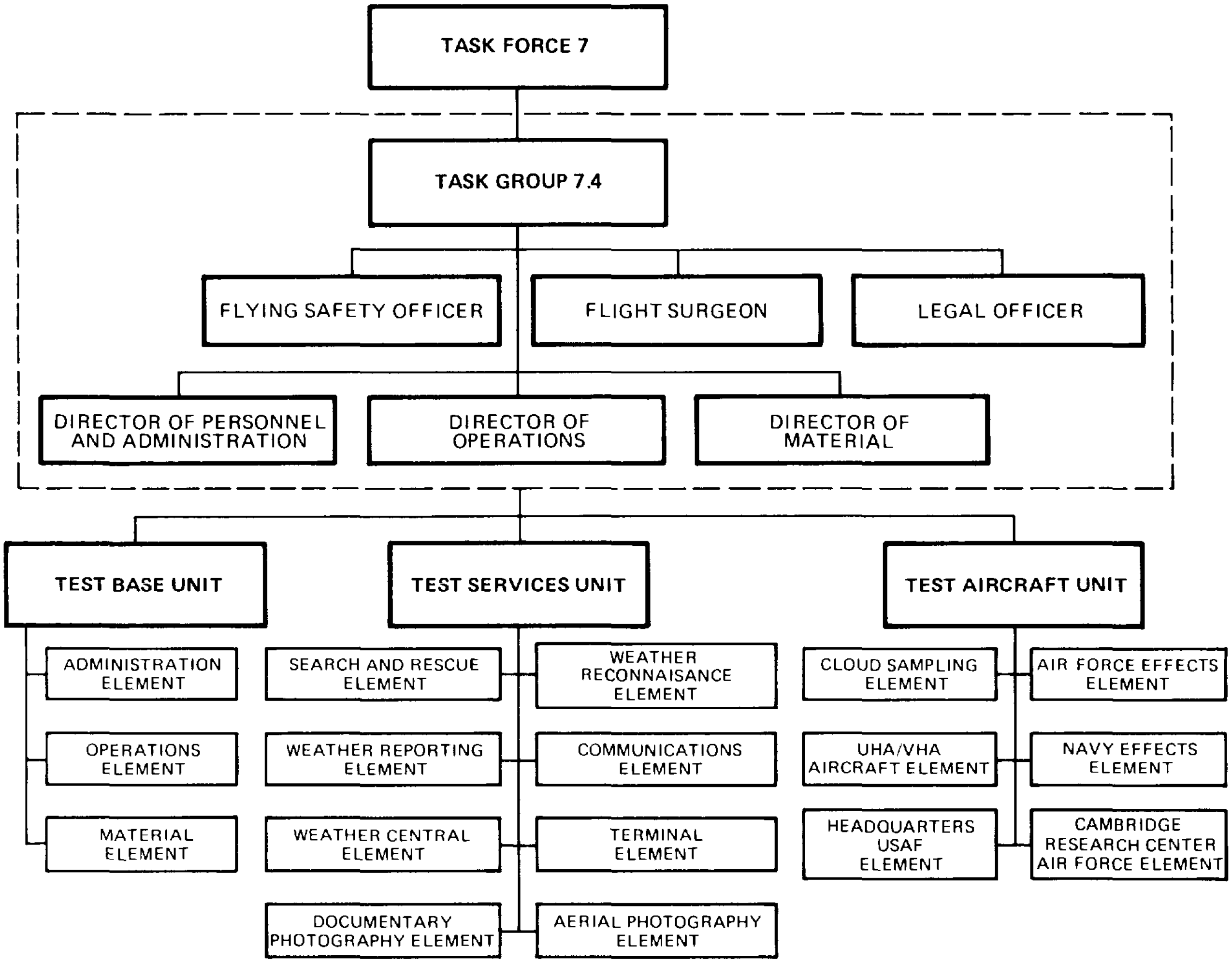

Figure 21. Organization of Task Group 7.4, HARDTACK.

3. Assist TG 7.1 in preparing cloud samples for shipment

4. Provide radiological monitors for special flights participating in test array

5. Provide an air evacuation capability using all aircraft assigned and attached to the TAU.

The TAU was subdivided into seven elements that carried out these assigned tasks.

<u>Cloud Sampling Element</u>. The 4926th Test Squadron (Sampling), Air Force Special Weapons Center (AFSWC), Kirtland AFB, augmented by personnel from the 4025th Strategic Reconnaissance Squadron of the 4080th Strategic Reconnaissance Wing, Strategic Air Command (SAC), made up the cloud sampling element. This element operated and maintained ten AFSWC B-57B aircraft and six SAC B-57D aircraft. Its mission was to collect the particulate and gaseous samples required by the AEC laboratories and Hq USAF. In addition, it also performed aircraft and personnel decontamination, provided radsafe devices, established radsafe

procedures, and maintained master records of radiation exposures for sampler crews and personnel connected with removal of cloud samples from aircraft.

Air Force Effects Element. This element was manned, trained, and equipped by Wright Air Development Center (WADC). It provided, operated, and maintained one B-52 aircraft.

Navy Effects Element. This element was manned, trained, and equipped by Naval Air Special Weapons Facility (NASWF). It operated and maintained two F4-Js, two A4Ds, and one P2V aircraft in support of Navy Bureau of Aeronautics projects.

SAC Indirect Bomb Damage Assessment (IBDA) Element. This element was manned, trained, and equipped by SAC and operated from Anderson AFB, Guam. A SAC liaison officer attached to the TAU coordinated its activities and participation. The IBDA element operated B-47 aircraft under the operational control of TG 7.4 when in the Enewetak Air Control Area.

High-Altitude Shot Aircraft Element. The 4928th Test Squadron (Atomic), Kirtland AFB, a subordinate unit of the 4925th Test Group and of AFSWC, was the specific unit involved with the high-altitude shot aircraft element. This element was manned, trained, and equipped by AFSWC. It maintained and operated two RB-36 aircraft to support technical projects during YUCCA, TEAK, and ORANGE.

Ionosphere Element. The 224th Operations Group from L.G. Hanscom Field manned the aircraft for the Air Force Cambridge Research Center (AFCRC). This element was manned, trained, and equipped by AFCRC. It operated one C-97 aircraft in support of ionospheric studies.

Hq USAF Element. This element was manned, trained, and equipped by Hq USAF and performed test detection studies.

TEST BASE UNIT. The TBU was manned, trained, and equipped by AFSWC, using the resources of the 4951st Support Squadron (Test) at Enewetak and the 4952nd Support Squadron, Kirtland AFB (personnel augmentation only). Two C-54s, eight L-20s, and three L-19s (on loan from the Army) were assigned to the 4951st. Pacific Air Forces (PacAF) provided three C-54 aircraft and supporting personnel of the interatoll airlift facility operated by the TBU. PacAF also provided a Helicopter Element composed of 15 aircraft and supporting personnel that were attached to the TBU. The primary areas of responsibility of the TBU were to:

1. Operate airbase facilities at Enewetak and Bikini, including supply, POL, crash rescue, firefighting, refueling, base operations, and interatoll air freight terminals
2. Operate an interatoll airlift system servicing Enewetak, Bikini, and other islands and atolls, with aerial photo C-54 aircraft assigned to the TSU assisting when required
3. Operate an interisland airlift system at Enewetak
4. Operate a helicopter and liaison aircraft interisland airlift system at Bikini (helicopter missions to be performed by HMR[L]-361)

5. Establish and operate a field maintenance system augmented by maintenance personnel from other units and elements of the task group
6. Maintain an air evacuation capability, using all aircraft assigned and attached to the TBU
7. Provide helicopters as required to the Commander TSU for SAR alert
8. Provide various support functions at Enewetak Island.

TEST SERVICES UNIT. The TSU and its assigned elements were manned, trained, and equipped by the Military Air Transport Service (MATS). The tasks assigned to the TSU were to:

1. Provide weather, communications, SAR, photographic, and air transport support
2. Provide maintenance personnel to augment the field maintenance system
3. Provide an air evacuation capability using all aircraft assigned or attached to the TSU
4. Coordinate with the TBU in scheduling Hq TG 7.4 and JTF 7 rated personnel for flying TSU aircraft to maintain proficiency.

The elements of the TSU that carried out its missions are described below.

Search and Rescue Element. The SAR Element operated and maintained seven amphibious SA-16 aircraft for air rescue and weather- and project-island resupply support missions.

Weather Reporting Element. The Weather Reporting Element operated the Enewetak Weather Station, maintained rawinsonde and surface observation stations at the weather islands and furnished personnel and equipment for four surface and two weather balloon observations daily at the radsafe stations at Ujelang, Wotho, and Rongelap atolls. Aircrew preshot weather briefings were prepared and presented to TG 7.4 aircrews by briefing officers of the Enewetak Weather Station.

Weather Reconnaissance Element. The Weather Reconnaissance Element operated and maintained ten WB-50 aircraft for weather and typhoon reconnaissance, low-altitude particulate sampling, and postshot cloud tracking, as required. The WB-50s functioned as backup sampler control aircraft.

Communications Element. The Communications Element provided Airways and Air Communications Service and navigational aids to the joint task force as required. It manned and operated weather/radsafe communications stations at Utirik, Tarawa, Kapingamarangi, Ujelang, Wotho, and Rongelap atolls, and Nauru and Kusaie islands.

Weather Central Element. The Weather Central Element, under the operational control of Hq JTF 7, supported the task force with weather forecasts and other special weather data.

MATS Terminal Element. The MATS Terminal Element administered and operated of the MATS terminal at Enewetak and provided limited maintenance for transient MATS aircraft.

Technical Photography Element. The Technical Photography Element comprised two RB-50 aircraft, supporting personnel, photographers, and photographic equipment to support the technical photography requirements of CJTF 7.

Aerial Photography Element. The Aerial Photography Element comprised three C-54 aircraft and supporting personnel and supported the TBU airlift effort as directed by CTG 7.4.

Documentary Photography Element. The Documentary Photography Element (Lookout Mountain Laboratory) comprised personnel and equipment to support the documentary photography requirements of JTF 7. It also assisted with technical photography as directed.

Task Group 7.5 (Base Support)

TG 7.5 was an organizational convenience to integrate the civilian contractor (H&N) that operated the EPG for the AEC into the militarily structured joint task force. H&N was directed in the EPG by the AEC Albuquerque Operations Office, which provided the commander for TG 7.5 during the periods of testing, when H&N became TG 7.5.

H&N had acted as the AEC Architect-Engineer-Construction-Management contractor at the EPG since the GREENHOUSE test series in 1951. H&N activities were continuous during these years. There were only a relatively few months that H&N had fewer than 1,000 employees at the EPG; the average from 1953 to 1958 was much higher (Reference C.5.2). H&N functions were to build and maintain the scientific stations required by the tests as well as the required support facilities for housing, transportation, supply, recreation, communications, etc. In some of these areas, the activities supplemented and complemented military activities, especially those support functions that had been provided by TG 7.2 on Enewetak Island. But the scope of the activities of TG 7.2, the continuing military presence in the EPG, had been shrinking over the years as H&N progressively took over its functions, such as stevedoring and construction. Finally, during HARDTACK, H&N even provided the personnel for the Consolidated Mess Hall on Enewetak, replacing the Army and Air Force enlisted personnel who had been assigned mess hall duties.

Peak TG 7.5 population during HARDTACK was 3,158 on 9 April 1958. Most of the TG 7.5 personnel were on Parry (1,858) and Eneu (643). The rest were in the camps on Enjebi and Runit islands at Enewetak Atoll and Bikini, Aerokjlol, and Aomen islands at Bikini Atoll. After Johnston Island was included in HARDTACK operations, a contingent of about 800 worked there. H&N was also responsible for construction of weather stations at various islands in the Marshalls.

CHAPTER 2

RADIOLOGICAL SAFETY

Radiological safety (radsafe) matters for all military and civilian task force personnel in HARDTACK was a command responsibility; that is, commanders at all levels were responsible for their own men under directives from higher command. This basic concept had been followed in the previous test series. However, each task group was also assigned radsafe duties for the benefit of the task group as a whole.

The discussion of radiological safety for HARDTACK in this chapter is as follows:

- The organization of the radsafe program and the assigned responsibilities of the various commands are described
- Criteria and standards for limiting personnel exposure to ionizing radiation are given and discussed, and the dosimetry program is described
- Plans and preparations are discussed, including personnel training, onsite facilities, radiac instruments, and preparations at Johnston Island
- Offsite and onsite radiation monitoring and control are discussed, including offsite manned and unmanned monitoring stations, cloud tracking, marine surveys, onsite radiological exclusion (radex) areas, general monitoring and control procedures, and fallout protection measures
- Preshot radsafe activities of weather monitoring and prediction, fallout prediction, danger area surveys, and personnel evacuation procedures are discussed
- Postshot radsafe activities are described, including reentry and recovery, cloud sampling, radiochemical samples, and decontamination.

ORGANIZATION AND RESPONSIBILITIES

HARDTACK radiological safety and organization is defined in Annex K of <u>JTF 7 Op Plan 1-58</u> (reproduced in Appendix A of this report). Commander Joint Task Force 7 (CJTF 7) was to "assume overall responsibility for the radiological safety of task force personnel and of populated islands." To carry out this responsibility, the JTF 7 operation plan further directed the establishment of a Fallout Plotting Center (FOPC) and a capability to keep the task force and the Commander in Chief, Pacific (CINCPAC) informed of the fallout situation at all times, including the announcement of safe reentry times. Fallout stations were to be set up and technical assistance given to personnel in the Trust Territory of the Pacific Islands. Monitors and couriers were to be provided for radioactive sample centers (see Appendix A).

In addition, the operation plan directed task group commanders to establish radsafe units within the task groups with adequate special clothing and radiac instrumentation. The task groups were also to provide a roster of their personnel for film badge preparation (Appendix A).

The radsafe program for Operation HARDTACK was divided into two parts: onsite and offsite. Onsite radsafe activities were conducted by the various task groups, with Task Group (TG) 7.1 given the responsibility for all radsafe functions associated with diagnostic experimental programs and for dosimetry and other technical services to the entire task force. Operation of the offsite program and the coordination of the onsite activities were conducted by the Radsafe Office of Hq JTF 7.

Radsafe Office

Radiological safety regulations were appended to the JTF 7 Radsafe Annex (see Appendix A). These regulations called for establishing a Radsafe Office and a Radsafe Center. The Radsafe Office consisted of the task force Radsafe Section, the Fallout Prediction Unit (FOPU), and the FOPC. It was the task force agency responsible for offsite radsafe programs and maintaining displays of radiological conditions. It disseminated information on the air and surface radex areas based on information generated by the FOPU. These predictions are presented in Chapters 4 and 5 of this report. Location of the office was at JTF 7 Headquarters on Parry Island, Enewetak.

Radsafe Center

The Radsafe Center's activities were focused on the shot atoll. The center provided information on the radiological situation for scientific working parties, set up checkpoints, and controlled reentry operations. At Bikini, it was located in Building 196 on Eneu Island except when the atoll was evacuated, when it moved to USS Boxer (CVS-21). At Enewetak, it was in Building 323 on Parry Island.

Task Group 7.1 (Scientific)

Although onsite radiological safety was a command responsibility, TG 7.1 was charged with the major onsite recovery operation functions. The JTF 7 operation plan (see Appendix A) specified that CTG 7.1 conduct the initial postshot radsafe and damage survey and prepare situation maps. CTG 7.1 was also to perform all monitoring associated with scientific missions, except aerial monitoring and monitoring the aircraft used to collect samples.

CTG 7.1 was to provide laboratory services and technical assistance to all task groups, including film badges, radsafe equipment, recording of exposures, and radiochemical analysis. TG 7.1 technical personnel were to assist task group commanders in the inspection of radiologically contaminated items, and maintain close liaison with CTG 7.5 on all radsafe matters of mutual interest.

CTG 7.1 directed Task Unit (TU) 7.1.6 to provide the necessary radsafe support for onsite operations. The radsafe missions of TU 7.1.6 were to (Reference C.1.1685)

- Perform all ground and aerial monitoring services associated with the scientific mission except those in conjunction with aircraft and airborne collection of scientific data; assist TG 7.5 radsafe organization during the operational phase
- Provide all laboratory and technical assistance to all task groups
- Provide all official personnel dosimetry services
- Issue and maintain monitoring instruments and protective clothing as required
- Supply decontamination facilities for personnel, vehicles, and equipment.

The organization is shown in Figure 22. Because both atolls were being used for testing at the same time, independent radsafe organizations were established at Bikini and Enewetak, with overall control maintained by CTU 7.1.6. The organization at each atoll was similar, varying only in the number of personnel assigned to the various sections. Each organization contained the following seven sections (Reference C.1.1685):

- Dosimetry and Records Section for maintaining personnel dosimetry records
- Plotting and Briefing Section for conducting all radiological surveys and briefing all personnel going into radex areas
- Monitor Section for providing all monitoring services and manning checkpoints
- Supply Section for providing radsafe supplies and laundry services using the laundry facilities furnished by TG 7.5
- Decontamination Section for operating facilities for personnel and equipment decontamination
- Instrument Repair Section for maintaining radsafe instruments
- Laboratory section for determining the amount of radioactivity in soil, water, air, and food samples.

Radsafe functions, with the exception of staff and supervisory functions and those assigned to TU 7.1.6, were performed as an additional duty by personnel of the various task groups. Since TU 7.1.6 was designated the major radsafe unit for onsite operations and given the responsibility for centralized and highly technical services, it was necessary to obtain trained technicians. Personnel for manning TU 7.1.6 were obtained from the services, mostly from the 1st Radiological Safety Support Unit (RSSU), an Army Chemical Corps unit stationed at Ft. McClellan, Alabama. Advisors were furnished by the Atomic Energy Commission (AEC) laboratories. The following is a breakdown of the total personnel in TU 7.1.6 as given by CTU 7.1.6 in his report (Reference C.1.1685):

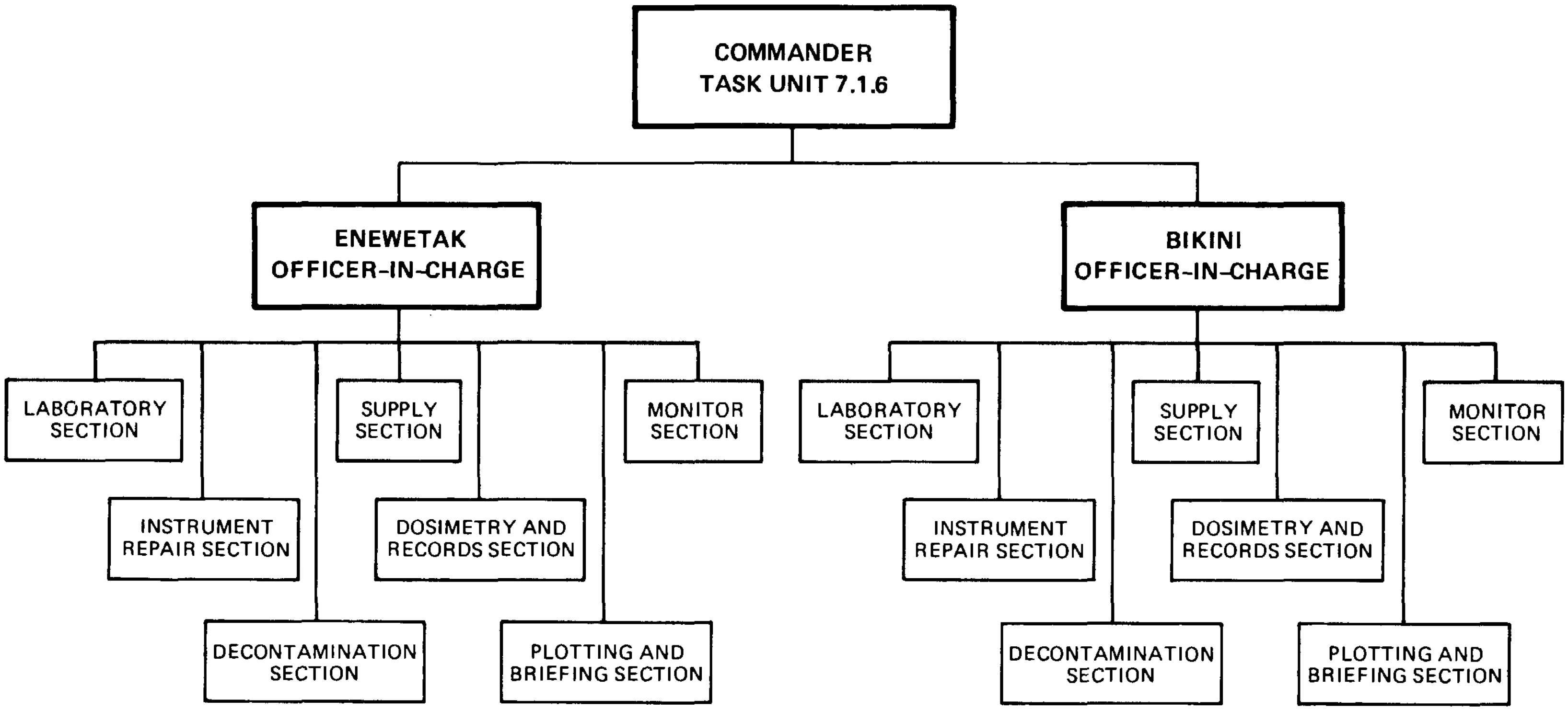

Figure 22. Organization of Task Unit 7.1.6, HARDTACK.

- Army -- 95 officers and enlisted men
- Navy -- 8 officers and enlisted men
- Air Force -- 12 officers and enlisted men
- Los Alamos Scientific Laboratory (LASL) -- 4 civilian health physicists
- University of California Radiation Laboratory (UCRL) -- 3 civilian health physicists.

Total personnel for TU 7.1.6 as derived from issued film badges differs slightly from this.

At the start of the operation, TU 7.1.6 Enewetak organizational strength was 55; that at Bikini, 45. The total, a reduction of 15 from the number used during Operation REDWING, was further reduced to 78 by mid-operation, a direct result of acquiring equipment that greatly reduced the manual processes involved in reading personnel film badges and posting the results (Reference C.1.1685).

Task Group 7.2 (Army)

Radiological duties of TG 7.2 were not as extensive as those of the other task groups. CTG 7.2 was responsible for maintaining a fallout plot displaying radiation intensities on Enewetak Island. TG 7.2 also had a contaminated clothing laundry facility for itself and TG 7.4 on Enewetak Island. TG 7.2 selected and trained ground monitor teams and decontamination personnel and established storage areas for miscellaneous contaminated equipment on Enewetak.

Task Group 7.3 (Navy)

TG 7.3 was responsible for emergency evacuation capability of all task force personnel as well as shipboard space for a TG 7.1 radsafe operations center (Reference B.0.1). TG 7.3 decontaminated aircraft at Bikini, and its ships gathered weather information for fallout prediction. It was responsible for radiological safety of embarked task force personnel during periods the joint task force was afloat. TG 7.3 provided monitors, decontamination crews, and decontamination facilities aboard each ship within the task group as well as monitors on each TG 7.3 multiengine aircraft. It equipped all vessels likely to be in the fallout area with water-spray (washdown) equipment and collected lagoon water samples, when and as directed. Through Marine Helicopter Transport Squadron (Light) 361 (HMR[L]-361), TG 7.3 provided helicopter service for radiological surveys and postshot recovery operations at Bikini, although the monitors were furnished by TG 7.1. Patrol Squadron 28 (VP-28), with a four-plane detachment from Patrol Squadron 22 (VP-22) flew radiological reconnaissance missions in the vicinity of the task force fleet and shot atoll and postshot radiological surveys of the northern Marshall Islands.

CTG 7.3 designated Boxer as the command center for afloat activities and directed that Boxer provide TG 7.1 with office space and space and facilities for personnel decontamination (Reference B.0.1, Annex G). Facilities for TG 7.3 radiac instrument repair and issue were another requirement. Space, facilities, and assistance were provided for the shipboard decontamination of HMR(L)-361 helicopters and facilities for the shipboard decontamination of all other aircraft at Bikini Atoll on an emergency basis.

The planned scientific program for the two underwater shots (WAHOO and UMBRELLA) required special radsafe considerations for early recovery of scientific data from contaminated ships. In addition, the whole target array would have to be moved after the first shot and repaired for the second underwater shot. Finally, all mooring hardware would have to be picked up and, when required, decontaminated. To assist this program, a special unit composed of 1 officer and 200 enlisted men was established as the Radiological Safety and Decontamination Unit for TG 7.3.

Task Group 7.4 (Air Force)

TG 7.4 had extensive radsafe responsibilities. TG 7.4 conducted weather reconnaissance flights and manned and supplied weather and radsafe monitoring stations at Utirik, Tarawa, Kapingamarangi, Ujelang, Wotho, and Rongelap atolls, and Nauru and Kusaie islands.

TG 7.4 also flew cloud-sampling and cloud-tracking missions. It was responsible for removal of the samples collected and placement of samples on special sample-return aircraft for shipment to laboratories in the United States. This sample packaging and shipment required special controls and monitoring and created significant radiation hazards to TG 7.4 personnel. In fact, persons in this operation were authorized a special radiation exposure limit of 10 R during HARDTACK because their exposures were accumulating rapidly. TG 7.4 also operated aircraft and personnel decontamination centers on Enewetak Island for its aircraft and personnel. A radsafe monitor was required on each multiengine aircraft. TG 7.4 was responsible for helicopter and liaison flights for radiological surveys and postshot recovery operations at Enewetak Atoll. Monitors for these flights were furnished by TG 7.1.

The TG 7.4 Nuclear Research Officer (NRO) was established as the focal point for TG 7.4 radiological safety (Reference B.4.2, Annex B, Appendix 5). He was to advise CTG 7.4 on radsafe matters and monitor TG 7.4 radsafe operations, which were divided among the Test Aircraft Unit (TAU), the Test Base Unit (TBU), and the Test Services Unit (TSU). The TAU flew the B-57 cloud-sampling aircraft, accomplished all monitoring on Enewetak airfield, removed, packaged, and shipped radioactive samples to laboratories in the United States, operated the aircraft and personnel decontamination centers at Enewetak, and controlled film badge issue within TG 7.4. The TBU assisted in decontamination operations, provided aircraft and crews to accomplish radiation surveys and postshot data-recovery operations at Enewetak, and maintained duty rosters (of all TG 7.4 personnel) for decontamination crews and for radiation monitoring teams. The TSU provided cloud-tracking aircraft for postshot radsafe fallout information and supported Project 2.88 with WB-50 cloud-sampling aircraft.

The TSU was to train an adequate number of personnel from each island weather station as radiological monitors and provide and maintain a minimum of two AN/PDR-39 and three AN/PDR-27C radiac instruments for each weather station (Reference B.4.2, Tab A).

Task Group 7.5 (Base Support)

The radsafe personnel of the AEC and its contractor, Holmes & Narver, Inc. (H&N), functioned as an independent radsafe organization for TG 7.5. This differed from previous operations, in which the AEC and its contract radsafe personnel were integrated into TU 7.1.6. Figure 23 is an organization chart of TG 7.5 radsafe functions.

The CTG 7.5 Radsafe Advisor was responsible for staff direction on all TG 7.5 radsafe policies. The AEC Radsafe Officer was responsible to the TG 7.5 Deputy Commander for supervising the radsafe operations and recommending protection measures. The H&N Radsafe Officer functioned as the Operations Officer and provided the necessary support. During periods when neither the Radsafe Advisor nor the Assistant Chief of Staff was at Eniwetok Proving Ground (EPG), the AEC Radsafe Assistant acted for the latter.

CTG 7.5 was directed to operate (1) decontamination facilities on Parry and Eneu islands for TG 7.1 and TG 7.5 equipment, (2) radsafe facilities on barges, and (3) laundries for contaminated clothing in support of all task force elements, except for such services performed by TG 7.3 on certain vessels and by TG 7.2 at the TG 7.2 laundry on Enewetak Island (Reference B.0.1).

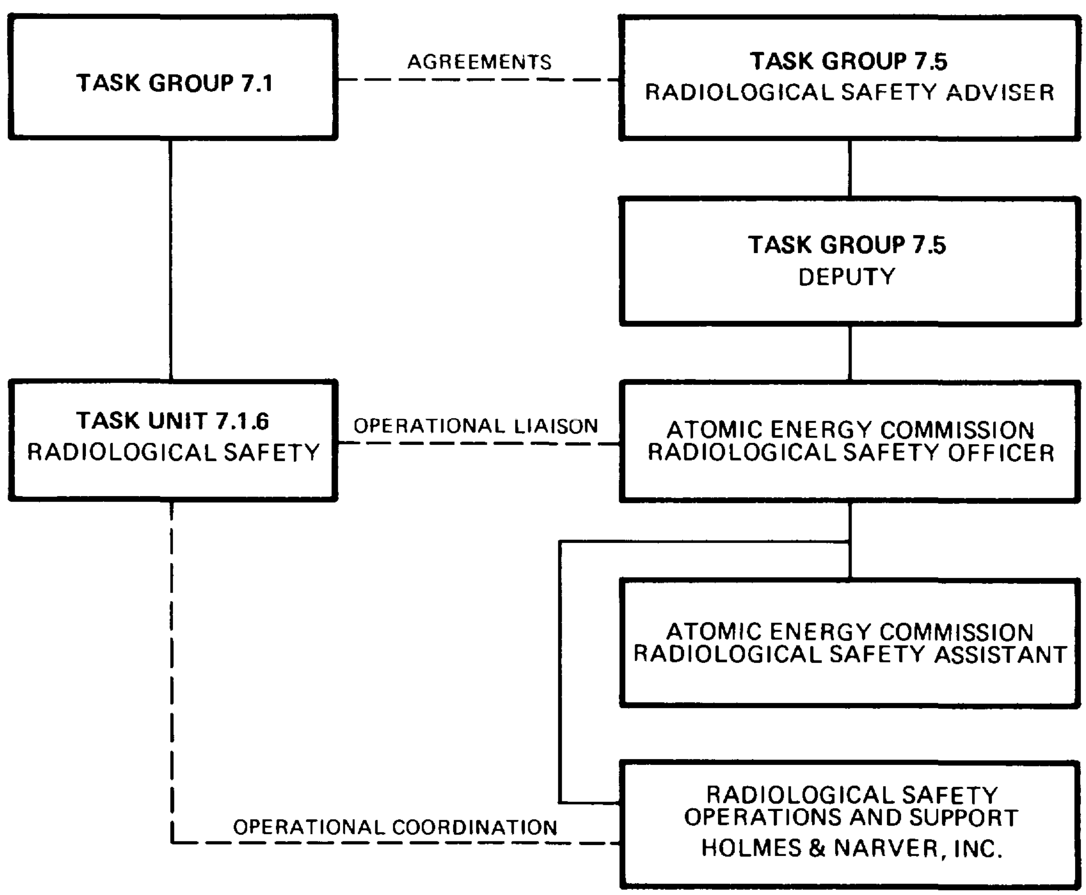

Figure 23. Radiological safety organization of Task Group 7.5 HARDTACK.

CTG 7.5 relinquished to CTG 7.1 the operational control of the radsafe facilities that were operated during nontest periods by H&N on 1 April 1958, while maintaining close liaison with CTG 7.1 on mutual radsafe matters during the operational phase. H&N continued to provide radsafe monitors to support TG 7.5 Operational control returned to CTG 7.5 on 3 September 1958, 16 days after the last detonation of the test series (Reference C.5.3).

PERSONNEL EXPOSURE STANDARDS

The radsafe regulations (see Appendix A) established standards that had the concurrence of the Surgeons General of the U.S. Army and U.S. Air Force; Chief, Bureau of Medicine and Surgery, U.S. Navy; and the Director, Division of Biology and Medicine, AEC. The regulations established Maximum Permissible Exposure (MPE) standards for individuals and Maximum Permissible Limit (MPL) exposure rates for contaminated personnel, clothing, equipment, land areas, etc. Parts of the regulations that pertain to MPE and MPL standards are as follows (Reference B.0.1):

> The Maximum Permissible Exposures (MPE's) and Maximum Permissible Limits (MPL's) as stated herein are applicable to a field experimental test of nuclear devices in peacetime wherein numbers of personnel engaged in these tests have been previously exposed or will be continuously exposed to potential radiation hazards. It may become necessary from a study of personnel records to reduce the MPE for certain individuals who have recently been over-exposed to radiation.
>
> Due to the special nature of field tests it is considered that a policy of strict adherence to the radiological standards prescribed for routine work is not realistic. The regulations set forth herein have been designated as a reasonable and safe compromise considering conservation of personnel exposures, the international import of the test and cost aspects of operational delays chargeable to excessive radiological precautions. In all cases other than emergencies or tactical situations the ultimate criteria will be limited by the MPE's for personnel. Special instances may arise such as in the case of an air-sea rescue within the RADEX in which operations will be carried out without regard to the MPE's and MPL's prescribed herein.

Thus, as in previous operations, MPE and MPL standards could be exceeded if dictated by an emergency or tactical situation.

Maximum Permissible Exposure Standards

MPE standards established the radiation exposure limits for personnel. Basically, the limit was set at 3.75 roentgens (R) (gamma only) per consecutive 13-week period with a maximum of 5 R for the operation, with exceptions for emergency and other tactical situations. The operation was defined as the period from 15 days before the first ready date to 15 days after the last shot. A special MPE of 10 R was authorized for crewmembers of air-sampling aircraft. In the event of operational error or emergency, an additional exposure of 10 R would be accepted. Any exposure in excess of 20 R total would be considered as an overexposure for aircrew samplers. Partway through the operation, sample-recovery personnel had their authorized exposures change from 5 R to 10 R. At the same time aircraft maintenance personnel had their maximum exposure raised from 5 R to 8 R.

The limit of 3.75 R per 13-week period was slightly greater than the National Committee on Radiation Protection and Measurements (NCRP) and the International Commission on Radiological Protection (ICRP) limit of 3 R per 13-week period in effect at that time. The MPE was considered a safe compromise, weighing the factors of conservation of personnel exposures, the international import of the test, and the cost aspects of operational delays chargeable to excessive radiological precautions. The limit of 5 R for the operation is equivalent to the yearly exposure currently permitted by Federal guidelines for radiation workers. Appropriate remarks were to be included in the medical records of personnel who exceeded the 3.75- and 5-R limits. Military personnel were to be advised that they should not be exposed further to radiation until sufficient time elapsed to bring their average radiation exposure down to 0.3 R per week. Civilian personnel in this category were to be informed that limitations on further radiation exposure were to be as determined by the laboratory or agency having administrative jurisdiction over such personnel.

Personnel whose previous radiation exposure was in excess of an age-prorated exposure (defined as five times the persons age on 1 February 1958 in excess of age 18) would under no circumstances be allowed to receive a total exposure from the operation in excess of 5 R. Regulations further limited cumulative exposure to no more than 50 R by the 30th birthday of any person, whereas the ICRP age-prorated exposure would have permitted 60 R at that age.

Authorization for individual exposures in excess of the established MPEs could be granted only by CJTF 7, and only in specific cases justified by operational requirements.

Before the establishment of the MPE, there was some debate regarding exposure limits in the correspondence among HARDTACK participants. It was suggested that the MPE for sampler aircraft crewmembers be established at 20 R, but this was rejected and the standard was set at 10 R with an additional 10 R for an emergency or accident allowance. A recommendation that personnel associated with recovery operations from the WAHOO and UMBRELLA underwater shots be permitted up to 5 R per shot and 10 R for the operation, based on the need for prompt recovery operations and the expectation of relatively high radiation levels, was not adopted. As it turned out, radiation exposure levels were considerably lower than expected. Concern was expressed because some of the planned sampler aircraft crewmembers may have had significant radiation exposure during PLUMBBOB (at the Nevada Test Site, 1957) and perhaps from earlier operations. The inclusion of a lifetime exposure limit addressed this concern. The task force philosophy was to use greater numbers of personnel to keep individual exposures within the established MPE.

Commanders employed their own criteria and measures to prevent exceeding the MPE standards for assigned personnel. For example, for priority early recovery of experiments from Howorth (DD-592), a noncommissioned target ship exposed during UMBRELLA, CTG 7.1 stated that reentry personnel could be exposed to 4 R/hr on board Howorth for not more than 40 minutes (Reference B.1.5, UMBRELLA-5). Surface units were instructed to back off if a field greater than 4 R/hr was detected. In interior shipboard spaces, protective breathing equipment was to be used following UMBRELLA if monitoring indicated airborne activity exposure rates in excess of 1 R/hr (Reference B.3.3, 27-58).

HARDTACK shots were planned in a sequence that put the shots likely to produce the most fallout toward the end of the test series. REDWING had taught planners that such a sequence minimized the possibilities of critical personnel becoming overexposed to radiation early in the operation. In addition, this sequencing would put fewer personnel at risk because of the reduced number of test participants toward the end of the series. For example, midway through the operation the number of ships was only half the peak number during the early part of the operation. For similar reasons, it was desirable for commanders to spread out the exposure of their personnel. CTG 7.3 instructed that every effort be made to limit the total exposure of TG 7.3 personnel to 2 R during UMBRELLA recovery missions to allow for subsequent exposures. Ships and aircraft were not to enter any radiation field in excess of 4 R/hr, except under special circumstances, and any stay times were to be calculated to keep exposures below 2 R (Reference B.3.3, 27-58).

Maximum Permissible Limits

MPLs for contamination on the skin, clothing, or equipment were established as criteria for decontamination levels to be met or as levels that required restriction of activity or other measures to protect personnel. All readings of surface contamination were to be made with geiger counters, with tube walls not substantially in excess of 30 mg/cm^2 with shield open unless otherwise specified, and the surface of the probe was to be held 1 to 2 inches (2.5 to 5 cm) from the surface under observation unless otherwise specified. For operational purposes, the MPLs were not considered applicable to spotty contamination, provided such areas could be effectively isolated from personnel (Reference B.0.1, Appendix 1 to Annex J). The MPLs established are summarized in Regulation 20 (Appendix A).

Personnel Dosimetry

A film badge program was used to maintain complete exposure information on all JTF 7 personnel entering the EPG during the operation. CTG 7.1 assigned overall badging responsibility to CTU 7.1.6. Beginning 1 April 1958, film badges were issued to all individuals upon their arrival at the EPG. Badges were worn at all times and turned in upon recall by TU 7.1.6, upon exit from any contaminated area, or upon departure from the EPG. The badge was a DuPont 559 film packet (502 and 834 film components) dipped in ceresin wax and then packaged in a rigid polyvinyl chloride case. The wax dip and the polyvinyl made the film packet moisture-resistant to allow wearing it for several months, if necessary, without deterioriation. As the operation progressed, test badges were recalled and processed to check the overall efficiency of the packaging. Badges were in use for as long as 6 months with no significant failure observed. Types of badges to be used by divers were pressure-tested to the equivalent of a depth of 300 feet (about 90 meters) to ensure they would not leak

(Reference B.3.4). During the operation, 62,000 badges were issued and processed and their readings recorded. Records were maintained on nearly 20,000 individuals.

Self-reading pocket dosimeters, Bendix Model 611, 0- to 5-R range, were also used to obtain quick information on the exposure of an individual while in a contaminated area.

To simplify recording the exposure information, each man was assigned an 8-digit identification number that coded individual personal data. The first four digits identified the individual's task group, task unit, and permanent home station or laboratory. The last four digits were used as an individual ID number within task units. It was necessary to decode these 8-digit numbers to prepare the summaries of the organizations' exposures presented in Chapters 3 and 6 through 10. Decoding was done using several documents that were physically separate from the list on which the individual exposure records were cumulated. Auxiliary documents generally proved adequate, but other documents were consulted to resolve what appeared to be incomplete or incorrect codes. Codes and their meanings as currently understood are presented in Appendix B.

To facilitate issuance of film badges, all personnel in Hq JTF 7, TG 7.1, TG 7.5, and certain units of other task groups (such as cloud-sampling crews of TG 7.4) were issued cards. They were similar to credit cards and showed the individual's full name and the 8-digit ID number. Use of these eliminated filling out cards by hand, thus expediting the issuance of badges. All the information on issued badges was keypunched on cards and stored on magnetic tapes by an IBM-704 computer at Parry.

All exposed film badges were developed using the standard techniques employed at LASL. The films were calibrated on a "constant time, variable distance" range, and the calibration curves were checked for accuracy approximately every 2 weeks. Density of the exposed film was read with the Eberline Film Badge Evaluation and Recording System, FS-3, in conjunction with an IBM-526 Summary Punch. The FS-3 was developed by the Eberline Instrument Corporation, Santa Fe, New Mexico, in close cooperation with TU 7.1.6. The punched IBM cards from the FS-3 were then used to post the individual's records on the IBM-704.

Identical film-processing stations were established at Enewetak and Bikini atolls for issuing, receiving, and processing film badges. Data records from Bikini were forwarded by data transmission equipment to Enewetak, where the data from both atolls were consolidated and stored on magnetic tape by the IBM-704. This method of computation and record-posting proved convenient since the daily exposure reports and cumulative exposure cards were prepared simultaneously with the posting of the new information to the computer tapes for storage. Updated total exposure information compiled by the computer was then transmitted back to Bikini by the same data link, where a duplicate file was maintained for daily use.

The computer was used to extract and print the complete exposure reports at the end of the operation, which eliminated the many hours of typing previously required and possible transcription errors in preparing these reports.

The resulting Consolidated List of Exposures (Radiological Safety Regulation 22a; see Appendix A) for all task force personnel was to be sent to the Chief, Armed Forces Special Weapons Project (AFSWP), and to the Director, Division of Biology and Medicine, AEC. A consolidated list of personnel in each task group was to be forwarded to each task group commander. Each task group commander was then to forward the individual records to each man's unit of permanent assignment for inclusion in the appropriate health records, although research has indicated that individual records were not always included in the files. Records of individuals exposed in excess of the regulations were to be noted so that they would not be exposed further to ionizing radiation until their average exposures were down to 0.3 R per week.

This new method of operation proved very satisfactory. It reduced the number of personnel employed in the Dosimetry and Records Section from 40 during Operation REDWING (1956) to a maximum of 16 during HARDTACK and considerably reduced human errors from manual operations (Reference C.1.1685).

PLANS AND PREPARATIONS

Training

Radsafe regulations directed that two levels of training -- basic indoctrination and technical -- be conducted, but allowed each task group to vary the scope of instruction according to the group's operational requirements. Basic indoctrination included nontechnical instruction in radsafe measures and techniques that was to be given to all task force personnel to encourage efficient performance of duties within the established MPE limits. Technical training was required for most personnel who staffed the task force radsafe organizations and performed the monitoring and other technical operations, such as decontamination and instrument repair. Technical instruction was to be obtained through existing service courses and at training sessions established at the task group level.

TASK GROUP 7.1. Training of TU 7.1.6 personnel was carried out in several places. Most of the 1st RSSU personnel were trained at Ft. McClellan, Alabama, using instructors within the unit. Approximately 50 men of the 1st RSSU participated as trainees in the 1957 Operation PLUMBBOB at the Nevada Test Site with the Reynolds Electrical and Engineering Company Radsafe Division. Instrument repair personnel were trained at the Navy facility at Treasure Island, San Francisco, California, and at LASL. Four Navy hospital corpsmen who provided most of the laboratory services were trained by LASL Health Division personnel.

Scientific project personnel in TG 7.1 and contractor personnel in TG 7.5 were trained as monitors for recovery and construction missions. Four-day courses were given in schools at Parry and Eneu islands for this purpose. The schools were in session for approximately 7 weeks. Personnel from TG 7.3 and TG 7.4 were also trained at the schools (Reference C.1.1685).

TASK GROUP 7.2. No specific references are available regarding TG 7.2 radsafe training.

TASK GROUP 7.3. Each commanding officer was responsible for ensuring that his ship was equipped and its crew trained in accordance with existing fleet instructions covering radiological safety. Beyond this, the staff of TG 7.3 established a radsafe training program using established naval schools ashore. All ships and units were advised of the recommended courses ashore and were encouraged to send representatives to take these courses. For example, Boxer personnel attended the following courses before deployment:

- ABC (Atomic, Biological, and Chemical) Defense (5 officers for 2 weeks)
- Atomic Defense Monitoring and Radiac Instrumentation (8 officers for 5 weeks)
- C-425 Practical Atomic Defense (91 enlisted men for 5 days)
- C-426 Atomic Defense Monitoring and Radiac Instruments (75 enlisted men for 5 days).

All Boxer personnel also received 3 hours of indoctrination aboard ship in (1) nuclear radiation effects on personnel, (2) general effects of atomic weapons and basic defensive measures, and (3) equipment and decontamination procedures. All men received a copy of "Is Radiation Dangerous to You?" and a number of radiology-related movies were shown (Reference C.3.3.9).

The existing programs of the naval training schools in shipboard radiological safety and decontamination were judged by the Schools Command, Treasure Island, to be either inadequate or unrealistic for training the 200-man TG 7.3 Radiological Safety and Decontamination Unit that had been formed for decontamination of the target ships exposed during the underwater shots. No previous test operation had employed a Radiological Safety and Decontamination Unit composed only of military personnel. Accordingly, the Naval Radiological Defense Laboratory (NRDL) devised a special 4-week training course attended by the Officer-in-Charge and all 17 petty officers of the unit, who in turn presented the same training program to all of the enlisted personnel of the unit (Reference C.3.3.30).

TASK GROUP 7.4. During early planning, the TG 7.4 Nuclear Research Officer (NRO) directed that (Reference B.4.4):

1. Each multiengine aircraft participating in D-day and D+1 missions have a qualified radsafe monitor aboard
2. Each element furnish two radiological monitors for each 50 personnel to be assigned to emergency fallout survey teams
3. Monitors complete an approved monitoring training program before the operation.

Qualifications of previously trained monitors would be subject to the approval of the NRO; others would be trained in the course given by TU 7.1.6.

For broad-based information, all TG 7.4 personnel were to be briefed on general and specific radiological problems associated with the operation. A special 1-day training course for Air Force and Army officers was held in April 1958 to prepare these personnel to serve as sample-return project officers (Reference C.4.3, p. 346).

By April 1958, almost all members of the 4926th Squadron had experience in sampling procedures during nuclear tests. A training program included radsafe courses. Because qualified aircrew observers were lacking in the 4926th, other personnel in TG 7.4 received radsafe training to increase the pool of trained observers and thereby lessen radiation exposure of any single individual. The 4926th also supervised similar training for the Strategic Air Command B-57D crews at Laughlin AFB (Reference C.4.1, pp. 73-74).

TASK GROUP 7.5. Before Operation HARDTACK, a course to train radsafe monitors was conducted by the H&N Radsafe Officer with the help of the AEC Radsafe Assistant.

Onsite Decontamination Facilities

Personnel decontamination facilities operated by TU 7.1.6 were located across the street from the radsafe buildings on Parry Island, as they had been during the previous series at Enewetak Atoll. These facilities consisted of "clean" and "hot" change areas and showers. A heavily used personnel decontamination station was also established on Runit for QUINCE and FIG. An equipment decontamination station was also established on Parry Island. An AN/MDQ-1 radiochemistry laboratory trailer obtained from the U.S. Army Signal Corps was parked near the radsafe building. TG 7.4 also operated both personnel and aircraft decontamination facilities on Enewetak Island.

For Bikini operations, a radsafe center was established aboard Boxer. Its decontamination facilities, however, were never used because the camp at Eneu Island was not significantly contaminated. An H&N barge was also equipped as a complete radsafe center, to be used in the event that afloat operations were required; but only the laundry facilities of the barge were used. Personnel and equipment decontamination facilities that duplicated those on Enewetak were established on Eneu adjacent to the radsafe building. An AN/MDQ-1 radiochemistry trailer was parked near the TG 7.1 administrative compound (Reference C.1.1685).

Decontamination and processing facilities were established afloat for the WAHOO and UMBRELLA underwater shots at Enewetak Atoll. Before the operation, NRDL proposed to Navy Bureau of Ships, which in turn proposed to Chief of Naval Operations (CNO), that a complete radsafe center afloat be established aboard an attack transport ship for WAHOO and UMBRELLA. It was believed that an afloat radsafe center would enhance early-time data recovery, which was considered critical, and increase the efficiency of the recovery operations by being closer than shore-based radsafe facilities.

In a letter to CJTF 7, CTG 7.3 did not concur with this proposal. He felt that data recovery was an activity of TG 7.1 and that the appropriate unit of TG 7.1 could oversee the radiological safety of the persons conducting them. Also, TG 7.3 planning was based on the premise that the target fleet would be decontaminated within Enewetak Lagoon with the technical and logistic support of established TG 7.1 radsafe facilities ashore.

Based on a conference among interested parties at AFSWP on 16 May 1957, CNO rejected the concept of a complete radsafe center afloat, reasoning that the responsibilities for radiological safety within the existing command structure were well established and advance logistic planning had already been completed (Reference B.3.9). An afloat radsafe support unit was desirable, but this could consist of a component of TG 7.1 radsafe personnel aboard an LSD or APA, the facilities of which were considered appropriate for decontamination needs. Thus, TG 7.1 remained as the formal focal point for radiological safety of the experimental units for the underwater shots. The assigned radsafe unit, TU 7.1.6, however, requested that TG 7.3 supply two men to handle the technical and organizational problems that might arise in decontaminating the target ships because personnel knowledgeable in ship decontamination were not available within TU 7.1.6.

Johnston Island Preparations

For Johnston Island shots, all radsafe facilities were afloat. Because of the high altitudes planned for the detonations at Johnston Island, radsafe planning there was limited to provisions for a launch mishap or premature detonation. Eleven TU 7.1.6 LASL and UCRL personnel were formed into a six-man team to be stationed on <u>Boxer</u> and a five-man backup team to be stationed at Hickam Field, Oahu, Hawaii. All personnel were well trained in the handling of alpha contamination, should an accident occur. Necessary decontamination equipment and radiac instruments were loaded aboard <u>Boxer</u> before it departed the EPG for Johnston Island (Reference C.1.1685).

Barring an accident, only TG 7.3 personnel of units directly involved in the recovery of instrumented rocket nosecones would be exposed to radioactive materials; thus, only personnel of those units were issued film badges for the Johnston Island operations (Reference B.3.3, 38-58 [J.I.]).

For TEAK, a WB-50 radiation sampler aircraft was on standby at Hickam Field, in case of an accident. For ORANGE, this same aircraft was airborne near Johnston Island.

RADIATION MONITORING AND CONTROL

Both onsite and offsite programs were developed for radiation monitoring and control. The Radsafe Center was responsible for the onsite program at Enewetak and Bikini atolls, and Johnston Island; the Radsafe Office was responsible for the offsite program at other locations.

Offsite Radsafe Programs

The offsite radsafe program was designed to protect persons in populated areas outside the EPG against radiation exposure, to obtain a complete record of radioactivity introduced by the tests in nearby populated areas, to assure that all reasonable radiation safeguards were employed, and to obtain data for investigating reports of incidents attributed to radioactivity from the tests. To do this, the task force operated an offsite program consisting of manned radsafe stations, radiation monitoring stations, and cloud tracking.

MANNED RADSAFE STATIONS. The task force, through a contract with the U.S. Public Health Service (USPHS), established fully equipped radsafe stations at

Rongelap, Ujelang, Utirik, and Wotho. These stations were operated by USPHS radiation health personnel (Reference C.1.1685).

Radsafe operations at four other temporary land-based JTF 7 weather stations on Tarawa, Nauru, Kapingamarangi, and Kusaie islands were controlled by CTG 7.4. They were charged with immediately reporting any significant radiation intensities that were measured. AN/PDR-27C and AN/PDR-39 radiac instruments were used and were exchanged biweekly, or as required. Also, each island had an automonitor (automatic radiation-recording device). All station personnel wore film badges that were exchanged once -- in mid-June 1958 (Reference C.4.2.2, pp. 355-363).

After a large-yield Enewetak shot or any Bikini shot, the manned radsafe stations were to check automonitor readings and periodically monitor the island and its facilities using the AN/PDR-27Cs to determine any significant increase over background. Station personnel were to submit a radiation level report to CJTF 7 every 12 hours (6 hours for Rongelap), starting at H+6,* for levels greater than 0.005 R/hr, but were to report immediately any abrupt increase in radiation levels or any radiation level increases above 0.010 R/hr and each 0.010 R/hr increment.

Personnel at these sites were instructed to stay indoors for protection if the radiation level rose above 0.010 R/hr and no instructions had been received from CJTF 7 or CTG 7.4. If severe late fallout (at H+12 or later) of 5 R/hr or greater was encountered, the island weather station commander was directed to have all personnel immerse themselves in the lagoon up to their necks and periodically duck their heads to rinse off any fallout particles.

All eight island weather stations were directed to conduct daily radiation surveys beginning on the day before the first shot and to report any unusual increases at once.

MONITORING STATIONS. In cooperation with the U.S. Weather Bureau, the U.S. Coast Guard, the Air Force Weather Service, the Hawaiian Sea Frontier, and the Hawaiian Territorial Health Department, a total of 15 radiation monitoring stations, in addition to the manned stations, were established at existing weather and USPHS installations throughout the Pacific area. These stations were equipped with continuous background recorders and standard military radiac instruments. Arrangements were made for station personnel to log instrument readings and to report the results through weather or routine radio channels. In addition, any significant reading above background was to be reported promptly to CJTF 7. The network equipment was installed and serviced by USPHS personnel attached to Hq JTF 7 (Reference C.1.1685).

CLOUD TRACKING. In addition to preshot surveillance of the danger area, Navy P2V aircraft based at Kwajalein tracked nuclear clouds on all events

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* The convention used throughout this report is that an expression such as "H+6" means H-hour (the detonation time) plus 6 hours. Similarly, "H-6" means 6 hours before the detonation. This convention is used in the same manner for D-day (the day of detonation).

expected to produce radioactive fallout. The aircraft reported to Air Operations Control (AOC) at either Enewetak or Bikini at shot time and were controlled by the Radsafe Office via telephone contact with the AOC. For shots where it was necessary to obtain information at altitudes and ranges beyond the capabilities of the P2Vs, the TG 7.4 Weather Reconnaissance Squadron of WB-50s was employed. The number of tracking flights required depended mainly upon the fission magnitude of the shot and the stability of the existing wind field (Reference C.1.6.2).

The JTF 7 Operations Plan 1-58 Radiological Safety Regulations specified that cloud-tracking aircraft were to turn back when radiation intensities in excess of 3 R/hr were encountered. The operation plan also directed TG 7.3 and TG 7.4 aircraft on other established flights between Enewetak and Bikini within 24 hours following any shot to report any radiation encountered.

Clouds were tracked by radar during the first 30 minutes after detonation to obtain reliable and useful information on cloud size, height, and general movements. Both ground and shipboard radars were used, and the information was telephoned to Hq JTF 7 (Reference C.1.6.2).

MARINE SURVEYS. Program 40 (Radiobiological Survey) was related to radiological safety. Objectives of the program were to determine the amounts and distribution of radioisotopes in seawater, soil, plants, and animals at the EPG, in the northern Marshalls, eastern Carolines, and other islands westward to the Palaus. Pretest surveys were done at Enewetak and Rongelap atolls. Postshot measurements were made and samples collected at the weather stations on Ponape and Kusaie islands and Tarawa, Ujelang, Utirik, Kapingamarangi, and Wotho atolls, and tuna catches unloaded in Japan were sampled (Reference C.1.1682).

USS Collett (DD-730) conducted a postoperational radiological survey of the waters of the EPG danger area prior to disestablishment of the danger area by the AEC (Reference C.3.4.12). Samples of water at five depths down to 328 feet (100 meters) and of plankton were to be obtained every 50 nmi (93 km) along a 2,225-nmi (4,121 km) track. USS Silverstein (DD-534) conducted similar postoperational sampling mission of ten points in the waters between the EPG and Guam (Reference C.3.4.40).

A number of other steps were taken to assure the safety of the task force, native populations, and transient surface and air traffic. For example, an emergency evacuation capability was constantly maintained. As far as can be determined from existing monitoring data and investigations of reported incidents, no significant fallout occurred on populated offsite areas or to transient surface craft and aircraft as a result of Operation HARDTACK (Reference C.1.6.2).

Onsite Monitoring and Control

RADIOLOGICAL EXCLUSION AREAS. The JTF 7 Radsafe Office was responsible for designating both air and surface radex areas. Preshot radex forecasts were revised based on the results of aerial and ground surveys. Lagoon water samples were also taken. All atoll and lagoon areas at or near a detonation site were considered contaminated until cleared for operations by the Radsafe Office. Entry control procedures were managed by the Radsafe Office. Entry to and exit from radex areas was only through established checkpoints. Personnel were not permitted beyond a radsafe checkpoint without an access pass, issued by the TU 7.1.6 Plotting and Briefing Officer, that stated the purpose and precise location of the entry. All vehicles used in radex areas were checked through established decontamination stations.

Surface radex areas were divided into two categories requiring different levels of protection and control:

- Full radex -- an area in which the gamma radiation intensity exceeded 0.1 R/hr
- Limited radex -- an area in which the gamma radiation intensity was between 0.01 and 0.1 R/hr.

Radex areas were not strictly defined for alpha contamination. Apparently, however, areas in which the alpha count by a survey meter with a probe area of 55 cm^2 exceeded 10,000 counts per minute (CPM) were considered full radex areas, and those in which the activity was between 1,000 and 10,000 CPM were considered limited radex areas (Reference C.5.3).

A full radex area required parties to be accompanied by certified monitors and all persons to wear full protective clothing. In a limited radex area, CTU 7.1.6 determined the kind of clothing to be worn. The function of the clothing was to prevent the radioactive contaminants from directly contacting the wearer, thus making decontamination easier and preventing the spread of the contaminants. Full protective field clothing is shown in use in Figure 24. Protective clothing to shield the wearer from contaminated washdown water is shown in Figure 25 and protective clothing worn by crewmen while recovering a radioactive object is shown in Figure 26.

Radsafe monitors kept work party leaders in radex areas advised of radiation intensities at all times. The party leader was expected to follow such advice and adhere to the established exposure limits.

Air radex areas were not to be entered by aircraft unless a tactical or emergency situation arose, in which case tactical exposure allowances applied. All multiengine aircraft were required to have a monitor capable of calculating allowable exposures.

RADIAC INSTRUMENTS. Electronic equipment utilized during the operation included portable survey instruments, air-sampling equipment, exposure-recording instruments, background monitoring detectors with recorder units, various types of test equipment, and radiation analysis instrumentation. Table 6 lists some of the types and distribution of radiac equipment and instrumentation for the major portion of the operation. Other equipment was available; for example, <u>Boxer</u> reported having PDR-T1B instruments aboard and HMR(L)-361 reported having PDR-10B instruments. Since all ships are reported to have arrived at the EPG fully equipped with radiac equipment, they too would have had equipment not accounted for in Table 6. The discussion in Reference C.5.3 indicates that, in general, overall equipment performance was adequate.

Figure 24. Protective clothing worn during data-recovery mission on Boken Island after HARDTACK, KOA.

Figure 25. Protective clothing for shipboard decontamination crewmembers, HARDTACK.

Figure 26. Protective clothing worn by USS Lansing (DER-388) crewmembers (standing) after recovering a radioactive pod that had been exposed to the high-altitude HARDTACK, TEAK shot. Project 8.6 personnel are examining the pod.

Table 6. Selected list of radiac equipment and instrumentation, HARDTACK.

Manufacturer	Model	Type	Number Available: Enewetak	Number Available: Bikini
Tracerlab, Inc.	AN/PDR-39	Gamma survey meter	122	80
Tracerlab, Inc.	AN/PDR-39 modified to 500 R	Gamma survey meter	4	2
Admiral Corp.	AN/PDR-27C	Beta gamma survey meter	36	4
Tracerlab, Inc.	AN/PDR-18	Gamma scintillation survey meter	12	8
Chatham Electronics	CDV-700	Beta gamma survey meter	60	40
Instrumentation assembled and installed by Kewaunee Mfg Co.	AN/MDQ-1	Radiochemistry trailer	1	1
Designed by Los Alamos Scientific Laboratory		Cumulative dosage alarm instrument dosimeter	5	5
Victoreen Instrument Co. modified by LASL	Thyac	Alpha scintillation survey	3	1
Beckman Instrument Co.	MX-5	Beta gamma survey meter	21	2
Eberline Instrument Co.	PAC-3-G	Alpha proportional survey meter	3	3
Eberline Instrument Co.	AM-1	Beta gamma continuous air monitor	1	2
Health and Safety Lab, Atomic Energy Commission, recorder portion manufactured by Evershed and Vignoles Ltd.)	TN-4D	Offsite gamma background monitor	33	2
Eberline Instrument Co.	FS-11	Film badge densitometer	2	1
Eberline Instrument Co.	FD-2	Densitometer	1	1
Jordan Instrument Co.	PRAM-5	Gamma aerial survey instrument	2	1
Riggs Electronics	UW-1	Gamma underwater instrument	4	2

Source: Reference C.5.3.

TG 7.2 Operations Plan 1-58 specified the use of the AN/PDR-18 gamma survey meter for TG 7.2 field and area surveys (Reference B.2). NRDL recommended that AN/PDR-27F and AN/PDR-18 Navy allowance gamma and beta radiacs and the "cutie pie" and Berkeley Model 2750, or equivalent, industrial monitoring radiacs be used for area and personnel monitoring and surveying (Reference B.3.5). The basic instrument used for the onsite aerial survey was the AN/PDR-39 gamma survey meter modified to read up to 500 R/hr. The instrument built by Jordan Instrument Co. (PRAM-5) that worked so well in Operation REDWING was never used because it could not be made to operate properly (Reference C.1.1685).

GENERAL PROCEDURES. The Operations Section of the Radsafe Center was responsible for conducting all radiological surveys on Enewetak Atoll, most of which were made by H-19 helicopters. H-21 helicopters were not used for surveys because of their lack of radiation shielding. In contrast to the H-19, where the pilot compartment was located above the engine, which provided shielding, the H-21 pilot compartment was a plastic bubble on the nose of the helicopter (Reference C.1.1685). Crewmembers in the passenger compartment of the H-19, however, were not shielded by the engine.

Normal aerial surveys included a preentry survey from H+1 to H+4, a detailed survey of the entire shot atoll from H+6 to H+8, and detailed surveys on the mornings of D+1, D+2, and D+3. Additional surveys were made as required. When necessary, data were radioed to the Radsafe Center from the survey helicopter. Plotting and briefing stations were maintained at the Radsafe Center and the J-3 office. Ground surveys of islands in the atoll were conducted when required (Reference C.1.1685).

The helicopter survey technique called for the pilot either to land the aircraft at a survey spot so that a ground reading could be obtained or to make a slow pass over the spot at an altitude of 25 feet (7.6 meters). Readings taken at 25 feet (7.6 meters) were doubled to approximate a ground reading. The doubling factor was experimentally determined and checked at various times during the operation. Experience indicated that any reading taken from an altitude of 50 feet (15.2 meters) or higher was difficult to correct to true ground values because of asymmetry in the radiation fields and the topography of the various islands (Reference C.1.1685).

On Bikini Atoll, as on Enewetak Atoll, the Operations Section of the Radsafe Center was responsible for all surveys. These surveys usually were conducted by helicopter, but ground vehicle surveys were carried out when required. Regular surveys were conducted on a schedule similar to that at Enewetak. On shots that required evacuation of the atoll, the preentry aerial surveys were launched from Boxer at sea. In these cases, the survey party first flew to Eneu to monitor the island and the ship anchorage for reentry and then proceeded with the remainder of the survey. Two crews usually surveyed simultaneously, one covering the southern half of the atoll, the other covering the northern half (Reference C.1.1685).

For the WAHOO and UMBRELLA underwater shots, monitoring was done from the surface units after an initial survey by air. Monitors on each surface unit were to continuously monitor the water, their unit, and target ships and ensure that their ship did not proceed into areas with readings exceeding 4 R/hr unless specifically instructed to do so. Monitors were also to calculate stay times so as to limit the exposure of any person to less than 2 R. These monitoring operations did not include actual boarding of the target ships. The primary purpose was to determine the general radiation intensities in the vicinity of and alongside the target ships. Recovery parties were allowed to proceed, based on this information, with the party monitor determining the radiation situation aboard ship (Reference B.3.3, 27-58, UMBRELLA).

Monitoring and control procedures for land surveys were developed before the operation. For example, the TG 7.2 Operations Plan 1-58 (Reference B.2) contains detailed procedures for monitoring land areas. A monitoring team was to comprise three men: a survey meter man, a recorder, and a radioman. If significant fallout was suspected, a rapid spot check survey was to be made at certain predetermined locations. Otherwise, a detailed routine survey was to be performed. Results of the surveys were to be reported to the TG 7.2 Radsafe Officer who would consolidate the readings on a ground intensity map of the area and plot the 0.01-R/hr isodose line indicating a radex area. Radex areas were to be marked with standard markers or placed under guard.

During the survey, the recorder and radioman were to advance in single file behind the survey meter man. Surveys of the ground were to be made with the probe at arms length so that all readings would be at about the same height above ground. Readings of vertical surfaces were to be made at a distance of 6 inches (15 cm). If an area in excess of 0.03 R/hr (a "hot spot") was discovered, the location and intensity were to be immediately radioed to the Radsafe Officer.

Teams were given further instruction regarding protective clothing and personnel and equipment decontamination procedures.

Use of barges for zero points required underwater radiation-measuring instruments for divers working on signal cables and mooring devices. Six special meters manufactured by the Isotopes Specialties Company, Burbank, California, were used. They were designed to withstand pressures encountered at depths of 100 feet (30.5 meters). These meters were hand-carried by SCUBA divers and proved to be easy to handle and read while under water (Reference C.1.1685).

CTG 7.3 promulgated radsafe measures for diving operations (Reference B.3.6). Divers were directed not to enter water having radioactivity exceeding 0.1 R/hr at the surface nor to remain in any underwater location where radioactivity exceeded 1 R/hr. In any proposed diving area, radioactivity was to be measured at the water surface, at a depth of 15 feet (4.6 meters), at mid-depth, at the bottom, and at the expected principal working depth. Each diver was to carry a special diving badge in addition to his regular badge. Divers were not permitted to enter the water with an incompletely healed wound that was open to the water. Underwater wounds and foreign objects in the eye were to be treated. To avoid radiation intake to the body, divers were cautioned not to swallow water.

Water samples from swimming areas and from the lagoons, where water was distilled for ships, were periodically taken and tested for contamination. No significant radioactivity was found in any of the ships' water samples

(Reference C.3.1, p. 77), but the swimming beach at Enewetak was closed for one day because of fallout from FIR (Reference C.1.1685).

FALLOUT PROTECTION MEASURES. Some precautionary measures were taken to reduce contamination from fallout. The Radiological Safety Plan of TG 7.3 (Annex G) describes measures that could be employed in advance to reduce contamination on TG 7.3 ships and aircraft in the event of their exposure to fallout and to reduce any decontamination effort. The document prescribed the use of the washdown systems installed on all ships whenever radiation levels were 0.005 R/hr in excess of background, if the radiation was from fallout and not from contaminated water (Reference B.3.7). Washdown systems also kept ship surfaces wet when fallout was expected so that contaminated particles would be less likely to stick. Figure 27 shows a washdown system in operation.

Some ships received fallout following FIR and KOA. Washdown systems were employed and, in general, were quite satisfactory in reducing radioactivity. An exception was USS De Haven (DD-727), where contaminated seawater after the shot was used to wash the ship; however, high exposure to the crew did not result. The highest badge reading on De Haven was 1.76 R (Reference C.3.3.15).

Figure 27. Washdown system operating on rear turrets of Killen (DD-593) during preparations for HARDTACK, UMBRELLA.

Most commanders expressed satisfaction with the washdown systems and radsafe equipment aboard their ships.

Target ships for the underwater shots were also equipped with washdown systems to reduce contamination and expedite reentry. Also, as part of scientific study, the ships were instrumented with film badges and gamma-intensity-time recorders.

HMR(L)-361 taped a double layer of barrier paper to the decks of its helicopters on reentry missions and instructed crew and passengers to don "booties" when entering from a radex area to minimize interior contamination (Reference B.3.8). Interior contamination of P2V aircraft cloud-sampling and -tracking aircraft was reduced by sealing air intake vents to the extent possible.

PRESHOT RADIOLOGICAL SAFETY

Before each shot, weather predictions were used to establish the danger area that might receive significant fallout. The danger area was searched to ensure clearance of all non-task-force ships, and task force personnel and equipment were evacuated as necessary.

Weather

Weather forecasting was an important part of the radsafe program because of the strong influence of wind speeds and directions on fallout patterns. In a 28 February 1958 letter to CINCPAC, CJTF 7 stated:

> The impact of fallout on populated islands will be one of the major factors in making a decision to shoot, and will be considered in its relation to forecast winds and other meteorological conditions.

The JTF 7 Operations Plan 1-58 established weather responsibilities among Hq JTF 7, TG 7.3, and TG 7.4 (Reference B.0.1).

JTF 7 Weather Central was located in Hq JTF 7 on Parry Island and was tasked with collecting all observable data and performing all analysis and prediction work. Analyses and presentations, in finished chart form, were to be transmitted to the Enewetak weather station and to the command ship via facsimile. The Radsafe Office, which was responsible for designating air and surface radex areas before shot time and for predicting and displaying fallout, was also located in Hq JTF 7, and presumably was closely associated with Weather Central.

The task force also established weather forecasting and observation stations on Enewetak Island and aboard Boxer. Boxer was responsible for maintaining technical control and coordinating the weather observation program afloat and the security patrol aircraft observational program. CTG 7.4 was given operational control of the Enewetak station. CJTF 7 maintained operational control over Boxer station as well as Weather Central. Both Boxer and Enewetak stations were responsible for plotting, displaying, and interpreting weather information provided by Weather Central. Boxer station provided operational forecasts and other weather services in support of waterborne operations, and the Enewetak station provided the same in support of air operations.

Weather information was to be obtained from JTF 7 Weather Central at Parry Island and the forecasting offices and observation stations at Enewetak Island and Kwajalein Naval Air Station. Weather observation stations were temporarily established by TG 7.4 at Tarawa, Kapingamarangi, Utirik, Wotho, Ujelang, and Rongelap atolls and Nauru and Kusaie islands as well as on TG 7.3 weather units afloat. Special winds-aloft and surface observations were made from TG 7.3 destroyers. WB-50s based at Enewetak Island and TG 7.3 security patrol aircraft based at Kwajalein made weather observations. U.S. Weather Bureau observations from stations at Majuro Atoll and Ponape, Wake, and Truk islands were used, as were routine Pacific Ocean area weather broadcasts.

CJTF 7 provided special rawinsonde (radar wind sounding) balloons to all JTF 7 weather stations, U.S. Weather Bureau stations, Kwajalein Naval Air Station, and TG 7.3 ships to make wind observations to support the operation. CJTF 7 also provided winds aloft sounding projectile (WASP) rockets for special wind observations by TG 7.3 destroyers. The rockets would explode at predetermined altitudes and release metallic foil strips (window) that would be carried by the wind and tracked by destroyer-based radar equipment.

At the beginning of the operation, CJTF 7 established five destroyer stations. Geographic coordinates of the weather stations and their locations with respect to the atolls were:

Alpha	260 nmi (482 km) from Enewetak bearing 262°
Bravo	225 nmi (417 km) from Enewetak bearing 325°
Charlie	200 nmi (370 km) from Bikini bearing 10°
Delta	50 nmi (93 km) from Bikini bearing 139°
Echo	50 nmi (93 km) from Enewetak bearing 130°.

As the operation progressed, CJTF 7 and CTG 7.3 agreed to maintain one destroyer at Station Bravo, one at Bikini to supplement *Boxer*'s D-1 observations, and a third at Enewetak (Reference C.3.1). The other four weather stations were used as needed. Another major change in procedure was made very early in the test series. As originally planned, the destroyer at Station Bravo would retire to a point south of the east-west centerline between Bikini and Enewetak on the night before a detonation as a precaution against unexpected fallout. This procedure, however, resulted in a lack of critical weather information immediately before shot time when it was most needed. During a conference between representatives of CJTF 7 and CTG 7.3 following YUCCA, it was decided to maintain the destroyer at Station Bravo at shot time and, if necessary, for up to 30 hours after the detonation. The JTF 7 FOPU would inform the destroyer of the best evasive courses to steer if fallout came near the ship. This new procedure was instituted on 30 April, six days before the second HARDTACK detonation, CACTUS, at Enewetak.

Weather observation capabilities were specified in the JTF 7 *Operations Plan 1-58* (Reference B.0.1) as follows:

- Bikini shipborne facilities -- minimum of eight surface, four rawinsonde, and one radiosonde daily, increasing to one rawinsonde every 2 hours and one radiosonde every 6 hours immediately preceding Bikini shot times

- Destroyers -- eight surface observations daily and, when directed, special winds-aloft measurements comprised of: high-altitude rawinsonde observations to 150,000 feet (45.7 km) via WASP rockets, and medium-altitude observations to 35,000 feet (10.7 km) via the WASP rawinsonde balloons
- Kwajalein Naval Air Station -- eight surface and four rawinsonde observations daily
- WB-50 -- two 12-hour weather missions daily, increasing to three or, if necessary, four missions daily 2 days before each shot
- Enewetak station -- hourly surface observations and four rawinsonde observations daily increasing to twelve daily when directed
- Temporary task force weather observation stations at Tarawa, Nauru, and Kapingamarangi -- eight surface observations daily and two rawinsonde observations daily, increasing to five daily when directed; at Kusaie and Utirik -- eight surface observations daily and four rawinsonde observations daily, increasing to eight daily when directed; and at Wotho, Ujelang, and Rongelap -- four surface observations and two pibal observations daily.

Fallout Prediction

The FOPU was established as part of the Radsafe Office to forecast radsafe information (fallout plot and air and surface radex areas) for each shot. No information has been found that describes the forecasting techniques used by the FOPU; however, many of the resultant predicted patterns are shown in the Operation HARDTACK Radiological Safety Final Report (Reference C.1.6.2) and are reproduced in Chapters 4 and 5 as appropriate.

Danger Area

The danger area for radioactive fallout was established a few days before each shot date, based on weather forecasts. CTG 7.3 established a 16-plane P2V squadron, comprised of Patrol Squadron 28 (VP-28) and four aircraft from Patrol Squadron 22 (VP-22), to search the danger area and these tracked the radioactive clouds in the postshot period.

Typically, on D-3 and D-2, CJTF 7 informed CTG 7.3 of the sectors to be searched on D-2 and D-1, respectively, based on the predicted fallout pattern. The Deputy CTG 7.3 aboard Boxer directed the security patrols and informed VP-28 at Kwajalein of the specific sector to be searched. Since the patrols were not conducted during a 10- to 12-hour period before each shot, the search zone was enlarged by 120 nmi (222 km) in all directions, allowing the patrol squadron to warn ships that might come into the danger area before the shot. Because of the irregular shapes of the forecast fallout patterns, a circular arc search pattern was employed to provide complete coverage to compensate for possible changes in wind patterns. Aircraft were assigned different radii from the atoll to ensure as complete search coverage as possible. This procedure also facilitated readjusting search areas during the search, particularly if time was short. The AOC was located aboard Boxer, or, in Boxer's absence, on the radar picket destroyer, USS Benner (DDR-807), which relayed the flight control patterns through the squadron base radio at Kwajalein.

During the later phases of the operation, when Boxer departed the EPG for Johnston Island, surveillance searches and radsafe flights were controlled from an air plot established in the Air Force weather communications facility on Parry Island. Although the air plot was physically integrated with the Air Force communications facility, it was controlled and directed by TG 7.3 (Reference C.3.1).

Personnel Evacuation

For shots at Enewetak or Bikini atolls, personnel were sight-mustered, typically at 1800 on D-1. All personnel in forecast land danger areas were reported to the atoll muster officer. For Enewetak events, these danger areas usually were all islands of Enewetak except Parry and Enewetak; for Bikini events, they included all islands of Bikini except Eneu. For some Bikini shots, however, the atoll was completely evacuated. When all personnel were out of the danger area, the completed muster was submitted to CJTF 7 by the task group muster officer. For complete evacuation of Bikini Atoll, all personnel were mustered as they boarded the ships. A relatively large number of personnel manned stations at Johnston Island for TEAK and ORANGE. These personnel were mustered at each of these stations, and the muster officer reported when all task group personnel were in safe locations. Those who were evacuated from Johnston Island were mustered aboard ships (Reference C.1.1682).

LCUs were the primary ship-to-shore evacuation vehicle. H-19 helicopters were used to evacuate priority personnel and late evacuees. For complete evacuation of Bikini, most evacuees were taken aboard Boxer and USNS Fred C. Ainsworth (T-AP-181). When Boxer was at Johnston Island, USS Monticello (LSD-35) was substituted. At Johnston Island, Boxer was the primary ship for evacuees.

TG 7.3 and TG 7.5 maintained a capability to evacuate all personnel in the event of severe fallout or other emergency.

POSTSHOT RADIOLOGICAL SAFETY

Reentry and Recovery

Procedures for reentry into radioactive areas were summarized as follows:

- Entry into a full radex area will require full protective clothing and a qualified monitor to accompany the party
- Entry into a limited radex area will require such protective clothing and monitoring support as deemed necessary by the TU 7.1.6 Plotting and Briefing Section
- Entry of personnel into full and limited radex areas will require access permits issued to party monitors or party

leaders by the TU 7.1.6 Plotting and Briefing Section at the Radsafe Center signifying that all radsafe procedures have been complied with

- Recovery and construction parties will be allowed to enter radioactive areas as necessary, but depending upon the current radiological situation (actual control of early entry on D-day will be exercised by J-3, TG 7.1).

Checkpoints for control of entry into radioactive areas would be established by TU 7.1.6 as required. Normally, checkpoints would be maintained by the Air Dispatcher's Office and at the marine landing. Personnel departing for radex areas were required to have access permits before passing the checkpoints. Upon return from a radex area, personnel and equipment would be monitored at the checkpoints. Personnel or equipment found to be contaminated above the established MPLs would be directed to the appropriate decontamination station. All personnel were to proceed to the Radsafe Center to exchange film badges upon return from a radex area.

Task unit commanders could request continuing radex area access permits for personnel in their task units, which allowed frequent entry to and exit from radex areas without obtaining separate permits for each entry and exit. All requests for continuing access permits were to be approved by CTU 7.1.6 and could be withdrawn at any time, depending on the radiological situation. Continuing access permits were not valid for more than one event or when certain individual cumulative exposures were reached.

TU 7.1.6 trained monitors for the various projects as required. If possible, projects were to provide their own monitors for entry into radex areas; otherwise, arrangements could be made with TU 7.1.6 to supply monitors. Party monitors, and any others deemed necessary, were briefed by the TU 7.1.6 Plotting and Briefing Section before receipt of an access permit. Monitors assigned to individuals or groups working in radex areas or with contaminated equipment during recovery operations kept the recovery party leader advised of radiation intensities at all times. Since the party leader was responsible for the radiological safety of all members of his party, he was expected to accept the monitor's advice and act accordingly. It was the responsibility of both the leader and the members of the recovery party to adhere to the established exposure limits. When eating or working in any radex area, sensible sanitary precautions were to be taken (Reference B.1.6).

Cloud Sampling

Manned aircraft collected air and particulate samples from radioactive clouds of all shots except the high-altitude shots, TEAK and ORANGE, to support scientific Projects 11.2, 21.2, and 2.8b. While the cloud-sampling operations were not in themselves radsafe-oriented, the real-time radiation measurements contributed to tracking of the cloud, and special radsafe procedures were established to ensure safety during recovery of the collected samples. Unmanned rockets also were used to collect cloud samples.

TG 7.4 was responsible for collecting cloud samples by manned aircraft. B-57 aircraft collected particulate matter on filter-paper assemblies mounted in the nose of the wingtip fuel tanks. These same aircraft collected gas samples from collection units mounted on each side of the fuselage near the tail of the plane. Intake air, filtered to remove particulates, was pumped into bottles aboard the aircraft. WB-50 aircraft were also used to support Project 2.8b by collecting particulate samples at low altitudes on filter paper assemblies mounted on top of the aircraft.

The MPE for these aircrews was 10 R gamma, plus an additional 10 R in the event of operational accident or emergency. Exposure in excess of 20 R would be considered an overexposure.

Procedures for removal of the particulate samples from the wingtip collectors of the B-57 were standardized and are described in detail in Reference C.4.4 (pp. 220-225). They were similar to those of previous operations, but with some modifications. Two towed trailers in tandem were used during sample removal to carry tools and sample containers. The samples were stored aboard another towed trailer.

Three people were directly engaged in particulate sample removals. A fourth person served as overall supervisor to ensure compliance with sample-removal procedures. Air Force operating procedures called for wearing a standard fatigue uniform without booties, and leather palm gloves. The trailers and personnel were brought to between 25 and 50 feet (7.6 and 15 meters) from the front of the aircraft. The minimum standoff distance of 25 feet (7.6 meters) was chosen based upon a possible radiation exposure rate of 0.5 R/hr from the filter paper, which frequently had intensities of 100 R/hr at a distance of 1 foot (0.3 meter). The first person advanced to the pod, cut the filter-retaining wire with a long-handled tool (which appears in photographs to be about 4 feet [1.2 meters] long), obtained long-handled tongs from the tool trailer, and returned to his original position beyond 25 feet (7.6 meters) from the aircraft. The second person advanced to the pod, inserted a hook at the end of a 9-foot (2.7-meter) pole into a ring on the filter assembly, and removed the assembly. The first person was ready to assist with the long-handled tongs if needed. The second person carefully carried the assembly at the end of the pole and deposited it into a shielded "cave" on the second tandem trailer. The first person removed the safety holding wire from the assembly with a long-handled tool, and the second person spread the holder so that the third person could insert a long-handled paper-rolling tool. Person number three rolled the paper, while the others stood well clear, and inserted the rolled paper into a shielded "pig" in front of the cave. The first person measured the radiation intensity in the pig using a long-handled probe and recorded the readings. Then persons number one and two lifted the pig (which closed shut automatically as it was lifted) from the trailer using a long-handled tool, carried the pig to the third trailer, and stored it in a section of a shielded box. Each wingtip filter paper was removed in this manner (Reference C.4.4).

Air Force ground crews from the TAU Nuclear Applications Section recovered the samples. Their cumulative radiation exposure rose as HARDTACK progressed. To avoid the loss of these key personnel, CTG 7.4 requested that their authorized exposure be increased from 5 R to 10 R; his request was approved (Reference C.4.2, p. 136).

No details on removal of the samples from the WB-50 aircraft that supported Project 2.8b are available, but presumably the procedures were similar to those for recovering the wingtip samples from the B-57 aircraft.

Details on removal of the gas bottles are not available, but the radiation exposure potential for personnel probably was significantly less than for particulate sample removal. In Operation REDWING (1956), recovery time for the gas bottles was typically less than 2 minutes because of the quick-disconnect couplings used.

Radiochemical Samples

Radiochemistry laboratory trailers were located on both Enewetak and Bikini atolls. These facilities did not perform detailed radiochemistry studies; they were for onsite support such as checking potable water and swimming areas to ensure task group personnel safety. For other radiochemistry studies, samples were collected and shipped to LASL and UCRL in the United States by Military Air Transport Service (MATS) aircraft. JTF 7 Operations Plan 1-58 specified that transportation of radioactive material to and from the forward area be in accordance with AEC regulations for escorted shipment of such material (Reference B.0.1).

Radioactive samples in each sample-return flight were accompanied to their destination by a sample-return officer who also acted as aircraft radsafe monitor. Before departure, each sample-return officer was given a survey instrument, film badges, and a TG 7.4 course of instruction. He would issue, and record issuance of, badges to the aircrew and any passengers and collect the badges as they deplaned.

Radioactive samples to be shipped were to be properly packaged and marked and stored aboard the aircraft in a way that minimized personnel exposure. After the samples were loaded, TG 7.4 radsafe personnel and the sample-return officer would inspect and monitor the aircraft and, based on radiation readings, mark an isolation area on the floor. The CTG 7.4 criterion was 0.02 R/hr, but the isolation area was marked more stringently at 0.01 R/hr (Reference C.4.1, pp. 136-139). All personnel aboard the plane were to be made aware that the cargo was radioactive and that they were to remain outside the isolation area.

Decontamination

Radiological decontamination of personnel, equipment, aircraft, ships, and land areas was required during HARDTACK. In general, decontamination was required when the contamination exceeded the established MPLs.

PERSONNEL. Personnel decontamination was required when radiation levels exceeded 0.007 R/hr (beta plus gamma) or 500 CPM alpha (55-cm^2 probe) for outer clothing or 0.001 R/hr (gamma) or 100 CPM alpha (55-cm^2 probe) on skin or underclothing (See Appendix A).

All personnel returning from radex areas were monitored at the checkpoints. If contaminated, they were processed through the personnel decontamination station adjacent to the Radsafe Center. Their protective clothing was deposited into receptacles in the contaminated side of the decontamination center. After showering, they were monitored again, and if found uncontaminated, proceeded to the clean side of the decontamination center to dress (Reference C.5.3).

Approximately 6,200 individuals were processed through Enewetak Atoll checkpoints, of which 860 were processed through the personnel decontamination station on Parry Island. H&N provided laundry services for the protective clothing. Identical decontamination facilities were located on Eneu Island, and 1,200 people were processed through the facility for Bikini operations. Laundry facilities were provided aboard an H&N barge. For WAHOO and UMBRELLA, decontamination facilities were established afloat.

For shots QUINCE and FIG, it was necessary to establish a personnel decontamination station on Runit. Traffic through this decontamination station was very heavy, and it was necessary to move the laundry barge from Bikini to handle the laundry load. Much of the clothing was disposed of because it was too difficult to reduce the alpha contamination to acceptable levels. Respirators and full face masks were cleaned for reuse but in many cases booties, surgeon caps and gowns, and coveralls were disposed of (Reference C.1.1685).

EQUIPMENT. Equipment and vehicle contamination MPLs were 0.007 R/hr (gamma plus beta) or 500 CPM fixed alpha (55-cm^2 probe). (When no change in alpha contamination level could be observed by checking the swipe of a 100-cm^2 area, it was referred to as fixed alpha.) Respiratory protective devices were maintained below a contamination level of 0.001 R/hr (beta plus gamma) or 100 CPM alpha (55-cm^2 probe).

The equipment decontamination station on Parry Island processed 800 items, including 56 vehicles and 9 helicopters. Numerous pieces of small equipment were cleaned for the various projects and for H&N. For Bikini operations, an equipment decontamination station that duplicated the Enewetak facilities was located adjacent to the radsafe building. One hundred and five vehicles and pieces of heavy construction equipment were decontaminated as well as numerous pieces of project and H&N equipment. Four aircraft required decontamination (Reference C.1.1685).

Normal procedure called for all heavy equipment returning from shot islands to be monitored upon removal from boats and taken to the decontamination station if necessary. Versene and citric acid were the common decontaminating agents employed, and a steam generator was used to provide hot solutions for the necessary washing. In a few instances, when steam and chemical cleaning failed, sandblasting was used to reduce the radioactive contamination to the permissible level. Materials that could not be decontaminated were placed in barrels, which were filled with concrete and dumped at sea (Reference C.5.3). When equipment was not needed immediately, it was held in an isolated parking area before decontamination to allow natural decay to reduce radioactivity levels (Reference C.1.1685).

AIRCRAFT. In HARDTACK, as in previous operations, contaminated aircraft were parked in isolation areas and, if time permitted, allowed to stand to permit radioactivity to decay. When necessary, aircraft were washed with high-pressure water hoses and chemicals. A general procedure for handling contaminated aircraft was (Reference C.4.4, pp. 233-235) as follows:

1. Returning aircraft (air sampling, cloud tracking, and ground survey) were taxied by the flight crew to the end of the runway and parked adjacent to the aircraft decontamination area

2. Flight crews deplaned according to standard operating procedures established by decontamination personnel

3. A cursory survey of each incoming aircraft was made to determine the extent and degree of contamination; if the average contamination level was above 0.02 R/hr, and if time allowed, the aircraft radioactivity was allowed to decay to this level

4. Prior to decontamination, the aircraft was towed to the designated washing area, which was selected so as to avoid secondary contamination of other aircraft or personnel

5. A detailed exterior survey of aircraft was made before any decontamination operation and the results recorded on appropriate forms or sketches showing beta plus gamma and gamma readings; the same survey was made and recorded for each crew position.

When monitoring, intensity readings were taken approximately 1 inch (2.5 cm) from the aircraft surface being monitored. Instrument probes were fitted with 1-inch (2.5-cm) wire offsets to aid in standardization of readings and to minimize the time devoted to each reading.

The techniques were time consuming and required great care. The first washing was done with decontamination trucks using 1 pound (0.45 kg) of detergent for each 100 gallons (379 liters) of water. The monitoring procedures were repeated. The second washing (if required) consisted of a mixture of one part "gunk" and three parts kerosene followed by a water and detergent rinse. Monitoring procedures were again repeated. If time permitted, and if required, a final washing used water and detergent.

During application of the decontamination agents, precautions were taken to avoid spreading contamination. The runoff area was monitored and, if necessary, outlined and marked as a contaminated area.

All personnel entering the aircraft decontamination area were processed first through the personnel decontamination center and issued hats, gloves, coveralls, and shoes. When departing the aircraft decontamination area, personnel were reprocessed through the personnel decontamination center according to the standard procedures.

As HARDTACK progressed, the radiation exposures of aircraft maintenance personnel rapidly approached the MPE limits. CTG 7.4 requested, and was granted, permission to change the allowable exposure limit of maintenance personnel from 5 R to 8 R for the operation (Reference C.4.1, p. 36).

NAVAL AIRCRAFT AND SHIPS. Radsafe preparations were extensive for the naval aircraft of VP-28. A radsafe officer and his assistants were designated on October 21, 1957, and the squadron began collecting radsafe supplies and equipment and sending officers and men to courses and lectures. A 20-man decontamination team, plus 6 officers and 1 petty officer, was established. Ventilating air ducts in the aircraft were sealed to prevent internal contamination, and 100 percent oxygen was recommended for breathing in contaminated areas. Flight crews, decontamination teams, and radiac repair teams were issued film badges and protective gear. Aircraft decontamination was done with fresh water. The June <u>VP-28 Op Phase Report</u> (Reference C.3.3.29) states that:

> The stubborn places [on aircraft] to decontaminate are the engines and radar dome. The aircraft have been returning in the evening and have parked until the next morning before decontamination procedures were initiated. . . . Maintenance personnel were warned. Dosimeters were issued to personnel working on the engine and they were monitored when they were finished.

Returning aircraft were instructed to fly through rain clouds when possible. By this method one aircraft reduced its inside intensity reading from 0.09 to 0.002 R/hr.

Some task force ships were significantly contaminated once following FIR and KOA when the fallout clouds of these two shots intermingled. On this occasion the washdown systems were employed with satisfactory results. Extent of this contamination and the ships involved are discussed in Chapter 4.

A special decontamination unit was organized and trained to decontaminate the target ships for WAHOO and UMBRELLA. No particular difficulties were encountered; the unit carried out its tasks well (Reference C.3.1). Since the contamination levels were considerably less than those expected, a large number of decontamination personnel was not necessary.

Decontamination of task force ships followed practices of earlier nuclear tests. The standard technique was the operation of a ship's washdown equipment during the period of fallout so that the contaminants would not have a chance to adhere to the ship's structure, followed up by monitoring of the ship to indicate places requiring high-pressure water-hosing and brushing.

In actuating washdown systems in response to instrument readings indicating the presence of radioactivity, units were warned to first check that the readings did not increase in the superstructure, which would indicate that the radioactive material was in the seawater surrounding the ship. Use of the washdown system was not appropriate under these circumstances, as it used the seawater and would thus worsen the situation it was meant to alleviate (Reference B.3.3, 15-18 [WAHOO] and 27-58 [UMBRELLA]).

The use of high-pressure hosing also required that care be exercised to keep personnel and nearby ships upwind so that the resulting spray would not come in contact with decontamination personnel or other ships. Decontamination of a task force ship remained the responsibility of its own crew, but technical assistance was always available from the TG 7.3 Decontamination Unit. The officer-in-charge of this unit was always available during shot operations at the APA decontamination center and could be contacted by a special radio link (Reference B.3.3, 15-58 [WAHOO] and 27-58 [UMBRELLA]).

LAND AREAS. A large area on Runit Island was heavily contaminated with alpha from QUINCE. Since the same area had to be used for FIG, it was necessary to partially decontaminate the land area. This is further described in Chapter 4.

MACK PHOTO TOWER. The Mack Photo Tower on Unibor in Enewetak Lagoon was subjected to radioactive fallout from several shots during the operation, and several attempts were made to decrease its radiation intensity.

On 16 May 1958, the tower had gamma radiation levels up to 5 R/hr. Using a firetruck on an LCU, the fire department attempted to lower the radiation level to a permissible level by hosing down the tower. However, the radiation level could not be reduced to less than 1 R/hr. On 22 May, the tower was hosed down again, but the east side of the tower still showed gamma readings of 1 R/hr. On 1 June, the tower was washed down with water and scrubbed with brushes, and the maximum reading on the east side was 0.45 R/hr.

To protect the tower from further fallout, a disposable canvas cover was placed over the top cab of the tower and a tent over the generators on the lower platform. On subsequent shots, the gamma intensities were reduced somewhat; however, SCAEVOLA contaminated both the lower and upper cabs with alpha-emitting material. At the close of the operation, the tower was again washed down, and the radiation intensities were 0.08 R/hr (gamma) and 50,000 CPM alpha (55-cm^2 probe) (Reference C.5.3).

CHAPTER 3

DOD EXPERIMENTAL PARTICIPATION

The experimental program for Operation HARDTACK focused on testing nuclear weapons developed by the Los Alamos Scientific Laboratory (LASL) and the University of California Radiation Laboratory at Livermore (UCRL). Interest in effects experiments was high, however, and the Department of Defense (DOD) sponsored five HARDTACK shots that were primarily concerned with effects experiments. Within the Joint Task Force 7 (JTF 7) organization this experimental program was managed and supervised by the scientific task group (Task Group [TG] 7.1). The DOD contributed both to weapon development and to effects experiments, with most of the participation in the effects experiments.

TG 7.1 was subdivided into task units that conducted their respective programs. Each of the Atomic Energy Commission (AEC) weapon development laboratories had a task unit that conducted its own experiments, with support for these experiments provided by additional task units.

Experiments for LASL were conducted by Task Unit (TU) 7.1.1, and TU 7.1.2 conducted the experiments for UCRL. TU 7.1.3 conducted weapon effects tests for the DOD. TU 7.1.4, TU 7.1.5, and TU 7.1.6 provided support services for both weapon development laboratories and for TG 7.1 as a whole. The predicted operational strength of DOD personnel participation is given in Table 7.

WEAPON DEVELOPMENT EXPERIMENTS

DOD participation in HARDTACK weapon development experiments included cloud sampler aircraft and aircrews for TU 7.1.1 and TU 7.1.2, staffing one TU 7.1.1 project by the Naval Research Laboratory (NRL), and performing many other support activities such as aircraft and ship patrols, security, instrumentation placement and recovery, and radioactive sample return.

Projects 11.2 and 21.2 -- Aircraft Sampling

Agencies: 4926th Squadron, Kirtland AFB

4025th Strategic Reconnaissance Squadron, Strategic Air Command (SAC)

Operations: Two-place B-57Bs from the 4926th and single-place SAC B-57Ds from the 4025th penetrated detonation clouds to collect weapon debris samples for analysis by LASL and UCRL. In the 33 events that cloud sampling was attempted, samplers flew 240 missions and logged 1,635 flying hours (Reference C.4.3, pp. 189-190). Shot-by-shot sampling for HARDTACK is given in Table 8. The B-57D was new to nuclear testing and allowed sampling at higher altitudes. Figure 28 shows a B-57D in flight and a close-up view of the collection filter fitted behind the nose of the wingtip pod. The potential for radiation exposure was high for both aircraft crews and ground crews handling the aircraft.

Table 7. Task Group 7.1 operational strength at Eniwetok Proving Ground, 1958.

Unit	Military Officers	Military Enlisted Men	Civilian	Operational Location
Hq Task Group 7.1	31	71	39	Parry and Hawaii
Task Unit 1 (Los Alamos Scientific Laboratory)	1	16	169	Parry
Task Unit 2 (University of California Radiation Laboratory)		3	192	Parry
Task Unit 3 (Department of Defense)	68	141	458	Parry
		7	1	Kusaie
	1	2	14	Wotho
	3	2		Kwajalein
	1	5		Rongelap
			4	Wake
Task Unit 4 (Sandia Corporation)			97	Parry
			2	Kwajalein
			2	Rongelap
Task Unit 5 (Edgerton, Germeshausen & Grier)			166	Parry
Task Unit 6 (Radiological Safety)	24	76	3	Parry
Task Unit 7 (United Nations Shot)	--	--	--	
Program 40 (Radiological Survey)[a]			3	Parry
			2	Rongelap
			2	Kwajalein
Total	129	323	1,154	

Note:

[a]Conducted by the Laboratory of Radiation Biology, University of Washington.

Table 8. HARDTACK B-57 cloud sampler missions.

Shot	Number of Aircraft B-57B	Number of Aircraft B-57D	Altitude Maximum (feet)	Altitude Maximum (km)	Altitude Minimum (feet)	Altitude Minimum (km)
YUCCA	?	?	--	--	--	--
CACTUS	4	1	13,800	4.21	10,000	3.05
FIR	3	3	48,000	14.63	8,000[a]	2.44[a]
BUTTERNUT	5	3	27,500	8.38	15,000	4.47
KOA	4	2	49,000	14.93	5,000[a]	1.52[a]
WAHOO	2	0	3,000	0.91	1,400	0.43
HOLLY	2	2	12,000	3.66	4,000	1.22
NUTMEG	6	0	18,000	5.49	6,000	1.83
YELLOWWOOD	4	2	45,000	13.72	8,000[a]	2.44[a]
MAGNOLIA	4	0	38,000	11.58	14,000	4.27
TOBACCO	4	0	18,000	5.49	9,000	2.74
SYCAMORE	5	1	43,500	13.26	2,700	0.82
ROSE	4	0	15,000	4.57	4,500	1.37
UMBRELLA	2	0	850	0.26	300	0.09
MAPLE	4	2	47,000	14.32	12,000[a]	3.66[a]
ASPEN	5	1	52,000	15.85	15,000	4.57
WALNUT	4	2	46,000	14.02	3,000[a]	0.91[a]
LINDEN	4	0	17,000	5.18	5,000	1.52
REDWOOD	4	1	49,000	14.93	9,500[a]	2.90[a]
ELDER	3	2	49,500	15.09	5,000[a]	1.52[a]
OAK	4	4	52,500	16.00	5,000[a]	1.52[a]
HICKORY	4	0	23,000	7.01	9,000	2.74
SEQUOIA	4	0	13,500	4.11	8,500	2.59
CEDAR	3	3	49,000	14.93	10,000[a]	3.05[a]
DOGWOOD	3	4	51,000	15.54	9,000[a]	2.74[a]
POPLAR	2	4	50,000	15.24	2,000[a]	0.61[a]
SCAEVOLA	1	0	1,500	0.46	1,500	0.46
PISONIA	3	2	48,000	14.63	3,000[a]	0.91[a]
JUNIPER	4	1	47,000	14.32	14,000	4.27
OLIVE	4	2	50,000	15.24	8,000[a]	2.44[a]
PINE	4	2	52,500	16.00	8,000[a]	2.44[a]
QUINCE	1	0	800	0.24	400	0.12
FIG	2		4,500	1.37	3,900	1.19

Note:

[a] Base of cloud (top of stem).

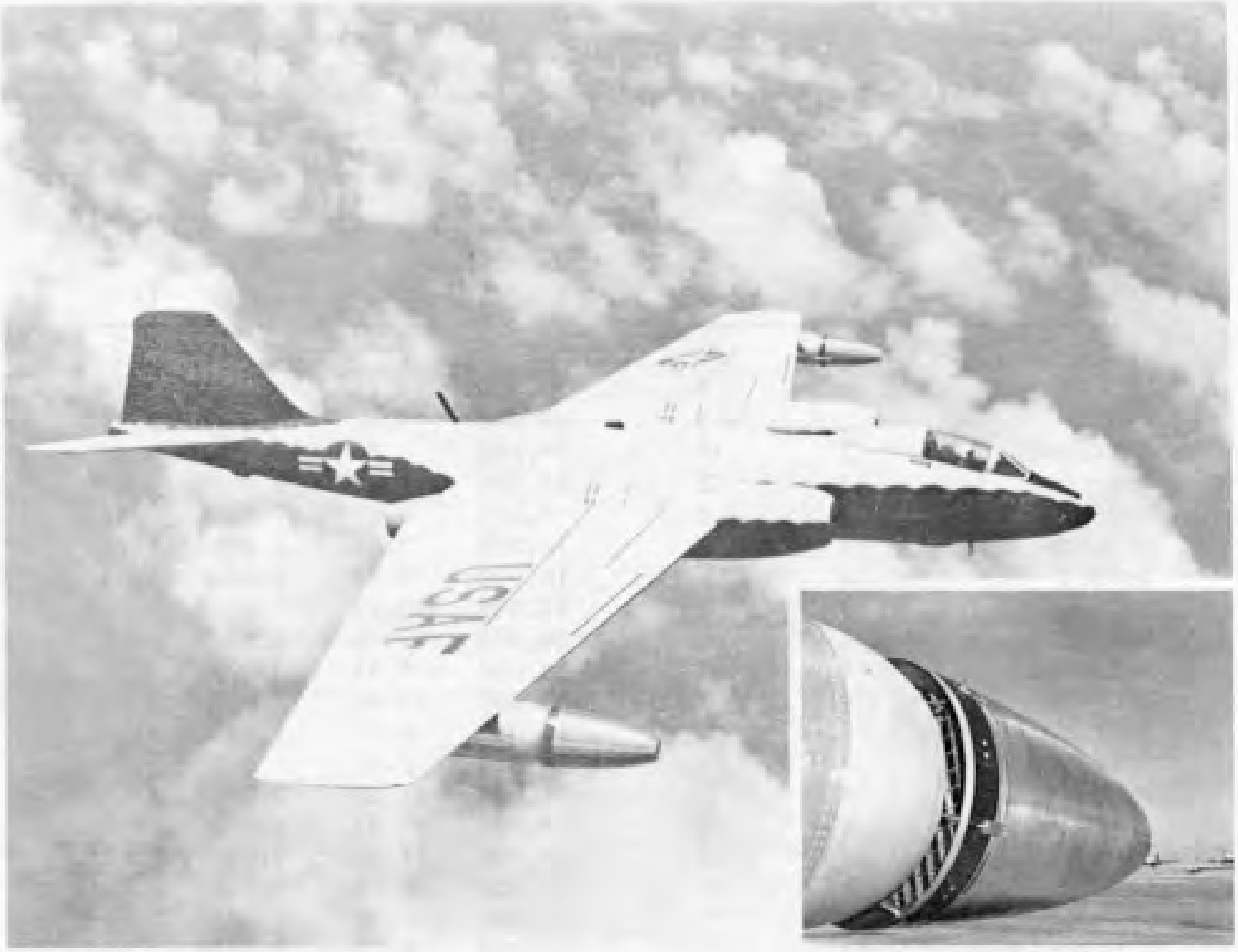

Figure 28. B-57D sampler, HARDTACK; close-up view of collection filter unit inset.

Shots: All except TEAK and ORANGE.

Staffing: Strength of the Test Aircraft Unit (TAU) of TG 7.4, the unit that conducted the sampling, peaked at 238. Exposures for 49 of these personnel are given in Table 9.

Project 18.1 -- Power-Time and Total-Thermal Measurements

Agency: Naval Research Laboratory (NRL)

Operations: Ground-based thermal measurements were made from Johnston Island.

Staffing: Twenty-nine NRL personnel were badged as part of TU 7.1.1; their exposures are given in Table 9. Maximum individual exposure was 1.878 R, but this figure cannot be attributed to the documented tasks of Project 18.1, nor to Projects 2.6 or 2.7, the other two projects with NRL personnel.

Table 9. HARDTACK personnel exposure, Department of Defense scientific experiments.

Element	No. of Persons Badged	Exposure Ranges (R)[a]										
		0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	5-10	10-15
WEAPON DEVELOPMENT EXPERIMENTS												
Aircraft Sampler Crews	49	1	3	2	1	3	2	1	2	1	27	6
Project 18.1	29	17	9	2	0	1						
Total Weapon Development Experiments	78	18	12	4	1	4	2	1	2	1	27	6
EFFECTS EXPERIMENTS												
Project 1.1	26	0	0	1	15	9	1					
1.2	7	0	0	3	4							
1.3	2				2							
1.4	1						1					
1.5	2			2								
1.6	2				1		1					
1.7	16				2	1	0	4	7	2		
1.8	9	1	0	3	5							
1.9	2			1		1						
1.10	2	1	1									
1.11	3			1	2							
1.12	4		1		1	1				1		
1.13	4			3	1							
Program 1 Total	80	2	2	14	33	12	3	4	7	3		
Project 2.1	4				3			1				
2.2	9		2	1	6							
2.3	18			2	12	3	1					
2.4	5					1	2	1		1		
2.4a	4				1	1	1		1			
2.6	6	4	2									
2.7			Shared personnel with Project 2.6									
2.8	14	2	2	2	7						1	
2.10	1						1					
2.14	2		2									
Program 2 Total	63	6	8	5	29	5	5	2	1	1	1	

Note:

[a] Basic Maximum Permissible Exposure (MPE) -- 5 R for the operation. Special MPE for air samplers was 10 R.

(continued)

Table 9. HARDTACK personnel exposure, Department of Defense scientific experiments (continued).

Element	No. of Persons Badged	Exposure Ranges (R)[a] 0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	5-10	10-15
Project 3.2	4		2				2					
3.3	12			6	5	1						
3.4	4		4									
3.5			Shared personnel with Project 3.3									
3.6	3			1				1	1			
3.7	1						1					
3.8	10			1	8	1						
Program 3 Total	34		6	8	13	2	3	1	1			
Project 4.1	1		1									
Project 5.1	1				1							
5.2	6			1	1				2	1	1	
5.3	5		1	1	1				2			
Program 5 Total	12		1	2	3				4	1	1	
Project 6.3	2					2						
6.3a	1								1			
6.5	3		1	1	1							
6.6	3	2			1							
6.7	2			2								
6.8	3				3							
6.9	4		2	2								
6.10	3	3										
6.12	2	1	1									
Program 6 Total	23	6	4	5	5	2			1			
Project 8.1	4			1	3							
8.2	4	1				3						
8.4	3	3										
8.6	7	1	3	2					1			
8.7	6		4	1	1							
Program 8 Total	24	5	7	4	4	3			1			
Project 9.1d	1	1										
9.2a	5	3		2								
9.2b	4	4										
Program 9 Total	10	8		2								
Total Effects Experiments	247	27	29	40	87	27	11	7	15	5	2	
TOTAL ALL PERSONNEL DOD EXPERIMENTS	325	45	41	44	88	29	13	8	17	6	29	6

Note:

[a]Basic Maximum Permissible Exposure (MPE) -- 5 R for the operation. Special MPE for air samplers was 10 R.

Source: Consolidated List of Exposures (Reference C.1.6.3).

EFFECTS EXPERIMENTS

TU 7.1.3, activated at the Eniwetok Proving Ground (EPG) on 15 March 1958, was organized to conduct weapon effects tests under the operational control of CTG 7.1, and the technical direction of Chief, Armed Forces Special Weapons Project (AFSWP). The staff for Operation HARDTACK was furnished by Field Command, AFSWP, with a small number of personnel from Headquarters, AFSWP, and from various armed services upon request from the Chief, AFSWP. Project personnel came from some 27 different organizations and participating agencies. The peak strength of TU 7.1.3 was reached on 12 April 1958 when 665 personnel assigned to it were in the EPG. Altogether, approximately 700 personnel participated in TU 7.1.3 effects experiments in HARDTACK.

The following tasks were assigned to TU 7.1.3:

1. Design and carry out experiments to determine the military effects of nuclear detonations as required by DOD
2. Review and approve construction and support requirements of the military effects program
3. Coordinate the operations associated with the firing of the DOD devices to assure optimum results for the special effects studies
4. Prepare technical reports of the military effects programs.

The effects experiments of TU 7.1.3 were conducted by projects that were grouped together into programs. These programs and their projects are discussed below; information on project operations pertinent to radiological exposures is emphasized. Details of the various projects were documented in weapons test reports, which are referenced in the project descriptions. Actual exposure information, drawn from the Consolidated List of Exposures (Reference C.1.6.3), is provided in Table 9 for those badged personnel who have been identified as having participated in TU 7.1.3 project activity.

Program 1 -- Blast and Shock Measurements

The blast and shock program was designed to document information on shock parameters in the propagation of the blast wave incident on and through the media of air, ground, and water. This program was composed of 13 projects.

Project 1.1 -- Underwater Pressure Measurements

Agencies: Naval Ordnance Laboratory (NOL)
Army Waterways Experiment Station (WES)

Operations: Self-contained gauges were suspended on lines from unmanned, moored target ships at various depths and distances from surface zero of the underwater shots, WAHOO and UMBRELLA. The target ships were three noncommissioned destroyers (Fullam [DD-474], Howorth [DD-592], and Killen [DD-593]), a tug (USS Chowanac [ATF-100]), miscellaneous units (SS Michael E. Moran [EC-2], LCM-22, LCM-52, YC-1, YFNB-12), and barges 17, 21, and

55. Operations required retrieval of the gauges after the shots. Project personnel were in the target-vessel area on the day following WAHOO but could not complete their activity due to the "level of radioactivity." One day after UMBRELLA, project personnel recovered gauges in the target area also.

Shots: WAHOO, UMBRELLA.

Staffing: The project report identifies 22 NOL and 4 WES personnel; their exposures are given in Table 9. Most exposures were less than 1.5 R and only one was in the 2 to 2.5 R range.

Project Report: Reference C.1.1606.

Project 1.2 -- Air Blast Measurements

Agency: Naval Ordnance Laboratory (NOL)

Operations: The objective was to determine airblast overpressures for the two underwater shots. Tethered balloons (Figure 29), surface stations, and rockets were used for instrument locations. The surface stations were on target ships. The rockets were fired remotely from Mut Island for WAHOO and UMBRELLA, and from Howorth for UMBRELLA only. The gauges on the balloons and the rockets were self-recording and required retrieval. The surface stations had both self-recording gauges and gauges that telemetered the information to a remote recording site.

Balloon recovery was not permitted until the day following the shots. Rocket recovery "commenced immediately after the [UMBRELLA] shot." Three LCMs, one LCU, and one DUKW, which arrived in the "probable impact area by H+1 hour," searched for the rockets, assisted by an L-20 and an H-21. The area the surface vessels were in is not clear, but presumably they would have been radiologically cleared. The position of the rockets at burst time appears to have been about 4,000 feet (1.2 km) northeast of the burst. Their parachute-borne descent was affected by the low-altitude winds. An LCU used by the project as a photo station about 20,000 feet (6.1 km) east-northeast of the surface zero was probably the LCU used in rocket-recovery operations. Other ships involved in controlling the search were USS Lansing (DER-388), some 30,000 feet (9.1 km) east-northeast of surface zero, and USS Joyce (DER-317), about 30,000 feet (9.1 km) north-northwest.

Shots: WAHOO, UMBRELLA.

Staffing: Seven civilians from NOL can be identified as participants in the field portion of the project. Their exposures are given in Table 9.

Project Report: Reference C.1.1607.

Project 1.3 -- Surface Phenomena Measurements

Agency: Naval Ordnance Laboratory (NOL)

Figure 29. Project 1.2 balloon in LCU inflated for raising, HARDTACK.

Operations: The primary objective was to measure the formation, growth, and dissipation of visible surface phenomena such as the spray dome, plume, and base surge. Photographic data were obtained from camera stations on Parry and Ikuren, from USS Mansfield (DD-728), LCU-479 and LCU-1123, and from aircraft. A secondary objective was measurement of temperature and humidity in the base surge by placing sensors and recorders on the target ships described in Project 1.1. Lookout Mountain Laboratory and Edgerton, Germeshausen, and Grier, Inc. (EG&G) operated cameras from three C-54 photo aircraft (voice calls, Pewter-1, -2, and -3) and an RB-50 (EG&G only). The C-54s flew at altitudes of 1,500 to 10,000 feet (457 meters to 3.05 km), and the RB-50 was at 24,000 feet (7.32 km). The surface photographic data from Ikuren, LCU-479, and LCU-1123 were obtained with unmanned cameras.

Recovery of the temperature and humidity sensors and recorders from the target array was a potential source of exposure. The project report states that following WAHOO, "as soon as the instrumented statons were declared radiologically safe," the equipment was removed. "All elements, shields, and cables used on Shot WAHOO were discarded because of contamination and were replaced for Shot UMBRELLA."

Shots: WAHOO, UMBRELLA.

Staffing: The project report identifies five NOL civilians as participants but only two appear on the Consolidated List. One of these two is the project officer, who was also project officer for Project 1.1. Probably the only field activity that project personnel undertook involved placement and retrieval of the temperature and humidity sensors on the target array.

Project Report: Reference C.1.1608.

Project 1.4 -- Land Crater Measurements

Agencies: Army Engineer Research & Development Laboratories
Holmes & Narver, Inc. (H&N)

Operations: The objective of this project was to measure physical characteristics of the apparent crater and lip from those shots detonated close to the ground or water surface. Physical characteristics of the craters were measured by photogrammetric techniques, lead-line soundings, and surveys. An RB-50 aircraft, probably from the 1371st Photo Mapping Squadron, equipped with a camera was used to make the mapping runs. Surveys were done by H&N. Pre- and postshot ground survey measurements were made on radii from surface zero out to 500 feet (152 meters) for CACTUS and from surface zero to 2,500 feet (762 meters) for KOA. A postshot survey of surface zero was made for FIG. Detailed crater measurements of CACTUS and KOA could not be made until radiation levels were low enough to permit safe reentry of survey crews. A boat was used for surveys of shot KOA (on D+4) and the underwater craters formed by the barge events. Some survey activity was not attempted until 1959 because of the KOA crater radioactivity.

Shots: CACTUS, BUTTERNUT, KOA, HOLLY, YELLOWWOOD, LINDEN, OAK, FIG.

Staffing: The project officer is identified in the project report; his exposure is recorded on the Consolidated List as 2.38 R.

Project Report: Reference C.1.1609.

Project 1.5 -- Free Field Pressure Measurements

Agency: Navy Electronics Laboratory (NEL)

Operations: Like Project 1.1, instrumentation for this project was strung on underwater lines from the target ships. Data were telemetered from one of the strings of instruments or were recorded at the surface on the target ships.

Recovery of the recorded data required "selected project personnel" to go via LCM to the target barges and the target Killen, but "because of radiation levels encountered" they were turned back until the next day. As the project participated in only this one event, the exposures accrued for the series must have been only in these operations.

Shot: WAHOO.

Staffing: Four NEL civilians are identified in the project report, but only two appear on the Consolidated List. Their badges registered between 0.5 and 1 R.

Project Report: Reference C.1.1610.

Project 1.6 -- Water Wave Measurements

Agency: Scripps Institution of Oceanography (SIO)

Operations: Objectives were to study wave generation mechanisms for the two underwater shots and to examine terminal effects of these waves by inundation studies. Instrumentation consisted of various types of underwater pressure-time recorders, shipboard-mounted inclinometers, cameras, and on-shore inundation gauges. For shot WAHOO, deep-moored, unmanned, floating instrument stations (coracles) were used.

Exposure was primarily associated with recovery of instrumentation. A close-in, submerged recorder was recovered the day after UMBRELLA. Two others were recovered after 400 dives during the following 2 weeks.

Shots: WAHOO, UMBRELLA.

Staffing: Three SIO men are identified in the project report, but only two are on the Consolidated List. The higher reading was between 2 and 2.5 R.

Project Report: Reference C.1.1611.

Project 1.7 -- Air Blast Measurements for Surface Shots

Agency: Ballistic Research Laboratories

Operations: This project obtained airblast measurements for the surface bursts CACTUS, KOA, FIG, and QUINCE. The project also supplied airblast instrumentation for several structures experiments. Operations involved placement and recovery of blast gauges near the surface zeroes. Instrument locations are summarized in Table 10. The radiation exposure potential was high because of the large number of instruments required to be recovered and replaced near surface zero locations. More than half of the project personnel were exposed to more than 2 R and three equalled or exceeded the 3.75 R quarterly limit.

Shots: CACTUS, FIR, BUTTERNUT, KOA, HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, MAPLE, ASPEN, WALNUT, ELDER, POPLAR, TEAK, QUINCE, ORANGE, FIG.

Staffing: Project personnel included 24 people, 4 of whom were Army. Only sixteen are on the Consolidated List.

Project Report: Reference C.1.1612.

Table 10. Location of Project 1.7 and Project-1.7-related experiments, HARDTACK.

Shot	Instrument Locations	Distance to Ground Zero (feet)	Distance to Ground Zero (km)	Shot	Instrument Locations	Distance to Ground Zero (feet)	Distance to Ground Zero (km)
CACTUS	Runit	470-7,860	0.14-2.40	MAGNOLIA	Billae	19,313	5.89
	Billae	14,170	4.32		Ananij	29,677	9.05
	Bijire	25,000	7.62		Parry	107,725	32.83
	Ananij	35,598	10.85				
	Parry	56,406	17.19	TOBACCO	Enjebi	3,996-6,394	1.22-1.95
					Bijire	37,893	11.55
FIR	Nam	5,715-5,826	1.74-1.78		Billae	45,668	13.92
					Runit	64,832	19.76
BUTTERNUT	Billae	19,500	5.96		Parry	107,927	32.90
	Ananij	29,704	9.05		Enewetak	120,000	36.58
	Bijire	29,910	9.12				
	Parry	51,037	15.56	SYCAMORE	Nam	5,715-5,826	1.74-1.78
	Bokoluo	80,062	24.40		Aerokoj	83,446	25.43
					Eneu	121,991	37.18
KOA	Bokaidrikdrik	1,550-3,358	0.47-1.02				
	Boken	3,751-6,024	1.14-1.84	ROSE	Billae	19,550	5.96
	Bokoluo	20,931	6.38		Bijire	29,910	9.12
	Bijire	47,542	14.49		Parry	51,037	15.56
	Billae	55,237	16.84		Enewetak	69,081	21.06
	Runit	74,132	22.60				
	Ananij	100,496	30.63	MAPLE	Aerokoj	19,550	5.96
	Parry	115,929	35.34		Eneu	82,977	25.29
HOLLY	Billae	19,125	5.83	ASPEN	Nam	5,715-5,826	1.74-1.78
	Ananij	29,684	9.05				
	Parry	51,847	15.80	WALNUT	Enjebi	5,995-8,254	1.83-2.52
NUTMEG	Eneman	638	0.19	ELDER	Enjebi	3,996	1.22
	Aerokoj	14,075	4.29				
	Eneu	68,054	20.74	POPLAR	Nam	5,715	1.74
YELLOWWOOD	Enjebi	5,995-8,254	1.83-2.52	QUINCE	Runit	40-700	0.012-0.21
	Bijile	38,940	11.87				
	Billae	46,418	14.15	FIG	Runit	40-700	0.012-0.21
	Runit	65,293	19.90				
	Ananij	91,967	28.03				
	Parry	107,725	32.83				

Project 1.8 -- Structural and Ground Motion

Agency: Stanford Research Institute

Operations: The objective of this project was to measure ground motion produced by nuclear detonations. Instrumentation was buried at various ranges and depths. For CACTUS the records were recovered on D+1 and the control station equipment was recovered on D+3. KOA recovery occurred on D+3. Data and equipment recovery involved work at close-in instrument sites. An instrument recovery operation at a KOA site on Boken left steel canisters behind as they were radioactive as a result of neutron activation.

Shots: CACTUS, KOA.

Staffing: The project party consisted of nine people, two arriving on 13 March and seven on 19 March 1958.

Project Report: Reference C.1.1613.

Project 1.9 -- Underground Loading Under High Yields

Agencies: Air Force Special Weapons Center
University of Illinois

Operations: The objective of this project was to study the transmission of airblast-induced pressure through soil and the loading produced on buried structures. Forty-three drums were buried at depths ranging from 0 to 20 feet (6.1 meters) to measure pressure about 3,000 feet (about 914 meters) from KOA surface zero and 600 feet (183 meters) from CACTUS surface zero. Data recovery was scheduled for D+3 at 0900. Four personnel (two H&N and two TG 7.1) were to depart Parry Island in a helicopter for Runit Island and remain there for 2 hours for retrieval according to documents (Reference B.1.5). However, since the drums were essentially self-recording gauges, a hurried recovery was probably not necessary, and actual recovery operations were delayed until considerable radioactive decay had occurred. Figure 30 is a photograph of the recovery operations on 21 July, more than 1 month after the shot.

Shots: CACTUS, KOA.

Staffing: Three men, an Air Force officer and two civilians from the University of Illinois, are identified by the project report. The Air Force officer is not on the Consolidated List, but the two civilians are, with exposures of 0.57 and 1.93 R.

Project Report: Reference C.1.1614.

Project 1.10 -- Blast Overpressure Measurements

Agency: Air Force Cambridge Research Center (AFCRC)

Operations: The objective of this project was to measure blast overpressures resulting from the YUCCA detonation. Five canisters were suspended from the YUCCA balloon by a nylon line.

Shot: YUCCA.

Staffing: Only the project officer, an Air Force Officer, and one civilian from AFCRC are identified as project personnel. They were badged and their exposures are given on Table 9.

Project Report: Reference C.1.1615.

Figure 30. Project 1.9, HARDTACK, KOA data recovery on Boken Island, 21 July 1958.

Project 1.11 -- Early Hydrodynamics

Agencies: Armour Research Foundation
Office of Naval Research

Operations: Objectives were to measure the total energy release and other hydrodynamic variables of both underwater shots and to determine the effective hydrodynamic yield of shot UMBRELLA. This project used pressure switches and a doppler system near surface zero for both shots. Project data recovery should not have exposed personnel to radiation, as data were telemetered.

Shots: WAHOO, UMBRELLA.

Staffing: Four civilians are noted in the project report, but only three appear on the Consolidated List.

Project Report: Reference C.1.1616.

Project 1.12 -- Shock Spectra Studies

Agencies: Air Force Ballistic Missile Division
TRW--Space Technologies Laboratory

Operations: The objective of this project was to measure directly the displacement shock-spectra near the ground surface of air-induced and ground-transmitted ground shocks produced by the blast waves from surface-burst detonations. Self-contained mechanical gauges were installed at ground level from 625 to 965 feet (191 to 294 meters) from CACTUS surface zero on Runit, and from 3,100 feet to 4,450 feet (0.95 to 1.36 km) from KOA surface zero on Boken. Some records were not recovered until October 1958 by Project 3.2 personnel. Recovery of heavy instruments from close-in sites required some exposure. One person from this project exceeded the 3.75 R quarterly MPE.

Shots: CACTUS, KOA.

Staffing: Four civilians identified in the project report are also noted on the Consolidated List.

Project Report: Reference C.1.1617.

Project 1.13 -- Characteristics of Ocean and Bottom for Shots WAHOO and UMBRELLA, including UMBRELLA Crater

Agencies: Office of Naval Research (ONR)
Navy Hydrographic Office (HO)
University of Washington

Operations: The objectives of this project were to conduct a preoperational oceanographic, hydrographic, and seismic survey of the sites for shots WAHOO and UMBRELLA; to provide environmental data in support of other scientific projects; and to determine the magnitude of the UMBRELLA crater. Navy interest in underwater cratering was to determine whether such a weapon could be used to block ship channels and make harbors inoperative. The preoperational work was completed in September and October 1957.

The operational phase of the work conducted in May and June 1958 included oceanographic work by USS Rehoboth (AGS-50) in support of either Project 1.13 or Project 40.1 (Radiological Survey). Personnel from ONR, HO, and the University of Washington participated in the operational portion. A TG 7.3 LCM equipped with an echo sounder surveyed the UMBRELLA crater on D+3.

Preshot survey activities should have resulted in no exposure. Project activity that could have led to exposure was the postshot (D+3) UMBRELLA crater survey. LCM-37 is noted as having made the preshot survey "just prior to shot time," and presumably was the craft used to do the postshot survey.

Shots: WAHOO, UMBRELLA.

Staffing: One ONR civilian and three HO civilians are identified in the project report and are on the Consolidated List. Their exposures are given in Table 9.

Project Report: Reference C.1.1618.

Program 2 -- Nuclear Radiation and Effects

This program had four major objectives: (1) to determine the gross radiological hazards resulting from underwater bursts, (2) to collect neutron energy spectrum data, (3) to measure radiation in the nuclear cloud, and (4) to determine the prompt neutron and gamma radiation and fallout contamination (Reference C.1.1682).

Project 2.1 -- Shipboard Radiation Vulnerability

Agencies: Naval Radiological Defense Laboratory (NRDL)
Task Element 7.3.1.5 (Target Decontamination Element)

Operations: The objectives were to determine the gamma radiation dose and dose rate histories on and in the three target-array destroyers and in the water adjacent to the ships. Target-array ships were equipped with operating washdown systems and were instrumented with film badges and gamma-intensity-time recorders. Badges were supplied and processed by TU 7.1.6. Personnel of the TG 7.3 Radiological Safety and Decontamination Unit, acting as TE 7.3.1.5, assisted in the installation of project instrumentation and its recovery.

Recovery of the gamma instrumentation and film badges exposed personnel to radiation. The project report does not state how soon personnel recovered the instruments and badges, but shows badge values for 24 hours, indicating D+1 reentry. Details of reentry to Howorth, one of the three target ships, are given under Project 2.2.

Shots: WAHOO, UMBRELLA.

Staffing: Four NRDL civilians are identified in the project report; their exposures are given in Table 9. However, personnel of TG 7.3 Radiological Safety and Decontamination Unit acting as TE 7.3.1.5 apparently also received the same exposure.

Project Report: Reference C.1.1619.

Project 2.2 -- Shipboard Contamination Ingress

Agencies: Naval Radiological Defense Laboratory (NRDL)
TE 7.3.1.5 (Target Decontamination Element)

Operations: Three ventilated compartments on the unmanned, moored, target destroyer Howorth were instrumented with film badges and recording radiation detectors. Its washdown system was operating before and after both underwater shots. Mice and guinea pigs were caged in the compartments to check for any inhalation of radioactive products. TG 7.3 elements assisted in the operations. WAHOO reentry operations took place at H+21:55. Recovery of Project 2.2 instruments and also Project 2.1 badges and instrumentation that were in shared spaces took 45 minutes. Self-reading pocket dosimeters registered 0.150 R as a maximum.

Post-UMBRELLA recovery began at H+2 when the recovery party turned off the washdown system that had been running on Howorth. Instrumentation was recovered, the washdown system turned back on, and personnel were off the ship in 45 minutes. No pocket dosimeter reading was greater than 0.2 R.

Shots: WAHOO, UMBRELLA.

Staffing: Five NRDL civilians are identified in the project report, one of whom was project officer for both Projects 2.1 and 2.2. Four Navy enlisted men from the TG 7.3 Radiological Safety and Decontamination Unit acting as part of TE 7.3.1.5 were also listed as being part of the project, and their exposures have been included with those given in Table 9.

Project Report: Reference C.1.1620.

Project 2.3 -- Characteristics of the Radiological Environment

Agencies: Naval Radiological Defense Laboratory (NRDL)
Army Signal Engineering Laboratory (SEL)

Operations: The primary objective of this project was to measure the gamma field at a number of positions within 10,000 yards (9.1 km) of each of the two underwater nuclear detonations. The gamma field was measured by about 20 gamma recorders installed on coracles moored in the lagoon and in the open sea. A Project 2.3 coracle is shown in Figure 31. Floating film packs (FFPs) (3-foot- [0.9-meter-] square styrofoam floats) were also moored in the lagoon area and additional FFPs were dropped from aircraft into the lagoon and in the open sea downwind after the UMBRELLA event. Instrumentation was recovered by helicopter and surface craft. Sample collection trays were also placed on the target-array vessels and the coracles.

For WAHOO, 48 FFPs were dropped into the target array from two helicopters between H-2 and H-1, the rest of the project instrumentation having been placed earlier. A second drop of 17 FFPs was made from an SA-16 at H+1 in areas that an aerial surveillance flight made between H-15 and H-1 minutes indicated were areas requiring coverage. At H+1 a helicopter retrieved a sample collector from the YC-2 barge in the target array. The only target ship that could be boarded on the first day was Killen, and at H+4:30 project personnel retrieved some samples collected on this ship. Project personnel also were on two fleet ocean tugs, USS Munsee (ATF-107) and USS Moctobi (ATF-105), and the TG 7.4 AVR looking for and retrieving the FFPs after the shot. The ships, however, did not enter the radex area. TG 7.4 helicopters spotted for the ships until H+4 (1800 hours), when the helicopters were required to return to Enewetak. Three coracles were also recovered by Munsee the first day and the rest the following day. They were

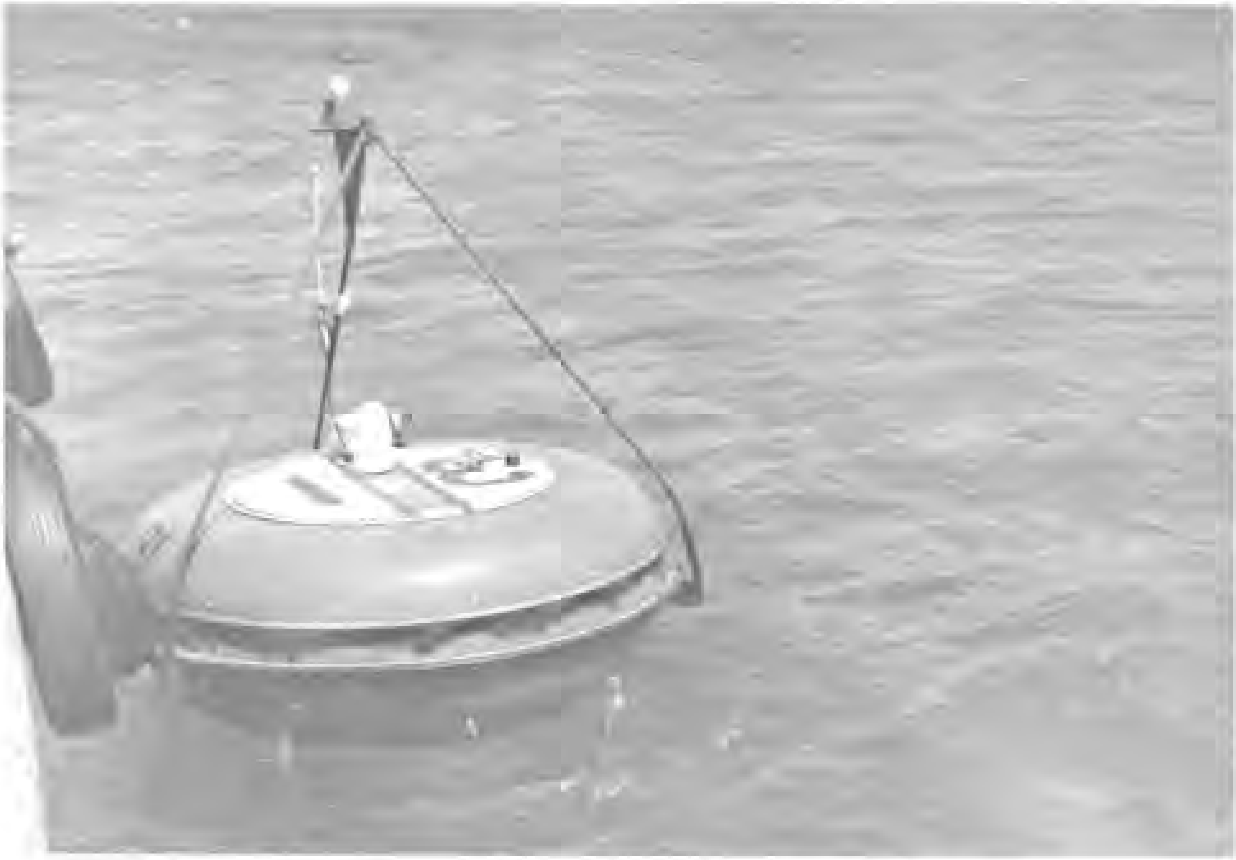

Figure 31. Project 2.3 coracle alongside a tug, HARDTACK.

all taken to a project working area on the beach at Parry. On D+2 project personnel completed recovery and surveyed the target ships.

For UMBRELLA, 14 FFPs were dropped outside the lagoon by TG 7.4 helicopters at H-2. The SA-16 dropped additional FFPs within the lagoon shortly after the shot. Two Marine Corps helicopters began FFP recovery at H+30 minutes in combination with the TG 7.4 AVR boat and completed recovery operations by H+5. Samples were recovered from the target area by TG 7.4 helicopter within 30 minutes of the detonation. The target ships were reboarded between H+1 and H+1:30, and samples were taken by project personnel. All the coracles were also recovered the first day and taken to the project work area at Parry.

The project report states that because of "the low degree of radioactive contamination, no special decontamination [of the coracles] was necessary." Radioactive samples were also collected, counted, and forwarded to NRDL for further work. A sample recovery center was set up near Parry Island airstrip for this phase of the work in order "to maintain proper contamination control."

Shots: WAHOO, UMBRELLA.

Staffing: The project officer cites 23 NRDL civilians, including himself, for project work; however, only 16 of these appear on the Consolidated List. Two men from SEL joined the project as consultants "in the field" and their exposures are included with the project personnel in Table 9.

Project Report: Reference C.1.1621.

Project 2.4 -- Neutron Flux Measurements

Agency: Army Chemical Warfare Laboratories (CWL)

Operations: The objective was to measure the neutron flux and dose. Detectors were mounted in steel holders and installed on steel buoys that were strung together in a line from Bokinwotme toward Enjebi. Each of the 25 buoys was fastened to a concrete anchor and to a cable on the bottom of the lagoon. The same line was used for both YELLOWWOOD and WALNUT. Both shots were fired at the same place. The detectors were placed from 917 to 4,100 yards (0.84 to 3.78 km) from surface zero for both shots.

All except one station were recovered on D+1 by a team of 13 people, who picked the buoys out of the water with a crane on an LCU and removed the attachment cable. This project also provided neutron measurements in support of Project 6.3 (for NUTMEG, MAPLE, HICKORY, and JUNIPER) and Project 8.6 (for TEAK and ORANGE).

Contaminated buoys could have caused exposure. The contaminated lagoon waters were dissipated by the lagoon's circulation so that almost all surface zero sites could be reentered within 24 hours without serious exposure to the boat crews (Reference C.1.1685). Some of the detectors themselves were contaminated by radioactive seawater, which complicated the data reduction. This should not in itself have been a source of exposure to the project personnel, as the detectors worked on the principle of neutron activation and were thus expected to be radioactive and would have been handled accordingly.

Shots: YELLOWWOOD, WALNUT.

Staffing: Five civilians from CWL are identified in the project report.

Project Report: Reference C.1.1622.

Project 2.4a -- Neutron Flux Measurements

Agency: Army Chemical Warfare Laboratories (CWL)

Operations: The objective was to measure the neutron flux and dose and gamma dose. Instrument lines were set up on the land area of Runit Island. Detectors were mounted in steel holders and attached to a cable from 30 to 900 yards (27 to 823 meters) from surface zero. Detectors were also installed on steel buoys in the lagoon at various distances from surface zero.

For the QUINCE shot, a balloon was used to support the instrumentation line almost directly above surface zero, and 13 stations were instrumented at slant ranges of 40 to 500 yards (37 to 457 meters).

For the FIG shot, a balloon was tethered on a cable 120 yards (110 meters) from surface zero, and other detectors were installed at slant ranges from 121 to 410 yards (111 to 375 meters). Detectors on land were recovered with a tractor that pulled the cable to a noncontaminated area where the detectors were detached. The time of recovery was scheduled for H+5 minutes using 10 people. Those detectors at stations on buoy lines were recovered by two DUKWs. The balloon was winched down following FIG, but the winch ran out of gas with the balloon halfway down. After refueling the winch motor, the balloon line was brought down and the balloon secured; even with this delay, the recovery personnel were out of the radex area by H+22 minutes.

Shots: QUINCE, FIG.

Staffing: The project report identifies seven CWL civilians, but only four are listed on the Consolidated List. This project was also active at the Nevada Test Site (NTS) during this time, and perhaps the three men not on the Consolidated List were only at NTS.

Project Report: Reference C.1.1679.

Project 2.6 -- Neutron Measurements

Agency: Naval Research Laboratory (NRL)

Operations: The ojective was to measure neutron flux versus range from high-altitude nuclear detonations. Pods carrying detectors were ejected from the Redstone delivery missiles for TEAK and ORANGE. These detectors then electronically recorded and telemetered the information to ground stations.

Shots: TEAK, ORANGE.

Staffing: Nine NRL civilians are cited in the project report, but three of these are not cited in the Consolidated List. The exposures were all either zero or less than 0.5 R.

Project Report: Reference C.1.1623.

Project 2.7 -- Prompt Nuclear Radiation Measurements

Agency: Naval Research Laboratory (NRL)

Operations: The objective was to measure, analyze, and report the initial nuclear radiations from the YUCCA high-altitude detonation. Detectors placed in a canister suspended from the shot balloon electronically recorded and transmitted data to surface stations.

Shot: YUCCA.

Staffing: Eight NRL civilians participated, of whom only six are on the Consolidated List. These six were also the Project 2.6 personnel.

Project Report: Reference C.1.1624.

Project 2.8 -- Fallout Measurements by Aircraft and Rocket Sampling

Agencies: Naval Radiological Defense Laboratory (NRDL)
University of California Radiation Laboratory (UCRL)
Los Alamos Scientific Laboratory (LASL)

Operations: The objective was to determine the relative contribution of selected radionuclides to both local and worldwide fallout by collection and analysis of cloud samples. Early cloud samples were collected with newly developed UCRL rocket samplers. B-57D and WB-50 aircraft collected fallout at high and low altitudes supervised by personnel of NRDL. Figure 28 shows the B-57D and sampling collectors shared with weapon development experiment Projects 11.1 and 21.2. Figure 32 shows one of the WB-50s used for the low-altitude sampling. Gas and particulates of the residual cloud were sampled with B-57 aircraft under the technical direction of LASL personnel. Particulate samples were collected at various times after the detonation, based on forecasts by the Fallout Prediction Unit. These collections were made at an altitude of 1,000 feet (305 meters) by WB-50 aircraft between H+4 and H+24. Rocket samples were not collected during

Figure 32. Project 2.8 WB-50 sampler, HARDTACK.

KOA and WALNUT due to technical difficulties, and the attempt was cancelled before OAK. Project rockets were also fired during CACTUS and YELLOWWOOD for system checks and nosecone recovery practice. P2V aircraft from Kwajalein NAS assisted in nosecone search and pickup was by boat. Rockets were remotely fired and only one was recovered, showing only slight radioactivity.

Shots: CACTUS, KOA, YELLOWWOOD, WALNUT, OAK.

Staffing: The three agencies conducting this experiment had separate functions, and each organization's personnel had different exposures. LASL coordinated the aircraft sampling, UCRL the rocket sampling attempts, and NRDL sample analysis. In the project report, 21 NRDL personnel are identified but only 5 are on the Consolidated List, which would show their actual presence at the EPG, and of these, several participated in other NRDL projects also. Eight UCRL personnel are identified and six of these are on the Consolidated List. It cannot be established what portions of their exposures are from the rocket portion of Project 2.8 activities and what may be from other activities. Three LASL civilians are also identified as coordinating and, again, how much of their exposure can be attributed to Project 2.8 is not clear since they also did aircraft sampling work for TU 7.1.1. All 14 exposures are given in Table 9.

Project Report: Reference C.1.1625.

Project 2.9 -- Gamma Dose Measurements

Agency: Army Chemical Warfare Laboratories (CWL)

Operations: The objective was to document initial gamma and total gamma dose at various distances from QUINCE and FIG. Incremental dose recorders were placed at various distances from 30 to 711 yards (27.4 to 650.1 meters) from surface zero on Runit Island. Film badge dosimeters were installed several days before each shot and recovered at approximately H+24 minutes. Instrumentation for the project and for Project 2.11 was recovered from balloon stations at H+15 minutes. Project 2.4 personnel recovered instrumentation from buoy stations and two other stations at H+18 minutes. Pickup of film badge dosimeters appears to have been done by Project 2.4 personnel.

Shots: QUINCE, FIG.

Staffing: Two CWL civilians are identified in the project report, but they are not on the Consolidated List. Project 2.9 may not have had any personnel at the EPG, the field work instrument placement and recovery being handled by CWL personnel assigned to other projects, notably Project 2.4.

Project Report: Reference C.1.1677.

Project 2.10 -- Residual Radiation

Agency: Army Chemical Warfare Laboratories (CWL)

Operations: The objective was to measure the radiation intensities and determine gamma decay rate of the radioactive areas after QUINCE and FIG. Fallout collection stations were used for ground survey points. Early recovery parties of Projects 2.4, 2.9, 2.10, and 2.11 obtained radiation readings. Surveys were made with meters held approximately 3 feet (1 meter) above the ground and away from the body.

An H-21 helicopter with survey equipment and two project personnel from Parry Island made aerial surveys beginning at H+1 minute. Starting at H+20 minutes at Runit Island, ground residual radiation was measured at approximately 300, 600, and 900 feet (91.4, 183, and 274.4 meters) from surface zero.

A crater survey was made by pulling a radiation detector along the ground toward the crater area using a cable that had been covered by sand before the shots so that it would survive the blast. The winch that pulled the cable was remotely controlled. The recorder was in a shelter with the winch 600 feet (183 meters) from surface zero. The recovery schedule is not given in the project report, but was probably done by the project personnel that left Parry Island at H+15 (see below) as there was a fallout detector located at the recorder site.

Alpha surveys were made on concrete slabs that had been laid around the surface zeroes before the shots. At H+30 minutes two project personnel with PAG-3G gas-flow alpha counters drove to the nearest slab and took readings at three points on the slab; they then proceeded toward surface zero and repeated the procedure. Readings were taken again at the same locations on D+1 and D+2. Air samplers were placed 300 and 600 feet (91.4 and 183 meters) from surface zero and activated by a timer at H-1 second. At H+1 the filter papers from these air samplers were recovered.

Four open collectors were placed at 600 and 300 feet (183 and 91.4 meters) from surface zero for fallout collection and activated by a signal at H-1 second. At H+15 minutes two project personnel departed Parry by helicopter to the north end of Runit, picked up a jeep, and drove to the fallout collectors 600 feet (183 meters) from surface zero. They also measured radiation intensities 3 feet (1 meter) above ground. They removed the fallout samples, returned to the helicopter, and flew to the south end of Runit Island. The samples were transferred to another helicopter and flown back to Parry.

For QUINCE, alpha monitoring was conducted throughout the area on D-day and D+1. A contaminated area in the downwind direction was very spotty. No alpha surveys were made of the FIG event. For shot QUINCE, considerable alpha-emitting activity was detected around surface zero. None in the downwind area was above 3,500 $\mu g/m^2$.

Shots: QUINCE, FIG.

Staffing: Two CWL civilians are identified in the project report, but only one is on the Consolidated List.

Project Report: Reference C.1.1678.

Project 2.11 -- Neutron, Thermal and Gamma Measurements at Various Altitudes

See Project 2.4a above.

Project 2.14 -- Fallout Contamination from a Very-Low-Yield Burst

Agency: Sandia Corporation (SC)

Operations: Fallout collectors were placed on the surface of Runit Island and on barges in the lagoon. Radiological survey devices were also used at some of the collection sites. Personnel picked up data on Runit starting one-half hour after the FIG detonation. Recovery of data from the buoys and barges began at the same time.

Shot: FIG.

Staffing: Only two SC personnel can be identified from the project report, each with exposures of less than 0.5 R.

Project Report: Reference C.1.1602.

Program 3 -- Structures and Equipment

This program was designed to determine the effects of underwater detonations on surface and subsurface ships and to study different types of land structures under various blast-loading conditions. Five of the eight projects were concerned with the response of ship structures and equipment to underwater detonations, and three were concerned with the response of land structures to airblast.

Project 3.1 -- Tapered Charge Testing of the DD-592 (Howorth)

Agency: Underwater Explosive Research Division, Norfolk Navy Shipyard

Operations: A series of tests employing high-explosive charges was held off the California coastline beginning in January 1958 in preparation for HARDTACK. There was no radiation exposure potential from this project.

Project Report: Reference C.1.1605.

Project 3.2 -- Test of Flexible Arches

Agencies: Air Force Special Weapons Center
Naval Civil Engineering Research Laboratory (NCEL)
Navy Bureau of Yards and Docks

Operations: The objective was to determine structural response of earth-covered, corrugated-steel arches to the CACTUS and KOA tests. Four prefabricated, corrugated-steel flexible arches were located with an aboveground covering of coral sand. One for the CACTUS shot was placed 980 feet (299 meters) from surface zero; the remaining three were used for KOA, placed on Boken 3,200 to 4,470 feet (0.98 to 1.36 km) from surface zero. Some instrumentation was also installed by Project 1.7 personnel.

For CACTUS, the first ground reentry was made 4 days after the shot and a 13-man recovery crew using two bulldozers and two cranes began excavating the structure on D+8. Radioactivity near the structures ranged up to 0.420 R/hr. Excavation took approximately 12 hours and was finished on D+9.

For KOA, aerial reconnaissance was made on D+1 and D+4, and ground reconnaissance was made on D+6 and D+7. Figure 24 shows personnel on one of these early reconnaissance missions. On D+6, radiation levels were from 0.3 to 1 R/hr at the three structures, and the decay was observed to be slow. Recovery excavations began 120 days after the shot, with 11 workmen using H&N heavy equipment.

Inspection of these close-in stations would have exposed participating personnel to radiation from the fission and activation products deposited near the burst point. Excavation also would have dispersed dust because of the heavy digging equipment used. As the three shelters dug in on Boken for the KOA test appear to be within 200 feet (61 meters) of the edges of the crater formed by the SEMINOLE test in 1956, some problem with contaminated dust during the placement and covering of these could have occurred if care were not taken with the covering material. Figure 33, a photograph taken from surface zero for KOA, shows the proximity of the SEMINOLE crater.

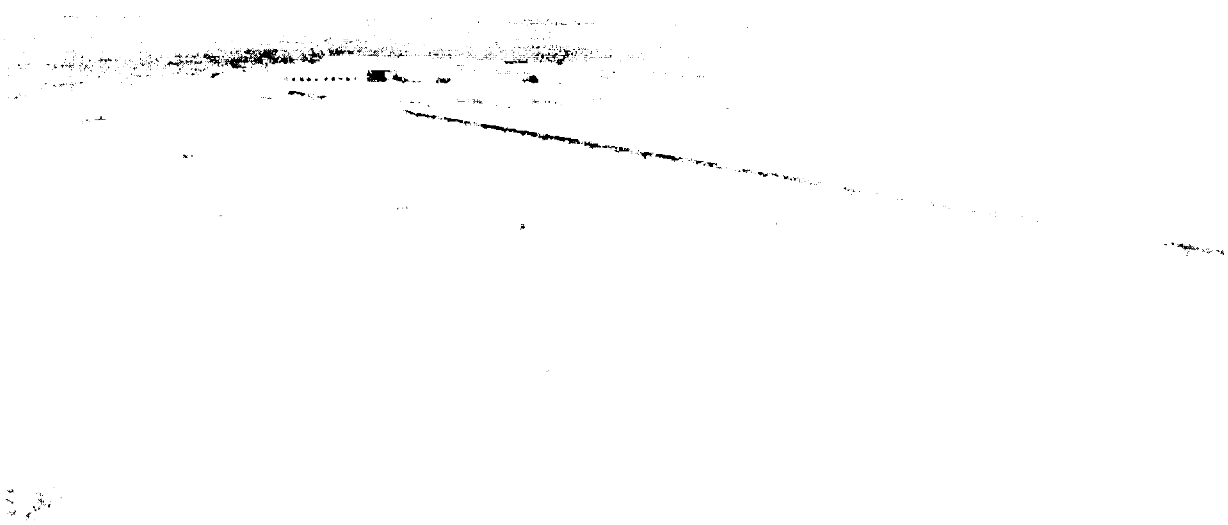

Figure 33. Project 3.2 sand-covered structure, HARDTACK.

Shots: KOA, CACTUS.

Staffing: The project report identifies two naval officers and three civilians from NCEL. One of the officers is not on the Consolidated List and may not have participated in field activities.

Project Report: Reference C.1.1626.

Project 3.3 -- Shock Studies of Naval Equipment

Agency: Navy David Taylor Model Basin (DTMB)

Operations: Instruments to measure and record shock motion were placed on the unmanned, instrumented ships for WAHOO and UMBRELLA (Fullam, Howorth, Killen, and Moran). Bonita (SSK-3) was instrumented and fully manned for WAHOO and instrumented and unmanned for UMBRELLA. Two operational destroyers, USS Mansfield and USS Orleck (DD-886), were instrumented only for WAHOO. The barge YFNB-12 and Squaw-29 were instrumented only for UMBRELLA. Squaw-29 (a specially built 4-compartment, submarine-like target) and YFNB-12 had been used during Operation WIGWAM (1955).

The primary recording medium for the project was photographic, either oscillograph paper or motion picture film. Cameras and oscillographs were well shielded in lead housings, but project objectives would have dictated as early recovery of these sensitive records as possible. For WAHOO, reboarding was on D+1 and for UMBRELLA was within hours of the shot. This recovery would have been the experimental activity leading to exposures.

Shots: WAHOO, UMBRELLA.

Staffing: The project report identifies 11 DTMB civilians and 1 Navy enlisted man as project participants. Maximum exposure was 1.6 R (the Navy enlisted man). Five other project personnel had exposures from 1 to 1.5 R and the remainder had exposures from 0.5 to 1 R.

Project Report: Reference C.1.1627.

Project 3.4 -- Loading and Basic Target Response for Surface Ships

Agency: Underwater Explosive Research Division (UERD), Norfolk Navy Shipyard

Operations: Gauges and recorders were placed on Fullam, Howorth, Killen, and Moran for shots WAHOO and UMBRELLA and, in addition, on a barge (YC-1) for shot WAHOO only. The primary recording medium was magnetic tape, and photographic paper was used for oscillograph recording. This paper would have required recovery and development as early as possible. Therefore, it may be assumed that some project personnel were among the first to reboard the target ships.

Shots: UMBRELLA, WAHOO.

Staffing: Four UERD civilians are identified in the project report. They were all badged with exposures less than 0.5 R.

Project Report: Reference C.1.1628.

Project 3.5 -- Submarine Hull Response

Agency: Navy David Taylor Model Basin

Operations: Instrumentation was placed on the only submerged target in the ship array for shot WAHOO, Bonita, which was manned 18,000 feet (about 5.5 km) from surface zero. The original plan called for Bonita to be unmanned and moored 10,500 feet (3.2 km) from surface zero, but unexpected rough sea conditions caused the loss of mooring cables.

For shot UMBRELLA, Bonita was unmanned, positioned bow-on at periscope depth, 2,880 feet (878 meters) from surface zero. Instrumentation was placed on the principal submerged target for shot UMBRELLA, Squaw-29 (a four-fifths-scale partial submarine model), placed 1,680 feet (512 meters) from surface zero. Operations of Project 3.5 were successful. Data from the submerged Squaw-29 were recorded on the barge, YFNB-12, to which Squaw-29 was cabled. After the tests, Squaw-29 was brought to the surface and towed to Pearl Harbor where it was inspected by project personnel for damage. Data recovery was undoubtedly done in conjunction with that of Project 3.3, conducted by the same agency.

Shots: WAHOO, UMBRELLA.

Staffing: Staff was apparently also shared with Project 3.3. All five men mentioned in the project report are also cited in the Project 3.3 report.

Project Report: Reference C.1.1629.

Project 3.6 -- Behavior of Deep Reinforced Concrete Slabs

Agencies: Air Force Special Weapons Center (AFSWC)
University of Illinois

Operations: The objective was to determine the dynamic behavior of deep, reinforced-concrete slabs close to surface zero. Precast concrete slabs were shipped to the EPG and placed at two stations 1,830 and 3,100 feet (558 and 945 meters) from the KOA surface zero. An instrumentation program was installed and operated by personnel of BRL (Project 1.7). An aerial inspection of Bokaidrikdrik Island in addition to photographing the stations was scheduled for D+2 at 0900 by a helicopter with five project personnel.

The posttest radiation environment was too high to begin data-recovery operations immediately after the test. Whether personnel from the project made ground-level inspections at early times following the test is not clear.

Shot: KOA.

Staffing: Four University of Illinois staff are identified as participants, but only three appear on the Consolidated List. Two AFSWC officers were the project officers, but they are not on the Consolidated List.

Project Report: Reference C.1.1630.

Project 3.7 -- Damage to Existing EPG Structures

Agencies: Army Engineering Waterways Experiment Station (WES)
Holmes & Narver, Inc.

Operations: The objective was to record damage to existing EPG structures by pre- and postshot examination. Self-recording measurements of air overpressure and acceleration were made at several stations along with some measurements of water-wave erosion. Damage surveys were performed by visual inspections, photographs, and level surveys. Gauges were furnished, calibrated, and read by personnel of BRL.

Inspection of structures would not necessarily have required visits to hot areas soon after a burst unless another shot was scheduled that might further damage a structure. In that case, damage from the preceding event might require documentation before the area's radioactivity had decayed.

Shots: CACTUS, FIR, BUTTERNUT, KOA, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, MAPLE, ASPEN, WALNUT, LINDEN, REDWOOD, ELDER, HICKORY, SEQUOIA, DOGWOOD, POPLAR, PISONIA, JUNIPER, OLIVE, PINE, FIG.

Staffing: Only the project officer from WES is identified in the project report; his exposure was recorded as 2.4 R in the Consolidated List.

Project Report: Reference C.1.1631.

Project 3.8 -- Technical and Engineering Services for Target Ships

Agency: Navy Bureau of Ships (BuShips)

Operations: The objective was to provide technical and engineering personnel to survey and document the damage sustained by target ships in shots WAHOO and UMBRELLA for Projects 3.1, 3.3, 3.4 and 3.5. A team of ten boarded the target ships, inspected them, and documented the damage. The time of the inspections is not given in the project report. There would have been no necessity to inspect quickly after the shots, but the post-WAHOO inspection needed to be completed in the 24 days before UMBRELLA.

Shots: WAHOO, UMBRELLA.

Staffing: Among the ten BuShips civilians identified with the project, the maximum exposure was 1.56 R. Nine personnel received over 1 R.

Project Report: Reference C.1.1632.

Program 4 -- Biomedical Studies

The objective of this one-project program was to determine the extent of chorioretinal damage caused by exposure to high-altitude nuclear detonations.

Project 4.1 -- Effects on Eyes From Exposure to Very High Altitude Bursts

Agency: Air Force School of Aviation Medicine

Operations: The project was to relate the experiments to theory and laboratory calculations of chorioretinal damage. This project required positioning rabbits and thermal recording devices operated by Project 8.1 at exposed stations both on the surface and in the air at various distances from the bursts. Animals were secured with one eye exposed to the burst while cameras took photographs. A photograph was also taken at shot time at each station to determine cloud density.

For shot TEAK, the stations were located at Johnston Island and on the destroyer USS De Haven (DD-727), located approximately 70 nmi (130 km) from Johnston Island; the tug USS Hitchiti (ATF-103), approximately 350 nmi (649 km) from Johnston Island; and two B-36s of Program 9 flying at an altitude of 15,000 feet (4.57 km) approximately 350 nmi (649 km) from surface zero.

For shot ORANGE, the stations were located on USS Boxer (CVS-21), 50 nmi (93 km) from Johnston Island; USS Epperson (DDE-719), 65 nmi (120 km) from Johnston Island; De Haven, 120 nmi (222 km); and a C-97 aircraft, 205 nmi (380 km) at an altitude of 24,000 feet (7.31 km). Project 4.1 was based at Johnston Island and at Oahu, Hawaii, where rabbits were examined and data evaluated. Three project personnel were located at Hickam AFB, Oahu, for the preparation and maintenance of airborne exposure stations.

Two project personnel were aboard Hitchiti, which returned to Pearl Harbor after the event, and each destroyer had two project personnel aboard. At H-8, the exposure stations on Johnston Island were readied and the project personnel were evacuated to Boxer. No project personnel were aboard the B-36; the C-97 had one project member aboard.

Shots: TEAK, ORANGE.

Staffing: Eight Air Force officers and one civilian are identified in the project report; however, as with most Johnston Island experiments, only one project member was badged.

Project Report: Reference C.1.1633.

Program 5 -- Aircraft Structures

This program was designed to determine the effects of nuclear weapons on aircraft structures. Manned B-52D, A4D-1, and F4-J aircraft were used. Provision was made to record the exposures of the effects aircraft flight crews separately, but this was not actually done.

Project 5.1 -- In-Flight Participation of B-52D

Agencies: Air Force Wright Air Development Center
Boeing Airplane Company

Operations: The objective was to determine the structural response of a B-52D when subjected to loads from blast effects. The aircraft was oriented inflight to receive various loadings. Positions at burst time are discussed in Chapter 4 under each test event in which it participated. The level of nuclear radiation was monitored in the aircraft during each test, but the incremental increase was not detectable above the background.

Shots: FIR, KOA, YELLOWWOOD, TOBACCO, SYCAMORE, ROSE, MAPLE, WALNUT, REDWOOD, ELDER, OAK, CEDAR, DOGWOOD.

Staffing: Only the project officer is identified. His radiation exposure is listed as 1.234 R on the Consolidated List.

Project Report: Reference C.1.1634.

Project 5.2 -- Weapon Effects on A4D-1 Aircraft

Agencies: Navy Bureau of Aeronautics
Naval Air Special Weapons Facility (NASWF)
Douglas Aircraft Company

Operations: The objective was to determine the structural response of A4D-1 aircraft to blast effects. Two A4Ds were positioned so as to receive varying thermal radiation and overpressures after detonation. Their positions are given in Chapter 4 for each shot in which they participated. The aircraft were operated by NASWF.

Both aircraft were instrumented to record nuclear radiation. Film badges were placed in various locations in the aircraft, and gamma dosimeters were worn by the pilots. These measurements are summarized in Table 11. In addition, sulfur was used as a fast neutron dosimeter. Unfortunately, many of the sulfur packets were impure; however, several measurements were made. The packets indicated the following neutron exposures of the pilots (Reference C.1.1635, p. 98):

CACTUS	Aircraft 827	0.105 rem		
MAGNOLIA	Aircraft 827	0.020 rem	Aircraft 831	0.030 rem
TOBACCO	Aircraft 827	0.020 rem	Aircraft 831	0.015 rem
WALNUT	Aircraft 827	0.015 rem	Aircraft 831	<0.010 rem.

Shots: BUTTERNUT, KOA, MAGNOLIA, ROSE, TOBACCO, WALNUT, YELLOWWOOD, CACTUS.

Staffing: Four naval officer pilots from NASWF and two civilians from Douglas Aircraft can be identified from the project report and the Consolidated

Table 11. Measured gamma radiation in Project 5.2 A4D-1 aircraft, HARDTACK.

Shot	Aircraft Number	Film Badges[a] (R)								
		1	2	3	4	5	6	7	8	9
CACTUS	827	0.77	0.64	0.49	1.73	1.74	1.66	---	---	---
	831	2.31	2.83	2.82	3.29	3.14	3.34	---	---	---
BUTTERNUT	827	0.78	0.82	0.79	1.15	1.13	1.09	---	0.22	0.16
	831	4.81	4.48	4.21	5.16	5.27	5.27	---	---	---
KOA	827	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01
	831	0.15	0.10	0.12	0.19	0.19	0.19	0.05	0.03	0.10
YELLOWWOOD	827	0.30	0.30	0.29	0.30	0.29	0.28	0.23	0.23	0.22
	831	0.31	0.28	0.26	0.28	0.28	0.27	0.23	0.24	0.24
MAGNOLIA	827	4.92	4.73	4.68	6.67	6.47	6.85	4.05	---	1.55
	831	4.93	3.99	4.35	5.39	5.63	5.42	4.21	---	4.29
TOBACCO	827	Data Not Available								
	831	Data Not Available								
ROSE	827	0.390	0.374	0.377	0.388	0.391	0.397	---	0.348	0.353
	831	0.542	0.529	0.520	0.545	0.555	0.551	0.494	---	0.419
WALNUT	827	0.653	0.539	0.540	0.748	0.687	0.654	0.732	---	0.667
	831	1.540	1.310	1.300	2.070	2.070	2.030	0.160	---	0.692

Notes:

[a]Film badge locations: 1 -- cockpit, horizontal; 2 -- cockpit, athwartships; 3 -- cockpit, fore and aft; 4 -- left nose wheel well, horizontal; 5 -- left nose wheel well, athwartships; 6 -- left nose wheel well; fore and aft; 7 -- pilot, lower right leg; 8 -- pilot, left sleeve; 9 -- pilot, left vest.

Source: Reference C.1.1635.

List. The pilots' exposures were all greater than 3 R and the highest was 5.3 R.

Project Report: Reference C.1.1635.

Project 5.3 -- Weapon Effects on FJ-4 Aircraft

Agencies: Navy Bureau of Aeronautics
Naval Air Special Weapons Facility (NASWF)
North American Aviation, Inc. (NAA)

Operations: The objective was to determine the structural response and effects of nuclear weapons on the FJ-4 aircraft. Two test aircraft were instrumented to record air overpressure. The aircraft were flown to preselected positions relative to the detonation point. For more detailed information on the position of these aircraft at H-hour, see Chapter 4 under each shot in which they participated. The aircraft were instrumented with film badges for gamma recording and sulfur samples for fast neutron activation measurements. Film badge measurements are shown in Table 12, as is the single neutron measurement.

Table 12. Measured gamma radiation in Project 5.3 FJ-4 aircraft, HARDTACK.

		Film Badges[a] (R)								
Shot	Aircraft No.	1	2	3	4	5	6	7	8	9
CACTUS[b]	467	0.77	0.81	0.71	3.30	3.71	2.95	0.77	0.55	0.52
	310	1.62	1.42	1.50	4.98	5.06	4.74	1.23	1.81	3.25
BUTTERNUT	467	0.22	0.24	0.24	0.94	0.98	0.91	0.16	0.17	0.48
	310	0.13	0.12	0.15	0.29	0.28	0.28	0.15	0.15	0.14
KOA	467	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.02
	310	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.02
YELLOWWOOD	467	0.16	0.14	0.13	0.14	0.14	0.16	0.16	0.17	0.13
	310	0.16	0.14	0.15	0.17	0.18	0.18	0.18	0.18	0.17
MAGNOLIA	467	0.84	0.90	0.93	1.72	1.67	1.61	0.76	0.46	1.10
	310	3.42	3.31	3.30	6.31	5.65	6.22	2.66	5.37	5.90
TOBACCO	467	Data Not Available								
	310	Data Not Available								
ROSE	467	0.22	0.24	0.25	0.48	0.51	0.43	0.29	0.27	0.23
	310	0.32	0.33	0.33	0.55	0.43	0.46	0.28	0.37	0.37
WALNUT	467	0.66	0.66	0.67	0.72	0.76	0.79	0.62	0.60	0.60
	310	0.76	0.74	0.70	1.40	1.30	1.30	0.69	0.44	0.44

Notes:

[a] Film badge locations: 1 -- cockpit, horizontal; 2 -- cockpit, athwartships; 3 -- cockpit, fore and aft; 4 -- ammunition bay, horizontal; 5 -- ammunition bay, athwartships; 6 -- ammunition bay, fore and aft; 7, 8, 9 -- pilot, random.

[b] Fast neutron dose measured in cockpit 0.135 rem.

Source: Reference C.1.1636.

Shots: CACTUS, BUTTERNUT, KOA, YELLOWWOOD, MAGNOLIA, TOBACCO, ROSE, WALNUT.

Staffing: Two naval officers from NASWF and three civilians from NAA can be identified from the project report and the Consolidated List. The pilots' exposures were 3.7 and 3.6 R. The civilian exposures were all below 1.5 R.

Project Report: Reference C.1.1636.

Project 5.4 -- Aircraft Tracking and Positioning

Agency: Field Command, Armed Forces Special Weapons Project

Operations: Project 5.4 was established during the latter part of the operation only to simplify budgetary functions required to extend the use of two radars for Program 5. Project 5.4 also supported Projects 8.2 and 8.6.

Project Report: None.

Program 6 -- Test of Service Equipment and Materials

The objectives of this program were to determine the effects of nuclear detonations on various components and equipment and, for the underwater shots, to determine the feasibility of using nuclear explosions for clearing mine fields.

Project 6.3 -- Radiation Effects on Various Equipment

Agency: Army Diamond Ordnance Fuze Laboratory

Operations: The objective was to determine the radiation effects on various electronic components when exposed to radiation resulting from the nuclear detonations. To attain the desired radiation level to the components, three stations were constructed on Lomilik and Eneman.

Neutron dosimetry was provided by Project 2.4. Detectors were attached to a cable at the three stations. A few hours after the detonation, a caterpillar tractor towed the cable to a point where the detectors could be detached from the cable without personnel radiation exposure. After recovery the detectors were returned to Project 2.4 for counting.

This project had instrument stations near surface zero locations and required recovery while the area was still radiologically hot. For example, recovery of the basic recorder required moving sandbags that shielded the instrumentation. This was done by lifting a cargo net that had been used in placing the sandbags before the shot, which apparently took about 15 to 20 minutes with a "cherry-picker." On at least one occasion the cargo net failed and the recovery required a longer stay in the area, which was near the burst point and was "hot" (about 2 R/hr). The two project personnel received exposures of 0.64 and 0.89 R on this particular recovery (Reference C.5.4).

Shots: NUTMEG, MAPLE, HICKORY, JUNIPER.

Staffing: Six civilians are identified with this project, but only two appear on the Consolidated List, the project officer with an exposure of 1.86 R and another with 1.71 R.

Project Report: Reference C.1.1637.

Project 6.3a -- Effects of Nuclear Radiation on Semiconductor Devices

Agency: Army Diamond Ordnance Fuze Laboratory

Operations: This appears to have been a specialized portion of the basic Project 6.3 operation with an interest in particular instrumentation.

Shots: NUTMEG, YELLOWWOOD, MAPLE, HICKORY.

Staffing: Two civilians were identified. One of these is on the Consolidated List with an exposure of 3.07 R.

Project Report: Reference C.1.1742.

Project 6.4 -- Electromagnetic Pulse Measurements

Agency: Army Signal Research and Development Laboratory (SRDL)

Operations: The objective was to record the electromagnetic pulse resulting from a nuclear detonation. Two measurement stations were used, one at Wotho (approximately 100 nmi [185 km] from Bikini and 240 nmi [445 km] from Enewetak) and one at Kusaie (440 nmi [815 km] from Enewetak and 460 nmi [852 km] from Bikini).

Shots: YUCCA, CACTUS, FIR, BUTTERNUT, KOA, HOLLY, NUTMEG.

Staffing: Three SRDL civilians are identified in the project report.

Project Report: Reference C.1.1638.

Project 6.5 -- Radar Fireball Observations

Agency: Army Signal Research and Development Laboratory (SRDL)

Operations: The objective was to investigate the nature of radar echoes from the fireball. Operations were conducted on Enewetak and Rongelap atolls. Two destroyers, USS Cogswell (DD-651) and De Haven, were used during TEAK and were stationed approximately 75 to 150 nmi (139 to 278 km) from Johnston Island on a bearing of 020° from the island. The Rongelap station participated only in the YUCCA and FIR events.

Shots: YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, TEAK.

Staffing: Three civilians identified in the project report are also on the Consolidated List.

Project Report: Reference C.1.1639.

Project 6.6 -- Radar Cloud Size Determination

Agency: Army Signal Research and Development Laboratory (SRDL)

Operations: The objective was to determine the height and horizontal dimensions of stabilized radioactive clouds. Weather radar sets were used at Enewetak, Rongelap, and Kwajalein. For TEAK and ORANGE, the equipment was located at Johnston Island and at Maui, Hawaii. On Enewetak Island the existing fixed-station radar equipment of the Air Weather Service was used by Project 6.6 personnel.

Shots: YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, YELLOWWOOD, MAGNOLIA, TEAK, ORANGE.

Staffing: Three SRDL civilians are identified in the project report.

Project Report: Reference C.1.1640.

Project 6.7 -- Mine Clearance Studies

Agency: Naval Ordnance Laboratory (NOL)

Operations: A field of 120 inert mines was laid inside Enewetak Lagoon north of the UMBRELLA surface zero at ranges of from 1,500 to 8,000 feet (0.46 to 2.44 km). The primary operation was the post-UMBRELLA recovery of these mines and their shipment to the United States for examination. Mine recovery was from USS Takelma (ATF-113) with the assistance of USS Lawrence County (LST-887), which acted as the collection point. Explosive Ordnance Disposal Unit One (EODU-1), Mine Detail Augmenting Unit 0302 (MDAU-0302), and divers from TG 7.3 aided in placement, but according to to the project report did not assist in first-day pickup. LCM-52 and LCM-58 of the boat pool are credited in the project report with assisting.

The greatest potential for exposure was during recovery operations. However, radiation levels were apparently low enough that the mine field area could be surveyed at H+1 from the Takelma and recovery could begin at the 8,000-foot (2.44-km) range at H+3. The mine field was upwind from the burst point and out of the area of the subsurface bubble, or pool of contaminated water. Diving operations began at D+4 (13 June) and continued until 16 June.

Shot: UMBRELLA.

Staffing: Only two NOL civilians are cited in the project report.

Project Report: Reference C.1.1641.

Project 6.8 -- Underwater Influence and Mine Reaction Measurements

Agency: Navy Mine Defense Laboratory (MDL)

Operations: To measure and record the pressure, acoustic, and magnetic signals generated by a nuclear detonation that might trigger mines. LCU-634, -1123, and -1317 were moored 8,300 to 44,750 feet (2.53 to 13.64 km) upwind from the UMBRELLA surface zero. They were connected by recording cables to various underwater sensors in the area. Divers from USS Chanticleer (ASR-7) planted the underwater sensors and USS Bolster (ARS-38) recovered them. Other shots also were monitored with this array. It is not clear whether the LCUs were manned for any or all shots.

Shots: WAHOO, YELLOWWOOD, TOBACCO, SYCAMORE, UMBRELLA.

Staffing: Two MDL civilians and one MDL naval officer who are identified in the project report also appear in the Consolidated List.

Project Report: Reference C.1.1642.

Project 6.9 -- Ionospheric Effects of High Altitude Nuclear Detonations

Agencies: Army Signal Research and Development Laboratory (SRDL)
Army Signal Radio Propagation Agency

Operations: Ionospheric sounders were operated at Wake and Kusaie islands.

Shots: YUCCA, FIR, BUTTERNUT, KOA.

Staffing: Two civilians from SRDL and two military from the Signal Radio Propagation Agency.

Project Report: Reference C.1.1643.

Project 6.10 -- Ionospheric Effects Produced by High-Altitude Bursts

Agency: Air Force Cambridge Research Center (AFCRC)

Operations: This project had instrumentation aboard the C-97 (No. 2596) of the 3245th Operations Group. The plane was based at Hickam Field, Oahu, Hawaii, and flew to the vicinity of Johnston Island to record burst data. It was 120 nmi (222 km) east-northeast of Johnston Island for the TEAK burst and 194 nmi (360 km) south of Johnston Island for the ORANGE burst. Altitude was nominally 10,000 feet (3 km). The plane was back at Hickam 3 hours after TEAK and 5 hours after ORANGE. The project also operated an ionospheric recorder on Sand Island.

Shots: TEAK, ORANGE.

Staffing: Apparently only three of the AFCRC military and civilians identified in the project report were badged. These possibly operated the ground station at Sand Island. Their exposures were zero.

Project Report: Reference C.1.1644.

Project 6.11 -- HF and VHF Attenuation and Reflection Phenomena

Agency: Stanford Research Institute (SRI)

Operations: The objective was to determine the radio signal attenuation and reflection characteristics of nuclear detonations and their residual clouds. Project instrumentation was installed on the 125-foot (38.1-meter) MV Acania. Acania was moored inside the Johnston Island reef. Under the original plan a ground-based instrumentation site was installed on Eneu at Bikini and on Japtan at Enewetak. This operated between 10 and 25 April until TEAK and ORANGE were moved to Johnston Island. This instrumentation was reinstalled on Johnston Island, French Frigate Shoals, and Wheeler AFB, Oahu. The units on French Frigate Shoals were provided by SRI and operated by personnel of the Army Signal Radio Propagation Agency.

Shots: TEAK, ORANGE (ground-based observations occurred on YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, NUTMEG, TOBACCO).

Staffing: No SRI personnel are on the Consolidated List, which is consistent with Johnston Island-only operations. Operation of the ground-based instrumentation at Enewetak and Bikini during the early phases of the series, however, should have resulted in SRI personnel being badged. Possibly other agencies operated the SRI instruments for the project.

Project Report: Reference C.1.1645.

Project 6.12 -- Effects of Very High Altitude Atomic Detonations on Pulsed Electromagnetic Transmission

Agency: Army Signal Research and Development Laboratory (SRDL)

Operations: The objective was to investigate the propagation of radio waves through regions disturbed by high-altitude nuclear detonations. Six Nike-Cajun rockets were launched from Johnston Island, each bearing a radio transmitter. Receiving stations were at Johnston Island, Maui Island, and on two destroyers. Destroyer stations were located along an azimuth of 20°T at 85 and 175 nmi (158 and 324 km) from Johnston Island for TEAK and 22° at 75 and 140 miles (139 and 259 km) for ORANGE. Signals received were recorded on magnetic tape. The destroyer stations were Epperson and De Haven for ORANGE and Cogswell and De Haven for TEAK.

Shots: TEAK, ORANGE.

Staffing: Only two of the SRDL civilians identified in the project report are also named on the Consolidated List.

Project Report: Reference C.1.1645.

Project 6.13 -- Effects of Very High Altitude Bursts on Airborne Radar

Agency: Massachusetts Institute of Technology (MIT), Lincoln Laboratory

Operations: Two radar-equipped Navy WV-2 airplanes were the operating stations for this project. They were approximately 150 to 200 nmi (279 to 370 km) from Johnston Island at an altitude of 8,000 to 10,000 feet (2.44 to 3.05 km) at burst time. The aircraft were based at Wheeler AFB, Hawaii, and were furnished by the Naval Air Development Unit, South Weymouth, Massachusetts.

Shots: TEAK, ORANGE.

Staffing: Apparently no MIT personnel were apparently badged, but there was no potential for gamma exposure from the high-altitude shots.

Project Report: Reference C.1.1659.

Program 8 -- Thermal Radiation and Effects

The objective of this program was to evaluate laboratory methods of scaling thermal effects with weapon yields.

Project 8.1 -- Effects of Thermal Radiation on Materials

Agency: Naval Material Laboratory (NML)

Operations: This project was divided into two parts. For YELLOWWOOD and WALNUT the objective was to document radiant exposure in skin simulant studies. For TEAK and ORANGE the objective was basic thermal radiation measurements.

For YELLOWWOOD and WALNUT, both detonated at the same position, a station was instrumented on Aej Island 25,500 feet (7.77 km) from the barge location. Data were recorded on oscillographs in an underground shelter. Stations were instrumented with 29 skin simulants. Radsafe conditions permitting, seven project personnel were scheduled to depart Parry for Aej Island by helicopter to retrieve their experiment. Two personnel were also scheduled to depart Parry for Aej Island by LCM to recover film. The approximate time of retrieval was planned to be 1 hour.

For TEAK and ORANGE, five stations were instrumented; three surface vessels were stationed approximately 75, 150, and 300 nmi (139, 278, and 556 km) from Johnston Island, a C-97 (the same airplane used in Project 4.1) was stationed 300 nmi (556 km) from Johnston Island, and one station with skin simulants was set up on Johnston Island. Surface vessels used during TEAK were Hitchiti, De Haven, and Cogswell. For ORANGE, surface vessels used were Boxer, De Haven, and Epperson.

Shots: YELLOWWOOD, WALNUT, TEAK, ORANGE.

Staffing: The project report identifies five men from NML as participants; however, only three appear on the Consolidated List with exposures of 0.86, 1.69, and 1.78 R. Another participant is mentioned in Project 4.1 documentation as being part of Project 8.1. His exposure was 1.90.

Project Report: Reference C.1.1647.

Project 8.2 -- Thermal Radiation Measurements

Agencies: Air Force Cambridge Research Center (AFCRC)
Cook Research Laboratories
American Science and Engineering

Operations: The objective was to measure, analyze, and report thermal radiation resulting from the HARDTACK high-altitude nuclear detonations. Two RB-36 aircraft were instrumented with thermal detectors and photographic equipment. Aircraft positions at burst time are discussed under Project 8.3.

Shots: TEAK, ORANGE.

Staffing: The project report identifies one Air Force officer and four civilians from AFCRC as well as two contractor employees. Only three of the AFCRC personnel and one contractor employee appear on the Consolidated List.

Project Report: Reference C.1.1648.

Project 8.3 -- Early Fireball Photography

Agency: Edgerton, Germeshausen & Grier (EG&G)

Operations: The objective was to provide photographic coverage of the high-altitude shots with cameras mounted in two RB-36 aircraft and other cameras on Boxer. Burst-time positions of the RB-36s were:

	RB-36 (15748)		RB-36 (15750)	
Shot	Altitude (feet/km)	Slant Range to Burst (feet/km)	Altitude (feet/km)	Slant Range to Burst (feet/km)
YUCCA	36,000/10.97	85,692/26.11	37,000/11.28	80,666/24.59
TEAK	30,500/9.30	447,900/136.51	30,500/9.30	450,220/137.22
ORANGE	30,500/9.30	448,422/136.67	30,500/9.30	453,091/138.10

Shots: YUCCA, TEAK, ORANGE.

Staffing: EG&G personnel manned this project, but the personnel cited in the project report are not on the Consolidated List.

Project Report: Reference C.1.1649.

Project 8.4 -- Thermal Radiation Spectrum Measurement

Agency: Naval Radiological Defense Laboratory (NRDL)

Operations: Spectrographic equipment was installed in the two RB-36 aircraft from Project 8.3.

Shots: YUCCA, TEAK, ORANGE.

Staffing: Three NRDL civilians whose exposures were all zero.

Project Report: Reference C.1.1650.

Projects 8.5a and 8.5b -- Airborne-Infra-Red Measurements

Agency: Navy Bureau of Aeronautics (BuAer)

Operations: The objective was to obtain basic data in the infrared region at airborne stations. A P2V patrol plane was instrumented with infrared detectors and recorders. Its positions with respect to the four shots in which it participated were:

Shot	Altitude (feet/km)	Slant Range (feet/km)
YUCCA	22,000/6.71	91,140/27.78
KOA	5,000/1.52	147,596/38.89
TEAK	22,000/6.71	394,940/120.38
ORANGE	22,000/6.71	394,940/120.38

This aircraft was operated by the Naval Air Special Weapons Facility (NASWF), Kirtland AFB.

Shots: YUCCA, KOA, TEAK, ORANGE.

Staffing: The single BuAer civilian who is identified does not appear on the Consolidated List.

Project Reports: References C.1.1651-1 and C.1.1651-2.

Project 8.6 -- Vulnerability of Missile Structures to Nuclear Detonations

<u>Agencies</u>: Air Force Wright Air Development Research Center (WADC)
Allied Research Associates (ARA)
University of Dayton Research Institute (UDRI)

<u>Operations</u>: Part of the experiment exposed a number of specimens inside the CACTUS fireball on 6 May. Recovery of the specimens began on 12 May when a party entered the reef with a tractor and attempted to pull the cable attached to the specimens away from surface zero. The cable broke loose on this attempt, and on the next day, another party entered and recovered some of the specimens. The next day two recovery parties entered with a crane and a DUKW and recovered more. Additional attempts were made to recover the remaining specimens on 15 May. Those recovered were removed to Parry Island and their tape recorders were shipped to UDRI for analysis. Project personnel returned to the EPG on 21 August 1958 and on 16 February 1959 to retrieve the remaining specimens.

A second part of the experiment involved the TEAK and ORANGE shots. An instrumented pod was affixed to the TEAK and ORANGE Redstone missiles. These pods, which carried test specimens, were ejected before burnout. The pod for TEAK was tracked by radar and recovered by <u>Lansing</u> several hours after the detonation; its handling during recovery is shown in Figures 25 and 26. The pod for ORANGE was not recovered.

Recovery of the specimens and instrumentation from the CACTUS shot exposed personnel to areas of high radiation as well as retrieving radioactive objects. Recovery of the pod from the high-altitude TEAK shot exposed personnel to an object that was radioactive. Nevertheless, the maximum measured exposure to project personnel was less than 1 R.

<u>Shots</u>: CACTUS, TEAK, ORANGE.

<u>Staffing</u>: Three WADC civilians, three ARA civilians, and a UDRI civilian are identified in the project report. The seven exposures given in Table 9 are from the <u>Consolidated List</u> and therefore do not include any exposures accrued during post-series specimen-recovery attempts on Runit.

<u>Project Report</u>: Reference C.1.1652.

Project 8.7 -- Thermal Radiation From a Low Yield Burst

<u>Agencies</u>: Army Chemical Warfare Laboratory (CWL)
Naval Radiological Defense Laboratory (NRDL)

<u>Operations</u>: The objective was to determine thermal radiant exposure versus distance from surface zero and to measure the total thermal radiant energy from a low-yield surface detonation. NRDL and CWL each had ten ground stations equipped with calorimeters and radiant exposure meters from 150 to 900 feet (46 to 274 meters) from surface zero on Runit. Instruments recorded data on smoked metal discs or by an ink pen on paper oscillograph so that prompt data recovery was not necessary. The plans, however, were for project personnel to leave Parry by helicopter at H+1 for initial data

recovery, with full recovery the following day. Actual data-recovery operations are not documented.

Shots: QUINCE, FIG.

Staffing: Four CWL civilians and three NRDL civilians are identified as participating, but only three of the CWL personnel were badged. High exposure for the project was 1.07 R.

Project Report: Reference C.1.1676.

Program 9 -- General Support

Project 9.1 -- General Support for Programs 1 through 9

Agency: Armed Forces Special Weapons Project

Operations: The objectives were to provide technical photography, motion picture and still photography, timing signals, and firing facilities as required.

Shots: All.

Project 9.1d -- Upper Atmospheric Properties during a Very-High-Altitude Nuclear Detonation

Agency: Cooper Development Corporation

Operations: Instrumented Nike sounding rockets were used to obtain supporting atmospheric data for TEAK.

Shots: TEAK.

Staffing: One Cooper Development employee is identified in the project report.

Project Report: Reference C.1.1653.

Project 9.2 -- Shot YUCCA Support

Agency: Armed Forces Special Weapons Project

Operations: This project designation was used to cover several nonexperimental activities related to the preparation and execution of the YUCCA test. The project was subdivided into three subprojects.

Project 9.2a -- YUCCA Device

Agency: Sandia Corporation (SC)

Operations: This subproject covered the SC preparation of the test device.

Project Report: None issued.

Project 9.2b -- Balloon Carrier

Agency: Balloon Development Laboratory, Air Force Cambridge Research Center (AFCRC)

Operations: This subproject covered development work on the balloon that carried the YUCCA device and work on launching and tracking techniques. This subproject also provided the launch crew.

Staffing: Three AFCRC officers and one civilian are identified in the project report.

Project Report: Reference C.1.1655.

Project 9.2c -- Aircraft Modification

Agencies: Armed Forces Special Weapons Center
Cook Electric
4928th Test Squadron (Atomic)

Operations: This subproject covered the conversion of two RB-36s into instrumentation platforms for Projects 8.3 and 9.4. This conversion involved the modification of the fuselage for the placement of cameras and other optical instruments, and the addition of special navigation aids.

Project Report: Reference C.1.1656.

Project 9.3a -- Operation of Missile Carrier for Very-High Altitude Nuclear Operations

Agencies: Army Ballistic Missile Agency (ABMA)
Army Picatinny Arsenal
Army Corp of Engineers
Chrysler Corporation

Operations: This project provided the Redstone missiles for lofting the TEAK and ORANGE devices to their burst points. A missile launch pad and tower and associated facilities, such as a liquid-oxygen plant, tracking radars, firing bunkers, etc., were built on Bikini Island. These were manned by project personnel in early April, when TEAK and ORANGE were rescheduled for Johnston Island. The project relocated there and launched the TEAK missile on 31 July and the ORANGE missile on 11 August. Onsite activities included assembly of the missile, checkout, test firing, adaption of the nuclear device and missile, and operation of support and tracking equipment.

Shots: TEAK, ORANGE.

Staffing: A total of 145 men (97 civil servants, 45 military, and 3 contractor personnel) participated at either the Bikini or Johnston Island sites or at both. Almost 100 of the men were from ABMA and most of these were from the Missile Firing Laboratory at Redstone Arsenal, Huntsville, Alabama. A maximum of 91 was on site at one time. During the firings at Johnston Island, 62 men were on site for TEAK and 58 for ORANGE. Six enlisted men from Ft. Sill, Oklahoma, were part of the firing party. Sixteen military engineers from Ft. Belvoir, Virginia, assisted by a "civilian contractor representative" operated the liquid-oxygen plants and provided maintenance assistance on the tactical engineer equipment. A team of four specialists from Picatinny Arsenal, New Jersey, "augmented by one contract civilian," installed and checked out the warhead adaption kit on the missiles. The presence of these organizations, other than ABMA, and even the identification of the contractor or contractors is not satisfactorily confirmed in the Consolidated List.

Project Report: Reference C.1.1657.

Project 9.4 -- Support for WAHOO and UMBRELLA

Agency: Office of Naval Research

Operations: This project designation was used to cover the extensive planning, ship modification, and testing leading to the underwater shots.

Shots: WAHOO, UMBRELLA.

CHAPTER 4

WEAPON DEVELOPMENT TESTS

Although the primary interest of the Department of Defense (DOD) was in nuclear effects experiments, it was also involved with the Atomic Energy Commission (AEC) weapon development testing. Selected military personnel were routinely assigned to duty at the AEC laboratories and several participated in test operations. Other military personnel were selected for duty just for the Pacific testing periods. The DOD had also provided general support to the operations, providing overall security and sharing with the AEC base support contractor responsibilities in transport, supply, housing, etc. Finally, the DOD had conducted experiments of military interest during the weapon development shots.

This chapter discusses the 30 AEC weapon development shots during the Pacific phase of HARDTACK. The first part of the chapter addresses the Bikini Atoll shots and the second part the Enewetak Atoll shots. Radiation and fallout, where they relate to DOD participation are discussed. DOD effects experiments, which are discussed in detail in Chapter 3, are mentioned if they took place during an AEC weapon development shot.

BIKINI WEAPON DEVELOPMENT TEST OPERATIONS

When Bikini was reopened to nuclear testing in 1954, it was an advance camp of Enewetak operations. Bikini was to be the location of the very-large-yield device detonations, avoiding the threat of damage to the Enewetak installations and the requirement to evacuate all the Enewetak task force personnel. The buildings on Bikini were considered expendable and the atoll was evacuated almost completely for each test shot. The task force was prepared to live aboard task force ships if radiological contamination of the islands occurred and did, in fact, live aboard them for 2 months in 1954, during CASTLE.

In 1956 during the REDWING series, test operations at Eniwetok Proving Ground (EPG) followed the same pattern, with the larger-yield test shots detonated at Bikini. The base of operations at Bikini shifted from Eneman in the middle of the southern chain of islands to Eneu at the southeast corner. This pattern of use had the advantages of keeping the facilities at Bikini simple. Scientific personnel could be housed at Enewetak and shuttled over to Bikini to live in temporary camps or houseboats as needed. Scientific equipment and the test devices could be assembled in the specialized facilities at Enewetak and ferried over for the tests.

For HARDTACK, however, the number of tests planned would not fit this pattern and a new procedure was adopted. Bikini became the site for University of California Radiation Laboratory (UCRL) testing activities. Facilities constructed on Eneu for HARDTACK (a device assembly area and barge slip, an administration building, and a communications building), although still considered expendable, made independent operations there much easier and avoided shuttling the large numbers of men and associated equipment required for the many tests scheduled to be conducted at Bikini during HARDTACK.

Test Sites

All of the test devices detonated at Bikini used barges as the surface zero point, and the barges were anchored in one of three areas for the shots. Two of these areas were over underwater craters formed in the lagoon during earlier tests. The first was southwest of Nam Island, the site of the BRAVO test in 1954; five of the HARDTACK shots were sited on barges in this area. The second was the western end of Eneman, the site of the ZUNI detonation in 1956. The land at this site had been carried away by the blast and replaced by lagoon water. This was the location for barges on which three large HARDTACK shots were detonated. The third area was south of Lomilik, where two shots were detonated.

Evacuation

At 1800 on the day before each test, a sight muster of all personnel was conducted at the various Bikini Atoll camps and was completed before evacuation (Reference C.1.1682). Camps at Bikini Atoll were located at Eneu, Bikini, Aerokoj, and Aomen islands. Eneu was the main camp. The Bikini Island camp was prepared for personnel who were building the launching tower for the TEAK and ORANGE events. This camp was closed in April before testing began, when the TEAK and ORANGE events were moved to Johnston Island.

The Aerokoj camp housed personnel preparing diagnostic experiments for tests in the ZUNI crater at the west end of Eneman. Eneman was linked by causeway to Aerokoj via Aerokojlol and Lele, facilitating dry-land access. The Aomen camp was a smaller camp that supported personnel working in the Lomilik area.

Houseboats, small utility landing craft modified with living quarters, were also used to temporarily house laboratory personnel who were finishing the work on the test devices and instrumentation on the shot barges. The devices had been assembled at the special facilities on Eneu and then placed on the shot barges there. The barges were then towed to the shot sites and the houseboats were moored nearby.

Aerokoj camp personnel were evacuated to either Eneu or Task Group (TG) 7.3 ships except for the REDWOOD and CEDAR tests.

The Aomen camp was evacuated for all events. Evacuation of all the islands, including the base camp at Eneu, was considered necessary only for FIR, SYCAMORE, and POPLAR, and even on these shots the firing team remained on Eneu along with communications specialists.

USNS Fred C. Ainsworth (T-AP-181) and USS Boxer (CVS-21) were the primary evacuation ships, with USS Monticello (LSD-35) replacing Boxer after it left for Johnston Island in July. Command elements of the task force, key scientific personnel, radiological safety (radsafe) teams, and those scheduled for early reentry and recovery by helicopter went aboard Boxer; project and H&N personnel evacuated on Ainsworth. Eneu-based helicopters went aboard Boxer so that recovery missions could be begun from afloat. TG 7.3 and TG 7.5 maintained an emergency capability to evacuate the entire atoll as well as Enewetak.

Recovery and Reentry

Whenever the ships evacuated for a shot, a P2V made a radiological survey of the anchorage before they returned. Upon notification that the area was clear, the ships reentered the lagoon. As they reentered, Boxer launched two radsafe helicopters whose first survey was made at Eneu. It was clear of contamination on all the Bikini HARDTACK tests.

One helicopter surveyed the northern islands and the second the southern. These helicopters were launched from Eneu for those tests with limited evacuation. The Aerokoj camp was reoccupied from Eneu by boat and aircraft as the radiological situation permitted.

High-priority, early data-recovery missions also used helicopters in their recovery operations. On all the Bikini tests, film data were recovered on Lele, Aerokojlol, Jelete, and Bikini during the first 2 to 3 hours after detonation. Helicopters used in these recoveries were launched from Boxer for those tests in which Eneu had been evacuated.

THE BIKINI SHOTS

Table 13 summarizes the Bikini tests, all UCRL devices. The yields of the Bikini HARDTACK shots have not yet been released. Information on predicted and measured fallout listed below has been extracted from the Operation HARDTACK Radiological Safety Final Report (Reference C.1.6.2) unless otherwise noted. The graphical presentation of fallout for each test is predicted. No contours of fallout based on measurements appear to have been constructed and published in the test literature (Reference A.4).

Table 13. HARDTACK Bikini detonations, 1958.

Shot	Local Time	Date	Barge Location
FIR	0550	12 May	4,000 feet (1.22 km) WSW of Nam (BRAVO crater)
NUTMEG	0920	22 May	600 feet (183 meters) W of Eneman (ZUNI crater)
SYCAMORE	1500	31 May	4,000 feet (1.22 km) WSW of Nam (BRAVO crater)
MAPLE	0530	11 June	900 feet (274 meters) S of Lomilik
ASPEN	0530	15 June	4,000 feet (1.22 km) WSW of Nam (BRAVO crater)
REDWOOD	0530	28 June	900 feet (274 meters) S of Lomilik
HICKORY	1200	29 June	600 feet (183 meters) W of Eneman (ZUNI crater)
CEDAR	0530	3 July	4,000 feet (1.22 km) WSW of Nam (BRAVO crater)
POPLAR	1530	12 July	7,500 feet (2.29 km) WSW of Nam (BRAVO crater)
JUNIPER	1620	22 July	600 feet (183 meters) W of Eneman (ZUNI crater)

No.	Type/ Tail No.	Mission	Call Sign	Altitude (feet)	Altitude (km)	Range or Course
	BUTTERNUT PARTICIPATING AIRCRAFT			Zero-Time Location Relative to Burst		
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 50 nmi (92.7 km) east
1	P2V	Barrier patrol	Student	4,500	1.4	North-south windbox 20 nmi (37.1 km) east
1	FJ-4	Project 5.3[a]	Kimono	14,074	4.29	15,578 feet (4.75 km) slant range
1	FJ-4	Project 5.3[a]	Cobalt	9,106	2.78	12,939 feet (3.94 km) slant range
1	A4-D/827	Project 5.2[b]	Clark	8,110	2.47	12,290 feet (3.75 km) slant range
1	A4-D/831	Project 5.2[b]	Barley	11,200	3.41	18,850 feet (5.75 km) slant range
1	B-57B	Sampler control	Opium 3	35,000	10.67	East-west racetrack 70 nmi (129.7 km) north
5	B-57B	Sampler	Hotshot 1-4, 8	Not airborne at burst time		
3	B-57D	Sampler	Hotshot 15-17	Not airborne at burst time		

Notes:

[a]Reference C.1.1636.

[b]Reference C.1.1635.

Source: Reference C.4.1 except as noted.

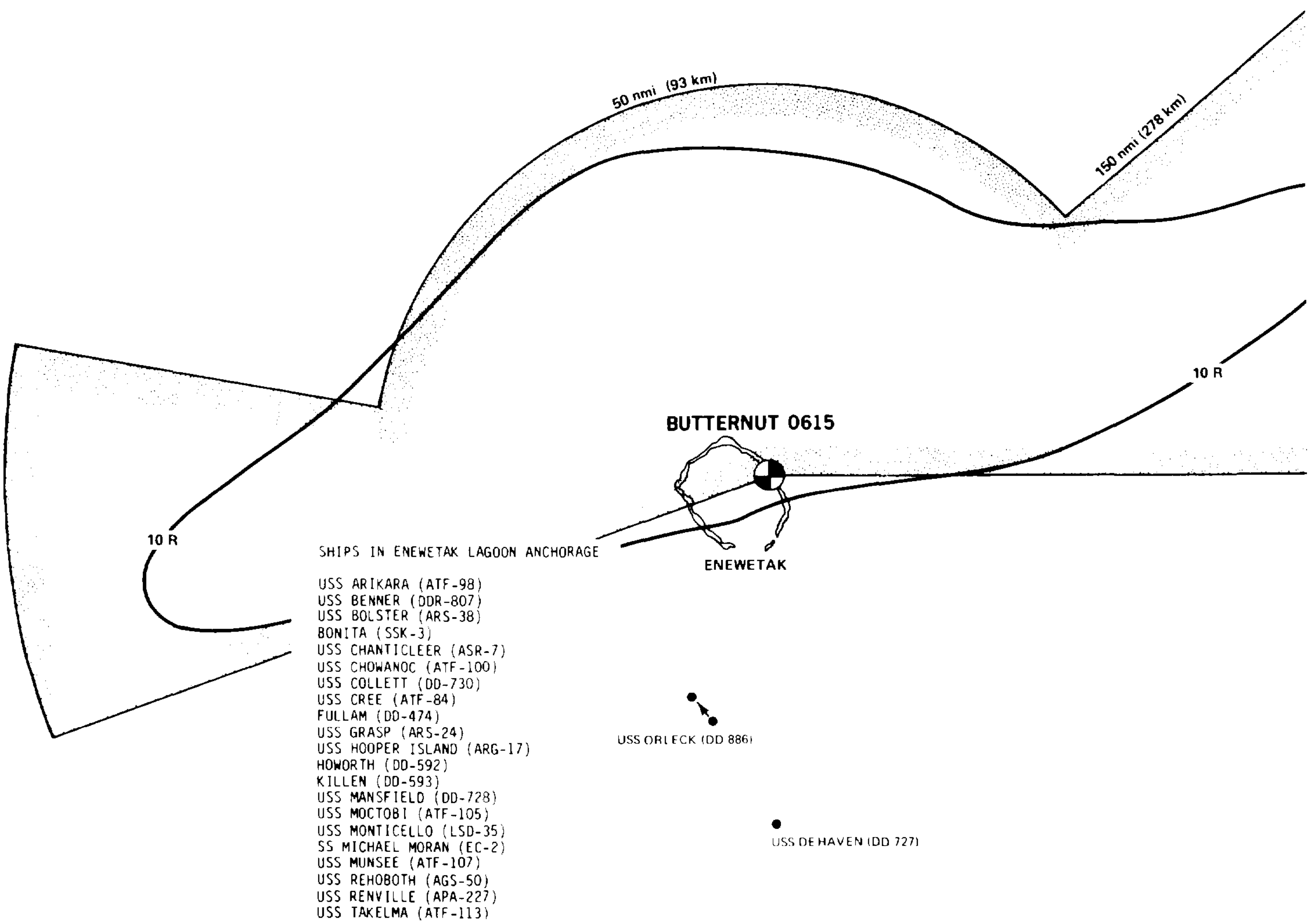

Figure 34. FIR and BUTTERNUT predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

FIR PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 80-90 nmi (148.3-166.8 km) west
1	B-52	Project 5.1[a]	Watchdog	30,000	9.14	93,300 feet (28.4 km) ground range southeast
1	B-57B	Sampler control	Opium 1	35,000	10.67	East-west racetrack 30 nmi (55.6 km) north
3	B-57B	Sampler	Hotshot Bravo 1-3	Not airborne at burst time		

Note:

[a]Reference C.1.1634.

Source: Reference C.4.1 except as noted.

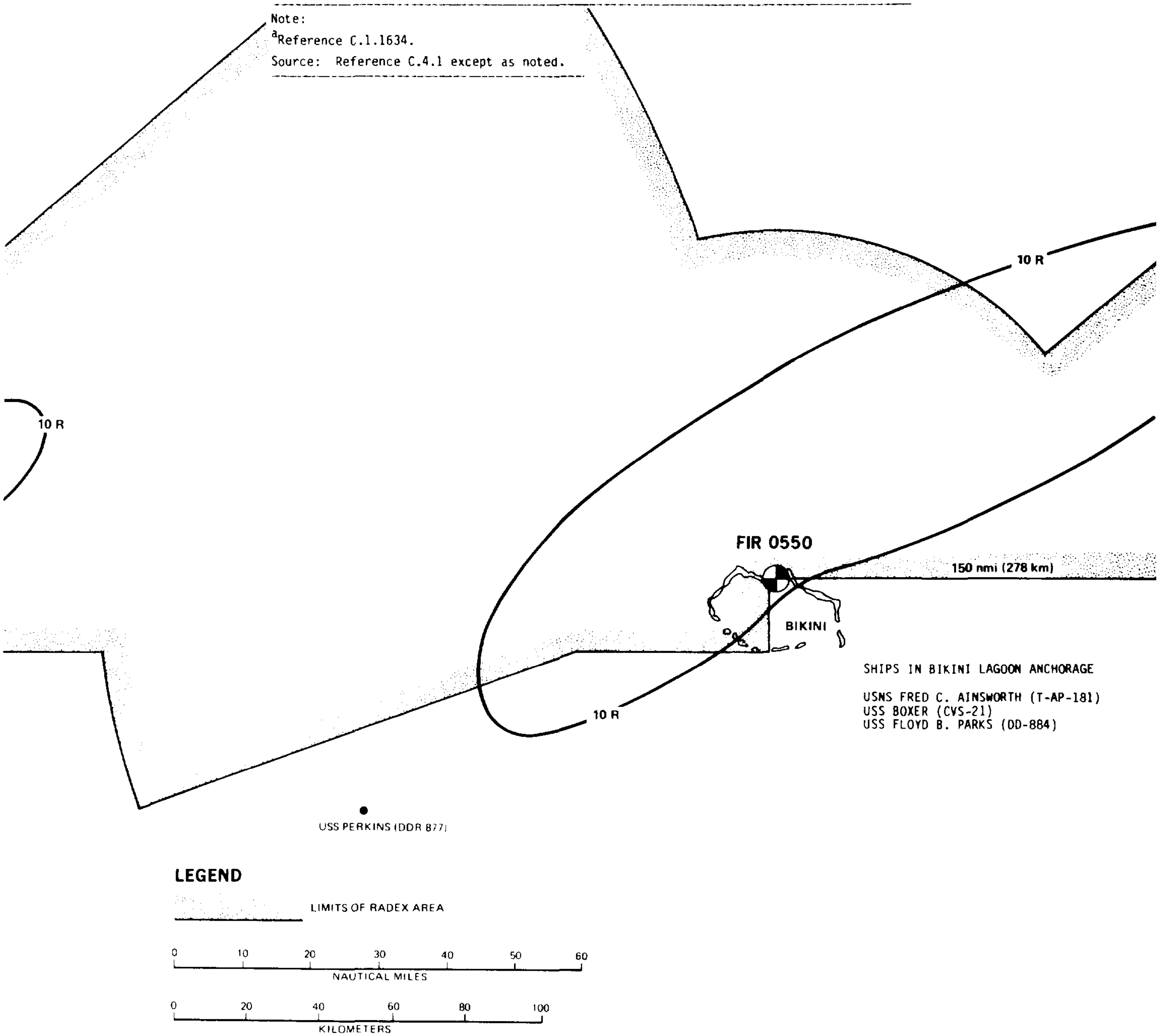

Figure 34. FIR and BUTTERNUT predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

FIR

FIR was the first Bikini shot, detonated at 0550 on 12 May on a barge in the BRAVO crater. Surface winds were 17 knots (31.5 km/hr) from east-northeast. It was followed by BUTTERNUT on Enewetak 25 minutes later.

DOD-sponsored experiments for FIR included Projects 3.7, 5.1, 6.4, 6.5, 6.6 and 6.11. Details of these are in Chapter 3. None of the DOD projects had instrumentation stations in the northern islands of the atoll that required manning or rapid data recovery. Project 6.11 did have a riometer station on Eneu, but whether it was manned is not clear. The predicted fallout pattern is shown in Figure 34 as well as the locations of fleet units at shot time and the surface radiological exclusion (radex). Participating aircraft and their locations relative to the burst are also shown in Figure 34.

All personnel were evacuated to Eneu Island, and the ships remained in Bikini Lagoon. After detonation, the cloud rose to 60,000 to 90,000 feet (18.3 to 27.4 km), and radar reports from Boxer showed that it moved along a bearing of 260° at approximately 12 knots (22.2 km/hr) during the first 12 minutes.

FIR reentry hour was scheduled for 12 May at 1100. Air and surface radex areas for H+5 through H+12 included the surface areas within a 1-nmi (1.85-km) radius around surface zero. A helicopter survey by Task Unit (TU) 7.1.6 (Radiological Safety) at H+3 indicated 0.036 R/hr at Aomen and 0.370 R/hr at Nam. Subsequent surveys found low-level contamination on several islands east and southwest of Nam (Reference C.1.1685).

The FIR cloud apparently continued to move on the 260° bearing and fallout occurred on Enewetak Atoll. The radiation intensity at Enewetak began to rise at 0300 on 14 May and peaked at about 0.025 R/hr in the afternoon. Figure 35 shows the Parry Island intensity reading for this period.

TG 7.3 ships preparing for WAHOO, both within the lagoon and in the target-array area to the southwest outside the lagoon, also received fallout. Table 14 lists the ships that noted washdown activation or other indication of fallout on 14 May.

USS John R. Craig (DD-885) was returning to Enewetak from weather station Bravo, 225 nmi (417 km) west of Enewetak, and it did not anchor at Enewetak until 1937. At 0813, however, it "changed course and speed to activate washdown" (Reference C.3.4.14).

The source of this fallout might be assumed to have been the KOA event detonated the day before (13 May) on Dridrilbwij at Enewetak, but apparently the KOA cloud and the FIR cloud intermingled somewhat (Reference C.1.1625). The TG 7.1 Radsafe Officer states that FIR was the source of the Enewetak fallout. The picture is somewhat further complicated by the log of USNS T-LST-664 at anchor at Bikini on the following morning (15 May), which noted 0.005 to 0.007 R/hr on its decks between 0400 and 0800.

Two film badges placed outside the Radsafe Center on Parry at 0845 on 14 May were retrieved at 0950 on 18 May. The badges showed 1.36 and 1.79 R (Reference C.5.3). The TG 7.1 Radsafe Officer's remark that "fallout from the

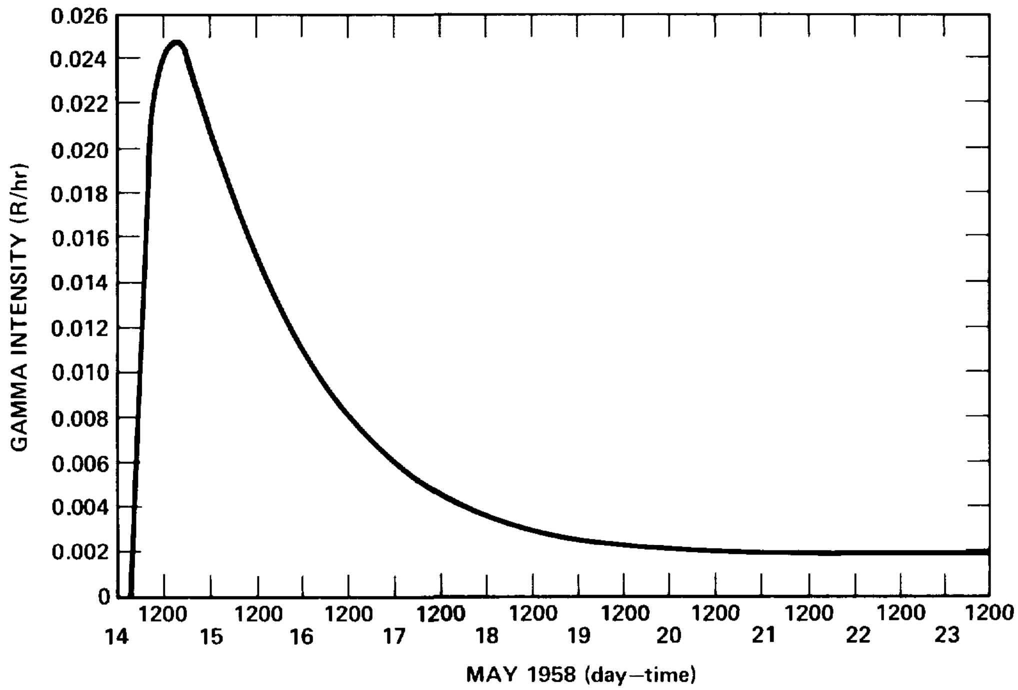

Figure 35. Parry Island gamma intensity readings after HARDTACK, FIR (source: Reference C.5.3, p. 21).

Table 14. Task Group 7.3 ships noting fallout on 14 May 1958.

Ship	Time	Remarks
USS Arikara (ATF-98)	1027-1038	Activated washdown system
USS Benner (DDR-807)	0945	Ship, 0.005 R/hr; surrounding seawater, 0.1 R/hr
USS Boxer (CVS-21)	0630	Before washdown, 0.02-0.03 R/hr maximum
USS Chowanoc (ATF-100)	1100	Maximum, 0.15 R/hr; low 0.015 R/hr
USS Cree (ATF-84)	0717	Before washdown, 0.032 R/hr maximum
USS De Haven (DD-727)	0845	Detected fallout; average, 0.012 R/hr, hot spots, 0.05 to 0.08 R/hr
USS Moctobi (ATF-105)	1012	Average 0.01 R/hr
USS Monticello (LSD-35)	0756	Background 0.007 to 0.01 R/hr after washdown
USS Orleck (DD-886)	0756	Overall average 0.008 R/hr
USS Rehoboth (AGS-50)	0836	Weather decks 0.02 R/hr
USS Renville (APA-227)	0510	"Significant" fallout
USS Takelma (ATF-113)	0730	0.015 R/hr

Sources: References C.3.3 and C.3.4.

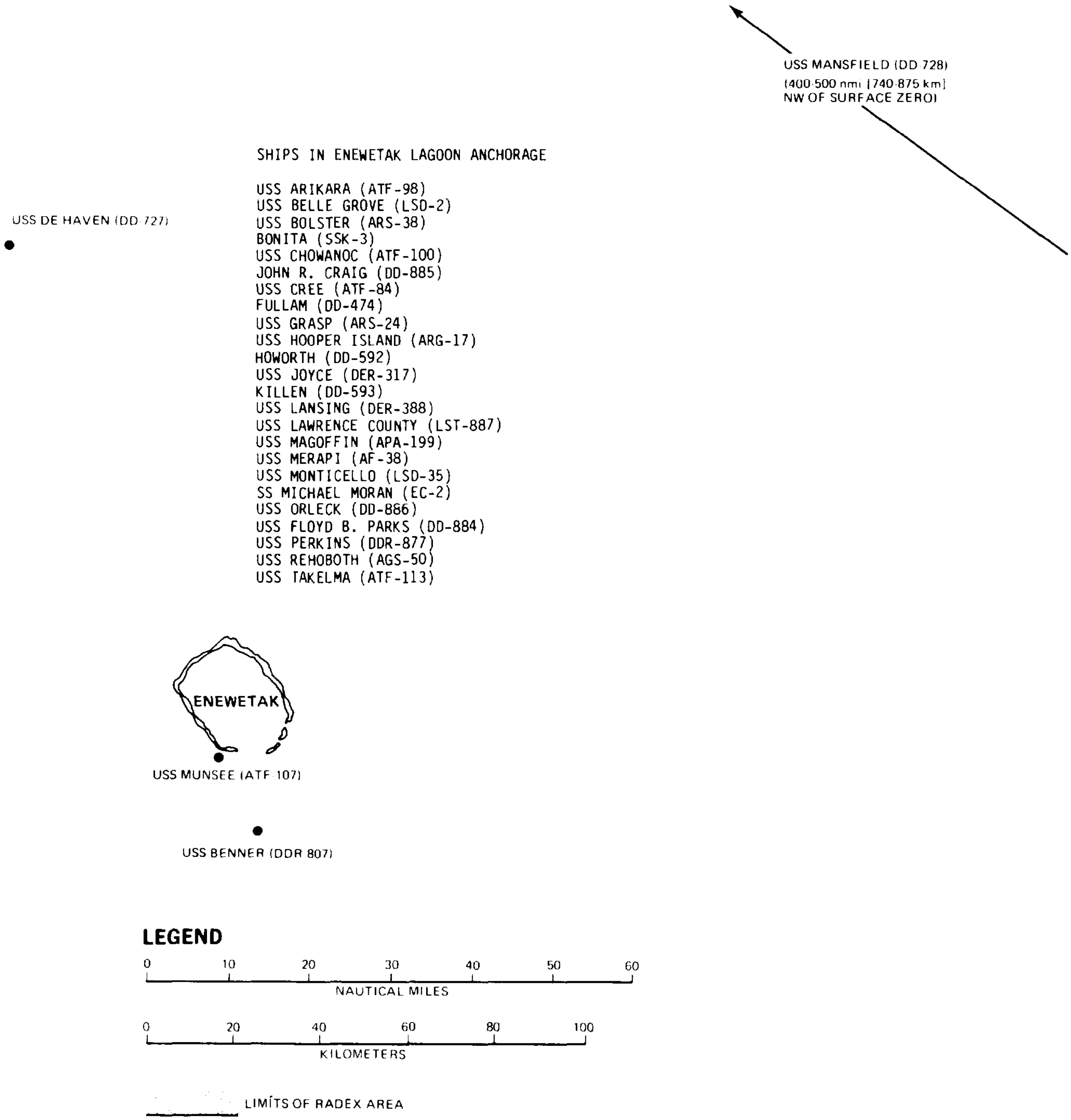

Figure 36. NUTMEG predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	WB-50	Low-altitude cloud sampler	Wilson 050	Not airborne at burst time		
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 75 nmi (139.0 km) west
2	C-54	Photo	Pewter 2,3	10,000	3.05	North-south racetrack 10 nmi (18.5 km) west
1	B-57B	Sampler control	Opium 1	20,000	6.10	East-west racetrack 20 nmi (37.1 km) north
6	B-57B	Samplers	Hotshot 1-6	25,000	7.62	North-south racetrack 75 nmi (139.0 km) west
1	RB-50		Carter 2			Photography

Source: Reference C.4.1.

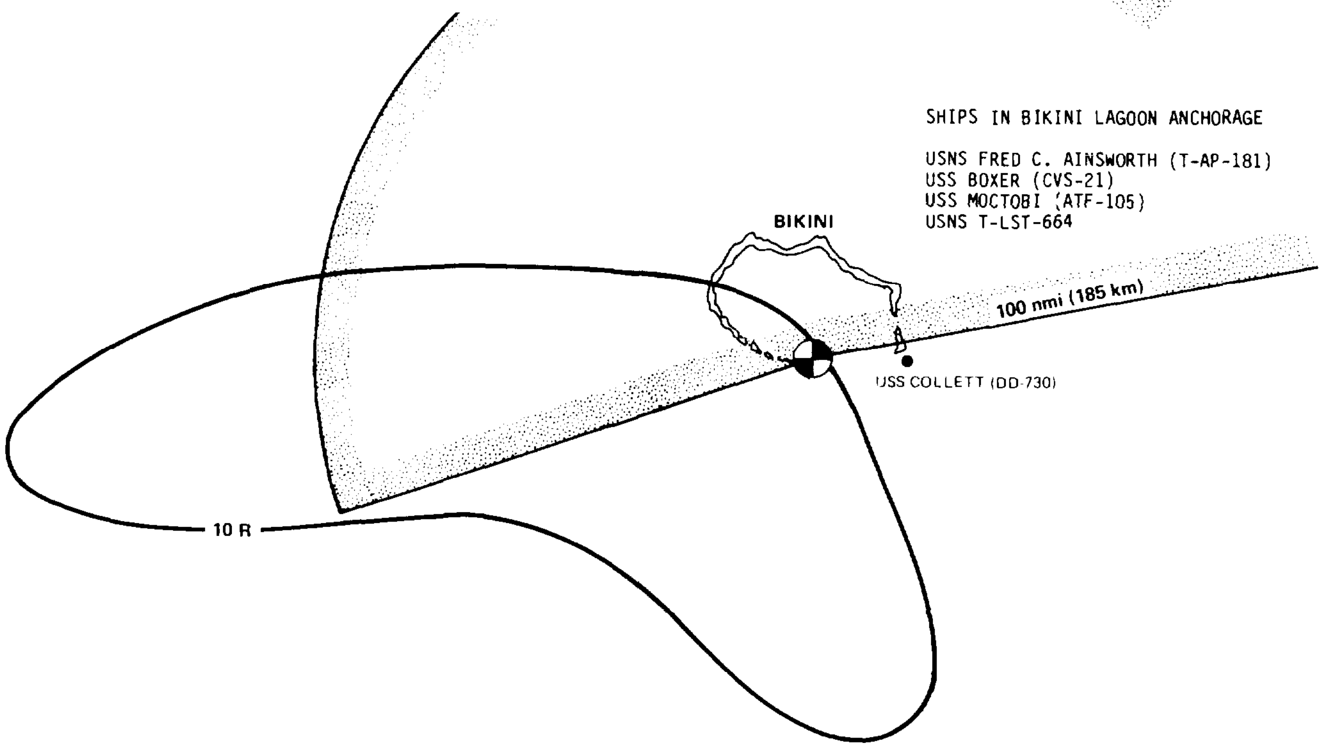

Figure 36. NUTMEG predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

FIR event on Bikini contributed approximately 1,200 to 1,500 mr total dose to those living at Eniwetok Atoll" (Reference C.1.1685) is probably based on these badges.

NUTMEG

The second Bikini shot, NUTMEG, was detonated at 0920 on 22 May on a barge in the ZUNI crater. Surface winds were 11 knots (20.4 km/hr) from the east.

DOD-sponsored experiments for NUTMEG were Projects 6.3, 6.3a, 6.4, 6.5, 6.6, and 6.11. Projects 6.3 and 6.3a had stations near the burst point on Eneman Island. It is not known if the Project 6.11 station on Eneu was manned for this test. All other DOD projects had instrumentation remote from the atoll. Details of the experimental projects are in Chapter 3. The predicted fallout pattern, surface radex area, locations of fleet units at burst time, and aircraft participation are shown in Figure 36.

Personnel of northern island locations were evacuated to Eneu and those on Aerokoj were evacuated to Ainsworth; the transfer was completed by about 2230 on D-1. Personnel from the Aerokoj camp and Eneman work area boarded LCUs at 1600 on D-1. Ainsworth withdrew from the lagoon to a position 10 nmi (18.5 km) east where those aboard viewed the detonation, but the rest of the ships remained in Bikini Lagoon.

The detonation cloud stabilized at 20,000 feet (6.1 km) by 0926. Radar from Boxer confirmed the cloud's position of 264° from surface zero, moving at 6 knots (11.1 km/hr) by 0940 and then dissipating. A nonproject search P2V aircraft at 5,000 feet (1.52 km) apparently found remnants of the cloud 60 nmi (111 km) west of the atoll that had maximum readings of 0.14 R/hr. Earlier, at about H+1:40, the P2V recorded 0.04 R/hr over the shot area.

TU 7.1.6 conducted two helicopter surveys at H+1. These are summarized (in R/hr) below:

Bokbata	0.002	Enidrik	0.125*
Nam	0.004	Jelete	3
Aerokoj	0.00007	Oroken	0.0008
Lele	0.100	Bokdrolul	0.0008
Eneman	30		

All other readings taken were zero.

SYCAMORE

SYCAMORE was detonated at 1500 on 31 May on a barge moored in the BRAVO crater. Surface winds were 15 knots (27.8 km/hr) from the east.

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* This reading is probably an error in the source document (Reference C.1.2). Another survey showed it at 25 R/hr at H+4 (Reference C.1.1685).

DOD-sponsored experiments for SYCAMORE were Projects 3.7, 5.1, 6.4, 6.5, 6.6, and 6.11. Only Project 6.11 had an instrument site at Bikini; located on Eneu, it was not manned for SYCAMORE. All other projects were either remote or airborne. Details of the experimental projects are in Chapter 3. The predicted fallout pattern is shown in Figure 37 as well as the locations of fleet units at shot time, the surface radex area, and aircraft participation.

The entire Bikini Atoll population was evacuated before shot time except for personnel at the timing and firing station and the communications building on Eneu. All ships and aircraft were evacuated from Bikini Lagoon before shot time. Light planes (L-19s and L-20s) from Eneu orbited Boxer, which was stationed 25 to 27 nmi (46 to 50 km) from Eneu on an azimuth of 160° to 190° until the shock wave passed.

The Fallout Prediction Unit (FOPU) predicted that the heaviest concentration of fallout would occur between the 300° and 340° radials. Almost all of the fallout was within the forecast area; however, some of the fallout was to the northeast because a small segment of the cloud moved in an easterly direction.

The P2V barrier patrol was completed at H+1. The initial search began from Bikini to Aerokoj and from Aerokoj across the lagoon. No radiation was recorded. The P2V then flew across the western portion of the lagoon and along the southern and northern island chains. A reading of 5 R/hr was recorded in the vicinity of surface zero. The aircraft then flew 120 nmi (222 km) east of Bikini. A second P2V barrier patrol arrived at H+3 and proceeded on a bearing of 280° for 120 nmi (222 km) from Bikini, followed by a line on the 20° bearing for 120 nmi (222 km). No significant readings were recorded. The H+1 radsafe helicopter survey found radiation levels of 2 to 10 R/hr on Nam, 0.280 R/hr on Enidrik, and 0.025 R/hr on Jelete. All other survey values were zero.

MAPLE

MAPLE was detonated on 11 June at 0530 on a barge just south of Lomilik. Surface winds were 22 knots (40.7 km/hr) from east-northeast.

The DOD-sponsored experiments for MAPLE were Projects 5.1, 6.3, and 6.3a. Projects 6.3 and 6.3a shared the same, rather close-in sites on Lomilik. The predicted fallout pattern is shown in Figure 38. Locations of the fleet units at burst time, aircraft participation, and the surface radex area are also shown in Figure 38.

All personnel from the Aerokoj and Aomen camps were evacuated to Eneu on D-1. A total of 1,101 men was accounted for. USS Benner (DDR-807) and Ainsworth remained in Bikini Lagoon in case an emergency evacuation from Bikini and Rongelap atolls was required.

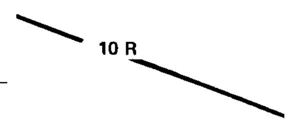
The 40,000-foot (12.2-km) cloud produced by the detonation was tracked by radar from Benner. By H+30 minutes the cloud had split apart with the upper portion ranging from 15,200 to 47,000 feet (4.6 to 14.3 km), moving east and spreading south. The lower portion of the cloud moved west.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type/ Tail No.	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 75 nmi (139.0 km) west
1	P2V	Barrier patrol	Wildroot 4	2,000	0.61	East-west racetrack 60 nmi (111.2 km) south
1	C-54	Photo	Pewter 2	6,000	1.83	Northwest-southeast racetrack 60 nmi (111.2 km) southwest
1	C-54	Photo	Pewter 3	6,000	1.83	Northeast-southwest racetrack 60 nmi (111.2 km) northwest
1	B-52/591	Project 5.1[a]	Watchdog	30,000	9.14	Unreported
2	B-57B	Sampler control	Opium 1,3	34,000 36,000	10.36 10.97	East-west racetrack 50 nmi (92.7 km) north
1	B-57B	Sampler	Hotshot 1	32,000	9.75	East-west racetrack 50 nmi (92.7 km) north
4	B-57B	Sampler	Hotshot 3-6	Not airborne at burst time		
1	B-57D	Sampler	Hotshot 12	Not airborne at burst time		

Note:

[a]Reference C.1.1634.

Source: Reference C.4.1 except as noted.



SHIPS IN ENEWETAK LAGOON ANCHORAGE

USS ARIKARA (ATF-98)
USS BOLSTER (ARS-38)
BONITA (SSK-3)
USS CACAPON (AO-52)
USS CHOWANOC (ATF-100)
USS DE HAVEN (DD-727)
FULLAM (DD-474)
USS GRASP (ARS-24)
USS HOOPER ISLAND (ARG-17)
HOWORTH (DD-592)
USS JOYCE (DER-317)
KILLEN (DD-593)
USS LANSING (DER-388)
USS LAWRENCE COUNTY (LST-887)
USS MAGOFFIN (APA-199)
SS MICHAEL MORAN (EC-2)
USS MUNSEE (ATF-107)
USS TAKELMA (ATF-113)

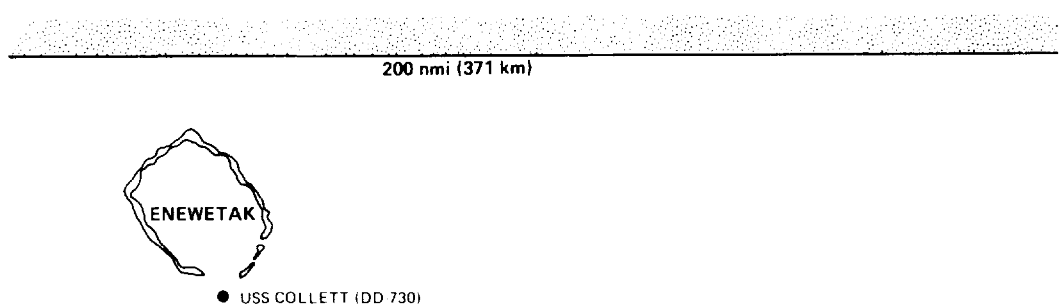


Figure 37. SYCAMORE predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

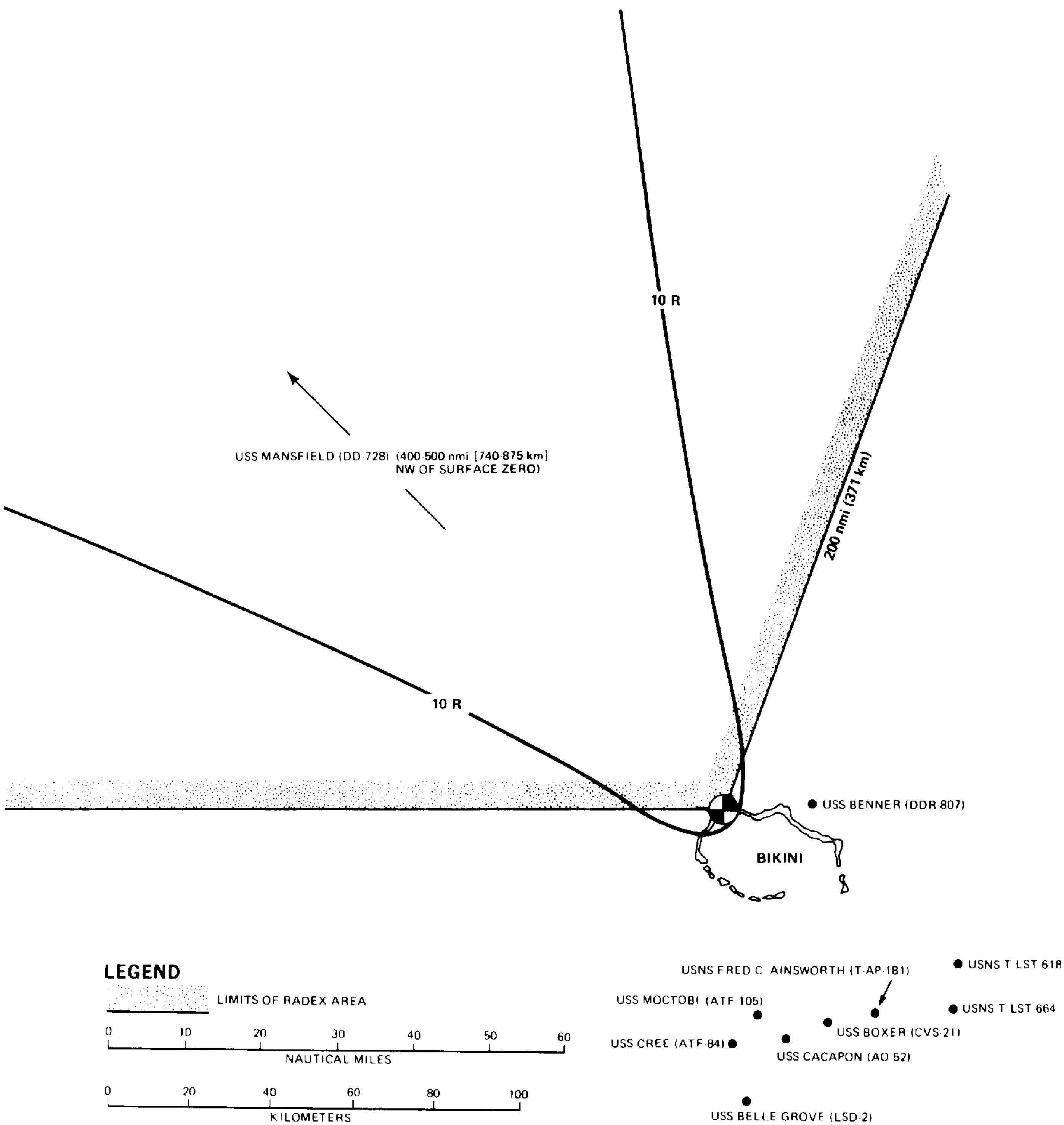


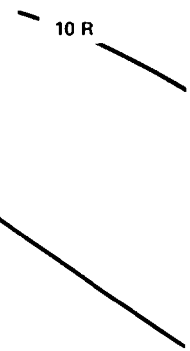
Figure 37. SYCAMORE predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 90 nmi (166.8 km) west
1	B-52	Project 5.1[a]	Watchdog	25,000	7.62	46,000 feet (14.0 km) ground range south
1	P2V	Barrier	Wildroot 10	2,000	0.61	East-west racetrack 50 nmi (92.7 km) south
2	B-57B	Sampler	Opium	35,000	10.67	East-west racetrack 40 nmi (74.1 km) north
1	B-57B	Sampler	Hotshot 6	35,000	10.67	East-west racetrack 38 nmi (70.4 km) north
4	B-57B	Sampler	Hotshot 3-5 plus Hotshot spare	Not airborne at burst time		
2	B-57D	Sampler	Hotshot 11,12	Not airborne at burst time		

Note:

[a]Reference C.1.1634.

Source: Reference C.4.1 except as noted.



SHIPS IN ENEWETAK LAGOON ANCHORAGE

USS ARIKARA (ATF-98)
USS BOLSTER (ARS-38)
BONITA (SSK-3)
USS CHOWANOC (ATF-100)
USS CREE (ATF-84)
FULLAM (DD-474)
USS GRASP (ARS-24)
USS HOOPER ISLAND (ARG-17)
HOWORTH (DD-592)
USS JOYCE (DER-317)
KILLEN (DD-593)
USS LANSING (DER-388)
USS LAWRENCE COUNTY (LST-887)
USS MAGOFFIN (APA-199)
USS MOCTOBI (ATF-105)
USS MONTICELLO (LSD-35)
SS MICHAEL MORAN (EC-2)
USS MUNSEE (ATF-107)
USS TAKELMA (ATF-113)

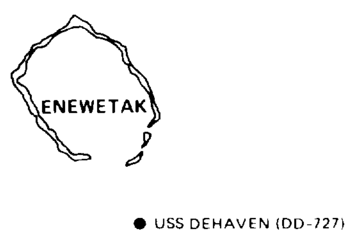


Figure 38. MAPLE predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

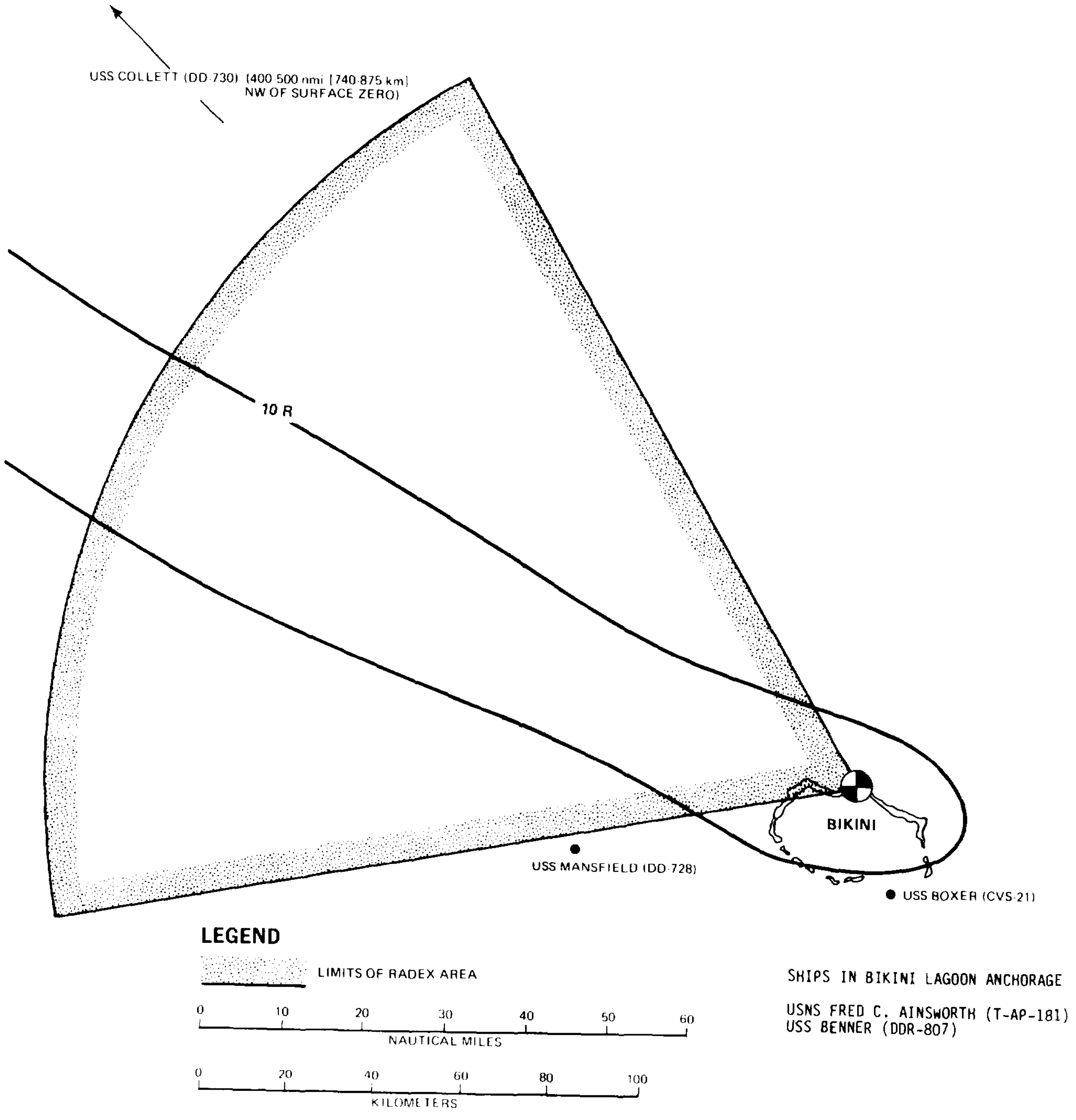


Figure 38. MAPLE predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

WALNUT PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type/ Tail No.	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	P2V	Barrier patrol	Wildroot 2	2,000	0.61	East-west racetrack 50 nmi (92.7 km) south
1	B-52	Project 5.1[a]	Watchdog	30,000	9.14	24,900 feet (7.59 km) ground range
1	A-4D/827	Project 5.2[b]	Clark	2,860	0.87	15,650 feet (4.77 km) slant range
1	A-4D/831	Project 5.2[b]	Barley	10,170	3.10	16,220 feet (4.94 km) slant range
1	FJ-4/467	Project 5.3[c]	Cobalt	3,996	1.22	16,351 feet (4.98 km) slant range
1	FJ-4/310	Project 5.3[c]	Kimono	10,809	3.29	16,752 feet (5.11 km) slant range
1	B-57B	Sampler control	Opium 3	35,000	10.67	East-west racetrack 35 nmi (64.9 km) north
4	B-57B	Sampler	Hotshot 2-5	Not airborne at burst time		
4	B-57D	Sampler	Hotshot 11, 16-18	Not airborne at burst time, except for Hotshot 11 whose altitude and position are unknown		
2	P2V	Project 2.8 rocket sampler	Wildroot 1,15	Not airborne at burst time		
2	WB-50	Project 2.8 low-altitude samplers	Massive 1,2	Not airborne at burst time		
1	B-57D	D+1 sampler	Hotshot 19	Not airborne at burst time		

Notes:
[a]Reference C.1.1634.
[b]Reference C.1.1635.
[c]Reference C.1.1636.
Source: Reference C.4.1 except as noted.

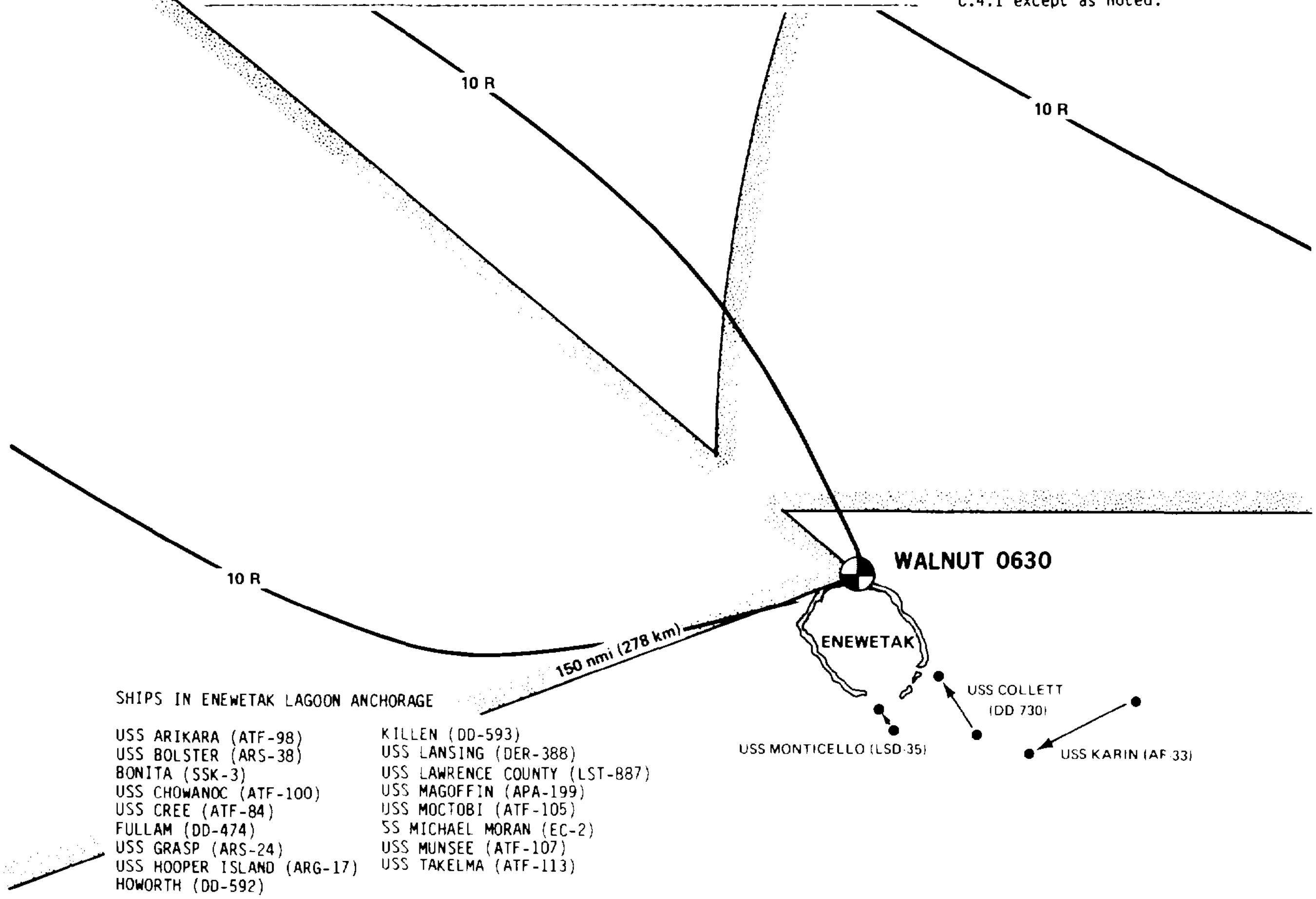


Figure 39. ASPEN and WALNUT predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

ASPEN PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 80 nmi (148.3 km) west
1	P2V	Barrier patrol	Wildroot 11	2,000	0.61	East-west racetrack 50-60 nmi (92.7-111.2 km) south
2	B-57B	Sampler control	Opium 1	36,000	11.10	East-west racetrack 40 nmi (74.1 km) north
4	B-57B	Sampler	Hotshot Bravo 2-5	Not airborne at burst time		
1	B-57B	Sampler	Hotshot Bravo 11	Not airborne at burst time		

Source: Reference C.4.1.

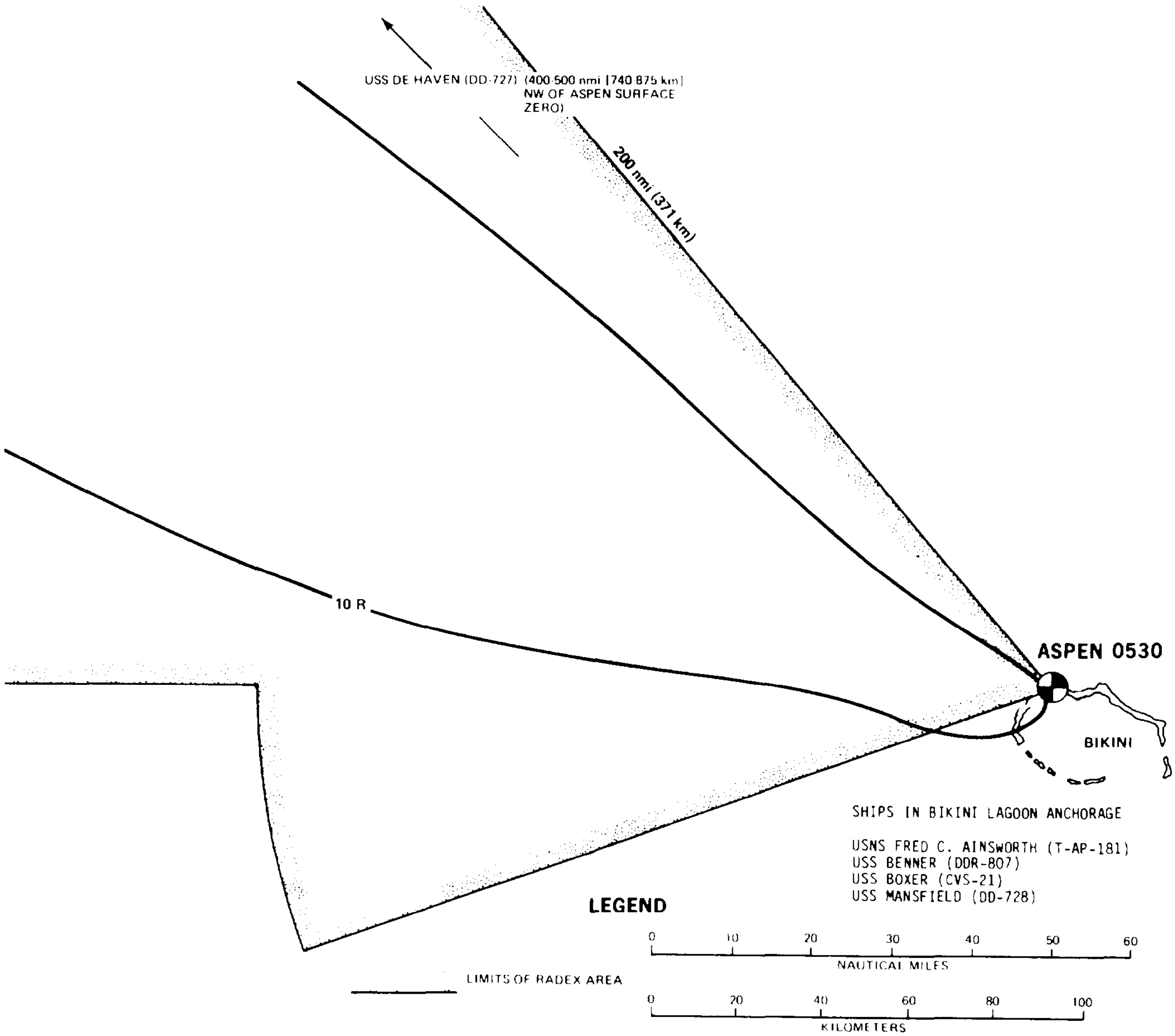


Figure 39. ASPEN and WALNUT predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

Helicopter radsafe surveys reported radiation intensities of 480 R/hr on Lomilik and 28 R/hr at Aomen at H+1, and 1.2 R/hr at Bokbata and 3.35 R/hr on Nam at H+10. All other readings were zero. All of the fallout was estimated to be within the forecast area. Considerable rainshower activity through H+24 diminished the carrying effect of the lower trade winds.

The barrier patrol P2V flew from Eneu to Bikini, to Aerokoj, to Enidrik, to Jelete, and back to Bikini at H+30 minutes, encountering only background radiation. The plane then proceeded to Bokdrolul and from Bikini due west. A reading of 1.5 R/hr was recorded to the extreme west. By 1810 another P2V was needed for barrier patrol because the upper portion of the cloud moved to the east, posing a potential for contaminating Eneu. Fallout from the west did not materialize, and reentry hour was at 2145. The area west of the lagoon was placed under radex control and surveyed by the second P2V until 2400. The air and surface radex areas were modified to enclose surface through 30,000 feet (9.14 km) radials, 270° through 340°, 10 through 170 nmi (18.5 to 315 km) from surface zero.

The Project 6.3 recorders were recovered on 18 June, requiring two project personnel, two radsafe monitors, and three H&N equipment operators. The recovery was considered an emergency situation as the instrumentation was needed to prepare for another event. Despite the week-long decay period, the area recorders were in a 2 R/hr field. Exposures of 0.5 to 1.13 R were recorded by the group (Reference C.5.4).

ASPEN

ASPEN was detonated on 15 June at 0530 on a barge in the BRAVO crater, 4,000 feet (1.22 km) southwest of Nam. Surface winds were 18 knots (33.4 km/hr) from the northeast.

No experiments were sponsored by DOD for this shot. Figure 39 shows the predicted fallout, locations of fleet units at burst time, the surface radex area, and aircraft participation.

All northern island personnel were evacuated to Eneu on D-1. Personnel from the Aerokoj camp were evacuated by LCU at approximately 2200 and remained aboard ship during the event. Boxer and Ainsworth remained in Bikini Lagoon for an emergency evacuation, if required.

The detonation produced a 48,600-foot (14.8-km) cloud as measured by radar from Benner. By H+30 minutes the cloud had moved well to the northwest of the lagoon.

Two helicopters began surveying from Eneu at H+2. No radiation was recorded by this survey. A survey at H+7 showed the following radiation readings (R/hr):

Bokbata	0.2	Eneman	0.9
Nam	0.12 - 0.24	Enidrik	0.08
Iroij	0.24	Jelete	0.008
Lomilik	0.24 - 0.8	Bokaetoktok	0.004

Surveys of other island locations at H+7 did not record any radiation.

The P2V reported over Eneu at H+30 minutes and flew across the eastern section of the lagoon, recording only background radiation. By H+1:45, the plane had searched the entire lagoon and recorded a maximum reading of 0.0055 R/hr 2 nmi (3.7 km) east of surface zero. All the fallout was estimated to be within the forecast area. The radsafe survey and barrier patrols completed, reentry hour was declared at 1900.

REDWOOD

REDWOOD was detonated on 28 June at 0530 on a barge south of Lomilik. Surface winds were 10 knots (18.5 km/hr) from the northeast. REDWOOD was followed by the ELDER detonation at Enewetak Atoll 1 hour later.

The only DOD-sponsored experiment for REDWOOD was Project 5.1. The predicted fallout pattern is shown in Figure 40, which also shows locations of the fleet units at burst time, the surface radex area, and aircraft participation.

All personnel were evacuated to the Aerokoj camp and Eneu for the shot. Ships remained in Bikini Lagoon, and Ainsworth stood by for emergency evacuation of Bikini Atoll, if required. The overpressure from REDWOOD was expected to be significant at Eneu and Aerokoj.

The detonation cloud rose quickly to 51,000 feet (15.6 km). The cloud base was at 28,000 feet (8.5 km) and the top stabilized at 55,000 feet (16.8 km) at 0610 as reported by the B-52 of Project 5.1. The cloud moved out of the lagoon area rapidly. At 0600, the barrier patrol P2V recorded only background radiation at 1,000 feet (305 meters) except in the area adjacent to surface zero. Iroij and Aomen had readings of 0.025 R/hr and 0.047 R/hr, respectively, at 0630. It then flew on radials of 260°, 270°, and 90° from Bikini Atoll for 100 nmi (185 km). The P2V found no fallout north or east of the predicted area and was released by 1100. The helicopter survey, which began at 1715, obtained readings of 0.5 to 0.6 R/hr at 100 feet (30 meters) altitude over the crater off Nam. Later surveys (1715) showed 20 R/hr over surface zero in the lagoon; 0.49 R/hr was recorded at Bokbata, 8 R/hr at Nam, 5.5 R/hr at Iroij, 16 R/hr at Lomilik, and 12 R/hr at Aomen. No radiation was recorded on any other islands.

HICKORY

HICKORY was detonated on 29 June at 1200 on a barge off the west end of Eneman, 4-1/2 hours after the OAK shot at Enewetak Atoll. Surface winds were 8 knots (14.8 km/hr) from the east.

Projects 6.3 and 6.3a were the only DOD-sponsored experiments for HICKORY. Their instrument stations were near the detonation point on Eneman. Details of the experimental projects are in Chapter 3. The predicted fallout pattern, locations of fleet units at burst time, the surface radex area, and aircraft participation are shown in Figure 41.

Most island-based personnel were evacuated to Eneu. Personnel from the Aerokoj camp were evacuated by LCU to Ainsworth and remained aboard ship during

ELDER PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo 2	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	P2V	Barrier patrol	Wildroot 14	8,000	2.44	East-west racetrack 50 nmi (92.7 km) south
1	B-52	Project 5.1[a]	Watchdog	25,000	7.62	5,200 feet (1.58 km) ground range
1	C-54	Photo	Pewter 2	6,000	1.83	North-south racetrack 25 nmi (46.3 km) west
1	C-54	Photo	Pewter 3	6,000	1.83	Northwest-southeast racetrack 30 nmi 55.6 km) southwest
1	B-57B	Sampler control	Opium	35,000	10.67	East-west racetrack 35 nmi (64.9 km) north
2	B-57B	Sampler	Hotshot 2, 3	Not airborne at burst time		
2	B-57D	Sampler	Hotshot 11, 14	Not airborne at burst time		

Note:
[a]Reference C.1.1634.
Source: Reference C.4.1 except as noted.

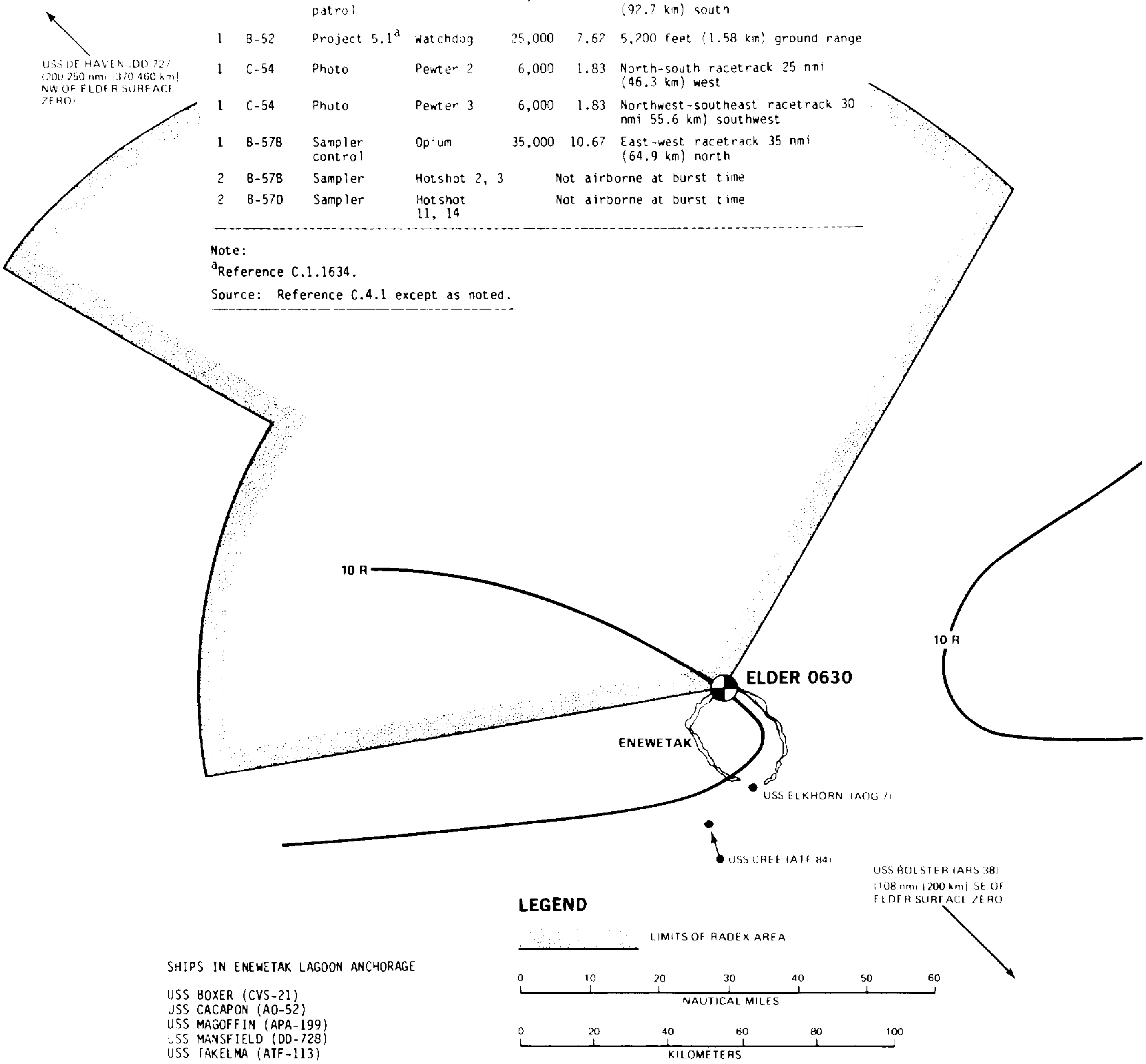


Figure 40. REDWOOD and ELDER predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

REDWOOD PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 80 nmi (148.3 km) west
1	B-52	Project 5.1[a]	Watchdog	25,000	7.62	5,200 feet (1.6 km) ground range
1	P2V	Barrier patrol	Wildroot 13	2,000	0.61	East-west racetrack 50-60 nmi (92.7-111.2 km) south
1	B-57B	Sampler control	Jagged	35,000	10.67	East-west racetrack 50-60 nmi (92.7-111.2 km) north
4	B-57B	Sampler	Hardtime 2-4, plus spare	Not airborne at burst time		
1	B-57B	Sampler	Hardtime 11	Not airborne at burst time		

Note:
[a]Reference C.1.1634.
Source: Reference C.4.1 except as noted.

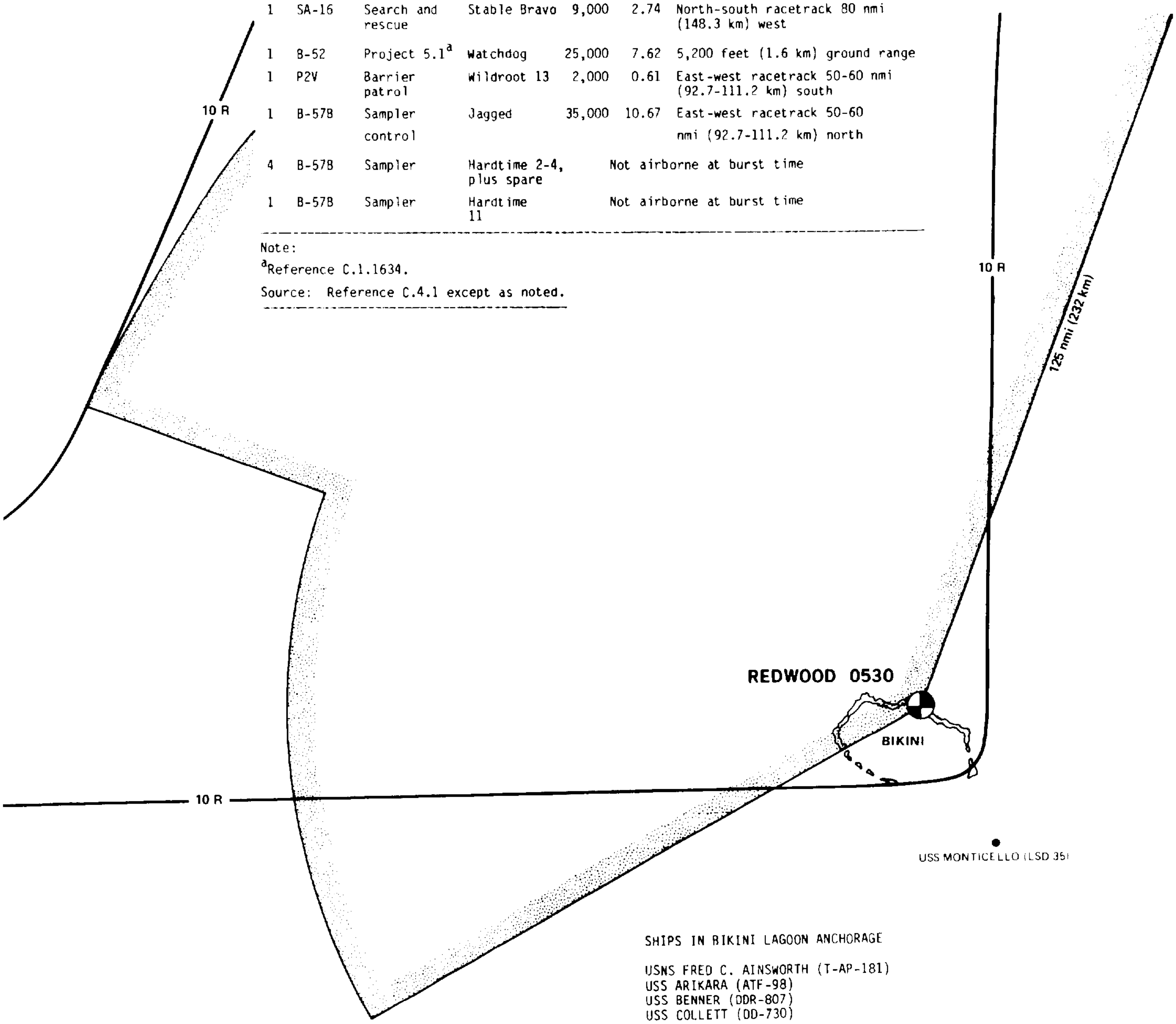


Figure 40. REDWOOD and ELDER predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

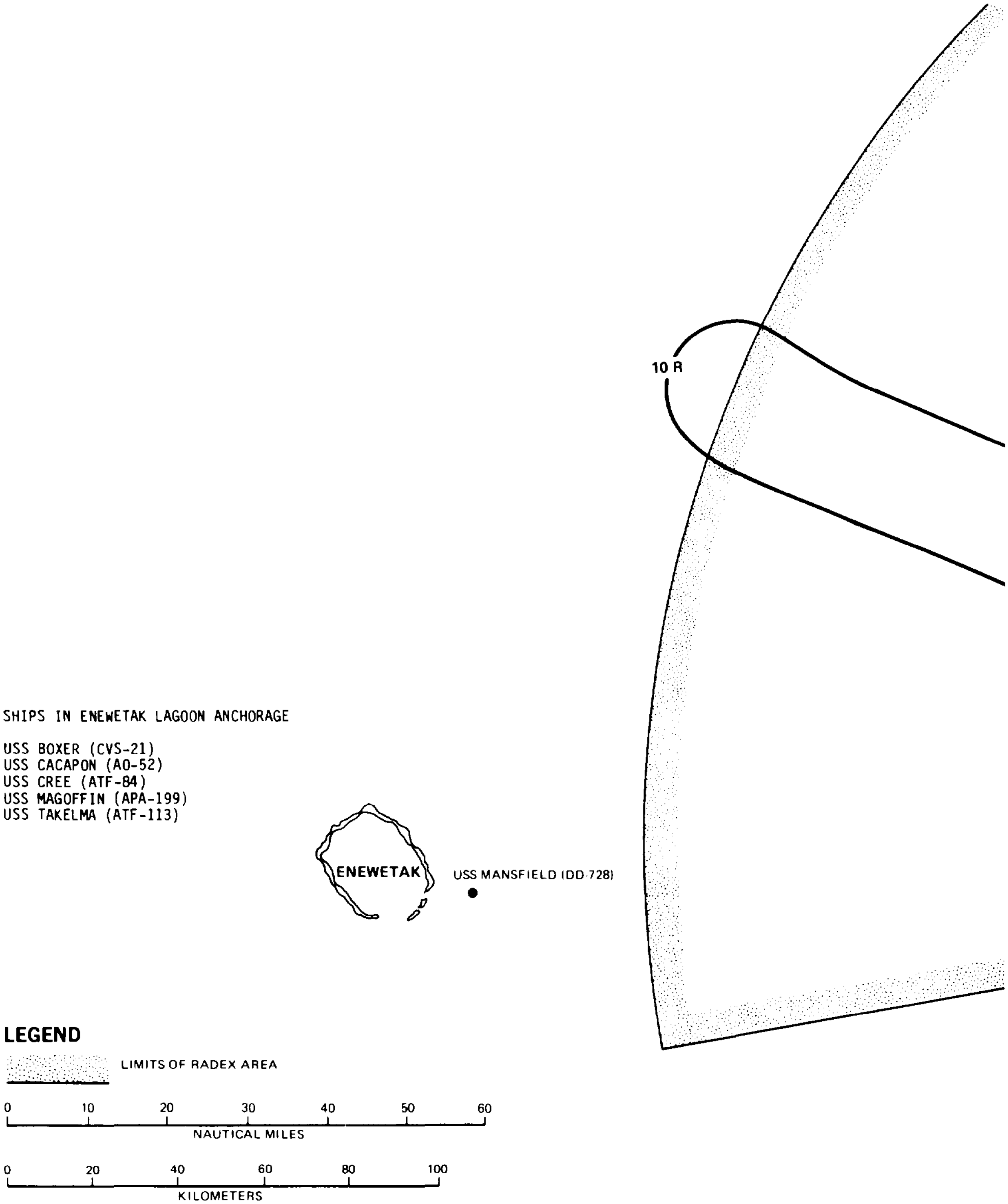


Figure 41. HICKORY predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 80 nmi (148.3 km) west
1	P2V	Barrier patrol	Wildroot 5	8,000	2.44	East-west racetrack 50-60 nmi (92.7-111.2 km) south
1	B-57B	Sampler control	Jagged	30,000	9.14	East-west racetrack 40-50 nmi (74.1-92.7 km) north
5	B-57B	Sampler	Hardtime 1-5	Not airborne at burst time		

Source: Reference C.4.1.

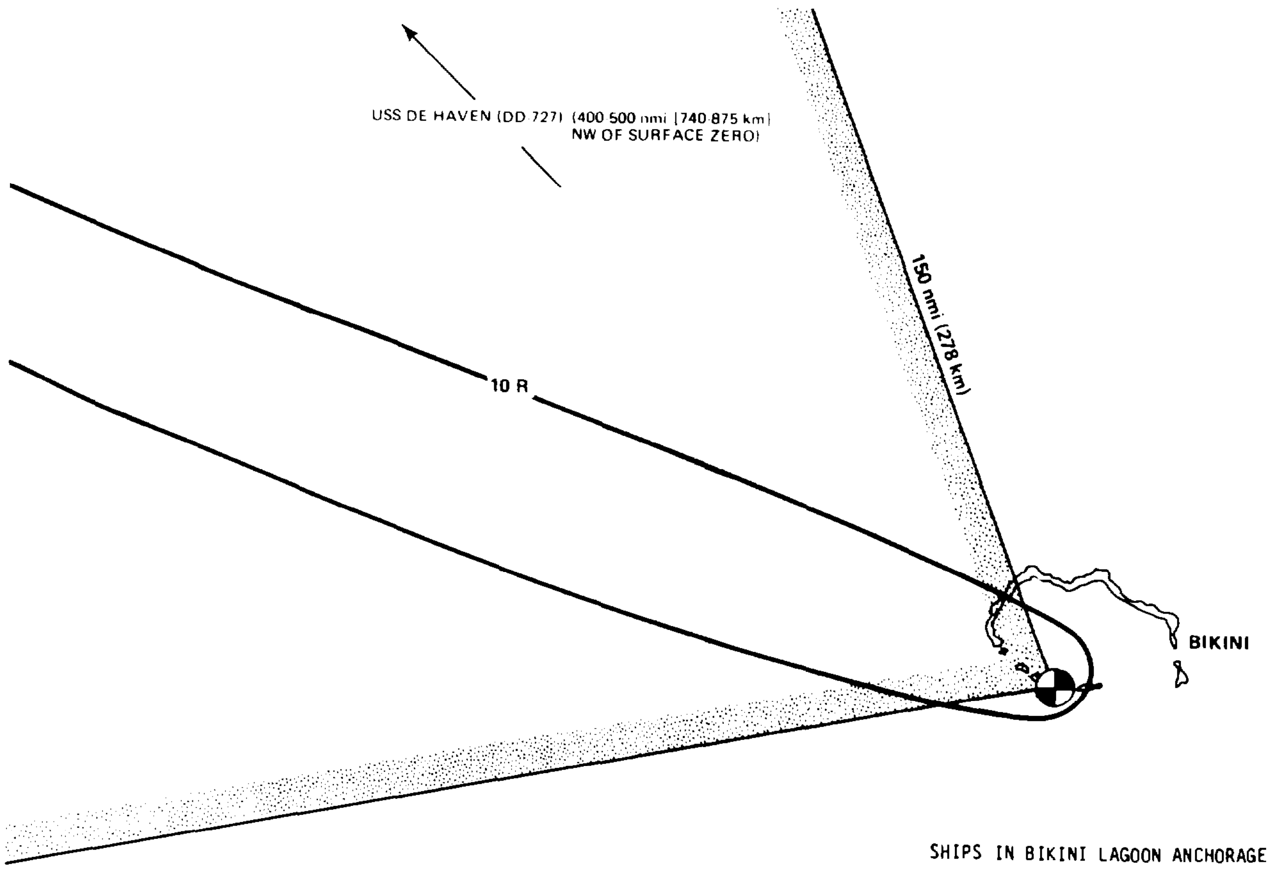


Figure 41. HICKORY predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 80 nmi (148.3 km) west
1	B-52	Project 5.1[a]	Watchdog	25,000	7.62	25,800 feet (7.86 km) ground range southeast
1	P2V	Barrier patrol	Wildroot 13	5,000	1.52	East-west racetrack 50-60 nmi (92.7-111.2 km) south
1	B-57B	Sampler control	Jagged	30,000	9.14	East-west racetrack 35-45 nmi (64.9-83.4 km) north
3	B-57B	Sampler	Hardtime 1-3 plus spare	Not airborne at burst time		
3	B-57D	Sampler	Hardtime 14-16	Not airborne at burst time		
1	SA-16	Sampler emergency	Stable 4			

Note:

[a]Reference C.1.1634.

Source: Reference C.4.1 except as noted.

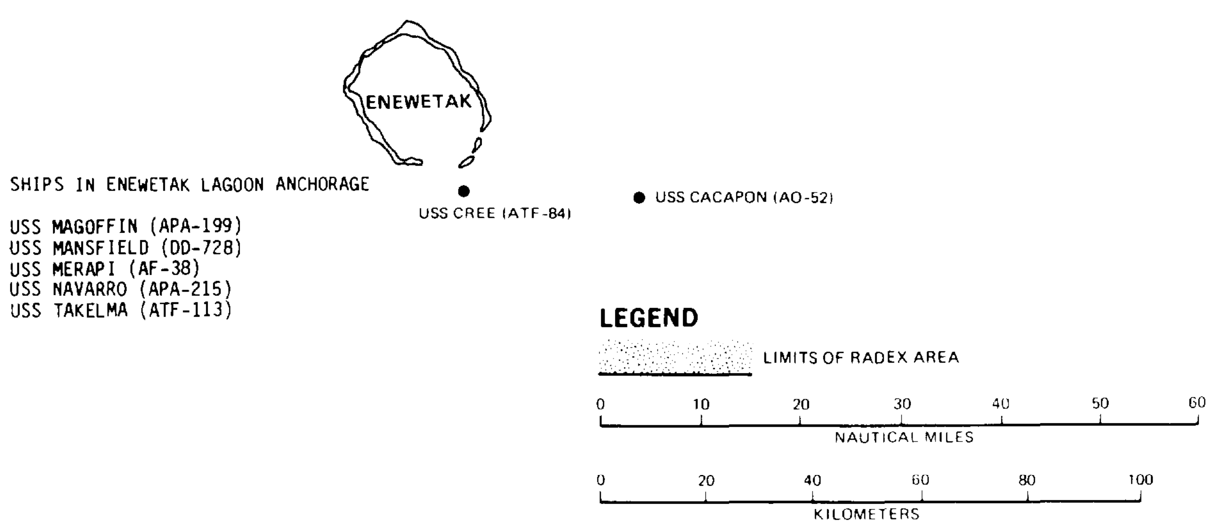


Figure 42. CEDAR predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

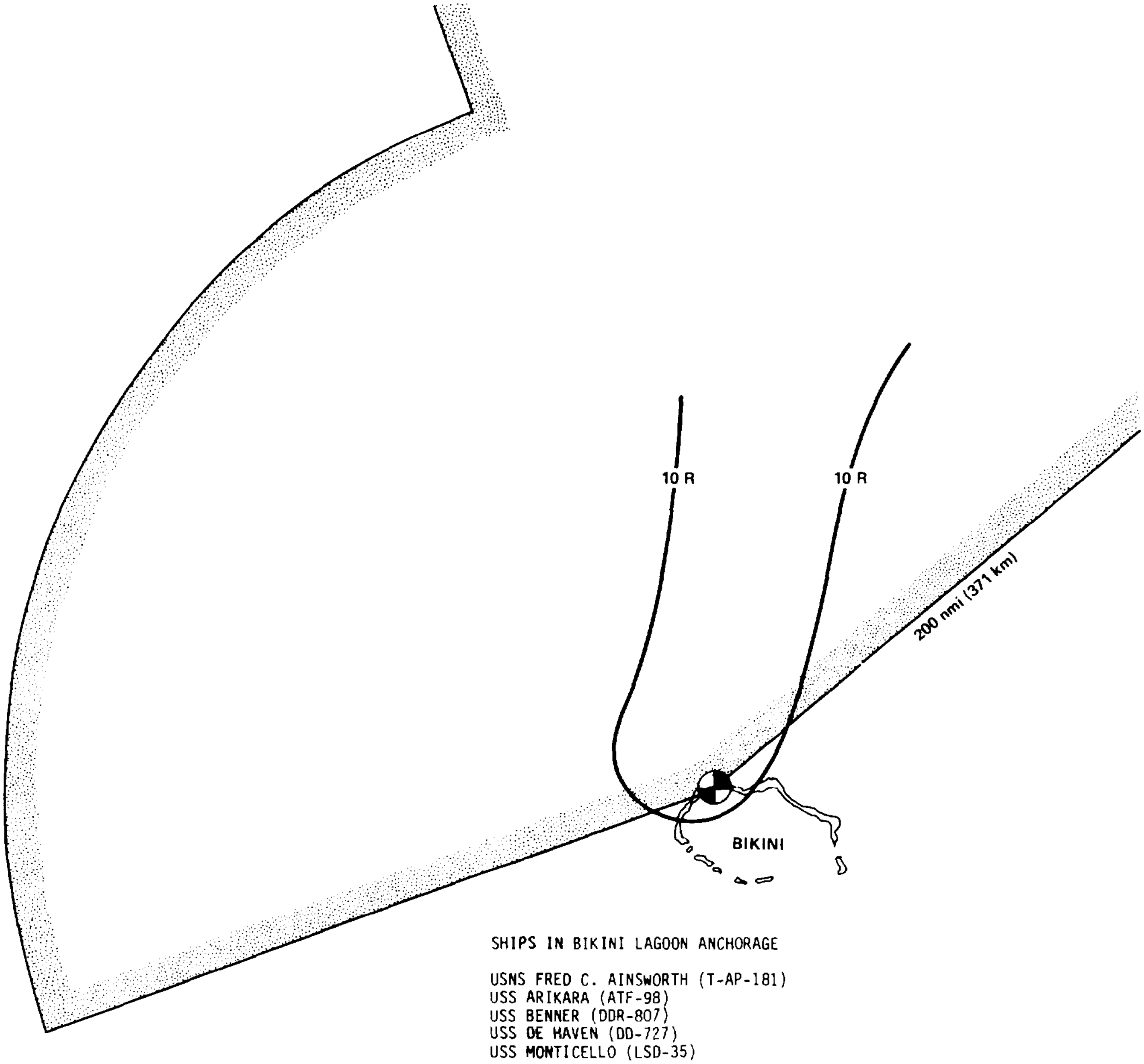


Figure 42. CEDAR predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

the event. The overpressure and thermal energy from HICKORY at Eneu were expected to be negligible. Ships remained in Bikini Lagoon.

The detonation cloud rose to 24,200 feet (7.4 km) with an estimated 12,000-foot (3.7-km) base. At 1230 over Eneu, the barrier patrol P2V reported that the cloud had moved outside the northwest corner of the atoll. The aircraft obtained zero readings on the eastern side of the atoll. Some isolated radioactive rainshowers were reported west of surface zero, and maximum radiation readings of 0.800 R/hr were reported over Bikdrin by 1305. The P2V then flew on a bearing of 260° from Bikini for 75 nmi (139 km), then north for 30 nmi (55.6 km) at 50 nmi (92.7 km) from surface zero to confirm the western extent of the fallout pattern. The actual fallout pattern was on a bearing of 265°, more southerly than predicted.

Radsafe operations were controlled through Benner located in Bikini lagoon. Radsafe helicopters took off at 1306 and obtained the following readings (R/hr) at H+3:

Bokbata	0.2	Lele	0.1
Nam	2.5	Eneman	0.8
Lomilik	8	Enidrik	20-40
Aomen	2	Lukoj	7.5
Bikdrin	0.01	Jelete	20.

Other atoll locations monitored showed no radiation.

Reentry hour was at 1330. Later in the evening, rain began to fall on Eneu and the background intensity began to rise slowly. A peak intensity of 0.0025 R/hr was reached at 2130, after which the intensity decreased (Reference C.5.3).

CEDAR

CEDAR was detonated on 3 July at 0530 on a barge in the BRAVO crater southwest of Nam, 4,000 feet (1.22 km) from the edge of the island. Surface winds were 16 knots (29.7 km/hr) from east-northeast. The detonation had been delayed 1 day because the shot barge was contaminated by fallout from the REDWOOD event.

The only DOD-sponsored experiment for CEDAR was Project 5.1, the B-52 experiment. The predicted fallout pattern is shown in Figure 42. Locations of fleet units at burst time, the surface radex area, and aircraft participation are also shown on Figure 42.

All personnel on the northern islands were evacuated to Eneu and Aerokoj for the shot. Ships remained in Bikini lagoon, and Ainsworth stood by for emergency evacuation of Eneu, if required.

The detonation produced a 50,000-foot (15.2-km) cloud with an estimated base of 35,000 feet (10.7 km). The barrier patrol P2V reported over Eneu by 0600 and flew over the lagoon at 1,000 feet (305 meters), recording its maximum reading of 0.049 R/hr at 0744 over Iroij. The plane then flew west for 90 nmi (166.7 km) after clearing the lagoon.

Radsafe operations were controlled through Benner, located in Bikini lagoon. The radsafe helicopters took off at 0700. Survey readings are summarized below (R/hr):

Bokbata	0.03	Eneman	22
Nam	0.4	Enidrik	22
Lomilik	18	Lukoj	1
Aomen	0.03	Jelete	0.15.

The readings at Lomilik, Eneman, Enidrik, and Lukoj may have been influenced by residue from the HICKORY shot. No radiation was recorded on any other island.

The FOPU predicted fallout along a bearing of 10^{o}; however, easterly winds began blowing at the lower altitudes causing light fallout along a westerly bearing. The barrier patrol P2V verified this fallout shift with readings from 0.020 to 0.090 R/hr out to 50 nmi (92.7 km) west of surface zero through 1200 (H+6:30).

Reentry hour was at 1100. A second SA-16 took off because both engines of a B-57 cloud sampler flamed out at 50,000 feet (15.4 km). The B-57 pilot managed to restart one and returned to Enewetak safely under escort by one of the SA-16s.

Radioactivity at Eneu began to rise after a rainshower in midafternoon; it was 0.004 R/hr at 1500, rising to 0.012 R/hr at 1645 and declining thereafter. The following morning at 0300 it was down to 0.005 R/hr. By noon on 5 July, radioactivity was 0.003 R/hr, and the next day it was 0.001 R/hr (Reference C.5.3.).

POPLAR

POPLAR was detonated on 12 July at 1530 on a barge southwest of Nam, 7,500 feet (2.29 km) from the edge of the island. Surface winds were 11 knots (20.4 km/hr) from east-northeast.

The only DOD-sponsored experiment for POPLAR was Project 3.7. The predicted fallout pattern, locations of fleet units at burst time, the surface radex area, and aircraft participation are shown in Figure 43.

All personnel and aircraft were evacuated from Bikini Atoll except communications and timing and firing personnel on Eneu. Ainsworth was the primary evacuation ship for POPLAR and berthed most of the personnel living ashore. Monticello, as flagship in Boxer's absence, evacuated Hq TG 7.1, TG 7.3, and TG 7.4 personnel and Marine Helicopter Transport Squadron (HMR[L]-361) personnel and others essential for prompt reentry. Boxer, which usually performed this function, had departed to Johnston Island to prepare for TEAK and ORANGE. Potentially damaging overpressure, thermal, and water-wave effects were expected both at Aerokoj and Eneu.

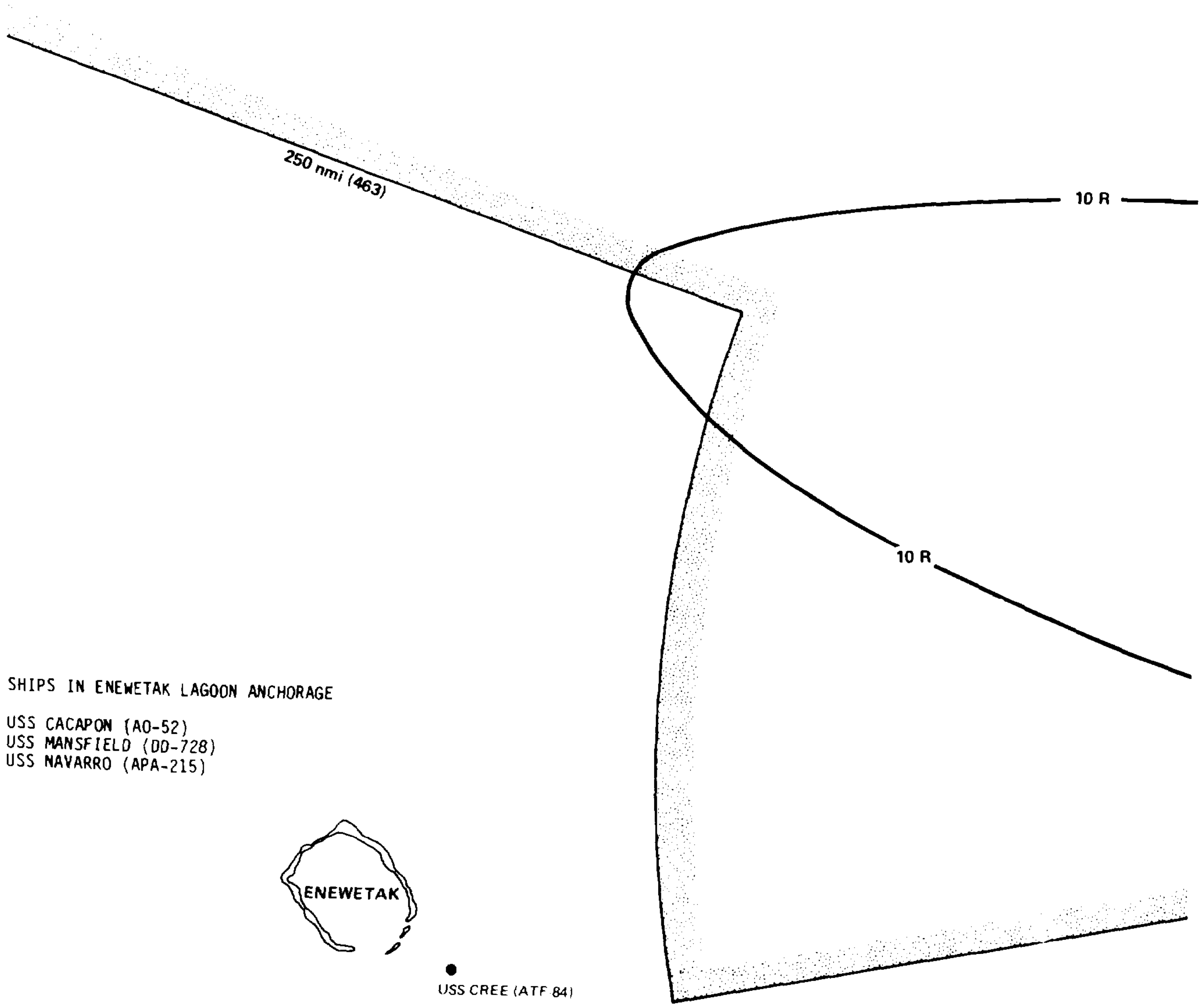


Figure 43. POPLAR predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	8,000	2.44	North-south racetrack 80 nmi (148.3 km) west
1	SA-16	USNS Fred C. Ainsworth, (T-AP-181) L-20 cover	Stable Cover	2,500	0.76	Orbit 45 nmi (83.3 km) southeast
3	L-20	Evacuatrd from Eneu		1,000	0.31	Orbit 45 nmi (83.3 km) southwest
1	C-54	Photo	Pewter 3	10,000	3.05	North-south racetrack 60-70 nmi (111.2-129.7 km) west
1	P2V	Barrier patrol	Wildroot 11	8,000	2.44	East-west racetrack 50-60 nmi (92.7-111.2 km) south
1	B-57B	Sampler control	Jagged	40,000	12.19	East-west racetrack 40-50 nmi (74.1-92.7 km) north
1	B-57B	Sampler photo	Hardtime photo	40,000	12.19	East-west racetrack 40-50 nmi (74.1-92.7 km) north
1	B-57B	Sampler	Hardtime 2	35,000	10.67	North-south racetrack 50-60 nmi (92.7-111.2 km) west
1	B-57B	Sampler	Hardtime 4	Not airborne at burst time		
4	B-57D	Sampler	Hardtime 11, 13,15,16	Not airborne at burst time		
1	P2V	Barrier patrol	Wildroot	Northwest of Bikini until midnight		

Source: Reference C.4.1.

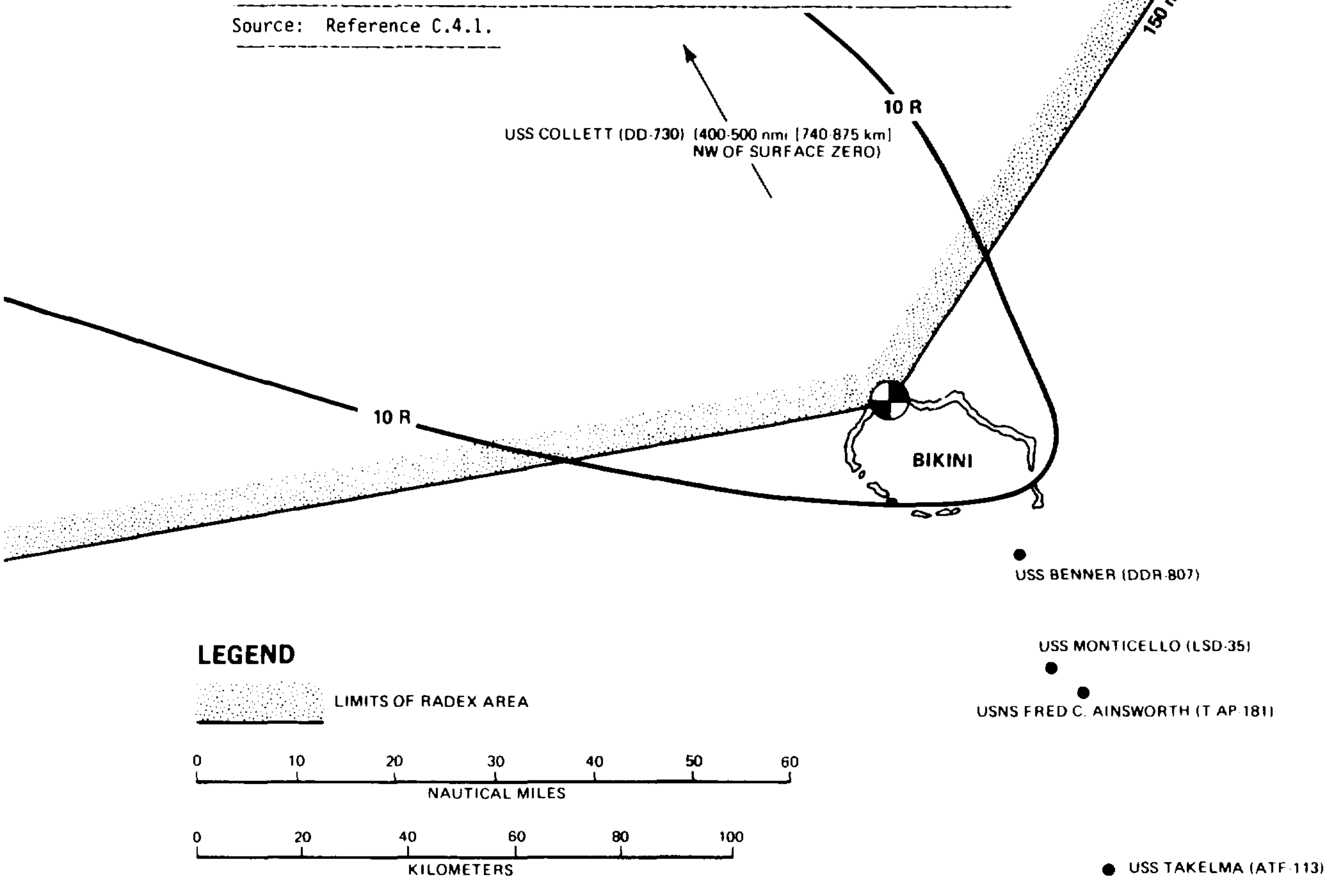


Figure 43. POPLAR predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

Participating aircraft included an SA-16 (Stable Bravo) that flew search and rescue (SAR) missions and another SA-16 (Stable Cover) that watched over three TG 7.4 L-20s that orbited Ainsworth during the detonation and then returned to Eneu airstrip.

The detonation cloud quickly rose above the tracking radar limits of 61,000 feet (18.6 km), and the base was established at 42,000 feet (12.8 km) at 1540.

The P2V reported over Bikini at 1650 and flew between Bikini and Aerokoj islands recording only background radiation. The plane then proceeded outbound on a bearing of 260° from Aerokoj for 40 nmi (74 km) and recorded a high reading of 0.100 R/hr. By 1745, the Bikini Atoll chain except for surface zero had been surveyed at 1,000 feet (305 meters), with Iroij reading 0.045 R/hr. Initial helicopter surveys began at 0700 and 0745 the following day, and at 1500 a detailed survey was made. The first surveys revealed between 0.08 and 0.16 R/hr on Eneman and 0.38 R/hr on Jelete. The results of the detailed survey (R/hr) were:

Bokonejien	130	Eneman	0.4
Nam	1.8	Enidrik	0.16
Iroij	0.6	Jelete	0.04
Odrik	0.3	Oroken	0.05
Lomilik	1.5	Bokdrolul	0.13
Aomen	0.2		

Reentry hour was at 1945 on the second day.

Due to communication difficulties with the P2V, its mission was aborted. A second P2V, controlled through Enewetak Air Operations Center, took off and flew on a northwesterly bearing until midnight.

Some portion of the cloud apparently continued westward; just after midnight the radiation monitor at Parry Island at Enewetak registered an increase to 0.0018 R/hr at 0345 and the air monitor showed 20,000 CPM. By 0630 the reading decreased to 0.0015 R/hr and 2,000 CPM at 0630 (Reference C.5.3).

About 0900 on the following day, the radioactivity reading began to rise on a southbound Japanese cartographic research vessel about 270 nmi (500 km) west of Enewetak. Later, at 1700 the ship encountered a rainsquall that lasted 3 hours and raised the radiation level aboard the ship further, to what was calculated to be about 0.00031 R/hr (Reference C.0.4). This is about the same level as the average pre-HARDTACK background on the non-shot islands of Bikini Atoll (see Table 3). The ship, Takuyo Maru, was accompanied by Satuma (sometimes Satsuma) Maru, whose position was "nearby" (NY Times, July 27, 1958). The position of Takuyo was 153°45'E, 12°23'N at the time of the rainout (Reference C.0.4).

Because the ships were equipped with radiation detection instruments, the crews were aware of the contamination. On advice from Japan, decontamination began in the early hours of the next day. Decks were washed with a detergent and flushed with seawater and freshwater. Radiation levels on deck were reduced to less than one-third (in terms of "counts per minute") of the peak value, and those on the bridge to about one-half.

The task force was informed of the incident through the Commander in Chief, Pacific, and the AEC. Meanwhile, the ships had proceeded to Rabaul in New Britain and were joined there by medical representatives of JTF 7 on 25 July. These representatives were the Joint Task Force Staff Surgeon, the TG 7.4 Flight Surgeon, and an officer of the U.S. Public Health Service who was a health physicist acting as Radiological Safety Advisor for TG 7.5. With the help of the Australian authorities in Rabaul, who provided medical laboratory assistance, the medical officers examined the 50-man crew of Takuyo and the 62-man crew of Satuma and took blood and urine samples. The ships were monitored for radiation on 26 July. This was an intensive monitoring of external and internal spaces and showed levels that were the same as the radioactive background at Rabaul, between 0.00006 and 0.00007 R/hr, or lower. The exception to this was portions of a gun on Satuma that registered 0.10 R/hr (beta plus gamma) and 0.0012 R/hr (gamma only). This gun had been covered since the departure from Japan and the canvas covering showed only background readings. The Satuma captain informed the U.S. party that the radiating portions of the gun were of metal of U.S. origin (Reference C.0.4). The ships' drinking water had been brought from Japan and was not distilled from seawater en route.

The task force party left on 28 July after giving the Japanese a formal statement that their findings "did not indicate evidence of radiation sickness or any contamination . . . which should delay your departure or normal use of the vessels" (Reference C.0.4).

JUNIPER

JUNIPER, the last nuclear detonation to occur at Bikini, was detonated on 22 July at 1620 on a barge 4,000 feet (1.22 km) from the west end of Eneman in the ZUNI crater. Surface winds were 17 knots (31.5 km/hr) from the east.

No DOD-sponsored experiments were scheduled for JUNIPER. The predicted fallout pattern is shown in Figure 44, which also shows the locations of fleet units at burst time, the surface radex area, and aircraft participation.

All personnel from up-island locations and the Aerokoj camp were evacuated to Eneu before the detonation. Ships remained in Bikini lagoon.

The detonation cloud rose to 40,000 feet (12.2 km) with an estimated 24,000-foot (7.3-km) base. The P2V reported over Eneu at 1650 and flew to Bikini, Iroij, and Aerokojlol, recording only background readings. Some "hot spots" were encountered near surface zero with the highest reading 0.032 R/hr at 1720. The plane then flew on a westerly bearing as a barrier patrol.

A helicopter began to survey the southern island chain at 1800 and recorded its maximum reading of 150 R/hr at 200 feet (61 meters) over Jelete. The survey also noted 0.005 R/hr at Eneu and 0.1 R/hr at Lele at H+3. The FOPU predicted fallout along a bearing of 290°; however, the wind shifted to the south throughout the evening. The P2V encountered 1.3 R/hr at 1744, 30 nmi (55.6 km) due west of Aerokojlol. To verify this shift and notify Enewetak if necessary,

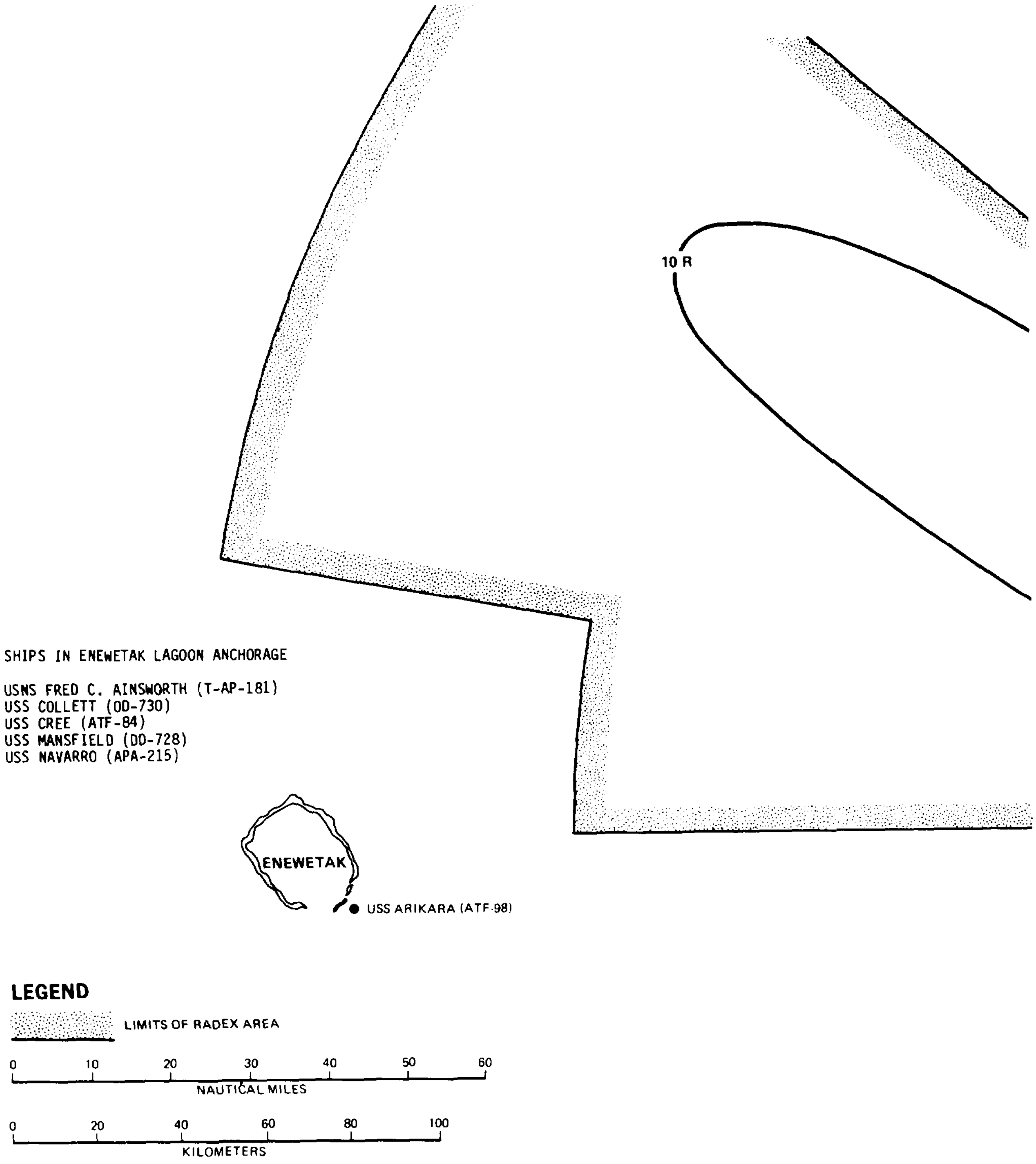
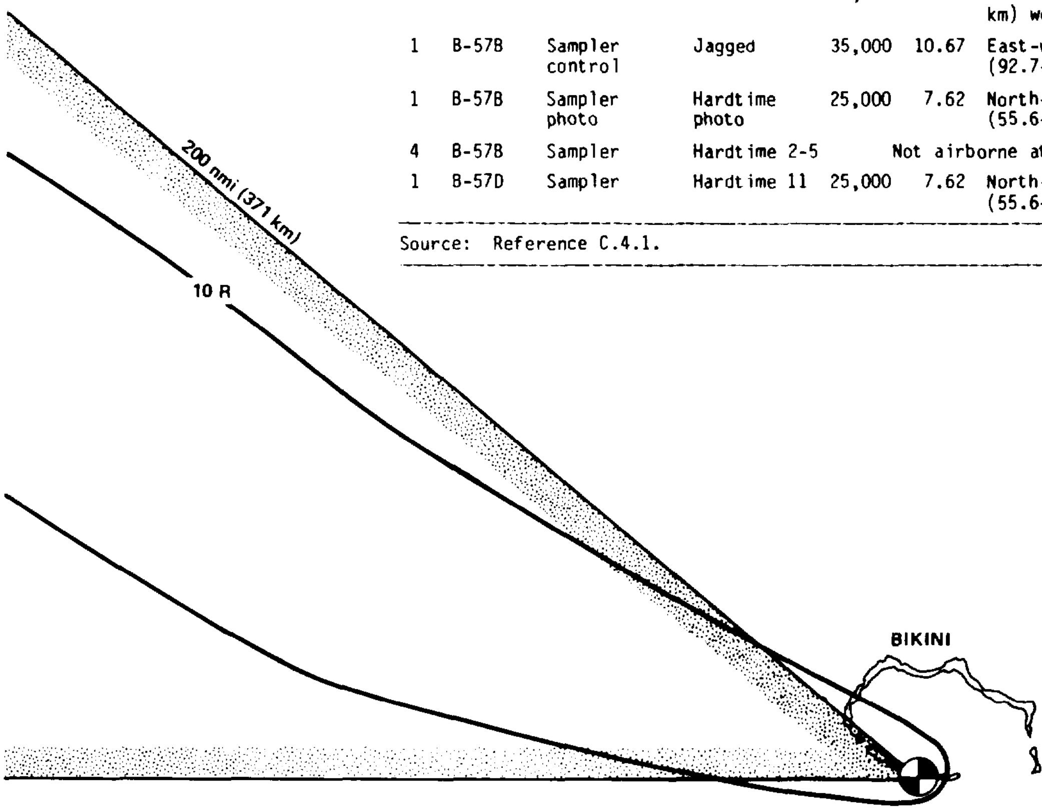


Figure 44. JUNIPER predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Bravo	9,000	2.74	North-south racetrack 80 nmi (148.3 km) west; aborted mission
1	SA-16	Search and rescue	Stable Bravo 2	9,000	2.74	North-south racetrack 80 nmi (148.3 km) west
1	P2V	Barrier patrol	Wildroot 4	8,000	2.44	East-west racetrack 50-60 nmi (92.7-111.2 km) south
1	C-54	Photo	Pewter 3	6,000	1.83	North-south racetrack 20 nmi (37 km) west
1	B-57B	Sampler control	Jagged	35,000	10.67	East-west racetrack 50-60 nmi (92.7-111.2 km) north
1	B-57B	Sampler photo	Hardtime photo	25,000	7.62	North-south racetrack 30-40 nmi (55.6-74.1 km) east
4	B-57B	Sampler	Hardtime 2-5	Not airborne at burst time		
1	B-57D	Sampler	Hardtime 11	25,000	7.62	North-south racetrack 30-40 nmi (55.6-74.1 km) east

Source: Reference C.4.1.



SHIPS IN BIKINI LAGOON ANCHORAGE

USS BENNER (DDR-807)
USS MONTICELLO (LSD-35)
USNS T-LST-664

Figure 44. JUNIPER predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK (continued).

the P2V worked on various tracks between Enewetak and Bikini until 0210 the next morning.

Reentry hour was at 1830.

ENEWETAK WEAPON DEVELOPMENT TEST OPERATIONS

In the concept of two-atoll testing adopted in 1954, Enewetak was to be the site of smaller-yield tests. In 1958, however, there was a change of policy, and some very-large-yield tests were conducted at Enewetak.

In the planning stage, Enewetak was to be the Los Alamos Scientific Laboratory (LASL) weapon development test site; however, because the weather at Bikini was unfavorable five UCRL tests were switched to Enewetak.

The weapon development shots at Enewetak had greater DOD participation than did the Bikini tests. The last two shots (QUINCE and FIG) were UCRL tests in which the DOD shared sponsorship, and a number of DOD projects participated in the four non-barge shots.

Test Sites

The area used for testing at Enewetak was the same as had been used for weapon testing since 1948: the arc extending from Runit to Enjebi and the group of islands just west of Enjebi at the extreme northern edge of the atoll. The islands themselves were used as detonation points for only four of the shots; the remainder were conducted on barges moored in three areas in the lagoon. The first of these barge areas was west of Runit, where four shots were fired at distances of from 1,000 to 10,000 feet (0.31 to 3.05 km) west of the island's center. The second area for barge shots was in the lagoon southwest of Enjebi 4,000 to 8,500 feet (1.22 to 2.59 km) from its southwest tip, from which seven shots were fired. These locations were about equidistant from Boken and Enjebi. The last barge location was on the reef 21,000 feet (6.40 km) southwest of Bokoluo where one shot was fired. The ground-surface tests included one on Dridrilbwij in the northern part of the atoll and three on Runit in the eastern part.

Evacuation

Northern island advance camps were set up to support work on the ground-surface shots. The task force population at the camp on Enjebi peaked at about 200 men just before the series began, declining to about 150 in early May when it was closed. This camp supported workers involved in the KOA site preparations on Dridrilbwij. An advance camp on Runit supported preparations for the CACTUS test and had a peak population of 275 before testing began. The total was about 175 in early May when it was closed.

Personnel from these northern island camps, as well as personnel who may have berthed aboard houseboats while working on shot barges, were evacuated to the base islands, Japtan, Parry, and Enewetak, before each shot. A small group remained in an instrumented site on Ananij, the closest occupied location. The base island camps were never evacuated, although an emergency evacuation capability was maintained.

During the May and June weapon development shots, considerable activity in the lagoon and just outside was related to the underwater shots, WAHOO and UMBRELLA. This activity centered on preparation, mooring, and recovery of target ships and involved a number of Navy ships based in Enewetak Lagoon anchorage. Logs of these ships often indicate that one of the weapon development shots was observed and some note that a potentially hazardous activity such as fuel transfer was stopped during the shot period. Usually, however, their activities proceeded independently of the shots being detonated in the area of the upper islands of the atoll.

Recovery and Reentry

All recovery and reentry operations were controlled from the base camp at Parry.

THE ENEWETAK SHOTS

Table 15 summarizes the Enewetak detonations. Yields for only four have been announced. As with the preceding section on the Bikini shots, all information on predicted fallout, cloud movement, and measured fallout has been extracted from the Operation HARDTACK Radiological Safety Final Report (Reference C.1.6.2).

CACTUS

CACTUS, detonated on 6 May at 0615, was the first Enewetak detonation of the HARDTACK series. It was a land-surface burst from a platform on the coral soil of Runit (Figure 16), with a yield of 18 KT. Surface winds were from the east at 14 knots (25.9 km/hr) at H+45 minutes.

The DOD-sponsored experiments for CACTUS were Projects 1.4, 1.7, 1.8, 1.9, 1.12, 2.8, 5.2, 5.3, 6.5, and 6.6. The instrument stations were all on Runit except those of Project 2.8, which had remotely operated, rocket-firing stations on Billae, Aomon, and Bokenelab. Details of the experimental projects are in Chapter 3. The predicted fallout pattern is shown in Figure 45, which also shows locations of fleet units at burst time and predicted surface radex area. Aircraft participation is shown in Table 16.

The detonation cloud reached an altitude of 19,000 feet (5.8 km) in the first 10 minutes, stabilizing at 15,000 feet (4.6 km) by H+20 minutes. Radar tracking began while the cloud was over the lagoon and indicated a west-southwesterly drift. The cloud divided into two parts at H+23 minutes and continued its west-southwesterly movement at 18 knots (33.4 km/hr).

At H+1 the cloud stretched across the lagoon from Runit to Biken at 5,000 to 10,000 feet (1.5 to 3.0 km). A thin dust cloud appeared northeast of Runit at high altitude, but radar or aircraft reports were unobtainable. By H+2, the cloud was well scattered and by H+3 almost completely dispersed.

The helicopter surveys at H+3 and H+5 indicated zero readings for all of the main islands except for Runit, Biken, and and the coral head, Unibor. The readings (R/hr) for Runit displayed the following pattern:

Table 15. HARDTACK Enewetak weapon development detonations, 1958.

Name	Local Time	Date	Location
CACTUS[a]	0615	6 May	Surface of north tip of Runit
BUTTERNUT	0615	12 May	4,000 feet (1.21 km) WSW of center of Runit
KOA[b]	0630	13 May	Surface of Dridrilbwij in large water tank
HOLLY	0630	21 May	2,000 feet (610 meters) WSW of center of Runit
YELLOWWOOD	1400	26 May	6,000 feet (1.83 km) SW of southwest tip of Enjebi
MAGNOLIA	0600	27 May	3,000 feet (914 meters) WSW of center of Runit
TOBACCO	1415	30 May	4,000 feet (1.22 km) SW of southwest tip of Enjebi
ROSE	0645	3 June	4,000 feet (1.22 km) WSW of center of Runit
WALNUT	0630	15 June	6,000 feet (1.83 km) SW of southwest tip of Enjebi
LINDEN	1500	18 June	4,000 feet (1.22 km) WSW of center of Runit
ELDER	0630	28 June	1 nmi (1.85 km) SW of southwest tip of Enjebi
OAK[c]	0730	29 June	21,000 feet (6.40 km) SW of Bokoluo
SEQUOIA	0630	2 July	2,000 feet (610 meters) WSW of center of Runit
DOGWOOD[d]	0630	6 July	4,000 feet (1.22 km) SW of southwest tip of Enjebi
SCAEVOLA[e]	1600	14 July	W of Runit
PISONIA	1100	18 July	10,000 feet (3.05 km) W of center of Runit
OLIVE[d]	0830	23 July	4,000 feet (1.22 km) SW of southwest tip of Enjebi
PINE[d]	0830	27 July	8,500 feet (2.59 km) SW of southwest tip of Enjebi
QUINCE[f]	1415	6 August	Surface, center of Runit
FIG[f,g]	1600	18 August	Surface, center of Runit

Notes:

[a] Yield 18 KT.

[b] Yield 1.37 MT.

[c] Yield 8.9 MT.

[d] UCRL device.

[e] Low-yield safety experiment.

[f] UCRL device, joint DOD sponsorship.

[g] Detonated over Nevada Test Site soil shipped from the Nevada Test Site.

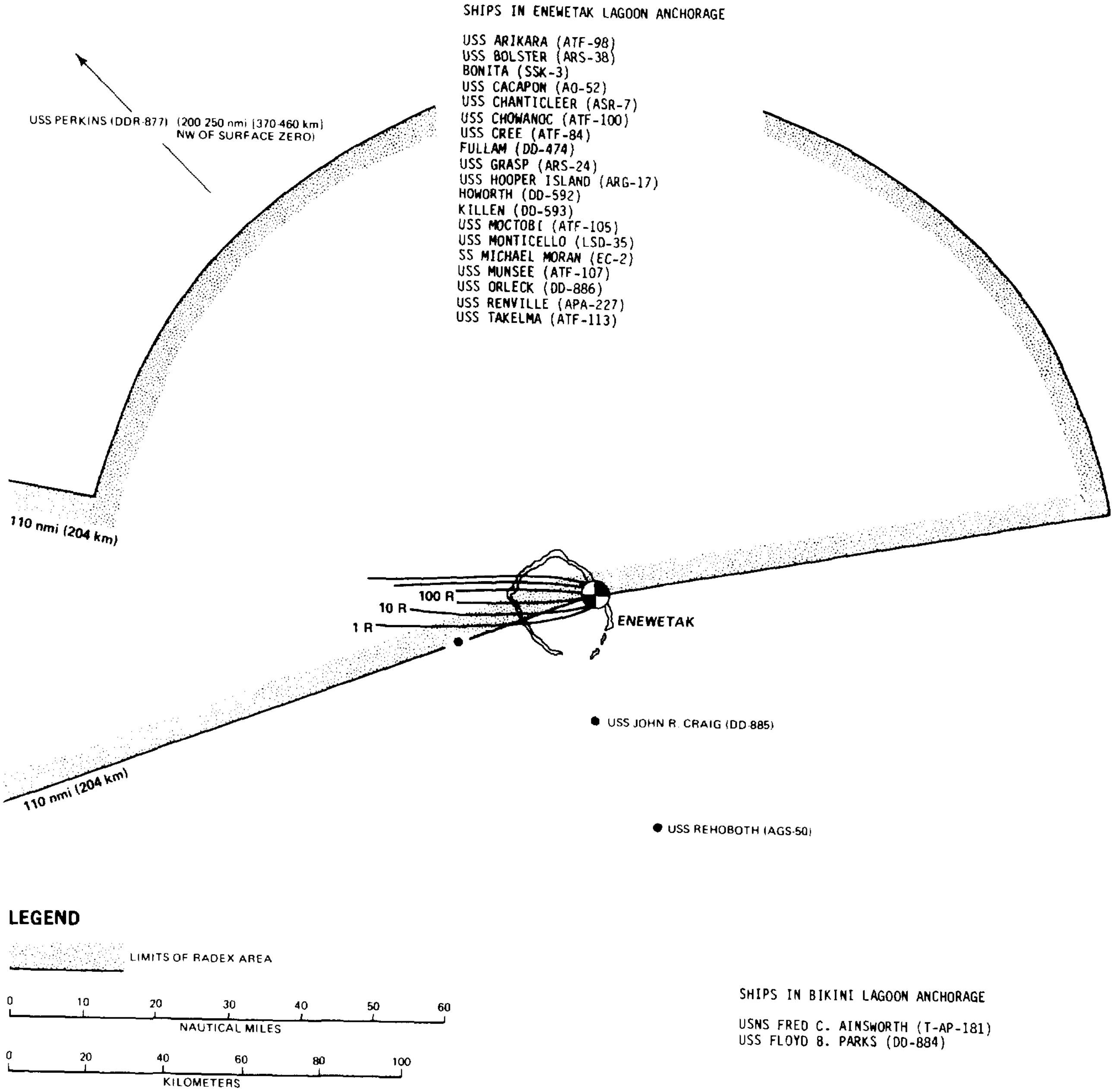


Figure 45. CACTUS predicted fallout, surface radex area, and ship positions, Operation HARDTACK.

Table 16. Aircraft participation in HARDTACK, CACTUS.

No.	Type/ Tail No.	Mission	Call Sign	Zero-Time Location Relative to Burst: Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable 7	7,000	2.13	North-south racetrack 30 nmi (55.6 km) east
1	WB-50		Massive 4	1,000-12,000	0.30-3.66	North-south racetrack 40 nmi (74.1 km) east
1	FJ-4/467	Project 5.3[a]	Kimono 2	4,164	1.27	9,109 feet (2.78 km) slant range
1	FJ-4/310	Project 5.3[a]	Kimono 1	8,238	2.51	9,612 feet (2.93 km) slant range
1	A4-D/827	Project 5.2[b]	Clark 1	3,000	0.9	8,930 feet (2.72 km) slant range
1	A4-D/831	Project 5.2[b]	Clark 2	10,410	3.17	10,410 feet (3.17 km) slant range
2	B-57B	Sampler control	Opium, Opium Bravo	15,000	4.57	East-west racetrack 30-40 nmi (55.6-74.1 km) north
4	B-57B	Sampler	Hotshot 4,5, 7,8	Not airborne at burst time		
1	B-57B	Sampler	Hotshot 10	Not airborne at burst time		
1	P2V	Barrier patrol	Wildroot	Not airborne at burst time		
1	RB-50	Photo	Carter 2	Not airborne at burst time		

Notes:

[a]Reference C.1.1636.

[b]Reference C.1.1635.

Source: Reference C.4.1 except as noted.

	H+3	H+5
North end (over burst point)	440	240
Mid-island	1.7	0.8
Southern tip	0.005	0

The H+3 survey revealed 0.85 R/hr at Biken, and 0.1 R/hr at Unibor.

The fallout forecast was accurate in extent and intensity. The main axis of the cloud was forecast to lie across the lagoon at a 270° angle; the actual angle was 250°. All of the fallout dropped within the area announced by the FOPU on D-1. Reentry hour was scheduled for 6 May at 1015. From H+6 to H+24, a 1-nmi (1.85-km) radius circling surface zero was considered the radex area.

BUTTERNUT

BUTTERNUT was detonated at 0615 on 12 May shortly after FIR had been fired at Bikini. BUTTERNUT was fired on a barge 4,000 feet (1.22 km) west of Runit. Surface winds were 12 knots (22.2 km/hr) from the east.

DOD-sponsored experiments for BUTTERNUT were Projects 5.1, 5.2, 5.3, 6.5a, 6.6, and 6.9. One of these projects required northern island stations. The predicted fallout pattern, locations of fleet units at shot time, surface radex area, and aircraft participation are shown in Figure 34.

The cloud rose to 35,000 feet (10.7 km), stabilizing at 30,000 feet (9.1 km). The main part of the cloud moved northwest, depositing most of the fallout in the open ocean.

Fallout was forecast to be over the entire northern half of Enewetak Atoll. However, only the northwest quadrant of the atoll received substantial contamination. Nearly all of the fallout was contained between 260° and 300° from surface zero. The radsafe helicopter survey results (R/hr) were:

	H+3	H+5		H+3	H+5
Bokoluo	0.65	0.24	Billae	0.001	
Bokombako		0.01	Runit	0.012	0.04
Kirunu		0.004	Biken		0.035
Louj		0.002	Unibor		<0.1
Bokinwotme		0.002	Drekatimon		30.0
Boken	0.002				

Personnel from the camp at Runit were evacuted to Parry before the shot. BUTTERNUT reentry was scheduled for 12 May at 1035. Ship and boats were notified to avoid the area 1 nmi (1.85 km) in radius around surface zero.

KOA

KOA was detonated at 0630 on 13 May at the west end of Dridrilbwij. The device was fired inside a large tank of water and had a yield of 1.37 MT. Surface winds were 16 knots (29.7 km/hr) from the northeast.

The DOD sponsored 15 experiments for KOA: Projects 1.4, 1.7, 1.8, 1.9, 1.12, 2.9, 3.2, 3.6, 5.1, 5.3, 6.4, 6.5, 6.6, 6.9, and 6.11. Instrumentation sites for the Program 1 structures projects were located on Bokaidrikdrik and Boken, close in to the burst point. The remaining DOD projects were either airborne or had data collection activities considerable distances from the burst point. For details of these project activities, see Chapter 3. The predicted fallout pattern is shown in Figure 46, which also shows the surface radex area and locations of fleet units at shot time. The extensive aircraft participation is given in Table 17. Not only were the usual SAR, barrier patrol, and sampler control aircraft present, but effects aircraft and an additional P2V to help locate Project 2.8 rocket nosecones were also used.

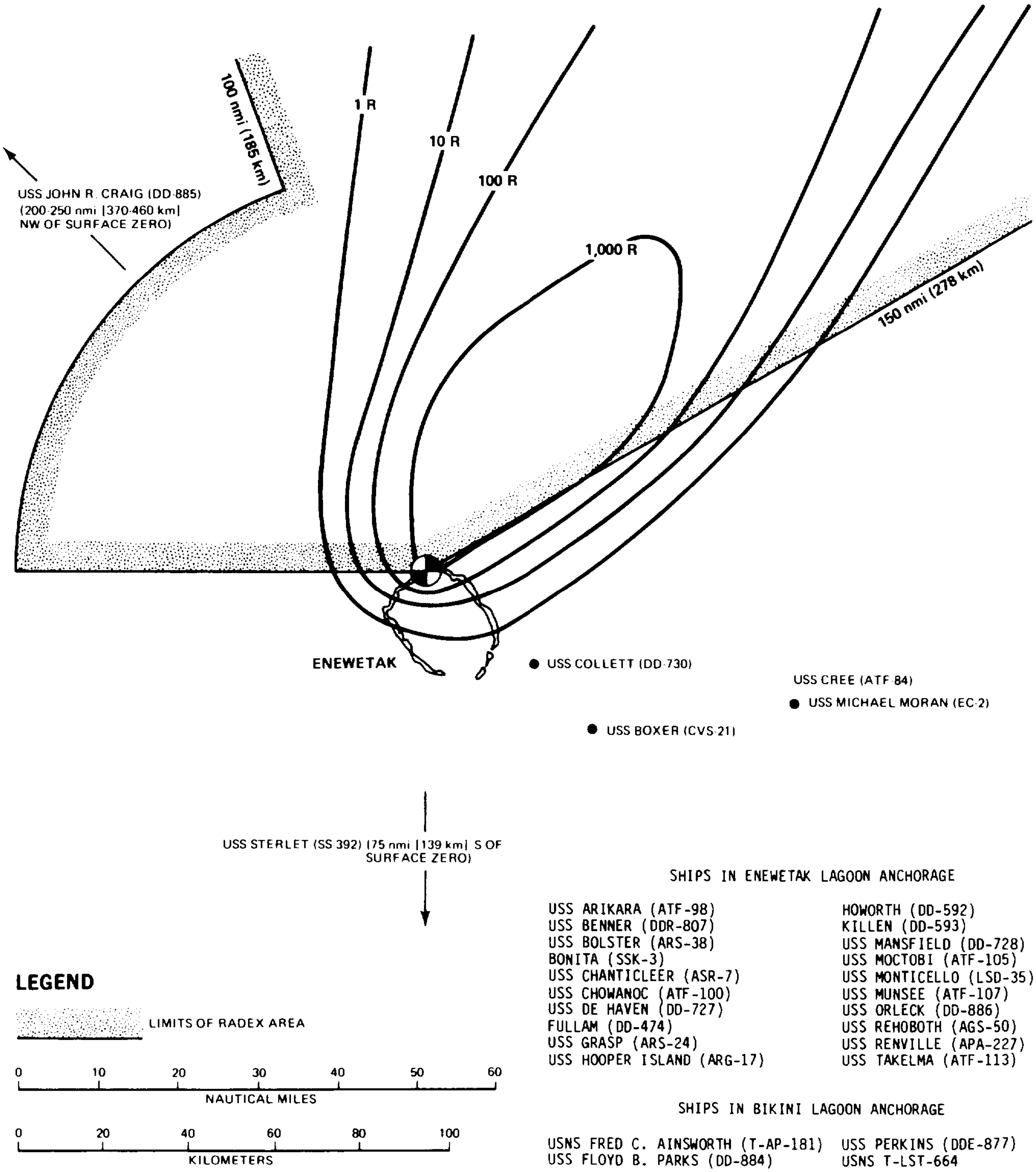


Figure 46. KOA predicted fallout, surface radex area, and ship positions, Operation HARDTACK.

Table 17. Aircraft participation in HARDTACK, KOA.

No.	Type/ Tail No.	Mission	Call Sign	Zero-Time Location Relative to Burst: Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	Northwest-southeast racetrack 40 nmi (74.1 km) northeast
1	P2V	Barrier patrol	Student	9,000	2.74	North-south racetrack 20 nmi (37.1 km) east
1	C-54	Photo	Pewter 2	6,000	1.83	North-south racetrack 40 nmi (74.1 km) west
1	C-54	Photo	Pewter 3	8,000	2.44	Northeast-southwest racetrack 40 nmi (74.1 km) northwest
1	B-52	Project 5.1[a]	Watchdog	30,000	9.14	125,000 feet (38.10 km) ground range
1	A-4D/827	Project 5.2[b]	Clark	3,000	0.91	19,800 feet (6.03 km) slant range
1	A-4D/831	Project 5.2[b]	Barley	12,000	3.66	18,550 feet (5.65) km slant range
1	FJ-4/467	Project 5.3[c]	Cobalt	4,000	1.12	19,264 feet (5.87 km slant range
1	FJ-4/310	Project 5.3[c]	Kimono	16,000	4.88	24,020 feet (7.32 km) slant range
1	B-57B	Sampler control	Opium	35,000	10.67	East-west racetrack 30 nmi (55.6 km) north
4	B-57B	Sampler	Hotshot 1-4	Not airborne at burst time		
4	B-57D	Sampler	Hotshot 15-18	Not airborne at burst time		
1	WB-50	Project 2.8 low-altitude sampler	Massive	Not airborne at burst time		
1	WB-50	Project 2.8 low-altitude sampler	Wilson Special	Not airborne at burst time		
1	P2V	Barrier patrol	Wildroot 21	Not airborne at burst time		

Notes:

[a]Reference C.1.1634. [b]Reference C.1.1635. [c]Reference C.1.1636.

Source: Reference C.4.1 except as noted.

Ships remained in the lagoon and all personnel except those authorized to remain on Ananij were evacuated to Enewetak, Parry, and Japtan islands.

The detonation cloud rose to 60,000 feet (18.3 km) at H+17 minutes northwest of Dridrilbwij. The main segment of the cloud moved north at 30,000 feet (9.1 km) within the first hour.

The initial helicopter survey was completed at 1030. Maximum ground readings of 40 R/hr were recorded on Bokombako. Other northern atoll islands had readings from 0.130 R/hr on Aomen to 50 R/hr on Boken. Radsafe surveys are summarized in Table 18.

Fallout was collected by a WB-50 assisting Project 2.8 at an altitude of 1,000 feet (305 meters) between the bearings 50° to 60° east-northeast of the burst point at ranges of 23 to 131 nmi (43 to 243 km) from surface zero from H+4 to H+12. A second Project 2.8 WB-50 collected a fallout sample also at 1,000 feet in a more northerly direction (20° bearing from burst point) 42 nmi (78 km) from surface zero. A WB-50 sent the following day flew in the same northeasterly direction (bearings 40° to 60°) to a range of 400 nmi (741 km) but found no fallout during a 6-hour search. The maximum offsite reading was 0.0015 R/hr at Rongelap.

Fallout was recorded at Enewetak the morning following KOA, but was apparently the result of the FIR shot on 12 May at Bikini. This is further discussed in this chapter under the FIR shot.

Table 18. HARDTACK, KOA radsafe survey summary (R/hr).

Island	H+4	D+1	D+2
Bokoluo		4.1	2.0
Bokombako	40	7	4
Bokaidrikdrik		16	16
Boken	50	3.4	12
Enjebi	14	2.6	1
Kidrinen		0.76	0.4
Bokenelab	2.1	0.18	0.1
Aej		0.16	
Eleleron		0.052	
Aomon	0.13		
Billae		0.18	
Runit			3.2
Biken	0.4		0.36
Unibor	<0.1		
Drekatimon	<0.1		

HOLLY

HOLLY was detonated at 0630 on 21 May on a barge west of Runit, 4,000 feet (1.22 km) from the nearest edge of the island. Surface winds were 16 knots (29.7 km/hr) from the east.

Project 6.6, the only DOD-sponsored experiment for HOLLY, was conducted on Enewetak Island. The predicted fallout pattern, the surface radex area, locations of fleet units at shot time, and aircraft participation are shown in Figure 47.

Parry, Enewetak, and Japtan islands were not evacuated. The LCUs and YTBs berthed alongside larger units by 2200 on D-1 to receive safety instructions. All other boats were secured by 2200 and their crews remained ashore for muster before shot time. The rest of the ships remained in Enewetak Lagoon.

The detonation produced a 15,000-foot (4.6-km) cloud that stabilized by H+15 minutes at an altitude of 12,000 feet (3.7 km) at the top and 7,500 feet (2.3 km) at its base. By H+30 minutes the cloud descended to 9,000 feet (2.7 km) and moved west-southwest. Before H+1, the cloud was too diffused for radar or visual tracking.

At H+55 minutes the barrier patrol P2V made contact with the southern edge of the cloud over Biken and recorded 0.500 R/hr at 5,000 feet (1.52 km). The results of the helicopter radsafe surveys at H+6.5 and H+26 were (R/hr):

	H+6.5	H+26
Bokoluo	0.28	
Bokombako	0.39	
Bokaidrikdrik	0.9	0.7
Boken	0.25	0.25
Enjebi	0.17	0.16
Kidrinen	0.050	0.050
Bokenelab		0.024
Aomon		0.004
Runit	1.0 - 2.5	0.015 - 0.9
Unibor	1.5 - 4.0	
Drekatimon	<0.100	

YELLOWWOOD

YELLOWWOOD was detonated at 1400 on 26 May 1958 on a barge 5,000 feet (1.52 km) southwest of Enjebi. Surface winds were 14 knots (25.9 km) from the east.

The DOD sponsored 13 experiments for YELLOWWOOD: Projects 2.4, 2.8, 3.7, 5.1, 5.2, 5.3, 6.4, 6.5, 6.6, 6.8, 6.9, 6.11, and 8.1. Instrument stations for Project 2.4 were located on buoys in the lagoon. The remaining projects had more distant stations or were primarily airborne. Details of the more distant stations or were primarily airborne. Details of the experimental projects are in Chapter 3. Figure 48 shows the predicted fallout pattern for YELLOWWOOD as well as locations of fleet units at burst time and the surface radex area. Aircraft participation is given in Table 19.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
2	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 25 nmi (46.3 km) east
1	B-57B	Sampler control	Opium 1	15,000	4.57	East-west racetrack 15 nmi (27.8 km) north
1	C-54	Photo	Pewter 3	7,000	2.13	
2	B-57B	Sampler	Hotshot 1,2,			Not airborne at burst time
2	B-57D	Sampler	Hotshot 13,14			Not airborne at burst time
1	P2V	Barrier patrol	Wildroot 5			Not airborne at burst time

Source: Reference C.4.1.

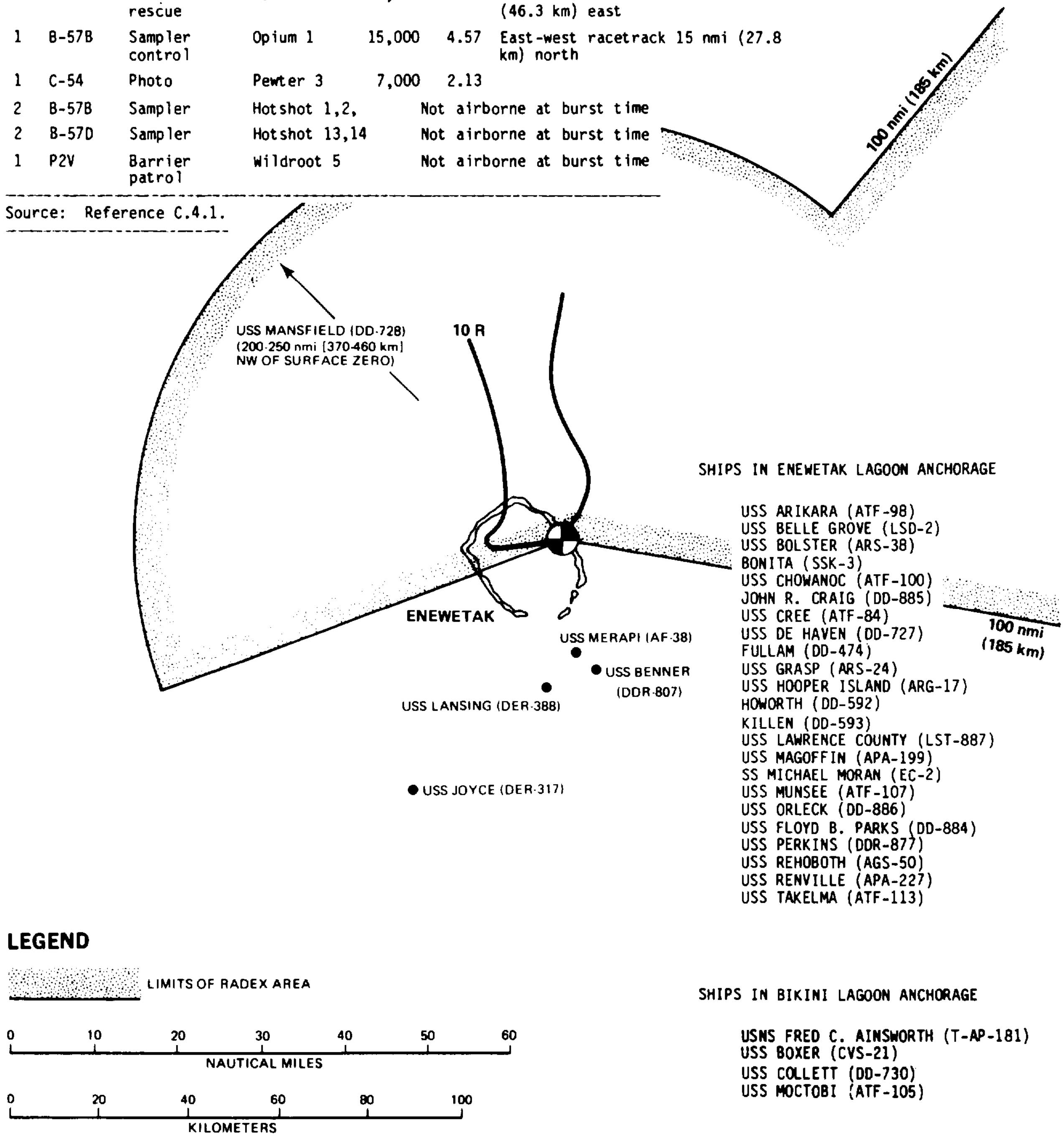


Figure 47. HOLLY predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

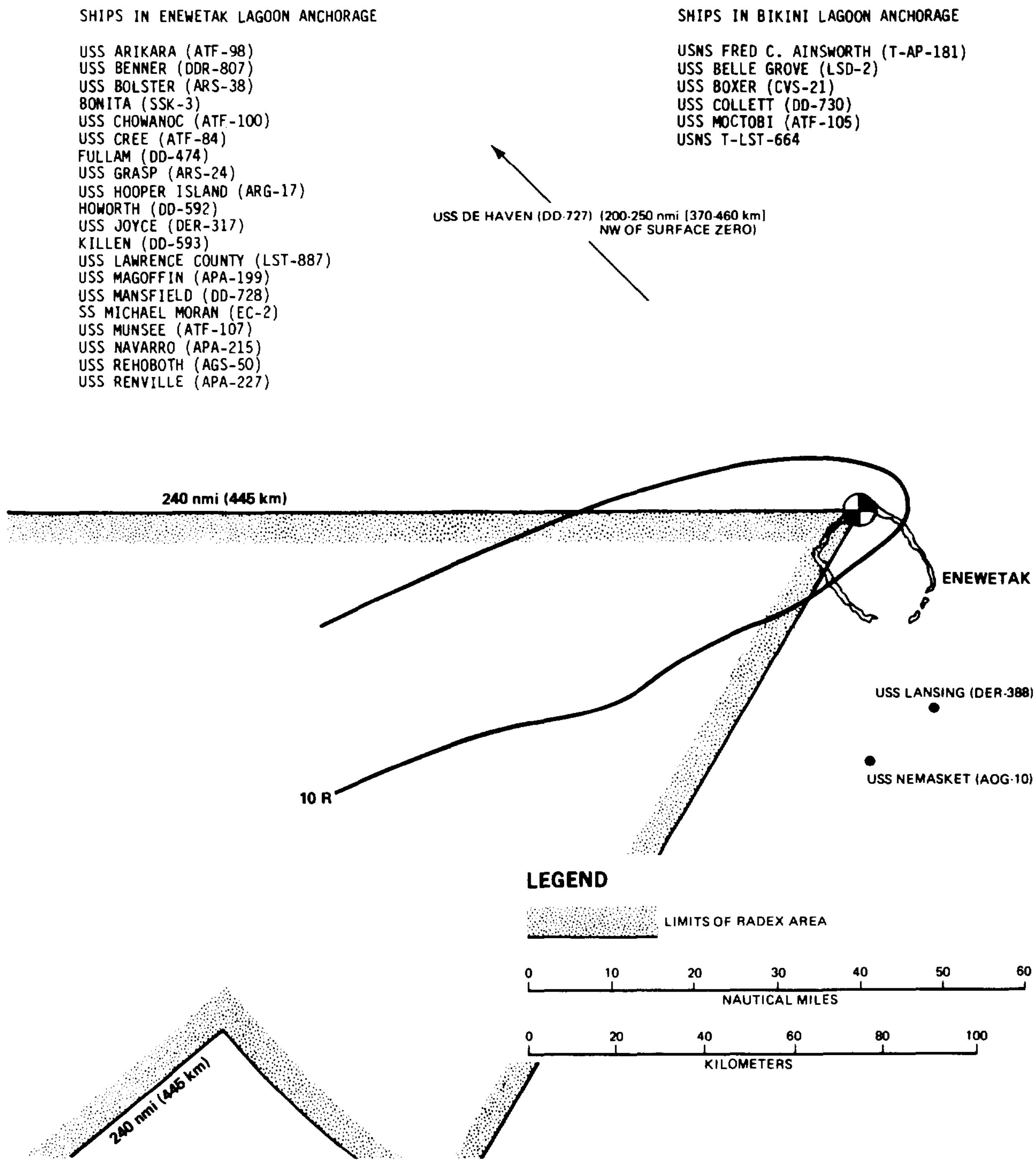


Figure 48. YELLOWWOOD predicted fallout, surface radex area, and ship positions, Operation HARDTACK.

Table 19. Aircraft participation in HARDTACK, YELLOWWOOD.

No.	Type/ Tail No.	Mission	Call Sign	Zero-Time Location Relative to Burst: Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	B-52	Project 5.1[a]	Watchdog	30,000	9.14	
1	A4-D/827	Project 5.2[b]	Clark	3,000	0.91	20,040 feet (6.11 km) slant range
1	A4-D/831	Project 5.2[b]	Barley	10,030	3.06	20,200 feet (6.16 km) slant range
1	FJ-4/467	Project 5.3[c]	Cobalt	3,137	0.96	22,477 feet (6.85 km) slant range
1	FJ-4/310	Project 5.3[c]	Kimono	13,067	3.98	20,899 feet (6.37 km) slant range
1	B-57B	Sampler control	Opium 1	35,000	10.67	East-west racetrack 50 nmi (92.7 km) north
4	B-57B	Sampler	Hotshot 1-4	Not airborne at burst time		
2	B-57D	Sampler	Hotshot 15,16	Not airborne at burst time		
1	P2V/1416	Barrier patrol	Wildroot 2	8,000	2.44	East-west racetrack 50 nmi (92.7 km) south

Notes:

[a]Reference C.1.1634.

[b]Reference C.1.1635.

[c]Reference C.1.1636.

Source: Reference C.4.1 except as noted.

Parry, Enewetak, and Japtan islands were not evacuated. The LCUs and YTBs were berthed alongside the larger units by 2200 on D-1 to receive safety instructions and the countdown. All other boats were secured by 2200 and their crews remained ashore for muster before event time.

The detonation produced a cloud approximately 50,000 feet (15.2 km) high with a 30,000-foot (9.1-km) base. The sampler pilots reported an initial cloud direction of 250° at 20 to 25 knots (37.0 to 46.3 km/hr).

The cloud, or a portion of it, formed a spiral over Enewetak Lagoon and was photographed (Figure 49) from the airfield there. Apparently, this cloud was of smaller particles that did not fall quickly or it moved off quickly as its presence was not noted in the several radsafe sources, and no fallout was observed in the surveys for Enewetak Island. It may be the cloud mentioned under MAGNOLIA. In addition to the readings below, Bokombako Island had a reading of 120 R/hr. Since Bokombako is adjacent to Bokoluo, which had readings of 200 R/hr, this seems reasonable (Reference C.1.6.1).

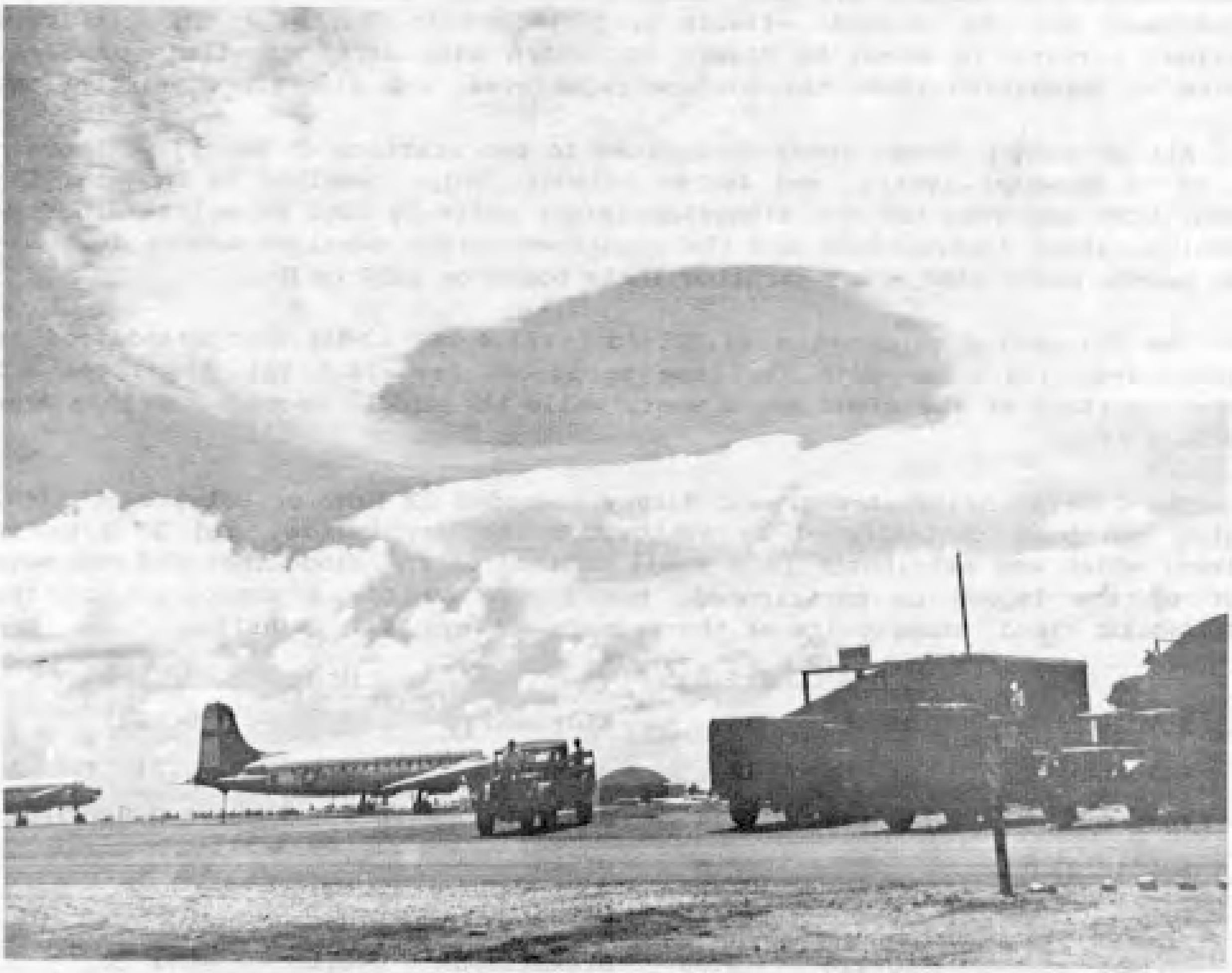


Figure 49. HARDTACK, YELLOWWOOD cloud over Enewetak.

The postshot helicopter survey at H+2.5 reported the results (R/hr):

Bokoluo	200	Aomon	0.004
Bokaidrikdrik	0.044	Bijire	0.004
Boken	0.2	Billae	0.002
Enjebi	0.12	Runit	0.1
Bokenelab	0.016	Unibor	<0.1
Aej	0.01	Drekatimon	<0.1
Eleleron	0.004		

MAGNOLIA

MAGNOLIA was detonated at 0600 on 27 May on a barge 3,000 feet (914 meters) southwest of the center of Runit. Surface winds were 14 knots (25.9 km/hr) from the east.

The DOD-sponsored experiments for MAGNOLIA were Projects 3.7, 5.2, and 5.3. Instruments for Project 3.7 were on Boken, Enjebi, and Runit. Details of this experiment and the aircraft effects projects are in Chapter 3. The predicted fallout pattern is shown in Figure 50, which also shows locations of fleet units at detonation time, the surface radex area, and aircraft participation.

All personnel except those authorized to man stations on Ananij were evacuated to Enewetak, Parry, and Japtan islands. Ships remained in Enewetak Lagoon. LCUs and YTBs berthed alongside larger units by 2200 on D-1 in order to receive safety instructions and the countdown. Crews remained ashore for muster before event time after securing their boats by 2200 on D-1.

The detonation produced a 44,000-foot (13.4-km) cloud that stabilized at 41,000 feet (12.5 km) with its base at 15,000 feet (4.6 km). The upper and lower sections of the cloud moved west, while the middle segment remained over surface zero.

The initial helicopter ground survey recorded 22 R/hr on Bokoluo at 0745, which had been contaminated by YELLOWWOOD the day before, and 35 R/hr on Biken, which was attributed to a small section of the cloud that did not move out of the lagoon as anticipated. See Figure 49 for a photograph of the YELLOWWOOD cloud. The results of the radsafe surveys were (R/hr):

	H+2	H+8.5		H+2	H+8.5
Bokoluo	22	16	Kidrinen		0.024
Bokombako		12	Bokenelab	0.18	0.01
Kirunu		2.4	Runit	0.9 - 2	1 - 2.8
Bokaidrikdrik		0.6	Biken	35	10
Boken	0.1	0.14	Unibor	<0.1	10
Enjebi	0.120	0.08	Drekatimon	<0.1	<0.1

The barrier patrol P2V flew from Jinedrol to Kidrenen at 0633 and reported readings of zero at 500 feet (152 meters). The plane then surveyed the northern chain and recorded the highest reading of 0.005 R/hr at 0647 over Bokoluo. The lagoon area was surveyed in 10° increments; 7 R/hr was recorded at 0735 in the center of the lagoon at 500 feet (152 meters). Reentry hour was 0730.

The barrier patrol and radsafe reconnaissance P2V (No. 1416) became contaminated following the detonation. The aircraft apparently flew through a cloud containing device debris while turning to avoid another area of radioactivity. The aircraft nose was reading 8 R/hr immediately after the maneuver. The plane landed at Enewetak rather than returning to Kwajalein. Upon landing at about 0900, the nose area and the reciprocating engines were reading approximately 5 R/hr and the bomb bay 0.6 R/hr. The crew, whose clothing and exposed skin were contaminated and read 0.007 R/hr maximum, left the plane and were decontaminated. By midafternoon the plane, which had been isolated, had cooled to 0.8 R/hr on the nose and 1.2 to 1.4 R/hr on the reciprocating engines. At this time, readings within the P2V disclosed 0.5 R/hr in the bow observation station, 0.2 R/hr in the forward cockpit and radar well, and lower readings elsewhere. Film badges worn by the flight crew were developed by TU 7.1.6; the

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type/ Tail No.	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	P2V	Barrier patrol	Wildroot 3	5,000	1.52	East-west racetrack 50 nmi (92.7 km) south
1	A4-D/827	Project 5.2[a]	Clark	7,960	2.43	10,380 feet (3.16 km) slant range
1	A4-D/831	Project 5.2[a]	Barley	11,270	3.43	11,320 feet (3.45 km) slant range
1	FJ-4/467	Project 5.3[b]	Cobalt	12,037	3.67	13,174 feet (4.02 km) slant range
1	FJ-4/310	Project 5.3[b]	Kimono	10,027	3.06	20,899 feet (6.37 km) slant range
1	B-57B	Sampler control	Opium	35,000	10.67	East-west racetrack 25 nmi (46.3 km) north
4	B-57B	Sampler	Hotshot 1-4	Not airborne at burst time		

[a]Reference C.1.1635.

[b]Reference C.1.1636.

Source: Reference C.4.1 except as noted.

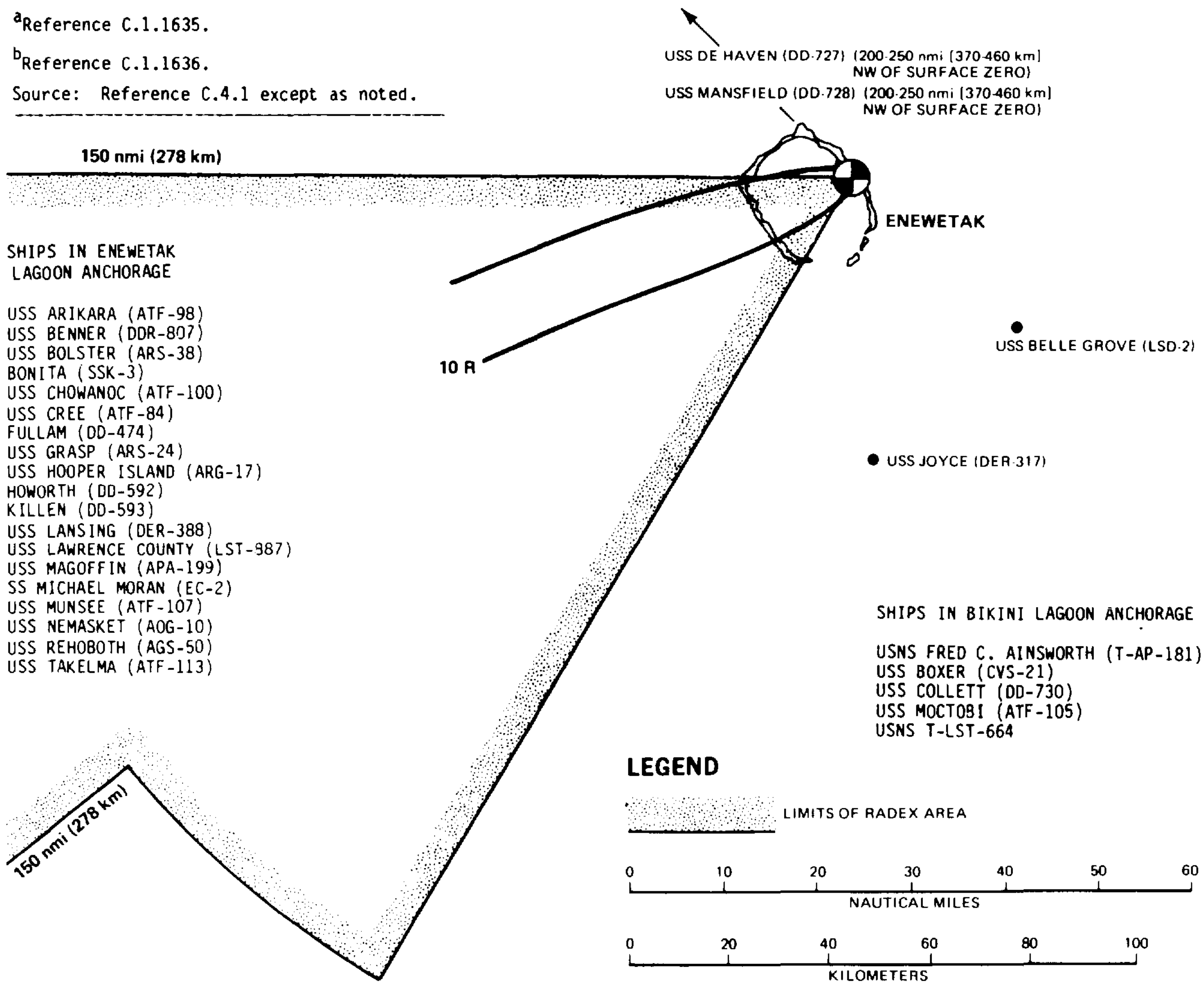


Figure 50. MAGNOLIA predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

highest of the ten crewmembers recorded 0.9 R. Four others were greater than 0.5 R, and the remaining five were less than 0.5 R (Reference C.3.3.29).

TOBACCO

TOBACCO was detonated at 1415 on 30 May on a barge 3,000 feet (914 meters) northwest of Enjebi. Surface winds were 12 knots (22.2 km/hr) from the east.

The DOD-sponsored experiments for TOBACCO were Projects 3.7, 5.1, 5.2, 5.3, and 6.8. The project activity for Project 3.7 was on Boken, Enjebi, and Runit. Project 6.8 simply monitored TOBACCO from stations off Enewetak and Parry islands. Details of the experimental projects are in Chapter 3. The predicted fallout pattern, surface radex area, locations of fleet units at burst time, and aircraft participation are shown in Figure 51.

Personnel ashore were evacuated to or remained at Parry, Enewetak, and Japtan islands. LCUs and YTBs berthed alongside larger units by 2200 on D-1 to receive safety instructions. All other boats were secured by 2200 on D-1 and their crews remained ashore for muster before shot time.

The detonation produced an 18,000-foot (5.5-km) cloud that stabilized at 16,000 feet (4.9 km) by 1430. The portion of the cloud below 10,000 feet (3.1 km) moved on a heading of 280° at 22 knots (40.7 km/hr), and the upper portion moved on a 325° heading at 10 knots (18.5 km/hr). Fallout was within the confines of the forecast fallout area.

The P2V flew barrier patrols between Runit and Biken at 1515. The plane recorded zero readings on this path and was sent northward from Biken, again obtaining no significant readings. The P2V then flew on a track 280° from Biken for 20 nmi (37 km) at 1630 but encountered no significant readings, after which it was released. A helicopter survey at 1615 was interrupted by a low cloud and rain over Runit but resumed by 1620. The maximum reading of 0.12 R/hr was recorded on Enjebi with other readings on the northern chain ranging from zero on Billae to 0.016 R/hr on Bokonelab. Later surveys included the islands west of Enjebi where fallout was heaviest. Readings from 4 to 100 R/hr were obtained between Bokoluo and Bokaidrikdrik (Reference C.1.1685).

Reentry hour was 1700. No radiation exposure potential existed in populated areas, and task force personnel were reported safe.

ROSE

ROSE was detonated at 0645 on 3 June on a barge southwest of Runit Island 4,000 feet (1.22 km) from the nearest edge of the island. Surface winds were 22 knots (40.7 km/hr) from the east.

The DOD-sponsored experiments for ROSE were Projects 3.7, 5.1, 5.2, and 5.3. Details of these projects are in Chapter 3. The predicted fallout area is shown in Figure 52, which also shows locations of fleet units at burst time, the surface radex area, and aircraft participation.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type/ Tail No.	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	P2V	Barrier patrol	Wildroot 12	2,000	0.61	East-west racetrack 50 nmi (92.7 km) south
1	B-52	Project 5.1[a]	Watchdog	26,000	7.92	
1	A4-D/827	Project 5.2[b]	Clark	5,100	1.55	12,190 feet (3.72 km) slant range
1	A4-D/831	Project 5.2[b]	Barley	11,050	3.37	12,590 feet (3.84 km) slant range
1	FJ-4/467	Project 5.3[c]	Cobalt	12,031	3.67	12,487 feet (3.81 km) slant range
1	FJ-4/310	Project 5.3[c]	Kimono	9,082	2.78	12,324 feet (3.76 km) slant range
1	B-57B	Sampler control	Opium	35,000	10.67	East-west racetrack 25 nmi (46.3 km) north
4	B-57B	Sampler	Hotshot 1-4	Not airborne at burst time		

Notes:

[a]Reference C.1.1634.

[b]Reference C.1.1635.

[c]Reference C.1.1636.

Source: Reference C.4.1 except as noted.

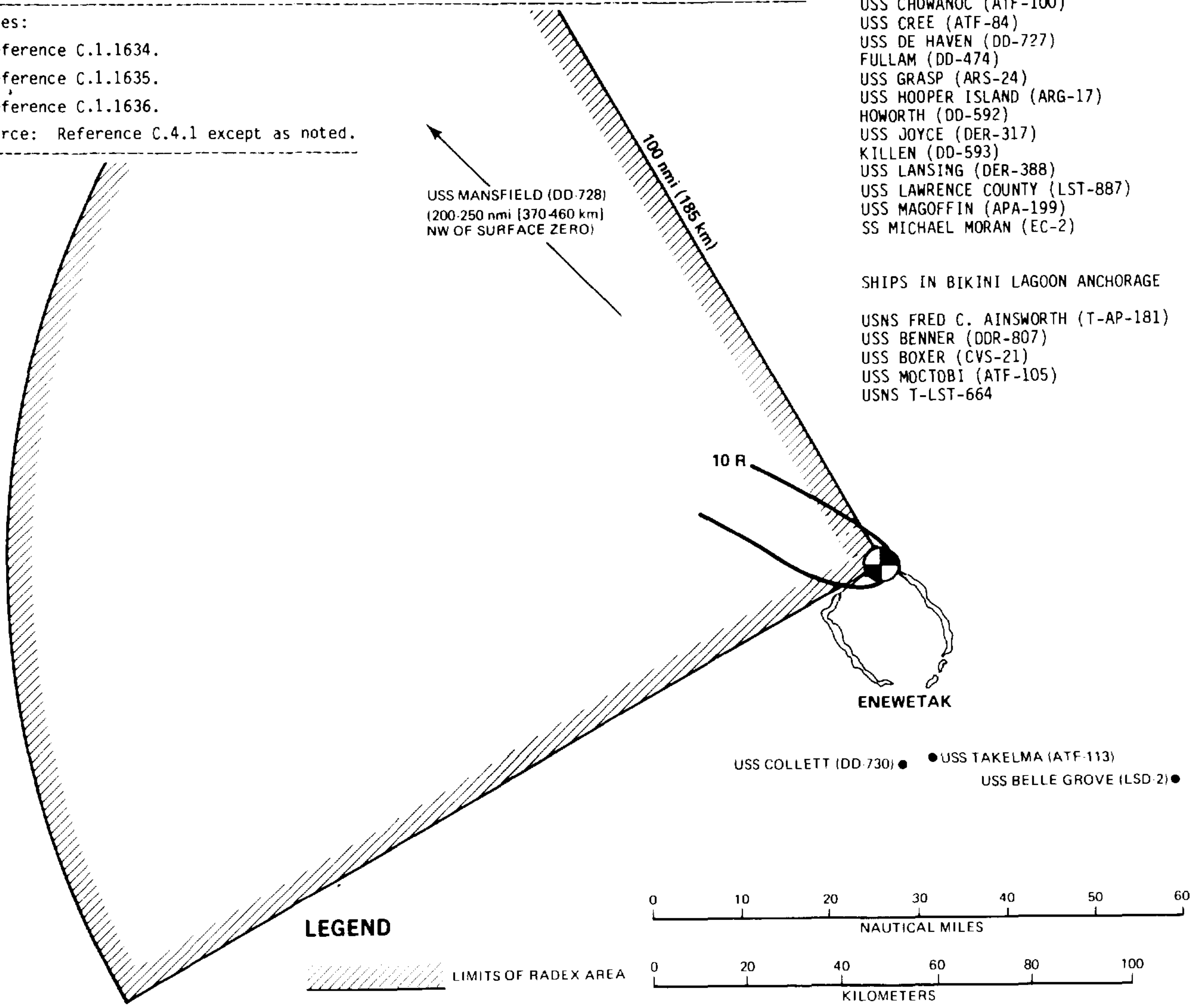


Figure 51. TOBACCO predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type/ Tail No.	Mission	Call Sign	Altitude (feet)	Altitude (km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	P2V	Barrier patrol	Wildroot 7	5,000	1.52	East-west racetrack 50 nmi (92.7 km) south
1	B-52	Project 5.1[a]	Watchdog	25,000	7.62	
1	A4-D/827	Project 5.2[b]	Clark	2,960	0.90	13,240 feet (4.04 km) slant range
1	A4-D/831	Project 5.2[b]	Barley	11,140	3.40	13,320 feet (4.06 km) slant range
1	FJ-4/467	Project 5.3[c]	Cobalt	4,004	1.22	11,464 feet (3.49 km) slant range
1	FJ-4/310	Project 5.3[c]	Kimono	13,059	3.98	13,306 feet (4.06 km) slant range
1	B-57B	Sampler control	Opium	35,000	10.67	East-west racetrack 25 nmi (46.3 km) north
1	B-57B	Sampler	Hotshot 4	35,000	10.67	East-west racetrack 24 nmi (44.5 nmi) north
3	B-57B	Sampler	Hotshot 1-3	Not airborne at burst time		

Notes:

[a]Reference C.1.1634.

[b]Reference C.1.1635.

[c]Reference C.1.1636.

Source: Reference C.4.1 except as noted.

SHIPS IN ENEWETAK LAGOON ANCHORAGE

USS ARIKARA (ATF-98)
USS BOLSTER (ARS-38)
BONITA (SSK-3)
USS CHOWANOC (ATF-100)
USS COLLETT (DD-730)
USS CREE (ATF-84)
USS DE HAVEN (DD-727)
FULLAM (DD-474)
USS GRASP (ARS-24)
USS HOOPER ISLAND (ARG-17)
HOWORTH (DD-592)
USS JOYCE (DER-317)
KILLEN (DD-593)
USS LANSING (DER-388)
USS LAWNRECE COUNTY (LST-887)
USS MAGOFFIN (APA-199)
SS MICHAEL MORAN (EC-2)
USS MUNSEE (ATF-107)
USS TAKELMA (ATF-113)

SHIPS IN BIKINI LAGOON ANCHORAGE

USNS FRED C. AINSWORTH (T-AP-181)
USS BENNER (DDR-807)
USS BOXER (CVS-21)
USS CACAPON (AO-52)
USS MONTICELLO (LSD-35)
USS MOCTOBI (ATF-105)
USNS T-LST-664

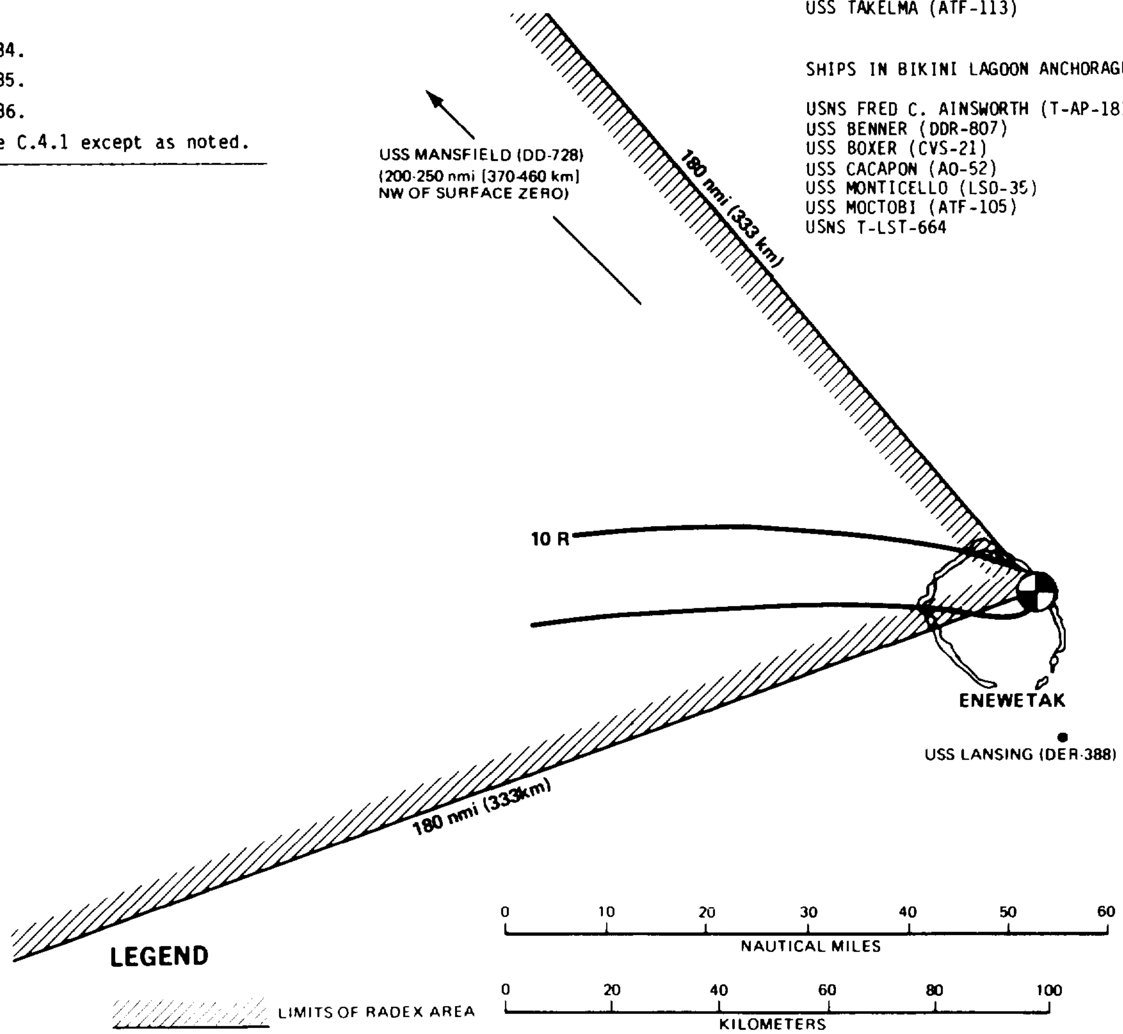


Figure 52. ROSE predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

All personnel were evacuated before the detonation from the northern island sites to Parry, Japtan, and Enewetak camps except those at manned stations on Ananij. LCUs and YTBs berthed alongside larger units by 2200 on D-1 to receive safety instructions. All other boats were secured by 2200 on D-1 and their crews remained ashore before shot time. The other ships remained in Enewetak Lagoon with closed ports and hatches on the sides facing Runit Island.

The detonation produced a 17,000-foot (5.2-km) cloud with a base at 5,000 feet (1.5 km). Most of the cloud moved in a westerly direction; however, the top of the cloud hovered over surface zero for a while. Fallout was well within the forecast area. A helicopter survey at 0825 revealed 1.2 R/hr near surface zero at 25 feet (7.6 meters) altitude, 0.05 R/hr on Enjebi, and 0.008 R/hr on Runit. Results of the H+3:15 radsafe helicopter survey were (R/hr):

Bokoluo	0.9	Enjebi	0.03
Bokombako	1	Kidrinen	0.14
Kirunu	1.9	Runit	0.2
Bokinwotme	0.18	Biken	0.25
Bokaidrikdrik	0.2	Drekatimon	0.12
Boken	0.02		

The P2V flew from Japtan to Kidrenen at 0720 and, finding no radiation, proceeded to Enjebi. The plane recorded 0.5 R/hr on Runit at 0735 and then flew across the lagoon. Significant readings were recorded only on a line west of the point of detonation. Reentry hour was declared at 0745 except for the western reef area, which was declared open at H+2.

WALNUT

WALNUT was detonated on 15 June at 0630, 1 hour after the ASPEN event at Bikini. The detonation site was a barge 5,000 feet (1.52 km) southwest of Enjebi Island. Surface winds were 17 knots (31.6 km/hr) from the east.

The DOD-sponsored experiments for WALNUT included Projects 2.4, 2.8, 3.7, 5.1, 5.2, 5.3, and 8.1. Project instrument station locations on Enewetak Atoll were on buoys in the lagoon and on Aej Island. Remotely launched rockets were fired from Bokenelab, Aomon, and Billae. The predicted fallout pattern for WALNUT is shown in Figure 39, which also shows the locations of fleet units at burst time, the surface radex area, and aircraft participation.

All personnel except those required to remain on Ananij Island were evacuated to Enewetak, Parry, and Japtan islands. Ships remained in Enewetak Lagoon, and LCUs and YTBs berthed alongside larger units by 2200 on D-1.

The detonation produced a 61,000-foot (18.6-km) cloud as reported by aircraft at H+30 minutes. The cloud moved rapidly to the northwest.

The results of the radsafe helicopter survey at H+8 are summarized below (R/hr):

Bokoluo	2	Kidrinen	0.036
Bokombako	2.2	Bokenelab	0.018
Kirunu	2	Aej	0.011
Louj	2.8	Aomon	0.01
Bokinwotme	8	Runit	<0.1
Bokaidrikdrik	1.1	Biken	0.06
Boken	1.1	Unibor	0.05
Enjebi	0.4		

At 2105, another helicopter survey encountered only background radiation with the exception of 0.3- to 0.500-R/hr readings in the water near Bokoluo Island.

The fallout was estimated to be within the forecast area. Reentry hour was 2030. The surface and air radex areas, from the surface to unlimited altitude, modified to enclose an area bearing 290°, clockwise through 320° west of the lagoon with its apex at surface zero, out to a radial distance of 300 nmi (556 km).

The WB-50 sampling long-range fallout for Project 2.8 encountered fallout at H+4 on a 320° bearing, 42 nmi (78 km) from surface zero. At H+18 another sample was taken on a 283° bearing, 140 nmi (259 km) from surface zero, and at H+13 at a bearing of 278°, 150 nmi (278 km) from surface zero.

LINDEN

LINDEN was detonated on 18 June at 1500 on a barge 4,000 feet (1.22 km) west of the center of Runit Island. Surface winds were 13 knots (24.1 km/hr) from the east.

No DOD-sponsored experiments were conducted during LINDEN. The predicted LINDEN fallout pattern is shown in Figure 53 as well as the locations of fleet units at burst time, the surface radex area, and aircraft participation. All personnel ashore remained at Enewetak, Parry and Japtan islands. LCUs and YTBs berthed alongside larger units by 2200 on D-1.

The detonation produced a 20,000-foot cloud (6.1-km) with a 7,000-foot (2.1-km) base, then stabilized at 19,000 feet (5.8 km). The main body of the cloud proceeded northwest, passing over Unibor and the northwest islands from Bokoluo to Enjebi. The cloud moved slowly (7 knots [13 km/hr]), delaying reentry until 1730.

A P2V followed the southern edge of the cloud as it moved to the northwest. The helicopter survey was curtailed because of nightfall. A detailed helicopter survey was made the following morning at 0815 and obtained a maximum reading of 10 R/hr at Unibor. Other results of the surveys were (R/hr):

Bokoluo	0.3	Boken	0.044
Bokombako	0.18	Runit	0.005 - 0.06
Kirunu	0.26	Biken	0.05
Louj	0.4	Unibor	10
Bokaidrikdrik	0.28		

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	P2V	Barrier patrol	Wildroot 3	1,500	0.46	East-west racetrack 50 nmi (92.7 km) south
1	B-57B	Sampler control	Opium 1	25,000	7.62	East-west racetrack 25 nmi (46.3 km) north
4	B-57B	Sampler	Hotshot 1-4	Not airborne at burst time		

Source: Reference C.4.1.

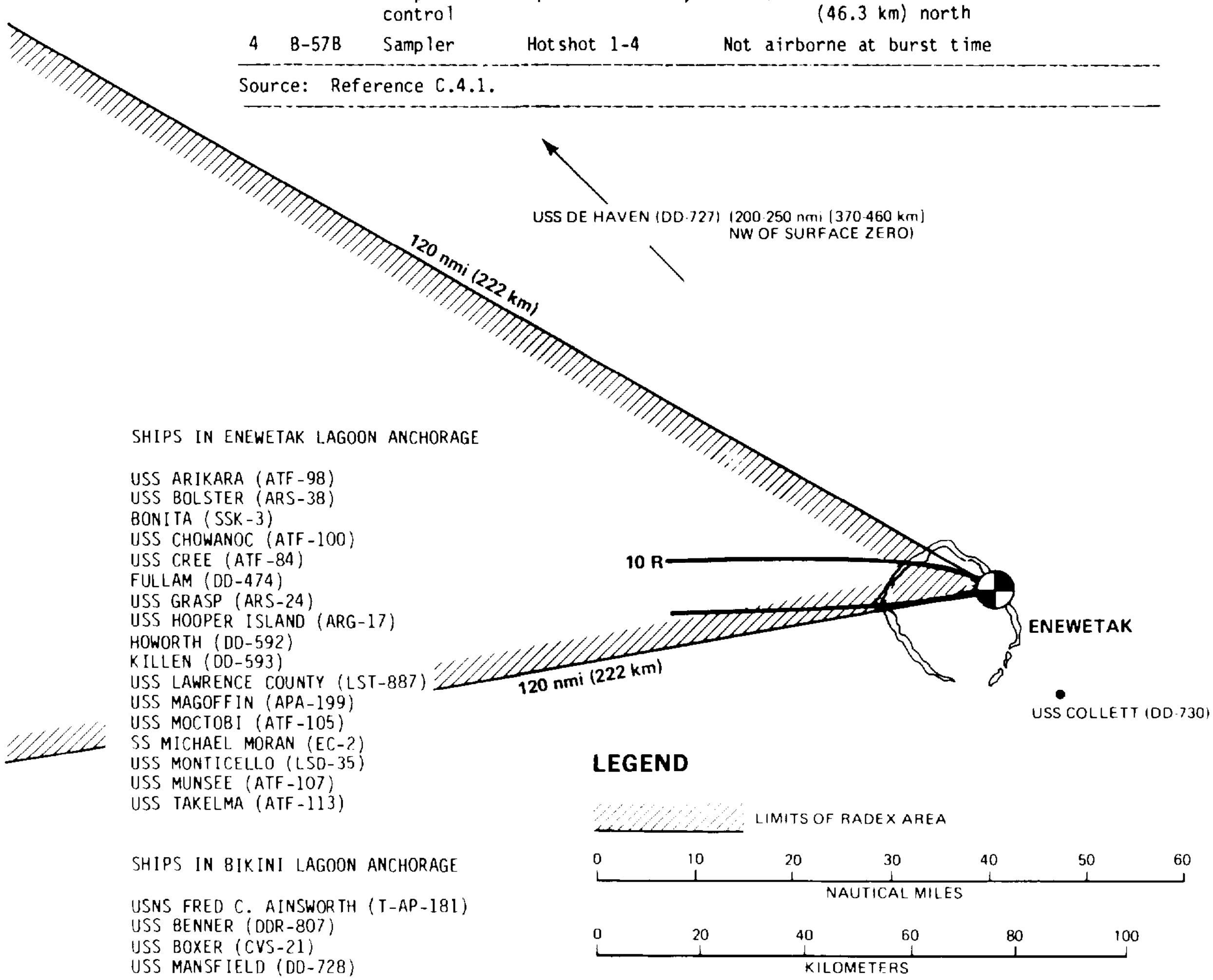


Figure 53. LINDEN predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

ELDER

ELDER, detonated on 28 June at 0630, was the second of a tandem shot with REDWOOD (detonated an hour earlier on Bikini). Radiation levels at the shot site delayed its scheduled detonation one day. The ELDER barge was 1 nmi (1.85 km) southeast of Enjebi Island. Surface winds were 17 knots (31.5 km/hr) from the east.

The only DOD-sponsored experiment for ELDER, Project 5.1, had no ground-based instrument stations in the detonation area. The predicted fallout pattern is shown in Figure 40. Locations of fleet units at burst time, the surface radex area, and aircraft participation are also shown in the figure.

All personnel at the atoll, except for those required at Ananij, were evacuated to Enewetak, Parry, and Japtan islands. LCUs and YTBs berthed along-side larger units by 2200 on D-1. All other boats were secured by 2200 on D-1 and the crews remained ashore for muster before shot time.

The cloud rose rapidly and passed beyond the upper limits of the weather radar (50,000 feet [15.2 km]) by H+2.5 minutes. Cloud height observations from the aircraft were not available until H+50 minutes when a cloud sampler reported the top of the cloud at 58,000 feet (17.7 km), indicating that the initial cloud height had been well over 65,000 feet (19.8 km). The main body of the cloud moved north, with the stem proceeding west to northwest. Movement of the cloud was very slow; the upper portion of the cloud could be observed directly over the atoll for several hours.

The P2V that flew barrier patrols at H+30 minutes cleared the lagoon south of a line from Runit to Biken at H+1. The rest of the lagoon was cleared by H+2:30 except for the islands from Bokoluo to Billae, and reentry hour was at 0930.

The H+7 radsafe survey results were (R/hr):

Bokoluo	1	Boken	0.14
Bokombako	0.4	Enjebi	0.18
Kirunu	0.26	Runit	<0.1
Louj	0.2	Biken	0.04
Bokaidrikdrik	0.14	Unibor	0.09

OAK

OAK, one of the largest detonations at Enewetak Atoll, was fired at 0730 on 29 June from a barge moored on the reef 21,000 feet (6.40 km) southwest of Bokoluo Island. It was followed at noon by the HICKORY shot at Bikini. OAK, a LASL device, had a yield of 8.9 MT. Surface winds were 14 knots (25.9 km/hr) east-southeast.

Two DOD-sponsored experiments were included for OAK: Projects 2.8 and 5.1. Only the aircraft took samples for Project 2.8 since the use of rockets had been discontinued. Details of the experimental projects are in Chapter 3. The predicted fallout pattern is shown in Figure 54, which also shows the locations of fleet units at burst time and the surface radex area. Aircraft participation is given in Table 20.

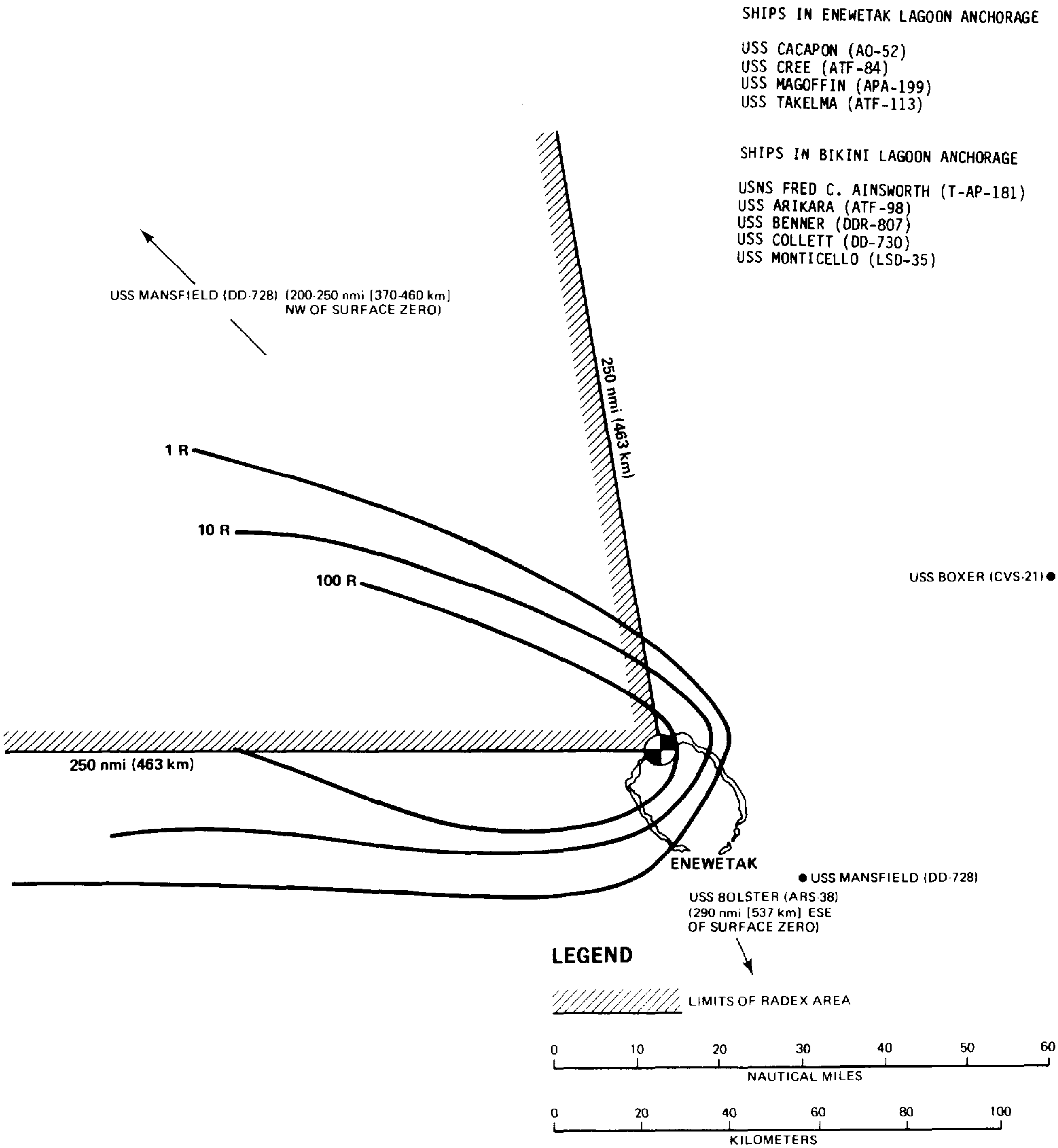


Figure 54. OAK predicted fallout, surface radex area, and ship positions, Operation HARDTACK.

Table 20. Aircraft participation in HARDTACK, OAK.

				Zero-Time Location Relative to Burst		
No.	Type	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 45 nmi (83.4 km) east
1	SA-16	Cover for Mosquitos and Pacemakers	Stable Echo 2	5,000	1.52	Orbit over *USS Boxer* (CVS-21) 55 nmi (101.9 km)
5	L-20	Evacuated from Enewetak	Mosquito 1-5	5,000	1.52	Orbit over *USS Boxer* 55 nmi (101.9 km)
3	L-19		Pacemaker 1-3	5,000	1.52	Orbit over *USS Boxer* 55 nmi (101.9 km)
1	P2V	Barrier patrol	Wildroot 8	9,000	2.74	East-west racetrack 50 nmi (92.7 km) south
1	B-52	Project 5.1[a]	Watchdog	25,000	7.62	161,000 feet (49.1 km) ground range
1	B-57B	Sampler control	Opium	35,000	10.67	East-west racetrack 35 nmi (64.9 km) north
3	B-57B	Sampler	Hotshot 3-5	Not airborne at burst time		
4	B-57D	Sampler	Hotshot 11, 12, 17, 18	Not airborne at burst time		
1	WB-50	Project 2.8 low-altitude sampler	Massive	Not airborne at burst time		
1	B-57D	Sampler	Hotshot 19	Not airborne at burst time		
1	B-57	Sampler	Hotshot spare	Not airborne at burst time		

[a]Reference C.1.1634.

Source: Reference C.4.1 except as noted.

No personnel were evacuated from Enewetak, Parry and Japtan islands, although buildings were braced (Figure 55) and sandbags were placed around some buildings to prevent wave runup damage (Figure 56). The light planes (five L-20s and three L-19s) were flown to a position 35 nmi (64.8 km) south-southeast of Enewetak Island, where they orbited over Boxer to avoid the blast effects from the large detonation. After the shock wave passed, the aircraft returned to Enewetak Island. After H-hour, Boxer left its position and proceeded to anchor in Enewetak lagoon.

The detonation cloud reached the stratosphere (at about 55,000 feet [16.8 km]) in less than 2 minutes. Early cloud height observations were not made because no aircraft were appropriately positioned. At H+3 a B-57 sampler aircraft reported the stabilized cloud at 67,000 feet (20.4 km). The initial height was estimated to be 78,000 feet (23.8 km). The lower portion of the cloud initially moved west at a speed of over 15 knots (27.8 km/hr). The portion of the cloud at 55,000 feet (16.8 km) remained in the vicinity of surface zero for several hours and then slowly moved southwest. The lagoon was swept with more caution than usual because of the unusually large yield of the device. Reentry hour was scheduled for 1130 after a thorough P2V sweep at 1,000 feet (305 meters). The atoll was free of contamination except for the islands from Bokoluo through Louj, which had an average intensity of 0.035 R/hr. The results of the D+1 radsafe surveys were (R/hr):

Bokoluo	0.24	Bokaidrikdrik	0.04
Bokombako	0.28	Boken	0.02
Kirunu	0.25	Enjebi	0.02
Louj	0.15	Runit	<0.1

The portion of the cloud that had moved southwest was reported 60 nmi (111.1 km) southwest at nightfall with an intensity of 0.350 R/hr as measured by the WB-50 sampler aircraft at low altitude. This part of the cloud was again detected early the next morning 200 nmi (371 km) southwest of Enewetak Island with an intensity of 0.040 R/hr.

The FOPU predicted fallout between the 280° and 320° radials. The actual pattern was more westerly with some contamination as far south as Ujelang. The FOPU also had predicted close-in values of 100 R for a 6-nmi (11-km) radius and 10 R for a 12-nmi (22-km) radius upwind of surface zero, but the initial P2V survey indicated that this did not occur.

The air and surface radex areas were revised for H+4 through H+12, surface to unlimited altitude with its apex on surface zero, to enclose an area bearing 260° clockwise through 340°, radial distances 50 through 300 nmi (93 through 556 km).

SEQUOIA

SEQUOIA was detonated on 2 July at 0630 on a barge 2,000 feet (610 meters) west-northwest of Runit Island. Surface winds were 17 knots (31.5 km) from the east.

Figure 55. Buildings on Parry Island braced and with open windows in preparation for HARDTACK, OAK.

Figure 56. Transformer at U.S. Coast Guard Loran station on Enewetak Island sandbagged in preparation for HARDTACK, OAK.

SEQUOIA had no DOD-sponsored experiments. The predicted fallout pattern is shown in Figure 57. The same figure also shows the location of fleet units at burst time, the surface radex area, and aircraft participation.

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	P2V	Barrier patrol	Wildroot 4	8,000	2.44	East-west racetrack 50 nmi (92.7 km) east
1	B-57B	Sampler control	Opium 1	15,000	4.57	East-west racetrack 10 nmi (18.5 km) north
4	B-57B	Sampler	Hotshot 1-4	Not airborne at burst time		

Source: Reference C.4.1.

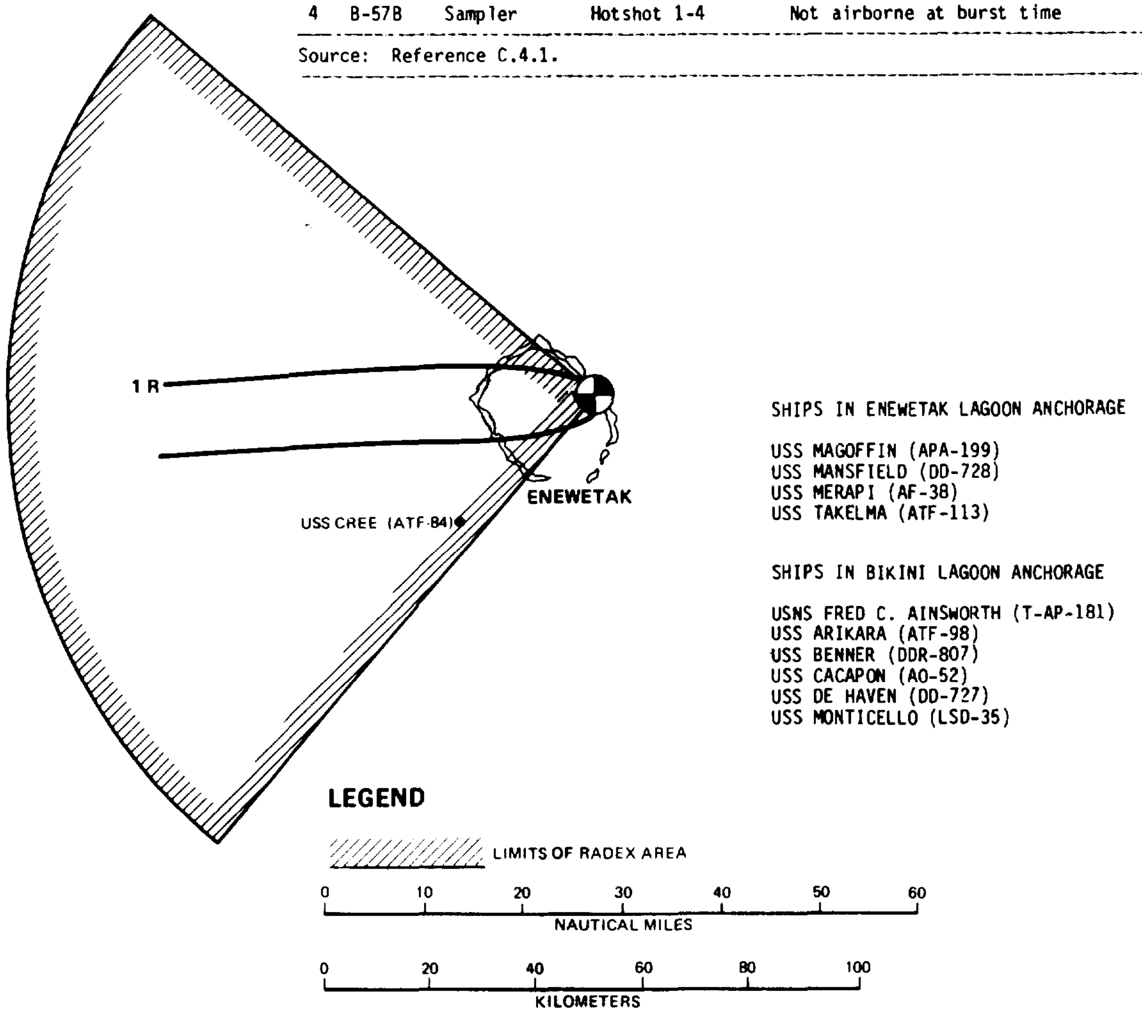


Figure 57. SEQUOIA predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

All personnel except those authorized to man stations at Ananij were evacuated to Enewetak, Parry, and Japtan islands. LCUs berthed alongside larger units by H-1 in order to receive safety instructions. All ships remained in the lagoon. The population at Enewetak Island at this time was 2,900 and at Parry, 2,700.

The cloud stabilized at 15,000 feet (4.6 km). The cloud moved within the trade-wind level at 275° at 17 knots (31.5 km/hr).

At 0630 the barrier patrol P2V recorded 0.030 to 0.040 R/hr over the debris in the water west of Runit Island. At 0725 the plane recorded 12 R/hr over the Runit airstrip. The H+8:30 radsafe survey found 2 R/hr 200 feet (61 meters) above surface zero, 0.1 R/hr at Bokoluo, between 0.175 and 0.3 R/hr on Runit, and 0.03 R/hr on Biken. Unibor read 3.4 R/hr for the photo tower lower platform and 4.6 R/hr for the upper platform.

The fallout pattern extended from the 260° and 290° radials from surface zero for 80 nmi (148.2 km), essentially as forecast. Reentry hour was declared at 0830. The air and surface radex areas for H+1:30 through H+6, surface through 18,000 feet (5.5 km), were modified to enclose an area with its apex on surface zero, bearing 240° through 290°, radial distance 20 through 100 nmi (37 through 185.2 km).

DOGWOOD

DOGWOOD was detonated on 6 July at 0630 on a barge southwest of Enjebi, 4,000 feet (1.22 km) from the edge of the island. Surface winds were 17 knots (31.5 km/hr) from the east. DOGWOOD was a UCRL device, the first from that laboratory to be detonated at Enewetak. Weather delays at Bikini had caused JTF 7 to change the location of the last five UCRL device tests from Bikini to Enewetak.

The only DOD-sponsored experiment for DOGWOOD was Project 5.1. The predicted fallout pattern, locations of fleet units at burst time, the surface radex area, and aircraft participation are shown in Figure 58.

All personnel ashore except those authorized to man stations at Ananij Island were evacuated to Enewetak, Parry, and Japtan islands before the detonation. Overpressure and thermal energy effects at sites on Enewetak, Parry, and Japtan islands were expected to be negligible. No adverse effects on subsequent operations were anticipated. All ships remained in the lagoon, with USS Navarro (APA-215) and Monticello standing by in case of an emergency evacuation from Enewetak, Parry, and Japtan islands.

The cloud rose to 58,000 feet (17.7 km), stabilizing at 54,000 feet (16.5 km) with a 35,000-foot (10.7-km) base. Radar reports indicated that the main body of the cloud moved at 17 knots (31.5 km/hr) on a 330° radial. Aircraft reports indicated that the cloud moved as a whole to the northwest during the first hour.

At 0645 the P2V began surveying the lagoon, completing its mission by 0745. No radioactivity was found except on Enjebi and the islands downwind of surface

		PARTICIPATING AIRCRAFT		Zero-Time Location Relative to Burst		
No.	Type/ Tail No.	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 35 nmi (64.9 km) east
1	P2V	Barrier patrol	Wildroot 4	8,000	2.44	East-west racetrack 50 nmi (92.7 km) south
1	B-52	Project 5.1[a]	Watchdog	25,000	7.62	26,000 feet (7.92 km) ground range
1	B-57B	Sampler control	Opium	35,000	10.67	East-west racetrack 35 nmi (64.8 km) north
1	B-57B	Sampler	Hotshot 11	35,000	10.67	North-south racetrack 40 nmi (74.1 km) east
3	B-57D	Sampler	Hotshot 2-4	Not airborne at burst time		
3	B-57D	Project 5.1	Hotshot 15-17	Not airborne at burst time		
1	P2V	Barrier patrol	Wildroot	Not airborne at burst time		

Note:

[a]Reference C.1.1634.

Source: Reference C.4.1 except as noted.

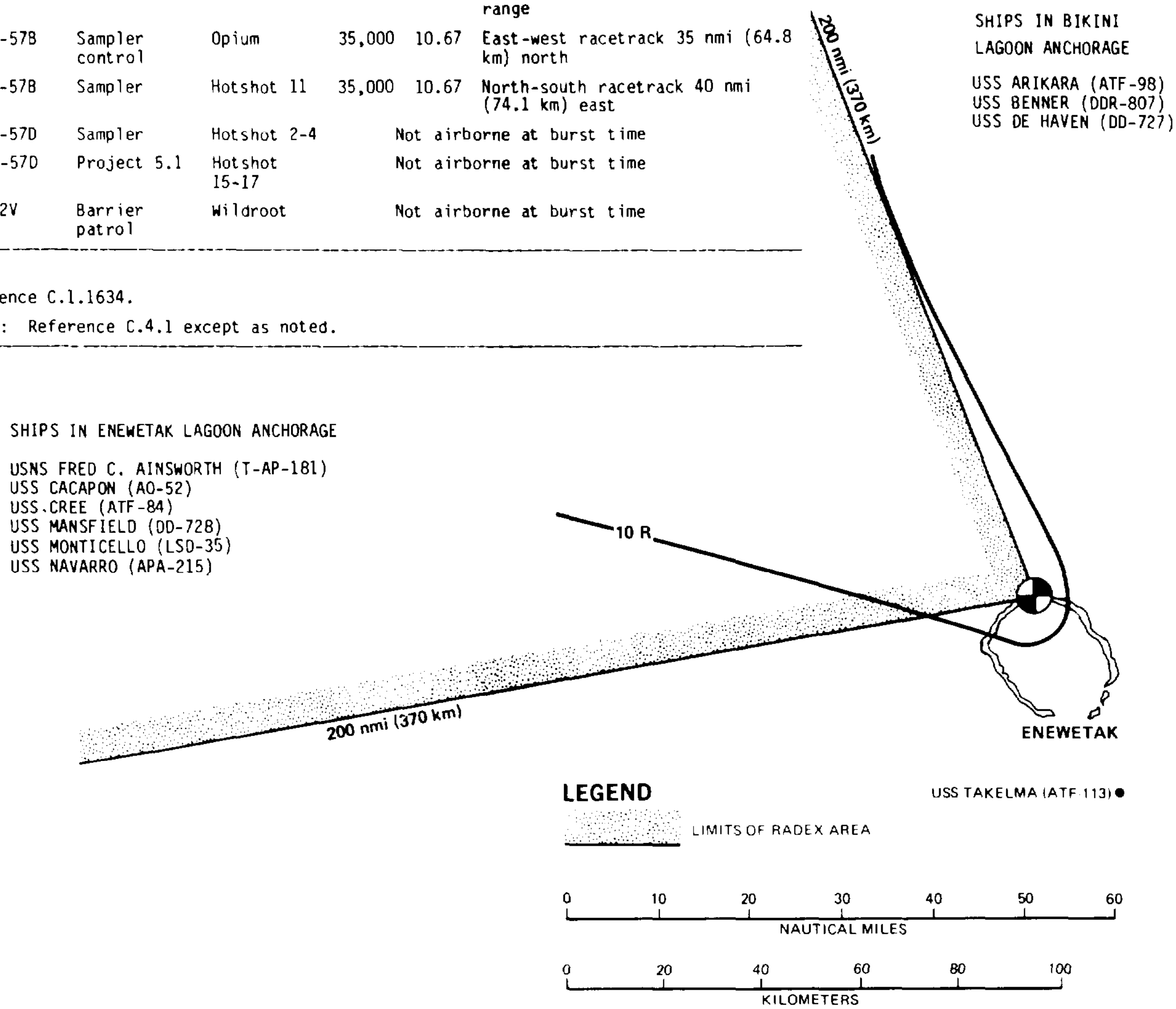


Figure 58. DOGWOOD predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

zero. Bokoluo had a reading of 1 R/hr, and Enjebi 0.035 R/hr. The aircraft then proceeded on a track 260° from Bokoluo and recorded 0.300 R/hr 35 nmi (65 km) out. Proceeding due north of Lujor, an unexpected intensity of 0.7 R/hr was found at a point 25 nmi (46 km) north. At this time the P2V reported that the aircraft's background would not fall below 0.13 R/hr, apparently due to radioactive contamination on the plane itself. Despite attempts to wash off the contaminants by flying through rainsqualls, the readings remained high. The P2V was instructed to land and was replaced by a standby.

The second aircraft flew north to determine whether radioactive debris was moving eastward. A 0.180-R/hr reading was taken on a 350° radial 40 nmi (74 km) from Lujor, indicating that fallout was present. At H+4, 0.3 R/hr was found on Unibor. At 1400, the P2V proceeded north of Lujor but obtained no significant readings. No easterly movement developed and the P2V was released. The actual fallout pattern was between the 260° and 350° radials, similar to that forecast. An H+8 survey revealed the following radiation (R/hr) on the islands of the atoll:

Bokoluo	1.4	Boken	0.28
Bokombako	2.3	Enjebi	0.2
Kirunu	0.65	Mijikadrek	0.006
Louj	0.7	Biken	0.02
Bokaidrikdrik	0.34		

Reentry hour was 0930. The radex areas were revised to enclose an area bearing 250° clockwise through 350° from surface zero, radial distance 45 to 200 nmi (83 to 370 km), surface to unlimited altitude. No known radiation exposure potential existed in populated areas or for task force personnel.

SCAEVOLA

SCAEVOLA was detonated on 14 July at 1600 on a barge west of Runit Island. Surface winds were 14 knots (26 km/hr) from the east. SCAEVOLA was a LASL experiment to test the device for its safety during handling and delivery. Its yield was low and the explosion did not destroy the shot barge but only damaged it.

No DOD-sponsored experiments were scheduled for SCAEVOLA. The predicted fallout pattern is shown in Figure 59, which also shows the locations of fleet units at burst time, the surface radex area, and aircraft participation.

All personnel except those required on Ananij were evacuated to Enewetak, Parry, and Japtan islands. Effects from the overpressure and thermal energy at sites on Enewetak, Parry, and Japtan were expected to be negligible.

The detonation produced a 1,500-foot (458-meter) cloud. The normal P2V was not deployed for SCAEVOLA. A helicopter survey, however, departed from Ananij Island at 1610 and reported 0.020 to 0.030 R/hr over the shot area.

Reentry hour was 1700. No known radiation exposure potential existed in populated areas or for task force personnel, and there were no adverse effects on subsequent operations. No appreciable fallout was estimated to exist outside of the area immediately adjacent to surface zero.

The shot barge was heavily contaminated with plutonium by SCAEVOLA. It was left at its mooring until 24 July. A line was put aboard by a YTL, which was then passed to USS Arikara (ATF-98) and then was towed to a location about

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type	Mission	Call Sign	Altitude (feet)	Altitude (km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 25 nmi (46.3 km) east
1	B-57B	Sampler control	Opium	10,000	3.05	East-west racetrack 15 nmi (27.8 km) N
1	B-57B	Sampler	Hotshot 1	10,000	3.05	East-west racetrack 15 nmi (27.8 km) north

Source: Reference C.4.1.

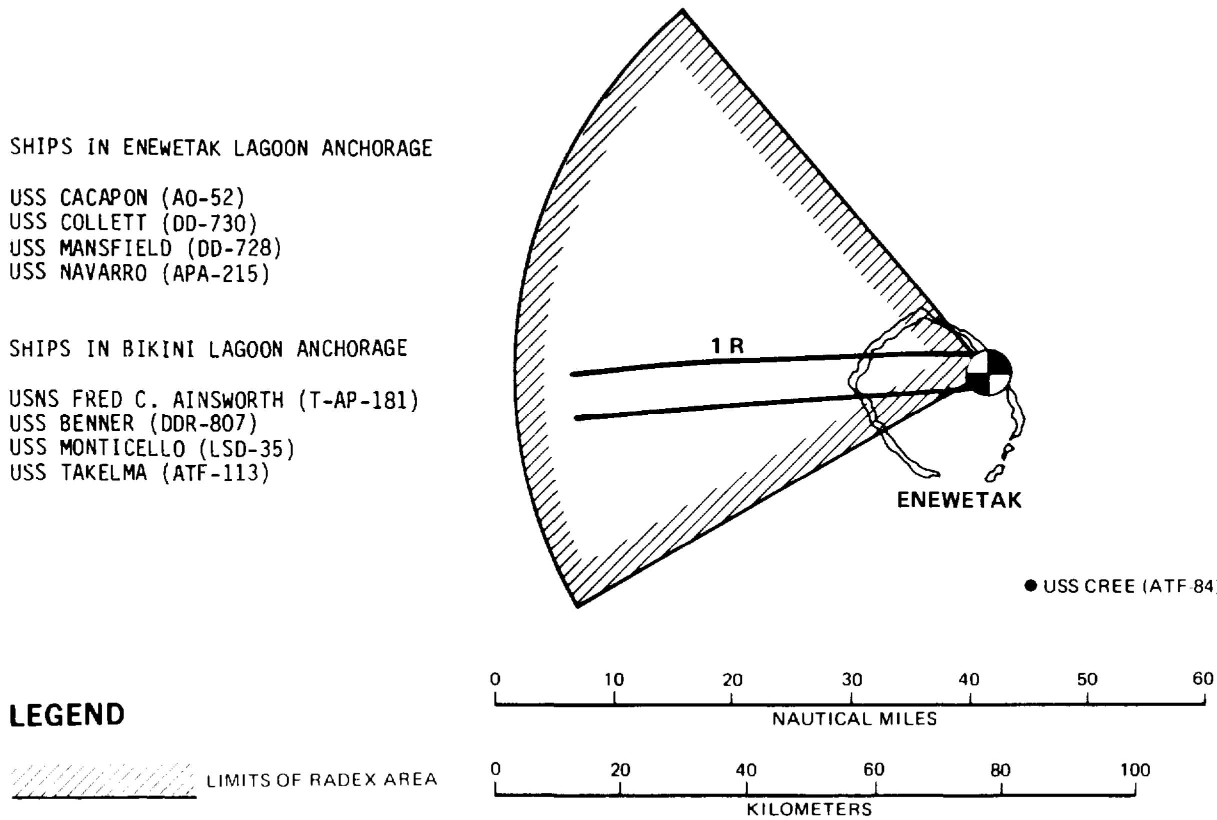


Figure 59. SCAEVOLA predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

9 nmi (16.7 km) south of the atoll. It was then set adrift in an area whose depth was about 1,000 fathoms (1.8 km). CTU 7.3.3 had dispatched USS Mansfield (DD-728) from Enewetak to sink the barge. This was done by gunfire at 162° 14.3'E, 11°12.6'N, about 9 nmi (17 km) south of the atoll. At 1747, Mansfield secured from general quarters and proceeded back to its anchorage at Enewetak (Reference C.3.4.27).

PISONIA

PISONIA was detonated on 18 July 1958 at 1100 on a barge 10,000 feet (3.05 km) west of Runit Island. Surface winds were 4 knots (7 km/hr) from north-northeast. PISONIA was the last LASL device tested during HARDTACK.

No DOD-sponsored experiments were scheduled for PISONIA. The predicted fallout pattern is shown in Figure 60, which also shows the locations of fleet units at burst time, the surface radex area, and aircraft participation.

All personnel except those authorized to man stations at Ananij were evacuated to Enewetak, Parry and Japtan islands before the shot. The blast overpressure at sites on Parry and Ananij was expected to be significant, with the possibility of damaging helicopters and light planes.

The cloud rose immediately to 55,000 feet (16.8 km). The P2V flew from Kidrenen to Ananij and then moved gradually across the upper portion of the lagoon on radials from Jinedrol. Heavy rainshowers caused isolated readings of 5 to 7 R/hr throughout the area adjacent to surface zero. The P2V was placed on barrier patrol on radials of 240° and 250° for 75 nmi (139 km) from Enewetak. A final clearing run was made to Ujelang and the plane was released by 1845.

Two M-boats were dispatched for data recovery at 1415. One turned back at Runit Island because of radioactive water and the other measured 1 R/hr at the Unibor photo tower. Both boats returned by 1800.

The weather prevented helicopter surveys until the following morning between 0700 and 0900. Readings of 0.001 R/hr were recorded on Runit and Billae islands. Other readings from the surveys were (R/hr):

Bokoluo	0.1	Bokaidrikdrik	0.04
Bokombako	0.16	Boken	0.006
Kirunu	0.1	Biken	0.02
Louj	0.05	Unibor	1 (at H+5)
Bokinwotme	0.25		

Fallout was estimated to have extended along a bearing of 270° for approximately 250 nmi (463 km), covering a larger than predicted area. Slight fallout occurred on Parry Island during a rainshower following the detonation. Intensity began to rise at 1420 with maximum readings of 0.034 R/hr at 1449. Another rainsquall occurred at 1452, when the radiation intensity dropped sharply and continued to decrease to 0.0003 R/hr at 1630. Rain puddles measured 0.004 R/hr, and tent areas were 0.003 R/hr on the outside and 0.002 R/hr on the inside of the tents during this episode. The fallout was not from the main body of the cloud but apparently brought down by the rain from a wisp of the main cloud.

Reentry hour was 1500. Weather and radsafe conditions delayed the recovery of some scientific and diagnostic data. The surface and air radex areas were revised to enclose an area bearing 234° clockwise through 300° from surface

				Zero-Time Location Relative to Burst		
PARTICIPATING AIRCRAFT				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 25 nmi (46.3 km) east
1	P2V	Barrier patrol	Wildroot 10	5,000	1.52	East-west racetrack 50 nmi (92.7 km) south
1	B-57B	Sampler control	Opium	30,000	9.14	East-west racetrack 30 nmi (55.6 km) north
1	B-57D	Sampler	Hotshot 11	25,000	7.62	North-south racetrack 35 nmi (64.9 km) east
2	B-57B	Sampler	Hotshot 2, 3	Not airborne at burst time		
2	B-57D	Sampler	Hotshot 14 and spare	Not airborne at burst time		

Source: Reference C.4.1.

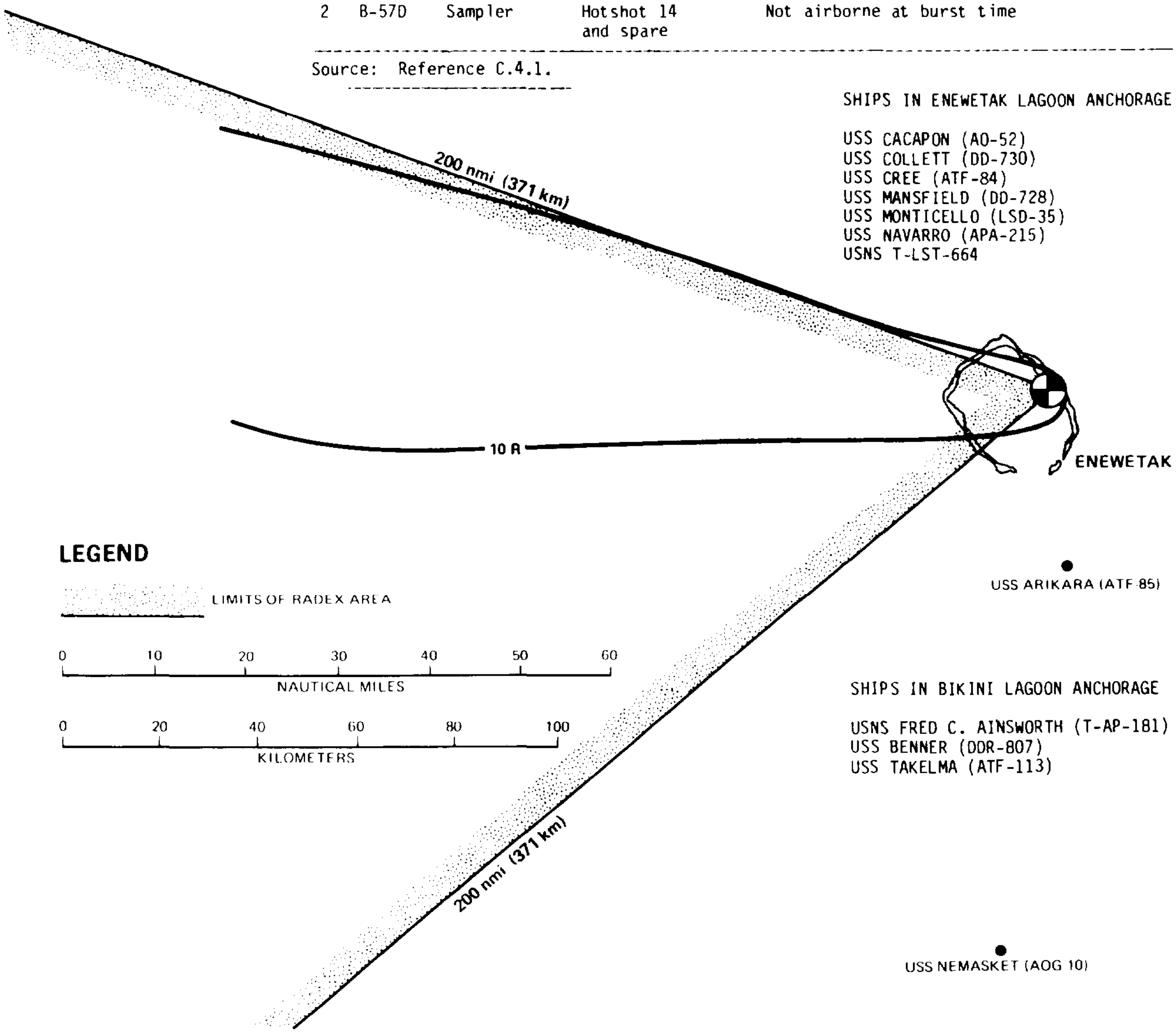


Figure 60. PISONIA predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

zero, at radial distances 20 nmi (37 km) to 250 nmi (463 km), surface to unlimited altitude.

OLIVE

OLIVE was detonated on 23 July at 0830 on a barge southwest of Enjebi Island, 4,000 feet (1.22 km) from the nearest land. Surface winds were 13 knots (24.1 km/hr) from the southeast. OLIVE was another UCRL device transferred to Enewetak from Bikini for detonation.

No DOD-sponsored experiments were scheduled for OLIVE. The predicted fallout pattern is shown in Figure 61, which also shows the locations of fleet units at burst time, the surface radex area, and aircraft participation. All personnel except those required on Ananij Island were evacuated to Enewetak, Parry, and Japtan islands before the shot.

The cloud rose to 50,000 feet (15.2 km) with an estimated 15,000-foot (4.6-km) base. The P2V aircraft reported its location over Jinedrol Island at 0900, then flew to Kidrenen, Runit, Biken, Billae, and back to Biken, recording only background radiation. The northern part of the atoll was slowly cleared, and a 0.0035-R/hr reading was recorded abeam surface zero at 0955. The P2V then flew out of the lagoon on westerly and northeasterly radials.

An H+3 helicopter survey reported 0.02 to 0.6 R/hr over Enjebi Island at 25 feet (7.6 meters), 0.002 R/hr at Bokenelab, 0.001 R/hr at Billae, and 0.0004 R/hr at Parry. Fallout was forecast along a bearing of 300°, but the wind pattern shifted more to the south at lower altitudes. Later surveys included the islands of Enjebi where fallout was heaviest. Readings from 0.075 to 6 R/hr were recorded (Reference C.1.1685).

Reentry hour was 1000. Air and surface radex areas were revised to enclose an area bearing 270° clockwise through 300° with its apex at surface zero, at radial distances of 20 through 250 nmi (37 through 463 km), surface to unlimited altitude.

PINE

PINE was detonated on 27 July at 0830 on a barge southwest of Enjebi Island, 8,500 feet (2.59 km) from the nearest land. Surface winds were 16 knots (29.7 km/hr) from the southwest.

No DOD-sponsored experiments were scheduled for PINE. The predicted fallout pattern is shown in Figure 62. The same figure also shows the locations of fleet units at burst time, the surface radex area, and aircraft particiption. Five L-20 and three L-19 light planes were evacuated from Enewetak Island before the shot to avoid possible damage. These aircraft flew to a position about 15 nmi (27.8 km) southeast of Enewetak Island and remained there until passage of the shock wave.

Personnel ashore remained at Parry, Enewetak, and Japtan islands unless they were authorized to be on other islands. LCUs berthed alongside larger units by H-1 in order to receive safety instructions. Because overpressure,

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
				Altitude		
No.	Type	Mission	Call Sign	(feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 25 nmi (46.3 km) east
1	P2V	Barrier patrol	Wildroot 7	5,000	1.52	East-west racetrack 50 nmi (92.7 km) south
1	B-57B	Sampler control	Opium	30,000	9.14	East-west racetrack 30 nmi (55.6 km) north
1	B-57B	Sampler	Hotshot photo	25,000	7.62	North-south racetrack 35 nmi (64.9 km) east
1	B-57D	Sampler	Hotshot 11	25,000	7.62	North-south racetrack 35 nmi (64.9 km) east
4	B-57B	Sampler	Hotshot 2-5	Not airborne at burst time		
1	B-57D	Sampler	Hotshot 16	Not airborne at burst time		

Source: Reference C.4.1.

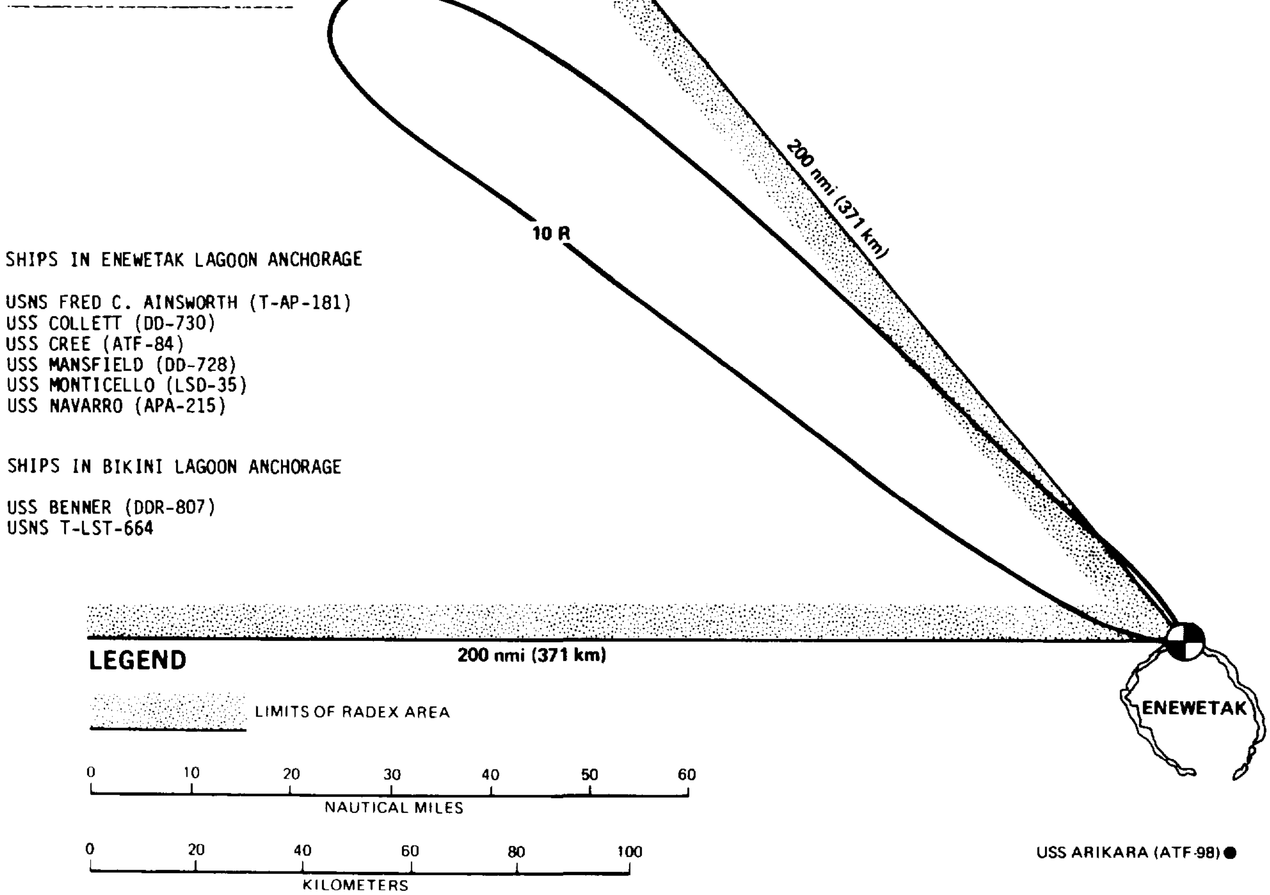
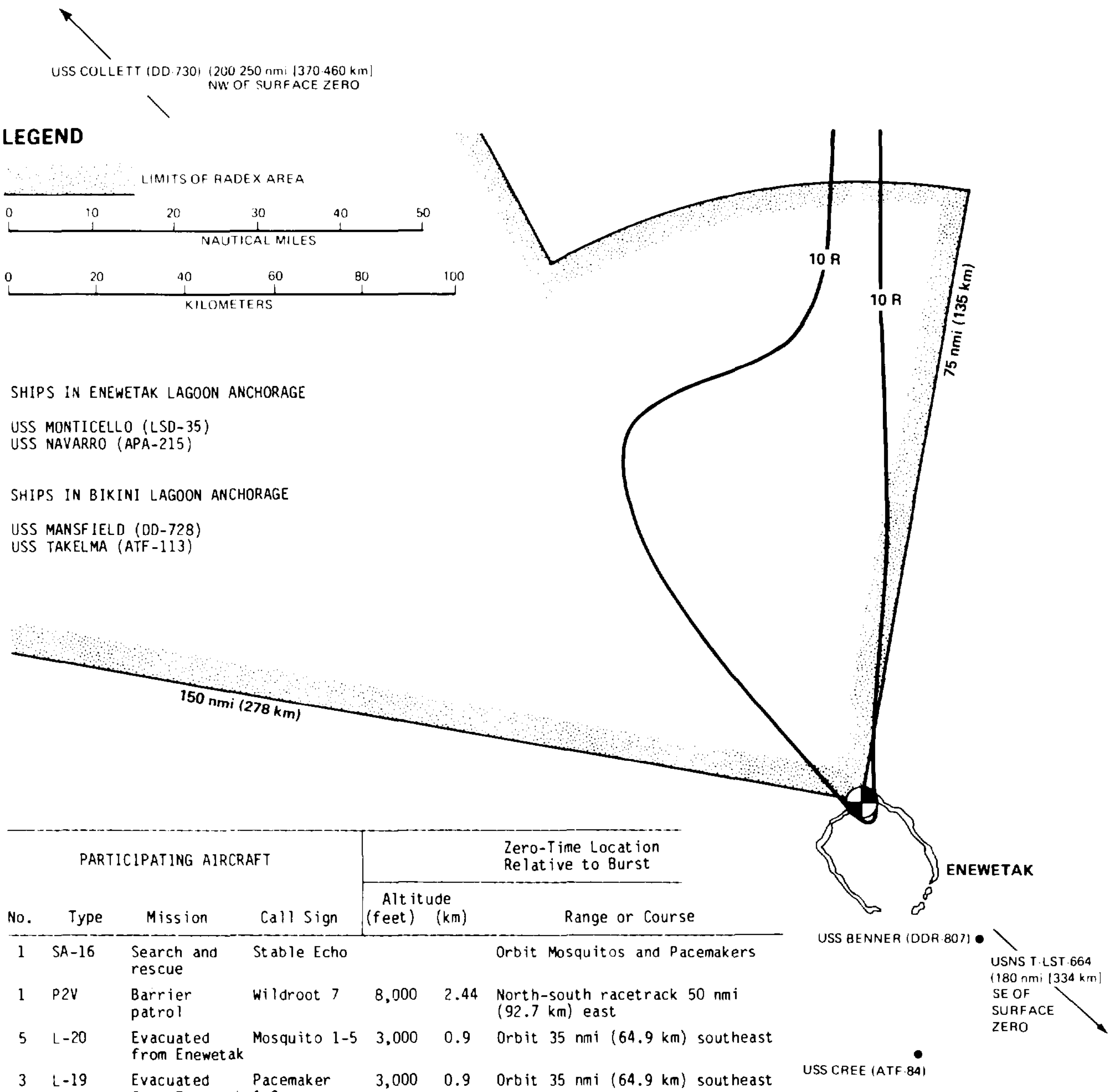


Figure 61. OLIVE predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.



PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo			Orbit Mosquitos and Pacemakers
1	P2V	Barrier patrol	Wildroot 7	8,000	2.44	North-south racetrack 50 nmi (92.7 km) east
5	L-20	Evacuated from Enewetak	Mosquito 1-5	3,000	0.9	Orbit 35 nmi (64.9 km) southeast
3	L-19	Evacuated from Enewetak	Pacemaker 1-3	3,000	0.9	Orbit 35 nmi (64.9 km) southeast
1	B-57B	Sampler control	Opium	35,000	10.67	East-west racetrack 35 nmi (64.9 km) north
1	B-57D	Sampler	Hotshot 11			Climbing $\geq$25 nmi (46.3 km) southeast
4	B-57B	Sampler	Hotshot 2-4 and spare	Not airborne at burst time		
2	B-57D	Sampler	Hotshot 15,16	Not airborne at burst time		
1	P2V	Barrier patrol	Wildroot 5	Not airborne at burst time		

Source: Reference C.4.1.

Figure 62. PINE predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

thermal energy, and water-wave heights were expected to be significant at sites on Parry, Japtan, and Ananij, special safety precautions were taken for all personnel and boats. Before H-1, all small boats were placed alongside larger units or secured to lines of buoys in deep water at least 200 yards (183 meters) from the shoreline. At H+5 minutes, small craft alongside larger units pulled clear until the water waves passed. All personnel were instructed to avoid the beach area at the waterline immediately after the detonation.

The cloud rose quickly to 66,000 feet (20.1 km) with an estimated 38,000-foot (11.6-km) base as measured by radar. A P2V began the radsafe survey on the southern end of the atoll by 0930, but aborted 20 minutes later over Biken Island after recording only background intensity. A second P2V survey at H+3 recorded a maximum of 0.037 R/hr on Enjebi. The second plane, plus a third, proceeded on a northwest and a northeast radial until 1607 to define the major fallout areas.

An H+3 helicopter survey recorded 0.003 R/hr on Runit at 50 feet (15.2 meters). Another survey at H+8 reported the following radiation intensities on the islands of the atoll (R/hr):

Bokoluo	0.1	Boken	0.83
Bokombako	0.1	Enjebi	0.3 - 0.1
Kirunu	0.1	Kidrinen	0.043
Louj	0.06	Biken	0.018
Bokaidrikdrik	1	Unibor	0.03

Fallout occurred within the forecast area, between the 320° and 10° radials.

Reentry hour was 1145. Surface and air radex areas were revised to enclose an area bearing 290° clockwise through 40° with its apex at surface zero, at a radial distance of 10 through 200 nmi (18.5 to 370.6 km), from surface to unlimited altitudes.

The aircraft participation included an SA-16 (Stable Echo) for SAR missions. A P2V (Wildroot 7) aborted, and a second P2V (Wildroot 5) replacing it also aborted. The first P2V (Wildroot 7) was repaired and resumed its original radsafe barrier patrol. A B-57 (Opium) directed the efforts of seven B-57 cloud samplers (Hotshots).

QUINCE and FIG

This pair of shots completed the HARDTACK testing activities at Enewetak. They were ground surface shots, using the same surface zero on Runit. Both were UCRL devices added to the basic HARDTACK schedule. The DOD shared sponsorship with the AEC, although both shots were related to weapon development work. The DOD-sponsored experiments were Projects 1.4, 1.7, 2.4, 2.9, 2.10, 2.11, 2.14, and 8.7. Instrumentation for these experiments was primarily on Runit itself or on barges in the lagoon west of Runit. One non-DOD station about 4,800 feet (1.5 km) from the burst point on the southeastern tip of the island was manned for these shots. Seven manned LCMs were in the lagoon less than 2 nmi (3.71 km) south of surface zero. Except for these and personnel on Ananij, all personnel were evacuated to base islands. Ship positions, surface radex areas, and aircraft participation for QUINCE are shown in Figure 63.

QUINCE was detonated at 1415 on 6 August. The cloud rose to 1,500 feet (457 meters) and contaminated an area of central Runit with alpha-emitting material. Because the same shot point was to be used for FIG, it was necessary to decontaminate the area before preshot preparations could be undertaken for FIG. An area of central Runit extending about 1,200 feet (366 meters) on both sides of the detonation point was designated as a full alpha radex area. A checkpoint was set up at the personnel pier, with decontamination facilities

PARTICIPATING AIRCRAFT				Zero-Time Location Relative to Burst		
No.	Type	Mission	Call Sign	Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 25 nmi (46.3 km) east
1	B-57B	Sampler control	Opium	10,000	3.05	East-west racetrack 10 nmi (18.5 km) north
2	B-57B	Sampler	Hotshot 1,2	15,000	4.57	North-south racetrack 20 nmi (37.1 km) east

Source: Reference C.4.1.

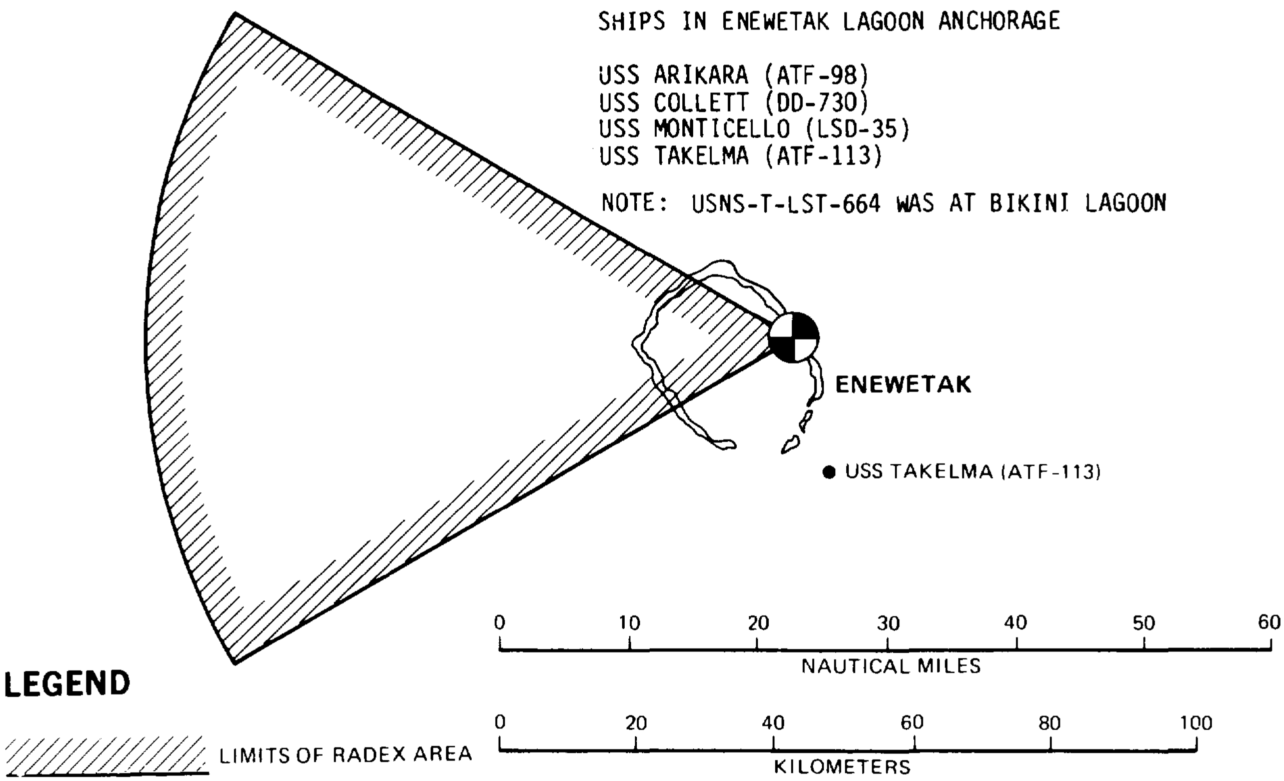


Figure 63. QUINCE predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

provided nearby. In addition, a barge with showering and laundering equipment was moved from Bikini and anchored offshore for personnel and protective clothing decontamination.

An access area was scraped with a road grader from the checkpoint to surface zero. Then a parking area of 75 by 25 feet (22.9 by 7.6 meters) was bladed on the upwind, or ocean, side of surface zero. Approximately 3 to 5 inches (7.6 to 12.7 cm) of contaminated topsoil was removed, picked up by a skiploader, and transported to an area on the west, or lagoon, side of the island. Finally, an area approximately 60 feet (18.3 meters) square at surface zero was scraped to a depth of 3 inches (7.6 cm), and the soil transported to the contaminated-material disposal site. The area still indicated alpha activity in excess of 20,000 CPM, as measured by PAC-3G instruments, and was roped off to prevent personnel from entering. All contaminated equipment and debris within the surface zero area also was discarded at the disposal site.

During the course of the work, 69 nose swipes were taken of personnel working in the area. None of the swipes showed detectable alpha activity. Urine samples were collected from seven heavy equipment operators. All urinalysis results were negative.

A tent was erected at surface zero to protect the instrumentation being prepared for the FIG shot. While project personnel were preparing the device for detonation, air samples were taken both inside and outside the tent.

Alpha contamination in the air inside the tent ranged from a few disintegrations per minute per cubic meter (DPM/m^3) up to 7,000 DPM/m^3, and outside the air contamination was as high as 33,000 DPM/m^3. Although the air contamination inside the tent was much lower than outside, wearing of respirators was required at all times. To keep the air contamination inside the tent to a minimum, the floor and sides of the tent were vacuumed several times daily. All personnel working in the surface zero area were monitored each time they returned through the checkpoint. Their living quarters were also monitored, and alpha swipes were taken at the mess hall on Parry. All swipes proved to be negative.

During this period and until recovery operations were completed after FIG, all vehicles and equipment entering the area north of the rope barrier at the checkpoint were required to remain there for monitoring and decontamination. Two jeeps and two weapon carriers transported personnel and equipment from the checkpoint to the surface zero area (Reference C.5.3).

Among the preparations for FIG was the importation of over 130 tons (118 tonnes) of soil from the Nevada Test Site and its emplacement in a conical plug beneath the intended burst point.

The forecast surface and air radex areas for FIG were issued as follows:

- H-hour through H+6 -- surface through unlimited altitude, apex on surface zero, area bearing 240° clockwise through 300°, radial distance 50 nmi (92.7 km)
- H-hour through H+1 -- circular area with a 1-nmi (1.85-km) radius around surface zero, surface and up.

Ship positions, the surface radex area, and participating aircraft for FIG are shown in Figure 64.

FIG was detonated on 18 August at 1600, producing a cloud that rose 5,000 to 6,000 feet (1.5 to 1.8 km) with a 4,300-foot (1.3-km) base. The radiation intensities at the crater were greater than 10,000 R/hr at H+30 minutes. Reentry hour was 1800. The surface and air radex areas were cancelled at 1900.

The H+20 radsafe survey reported the following radiation intensities (R/hr) on islands of the atoll:

PARTICIPATING AIRCRAFT

No.	Type	Mission	Call Sign
1	SA-16	Search and rescue	Stable Echo
1	B-57B	Sampler	Opium
3	B-57B	Sampler and spare	Hotshot 1,2

Source: Reference C.4.1.

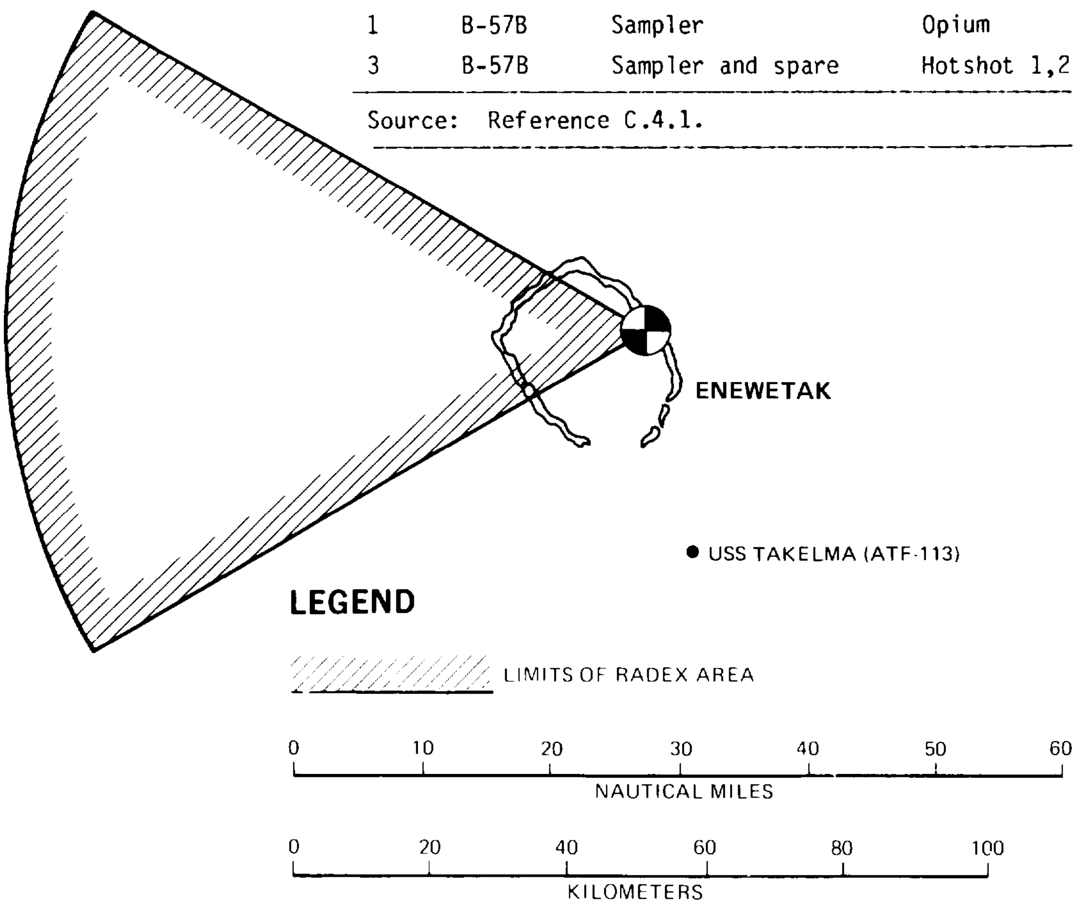


Figure 64. FIG predicted fallout, surface radex area, ship positions, and aircraft participation, Operation HARDTACK.

Bokoluo	0.05	Bokaidrikdrik	0.3
Bokombako	0.1	Boken	0.008
Kirunu	0.025	Runit	1
Louj	0.075	Biken	0.01
Bokinwotme	0.015		

The radsafe checkpoint established after QUINCE was reinstituted to control the flow of personnel working on recovery operations because of high levels of fission products in the surface zero area. Approximately 1,600 checks of men passing through this checkpoint were made during FIG recovery missions (Reference C.1.1685).

CHAPTER 5

DEPARTMENT OF DEFENSE EFFECTS TESTS

Of over 100 nuclear tests in the Pacific and in Nevada, starting with the CROSSROADS tests at Bikini in 1946, only 13 were designed as weapon effects tests primarily for the benefit of the Department of Defense (DOD). The remainder were Atomic Energy Commission (AEC) weapon development tests in which the DOD conducted experiments on a noninterference basis. By 1958, the DOD wanted information on weapon effects that could only be derived from experiments whose complexity effectively precluded the use of nuclear devices that were themselves under development. In addition to this requirement for a proven nuclear weapon, the DOD had special placement requirements for the weapon and the experimental array. Because of these factors, some DOD tests emerged in 1958 as separate operations devoted to the interest in underwater and high-altitude explosion effects.

THE UNDERWATER TESTS

Background and Planning

Operation HARDTACK included two underwater weapon effects tests, WAHOO and UMBRELLA, one inside the lagoon at Enewetak and one outside in the open ocean. These tests were principally of interest to the Navy because of the information they were designed to produce on the employment of nuclear weapons for anti-submarine warfare. A heavily instrumented array of target vessels was deployed for both events. The Navy also conducted an operational exercise during WAHOO (the test in the open sea) in which seven destroyers and two submarines participated.

The United States had conducted two underwater weapon effects tests before HARDTACK. In July 1946, Joint Task Force 1 had detonated shot BAKER, the first underwater nuclear weapon test, in 90 feet (27.4 meters) of water in Bikini Lagoon. This test, the second of the two shots in Operation CROSSROADS, employed a large number of moored, unmanned surface ships and submarines as target vessels. The objective of shot BAKER was to collect data on the effects of an underwater detonation on naval ships. Nine years later, in May 1955, the United States conducted Operation WIGWAM, a single deep-water test detonated at 2,000 feet (610 meters) in the Pacific Ocean, 500 nmi (926 km) southwest of San Diego, California. During Operation WIGWAM a fleet ocean tug towed the device barge and an array of three unmanned submarine-type hulls suspended beneath floats at various distances from the tug. Like BAKER, WIGWAM was an extensive scientific program to record data on the effects of an underwater detonation on naval systems, in this case a detonation in deep water.

In October 1955, the Naval Ordnance Laboratory (NOL) at White Oak, Maryland, established an advisory group charged with recommending further theoretical and experimental requirements for future underwater tests. After examining the underwater testing problem, the advisory group expressed the view that additional underwater tests were essential. The group asserted that "a test is considered important and economically justified, if there is a requirement for data which cannot be obtained from prior atomic tests, high explosive tests, or theory" (Reference D.4).

Navy planning for the HARDTACK underwater testing program began in early 1956. On 1 February 1956, the Atomic Energy Division (Op 36) of the Office of the Chief of Naval Operations (CNO) directed the cognizant Navy offices and bureaus to initiate planning and procurement of materiel for the underwater testing program (Reference C.3.2, Sep 57-Mar 58).

As the scientific and operational requirements for WAHOO and UMBRELLA clearly emerged in March 1957, it was evident that Enewetak rather than Bikini was the suitable location for the tests. Primary considerations in choosing Enewetak were the uniformity of the sea bottom southwest of Enewetak, the relatively flat and unobstructed lagoon bed within the atoll, and the advantages offered by the scientific installations and operational facilities of Parry and Enewetak islands. Bottom conditions were extremely important because of the need to establish moorings for target-array vessels both inside the lagoon and outside the atoll in deep water.

The complexity of the Navy's operational role in carrying out the underwater tests had ramifications for the organizational structure of Task Group (TG) 7.3 as well. The unique responsibilities of WAHOO and UMBRELLA were reflected in the addition of a Technical Director and Special Projects Division to the staff of TG 7.3. The Special Projects Division, particularly the Special Projects Unit, was responsible for all phases of operations connected with the target ships and their positioning within the array. The Special Projects Unit, composed of seven officers and one hundred fifty-nine enlisted men, was "to provide the necessary manpower and technical Navy assistance for towing, positioning in the array, and general maintenance" (Reference C.3.1).

The evolving scientific program for the underwater tests presented the Navy with a unique set of operational problems. Commander Task Group (CTG) 7.3 described the situation confronting planners in 1956 and 1957 (Reference C.3.1):

> The validity of scientific data was dependent upon positioning of target array vessels with exactitude, and once positioned to remain so within narrow limits of tolerance until H-hour. Within the confines of a shallow lagoon or sheltered harbor the exercise would have been fairly easy. However, such was not the case, as WAHOO was a deep water detonation at 500 feet depth requiring that the ships be positioned in depths of water ranging from 400 to 800 fathoms in the open sea, with a maximum mooring leg in 1000 fathoms. Under this condition, wind, sea, currents and tides had to be known or accurately predicted and accounted for, and significant changes in any one of them could wreak havoc with the best laid plans.

Flush-deck steel barges were used as working platforms for target-array moors (see Figure 65). These barges were anchored through buoys to the ocean bottom and the target ships were then put into position by mooring them to the barges. The targets were to be three destroyers, a merchant marine hull, an active submarine, and Squaw-29 (a submarine mockup target used for the WIGWAM test).

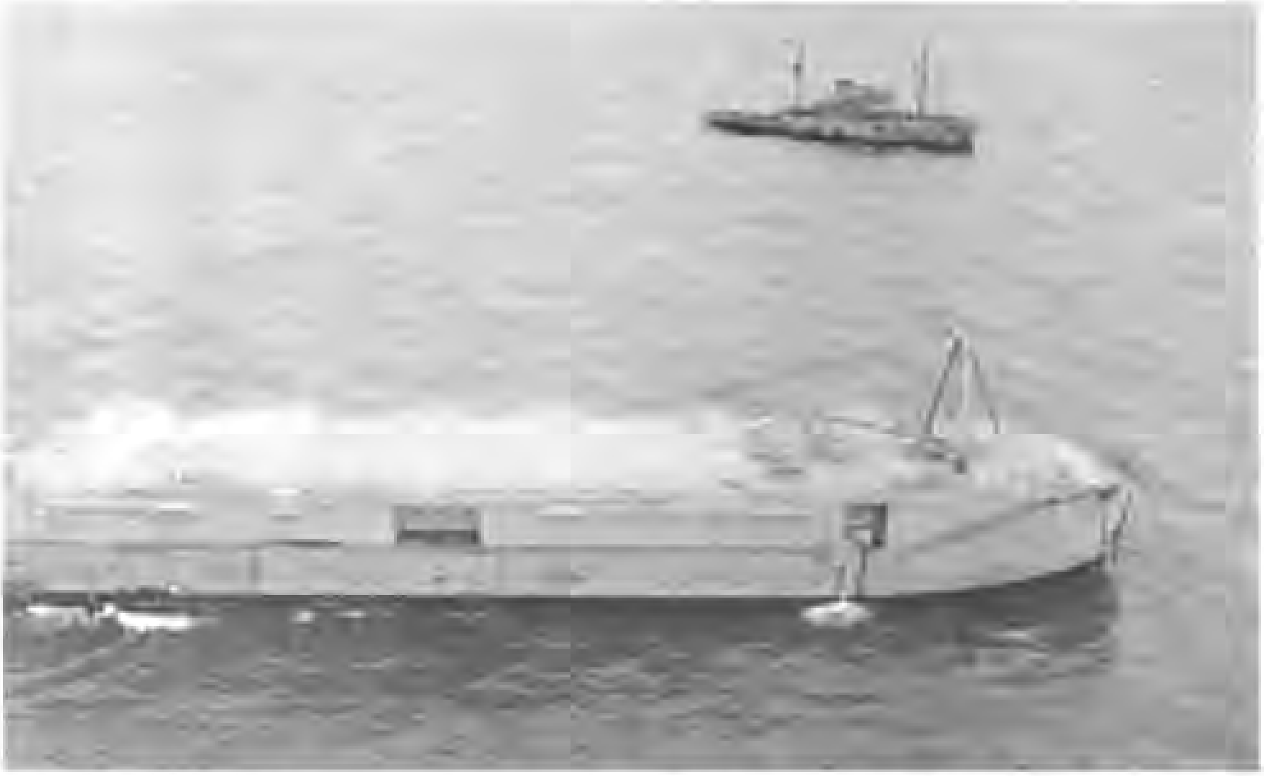


Figure 65. Flush-deck steel barge with washdown system; USS Bolster (ARS-38) is in background, HARDTACK.

A deep-mooring project had no precedent. Thus, to test the mooring design and to train operating forces, the Navy conducted two practical exercises, one at Enewetak in March 1957 and one off Barbers Point, Hawaii, in November 1957.

A major change in the planned array was the decision to omit the operational submarine, Bonita (SSK-3), as an unmanned target. The final report of CTG 7.3 (Reference C.3.1) offers the following reason for this decision:

> Original planning called for the submarine BONITA to be moored in the array in an unmanned condition and submerged to periscope depth at a distance of 10,500 feet from ground zero. Due to heavy seas and adverse weather it was considered that the BONITA could not be positioned between the two YC mooring barges with safety. AFSWP was requested to authorize a change in plans which called for the BONITA to be manned at periscope depth at a distance of 12,500 feet from ground zero. To provide an additional safety factor, however, the position eventually approved for BONITA was 18,000 feet from ground zero.

The Commander in Chief, Pacific (CINCPAC) provided Bonita from among the operating forces of his command. The other target vessels required for WAHOO and UMBRELLA were decommissioned ships acquired from two Navy reserve fleets. In July 1957, representatives from the Navy's Bureau of Ships (BuShips) selected the Liberty ship hull, SS Michael Moran (EC-3), from the U.S. Maritime

Administration Reserve Fleet at Suisun Bay, California. During the same month BuShips also chose three destroyers, Fullam (DD-474), Howorth (DD-592), and Killen (DD-593), from the Reserve Fleet Group, Long Beach, California (Reference C.3.2, Sep 57-Mar 58).

Extensive shipyard work on the destroyers was necessary because the objectives of WAHOO and UMBRELLA included a determination of the effect of such bursts on ships in operating condition. Long Beach Naval Shipyard performed the necessary modifications and renovations on all three ships, starting in September 1957 and extending through January 1958. This work included installation of full-coverage washdown systems.

The same shipyard also prepared Moran. Like the destroyers, the Liberty ship hull had a washdown system installed. However, the scientific program did not require the ship to be in an operational condition. Instead, various kinds of machinery and other equipment were installed on board to measure blast and shock effects.

When work on the target vessels was complete, they were towed to Pearl Harbor and from there to Enewetak. USS Grasp (ARS-24) arrived at Enewetak with Moran in tow on 3 March 1958 (Reference C.3.4.19). The icebreaker USS Staten Island towed the three destroyers, arriving at Enewetak on 19 April 1958 (Reference C.3.4.2.1).

For the WAHOO operational training exercise, seven destroyer types and two submarines participated as the Operational Exercise Element. The participating destroyers were from Destroyer Squadron 1, which included USS Orleck (DD-886), USS Floyd B. Parks (DD-884), and USS John R. Craig (DD-885), and from Destroyer Squadron 9, which included USS Mansfield (DD-728), USS De Haven (DD-727), USS Collett (DD-730), and USS Benner (DDR-807). All seven ships were equipped with washdown systems. The two submarines were USS Sterlet (SS-392) and Bonita.

Planning for the operational training exercise began in early October 1957, when CNO concurred with a CINCPAC request for an indoctrination and training exercise during WAHOO. Involved were CNO; CINCPAC; Commander, Training Command, Pacific Fleet; CTG 7.3; and, to a lesser degree, certain Atlantic fleet commands. The purpose of the exercise, as outlined in a letter from CTG 7.3 to CINCPAC on 10 May 1958 (reproduced in the CTG 7.3 Final Report, Reference C.3.1), was to provide personnel indoctrination and training by observation of certain weapon effects associated with underwater nuclear detonations. This same letter also included a set of safety provisions describing safe ranges for surface and submarine types. Radiological monitoring requirements were that:

> All units will monitor on deck with RADSAFE instruments commencing at H-0.5. Use AN/PDR 27 and AN/PDR 18 in conjunction. Instruments on forecastle, fantail, and bridge areas and in the operating fire rooms. Any additional instruments required will be furnished by Commander Task Group 7.3.

In an 8 April 1958 letter from CINCPAC to Commander Joint Task Force 7 (CJTF 7), the Pacific Navy commander stated that a quota of four observers for each destroyer and submarine participating in the WAHOO operational training exercise had been established. These quotas were allocated to both Atlantic and Pacific Fleet personnel. Little documentation is available that identifies these observers. Only one of the participating destroyers, Benner, identified its four assigned observers, reporting the presence of two Commander Destroyer Forces, Atlantic, observers, one observer from Cruiser-Destroyer Force, Pacific, and one observer from the staff of CINCPAC (Reference C.3.3.4).

Task Group Participation

The two underwater shots were conducted under the normal JTF 7 organization. TG 7.1 (Scientific) was extensively involved in conducting a variety of scientific programs for each of the underwater shots. TG 7.2 (Army) played no direct role in WAHOO and UMBRELLA. TG 7.3 (Navy) had the greatest interest in the underwater shots and was the largest and most active participant. TG 7.4 (Air Force) was an active, but limited, participant. TG 7.5 (Base Support) provided numerous support operations.

TASK GROUP 7.1 (SCIENTIFIC). Task Unit (TU) 7.1.3 (Field Command Weapons Test Unit) in TG 7.1 was responsible for the scientific programs associated with underwater tests. Staff personnel for TU 7.1.3 were furnished by Field Command, Armed Forces Special Weapons Project (AFSWP), with a small number of additional personnel furnished by Hq AFSWP. Operational personnel came from several service laboratory organizations. This is further discussed in Chapter 3.

TASK GROUP 7.3 (NAVY). Missions assigned by CTG 7.3 to support WAHOO and UMBRELLA were similar. For WAHOO, the specific missions were to:

- Conduct a training exercise for destroyers and submarines in connection with the event
- Properly position the target array, including the submergence of Bonita
- Assist in the placement of the weapon
- Have the main engines of the target DDs and various auxiliary machinery in operation during the event
- Evacuate all personnel from target-array vessels before detonation
- Decontaminate target-array units when directed
- Salvage all target-array units as necessary
- Assist in recovery of floating instrumentation after the event
- Furnish ship and boat transportation to and from target array for evacuation and reentry
- Return target array to the lagoon as soon as feasible after WAHOO in preparation for UMBRELLA
- Provide aerial surveillance of assigned sector
- Take radioactive water samples at about H+30 minutes, or when designated, provided they are not obtained by TG 7.4 helicopters.

Specific missions for UMBRELLA were to:

- Properly position the target array, including the submergence of Bonita and Squaw-29
- Assist in the placement of the weapon
- Evacuate all targets before detonation
- Decontaminate target-array units when directed
- Salvage target-array units as necessary
- Furnish ship and boat transportation to and from the target array for evacuation and reentry
- Perform all diving operations for placement and recovery of underwater mines and instrumentation
- Recover vital samples such as radiochemical water samples, test animals, sample collectors, rocket canisters, coracles and film packs, balloons, and gauge strings immediately after radsafe survey and when radiological safety permits
- Provide Radsafe and Decontamination Center afloat
- Maintain all TG 7.3 units and personnel in safe positions
- Recover mines after the event when safety permits
- Provide aerial surveillance on assigned sector on D-day until H-1 and furnish aircraft for barrier patrol
- Recover less vital instrumentation, gauge strings, and coracles inside lagoon on D+1 and until completed.

Buildup of Navy ships in the Eniwetok Proving Ground (EPG) before WAHOO had been steady. Immediately following WAHOO, the number of Navy ships in the EPG peaked, decreasing thereafter until the end of the operation and rollup. Figure 66 depicts this change in the level of naval effort. During WAHOO, 27 Navy ships participated at Enewetak. UMBRELLA, 24 days later, involved 19 Navy ships at Enewetak. At least two factors explain the difference in level of involvement. First, WAHOO was used as an opportunity to conduct an operational test exercise with fleet units. Destroyer Squadron 1 was due to be relieved by Destroyer Squadron 9 before the WAHOO event, but the former was delayed to allow both squadrons to participate in the shot. The second reason was that the Navy support requirements for the deep-water WAHOO event were greater than for the shallower UMBRELLA shot.

TASK GROUP 7.4 (AIR FORCE). TG 7.4 carried out a number of assignments in the two underwater shots.

Aircraft flew photographic missions for Project 1.3 and sampling missions for Project 11.2. TG 7.4 SA-16 amphibians were in flight on alert for SAR missions and also dropped floating film packs (FFPs) for Project 2.3. SA-16s and Air Force H-19s also participated in the postshot recovery of these FFPs. A TG 7.4 AVR removed the arming party from the zero barge. TG 7.4 was responsible for its own aircraft decontamination (Reference C.4.2).

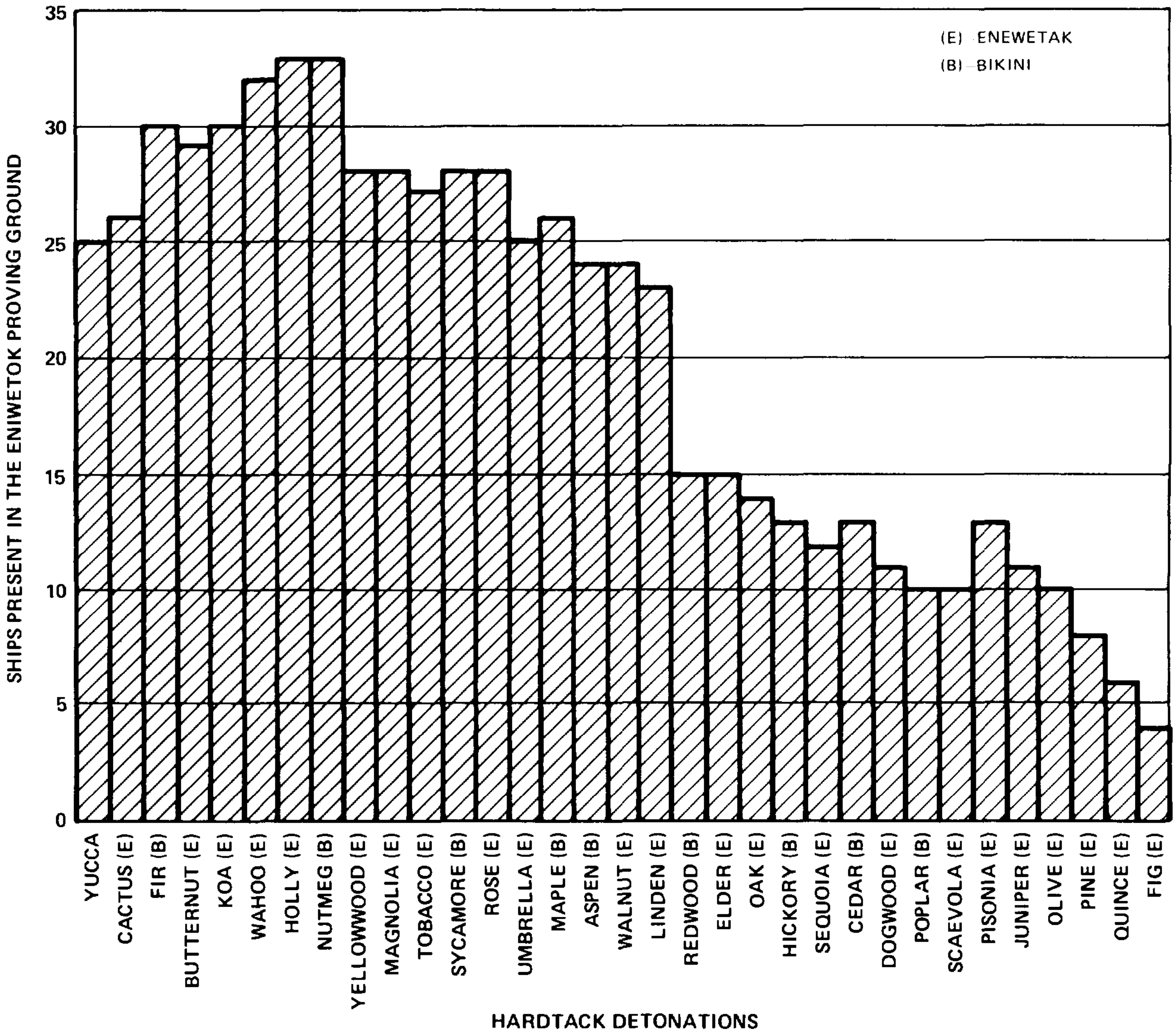


Figure 66. Naval unit participation in HARDTACK.

UMBRELLA was not expected to produce significant fallout outside of the target array and downwind islands at Enewetak. However, postshot cloud sampling, barrier patrols, and one surveillance radiation survey flight were flown (Reference C.4.2). The barrier patrol was flown by a TG 7.3 Patrol Squadron 28 (VP-28) P2V aircraft from Naval Air Station (NAS), Kwajalein.

WAHOO

Table 21 identifies the TG 7.3 units present for the event.

TARGET-ARRAY MOORING. Weapon effects information requirements and the scientific program demanded precise positioning of the target vessels. For the UMBRELLA shot in shallow water, this presented no problem. However, for the deep-water WAHOO shot, target ships had to be moored in depths of water ranging from 2,400 to 4,800 feet (732 to 1,463 meters), requiring the maximum mooring

Table 21. Task Group 7.3 participation in HARDTACK, WAHOO.

Element	Mission	Units Participating
7.3.5.0	Flagship	USS Boxer (CVS-21) Four helicopters
7.3.5.1	Mooring, Towing, and Recovery	USS Grasp (ARS-24) USS Bolster (ARS-38) USS Takelma (ATF-113) USS Arikara (ATF-98) USS Chowanoc (ATF-100) USS Moctobi (ATF-105) USS Munsee (ATF-107) USS Cree (ATF-84) USS Chanticleer (ASR-7)
7.3.5.2	Surface Transportation and Boat Pool	USS Monticello (LSD-35) TG 7.3 Special Projects Unit TG 7.3 Boat Pool Detachment Twelve LCMs
7.3.5.3	Decontamination	USS Renville (APA-227) TG 7.3 Decontamination Element
7.3.5.4	Operational Exercise	USS Orleck (DD-886) USS Floyd B. Parks (DD-884) USS John R. Craig (DD-885) USS Mansfield (DD-728) USS De Haven (DD-727) USS Collett (DD-730) USS Benner (DDR-807) USS Sterlet (SS-392) Bonita (SSK-3)
7.3.5.5	Oceanographic and Observation	USS Rehoboth (AGS-50) USS Hooper Island (ARG-17)
7.3.5.7	Surface Targets	Howorth (DD-592) Fullam (DD-474) Killen (DD-593) SS Michael Moran (EC-2)

Source: Reference B.0.4.10, WAHOO.

leg to be in 6,000 feet (1,829 meters) of water. Such deep-water mooring had never been done before and was considered impractical by many experienced hands (Reference C.3.1).

The critical preshot preparations for WAHOO included two practical exercises to establish the capability of the deep-water mooring concept. The first of these tests was in March 1957 at the proposed WAHOO site outside Enewetak Lagoon. One leg of the moor design was laid and determined to be completely adequate. The second test took place off Barbers Point, Hawaii, in November 1957, in which a complete three-leg fixed moor was placed in 2,400 feet (732 meters) of water. This test proved that the design features of the complete mooring were successful (Reference C.3.1).

What remained to be seen was whether wind and sea factors at the WAHOO site had been adequately predicted. The deep-water mooring design had been predicated on these factors. There was proof that the moor could be laid, but whether it would hold the target array in the required positions for the necessary period of time to obtain satisfactory test results was uncertain.

The number of mooring legs in the array design required a minimum of four fleet ocean tugs and one salvage ship. The mooring plan called for laying moors for eight barges. These flush-deck steel barges were selected to provide a suitable working platform. Each barge would be moored with three or four legs. Additionally, four standard mooring buoys would be laid. Target ships would be affixed to the mooring barges and buoys just before the WAHOO event. A final requirement was for the surface-zero buoy and its instrumentation barge to suspend the WAHOO weapon at a 500-foot (152-meter) depth (Reference C.3.1).

Actual mooring operations at Enewetak began on 19 March with the mooring of the WAHOO surface-zero buoy. Operating ships participating in the deep-mooring project are listed in Table 22. Two types of Navy barges and one type of Army barge were used in the operation. The target moors employed Navy standard 250-ton YC barges, 110 feet (34 meters) by 34 feet (10.4 meters); Navy standard 500-ton YC barge, 110 feet (34 meters) by 34 feet (10.4 meters); and Army standard 250-ton BC barges, 110 feet (34 meters) by 32 feet (9.8 meters) (Reference B.3.2):

Navy YC Barges		Army BC Barges
YC-1354	YC-1415	BC-6515
YC-1413	YC-1416	BC-6518
YC-1414	YC-1417	

Table 22. Task Group 7.3 deep-mooring project vessels for HARDTACK, WAHOO.

Fleet Ocean Tugs	Salvage Ships	Harbor Tugs
USS Cree (ATF-84)	USS Grasp (ARS-24)	YTB-182
USS Arikara (ATF-98)	USS Bolster (ARS-38)	YTB-188
USS Chowanoc (ATF-100)		
USS Moctobi (ATF-105)		
USS Takelma (ATF-113)		

Source: Reference C.3.1.

The surface-zero buoy was laid on 21 March, but work on the last moor was not completed until 14 May. Sea conditions and some unforeseen technical problems in laying the mooring pattern resulted in a 1-day delay in scheduled shot time.

The assembled target vessels made up the Special Projects Element of TG 7.3, together with Squaw-29 and the barge YFNB-12. Between 4 and 15 May, the ships and personnel of the Special Projects Unit, the Technical Assistance Unit, and the Mooring Element prepared the target array for WAHOO. The target ships were towed out of Enewetak Lagoon and positioned on their respective barges and individual moors. On 14 May, USS Cree (ATF-84) towed Moran into its mooring position broadside, 2,300 feet (701 meters) from surface zero. On 15 May the three destroyers were moved: USS Bolster (ARS-38) towed Howorth to its moor, where it was positioned broadside to the detonation site; USS Takelma (ATF-113) towed Killen to its moor, where it was positioned head-on to surface zero; and USS Arikara (ATF-98) towed Fullam to its moor, where it was positioned stern-on to surface zero (Reference C.3.1).

Throughout the deep-water mooring operation, wind and sea conditions were more severe than expected. Many legs had to be replaced, and the ultimate success of the operation was doubtful.

The commander of the Technical Assistance Unit reported in early May to CTG 7.3 that the roughness of the seas had convinced the commander of the Mooring Element that it would be necessary to place the target ships in position on one day and fire the shot the next morning. Moreover, the commander of the Mooring Element considered it impossible to safely submerge or even to attempt to place the unmanned Bonita between the buoys and the adjacent barges. He recommended manning and repositioning Bonita in calmer waters near the training exercise sector to assure saving Bonita for shot UMBRELLA. CTG 7.3 approved the recommendation, and consequently Bonita was manned and positioned 18,000 feet (5.5 km) from surface zero. The merchant hull, Moran, was placed in the mooring array 2 days before the shot and the three destroyers 1 day before.

Target ship and barge positions are shown in Figure 67. The actual distances from surface zero, based on an Air Force aerial survey of the array just before the WAHOO detonation on 16 May, are given in Table 23.

RADIOLOGICAL SAFETY PLANNING. The planned scientific program for both underwater shots required special attention to decontamination and attendant radsafe considerations. Early recovery of scientific data from contaminated ships would be required. In addition, the entire target array would then have to be moved and repaired after WAHOO for the UMBRELLA shot. Finally, all mooring hardware would have to be retrieved and, if required, decontaminated. To assist in these requirements, TG 7.3 Radiological Safety and Decontamination Unit, composed of 1 officer and 200 enlisted men, was established. All of its petty officers were sent to a special 4-week radsafe course. These petty officers then trained the rest of the unit (Reference C.3.1).

Members of JTF 7 received explicit notice concerning radiological safety and other hazards associated with WAHOO. On 30 April, Hq TG 7.1 distributed

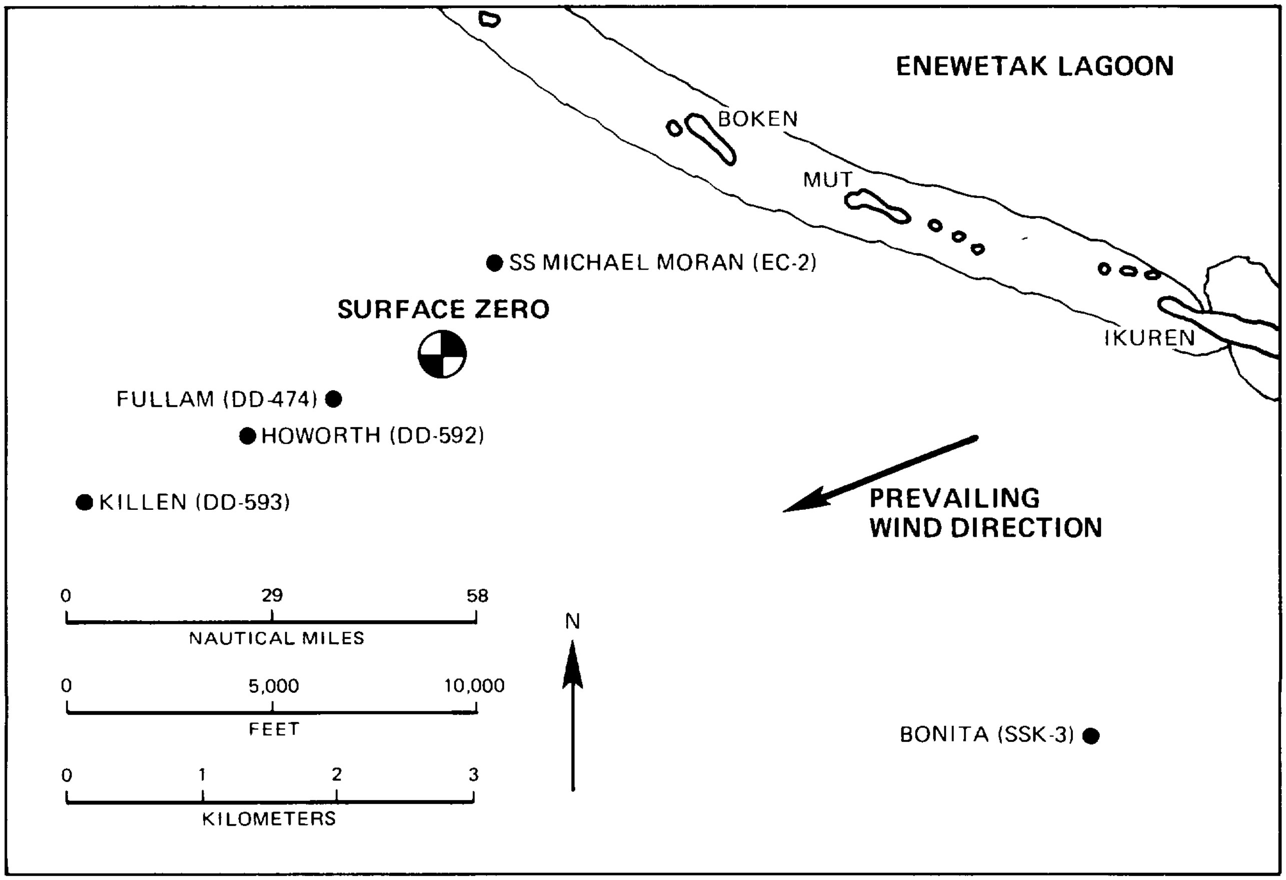


Figure 67. HARDTACK, WAHOO target array.

Table 23. Target ship and barge distances from surface zero, HARDTACK, WAHOO.

Target	Distance (feet)	Distance (km)	Target	Distance (feet)	Distance (km)
YC-1	3,414	1.04	DD-592	4,835	1.47
EC-2	2,346	0.72	YC-6	6,250	1.91
YC-2	1,915	0.58	YC-7	7,845	2.39
YC-4	2,014	0.61	DD-593	8,887	2.71
DD-474	2,915	0.89	YC-9	9,883	3.01
YC-5	4,337	1.32	YC-8	10,108	3.08

Source: Reference C.3.1.

Operations Letter, WAHOO-1 (Reference B.1.5). The letter predicted that no airblast or wave action problems would occur, and that the radioactive debris would be carried southwest by surface winds and water currents; therefore no radiation effects within the lagoon were anticipated.

Later, in its Radiological Safety Recovery Concept section, this letter outlined postshot planning (Reference B.1.5, WAHOO-1):

> The target array ships will have been exposed to a continuous wash down treatment from the time the crews were evacuated until after the fallout from the shot subsides.
>
> Under the direction of CTG 7.3, ships of the target array support unit will be located south of the atoll at shot time. Following the detonation, radiation levels permitting, the ATF's will salvage and/or tow to quieter waters of the lagoon the ships remaining in the target array. Priority of recovery will be given to . . . the EC-2.
>
> Re-entry by project personnel on to the target array will take place after rad-safe clearance has been obtained from CTU-6. For most projects this will be after the ships have been re-anchored in the lagoon.

On 12 May, CJTF 7 issued Operation Order 13-58 (WAHOO Event) (Reference B.0.4.10), which stated:

> WAHOO is not expected to produce significant fallout outside the target array. Cloud tracking flights will not be required. One surveillance flight on D-day and post-shot cloud sampling will be required.
>
> There will be no general re-entry hour established. Each target in the array will require a separate RADEX analysis. Clearance for towing and/or boarding will be established for each vessel in the array.
>
> There will be no air blast or thermal effects from this shot which will affect the occupied camps or ships outside of the target array. This event may be watched without goggles.

In this order, TG 7.3 was directed to conduct an aerial surveillance beginning at sunrise on D-day and continuing until H+1. This mission was flown by VP-28 P2Vs from NAS Kwajalein. The Mooring, Towing, and Recovery Element was directed to tow the target ships to the prescribed decontamination berth in the vicinity of TG 7.1 Radsafe Operations Center afloat.

On 12 May, CTG 7.1 distributed Operational Letter WAHOO-3, an evacuation and reentry check list for Enewetak Atoll from WAHOO D-3 through WAHOO D+2. This letter outlined the planned recovery procedures. Procedures included protective clothing for all personnel in the LCMs as well as those on other surface vessels who were involved in recovery operations. Personnel without protective clothing were to avoid washdown water. TG 7.3 was to monitor target-recovery ships and decontaminate them (Reference B.1.5, WAHOO-3).

SHOT OPERATIONS. The prodigious mooring effort was completed one day behind schedule. When the mooring array was ready and the target ships in place, the weather was good and complete aerial coverage was possible. Weather conditions at H-hour for shot WAHOO were scattered cumulus clouds with bases at 2,300 feet (0.7 km) and tops at 4,000 feet (1.2 km), high cirrus overcast, temperature 87.5°F, (36°C) and surface winds of 15 knots (27.8 km/hr) from the east. The surface radex area from shot time to H+24 was between the azimuths of 230° and 280° extending 60 nmi (78 km). The same area up to an altitude of 13,000 feet (4 km) was defined as the air radex for 2 hours after the shot. Aircraft participation is summarized in Table 24.

WAHOO was detonated at 1330 on 16 May. A spray dome appeared on the surface within the first second following the detonation, reaching its maximum height of 840 feet (256 meters) in 7 seconds. It appeared as an inverted cone with sides sloping at about 45° with a rounded or blunted tip. Plumes began to break out of this cone in all directions about 6 seconds after the burst. At about 12 seconds the rise of the vertical plume slowed noticeably, but the

Table 24. Aircraft participation in HARDTACK, WAHOO.

				Zero-Time Location Relative to Burst		
No.	Type	Mission	Call Sign	Altitude (feet)	Altitude (km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 25-30 nmi nmi (46.3-55.6 km) east
1	RB-50	Project 1.3[a] photo	Carter 1	25,000	7.62	Directly overhead
1	RB-50		Carter 2	2,500	0.76	Orbiting 25 nmi (46.3 km) northeast
1	C-54	Photo	Pewter 1	1,500	0.46	19,000 feet (5.79 km) horizontal range north-northwest
1	C-54	Photo	Pewter 2	10,600	3.23	20,000 feet (6.10 km) horizontal range north-northwest
1	C-54	Photo	Pewter 3	8,100	2.47	19,000 feet (5.79 km) horizontal range west-southwest
1	B-57B	Sampler control	Opium	20,000	6.10	East-west racetrack 25 nmi (46.3 km) north
2	B-57B	Sampler	Hotshot 1,2	Not airborne at burst time		
1	SA-16	Project 2.3[b]	Stable 3	Not airborne at burst time		
1	WB-50	Sampler	Wilson 3	Not airborne at burst time		

Notes:

[a]Reference C.1.1608.

[b]Reference C.1.1621.

Source: Reference C.4.1 except as noted.

lateral plumes continued to spread. Figure 68 shows WAHOO at about this time. Maximum height of the plumes was about 1,600 feet (488 meters) 15 seconds after the burst. By 20 seconds the lateral plumes had collapsed and the maximum diameter of the dome and plumes was about 3,800 feet (1.2 km). At this point, much of the spray formed in the plumes spread out around the burst surface zero as a base surge.

A base surge is a cloud that rolls outward from the bottom of the column produced by a nuclear detonation. In an underwater detonation, the visible surge is a cloud of water droplets flowing almost as if it were a fluid. After the water evaporates, an invisible base surge of radioactive particles may persist.

After about 1.7 minutes the radius of the visible ring of vapor forming the base surge was about 8,000 feet (2.4 km) in the downwind direction and it had an estimated maximum height of 1,100 to 1,400 feet (335 to 427 meters). The downwind edge was observed to move at about 21 knots (38.9 km/hr). The

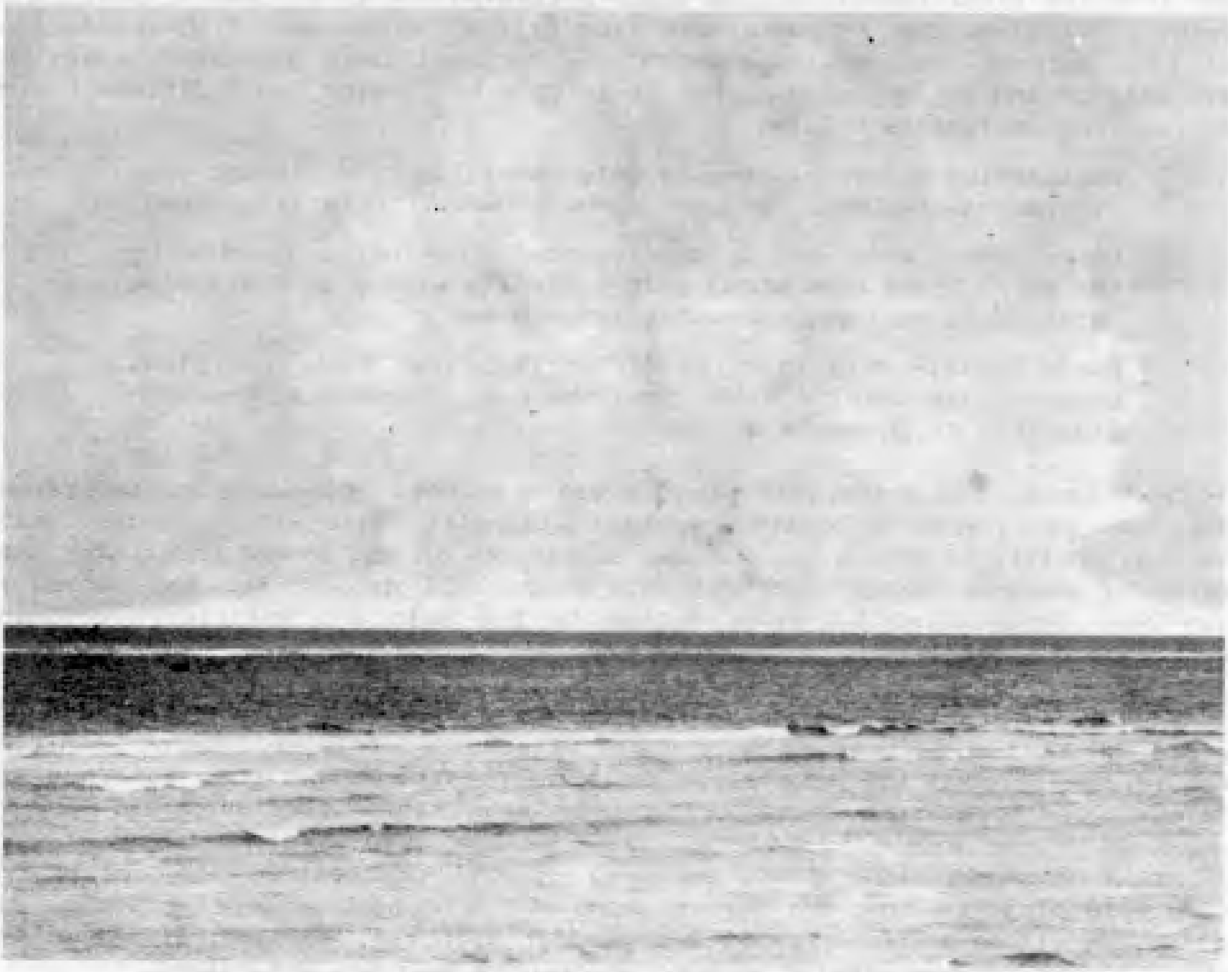


Figure 68. HARDTACK, WAHOO detonation spray dome and plumes.

base surge continued to move out from surface zero and was seen for about 3.5 minutes. Some patches were still visible from the air for about 25 minutes.

After the plume and base surge had disappeared a large foam patch could be seen at the surface zero area. This expanded from a radius of about 4,000 feet (1.2 km) at H+2.4 minutes to a radius of about 6,000 feet (1.8 km) at H+16 minutes. After this, the edge was not visible in its entirety, although a portion could still be seen at H+25 minutes.

The fallout and contaminated surface water remained well within the forecast fallout area and published radiological exclusion (radex) area. Reentry hour was immediately after the shot. A helicopter survey was made at H+4 with moderate readings reported along the southwestern chain. Maximum intensity was 0.030 R/hr, recorded on Biken Island (Reference C.1.6.2, Vol 2). An estimate of the cumulative dose to H+6 has been made (Reference A.4) and this is shown in Figure 69. This figure also shows the positions of the ships present at shot time and the target array.

Graphic descriptions of the personnel reactions to the WAHOO detonation came from the final reports of the ships participating in the WAHOO operational training exercise. Two extremes were from Orleck, which was 10,300 yards (9.4 km) from surface zero and observed that "No significant personnel reactions were noted," and De Haven, at 5,900 yards (5.4 km), which had a different view and reaction (Reference C.3.5):

> Engineering Spaces--Personnel were generally calm, though considered it violent. In some cases personnel were frightened.
>
> Lower Sound Room--Shock wave sounded like water rushing by the ship. Shock wave shook ship violently with a loud cracking noise. Personnel were somewhat frightened.
>
> Bos'n Locker--Ship vibrated violently, first fast then slow. Sounded like water pouring into the ship. Personnel were considerably frightened.

On balance, the scientific program was a success. Placement of the target ships was calculated to obtain important scientific data without jeopardizing the availability of the ships for use as targets in the second underwater shot test. For example, Moran received only minor hull damage, but was judged to have been immobilized by shock damage to its main and auxiliary equipment (Reference C.1.1627).

Washdown systems on the target ships and barges were active for 5-1/2 hours before detonation as well as many hours afterwards. This self-decontamination measure ran through the base surge exposure phase and continued to flood and drain exposed deck areas of contaminants for many hours after exposure.

EARLY RECOVERY OPERATIONS. Recovery operations obtained the results of scientific projects from the target ships and nontarget monitoring sites. Recovery operations necessarily were dependent upon the radiological situation, hence radsafe surveys started as soon as reentry hour was determined.

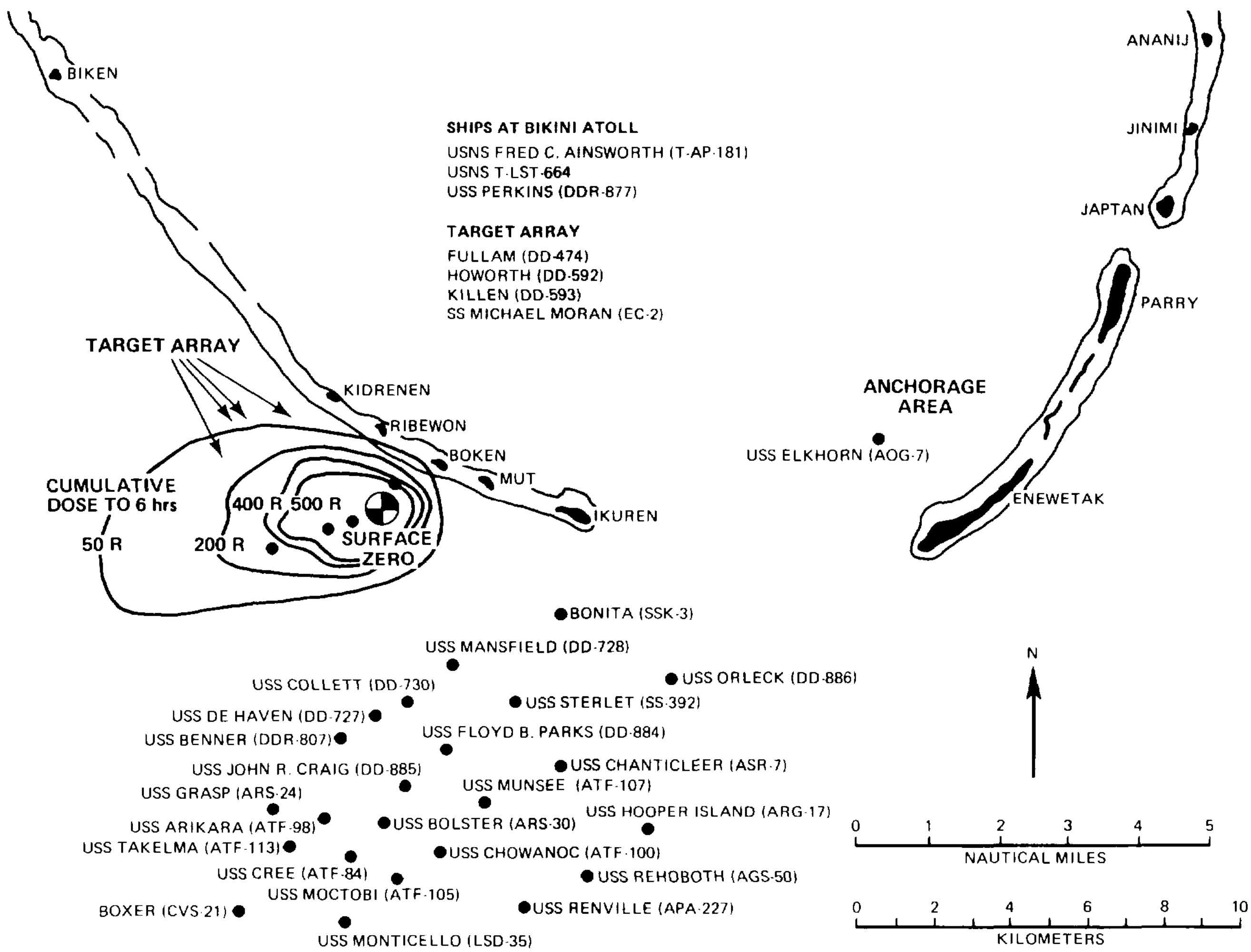


Figure 69. Ship positions at HARDTACK, WAHOO, and cumulative dose to H+6.

USS Moctobi (ATF-105) approached the target array 15 minutes after the detonation to make the initial radsafe survey. Moctobi first approached Killen (the target ship at the greatest range downwind) and took radiological readings. After 25 minutes, Moctobi maneuvered to stand clear of the target array. It recorded readings of 0.015 R/hr in the ship's motor room and 0.0125 R/hr in its engine room (Reference C.3.4.29). It is not clear from the log who went aboard Killen or how the readings were taken. Personnel from Projects 2.1, 2.2, and 2.3 were aboard Moctobi and had instrumentation on Killen and possibly boarded it (Reference C.1.1621). The TG 7.3 Radiological Safety and Decontamination Unit picked up badges for some of the Program 2 projects and possibly supplied personnel to the early boarding group. TU 7.1.6, however, is the most likely source of these early boarders. At 1440, 1 hour and 10 minutes after the detonation, Moctobi approached the area over the bubble formed by the detonation to obtain a 5-gallon (19-liter) surface water sample from the 5-R/hr area. The ship's log reports that at 1505 the ship entered a 3.8-R/hr field and began taking water samples from the bubble area. At 1530, Moctobi rendezvoused with USS Monticello (LSD-35) to transfer the water samples. These water samples were taken by helicopter from Monticello to the airstrip at Parry Island. Moctobi returned to Killen, approaching within 50 yards (46 meters) to take radiological readings. It then approached Moran for similar monitoring. During Moctobi's initial radsafe survey, other tugs in the recovery element were also directed to the target array to obtain postshot radsafe readings at other locations (Reference C.0.2, WAHOO).

An attempt was made on D-day to approach Moran to remove some mechanical shock gauges, but the area was not cleared for entry. On D+1, project personnel once again came alongside Moran and successfully transferred the mechanical gauge line. At the same time, part of an electronic gauge string was recovered, but due to tangling and the "level of radioactivity," only three gauges were recovered before the string was cut loose (Reference C.1.1606).

Project 2.2 personnel recovered data from Howorth on D+1. The ship's washdown system had operated until approximately H+19 (Reference C.1.1628):

> The recovery party boarded the ship at H+21 hours 55 minutes (1125) to recover samples, instruments, charts, and Project 2.1 film badges, which had been installed in Project 2.2 test spaces. Recovery was completed in 45 minutes. No pocket dosimeter exceeded 150 mr.

The report of Project 3.4 personnel also indicates that radiological conditions delayed their recovery of Moran (Reference C.1.1628):

> The EC-2 was towed to the lagoon after Shot Wahoo [on 17 May D+1]. Because of the susceptibility of photographic film to damage from radiation, the films in the EG&G motion-picture cameras were removed from the EC-2 at the earliest practical time. In addition, the project records were removed as soon as reentry to the target ships was permitted. As soon after Shot Wahoo as possible, the project carried out detailed damage measurements on the hull of the EC-2; these were made with a surveyor's transit in sufficient detail to yield actual damage contours of the ship's hull. As soon as the target ships were reasonably free from radiological contamination, instrumentation engineers boarded the target ships, conducted a detailed inspection, and prepared a damage report on the instrumentation installations.

The project report does not quantify references in the foregoing quote to "earliest practical time," "as soon as reentry was permitted," or "reasonably free from radiological contamination." The dates, times, and the radiation level upon entering are not known.

REMAINING RECOVERY AND DECONTAMINATION OPERATIONS. On D+1, the recovery unit sortied to the WAHOO operating area to continue recovery operations. A memorandum of a telephone conversation between the Deputy CTG 7.3 and his Chief of Staff states that at about 1100 on 17 May, the following recovery action was taking place (Reference C.3.6):

- Takelma was standing by Killen and was expected to leave with Killen in tow for the lagoon within the hour.

- Chowanoc was standing by and washing down Howorth with the assistance of YTB-182.
- Arikara was washing down Fullam.
- Moctobi was standing by barges YC-8 and YC-9 to return them to the lagoon.
- Cree, with Bolster assisting, was standing by Moran. One strip of gauges was still to be recovered. Moran was expected to be under tow within the hour.
- Grasp was proceeding to recover coracle No. 1, which went adrift and was bearing about 260° 10.5 nmi (19.5 km) from surface zero.

A second, up-dating telephone call was received from the Deputy CTG 7.3 at 1245. Moran was reported in tow. Howorth and Killen were expected to be in tow shortly. The radiological situation on Fullam was improving, the gauges were expected to be removed from the ship, and the ship was expected to be in tow late in the day (Reference C.3.6).

Each of the TG 7.3 tugs, salvage craft, and boats had radsafe monitors aboard to assist in reducing the chance of accidental radiation overexposure. Each ship commander was ultimately responsible for accepting or rejecting advice from the monitor. CTG 7.3 WAHOO Operation Order 15-58 anticipated that differences of opinion regarding radiological safety and contamination control procedures might arise. In cases of dispute, the final decision was to be requested from the Officer-in-Charge, TG 7.3 Radiological Safety and Decontamination Unit, embarked on USS Renville (APA-227) (Reference B.3.3, 15-58 WAHOO).

Once the contaminated WAHOO target ships were inside the lagoon, recovery was supported by the TG 7.3 Boat Pool Detachment, which transported decontamination personnel and equipment between Renville and the array craft. CTG 7.3 warned that (Reference B.3.3, 15-58, WAHOO):

> Careful control of possible contamination of these craft and their crews will be maintained by the OIC, DECON Unit; in so far as possible, craft initially assigned will be utilized until completion of decontamination of array craft.

After the target ships were towed into Enewetak Lagoon, they were allowed to cool and, when permitted, recovery operations were completed and the target ships prepared for shot UMBRELLA (Reference C.3.3.30). On 25 May, nine days after shot WAHOO, Grasp towed Moran to berth B-3 mooring, and YTB-182 and -188 nested the three destroyer target ships alongside USS Hooper Island (ARG-17) at buoy B-1 (Reference C.3.1).

UMBRELLA

Table 25 displays the TG 7.3 units present for the event.

TARGET-ARRAY PREPARATIONS. Preparation of the array for UMBRELLA proceeded concurrently with the salvage of the targets from the WAHOO array, beginning on 20 May 1958.

Table 25. Task Group 7.3 units participating in HARDTACK, UMBRELLA.

Task Unit/ Element	Mission	Units Participating
7.3.1	Technical Coordination	
7.3.3	Science Weather Reconnaissance and Security	
7.3.5	UMBRELLA Test and Exercise	
7.3.5.0	Flagship	USS Monticello (LSD-35)
7.3.5.1	Decontamination	USS Magoffin (APA-199) Task Group 7.3 Radiological Safety and Decontamination Unit
7.3.5.2	Surface Transportation and Boat Recovery	USS Monticello (LSD-35) Task Group 7.3 Boat Pool Detachment Enewetak 1 LSD, 4 LCMs, 2 YTBs
7.3.5.3	Canister Tracking and Balloon Gauge Recovery	USS Joyce (DER-317) USS Lansing (DER-388) LCU-1376 LCM -49, -56, -58 Task Group 7.4 L-20, two helicopters
7.3.5.4	Coracle and Film Pack Recovery	USS Boxer (CVS-21) HRS-19 helicopters LCU-1384, H&N LCU USS Munsee (ATF-107) LCM-51 Task Group 7.4 AVR
7.3.5.5	Water Sampling	USS Arikara (ATF-98)
7.3.5.6	Gauge String Recovery	USS Chowanoc (ATF-100) LCM-22, -52
7.3.5.7	Weapon Placement, Submarine and Squaw Recovery and Salvage	USS Bolster (ARS-38) USS Grasp (ARS-24) USS Cree (ATF-84) USS Takelma (ATF-113) LCM-21
7.3.5.8	Mine Recovery	USS Lawrence County (LST-887) USS Takelma (ATF-113)
7.3.5.9	Observation	USS Hooper Island (ARG-17) USS Moctobi (ATF-105)

Source: Reference C.0.2, UMBRELLA.

Mooring buoys for the UMBRELLA target ships had already been placed by Moctobi in Enewetak Lagoon when a new array plan was developed. Surface zero was moved 0.2 nmi (0.37 km) in order to accommodate the position of associated experimental equipment. The buoys were moved approximately 1,200 feet (366 meters) in order to conform with the new target-array plan (Reference C.3.1). For UMBRELLA, two additional target vessels were used: Bonita (unmanned) would be submerged 2,900 feet (884 meters) from surface zero, and Squaw-29 would be submerged 1,600 feet (488 meters) from surface zero. The other target ships were located at various distances from surface zero. The target-array positioning relative to the UMBRELLA surface zero is shown in Figure 70.

Of the two underwater shots, WAHOO presented by far the more difficult set of operational and support problems for TG 7.3. In his HARDTACK Summary Report, the Chief, AFSWP, stated the post-WAHOO, pre-UMBRELLA view (Reference C.1.1660):

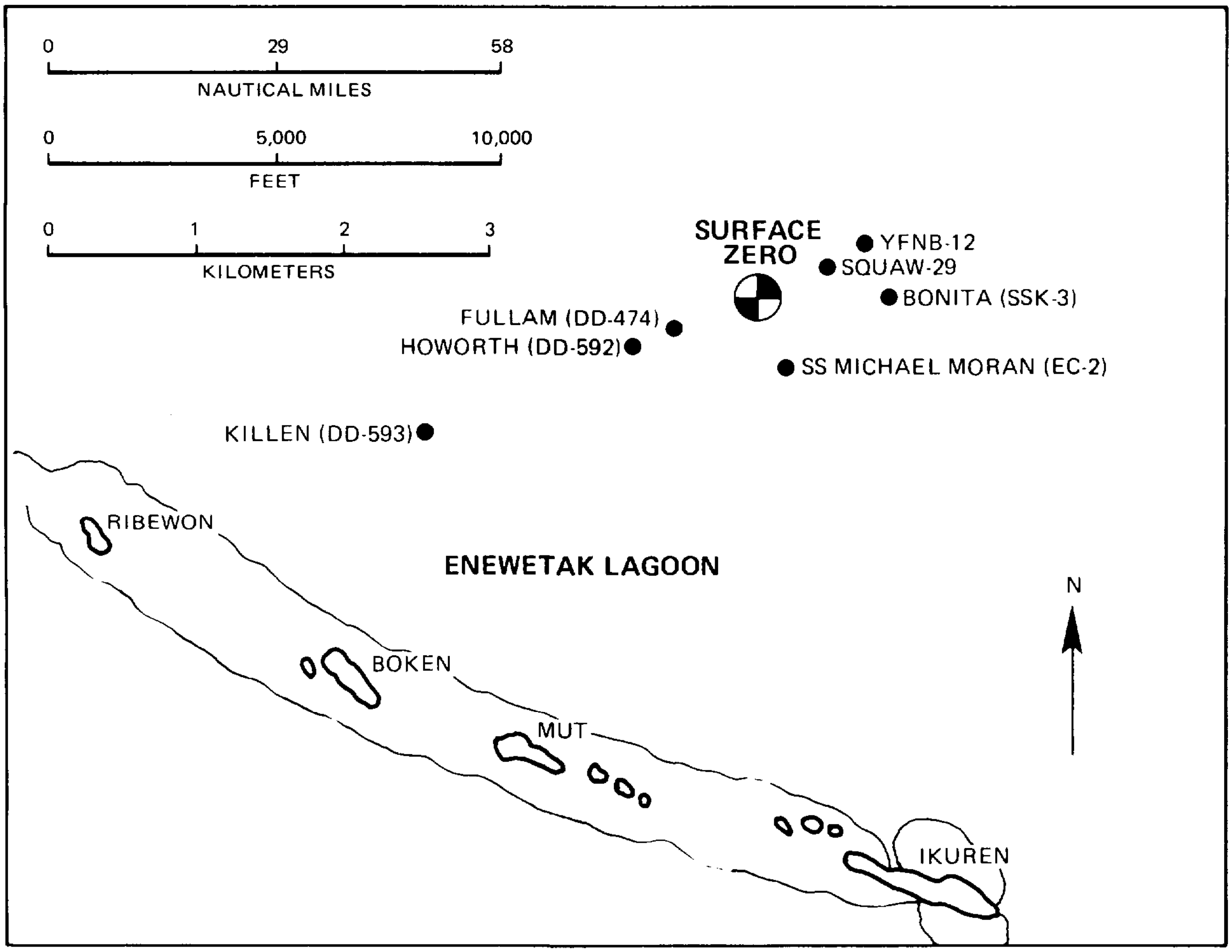


Figure 70. HARDTACK, UMBRELLA target array.

Since very little damage had been done to the majority of the targets by Wahoo, the refurbishing of targets consisted mainly of cleaning up. On the EC-2 which was the one badly damaged target, the only repairs made were those necessary to provide power supplies and to insure safety of the ship and proper operation of scientific equipment.

Umbrella benefited from the experience of Wahoo. With the reduced mooring problem, the preparations could be more realistically scheduled and the execution was smooth. The projects had adequate time in which to double-check all details, and the exhaustive rehearsals eliminated most potential sources of trouble. The excellent results obtained reflected the superiority of the preparations.

On 9 June the target array was complete and Grasp lowered the shot device at surface zero. Figure 71 shows Grasp in this operation and Figure 72 is the LCU that served as the platform for the firing racks and surface-zero instrumentation. The device itself was suspended from the buoy shown.

RADIOLOGICAL SAFETY PLANNING. Radsafe planning generally followed WAHOO plans. CTG 7.1 provided the general concept of radsafe operations and identified the priority of scientific projects that were to be recovered before decontamination. These early recovery projects were (Reference B.1.5, UMBRELLA-5):

- Project 1.1 -- float equipment and some gauge strings
- Project 1.2 -- rocket nosecones and canisters from balloons
- Project 2.2 -- animal recoveries and air samples from Howorth
- Project 2.3 -- fallout samples on destroyers and some barges; coracles and FFPs; and radioactive water samples.

WAHOO experience also contributed to UMBRELLA plans. In a memorandum to the TG 7.3 Chief of Staff, the TG 7.3 Assistant Plans and Operations Officer (Atomic Defense) discussed the WAHOO radiological experience. He addressed practical problems of conducting the scientific program while meeting the constraints of individual exposure level limits. For example, he recommended that no decontamination be attempted on the day of the UMBRELLA shot. His advice was that TG 7.3 decontamination personnel wait several days to allow for some decay to take place before they were exposed. Appendix A of this report contains a copy of this memorandum.

SHOT OPERATIONS. A successful, full-scale UMBRELLA rehearsal was held on 4 June, 5 days before the scheduled event. Everything was determined to be ready and on 9 June the countdown went normally with only a 15-minute delay. Washdown systems were in operation on all target ships before the shot. The entire target array was in place and appeared to be properly positioned. Table 26 summarizes aircraft participation. The weather was clear with scattered clouds. The wind was 15 to 17 knots (27.8 to 31.5 km/hr), gusting to 20 knots (37 km/hr) from east-northeast. Swells in the target area were approximately 4 feet (1.2 meters) high. Visibility was hazy. The air and surface radex areas

Figure 71. USS Grasp (ARS-24) with HARDTACK, UMBRELLA device and lowering rigging.

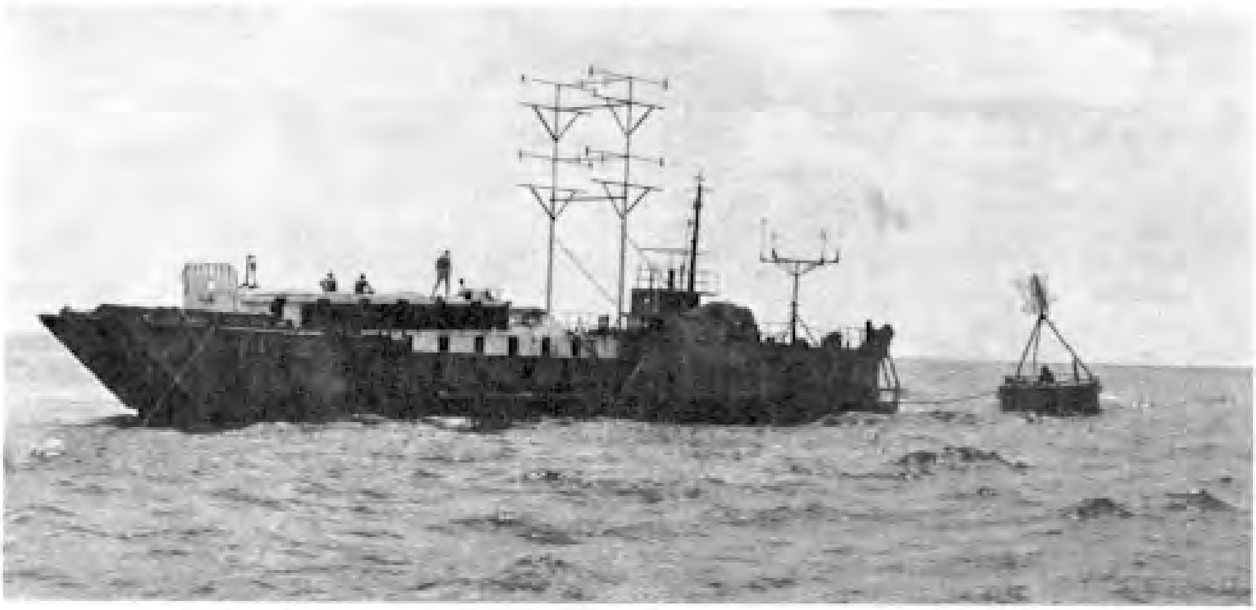


Figure 72. HARDTACK, UMBRELLA surface zero (LCU and buoy).

Table 26. Aircraft participation in HARDTACK, UMBRELLA.

No.	Type	Mission	Call Sign	Zero-Time Location Relative to Burst: Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable Echo	7,000	2.13	North-south racetrack 24 nmi (44.5 km) east
1	P2V	Barrier patrol	Wildroot 7	2,000	0.61	East-west racetrack 24 nmi (44.5 km) south
1	RB-50	Project 1.3[a] photo	Carter 1	24,000	7.31	Directly overhead
1	RB-50		Carter 2	5,000	1.52	Northwest-southeast racetrack 16 nmi (29.7 km) northeast
1	C-54	Project 1.3[a] photo	Pewter 1	1,500	0.46	20,500 feet (6.25 km) horizontal range north-northwest
1	C-54	Project 1.3[a]	Pewter 2	10,000	3.05	19,400 feet (5.91 km) horizontal range north-northwest
1	C-54	Project 1.3[a]	Pewter 3	9,000	2.74	19,000 feet (5.79 km) horizontal range west-southwest
2	B-57B	Sampler control	Opium 1,3	15,000	4.57	East-west racetrack 16 nmi (29.7 km) north
2	B-57B	Sampler	Hotshot 1,2			East-west racetrack 16 nmi (29.7 km) north
1	SA-16	Project 2.3[b]	Stable Echo 2	Not airborne at burst time		
1	H-19		Effort 12	1,500	0.46	Unknown
3	H-19		Effort 10,14,15	Not airborne at burst time		
3	H-21	Project 2.3[b]	Effort 1,6,9	Not airborne at burst time		
1	L-20	Project 1.?[c]	Mosquito 7	Not airborne at burst time		

Notes:

[a]Reference C.1.1608.

[b]Reference C.1.1621.

[c]Reference C.1.1607.

Sources: ' References C.4.1 and C.1.1608, except as noted.

were between the azimuths of 240° and 290° extending to a range of 50 nmi (93 km) from surface zero. At 1115 the UMBRELLA weapon was fired.

The spray dome emerged from the lagoon in less than one-tenth of a second. Later examination of films showed dark jets of spray with velocities of about 2,000 ft/sec (610 m/sec) on the leading edge of this dome. These are assumed to be remnants of the surface-zero LCU and buoys. The dome became more column-shaped as plumes of spray emerged. In spite of the plumes, its columnar form was retained. The dome and plumes rose to a maximum height of about 5,000 feet (1.5 km) in about 20 seconds. The frontispiece shows the column at about its maximum height.

CTG 7.3's final report (Reference C.3.1) described the detonation:

> The shot appeared as a huge depth charge in shape and appearance with a high rising central column and rolling base surge that enveloped all target ships and obscured the nearby islands from view. The base surge appeared to reach out for a distance of approximately 10,000 feet downwind and a somewhat lesser distance upwind. The coral bottom was pulverized and the water was churned to milky white in the immediate area of the shot, that soon spread out to a distance of at least 6,000 feet in all directions.

Figure 73 shows target ships in this turbid water.

Figure 73. HARDTACK, UMBRELLA target ships in foam patch and turbid waters.

The base surge was visible from the air as a ring for 25 minutes. The foam patch was visible for slightly longer.

On schedule at H+20 minutes, a P2V aircraft made a radiological survey of the area at 1,500 feet (457 meters). The highest reading, 0.350 R/hr, was made over surface zero at 1137, 22 minutes after the detonation. All other readings were insignificant and reentry hour was declared at 1145, with the exception of the area west of the lagoon (Reference C.1.6.2, Vol 1).

Two radsafe boats entered the target area at 1200 and surveyed the six major ships in the target array. The highest recorded reading, 0.0015 R/hr, was made off the stern of Moran at 1225. By 1315, the area was declared sufficiently clear to allow the project recovery operations to begin. All fallout was estimated to be within the first hour and well within the forecast fallout plot (Reference C.1.6.2, Vol 1). Cumulative dose for the first 6 hours after detonation is shown in Figure 74, which also shows the positions of the task force fleet and the target array at the time of detonation.

EARLY RECOVERY OPERATIONS. All washdown systems were operating before and at detonation time, however (Reference C.3.1):

> When the base surge cleared the target array, the washdown systems on all three destroyers and YFNB-12 continued to work effectively, but the system on Moran had stopped working.

The first TG 7.3 ship to be involved in recovery operations was Arikara. Immediately after the shot, Arikara entered the shot area to obtain radioactive water samples. At approximately H+30 minutes, two L-19 light planes with TU 7.1.6 personnel of TG 7.1 aboard were scheduled to make preentry radiation surveys; however, the TG 7.4 final report does not show any L-19 participation on D-day (Reference C.4.1). TG 7.4 did schedule and fly an L-20 mission in support of canister recovery operations. At about the same time one LCM made a radiation survey of Howorth and Killen, while a second LCM made a similar survey of Moran and Fullam (Reference C.0.2, UMBRELLA).

A CJTF 7 message summarizing the D-day situation at 2000 stated that photographic coverage had been successful, that cloud and water samples were recovered successfully, and that recovery results of FFPs, coracles, and rocket canisters were excellent. Additionally, it stated that gauge strips and canisters aboard target ships were observed to be in place, and that recovery would be on D+1 (Reference C.0.2, UMBRELLA Folder).

Four HRS-3 helicopters from Marine Helicopter Transport Squadron 361 (HMR[L]-361) flew from USS Boxer (CVS-21) on coracle and FFP recovery missions. CTG 7.3 instructions for these missions show the concern with radiological safety (Reference B.3.5, 27-58):

> Helicopters will fly in pairs from BOXER. One will be equipped with basket and one with chicken hooks [two retrieval devices]. Helicopters . . . will not fly over milky water at any time.

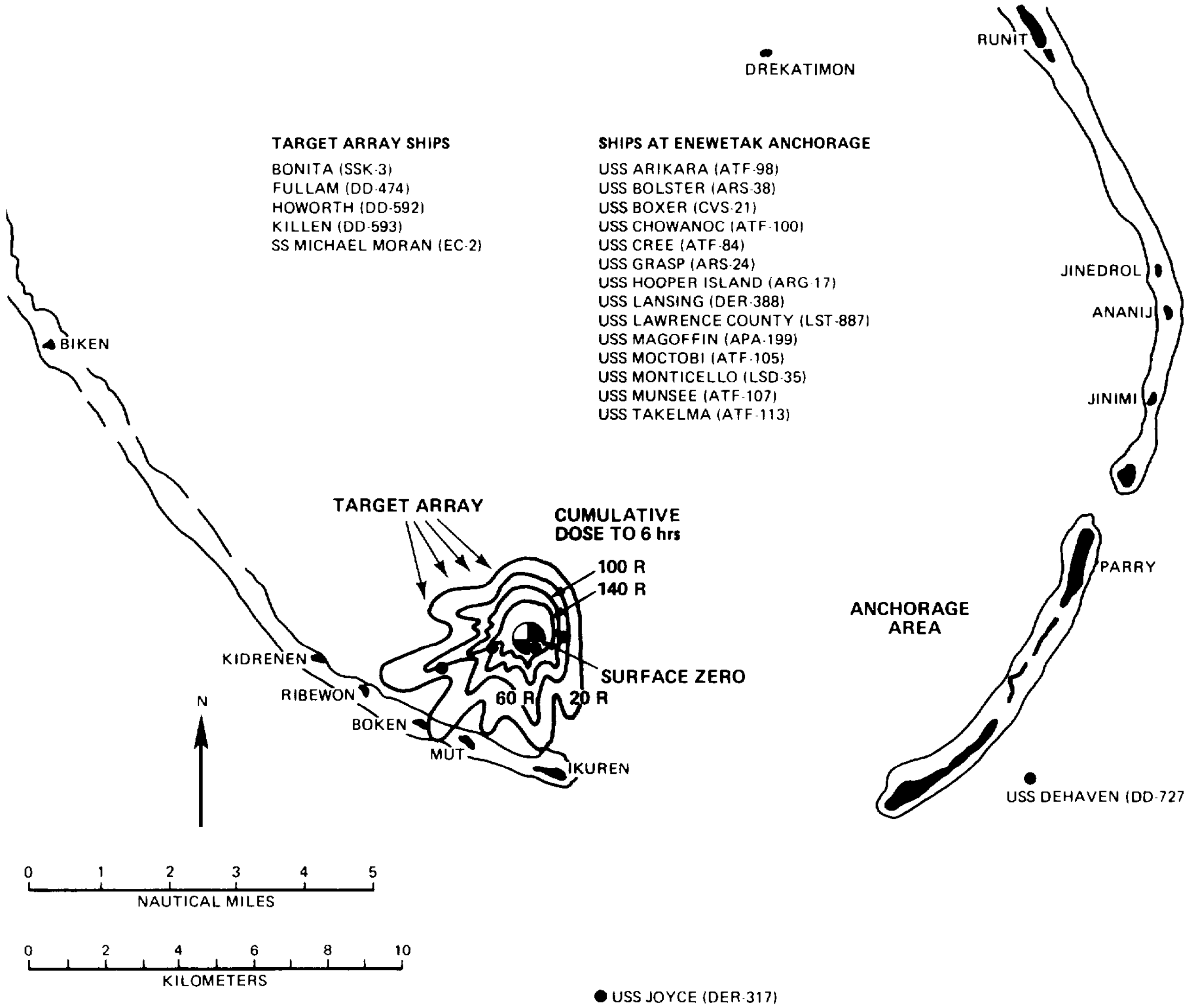


Figure 74. Ship positions at HARDTACK, UMBRELLA, and cumulative dose to H+6.

In order to prevent loss of valuable scientific data, some projects required priority recovery before decontamination of the ships by TG 7.3. The reports of these priority recovery projects identify Navy units involved.

TG 7.3 Boat Pool Detachment support of the recovery missions placed boat pool personnel in positions of potential radiological exposure. Personnel exposure data (see Chapter 7) indicate that this exposure was spread evenly among crewmembers.

Several other post-UMBRELLA maneuvers involved possible radiological exposure for TG 7.3 personnel. The submarine Bonita had been moored and submerged unmanned as part of the target array. At approximately H+1, Grasp and Bolster entered the target-array area. Grasp began to surface the submarine, using divers who manipulated the submarine's air tanks. Bolster began to surface Squaw-29 with compressed air from the YFNB. The radiological picture at this time was (Reference C.3.1):

> Upon entering the array area near the BONITA, radiac meter readings at 1300 hours indicated 100 mr over water, growing to 380 mr over water at 1320 hours and 180 mr in the water at the surface. A radiac sub-surface probe gave gradually increasing radiation readings with increasing depth to about two roentgens at 140 feet depth and 30 roentgens on the bottom. At 1355 the GRASP reported 350 mr at the seachest [seawater intake].

At 1504 Bonita was surfaced and taken in tow at 1605 by Cree to shallow water for removal of ballast weights. During the day, Bolster had surfaced Squaw-29 several times, but because of a leaking airhose had difficulty in keeping it surfaced. Bolster and Moctobi remained in the area overnight, watching over all of the target ships (Reference C.3.1).

Chowanoc entered the test area at H+2 for Project 1.1 and recovered four floating instrument cans and put two others in safe position on a beach by using LCM-22 and -52. On D+1, Chowanoc and three LCMs recovered all mechanical gauge strings but one, the two instrument cans from the beach (with assistance from a DUKW), and the electronic data tapes from Howorth and barge 55. On D+2, an 1,800-foot (549-meter) mechanical gauge line was recovered by divers and brought aboard Chowanoc. No radiation level information is available concerning these gauge strings (Reference C.1.1606).

USS Joyce (DER-317), USS Lansing (DER-388), LCU-1376, LCM-49, -56 and -58, and a TG 7.4 L-20 and one H-21 tracked canisters and recovered balloon gauges for Project 1.2. The LCU and LCMs were tasked to sweep the anticipated rocket impact area. Their radsafe instructions were to back down if a field greater than 4 R/hr was detected. The impact area, however, was upwind of the burst point, and the project report does not mention radiological complications. Only one of the balloon-supported gauge strings was retrieved, and this retrieval was uneventful (Reference C.1.1607).

For Project 2.2, priority animal recoveries and air samples from Howorth were required. Postshot operations started at H+2. At that time the recovery party boarded the ship from YTB-182 and deactivated the washdown system. Recovery was completed, the washdown system reactivated, and personnel debarked by H+2:45. No pocket dosimeter reading was greater than 0.200 R (Reference C.1.1620). CTG 7.1 noted on 3 June that he "will tolerate 4 r/hr on board DD-592 for not more than 40 min" (Reference B.1.5, UMBRELLA-5):

Radiac readings taken on board Takelma during the minefield recovery operation indicated that the water contamination was of minor tactical significance. Readings for the string of mines closest to surface zero were taken on D+3. The gamma radiation level on the ship was 0.0015 R/hr. Maximum mine case readings were 0.150 to 0.200 R/hr. Maximum cable readings were 0.015 to 0.020 R/hr (Reference C.1.1641).

REMAINING RECOVERY OPERATIONS. Decontamination of the target ships started as soon as priority project recoveries were completed. By 22 June, three days after UMBRELLA, the radiological picture allowed Cree, Moctobi, and Arikara to tow the three target destroyers to the anchorage area and nest them alongside Hooper Island. On the same day, Cree returned to the target-array area and towed Moran to its anchorage. Recovery of buoys, anchors, and cables began as soon as possible after UMBRELLA and was completed approximately 2 weeks later (Reference C.3.1).

After post-UMBRELLA inspections, all target destroyers were readied for sea before tow-away. On 22 June, Fullam and Killen were towed by Chowanoc and Munsee, respectively, to Pearl Harbor Naval Shipyard, arriving on 11 July. Howorth was probably towed by Moctobi at the same time. Later, Howorth was towed by Munsee to San Francisco Naval Shipyard. Detailed machinery inspections of the target destroyers were conducted at these shipyards (Reference C.1.1632).

Moran was considered unseaworthy for a lengthy tow and on 21 June was sunk in deep water off Ikuren Island, Enewetak Atoll, by naval gunfire from Collett, Arikara, Cree, Hooper Island, Takelma, Magoffin, and Munsee.

HIGH-ALTITUDE SHOTS

Background and Planning

Increased interest in the possibility of using nuclear detonations in a defensive role against aircraft and ballistic missile attack led the DOD to sponsor three test events at altitudes well above the Earth's lower and denser atmospheric layers. These events are summarized in Table 27. The yield for YUCCA has not been announced; ORANGE and TEAK were in the megaton range.

Table 27. HARDTACK high-altitude events.

Name	Date/Time	Location	Altitude
YUCCA	28 Apr/1440	85 nmi (157 km) northeast of Enewetak	86,000 feet (26.2 km) by balloon
TEAK	31 July/2350	Over Johnston Island	252,000 feet (76.8 km) by rocket
ORANGE	11 Aug/2330	41.6 km south of Johnston Island	141,000 feet (42.98 km) by rocket

These shots were designed to study the following:

- How burst altitude affects the proportion of the bomb's energy that appears as airblast and thermal energy
- The effect of high-altitude bursts on materials
- The effect of high-altitude bursts on radio and radar propagation.

Altitudes at which the weapons were to be detonated required different techniques than had been used in previous nuclear weapon testing.

The YUCCA device was raised to its final altitude by a large, untethered, helium-filled balloon. Balloons had been used to replace the towers for several of the 1957 PLUMBBOB tests at the Nevada Test Site (NTS), but these had been tethered to control their positions and to pull the weapons down with winches if required.

TEAK and ORANGE were boosted to their detonation altitudes by Redstone rockets. A rocket had been used in Operation PLUMBBOB (1957 at NTS) to position test detonations, but this had been a low-yield weapon, not the megaton-range devices used for TEAK and ORANGE.

YUCCA

Detonation of a nuclear weapon at the altitude planned for YUCCA would not expose task force personnel to nuclear radiation. However, during the process of placement of the device by free balloon, malfunctions potentially could lead to exposures. Safety planning for YUCCA focused on the procedures in the placement process where problems could arise.

SAFETY PLANNING. High-altitude research balloons, such as that used to carry the YUCCA weapon, are large envelopes of lightweight plastic. During the time required to inflate the balloon and complete final operations on the payload (almost 1 hour for YUCCA), the balloon is subject to the actions of surface winds. These winds act on the envelope and exert a force on the attached inflation apparatus and payload. To prevent the equipment and payload, in this case a nuclear bomb, from being dragged about, they are restrained and the plastic envelope absorbs the force of the winds, subjecting it to possible tearing and destruction. Therefore, in order to launch the balloon successfully, it is usually inflated and launched in still air, or a mobile system is used to keep the floating, but still tethered, balloon over the payload.

Balloon flight-testing for YUCCA began in 1956 at various locations in the United States, and in 1957 attempts were made by the Air Force Cambridge Research Center (AFCRC) to launch large balloons from the airfield at Enewetak Island. Because of the high surface winds at Enewetak, these launches were generally not satisfactory and another scheme, launch from an aircraft carrier, was devised. The aircraft carrier could move at the same speed and in the same direction as the surface wind to keep the inflating balloon in still air for the launch. The practicality of this was demonstrated with five successful launches from Boxer off San Diego in September 1957. Eleven more launches were made from Boxer in the waters of the EPG from 9 March to 18 April 1958 just before HARDTACK. The purpose of these flights was to familiarize the Air Force launch crew and Boxer crew with launch procedures. These flights were also used to check instrumentation and telemetry systems. In all, 86 balloons were launched in preparation for YUCCA (Reference C.1.1654).

Control of the nuclear weapon thus launched on the free balloon lay with the wind and the lifting power of the balloon. Actuation of the detonation was to be controlled by the task force commander through a radio link. For proper placement of test instrumentation aircraft and ships, as well as safety, it was important to be able to predict accurately the ultimate position of the weapon as well as the path it would take to get there.

The balloon's lifting power and consequent climb performance were well understood and could be modified by varying the amount of helium gas used as the payload weight was modified with instrument changes. Winds aloft were measured on the morning of the launch. Based upon a general knowledge of the meteorology of the EPG, a flight profile was drawn up. A YUCCA Firing Area had been established, a 25- x 25-nmi (46.3- x 46.3-km) square of open ocean in the EPG, generally between Enewetak and Bikini and centered on 12°17'30"N and 163°21'E. Working backward from the desired burst point and time, the expected flight path was used to predict the proper balloon release point and time. From this calculation, Boxer steamed to a release position that would allow the balloon-borne weapon to be at the proper place and time for detonation.

The arming and fuzing system was equipped with several devices to ensure safety during the launch sequence and in case of a dud. Electrically actuated explosive squibs were capable of cutting the bomb loose from the balloon rigging so that it would quickly fall to the sea if it were a dud. These squibs were important protective devices. However, during the launch preparations, it was possible to actuate the squibs while the weapon was being held in the launcher by the balloon's rigging. The launcher was a very large forklift, and the drop to the deck was such that damage to the weapon was possible. Therefore, while the device was in the launcher a mechanical pin prevented the bomb from dropping in case of an accidental firing of the cut-down squibs. This safing pin was among the last things removed from the rigging before the balloon's release.

Two other pins were also removed at launch. These pins prevented electric current from flowing to the arming circuitry so that the weapon could not be fired before launch. They also prevented operation of the baroswitch system. This system sensed the atmospheric pressure, and if the pressure fell below the value at 40,000 feet (12.2 km), it enabled the arming process to take place. If the balloon ascended above 40,000 feet (12.2 km), then through malfunction started to descend below 40,000 feet (12.2 km), the baroswitch would sense this and prevent arming. The baroswitch system also activated an electrical timer at 40,000 feet (12.2 km) altitude. The timer ran for 190 minutes and then gave signals to fire the weapon and the cut-down squibs. Thus, had the radio command to fire failed to detonate the weapon, it would have been fired by the electrical timer 190 minutes after the balloon rose above 40,000 feet (12.2 km) altitude or it would have been dropped by the cut-down squibs if it were a dud. The bomb would have been cut down 5 hours after launch even if the radio command to fire or be cut down and the electric timer's action to fire or be cut down had failed. Two mechanical clock timers actuated at launch would have activated the cut-down squibs.

In summary, the device was mechanically held on deck so that it could not be dropped. Mechanical locks on the arming and firing circuitry prevented firing on deck. The baroswitch system prevented it from being fired below 40,000 feet (12.2 km) altitude. It could be cut down at any time by radio command or would be automatically cut down if it misfired.

There was a possibility that the weapon would remain intact in the seawater if it were cut down and fell from a low altitude. If this occurred there was a remote possibility that the seawater could provide electrical conduction paths in the device such that the firing circuit could be completed and a detonation could occur. To prevent such an incident, two saltwater-activated probes were installed to activate an explosive puncture switch to short out the high-voltage unit and prevent generation of the current necessary to initiate detonation. On the other hand, it was thought advisable to have the weapon sink rather than float if it did land intact in the water. Therefore, plugs were installed that would dissolve in the saltwater after about 4 hours. The weapon case would then flood and sink.

SHOT OPERATIONS. The test plan was for the balloon to rise to its maximum altitude and drift to its final position. In addition to the nuclear weapon, it trailed wire with various instruments to measure and telemeter information to the aircraft below and Boxer. The aircraft also had instruments to detect and record information about the burst and its effects.

DOD projects of TU 7.1.3 participating in YUCCA included:

- Project 1.10 -- Blast Overpressure Measurements
- Project 2.7 -- Prompt Nuclear Radiation Measurements
- Project 6.4 -- Electromagnetic Pulse Measurements
- Project 6.5a -- Radar Fireball Observations
- Project 6.6 -- Radar Cloud Size Determination
- Project 6.9 -- Ionospheric Effects of High Altitude Nuclear Detonations
- Project 8.2 -- Thermal Radiation Measurements
- Project 8.3 -- Early Fireball Photography
- Project 8.4 -- Thermal Radiation Spectrum Measurements
- Project 8.5 -- Airborne Infra-Red Measurements
- Project 9.2 -- Balloon Carrier.

Recording instrumentation for these projects was either in the aircraft, on Boxer, or in more remote island locations. No recovery of recorders or samples was required.

Two RB-36s were flying a circular course centered on the downward projection of the predicted air zero. The radius of this path was 12 nmi (22.2 km) and their altitudes were 36,000 and 37,000 feet (10.97 and 11.28 km). Similarly, a P2V circled a radius of 9.5 nmi (17.6 km) at an altitude of 25,000 feet (7.62 km). The SAR SA-16 was flying a north-south racetrack course at 7,000 to 9,000 feet (2.13 to 2.74 km) altitude about 70 nmi (130 km) west of the projected air zero.

Boxer departed Bikini Atoll at 1900 on 27 April for a predetermined position for the YUCCA launching. Boxer arrived at the launch site coordinates of 12°25'N, 164°4'E by 0600 on 28 April. At that time a weather balloon was released to track winds at altitudes up to 90,000 feet (27.4 km). This allowed for a reasonable forecast of the flight path.

From 0630 to 0830 the special launch equipment required was readied and the instrumentation canisters to be carried by the balloon were placed on the flight deck. Figure 75 is an aerial view of Boxer showing the YUCCA launcher near the stern and the vans on the foredeck. Boxer was not underway at the time of the photo. The YUCCA weapon was brought to the launch area at about 0830. Boxer brought the weapon, stored in a special container within the nuclear safety magazine to the EPG after picking it up in February at the San Diego Naval Base. Before the test, preliminary work on the weapon was done in a Sandia van on Boxer's deck. At 0800, Boxer had begun its downwind course, attempting to keep the air motion on the deck below 10 knots (18.5 km/hr) while keeping the ship's pitch and roll to a minimum.

During the next hour and 20 minutes, the uninflated balloon was laid out in preparation for inflation and the instrument canisters and the YUCCA bomb were rigged. Attachment of radar reflectors, the nuclear device, and instrumentation to the uninflated balloon completed the rigging.

Figure 75. Aerial view of USS Boxer (CVS-21) with HARDTACK, YUCCA launcher on the stern and special vans on the bow.

At 1005 the Sandia Corporation arming party began preliminary device check-out, and the amount of helium to be used was calculated by the AFCRC balloon-launch crew. Boxer maneuvered to eliminate any relative wind on the flight deck after 1015. At 1034 the arming party notified the AFCRC personnel to start the inflation. From 1034 to 1059 the balloon was filled with helium (Figure 76a). At 1101 the balloon, hitherto restrained in a horizontal position on canvas on the flight deck, was released to assume a vertical position, restrained only at its base by the launcher (Figure 76b). It was 80 feet (24 meters) high. From 1103 to 1115 the arming party finished readying the weapon for firing. At 1124 checks at the launcher verified that the safing pins were out and the tracking beacon on. At 1125 YUCCA was released.

After releasing the balloon, Boxer headed for a point 35 nmi (64.9 km) northwest of the predicted zero position at 25 knots (46.3 km/hr). Figure 77 shows the path of the balloon, Boxer's course, other ship positions, and scientific aircraft locations.

Originally, USS Perkins (DDR-877) was placed about 25 nmi (46.3 km) from Boxer in case delays caused Boxer to lose radar contact with the balloon. Perkins's orders were changed to put it south of Bikini for the shot. Orleck provided weather information and proved valuable on the final run.

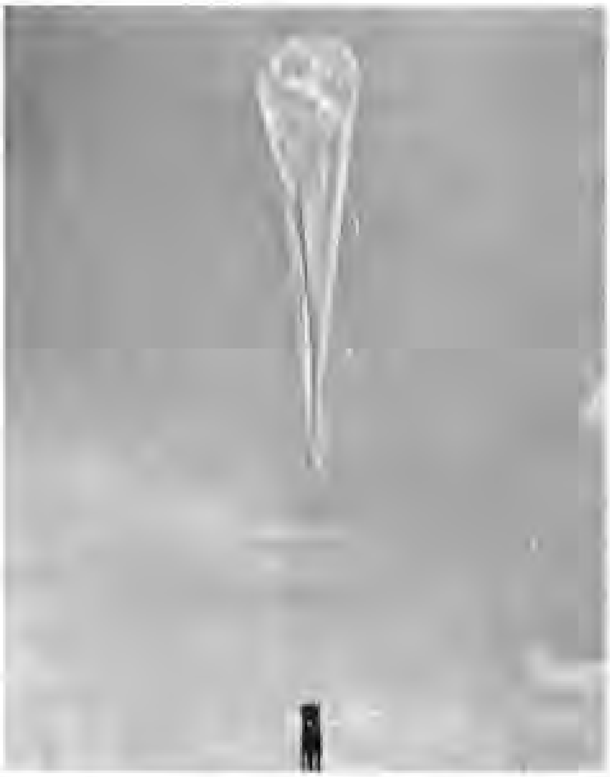


Figure 76a. Balloon being inflated with HARDTACK, YUCCA launcher in background.

Figure 76b. HARDTACK, YUCCA balloon upright, still restrained at launcher.

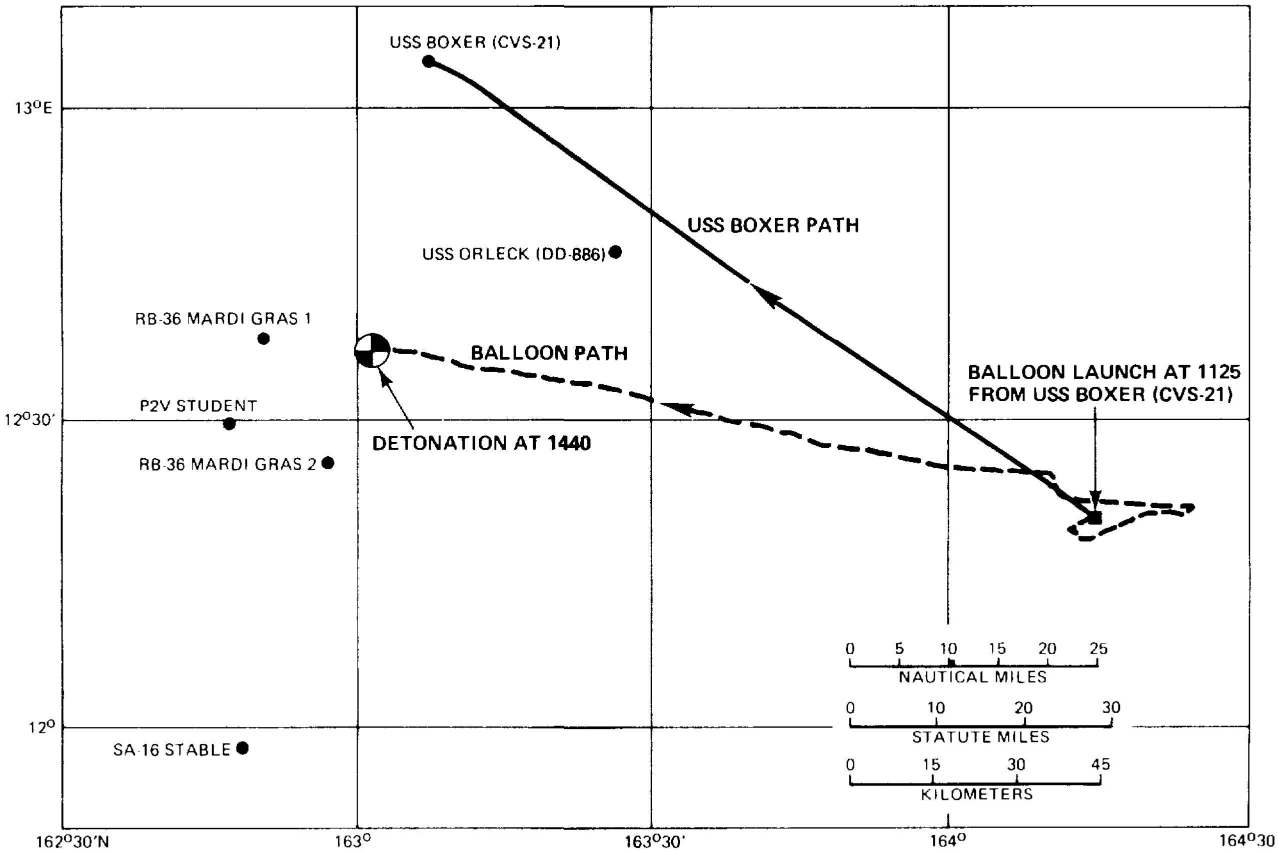


Figure 77. HARDTACK, YUCCA balloon path and detonation area.

The balloon climbed rapidly. It reached 7,000 feet (2.1 km), in 7 minutes and 12,000 feet (3.7 km) in 15 minutes. At 1206 the balloon reached 40,000 feet (12.2 km), where the baroswitch system permitted arming and actuated the backup electrical timer. At 1253 the balloon was at 85,000 feet (26 km). At 1330, all air and boat travel between Bikini and Enewetak was closed. The surface and air radex areas that had been issued stated that the area within a 140-nmi (259.4-km) radius of 12°17'30"N and 153°21'E was considered hazardous to surface vessels and aircraft from surface to unlimited altitudes.

YUCCA was command-detonated at 1440, after a delay because one of the RB-36 aircraft was out of position. The burst was visible from Enewetak (Figure 78), but was at such a distance that no protective goggles were necessary there. The shock wave reached Boxer 3 minutes and 16 seconds after the detonation. Table 28 summarizes positions of the participating aircraft.

TEAK and ORANGE

These two test events were scheduled for April and May. They were DOD tests that required large boosters to lift megaton-range-yield warheads to altitudes of 250,000 feet (76.2 km) for TEAK and 125,000 feet (38.1 km) for ORANGE. The assigned launch rocket was the Redstone, an Army tactical missile fueled by an alcohol and liquid-oxygen mixture. A Redstone had been used to launch the first U.S. Earth satellite, Explorer I, on 31 January 1958.

Figure 78. HARDTACK, YUCCA as viewed from Enewetak Island.

Table 28. Participation aircraft in HARDTACK, YUCCA.

No.	Type	Mission	Call Sign	Zero-Time Location Relative to Burst: Altitude (feet)	(km)	Range or Course
1	SA-16	Search and rescue	Stable	7,000-9,000	2.13-2.74	North-south racetrack 75 nmi (139.0 km) west
1	RB-36	Projects 8.2 through 8.4[a]	Mardi Gras 1	37,000	11.28	14.5 nmi (26.9 km) slant range
1	RB-36	Project 8.2 through 8.4[a]	Mardi Gras 2	36,000	10.97	14.1 nmi (26.1 km) slant range
1	P2V	Project 8.6[a]	Student	25,000	7.62	18.8 nmi (34.8 km) range
3	B-57B	Sampler				Not airborne at burst time
1	WB-50	Weather				Not airborne at burst time

Note:

[a]Reference C.1.1654.

Source: Reference C.4.1 except as noted.

The necessary launch structures, a pad, a moveable tower with working stations and elevators, liquid-oxygen plant, firing bunker, tracking stations, etc. had been constructed on Bikini Island. The construction had begun in October 1957 and was completed on schedule early in April 1958. The Redstone and the Army Ballistic Missile Agency (ABMA) support crew for TEAK were assembled and in place. TEAK warhead had been brought over from Parry to Bikini and was ready. Backup warheads and missiles were in various stages of preparation.

Results of theoretical calculations on the optical thermal yield of these weapons when detonated in the upper atmosphere became available indicating that such detonations would be bright enough to cause permanent retinal injury to observers of the bursts. These calculations had only recently been completed by Los Alamos Scientific Laboratory. They were supported by the DOD. Because some 11,000 Micronesians would have been close enough to view the very-high-altitude bursts at the EPG, thus risking retinal damage, the Secretary of Defense and the Chairman of the AEC decided on 7 April to change the location of the test to Johnston Island (Reference D.1, p. 15).

OPERATION NEWSREEL. The code word NEWSREEL was assigned, whose meaning was "Johnston Island as a site for TEAK and ORANGE," and test dates of 1 August and 15 August were set. Physical preparations were renewed. Construction personnel and launch equipment were moved from Bikini Island. The launch complex at Johnston Island as completed in July is shown in Figure 79. Organizational changes then included Johnston Island in organization charts as another location in the EPG. A special planning guide was issued by Hq JTF 7 to assist task force units of the task force in planning and executing their activities in connection with transferred events (Reference B.0.5).

Johnston Island was well situated for the high-altitude tests because of its isolation, the nearest inhabited island being 538 statute miles (866 km) away. On the other hand, operations there had to consider aircraft and ship routes from Hawaii to Asia, as well as the close-in hazards of missile launch in a confined area and the firing of missiles over water areas used for ship anchorage.

The planning guide issued by the joint task force commander included an analysis of the "nuclear and nonnuclear hazards" associated with firing TEAK and ORANGE and indicated these were (Reference B.0.5):

> That the hazards to personnel from blast and from thermal and nuclear radiation effects are expected to be negligible.
>
> That the chance of hazards resulting from falling missile stages, pods, and other hardware will be remote.
>
> That the probability of hazards resulting from failure to launch or malfunction of the thrust and guidance systems while at low altitudes is expected to be acceptably low. A nuclear detonation is effectively impossible under these circumstances.
>
> That the probability of a full-scale detonation of the missile on the launch pad or while at low altitude is considered to be extremely low; that the missile burning on the launch pad

Figure 79. Launch complex at Johnston Island; HARDTACK, TEAK Redstone is in the gantry.

could possibly produce serious local hazards: and that these hazards would result chiefly from the blast associated with the detonation of the high explosive and rocket fuel and resultant oxidation and scatter of the nuclear material.

That the hazard of primary concern is flashblindness and/or retinal burn expected to result from the programmed detonation. This hazard is calculated to extend to a range of 435 statute miles at the surface and to a range of 600 statute miles at 20,000 feet, and 500 statute miles at 5,000 feet.

That a full-scale detonation on the surface would possibly produce the following radiation dosage:

Range in statute miles from detonation	Infinity Dose (R)
200	100
400	10
500	5
700	2
800	1

The planning guide promulgated the following safety measures:

> A danger area will be established to protect all ships and aircraft. A special hazardous area will be delineated within the established danger area and a minimum number of Joint Task Force SEVEN personnel and units will participate in this special hazardous area.
>
> Personnel not essential to the operation will be evacuated from the local area (special hazardous area) in Task Force ships. Essential personnel will be either in the protected blockhouse or the underground hospital or other designated facility. A Radiological Safety Unit will be maintained aboard the command ship. A second Radiological Safety Unit will be held in reserve in the Hawaiian area.
>
> Joint Task Force SEVEN personnel will be protected from eye damage by high-density glasses or by being required to be below decks in Task Force ships. Those in the blockhouse or underground hospital will be adequately shielded by these structures. Those who must, for operational considerations, be in Task Force aircraft or topside in ships will hear the countdown and be instructed to turn from the flash and cover their eyes. Prior to the detonations, notices to mariners and airmen will be disseminated. Thorough searches will be conducted to ensure that no surface shipping is in the danger area. Through military and CAA channels, aircraft will be grounded at safe locations or routed at safe distances and altitudes. The nearest populated land area is French Frigate Shoal, 538 statute miles north-northeast of Johnston Island. This area is well out of range of flash blindness and/or retinal burn hazard. Populated areas at all elevations in the main Hawaiian chain are outside the hazard area.
>
> A radiation monitoring network will be operated throughout the Hawaiian Islands to ensure that reliable data are available to responsible agencies.
>
> Present calculations indicate that thermal hazard to surface installations from TEAK is negligible. For ORANGE, calculations indicate that . . . [the] flux may ignite moderately combustible materials on the island or behind windows in houses . . . . It is necessary that the island be carefully cleaned up prior to ORANGE detonation with particular reference to exposed inflammable materials.

DANGER AREA AND PATROL. The primary concern was the danger of retinal damage. A circular danger area with a radius of 400 nmi (740 km) was established around Johnston Island. Patrol of this area to ensure that no transient ships were in the area was the responsibility of a force of patrol and early-warning aircraft based at NAS Barbers Point, Oahu, Hawaii. The squadrons contributing aircraft for this and the aircraft are listed in Table 29.

Table 29. Task Group 7.3.5.5 aircraft participation, HARDTACK, TEAK and ORANGE.

Squadron	Model	Bureau of Aeronautics Number	Voice Call
VA(HM)10	P2V-5F	131489	The Prophet 6
VA(HM)10	P2V-5F	131532	The Prophet 10
VA(HM)10	P2V-5F	131487	The Prophet 7
VP-1	P2V-5F	131408	Backdoor 2
VP-1	P2V-5F	131427	Backdoor 10
VP-21	P2V-5F	131431	Backdoor 7
VP-22	P2V-5F	131432	Arm Chair 3
VP-22	P2V-5F	128393	Arm Chair 4
VP-22	P2V-5F	128367	Arm Chair 12
VP-28	P2V-5F	131425	Wildroot 2
VP-28	P2V-5F	131416	Wildroot 3
VP-28	P2V-5F	131526	Wildroot 4
VP-28	P2V-5F	131420	Wildroot 5
VP-28	P2V-5F	131402	Wildroot 8
VP-28	P2V-5F	131449	Wildroot 9
VP-28	P2V-5F	131436	Wildroot 10
VP-29	P2V-5F	131462	Wildroot 11
VP-29	P2V-5F	131446	Wildroot 12
VW-1	WV-2	143196	Rain Proof 5
VW-1	WV-2	145926	Rain Proof 1
VW-3	WV-2	145933	Discovery 10
VW-3	WV-2	145924	Discovery 3
VW-3	WV-2	143229	Discovery 2

Source: Reference B.3.3.

Two days before each shot, a Notice to Mariners was issued and patrols begun. Eight planes flew courses that collectively covered the danger area. Most started their patrol from NAS Barbers Point, but three flew from Johnston Island itself. Search was both visual and with radar. The mileage each aircraft covered was from 1,800 to 2,800 nmi (3,336 to 5,189 km). On D-1 the flights were repeated with slightly varying courses. The shots were scheduled for just before midnight, and on D-day the flights were again repeated except that one of the Johnston Island flights was eliminated. Patrols were made during daylight hours. If a ship was found within the danger area, it was identified and the task force informed of its location. A message was dropped to the ship informing it of the danger area and advising it of the most direct course out of the area. If the ship did not respond, the P2Vs were authorized to "buzz" the ship at masthead altitude, indicating by its direction of flight the direction the ship should take. The number of ships found in the danger area and their identities and responses do not appear in the records.

The task force commander advised the Civil Aeronautics Authority that it would be dangerous for aircraft to fly within 521 nmi (965 km) of Johnston Island. This notice was given on 30 July, but no other public announcements of the imminent tests were issued.

MUSTER AND EVACUATION. Accounting for personnel on Johnston Island began the day before the shot. The process was greatly simplified compared to the EPG proper because only about a thousand men had to be accounted for. There was, however, a relatively large group that remained on Johnston Island whose whereabouts had to be known during the arming, missile launch, and detonation operations. This required a muster officer in the Command Post in Johnston Island to report to CJTF 7 that all were in safe locations. Manned stations for TEAK and ORANGE on Johnston Island or in the lagoon are summarized in Table 30. The exact location of MV Acania is not known, but a photo (Figure 80) shows it anchored just off the north side of Johnston Island about 10 days before launch. As the ship was carefully anchored so that its antenna would point in a fixed direction (Reference C.1.1645), this anchorage may have been its position during the shots also.

The evacuation was conducted on the D-day by small boats, LCUs, and LCMs that could use the Johnston Island pier. They moved the personnel to Boxer, which had come up from the EPG to support TEAK and ORANGE operations. Plans had called for the discharge of the personnel from the small boats onto a float moored to Boxer. From the float they were to enter Boxer by ladder. Before evacuation it was determined that the rough seas at Johnston Island would make this hazardous and an alternate scheme was adopted. Holmes & Narver, Inc. (H&N), fabricated a large openwork cage that personnel could enter on the deck of the LCU. This cage was then hoisted by a crane on Boxer and was deposited directly on the hangar deck of the carrier. Helicopter evacuation was available for key or infirm personnel. The island was quickly evacuated. In the late afternoon before the midnight shots, Boxer proceeded 50 to 70 nmi (93 to 130 km) northeast of Johnston Island. The following morning, the evacuees were returned to Johnston Island.

RADIOLOGICAL SAFETY OPERATIONS. The radsafe operation emphasized the possibility of an accident during launch, which could spread the radioactive material due to the weapon high-explosive and missile fuel detonating and burning. Therefore, in selecting the 11 men for work at Johnston Island, CTU 7.1.6 considered field experience with alpha contaminants most important. The men selected were in two groups. Six were flown to Johnston Island just before the shots and the remainder stayed on alert in Hawaii at Hickam AFB to be flown in if necessary. The Radsafe Center on Boxer was used by members of the team.

SCIENTIFIC DATA RECOVERY. The scientific information to be collected from the experiments was gathered in several general ways. The first involved use of instruments on the ground, ships, aircraft, or small rocket to record nuclear, thermal, or radiofrequency radiations from the burst. Another used

Table 30. Manned stations on or near Johnston Island, HARDTACK, TEAK and ORANGE.

Station	Distance from Launch	Groups Using
Launch bunker (J-6002)	350 feet (107 meters) west	Joint Task Force 7 Missile Safety Task Group 7.1 command arm and fire Project 9.3a Redstone control Project 2.6 telemetry reception Project 32.1 receiving station Task Unit 7.1.5 countdown and fire
Hq building basement (T-249)	1,000 feet (305 meters) west	Project 6.11 riometers Project 6.12 rocket control Project 32.3 receiving station Project 32.4 microbarograph
Hospital basement (P-405)	1,500 feet (458 meters) west	Headquarters Joint Task Force 7 Project 6.12
Older building basement (P-233)	1,080 feet (329 meters) west	Hq USAF Station
Photo-optical building with 2-man shelter	1,000 feet (305 meters) north	Project 10.3 Project 18.1
Sand Island (west portion)	5,500 feet (1.7 km) east	Project 32.4
Sand Island (west portion)	6,800 feet (2.1 km) east	Project 5.4 Project 6.10 Project 8.6
MV Acania	"Inside J.I. reef"	Project 6.11

Sources: Memo, CJTF 7, Subject Johnston Island Evacuation, 7/12/58; Reference C.1.1645.

Figure 80. MV Acania anchored off Johnston Island north shore, HARDTACK.

these types of remote stations to observe and record changes in the ionosphere and radio propagation from the burst. Another method involved use of small, instrumented containers (or pods) that were attached to the Redstone missile itself. The pods were detached by small explosive charges from the missile as it rose from the lower, denser atmosphere. The pods were equipped with instruments and radio transmitters that telemetered data to the surface stations and were, from a radsafe point of view, innocuous, like the rocket-borne instrument stations. However, one pod carried instrumentation that required physical retrieval for interpretation. In addition, rockets equipped to collect weapon debris samples were launched in a trajectory that would carry them near the burst. These rockets also required retrieval.

POD AND SAMPLER ROCKET RECOVERY OPERATIONS. Pods and sampler rockets were equipped with radio beacons, flashing lights, and a dye dispenser to make them visible as they floated in the sea. Two P2Vs from VP-28 were stationed on Johnston Island to lead the search for these. Because of the hazards of small instrument rockets being fired from Johnston Island the aircraft remained on the ground until 30 minutes after the burst. One then took off and flew at low altitude, 500 to 1,500 feet (153 to 458 meters), until the radio beacon or flashing light was observed. If the search continued until daylight, the dye in the water was another location aid. Radio communications were maintained with surface ships that coordinated the search and, after the pod or sample rocket was discovered, made the actual pickup. The P2V dropped a smoke flare to aid in guiding ships to the pod. The second P2V was a spare to be used if the first had to retire because of mechanical problems or because the search was extended beyond its endurance.

Surface ships used in the recovery were Lansing for the pods and USS Safeguard (ARS-25) for the sampler rockets. The deck of Lansing was considered to be too small for the 1,300-pound (590-kg), lead-lined pig that the sampler rocket would require if it were as hot as predicted, 50 R/hr at 1 meter.

TEAK OPERATIONS. On 31 July, 727 men were evacuated from Johnston Island to Boxer. With the 187 men who had been evacuated the day before, this left about 175 on Johnston Island. Distribution of the personnel remaining on the island is not known exactly. A JTF 7 memorandum of 12 July estimated that 102 TG 7.1 personnel would remain to man project instrumentation, and that 28 personnel of the Base Command would also be required to remain. These latter probably kept the airfield functioning so that the VP-28 P2V could be dispatched after the shot for pod recovery operations. H&N reported that 24 of its men remained to carry out essential TG 7.5 duties.

Ship positions for TEAK are shown in Figure 81 and participating aircraft are given in Table 31.

The TEAK Redstone rocket is shown in Figure 82. It was launched from Johnston Island at 13 minutes before midnight. After a 3-minute flight the warhead was detonated at a 250,000-foot (76.2-km) altitude, producing a spectacular display that was visible from Honolulu 700 nmi (1,297 km) away.

A Honolulu resident described the burst in a page-1 story in the 1 August Honolulu Star-Bulletin:

> 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.

Other descriptions in the same issue emphasized the red feature that appeared. From Mt. Haleakela on Maui, observers reported that this red shell appeared to pass overhead about 40 minutes after the detonation.

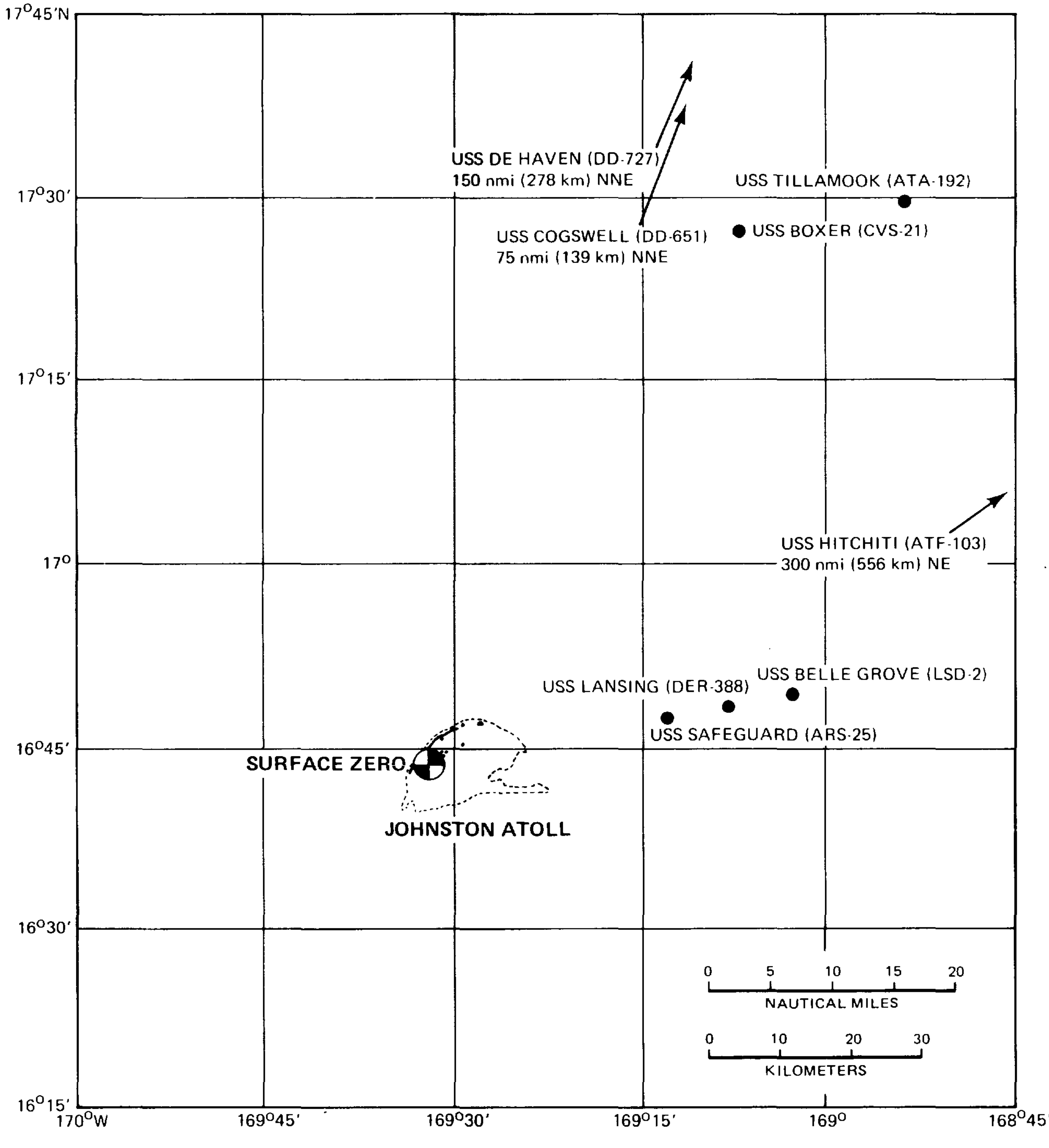


Figure 81. Ship positions, HARDTACK, TEAK.

Table 31. Aircraft participation in HARDTACK, TEAK.

No.	Type	Mission	Call Sign	Altitude (feet)	Altitude (km)	Zero-Time Location Relative to Burst: Range or Course
1	P2V	Project 8.5	Student	21,920	6.68	47.6 nmi (88.2 km) horizontal range north
2	RB-36	Projects 8.2-8.4	Goldenrod Bigamy	30,500	9.30	75 nmi (139 km) slant range north and north-northeast
1	C-97	Project 6.10	Floyd			220 km northeast
1	C-97	Project 4.1	Excelsior	20,000	6.10	305 nmi (565 km) northeast
2	WV-2	Project 6.13	High Port Inhale	8,000 10,000	2.44 3.05	190 nmi (352 km) east-northeast
1	P2V	Project 8.6	Wildroot	Not airborne at burst time		
1	C-54	SAR	Pluto	10,000	3.05	60 nmi (111.2 km) north
1	C-54	Observer	Demand			80 nmi (148.3 km) north
1	C-54	Hq USAF	Tissue			

Sources: References B.4.3.39-B.4.3.58 (ORANGE), C.1.1633, C.1.1649, C.1.1659.

Figure 82. HARDTACK, TEAK Redstone rocket.

The detonation spread a layer of fission debris in the upper atmosphere, and destroyed the ability of the normally ionized layers of the upper atmosphere to bend radio waves back to the Earth, thus cutting many trans-Pacific high-frequency communication circuits. This blackout lasted 9 hours in Australia and at least 2 hours in Hawaii. Honolulu telephone service was apparently not affected; the Honolulu police registered over 1,000 extra calls that night as startled residents asked for information on what they had seen.

On Johnston Island, a P2V took off about 30 minutes after the shot and began to search for the instrument pod and sampler rockets. The pod was located at about H+2 by the P2V and was picked up by Lansing at about H+5. Since the pod had been only about 23,000 feet (7.0 km) from the megaton-range explosion in the extremely thin upper atmosphere, it was subject to neutron activation as well as fission-product contamination. Upon recovery the pod was observed to have gamma radiation levels from 0.1 to 0.3 R/hr. Disposable gloves were worn while handling the pod to protect the hands from low-energy beta radiation and to prevent the accidental spreading of contamination. The pod was transferred from Lansing to an LCM and then to Johnston Island where it was similarly handled (Figure 83). The sampler rockets broke up in flight soon after launch and thus were not contaminated (Reference C.1.1601).

As would be expected with a nuclear burst at this altitude, no detectable increase occurred in the natural radiation background in the test area or off site.

On 1 August, the Project 9.3a personnel were back on Johnston Island, cleaning and painting the launch pad. On the following day, a Redstone was

Figure 83. HARDTACK, TEAK pod at Johnston Island.

placed upright on the pad and the final preparations for the ORANGE event began.

ORANGE OPERATIONS. From 1 through 7 August the individual systems for the Redstone were checked and from 8 to 10 August general checkouts and simulated flight tests were run. On 11 August the launch countdown began.

Because of public interest in Hawaii, CINCPAC announced on Monday, 11 August, that a nuclear test was to be conducted at Johnston Island sometime between 2200 and 0600 (Hawaiian time) that night. This was in addition to the Notice to Mariners issued before TEAK that was still in effect.

Evacuation of Johnston Island personnel had gone so smoothly for TEAK that it was decided that for ORANGE it need not begin before the day of the shot. Eight hundred eight men were evacuated to Boxer on 11 August, leaving about one hundred forty-five men at the manned stations.

Ship locations are shown in Figure 84 and Table 32 shows aircraft participation.

The Redstone launch was at 2327 and at 2330 the ORANGE warhead was detonated.

The show in Honolulu was somewhat of a disappointment after the TEAK display. There was a brilliant flash for about a second, which "dimmed to a rose glow and faded away." From the heights of Mt. Haleakela on Maui, the view was described as a "dark brownish red mushroom rose in the sky . . . then died down turning to white with a dark red rainbow." This was visible for 10 minutes or so (Star-Bulletin, Aug 12).

The widespread disruption of radiofrequency communications that had followed the TEAK shot was not repeated for ORANGE. Representatives of RCA and Mackay Radio and Telegraph reported no problems during the night (Star-Bulletin, August 12). However, a later report stated that aircraft flying from the West Coast to Hawaii were out of touch with air controllers in either Hawaii or the United States for periods of from 10 minutes to 2 hours starting at 0530, August 12. Whether this radio blackout was a delayed result of the ORANGE test or a consequence of solar flares was not known (Star-Bulletin, August 13).

At Johnston Island the attempts to recover the Project 8.2 pod failed. It could not be located despite of aerial and surface ship searches through the night and into daylight the next morning. The sampler rocket nosecones were all located by the P2V and recovered by Safeguard. One nosecone was radioactive, but the intensity of its radiation is not reported in the project report. A later analysis showed that this radioactivity was induced by the neutrons from the burst and was not the result of warhead debris contamination.

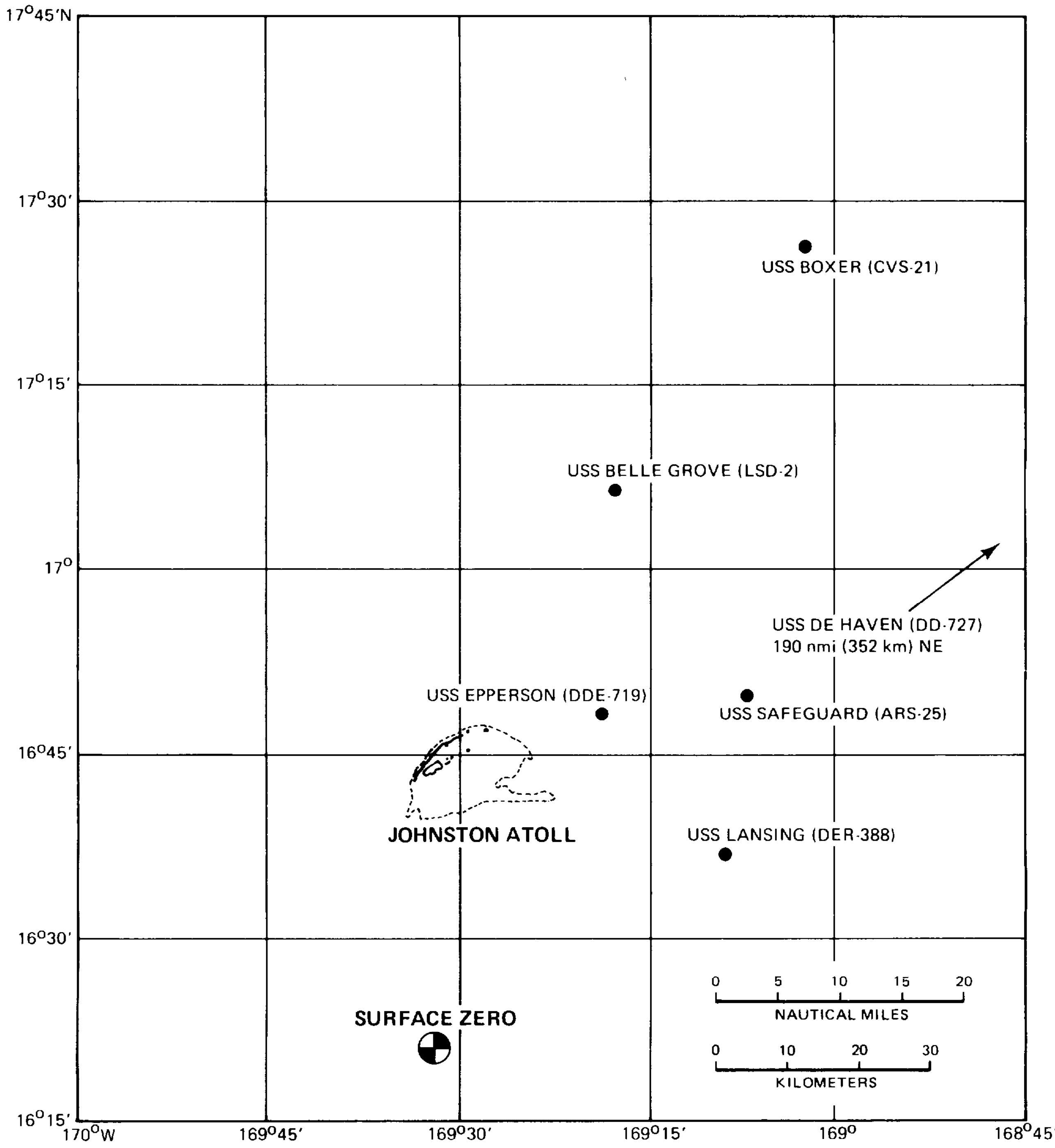


Figure 84. Ship positions, HARDTACK, ORANGE.

Table 32. Aircraft participation in HARDTACK, ORANGE.

				Zero-Time Location Relative to Burst		
No.	Type	Mission	Call Sign	Altitude (feet)	Altitude (km)	Range or Course
1	P2V	Project 8.5	Student	22,000	6.71	64.6 nmi (119.7 km) horizontal range north
2	RB-36	Projects 8.2-8.4	Goldenrod Bigamy	30,500	9.30	75 nmi (139.0 km) slant range north and northeast
1	C-97	Project 6.10	Floyd			360 km northeast
1	C-97	Project 4.1	Excelsior	15,000	4.57	226 nmi (418.8 km) northeast
2	WV-2	Project 6.13	High Port Inhale	8,000-10,000	2.44-3.05	190 nmi (352.1 km) east-northeast
1	P2V	Project 8.6	Wildroot	Not airborne at burst time		
1	SC-54	SAR	Pluto	10,000	3.05	60 nmi (111.2 km) north
1	C-54	Hq USAF	Tissue			
1	C-54	Observer	Demand			80 nmi (148.3 km) north
1	WB-50	Cloud tracking	Wilson Special			

Sources: References B.4.3.32-B-4.3.58 (TEAK), C.1.1633, C.1.1649, C.1.1659.

CHAPTER 6

U.S. ARMY PARTICIPATION

More than 1,500 Army personnel were participants in HARDTACK operations. Most of served in Task Group (TG) 7.2, which provided support for the Enewetak Island base and military police services throughout both Bikini and Enewetak atolls. Army personnel and civilians from Army laboratory agencies also provided personnel for several experimental projects by TG 7.1.

Enumeration of Army personnel who participated in either the joint-Department of Defense (DOD) organizations or in an Atomic Energy Commission (AEC) laboratory is not possible from the Consolidated List of Exposures (Reference C.1.6.3), as this does not display any service affiliation, rank, or serial number information. It is certain that some Army personnel were in these organizations, and their exposures are included in the summaries in Chapter 11.

Army personnel representing Army agencies, however, are identifiable from the Consolidated List, and their participation is summarized below by task group affiliation. Both military and civilian personnel with Army organizations are intermingled for the reason given in the previous paragraph. Distribution of the exposures for participating Army organizations is shown in Table 33. Mean exposure for Army personnel in TG 7.1 was 1.25 R and for those in TG 7.2 was 1.49 R. Collective exposure for all Army personnel was about 2,255 man-roentgen, and the mean for all Army personnel was 1.43 R.

Army Ballistic Missile Agency (ABMA), Redstone Arsenal, Alabama. This agency was responsible for the Redstone missiles used to launch the TEAK and ORANGE test devices. This activity was designated Project 9.3a. Ninety-one ABMA personnel were badged, although more were in the field. Project activity was on Bikini Island, mainly in the period before testing began, and on Johnston Island.

Ballistic Research Laboratories (BRL), Aberdeen Proving Ground, Maryland. This laboratory contributed 17 men for the airblast experiment, Project 1.7. Three exceeded 3.75 R exposure.

Chemical Warfare Laboratory (CWL), Edgewood Arsenal, Maryland. This laboratory manned projects in both nuclear and thermal radiation. These projects were 2.4, 2.4a, 2.9, 2.10, and 8.7. Total number of personnel was 35, of which 3 exceeded the series Maximum Permissible Exposure (MPE) of 3.75 R.

Diamond Ordnance Fuze Laboratory (DOFL), Washington, D.C. The laboratory manned two interrelated projects, 6.3 and 6.3a. Fifteen men were badged and one barely exceeded the series MPE of 3.75 R with a badge reading of 3.755 R.

Engineer Research and Development Laboratory (ERDL), Ft. Belvoir, Virginia. The laboratory supplied the two men who conducted Project 1.4, a crater survey.

Table 33. HARDTACK personnel exposures, U.S. Army organizations.

Element	No. of Persons Badged	Exposure Ranges (R)											High (R)
		0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	Over 5	Over 3.75[a]	
Task Group 7.1 Army Organizations													
ABMA	91	85	4	2								0	1.00
BRL	17	0	0	0	2	1	0	4	8	2		3	4.55
CWL	35	0	7	1	7	5	7	1	4	2	1	3	6.63
DOFL	15	0	3	4	2	3	1	0	2			1	3.76
ERDL	2	0	1	0	0	0	1					0	2.40
SRDL	39	13	11	7	8							0	1.34
WES	6	0	0	1	3	0	1	1				0	2.95
1st RSSU	94	1	5	11	12	20	15	7	15	7	1	12	5.34
US ATC, Ft. Devens	2	0	0	0	1	0	0	0	1			0	3.29
Total Army TG 7.1	301	99	31	26	35	29	25	13	30	11	2	19	6.63
TG 7.2 Army Organizations													
Admin Det	627	14	39	92	125	236	103	15	3			0	3.57
Ops Det	504	22	28	97	46	171	101	29	10			1	3.81
1st Prov MP	139	1	14	43	18	52	9	2				0	2.67
Unidentified	3	0	1	0	0	1	1					0	2.08
Total Army TG 7.2	1,273	37	82	232	189	460	214	46	13			1	
Total Army	1,574	136	113	258	224	489	239	59	43	11	2	20	6.63

Note:

[a]HARDTACK Maximum Permissible Exposure.

Source: Consolidated List of HARDTACK Exposures (Reference C.1.6.3).

Signal Engineering Laboratory (SEL), Ft. Monmouth, New Jersey. This laboratory furnished special instrumentation for Project 2.3. Another laboratory from Ft. Monmouth, the Evans Signal Laboratory (ESL), also furnished personnel, and both were merged into the Signal Research and Development Laboratory (SRDL), under whose authorship the HARDTACK project report appears. Therefore, all the exposures have been similarly combined under SRDL below.

Signal Radio Propagation Agency (SRPA), Ft. Monmouth, New Jersey. This agency was separate from the several signal laboratories at Ft. Monmouth. It is credited with providing operating personnel for Project 6.9, an SRDL project. However, personnel cited in the project report are noted in the Consolidated List as being with SRDL.

Signal Research and Development Laboratory (SRDL), Ft. Monmouth, New Jersey. This organization was apparently the successor to SEL and ESL and appears to have come into existence during the time that HARDTACK was being conducted. SRDL, or its predecessors, conducted Projects 6.4, 6.5, 6.6, 6.9, and 6.12 as well as providing instrumentation for Project 2.3. Included in the exposures in Table 33 are also those of the SRPA.

Waterways Experiment Station (WES), Vicksburg, Mississippi. WES provided the project officer for the survey of HARDTACK blast damage to existing EPG structures and contributed at least four men for Project 1.1.

1st Radiological Safety Support Unit (1st RSSU), Ft. McClellan, Alabama. This unit provided the corps of personnel for TU 7.1.6, the basic radsafe organization for the task force. Personnel from TU 7.1.6 conducted radiological surveys, monitored reentry missions, issued film badges, etc. Twelve of the ninety-four men from the 1st RSSU had exposures exceeding 3.75 R, with the highest reading being 5.338 R.

Two additional Army units are cited on the Consolidated List and these were to participate in TU 7.1.7, the group preparing the UN demonstration shot that was later cancelled. The two Army units coded on the list were both from Ft. Devens, Massachusetts. The first, styled "Trans, C., U.S. ATC," had two men badged. The second, "631 Q.M., Trk., Co.," had no men badged. The role of these men in TU 7.1.7 is not clear. The others badged as part of this task unit were from the AEC weapon organizations or their contractors, or were from the Armed Forces Special Weapons Project (AFSWP).

In addition, several unnamed Army units are acknowledged to have contributed personnel to the ABMA activities on Project 9.3a. The Consolidated List does not show organizations that could fit the description given for these groups, but this is consistent with Project 9.3a locations, that is, primarily Johnston Island or pre-series Bikini. Locations from which the personnel came and the numbers as cited in Reference C.1.1657 are as follows:

Ft. Belvoir, 16 engineers to operate liquid-oxygen plant

Ft. Sill, 6 artillery specialists, Redstone firing

Picatinny Arsenal, 4 warhead adaption kit experts.

The final area of U.S. Army participation in HARDTACK was the provision of almost all personnel for TG 7.2. This group was divided into two detachments, an Administrative Detachment and an Operations Detachment, and the 1st Provisional Military Police Company. The collective exposure of these elements is given in Table 33.

CHAPTER 7

U.S. NAVY PARTICIPATION

Over 8,700 Navy personnel participated in the HARDTACK series. More than 8,300 of these served in the approximately 40 ship, air, and specialized support units in Task Group (TG) 7.3. This group provided air and surface patrol for the Enlwetok Proving Ground (EPG), logistic support for the task force, instrumentation platforms for the scientific organizations, weather observations for test planning, and a variety of special services involving mooring, salvage, and transportation for the underwater phase of HARDTACK.

Nearly 400 naval personnel and civilians from Navy research organizations participated in the scientific experiments of TG 7.1.

Enumeration of Navy personnel who participated in either the joint-Department of Defense (DOD) organizations or in an Atomic Energy Commission (AEC) laboratory is not possible from the Consolidated List of Exposures (Reference C.1.6.3), as this does not display any service affiliation, rank, or serial number information. It is certain that Navy personnel were in these organizations, and their exposures are included in the summaries in Chapter 11.

Navy personnel representing Navy agencies, however, are identifiable from the Consolidated List, and their participation is summarized in this chapter by their task group affiliation. Both military and civilian personnel with Navy organizations are intermingled for the reason given in the previous paragraph. Table 34 summarizes the number of Navy personnel participating and displays the distribution of their exposures. The mean exposure for Navy personnel serving in TG 7.1 was 1.19 R and that of those serving in TG 7.3 was 0.52 R. Collective exposure for all Navy personnel was 4,735 man-roentgen, and the mean was 0.53 R.

TASK GROUP 7.1 (SCIENTIFIC)

Bureau of Aeronautics (BuAer), Washington, D.C. BuAer organized and supervised aircraft effects experiments, Projects 5.2 and 5.3, as well as the thermal project (8.5). A large number of men were badged using an organization code shared by BuAer, the Naval Air Special Weapons Facility (NASWF) (the organization that actually conducted the experiments), and North American Aviation (NAA) and Douglas Aircraft (the firms that manufactured the aircraft used). Most of the identifiable men appear to have belonged either to NASWF or the contractors, and apparently few BuAer personnel were at the test site.

Bureau of Ordnance (BuOrd), Washington, D.C. An organization identification code was assigned to this organization in the Consolidated List, but the personnel badged thereunder appear to be Bureau of Ships (BuShips) personnel, and their exposures have been added to that organization.

Table 34. HARDTACK personnel exposures, U.S. Navy organizations.

Element	No. of Persons Badged	Exposure Ranges (R) 0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	Over 4	Over 3.75[a]	High (R)
U.S. Navy in Task Group 7.1												
BuShips	12	0	0	3	8	1					0	1.56
DTMB	13	0	0	7	5	1					0	1.62
HO	10	0	3	7							0	0.95
MDL	20	0	0	2	11	6	1				0	2.06
NASWF	105	4	7	15	21	28	21	3	4	2	2	5.34
NCEL	7	0	2	0	0	3	2				0	2.13
NEL	15	0	0	8	5	2					0	1.83
NML	6	0	0	1	2	3					0	1.90
NOL	45	0	1	6	27	10	1				0	2.42
NRDL	81	7	9	11	28	15	6	3	1	1	1	5.96
NRL (TU 7.1.1)	29	17	9	2	0	1					0	1.87
NRL (TU 7.1.3)	17	11	4	2							0	0.75
NRL Total	46	28	13	4	0	1					0	0.87
ONR	1	0	0	0	1						0	1.46
UERD	21	0	2	15	3	0	0	1			0	2.51
Total 7.1 Navy	382	39	37	79	111	70	31	7	5	3	3	5.96
U.S. Navy in Task Group 7.3												
TG 7.3 Organizations												
CTG 7.3 and Staff	88	9	19	18	18	16	7	1			0	2.660
TE 7.3.1.2	1	0	0	0	1						0	1.220
TE 7.3.6.4 (Bikini Boat Pool)	221	7	80	72	14	41	7				0	2.340
TG 7.3 Units and Detachments												
Boat Pool Det	209	6	41	60	44	42	8	7	1		1	3.792
Radsafe & Decon Unit	182	2	38	125	15	2					0	1.990
Spec Proj Unit	148	0	20	68	41	10	3	3	2	1	1	4.366
TG 7.3 Other Naval Organizations												
Destroyer Squadron 1	13	8	4	1							0	1.070
VP-22 and VP-28	283	154	95	30	1	1	1	1			0	2.742
TG 7.3 Ships												
USNS *Fred C. Ainsworth* (T-AP-181)	195	2	112	78	3						0	1.240
USS *Arikara* (ATF-98)	65	0	0	5	28	25	5	2			0	2.760
USS *Belle Grove* (LSD-2)	254	9	222	20	2	0	1				0	2.482

Note:

[a]HARDTACK Maximum Permissible Exposure.

Source: Consolidated List of Exposures (Reference 1.6.3).

(continued)

Table 34. HARDTACK personnel exposures, U.S. Navy organizations (continued).

Element	No. of Persons Badged	Exposure Ranges (R)										High (R)
		0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	Over 4	Over 3.75[a]	
USS Benner (DDR-807)	256	21	93	128	13	1					0	1.600
USS Bolster (ARS-38)	84	3	7	52	21	1					0	1.780
USS Bonita (SSK-3)	51	1	34	14	0	0	0	0	2		1	3.788
USS Boxer (CVS-21)	1,100	48	160	754	127	9	2				0	2.240
USS Cacapon (AO-52)	220	12	130	71	5	1	1				0	2.060
USS Chanticleer (ARS-7)	101	3	94	3	0	0	1				0	2.130
USS Chowanoc (ATF-100)	68	1	0	25	32	8	1	1			0	2.690
USS Collett (DD-730)	245	11	91	132	11						0	1.280
USS Comstock (LSD-19)	233	231	2								0	0.170
USS John R. Craig (DD-885)	241	11	224	4	2						0	1.240
USS Cree (ATF-84)	64	1	4	54	5						0	1.280
USS De Haven (DD-727)	236	12	34	163	21	6					0	1.960
USS Grasp (ARS-24)	80	2	4	36	28	8	2				0	2.280
USS Hooper Island (ARG-17)	400	17	241	128	12	2					0	1.540
USS Joyce (DER-317)	160	90	70								0	0.409
USS Karin (AF-33)	93	32	60	1							0	0.609
USS Lansing (DER-388)	162	93	69								0	0.148
USS Lawrence County (LST-887)	115	3	90	22							0	0.994
USS Magoffin (APA-199)	338	0	21	293	21	3					0	1.716
USS Mansfield (DD-728)	256	13	103	129	11						0	1.320
USS Merapi (AF-38)	20	1	19								0	0.309
USS Moctobi (ATF-105)	68	3	5	44	16						0	1.454
USS Monticello (LSD-35)	291	18	136	127	8	1	1				0	2.084
USS Munsee (ATF-107)	64	0	5	49	9	0	1				0	2.200
USS Navarro (APA-215)	315	110	205								0	0.197
USS Orleck (DD-886)	240	6	231	2	1						0	1.096
USS Floyd B. Parks (DD-884)	237	10	221	5	0	1					0	1.960
USS Perkins (DDR-877)	235	8	224	3							0	0.940
USS Rehoboth (AGS-50)	164	1	152	11							0	0.966
USS Renville (APA-227)	330	6	295	24	5						0	1.359
USS Sterlet (SS-392)	79	18	61								0	0.310
USS Takelma (ATF-113)	70	1	5	5	36	20	2	1			0	2.917
USNS T-LST-664	47	1	4	41	1						0	1.200
Total Navy TG 7.3	8,322	985	3,725	2,797	552	198	43	16	5	1	3	4.36
Total Navy JTF 7	8,704	1,024	3,762	2,875	663	268	74	23	10	4	6	5.96

[a] HARTDTACK Maximum Permissible Exposure.

Source: Consolidated List of Exposures (Reference 1.6.3).

Bureau of Ships (BuShips), Washington, D.C. This organization guided the naval effects tests, WAHOO and UMBRELLA. This work was designated Project 3.8.

Bureau of Yards and Docks (BuDocks), Washington, D.C. BuDocks participated in Project 3.2, but the presence of BuDocks personnel at the EPG is not confirmed by the Consolidated List.

David Taylor Model Basin (DTMB), Carderock, Maryland. Personnel from DTMB manned Projects 3.3 and 3.5 in the ship vulnerability program for the underwater shot tests. Thirteen men were badged.

Hydrographic Office (HO), Washington, D.C. Ten HO scientific personnel participated in Project 1.13, study of the crater formed by the underwater shot, UMBRELLA. Operating from USS Rehoboth (AGS-50), all ten were badged.

Mine Defense Laboratory (MDL), Panama City, Florida. This laboratory provided personnel for Project 6.8 on UMBRELLA. Twenty men were badged.

Naval Air Special Weapons Facility (NASWF), Kirtland AFB, New Mexico. This unit provided the air and support crews for the aircraft used by Projects 5.2, 5.3, and 8.5. NASWF personnel were badged in both TG 7.1 and in TG 7.4, where they were considered as a part of the Test Aircraft Unit (TAU). Exposures of the 68 badged with TG 7.1 and the 37 badged with TG 7.4 are combined under TG 7.1 in Table 34. Two exceeded the MPE of 3.75 R, the high being 5.34 R.

Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California. NCEL manned Project 3.2. This project involved buried structures close to the CACTUS and KOA shots. Seven men were badged.

Naval Electronics Laboratory (NEL), San Diego, California. NEL manned Project 1.5 using submerged blast gauges to study the oceanic effects on the propagation of the shock waves from the underwater tests.

Naval Materials Laboratory (NML), Brooklyn, New York. NML personnel made thermal radiation measurements in Project 8.1.

Naval Ordnance Laboratory (NOL), White Oak, Silver Spring, Maryland. NOL was one of the larger naval laboratory contingents. This group manned three projects in the blast program, Projects 1.1, 1.2, and 1.3, as well as Project 6.7 on underwater effects on mines.

Naval Radiological Defense Laboratory (NRDL), San Francisco, California. NRDL personnel participated in fallout and nuclear radiation Projects 2.1, 2.2, 2.3, and 2.8 and thermal radiation Projects 8.4 and 8.7. Of the 81 NRDL men on the Consolidated List one exposure was over the Maximum Permissible Exposure (MPE) of 3.75.

Naval Research Laboratory (NRL), Washington, D.C. NRL had experimental groups in both the Los Alamos Scientific Laboratory (LASL) task unit, Project 18.1, and in the DOD nuclear radiation program, Projects 2.6 and 2.7. These activities had different exposure histories and, as it is possible to clearly differentiate the personnel involved in each, the summaries of Table 34 are shown first by task unit and then combined.

Office of Naval Research (ONR), Washington, D.C. ONR directed Project 1.11 and supplied the Project Officer for Project 1.13. The only person from ONR at the EPG appears to be this Project Officer.

Underwater Explosion Research Division (UERD), Portsmouth, Virginia. UERD personnel worked on Project 3.1, which was the pretest activity for Project 3.4, and then on the project itself at the EPG. Twenty-one personnel are identified with UERD on the Consolidated List.

TASK GROUP 7.3 (NAVY)

Most Navy participants were in TG 7.3. The organization of TG 7.3 was extremely fluid during the operational phases of HARDTACK; the constituent parts of many of the formal task units (TU) and task elements (TE) were changed, as were their missions, from event to event.

The units discussed here are consequently not strictly those identified in TG 7.3 organizational listings but fall into three groupings. The first is TG 7.3 organizations whose functions, identities, and experiences remained reasonably constant throughout the series. The second is detachments that had separate TG 7.3 identities and experiences. The third grouping is Navy ship- and shore-based units that had separate identities.

Commander Task Group 7.3 Staff and Headquarters

CTG 7.3 and his staff arrived in the EPG at various times beginning in January 1958 and remained there until the end of HARDTACK in August 1958.

During the interim and preoperational phases, the staff consisted of 12 officers and 12 enlisted men at Washington, D.C. For the operational phase, staff size expanded to a total of 24 officers and 22 enlisted men on Parry Island and aboard the flagship, USS Boxer (CVS-21).

From 15 March to 25 June 1958, the Deputy CTG 7.3 and half the staff usually remained on Boxer. The second part of the staff, TG 7.3 Staff Detachment, was headed by the Logistics Officer on Parry Island, Enewetak. CTG 7.3 divided his time between these two locations and was in overall command. The staff aboard Boxer had primary responsibility for administration and communication files, aircraft control, and nonadministrative affairs at Bikini. The Staff Detachment at Enewetak had primary responsibility for handling surface ships, nonadministrative Enewetak matters, and logistics functions. Bikini administrative matters were handled by the Senior Officer Present Afloat (Administration) (SOPA [Admin]) aboard USS Benner (DDR-807). At Enewetak, adminstrative matters were the function of Commander, Destroyer Squadron 1 from 24 March to 20 May 1958; Commander, Destroyer Squadron 9 handled this responsibility for the remainder of the exercise.

After 25 June, CTG 7.3 Administrative Headquarters transferred from Boxer to Building 221 at Parry Island. On 13 July the Deputy CTG 7.3 became task unit commander for TEAK and ORANGE, with five officers and four enlisted men aboard Boxer at Johnston Island. The liaison officer for TG 7.3 had arrived at Johnston Island early in July, before the arrival of the Deputy CTG 7.3 at Johnston Island. The liaison office continued in force until completion of the Johnston Island phase of Operation HARDTACK.

The staff returned to the United States in different groups at different times. Those aboard Boxer left Johnston Island for Pearl Harbor on 13 August. The liaison officer at Johnston Island remained there until completion of the high-altitude shots on 11 August. Upon completion of activities in the EPG, most CTG 7.3 staff returned to Washington, D.C. One officer and approximately fifteen enlisted men remained to complete rollup and turn in material to the CTG 7.3 warehouse on Enewetak Island (Reference C.3.1).

More men were badged with CTG 7.3 and staff designations than the staff itself including the TG 7.3 Special Diving Team (see below, p. 284), accounting for the difference between the functional discussion and Table 34.

Task Element 7.3.1.2 (Technical Assistance)

TE 7.3.1.2 was assigned to carry out tasks relating specifically to WAHOO and UMBRELLA and consisted only of two officers, a Technical Director and a Scientific Machinery Officer. Its mission was to provide services for the target-array ships, to collect scientific data as directed, and to assist in installation of instrumentation. Available documentation identifies only the Technical Director. He arrived in the EPG on 27 April and departed on 25 July.

Task Element 7.3.6.4 (Bikini Boat Pool)

This task element provided boat pool support for TG 7.3 at both Bikini and Enewetak atolls throughout the entire operation. Headquartered on Eneu Island at Bikini, the boat pool consisted of three officers and two hundred twenty-four enlisted men (Reference C.3.3.6). The boat pool was sent to the EPG from the U.S. Naval Amphibious Base, Coronado, California, in four separate groups, each accompanied by boat pool equipment and craft.

Craft used by the boat pool were 13 LCMs, 1 LCPL, 2 LCPRs, and 1 YFNB (Reference B.4.2). Its primary missions were the logistic and administrative support of the ships of TG 7.3, furnishing transportation personnel, supplies, and equipment for TG 7.3 including interatoll lifts by the smaller craft, off-atoll site construction, and movement of vehicles and cargo to Johnston Island by USS Belle Grove (LSD-2), USS Monticello (LSD-35), USS Comstock (LSD-19), and USS LST-664. The boat pool was also responsible for all waterborne transportation within the lagoons at Enewetak and Bikini that required the use of small craft (Reference C.3.3.6).

Task Group 7.3 Boat Pool Detachment

This unit coexisted with TE 7.3.6.4 (Bikini Boat Pool Element). The TG 7.3 Boat Pool Detachment was responsible for supporting the two underwater shots, UMBRELLA and WAHOO. It was staged from the U.S. Naval Amphibious Base, Coronado, California (Reference C.3.1). The unit consisted of 3 officers and 189 enlisted men and arrived at the EPG aboard Monticello on 18 April 1958. Craft used by the Boat Pool Detachment consisted of one diving boat, two LCUs, twelve LCM-3s, and two YTBs. These craft were specifically assigned to support the target-array vessels and were brought out with the Boat Pool Detachment on Monticello.

The detachment is assumed to have departed the EPG soon after shot UMBRELLA. Detachment personnel came in contact with the contaminated target vessels following WAHOO and UMBRELLA. Radiological safety (radsafe) support was provided by the TG 7.3 Radiological Safety and Decontamination Unit and, according to the commanding officer of the detachment, "briefing instruction and precautionary measures were adequate" (Reference C.3.3.5).

Task Group 7.3 Radiological Safety and Decontamination Unit

The Radiological Safety and Decontamination Unit's responsibilities included the training and organization of personnel; development and improvement of techniques and procedures for use of radiological detection equipment; protection or removal of exposed personnel, and the decontamination of personnel, structures, and test equipment following the two underwater detonations (Reference C.3.3.30). It was formed on 19 August 1957 at the U.S. Naval Amphibious Base, Coronado, California.

The commanding officer of the unit considered the Navy training programs in shipboard radiological safety and decontamination "inadequate or unrealistic" (Reference C.3.3.30). Consequently, a special training course was prepared by members of the NRDL and approved by the Bureau of Naval Personnel. The course was presented to the commanding officer and 17 of his personnel over a period of 30 days at the U.S. Naval Schools Command, Treasure Island, California. These participants, in turn, presented the course to approximately 155 rated and nonrated men of the unit at the Naval Amphibious Base at Coronado, California.

USS Renville (APA-227) transported the Radiological Safety and Decontamination Unit to the EPG. The two forward main-deck troop heads (bathrooms) were converted to decontamination shower stations. This involved converting the saltwater showers to fresh water, removing all old paint and rust, cutting a small door in the forward bulkhead of the heads, and repainting all of the surfaces (except the deck) in order to prevent "even the slightest amount of accumulation of radioactive contamination when the showers were put in use" (Reference C.3.3.30).

The forward main-deck and second-deck troop spaces, after all bunks were removed, were converted to "dress-out" stations, supply and issue centers, and radiac instrument repair stations. A portable saltwater shower was also installed in the port well-deck and provisions were made to divert the contaminated runoff water from the saltwater shower to a scupper. In order to test this equipment, the unit conducted "many trials" using luminous chalk powder and grease sprayed on personnel "to represent the radioactive contamination they might have acquired on their clothing and bodies while aboard the target ships" (Reference C.3.3.30).

While in transit to the EPG, the commanding officer of the Radiological Safety and Decontamination Unit presented 139 hours of lectures to Renville's officers and men. Topics covered were the mission and tasks of the unit, the use and maintenance of radiac equipment, radsafe regulations, nuclear test operation hazards, precontamination preparations and preventive measures, decontamination procedures, and radiological exposure and contamination control (Reference C.3.3.30).

From the time of its arrival in the EPG on 8 April until its departure on 3 July, the unit was engaged in actual decontamination operations or assisted other task units and project groups in their operations before, during, and after WAHOO and UMBRELLA (Reference C.3.3.30). On 21 May USS Magoffin (APA-199) relieved Renville and the Radiological Safety and Decontamination Unit was transfered to it. On 3 July the unit left the EPG aboard Magoffin (Reference C.3.4.2.6).

Radsafe protective clothing and decontamination services were provided to 1,237 personnel, other than the decontamination teams, by the Radiological Safety and Decontamination Unit (Reference C.3.3.30).

Navy Diving Units

Navy underwater diving activities for HARDTACK were both extensive and unique. Navy divers participated in the placement and recovery of mines, underwater instruments, and mooring arrays, and conducted standard salvage and repair operations as well. Diving operations in support of WAHOO and UMBRELLA were particularly demanding.

Diving operations were organized differently from other Navy missions. Navy divers were usually assigned to each ship in the task group and were not normally collected into a specific task unit or element. Although a large amount of diving work for HARDTACK was conducted by divers operating out of individual ships, two special diving teams (TG 7.3 Special Diving Team and the Explosives Ordnance Disposal Unit One [EODU-1]) were used to supplement the diving personnel distributed throughout the task force. Most of the work done by these two special teams was part of the underwater work required by WAHOO and UMBRELLA. Of these two shots, UMBRELLA required the most extensive effort (References C.1.1641, C.1.1628, and C.3.1).

The CTG 7.3 staff conducted a census of TG 7.3 personnel in February 1958 and determined that 85 divers were available. CTG 7.3 and the Chief Diving Officer also determined that HARDTACK would require the services of one officer and eighty-one enlisted divers in addition to the Medical Diving Officer and the Chief Diving Officer himself (Reference C.3.1).

The Chief Diving Officer centralized diving personnel on nine ships: USS Chanticleer (ASR-7) was assigned 28 divers; USS Grasp (ARS-24) and USS Bolster (ARS-38) were each assigned nine divers; and USS Moctobi (ATF-105), USS Arikara (ATF-98), USS Munsee (ATF-107), USS Chowanoc (ATF-100), USS Takelma (ATF-113), and USS Cree (ATF-84) were each assigned three divers. In addition, a TG 7.3 Special Diving Team of one officer and eight enlisted men was organized to act as an independent mobile unit to supplement the diving personnel on the individual ships (Reference C.3.1). Equipment for all diving operations was provided by the specific ships involved. The TG 7.3 Special Diving Team, however, did have its own equipment store and operated out of Enewetak Island (where it was quartered) and Parry Island (where most diving operations originated) (Reference C.3.1).

In addition to TG 7.3 Special Diving Team and to the general corps of divers distributed throughout the task force, another unit, EODU-1, normally stationed in Hawaii, was requested specifically for the underwater shots WAHOO and UMBRELLA by UERD of the Norfolk Navy Shipyard. UERD and EODU-1 were assisted on both occasions by divers from both the general divers pool and from the TG 7.3 Special Diving Team. Civilian divers from Scripps Institution of Oceanography also assisted UERD and EODU-1 during UMBRELLA in support of Project 6.7 (References C.1.1605, C.1.1628, C.1.1641). EODU-1 helped to place pressure gauges on the sides and bottoms of target ships for shots WAHOO and UMBRELLA in support of Project 3.4 and also provided logistic support for Project 6.7 for UMBRELLA.

A total of 800 hours of underwater work was conducted during HARDTACK. Because many of the dives were to depths of 150 feet (46 meters), a large portion of work time was spent in the decompression phase of the diving operation. Out of a total of 1,560 dives, 686 required decompression pauses in the ascent stage. Most of the other dives were made at depths of less than 30 feet (9 meters) (Reference C.3.1).

All types of diving operations, including hard-hat and snorkle diving, were conducted during the test series, although SCUBA was the most common. Of the 85 registered divers, 76 made at least one recorded dive during the test series. Individual divers who made between 30 and 60 dives each were common, but a large number of divers made only 5 or less (Reference C.3.1).

Because underwater missions posed a peculiar set of radsafe problems, detailed preparations were made to develop safe operating procedures. For example, there was concern about internal radiation intake due to swallowing water and possible wounds to the hands that would allow direct particulate entry. The Diving Medical Officer and the CTG 7.3 Staff Radiological Safety Officer consulted in the United States on underwater radsafe problems before the Medical Officer was officially attached to the staff of CTG 7.3. During the planning phase of HARDTACK, CTG 7.3 believed it "unlikely that any event other than Shot UMBRELLA would present any significant [radiological] hazard" but that "lacking proof to the contrary, it was held necessary to assume that diving operations would be required in the presence of a considerable underwater radiological hazard following that event [UMBRELLA]" (Reference C.3.1).

No serious radiological problems for Navy diving units occurred during HARDTACK. Concern about the possible exposure of divers participating in the UMBRELLA exercise proved unfounded. The Diving Medical Officer noted in the CTG Final Report (Reference C.3.1) that "during the week following UMBRELLA, few dive badges gave readings as high as 20 mr even from longer dives in radioactive areas." Indeed, the greatest exposure received by any diver during HARDTACK was 2.660 R, well below the 3.75-R limit specified for the test series, and this exposure was recorded by a non-SCUBA diver who was not involved in any UMBRELLA diving operations. Exposure information for the divers as a unit is not available, but is contained in the dosimetry of the ship units from which the men dove. The Chief Diving Officer noted that the most serious problems incurred during diving operations were due to a lack of enough decompression equipment (Reference C.3.1).

As a result of these findings, the final report of CTG 7.3 concluded:

> . . . that underwater radiation proved to be an almost negligible problem. Dosage received by divers was small even in the limited areas where significant radiation levels were found.

The Diving Operations report appended to the Final Report reached a similar conclusion but added that "the fact that underwater radiation was virtually no problem during HARDTACK does not warrant the conclusion that precautions of the kind applied are not necessary" (Reference C.3.1).

Task Group 7.3 Special Projects Unit

The Special Projects Unit was assigned to Operation HARDTACK specifically for participation in shots WAHOO and UMBRELLA. Formed on 12 July 1957 at the U.S. Naval Amphibious Base, Coronado, California, the duties of this unit were to prepare the target vessels, to bring them to the EPG, and to moor them for WAHOO and UMBRELLA. The Special Projects Unit supplied crews for the target ships when they were not serving as targets (Reference C.3.3.31).

On 2 March 1958, the target merchant ship, SS Michael Moran (EC-2), towed by Grasp, arrived at the EPG. A month later, on 9 April, a contingent of the Special Projects Unit, composed of personnel who were not part of the crews of the target vessels, arrived at the EPG aboard Renville. The three target destroyers, Fullam (DD-474), Howorth (DD-592) and Killen (DD-593), towed by the icebreaker USS Staten Island, reached the EPG on 19 April. On 23 April, the target vessels Squaw-29 and YFNB-12, towed by Cree, arrived at the EPG. Crews of the target destroyers were berthed aboard these ships until WAHOO was detonated on 16 May, after which the crews transferred to USS Hooper Island (ARG-17). The crew of Moran was berthed and messed on shore, and the crews of Squaw-29 and YFNB-12 (along with the unit's administration group) berthed and messed on Renville. Personnel of the latter unit prepared the target vessels for the tests, moored them in position, and performed various maintenance duties on the target ships, then disembarked before the detonations (Reference C.3.3.31).

Members of the Special Projects Unit encountered radioactivity from WAHOO and UMBRELLA while they helped tow the vessels out of the target-array area and aided in their decontamination. The maximum individual exposure reported was 4.36 R.

Members of the Special Projects Unit were detached from TG 7.3 at various times throughout late July and August. The target vessels were towed from the EPG to Pearl Harbor by Grasp, Moctobi, Chowanoc, and Munsee on 22 June.

Destroyer Squadrons

Commander Destroyer Squadron 1 and staff, from San Diego, California, was in the EPG for five shots of the HARDTACK series between 24 March and 20 May. The ships present were USS Perkins (DDR-877), USS Floyd B. Parks (DD-884), USS John R. Craig (DD-885), and USS Orleck (DD-886). Destroyers made weather observations at Enewetak, at Bikini in conjunction with Boxer, and from weather station Bravo (330°T, 260 nmi [482 km] from Enewetak). Additional destroyer assignments included search and rescue (SAR), aircraft control.

Following WAHOO, Destroyer Squadron 1 was relieved by elements of Destroyer Squadron 9: USS Mansfield (DD-728), USS Collett (DD-730), USS Benner, and USS De Haven (DD-727). The home port of Destroyer Squadron 9 was Long Beach, California. Between 17 and 20 May, ships of the squadron received training and equipment from their counterparts in Destroyer Squadron 1. Destroyer Squadron 9 remained in the EPG for the remainder of the HARDTACK series.

Separate exposure information has been found for the Commander and staff of Destroyer Squadron 1, but none has been found for Destroyer Squadron 9 and staff. It was probably incorporated with the exposures filed for Mansfield (see Table 34).

Explosive Ordnance Disposal Unit One

Explosive Ordnance Disposal Unit One (EODU-1) was a special unit trained to render safe or dispose of naval explosives. It was based at San Diego, California. The exact size of the unit is not known (Reference C.1.1641).

During the HARDTACK series, EODU-1 was assigned to TG 7.3 to lay four mine fields involving a total of approximately 140 mines in support of Project 6.7 for UMBRELLA. The unit was stationed aboard USS Lawrence County (LSD-887). EODU-1 established and provided logistic support for the project and conducted diving operations in support of project activities. It assembled most of the mechanical gear required for Project 6.7 activities during UMBRELLA on board Lawrence County and participated in SAR operations as well (Reference C.3.1).

After completion of its support activities for UMBRELLA, the unit moved to Pearl Harbor with Project 6.7 mines. EODU-1 returned to San Diego in July (Reference C.1.1641).

No exposure information is available on EODU-1 as a unit.

Mine Detail Augmenting Unit 0302

Mine Detail Augmenting Unit 0302 (MDAU-0302) was a special Navy unit assigned to TG 7.3 to support Project 6.7 during UMBRELLA. MDAU-0302 performed preshot assembly on naval mines and conducted operational tests on mines to be used during UMBRELLA. MDAU-0302 was stationed on Takelma during UMBRELLA. It also engaged in postoperational activities after UMBRELLA and helped in Project 6.7 mine recovery (Reference C.1.1641).

There is no specific exposure information currently available on MDAU-0302; their exposures probably are included with other units.

Patrol Squadron 28

Members of Patrol Squadron 28 (VP-28), based at Naval Air Station (NAS) Barbers Point, Hawaii, augmented by four P2V-5F aircraft and flight crews from Patrol Squadron 22 (VP-22), participated in all HARDTACK shots (Reference C.3.3.29). Based at NAS Kwajalein during the shot series, the reinforced squadron consisted of 16 P2V-5F aircraft and had 285 badged personnel. Tasks assigned this command were to (Reference C.3.3.29):

- Conduct searches of designated areas
- Detect, warn, and escort any unauthorized craft out of the danger area
- Assist in the collection of scientific data and provide radiological surveys
- Carry out SAR assignments
- Participate in sampler rocket nosecone recovery operations.

Typically beginning 3 days before a scheduled shot, VP-28 aircraft, acting under the direction of the Deputy CTG 7.3, swept the danger area and approximately 120 nmi (222 km) beyond to ensure that no unauthorized vessels were close enough for radiological exposure (Reference C.3.1). Finally, members of the squadron conducted an evaluation of radiac installations in P2V-5F aircraft during underwater shots to determine radioactivity at the base surge in order to test whether antisubmarine-warfare- (ASW) type aircraft could deliver atomic weapons.

Kwajalein flight operations were inaugurated on 4 April. Daily area searches took place, as well as ASW and SAR and radiological survey flights (Reference C.3.3.29). Several units participated in TEAK and ORANGE by searching the danger area and conducting "highly successful" nosecone recovery operations (Reference C.3.3.29).

The 7 June 1958 Operational Phase report shows the effectiveness of decontamination procedures conducted in May 1958 (Reference C.3.3.29):

> Results of personnel decontamination have been excellent . . . . Most of the flight crews returned clean, even though radiation levels of 100 to 500 milliroentgens/hour and above were encountered. The highest level of contamination recorded at the change house was 6 MR [per hour] on the skin and 10 MR [per hour] on clothing. Five crews or parts thereof have been decontaminated . . . . Five members of one crew after over five showers still had a reading of .2 to .5 MR [per hour] . . . in their eyes. These people were sent to the doctor for further checking and cleaning. They were monitored daily and by the fourth day the intensities obtained from their eyes had returned to background count . . . . This was the crew that had the highest contamination for the month [of June].
>
> All aircraft have been below the maximum intensity of 60 MR [per hour] established as a maximum before beginning decontamination work. The highest contamination on aircraft at

> Kwajalein was 127 MR [per hour]. One aircraft was contaminated to 33 roentgens/hr and landed immediately at Eniwetok and was given preliminary decontamination there . . . the crew . . . film badges indicated a dose of about 900 MR. The contamination they had was mostly on their hands where they had touched the aircraft upon leaving it. Six aircraft have been decontaminated. All have been reduced to less than 1 MR [per hour] maximum reading inside. One was released with a 20 MR [per hour] intensity on the engines.

In June, the highest aircraft radiation level on landing was 0.273 R/hr. The average intensity during this month was 0.093 R/hr. Contamination levels remained about the same for the remainder of the operation (Reference C.3.3.29).

Ships

The following U.S. Navy ships participated. The primary source for information on ship positions, radiation readings, and use of washdown systems is the individual ship's log, a legal document.

USNS Fred C. Ainsworth (T-AP-181)

The Military Sea Transportation Service (MSTS) ship Fred C. Ainsworth was part of TU 7.3.9. This troop transport was assigned as the primary evacuation ship for personnel on Bikini during most of the tests. The ship moved to Enewetak on 21 July where it was reassigned to support the emergency evacuation unit for Enewetak for shot OLIVE before leaving the EPG on 25 July.

Ainsworth also operated as a hotel ship for personnel involved in Bikini-based operations. It housed command post TG 7.5, personnel from TG 7.1 and TG 7.5, and personnel from TU 7.1.2 (University of California Radiation Laboratory) and TU 7.1.6 (Bikini Radsafe Group). Radsafe trailers were kept on board. In addition, the ship also coordinated with Boxer as a floating administration and communications center.

The ship conducted numerous radsafe drills during HARDTACK and frequently tested its washdown system. Its log provides detailed accounts of background radiation readings made throughout the test series. The highest reading was 0.0035 R/hr, recorded on 3 July after the CEDAR detonation at Bikini (Reference C.3.4.1). The crew was badged; exposure data appear in Table 34.

Ainsworth's log (Reference C.3.4.1) shows the following ship movements:

30 March		Left San Francisco
5 April	0001	Arrived Pearl Harbor
5 April	0956	Left Pearl Harbor
13 April	0940	Arrived Enewetak
25 July	2030	Left EPG via Bikini
6 August	0730	Arrived San Diego.

Ainsworth was out of the test operating area for shots PINE, TEAK, QUINCE, ORANGE, and FIG. Summaries of the ship's operational activities for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). Anchored in berth N-7, Bikini, approximately 160 nmi (297 km) from shot site. Background reading between 1300 and 1440 was 44 clicks per minute (0.00001 R/hr). At 1320 all below-deck closures were made and at 1330 the washdown system was hooked up. Decks were cleared of personnel not having high-density goggles at 1345 and by 1355 all safety precautions were in effect. Background readings taken at 20-minute intervals after detonation yielded 0.00001 R/hr. From 1600 to 2000 the background count was checked every 20 minutes, averaging less than 0.00001 R/hr. From 2000 to 2200 average background at 30 stations was less than 0.00001 R/hr. On 29 April background readings taken every 20 minutes at various ship locations remained constant at 0.00001 R/hr or less. From 30 April to 5 May took hourly background counts; no reading exceeded 0.00001 R/hr. On 2 May at 0205 tested washdown system.

- CACTUS (Enewetak, 6 May, 0615). Anchored in berth N-7, Bikini. Began continuous monitoring on bridge deck at 0625; background readings throughout the day averaged 0.00001 R/hr or less at all stations. On 7 May at 0205 tested washdown system. From 7 to 11 May took background counts every 20 minutes; none exceeded 0.00001 R/hr. On 11 May from 0205 to 0445 tested washdown system.

- FIR (Bikini, 12 May, 0550). Anchored in berth N-7, Bikini, approximately 15 nmi (28 km) from shot site. At 0200 washdown system ready for instant use. Countdown began at 0510 and at 0525 all closing appliances tested and closures made in compliance with instructions. At H+1:31 minutes shock wave arrived. At 0600 began continuous monitoring of bridge; at 0615 opened ship for ventilation. Average background count at 1025 was less than 0.00001 R/hr. Opened main deck side ports at 1330. Background count remained 0.00001 R/hr or less.

- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth N-7, Bikini. Continued radiation monitoring as noted for FIR (above).

- KOA (Enewetak, 13 May, 0630). Anchored in berth N-7, Bikini. Took background readings throughout the day every 20 minutes, average 0.00001 R/hr. On 14 May background readings taken hourly; at 2350 radiac reading 0.00009 R/hr. On 15 May between 0100 and 0400 background count taken hourly; maximum background count recorded on bridge was 0.00007 R/hr, and in engine room highest reading was 0.00013 R/hr. Between 0400 and 0800 background count taken every 30 minutes, maximum reading 0.001 R/hr. At 1150 radiac count for watch averaged 0.00031 R/hr; at 1320 highest background count on bridge 0.001 R/hr, in engine room highest 0.00025 R/hr. From 1600 to 2000 radiac readings averaged 0.00043 R/hr.

- WAHOO (Enewetak, 16 May, 1330). Moored to buoy N-1, Bikini. On 17 May at 0400 background count on bridge 0.0006 R/hr, in engine room 0.00013 R/hr; from 0400 to 0800 average for watch 0.0005 R/hr. At

0916 prepared washdown system. At 0924 held atomic defense drill, turned on washdown system to counteract fallout, and at 0932 secured washdown system. At 1150 radiac reading for deck averaged 0.00031 R/hr; at 1300 background readings on bridge and in engine room averaged 0.0004 R/hr. From 1600 to 2400 average background reading was 0.0003 R/hr. From 17 to 21 May conducted hourly background counts; no background exceeded 0.001 R/hr.

- HOLLY (Enewetak, 21 May, 0630). Moored to buoy N-1, Bikini. At 0805 closed up portholes and weather deck doors and at 0820 opened ship for ventilation. From 0800 to 1200 background reading on decks averaged 0.00010 R/hr and in engine room 0.00012 R/hr. From 1200 to 1600 average background count was 0.00013 R/hr; from 2000 to 2400 average background reading on deck was 0.00010 R/hr and in engine room 0.00011 R/hr.

- NUTMEG (Bikini, 22 May, 0920). Moored to buoy N-1, Bikini, approximately 10 nmi (19 km) east of shot site. From 0001 to 0400 background readings averaged 0.00001 R/hr. At 0830 closed main deck side ports. At 0857 held atomic defense drill and closed up weather deck doors, portholes. At 0927 opened ship for ventilation; at 1000 background count 0.00004 R/hr. At 1042 activated washdown sprinkler system; at 1100 background count on deck 0.00008 R/hr. Background reading taken every 20 minutes for remainder of day with no average exceeding 0.0002 R/hr. From 23 to 25 May continued taking background counts; no value exceeded 0.0002 R/hr.

- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in berth N-16, Bikini. From 0001 to 0400 background count 0.00008 R/hr; from 0400 to 0800 maximum reading 0.00007 R/hr and from 0800 to 2000 background count 0.00007 R/hr. From 2000 to 2400 background count averaged 0.0001 R/hr.

- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in berth N-16, Bikini. From 0001 to 0400 background count averaged 0.000093 R/hr. At 0745 all open decks monitored, maximum reading 0.0001 R/hr; from 0800 to 1200 background count averaged 0.00005 R/hr; at 1300 background readings at ten checkpoints averaged 0.000095 R/hr. At 1917 all weather decks monitored, maximum reading 0.00007 R/hr. At 2350 background count averaged 0.00006 R/hr. From 28 to 29 May conducted background radiation checks, finding no value in excess of 0.0001 R/hr.

- TOBACCO (Enewetak, 30 May, 1415). At 0110 embarked 60 passengers as part of SYCAMORE rehearsal. At 0738 anchored in anchorage N-7, Bikini.

- SYCAMORE (Bikini, 31 May, 1500). At 0030 embarked 60 passengers, total aboard 680. At 0133 underway for operating area. At 0814 anchored in N-16, Bikini. At 1047 underway for operating area. At 1430 all zones buttoned up. At 1450 background count 0.00005 R/hr; at 1455 background count 0.00007 R/hr. Steaming approximately 34 nmi (63 km) southeast of shot site at time of detonation. At 1503:53 shock wave reached ship, barometer rose 0.02. At 1505 began continuous monitoring of bridge deck; at 1547 background reading averaged 0.00005 R/hr. At 1721 anchored in berth N-16, Bikini. Continuous monitoring of bridge until 1900; after 1900 monitored deck every 20 minutes, no value greater than 0.00007 R/hr recorded.

- ROSE (Enewetak, 3 June, 0645). Anchored in berth N-7, Bikini. Background count taken hourly. At 1000 background count averaged 0.00004 R/hr; at 1335 background count 0.00005 R/hr; at 1919 highest background for watch 0.00006 R/hr. From 4 to 8 June periodically checked background, no value in excess of 0.00007 R/hr.
- UMBRELLA (Enewetak, 9 June, 1115). Moored to buoy N-1, Bikini.
- MAPLE (Bikini, 11 June, 0530). Moored to buoy N-1, Bikini, approximately 12 nmi (22 km) southeast of shot site. At 0515 all closures made throughout ship. At 0540 began continuous monitoring of bridge deck. At 0700 opened ship for ventilation. Background readings taken throughout day, none exceeding 0.00004 R/hr.
- ASPEN (Bikini, 15 June, 0530). Moored to buoy N-1, Bikini, approximately 15 nmi (28 km) southeast of shot site. At 0515 all closures made throughout ship. At 0540 began continuous monitoring and at 0635 opened ship for ventilation. Continued monitoring procedure, maximum reading 0.00003 R/hr. Background checked throughout day, no value greater than 0.00008 R/hr recorded.
- WALNUT (Enewetak, 15 June, 0630). Moored to buoy N-1, Bikini. At 0515 all closures made throughout ship. At 0540 began continuous monitoring and at 0635 ship opened for ventilation. Continued monitoring procedure, maximum reading 0.00003 R/hr. Background checked throughout day, no value greater than 0.00008 R/hr recorded.
- LINDEN (Enewetak, 18 June, 1500). Moored to buoy N-1, Bikini. At 1345 background count averaged 0.00003 R/hr. Ship monitored throughout day, no value in excess of 0.00004 R/hr. From 19 to 27 June background counts taken periodically, no value greater than 0.00008 R/hr recorded.
- REDWOOD (Bikini, 28 June, 0530). Moored to buoy N-1, Bikini, approximately 12 nmi (22 km) east of shot site. At 1345 background count averaged 0.00003 R/hr. Ship monitored throughout day, no value in excess of 0.00004 R/hr recorded.
- ELDER (Enewetak, 28 June, 0630). Moored to buoy N-1, Bikini. At 0520 all closures made throughout ship. At 0630 opened ship for ventilation. At 0710 continuously monitored bridge deck; at 1150 background count on deck averaged 0.00004 R/hr. Background taken every 20 minutes for remainder of day, with no reading greater than 0.00003 R/hr recorded.
- OAK (Enewetak, 29 June, 0730). Moored to buoy N-1, Bikini. At 0637 background read 0.00003 R/hr. At 1150 maximum background count was 0.00003, all zones closed.
- HICKORY (Bikini, 29 June, 1200). Moored to buoy N-1, Bikini, approximately 10 nmi (19 km) east of shot site. At 1150 maximum background count was 0.00003 R/hr, all zones closed. At 1200:58

shock wave reached vessel; atomic, biological, and chemical warfare teams mustered to decontamination station. At 1205 took atomic defense drill stations, began a rapid survey of vessel on open deck, and vessel rebuttoned up. At 1206 hospital teams manned and ready and at 1207 monitoring teams directed to make a rapid survey, not to fully dress. At 1210 monitoring teams conducted a rapid survey. Survey at 1220 recorded 0.00005 R/hr using radiac instruments 343 and 349. At 1222 hospital monitored all exposed personnel. Monitored background every 20 minutes for rest of day, no value in excess of 0.00005 R/hr recorded. From 30 June to 1 July monitored radiation periodically, no value greater than 0.00003 R/hr.

- SEQUOIA (Enewetak, 2 July, 0630). Moored to buoy N-1, Bikini. Background counts taken throughout day, no values in excess of 0.00003 R/hr recorded.
- CEDAR (Bikini, 3 July, 0530). Moored to buoy N-1, Bikini, 15 nmi (28 km) southeast of shot site. At 0505 all closures made throughout ship. At 0540 began continuous monitoring of bridge deck; at 0638 reading 0.00004 R/hr. At 1323 washdown system readied. At 1326 highest background reading obtained 0.0017 R/hr and at 1926 maximum background reading was 0.002 R/hr. At 2350 background count averaged 0.0035 R/hr. From 4 to 5 July readings taken periodically, no value in excess of 0.003 R/hr recorded.
- DOGWOOD (Enewetak, 6 July, 0630). Moored to buoy N-1, Bikini. At 0639 background reading 0.0008 R/hr; took background readings periodically through day, no value exceeding 0.0008 R/hr recorded. From 7 to 11 July took periodic background reading, finding no average value in excess of 0.00075 R/hr.
- POPLAR (Bikini, 12 July, 1530). At 0210 underway for Bikini operating area; at 0236 background averaged 0.00008 R/hr. Steaming approximately 35 nmi (65 km) southeast of shot site at time of detonation. Background count at checkpoint 0.00015 R/hr. At 2019 anchored in berth N-8, Bikini. Background counts taken every 20 minutes through 13 July.
- SCAEVOLA (Enewetak, 14 July, 1600). Anchored in berth N-8, Bikini. Background counts taken every 20 minutes, none exceeding 0.0001 R/hr recorded. From 15 to 17 July took hourly background counts, none exceeding 0.0001 R/hr.
- PISONIA (Enewetak, 18 July, 1100). Anchored in berth N-8, Bikini. Took periodic background readings through 20 July, no reading in excess of 0.0008 R/hr recorded.
- OLIVE (Enewetak, 23 July, 0830). Anchored in berth D-5, Enewetak, 18 nmi (33 km) southeast of shot site. At 0808 took atomic defense drill stations and closed all doors and openings on weather deck. Secured from atomic defense drill at 0840. Highest background reading 0.00007 R/hr. On 24 July took background counts every 20 minutes; at 1610 underway for Bikini. On 25 July at 0715 anchored in berth N-7, Bikini.

USS Arikara (ATF-98)

The fleet tug Arikara was in the EPG for 29 of the 35 shots. Arikara was assigned to decontaminate, position, and salvage target-array ships; to assist with moorings for both underwater shots; and to collect scientific data.

Arikara also was assigned by CTG 7.3 to specific task elements for particular shots: TE 7.3.5.1 (Mooring, Towing, and Recovery Element) for WAHOO, TE 7.3.5.5 (Water Sampling Element) for UMBRELLA, and TE 7.3.9.2 (Rongelap Evacuation Element) for POPLAR.

Arikara's crew had the highest mean exposure for the series of all the badged ships. The ship received fallout on 14 May 1958 and activated its washdown system. The crew was badged; exposure data appear in Table 34.

For WAHOO, Arikara, in conjunction with Bolster, helped to decontaminate the target-array destroyer Fullam. Arikara spent 2 days decontaminating the vessel by periodically hosing it down and monitoring it. Members of Arikara's damage control party wore complete radsafe outfits during the decontamination process (Reference C.0.2, UMBRELLA). No readings are available concerning any exposure the decontamination teams might have received.

After UMBRELLA, Arikara, working with project personnel of the joint task force radsafe team from TU 7.1.6, obtained radioactive water samples. During this activity, all topside personnel who engaged in water sampling operations wore complete radsafe protective clothing. Arikara was the only ship allowed to enter an area having radiological readings greater than 4 R/hr without specific authorization from the TG 7.3 representative aboard Monticello (Reference C.0.2, UMBRELLA). After collecting water samples, Arikara recovered Project 1.2 canisters from outside the lagoon (Reference C.3.4.2).

On 24 July, Arikara towed the barge used for SCAEVOLA from Enewetak Lagoon to the place some 9 nmi (16.7 km) south of the lagoon where it was sunk by gunfire from Mansfield (Reference C.3.3.27).

Arikara's log (Reference C.3.4.2) shows the following movements:

1 March	0903	Left Pearl Harbor
9 March	1233	Arrived at Kwajalein
12 March	0812	Left Kwajalein (with YON-32 in tow)
15 March	1342	Arrived Enewetak
15 August	1130	Left Enewetak (in company with USS Karin [AF-33])
26 August	1257	Arrived Pearl Harbor.

Arikara was out of the test operating area for shots POPLAR, SCAEVOLA, PINE, TEAK, ORANGE, and FIG. Summaries of the ship's operational activities for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). Anchored in berth B-2, Enewetak, 85 nmi (158 km) southwest of shot site. At 1330 went to general quarters.
- CACTUS (Enewetak, 6 May, 0615). Moored approximately 10 nmi (19 km) south of shot site at time of detonation. Went to general quarters in preparation for shot. At 0556 washdown system rigged. At 0615:48 shock wave reached ship.
- FIR (Bikini, 12 May, 0550). Anchored in berth B-2, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth B-2, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0545 went to general quarters. At 0605 washdown system ready for instant use. Shock wave reached ship at 0615:40. At 0820 anchored in berth K-8, Enewetak. Shifted anchorage to berth G-7, Enewetak, at 1520.
- KOA (Enewetak, 13 May, 0630). On 12 May at 1520 anchored in berth G-7, Enewetak, approximately 10 nmi (19 km) south of shot site. On 13 May at 0615 washdown system rigged for use. On 14 May at 1027 activated washdown system throughout the ship; at 1038 secured washdown system.
- WAHOO (Enewetak, 16 May, 1330). At 1156 took position 10°T, distance 9,000 yards (8.2 km) from zero buoy. Remained on station, bearing 190° from surface zero. At 1548 stopped in new position in vicinity of Bolster. On 17 May at 0730 approached target array to prepare to take Fullam in tow. Approached Fullam at 0915, completed washdown operations on Fullam at 1130, and had Fullam in tow at 1533. At 2038 anchored in berth L-9, Enewetak. On 19 May at 0938 underway to moor Fullam to mooring buoy. At 1041 cast off tow near mooring buoy L-4, Enewetak and underway to operational area at 1043. At 1315 underway with YC-1415 in tow. At 1635 anchored in berth G-2, Enewetak. On 20 May at 0812 underway to lagoon operational area. From 1058 to 1742 brought buoy legs aboard. At 1939 anchored in berth B-2, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth B-2, Enewetak, approximately 10 nmi (19 km) south of shot site.
- NUTMEG (Bikini, 22 May, 0920). At 0815 underway from berth B-2, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in Enewetak Lagoon, approximately 18 nmi (33 km) from shot site. At 1108 received LCU-1376 alongside for countdown and safety instruction. At 1401:30 shock wave reached the ship. At 1500 underway to operational area for UMBRELLA mooring operations.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in berth C-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). Anchored in berth C-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Moored to Hooper Island in berth B-1, Enewetak.

- ROSE (Enewetak, 3 June, 0645). Moored in berth B-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0724 anchored in berth B-2, Enewetak.
- UMBRELLA (Enewetak, 9 June, 1115). At 0322 anchored in berth 117, Enewetak, approximately 7,400 yards (6.8 km) east of surface zero at time of detonation. At 1035 ship washdown system rigged. At 1154 underway to approach contaminated water in shot area. At 1253 completed picking up water samples. At 1350 delivered water samples to Parry. At 1552 underway to locate canisters outside lagoon. At 1817 anchored in berth C-1, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored in berth C-1, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Anchored in berth D-1, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). At 0615 all hands were directed to take cover; all doors and ports on portside were secured in preparation for shot. Anchored approximately 18 nmi (33 km) southeast of shot site at time of detonation. At 0824 underway to retrieve 13 dan buoys. At 1428 anchored in Enewetak Lagoon.
- LINDEN (Enewetak, 18 June, 1500). At 1445 all hands instructed to take cover, all ports and hatches on portside closed in preparation for shot. Anchored approximately 10 nmi (19 km) south of shot site at time of detonation. On 21 June engaged in gunnery practice during which Moran, the target, was sunk.
- REDWOOD (Bikini, 28 June, 0530). Anchored approximately 12 nmi (22 km) southeast of shot site at time of detonation.
- ELDER (Enewetak, 28 June, 0630). Anchored at Bikini Lagoon at berth N-2, Eneu Island.
- OAK (Enewetak, 29 June, 0730). Anchored in berth N-2, Eneu Island.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth N-2, Eneu Island, approximately 10 nmi (19 km) east of shot site. At 1000 set condition ABLE on portside in preparation for scheduled detonation.
- SEQUOIA (Enewetak, 2 July, 0630). Anchored in berth N-2, Eneu Island.
- CEDAR (Bikini, 3 July, 0530). Anchored in berth N-3, Eneu Island, 15 nmi (28 km) southwest of shot site. At 0500 closed all ports and doors on portside of ship.
- DOGWOOD (Enewetak, 6 July, 0630). Anchored in berth N-2, Eneu Island.
- PISONIA (Enewetak, 18 July, 1100). At 1040 closed all ports and hatches on starboard side. Steaming approximately 19 nmi (35 km) south of shot site at time of detonation.
- JUNIPER (Bikini, 22 July, 1620). At 1137 underway for SAR station off Enewetak Island.
- OLIVE (Enewetak, 23 July, 0830). Steaming on SAR station approximately 22 nmi (41 km) southeast of shot site.

- QUINCE (Enewetak, 6 August, 1415). At 0723 underway for SAR station. Steaming approximately 10 nmi (19 km) southeast of shot site at time of detonation.

USS Belle Grove (LSD-2)

The dock landing ship Belle Grove was present in the EPG for 21 of the 35 HARDTACK shots. It was at Johnston Island when HARDTACK began, but went to Enewetak after YUCCA. Its general activities involved shuttling LCUs and other cargo among Pearl Harbor, Johnston Island, Enewetak, and Bikini. Because of its assignments, however, it was often away from the actual testing areas of the EPG. On 10 June it departed for Pearl Harbor.

Belle Grove returned to Johnston Island for a second tour of duty in the EPG on 15 July, three days before PISONIA was detonated at Enewetak. It remained at Johnston Island until the end of Operation HARDTACK, departing for Pearl Harbor on 19 August. Belle Grove did return to Johnston Island on 27 August and participated in rollup activities at Enewetak on 4 September, leaving for Pearl Harbor that same day (Reference C.3.3.3).

During its second tour of duty in the EPG, Belle Grove was assigned a number of specific tasks for TEAK and ORANGE. It was assigned to TE 7.3.5.9 (Event Evacuation Element), to assist Boxer in the emergency evacuation of Johnston Island if needed.

The captain was also assigned to act as CTE 7.3.5.1 (Commander Special Transport Element). CTG 7.5 boat pool was stationed aboard Belle Grove from 17 July until the end of the Johnston Island phase of HARDTACK (11 August). It provided the boat pool with fuel and docking facilities and personnel with berthing and messing facilities.

Belle Grove's commanding officer registered a complaint to CTG 7.3 regarding radsafe procedures (Reference C.3.3.3):

> . . . on two occasions BELLE GROVE returned from Johnston Island to Enewetak on days when shots were scheduled and did not hold the Op Order for these shots. This led to considerable uncertainty as to the nature of the radiological safety precautions required.

He recommended that:

> . . . positive means be employed to ensure that all ships in or entering the Danger Area have the required Op Orders or are issued necessary radiological safety instructions by other means.

The crew was badged and the exposure data appear in Table 34.

Belle Grove's log (Reference C.3.4.3) showed the following ship movements:

11 April	0900	Left Pearl Harbor
20 April	0841	Arrived Enewetak

4 September	1448	Left Enewetak
11 September	0958	Arrived Pearl Harbor.

Summaries of Belle Grove's operational activities for CACTUS, HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, TEAK, and ORANGE follow.

- CACTUS (Enewetak, 6 May, 0615). On 5 May at 1829 underway for Bikini. Approximately 133 nmi (246 km) east of shot site at time of detonation.
- HOLLY (Enewetak, 21 May, 0630). Moored at berth B-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- NUTMEG (Bikini, 22 May, 0920). Moored at berth B-1, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). At 0927 anchored in berth N-12, Bikini; at 0953 Army barge debarked. At 1129 underway for Enewetak.
- MAGNOLIA (Enewetak, 27 May, 0600). Steaming en route to Enewetak, approximately 24 nmi (44 km) southeast of shot site.
- TOBACCO (Enewetak, 30 May, 1415). At 0934 underway for Bikini; approximately 41 nmi (76 km) southeast of shot site at time of detonation.
- SYCAMORE (Bikini, 31 May, 1500). At 1207 maneuvered in assigned operating area while awaiting nuclear test. Steaming approximately 38 nmi (70 km) south of shot site at time of detonation. At 1913 anchored in berth N-12, Bikini.
- TEAK (Johnston Island, 31 July, 2350). At 1736 underway from Johnston Island en route to operating area. At 2224 observed an unidentified falling object of extreme brilliance at 0°, position angle 40, Johnston Island bore 262°, 29 nmi (54 km). Steaming approximately 30 nmi (56 km) from shot site at time of detonation. On 1 August at 0246 anchored in anchorage A-7, Johnston Island.
- ORANGE (Johnston Island, 11 August, 2330). On 11 August at 1641 underway to operating area. Approximately 47 nmi (87 km) from shot site at time of detonation. At 2335 received shock wave. On 12 August at 0819 anchored in anchorage A-7, Johnston Island.

USS Benner (DDR-807)

The radar picket destroyer Benner was present in the EPG for 29 shots of the HARDTACK series, from 11 May to 1 August 1958. Its major responsibilities included weather observations, SAR assignments, nosecone recovery, and, after 29 May, due to its enhanced electronics equipment, it conducted all Air Operations Center (AOC) functions at Bikini in Boxer's absence.

The commanding officer of Benner noted the following events in his final report for HARDTACK (Reference C.3.3.4):

> On 14 May about 0700 a background level of about two (2) milli-roentgens [per hour] was noticed in and around the

> bridge and pilot house area. The discovery was made through the use of an AN/SPD-1 Stationary Navy radiac unit. Following this the entire ship was monitored and hot spots of five (5) milli-roentgens [per hour] were found. Ship's personnel commenced a scrub down of the entire ship with salt water about 0830. At 0930 an overall level of 5 milli-roentgens [per hour] was reached. At about 0945 it was discovered that the sea water had an intensity reading of about 10 milli-roentgens [per hour]. Ship's force stopped washing and scrubbing down with sea water and dried off the ship with swabs. At about 0700 on 15 May the overall intensity had dropped to about three (3) milli-roentgens [per hour].

No other reports are available that indicate further radiological exposure. The water washdown system operated satisfactorily (Reference C.3.3.4). Its crew was badged. Exposure data appear in Table 34.

Benner's log (Reference C.3.4.4) showed the following movements:

5 May	0909	Left Pearl Harbor
11 May	1455	Arrived Enewetak
1 August	0800	Left Enewetak
6 August	0733	Arrived at Yokosuka.

Benner was out of the test operating area for shots YUCCA, CACTUS, TEAK, QUINCE, ORANGE, and FIG. Summaries of the operational activities of Benner for the remaining shots follow.

- FIR (Bikini, 12 May, 0550). Anchored in berth D-2, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth D-2, Enewetak, approximately 10 nmi (19 km) south of shot site.
- KOA (Enewetak, 13 May, 0630). Moored at berth N-3, Enewetak, approximately 20 nmi (37 km) southeast of shot site.
- WAHOO (Enewetak, 16 May, 1330). At 0545 five exercise observers reported aboard. At 0612 underway for WAHOO, reporting on station at 1003. At 1145 went to general quarters. At 1325 set material condition "Circle W." Steaming approximately 6,500 yards (5.9 km) south of surface zero at time of detonation. At 1350 secured from general quarters. At 1524 anchored in anchorage F-3, area A, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). At 0030 launched and tracked weather balloon. At 0300 took station 6 nmi (11 km) east of Enewetak Island for SAR assignment. Steaming approximately 16 nmi (30 km) southeast of shot site at time of detonation. At 1442 anchored in berth F-3, Enewetak.
- NUTMEG (Bikini, 22 May, 0920). At 0406 underway for SAR station; approximately 200 nmi (371 km) west-southwest of shot site at time of detonation.

<u>Benner</u> (continued)

- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in berth F-3, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 1606 underway for nosecone recovery operations, completing operations at 1941.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in berth F-3, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). On 29 May at 2220 departed Bikini Lagoon en route to operating area off east coast of Eneu Island for SYCAMORE rehearsal. On 30 May at 0748 anchored in berth N-3, Bikini.
- SYCAMORE (Bikini, 31 May, 1500). Steaming independently as AOC in assigned operating area 20 nmi (37 km) east of Bikini Atoll to make weather observations. Steaming approximately 12 nmi (22 km) east of shot site at time of detonation.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth N-3, Bikini.
- UMBRELLA (Enewetak, 9 June, 1115). Moored at berth N-10, Bikini.
- MAPLE (Bikini, 11 June, 0530). Moored at berth N-10, Bikini, approximately 12 nmi (22 km) southeast of shot site.
- ASPEN (Bikini, 15 June, 0530). Moored at berth N-10, Bikini, approximately 15 nmi (28 km) southeast of shot site.
- WALNUT (Enewetak, 15 June, 0630). Moored at berth N-10, Bikini.
- LINDEN (Enewetak, 18 June, 1500). Moored at berth N-10, Bikini.
- REDWOOD (Bikini, 28 June, 0530). Moored at berth N-10, Bikini, approximately 12 nmi (22 km) southeast of shot site.
- ELDER (Enewetak, 28 June, 0630). Moored in berth N-10, Bikini.
- OAK (Enewetak, 29 June, 0730). Anchored in berth N-4, Bikini.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth N-4, Bikini, approximately 10 nmi (19 km) east of shot site.
- SEQUOIA (Enewetak, 2 July, 0630). Anchored in berth N-4, Bikini.
- CEDAR (Bikini, 3 July, 0530). Moored at berth N-10, Bikini, approximately 15 nmi (28 km) southeast of shot site.
- DOGWOOD (Enewetak, 6 July, 0630). Anchored in berth N-4, Bikini.
- POPLAR (Bikini, 12 July, 1530). At 0001 underway for operating area BG 20-30-LR to make weather observations. Steaming approximately 20 nmi (37 km) southeast of shot site at time of detonation. At 2043 anchored in berth N-4, Bikini.
- SCAEVOLA (Enewetak, 14 July, 1600). Anchored in berth N-4, Bikini.
- PISONIA (Enewetak, 18 July, 1100). Anchored in berth N-4, Bikini.
- JUNIPER (Bikini, 22 July, 1620). Anchored in berth N-4, Bikini, approximately 10 nmi (19 km) east of shot site.
- OLIVE (Enewetak, 23 July, 0830). Anchored in berth N-4, Bikini.

- PINE (Enewetak, 27 July, 0830). Steaming en route to Enewetak. From 0221 to 0435 conducted weather observations. Steaming approximately 22 nmi (41 km) southeast of shot site at time of detonation. At 1247 anchored in berth D-2, Enewetak.

USS Bolster (ARS-38)

The salvage ship Bolster was in the EPG for 20 of the 35 shots (15 March to 27 June). General tasks assigned were to prepare moorings for shots WAHOO and UMBRELLA, to position and salvage target array ships upon completion of the shots, and to collect scientific data.

Bolster was extremely busy fulfilling the special assignments for WAHOO and UMBRELLA (Reference C.3.3.7). CTG 7.3 assigned it to TE 7.3.5.1 (Mooring, Towing, and Recovery Element) for WAHOO and TE 7.3.5.7 (Weapon Placement, Submarine and Squaw Recovery and Salvage Element) for UMBRELLA. For UMBRELLA, it performed required salvage work to prevent the sinking of a target-array vessel. It also recovered the target submarine, Bonita (SSK-3), and the submersible, scale-model target Squaw-29 after the shot when safety conditions permitted (Reference C.0.2, UMBRELLA). Following UMBRELLA, Bolster engaged in instrument recovery operations for Project 6.8.

Bolster's log (Reference C.3.4.5) did not record any radioactivity following any shot. It did participate in hosing and monitoring the target-array ships Fullam and Killen after WAHOO. Arikara and Bolster crews required 2 days to reduce the radioactivity of Fullam to within acceptable levels (Reference C.0.2, WAHOO). During washdown, participating crewmembers wore complete radsafe outfits (Reference C.0.2, UMBRELLA). No values are available for any exposure Bolster crewmen may have received while decontaminating Fullam and Killen, although their total exposure for the series is listed in Table 34.

Bolster's log (Reference C.3.4.5) shows the following movements:

1 March	1409	Left Pearl Harbor with AFDL-27 in tow
15 March	1052	Arrived Bikini Atoll
27 June	1847	Left Enewetak with YTB-188 in tow
9 July	1049	Arrived Pearl Harbor.

Bolster was out of the operating area for shots OAK, HICKORY, SEQUOIA, CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, PINE, TEAK, QUINCE, ORANGE, and FIG. Summaries of the ship's operational activities for the remaining shots follow.

- YUCCA, Bikini, 28 April, 1440). At 1105 underway to deep moor operating area. Steaming approximately 85 nmi (158 km) southwest of shot site at time of detonation.

- CACTUS (Enewetak, 6 May, 0615). Anchored in berth C-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0825 underway to position buoy for local operations. At 1840 moored alongside Moran at area C-3, Enewetak.

- FIR (Bikini, 12 May, 0550). Anchored in area C-1, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in area C-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0615:41.5 received shock wave from BUTTERNUT. From 1510 to 2050 engaged in outside mooring operations.
- KOA (Enewetak, 13 May, 0630). Anchored in area C-1, Enewetak, approximately 20 nmi (37 km) southeast of shot site. Felt shock wave from KOA shot 93 seconds after detonation. From 0723 to 1555 engaged in mooring operations on YC-7 in operating area.
- WAHOO (Enewetak, 16 May, 1330). On 16 May at 0730 cast off YTB-182 tow in target-array area. At 1303 sounded general quarters. Underway on assigned station, approximately 9,000 yards (8.2 km), bearing 180° from surface zero at time of detonation. At 1330:4.5 hydraulic shock wave from WAHOO felt aboard ship, no perceptible base surge at station. At 1412 secured from general quarters. On 17 May washed down and monitored Killen from 0827 to 0847. At 1030 stood by Moran to assist Cree in removing Moran from moor, assisting in its removal at 1220. Washed down Fullam between 1321 and 1343. From 1507 to 1608 picked up Project 2.3 coracles. Took YO in tow at 1703. At 2214 anchored in area C-1, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth C-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0746 underway to UMBRELLA target-array area inside Enewetak Lagoon. From 0900 to 1705 engaged in repositioning zero-buoy legs. At 1814 anchored in berth C-1, Enewetak.
- NUTMEG (Bikini, 22 May, 0920). At 0638 underway for UMBRELLA zero buoy in Enewetak Lagoon.
- YELLOWWOOD (Enewetak, 26 May, 1400). At 1235 underway from mooring area in Enewetak Lagoon for evacuation for YELLOWWOOD. At 1300 anchored in area O-10, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 1401:29 shock wave passed. At 1507 underway to UMBRELLA mooring area to continue mooring operations.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored at Enewetak, approximately 10 nmi (19 km) south of shot site. Shock wave passed at H+51 seconds. At 0702 underway from anchorage area to UMBRELLA mooring area.
- TOBACCO (Enewetak, 30 May, 1415). Moored to Squaw-29 in Enewetak target area. Began diving operations on Squaw-29 at 0953. Approximately 18 nmi (33 km) southeast of shot site at time of detonation. At 1642 ceased diving operations.
- SYCAMORE (Bikini, 31 May, 1500). Anchored at Enewetak.
- ROSE (Enewetak, 3 June, 0645). At 0622 underway from target-array area to anchorage area. Approximately 10 nmi (19 km) south of shot site at time of detonation. At 0730 anchored at Enewetak.
- UMBRELLA (Enewetak, 9 June, 1115). At 0817 underway from target-array area to take UMBRELLA station. At 0920 anchored in berth 250, Enewetak, approximately 7,500 yards (6.9 km) from surface

zero. At 0925 YFNB-12 crew reported aboard. At 1159 underway with Grasp to return to shot area. From 1225 to 1434 in vicinity of target array. At 1442 anchored in Enewetak Lagoon. On 10 June at 0912 underway for target-array area from zero-buoy area. At 1230 began instrument recovery in Platform 3 area with divers. At 1930 secured all diving and instrument recovery operations due to darkness.

- MAPLE (Bikini, 11 June, 0530). Moored at 4-point moor, Enewetak. At 0700 began instrument recovery and diving operations. On 12 June at 0810 conducted diving operations. On 13 June at 0820 released from LCU leg upon order from Project 6.8 leader. On 14 June at 0717 continued diving operations to retrieve instruments. At 2151 anchored in berth C-1, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Moored in berth C-1, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Moored in berth C-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- LINDEN (Enewetak, 18 June, 1500). At 1334 began inspection dives on BC-6529 for salvage preparations. Moored approximately 10 nmi (19 km) south of shot site at time of detonation. At 1600 secured from diving operations.
- REDWOOD (Bikini, 28 June, 0530). Underway for Pearl Harbor, approximately 156 nmi (289 km) southwest of shot site at time of detonation, bearing 236°.
- ELDER (Enewetak, 28 June 0630). Underway for Pearl Harbor, approximately 108 nmi (200 km) southeast of shot site at time of detonation, bearing 143°.
- OAK (Enewetak, 29 June 0750). Underway for Pearl Harbor, approximately 290 nmi (537 km) east-southeast of shot site, bearing 16°.

Bonita (SSK-3)

The hunter-killer submarine Bonita was declared "out of commission, in service" on 31 October 1957, before its use as an underwater target during Operation HARDTACK. It carried a full crew, however, for its participation in the HARDTACK test series. It arrived at Enewetak on 15 April and remained in the EPG from shot YUCCA through shot LINDEN. It left for Pearl Harbor on 22 June.

Bonita's primary activities were conducted during WAHOO and UMBRELLA. The ship acted as a target vessel in support of Projects 3.3, 3.5, and 3.8. For WAHOO, it was submerged with a full crew at a distance of 6,000 yards (5.468 km), bearing 120° from surface zero. Bonita was unmanned for UMBRELLA, moored 2,900 feet (884 meters) from surface zero (References C.3.3.8 and C.3.4.6).

Bonita was returned to its mooring at Enewetak after UMBRELLA and remained there until it left the EPG (Reference C.3.4.6).

Its crew was badged and exposure data appear in Table 34. Two members of the crew recorded a radiological exposure in the 3- to 4-R range, with a high reading of 3.788 R. Ninety-six percent recorded exposures below the 1.0-R level.

3 April	1801	Left Pearl Harbor
15 April	1800	Arrived Enewetak
22 June	0604	Left Enewetak
5 July	1000	Arrived Pearl Harbor.

It was out of the test operating area for shots REDWOOD, ELDER, OAK, HICKORY, SEQUOIA, CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, PINE, TEAK, QUINCE, ORANGE, and FIG. Summaries of the operational activities of the vessel for the rest of the shots follow.

- YUCCA (open ocean, 28 April, 1440). Moored in nest of four ships to portside of Fullam along starboard side of Hooper Island at berth B-1, Enewetak, approximately 85 nmi (158 km) southwest of shot site.
- CACTUS (Enewetak, 6 May, 0615). Moored at berth B-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0610 secured all hull openings in accordance with Operation Order 13-58. At 0625 opened hull openings and resumed normal routine.
- FIR (Bikini, 12 May, 0550). Moored in Enewetak Lagoon.
- BUTTERNUT (Enewetak, 12 May, 0615). Moored portside to Fullam along starboard side of Hooper Island in Enewetak Lagoon, approximately 10 nmi (19 km) south of shot site.
- KOA (Enewetak, 13 May, 0630). Moored portside to Killen in a nest of three ships along starboard side of Hooper Island, approximately 18 nmi (33 km) southeast of shot site at time of detonation. At 0706 underway from nest in accordance with CTG 7.3 message. At 1659 anchored in berth D-2; shifted berths until anchoring in berth E-3, Enewetak, at 1833.
- WAHOO (Enewetak, 16 May, 1330). At 0618 underway to local operating area. At 1147 submerged 6,000 yards (5.49 km) from shot site. Surfaced at 1336, magnesyn compass out of commission. At 1650 returned to Enewetak Lagoon, moored portside to starboard of USS Sterlet (SS-392) in a nest of submarines along the starboard side of Hooper Island in berth B-1, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Moored portside to Belle Grove along starboard side of Hooper Island at berth B-1, Enewetak, approximately 10 nmi (19 km) south of shot site at time of detonation.
- NUTMEG (Bikini, 22 May, 0920). Moored at berth O-6, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). At 1052 moored portside to Killen along starboard side of Hooper Island at berth B-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.

- MAGNOLIA (Enewetak, 27 May, 0600). Moored portside to Killen along starboard side of Hooper Island at berth B-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). Moored portside to Killen along starboard side of Hooper Island at berth B-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Moored at berth B-1, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Moored portside to Killen along starboard side of Hooper Island at berth B-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- UMBRELLA (Enewetak, 9 June, 1115). Moored at target-array site, Enewetak Lagoon, 2,900 feet (884 meters) from surface zero. At 1607 taken under tow by Cree. At 2207 moored at berth B-1, Enewetak, alongside Hooper Island. Underwent decontamination by Hooper Island from 0940 to 1125 on 10 June.
- MAPLE (Bikini, 11 June, 0530). Moored at berth B-1, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Moored at berth B-1, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Moored portside to Fullam along starboard side of Hooper Island at berth B-1, Enewetak.
- LINDEN (Enewetak, 18 June, 1500). Moored portside to Fullam along starboard side of Hooper Island at berth B-1, Enewetak, approximately 10 nmi (19 km) south of shot site. On 22 June at 0604 underway for Pearl Harbor.

USS Boxer (CVS-21)

The antisubmarine aircraft carrier Boxer was an important part of the HARDTACK series, serving as command ship for the CJTF 7, flagship for CTG 7.3, as headquarters ship for the CTG 7.1 and CTG 7.4, and AOC for Air Force personnel (Reference C.3.1). In addition to these responsibilities, it was assigned the following shot-specific tasks:

YUCCA	TE 7.3.5.1	Launch and Track Element
FIR	TU 7.3.9	Bikini Evacuation Unit
WAHOO	TE 7.3.5.0	Flagship Element
NUTMEG	TU 7.3.9	Bikini Evacuation Unit
SYCAMORE	TE 7.3.9.1	Bikini Evacuation Element
UMBRELLA	TE 7.3.5.4	Coracle and Film Pack Recovery Element
ASPEN	TE 7.3.9.1	Bikini Evacuation Element
WALNUT	TE 7.3.2.4	Nose Cone Recovery Element
OAK	TU 7.3.5	Light Aircraft Evacuation Unit
TEAK	TE 7.3.5.9	TEAK Evacuation Element
ORANGE	TE 7.3.5.0	ORANGE Flagship Element

ORANGE	TE 7.3.5.2	ORANGE Recovery Element
ORANGE	TE 7.3.5.9	ORANGE Evacuation Element.

Boxer's assigned missions for these tasks included participation in Projects 1.10, 2.3, 2.7, 8.6, 9.2, 32.3, 32.5, 32.6, and 34.2. In addition, it aided in weather observations and carried Marine Helicopter Transport Squadron 361 (HMR[L]-361). Finally, it transported many of the devices used in the DOD events to the EPG, as well as their guard, the Marine Corps detachment. The detachment was picked up in San Diego in February 1958 (Reference C.1.1682).

The primary mission of Boxer was to serve as the command headquarters ship. It stored materials and fuel for smaller ships, housed the communications center, weather center, and sea-based administrative facilities such as SOPA (Admin) Bikini or the administration of Johnston Island when these areas were evacuated for certain of the tests. During TEAK and ORANGE, Boxer received all personnel evacuated from Johnston Island and also received evacuees from Bikini during operations there. It launched the balloon that carried the YUCCA device on 28 April (Reference C.3.1), aided in Project 2.3 coracle and floating film pack (FFP) recovery following UMBRELLA, and recovered sampler rocket nosecones after WALNUT and TEAK.

Radsafe planning aboard Boxer was extensive. Before the ship's departure for the EPG, an interim washdown system was installed and tested at sea off San Diego. Radiac instruments were overhauled and calibrated, the ship's decontamination stations were overhauled and rearranged, piping and showers were checked and painted, and protective clothing (including coveralls, gloves, goggles, overshoes, utility caps, and respirators) was brought aboard. In addition to the "various and sundry detergents and cleaning compounds already on board," an "ample supply of decontamination materials was procured." A portable, steam jet cleaner using fresh or seawater was obtained, and space aboard ship was allotted for the CTG 7.3 Radsafe Office, storeroom, and decontamination stations. Selected ships personnel also received radsafe training. This is described in Chapter 2.

For the operation itself, 18 radiological monitoring teams and 2 decontamination squads were organized and placed under the direct control of the radsafe officer. These teams were used extensively on shot days for fallout watch and decontamination. Fallout watches began at H+5 minutes and each watch lasted 2 hours. Hourly surveys were made continually from Boxer's arrival in the EPG. These reports had a dual function: to determine arrival of fallout and then to determine average radiation background levels.

The washdown system was activated once according to Boxer Operation Phase Report (Reference C.3.3.9):

> Only one instance of contamination by fallout occurred. This was on 14 May 1958 at 0630 M while at anchor in Eniwetok Atoll after the KOA shot. Intensities topside rose to an average of 8 MR/HR (Gamma) with high levels of 20-30 MR/HR. Washdown system was not activated immediately due to flight operations, however conditions ZEBRA & CIRCLE WILLIAM were set and all monitoring stations manned. After approximately 1 hour of

> washdown operation intensity had dropped to 4 MR/HR and subsequently decayed to background. All exposed personnel were passed through the after decontamination station and all clothing reading 5 MR/HR above background was segregated and stowed. Hot spots were roped off and marked. Monitors booties and gloves were the most highly contaminated and were handled as noted [above]. All clothing was laundered and returned to owners. Washdown system and hosing with salt and fresh water lowered intensities throughout flight deck and hangar deck areas. Much difficulty was experienced with traffic control of ships company and observers, contamination being tracked throughout the ship by means of shoes getting wet on hangar or flight deck.

The effectiveness of the washdown system was adequate to "level-off the rise in fallout," but its effectiveness on decontaminating the wooden flight deck was considered poor by the commanding officer and only 30 percent effective in decontaminating the exposed, topside painted steel surfaces. Navy all-purpose soap was used with fresh water for the "small amount of personnel decontamination encountered." Laundry services aboard ship were utilized for clothing contaminated under 0.0001 R/hr. The CTG 7.3 radsafe laundry on Eneu Island decontaminated the booties and gloves that had a higher level of contamination. Natural decay "was the only possible means available for decontaminating contaminated manila line, jumpers, running riggings, rubber-lined fire hoses, life nets and the ship's fenders" (Reference C.3.3.9).

The crew was badged; the exposure data appear in Table 34.

Boxer's log (Reference C.3.4.7) shows the following movements:

15 February	1008	Left San Diego
21 February	0840	Arrived Pearl Harbor
24 February	1000	Left Pearl Harbor
3 March	0752	Arrived Enewetak
13 August	1329	Left Johnston Island
15 August	1120	Arrived Pearl Harbor.

It was out of the test operating area for shots SEQUOIA, CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, PINE, QUINCE, and FIG. Summaries of the ship's operational activities for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). On 27 April at 1902 underway from Bikini. On 28 April at 0951 set HARDTACK Condition Electronic Safety. At 1125 launched high-altitude balloon carrying the nuclear device for YUCCA. Approximately 35 nmi (65 km) from a point under the nadir of the burst at shot time. At 1441 began radiation monitoring. At 1838 launched two helicopters for Enewetak; at 1945 recovered two helicopters. On 29 April at 0751 anchored in berth N-20, Bikini.

- CACTUS (Enewetak, 6 May, 0615). Approximately 10 nmi (19 km) from shot site at time of detonation, preparing to enter Enewetak Atoll. At 0849 anchored in anchorage E-5, Enewetak. At 1801 underway from Enewetak to Bikini.
- FIR (Bikini, 12 May, 0550). Anchored in berth N-20, Bikini, approximately 15 nmi (28 km) southeast of shot site. Shock wave passed the ship at H+1.5 minutes. At 0555 began radiation monitoring of all exposed surfaces; at 1200 ceased radiation monitoring of exposed areas.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth N-20, Bikini.
- KOA (Enewetak, 13 May, 0630). Steaming en route from Bikini to Enewetak, approximately 27 nmi (50 km) southeast of shot site, at time of detonation. At 0632 shock wave passed the ship. At 0753 launched one helicopter. At 0900 anchored in anchorage E-4, Enewetak. On 14 May at 0736 began washdown of all topside areas due to above-average radiation readings; at 0805 completed washdown of topside areas. At 0823 launched one helicopter for Enewetak. At 0835 underway for Enewetak operating area. Between 0920 and 1010, 1047 and 1056, and 1130 and 1144 washdown system on; at 1016 steered to remove washdown water from the ship.
- WAHOO (Enewetak, 16 May, 1330). At 0837 conducted preparations for underwater detonation. Steaming approximately 12,000 yards (11 km) from surface zero at time of detonation. Shock wave reached ship 6 seconds after detonation; starboard running light carried off by shock wave.
- HOLLY (Enewetak, 21 May, 0630). Anchored in anchorage N-20, Bikini.
- NUTMEG (Bikini, 22 May, 0920). Anchored in anchorage N-20, Bikini, approximately 10 nmi (19 km) east of shot site. Shock wave passed at H+50 seconds.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in anchorage N-20, Bikini.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored at Bikini.
- TOBACCO (Enewetak, 30 May, 1415). At 0232 underway for Bikini operating area for SYCAMORE rehearsal. At 0713 anchored in berth N-20, Bikini.
- SYCAMORE (Bikini, 31 May, 1500). At 0227 underway from Bikini. At 0335 launched weather balloon. At 1205 launched and recovered helicopter. Steaming approximately 31 nmi (57 km) southeast of shot site at time of detonation. At 1502 shock wave passed; at 1505 commenced radiation monitoring. At 1631 anchored in anchorage N-20, Bikini.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth N-20, Bikini.
- UMBRELLA (Enewetak, 9 June, 1115). At 0746 anchored in anchorage 107, Enewetak, approximately 7,900 yards (7 km) from surface zero. Shock wave passed ship 3.5 seconds after detonation.

- MAPLE (Bikini, 11 June, 0530). Approximately 14 nmi (26 km) from shot site at time of detonation. At 0703 anchored in berth N-20, Bikini.
- ASPEN (Bikini, 15 June, 0530). Anchored in berth N-20, Bikini, approximately 15 nmi (28 km) southeast of shot site.
- WALNUT (Enewetak, 15 June, 0630). Anchored in berth N-20, Bikini.
- LINDEN (Enewetak, 18 June, 1500). Anchored in berth N-20, Bikini.
- REDWOOD (Bikini, 28 June, 0530). Anchored in berth D-4, Enewetak.
- ELDER (Enewetak, 28 June, 0630). Anchored in berth D-4, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 0631 shock wave passed ship, began radiation monitoring.
- OAK (Enewetak, 29 June, 0730). Steaming approximately 52 nmi (96 km) from shot site at time of detonation. Shock wave passed the ship at H+4:33 minutes. At 0951 anchored in berth D-7, Enewetak.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth D-7, Enewetak.
- TEAK (Johnston Island, 31 July, 2350). At 1055 boarded evacuees. At 1757 underway for operating area. At 2228 sighted brilliant medium-altitude flash bearing 335°T, range undetermined. Approximately 50 nmi (93 km) from shot site at time of detonation. At 2355:15 shock wave passed ship. On 1 August at 0434 anchored in anchorage B-2, Johnston Island.
- ORANGE (Johnston Island, 11 August, 2330). At 1730 underway in Johnston Island operating area; at 2222 on station. Approximately 70 nmi (130 km) from shot site at time of detonation. Shock wave reached ship at H+7:20 minutes. On 12 August at 0957 anchored in anchorage B-1, Johnston Island.

USS Cacapon (AO-52)

Cacapon was present for 15 of the 35 shots conducted during Operation HARDTACK. A fleet oiler, its primary duty was to supply fuel to the various units of the task force at Bikini, Enewetak, and Johnston Island. It also supported the gasoline tankers by providing aviation gas to units in the task force when necessary. It made three separate tours of the EPG during HARDTACK.

Cacapon was active in the preoperational phase and was present in the EPG for YUCCA and CACTUS. It made a number of Pearl Harbor, Bikini, Enewetak, and Johnston Island shuttles during the remainder of HARDTACK, leaving the EPG immediately before the JUNIPER event on 22 July.

Because of the significant amount of time Cacapon spent in the EPG during HARDTACK, the crew was badged. The highest reading recorded among its crew was 2.060 R. Eighty-six percent of the crewmembers had readings below the 1.0-R level. The exposure data are presented in Table 34. The ship was provided with an interim washdown system (Reference C.3.4.8).

Cacapon's log (Reference C.3.4.8) shows the following movements:

Cacapon (concluded)

24 February	1447	Left San Pedro, California
10 March	1424	Arrived Bikini
20 July	0750	Left Enewetak
21 July	1021	Arrived Kwajalein
22 July	0951	Left Kwajalein
28 July	1505	Arrived Pearl Harbor.

It was out of the test operating area for shots FIR, BUTTERNUT, KOA, WAHOO, HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, UMBRELLA, MAPLE, ASPEN, WALNUT, LINDEN, JUNIPER, OLIVE, PINE, TEAK, QUINCE, ORANGE, and FIG. Summaries of the operational activities of Cacapon for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). Anchored at Bikini, approximately 160 nmi (297 km) southeast of shot site.
- CACTUS (Enewetak, 6 May, 0615). On 5 May at 1947 anchored in berth C-4, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). Moored at berth B-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Moored at berth B-1, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth N-18, Bikini.
- REDWOOD (Bikini, 28 June, 0530). Anchored in berth F-4, Enewetak Lagoon.
- ELDER (Enewetak, 28 June, 0630). Anchored in berth F-4, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- OAK (Enewetak, 29 June, 0730). Anchored in berth F-4, Enewetak Lagoon, approximately 22 nmi (41 km) southeast of shot site.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth F-4, Enewetak Lagoon.
- SEQUOIA (Enewetak, 2 July, 0630). Anchored at Bikini.
- CEDAR (Bikini, 3 July, 0530). Steaming independently en route from Bikini to Enewetak. Approximately 160 nmi (297 km) west-southwest of shot site at time of detonation. At 0700 anchored in berth F-4, Enewetak.
- DOGWOOD (Enewetak, 6 July, 0630). Anchored in berth F-4, Enewetak Lagoon, approximately 18 nmi (33 km) southeast of shot site.
- POPLAR (Bikini, 12 July, 1530). Anchored in berth F-4, Enewetak Lagoon.
- SCAEVOLA (Enewetak, 14 July, 1600). Anchored in berth F-4, Enewetak Lagoon, approximately 10 nmi (19 km) south of shot site.
- PISONIA (Enewetak, 18 July, 1100). Anchored in berth F-4, Enewetak Lagoon, approximately 10 nmi (19 km) south of shot site. On 20 July at 0750 underway for Kwajalein Atoll.

USS Chanticleer (ASR-7)

The submarine rescue ship Chanticleer was in the EPG for 6 of the 35 shots, from 31 March to 16 May during Operation HARDTACK. Its assigned general task was participation in the deep sea mooring detail for WAHOO and UMBRELLA. Divers used the ship as a base for the mooring operations. The ship's personnel assisted in laying the mooring legs. Most of the mooring work was completed before any shots were fired.

Chanticleer was assigned the task of recovering strings of instruments from the water for Projects 1.1, 1.5, and 1.13 following WAHOO (WAHOO Shot Folder). However, Chanticleer's log (Reference C.3.4.9) states that it left the EPG immediately following WAHOO and does not refer to recovery of submerged scientific instruments.

Chanticleer had no recorded instances of radioactive contamination as a result of HARDTACK operations. The crewmembers were badged; exposure data appear in Table 34.

Chanticleer's log (Reference C.3.4.9) shows the following movements:

24 March	1610	Left Yokosuka, Japan
31 March	1644	Arrived Enewetak
16 May	0702	Left Enewetak
24 May	0803	Arrived Pearl Harbor.

Summaries of its operational activities for YUCCA, CACTUS, FIR, BUTTERNUT, KOA, and WAHOO follow.

- YUCCA (open ocean, 28 April, 1440). Moored to a 5-point moor in berth 129, Enewetak, approximately 85 nmi (158 km) southwest of shot site.
- CACTUS (Enewetak, 6 May, 0615). Anchored in berth G-1, Enewetak, approximately 10 nmi (19 km) south of shot site. From 1021 to 1535 engaged in multiple-point mooring detail. At 1225 moored to 5-point moor in berth 209, Enewetak.
- FIR (Bikini, 12 May, 0550). Anchored in berth G-1, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth G-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 1106 underway to recover mooring buoys; at 1650 completed recovery.
- KOA (Enewetak, 13 May, 0630). Anchored in berth G-1, Enewetak, approximately 20 nmi (37 km) southeast of shot site.
- WAHOO (Enewetak, 16 May, 1330). At 0702 underway approximately 9,000 yards (8.2 km) southeast of surface zero at time of detonation, bearing 145°. At 1805 departed for Pearl Harbor.

USS Chowanoc (ATF-100)

The fleet tug Chowanoc was in the EPG for 18 of the 35 shots. It was responsible for positioning and retrieving target-array ships upon the completion of each shot (Reference B.3.1). Its primary responsibility was mooring YCs for the WAHOO target array (Reference C.3.3.11). It also collected scientific information for Projects 1.1 and 1.2.

Chowanoc was assigned by CTG 7.3 to TE 7.3.5.1 (Mooring, Towing, and Recovery) for WAHOO and TE 7.3.5.6 (Gage String Recovery) for UMBRELLA. Its crew worked with Project 1.1 personnel in recovering Project 1.1 gage strings in the vicinity of the target array (Reference C.0.2, UMBRELLA).

Chowanoc's commanding officer reported on 13 June that "no opportunities arose as to necessitate use of decontamination materials" (Reference C.3.3.11), although, according to the ship's log, on 14 May it received radioactive fallout. The highest reading on the ship at 1100 was 0.150 R/hr and the lowest reading was 0.015 R/hr. After 15 minutes, the washdown system was secured and the ship was scrubbed down. This continued until the ship's radiation readings fell to a range of 0.004 to 0.018 R/hr (Reference C.3.4.10). The crew was badged and exposure data appear in Table 34.

It was responsible for towing the target-array destroyer Howorth from the target array to a berth at Enewetak. On 26 June, Chowanoc was towing two targets, YFNB-12 and Fullam, to Pearl Harbor.

Chowanoc's log (Reference C.3.4.10) shows the following movements:

14 March	1535	Arrived Enewetak
22 June	0837	Left Enewetak in company with Grasp, Lawrence County, Moctobi, and Munsee, towing the target ship Fullam
11 July	1209	Arrived Pearl Harbor.

It was out of the test operating area for shots REDWOOD, ELDER, OAK, HICKORY, SEQUOIA, CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, PINE, TEAK, QUINCE, ORANGE, and FIG. Summaries of the ship's operational activities for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). At 1144 moored to Moran in Enewetak, approximately 85 nmi (158 km) southwest of shot site. At 1458 underway to shift berths; at 1508 anchored in berth B-4, Enewetak.
- CACTUS (Enewetak, 6 May, 0615). Anchored in anchorage N-4, Enewetak, approximately 10 nmi (19 km) south of shot site. At 1038 anchored in berth D-1, Enewetak.
- FIR (Bikini, 12 May, 0550). Anchored in berth M-3, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth M-3, Enewetak, approximately 10 nmi (19 km) south of shot site.

- KOA (Enewetak, 13 May, 0630). Anchored in anchorage C-4, Enewetak, approximately 20 nmi (37 km) southeast of shot site. At 0651 underway to lay moor. At 1820 anchored in anchorage B-4, Enewetak. On 14 May at 1100 monitored ship; had high reading of 0.150 R/hr, low reading of 0.015 R/hr, started washdown system; at 1115 secured washdown system, scrubbed down until low reading of 0.004 R/hr and high of 0.018 R/hr were recorded.
- WAHOO (Enewetak, 16 May, 1330). At 0815 on station for WAHOO, 9,000 yards (8.2 km) from surface zero. At 1400 en route to target-array area. On 17 May at 0817 began retrieving Howorth from target array, taking Howorth in tow at 1606. At 2027 anchored in anchorage L-5, Enewetak. On 19 May at 0910 underway for operations. At 1145 tripped tow wire to the Howorth and transferred tow to nest of destroyers consisting of Killen and Fullam. At 1350 took YC-6 in tow. At 1638 anchored in berth E-3, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored in anchorage E-2, Enewetak, approximately 10 nmi (19 km) south of shot site.
- NUTMEG (Bikini, 22 May, 0920). Anchored in anchorage D-2, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in anchorage D-2, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 0930 LCU-373 moored along portside, offloaded installation for UMBRELLA array.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in berth D-2, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0752 underway to lay anchors for UMBRELLA mooring array.
- TOBACCO (Enewetak, 30 May, 1415). At 1155 anchored in berth D-2, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Anchored in berth D-2, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth D-2, Enewetak, approximately 10 nmi (19 km) south of shot site.
- UMBRELLA (Enewetak, 9 June, 1115). At 0727 anchored in berth 235, Enewetak, approximately 8 nmi (15 km) east of shot site. At 1205 underway for target-array area. At 1400 began recovery of instruments with LCM-22 and -52. From 1633 to 1943 in center of target array. At 1949 anchored in anchorage D-2, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored in anchorage D-3, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Moored starboard side to YFNB-12, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Moored starboard side to YFNB-12, approximately 18 nmi (33 km) southeast of shot site.
- LINDEN (Enewetak, 18 June, 1500). Moored starboard side to YFNB-12, approximately 10 nmi (19 km) south of shot site. On 22 June at 0837 underway from Enewetak to Pearl Harbor with YFNB-12 and Fullam in tow.

USS Cogswell (DD-651)

The destroyer Cogswell took part only in the TEAK shot. Although originally scheduled as a participant in both TEAK and ORANGE, a disabling accident to the foremast forced it to turn over its duties to USS Epperson (DDE-719) (Reference C.3.1). During TEAK, it served as part of TE 7.3.5.6 (Scientific Data Element) and handled duties involved with Scientific Projects 4.1, 6.5, and 8.1 (Reference C.3.3.18).

Cogswell rehearsed for its role in the TEAK event on 24 July. During the remainder of its stay at Johnston Island, it steamed on lifeguard station and made weather observations. According to CTG Op Order 38-58, only the crews of ships involved in nosecone recovery operations would be badged since "no nuclear radiation hazard is expected except in nosecone recovery" (Reference B.3.3, 38-58).

On 31 July at 1027 Cogswell was underway from anchorage for shot TEAK. At 2350 (H-hour) all topside hatches were closed, and all topside personnel were instructed to look to port. The ship was approximately 75 nmi (139 km) from shot site, bearing 20°. On 1 August at 0844 anchored at Johnston Island, and at 1249 was underway for Pearl Harbor in company with De Haven.

Because it was not involved in these operations, it received no badges and exposures are thus not included in Table 34 (Reference B.3.3, 38-58).

Cogswell's log (Reference C.3.4.11) shows the following movements:

25 June	0925	Left San Diego for Johnston Island via Pearl Harbor accompanied by USS Ammen and USS Ingersoll
10 July	0931	Arrived Johnston Island
1 August	1249	Left Johnston Island with De Haven
3 August	0939	Arrived Pearl Harbor.

USS Collett (DD-730)

The destroyer Collett participated in 30 of the 35 shots of the HARDTACK series. Its primary mission was the measurement of winds aloft using balloons, 5-inch gun-fired "window" projectiles, and high-altitude sounding projectile (HASP) rocket bursts (Reference C.3.3.12). The ship's duty as part of the Rongelap Evacuation Element for SYCAMORE and HICKORY was to provide an emergency evacuation capability. During WAHOO, the ship was stationed 5,500 yards (5 km) on a true bearing of 171° from surface zero at shot time. No damage occurred to the ship as a result of that event. It did not participate in any of the HARDTACK scientific projects nor did it take part in the Johnston Island operations.

The commanding officer of the ship, in a report dated 13 June, mentioned that "the water washdown system was activated only once when the reading became 5 MR [per hour] above background" (Reference C.3.3.12). The ship log does not provide additional information on this episode, but it probably refers to the general fallout noted on 14 May. The crew was badged and exposure data are in Table 34.

The ship received a special mission on 21 June when CTG 7.3 ordered it and other TG 7.3 ships to sink Moran, a target vessel for the WAHOO and UMBRELLA events. Collett carried out this mission by using Moran as a gunnery target ship to exercise its crew at 5-inch main battery practice.

Collett also escorted the yacht Phoenix to Kwajalein on 2 July after it had been intercepted by the U.S. Coast Guard vessel Planetree. Phoenix was making a protest sail in the EPG danger area.

During 8 through 14 August, Collett served as the host ship for scientific personnel and special equipment to survey of the water within the EPG danger area. It covered 2,000 nmi (3,706 km), stopping 38 times to take water samples (Reference C.3.3.12). The objective of the project was to evaluate the radioactivity.

Collett's log (Reference C.3.4.12) shows the following movements:

5 May	0857	Left Pearl Harbor with Destroyer Division 91
11 May	1513	Arrived Enewetak
16 August	1220	Left Enewetak
21 August	0908	Arrived Yokosuka.

It was out of the test operational area for shots YUCCA, CACTUS, TEAK, ORANGE, and FIG. Summaries of its operational activities for the remaining shots follow.

- FIR (Bikini, 12 May, 0550). Anchored in berth F-4, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth F-4, Enewetak, approximately 10 nmi (19 km) south of shot site.
- KOA (Enewetak, 13 May, 0630). At 0152 underway for SAR patrol. At 0630 witnessed atomic explosion bearing 315°T, range 18 nmi (33 km). At 0632 shock wave passed ship. From 1252 to 1447 engaged in rehearsal exercise with Benner and Orleck. At 1634 anchored at berth F-2, Enewetak.
- WAHOO (Enewetak, 16 May, 1330). At 1200 manuevered while keeping station on a radar reflection buoy marking surface zero; at 1205 on station 351°T, 5,500 yards (5 km) from a reflection buoy marking surface zero. At 1246 set general quarters. At 1330 shock wave passed the ship, all departments reported no apparent damage. At 1412 secured from general quarters, detached from station assignment. At 1516 anchored in berth C-4, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth N-3, Bikini.
- NUTMEG (Bikini, 22 May, 0920). At 0820 underway for weather observation data. Approximately 10 nmi (19 km) east of shot site at time of detonation.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in berth N-3, Bikini.

Collett (continued)

- MAGNOLIA (Enewetak, 27 May, 0600). Approximately 200 nmi (371 km) east of shot site at time of detonation, tracking weather balloons. At 0802 anchored in berth N-3, Bikini.
- TOBACCO (Enewetak, 30 May, 1415). Approximately 23 nmi (43 km) south of shot site at time of detonation. At 1735 entered Enewetak Lagoon. At 1745 underway for SAR station 5 to 7 nmi (9 to 13 km) from Enewetak Island.
- SYCAMORE (Bikini, 31 May, 1500). Steaming on SAR station 7 nmi (13 km) east of Enewetak Island.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth F-3, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0830 underway for fueling barge.
- UMBRELLA (Enewetak, 9 June, 1115). At 0507 tracked weather balloon. Steaming independently within a 30-nmi (56-km) radius of weather station Bravo, approximately 275 nmi (510 km) from shot site, at time of detonation.
- MAPLE (Bikini, 11 June 0530). Steaming in vicinity of weather station Bravo, approximately 375 nmi (695 km) northwest of shot site, at time of detonation.
- ASPEN (Bikini, 15 June, 0530). Steaming in an area 5 to 7 nmi (9 to 12 km) east of Enewetak Island.
- WALNUT (Enewetak, 15 June 0630). Steaming in an area 5 to 7 nmi (9 to 13 km) east of Enewetak Island; approximately 22 nmi (41 km) south of shot site at time of detonation. Anchored in berth D-3, Enewetak, after the test.
- LINDEN (Enewetak, 18 June, 1500). At 0920 underway for SAR patrol. Witnessed explosion at 13 nmi (24 km) range, bearing 335°T. At 1738 released from SAR duties. At 1854 anchored in berth D-3, Enewetak.
- REDWOOD (Bikini, 28 June, 0530). Anchored in berth N-3, Bikini, approximately 12 nmi (22 km) southeast of shot site. At 0539 underway from Bikini Atoll.
- ELDER (Enewetak, 28 June, 0630). Underway from Bikini Atoll, approximately 200 nmi (371 km) east of shot site, at time of detonation.
- OAK (Enewetak, 29 June, 0730). Anchored in berth N-3, Bikini.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth N-3, Bikini, approximately 10 nmi (19 km) east of shot site. At 1210 underway for Rongelap Island; at 1231 orders reversed and at 1258 anchored in berth N-3, Bikini, on 15-minute notice for getting underway.
- SEQUOIA (Enewetak, 2 July, 0630). On 1 July at 1201 underway to rendezvous at 11°N, 170°E with Planetree (WAGL-307), a U.S. Coast Guard vessel, and the yacht Phoenix. Steaming independently within EPG, tracking Planetree and Phoenix, approximately 400 nmi (741 km) from shot site, at time of detonation. At 0915 joined Planetree. At 1043 assumed surveillance of Phoenix and released

Planetree to carry out duties. At 1100 proceeded to lead Phoenix out of danger area.

- CEDAR (Bikini, 3 July, 0530). Steaming in company with Phoenix to Kwajalein. Approximately 220 nmi (408 km) east of shot site at time of detonation.
- DOGWOOD (Enewetak, 6 July, 0630). Steaming en route to Kwajalein Atoll with Phoenix. On 4 July at 1726 moored at Kwajalein. Anchored approximately 310 nmi (574 km) southeast of shot site at time of detonation.
- POPLAR (Bikini, 12 July, 1530). At 0001, 0230, 0515, and 1125 launched and tracked weather balloons. Steaming approximately 375 nmi (695 km) northwest of shot site at time of detonation.
- SCAEVOLA (Enewetak, 14 July, 1600). Anchored in berth C-2, Enewetak, approximately 10 nmi (19 km) south of shot site. On 15 July at 1055 four divers conducted an underwater inspection of the hull and sonar dome; at 1350 secured from diving operations.
- PISONIA (Enewetak, 18 July, 1100). Anchored in berth C-2, Enewetak, approximately 10 nmi (19 km) south of shot site.
- JUNIPER (Bikini, 22 July, 1620). Anchored in berth C-2, Enewetak.
- OLIVE (Enewetak, 23 July, 0830). Anchored in berth C-2, Enewetak. At 0830 observed atomic blast off the port beam, distance 18 nmi (33 km). At 0831 shock wave passed over the ship.
- PINE (Enewetak, 27 July, 0830). Steaming in vicinity of weather station Alpha at time of detonation, approximately 230 nmi (426 km) west of shot site.
- QUINCE (Enewetak, 6 August, 1415). Moored at deep water pier at Parry Island, Enewetak, approximately 10 nmi (19 km) south of shot site.

USS Comstock (LSD-19)

The dock landing ship Comstock was one of four such ships assigned to HARDTACK. It was primarily involved in the preoperational phase of HARDTACK, having first arrived in the EPG on 20 January 1958 (Reference C.3.3.13). During this period, Comstock ferried LCUs between Enewetak and Bikini. The ship departed from Johnston Island 3 days before shot YUCCA, and then returned to Johnston Island for a 1-day visit on 1 May, 5 days before CACTUS was detonated at Enewetak. It remained in the vicinity of the U.S. west coast for the rest of the year (Reference C.3.4.13).

Its commanding officer registered a number of complaints with CTG 7.3 regarding the ship's assignments for HARDTACK. In a memo of 22 March to CTG 7.3 he noted that the "majority of Comstock moves seem to have been a frenzy of drastic last moment changes in load, destination, and personnel, and no substantial advance planning in evidence." He added that the ship's crew was given "no special training" and that he himself had "no amplifying information" regarding the ship's duties (Reference C.3.3.13).

The ship's crew was badged; and exposure data appear in Table 34.

Comstock's log (Reference 3.4.13) shows the following movements:

20 January	0744	Arrived Enewetak
1 May	1244	Left Johnston Island
11 May	0825	Arrived San Diego.

USS John R. Craig (DD-885)

The destroyer John R. Craig was present in the EPG for eight shots of the HARDTACK series, from 24 March to 22 May 1958. The ship's general duties consisted of security patrols, weather observations, and SAR assignments. It also took part in WAHOO as a member of TE 7.3.5.4 (Operational Exercise Element). Craig's mission was to measure winds aloft using balloons, 5-inch gun fired projectiles, which contained radar-reflecting material called "window," and HASP rocket bursts (Reference C.3.3.14).

Radsafe training took place in the United States. Refresher courses at the Fleet Training Group, San Diego, California, augmented the training; "self-administered shipboard training" was conducted as well. The commanding officer considered his crew "adequately trained." His only complaint concerned a "deficiency . . . in the availability of information prescribing maximum limits of radiation exposures, particularly in respect to the safe limits for foodstuffs" (Reference C.3.3.14). On May 14, Craig encountered fallout and activated its washdown system to clean the ship. No other encounters were reported. The crew was badged and exposures are recorded in Table 34.

Craig's log (Reference C.3.4.14) shows the following movements:

17 February	1415	Left San Diego for Enewetak via Pearl Harbor, Pago Pago, Auckland, and Suva (Fiji), accompanied by Perkins, Parks, and Orleck
24 March	0815	Arrived Enewetak
22 May	1200	Left Enewetak for Yokosuka accompanied by Parks, Orleck, and Perkins
27 May	0748	Arrived Yokosuka.

Summaries of its operational activities for YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, and NUTMEG follow.

- YUCCA (open ocean, 28 April, 1440). Moored portside to YOS-32 for fuel in berth N-3, Enewetak. At 1315 closed all topside doors and hatches, mustered crew at foul-weather parade. Moored approximately 85 nmi (158 km) southwest of shot site at time of detonation. At 1500 opened all topside doors and hatches. At 1910 anchored in berth E-3, Enewetak.

- CACTUS (Enewetak, 6 May, 0615). Steaming on SAR station approximately 18 nmi (33 km) south of shot site at time of detonation. At 0900 released from SAR duties. At 1229 anchored in berth D-5, Enewetak.

- FIR (Bikini, 12 May, 0550). Steaming on weather station Bravo, approximately 375 nmi (695 km) northwest of shot site at time of detonation.
- BUTTERNUT (Enewetak, 12 May, 0615). Steaming approximately 250 nmi (463 km) northwest shot site at time of detonation.
- KOA (Enewetak, 13 May, 0630). Steaming on weather station Bravo, approximately 250 nmi (463 km) northwest of shot site at time of detonation. At 0650 completed observing weather balloon. Launched weather balloons throughout remainder of day. On 14 May at 0808 set gas-tight envelope. At 0813 changed course and speed to activate washdown system. At 0825 washdown system activated, stopped washdown system periodically to monitor topside areas. At 1937 anchored in berth E-5, Enewetak.
- WAHOO (Enewetak, 16 May, 1330). At 0615 underway for local operations. At 1000 on station DD-7; at 1130 went to general quarters. Steaming on station DD-7, approximately 8,000 yards (7 km), bearing 175° from surface zero at time of detonation. At 1416 proceeded to SAR station. At 1658 anchored in berth D-3, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth D-3, Enewetak, approximately 10 nmi (19 km) south of shot site.
- NUTMEG (Bikini, 22 May, 0920). Anchored in berth D-3, Enewetak. On 22 May at 1200 underway for Yokosuka, Japan.

USS Cree (ATF-84)

The fleet tug Cree was in the EPG for 31 of the 35 HARDTACK shots. It was responsible for positioning and salvaging target ships. It also assisted in laying deep-sea moors for target-array vessels for WAHOO and shallower moors for UMBRELLA. Following UMBRELLA, it performed salvage work to prevent sinking of target-array units. On the later tests, it was used as an SAR ship.

On 14 May, Cree recorded fallout of 0.032 R/hr intensity. As a result, the ship's washdown system was activated from 0717 to 0725 and 0747 to 0808 (Reference C.3.4.15). Its crew was badged; exposure data appear in Table 34.

On 17 May, Cree towed the target ship Moran away from the target-array area after shot WAHOO. It is unclear whether it decontaminated this ship or if, in fact, any decontamination was necessary. It subsequently towed YFNB-20 to San Diego, California.

Cree's log (Reference C.3.4.15) showed the following movements:

31 March	1733	Arrived Pearl Harbor
9 April	1146	Left Pearl Harbor with Squaw-29 and YFNB-12 in tow
23 April	1335	Arrived Enewetak
30 July	1609	Left Enewetak with YFNB-20 in tow
11 August	1220	Arrived Pearl Harbor.

Cree (continued)

It was out of the test operating area for shots TEAK, QUINCE, ORANGE, and FIG. Summaries of the its operational activities for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). At 1018 underway to operating area. At 1236 made background count of pilot house with AN/PDR-27F. Approximately 92 nmi (170 km) southwest of shot site at time of detonation. At 1741 began salvage and recovery operations of barge BC-6529. At 1834 sent out salvage party. On 29 April at 0700 continued recovery operations on barge BC-6529.
- CACTUS (Enewetak, 6 May, 0615). Anchored in Enewetak Lagoon, approximately 10 nmi (19 km) south of shot site.
- FIR (Bikini, 12 May, 0550). Anchored in anchorage D-3, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in anchorage D-3, Enewetak, approximately 10 nmi (19 km) south of shot site.
- KOA (Enewetak, 13 May, 0630). Steaming in operating area with Moran in tow at time of detonation, approximately 48 nmi (89 km) southeast of shot site. At 0637:58 shock wave arrived. On 14 May at 0717 activated ship washdown system, recording a high reading of 0.032 R/hr; at 0725 secured washdown system. At 0747 reactivated washdown system; at 0808 secured washdown system.
- WAHOO (Enewetak, 16 May, 1330). Operating on station at time of detonation, approximately 10,000 yards (9.1 km) from shot site. At 1330:8.2 shock wave passed. At 1350 damage control reported all underwater structures checked and no damage found. At 1947 proceeded to night steaming area. On 17 May at 1205 began towing Moran. At 1530 anchored in berth L-6, Enewetak. At 1745 LCM-25 took off seven divers and officer in charge.
- HOLLY (Enewetak, 21 May, 0630). Anchored at anchorage G-3, Enewetak, approximately 10 nmi (19 km) south of shot site. Shock wave reached ship 46.1 seconds after detonation. At 0721 underway for operating area. From 0814 to 1221 recovered legs of mooring buoys. At 1324 anchored at anchorage G-3, Enewetak.
- NUTMEG (Bikini, 22 May, 0920). At 0842 moored at anchorage C-1, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). At 0814 underway to UMBRELLA test area. At 1030 began to lay mooring buoy legs. At 1302 anchored out of danger area, approximately 18 nmi (33 km) southeast of shot site. Received shock wave 1:29.5 minutes after detonation. At 1920 anchored in anchorage G-3, Enewetak.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored at anchorage G-3, Enewetak, approximately 10 nmi (19 km) south of shot site. Shock wave arrived 44.8 seconds after detonation. At 0723 underway to UMBRELLA area to lay buoys.
- TOBACCO (Enewetak, 30 May, 1415). Anchored at anchorage G-3, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Anchored off Mut Island, Enewetak.

- ROSE (Enewetak, 3 June, 0645). Anchored at anchorage M-6, Enewetak, approximately 10 nmi (19 km) south of shot site. Shock wave arrived 50.5 seconds after detonation. At 0709 underway for target-array area; at 0756 anchored north of Mut Island.
- UMBRELLA (Enewetak, 9 June, 1115). Anchored in berth C-249, Enewetak, approximately 3.9 nmi (7.2 km) from shot site. At 1158 underway to target-array area. At 1604 took the Bonita in tow. At 1915 anchored in anchorage C-1, Enewetak. At 2139 cast off wire from Bonita. On 10 June at 0756 underway to target-array area. At 0928 arrived in target area and began recovery of barge YC-1415 and anchors with clumps. At 1533 took barge YC-1415 in tow. At 1744 anchored in anchorage C-1, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored in anchorage C-1, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Anchored in anchorage C-1, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Anchored in anchorage C-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- LINDEN (Enewetak, 18 June, 1500). At 1435 began preparations for test. Anchored approximately 10 nmi (19 km) south of shot site at time of detonation. At 1635 anchored in berth C-1, Enewetak.
- REDWOOD (Bikini, 28 June, 0530). On 27 June at 2237 underway for SAR station 5. Approximately 210 nmi (389 km) west of shot site at time of detonation. On 28 June at 1120 anchored in berth C-1, Enewetak.
- ELDER (Enewetak, 28 June, 0630). Approximately 25 nmi (46 km) south of shot site at time of detonation. At 1120 anchored in berth C-1, Enewetak.
- OAK (Enewetak, 29 June, 0730). Anchored in berth C-1, Enewetak, approximately 22 nmi (41 km) southeast of shot site.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth C-1, Enewetak.
- SEQUOIA (Enewetak, 2 July, 0630). On 1 July at 2234 underway for SAR station 5. Steaming approximately 19 nmi (35 km) southwest of shot site at time of detonation. At 1140 released from SAR mission. At 1227 anchored in berth C-1, Enewetak.
- CEDAR (Bikini, 3 July, 0530). On SAR station 5, approximately 200 nmi (371 km) west of shot site, at time of detonation. At 1310 released from SAR mission. At 1402 anchored in berth C-1, Enewetak.
- DOGWOOD (Enewetak, 6 July, 0630). Anchored in berth C-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- POPLAR (Bikini, 12 July, 1530). At 1158 underway for SAR station, arriving on station at 1243, approximately 7 nmi (13 km) east of Enewetak Island. At 1819 released from SAR mission. At 1912 anchored in berth D-1, Enewetak.
- SCAEVOLA (Enewetak, 14 July, 1600). At 1315 on SAR station, approximately 18 nmi (33 km) south of shot site. At 1700 released from SAR duty. At 1759 anchored in berth C-1, Enewetak.

- PISONIA (Enewetak, 18 July, 1100). Moored alongside Cacapon at time of detonation, approximately 10 nmi (19 km) south of shot site. At 1239 anchored in anchorage C-1, Enewetak.
- JUNIPER (Bikini, 22 July, 1620). Anchored in berth C-1, Enewetak.
- OLIVE (Enewetak, 23 July, 0830). Anchored in berth C-1, Enewetak, approximately 18 nmi (33 km) south of shot site.
- PINE (Enewetak, 27 July, 0830). Steaming on SAR station at time of detonation, approximately 32 nmi (59 km) south of shot site. At 1340 anchored in berth C-1, Enewetak.

USS De Haven (DD-727)

The destroyer De Haven was at the EPG for 27 shots of the HARDTACK series. The ship's primary duties were to conduct weather observations and SAR patrols. Assignments included support of Projects 4.1, 6.5, 6.12, and 8.1.

De Haven spent the first week after its arrival in the EPG preparing to participate in shot WAHOO (Reference C.3.3.15). Following that event, it was involved mainly with weather observations and SAR assignments. On 8 July, it left for Johnston Island, where it began rehearsals for the Johnston Island phase of HARDTACK.

Its commanding officer considered that the training of all hands in radiological safety was adequate. He noted one radiological encounter (Reference C.3.3.15):

> On 14 May DeHaven recorded an unexpected fallout with average background count of 12 milliroentgens [per hour] with hot spots reading 50-80 milliroentgens [per hour]. Immediate decontamination procedures in accordance with available information were carried out. No recommendations were received to alleviate the concern by DeHaven. Decontamination teams worked throughout the day and night and by 1500 M the background of the ship was reduced to 4 milliroentgens [per hour] and "hot" material was surveyed or isolated with some isolated spots remaining on board reading over 10 milliroentgens [per hour]. After discussion at a WAHOO conference 14 May at 2100M, no recommendations resulted until several days later when the acceptable background was changed from 1 to 10 milliroentgens [per hour].

No other encounters with radioactivity were reported. The ship's crew was badged and exposure data appear in Table 34.

De Haven's log (Reference C.3.4.16) shows the following movements:

5 May	0915	Left Pearl Harbor in company with Destroyer Division 91
12 May	1247	Arrived Enewetak
12 August	1501	Left Johnston Island.

It was out of the test operational area for shots YUCCA, CACTUS, PISONIA, JUNIPER, OLIVE, PINE, QUINCE, and FIG. Summaries of the vessel's operational activities for the rest of the shots follow.

- FIR (Bikini, 12 May, 0550). Steaming en route to Enewetak. At 0549 observed FIR detonation bearing 60°, distance approximately 180 nmi (334 km).
- BUTTERNUT (Enewetak, 12 May, 0615). At 0615 observed detonation bearing 0°, distance approximately 45 nmi (83 km). At 1247 moored portside to YOS-32 at berth N-4, Enewetak. At 1449 anchored at G-3, Enewetak.
- KOA (Enewetak, 13 May, 0630). Anchored in berth G-3, Enewetak. At 0225 prepared to get underway on 15-minute notice. At 0630 observed nuclear detonation on Dridrilbwij Island 18 nmi (33 km) away. On 14 May at 0845 detected readings of 0.009 to 0.016 R/hr on topside of ship; commenced washdown. At 0904 changed speed to 15 knots (28 km/hr). At 1514 anchored in berth G-3, Enewetak. At 1830 ship decontaminated to an acceptable level.
- WAHOO (Enewetak, 16 May, 1330). At 1106 on assigned station. At 1330 observed detonation bearing 182°, approximately 3 nmi (6 km).
- HOLLY (Enewetak, 21 May, 0630). Anchored in anchorage D-4, Enewetak; ship ready to get underway on 15 minutes notice. Between 0250 and 0450 launched and tracked weather balloons. At 0630 observed detonation from approximately 10 nmi (19 km) south.
- NUTMEG (Bikini, 22 May, 0920). At 0305 underway to weather station Bravo. Steaming approximately 225 nmi (417 km) west-northwest of shot site at time of detonation.
- YELLOWWOOD (Enewetak, 26 May, 1400). Steaming on weather station BRAVO, approximately 200 to 250 nmi (371 to 463 km) northwest of shot site at time of detonation, launching weather balloons.
- MAGNOLIA (Enewetak, 27 May, 0600). Steaming on weather station BRAVO, approximately 200 to 250 nmi (371 to 463 km) northwest of shot site, at time of detonation.
- TOBACCO (Enewetak, 30 May, 1415). Anchored in anchorage D-4, Enewetak. Launched weather balloons between 0445 and 1241. Approximately 18 nmi (33 km) southeast of shot site at time of detonation.
- SYCAMORE (Bikini, 31 May, 1500). Anchored in anchorage D-4, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Anchored in anchorage D-4, Enewetak. Launched weather balloons between 0140 and 0447. Approximately 10 nmi (19 km) south of shot site at time of detonation.
- UMBRELLA (Enewetak, 9 June, 1115). On 9 June steamed independently on SAR station bearing 90°, 5 to 7 nmi (9 to 13 km) from Enewetak. Observed detonation bearing 280°T, approximately 7 nmi (13 km) from shot site. At 1413 anchored in D-4, Enewetak.

De Haven (continued)

- MAPLE (Bikini, 11 June, 0530). Steaming on SAR station Fred, approximately 205 nmi (380 km) west-southwest of shot site.
- ASPEN (Bikini, 15 June, 0530). Steaming independently on weather station Bravo. Observed detonation bearing 110°, approximately 370 nmi (686 km) from shot site.
- WALNUT (Enewetak, 15 June, 0630). Steaming independently on weather station Bravo. Observed detonation bearing 160°, approximately 225 nmi (417 km) from shot site. At 0655 heard three detonations of unknown position.
- LINDEN (Enewetak, 18 June, 1500). Steaming independently on weather station Bravo Prime, approximately 225 nmi (417 km) northwest of shot site at time of detonation.
- REDWOOD (Bikini, 28 June, 0530). Steaming independently on weather station Bravo, approximately 370 nmi (686 km) northwest of shot site.
- ELDER (Enewetak, 28 June, 0630). Steaming independently on weather station Bravo, approximately 225 nmi (417 km) northwest of shot site, at time of detonation.
- OAK (Enewetak, 29 June, 0730). Steaming independently on weather station Bravo Prime, approximately 225 nmi (417 km) north of shot site, at time of detonation.
- HICKORY (Bikini, 29 June, 1200). Steaming independently on weather station Bravo Prime, approximately 370 nmi (686 km) north of shot site, at time of detonation.
- SEQUOIA (Enewetak, 2 July, 1200). Steaming independently from weather station Bravo Prime, approximately 200 nmi (371 km) east of shot site, at time of detonation.
- CEDAR (Bikini, 3 July, 0530). Anchored in anchorage N-3, Bikini, approximately 15 nmi (28 km) southeast of shot site.
- DOGWOOD (Enewetak, 6 July, 0630). Anchored in anchorage N-3, Bikini.
- POPLAR (Bikini, 12 July, 1530). At 1100 underway for Johnston Island; approximately 250 nmi (463 km) from shot site at time of detonation.
- SCAEVOLA (Enewetak, 14 July, 1600). Underway to Johnston Island, approximately 1,240 nmi (2,298 km) from shot site at time of detonation. On 15 July at 0803 anchored in anchorage A-4, Johnston Island.
- TEAK (Johnston Island, 31 July, 2350). At 1034 underway from Johnston Island to assigned station. At 2353 observed detonation bearing 20°, at a range of approximately 150 nmi (278 km). On 1 August at 0655 anchored in anchorage A-4, Johnston Island.
- ORANGE (Johnston Island, 11 August, 2330). At 1037 underway for ORANGE event. At 2321 shifted steering control to aftersteering until after detonation. Steaming 168 nmi (311 km) northeast of

Johnston Island at time of detonation. At 2335 shifted steering control back to the bridge. On 12 August at 0736 anchored in anchorage A-4, Johnston Island. At 0935 seven civilians and Air Force personnel departed ship. At 1501 underway for Pearl Harbor.

USS Elkhorn (AOG-7)

USS Elkhorn was one of three small gasoline tankers that supplied units involved in Operation HARDTACK with various fuels. It made five trips to the EPG during the series and number of shuttle trips between Enewetak and Bikini. It was present for three of the HARDTACK shots. During shot WAHOO, Elkhorn was moored at the Enewetak petroleum, oil, and lubricants (POL) buoy. The ship moved to Parry Island immediately after WAHOO and left for Midway Island that evening. During the REDWOOD shot at Bikini, it was changing anchorages at Enewetak. The ship made its final visit to Enewetak 2 days before PISONIA and left the EPG the same day. It was not fitted with a washdown system and its crew was not badged. It does not appear in Table 34. Elkhorn's log (Reference C.3.4.17) shows the following movements:

3 March	1600	Left Pearl Harbor
13 March	0847	Arrived Enewetak
16 July	1958	Left Enewetak
25 July		Arrived Pearl Harbor.

Summaries of its operational activities for WAHOO, REDWOOD, and ELDER follow.

- WAHOO (Enewetak, 16 May, 1330). Moored to POL buoys, Enewetak, approximately 8 nmi (15 km) east of shot site. At 2351 underway for Midway Island.
- REDWOOD (Bikini, 28 June, 0530). At 0522 underway for anchorage at Enewetak. Steaming approximately 200 nmi (371 km) west of shot site at time of detonation. At 0640 anchored at Enewetak. At 0725 underway for Guam.
- ELDER (Enewetak, 28 June, 0630). Steaming approximately 18 nmi (33 km) southeast of shot site at time of detonation. At 0640 anchored at Enewetak. At 0725 underway for Guam.

USS Epperson (DDE-719)

Epperson took part only in the very-high-altitude shot ORANGE, detonated 11 August at Johnston Island. It participated in that event because of a disabling accident to the foremast of Cogswell. Scientific project personnel aboard Cogswell, assisted by Pearl Harbor Naval Shipyard workers, transferred to Epperson (Reference C.3.1).

It was assigned to TE 7.3.5.6 (Scientific Data Element) and supported Projects 4.1, 6.5, and 8.1 (Reference C.3.3.18). At the time of the ORANGE detonation, it was on a bearing 25°T, at a distance of 30 nmi (56 km) from Johnston Island.

Epperson left for Johnston Island 2 days after its assignment to HARDTACK. The brief time between its assignment and its departure prohibited detailed planning and training, but its crew received lectures on safety and security en route. According to CTG 7.3 Op Order 38-58, only ships involved in nosecone recovery operations would be badged since "no nuclear radiation hazard is expected except in nosecone recovery" (Reference B.3.3, 38-58). Because Epperson was not involved in these operations, it received no badges and thus does not appear in Table 34.

Epperson's log (Reference C.3.4.18) shows the following movements:

5 August	1248	Left Pearl Harbor
7 August	0635	Arrived Johnston Island
12 August	1143	Left Johnston Island
13 August	1842	Arrived Pearl Harbor.

Fullam (DD-474)

The unmanned destroyer Fullam was used as a target ship for underwater shots WAHOO and UMBRELLA. It was towed to Pearl Harbor by Chowanoc on 22 June after the underwater shots.

USS Grasp (ARS-24)

The naval salvage ship Grasp was present in the EPG for 18 of the 35 HARDTACK shots (3 March to 22 June). Its tasks included positioning, salvaging, and decontaminating the target ships. It also transported personnel, collected scientific data for Projects 1.11 and 34.3, and assisted with moors for both underwater shots. For both shots, it also assisted TG 7.1 in weapon placement and TG 7.1 personnel evacuation. For UMBRELLA it assisted in positioning the target submarine Bonita and the scale-model, submersible target vessel Squaw-29 before the event and evacuated Bonita personnel. Later it performed salvage work to prevent the sinking of target-array units and it recovered Bonita and Squaw-29 when the area was radiologically safe (Reference C.0.2, UMBRELLA). It also recovered Project 2.3 coracles following WAHOO. For both underwater shots, the arming and firing parties departed from and returned to Grasp (Reference C.0.2, WAHOO and UMBRELLA).

Following UMBRELLA, Grasp towed Squaw-29 and YFNB-12 to the south end of Enewetak Lagoon, but did not decontaminate these vessels. It towed the target lighter YC-1354; salvaged target vessels BC-6529, YC-1354, and Squaw-29; secured moorings; towed the landing craft LCM-21; and surfaced Bonita (Reference C.3.4.19).

Grasp reported no instances of radioactive contamination before its departure on 22 June. The crew was badged; its exposure data are in Table 34.

Grasp's log (Reference C.3.4.19) shows the following movements:

17 February	1025	Left Pearl Harbor with Moran in tow
3 March	2005	Arrived at Enewetak

22 June	0620	Left Enewetak towing Squaw-29, sailing in company of Moctobi, Chowanoc, Munsee, and Lawrence County
6 July	1201	Arrived Pearl Harbor.

It was out of the test operating area for shots REDWOOD, ELDER, OAK, HICKORY, SEQUOIA, CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, PINE, TEAK, QUINCE, ORANGE, and FIG. Summaries of the operational activities of Grasp for the remaining shots follow.

- (YUCCA (open ocean, 28 April, 1440). At 0550 underway to lay leg of buoy in WAHOO target-array area. Approximately 85 nmi (158 km) southwest of shot site at time of detonation. At 1704 anchored in berth C-1, Enewetak.
- CACTUS (Enewetak, 6 May, 0615). At 0015 anchored in berth C-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- FIR (Bikini, 12 May, 0550). Anchored in berth C-1, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth C-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- KOA (Enewetak, 13 May, 0630). Anchored in berth C-1, Enewetak, approximately 20 nmi (37 km) south of shot site.
- WAHOO (Enewetak, 16 May, 1330). At 0840 underway for station; at 1116 arrived on station. Maneuvering on station approximately 9,000 yards (8 km) from surface zero at time of detonation. At 1921 anchored in berth C-1, Enewetak. On 17 May from 1337 to 1621 recovered Project 2.3 coracles. At 1828 anchored in berth C-1, Enewetak. On 19 May at 0826 took YC-1354 in tow upside down and sent divers under YC-1354 to connect tow wire and free YC-1354 from moorings. At 1240 all divers aboard, YC-1354 free from moorings and in tow. From 1407 to 1425 diver down to connect tow wire. At 1748 anchored in berth C-1, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth C-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- NUTMEG (Bikini, 22 May, 0920). Anchored in berth C-1, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in berth C-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in berth C-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). At 0830 commenced salvage and diving operations, attempting to float sunken barge. Anchored approximately 18 nmi (33 km) southeast of shot site at time of detonation. At 1800 secured from salvage and diving operations.
- SYCAMORE (Bikini, 31 May, 1500). At 0825 moored in berth C-1, Enewetak.

- ROSE (Enewetak, 3 June, 0645). Moored in berth C-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0800 began preparing Bonita for mooring.
- UMBRELLA (Enewetak, 9 June, 1115). From 0630 to 0746 at zero buoy lowering UMBRELLA device. At 0904 anchored in berth 251, Enewetak, approximately 7,300 yards (7 km) from surface zero. At 1154 underway to operating area, proceeding to Bonita and from zero buoy en route to YC-1415. At 1253 anchored to recover Bonita; at 1345 began diving operations to clear screw of LCM-21; at 1426 commenced heaving in anchor to clear YC-1415 from Bonita; from 1451-1503 engaged in diving operations to surface Bonita. After mooring at deep water pier and berth C-1, Enewetak, underway at 1914 for Bonita to remove clumps. At 2118 completed removing clumps from Bonita. At 2133 anchored in berth C-1, Enewetak. On 10 June at 0748 underway for UMBRELLA operating area. At 0950 began salvage of Squaw-29; at 1132 brought aboard clumps from beneath Squaw-29. After surfacing Squaw-29 at 1144, it sank. At 1305 resurfaced Squaw-29 and placed salvage party aboard, party secured loose valves and deck patches; at 1445 removed salvage party from Squaw-29 and cut anchor chains. At 1535 underway with YFNB-12 and Squaw-29 in tow.
- MAPLE (Bikini, 11 June, 0530). Anchored in Enewetak Lagoon.
- ASPEN (Bikini, 15 June, 0530). Moored starboard to Moran at Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Moored starboard to Moran at Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- LINDEN (Enewetak, 18 June, 1500). At 1003 anchored 500 feet (152 meters) from deep water pier, Enewetak, and began salvage and diving operations. Approximately 10 nmi (19 km) southeast of shot site.

USS Hitchiti (ATF-103)

The fleet tug Hitchiti participated in HARDTACK only for shot TEAK at Johnston Island. It was used for Project 4.1, a biological experiment exposing laboratory rodents placed in special containers aboard ship to TEAK to determine bodily physical effects of the blast (Reference C.3.1). Its crew was apparently not badged.

On 31 July at 1328, Hitchiti arrived off Johnston Island for the TEAK shot at 2350. At 2000 it began steering on various courses while conducting biological tests and was steaming approximately 300 nmi (556 km) northeast of the shot site at the time of detonation. At 2351 it secured from biological tests and was underway for Pearl Harbor.

Hitchiti's log (Reference C.3.4.20) shows the following movements:

29 July	1745	Left Pearl Harbor
31 July	1328	Arrived Johnston Island

31 July	2351	Left Johnston Island
2 August	0904	Arrived Pearl Harbor.

USS Hooper Island (ARG-17)

The naval repair ship (a converted Liberty merchant hull) Hooper Island was present at Enewetak for 18 of the 35 HARDTACK shots, from 19 April until 23 June. It provided special services to the target array ships, which included fuel transfer, and telephone, steam, electricity, and flushing water (Reference C.3.4.21).

During shot WAHOO, Hooper Island took 793 people aboard to observe the shot 12,000 yards (10 km) from surface zero (Hooper Island log). During UMBRELLA, it evacuated Parry Island personnel from Enewetak Lagoon, carried and provided facilities for observers, and discharged the observers at Parry Island after shot UMBRELLA was completed (Reference C.0.2, UMBRELLA).

Hooper Island decontaminated the target submarine, Bonita, on 10 June between 0940 and 1125 following UMBRELLA. No figures are available on the amount of contamination, if any, received from this task. Its commanding officer reported one instance of fallout that required the use of the washdown system. On that date (unspecified), fallout intensities reached 0.007 R/hr. The system was described as 90 percent effective, although there were "minor difficulties in control of run-off and decontamination of deck drains" (Reference C.3.3.20). The crew was badged and exposures appear in Table 34.

The commanding officer reported examples of differing interpretations of radsafe regulations: "Target ships alongside [Hooper Island] after UMBRELLA were not allowed to have crews aboard. Yet civilian technicians clad only in shorts and Japanese go-aheads [sandals], worked on them all day. The all-time record was established when decontamination crews, wearing full rubber suits, masks, hoods, and boots, were observed inspecting a gun mount on top of which a man was sunbathing--stark naked" (Reference C.3.3.20).

Hooper Island's log (Reference C.3.3.21) shows the following movements:

15 March	1300	Left San Diego
19 April	0930	Arrived Enewetak
23 June	0831	Left Enewetak
4 July	1142	Arrived Pearl Harbor.

It was out of the test operating area except for shots YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, UMBRELLA, MAPLE, ASPEN, WALNUT, and LINDEN. Summaries of the ship's activities for these shots follow.

- (YUCCA (open ocean, 28 April, 1440). Moored to buoy B-1, Enewetak. On 25 April at 0001 began furnishing steam, electrical power, fire main, and flushing water pressure to Howorth, Killen, Fullam, and Bonita. Remained moored approximately 85 nmi (158 km) southwest of the shot site at time of detonation.

- CACTUS (Enewetak, 6 May, 0615). Moored approximately 10 nmi (19 km) south of shot site at time of detonation.
- FIR (Bikini, 12 May, 0550). Moored to buoy B-1, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Moored to buoy B-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- KOA (Enewetak, 13 May, 0630). Moored to buoy B-1, Enewetak, approximately 20 nmi (37 km) southeast of shot site.
- WAHOO (Enewetak, 16 May, 1330). At 0857 underway from buoy B-1, Enewetak, for test area. On station 12,000 yards (11 km) from zero point at time of detonation, bearing 140°T. At 1555 moored to buoy B-1, Enewetak. At 1600 Bonita and Sterlet moored alongside. At 1620 secured power; at 1715 restored power.
- HOLLY (Enewetak, 21 May, 0630). Moored to buoy B-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- NUTMEG (Bikini, 22 May, 0920). Moored to buoy B-1, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Moored to buoy B-1, Enewetak, approximately 30 nmi (56 km) southeast of shot site.
- MAGNOLIA (Enewetak, 27 May, 0600). Moored to buoy B-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). Moored to buoy B-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Moored to buoy B-1, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Moored to buoy B-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- UMBRELLA (Enewetak, 9 June, 1115). At 0705 embarked 76 enlisted men, 6 officers, and 8 civilian observers. At 0924 anchored in area C-234, Enewetak, approximately 10,500 yards (9.6 km) from surface zero. At 1240 underway to buoy B-1, Enewetak; at 1337 moored to buoy B-1, Enewetak. At 1413, 93 observers departed the ship for Enewetak and Parry islands. On 10 June at 0940 commenced washdown of Bonita; at 1125 secured washdown of Bonita.
- MAPLE (Bikini, 11 June, 0530). Moored to buoy B-1, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Moored to buoy B-1, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Moored to buoy B-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- LINDEN (Enewetak, 18 June, 1500). Moored to buoy B-1, Enewetak, approximately 10 nmi (19 km) south of shot site.

Howorth (DD-592)

The unmanned destroyer Howorth was used as a target ship for underwater shots WAHOO and UMBRELLA. It was towed to Pearl Harbor by Chowanoc on 22 June after the underwater shots.

USS Joyce (DER-317)

The radar picket destroyer escort Joyce was in the EPG during nine shots, from 21 May until 12 June. Its primary function was to conduct SAR operations. No unusual incidents occurred during the its SAR patrols (Reference C.3.3.21). During shot UMBRELLA, the Joyce was assigned to TE 7.3.5.3 (Canister Tracking and Balloon Gauge Recovery), which included the support to Project 1.2.

Radiation levels on board never exceeded "radiological safety limits" (Reference C.3.3.21). When tested, the water washdown system proved 90 percent effective, but the system was never activated because the ship was never radiologically contaminated. Radsafe training for shipboard personnel included a 2-week course in monitoring and radiac instruments attended by eight enlisted personnel, a 5-week course in ABC defense for one officer, a series of lectures by the TG 7.3 Radsafe Team for the entire ship's company, shipboard instruction on radiation exposure and monitoring techniques, and drills in setting the gas-tight envelope aboard ship (Reference C.3.3.21). The crew was badged and exposure data appear in Table 34. Joyce's log (Reference C.3.4.22) shows the following movements:

13 May	0905	Left Pearl Harbor in company with USS Lansing (DER-388)
21 May	0938	Arrived Enewetak in company with Lansing
12 June	1438	Left Enewetak in company with Lansing
17 June	1151	Arrived Pearl Harbor

Summaries of its operational activities for HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, UMBRELLA, and MAPLE follow.

- HOLLY (Enewetak, 21 May, 0630). Steaming en route to Enewetak. Approximately 36 nmi (67 km) from shot site at time of detonation. At 0938 anchored in berth F-4, Enewetak.
- NUTMEG (Bikini, 22 May, 0920). Anchored in berth F-4, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in berth F-4, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 1401:27 shock wave arrived. At 1840 underway for SAR station 5 to 7 nmi (9 to 13 km) east of Enewetak.
- MAGNOLIA (Enewetak, 27 May, 0600). On SAR station approximately 31 nmi (57 km) south of shot site. At 0601:09 shock wave arrived. At 0845 released from SAR duty. At 0953 anchored in berth F-4, Enewetak.
- TOBACCO (Enewetak, 30 May, 1415). Anchored in berth F-4, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Anchored at berth F-4, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth F-4, Enewetak; at 0645 observed detonation 5°T, 9 nmi (17 km) distant. Shock wave arrived at 0645:37.

- UMBRELLA (Enewetak, 9 June, 1115). From 0813 to 0913 underway for participation in shot UMBRELLA. At 1115 observed detonation bearing 160°T, 5 nmi (9 km) distant; 7 seconds later felt shock wave. At 1128 underway for local operations. At 1907 anchored in anchorage 117, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored in berth F-4, Enewetak.

USS Karin (AF-33)

The naval refrigerated store ship Karin provided transportation services and logistic support to the EPG from 20 March until 17 June. During that time, 18 shots of the HARDTACK series took place, although for most of these it was either at Pearl Harbor or at sea between Hawaii and the EPG. The ship was in the vicinity only during two shots. The crew was badged and exposure data appear in Table 34. Whether the ship was equipped with a washdown system is not documented. Karin's log (Reference C.3.4.23) shows the following movements:

10 March	1202	Left Pearl Harbor
20 March	0739	Arrived Bikini
25 March	1426	Left for Pearl Harbor
6 April	1142	Arrived Pearl Harbor
19 April	0956	Left Pearl Harbor
17 June	0759	Left Enewetak
27 June	2039	Arrived Pearl Harbor.

Summaries of its operational activities for ASPEN and WALNUT follow.

- ASPEN (Bikini, 15 June, 0530). On 14 June at 1324 underway for Enewetak. On 15 June steaming 175 nmi (324 km) west of shot site at time of detonation. At 0600 all hands below decks.
- WALNUT (Enewetak, 15 June, 0630). At 0600 all hands below deck. Steaming approximately 28 nmi (52 km) southeast of shot site at time of detonation. At 0838 moored starboard side to deep water pier, Parry Island, Enewetak.

Killen (DD-593)

The unmanned destroyer Killen was used as a target ship for underwater shots WAHOO and UMBRELLA. It was towed to Pearl Harbor by Munsee on 22 June after the underwater shots.

USS Lansing (DER-388)

The radar picket destroyer escort Lansing was present in the EPG for 11 shots of the HARDTACK series, from 21 May to 12 August. Its principal tasks included SAR assignments and scientific material recovery operations. It participated in Projects 1.2, 8.6, 32.3, 32.5, and 32.6. The major reason for Lansing's assignment to the EPG was to participate in UMBRELLA. During its stay in the EPG, it was involved in UMBRELLA rehearsals and SAR operations.

Three days after UMBRELLA, Lansing returned to Pearl Harbor. One month later it left Pearl Harbor for Johnston Island, where it was involved in TEAK and ORANGE rehearsals. The task assigned was the recovery of nosecones and scientific instruments from the TEAK and ORANGE rockets (Reference C.3.3.22).

The 9 June Lansing log entry indicates that "radiation readings [were] normal" immediately following UMBRELLA (Reference C.3.4.24). Its crew received film badges for TEAK and ORANGE because it was involved in nosecone recovery operations, the only aspect of the Johnston Island tests expected to involve radiation exposure. The ship recovered 13 nosecones. Exposures of the crew appear in Table 34. The commanding officer of Lansing wrote in his final report (Reference C.3.3.22) that:

> The effectiveness of decontamination materials, procedures, and equipment could not be properly evaluated by this command due to the lack of contamination on board.

Lansing's log (Reference C.3.4.24) shows the following movements:

13 May	0900	Left Pearl Harbor in company with Joyce
21 May	0854	Arrived Enewetak
12 August	1902	Left Johnston Island
14 August	1452	Arrived Pearl Harbor.

Summaries of its operational activities for HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, UMBRELLA, and MAPLE follow.

- HOLLY (Enewetak, 21 May, 0630). At 0630 device fired on schedule, no effects on this vessel; observed mushroom cloud at 8°, 18 nmi (33 km) range. At 0854 anchored at berth E-5, Enewetak.
- NUTMEG (Bikini, 22 May, 0920). Anchored at berth E-5, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). From 0703 to 0950 participated in test rehearsal. At 1048 underway to SAR station in connection with YELLOWWOOD; at 1139 arrived at SAR station. Steaming on station approximately 25 nmi (46 km) southeast of shot site at time of detonation. At 1402 ship observed shock wave. At 1735 relieved of SAR mission. At 1839 anchored in berth E-5, Enewetak.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in berth E-5, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). Anchored at berth E-5, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 1416.5 shock wave observed by vessel.
- SYCAMORE (Bikini, 31 May, 1500). Anchored in berth E-5, Enewetak.
- ROSE (Enewetak, 3 June, 0645). On lifeguard station, 5 to 7 nmi (9 to 13 km) east of Enewetak. Observed fireball bearing 325°, approximately 15 nmi (28 km) distant. Felt shock wave 1 minute, 5 seconds after observing fireball. At 1014 anchored in area E-5, Enewetak.

- UMBRELLA (Enewetak, 9 June, 1115). At 0911 anchored in anchorage 95, Enewetak. Received LCU-137, LCM-58, and LCM-56 alongside from 0926 to 0955. At 1115 underwater shot detonated 250°, 10,000 yards (9.1 km) distant, blast effect and slight underwater shock felt 6 seconds after detonation, radiation readings normal. At 1130 underway. At 1412 manuevered to recover Project 2.3 coracle pack; at 1630 maneuvered to recover Project 2.3 FFP bearing the number 10. Between 1650 and 1718 maneuvered to Project 1.2 balloons. At 1901 anchored in anchorage 116, Enewetak. On 10 June at 0752 underway for UMBRELLA recovery assignment. At 1330 anchored in area E-5, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored in anchorage E-5, Enewetak.
- TEAK (Johnston Island, 31 July, 2350). At assigned position 20 nmi (37 km), bearing 80° from detonation.
- ORANGE (Johnston Island, 11 August, 2330). At assigned position 28 nmi (52 km), bearing 56° from detonation.

USS Lawrence County (LST-887)

The tank landing ship Lawrence County was in the EPG for 12 of the 35 HARDTACK shots. Its general mission was to provide diesel oil to smaller units when the oiler was absent, berth and mess JTF 7 personnel aboard for project work, and transport NOL Project 6.7 mines and associated equipment from Pearl Harbor. It also embarked personnel from EODU-1 and MDAU-302 (Reference C.3.3.23).

As an element of TE 7.3.5.8 (Mine Recovery), it retrieved and decontaminated planted mines and associated gear used in UMBRELLA (Reference C.3.3.23).

It reported no fallout as a result of the shots and it did not report any contamination from its work with Project 6.7. The crew was badged; exposure data appear in Table 34.

Lawrence County's log (Reference C.3.4.25) shows the following ship movements:

7 May	0801	Left Pearl Harbor
19 May	1048	Arrived Enewetak
22 June	0650	Left Enewetak in company with Grasp, Munsee, and Moctobi
5 July	0823	Arrived Pearl Harbor.

Summaries of its operational activities for HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, UMBRELLA, MAPLE, ASPEN, WALNUT, and LINDEN follow.

- HOLLY (Enewetak, 21 May, 0630). Anchored in Area E-4, approximately 10 nmi (19 km) south of shot site. At 0615 tightened anchorage. Shock wave felt at 0632.

- NUTMEG (Bikini, 22 May, 0920). Anchored in Area E-4, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in area D-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site. Shock wave felt at 1402.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in Area D-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). At 0740 anchored in area D-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Anchored in area D-1, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Anchored in area D-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- UMBRELLA (Enewetak, 9 June, 1115). At 0753 anchored in anchorage 237, Enewetak, approximately 8 nmi (15 km) east of shot site. At 1932 anchored in D-1, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored in area E-3, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Anchored in area E-3, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Anchored in area E-3, Enewetak, approximately 18 nmi (33 km) southeast of shot site. Shock wave felt at 0632.
- LINDEN (Enewetak, 18 June, 1500). Anchored in area E-3, Enewetak, approximately 10 nmi (19 km) south of shot site. Shock wave received at 1501.

USS Magoffin (APA-199)

The attack transport Magoffin was at Enewetak from 20 May to 3 July for 18 of the 35 HARDTACK shots. It was sent to relieve Renville on 20 May and was itself relieved by USS Navarro (APA-215) on 2 July. The general tasks assigned Magoffin in CTG 7.3 Operations Order 1-58 included providing transportation and special services (notably personnel decontamination) as required, providing services to target-array ships, and assisting in collection of scientific data (Reference B.3.3.1, 1-58). On 21 May when it relieved Renville, the Radiological Safety and Decontamination Unit transferred all personnel and equipment (Reference C.3.3.30). Magoffin also carried the Special Projects Unit. Both units were aboard during UMBRELLA, although 75 of the enlisted men in the Special Projects Unit had left on Hooper Island on 23 June (Reference C.3.4.21). In addition to these tasks, it was to provide facilities and assist the Radiological Safety and Decontamination Unit in its activities.

Magoffin served as the floating radsafe center. The floating radsafe center was established to minimize the spread of contamination by providing a central depot for radsafe clothing and equipment distribution. It provided shower facilities separate from the rest of the ship. This allowed crewmen to bathe immediately following contamination, eliminating time otherwise spent in transit to a shore-based decontamination facility.

Magoffin (continued)

Problems concerning size and location of decontamination facilities aboard were addressed by the commanding officer of Magoffin decontamination unit (Reference C.3.3.30):

> In the interest of planning for future test operations and the use of an APA for support of a Decontamination Unit, it is desired to mention that the present Decontamination facilities aboard these ships are most inadequate in size and unrealistic in their locations if contamination control, a major problem, is to be observed.

One instance of activating the ship's washdown system was reported. On 21 May following shot HOLLY, the washdown system was on from 0643 to 0646. At 0658 repair parties were sent on the deck for monitoring purposes. By 0732 conditions were normal (Reference C.3.4.26). No information is available on the level of radiation aboard ship. The crew was badged; exposure data appear in Table 34.

Magoffin's log (Reference C.3.4.26) shows the following movements:

13 May	0543	Left Pearl Harbor
20 May	0745	Arrived Enewetak
3 July	0739	Left Enewetak
8 July	1017	Arrived Yokosuka.

Summaries of its operational activities for HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, UMBRELLA, MAPLE, ASPEN, WALNUT, LINDEN, REDWOOD, ELDER, OAK, HICKORY, SEQUOIA, and CEDAR follow.

- HOLLY (Enewetak, 21 May, 0630). Anchored approximately 10 nmi (19 km) south of shot site at time of detonation. At 0643 activated water washdown system; at 0646 secured washdown system. At 0658 repair parties on deck for monitoring purposes. At 0732 normal conditions set topside.
- NUTMEG (Bikini, 22 May, 0920). Anchored in berth O-7, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored approximately 18 nmi (33 km) southeast of shot site at time of detonation.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in berth K-3, Enewetak, approximately 10 nmi (19 km) south of shot site.
- TOBACCO (Enewetak, 30 May, 1415). Anchored in berth E-3, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- SYCAMORE (Bikini, 31 May, 1500). Anchored in berth B-3, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth 166, Enewetak, approximately 10 nmi (19 km) south of shot site.
- UMBRELLA (Enewetak, 9 June, 1115). At 0755 anchored in berth 246, Enewetak, approximately 7,100 yards (6.5 km) northeast of surface zero. At 1157 underway for berth 191. At 1227 anchored in berth 191, Enewetak.

- MAPLE (Bikini, 11 June, 0530). Anchored in berth 191, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Anchored in berth C-4, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Anchored in berth C-4, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- LINDEN (Enewetak, 18 June, 1500). Anchored in berth G-2, Enewetak, approximately 10 nmi (19 km) south of shot site. At 1504 secured from general quarters, with exception of repair parties.
- REDWOOD (Bikini, 28 June, 0530). On 27 June at 1552 anchored in berth G-1, Enewetak.
- ELDER (Enewetak, 28 June, 0630). Anchored in berth G-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- OAK (Enewetak, 29 June, 0730). Anchored in berth G-1, Enewetak, approximately 22 nmi (41 km) southeast of shot site. At 0747 underway to berth M-3, Enewetak; at 0808 anchored there. At 1351 anchored in berth G-1, Enewetak.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth M-3, Enewetak.
- SEQUOIA (Enewetak, 2 July, 0630). Anchored in berth G-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- CEDAR (Bikini, 3 July, 0530). Anchored in berth G-1, Enewetak. At 0739 underway for Yokosuka, Japan.

USS Mansfield (DD-728)

The destroyer Mansfield was present in the EPG for 29 of the 35 HARDTACK shots, from 11 May to 1 August. Its primary functions were weather observations and SAR assignments. In addition, it was flagship for Commander, Destroyer Squadron 9, who was responsible for all commissioned destroyers and submarines involved in WAHOO and who served as CTU 7.3.2, CTU 7.3.3, and SOPA (Admin), Enewetak (Reference C.3.3.17). Mansfield did not participate in any HARDTACK scientific projects. On 24 July, Mansfield gunners sank the SCAEVOLA shot barge in 1,000 fathoms (1.829 km) of water, 9 nmi (16.7 km) south of Enewetak. It arrived in time to take part in the various WAHOO rehearsals. On 25 July Mansfield escorted the Japanese vessel Kampia Maru out of the EPG (Reference C.3.3.17) before shot PINE.

According to the Operational Phase Report of the commanding officer of Mansfield, dated 13 June 1958, "No instance involving either the safety of the ship or the crew was noted" as a result of any radiological exposure (Reference C.3.3.17). For an hour on 14 May, it tested its washdown system, but no record available indicates that it encountered radioactivity from any of the shots. The crew was badged and exposure data appear in Table 34.

The Mansfield's log (Reference C.3.4.27) records the following ship movements:

5 May	0929	Left Pearl Harbor in company with TU 52.8.1, composed of Destroyer Division 91
11 May	1457	Arrived Enewetak

Mansfield (continued)

1 August	0800	Left Enewetak in company with Benner
21 August	0912	Arrived at Yokosuka.

It was out of the test operating area for shots YUCCA, CACTUS, TEAK, QUINCE, ORANGE, and FIG. Summaries of the ship's operational activities for the rest of the tests follow.

- FIR (Bikini, 12 May, 0550). Anchored in berth D-1, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth D-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0548 went to general quarters in final preparation for BUTTERNUT. Observed detonation at 0615. At 0629 secured from general quarters.
- KOA (Enewetak, 13 May, 0630). Anchored in berth D-1, Enewetak Lagoon, approximately 20 nmi (37 km) southeast of shot site. At 0545 exercised crew at general quarters. At 0650 secured from general quarters. On 14 May at 0634 underway for WAHOO rehearsal. At 0827 conducted antisubmarine warfare operation. From 0845 to 0946 tested washdown system.
- WAHOO (Enewetak, 16 May, 1330). At 1230 exercised the crew at general quarters. At 1330 observed WAHOO detonation, steaming 5,000 yards (4.6 km) from surface zero. At 1410 secured from general quarters. At 1459 anchored in berth E-4, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). On weather station Bravo, steaming approximately 260 nmi (482 km) from shot site, at time of detonation.
- NUTMEG (Bikini, 22 May, 0920). On weather station Bravo, steaming approximately 400 nmi (741 km) from shot site, at time of detonation.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in berth D-3, Enewetak, approximately 18 nmi (33 km) from shot site.
- MAGNOLIA (Enewetak, 27 May, 0600). Steaming independently en route to weather station Bravo, approximately 225 nmi (417 km) from shot site, at time of detonation.
- TOBACCO (Enewetak, 30 May, 1415). Steaming independently on weather station Bravo, approximately 260 nmi (482 km) from shot site.
- SYCAMORE (Bikini, 31 May, 1500). Steaming on weather station Bravo, approximately 400 nmi (741 km) from shot site.
- ROSE (Enewetak, 3 June, 0645). Steaming on weather station Bravo, approximately 260 nmi (482 km) from shot site.
- UMBRELLA (Enewetak, 9 June, 1115). On 8 June at 0755 underway for weather station Delta; approximately 170 nmi (315 km) east of shot site at time of detonation.
- MAPLE (Bikini, 11 June, 0530). Steaming independently on weather station Delta Prime, approximately 35 nmi (65 km) west of shot site, at time of detonation.

- ASPEN (Bikini, 15 June, 0530). Anchored in berth N-3, Bikini, approximately 15 nmi (28 km) southeast of shot site. Felt shock wave at 0531:40.
- WALNUT (Enewetak, 15 June, 0630). Steaming approximately 200 nmi (371 km) east of shot site at time of detonation.
- LINDEN (Enewetak, 18 June, 1500). Anchored in berth N-3, Bikini.
- REDWOOD (Bikini, 28 June, 0530). Anchored in anchorage D-6, Enewetak.
- ELDER (Enewetak, 28 June, 0630). Anchored in anchorage D-2, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 0510 began preparations for getting underway on 15-minute notice. At 0631:25 felt shock wave.
- OAK (Enewetak, 29 June, 0730). Steaming on SAR station 5 to 7 nmi (9 to 13 km) east of Enewetak Island. At 0701 exercised the crew at general quarters for OAK. Steaming approximately 23 nmi (43 km) from shot site at time of detonation. At 0738 secured from general quarters. At 1721 anchored at anchorage D-2, Enewetak.
- HICKORY (Bikini, 29 June, 1200). Steaming on SAR station 5 to 7 nmi (9 to 13 km) east of Enewetak Island.
- SEQUOIA (Enewetak, 2 July, 0630). Anchored in berth D-2, Enewetak, approximately 10 nmi (19 km) south of shot site.
- CEDAR (Bikini, 3 July, 0530). Anchored in berth D-2, Enewetak.
- DOGWOOD (Enewetak, 6 July, 0630). Anchored in berth D-2, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- POPLAR (Bikini, 12 July, 1530). Anchored in berth D-2, Enewetak.
- SCAEVOLA (Enewetak, 14 July, 1600). Anchored in berth D-2, Enewetak, approximately 10 nmi (19 km) south of shot site.
- PISONIA (Enewetak, 18 July, 1100). Anchored in berth D-2, Enewetak, approximately 10 nmi (19 km) south of shot site. At 1055 exercised the crew at atomic defense drill.
- JUNIPER (Bikini, 22 July, 1620). Anchored in D-2, Enewetak.
- OLIVE (Enewetak, 23 July, 0830). Anchored in berth D-2, Enewetak, approximately 18 nmi (33 km) southeast of shot site. On 25 July at 0736 underway. At 1120 sighted Japanese sampan K02-972 No. 3 Kampia Maru; at 1149 laid alongside Kampia Maru and instructed it to proceed on course 180°T to clear Enewetak Atoll danger area; at 1300 completed escorting Kampia Maru out of danger area.
- PINE (Enewetak, 27 July, 0830). At 0636 anchored in berth N-3, Bikini.

USS Merapi (AF-38)

The refrigerated store ship Merapi provided logistic support to the EPG from 7 April to 4 July. During that time, 24 shots of the HARDTACK series took place, although for most of it was not in the immediate area, but rather between Pearl Harbor and the EPG. The crewmembers were badged; exposure data appear in Table 34. Merapi's log (Reference C.3.4.28) shows the following ship movements:

28 March	0825	Left Pearl Harbor
7 April	0705	Arrived Enewetak
4 July	1108	Left Bikini
14 July	0725	Arrived at Pearl Harbor.

Summaries of its operational activities for HOLLY, NUTMEG, OAK, HICKORY, SEQUOIA, and CEDAR follow.

- HOLLY (Enewetak, 21 May, 0630). Steaming approximately 14 nmi (26 km) south of shot site at time of detonation. At 0835 moored starboard side to deep water pier, Parry Island, Enewetak.
- NUTMEG (Bikini, 22 May, 0920). Anchored at berth F-6, Enewetak.
- OAK (Enewetak, 29 June, 0730). Steaming approximately 310 nmi (574 km) east of shot site.
- HICKORY (Bikini, 29 June, 1200). Steaming approximately 80 nmi (148 km) east of shot site. At 1839 anchored at berth N-12, Bikini.
- SEQUOIA (Enewetak, 2 July, 0630). Moored to deep water pier, Enewetak, approximately 10 nmi (19 km) south of shot site.
- CEDAR (Bikini, 3 July, 0530). Moored to deep water pier, Enewetak.

USS Moctobi (ATF-105)

The fleet ocean tug Moctobi was in the EPG for 18 of the 35 HARDTACK shots. The general tasks assigned it were to assist in scientific projects, to position and salvage target-array ships, and to assist in moorings for both underwater shots (Reference B.3.3, 1-58).

The day after WAHOO, Moctobi was assigned to make the initial radsafe reentry survey with members of TU 7.1.6 aboard. This survey included sailing into radioactive waters and monitoring the target ships (WAHOO Shot Folder). In addition, it collected water samples from the bubble area created by the shot, which was reading 3.8 R/hr (Reference C.3.4.29).

On 14 May, the day after shot KOA, it reported receiving radioactive fallout. At 1012 the ship began decontamination procedures when radioactive fallout averaging 0.010 R/hr was detected. Throughout the rest of the day monitoring and decontamination procedures took place as necessary (Reference C.3.4.29). The crew was badged; exposure data appear in Table 34.

The Moctobi's log shows the following ship movements:

20 January	1407	Left Pearl Harbor
3 February	0940	Arrived Bikini

22 June	0714	Left Enewetak in company with Grasp, Bonita, Chowanoc, Munsee, and Lawrence County
6 July	1039	Arrived Pearl Harbor.

It was out of the test operating area for shots REDWOOD, ELDER, OAK, HICKORY, SEQUOIA, CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, PINE, TEAK, QUINCE, ORANGE, and FIG. The operational activities of Moctobi for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). At 1435 observed all safety precautions for pending detonation. Approximately 85 nmi (158 km) southwest of shot site at time of detonation.
- CACTUS (Enewetak, 6 May, 0615). Anchored in anchorage E-2, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0600 secured all battle ports and hatches preparatory to atomic detonation. Shock wave passed the ship at 0616.
- FIR (Bikini, 12 May, 0550). Anchored at Enewetak. Received brilliant light effects from detonation at Bikini.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth C-4, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0555 closed all doors and ports on portside, all hands took cover for local blast. Received blast effect, no apparent damage, began continuous fallout monitoring at 0616.
- KOA (Enewetak, 13 May, 0630). Anchored in berth N-4, Enewetak, approximately 20 nmi (37 km) south of shot site. At 0631:28 shock wave arrived, monitors commenced operations, no apparent radiation. On 14 May at 1012 began decontamination procedures after recording radiation averaging 0.010 R/hr.
- WAHOO (Enewetak, 16 May, 1330). Underway in assigned operating area (estimated 6 nmi [11 km] south of shot site); experienced shock wave 10 seconds after detonation. At 1345 approached shot array to monitor Killen; at 1410 stood clear of target array; at 1415 produced readings of 0.015 R/hr in motor room, 0.0125 R/hr in engine room. At 1440 steamed to bubble area in order to obtain water samples. At 1505 entered 3.8-R/hr field and began obtaining water samples. At 1530 rendezvoused with Monticello to transfer water samples. At 1541 proceeded toward Killen for monitoring procedure; at 1615 approached within 50 yards (46 meters) of Killen and recorded readings as applicable. At 1650 closed in on Moran for monitoring purposes. At 1730 moved away from Moran, in vicinity of shot area. At 1825 began search and recovery of FFPs in area 3 to 5 nmi (6 to 9 km) southwest of shot array, picking up FFPs between 1845 and 2030. At 2256 anchored in berth F-2, Enewetak. On 17 May from 1015 to 1651 in operating area; from 1345 to 1651 retrieved Project 2.3 coracle buoys. At 1821 anchored in F-2, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth N-4, Bikini.
- NUTMEG (Bikini, 22 May, 0920). Anchored in berth N-2, Bikini, approximately 10 nmi (19 km) south of shot site. At 0900 began making

preparations for detonation. At 0921 shock wave passed ship, no casualties.

- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in berth N-1, Bikini.
- MAGNOLIA (Enewetak, 27 May, 0600). Steaming independently in assigned area, approximately 200 nmi (371 km) east of shot site. At 0600 observed atomic flash from detonation at Enewetak.
- TOBACCO (Enewetak, 30 May, 1415). Anchored in berth N-8, Bikini.
- SYCAMORE (Bikini, 31 May, 1500). Steaming approximately 28 nmi (52 km) south of shot site at time of detonation. At 1500 observed nuclear detonation, experienced no shock wave.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth N-4, Bikini.
- UMBRELLA (Enewetak, 9 June, 1115). Anchored at berth C-239, Enewetak, approximately 5 nmi (9 km) northeast of surface zero. At 1416 underway to close on target array; at 1432 cleared target array. At 1637 anchored in berth B-192, Enewetak. On 10 June at 1302 underway in target array area. From 1500 to 1625 took Killen in tow; at 1530 recovered crown buoy. At 1756 anchored in berth B-170, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored at Enewetak.
- ASPEN (Bikini, 15 June, 0530). Anchored in berth D-1, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Anchored in berth D-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 0631 experienced shock wave from detonation.
- LINDEN (Enewetak, 18 June, 1500). Anchored in berth D-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 1501 experienced shock wave. On 22 June at 0627 underway for Pearl Harbor.

USS Monticello (LSD-35)

The dock landing ship Monticello was involved in several aspects of HARDTACK, being in the area from 18 April to 15 August. The ship was present in the EPG for 34 of the 35 shots. It left Enewetak for Pearl Harbor via Johnston Island on 15 August, 3 days before shot FIG, the final shot of HARDTACK (Reference C.3.4.30).

In the preoperational phase of Operation HARDTACK, Monticello transported 12 LCMs and the JTF 7 barge from the continental United States to the EPG. The ship was ordered to remain on standby should additional support craft be needed. From 18 to 22 April, it transported the shot devices for SYCAMORE and POPLAR to Bikini Island and then returned to Enewetak (Reference C.3.3.27).

During the operational phase of HARDTACK, Monticello was initially assigned a number of general logistic support tasks. These included carrying, maintaining, and fueling 12 LCMs of the TG 7.3 Boat Pool Detachment and assisting in the maintenance of a number of smaller support craft berthed at Parry Island. This support role required that the ship provide normal shipboard administration, berthing, messing, disbursing, and other facilities to those personnel from the Boat Pool Detachment who were stationed aboard, as well as disbursing services for the Boat Pool Detachment personnel stationed ashore at Enewetak and Parry islands and for crews of the YTB-182 and -188 and the two LCUs stationed at Enewetak. It provided interatoll transportation and off-atoll support for operational personnel. The ship also provided LCM transportation to the target-array areas and to other operating ships servicing the target-array areas. Finally, as part of its general logistic responsibilities, it serviced the Holmes & Narver unit on Parry Island with diesel fuel.

In addition to these general responsibilities, Monticello had specific assignments for a large number of the HARDTACK shots. It acted as part of the emergency evacuation unit for both Enewetak and Bikini for several shots and participated in nosecone recovery operations for CACTUS, KOA, WALNUT, and PINE.

Monticello was assigned specific duties as part of the Navy's activities during shots WAHOO and UMBRELLA. It transported to the WAHOO target array rad-safe instruments from Renville, the pontoon float for Project 1.11, and an LCM for Project 34.3. After WAHOO it participated in decontaminating Moran and three other target vessels (Reference C.0.2, WAHOO). It acted as flagship during UMBRELLA (Reference C.3.3.27).

After shot WAHOO, Monticello transported cargo and passengers to Rongelap and returned to Enewetak on 22 May. The ship then made a trip to Johnston Island with cargo and returned to Enewetak on 3 June.

For POPLAR, it again acted as flagship and housed CTU 7.3.9 (Evacuation Unit). It was assigned to evacuate the headquarters units for TG 7.1, TG 7.4, and TG 7.3 stationed on Eneu Island. It housed two radsafe damage survey teams operating out of Eneu for POPLAR (Reference C.0.2, POPLAR).

Monticello returned to Johnston Island on 22 August and participated in rollup activities there. The ship departed for Pearl Harbor on 24 August (Reference C.3.4.30).

Its commanding officer noted in a portion of a report to CTG 7.3 dated 28 April (before HARDTACK began) that the "overall condition of rad-safe training [was] good," but recommended in another section dated 12 June that "ships should carry at least 25 percent above allowance of decontamination equipment and clothing for their own use and for their own teams" (Reference C.3.3.27). In the same report he also recommended that in the future the "Task Force Commander provide a daily background count for the EPG."

The crew was badged; exposure data appear in Table 34.

Monticello's log (Reference C.3.4.30) records the following ship movements:

11 April	1155	Left Pearl Harbor
18 April	1402	Arrived Enewetak
24 August	1424	Left Johnston Island
26 August	0748	Arrived Pearl Harbor.

Monticello (continued)

It was out of the test operating area for shots HOLLY, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, TEAK, ORANGE, and FIG. The vessel's operating activities for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). Anchored in berth D-1, Enewetak, 78 nmi (145 km) from the shot site, bearing 48°.
- CACTUS (Enewetak, 6 May, 0615). Anchored in anchorage area A, berth G-2, Enewetak, 10 nmi (19 km) from the shot site, bearing 350°. At 0616 the base surge [sic; shock wave] passed over ship. At 0914 underway for WAHOO target-array area.
- FIR (Bikini, 12 May, 0550). Anchored in berth G-2, Enewetak.
- BUTTERNUT, Enewetak, 12 May, 0615). Anchored in berth G-2, Enewetak, 10 nmi (19 km) from shot site, bearing 330°. At 0616 shock wave passed over ship. At 0849 underway for WAHOO target-array area.
- KOA (Enewetak, 13 May, 0630). Anchored in berth G-2, Enewetak, 18 nmi (33 km) from shot site, bearing 340°. At 0630 shock wave passed over. From 0930 to 1610 in WAHOO target-array area launching and recovering LCMs. At 1648 anchored in berth H-2, Enewetak. On 14 May at 0615 obtained fallout readings of 0.005 R/hr; at 0645 began decontamination procedures, washdown system activated, monitoring teams on station. At 0756 secured washdown system, background readings averaging between 0.007 and 0.010 R/hr.
- WAHOO (Enewetak, 16 May, 1330). Steamed in assigned sector, 6 nmi (11 km) from shot site, bearing 5°. At 1354 and 1807 recovered helicopters; at 1600 and 1855 launched helicopters. At 2012 anchored in berth H-2, Enewetak. On 17 May from 0702 to 1712 in target array area launching and recovering helicopters. At 1833 anchored in berth H-2, Enewetak.
- NUTMEG (Bikini, 22 May, 0920). At 0725 anchored in berth H-2, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Steaming off Eneu Island, Bikini.
- UMBRELLA (Enewetak, 9 June, 1115). Anchored in berth 249, Enewetak, 4 nmi (7 km) from shot site, bearing 210°. At 1220 anchored in berth 208, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored in berth G-2, Enewetak.
- ASPEN (Bikini, 15 June, 0530). At 0506 underway from anchorage in Enewetak. Approximately 200 nmi (371 km) west of shot site at time of detonation.
- WALNUT (Enewetak, 15 June, 0630). At 0506 underway from anchorage. At 0604 steaming on station off Parry Island. Operating 20 nmi (37 km) from shot site at time of detonation, bearing 340°. At 0642 began helicopter launching and recovery operations. At 0804 engaged in nosecone recovery operations. At 1329 manuevered as plane guard and conducted postshot recovery operations. At 1807 anchored in berth F-3, Enewetak.

- LINDEN (Enewetak, 18 June, 1500). At 0732 anchored in berth F-3, Enewetak, 11 nmi (20 km) from shot site, bearing 0°.
- REDWOOD (Bikini, 28 June, 0530). Operating 21 nmi (39 km) from shot site at time of detonation, bearing 330°T. At 0720 anchored in berth N-11, Bikini.
- ELDER (Enewetak, 28 June, 0630). Steaming off Bikini Atoll.
- OAK (Enewetak, 29 June, 0730). Anchored in berth N-11, Bikini.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth N-11, Bikini, 11 nmi (20 km) from shot site, bearing 260°. At 1228 anchored in berth N-2, Bikini.
- SEQUOIA (Enewetak, 2 July, 0630). Anchored in Eneu anchorage, Bikini.
- CEDAR (Bikini, 3 July, 0530). Anchored in Eneu anchorage, 18 nmi (33 km) from shot site, bearing 300°. At 1844 underway for Enewetak Atoll.
- DOGWOOD (Enewetak, 6 July, 0630). Anchored in berth E-4, Enewetak, 17 nmi (32 km) from shot site, bearing 350°. At 0710 received LCU-440.
- POPLAR (Bikini, 12 July, 1530). At 0235 underway for operating area. From 0845 to 1350 engaged in flight operations. Operating 31 nmi (57 km) from shot site at time of detonation, bearing 327°. At 2024 anchored in berth N-3, Bikini.
- SCAEVOLA (Enewetak, 14 July, 1600). Anchored at Bikini.
- PISONIA (Enewetak, 18 July, 1100). At 0739 anchored in berth D-4, Enewetak, 8 nmi (15 km) from shot site, bearing 345°. At 1100:45 shock wave arrived. At 1113 sighted water spout bearing 345°, distance 8 nmi (15 km).
- JUNIPER (Bikini, 22 July, 1620). Anchored in Eneu anchorage. Observed detonation 11 nmi (20 km) from shot site, bearing 260°. Shock wave arrived at ship at 1621.
- OLIVE (Enewetak, 23 July, 0830). At 0755 anchored in berth G-2, Enewetak, 19 nmi (35 km) from shot site, bearing 340°. At 1228 offloaded barges. At 1837 underway for Bikini.
- PINE (Enewetak, 27 July, 0830). Anchored in berth D-3, Enewetak, 17 nmi (32 km) from shot site, bearing 340°. Shock wave arrived at 0831:45.
- QUINCE (Enewetak, 6 August, 1415). Approximately 10 nmi south (19 km) of shot site at time of detonation.

SS Michael Moran (EC-2)

Title to this Liberty ship hull was transferred to the Navy from the Maritime Commission in September 1957. It was used as a target ship for the two underwater shots, (WAHOO (Enewetak, 16 May, 1330) and UMBRELLA (Enewetak, 9 June, 1115). As the result of damage received from shot UMBRELLA, Moran was considered unseaworthy for a lengthly tow, and it was sunk by naval gunfire on 21 June in deep water off Ikuren Island, Enewetak Atoll.

USS Munsee (ATF-107)

The fleet ocean tug Munsee was in the EPG for 18 of the 35 HARDTACK shots. Its general mission assignment included deep-water mooring for target-array vessels for UMBRELLA and WAHOO and participation in Project 2.3 (Reference B.3.3, 1-58).

Its functions during UMBRELLA were the complete placement of Project 2.3 coracles and FFPs and then recovery of those placed outside the lagoon after shot UMBRELLA. Additionally, it was to recover the fixed coracles inside the lagoon on D+1 for UMBRELLA and to search for any coracles torn loose from their moorings and not previously recovered. This involved working with and retrieving coracles exposed to radioactive contamination (Reference C.3.1), and each crewman working in the recovery effort topside was required to wear a full radsafe outfit (Reference C.0.2, UMBRELLA). No incidents of accidental contamination were reported as a result of Project 2.3 activities.

Munsee reported no incidents of radioactive contamination following a shot, nor are there reports of activating the washdown system. Its crew was badged and exposure data are provided in Table 34.

It actively participated in only WAHOO and UMBRELLA. It was on standby, however, as an emergency evacuation ship for shot KOA (Reference B.3.3, 16-58).

The Munsee's log (Reference C.3.4.31) records the following ship movements:

1 March	1241	Left Pearl Harbor
14 March	1458	Arrived Enewetak
22 June	0909	Left Enewetak
11 July	1433	Arrived Pearl Harbor.

It was out of the test operating area for shots REDWOOD, ELDER, OAK, HICKORY, SEQUOIA, CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, PINE, TEAK, QUINCE, ORANGE, and FIG. Summaries of the ship's operational activities for the remaining shots follow.

- YUCCA (open ocean, 28 April, 1440). Anchored at berth E-4, Enewetak, approximately 85 nmi (158 km) southwest of shot site.
- CACTUS (Enewetak, 6 May, 0615). Anchored approximately 10 nmi (19 nmi) south of shot site at time of detonation. At 1212 underway for Project 2.3 operations.
- FIR (Bikini, 12 May, 0550). Anchored at Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored approximately 10 nmi (19 km) south of shot at time of detonation. At 1123 underway for Project 2.3 operations. At 2026 anchored at berth E-2, Enewetak.

- KOA (Enewetak, 13 May, 0630). Anchored in berth E-2, Enewetak, approximately 20 nmi (37 km) southeast of shot site. At 0840 underway for local operating area. At 2039 anchored at berth E-2, Enewetak.
- WAHOO (Enewetak, 16 May, 1330). At 0735 LCM-57 came alongside to debark Project 2.3 personnel. Underway in operating area approximately 6 nmi (11 km) south of surface zero at time of detonation. At 2107 anchored at anchorage D-2, Enewetak. On 17 May at 0749 underway for Project 2.3 operations. At 1807 anchored at D-2, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored at berth D-2, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0938 underway for Boken Island, Enewetak.
- NUTMEG (Bikini, 22 May, 0920). Anchored off Boken island, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored in anchorage D-2, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored in anchorage D-2, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0830 underway to plant five coracle moors for UMBRELLA. At 1762 anchored at berth D-2, Enewetak.
- TOBACCO (Enewetak, 30 May, 1415). At 1250 anchored off Mut Island, Enewetak, approximately 20 nmi (37 km) south of shot site. At 1519 underway for anchorage D-2, Enewetak; at 1608 anchored at berth E-2, Enewetak.
- SYCAMORE (Bikini, 31 May, 1500). Anchored at Enewetak.
- ROSE (Enewetak, 3 June, 0645). Anchored in anchorage C-1, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0754 underway to lay coracle.
- UMBRELLA (Enewetak, 9 June, 1115). Anchored approximately 3.8 nmi (7 km) from shot site. At 1132 underway for day's operations. At 1551 anchored in anchorage E-2, Enewetak. At 1614 underway to target-array area. At 2036 anchored in anchorage E-2, Enewetak; shifted to anchorage B-136, Enewetak, at 2235.
- MAPLE (Bikini, 11 June, 0530). Anchored at berth E-2, Enewetak. At 0746 underway for local operating area to search for moorings. At 1241 anchored at berth E-2, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Anchored at Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Anchored at berth E-2, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- LINDEN (Enewetak, 18 June, 1500). At 0759 underway to refuel from LST-887. At 1112 anchored in anchorage E-2, Enewetak, approximately 10 nmi (19 km) south of shot site. On 22 June at 0909 underway for Pearl Harbor with Chowanoc and four other ships.

USS Navarro (APA-215)

The attack transport Navarro was in the EPG for 10 of the HARDTACK shots, from 2 July to 5 August 1958. It was assigned the task of providing transportation and evacuation capability. Navarro replaced Magoffin on 2 July (Reference B.3.3, 1-58).

Unlike Magoffin and Renville, there is no evidence to suggest that Navarro served as a radiation decontamination center. It was not singled out for particular task work in the operation orders.

There are no reported incidents of radioactive contamination aboard Navarro. The crewmembers were badged and their exposure data appear in Table 34.

Navarro's log (Reference C.3.4.32) shows the following ship movements:

2 July	1742	Arrived Enewetak
5 August	1935	Left Enewetak
19 August	0833	Arrived Long Beach.

Summaries of its operational activities for CEDAR, DOGWOOD, POPLAR, SCAEVOLA, PISONIA, JUNIPER, OLIVE, and PINE follow.

- SEQUOIA (Enewetak, 2 July, 0630). En route Enewetak, 150 (278 km) southwest of Enewetak Atoll.
- CEDAR (Bikini, 3 July, 0530). Anchored at berth G-3, Enewetak. Horizon fully lighted by detonation for approximately 2 seconds and slight shock wave felt.
- DOGWOOD (Enewetak, 6 July, 0630). Anchored in berth G-3, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 0835 anchored at berth K-3, Enewetak.
- POPLAR (Bikini, 12 July, 1530). Anchored at berth K-3, Enewetak.
- SCAEVOLA (Enewetak, 14 July, 1600). Anchored in berth K-3, Enewetak, approximately 10 nmi (19 km) south of shot site.
- PISONIA (Enewetak, 18 July, 1100). Anchored in berth K-3, Enewetak, approximately 10 nmi (19 km) south of shot site.
- JUNIPER (Bikini, 22 July, 1620). Anchored at Enewetak.
- OLIVE (Enewetak, 23 July, 0830). Anchored in berth K-3, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- PINE (Enewetak, 27 July, 0830). Anchored in berth K-3, Enewetak, approximately 18 nmi (33 km) southeast of shot site. On 5 August at 1935 underway for Pearl Harbor.
- TEAK (Johnston Island, 31 July, 2350). Anchored at Enewetak.

USS Nemasket (AOG-10)

The gasoline tanker Nemasket was one of three petroleum carriers that supplied HARDTACK units with various fuels. Although it made four trips to the

EPG during the series, it was actually present only for YELLOWWOOD, MAGNOLIA, and PISONIA. No effects from the detonations were recorded in the ship's log. The ship did not have a washdown system and its crew was not badged (Reference C.3.4.33).

Nemasket's log (Reference C.3.4.33) shows the following ship movements:

8 April	1708	Arrived Kwajelein
10 April	0803	Left Kwajalein
17 April	1449	Arrived Pearl Harbor
16 May	1542	Left Pearl Harbor
26 May	1658	Arrived Enewetak
1 August	1356	Left Bikini
6 August	0716	Arrived Midway.

Summaries of its operational activities for YELLOWWOOD, MAGNOLIA, and PISONIA follow.

- YELLOWWOOD (Enewetak, 26 May, 1400). En route to Enewetak; steaming approximately 30 nmi (56 km) south of shot site at time of detonation. At 1658 moored to POL buoys off Enewetak.
- MAGNOLIA (Enewetak, 27 May, 0600). Moored to POL buoy off Enewetak Atoll, 11 nmi (20 km) from shot site, bearing 35°. At 0600 observed detonation.
- PISONIA (Enewetak, 18 July, 1100). Steaming en route to Enewetak, approximately 62 nmi (115 km) south of shot site, at time of detonation. At 1646 moored to POL buoys off Enewetak Atoll. On 19 July at 1558 underway for Guam.

USS Orleck (DD-886)

The destroyer Orleck was in the EPG for eight shots of the HARDTACK series: YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, and NUTMEG. The ship played specific roles in four of these events, was within reasonable proximity of two additional detonations, and more than 50 nmi (93 km) from the remaining two (Reference C.3.4.34). Its general duties consisted of weather observations, SAR responsibilities, antisubmarine watches, and nosecone recovery rehearsals and operations (Reference C.3.3.16). It was assigned the following responsibilities:

YUCCA	TE 7.3.5.2	Surface Weather Element
CACTUS	TE 7.3.2.4	Nose Cone Recovery Element
KOA	TE 7.3.2.2	Nose Cone Recovery Unit
WAHOO	TE 7.3.5.4	Operational Exercise Element.

In addition, the ship's crew participated in Project 1.6 during WAHOO (Reference C.0.2, WAHOO).

Orleck (continued)

Between 12 and 15 April 1958, Orleck, together with Craig, investigated the possible presence of an unknown submarine. It was eventually determined that none had entered the EPG (Reference C.3.3.16). Nosecone recovery rehearsals took place between 24 and 26 April. For YUCCA, it was positioned in weather station Delta between Enewetak and Bikini to provide weather statistics for the operation (Reference C.1.1654). The ship assumed a different role for CACTUS and KOA. For CACTUS, it served as nosecone recovery control ship in the event that any nosecones fell into the open sea, but none did (Reference C.1.1625). Orleck was once again nosecone recovery control ship for shot KOA, but on this event no rockets were fired (Reference C.1.1625). Its duties during WAHOO involved tracking the target submarines.

Its crew received radioactive fallout following KOA on 14 May. From 0756 until 0840 the ship's washdown system was turned on and the ship manuevered along various courses to keep into the wind. After the system was secured, firehoses, boiler compound, and scrub brushes were used by the crew for further decontamination. This procedure lowered the "overall average contamination from 8 MR/hr. to 1.5 MR/hr. in several hours." The washdown system was turned on again the same day at 1331 so that aerial and shipboard photographers could film the procedure (Reference C.3.4.34). The crew was badged and exposure data are provided in Table 34.

The commanding officer Orleck had specific complaints about his ship's water washdown system (Reference C.3.4.16):

> The water washdown system was 100% effective in overall spray coverage and 50% effective as a decontaminant. It was defective in that the plastic joints were in constant need of repair.

In addition, the radiac instruments aboard ship were contaminated during fallout and ship's personnel "had a tendency to leave instruments in the 'on' position." The commanding officer pointed out, however, that the "decontamination procedures," which combined the "washdown system and fire hoses, boiler compound, and scrub brushes," were effective.

Orleck's log (Reference C.3.4.34) shows the following ship movements:

17 February	0848	Left Pearl Harbor
24 March	0815	Arrived Enewetak
22 May	1124	Left Enewetak
17 August	0739	Arrived Midway.

Summaries of its operational activities YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, and NUTMEG follow.

- YUCCA (open ocean, 28 April, 1440). At 1425 all personnel to shelter within ship; approximately 45 nmi (83 km) east of shot site at time of detonation. At 1450 underway for weather station Delta to launch and track weather balloons.
- CACTUS (Enewetak, 6 May, 0615). At 0545 began countdown for CACTUS; at 0605 all hands took shelter. Approximately 10 nmi (19 km) south

of shot site at time of detonation. At 0615:34 shock wave from CACTUS passed.

- FIR (Bikini, 12 May, 0550). On 12 May at 0054, 0251, 0445 launched and tracked weather balloons in vicinity of Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). At 0600 began preparations for BUTTERNUT. Steaming on SAR station approximately 10 nmi (19 km) east of shot site at time of detonation. AT 0616 received shock wave. At 0757 launched and tracked weather balloon. At 1053 anchored in berth E-3, Enewetak.
- KOA (Enewetak, 13 May, 0630). At 0600 began countdown for detonation, anchored approximately 20 nmi (37 km) southeast of shot site. At 0631:29 shock wave passed. At 1142 underway for sea. On 14 May at 0742 began preparations for water washdown to remove radioactive fallout; at 0756 activated washdown system, maneuvered various courses into the wind to afford maximum coverage; at 0840 secured washdown system. At 1040 secured from general quarters with exception of decontamination teams.
- WAHOO (Enewetak, 16 May, 1330). At 0620 underway for WAHOO detonation. At 0749 arrived in area. At 1115 took bathythermograph (B/T) measurement. At 1330 arrived at H-hour position, 9,600 yards (8.8 km) from shot site, bearing 120^{o}T. Proceeded to maneuver in vicinity of H-hour position at 15 knots (28 km/hr), while attempting to maintain sonar contact with the submarines Bonita and Sterlet. At 1355 ceased tracking submarines. At 1356 bridge lost steering control; at 1400 steering control regained. At 1508 anchored in berth E-2, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth E-3, Enewetak, approximately 10 nmi (19 km) from shot site. At 0630:44 shock wave arrived.
- NUTMEG (Bikini, 22 May, 0920). Anchored in berth E-2, Enewetak.

USS Floyd B. Parks (DD-884)

The destroyer Parks' participation in HARDTACK covered eight shots, although the ship was close to only three of these. Its primary mission was the measurement of winds aloft by means of balloons, 5-inch window projectiles, and HASP rockets. Its other major function was as an SAR ship, an assignment it carried out not only for YUCCA, but also occasionally in the waters around Enewetak and Bikini atolls as well (Reference C.3.3.16).

The crew underwent instruction in radiological safety on board the ship while en route to the EPG. The commanding officer reported "All personnel were indoctrinated in RADSAFE procedures and the monitoring and decontamination teams were regularly exercised . . . . On 27 March, TG 7.3 RADSAFE representatives inspected ship's procedures and lectured repair parties" (Reference C.3.3.16). Available information indicates the ship did not encounter significant radioactivity during HARDTACK. Crewmembers were badged and their exposures are recorded in Table 34.

Parks's log (Reference C.3.4.35) records the following ship movements:

17 February	0907	Left San Diego
24 March	0816	Arrived Enewetak
22 May	1158	Left Enewetak
25 August	1351	Arrived San Diego.

Summaries of its operational activities for YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, and NUTMEG follow.

- YUCCA (open ocean, 28 April, 1440). At 0703 underway to SAR station 6 nmi (11 km) east of Enewetak Island. At 1300 secured ship for detonation. Steaming at time of detonation, bearing 189° approximately 80 nmi (148 km) from shot site.
- CACTUS (Enewetak, 6 May, 0615). Anchored at berth N-3, Bikini.
- FIR (Bikini, 12 May, 0550). Anchored in berth N-3, Bikini, approximately 15 nmi (28 km) southeast of shot site.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in berth N-3, Bikini.
- KOA (Enewetak, 13 May, 0630). Anchored at berth N-3, Bikini. At 1559 underway for Enewetak. On 14 May at 1508 anchored at berth C-4, Enewetak.
- WAHOO (Enewetak, 16 May, 1330). At 0615 underway to WAHOO test area, D-6. Steaming approximately 8 nmi (15 km) east of shot site at time of detonation. At 1519 anchored in berth D-4, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Anchored at berth D-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- NUTMEG (Bikini, 22 May, 0920). Anchored at berth D-1, Enewetak.

USS Perkins (DDR-877)

The radar picket destroyer Perkins participated in eight shots of the HARDTACK series, from 4 April to 22 May 1958. However, it was near only HOLLY. During the other detonations, it remained over 50 nmi (93 km) from ground zero. The ship's general duties consisted of weather observations, SAR assignments, and security patrols (Reference C.3.3.16). Originally, CTG 7.3 scheduled Perkins to take part in YUCCA in TE 7.3.5.1 (Launch and Track) and FIR in TU 7.3.9 (Bikini Evacuation). On YUCCA day, it tracked weather balloons instead. It did not take part in any of the HARDTACK scientific projects.

Its original role as lifeguard and escort for Boxer for YUCCA, the balloon-launched shot, required extensive rehearsals because of the difficulties of launching a balloon at sea. From 20 to 23 January, Perkins and Boxer conducted special operations off Port Hueneme, California. Additional rehearsals occurred between 7 and 9 April and 17 and 19 April, and on 22 and 26 April in the EPG. Perkins' crew was badged; exposure data are presented in Table 34.

It received radsafe training before the ship's departure from San Diego, California. Training continued on the trip to the EPG. In addition, as was reported by the commanding officer (Reference C.3.3.16):

Monitoring and decontamination teams were given approximately six hours of additional training. After arrival in EPG the monitoring and decontamination teams were given further training by members of CTG 7.3 RADSAFE team. The whole ship's company also received a RADSAFE lecture by the team of about one hour's duration upon arrival.

Perkins's log (Reference C.3.4.36) shows the following ship movements:

1 April	1719	Left Guam
4 April	1540	Arrived Enewetak
22 May	1145	Left Enewetak
27 May	0810	Arrived Yokosuka.

Summaries of its operational activities for YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, and NUTMEG follow.

- YUCCA (open ocean, 28 April, 1440). On 28 April at 0658 proceeded to station. At 1132 arrived on station for YUCCA. At 1223 proceeding to new station bearing 0^{o} , 12 nmi (22 km) from 12^{o}3'N, 162^{o}57'E. At 1300 ordered to remain south of Bikini to track weather balloon. Between 20 and 60 nmi (37-111 km) south of Bikini at shot time. At 2017 anchored in berth D-4, Enewetak.
- CACTUS (Enewetak, 6 May, 0615). Steaming approximately 265 nmi (491 km) northwest of shot site at time of detonation.
- FIR (Bikini, 12 May, 0550). Between 0417 and 0422 launched balloons. At 0552 observed FIR detonation approximately 70 nmi (130 km) from shot site.
- BUTTERNUT (Enewetak, 12 May, 0615). Approximately 125 nmi (232 km) from shot site at time of detonation. At 0932 moored to buoy N-10, Bikini.
- KOA (Enewetak, 13 May, 0630). Moored to buoy N-10, Bikini, while launching and tracking weather balloons.
- WAHOO (Enewetak, 16 May, 1330). Moored to buoy N-10, Bikini.
- HOLLY (Enewetak, 21 May, 0630). At 0615 went to general quarters. Anchored approximately 10 nmi (19 km) south of shot site at time of detonation. At 0635 secured from general quarters, remained on 15-minute standby.
- NUTMEG (Bikini, 22 May, 0920). Anchored at berth C-4, Enewetak.

USS Rehoboth (AGS-50)

The surveying ship Rehoboth was at Enewetak for the first ten shots of HARDTACK (28 April to 27 May). On 28 May it sailed from Enewetak to Johnston Island where it remained until 9 June.

For WAHOO, it supported Projects 1.1, 1.5, and 1.13, and to a lesser extent Projects 1.3 and 1.6. Its primary task was to find the temperature and density distributions of the seawater at shot time. This necessitated taking preshot readings to determine cycles of oceanographic variables and to correlate temperature to ocean depth. As a corollary function, it participated in the AEC waterborne contamination studies. This included monitoring fallout, predicting the spread of radioactive material, and determining the potential threat of radioactive contamination to Japanese tuna fisheries.

Rehoboth reported several instances of receiving radioactive fallout. The highest reading was recorded on 14 May, the day following KOA, and as a result the ship's washdown system was activated at 0836. Readings of 0.020 R/hr on the weather decks prompted this. When the washdown system was secured at 0924, the reading for the weather decks was 0.015 R/hr. From 0925 to 1100 the ship was scrubbed down. The next recorded reading was 0.010 R/hr at 1000. By 1100 the average reading was down to 0.008 R/hr.

Following the WAHOO detonation, the ship monitored radiation levels of the seawater. On 18 May from 1302 to 1345 it operated in the area around WAHOO surface zero collecting information for scientific projects. There is no indication that the ship was contaminated from these activities before leaving for Johnston Island on 28 May.

Rehoboth's crew and embarked scientists were badged; exposure data are presented in Table 34.

Rehoboth's log (Reference C.3.4.37) shows the following ship movements:

21 April	0800	Left Pearl Harbor
29 April	1037	Arrived Enewetak
9 June	1645	Left Johnston Island
12 June	0954	Arrived Pearl Harbor.

Summaries of its operational activities for YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, HOLLY, NUTMEG, YELLOWWOOD, and MAGNOLIA follow.

- YUCCA (open ocean, 28 April, 1440). Took deep water temperature observations throughout day. Steaming approximately 210 nmi (389 km) southeast of shot site at time of detonation.
- CACTUS (Enewetak, 6 May, 0615). On 30 April at 1645 and on 1 May at 0435 monitoring patrol reported average radioactivity of 0.00001 R/hr; at 1230 monitor reported average background radioactivity at 0.00001 R/hr. On 6 May at 0604 secured all portside doors and hatches. Steaming approximately 33 nmi (61 km) southeast of shot site at time of detonation. At 0619 relaxed portside closure.
- FIR (Bikini, 12 May, 0550). Anchored in berth D-5, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in at berth D-5, Enewetak, approximately 10 nmi (19 km) south of shot site.
- KOA (Enewetak, 13 May, 0630). Anchored in berth D-5, Enewetak, approximately 20 nmi (37 km) southeast of shot site. At 0631 shock wave hit the ship. On 14 May at 0836 activated water washdown

system after obtaining a 0.020-R/hr reading throughout weather decks. At 0925 commenced weather deck scrubdown until 1100; at 1000 reading was 0.010 R/hr; at 1100 average readings 0.008 R/hr. At 1450 underway for local operations on Project 1.13, steamed on oceanographic and B/T stations.

- WAHOO (Enewetak, 16 May, 1330). Steaming on oceanographic survey stations making observations, approximately 12,000 yards (11 km) from surface zero. At 1401 began maneuvering on various courses and speeds while determining 0.010-R/hr curve.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth G-16, Enewetak, approximately 10 nmi (19 km) south of shot site.
- NUTMEG (Bikini, 22 May, 0920). Anchored in berth G-6, Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored approximately 18 nmi (33 km) southeast of shot site at time of detonation.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored at berth G-6, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0600:45 shock wave arrived from nuclear blast. On 28 May at 1907 underway for Johnston Island.

USS Renville (APA-227)

During HARDTACK, attack transport Renville was in the EPG for seven of the thirty-five shots. Its primary mission was to act as a floating radsafe decontamination center. Its assigned tasks included berthing and messing the Special Projects Unit, Radiological Safety and Decontamination Unit, personnel from the target submarine Bonita (when facilities were unavailable on Hooper Island), and scientific personnel when required in connection with target-array functions. Renville transported personnel from the Radiological Safety and Decontamination Unit and some members of the Special Projects Unit to the EPG. It provided equipment, clothing, and a place to scrub down to crews decontaminating WAHOO target ships. It also provided administrative support, office facilities, medical care, and other necessary functions for the personnel stationed aboard. When it left the EPG on 22 May, it transferred decontamination personnel, records, and materials to its relief ship, Magoffin.

Renville experienced radioactive contamination following KOA and WAHOO (Reference C.3.4.38). On 14 May, the day after shot KOA, at 0510 it reported receiving "significant" fallout. Its washdown system was activated and the crew sent to general quarters for a chemical attack at 0520. At 0835 the crew was secured from general quarters. Renville's log does not exactly specify what constituted "significant" fallout. Twelve minutes after WAHOO was detonated, it received fallout. From 1342 to 1352 the washdown system was activated. No values are available to quantify the intensity of fallout (Reference C.3.4.38). The crew was badged and exposure data appear in Table 34.

Renville's log (Reference C.3.4.38) records the following ship movements:

24 March	0616	Left San Diego
9 April	0956	Arrived Enewetak

21 May	1657	Left Enewetak
3 June	1330	Arrived San Diego.

Summaries of its operational activities for YUCCA, CACTUS, FIR, BUTTERNUT, KOA, WAHOO, and HOLLY follow.

- YUCCA (open ocean, 28 April, 1440). Moored approximately 85 nmi (158 km) southwest of shot site at time of detonation.
- CACTUS (Enewetak, 6 May, 0615). Anchored in anchorage N-4, Enewetak, approximately 10 nmi (19 km) south of shot site. The shock wave from the detonation arrived 57.4 seconds after H-hour.
- FIR (Bikini, 12 May, 0550). Anchored in anchorage N-4, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Anchored in anchorage N-4, Enewetak, approximately 10 nmi (19 km) south of shot site. The shock wave arrived 51.8 seconds after H-hour.
- KOA (Enewetak, 13 May, 0630). Anchored in anchorage N-4, Enewetak, approximately 20 nmi (37 km) southeast of shot site. At 1305 anchored in anchorage F-5, Enewetak. On 14 May at 0510 began receiving significant fallout; at 0520 activated washdown system, crew at general quarters for a chemical attack; at 0835 secured from general quarters.
- WAHOO (Enewetak, 16 May, 1330). At 0623 underway for operating area. Steaming approximately 12,000 yards (11 km) from shot site at time of detonation; shock wave reached the ship 8.4 seconds after detonation. At 1342 activated washdown system; at 1352 secured washdown system.
- HOLLY (Enewetak, 21 May, 0630). Anchored in berth N-5, Enewetak, approximately 10 nmi (19 km) south of shot site. Shock wave arrived 53.5 sec after detonation. At 1657 underway for Pearl Harbor.

USS Safeguard (ARS-25)

The salvage ship Safeguard participated in shots TEAK and ORANGE at Johnston Island. Its primary effort was retrieving two radioactive nosecones for Project 32.5. Its secondary mission in TEAK was recovering six Project 32.6 nonradioactive nosecones. Similarly in shot ORANGE, its primary mission was recovery of three radioactive nosecones from Project 32.5 (Reference B.3.3, 38-58).

The high-altitude shots themselves presented no reasonable possibility of nuclear radiation exposure. However, some exposure was anticipated in the nosecone recovery efforts. Before the shots, CTG 7.3 ordered that film badges be issued to the units involved in handling nosecones (Reference B.3.3, 38-58). The badges and instructions were to be furnished upon arrival in the EPG. Some units were issued film badges at Johnston Island, for example De Haven and Cogswell. However, no exposure information is available for Safeguard, a ship specifically involved in the pickup of contaminated nosecones. The radiochemical sampler cones were not as radioactive as expected (Reference C.1.1601), but according to plan, badges and exposure readings should be available.

Safeguard's log (Reference C.3.4.39) shows the following movements:

24 July	1913	Left Pearl Harbor
30 July	0041	Arrived Johnston Island
13 August	1130	Left Johnston Island
16 August	0614	Arrived Pearl Harbor.

It was out of the test operating area except for shots TEAK and ORANGE. Summaries of the ship's activities for these shots follow.

- TEAK (Johnston Island, 31 July, 2350). At 1722 underway for assigned station; at 2044 arrived on station. Steaming on station, approximately 25 nmi (46 km) from surface zero at time of detonation. At 2340 underway to look for nosecone. On 1 August at 1127 discontinued search for nosecone. At 1149 anchored in anchorage A-1, Johnston Island. From 1541 to 1700 engaged in search pattern for recovery element on northwest side of Johnston Island. At 1814 anchored in anchorage A-1, Johnston Island. On 5 August at 1004 anchored near buoy Alpha, Johnston Island. From 1100 to 1200 engaged in diving operations.
- ORANGE (Johnston Island, 11 August, 2330). At 1655 underway for assigned station; at 2000 arrived on station. Steaming on station, approximately 38 nmi (70 km) from surface zero of shot ORANGE at time of detonation. On 12 August at 0400 searched for nosecones; at 0440, 0500, and 0643 recovered rocket nosecones in impact area. At 1153 anchored at anchorage A-1, Johnston Island. On 13 August at 1130 underway for Pearl Harbor.

USS Silverstein (DE-534)

The destroyer escort Silverstein did not participate in any of the shots of the HARDTACK series, but its mission resulted directly from the operation. It arrived in the EPG on 31 August, 13 days after the last HARDTACK event. Its mission was to aid in a water survey of radioactivity between the EPG and Guam. Between 31 August and 13 September, the it traveled round trip between Enewetak and Guam, stopping approximately every 250 nmi (463 km) to take water samples (Reference C.3.4.40).

The crew was apparently not badged because there was no potential for exposure; therefore exposure data for the crew are thus not included in Table 34. Silverstein's log (Reference C.3.4.40) shows the following movements:

4 August	0901	Left Pearl Harbor
25 August	0703	Left Swains Island
31 August	1057	Arrived Enewetak
13 September	1302	Left Enewetak
18 September	1331	Arrived Pearl Harbor.

USS Sterlet (SS-392)

The fleet submarine Sterlet was a target ship for WAHOO. All of its 79 crewmembers were badged; their exposures are shown on Table 34. Sixty-one of the seventy-nine badged crewmembers show slight (0 to 0.5 R) exposure. This was probably due to shot FIR fallout on 14 May rather than effects of shot WAHOO during which Sterlet was submerged.

Sterlet's log (Reference C.3.4.41) records the following ship movements:

3 May	1803	Left Pearl Harbor
13 May	1219	Arrived Enewetak
17 May	1600	Left Enewetak
24 May	0857	Arrived Pearl Harbor.

Sterlet was out of the test operating area for all test shots except BUTTERNUT, KOA, and WAHOO. Operational activities for the vessel for these shots follow.

- BUTTERNUT (Enewetak, 12 May, 0615). Steaming for Enewetak, approximately 268 nmi (496 km) southeast of the shot site, bearing 112°.
- KOA (Enewetak, 13 May, 0630). Steaming for Enewetak, approximately 75 nmi (139 km) south of shot site, bearing 175°. At 1719 moored at anchorage B-3, Enewetak. On 14 May at 0623 underway from anchorage. At 1455 moored at B-1, Enewetak. On 15 May at 1110 underway from buoy. At 1630 moored at buoy B-1, Enewetak.
- WAHOO (Enewetak, 16 May, 1330). At 0625 underway from buoy; at 1130 submerged on various courses at various speeds. Submerged at periscope depth and maneuvered approximately 6,500 yards (6 km) southeast of shot site at time of detonation, bearing 145°. At 1408 surfaced. At 1634 moored at berth B-1, Enewetak. On 17 May at 1600 underway for Pearl Harbor.

USS Takelma (ATF-113)

The fleet ocean tug Takelma was in the EPG for all 35 HARDTACK shots, arriving 15 March and departing 20 August. Its general mission was positioning, recovering, and decontaminating target ships; assisting in laying deep-water moorings for underwater shots; and participating in Projects 6.7 and 6.8 (Reference B.3.1).

On 9 June it began retrieving mines it had previously laid. It was also assigned to recover the wooden racks supporting the mines on the day following UMBRELLA, 10 June (Reference C.3.4.43).

On 14 May, the day after shot KOA, at 0615 the background count aboard increased to 0.005 R/hr. By 0730 the count had risen to 0.015 R/hr and at 1240 the washdown system was activated (Reference C.3.4.43). The system reduced the contamination by 50 percent (Reference C.3.3.32). The next day from 0001 to 0400, the average radiation level on Takelma, while it was located in the area southeast of the WAHOO array, was 0.003 R/hr (Reference C.3.4.43).

Following WAHOO, on 17 May it assisted in washing down the target destroyer, Killen. No values are available to quantify the degree of exposure caused by Killen's decontamination.

On 11 August, it scuttled a barrel of radioactive waste. The barrel was aboard from 1334 to 1516 (Reference C.3.4.43). There is no reference to where the container was scuttled, nor is there any information concerning any possible exposure the crew may have encountered during this operation. The crew was badged and exposure data appear in Table 34.

It departed the EPG on 20 August with barges YCV-9 and YCV-12 in tow. Takelma's log (Reference C.3.4.43) records the following ship movements:

1 March	0956	Left Pearl Harbor
15 March	1542	Arrived Enewetak
20 August	1311	Left Enewetak with barges YCV-9 and YCV-12 in tow.

It was out of the test operating area for OLIVE, TEAK, and ORANGE. Summaries of Takelma's activities for the remaining shots follow:

- YUCCA (open ocean, 28 April, 1440). At 0940 underway from berth D-3, Enewetak, for local operating area near deep-sea moors. At 1300 began countdown for YUCCA test. Steaming in operating area approximately 96 nmi (178 km) southwest of shot site at time of detonation. At 2156 anchored in berth D-3, Enewetak.
- CACTUS (Enewetak, 6 May, 0615). Moored to YFNB-12 in berth C-3, Enewetak, approximately 10 nmi (19 km) south of shot site; shock wave passed 47 seconds after detonation.
- FIR (Bikini, 12 May, 0550). Moored to YFNB-12 in berth C-3, Enewetak.
- BUTTERNUT (Enewetak, 12 May, 0615). Moored to YFNB-12 in berth C-3, Enewetak, approximately 10 nmi (19 km) south of shot site. Felt and heard shock wave 40 seconds after detonation.
- KOA (Enewetak, 13 May, 0630). Moored to YNFB-12 in berth C-3, Enewetak, approximately 20 nmi (37 km) southeast of shot site. Heard and felt shock wave 1.5 minutes after detonation. On 14 May at 0615 noted background count of radiation increasing to 0.005 R/hr; at 0730 radiation background count 0.015 R/hr. At 0828 underway with Killen in tow. At 1240 activated washdown system in array area; at 1256 secured washdown system. On 15 May from 0001 to 0400 average shipboard contamination in area southeast of WAHOO array 0.003 R/hr. At 1535 disconnected tow wire to Killen.
- WAHOO (Enewetak, 16 May, 1330). On 15 May at 2232 proceeded to operating area with decontamination party aboard. Steaming approximately 10,000 yards (9 km) from surface zero at time of detonation. On 17 May at 0720 maneuvered in operating area to wash down target. Between 1311 and 1811 towed Killen and moored the ship to buoy at berth L-4, Enewetak. At 1833 moored at berth C-3, Enewetak.

- HOLLY (Enewetak, 21 May, 0630). Moored to YFNB-12 in berth C-3, Enewetak, approximately 10 nmi (19 km) south of shot site. Heard and felt shock wave 40 seconds after detonation.
- NUTMEG (Bikini, 22 May, 0920). Moored at Enewetak.
- YELLOWWOOD (Enewetak, 26 May, 1400). At 0757 underway from the Lawrence County for local operating area. At 0945 commenced laying mines and floats. At 1157 moored to the Lawrence County in berth D-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site. At 1401:29 felt shock wave from test site.
- MAGNOLIA (Enewetak, 27 May, 0600). Moored to Lawrence County in berth D-1, Enewetak, approximately 10 nmi (19 km) south of shot site. Heard and felt shock wave 45 seconds after detonation.
- TOBACCO (Enewetak, 30 May, 1415). At 1334 underway from Enewetak to continue mine-laying operation. Operating approximately 23 nmi (43 km) south of shot site. At 1416:26 felt shock wave. At 1733 moored to Lawrence County.
- SYCAMORE (Bikini, 31 May, 1500). Moored to Lawrence County in berth D-1, Enewetak.
- ROSE (Enewetak, 3 June, 0645). Anchored in berth C-3, Enewetak, approximately 10 nmi (19 km) south of shot site. At 0858 underway with Fullam in tow for local operating area.
- UMBRELLA (Enewetak, 9 June, 1115). At 1036 completed preparation for detonation. Anchored approximately 10,000 yards (9 km) from surface zero at time of detonation. At 1208 underway for array area. From 1357 to 1818 retrieved mines. At 1944 moored at berth D-1, Enewetak. From 2012 to 2045 offloaded wood baulks [timbers] and mines. On 10 June at 0730 underway for local operating area. From 0825 to 1300 retrieved baulks and mines. At 1615 anchored in berth C-3, Enewetak.
- MAPLE (Bikini, 11 June, 0530). Anchored in berth C-3, Enewetak.
- ASPEN (Bikini, 15 June, 0530). Anchored in berth C-3, Enewetak.
- WALNUT (Enewetak, 15 June, 0630). Anchored in berth C-3, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- LINDEN (Enewetak, 18 June, 1500). Anchored in berth D-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- REDWOOD (Bikini, 28 June, 0530). Anchored in berth C-1, Enewetak.
- ELDER (Enewetak, 28 June, 0630). Anchored in berth C-1, Enewetak, approximately 18 nmi (33 km) southeast of shot site.
- OAK (Enewetak, 29 June, 0730). Anchored in berth C-1, Enewetak, approximately 22 nmi (41 km) southeast of shot site.
- HICKORY (Bikini, 29 June, 1200). Anchored in berth C-1, Enewetak.
- SEQUOIA (Enewetak, 2 July, 0630). Anchored in berth D-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- CEDAR (Bikini, 3 July, 0530). Anchored at Enewetak.

- DOGWOOD (Enewetak, 6 July, 0630). On SAR station approximately 24 nmi (44 km) southeast of shot site at time of detonation.
- POPLAR (Bikini, 12 July, 1530). On 11 July at 1843 underway to operating area with BC-6524, BC-352, and YFN-1320 in tow. Approximately 52 nmi (96 km) southeast of shot site at time of detonation. Felt shock wave 45 seconds after detonation.
- SCAEVOLA (Enewetak, 14 July, 1600). Anchored in berth N-4, Bikini.
- PISONIA (Enewetak, 18 July, 1100). Steaming approximately 250 nmi (463 km) east-southeast of shot site at time of detonation.
- JUNIPER (Bikini, 22 July, 1620). At 0952 underway from berth N-3, Bikini, to Rongelap. Steaming approximately 100 nmi (185 km) east of shot site at time of detonation. Steamed to Taka Atoll after detonation.
- QUINCE (Enewetak, 6 August, 1415). Anchored in berth D-1, Enewetak, approximately 10 nmi (19 km) south of shot site.
- PINE (Enewetak, 27 July, 0830). Anchored at Bikini in berth N-10.
- FIG (Enewetak, 18 August, 1600). At 0727 underway for local SAR area; approximately 17 nmi (32 km) south of shot site at time of detonation. At 1630 relieved from SAR duty. At 1751 moored portside to deep water pier, Enewetak.

USS Tillamook (ATA-192)

Tillamook was the only auxiliary ocean tug that participated in HARDTACK. It was out of the test operational area for all shots except TEAK. The tug first arrived in the EPG at Johnston Island on 14 June, where it remained at anchor during shots ASPEN and WALNUT. On 17 June it took gasoline barge YOGN-115 in tow for Pearl Harbor.

On 28 July the Tillamook returned to Johnston Island. On 31 July at 1301 it was underway for an observation station, bearing 45°T, 60 nmi (111 km) from Johnston Island. At 2030 it arrived on station and at 2350 observed the TEAK detonation, bearing approximately 220°T, distance 60 nmi (111 km), position angle 85°. On 1 August at 0828 Tillamook anchored in anchorage Alpha-5, Johnston Island. On 6 August at 1424 it was underway for Pearl Harbor with barge YB-11 in tow (Reference C.3.4.44).

Its crew was not badged and is not represented in Table 34. Tillamook did not have a washdown system.

Tillamook's log (Reference C.3.4.44) records the additional following ship movements:

9 June	1721	Left Pearl Harbor
14 June	0922	Arrived Johnston Island
6 August	1424	Left Johnston Island
11 August	0719	Arrived Pearl Harbor.

USS Tombigbee (AOG-11)

Tombigbee was one of three gasoline tankers that supplied units involved in HARDTACK with various fuels. It was involved in the preoperational phase of HARDTACK and left the EPG on 24 April for Guam, four days before YUCCA, the first shot of the HARDTACK series. It made four trips to Enewetak during the test series but was not actually present in the lagoon for any of the shots. The ship did not have a washdown system and its crew was not badged; thus the ship's crew is not represented in Table 34.

Tombigbee's log (Reference C.3.4.45) shows the following ship movements:

12 April	1003	Left Pearl Harbor
22 April	1215	Arrived Enewetak Atoll
15 August	0822	Left Enewetak
23 August	1652	Arrived Pearl Harbor.

It was out of the test operating area except for shots CACTUS and MAPLE. Summaries of the ship's operational activities for these two shots follow.

- CACTUS (Enewetak, 6 May, 0615). Steaming approximately 125 nmi (232 km) southeast of shot site at time of detonation.
- MAPLE (Bikini, 11 June, 0530). At 0530 observed bright flash on horizon bearing 340°T, believed to to be A-bomb blast. Ship about 130 nmi (241 km) southeast of shot site.

USS Tortuga (LSD-26)

Although initial planning for HARDTACK outlined an extensive mission for the dock landing ship Tortuga before, during, and after the scheduled test series, the ship participated only in the preoperational activities that established bases in the EPG (Reference C.3.4.46). It shuttled men and material between Enewetak and Bikini a number of times during March and April of 1958, and then departed the EPG on 14 April, 2 weeks before shot YUCCA, the first shot of the HARDTACK series. Because of its proposed assignment, it was outfitted with a washdown system. Its crew was badged and given extensive instructions on radsafe procedures (Reference C.3.3.34). No exposures were recorded for the ship, however, and therefore its crew is not included in Table 34.

The Tortuga's log shows the following movements:

21 February	0908	Left Pearl Harbor
1 March	1610	Arrived Enewetak
14 April	1227	Left Bikini in company with Merapi
25 April	0833	Arrived Pearl Harbor.

USNS T-LST-664

This civilian-manned MSTS tank landing ship was present for 15 of the 35 shots of the test series. Initially the ship was engaged in the delivery of heavy construction equipment and material to the EPG. The ship was assigned to TE 7.3.2.1 (Transportation and Service, Enewetak) (Reference C.3.4.42).

On a number of occasions it was designated as the emergency evacuation ship for Parry Island, Enewetak, to act either as the primary evacuation vessel or as a support vessel.

It also participated in rollup activities at weather stations at Wotho, Rongelap, Ugelang, Enewetak, and Bikini atolls, and Nauru, Kusaie, and Johnston islands. During this postoperational phase the ship helped to transport TG 7.4 and TG 7.5 cargo from the EPG to Pearl Harbor in late August and early September 1958 (Reference C.3.4.42).

The crew of T-LST-664 was badged and given radsafe training. During HARDTACK four separate training films on atomic operations and radiological safety were shown on board with an average of 20 crewmembers attending each film session. After shot KOA, the ship recorded a maximum radiation reading topside of 0.007 R/hr. The ship was not equipped with a washdown system and a deck-crew decontamination team manually washed down the exposed sections of the ship. Exposure data are presented in Table 34.

T-LST-664's log (Reference C.3.4.42) shows the following ship movements:

2 April	1700	Left Nauru Atoll, Gilbert Islands
11 April	1318	Arrived Enewetak Atoll.

It remained in the EPG area until after 30 August 1958. T-LST-664 was out of the test operating area except for shots KOA, WAHOO, HOLLY, NUTMEG, YELLOWWOOD, MAGNOLIA, TOBACCO, SYCAMORE, ROSE, PISONIA, JUNIPER, OLIVE, PINE, QUINCE, and FIG. Summaries of the ship's operational activities for these shots follow.

- KOA (Enewetak, 13 May, 0630). At 0630 arrived Bikini Atoll. At 0833 anchored at berth N-2, Bikini. On 15 May geiger counter readings taken hourly. From 0400 to 0800 geiger counter readings of 0.005 to 0.007 R/hr recorded and deck crew began washing down all weather decks. From 1200 to 1600 geiger counter readings of 0.001 to 0.002 R/hr on deck. From 1600 to 2400 hourly geiger counter readings taken, averaging 0.003 R/hr on deck.
- WAHOO (Enewetak, 16 May, 1330). Anchored in berth N-2, Bikini. From 0000 to 0400 took hourly geiger counter readings. From 0800 to 1200 hourly geiger counter readings recorded 0.002 R/hr. For rest of day hourly geiger counter readings taken, maximum encountered 0.001 R/hr. On 17 May until 1600 hourly geiger counter readings taken, maximum encountered 0.0007 R/hr. At 1721 underway for Parry Island, Enewetak.
- HOLLY (Enewetak, 21 May, 0630). Steaming approximately 121 nmi (224 km) east of shot site at time of detonation.

- NUTMEG (Bikini, 22 May, 0920). Anchored in berth N-4, Bikini, approximately 10 nmi (19 km) east of shot site. At 0921 noted arrival of shock wave.
- YELLOWWOOD (Enewetak, 26 May, 1400). Anchored at Bikini.
- MAGNOLIA (Enewetak, 27 May, 0600). Anchored at Bikini.
- TOBACCO (Enewetak, 30 May, 1415). At 0857 anchored at Bikini Atoll.
- SYCAMORE (Bikini, 31 May, 1500). En route to assigned area; at 1140 arrived on station. Steaming in assigned area approximately 40 nmi (74 km) southeast of shot site at time of detonation. At 1806 anchored in berth N-2, Bikini. On 1 June from 0000 to 0400 geiger counter readings 0.0001 R/hr; from 2000 to 2400 maximum of 0.00016 R/hr obtained with geiger counter.
- ROSE (Enewetak, 3 June, 0645). Anchored at Bikini.
- PISONIA (Enewetak, 18 July, 1100). On 18 July at 1040 bow ramp closed, unloading operations ceased. Moored approximately 10 nmi (19 km) south of shot site at time of detonation. At 1110 bow doors reopened. At 1114 wave from lagoon test struck ship on portside, ship surged and shifted alongside dock. At 1542 underway for Bikini Atoll.
- JUNIPER (Bikini, 22 July, 1620). Moored at Bikini Atoll, approximately 10 nmi (19 km) east of shot site.
- OLIVE (Enewetak, 23 July, 0830). Moored at Bikini Atoll.
- PINE (Enewetak, 27 July, 0830). Steaming approximately 180 nmi (334 km) southeast of shot site at time of detonation, bound for Nauru Island.
- QUINCE (Enewetak, 6 August, 1415). Moored at (Bikini Atoll).
- FIG (Enewetak, 18 August, 1600). Moored at Bikini approximately 190 nmi (352 km) east of shot site at time of detonation. At 1630 underway for Enewetak Atoll.

CHAPTER 8

U.S. AIR FORCE PARTICIPATION

About 3,800 Air Force personnel participated in HARDTACK. Air Force pilots collected radioactive cloud samples and ground crews serviced and decontaminated their planes. Air Force planes served as instrumentation platforms for other scientific experiments, flew radioactive samples back to U.S. laboratories, and provided logistic support. The Air Force provided the bulk of the weather prediction service for the task force, provided air traffic control, and operated the Enewetak airfield. Air Force laboratory organizations also provided personnel for several of the experiments in Task Group (TG) 7.1.

Enumeration of Air Force personnel who participated as individuals in either the joint-Department-of-Defense (DOD) organizations or in an Atomic Energy Commission (AEC) laboratory is not possible from the Consolidated List of Exposures (Reference C.1.6.3), as this does not display any service affiliation, rank, or serial number information. It is certain that Air Force personnel were in these organizations (Commander Joint Task Force 7 [CJTF 7] was an Air Force officer, for example), and their exposures are included in the summaries in Chapter 11.

Air Force personnel representing Air Force agencies, however, are identifiable from the Consolidated List and their participation is summarized in this chapter by their task group affiliation. Both military and civilian personnel with Air Force organizations are intermingled for the reason given in the previous paragraph. Table 35 indicates the number of personnel from Air Force organizations and the distribution of their exposures. The mean exposure of Air Force personnel identified as serving in Hq JTF 7 was 0.78 R and those serving in TG 7.1 had a mean of 0.77 R. The largest group served in TG 7.4 and had a mean exposure of 1.22 R. Collective exposure for all Air Force personnel was 4,555 man-roentgens and the mean was 1.20 R.

HEADQUARTERS JOINT TASK FORCE 7

A group within the block of exposures for Hq JTF 7 can be positively identified as Air Force, but the unit designation is unclear. Eight men were badged as "Hq 1608th Transportation Group, Charleston SC." A 1608th Transport Wing was at Charleston as well as a 1608th Maintenance Group. Just which unit the men represent cannot be determined without reference to detailed personnel records.

TASK GROUP 7.1 (SCIENTIFIC)

Ballistic Missile Division (AFBMD), Inglewood, California. This organization sponsored Project 1.12; however, AFBMD personnel may not have been in the Eniwetok Proving Ground (EPG). An organization code was preassigned to AFBMD on the Consolidated List, but four of the five men listed there are identified as being with the contractor (TRW) who actually conducted Project 1.12. It is not possible to affiliate the fifth man, but in this report

Table 35. HARDTACK personnel exposures, U.S. Air Force organizations.

Element	No. of Persons Badged	Exposure Ranges (R)												
		0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	5-10	10-15	Over 3.75[a]	High (R)[b]
Air Force in Hq JTF 7	8	3	0	0	5								0	--
Air Force in TG 7.1														
AFCRC	58	39	11	4	1	3							0	--
AFSAM	3	0	1	0	2								0	--
WADC	67	14	8	10	7	8	11	6	3				0	--
Total Air Force in TG 7.1	128	53	20	14	10	11	11	6	3				0	--
Air Force in TG 7.4														
Hq AFSWC	2		1		1								0	--
4925th Test Group	62	61			1								0	--
4950th Test Group	90	6	7	5	19	35	6	0	4	3	5		9	7.58
4926th Test Sq	167	2	2	5	5	14	22	21	27	9	55	5	78	11.23
4951th Support Sq	430	44	79	43	61	105	71	22	5				0	--
4952nd Support Sq	352	35	62	49	30	68	76	20	8	2	1	1	4	10.18
Hq USAF	20	4	8	4	3	1							0	--
Hq MATS	8	0	0	0	1	3	4						0	--
PACD MATS	2	0	0	0	1	1							0	--
MATS Terminal	1,011	262	360	222	91	52	20	3	1				0	--
Hq AWS	21	1			5	7	7				1		1	5.41
6th Weather Sq	142	3	53	38	24	20	3	1					0	--
57th Wthr Recon Sq	388	23	10	28	133	153	33	6	2				0	--
Hq AACS	7	0	0	0	1	6							0	--
1253rd AACS Sq	402	42	143	22	77	103	13	1	1				0	--
1352nd M Pctr Sq	26	3	3	10	8	1	1						0	--
1371st Map Ph Sq	83	2	1	12	15	24	14	13	2				0	--
64th ARS	168	9	21	11	21	34	51	15	6				0	--
24th Helicopter Sq	120	11	17	6	16	31	18	6	13	2			3	4.2
4080th Str Recon Wg	130	13	14	5	8	33	23	4	16	2	11	1	17	12.41
TG 7.4 Visitors	28	21	5	1									0	--
Total Air Force in TG 7.4	3,659	542	786	461	522	691	362	112	85	18	73	7	112	12.41
Total Air Force	3,795	598	806	475	537	702	373	118	88	18	73	7	112	12.41

Note:

[a]HARDTACK Maximum Permissible Exposure.

[b]Highs are recorded on this chart only for those organizations having exposures greater than 3.75 R.

Source: Consolidated List of HARDTACK Exposures (Reference C.1.6.3).

he has been considered an unacknowledged employee of the contractor; therefore, AFBMD is not represented in Table 35.

Cambridge Research Center (AFCRC), Bedford, Massachusetts. This Air Force laboratory organization manned Projects 1.10, 6.10, 8.2, and 9.2b. These four projects were all connected with the high-altitude shots: one was an airblast experiment, one was an experiment measuring the response of the ionosphere to the detonations, one was an experiment to measure the thermal output, and one was the YUCCA weapon ballon support project. Personnel from the airblast experiment and the balloon launch were on USS Boxer (CVS-21) during the conduct of the projects and the other two experiments were largely airborne. AFCRC project support personnel were also assigned to TG 7.4 Test Aircraft Unit (TAU). Twelve men, all with zero exposures, were badged with TG 7.4 and have been combined with the forty-six identified with TG 7.1 to list all AFCRC exposures in a single entry. Personnel included both civilian and military.

School of Aviation Medicine (AFSAM), Brooks AFB, Texas. This organization manned Project 4.1, which measured the response of the eyes of experimental animals to the high-altitude nuclear explosions. Three AFSAM personnel were badged, at least one of whom was an Air Force officer.

Special Weapons Center (AFSWC), Kirtland AFB, New Mexico. This organization was not only the parent organization of a great many of the operational elements of TG 7.4, but it also supplied the project officer, an Air Force officer, for two structures tests (Projects 1.9 and 3.6). However, his name does not appear on the Consolidated List, either under TG 7.1 or TG 7.4, and the organization code assigned for AFSWC personnel operating in TG 7.1 was actually used for another organization. AFSWC is further discusssed under TG 7.4.

Wright Aeronautical Development Center (WADC), Wright-Patterson AFB, Ohio. WADC participated in two areas. One was the B-52 exposure experiment (Project 5.1), and the other was the materials response experiment (Project 8.6) conducted both for tower shots at Enewetak and high-altitude tests at Johnston Island. WADC personnel were badged with both TG 7.1 and TG 7.4, with the operational aspects of WADC Project 5.1 falling under TG 7.4 TAU. Since TG 7.4 did not participate in Project 8.6, the WADC personnel involved in this project were badged under TG 7.1. In Table 35, the exposures have been combined with TG 7.1 for simplicity.

3245th Operations Group, L.G. Hanscom Field, Massachusetts. This unit provided the aircraft commander and presumably the crew for C-97 No. 2596, the Project 6.10 aircraft. Apparently, none was badged, as the commander's name does not appear on the Consolidated List, nor was a code assigned. As flights were made only for TEAK and ORANGE, the lack of badging is consistent with JTF 7 policy.

TASK GROUP 7.4 (AIR FORCE)

Headquarters, Air Force Special Weapons Center (AFSWC), Kirtland AFB, New Mexico.

4925th Test Group (Atomic), Kirtland AFB

4928th Test Squadron (Atomic), Kirtland AFB

4950th Test Group (Nuclear), Kirtland AFB

4926th Test Squadron (Sampling), Kirtland AFB

4951st Support Squadron (Test), Enewetak

4952nd Support Squadron, Kirtland AFB

AFSWC carried out nuclear and related missions at the direction of the Air Research and Development Command (ARDC) for the Air Force. It organized the 4925th and the 4950th Test Groups to conduct nuclear testing missions for the Air Force.

The 4925th Test Group (Atomic) planned and furnished some support to YUCCA at Enewetak and TEAK and ORANGE at Johnston Island through its subordinate squadron, the 4928th. The 4928th Test Squadron (Atomic) provided the crews for the two RB-36s used as instrument platforms for Projects 8.2, 8.3, and 8.4 while the B-36s were being modified for the tests. It is not clear whether this unit flew the aircraft during the tests themselves. The unit is not cited in either TG 7.1 or TG 7.4 organizations on the Consolidated List; however, since experimental teams in aircraft stations for TEAK and ORANGE were not badged, it is possible that aircrews from this unit were present but were unbadged.

The 4950th Test Group (Nuclear) was responsible for Air Force participation in the nuclear tests both at the Nevada Test Site (NTS) and in the Pacific. The group had four subordinate squadrons, three of which were at the EPG during HARDTACK. The 4926th Test Squadron provided aircraft, crews, and support personnel for cloud-sampling programs with ten B-57B aircraft and associated maintenance personnel and equipment. The 4951st Support Squadron (Test) provided the permanent Air Force contingent to support Pacific testing operations. It was responsible for all Air Force support to joint task force elements during periods when TG 7.4 was not functioning in the Pacific. When TG 7.4 became operational in preparation to actively support a test series, the 4951st became the Test Base Unit (TBU) under the control of TG 7.4 as a subordinate of 4950th Test Group (Nuclear). The 4952nd Support Squadron was originally established to augment the 4935th Support Squadron at NTS and the 4951st Support Squadron at Enewetak. Additional personnel were authorized for HARDTACK.

Hq, Wright Air Development Center (WADC), Wright-Patterson AFB, Ohio. WADC perpersonnel are listed under TG 7.1.

Cambridge Research Center (AFCRC), Bedford, Massachusetts. AFCRC personnel are listed under TG 7.1.

Hq USAF, Washington, D.C. This organization used aircraft of the TAU and the Test Support Unit (TSU) for its cloud sample investigations.

Hq, Military Air Transport Service (MATS), Andrews AFB, Maryland.

Pacific Division (PACD) MATS, Parks AFB, California

MATS Terminal Element, Enewetak

MATS was responsible for organizing the TSU of TG 7.4 for HARDTACK. It tasked several subordinate headquarters, including Air Weather Service (AWS), Airways and Air Communication Services (AACS), Air Photographic and Charting Service (APCS), and the Air Rescue Service (ARS), to provide personnel and equipment for the following TSU elements:

Search and Rescue (SAR) Element	Communications Element
Weather Reporting Element	MATS Terminal Element
Weather Central Element	Photo Element (Documentary)
Weather Reconnaissance Element	Photo Element (Aerial).

PACD MATS provided the MATS Terminal Element at Enewetak and airlift for sample-return cargos. The 1501st Air Transport Wing at Travis AFB, California, provided the commander for the Terminal Element and aircraft and spare parts to the 1502nd Air Transport Wing whenever C-97 aircraft were used for sample return. The 1502nd at Hickam AFB provided the personnel to man the MATS Terminal and was responsible for returning radioactive samples from Enewetak. The 1705th, at McChord AFB, Washington, supported the 1502nd whenever C-118 aircraft were used for sample return. The Senior Naval Officer, MATS Units, Naval Air Station (NAS), Moffett, California, supported the 1502nd whenever R7V aircraft were used for sample return.

The MATS Terminal Element worked for the TSU and operated the air terminal at Enewetak. It handled personnel, mail, and cargo entering and leaving the EPG. It also performed customs inspections and organizational maintenance on MATS aircraft and provided forward supply support.

Table 36 summarizes the locations and commands from which personnel were drawn by MATS to man the TSU.

Hq, Air Weather Service, Washington, D.C.

6th Weather Squadron, Tinker AFB, Oklahoma

57th Weather Reconnaissance Squadron, Hickam AFB, Hawaii

This organization was subordinate to MATS. It tasked the 6th Weather Squadron with providing the Weather Reporting Element for HARDTACK. AWS also tasked the 1st Weather Wing at Wheeler AFB, Hawaii, to provide two briefers for the Weather Reporting Element. The 1st Weather Wing was subordinate to the 10th Weather Group.

The 6th Weather Squadron was part of the 4th Weather Group. It established and manned the Weather Reporting Element Provisional (WREP) in the TSU for HARDTACK. Detachment 25 of the 15th Weather Squadron, the permanent weather reporting organization at the EPG, was subordinate to the 1st Weather Wing at Wheeler AFB, Hawaii. When the 6th Weather Squadron became operational at the EPG, Detachment 25 came under its operational control.

The 57th Weather Reconnaissance Squadron established and manned the Weather Reconnaissance Element in the TSU. It flew WB-50Ds on weather reconnaissance, nuclear cloud tracking, and special cloud sampling missions.

Hq, Airways and Air Communications Service, Andrews AFB, Maryland. This organization was charged with providing equipment and personnel to support the Air Force communications responsibilities. The 1253rd AACS Squadron (Enewetak, Marshall Islands) of the 1810th AACS Group and the 1808th AACS Wing (Hickam AFB, Territory of Hawaii) provided AACS services in support of JTF 7 requirements during interim periods between nuclear test series as well as during the operational phases. Responsibilities included operating the Air Force portion of the joint relay center, the weather central facilities on Parry Island and base weather facilities on Enewetak, the control tower on Enewetak, the TG 7.4 communications center on Enewetak, and aircraft/airfield navigational aids at various locations.

Table 36. Manning for Task Group 7.4 Test Services Unit, HARDTACK.

Officers	Enlisted	Station	Command	Unit Assigned
6	11	Andrews AFB, Maryland	MATS	Headquarters, TSU
24	98	Norton AFB, California	ARS	SAR Element
3	6	Clark Field, Philippines	ARS	SAR Element
3	6	Naha AB, Okinawa	ARS	SAR Element
3	0	Hickam AFB, Hawaii	ARS	SAR Element
9	0	U.S. bases[a]	AWS	Weather Central Element
0	12	Overseas bases[a]	AWS	Weather Central Element
47	298	Hickam AFB, Hawaii	AWS	Weather Reconnaissance Element
15	19	McClellan AFB, California	AWS	Weather Reconnaissance Element
6	112	Tinker AFB, Oklahoma	AWS	Weather Reporting Element
7	18	Overseas bases[a]	AWS	Weather Reporting Element
9	142	U.S. bases[a]	AACS	Communications Element
1	0	Scott AFB, Illinois	AACS	Communications Element
1	76	Johnson AB, Japan	AACS	Communications Element
4	6	Lookout Mountain AFS, California	APCS	Photo Element (Documentary)
16	36	Palm Beach AFB, Florida	APCS	Photo Element (Aerial)
2	21	Overseas bases[a]	PACD	MATS Terminal Element

Note:

[a]The only detail on station location presented.

Hq, Air Photographic and Charting Service, Palm Beach AFB, Florida.

1371st Mapping and Photo Squadron, Palm Beach AFB, Florida

1352nd Motion Picture Squadron, Lookout Mountain AFS, California

This organization was the higher headquarters of Lookout Mountain Laboratory, California, which was responsible for technical and documentary photo coverage. It also commanded the 1370th Photo Mapping Group located at Palm Beach AFB. A unit identification code was set up for this unit, but no personnel were badged with this code.

The 1371st Mapping and Photo Squadron was subordinate to the 1370th Photo Mapping Group. This squadron provided the two RB-50 and the three

C-54Gs, along with supporting crews and maintenance for photographic coverage during HARDTACK. It formed the Aerial Photo Element.

The 1352nd Motion Picture Squadron formed the Documentary Photo Element of the TSU and was responsible for both technical and documentary photography. It manned ground and shipboard positions as well as the five air platforms provided by the 1371st Motion Picture Squadron. This squadron consisted of both civilian and military personnel.

Hq, Air Search and Rescue Service, Washington, D.C. A unit code was established for this organization (or rather for ARS for Air Rescue Service), but only the subordinate unit, the 64th Air Rescue Squadron from Norton AFB, California, had personnel badged. The 64th ARS, a subordinate unit of the 8th Air Rescue Group, performed SAR missions for HARDTACK. It furnished five SA-16s with associated crews, maintenance personnel, and equipment. The 2nd Air Rescue Group, operating in the Pacific area, was tasked to provide two SA-16s with crews, in addition to three rated pilots who were to be SAR controllers working in the AOC at Enewetak. The 2nd Air Rescue Group met these obligations by drawing aircraft and personnel from its three subordinate units, the 31st ARS (Clark AB, Philippine Islands), 33rd ARS (Naha AB, Okinawa), and 36th ARS (Hickam AFB, Territory of Hawaii). Exposures from all these squadrons were apparently entered under the 64th ARS code.

Hq, Pacific Air Force (PacAF), Hickam AFB, Territory of Hawaii. This was part of the Pacific Joint Command at Hawaii. PacAF supplied the 24th Helicopter Squadron (Detachment 1), (Enewetak Atoll, Marshall Islands), and three C-54s with supporting personnel to the TBU. The 24th Helicopter Squadron came from the PacAF in Japan and was assigned to the TBU during HARDTACK for helicopter lift on Enewetak. It had eight H-19s and nine H-21s. The unit lost one H-19 and one H-21 during HARDTACK. A detachment of the 24th Squadron was permanently stationed at Enewetak. The Consolidated List does not show anyone badged under the unit code for PacAF, however.

Hq, Strategic Air Command (SAC), Offutt AFB, Omaha, Nebraska. This major headquarters provided six B-57D aircraft with crews and support personnel to assist the TAU in its cloud-sampling mission. The Consolidated List does not reflect anyone under the unit code.

4080th Strategic Reconnaissance Wing, Laughlin AFB, Texas. This unit is the parent organization of the 4025th Strategic Reconnaissance Squadron that provided six B-57D aircraft, with crews, to the TAU for cloud sampling. The Consolidated List does not show the 4025th squadron personnel separately but incorporates them under the unit code for the 4080th Wing.

Unit codes were also provided for Hq Air Research and Development Command (ARDC) and Hq Air Materiel Command (AMC), but the Consolidated List does not reflect any personnel that used these codes during the badging process.

Twenty-seven visitors were also badged with TG 7.4. These have been included in Table 35, as they were probably Air-Force-connected personnel. Other visitors were badged with another code associated with Hq JTF 7.

CHAPTER 9

U.S. MARINE CORPS PARTICIPATION

Marine Corps units participating in HARDTACK were the helicopter squadron from USS Boxer (CVS-21) and the Marine detachment on the same ship. These units are discussed in this chapter, and their exposure data are presented in Table 37. Collective exposure of Marine Corps personnel was 143 man-roentgens and the exposure mean was 0.65 R.

Table 37. HARDTACK personnel exposures, U.S. Marine Corps organizations.

Element	No. of Persons Badged	Exposure Ranges (R)								High (R)
		0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	
HMR(L)-361	168	3	69	68	19	5	2	1	1	3.23
USS Boxer (CVS-21) Detachment	50	20	2	12	13	2	1	0	0	2.24
AFSWP	1	1								0
Total USMC	219	24	71	80	32	7	3	1	1	3.23

Source: Consolidated List of HARDTACK Exposures (Reference C.1.6.3).

HELICOPTER TRANSPORT SQUADRON 361 (LIGHT) (HMR[L]-361)

This squadron, consisting of 36 officers, 134 enlisted men, and 15 helicopters, was in the EPG for all 35 shots of the HARDTACK series. Elements began arriving at the EPG as early as January 1958 and took over operational control of the Bikini Inter-Atoll Transport Service. By 13 February the entire squadron had arrived in the EPG. The squadron was split with the majority of personnel and helicopters stationed ashore. Occasionally, smaller detachments operated from Boxer and USS Monticello (LSD-35). Those on shore were at Eneu Island in Bikini Atoll (Reference C.3.3.25).

The general duties of HMR(L)-361 were to provide ship-to-shore and inter-island airlift, to support preshot and postshot damage surveys and recovery of scientific data, to assist in the preshot evacuation of Eneu Island if necessary, to provide emergency evacuation capabilities, to maintain helicopter search and rescue (SAR) crews as a backup support for Joint Task Force 7 (JTF 7); to conduct scientific project data-recovery flights, and to carry out radiological survey flights (Reference B.3.3, HMR[L]-361 1-58).

On 28 April, two helicopters participated in YUCCA as photography platforms for pictures of the ascent of the balloon carrying the YUCCA weapon. During FIR, detonated at Bikini on 12 May, the squadron conducted six radsafe flights and made eight scientific recoveries of nosecones and instrument packages. Four helicopters took part in WAHOO. On two occasions a detachment of HMR(L)-361 operated from Monticello and Boxer in support of scientific data recovery operations at Enewetak (Reference C.3.1).

Radsafe planning was extensive. The following training took place before the squadron's deployment to the EPG (Reference C.3.3.25):

> Until the notification that HMR(L)-361 would be deployed to the PPG, the Rad-Safe training of the squadron had been in accordance with the current directives. When notification of deployment was received, the following intensive training program commenced: Thirteen (13) enlisted flight personnel were sent to the ABC School under the direction of CG AirFMFPac. One (1) officer was sent to the AirFMFPac Rad-Safe School, and two (2) officers were sent to the ABC School at USNS Treasure Island for a period of six (6) weeks. To insure repair of all of the squadron radiac instruments, two (2) enlisted men were sent to the Radiac Repair School at USNS, Treasure Island. Four (4) teams of four (4) men each were assigned to, and trained in monitoring of aircraft. The monitor of each team was an NCO, and they were scheduled to attend a monitoring school conducted by the AEC and U.S. Army in the PPG.
>
> Before deployment of the squadron, the Rad-Safe Officer Task Group 7.3 briefed the unit on its mission. He gave a series of lectures, and suggested the necessary instruments and equipment. The suggested items were obtained prior to departure of detachment Baker. In order to provide radiological defense capability for the squadron, the Rad-Safe officer 7.3 established a radiac instrument requirement. This requirement was forwarded to the Commandant of the Marine Corps by CTG 7.3 and the instruments were shipped to the Squadron from Marine Corps Supply Forwarding Annex, San Francisco, California. The squadron was further directed that upon completion of the operation, the instruments would be returned to the Navy Stocking activity from which received.

During the operation itself, the squadron instituted several additional precautions. Two sheets of barrier paper 72 inches (1.83 meters) wide were taped to the deck of each helicopter assigned a Radsafe mission and eight pairs of booties were stored in each helicopter as a "walkout kit." Protective clothing was issued to pilots, crew, and passengers during radsafe missions. These missions involved the following (Reference C.3.3.25):

> The Rad Safe flights consisted of two (2) types. One was a survey and damage flight. On this flight the pilot would fly a Rad Safe team to a pre-determined area, the monitor would take contamination readings and radio the reading and location

back to a control center on NAN Island. The control center plotted the readings on an atoll map. This gave a complete picture of Radex areas and their locations. The other mission was a flight to photo towers on various islands, the aircraft were landed and the photo crew disembarked, entered the tower, and recovered the film. Since most of the areas where the towers were located were contaminated, the aircraft would take off and orbit until recalled by a flare for passenger pick-up and return to NAN Island.

Aircraft returning from contaminated areas were landed on the decontamination ramp and monitored by squadron personnel. If contamination was present, pilots, crew, and passengers were monitored and handled as deemed necessary by the Rad Safe unit mentioned above.

When necessary, aircraft were decontaminated by washdown from the unit installed in the decontamination ramp. This unit delivers from 40 to 100 psi water pressure which was found to be sufficient. The 200 gallon decontamination units brought by the squadron except for detergent were not needed. The average reading per aircraft during a period was 50 MR [per hour] and the highest reading encountered on an aircraft was three (3) roentgens [per hour]. This aircraft was sufficiently decontaminated with washdown in 45 minutes. All other aircraft were decontaminated in approximately 5-10 minutes.

Table 38 provides a summary of HMR(L)-361 operational activities.

Table 38. Marine Helicopter Transport Squadron 361 (Light) operational statistical summary, HARDTACK.

Month	Number of Helicopters Assigned	Sorties Flown: Scientific	Sorties Flown: Other	Total Sorties
Jan	7	0	63	63
Feb	7	1	679	680
Mar	15	0	2,284	2,284
Apr	15	2	3,049	3,051
May	15	38	2,041	2,079
1 - 15 Jun	15	38	649	687
16 - 30 Jun	15	20	618	638
Jul	15	29	467	496

Source: Reference C.3.1.

MARINE DETACHMENT USS BOXER (CVS-21)

Marines on Boxer guarded the nuclear weapons carried aboard for the YUCCA, WAHOO, and UMBRELLA events. This group may have also guarded the University of California Radiation Laboratory devices at Eneu. Fifty men on the Boxer portion of the Consolidated List can be identified as Marines; their exposure data are shown in Table 37.

OTHER MARINE PARTICIPATION

One Marine officer served in the Armed Forces Special Weapons Project (AFSWP) contingent and others may have been in AFSWP, in the JTF 7 cadre, or in Task Unit 7.1.6. The Marine Corps had supplied personnel for these joint Department of Defense groups in prior Pacific nuclear weapon tests. Because the Consolidated List does not display service affiliation or rank, however, this source alone cannot be used to identify such Marine Corps participation.

CHAPTER 10

JOINT DEPARTMENT OF DEFENSE, OTHER U.S. GOVERNMENT, CONTRACTOR, AND FOREIGN PARTICIPATION

There were 5,360 other participants in HARDTACK from joint Department of Defense (DOD) organizations, other U.S. government agencies, primarily Atomic Energy Commission (AEC), and contractors as well as a few visitors. The number of personnel in these organizations and the distributions of their exposures are shown in Table 39. Mean exposure of the personnel from the several groups were: joint DOD agencies, 1.01 R; AEC and its contractors, 1.05 R; U.S. Coast Guard, 1.64 R; DOD contractors, 0.91 R; visitors and others, 0.59 R. Collective exposure was 5,410 man-roentgens and the mean exposure for the 5,360 was 1.01 R.

JOINT DEPARTMENT OF DEFENSE ORGANIZATIONS

These organizations, made up of military personnel from the several services and civilians employed by the DOD, were subordinate to the Joint Chiefs of Staff.

Armed Forces Special Weapons Project (AFSWP), Washington, D.C., and Albuquerque, New Mexico. This agency planned and coordinated the DOD scientific program. AFSWP personnel acted as the directors of the various programs in Task Unit (TU) 7.1.3. No distinction is made in the Consolidated List (Reference C.1.6.3) between personnel from Hq AFSWP in Washington, D.C., and its Field Command in Albuquerque. The exposure data presented in Table 39 are therefore similarly mixed.

Joint Task Force 7 (JTF 7). In a sense all participants in HARDTACK were members of JTF 7. JTF 7 was the agency conducting the tests and all personnel at Eniwetok Proving Ground (EPG) were subordinate to CJTF 7. A much smaller group, however, formed a permanent planning and coordination staff. This cadre was the group whose exposures are presented in Table 39 under JTF 7. This group was the Commander, members of his staff, and also a variety of others, including apparently the mess personnel who served the staff when it was aboard USS Boxer (CVS-21).

ATOMIC ENERGY COMMISSION

AEC participation was primarily through the weapon laboratories operated for the AEC at Los Alamos, New Mexico (Los Alamos Scientific Laboratory [LASL]) and Livermore, California (University of California Radiation Laboratory [UCRL]); and at Albuquerque, New Mexico, by Sandia Laboratory (a Western Electric subsidiary). The AEC contracted with private organizations to support its weapon development tests in addition to the support it received from the DOD. The following AEC laboratories and contractors in Table 39 are listed with personnel exposure data.

Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico. This laboratory provided the devices that were tested at Enewetak Atoll. It required DOD support in cloud sampling. A DOD laboratory (Naval Research Laboratory

Table 39. HARDTACK personnel exposures, joint Department of Defense, other U.S. Government, contractor, and foreign participant organizations.

Element	No. of Persons Badged	Exposure Ranges (R) 0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	Over 5	Over 3.75[a]	High
Joint DOD													
AFSWP	105	22	18	12	28	17	4	2	2			0	3.59
JTF 7 Staff	75[b]	12	10	9	15	23	6					0	
Total	180	34	28	21	43	40	10	2	2			0	
AEC Labs and Contractors													
LASL	401	54	79	65	99	60	23	9	10	1	1	5	5.26
UCRL	389	71	168	78	43	17	6	5	0	1		1	3.77
Sandia	192	69	64	27	19	6	5	1	1			0	
EG&G	237	46	50	62	40	21	10	4	3		1	1	5.13
H&N	3,436	680	481	379	524	805	345	112	91	19		34	4.72
Total	4,655	920	842	611	725	909	389	131	105	21	2	41	5.26
USCG Loran-C Sta.	14	0	1	2	1	5	5					0	2.19
DOD Contractors													
ARA	4	1	1	2								0	
ARF	8	0	0	5	3							0	
Boeing	29	2	0	15	12							0	
Cook	1	1										0	
Cooper	6	5	0	1								0	
Douglas	5[b]	0	0	1	4							0	
NAA	2	0	0	1	1							0	
SIO	9	0	0	0	6	2	1					0	
SRI	29	1	15	8	5							0	
STL	5	0	1	0	1	1	0	1	0	1		1	4.05
UDRI	1	0	0	0	0	0	0	0	1			0	
U of Illinois	5	0	0	2	0	1	0	1	1			0	
U of Washington	9	0	4	3	0	2						0	
Total	113	10	21	38	32	6	1	2	2	1		1	4.05
Visitors	387[c]	128	126	37	33	48	14	1				0	
Other	11	2	3	1	3	1	1					0	
Total All Elements	5,360	1,094	1,021	710	837	1,009	420	136	109	22	2	42	5.26

Notes:

[a] HARDTACK Maximum Permissible Exposure.

[b] One reading illegible in source document has not been included.

[c] Two readings illegible in source document have not been included.

Source: Consolidated List of HARDTACK Exposures (Reference 1.6.3).

[NRL]) was involved in weapon development experiments. LASL participated in DOD Project 2.8 and had individual DOD personnel assigned.

University of California Radiation Laboratory (UCRL), Livermore, California. UCRL provided devices tested at Bikini and, toward the end of the series, at Enewetak, also. It required DOD support for cloud sampling and may have had DOD personnel on individual assignment. It participated in DOD Project 2.8.

Sandia Laboratory, Albuquerque, New Mexico. This laboratory provided the devices and the arming and fuzing for the DOD effects tests. It also participated in DOD Projects 2.14 and 9.2a.

Edgerton, Germeshausen, and Grier (EG&G), Boston, Massachusetts, and Las Vegas, Nevada. EG&G provided the timing and firing for device detonation and timing and photographic services to experiments including those of the DOD. It also participated in DOD Project 8.3.

Holmes & Narver (H&N), Los Angeles, California. As Task Group (TG) 7.5, H&N fed and sheltered the task force personnel except on Navy ships and on Enewetak Island. It built scientific stations and aided in the recovery of scientific data including that from DOD experiments and it also participated as part of DOD Project 3.7. Table 39 presents exposures of all TG 7.5 as equivalent to H&N, although TG 7.5 may have a few AEC personnel involved.

OTHER U.S. GOVERNMENT

Other U.S. Government agencies participated, but complete identification is difficult because of the sparse identifying information presented in the Consolidated List. Examples of such other government participation are the U.S. Public Health Service officer serving as the Radiological Health Advisor for TG 7.5 and the U.S. Weather Bureau scientist badged with JTF 7 staff. One non-DOD and non-AEC Federal government agency that had a participating unit was the U.S. Coast Guard Loran unit.

U.S. Coast Guard (USCG). The USCG operated a Loran station on the island of Enewetak as an aid to trans-Pacific navigation. During HARDTACK, this station was included for administrative purposes with TG 7.2, the primary housekeeping group on Enewetak Island.

DOD CONTRACTORS

Allied Research Associates (ARA), Boston, Massachusetts. ARA participated as a Wright Air Development Center (WADC) contractor on Project 8.6.

Armour Research Foundation (ARF) of the Illinois Institute of Technology, Chicago, Illinois. ARF was the contractor that conducted Project 1.11 and had eight men at the EPG.

Boeing Airplane Company, Seattle, Washington, and Witchita, Kansas. Boeing was the manufacturer of the B-52 used in Project 5.1 and provided a group of 29 personnel to support this effort.

Cook Electric, Chicago, Illinois. A Cook subsidiary modified the RB-36s used in thermal experiments (Projects 8.2 and 8.3) carried out in connection with the high-altitude shots. One Cook employee was badged with the Air Force Cambridge Research Center contingent; his badge recorded zero exposure.

Cooper Development, Monrovia, California. This company provided small rockets for several of the high-altitude experiments.

Douglas Aircraft Company, El Segundo and Long Beach, California. Douglas manufactured the aircraft for Project 5.2. Two Douglas employees from El Segundo were badged with the Naval Air Special Weapons Facility (NASWF), the project agency. Four others were badged as Douglas Aircraft, Long Beach, California.

Lincoln Laboratory, Massachusetts Institute of Technology, Bedford, Massachusetts. This laboratory staffed Project 6.13. No exposures are entered in the Consolidated List for this organization as the personnel were located in aircraft stations based in Hawaii during the TEAK and ORANGE shots, which were the only ones Project 6.13 was involved with.

North American Aviation (NAA), Columbus, Ohio. NAA manufactured the F4-Js used in Project 5.3. Two representatives were badged with the NASWF contingent.

Scripps Institution of Oceanography (SIO), La Jolla, California. SIO made Project 1.6 wave measurements for the underwater shots.

Stanford Research Institute (SRI), Menlo Park, California. SRI had two projects, 1.8 and 6.11. Project 1.8 involved data recovery near the surface bursts at Enewetak, and Project 6.11 involved remote electromagnetic measurements during the high-altitude shots using the motor vessel MV Acania at Johnston Island.

TRW Space Technology Laboratory (STL), El Segundo, California. STL conducted Project 1.12, which required recovery of ground shock instrumentation near the surface bursts CACTUS and KOA. Project sponsor was the Air Force Ballistic Missile Division.

University of Dayton Research Institute (UDRI), Dayton, Ohio. UDRI provided at least one man for WADC Project 8.6, which involved the recovery of material samples from the area around surface detonations.

University of Illinois, Champaign-Urbana, Illinois. The University of Illinois participated in two Air Force structures response experiments, Projects 1.8 and 6.11.

University of Washington, Seattle, Washington. The University of Washington participated with other agencies in Project 1.13, which involved not only pre- and postoperational oceanic surveys, but also sounding of the UMBRELLA crater at H+3.

FOREIGN AND DOMESTIC VISITORS

A total of 385 persons was badged under a unit code apparently set aside for visitors. The Consolidated List contains at least 22 names of men who were military officers from nations allied to the United States in the North Atlantic Treaty Organization or the South East Asia Treaty Organization, or through some other treaty. Countries represented were Spain, Italy, the Philippines, the United Kingdom, Canada, France, Belgium, Australia, Iran, Greece, Norway, Turkey, New Zealand, Portugal, Denmark, China (Taiwan), Korea, the Netherlands, and West Germany. Intermingled on the list were individuals from U.S. military organizations, cabinet members, and other government personnel. These are all listed under "Visitors" in Table 39.

OTHER

All exposures on the Consolidated List that appear to have an organization code that is not understood and the person's name cannot be readily associated with some unit or function have been listed as "Other" in Table 39. Included are unit codes that appear to be the result of keypunch errors.

CHAPTER 11

PERSONNEL EXPOSURES

Personnel exposures are summarized in Table 40 by task group. The group with the highest mean exposure was Task Group (TG) 7.2, the U.S. Army group on Enewetak Island. This higher exposure is probably a result of the 14 May fallout incident attributed to the FIR shot at Bikini on 12 May. The Joint Task Force 7 (JTF 7) Radsafe Officer's estimate that personnel "living at Eniwetok atoll" would receive between 1.2 and 1.5 R exposure from the elevated background that lasted for several days (Reference C.1.1682) (see Figure 35) seems validated in the TG 7.2 and U.S. Coast Guard Loran-C Station personnel exposures (see Table 39). These personnel would be those who could be most accurately described as "living at Eniwetok."

Other groups also lived on the base islands and experienced the FIR fallout, but these groups' exposures are made up of individual exposures that resulted from experimental activities or activities on shipboard on in other locations, making direct comparisons difficult.

The mean exposure of all badged personnel was less than 1 R (0.87 R) and only 180 men, or 0.9 percent, exceeded the general Maximum Permissible Exposure (MPE) of 3.75 R. Of these 180, 139 were Department of Defense (DOD) personnel or DOD civilians. Of the 139, 86 were in the TG 7.4 units that collected cloud samples, and the actual cloud sampler personnel had a special MPE of 10 R. The remainder were in TG 7.4 units that may have been involved in some aspect of the sample collection such as aircraft decontamination and maintenance of the aircraft, in TG 7.3 and TG 7.4 units involved in providing transportation services for radiological surveys and early data recovery missions, or in the scientific projects of TG 7.1.

A very large number of men, 43.9 percent of the total, had badges that showed either no exposure or had less than 0.5 R exposure.

An overall exposure trend during testing at the EPG during the 1950s is apparent. The CASTLE series had an average exposure of about 1.7 R, mainly because of unusually heavy and extended fallout from BRAVO shot. The REDWING series had about the same average, chiefly because of fallout from TEWA shot; however, with few exceptions everyone was badged during REDWING, something not previously done. The average exposure during HARDTACK of 0.087 R was half that of the above two series and the policy of badging everyone continued. The one group of participants who consistently received high exposure was the sampler pilots who flew through the radioactive cloud to collect cloud samples. This had to be done as soon as possible after detonation, and there was little reduction in exposures for personnel on these missions from CASTLE through HARDTACK.

Table 40. HARDTACK personnel exposures by task group.

Element	No. of Persons Badged	Exposure Ranges (R) 0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	5-10	Over 10	Over 3.75[a]	High	Collective Exposure (man-R)	Mean Exposure (R)
Hq JTF 7 and Visitors	481	145	139	47	56	72	21	1					0	2.52	316	0.66
Percent		30.1	28.9	9.8	11.6	15.0	4.4	0.2								
Task Group 7.1	2,248[b]	463	488	401	417	237	116	49	56	15	6		30	6.63	2,058	0.92
Percent		20.6	21.7	17.8	18.5	10.5	5.2	2.2	2.5	0.7	0.3		1.3			
Task Group 7.2	1,287	37	83	234	190	465	219	46	13				1	3.81	1,919	1.49
Percent		2.9	6.5	18.2	14.8	36.1	17.0	3.6	1.0				0.08			
Task Group 7.3	8,540[c]	1,008	3,796	2,877	584	205	46	17	6	1			3	4.36	4,371	0.52
Percent		11.8	44.5	33.6	6.8	2.4	0.5	0.2	0.07	0.01			0.04			
Task Group 7.4	3,659	542	786	461	522	691	362	112	85	18	73	7	112	12.41	4,456	1.22
Percent		14.8	21.5	12.6	14.3	18.9	9.9	3.1	2.2	0.5	1.9	0.2	3.07			
Task Group 7.5	3,436	680	481	379	524	805	345	112	91	19			34	4.49	3,457	1.01
Percent		19.8	14.0	11.0	15.3	23.4	10.0	3.3	2.6	0.6			0.99			
Total JTF 7	19,651	2,875	5,773	4,399	2,293	2,475	1,109	337	251	53	79	7	180	12.41	17,158	0.87
Percent		14.6	29.4	22.4	11.7	12.6	5.6	1.7	1.3	0.3	0.4	0.04	0.9			

Notes:

[a]HARDTACK Maximum Permissible Exposure.

[b]Includes 301 Army, 382 Navy, and 128 Air Force personnel.

[c]Includes 218 Marine Corps personnel.

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The sources consulted for this report are listed below. They are organized into sections based upon their relationship to the body of nuclear testing information.

The first section (A) contains basic references pertinent to nuclear weapons development and effects and to all or several atmospheric nuclear tests. These are generally monographs published and distributed through regular trade channels and are available in bookstores and libraries with the exceptions noted.

The second and third sections are documents generated by Joint Task Force 7 (JTF 7) and its subordinate organizations. The second section (B) contains planning documents for HARDTACK, and the third (C) after-action reports. These JTF 7 references are arranged in a fashion that reflects the JTF 7 organization.

The fourth section (D) lists other reports by non-task-force organizations concerning HARDTACK.

An availability code appears at the end of many reference citations for those who wish to read or obtain copies. Availability status was correct at the time the reference list was prepared. Many documents indicated as unavailable will become available during the declassification review process. The Department of Energy Coordination and Information Center (DOE CIC) and NTIS will be provided future DNA-WT documents bearing an "EX" after the report number.

Source documents with an availability code of DOE CIC may be reviewed at the following address:

Department of Energy
Coordination and Information Center
(Operated by Reynolds Electrical & Engineering Co., Inc)
ATTN: Mr. Richard V. Nutley
2753 S. Highland
P.O. Box 14100
Las Vegas, Nevada 89114
Telephone: (702) 734-3194; FTS: 598-3194.

Source documents bearing an NTIS availability code may be purchased at the following address:

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Springfield, Virginia 22161
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When ordering by mail or phone, please include both the price code and the NTIS number. The price code appears in parentheses before the NTIS order number; e.g., (A07) AD 000 000.

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

Reference citations with no availability codes may be available at the location cited or in a library.

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JOINT TASK FORCE 7

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Army Engineer Waterways Experiment Station
August 1960 WT-1606

C.1.1607 Airblast Phenomena from Underwater Bursts, Operation HARDTACK, Project 1.2***
P. Hanlon, H.B. Benefile
Naval Ordnance Laboratory
September 1961 WT-1607

C.1.1608 Surface Phenomena from Underwater Bursts***
E. Swift, Jr., G.A. Young, R.L. Willey, J. Goertner, D. Phillips
Naval Ordnance Laboratory
March 1962 WT-1608

C.1.1609 Physical Characteristics of Craters from Near-Surface Nuclear Detonations, Operation HARDTACK, Project 1.4***
A.W. Patteson
Army Engineer Research and Development Laboratories
May 1960 WT-1609

C.1.1610 Refraction of Shock from a Deep-Water Burst, Operation HARDTACK, Project 1.5***
C.J. Burbank, T. McMillian, C.T. Johnson, J.E. Rusconi
Navy Electronics Laboratory
October 1960 WT-1610

C.1.1611 Water-Wave Measurements, Operation HARDTACK, Project 1.6***
L.W. Kidd, R.H. Johnson
Scripps Institution of Oceanography
June 1961 WT-1611

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1612 Airblast Phenomena and Instrumentation of Structures, Operation HARDTACK, Project 1.7***
J.J. Meszaros, R.E. Reisler, R.C. Wise
Army Ballistic Research Laboratories
July 1962 WT-1612

C.1.1613 Ground Motion Produced by Nuclear Detonations; Operation HARDTACK, Project 1.8***
E.H. Bultmann, Jr., G.F. McDonough, G.K. Sinnamon
May 1961 WT-1613

C.1.1614 Loading on Buried Simulated Structures in High-Overpressure Regions, Operation HARDTACK, Project 1.9***
University of Illinois, Air Force Special Weapons Center
May 1961 WT-1614

C.1.1615 Blast Overpressure from Very-High-Altitude Bursts, Operation HARDTACK, Project 1.10***
J.T. Pantall, N.A. Haskell
Air Force Cambridge Research Laboratories
September 1960 WT-1615

C.1.1616 Yield and Energy Partition of Underwater Bursts, Operation HARDTACK, Project 1.11***
F.B. Porzel, R.G. Dickens, W.E. Bard, T.H. Schiffman
IIT Research Institute
June 1961 WT-1616

C.1.1617 Ground-Shock Spectra from Surface Bursts, Operation HARDTACK, Project 1.12***
J.F. Halsey, M.V. Barton, J.M. Lindahl, R.E. Hutton
TRW Systems, Inc., Air Force Air Research and Development Command
September 1960 WT-1617

C.1.1618 Characteristics of Ocean and Bottom for Shots WAHOO and UMBRELLA, Including UMBRELLA Crater, Operation HARDTACK, Project 1.13***
J.W. Winchester, A.W. Anderson, Q.H. Carlson, W.R. Deebel
Office of Naval Research, Navy Hydrographic Office
February 1961 WT-1618

C.1.1619 Shipboard Radiation from Underwater Bursts, Operation HARDTACK, Project 2.1***
M.M. Bigger, H.R. Rinnert, H.A. Zagorites
Naval Radiological Defense Laboratory
March 1961 WT-1619

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1620 Shipboard Contaminant Ingress from Underwater Bursts, Operation HARDTACK, Project 2.2***
M.M. Bigger, J.K. Gong, F.K. Kawahara, R.K. Fuller, W.L. Milne, S.Y. Cohn
Naval Radiological Defense Laboratory
December 1961 WT-1620

C.1.1621 Characteristics of the Radioactive Cloud from Underwater Bursts, Operation HARDTACK, Project 2.3***
E.C. Evans, T.H. Shirasawa
Naval Radiological Defense Laboratory
January 1962 WT-1621

C.1.1622 Neutron Flux from Large-Yield Bursts, Operation HARDTACK, Project 2.4***
J.W. Kinch, D.L. Rigotti, J. Anderson, R.L. Bain, J.H. Rugheimer
Army Chemical Center
May 1960 WT-1622

C.1.1623 Neutron Flux from Very-High-Altitude Bursts, Operation HARDTACK, Project 2.6***
T.D. Hanscome, P.B. Alers, P.A. Caldwell, R.J. Drachman, S.G. Gorbics, H.K. Holmgren, E.C. Jones, C.A. Pearse, R.C. Waddel
Naval Research Laboratory
May 1961 WT-1623

C.1.1624 Nuclear Radiation from a Detonation at Very-High Altitude***
P.A. Caldwell, et al.
U.S. Naval Research Laboratory
18 July 1958 ITR-1624

C.1.1625 Fallout Measurements by Aircraft and Rocket Sampling, Operation HARDTACK, Project 2.8***
S.L. Whitcher, L.R. Bunney, R.R. Soule, R.A. Daroza
Naval Radiological Defense Laboratory, Lawrence Radiation Laboratory
September 1961 WT-1625

C.1.1626 Response of Earth-Confined Flexible Arch Structures in High-Overpressure Regions, Operation HARDTACK, Project 3.2***
J.C. Ledous, P.J. Rush
Naval Civil Engineering Laboratory
January 1961 WT-1626

*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1627 <u>Shock Loading in Ships from Underwater Bursts and Response of Shipboard Equipment, Operation HARDTACK, Project 3.3</u>***
H.L. Rich, R.L. Bort, E.T. Habib, R.E. Baker, W.E. Carr, R.E. Converse, Jr., K.J. Cornelius, F. Weinberger
Navy David Taylor Model Basin
September 1961 WT-1627

C.1.1628 <u>Loading and Response of Surface-Ship Hull Structures from Underwater Bursts, Operation HARDTACK, Project 3.4</u>***
W.W. Murray
Navy Norfolk Naval Shipyard
December 1961 WT-1628

C.1.1629 <u>Loading and Response of Submarine Hulls from Underwater Bursts, Operation HARDTACK, Project 3.5</u>***
H.L. Rich, F. Weinberger, E.T. Habib, R.L. Bort, W.J. Sette
Navy David Taylor Model Basin
December 1960 WT-1629

C.1.1630 <u>Behavior of Deep Reinforced-Concrete Slabs in High-Overpressure Regions, Operation HARDTACK, Project 3.6</u>***
<u>E.H. Bultmann, Jr., J.D. Haltiwanger, R.N. Wright, J.T. Hanley</u>
Air Force Weapons Laboratory, University of Illinois
June 1961 WT-1630

C.1.1631 <u>Damage to Existing EPG Structures, Operation HARDTACK, Project 3.7</u>***
W.J. Flathau, R.A. Cameron
Army Engineer Waterways Experiment Station, Holmes and Narver, Inc.
October 1960 WT-1631

C.1.1632 <u>Assessment for Ship Damage and Preparation of Targets for Shots WAHOO and UMBRELLA, Operation HARDTACK, Project 3.8</u>***
J.J. Kearns, R.H. Oliver, J.R. Sullivan, K.R. Lovell, C.F. Janes, E.J. Gutowski, F.J. Wellings, A.J. Giddings, J.R. Wakefile, F.W. Kamph
Navy Bureau of Ships
November 1961 WT-1632

C.1.1633 <u>Effects on Eyes from Exposure to Very-High-Altitude Bursts, Operation HARDTACK, Project 4.1</u>***
J.E. Pickering, W.T. Culver, R.G. Allen, R.E. Benson, F.M. Morris, D.B. Williams, S.J. Wilson, R.W. Zellmer, E.O. Richey
Air Force School of Aviation Medicine
October 1960 WT-1633

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1634 In-Flight Structural Response of a B-52 Aircraft to Side Loading from a Nuclear Detonation, Operation HARDTACK, Project 5.1***
W.R. Lounsberry
Air Force Flight Dynamics Laboratory
September 1961 WT-1634

C.1.1635 In-Flight Structural Response of AD-1 Aircraft to Nuclear Detonations, Operation HARDTACK, Project 5.2***
L.A. Cos, R.J. Harter, L.E. Sattler
Navy Bureau of Naval Weapons, Douglas Aircraft Company
February 1962 WT-1635

C.1.1636 In-Flight Structural Response of FJ-4 Aircraft to Nuclear Detonations, Operation HARDTACK, Project 5.3***
J.H. Walls, R.W. Harr, D.A. Smith, K.C. Holmboe, G.A. Bierce
North American Aviation, Inc., Navy Bureau of Aeronautics
October 1961 WT-1636

C.1.1637 Effects of Nuclear Radiatioan on Electronic Fuze Components and Materials, Operation HARDTACK, Project 6.3***
E.E. Conrad, B.J. Dobriansky, A. Simon, R.W. Tucker, F.N. Wimenitz, E. Conesc
Diamond Ordnance Fuze Laboratory
June 1961 WT-1637

C.1.1638 Wave Form of Electromagnetic Pulse from Nuclear Detonations, Operation HARDTACK, Project 6.4***
F. Lavicka, G. Lang
Army Signal Research and Development Laboratory
September 1960 WT-1638

C.1.1639 Radar Determination of Fireball Phenomena, Operation HARDTACK, Project 6.5***
E. Baker, T. Viars, W.S. McAfee, I.A. Balton
Army Signal Research and Development Laboratory
May 1960 WT-1639

C.1.1640 X-Band Radar Determination of Nuclear-Cloud Parameters, Operation HARDTACK, Project 6.6***
C.W. Bastian, R. Robbiani, J. Hargrave
Army Signal Research and Development Laboratory
April 1960 WT-1640

C.1.1641 Naval-Mine-Field Clearance by Underwater Bursts, Operation HARDTACK, Project 6.7***
G.M. Davidson, J.W. Brooks
Naval Ordnance Laboratory
August 1960 WT-1641

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1642 Feasibility of Wide-Area Clearance of Naval Influence Mines by Nuclear Weapons, Operation HARDTACK, Project 6.8***
M.H. Naeseth, L.A. Kish, G.D. McKissock, M.A. Elliott, E.A. Hogge
Navy Mine Defense Laboratory
October 1960 WT-1642

C.1.1643 Effects of Nuclear Detonations on the Ionosphere***
B.D. Jones et al.
U.S. Army Signal Research and Development Laboratory
25 July 1958 ITR-1643

C.1.1644 Ionization Produced by High-Altitude Bursts, Operation HARDTACK, Project 6.10***
G. Gassmann
Air Force Cambridge Research Laboratories
December 1961 WT-1644

C.1.1645 HF and VHF Attenuation and Reflection Phenomena, Operation HARDTACK, Project 6.11***
L.T. Dolphin, R.B. Dyce
Stanford Research Institute
June 1961 WT-1645

C.1.1646 Effects of High-Altitude Bursts on Pulsed Electromagnetic Transmissions, Operation HARDTACK, Project 6.12***
W.S. McAfee, O.E. Johnson, F.J. Lavicka
Army Signal Research and Development Laboratory
December 1961 WT-1646

C.1.1647 Effects on Materials of Thermal Radiation from Nuclear Detonations, Operation HARDTACK, Project 8.1***
W.L. Derksen, J.A. Carter, A. Hirschman, G.B. Delhery, H. Korbel
September 1960 WT-1647

C.1.1648 Thermal Radiation from High-Altitude Bursts, Operation HARDTACK***
R.M. Brubaker, H.P. Gauvin, A.T. Stair, J.P. Cahill, D.J. Baker, E.A. Jones, J.W. Carpenter
Air Force Cambridge Research Laboratories, Cook Research Laboratories, American Science and Engineering
October 1961 WT-1648

C.1.1649 Growth of Fireball Radii at Very High Altitudes, Operation HARDTACK***
L. Fussell, R.C. Schneiderhan
EG&G
May 1961 WT-1649

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1650 Early Time Spectra of Very-High-Altitude Nuclear Detonations, Operation HARDTACK, Project 8.4***
W.J. Parker, R.J. Jenkins, E.C.Y. Inn
Naval Radiological Defense Laboratory
June 1960 WT-1650

C.1.1651-1 Narrow-Band Infrared Spectral Irradiance of High-Altitude Bursts, Operation HARDTACK, Project 8.5A***
R. Zirkind
Navy Bureau of Naval Weapons
December 1961 WT-1651-1

C.1.1651-2 Narrow-Band Infrared Spectral Irradiance of High-Altitude Bursts, Operation HARDTACK, Project 8.5B***
R. Zirkind
Navy Bureau of Naval Weapons
December 1961 WT-1651-2

C.1.1652 Vulnerability of Missile Structures to Nuclear Detonations, Operation HARDTACK, Project 8.6***
C.J. Cosenza, F.E. Barnett, M. Annis, H.E. Stubbs, G.W. Clark, W.P. Boquist, R.W. Milligan, R.G. Phillips, A.C. Wilvert, D.A. Kahle
Wright Air Development Division, Allied Research Associates, University of Dayton Research Institute
May 1962 WT-1652
AD 339 488L

C.1.1653 Temperature, Density, and Pressure of Upper Atmosphere During a Very-High Altitude Nuclear Detonation***
R.E. Loftman
Cooper Development Corporation
17 October 1958 ITR-1653

C.1.1654 Shot YUCCA: A Very-High-Altitude Nuclear Detonation***
H.C. Henry
Field Command, AFSWP
7 July 1958 ITR-1654

C.1.1655 Operation of Balloon Carrier for Very-High-Altitude Nuclear Detonations***
A.E. Gilpatrick, et al.
Air Force Cambridge Research Laboratory
25 July 1958 ITR-1655

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1656 Aircraft Modification and Instrumentation for High-Altitude Technical Photography***
J.G. James
Field Command, AFSWP
20 March 1958 ITR-1656

C.1.1657 Operation of Missile Carrier for Very-High-Altitude Nuclear Detonations, Operation HARDTACK, Project 9.3A***
G.P. Elliott, B. Kennedy, D. Grau
Army Ballistic Missile Agency
May 1959 WT-1657

C.1.1658 Shots WAHOO and UMBRELLA: Two Underwater Nuclear Test Detonations***
C.G. Menderhall
Field Command AFSWP
March 1959 ITR-1658

C.1.1659 Study of Very-High-Altitude Bursts with Airborne UHF Radar, Operation HARDTACK, Project 6.13***
V.L. Lynn, M.A. Herlin, J.S. Clark, W.G. Clay, A.I. Grayzel, J.H. Pannell
Massachusetts Institute of Technology
July 1960 WT-1659

C.1.1660 Technical Summary of Military Effects Programs 1-9***
DCS Field Command AFSWP
23 September 1959 ITR-1660

C.1.1676 Thermal Radiation from Very-Low-Yield Bursts, Operation HARDTACK, Projects 8.7/2.12D***
J.J. Mahoney, J.C. Maloney, S.D. Furrow, D.T. Kilminster, M.J. Alvares, T.S. Dahlstrom, J.C. Ulberg
Chemical Warfare Laboratories, Naval RAdiological Defense Laboratory
June 1960 WT-1676

C.1.1677 Gamma Dose from Very-Low-Yield bursts, Operation HARDTACK, Projects 2.9/2.12B***
J.C. Maloney, M. Morgenthau
Army Chemical Center
August 1960 WT-1677

C.1.1678 Residual Radiation from a Very-Low-Yield burst, Operation HARDTACK, Project 2.10***
M. Morgenthau, M. Schumchyk
Army Chemical Center
December 1960 WT-1676

*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1679 Neutron Flux from Very-Low-Yield Bursts, Operation HARDTACK, Projects 2.4A/2.11/2.12A***
D.L. Rigotti, J.W. Kinch, J.H. McNeilly, J.L. Tarbox, N. Klein, P.A. Pankow, T.R. Adams
Army Chemical Center
August 1960 WT-1679

C.1.1682 Report of the Commander Task Group 7.1***
Joint Task Force 7
May 1959 WT-1682

C.1.1685 Radiological Safety, Operation HARDTACK, Report to the Scientific Director***
G.L. Jacks, G.C. Zimmerman
Los Alamos Scientific Laboratory
October 1959 WT-1685

C.1.1686 Timing and Firing, Operation HARDTACK***
EG&G
September 1959 WT-1686

C.1.1688 Technical Photography, Operation HARDTACK***
EG&G
August 1960 WT-1688

C.1.1689 Sea-Water Radiological Monitoring Methods, Operation HARDTACK, Project 40.1***
J.W. Duckworth, F.W. Chambers, W.H. Chapman, R.E. Severance
Naval Medical Research Institute
June 1959 WT-1689

C.1.1690 Power Time and Total Thermal Measurements, Operation HARDTACK, Project 18.1***
D.F. Hansen, J.E. Perry, A.G. Rockman
Naval Research Laboratory
July 1960 WT-1690

C.1.1737 Test Results for Automatic Yield Indicators, Operation HARDTACK, Project 43.10***
M. Cowan, Jr., D.N. Munro, H.H. Sander
Sandia Corporation
October 1960 WT-1737

C.1.1738 Fireball Yields, Operation HARDTACK, Project 10.1***
J.F. Mullaney, C.P. Cadenhead, R.S. Cooper, R.W. Humphrey
Los Alamos Scientific Laboratory
February 1962 WT-1738

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.1.1742 <u>Effects of Nuclear Radiation on Semiconductor Devices, Operation HARDTACK, Project 6.3A</u>***
W.V. Behrens, J.M. Shaull
Harry Diamond Laboratories
May 1961 WT-1742

Task Group 7.2

C.2 <u>Final Report</u>***
WNRC 66A3264, Box 1

Task Group 7.3

C.3.1 <u>Final Report of the Commander</u>
Mar-Aug 1958
NTIS (MF/A01) AD A078 572*

C.3.2 CTG 7.3 to CJTF 7 <u>History</u>***
March 1 1957-September 1 1957, WNRC 61A-1433 Box 3-176
September 1957-March 1 1958, WNRC 61A-1740 Box 5

C.3.3 After-Action reports to CTG 7.3 filed by the commanding officers of TG 7.3 units are filed in the Washington National Records Center at Suitland, Maryland, under the accession number 61A1740. The reports are in Box 12 with the exception of the HMR(L)-361 report, which is in Box 5, and the <u>Moctobi</u> and Patrol Squadron 28 reports in Box 13. The titles are usually <u>Operations Phase Report</u>, although some are titled <u>Planning and Operation Phase</u>, and other units have separate reports for the planning and operational phase.

C.3.3.1 <u>USNS Fred C. Ainsworth</u>***
C.3.3.2 <u>USS Arikara</u>***
C.3.3.3 <u>USS Belle Grove</u>***
C.3.3.4 <u>USS Benner</u>***
C.3.3.5 Boat Pool Detachment***
C.3.3.6 Boat Pool (TE 7.3.6.4)***
C.3.3.7 <u>USS Bolster</u>***
C.3.3.8 <u>Bonita</u>***
C.3.3.9 <u>USS Boxer</u>***
C.3.3.10 <u>USS Chanticleer</u>***
C.3.3.11 <u>USS Chowanoc</u>***
C.3.3.12 <u>USS Collett</u>***
C.3.3.13 <u>USS Comstock</u>***
C.3.3.14 <u>John R. Craig</u>***
C.3.3.15 <u>USS De Haven</u>***

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.3.3.16 Destroyer Squadron 1***
C.3.3.17 Destroyer Squadron 9***
C.3.3.18 USS Epperson***
C.3.3.19 USS Grasp***
C.3.3.20 USS Hooper Island***
C.3.3.21 USS Joyce***
C.3.3.22 USS Lansing***
C.3.3.23 USS Lawrence County***
C.3.3.24 USS Mansfield***
C.3.3.25 Marine Helicopter Transport Squadron (Light) 361***
C.3.3.26 USS Moctobi***
C.3.3.27 USS Monticello***
C.3.3.28 USS Munsee***
C.3.3.29 Patrol Squadron 28***
C.3.3.30 Radiological Safety and Decontamination Unit***
C.3.3.31 Special Projects Unit***
C.3.3.32 USS Takelma***
C.3.3.33 Technical Coordinating Unit***
C.3.3.34 USS Tortuga***

C.3.4 Ship logs also were consulted for after-action reports. The following ship's logs were located at the Washington National Records Center, Suitland, Maryland. All are unclassified.

C.3.4.1 USNS Fred C. Ainsworth***
C.3.4.2 USS Arikara***
C.3.4.3 USS Belle Grove***
C.3.4.4 USS Benner***
C.3.4.5 USS Bolster***
C.3.4.6 Bonita***
C.3.4.7 USS Boxer***
C.3.4.8 USS Cacapon***
C.3.4.9 USS Chanticleer***
C.3.4.10 USS Chowanoc***
C.3.4.11 USS Cogswell***
C.3.4.12 USS Collett***
C.3.4.13 USS Comstock***
C.3.4.14 USS John R. Craig***
C.3.4.15 USS Cree***
C.3.4.16 USS De Haven***
C.3.4.17 USS Elkhorn***
C.3.4.18 USS Epperson***
C.3.4.19 USS Grasp***
C.3.4.20 USS Hitchiti***
C.3.4.21 USS Hooper Island***
C.3.4.22 USS Joyce***
C.3.4.23 USS Karin***

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

C.3.4.24 USS Lansing***
C.3.4.25 USS Lawrence County***
C.3.4.26 USS Magoffin***
C.3.4.27 USS Mansfield***
C.3.4.28 USS Merapi***
C.3.4.29 USS Moctobi***
C.3.4.30 USS Monticello***
C.3.4.31 USS Munsee***
C.3.4.32 USS Navarro***
C.3.4.33 USS Nemasket***
C.3.4.34 USS Orleck***
C.3.4.35 USS Floyd B. Parks***
C.3.4.36 USS Perkins***
C.3.4.37 USS Rehoboth***
C.3.4.38 USS Renville***
C.3.4.39 USS Safeguard***
C.3.4.40 USS Silverstein***
C.3.4.41 USS Sterlet***
C.3.4.42 USNS T-LST-664***
C.3.4.43 USS Takelma***
C.3.4.44 USS Tillamook***
C.3.4.45 USS Tombigbee***
C.3.4.46 USS Tortuga***

C.3.5 Training Exercise Report***
CTG 7.3
6 July 1958 61A 1433 Box 6 File 84

C.3.6 Memoranda of Calls Deputy CJTG 7.3 to JTG 7.3***

Task Group 7.4

C.4.1 Final Report TG 7.4 Eniwetok,*** WNRC 61A1433, Box 5

C.4.2 Final History Task Group 7.4***

C.4.2.1 History of the Test Services Unit 1958***

C.4.2.2 History of the Weather Rep. and Forecast Element (2 vol)***

C.4.2.3 Final Report Communications Element***

C.4.2.4 Final Report Aerial Photo Element***

C.4.2.5 Narrative Mission Account 24th HELIRON***

C.4.3 History of AF Special Weapons Center (2 for 1958)***

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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

Task Group 7.5

C.5.1 Report of the Manager USAEC/ALO***
WNRC 61A1433, Box 5

C.5.2 Completion Report Operation HARDTACK Phase I***
H&N

C.5.3 TG 7.5 Radiological Safety Support
OTO 58-3
NTIS AD A078 823*

C.5.4 Job Report 942***
Holmes & Narver, Inc.
21 December 1958

OTHER HARDTACK REFERENCES

D.1 United States High-Altitude Test Experiences
H. Hoerlin
Los Alamos Scientific Laboratory
October 1976 LA 6405
NTIS LA 6405*

D.2 Completion Report--Operation Castle***
Holmes & Narver, Inc.
1954

D.3 Radiological Support of Project PACE***
E.L. Kinsley, Maj USAF
AFWL
1 January 1973

D.4 PAGE Committee on Recommendations for Navy Tests on Operation HARDTACK***
Naval Ordnance Laboratory
November 1957 NAVORD 4457

*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

APPENDIX A

RADIOLOGICAL SAFETY DOCUMENTS

Headquarters, Joint Task Force SEVEN
Washington 25, D.C.
1 October 1957

<u>Annex K to JTF SEVEN Operation Plan 1-58</u>

RADIOLOGICAL SAFETY OPERATIONS

1. Radiological safety of all task force military and civilian personnel is a command responsibility and radiological safety activities will be performed through normal command channels.

2. The Commander, Joint Task Force SEVEN will:

   a. Assume overall responsibility for the radiological safety of Task Force personnel and of populated islands.

   b. Inform CINCPAC of radiological hazards which may develop in areas outside the Task Group responsibility.

   c. Furnish technical advisory assistance to Task Group Radiological Safety Officers, to Trust Territory personnel, and to certain other agencies.

   d. Maintain a fallout plotting center (FOPC) with displays of current air and surface radexes, radiological situation maps of atolls, peripheral aerial and surface areas, and such allied data as may be appropriate.

   e. Maintain a fallout prediction unit (FOPU) with the assigned mission of preparing fallout forecasts for each shot.

   f. Establish and maintain radiological monitoring stations on certain populated islands of the Trust Territories of the Pacific Islands.

   g. Arrange for monitors and couriers to accompany radioactive and special cargo shipments on sample return aircraft and to monitor loading and unloading of such cargo.

   h. Subsequent to each detonation, announce "<u>R-Hour</u>". (R-hour is the earliest time after a detonation that general re-entry can commence to all areas except the Radiological Exclusion Area (RADEX).

*********Above paragraph added by Change 2.

3. Task Group Commanders will:

   a. Provide a radiological safety unit within their task group, and insure that this unit is prepared to carry out the radiological safety mission of their respective task group.

   b. Provide necessary special clothing and radiac equipment to include spare parts and repair and calibration facilities. The requirements of TG 7.5 will be included in the allowances of CTG 7.1 for issue to

TG 7.5 personnel as necessary during the operational phase, and for subsequent loan or sale to TG 7.5 for post-operational use at the Eniwetok Proving Ground.

c. Provide CTG 7.1 with a roster to Task Group personnel for the purpose of preparing and maintaining film badges.

4. The Commander, TG 7.1 will:

a. Perform all ground monitoring services associated with scientific missions except those in conjunction with aircraft and airborne collection of scientific data. Conduct the initial post-shot radsafe and damage survey.

*********Last sentence added by Change 4.

b. Provide laboratory services and technical assistance to all task groups, to include:

(1) Provision of standard-type film badges and specified supplementary items of personnel radiological safety equipment.

(2) Laboratory services to develop and interpret film badges.

(3) Record of exposures from film badges.

(4) Laboratory services for the radiochemical analysis of water samples.

(5) Monitoring the removal and packaging of radioactive sources and samples, except as indicated in paragraph 4.a., above.

c. Provide radiological safety surface situation maps after shot times to the JTF SEVEN Headquarters and task group commanders.

d. Provide technical personnel to assist task group commanders in the inspection of radiologically contaminated items and the certification of destruction, disposal or unserviceability of such items, as required.

e. Maintain radiological safety centers (RADSAFE CENTER) as necessary for the control of TG 7.1 RadSafe Operations at BIKINI AND ENIWETOK.

f. Provide personnel and equipment decontamination facilities for radiological safety recovery and survey operations.

*********Above paragraph deleted by Change 1.

f. At a time mutually agreeable between CTG 7.1 and CTG 7.5 assume operational control of the rad-safety facilities and services presently being maintained by the AEC support contractor.

*********Above paragraph substituted by Change 1.)

g. Assume radiological safety responsibilities of TG 7.5 during the operational phase.

*********Above paragraph deleted by Change 1.

g. Maintain close liaison with TG 7.5 on all rad-safety matters of mutual interest. The assignment and supervision of support contractor personnel on common services, such as dosimetry, decontamination, and instrument repair, will be accomplished by agreement between CTG 7.5 and CTG 7.1.

*********Above paragraph substituted by Change 1.

h. Integrate, within TG 7.1, key radiological safety personnel made available by CTG 7.5. Such personnel will assist CTG 7.1 during the operational phase and will be assigned duties consistent with their training in radiological safety.

*********Above paragraph deleted by Change 1.

5. The Commander, TG 7.2 will:

a. Perform all ground monitoring services associated with FRED Island except in those areas or activities assigned to other task groups.

b. Provide own radiological safety monitors and decontamination personnel.

c. Upon approval of CJTF SEVEN, make available through Army Depot Supply, on requisition to all task groups, military radiac equipment and spare parts, high density goggles, and special clothing, including shoes.

d. Provide laundry facilities for contaminated clothing for TG 7.4.

e. Provide contaminated miscellaneous equipment storage area with the necessary security.

6. The Commander, TG 7.3 will:

a. Provide monitors and decontamination crews aboard each ship within the task group.

b. Provide own radiological safety monitors including one airborne monitor for each multi-engine aircraft crew assigned to TG 7.3.

c. Provide facilities for personnel decontamination aboard ship, as required.

d. Provide space aboard ship for the radiological safety unit of TG 7.1.

e. Provide decontamination crews for all aircraft at BIKINI Atoll.

f. Provide necessary helicopter air service for radiological surveys and post-shot recovery operations at BIKINI (monitors furnished by TG 7.1).

g. Collect lagoon water samples, when and as directed.

h. Provide water spray equipment aboard all vessels likely to be in the fallout area.

i. Provide radiological aerial reconnaissance service in the vicinity of the Task Force Fleet and Shot Atoll for a period of six hours commencing at H-Hour.

j. Provide aircraft for post-shot aerial radiological survey of the Northern Marshall Islands starting at approximately H plus six hours. Reports will be prepared in accordance with paragraph 7.h., below.

k. Provide for air-to-ground reporting to approximate air radiation intensities encountered by all TG 7.3 aircraft operating between ENIWETOK AND BIKINI from H-hour to H plus 24 hours. It is not contemplated that aircraft should be scheduled for this specific requirement alone.

l. Ensure that re-entry of ships into the lagoon after a detonation does not commence until "R-Hour" is announced.

*********Above paragraph added by Change 2.

7. The Commander, TG 7.4 will:

a. Provide own radiological safety monitors, including one airborne monitor for each multi-engine aircraft crew assigned to TG 7.4.

b. Provide for and supervise personnel and aircraft decontamination on FRED Island.

c. Provide necessary helicopter and liaison air service for radiological surveys and post-shot recovery operations at ENIWETOK Atoll (monitors furnished by TG 7.1.

d. Provide cloud tracking aircraft for post-shot radiological safety "situation data" up to radius of 500 miles in the significant quadrant for a period of 48 hours, starting at approximately H plus six hours. Reports will be prepared in accordance with paragraph 7.h., below.

e. Provide monitoring services and crews for the removal of radioactive samples or data collected by aircraft.

f. Provide aircraft for post-shot aerial radiological survey of the Northern Marshall Islands starting at approximately H plus six hours. Reports will be prepared in accordance with paragraph 7.h., below.

g. Provide for the reporting of radiation intensities encountered at outlying weather stations.

h. Report approximate air radiation intensities encountered on regularly established weather reconnaissance or cloud tracking flights, and from aircraft operating between ENIWETOK and BIKINI from H-Hour to H plus 24 hours. Reports will indicate the approximate position, altitude and order of magnitude of radiation encountered.

8. The Commander, TG 7.5 will:

a. Develop a schedule of requirements for radiological safety services required from CTG 7.1 and assist CTG 7.1 in the decontamination of AEC facilities and equipment, as necessary.

*********Above paragraph deleted by Change 1.

a. At a time mutually agreeable between CTG 7.1 and CTG 7.5, relinquish to CTG 7.1 the operational control of the rad-safety facilities operated during non-test periods by the AEC support contractor.

*********Above paragraph substituted by Change 1.

b. Provide key radiological safety personnel for integration into and training with the radiological safety organization of TG 7.1 during the operational phase. The total number and qualifications of such personnel will be as determined necessary by CTG 7.5, commensurate with the assumption of responsibilities indicated in paragraph 8.c., below.

*********Above paragraph deleted by Change 1.

b. Maintain close liaison with CTG 7.1 on mutual rad-safety matters during the operational phase. Support contractor personnel will be assigned to work as mutually agreed between CTG 7.1 and CTG 7.5. The total number and qualifications of TG 7.5 personnel will be as determined necessary by CTG 7.5, commensurate with the assumption of responsibilities indicated in paragraph 8c below.

*********Above paragraph substituted by Change 1.

c. Assume residual task force radiological safety functions at the Eniwetok Proving Ground upon completion of the operational phase. Required equipment and supplies will be made available at that time to CTG 7.5 on a loan or sale basis from stocks provided by CTG 7.1.

*********Above paragraph deleted by Change 1.

c. At a time mutually agreeable between CTG 7.1 and CTG 7.5 resume operational control of rad-safety facilities and services. Required equipment and supplies will be made available at that time to CTG 7.5 on a loan or sale basis from stocks provided by CTG 7.1.

*********Above paragraph substituted by Change 1.

d. Provide own rad-safety monitors for support of TG 7.5 operations.

*********Above paragraph added by Change 1.

HEADQUARTERS, Joint Task Force SEVEN
Arlington Hall Station
Arlington 12, Virginia
8 February 1958

Appendix 1 to Annex K to JTF SEVEN Operations Plan No. 1-58

RADIOLOGICAL SAFETY REGULATIONS

1. RADIOLOGICAL SAFETY OFFICE AND CENTER

a. A JTF SEVEN Radiological Safety Officer (RADSAFE OFFICE) and a TG 7.1 Radiological Safety Center (RADSAFE CENTER) will be established and maintained. The RADSAFE OFFICE, composed of the Task Force RadSafe Section, the Fallout Prediction Unit (FOPU), and Fallout Plotting Center (FOPC), will operate as the task force staff agency responsible for the operation of the off-atoll RadSafe program, dissemination of shot briefing material and the maintenance of displays of radiological information. The RADSAFE CENTER will be established by CTG 7.1 and will serve as operations headquarters for the radiological safety activities of TG 7.1.

b. Detailed Duties

(1) RADSAFE OFFICE

(a) The RADSAFE OFFICE will disseminate the air and surface RADEX prior to shot time (forecast), and will originate messages from time to time after shot time announcing R (Reentry) hour, radiological clearances of previously closed areas, radiological directives to task groups, advisories to commands external to the task force and revisions of the air and surface RADEX, as required.

(b) The RADSAFE OFFICE (FOPU) will be responsible for the preparation of RadSafe forecast information (fallout plot, surface and air RADEX) for each shot.

(c) The RADSAFE OFFICE (FOPC) will maintain displays of radiological information pertinent to the test area, and having an impact outside this area to include radiation levels on atoll islands and lagoon. RADEX information, cloud trajectories and their relation to occupied atolls, air and surface routes continguous to the danger area, ship movements in the danger area, results of water sampling and such other items of special radiological consideration as may be required by the operation or the scientific projects.

(d) Physical location of RADSAFE OFFICE:

1 Operations Division (J-3), JTF SEVEN Headquarters Building, PARRY Island.

(2) RADSAFE CENTER

(a) The RADSAFE CENTER will maintain radiological situation data on lagoon waters and islands of the shot atoll, based on air and ground survey information, supplemented by monitor reports. This information will be the basis of the periodic situation reports or maps and briefing information furnished to the Task Force and Task Group Commanders.

(b) The RADSAFE CENTER will provide information for the planning of TG 7.1 radiological safety operations and for the disposition of all working parties within the contaminated area. It will establish radiological safety check points. It will maintain an operations table giving details for all groups who plan to enter contaminated areas each day, including name of monitor, destination, general type of mission (program of project number) and time of departure and return.

(c) The RADSAFE CENTER will provide special clothing to previously designated recovery personnel, have cognizance over working schedules of the radio chemical laboratory, photodosimetry developing facilities, contaminated laundry, personnel decontamination facilities, radiac repair, etc., of TG 7.1. Personnel decontamination facilities afloat will be coordinated with existing ship facilities.

(d) Physical Location of RADSAFE CONTROL:

<u>1</u> For BIKINI Atoll shots: The RADSAFE CENTER will be in the RadSafe Building (No 196) on ENYU (NAN) Island. During evacuation periods prior to shots, RadSafe Control will be maintained from the USS BOXER.

<u>2</u> For ENIWETOK Atoll shots: THE RADSAFE CENTER will be in the RadSafe Building (No 323) on PARRY (ELMER) Island.

2. GENERAL

a. Radiological Defense (RadDefense) Operations or Radiological Safety (RadSafe) Operations, short term RadOps, are general terms. They are used to denote the means by which a unit can control and confine the damage and radiological effects of an atomic explosion or of avoiding health hazards to personnel. They are interpreted to include measures such as training, organization, distribution of radiological personnel, development of techniques and procedures, use of detecting equipment, protection or removal of exposed personnel and decontamination of personnel, structures and equipment.

b. Following each detonation there will be areas of surface radiological contamination and areas of air radiological contamination. These areas are designated as Radiological Exclusion Areas (RADEX). Prior to shot times, the forecast air and surface RADEX will be disseminated by CJTF SEVEN in the target area. These RADEXES will represent a forecast from H-Hour until dissemination of a later surface and air RADEX at about H plus 6 hours. The later RADEXES will be based upon the master radiological "situation map" maintained in the RADSAFE OFFICE of CJTF SEVEN. Since the air RADEX after shot times will be based on monitored tracking by aircraft over significant large ocean areas, information promulgated from the forecast air RADEX may have to be extended beyond the originally anticipated six-hour period.

c. The surface RADEX will be determined by actual survey with Radiation Detection, Indication and Computation (RADIAC) equipment after shot time. The most rapid method of accomplishing surface surveys in the early stages will be by aircraft and helicoper flight in and around the surface of contaminated areas. From the radiation intensities measured at a known altitude, it is possible to obtain an estimate of radiation dosage rates which would be encountered on the surface of the ground or water. Actual water samples from the lagoon will also be utilized. Ground survey will follow these guides to determine definitely the contaminated regions and objects. Formal ground survey of the shot atoll, as feasible, will be accomplished on H plus 24 hours.

3. The Maximum Permissible Exposures (MPE's) and Maximum Permissible Limits (MPL's) as stated herein are applicable to a field experimental test of nuclear devices in peacetime wherein numbers of personnel engaged in these tests have been previously exposed or will be continuously exposed to potential radiation hazards. It may become necessary from a study of personnel records to reduce the MPE for certain individuals who have recently been over-exposed to radiation.

4. Due to the special nature of field tests it is considered that a policy of strict adherence to the radiological standards prescribed for routine work is not realistic. The regulations set forth herein have been designated as reasonable and safe compromise considering conservation of personnel exposures, the international import of the test and the cost aspects of operational delays chargeable to excessive radiological precautions. In all cases other than emergencies or tactical situations the ultimate criteria will be limited by the MPE's for personnel. Special instances may arise such as in the case of an air-sea rescue within the RADEX in which operations will be carried out without regard to the MPE's and MPL's prescribed herein.

5. Task Force radiation dosage control will start on first shot ready date minus fifteen days and terminate upon departure of individuals from the forward area, or on the last shot plus fifteen days, whichever occurs first. All personnel will be considered to have arrived at the Eniwetok Proving Ground by first shot ready data minus 15 days. Prior and subsequent to this period, radiation dosage control will be as prescribed by CTG 7.5.

RADIOLOGICAL SAFETY REGULATIONS

6. MPE

a. MPE for personnel participating in this operation is 3.75 roentgens (gamma only) per consecutive 13 week period, with a maximum of 5.0 r for the Operation.

b. A special MPE of 10 roentgens (gamma only) is authorized for the operational period for crew members of air-sampling aircraft.

(1) In event of operational error or emergency an additional dose of 10 roentgens (gamma only) will be accepted.

(2) Any dose in excess of this 20 roentgens total will be considered as an over-exposure and will be properly accounted for in writing by the Commander of the unit.

7. Authorization for individual exposures in excess of the established MPE will be granted only by the Commander, JTF-7 and only in specific cases for which operational requirements provide justification.

8. In view of existing recommendations of the National Committee on Radiation Protection and the International Commission on Radiological Protection and those proposed by these bodies for the very near future the MPE for all personnel participating in this Operation is limited as follows. Personnel whose previous radiation dose history indicates that their total accumulated dose to 1 January 1958 is equal to or in excess of the age-prorated dose (defined as: 5 rem [present age in years minus 18 years]) will under no conditions be allowed to receive a total dose in excess of 5 rem under the conditions as described in para 6 a. & b. above, and provided his total accumulated dosage does not or will not exceed 50 rem on his 30th birthday.

9. Those individuals exposed to ionizing radiation in excess of the value computed by para 6 a. above, will be informed that appropriate remarks will be included in their medical records. Military personnel in this category will be advised that they should not be exposed to further radiation until sufficient time has elapsed in order to bring their average radiation dose down to 0.3 roentgens per week. Civilian personnel in this category will be informed that limitations on further radiation exposure will be as determined by the laboratory or agency having administrative jurisdiction over such personnel.

10. All atoll land and lagoon areas in or near which a detonation takes place will be considered contaminated until cleared for operations by the Task Force Commander. Entry to and exit from contaminated areas will be via RadSafe check points only.

11. Contaminated land and water areas will be delineated as such. Personnel entering these areas will be subject to clearances by the RadSafe Center, TG 7.1, and will normally be accompanied by a RadSafe Monitor. RadSafe clothing and equipment will be issued to the personnel.

12. Contaminated land areas of intensities less than 10mr/hr (gamma only) will be considered unrestricted from a RadSafe standpoint. Areas coming within this limitation will be designated specifically by CJTF SEVEN prior to unrestricted entry.

13. RadSafe monitors assigned to individuals or groups working in contaminated areas or within contaminated equipment during recovery operations will act in an advisory capacity to keep the recovery party leader informed of radiation intensities at all times. The recovery party leader is expected to accept this advice and act accordingly. It is the responsibility of both the leader and the members of the recovery party to adhere to the limits established in these regulations.

14. Film badges, dosimeters and protective clothing (coveralls, booties, caps, gloves, dust respirators, etc.,) as deemed necessary will be issued to personnel entering contaminated areas by appropriate task group RadSafe supply sections.

15. All personnel within viewing distance of an atomic detonation who are not supplied with protective goggles will turn away from the detonation point and close their eyes during the time of burst. At least ten seconds should be allowed before looking directly at the burst.

16. The arrival and proposed use of radioactive sources at the Eniwetok Proving Ground will be reported to the RadSafe Officer of TG 7.1.

17. Transportation of radioactive material to and from the forward area shall be in accordance with AEC regulations for escorted shipment of such material. The assignment of couriers and RadSafe monitors will be subject of separate instructions. No radioactive material shall be removed from the test site except as authorized in experimental projects.

18. All samples of radioactive material which are couriered in aircraft will be packaged and loaded so as to reduce radiation to a minimum. Prior to departure of such aircraft, Sample Return Director, JTF SEVEN will have a survey made of the aircraft cargo to determine if adequate precautions have been taken. The following criteria will determine space and packaging requirements:

    a. Prior exposure of aircraft crew, courier and passengers.

    b. Anticipated future exposures on trip, considering length of trip, compartmental loading requirements and capability to isolate personnel from radioactive material.

19. All air and surface vehicles or craft used in contaminated areas will be checked through the appropriate task group decontamination section upon return from such areas.

RADIOLOGICAL SAFETY REGULATIONS

20. The MPL's listed herein are to be regarded as advisory limits for control under average conditions. All readings of surface contamination are to be made with Geiger Counters, with tube walls not substantially in excess of 30 mg/cm^2 with shield open unless otherwise specified. The surface of the probe should be held one inch to two inches from the surface that is under observation unless otherwise specified. For operational purposes the contamination MPL's presented below will not be considered applicable to spotty contamination provided such areas can be effectively isolated from personnel.

   a. Personnel and Clothing MPL's:

      (1) Skin readings should not be more than 1.0 mr/hr. Complete decontamination by bathing will be utilized for readings in excess of this level. If the body is generally contaminated and especially if contamination is on the eyes or gonads, special efforts should be made to reduce the contamination levels. In general, however, it is not considered profitable to abrade the skin or epilate the scalp in an attempt to reduce stubborn contamination below 1 mr/hr (about 1000 cpm).

      (2) Underclothing and body equipment such as the internal surfaces of respirators should be reduced to 2 mr/hr.

      (3) Outer clothing should be reduced to 7 mr/hr.

   b. Vehicle MPL's: The interior surfaces of occupied sections of vehicles should be reduced to 7 mr/hr. The outside surfaces of vehicles should be reduced to less the 7 mr/hr (gamma only) at five or six inches from the surface.

   c. Ship and Boat MPL's:

      (1) Ship and boat MPL's cannot be quantitatively established. They are dependent upon location of contamination, use of space, personnel hazard, etc. Specified instructions will be issued by CTG 7.3 upon reporting of contamination as required by para 2 d. of Appendix 4 to Annex G.

      (2) For ships and boats operating in contaminated waters, reasonable allowances will be made to differentiate between the relative contribution to the total flux from fixed contamination and that due to "shine" from contaminated waters.

      (3) In general, ships and boats operating in waters near shot sites after shot times may become contaminated. Monitors shall be aboard all such craft operating after shot time, either as passengers or members of the crew, until such time as radiological restrictions are lifted.

(4) At the conclusion of the operation, final clearances will be granted by task group commanders or by commanding officers, if so ordered, to those ships and boats showing no point of contamination greater than 15 mr/day (beta and gamma) and no detectable alpha. Other ships and boats will be granted operational clearances by task group commanders or by commanding officers if so ordered. An operational clearance implies that contamination exists and that special procedures as necessary are instituted aboard ship.

(5) Individuals on board ships of the Task Force shall be protected collectively from hazards of blast, heat, and radioactivity by movement and positioning of ships.

(6) Ships with personnel aboard will not be placed inside the 1.0 psi line unless specifically directed otherwise. Bearings of danger from immediate radioactive fallout for ship operations will be established by CJTF SEVEN on the basis of forecast wind directions at the intended time of detonation.

d. Aircraft MPL's:

(1) The interior surfaces of occupied sections of aircraft should be reduced to 7 mr/hr.

(2) No aircraft in the air at H-Hour will be at slant ranges from ground zero less than as determined by the following effects unless specifically directed otherwise. (Based on maximum predicted yield and 20 mile visibility.)

(a) Blast (at predicted shock arrival): 0.5 psi.

(b) Thermal (H-Hour): Fabric control surfaces: 1.0 cal/cm^2

Metal control surfaces: 6.0 cal/cm^2

(3) After detonation no aircraft shall operate inside the air RADEX, or closer than 10 nautical miles from the rising or visible cloud, unless specifically directed otherwise. Non-expected aircraft involved in routine operations encountering unexpected regions of aerial contamination will execute a turnout immediately upon detecting such contamination. Cloud tracking aircraft will execute turnout from contaminated areas at a level of not more than 3.0 r/hr. If a tactical or emergency situation arises where aircraft must enter the air RADEX or visible cloud, tactical exposure allowances shall apply.

(4) All multi-engine task force aircraft in the air at H-Hour within 100 miles of the detonation point shall carry a person designated

as radiological safety monitor, equipped with suitable radiac equipment and a RADEX plot. This monitor shall be capable of calculating allowable exposures under both tactical and operational conditions.

(5) All persons in aircraft at shot time, or at subsequent times, shall wear film badges when engaged in operations in or near the cloud or RADEX track.

(6) Crew members of aircraft in the air at zero hour will take special precautions to avoid (for at least 10 seconds) the direct and reflected light resulting from the burst, at the discretion of the airplane commander. This may be accomplished by protective high density goggles, by turning away from the burst with eyes closed, by covering the eyes with the forearm, by turning cockpit lights up to highest intensity or by any combination of the above.

21. In air and water the following continuous levels of radioactivity are considered safe from the standpoint of personnel drinking and breathing (μCi-microcurie):

Water   Beta-Gamma Emitter

5×10^{-3} μCi/cc (calculated to H plus 3 days)

22. The RadSafe Officer, TG 7.1 will maintain standard-type film badge records of radiation exposures for all task force personnel. Records will indicate full name, rank or rate, serial or service number, if applicable, organization, home station or laboratory, date of exposure and remarks such as limitations on assignment because of over-exposure. Upon completion of the operation, disposition of these records will be as follows:

a. A consolidated list of exposures listing all personnel in the Task Force by full name, rank or rate, serial or service number, if applicable, organization, home station or laboratory and exposure in milliroentgens, will be forwarded to the Chief, AFSWP.

b. A consolidated list of personnel and exposures, as indicated in para 2 a. above, will be forwarded to the Director, Division of Biology and Medicine, AEC.

c. A consolidated list of personnel and exposures of each task group will be forwarded to each Task Group Commander.

(1) Upon receipt of this list, Task Group Commanders will forward the individual records of Navy and Air Force military and civilian personnel to the individual's unit of permanent assignment for inclusion in the individual's health record (Medical History Sheets, Standard Form 600 and the Individual Health Record for Navy and Air Force personnel, respectively). For those military personnel exposed to ionizing radiation in excess of that defined

in para 6 above, a statement will be included to the effect that the individual is not to be subjected to ionizing radiation before a specific date, the date to be computed by the Task Group RadSafe Office, to allow sufficient time to elapse in order to bring the average dose down to 0.3 roentgens per week. Limitations on Navy and Air Force civilian personnel with reference to over-exposures will be as determined by the laboratory or agency having administrative jurisdiction over such personnel.

(2) Individual records of Army military and civilian personnel will be forwarded to Task Group Commanders in accordance with AR 40-414 dated 26 November 1957 to their unit of permanent assignment for inclusion in the individual's field military 201 file, or the civilian personnel 201 file (whichever is applicable). These records will indicate total exposure and inclusive dates and a space for remarks such as limitations on assignment (as indicated in para 6 above) because of over-exposure.

d. Individual records of AEC controlled and administered civilian personnel will be processed by Task Group Commanders in accordance with special instructions prescribed by the laboratory or agency having admininstrative jurisdiction over such personnel.

e. Upon completion of provisions of para 22 a.b.c. above, letter reports will be submitted by Task Group Commanders through channels to the Surgeon General, USA; the Chief, Bureau of Medicine and Surgery, USN; the Surgeon General, USAF, and the Director, Division of Biology and Medicince, AEC, indicating, in general, the action taken to dispose of individual dose records, comments on over-exposures, if applicable, and any pertinent remarks considered of interest to the above offices.

f. All exposed film badges, calibration films and curves, and cumulative dosage record cards for all personnel in Joint Task Force SEVEN will be forwarded by RadSafe Office, Task Group 7.1, to the Director, Test Division, Albuquerque Operations Office, AEC, for permanent retention and storage.

23. Training: The inclusion of radiological safety organizations through the Task Force will require two general levels of training; Basic Indoctrination and Technical Training. The scope of instruction within each of these levels will vary in accordance with the requirements of different operational and staff levels. Basic indoctrination will include primary, nontechnical instruction in radiological safety measures and techniques. This must be imparted to all personnel of the Task Force to enable them to perform their assigned duties efficiently within the allowable low exposures regardless of the presence of radioactive contaminants. Techncial training will include the training of the majority of the personnel who will be required to staff the Task Force Radiological Safety Organizations and perform the technical operations involved. This will be accomplished through the utilization of existing Service courses and establishment of suitable courses at task group level. This instruction will be designed to train

radiological defense monitors, decontamination personnel and radiological instrument repairmen.

24. These regulations have the concurrence of the Surgeon General, USA; Chief, Bureau of Medicine and Surgery, USN; the Surgeon General, USAF, and the Director, Divison of Biology and Medicine, AEC.

25 May 1958

MEMORANDUM

From: 32
To: 01
Via: 30, 33

Subj: Factors to be considered in early recovery and early reentry

1. There is no limit on the intensity of the radiation field into which a person can enter. There is however the practical limit that he must enter the field, perform his mission, and remove himself from the field without overexposure.

2. Project personnel who are being used specifically for the recovery can of course be exposed to the total allowable dose of 3.75 r. For Decon, Special Projects and Boat Pool personnel of Task Group 7.3 a one-time exposure as above is not feasible since they are required to remain in the area for several tasks.

3. It is recommended that we furnish boats with monitors to transport the early recovery personnel to their desired location. On entry, the boat coxswain should take his advice from the project monitor and if project personnel desire delivery to a target he should comply with their desires. Upon delivery of the personnel, the boat, if not required alongside, should lie off the target and wait for the project personnel. At this time the boat coxswain should take advice from the 7.3 monitor as to the safest location to wait. In no case is he to proceed further away from the target ship than hailing distance. He must maintain a careful watch for recall by the personnel aboard the target. The boat will not leave the target area until all personnel are removed from the target.

4. The only factor which must be considered in the exposure to ships and boats is the buildup of background aboard due to the assimilation of radioactivity in the salt water systems due to steaming in hot water. From the experience gained by the MOCTOBI the buildup factor does not appear to be too great. The maximum intensity remaining aboard after steaming in water of about an average of 1 r/hr for one half hour was only 75 mr/hr. This was one isolated spot at the salt water intake valve. By assuring that personnel maintained a safe distance from this hot spot, normal ships operations were continued.

5. It is recommended that upon completion of the initial radsafe survey by TU-6 the ships and boats of Task Group 7.3 be authorized by CTG 7.3 to proceed on their assigned missions, obtaining the radiological picture and advice from the monitors assigned. As an arbitrary figure it is recommended that stay times for ships be computed so that the maximum dose to anyone on boat is 2.0 r. This figure should allow for a fairly realistic amount of time in the area and still allow some dosage to these personnel for subsequent operations following U Day.

6. The Task Group 7.3 Special Projects personnel should remain clear of the area on U Day as they will be required to get the ships ready for tow and hence must have some dosage available.

7. I do not recommend that any decontamination be attempted on U Day. The Task Group 7.3 DeCon personnel should be saved for subsequent days allowing for some decay to take place before they are exposed.

8. It is recommended that the only tasks that be attempted on U Day are as follows:

a. Gross radiological survey using one ship.

b. Pickup of required water sample.

c. Any early recovery required by projects. This recovery should be planned without the use of ships power. However, ships power might be available by use of diesel generator.

9. It is strongly recommended that recovery of instruments and Decon not be attempted concurrently. A much more thorough and rapid decontamination can be performed if the ship is turned over for decon alone.

10. Early decon of the targets will result in a much smaller dosage to the personnel going aboard thereafter, to recover instruments and make the ships ready for tow.

11. Boats should be assigned for each specific task to be performed. Under no circumstances, until full rasdafe picture can be determined by a detailed survey, should boats be called away from a target ship or directed to another target and leave personnel aboard a radex ship.

12. For radiological safety, of all personnel involved, it is strongly recommended that the dispatching of boats be vested in one individual only and this individual designated in our Op-Order.

APPENDIX B

HARDTACK PERSONNEL EXPOSURE UNIT-IDENTIFICATION CODES

THE RECORDING SYSTEM

The processing of personnel film badge records was a semiautomated process during HARDTACK. The film was developed manually, but the reading of the developed density of the film was done by machine and the equivalent gamma exposure was then automatically punched into an IBM card that had been prepunched (or was subsequently punched) manually with the 8-digit identification number of the man who wore the badge. The purpose of this appendix is to discuss this 8-digit identification number or code.

After punching, the cards were then read into magnetic tapes that were processed by an IBM 704, a large, general-purpose computer, which in 1958 was a top-of-the-line scientific machine. It had been brought to the EPG for the use of the task force and placed in a specially constructed building on Parry (Bldg 453) that provided the air-conditioning required by the vacuum tube computers. This computer then made up the lists of exposures. Data could be transmitted to and from Bikini so that cards could be read into the computer from there and Bikini could receive data from which lists could be generated by a local printer. The computer could have been easily programmed to be capable of making lists sorted by organization, by name, and by exposure. The Radsafe Officer noted that daily lists were provided automatically at the time of the update of the tape. At the end of the operation the contents of the tape were printed out by the computer using a program that sorted the data by Task Group, by Task Unit, by an arbitrary code, and then alphabetically by the man's name. This list is apparently the one in the Washington National Record Center, Suitland, Maryland, which is designated as the Consolidated List of Exposures (Reference 1) in this report.

THE IDENTIFICATION CODES

The Consolidated List devotes a single line for each man and the format is as follows:

TG 7.1 TU 2 ORG 03 ID=1234 DOE JOHN A TOTAL DOSE=01111

The underscores in the example above indicate how the 8-digit identification number assigned to each man was used. The first digit was the man's Task Group with the exception that the JTF 7 Hq personnel were identified as "TG 7.6," a subordinate organization that did not exist. Why this was used instead of the zero one would expect is not clear. The second, third, and fourth digits were used differently in the several Task Groups. In TG 1 the second digit meant just what the Consolidated List said; that is, it indicated the badge wearer's Task Unit, and the third and fourth were used for organizational identification. This was not exactly how the remaining Task Groups assigned the identification numbers, but all used the last four of the eight digits for a man's individual identification number within an organization.

Unfortunately, the program used to list the exposures (and indeed they were exposures in spite of the Consolidated List's notation "TOTAL DOSE" was deficient in that it did not provide a key to the codes. It has been necessary to refer to documents of the era, which purport to give the key to portions of the Consolidated List. These documents have proved adequate, but there do appear to be exceptions and conflicts when the actual names listed for each code are examined.

In addition to the problems introduced by coding the organizational identities and not providing an intrinsic decoder, the system was vulnerable to errors. A single keystroke error could either assign a man's exposure to another man in his own organization or to a man in another organization in a different Task Unit or even a different Task Group. It could also create a new organization depending on which digit was miskeyed. Apparently it could not create a new man, since each number on the Consolidated List has a name attached; whereas it is apparent that a few organizations on the Consolidated List were created by keypunch errors. The commander of TU 7.1.6 (Radsafe) noted in his report that "the majority of the errors . . . resulted from improper assignment of the eight digit identification numbers" (Reference 2).

What follows is a list of the codes found on the Consolidated List with what current research indicates is the proper organization. If there are no remarks, the current work basically agrees with or accepts what the contemporaneous documents may have had. Note should be made of the fact that the Consolidated List dose not show rank, serial number, or service branch. This deprives the current investigation of a tool that could help verify these assumptions on the code meanings. The number of men from each organization is shown in parentheses following the organization number.

TASK GROUP 7.1

Two lists of the codes used for TG 7.1 have been found. One is titled Index of Organizations (Reference 3) and is on a microfilm file of JTF 7 material held by the Reynolds Electrical and Engineering Company, Inc. and the other was sent by the USAF Surgeon General to the Navy Surgeon General in January 1959 (Reference 4). The deficiency with the Index as a decoding key is that it was made up before the operation began, before TG 7.1 moved to the EPG from its home at LASL, and did not reflect exactly how the codes were used in the field. The list transmitted by the USAF letter is substantially identical to the TG 7.1 Index as it was apparently derived from it rather than being derived from the actual use of the codes, contrary to what one might gather from the date of transmittal.

A field-expedient measure that may have been devised to take care of organizations whose presence at the EPG was perhaps unanticipated was the badging of their personnel as belonging to a sponsoring or related organizations. This makes counts of personnel by organizational affiliation somewhat fuzzy. However, the Index is very usable and forms about the only basis possible to begin the enumeration of the organizational participation in TG 7.1.

Note that in TG 7.1, the second digit was the Task Unit and the third and fourth were the organization. The organization's number was dependent on the

Task Unit. That is, there were as many organizations designated as 01 as there were Task Units in TG 7.1. The codes were as follows:

Task Unit 1

Org 01	(235)	Los Alamos Scientific Laboratory (LASL)
02	(29)	Naval Research Laboratory (NRL); see also TU 3 Org 12

Task Unit 2

Org 01	(388)	University of California Radiation Laboratory (UCRL); see also TU 6 Org 3 and TU 7 Org 4
02	(7)	Sandia Corporation
07	(1)	Not assigned in the Index. Lack of sequence suggests key-punch errors.
22	(1)	

Task Unit 3

Org 01	(49)	Naval Ordnance Laboratory (NOL) amd Army Waterways Experiment Station (WES). This code was preassigned to NOL, but at least four WES personnel who worked on an NOL project were badged under this code.
02	(2)	Engineer R&D Laboratory, Ft. Belvoir
03	(15)	Not assigned but seems clearly to be Naval Electronics Laboratory (NEL), San Diego
04	(10)	Scripps Institution of Oceanography (SIO) and Office of Naval Research (ONR). In the Index, SIO only was assigned but ONR had at least one man with this code.
05	(2)	Aberdeen Proving Ground (APG). See also TU 7.1.3 Org 37, Ballistic Research Laboratories (BRL), APG.
06	(29)	Stanford Research Institute (SRI)
07	(3)	Air Force School of Aerospace Medicine (AFSAM). Index assigns to AFSWC.
08	(44)	Air Force Cambridge Research Center (AFCRC). See also Org 34 (Ionospheric Physics Lab, AFCRC) and TG 7.4 Org 09.
09	(8)	Armour Research Foundation (ARF)
10	(81)	Naval Radiological Defense Laboratory (NRDL)
11	(29)	Chemical Warfare Laboratory (CWL), Army Chemical Center. See also Org 45.
12	(17)	Naval Research Laboratory (NRL).
13	(21)	Underwater Explosion R&D Laboratory (UERD), Norfolk Navy Shipyard.
14	(7)	Naval Civil Engineering Laboratory (NCEL).

15 (13) David Taylor Model Basin (DTMB).

16 (2) Army Waterways Experiment Station (WES); see also TU 3 Org 01

17 (9) Navy Bureau of Ships (BuShips). See also Org 39.

18 (50) Wright Air Development Center (WADC) and WADC contractors Allied Research Associates (ARA) University of Dayton Research Institute (UDRI). The code was preassigned to WADC only. For WADC see also TG 7.4 Org 04.

19 (72) Naval Air Special Weapons Evaluation Facility (NASWEF) and contractors Douglas Aircraft and North American Aviation (NAA).

20 (15) Diamond Ordnance Fuze Laboratory (DOFL)

21 (15) Evans Signal Laboratory (ESL)

22 (20) Mine Defense Laboratory (MDL)

23 (6) Naval Materials Laboratory (NML)

24 (8) Edgerton, Germeshausen & Grier (EG&G), Las Vegas; see also TU 5 Org 01, 02.

25 (0) Assigned to BuAer on Index but none badged.

26 (0) Assigned to Cooper Development Corporation but not used. See Org 41.

27 (8) Sandia Corporation; see also TU 2 Org 1, and TU 4 Org 01.

28 (91) Army Ballistic Missile Agency (ABMA)

29 (5) University of Illinois

30 (29) Boeing Airplane Co.

31 (0) Assigned to BuAer rep at NAA but not used

32 (0) Assigned to Navy Bureau of Yards and Docks but not used.

33 (104) Armed Forces Special Weapons Project (AFSWP); see also TU 7 Org 05.

34 (2) Ionospheric Physics Lab, AFCRC. See also Org 08.

35 (1) Mercury, Nevada (NTS). The organizational meaning of this place name is not understood.

36 (4) Douglas Aircraft, Long Beach, California

37 (15) Ballistics Research Laboratories (BRL), APG, Maryland. See also TU 7.1.3 Org 05.

38 (9) University of Washington Fisheries Laboratory

39 (3) Navy Bureau of Ships (BuShips). Index shows Navy Bureau of Ordnance, but personnel identified appear to be BuShips. See also Org 17.

40 (24) Army Signal R&D Laboratory (SRDL), Ft. Monmouth, New Jersey

41 (6) Cooper Development Corporation, Monrovia, California. Index assigns to ONR.

42 (5) TRW Space Technology Laboratories (STL). Index says AF Ballistic Missile Division, which sponsored TRW work.

43 (10) Navy Hydrographic Office (HO).

44 (2) Not assigned and identification of two men on the list has not been made. Unknown organization.

44 (6) Not assigned but men appear to be from Army Chemical Warfare Lab (CWL) (Org 11).

Task Unit 4

Org 01 (177) Sandia Corporation; see also TU 2 Org 02 and TU 3 Org 27.

Task Unit 5

Org 01 (106) EG&G, Las Vegas; see also TU 3 Org 24

02 (122) EG&G, Boston

24 (1) Not assigned, probably keystroke error.

Task Unit 6

Org 01 (20) Los Alamos Scientific Laboratory (LASL); see also TU 1 Org 01

02 (94) 1st Radiological Safety Unit (RSSU)

03 (1) University of California Radiation Laboratory (UCRL); see also TU 2 Org 02

04 (2) Not assigned in Index, unknown organization.

Task Unit 7

Org 01 (146) LASL

02 (0) Sandia, assigned but not used

03 (0) EG&G, Las Vegas, assigned but not used

04 (2) UCRL

05 (1) AFSWP Field Command

06 (2) Army Transportation Corp, Ft. Devens, Massachusetts

07 (0) Assigned 631 QM Trk Co, Ft. Devens, not used.

TASK GROUP 7.2

Task Unit designation was not used in TG 7.2 organizational structure.

Org 01 (627) Administrative Detachment, U.S. Army

02 (504) Operational Detachment, U.S. Army

03 (139) 1st Provisional MP Co., 720th MP Battalion

04 (14) U.S. Coast Guard Loran Station.

There are three additional codes in the Consolidated List that begin with the numeral "2", but each has a number in the second field dedicated to Task Unit, but which was a zero in the "legitimate" TG 7.2 codes. The codes were 2116, 2201, and 2346 and each organization had one man. They are probably key-punch errors, although the American Red Cross had one representative at Enewetak as did the Army-Air Force Exchange System (AAFES) as noted in the CJTF 7 Op Plan 1-58. As these may have been considered a part of TG 7.2 for administrative purposes, two of the three exposures could be correctly associated with TG 7.2.

TASK GROUP 7.3

TG 7.3 used the second, third, and fourth digits as a single field to identify the naval units and organizations in the Task Group, although in the Consolidated List the listing program has broken the numbers apart to indicate "TU" and "ORG." These 3-digit organization numbers used the ship hull number or some part of it in the organization number. A CTG 7.3 memorandum (Reference 5) before the series listed most of the codes that appear on the list.

Org 001	(88)	Staff TG 7.3
002	(221)	TG 7.3 Boat Pool
003	(209)	TG 7.3 Boat Pool Detachment
004	(182)	TG 7.3 Decontamination Unit
005	(148)	TG 7.3 Special Projects Unit
007	(100)	USS Chanticleer (ASR-7)
009	(0)	Assigned to Commander, Destroyer Squadron 9 (but not used)
011	(13)	Commander, Destroyer Squadron 1
012	(254)	USS Belle Grove (LSD-2)
013	(51)	Bonita (SSK-3)
017	(400)	USS Hooper Island (ARG-17)
019	(233)	USS Comstock (LSD-19)
021	(1,100)	USS Boxer (CVS-21)
022	(203)	Patrol Squadrons 22 and 28 (VP-22, VP-28)
024	(80)	USS Grasp (ARS-24)
026	(0)	Assigned USS Tortuga (LSD-26) but not used
033	(93)	USS Karin (AF-33)
035	(291)	USS Monticello (LSD-35)
038	(84)	USS Bolster (ARS-38)
050	(164)	USS Rehoboth (AGS-50)
052	(220)	USS Cacapon (AO-52)
084	(64)	USS Cree (ATF-84)

098 (65) _USS Arikara_ (ATF-98)

100 (68) _USS Chowanoc_ (ATF-100)

102 (1) Not assigned, probably a key punch error

105 (68) _USS Moctobi_ (ATF-105)

107 (64) _USS Munsee_ (ATF-107)

113 (70) _USS Takelma_ (ATF-113)

138 (20) _USS Merapi_ (AF-38)

181 (195) _USNS Fred C. Ainsworth_ (T-AP-181)

199 (338) _USS Magoffin_ (APA-199)

215 (315) _USS Navarro_ (APA-215)

227 (330) _USS Renville_ (APA-227)

317 (160) _USS Joyce_ (DER-317)

361 (168) HMR(L)-361

388 (162) _USS Lansing_ (DER-388)

392 (79) _USS Sterlet_ (SS-392)

534 (0) Assigned _USS Silverstein_ (DE-534), but not used

618 (57) Not assigned but used for T-LST-618

664 (47) Not assigned but used for T-LST-664

727 (236) _USS De Haven_ (DD-727)

728 (256) _USS Mansfield_ (DD-728)

730 (245) _USS Collett_ (DD-730)

807 (256) _USS Benner_ (DDR-807)

877 (235) _USS Perkins_ (DDR-877)

884 (237) _USS Floyd B. Parks_ (DD-884)

885 (241) _USS John R. Craig_ (DD-885)

886 (240) _USS Orleck_ (DD-886)

887 (115) _USS Lawrence County_ (LST-887)

900 (22) Not assigned, but used for crews of UF-1 aircraft based at NAS Kwajalein.

TASK GROUP 7.4

TG 7.4 _Regulation 160-1_ (Reference 6) showed the system devised for the Air Force task group. The second digit was used either for subordinate TG 7.4 elements

1 (93) Hq TG 7.4

2 (401) Test Aircraft Unit (TAU)

3 (903) Test Base Unit (TBU)

4 (2,265) Test Services Unit (TSU)

or for functional definition

5 (49) Sampler crew

6 (0) Effects aircrews (assigned but not used),

or for visitors

7 (0) Distinguished Visitors (assigned but not used)

8 (27) Official observers.

The third and fourth digits designated the organization. This designation was independent of the second digit; that is, organization 01 was always the 4950th Test Group no matter what was in the second digit. This system allowed tallies of an organization's exposures to be made simply, independent of its personnel's particular participation group. It also allowed simple tallies of high potential exposure groups to be made independently of which organization furnished the men. This was used only for sampler crews, however. In this, the assumption is that in code assignment the sampler personnel were entered as 5 in the second field rather than as simply personnel of the TAU (2), which, of course, they were also.

Org 01	(118)	4950th Test Group
02	(167)	4926th Test Squadron
03	(430)	4951st Support Squadron
04	(352)	4952nd Support Squadron
05	(2)	HQ, AF Special Weapons Center
06	(62)	4925th Test Group
07	(0)	Hq, Air Research and Development Command (ARDC)
08	(21)	Hq, Wright Air Development Center (WADC)
09	(12)	AF Cambridge Research Center (CRC)
10	(20)	AF Office of Atomic Testing (AFOAT)
11	(0)	Hq, Air Materiel Command (AMC)
12	(8)	Hq, Military Air Transport Service (MATS)
13	(21)	Hq, Air Weather Service (AWS)
14	(7)	Hq, Air and Airways Communications Service (AACS)
15	(0)	Hq, Air Photographic and Charting Service (APCS)
16	(0)	HQ, Air Search and Rescue Service (ASRS), TG 7.4 Reg 160-1 showed ARS, Air Rescue Service
17	(2)	PACD MATS
18	(168)	64th Air Research Squadron
19	(142)	6th Weather Squadron

20 (388) 57th Weather Reconnaissance Squadron

21 (402) 1253rd AACS Squadron

22 (1,011) MATS Terminal Element

23 (83) 1371st Mapping and Photo Squadron

24 (26) 1352nd Motion Picture Squadron

25 (0) Hq, Pacific Air Force (PacAF)

26 (119) 24th Helicopter Squadron

27 (0) Hq, Strategic Air Command (SAC)

28 (130) 4080th Strategic Reconnaissance Wing

29 (36) Naval Air Special Weapons Facility

30 (1) Unassigned in 160-1

TASK GROUP 7.5

The Base Support Group (Holmes & Narver [H&N]) system has not been completely decoded. It refers to personnel and activities of lesser interest to DOD participation. According to Reference 3 a 0, 1, or 2 in the second digit indicated H&N proper. These were further coded in the third and fourth digits to reflect the divisions within the H&N organization such as Construction and Maintenance, Supply, Engineering, etc. Personnel with numbers 3 or higher in this record field were AEC or AEC visitors according to Reference 3. There were fewer than 100 in these higher numbers and they were not further subdivided by use of fields three and four. In Chapter 10 these all have been grouped as simply H&N.

TASK GROUP 6

There was no TG 6. This designation was used on the Consolidated List to designate Hq JTF 7 personnel and visitors. In the Index (Reference 3), several organizations are identified with the code, but several of these identifications appear to be inconsistent with the actual personnel on the Consolidated List. For all organizations, a zero was used for the second digit, indicating no subdivision. Identifiable organizations are as follows:

Org 00 (0) Assigned JTF 7 but not used

01 (6) Commander and Deputy Commander JTF 7 plus one other name. Org code assigned to LASL in the Index.

02 (385) U.S. and foreign visitors assigned to Hq JTF 7

03 (19) JTF 7 Staff but org code assigned to AFSWP, FC

04 (15) JTF 7 Staff but org code assigned to AEC, Las Vegas

05 (12) JTF 7 Staff but org code assigned to Public Health Service

06 (2) JTF 7 Staff. Org code was assigned to USAF Surgeon General.

07 (0) Assigned to Sanitary Engineer Center, Cincinnati, Ohio, but not used.

08 (3) JTF 7 Staff but org code assigned to Navy Hydrographic Office

09 (8) Hq 1608th Air Transport Group, Charleston, South Carolina

10 (19) Mess personnel USS Boxer

11 (0) Assigned to Hq USAF but not used

12 (0) Assigned 1090th Special Reporting Wing, Sandia Base, but not used.

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APPENDIX C

ISLAND SYNONYMS

CAPITALIZED entries are the code names used by the joint task force for the islands. Underscored entries are the names of the islands as used in this report. All other entries are spellings of the islands that may appear in other literature.

Aaraanbiru	VERA - Alembel - Arambiru (Enewetak Atoll)
ABLE	Bokbata - Bokobyaada (Bikini Atoll)
Adrikan	YOKE - Arriikan (Bikini Atoll)
Aej	OLIVE - Aitsu (Enewetak Atoll)
Aerokoj	OBOE - Airukiiji (Bikini Atoll)
Aerokojlol	PETER - Airukiraru (Bikini Atoll)
Airukiiji	OBOE - Aerokoj (Bikini Atoll)
Airukiraru	PETER - Aerokojlol (Bikini Atoll)
Aitsu	OLIVE - Aej (Enewetak Atoll)
Alembel	VERA - Aaraanbiru - Arambiru (Enewetak Atoll)
ALFA	Bokaetoktok - Bokoaetokutoku (Bikini Atoll)
ALICE	Bokoluo - Bogallua (Enewetak Atoll)
ALVIN	Jinedrol - Chinieero (Enewetak Atoll)
Ananij	BRUCE - Aniyaanii (Enewetak Atoll)
Anerowij	TOM - Munjor - Munjur (Enewetak Atoll)
Aniyaanii	BRUCE - Ananij (Enewetak Atoll)
Aomen	GEORGE - Aomoen (Bikini Atoll)
Aomoen	GEORGE - Aomen (Bikini Atoll)
Aomon	SALLY (Enewetak Atoll)
Arambiru	VERA - Alembel - Aaraanbiru (Enewetak Atoll)
Arriikan	YOKE - Adrikan (Bikini Atoll)
BAKER	Bokonejien (Bikini Atoll)
BELLE	Bokombako - Bogombogo (Enewetak Atoll)
Bigiren	ROGER - Bikdrin (Bikini Atoll)
Biijiri	TILDA - Bijire - Bijile - Bikile (Enewetak Atoll)
Bijile	TILDA - Bijire - Biijiri - Bikile (Enewetak Atoll)
Bijire	TILDA - Bijile - Biijiri - Bikile (Enewetak Atoll)
Bikdrin	ROGER - Bigiren (Bikini Atoll)
Biken	LEROY - Rigile - Rigili (Enewetak Atoll)
Bikile	TILDA - Bijire - Bijile - Biijiri (Enewetak Atoll)
Bikini	HOW - (Bikini Atoll)
Billae	WILMA - Piiraai - Piirai (Enewetak Atoll)
Billee	LUCY - Kidrinen - Kirinian (Enewetak Atoll)
Bogairikk	HELEN - Bokaidrikdrik - Bogeirik - Bokaidrik (Enewetak Atoll)
Bogallua	ALICE - Bokoluo (Enewetak Atoll)
Bogan	IRWIN - Boken - Pokon (Enewetak Atoll)
Bogeirik	HELEN - Bokaidrikdrik - Bogairikk - Bokaidrik (Enewetak Atoll)
Bogen	REX - Jedrol - Jieroru (Enewetak Atoll)
Bogombogo	BELLE - Bokombako (Enewetak Atoll)

Bogon	IRENE - Boken (Enewetak Atoll)
Bokaetoktok	ALFA - Bokoaetokutoku (Bikini Atoll)
Bokaidrik	HELEN - Bokaidrikdrik - Bogairikk - Bogeirik (Enewetak Atoll)
Bokaidrikdrik	HELEN - Bogairikk - Bogeirik - Bokaidrik (Enewetak Atoll)
Bokandretok	WALT (Enewetak Atoll)
Bokbata	ABLE - Bokobyaada (Bikini Atoll)
Bokdrolul	BRAVO - Bokororyuru (Bikini Atoll)
Boken	IRENE - Bogon (Enewetak Atoll)
Boken	IRWIN - Pokon - Bogan (Enewetak Atoll)
Bokenelab	MARY - Bokonaarappu - Bokonarppu (Enewetak Atoll)
Bokinwotme	EDNA - Sanildefonso (Enewetak Atoll)
Boko	SAM (Enewetak Atoll)
Bokoaetokutoku	ALFA - Bokaetoktok (Bikini Atoll)
Bokobyaada	ABLE - Bokbata (Bikini Atoll)
Bokoluo	ALICE - Bogallua (Enewetak Atoll)
Bokombako	BELLE - Bogombogo (Enewetak Atoll)
Bokonaarappu	MARY - Bokenelab - Bokonarppu (Enewetak Atoll)
Bokonarppu	MARY - Bokenelab - Bokonaarappu (Enewetak Atoll)
Bokonejien	BAKER (Bikini Atoll)
Bokonfuaaku	ITEM (Bikini Atoll)
Bokororyuru	BRAVO - Bokdrolul (Bikini Atoll)
BRAVO	Bokdrolul - Bokororyuru (Bikini Atoll)
BRUCE	Ananij - Aniyaanii (Enewetak Atoll)
Buganegan	HENRY - Mut - Mui (Enewetak Atoll)
CHARLIE	Nam - Namu (Bikini Atoll)
Chieerete	WILLIAM - Jelete (Bikini Atoll)
Chinieero	ALVIN - Jinedrol (Enewetak Atoll)
Chinimi	CLYDE - Jinimi (Enewetak Atoll)
CLARA	Kirunu - Eybbiyae - Ruchi (Enewetak Atoll)
CLYDE	Jinimi - Chinimi (Enewetak Atoll)
Coca	(Bikini Atoll)
Cochita	DAISY - Louj - Lidilbut (Enewetak Atoll)
DAISY	Louj - Cochita - Lidilbut (Enewetak Atoll)
DAVID	Japtan - Muti (Enewetak Atoll)
DOG	Iroij - Yurochi (Bikini Atoll)
Drekatimon	OSCAR (Enewetak Atoll)
Dridrilbwij	GENE - Teiteiripucchi (Enewetak Atoll)
EASY	Uorikku - Odrik (Bikini Atoll)
Eberiru	RUBY - Eleleron (Enewetak Atoll)
EDNA	Bokinwotme - Sanildefonso (Enewetak Atoll)
Eleleron	RUBY - Eberiru (Enewetak Atoll)
Elle	NANCY - Yeiri (Enewetak Atoll)
ELMER	Parry - Medren (Enewetak Atoll)
Elugelab	FLORA - Eluklab (Enewetak Atoll)
Eluklab	FLORA - Elugelab (Enewetak Atoll)
Eneman	TARE - Eninman (Bikini Atoll)
Eneu	NAN - Enyu (Bikini Atoll)
Enewetak	FRED - Eniwetok (Enewetak Atoll)
Engebi	JANET - Enjebi (Enewetak Atoll)
Eniairo	KING (Bikini Atoll)
Enidrik	UNCLE - Eniirikku - (Bikini Atoll)

Eniirikku	UNCLE - Enidrik (Bikini Atoll)
Eninman	TARE - Eneman (Bikini Atoll)
Eniwetok	FRED - Enewetak (Enewetak Atoll)
Enjebi	JANET - Engebi (Enewetak Atoll)
Enyu	NAN - Eneu (Bikini Atoll)
Eybbiyae	CLARA - Kirunu - Ruchi (Enewetak Atoll)
FLORA	Eluklab - Elugelab (Enewetak Atoll)
FOX	Lomilik - Romurikku (Bikini Atoll)
FRED	Enewetak - Eniwetok (Enewetak Atoll)
GENE	Dridrilbwij - Teiteiripucchi (Enewetak Atoll)
GEORGE	Aomen - Aomoen (Bikini Atoll)
Giriinien	KEITH - Kidrenen - Grinem (Enewetak Atoll)
GLENN	Ikuren - Igurin (Enewetak Atoll)
Grinem	KEITH - Kidrenen - Giriinien (Enewetak Atoll)
HELEN	Bokaidrikdrik - Bogairikk - Bogeirik - Bokaidrik (Enewetak Atoll)
HENRY	Mut - Buganegan - Mui (Enewetak Atoll)
HOW	Bikini (Bikini Atoll)
Igurin	GLENN - Ikuren (Enewetak Atoll)
Ikuren	GLENN - Igurin (Enewetak Atoll)
Inedral	URIAH (Enewetak Atoll)
Ionchebi	MIKE (Bikini Atoll)
IRENE	Boken - Bogon (Enewetak Atoll)
Iroij	DOG - Yurochi (Bikini Atoll)
IRWIN	Boken - Bogan - Pokon (Enewetak Atoll)
ITEM	Bokonfuaaku (Bikini Atoll)
JAMES	Ribewon - Libiron - Ribaion (Enewetak Atoll)
JANET	Enjebi - Engebi (Enewetak Atoll)
Japtan	DAVID - Muti (Enewetak Atoll)
Jedrol	REX - Jieroru - Bogen (Enewetak Atoll)
Jelete	WILLIAM - Chieerete (Bikini Atoll)
Jieroru	REX - Jedrol - Bogen (Enewetak Atoll)
JIG	Yomyaran (Bikini Atoll)
Jinedrol	ALVIN - Chinieero (Enewetak Atoll)
Jinimi	CLYDE - Chinimi (Enewetak Atoll)
KATE	Mijikadrek - Mujinkarikku - Muzinbaarikku (Enewetak Atoll)
KEITH	Kidrenen - Giriinien - Grinem (Enewetak Atoll)
Kidrenen	KEITH - Giriinien - Grinem (Enewetak Atoll)
Kidrinen	LUCY - Billee - Kirinian (Enewetak Atoll)
KING	Eniairo (Bikini Atoll)
Kirinian	LUCY - Kidrinen - Billee (Enewetak Atoll)
Kirunu	CLARA - Eybbiyae - Ruchi (Enewetak Atoll)
Lele	SUGAR - Reere (Bikini Atoll)
LEROY	Biken - Rigile - Rigili (Enewetak Atoll)
Libiron	JAMES - Ribewon - Ribaion (Enewetak Atoll)
Lidilbut	DAISY - Louj - Cochita (Enewetak Atoll)
Lojwa	URSULA - Rojoa (Enewetak Atoll)
Lomilik	FOX - Romurikku (Bikini Atoll)
Louj	DAISY - Cochita - Lidilbut (Enewetak Atoll)

LOVE	<u>Rochikarai</u> (Bikini Atoll)
LUCY	<u>Kidrinen</u> - Billee - Kirinian (Enewetak Atoll)
<u>Lujor</u>	PEARL - Rujiyoru - Rujoru (Enewetak Atoll)
<u>Lukoj</u>	VICTOR - Rukoji (Bikini Atoll)
MACK	<u>Unibor</u> (Enewetak Atoll)
MARY	<u>Bokenelab</u> - Bokonaarappu - Bokonarppu (Enewetak Atoll)
Medren	ELMER - <u>Parry</u> (Enewetak Atoll)
<u>Mijikadrek</u>	KATE - Mujinkarikku - Muzinbaarikku (Enewetak Atoll)
MIKE	<u>Ionchebi</u> (Bikini Atoll)
Mui	HENRY - <u>Mut</u> - Buganegan (Enewetak Atoll)
Mujinkarikku	KATE - <u>Mijikadrek</u> - Muzinbaarikku (Enewetak Atoll)
<u>Munjor</u>	TOM - Anerowij - Munjur (Enewetak Atoll)
Munjur	TOM - <u>Munjor</u> - Anerowij (Enewetak Atoll)
<u>Mut</u>	HENRY - Buganegan - Mui (Enewetak Atoll)
Muti	DAVID - <u>Japtan</u> (Enewetak Atoll)
Muzinbaarikku	KATE - <u>Mijikadrek</u> - Mujinkarikku (Enewetak Atoll)
<u>Nam</u>	CHARLIE - Namu (Bikini Atoll)
Namu	CHARLIE - <u>Nam</u> (Bikini Atoll)
NAN	<u>Eneu</u> - Enyu (Bikini Atoll)
NANCY	<u>Elle</u> - Yeiri (Enewetak Atoll)
OBOE	<u>Aerokoj</u> - Airukiiji (Bikini Atoll)
<u>Odrik</u>	EASY - Uorikku (Bikini Atoll)
OLIVE	<u>Aej</u> - Aitsu (Enewetak Atoll)
<u>Oroken</u>	ZEBRA - Ourukaen (Bikini Atoll)
OSCAR	<u>Drekatimon</u> (Enewetak Atoll)
Ourukaen	ZEBRA - <u>Oroken</u> (Bikini Atoll)
<u>Parry</u>	ELMER - Medren (Enewetak Atoll)
PEARL	<u>Lujor</u> - Rujiyoru - Rujoru (Enewetak Atoll)
PERCY	<u>Taiwel</u> (Enewetak Atoll)
PETER	<u>Aerokojlol</u> - Airukiraru (Bikini Atoll)
Piiraai	WILMA - <u>Billae</u> - Piirai (Enewetak Atoll)
Piirai	WILMA - <u>Billae</u> - Piiraai (Enewetak Atoll)
Pokon	IRWIN - <u>Boken</u> - Bogan (Enewetak Atoll)
Reere	SUGAR - <u>Lele</u> (Bikini Atoll)
REX	<u>Jedrol</u> - Bogen - Jieroru (Enewetak Atoll)
Ribaion	JAMES - <u>Ribewon</u> - Libiron (Enewetak Atoll)
<u>Ribewon</u>	JAMES - Libiron - Ribaion (Enewetak Atoll)
Rigile	LEROY - <u>Biken</u> - Rigili (Enewetak Atoll)
Rigili	LEROY - <u>Biken</u> - Rigile (Enewetak Atoll)
<u>Rochikarai</u>	LOVE (Bikini Atoll)
ROGER	<u>Bikdrin</u> - Bigiren (Bikini Atoll)
Rojoa	URSULA - <u>Lojwa</u> (Enewetak Atoll)
Romurikku	FOX - <u>Lomilik</u> (Bikini Atoll)
RUBY	<u>Eleleron</u> - Eberiru (Enewetak Atoll)
Ruchi	CLARA - <u>Kirunu</u> - Eybbiyae (Enewetak Atoll)
Rujiyoru	PEARL - <u>Lujor</u> - Rojoru (Enewetak Atoll)
Rujoru	PEARL - <u>Lujor</u> - Rujiyoru (Enewetak Atoll)
Rukoji	VICTOR - <u>Lukoj</u> (Bikini Atoll)
<u>Runit</u>	YVONNE (Enewetak Atoll)

SALLY	Aomon (Enewetak Atoll)
SAM	Boko (Enewetak Atoll)
Sanildefonso	EDNA - Bokinwotme (Enewetak Atoll)
SUGAR	Lele - Reere (Bikini Atoll)
Taiwel	PERCY (Enewetak Atoll)
TARE	Eneman - Eninman (Bikini Atoll)
Teiteiripucchi	GENE - Dridrilbwij - (Enewetak Atoll)
TILDA	Bijire - Bijile - Biijiri - Bikile (Enewetak Atoll)
TOM	Munjor - Anerowij - Munjur (Enewetak Atoll)
UNCLE	Enidrik - Eniirikku (Bikini Atoll)
Unibor	MACK (Enewetak Atoll)
Uorikku	EASY - Odrik (Bikini Atoll)
URIAH	Inedral (Enewetak Atoll)
URSULA	Lojwa - Rojoa (Enewetak Atoll)
VAN	(Enewetak Atoll)
VERA	Alembel - Aaraanbiru - Arambiru (Enewetak Atoll)
VICTOR	Lukoj - Rukoji (Bikini Atoll)
WALT	Bokandretok (Enewetak Atoll)
WILLIAM	Jelete - Chieerete (Bikini Atoll)
WILMA	Billae - Piirai - Piiraai (Enewetak Atoll)
Yeiri	NANCY - Elle (Enewetak Atoll)
YOKE	Adrikan - Arriikan (Bikini Atoll)
Yomyaran	JIG (Bikini Atoll)
Yurochi	DOG - Iroij (Bikini Atoll)
YVONNE	Runit - (Enewetak Atoll)
ZEBRA	Oroken - Ourukaen (Bikini Atoll)

APPENDIX D

TERMS, ABBREVIATIONS, ACRONYMS, AND UNITS

Many of the definitions in this glossary relating to nuclear device and radiation phenomena have been quoted or extracted from The Effects of Nuclear Weapons (3rd edition), S. Glasstone and P.J. Dolan, 1977.

AACS. Airways and Air Communication Service (Air Force).

AAU. Administrative Area Unit (Army).

ACC. Army Chemical Center, Edgewood Arsenal, Maryland.

accelerometer. An instrument for determining the acceleration of the system with which it moves.

AD. Destroyer tender (Navy).

AEC. Atomic Energy Commission, Washington, D.C. Independent agency of the Federal government with statutory responsibilities for atomic energy matters. No longer exists; its functions have been assumed by the Department of Energy and the Nuclear Regulatory Commission.

AF. Store ship (Navy); also Air Force.

AFB. Air Force Base.

AFCRC. Air Force Cambridge Research Center.

AFDL. Small floating dry dock (Navy).

AFSWC. Air Force Special Weapons Center, Kirtland AFB, New Mexico.

AFSWP. Armed Forces Special Weapons Project.

AGC. Amphibious force flagship, later LCC (Navy).

airburst. The detonation of a nuclear device in the air at a height such that the expanding fireball does not touch the Earth's surface when the luminosity (emission of light) is at a maximum.

air particle trajectory. The direction, velocity, and rate of descent of windblown radioactive particles.

AK. Cargo ship (Navy).

AKA. Attack cargo ship, later LKA (Navy).

allowable dose. See MPL.

alpha emitter. A radionuclide that undergoes transformation by alpha-particle emission.

alpha particle. A charged particle emitted spontaneously from the nuclei of some radioactive elements. It is identical with a helium nucleus, having a mass of 4 units and an electric charge of 2 positive units. See also radioactivity.

alpha rays. A stream of alpha particles. Loosely, a synonym for alpha particles.

AMN. Airman; enlisted Air Force personnel.

AMS. Army Map Service, Washington, D.C.

AN/PDR-39. An ion-chamber-type survey meter; this was the standard radsafe meter. Others in use included the Navy version, the AN/PDR-T1B, the AN/PDR-18A and -18B, and lower-range Geiger-Mueller instruments (AN/PDR-27, Beckman MX-5, and Nuclear Corporation 2610). Other radiac devices were also used.

AO. Oiler (Navy).

AOC. Air Operations Center.

AOG. Gasoline tanker (Navy).

AP. Transport ship (Navy).

APO. Army Post Office.

APD. High-speed transport ship (Navy).

APG. Aberdeen Proving Ground, Maryland.

ARA. Allied Research Associates, Boston, Massachusetts.

arming. The changing of a nuclear device from a safe condition (that is, a condition in which it cannot be accidentally detonated) to a state of readiness for detonation.

ARS. Salvage ship (Navy); also Air Rescue Service (Air Force).

ARSD. Salvage lifting ship (Navy).

ASA. Army Security Agency.

ATA. Auxiliary ocean tug (Navy).

ATF. Fleet ocean tug (Navy).

atoll. A ring of coral reefs, usually with small islets, that surrounds a lagoon. Most are isolated reefs rising from the deep sea that have built up on submerged volcanoes. They vary considerably in size; the largest atoll, Kwajalein in the Marshall Islands, has an irregular shape that extends for 84 miles (135 km). See also coral reef.

atomic bomb (or weapon). A term sometimes applied to a nuclear weapon utilizing fission energy only. See also fission, nuclear device.

atomic explosion. See nuclear explosion.

attenuation. The process by which radiation is reduced in intensity when passing through some material. It is due to absorption or scattering or both, but it excludes the decrease of intensity with distance from the source (inverse square law, which see).

AU. Army Unit.

AV. Seaplane tender (Navy).

AVR. Aircraft rescue vessel (Navy).

AW. Distilling ship (Navy).

B-29. A 4-engine, propeller-driven bomber developed by Boeing, used for weather reconnaissance, cloud tracking, aerial sampling and photography, and aerial refueling at the EPG. These versions designated RB-29, WB-29, and KB-29.

B-36. A long-range, strategic bomber powered by six pusher propeller engines, supplemented by four jet engines. Developed by Consolidated Aircraft. Used as the subject of effects experiments and as a sampler controller aircraft. Also designated FB-36, RB-36, and WB-36.

B-50. A 4-engine bomber developed by Boeing, with some features like those of the B-29, but having a taller tail fin and larger engines and nacelles.

B-52. Eight-engine jet bomber built by the Boeing Company.

B-57. U.S. version of English Electric Canberra bomber used as cloud-sampling aircraft.

background radiation. The radiation of man's natural environment, consisting of that which comes from cosmic rays and from the naturally radioactive elements of the Earth, including that from within man's body. The term may also mean radiation extraneous to an experiment.

base surge. The particulate dust cloud that rolls out from the bottom of the cloud column produced by the detonation of a nuclear device. For underwater bursts, the base surge is a cloud of water droplets, and the flowing properties are those of a homogeneous liquid.

bathythermograph. A device for obtaining a record of temperature with depth in the upper 1,000 feet (300 meters) of the ocean, from a ship underway.

becquerel (Bq). See curie.

beta burns. Beta particles that come into contact with the skin and remain for an appreciable time can cause a form of radiation injury sometimes referred to as "beta burn." In an area of extensive early fallout, the whole surface of the body may be exposed to beta particles.

beta emitter. A radionuclide that disintegrates by beta particle emission. All beta-active elements existing in nature expel negative particles, i.e., electrons or, more exactly, negatrons. Beta-emitting particles are harmful if inhaled or ingested or remain on the skin.

beta particle (ray). A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most, if not all, of the direct fission products emit negative beta particles (negatrons). Physically, the beta particle is identical to an electron moving at high velocity.

bhangmeter. A device that measures bomb yield based on light generated by the explosion.

blast. The detonation of a nuclear device, like the detonation of a high explosive such as TNT, results in the sudden formation of a pressure or shock wave, called a blast wave in the air and a shock wave when the energy is imparted to water or earth.

blast wave. An air pulse in which the pressure increases sharply at the front followed by winds propagated from an explosion.

blast yield. That portion of the total energy of a nuclear explosion that manifests itself as blast and shock waves.

bomb debris. See weapon debris.

BRL. Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland (Army).

BuAer. Bureau of Aeronautics (Navy).

BuMed. Bureau of Medicine and Surgery (Navy).

burst. Explosion; or detonation. See also airburst, high-altitude burst, surface burst.

BuShips. Bureau of Ships (Navy).

C-47. A twin-engine transport aircraft manufactured by Douglas Aircraft Company (Air Force version of the DC-3).

C-54. A 4-engine military cargo and personnel transport manufactured by Douglas Aircraft Company (Air Force version of the DC-4).

cab. The shelter that covers a nuclear device being prepared for test. May be located on a tower, on the Earth's surface, or on a barge.

Canberra. An RAF twin-turbojet, all-weather, tactical bomber developed by English Electric. Also built in the United States and used by the Air Force as the B-57.

cathode-ray tube. A vacuum tube in which cathode rays (electrons) are beamed upon a fluorescent screen to produce a luminous image. The character of this image is related to, and controlled by, one or more electrical signals applied to the cathode-ray beam as input information. The tubes are used in measuring instruments such as oscilloscopes and in radar and television displays.

cave. A heavily shielded enclosure in which radioactive materials can be remotely manipulated to avoid radiation exposure of personnel.

CDC. Center for Disease Control.

Ci; c. Abbreviation for curie, which see. Ci is preferred now but c was the abbreviation used in the 1950s.

CIC. Counter-Intelligence Corps (Army).
Combat Information Center (Navy).

CINCPAC. Commander-in-Chief, Pacific.

CJTF 7. Commander, Joint Task Force 7.

closed area. The land areas of Bikini and Enewetak and the water areas within 3 miles of them that the United States closed to unauthorized persons.

cloud chamber effect. See Wilson cloud.

cloud column (funnel). The visible column of weapon debris (and possibly dust or water droplets) extending upward from the point of a nuclear burst.

cloud phenomena. See fallout, fireball, radioactive cloud.

CNO. Chief of Naval Operations.

collimate. To align nuclear weapon radiant outputs within an assigned solid angle through the use of baffles in order to enhance measurements.

Co. Chemical symbol for cobalt.

cobalt. Metallic element with radionuclide ^{60}Co used as calibration source for gamma instruments.

ComAirPac. Commander Naval Air Force Pacific (Navy).

ComServPac. Commander Service Forces Pacific (Navy).

Condition "Purple". See Purple conditions.

Consolidated List. Consolidated List of Radiological Exposures. The list that covers all recorded individual radiological exposures for joint task force participants.

contamination. The deposit of radioactive material on the surfaces of structures, areas, objects, and personnel following a nuclear detonation. This material generally consists of fallout in which fission products and other device debris have become incorporated with particles of dust, vaporized components of device platforms, etc. Contamination can also arise from the radioactivity induced in certain substances by the action of neutrons from a nuclear explosion. See also decontamination, fallout, weapon debris.

coracle. A small circular craft moored inside Enewetak Atoll that was instrumented to measure gamma radiation from the two underwater shots WAHOO and UMBRELLA.

coral reef. A complex ecological association of bottom-living and attached shelled marine animal fossils that form fringing reefs, barrier reefs, and atolls. The lagoons of barrier reefs and atolls are important places for the deposition of fine-grained calcium carbonate mud.

CPM. Counts per minute, a measure of radioactive material disintegration.

crater. The depression formed in the surface of the Earth by a surface or underground explosion. Crater formation can occur by vaporization of the surface material, by the scouring effect of airblast, by throwout of disturbed material, or by subsidence.

CRL. Chemical Research Laboratory (Army).

Cs. Chemical symbol for cesium.

C/S. Chief of Staff.

CTG. Commander Task Group.

curie (Ci). A unit of radioactivity; it is the activity of a quantity of any radioactive species in which 3.700×10^{10} (37 billion) nuclear disintegrations occur per second (approximately the radioactivity of 1 gram of radium). The gamma curie is sometimes defined correspondingly as the activity of material in which this number of gamma-ray photons is emitted per second. This unit is being replaced by the becquerel (Bq), which is equal to one disintegration per second.

cutie pie. The CP-3DM portable beta-gamma survey meter using an ionization chamber as the detector volume to measure radiation exposure. Usually used at higher radiation levels for both detecting and measuring ionizing radiation. A removable end-cap acts as a shield for the detector, allowing the instrument to indicate combined beta and gamma radiation when the cap is removed, or gamma radiation only when the cap is in place.

CVE. Escort aircraft carrier (Navy).

CW net. Carrier wave network. An organization of stations capable of direct radio communications on a common channel or frequency.

dan buoy. A floating temporary marker buoy such as one used in minesweeping and antisubmarine warfare operations.

D-day. The term used to designate the unnamed day on which a test takes place. The equivalent rule applies to H-hour. Time in plans is indicated by a letter that shows the unit of time employed in figures, with a minus or plus sign to indicate the amount of time before or after the reference event, e.g., D+7 means 7 days after D-day, H+2 means 2 hours after H-hour.

DDE. Escort destroyer (Navy).

DE. Destroyer escort (Navy).

debris (radioactive). See weapon debris.

decay (radioactive). The decrease in activity of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation, or by gamma photons alone. Every decay process has a definite half-life.

decontamination. The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of natural decay; and (3) covering the contamination in order to attenuate the radiation emitted.

device. Nuclear fission and fusion materials, together with their arming, fuzing, firing, chemical-explosive components, that have not reached the development status of an operational weapon.

diagnostic measurements or experiments. Experiments whose purpose is to study the explosive disassembly of a nuclear detonation (as opposed to effects measurements, which see).

DM. Minelayer destroyer (Navy). Converted destroyers designed to conduct high-speed minelaying operations.

DMA. The Division of Military Applications of the Atomic Energy Commission.

DOD. Department of Defense. The Federal executive agency responsible for the defense of the United States. Includes the four services and special joint defense agencies. Reports to the President through the Secretary of Defense.

DOFL. Diamond Ordnance Fuze Laboratory (Army). Later, the U.S. Army Harry Diamond Laboratory.

dose. A general term denoting the quantity of ionizing radiation absorbed. The unit of absorbed dose is the rad (which see). In soft body tissue the absorbed dose in rads is essentially equal to the exposure in roentgens. The biological dose (also called the RBE dose) in rems is a measure of biological effectiveness of the absorbed radiation. Dosage is used in older literature as well as exposure dose and simply exposure, and care should be exercised in their use. See also exposure.

dose rate. As a general rule, the amount of ionizing (or nuclear) radiation that an individual or material would receive per unit of time. It is usually expressed as rads (or rems) per hour or multiples or divisions of these units such as millirads per hour. The dose rate is commonly used to indicate the level of radioactivity in a contaminated area. See survey meter.

dosimeter. An instrument for measuring and registering the total accumulated dose of (or exposure to) ionizing radiation. Instruments worn or carried by individuals are called personnel dosimeters.

dosimetry. The measurement and recording of radiation doses and dose rates. It is concerned with the use of various types of radiation instruments with which measurements are made. See also dosimeter, survey meter.

DPM. Disintegrations per minute, a measure of radioactivity, literally atoms disintegrating per minute. Difficult to directly compare with roentgens per hour for mixtures of radionuclides.

drogue. A sea anchor or similar drag device used to pull out a parachute.

DTMB. David Taylor Model Basin, Carderock, Maryland (Navy).

DUKW. Two-and-one-half-ton amphibious truck.

dynamic pressure. Air pressure that results from the mass air flow (or wind) behind the shock front of a blast wave.

effects measurements or experiments. Experiments whose purpose is to study what a nuclear explosion does to materials, equipment, and systems. Includes also measurement of the changes in the environment caused by the detonation, such as increased air pressures (blast), thermal and nuclear radiation, cratering, water waves, etc.

EG&G. Edgerton, Germeshausen & Grier, Boston, Massachusetts (now EG&G, Inc.). An AEC contractor. Provided timing and firing electronics and technical film coverage.

electromagnetic radiation. Electromagnetic radiations range from X-rays and gamma rays of short wavelength (high frequency), through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength.

electron. A particle of very small mass and electrically charged. As usually defined, the electron's charge is negative. The term negatron is also used for the negative electron and the positively charged form is called a positron. See also beta particles.

EODU. Explosive Ordnance Disposal Unit (Navy).

EPG. Eniwetok Proving Ground.

ETA. Estimated time of arrival.

ETD. Estimated time of departure.

exposure. A measure expressed in roentgens of the ionization produced by gamma rays (or X-rays) in air. The exposure rate is the exposure per unit time (e.g., roentgens per hour). See dose, dose rate, roentgen.

exposure rate contours. Lines joining points that have the same radiation intensity to define a fallout pattern, represented in terms of roentgens per hour.

fallout. The process or phenomenon of the descent to the Earth's surface of particles contaminated with radioactive material from the radioactive cloud. The term is also applied in a collective sense to the contaminated particulate matter itself. The early (or local) fallout is defined, somewhat arbitrarily, as particles reaching the Earth within 24 hours after a nuclear explosion. The delayed (or worldwide) fallout consists of the smaller particles, which ascend into the upper troposphere and stratosphere and are carried by winds to all parts of the Earth. The delayed fallout is brought to Earth, mainly by rain and snow, over extended periods ranging from months to years.

fathometer. A depth-sounding instrument. The depth of water is measured by noting the time the echo of a sound takes to return from the bottom.

FEAF. Far East Air Forces.

FFP. Floating film pack.

film badges. Used for the indirect measurement of ionizing radiation. Generally contain two or three pieces of film of different radiation sensitivities. They are wrapped in paper (or other thin material) that blocks light but is readily penetrated by gamma rays. The films are developed and the degree of fogging (or blackening) observed is a measure of the gamma-ray exposure, from which the absorbed dose is calculated. Film badges can also measure beta and neutron radiation.

fireball. The luminous sphere of hot gases that forms a few millionths of a second after a nuclear explosion as the result of the absorption by the surrounding medium of the thermal X-rays emitted by the extremely hot (several tens of millions of degrees) device residues. The exterior of the fireball in air is initially sharply defined by the luminous shock front and later by the limits of the hot gases themselves.

fission. The process of the nucleus of a particular heavy element splitting into two nuclei of lighter elements, with the release of substantial amounts of energy. The most important fissionable materials are uranium-235 and plutonium-239; fission is caused by the absorption of neutrons.

fission detectors. Radiation pulse detector of the proportional counter type in which a foil or film of fissionable materials is incorporated to make it respond to neutrons.

fission products. A general term for the complex mixture of substances produced as a result of nuclear fission. A distinction should be made between these and the direct fission products or fission fragments that are formed by the actual splitting of the heavy-element nuclei into nuclei of medium atomic weight. Approximately 80 different fission fragments result from roughly 40 different modes of fission of a given nuclear species (e.g., uranium-235 or plutonium-239). The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains over 300 different radionuclides of 36 elements.

fixed alpha. Alpha radioactivity that cannot be easily removed as evidenced by no measured change in a swipe of a 100-cm^2 area.

fluorescence. The emission of light (electromagnetic radiation) by a material as a result of the absorption of energy from radiation. The term may refer to the radiation emitted, as well as to the emission process.

forward area. The Eniwetok Proving Ground and adjoining areas (e.g., Kwajalein).

FPO. Fleet Post Office (Navy).

fusion. The combination of two light nuclei to form a heavier nucleus, with the release of the difference of the nuclear binding energy of the fusion products and the sum of the binding energies of the two light nuclei.

gamma rays. Electromagnetic radiations of high photon energy originating in atomic nuclei and accompanying many nuclear reactions (e.g., fission, radioactivity, and neutron capture). Physically, gamma rays are identical with X-rays of high energy; the only essential difference is that X-rays do not originate from atomic nuclei of high energy. Gamma rays can travel great distances through air and can penetrate considerable thickness of material, although they can neither be seen nor felt by human beings except at very high intensities, which causes an itching and tingling sensation of the skin. They can produce harmful effects even at a long distance from their source (The Effects of Nuclear Weapons, 3rd edition).

Geiger-Mueller (GM) counter. A gas discharge pulse counter for ionizing radiation. See also AN/PDR-39 and ion-chamber-type survey meter.

GMT. Greenwich Mean Time.

gray (Gy). A recently introduced ICRP term; 1 Gy equals 100 rad.

ground zero. See surface zero.

gunk. A viscous commercial preparation that is soluble both in water and petroleum derivatives. It acts as a wetting agent in removing grease and particulate matter from metal and other nonporous surfaces.

H-19. Large utility helicopter manufactured by Sikorsky Aircraft Division of United Aircraft Corporation.

H-hour. Time zero, or time of detonation. When used in connection with planning operations it is the specific hour on which the operation event commences. See D-day.

half-life. The time required for a radioactive material to lose half of its radioactivity due to decay. Each radionuclide has a unique half-life.

HE. High explosive.

HF. High-frequency radio communications. The HF band is from 3 to 30 kHz.

high-altitude burst. Defined, somewhat arbitrarily, as a detonation in or above the stratosphere. The distribution of the energy of the explosion between blast and thermal radiation changes appreciably with increasing altitude.

HMR. Marine Helicopter Transport Squadron.

hodograph. A common hodograph in meteorology represents the speed and direction of winds at different altitude increments.

HO. Navy Hydrographic Office.

hot; hot spot. Commonly used colloquial term meaning a spot or area relatively more radioactive than some adjacent area.

HRS-2. Transport helicopter manufactured by Sikorsky Aircraft Company.

IBDA. Indirect Bomb Damage Assessment. A revised target analysis based on new data such as actual weapon yield, burst height, and surface zero obtained by means other than direct assessment.

ICRP. International Commission on Radiological Protection.

initial radiation. Electromagnetic radiations of high energy emitted from both the fireball and the radioactive cloud within the first minute after a detonation. It includes neutrons and gamma rays given off almost instantaneously, as well as the gamma rays emitted by the fission products and other radioactive species in the rising cloud. Initial radiations from ground or near-ground bursts activate both earth materials and device debris to create contamination.

inverse square law. The decrease in radiation intensity with distance from a single-point source is in proportion to the square of the distance removed.

ion-chamber-type survey meter. A device for measuring the amount of ionizing radiation. Consists of a gas-filled chamber containing two electrodes (one of which may be the chamber wall) between which a potential difference is maintained. The radiation ionizes gas in the chamber and an instrument connected to one electrode measures the ionization current produced.

ionization. The process of adding electrons to, or knocking electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, and nuclear radiation can cause ionization.

ionizing radiation. Any particulate or electromagnetic radiation capable of producing ions, directly or indirectly, in its passage through matter. Alpha and beta particles produce ion pairs directly, while gamma rays and X-rays liberate electrons as they traverse matter, which in turn produce ionization in their paths.

ionosphere. The region of the atmosphere, extending from roughly 40 to 250 miles (64 to 400 km) above the Earth, in which there is appreciable ionization. The presence of charged particles in this region profoundly affects the propagation of radio and radar waves.

irradiation. Exposure of matter to radiation.

isodose lines. Dose or dose-rate contours. In fallout, contours plotted on a radiation field within which the dose rate or the total accumulated dose is the same.

isotope. Atoms with the same atomic number (same chemical element) but different atomic weight; i.e., the nuclei have the same number of protons but a different number of neutrons.

JCS. Joint Chiefs of Staff.

JTF 7. Joint Task Force 7 was a combined force of personnel of the Department of Defense (Air Force, Army, Marine Corps, Navy), the AEC, and their contractors. JTF 7 was responsible for all aspects of nuclear weapon tests in the Pacific testing area during 1958.

kiloton convention. Relates nuclear explosion energy to TNT explosion energy by using the approximate energy release of 1,000 tons of TNT as the measuring unit.

kinetic energy. Energy associated with the motion of matter.

L-20. Single-engine, 2-place light aircraft used in Enewetak airlift.

LASL. Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

LCM. Mechanized landing craft (Navy).

LCP(L). Personnel landing craft, large (Navy).

LCP(R). Personnel landing craft, ramp (Navy).

LCT. Tank landing craft (Navy).

LCU. Utility landing craft (Navy).

LML. Lookout Mountain Laboratory, Hollywood, California (Air Force).

Loran. Long-range aid to navigation system. Loran stations were maintained by the U.S. Coast Guard Station on Enewetak Island and Johnston Atoll.

LSD. Dock landing ship (Navy).

LSIL. Infantry landing ship, large (Navy).

LST. Tank landing ship (Navy).

magnetometer. An instrument for measuring changes in the geomagnetic field.

MATS. Military Air Transport Service; later, Military Airlift Command.

megaton (energy). Approximately the amount of energy that would be released by the explosion of one million tons of TNT.

microcurie. One-millionth of a curie.

micron. One-millionth of a meter (i.e., 10^{-6} meter or 10^{-4} centimeter); it is roughly four one-hundred-thousandths (4×10^{-5}) of an inch.

milliroentgen. One-thousandth of a roentgen.

MPL. Maximum Permissible Limit. That amount of radioactive material in air, water, foodstuffs, etc. that is established by authorities as the maximum that would not create undue risk to human health.

mR; mr. Abbreviation for milliroentgen.

MSTS. Military Sea Transportation Service, (Navy).

mushroom cap. Top of the cloud formed from the fireball of a nuclear detonation.

MV. Motor vessel.

MWB. Motor whale boat.

NAS. Naval Air Station.

NBS. National Bureau of Standards.

NCO. Noncommissioned officer.

NCRP. National Committee on Radiation Protection and Measurements. Before 1956 simply the National Committee on Radiation Protection.

NEL. Naval Electronics Laboratory.

neutron. A neutral elementary particle (i.e., with neutral electrical charge) of approximately unit mass (i.e., the mass of a proton) that is present in all atomic nuclei, except those of ordinary (light) hydrogen. Neutrons are required to initiate the fission process, and large numbers of neutrons are produced by both fission and fusion reactions in nuclear explosions.

neutron flux. The intensity of neutron radiation. It is expressed as the number of neutrons passing through 1 cm^2 in 1 second.

nmi. Nautical miles.

NPG. Nevada Proving Ground, now the Nevada Test Site (NTS).

NRDL. Naval Radiological Defense Laboratory.

NRL. Naval Research Laboratory.

NSC, TI. Naval Schools Command, Treasure Island, California.

NTPR. Nuclear Test Personnel Review.

NTS. Nevada Test Site.

nuclear cloud. See radioactive cloud.

nuclear device (or weapon or bomb). Any device in which the explosion results from the energy released by reactions involving atomic nuclei, either fission or fusion, or both. Thus, the A- (or atomic) bomb and the H- (or hydrogen) bomb are both nuclear weapons. It would be equally true to call them atomic weapons, since the energy of atomic nuclei is involved in each case. However, it has become more or less customary, although it is not strictly accurate, to refer to weapons in which all the energy results from fission as A-bombs. In order to make a distinction, those weapons in which part of the energy results from thermonuclear (fusion) reactions of the isotopes of hydrogen have been called H-bombs or hydrogen bombs.

nuclear explosion. Explosive release of energy due to the splitting, or joining, of atoms. The explosion is observable by a violent emission of ultraviolet, visible, and infrared (heat) radiation, gamma rays, neutrons, and other particles. This is accompanied by the formation of a fireball. A large part of the energy from the explosion is emitted as blast and shock waves when detonated at the Earth's surface or in the atmosphere. The fireball produces a mushroom-shaped mass of hot gases and debris, the top of which rises rapidly. See also radiation, gamma rays, fireball, nuclear weapon, fission, fusion, blast.

nuclear fusion. See thermonuclear fusion.

nuclear radiation. Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the weapons standpoint, are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true; X-rays, for example, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atomic nuclei.

nuclear tests. Tests carried out to supply information required for the design and improvement of nuclear weapons and to study the phenomena and effects associated with nuclear explosions.

nuclide. Any species of atom that exists for a measurable length of time. The term nuclide is used to describe any atomic species distinguished by the composition of its nucleus; i.e., by the number of protons and the number of neutrons. Isotopes of a given element are nuclides having the normal number of protons but different numbers of neutrons in this nuclei. A radionuclide is a radioactive nuclide.

NYKOPO. New York Operations Office (Atomic Energy Commission).

off-scale. Radiation (or other physical phenomena) greater than the capacity of a measuring device to measure.

ONR. Office of Naval Research, Washington, D.C.

ORNL. Oak Ridge National Laboratory, Tennessee.

oscilloscope. The name generally applied to a cathode-ray device.

overpressure. The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast) wave from an explosion.

P2V. Twin-engine patrol bomber used for maritime patrol and antisubmarine warfare. Developed by Lockheed for the U.S. Navy. Used in nuclear tests as controller and transient ship search.

PC. Patrol craft (Navy).

peak overpressure. The maximum value of the overpressure (which see) at a given location.

permissible dose. That dose of ionizing radiation that is not expected to cause appreciable bodily injury to a person at any time during his lifetime.

phantom. A volume of material closely approximating the density and effective atomic number of tissue. The phantom absorbs ionizing radiation in the same manner as tissue; thus, radiation dose measurements made within the phantom provide a means of approximating the radiation dose within a human or animal body under similar exposure conditions. Materials commonly used for phantoms are water, masonite, pressed wood, plexiglas, and beeswax.

pibal. Pilot balloon observation. A method of winds-aloft observation done by recording the elevation and azimiuth of a rising pilot balloon. This tracking is visual using a theodolite.

pig. A heavily shielded container (usually lead) used to ship or store radioactive materials.

POL. Petroleum, oil, and lubricants. The storage area for these products is referred to as a POL farm.

prompt radiation. Neutrons and gamma rays emitted almost simultaneously following a nuclear fission or fusion.

proton. A particle carrying a positive charge and physically identical to the nucleus of the ordinary hydrogen atom.

Purple conditions. A shipboard warning system used in radiological defense. Various numbered conditions were sounded when radioactive fallout was to be encountered. Responses to the sounded warnings included closing of various hatches and fittings, turning off parts of the ventilation system, and removing personnel from a ship's open decks. The higher the Purple condition number, the more severe the radiological situation.

"Q"-clearance. A security clearance granted by the Atomic Energy Commission, based upon a background investigation.

R; r. Symbol for roentgen.

R5D. Four-engine propeller transport manufactured by the Douglas Aircraft Company for the Navy and the Air Force, where it was designated C-54. Commercial versions were designated DC-4.

Ra. Chemical symbol for radium.

rad. Radiation absorbed dose. A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of ionizing radiation per gram (or 0.01 J/kg) of absorbing material, such as body tissue. This unit is presently being replaced in scientific literature by the Gray (Gy), numerically equal to the absorption of 1 joule of energy per kilogram of matter.

RadDefense. Radiological defense. Defense against the effects of radioactivity from atomic weapons. It includes the detection and measurement of radioactivity, the protection of persons from radioactivity, and decontamination of areas, places, and equipment. See also radsafe.

radex area. Radiological exclusion area. Following each detonation there were areas of surface radiological contamination and areas of air radiological contamination. These areas were designated as radex areas. Radex areas were used to chart actual or predicted fallout and also used for control of entry and exit.

radiac. Radiation detection, indication, and computation.

radiation. The emission of any rays, electromagnetic waves, or particles (e.g., gamma rays, alpha particles, beta particles, neutrons) from a source.

radiation decay. See decay (radioactive).

radiation detectors. Any of a wide variety of materials or instruments that provide a signal when stimulated by the passage of ionizing radiation; the sensitive element in radiation detection instruments. The most widely used media for the detection of ionizing radiation are photographic film and ionization of gases in detectors (e.g., Geiger counters), followed by materials in which radiation induces scintillation.

radiation exposure. Exposure to radiation may be described and modified by a number of terms. The type of radiation is important: alpha and beta particles, neutrons, gamma rays and X-rays, and cosmic radiation. Radiation exposure may be from an external radiation source, such as gamma rays, X-rays, or neutrons, or it may be from radionuclides retained within the body emitting alpha, beta, or gamma radiation. The exposure may result from penetrating or nonpenetrating radiation in relation to its ability to enter and pass through matter -- alpha and beta particles being considered as nonpenetrating and other types of radiation as penetrating. Exposure may be related to a part of the body or to the whole body. See also whole-body irradiation.

radiation intensity. Degree of radiation. Measured and reported in roentgens (R), rads, rems, and rep, multiples and divisions of these units, and multiples and divisions of these units as a function of exposure rate (per hour, day, etc.).

radioactive (or nuclear) cloud. An all-inclusive term for the cloud of hot gases, smoke, dust, and other particulate matter from the weapon itself and from the environment, which is carried aloft in conjunction with the rising fireball produced by the detonation of a nuclear weapon.

radioactive nuclide. See radionuclide.

radioactive particles. See radioactivity.

radioactive pool. A disk-like pool of radioactive water near the surface formed by a water-surface or subsurface detonation. The pool gradually expands into an annular form, then reverts to a larger irregular disk shape at later times with a corresponding attenuation of radioactivity.

radioactivity. The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an (unstable) nuclide. As a result of this emission the radioactive nuclide is converted (decays) into the isotope of a different (daughter) element, which 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.

radiological survey. The directed effort to determine the distribution and dose rate of radiation in an area.

radionuclide. A radioactive nuclide (or radioactive atomic species).

radiosonde. A balloon-borne instrument for the simultaneous measurement and transmission of meteorological data, consisting of transducers for the measurement of pressure, temperature, and humidity; a modulator for the conversion of the output of the transducers to a quantity that controls a property of the radiofrequency signal; a selector switch, which determines the sequence in which the parameters are to be transmitted; and a transmitter, which generates the radiofrequency carrier.

radiosonde balloon. A balloon used to carry a radiosonde aloft. These balloons have daytime bursting altitudes of about 80,000 feet (25 km) above sea level. The balloon measures about 5 feet (1.5 meters) in diameter when first inflated and may expand to 20 feet (6 meters) or more before bursting at high altitude.

radium. An intensely radioactive metallic element. In nature, radium is found associated with uranium, which decays to radium by a series of alpha and beta emissions. Radium is used as a radiation source for instrument calibration.

radsafe. Radiological safety. General term used to cover the training, operations, and equipment used to protect personnel from potential overexposures to nuclear radiation during nuclear tests.

rainout. Removal of radioactive particles from a nuclear cloud by rain.

rawin. Radar wind sounding tests that determine the winds aloft patterns by radar observation of a balloon.

rawinsonde. Radar wind sounding and radiosonde (combined).

RB-29. Reconnaissance version of the B-29.

RBE. Relative biological effectiveness. A factor used to compare the biological effectiveness of absorbed radiation doses (i.e., rads) due to different types of ionizing radiation. For radiation protection the term has been superseded by Quality Factor.

rem. A special unit of biological radiation dose equivalent; the name is derived from the initial letters of the term "roentgen equivalent man (or mammal)." The number of rems of radiation is equal to the number of rads absorbed multiplied by the RBE of the given radiation (for a specified effect). The rem is also the unit of dose equivalent, which is equal to the product of the number of rads absorbed multiplied by the Quality Factor and the distribution factor for the radiation. The unit is presently being replaced by the sievert (Sv).

rep. An obsolete special unit of absorbed dose.

residual nuclear radiation. Nuclear radiation, chiefly beta particles and gamma rays, that persists for a time following a nuclear explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout, and to some extent by earth and water constituents and other materials in which radioactivity has been induced by the capture of neutrons.

R-hour. Reentry hour.

riometer. Relative ionospheric opacity meter. A device that measures the intensity of cosmic (radiofrequency) noise.

roentgen (R; r). A special unit of exposure to gamma (or X-) radiation. It is defined precisely as the quantity of gamma (or X-) rays that will produce electrons (in ion pairs) with a total charge of 2.58 x 10^{-4} coulomb in 1 kilogram of dry air under standard conditions. An exposure of 1 roentgen results in the deposition of about 94 ergs of energy in 1 gram of soft body tissue. Hence, an exposure of 1 roentgen is approximately equivalent to an absorbed dose of 1 rad in soft tissue.

rollup. The process for orderly dismantling of facilities no longer required for nuclear test operations and their transfer to other areas.

RSSU. Radiological Safety Support Unit (Army).

SA-16. Air Force general-purpose amphibian for air-sea rescue work. Manufactured by Grumman Aircraft Engineering Corporation, New York. Redesignated UY-16.

SAC. Strategic Air Command (Air Force).

sampler aircraft. Aircraft used for collection of gaseous and particulate samples from nuclear clouds to determine the level of radioactivity or the presence of radioactive substances.

SAR. Search and rescue operations.

SC. Sandia Corporation, Albuquerque, New Mexico.

scattering. The diversion of radiation (thermal, electromagnetic, and nuclear) from its original path as a result of interactions (or collisions) with atoms, molecules, or larger particles in the atmosphere or other media between the source of the radiations (e.g., a nuclear explosion) and a point some distance away. As a result of scattering, radiations (especially gamma rays and neutrons) will be received at such a point from many directions instead of only from the direction of the source. See also skyshine.

SCEL. Signal Corps Engineering Laboratories, Ft. Monmouth, New Jersey (Army).

scintillation. A flash of light produced by ionizing radiation in a fluor or a phosphor, which may be crystal, plastic, gas, or liquid.

SCUBA. Self-contained breating apparatus.

seamount. A submarine mountain rising above the deep sea floor, commonly from 3,000 to 10,000 feet (1 to 3 km) and having the summit 1,000 to 6,000 feet (0.3 to 1.8 km) below sea level.

SEL. Signal Engineering Laboratory (Army).

shear (wind). Refers to differences in direction (directional shear) of wind at different altitudes.

shielding. Any material or obstruction that absorbs (or attenuates) radiation and thus tends to protect personnel or equipment from the effects of a nuclear explosion. 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 for gamma radiation shielding. See also attenuation.

shock. Term used to describe a destructive force moving in air, water, or earth caused by detonation of a nuclear detonation.

shock wave. A continuously propagated pressure pulse (or wave) in the surrounding medium, which may be air, water, or earth, initiated by the expansion of the hot gases produced in an explosion.

sievert (Sv). A recently introduced ICRP measure of "dose equivalent" that takes into account the "quality factor" of different sources of ionizing radiation. One sievert equals 100 rem.

SIO. Scripps Institution of Oceanography, La Jolla, California.

skyshine. Radiation, particularly gamma rays from a nuclear detonation, reaching a target from many directions as a result of scattering by the oxygen and nitrogen in the intervening atmosphere.

slant range. The straight-line distance of an aircraft at any altitude from surface zero or the distance from an airburst to a location on the ground.

SRI. Stanford Research Institute, Stanford, California.

stratosphere. Upper portion of the atmosphere, approximately 7 to 40 miles (11 to 64 km) above the Earth's surface, in which temperature changes but little with altitude and cloud formations are rare.

streamline. In meteorology, the direction of the wind at any given time.

surface burst. A nuclear explosion on the land surface, an island surface or reef, or on a barge.

surface zero. The point on the surface of land or water at, or vertically below or above, the center of the burst of a nuclear weapon.

survey meters. Portable radiation detection instruments especially adapted for surveying or inspecting an area to establish the existence and amount of radiation present, usually from the standpoint of radiological protection. Survey instruments are customarily powered by self-contained batteries and are designed to respond quickly and to indicate directly the exposure-rate conditions at the point of interest. See AN/PDR-36, Geiger-Mueller counter, and ion-chamber-type survey meter.

survey, radiation. Evaluation of the radiation hazards associated with radioactive materials.

T-AP. Personnel transport (Military Sea Transportion Service).

TAU. Test Aircraft Unit.

TBU. Test Base Unit.

TDY. Temporary duty assignment.

TG. Task Group.

TE. Task Element.

thermal radiation. Electromagnetic radiation emitted in two pulses from a surface or airburst from the fireball as a consequence of its very high temperature; it consists essentially of ultraviolet, visible, and infrared radiation. In the first pulse, when the temperature of the fireball is extremely high, ultraviolet radiation predominates; in the second pulse, the temperatures are lower and most of the thermal radiation lies in the visible and infrared regions of the spectrum.

thermonuclear fusion. Refers to the processes in which very high temperatures are used to bring about the fusion of light nuclei, such as those of the hydrogen isotopes (deuterium and tritium), with the accompanying liberation of energy. The high temperatures required to initiate the fusion reaction are obtained by means of a fission explosion. See also fusion.

TNT equivalent. A measure of the energy released as the result of the detonation of a nuclear device or weapon, expressed in terms of the mass of TNT that would release the same amount of energy when exploded. The TNT equivalent is usually stated in kilotons (thousands of tons) or megatons (millions of tons). The basis of the TNT equivalence is that the explosion of 1 ton of TNT is assumed to release 1 billion calories of energy. See also megaton, yield.

trapped radiation. Electrically charged particles moving back and forth in spirals along the north-south orientation of the Earth's magnetic field between mirror points, called conjugate points. Negatively charged particles drift eastward as they bounce between northern and southern conjugate points and positively charged particles drift westward, thus forming shells or belts of radiation above the Earth. The source of the charged particles may be natural, from solar activity (often called Van Allen belts), or artifical, resulting from high-altitude nuclear detonations.

tropopause. The boundary dividing the stratosphere from the lower part of the atmosphere, the troposphere. The tropopause normally occurs at an altitude of about 25,000 to 45,000 feet (7.6 to 13.7 km) in polar and temperate zones, and at 55,000 feet (16.8 km) in the tropics. See also stratosphere, troposphere.

troposphere. The region of the atmosphere, immediately above the Earth's surface and up to the tropopause, in which the temperature falls fairly regularly with increasing altitude, clouds form, convection is active, and mixing is continuous and more or less complete.

Trust Territory. The Marshall Islands were included in the Trust Territory of the Pacific Islands under the jurisdiction of the United Nations. Assigned by the United Nations to the United States in trust for administration, development, and training.

TU. Task Unit.

TSU. Test Services Unit.

TSUP. Test Support Unit (Provisional).

type commander. The officer or agency having cognizance over all Navy ships of a given type. This is in addition to the particular ship's assignment in a task force, fleet, or other tactical subdivision.

UCLA. University of California, Los Angeles.

UCRL..University of California Radiation Laboratory, Livermore, California.

UF-1. The Navy designation for the SA-16A.

UHF. Ultra-high frequency.

ultraviolet. Electromagnetic radiation of wavelengths between the shortest visible violet (about 3,850 angstroms) and soft X-rays (about 100 angstroms).

USFS. U.S. Forest Service.

USNS. United States Navy Ship; vessels of this designation are manned by civilian crews.

VA. Veterans Administration.

versene. A detergent.

VHF. Very-high-frequency radio communications. The VHF band is from 30 to 300 kHz.

VP. Aviation patrol squadron (Navy).

VR. Air transport squadron (Navy).

WADC. Wright Air Development Center, Wright-Patterson AFB, Ohio (Air Force).

warhead. The portion of the missile or bomb containing the nuclear device.

WASP. Five-inch shells fired to spread radar-trackable material (window) to study high-altitude winds.

WB-29. Weather reconnaissance version of B-29 used for cloud tracking and sampling.

weapon debris. The radioactive residue of a nuclear device after it has been detonated, consisting of fission products, various products of neutron capture, weapon casing and other components, and uranium or plutonium that has escaped fission.

WES. Waterways Experiment Station (Army).

whole-body irradiation. Exposure of the body to ionizing radiation from external radiation sources. Critical organs for the whole body are the lens of the eye, the gonads, and the red-blood-forming marrow. As little as only 1 cm^3 of bone marrow constitutes a whole-body exposure. Thus, the entire body need not be exposed to be classed as a whole-body exposure.

Wilson cloud. A mist or fog of minute water droplets that temporarily surrounds a fireball following a nuclear detonation in a humid atmosphere. This is caused by a sudden lowering of the pressure (and temperature) after the passing of the shock wave (cloud chamber effect) and quickly dissipates as temperatures and pressures return to normal.

worldwide fallout. Consists of the smaller radioactive nuclear detonation particles that ascend into the upper troposphere and the stratosphere and are carried by winds to all parts of the Earth. The delayed (or worldwide) fallout is brought to Earth, mainly by rain and snow, over extended periods ranging from months to years.

WT. Prefix of Weapon Test (WT) report identification numbers. These reports were prepared to record the results of scientific experiments.

YAG. Miscellaneous auxiliary ship (Navy).

YC. Open lighter (non-self-propelled; Navy).

YCV. Aircraft transportation lighter, non-self-propelled (Navy).

YFN. Covered lighter, non-self-propelled (Navy).

YFNB. Large covered lighter (Navy).

yield. The total effective energy released in a nuclear detonation. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation (including residual radiation), thermal radiation, and blast and shock energy, the actual distribution depending upon the medium in which the explosion occurs and also upon the type of weapon. See TNT equivalent.

yield (blast). That portion of the total energy of a nuclear detonation that is identified as the blast or shock wave.

yield (fission). That portion of the total explosive yield attributable to nuclear fission, as opposed to fusion. The interest in fission yield stems from the interest in fission product formation and its relationship to radioactive fallout.

YO. Fuel oil barge, self-propelled (Navy).

YOG. Gasoline barge, self-propelled (Navy).

YOGN. Gasoline barge non-self-propelled (Navy).

YON. Oil storage barge, non-self-propelled (Navy).

ZI. Zone of Interior (conterminous United States).

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Huntington, WV
ATTN: Director

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

Veterans Administration - RO
Fort Harrison, MT
ATTN: Director

Veterans Administration - RO
Lincoln, NE
ATTN: Director

Veterans Administration - RO
Reno, NV
ATTN: Director

Veterans Administration - RO
Manchester, NH
ATTN: Director

Veterans Administration - RO
Newark, NJ
ATTN: Director

Veterans Administration - RO
Milwaukee, WI
ATTN: Director

Veterans Administration - RO
Albuquerque, NM
ATTN: Director

Veterans Administration - RO
Buffalo, NY
ATTN: Director

Veterans Administration -RO
New York, NY
ATTN: Director

Veterans Administration -RO
Winston Salem, NC
ATTN: Director

Veterans Administration - RO
Fargo, ND
ATTN: Director

Veterans Administration - RO
Cleveland, OH
ATTN: Director

Veterans Administration - RO
Muskogee, OK
ATTN: Director

OTHER GOVERNMENT AGENCIES (Continued)

Veterans Administration - RO
Portland, OR
ATTN: Director

Veterans Administration - RO
Pittsburgh, PA
ATTN: Director

Veterans Administration - RO
Philadelphia, PA
ATTN: Director

Veterans Administration - RO
APO San Francisco
ATTN: Director

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

Veterans Administration - RO
Columbia, SC
ATTN: Director

Veterans Administration - RO
Sioux Falls, SD
ATTN: Director

Veterans Administration - RO
Houston, TX
ATTN: Director

Veterans Administration - RO
Waco, TX
ATTN: Director

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

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

Veterans Administration - RO
Roanoke, VA
ATTN: Director

Veterans Administration - RO
Cheyenne, WY
ATTN: Director

Veterans Administration - RO
San Diego, CA
ATTN: Director

Veterans Administration - RO
Boise, ID
ATTN: Director

Veterans Administration - RO
Detroit, MI
ATTN: Director

OTHER GOVERNMENT AGENCIES (Continued)

Veterans administration - RO
Nashville, TN
ATTN: Director

The White House
ATTN: Domestic Policy Staff

DEPARTMENT OF DEFENSE CONTRACTORS

Advanced Research & Applications Corp
ATTN: H. Lee

JAYCOR
ATTN: A. Nelson
10 cy ATTN: Health & Environment Div

Kaman Tempo
6 cy ATTN: E. Martin
ATTN: DASIAC

Kaman Tempo
ATTN: R. Miller

Kaman Tempo
10 cy ATTN: C. Jones
ATTN: DASIAC

National Academy of Sciences
ATTN: C. Robinette
ATTN: Medical Follow-up Agency
ATTN: National Materials Advisory Board

Pacific-Sierra Research Corp
ATTN: H. Brode, Chairman SAGE

R & D Associates
ATTN: P. Haas

Rand Corp
ATTN: P. Davis

Rand Corp
ATTN: B. Bennett

Science Applications, Inc
ATTN: Tech Library

Science Applications, Inc
10 cy ATTN: L. Novotney

OTHER

Adams State College
ATTN: Govt Publication Lib

Akron Public Library
ATTN: Govt Publication Librarian

Alabama St Dept of Archives & History
ATTN: Military Records Division

University of Alabama
ATTN: Reference Dept/Documents

OTHER (Continued)

Albany Public Library
ATTN: Librarian

Alexander City State Jr College
ATTN: Librarian

Allegheny College
ATTN: Librarian

Allen County Public Library
ATTN: Librarian

Altoona Area Public Library
ATTN: Librarian

American Statistics Index
ATTN: Cathy Jarvey

Anaheim Public Library
ATTN: Librarian

Andrews Library, College of Wooster
ATTN: Government Documents

Angelo State University Library
ATTN: Librarian

Angelo Iacoboni Pub Lib
ATTN: Librarian

Anoka County Library
ATTN: Librarian

Appalachian State University
ATTN: Library Documents

Arizona State University Library
ATTN: Librarian

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

Arkansas College Library
ATTN: Library

Arkansas Library Comm
ATTN: Library

Arkansas State University
ATTN: Library

University of Arkansas
ATTN: Government Documents Div

Austin College
Arthur Hopkins Library
ATTN: Librarian

Atlanta Public Library
ATTN: Ivan Allen Dept

Atlanta University Center
ATTN: Librarian

OTHER (Continued)

Auburn Univ at Montgomery Lib
ATTN: Librarian

B. Davis Schwartz Mem Lib
ATTN: Librarian

Bangor Public Library
ATTN: Librarian

Bates College Library
ATTN: Librarian

Baylor University Library
ATTN: Docs Dept

Beloit College Libraries
ATTN: Serials Docs Dept

Bemidji State College
ATTN: Library

Benjamin F. Feinberg Library
State University College
ATTN: Government Documents

Bierce Library, Akron University
ATTN: Government Documents

Boston Public Library
ATTN: Documents Department

Bowdoin College
ATTN: Librarian

Bowling Green State Univ
ATTN: Govt Docs Services

Bradley University
ATTN: Govt Publication Librarian

Brandeis University Lib
ATTN: Documents Section

Brigham Young University
ATTN: Librarian

Brigham Young University
ATTN: Documents Collection

Brookhaven National Laboratory
ATTN: Technical Library

Brooklyn College
ATTN: Documents Division

Broward County Library Sys
ATTN: Librarian

Brown University
ATTN: Librarian

Bucknell University
ATTN: Reference Dept

OTHER (Continued)

Buffalo & Erie Co Pub Lib
ATTN: Librarian

Burlington Library
ATTN: Librarian

California at Fresno State Univ Lib
ATTN: Library

California at San Diego University
ATTN: Documents Department

California at Stanislavs St Clg Lib
ATTN: Library

California St Polytechnic Univ Lib
ATTN: Librarian

California St Univ at Northridge
ATTN: Gov Doc

California State Library
ATTN: Librarian

California State Univ at Long Beach Lib
ATTN: Librarian

California State University
ATTN: Librarian

California State University
ATTN: Librarian

California Univ Library
ATTN: Govt Publications Dept

California Univ Library
ATTN: Librarian

California University Library
ATTN: Govt Documents Dept

California University Library
ATTN: Documents Sec

California University
ATTN: Government Documents Dept

Calvin College Library
ATTN: Librarian

Calvin T. Ryan Library
Kearney State College
ATTN: Govt Documents Dept

Carleton College Library
ATTN: Librarian

Carnegie Library of Pittsburgh
ATTN: Librarian

Carnegie Mellon University
ATTN: Director of Libraries

OTHER (Continued)

Carson Regional Library
ATTN: Gov Publications Unit

Case Western Reserve University
ATTN: Librarian

University of Central Florida
ATTN: Library Docs Dept

Central Michigan University
ATTN: Library Documents Section

Central Missouri State Univ
ATTN: Government Documents

Central State University
ATTN: Library Documents Dept

Central Washington University
ATTN: Library Docs Section

Central Wyoming College Library
ATTN: Librarian

Charleston County Library
ATTN: Librarian

Charlotte & Mechlenburg County Pub Lib
ATTN: E. Correll

Chattanooga Hamilton Co
ATTN: Librarian

Chesapeake Pub Lib System
ATTN: Librarian

Chicago Public Library
ATTN: Governments Publications Dept

State University of Chicago
ATTN: Librarian

Chicago University Library
ATTN: Director of Libraries
ATTN: Documents Processing

Cincinnati University Library
ATTN: Librarian

Claremont Colleges Libs
ATTN: Doc Collection

Clemson University
ATTN: Director of Libraries

Cleveland Public Library
ATTN: Documents Collection

Cleveland State Univ Lib
ATTN: Librarian

Coe Library
ATTN: Documents Division

OTHER (Continued)

Colgate Univ Library
ATTN: Reference Library

Colorado State Univ Libs
ATTN: Librarian

Colorado University Libraries
ATTN: Director of Libraries

Columbia University Library
ATTN: Documents Service Center

Columbus & Franklin Cty Public Lib
ATTN: Gen Rec Div

Compton Library
ATTN: Librarian

Connecticut State Library
ATTN: Librarian

University of Connecticut
ATTN: Govt of Connecticut

Connecticut University
ATTN: Director of Libraries

Cornell University Lib
ATTN: Librarian

Corpus Christi State University Lib
ATTN: Librarian

Culver City Library
ATTN: Librarian

Curry College Library
ATTN: Librarian

Dallas County Public Library
ATTN: Librarian

Dallas Public Library
ATTN: Librarian

Dalton Jr College Library
ATTN: Librarian

Dartmouth College
ATTN: Librarian

Davenport Public Library
ATTN: Librarian

Davidson College
ATTN: Librarian

Dayton & Montgomery City Pub Lib
ATTN: Librarian

University of Dayton
ATTN: Librarian

OTHER (Continued

Decatur Public Library
ATTN: Librarian

Dekalb Comm Coll So Cpus
ATTN: Librarian

Delaware Pauw University
ATTN: Librarian

University of Delaware
ATTN: Librarian

Delta College Library
ATTN: Librarian

Delta State University
ATTN: Librarian

Denison Univ Library
ATTN: Librarian

Denver Public Library
ATTN: Documents Div

Dept of Lib & Archives
ATTN: Librarian

Detroit Public Library
ATTN: Librarian

Dickinson State College
ATTN: Librarian

Drake Memorial Learning Resource Ctr
ATTN: Librarian

Drake University
ATTN: Cowles Library

Drew University
ATTN: Librarian

Duke University
ATTN: Public Docs Dept

Duluth Public Library
ATTN: Documents Section

Earlham College
ATTN: Librarian

East Carolina University
ATTN: Library Docs Dept

East Central University
ATTN: Librarian

East Islip Public Library
ATTN: Librarian

East Orange Public Lib
ATTN: Librarian

East Tennessee State Univ Sherrod Lib
ATTN: Documents Dept

OTHER (Continued)

East Texas State University
ATTN: Library

Eastern Branch
ATTN: Librarian

Eastern Illinois University
ATTN: Librarian

Eastern Kentucky University
ATTN: Librarian

Eastern Michigan University Lib
ATTN: Documents Libn

Eastern Montana College Library
ATTN: Documents Dept

Eastern New Mexico Univ
ATTN: Librarian

Eastern Oregon College Library
ATTN: Librarian

Eastern Washington Univ
ATTN: Librarian

El Paso Public Library
ATTN: Documents & Geneology Dept

Elko County Library
ATTN: Librarian

Elmira College
ATTN: Librarian

Elon College Library
ATTN: Librarian

Enoch Pratt Free Library
ATTN: Documents Office

Emory University
ATTN: Librarian

Evansville & Vanderburgh County Pub Lib
ATTN: Librarian

Everett Public Library
ATTN: Librarian

Fairleigh Dickinson Univ
ATTN: Depository Dept

Florida A & M Univ
ATTN: Librarian

Florida Atlantic Univ Lib
ATTN: Div of Public Documents

Florida Institute of Tech Lib
ATTN: Federal Documents Dept

Florida Intl Univ Library
ATTN: Docs Section

OTHER (Continued)

Florida State Library
ATTN: Documents Section

Florida State University
ATTN: Librarian

University of Alaska
ATTN: Director of Libraries

Fond Du Lac Public Lib
ATTN: Librarian

Fort Hays State University
ATTN: Librarian

Fort Worth Public Library
ATTN: Librarian

Free Pub Lib of Elizabeth
ATTN: Librarian

Free Public Library
ATTN: Librarian

Freeport Public Library
ATTN: Librarian

Fresno County Free Library
ATTN: Librarian

Gadsden Public Library
ATTN: Librarian

Garden Public Library
ATTN: Librarian

Gardner Webb College
ATTN: Documents Librn

Gary Public Library
ATTN: Librarian

Georgetown Univ Library
ATTN: Govt Docs Room

Georgia Inst of Tech
ATTN: Librarian

Georgia Southern College
ATTN: Librarian

Georgia Southwestern College
ATTN: Director of Libraries

Georgia State Univ Lib
ATTN: Librarian

University of Georgia
ATTN: Dir of Libraries

Glassboro State College
ATTN: Librarian

Gleeson Library
ATTN: Librarian

OTHER (Continued)

Government Publications Library-M
ATTN: Director of Libraries

Graceland College
ATTN: Librarian

Grand Forks Public City-County Library
ATTN: Librarian

Grand Rapids Public Library
ATTN: Director of Libraries

Greenville County Library
ATTN: Librarian

Guam RFK Memorial University Lib
ATTN: Fed Depository Collection

University of Guam
ATTN: Librarian

Gustavus Adolphus College
ATTN: Library

Hardin-Simmons University Library
ATTN: Librarian

Hartford Public Library
ATTN: Librarian

Harvard College Library
ATTN: Director of Libraries

Harvard College Library
ATTN: Librarian

University of Hawaii
ATTN: Government Docs Collection

Hawaii State Library
ATTN: Federal Documents Unit

University of Hawaii at Monoa
ATTN: Director of Libraries

University of Hawaii
ATTN: Librarian

Haydon Burns Library
ATTN: Librarian

Henry Ford Comm College Lib
ATTN: Librarian

Herbert H. Lehman College
ATTN: Library Documents Division

Hofstra Univ Library
ATTN: Documents Dept

Hollins College
ATTN: Librarian

Hoover Institution
ATTN: J. Bingham

OTHER (Continued)

Hopkinsville Comm College
ATTN: Librarian

University of Houston, Library
ATTN: Documents Div

Houston Public Library
ATTN: Librarian

Hoyt Public Library
ATTN: Librarian

Humboldt State College Library
ATTN: Documents Dept

Huntington Park Library
ATTN: Librarian

Hutchinson Public Library
ATTN: Librarian

Idaho Public Lib & Info Center
ATTN: Librarian

Idaho State Library
ATTN: Librarian

Idaho State University Library
ATTN: Documents Dept

University of Idaho
ATTN: Documents Sect
ATTN: Dir of Libraries

University of Illinois, Library
ATTN: Documents Section

Illinois State Library
ATTN: Government Documents Branch

Illinois Univ at Urbana Champaign
ATTN: P. Watson, Documents Library

Illinois Valley Comm Coll
ATTN: Library

Indiana State Library
ATTN: Serial Section

Indiana State University
ATTN: Documents Libraries

Indiana University Library
ATTN: Documents Department

Indianapolis Marion Cty Pub Library
ATTN: Social Science Div

Iowa State University Library
ATTN: Govt Documents Dept

Iowa University Library
ATTN: Government Documents Dept

OTHER (Continued)

Butler University, Irwin Library
ATTN: Librarian

Isaac Delchdo College
ATTN: Librarian

James Madison University
ATTN: Librarian

Jefferson County Public Lib
ATTN: Librarian

Jersey City State College
ATTN: Librarian

Johns Hopkins University
ATTN: Documents Library

John J. Wright Library, La Roche College
ATTN: Librarian

Johnson Free Public Lib
ATTN: Librarian

Kahului Library
ATTN: Librarian

Kalamazoo Public Library
ATTN: Librarian

Kansas City Public Library
ATTN: Documents Div

Kansas State Library
ATTN: Librarian

Kansas State Univ Library
ATTN: Documents Dept

University of Kansas
ATTN: Director of Libraries

Kent State University Library
ATTN: Documents Div

Kentucky Dept of Library & Archives
ATTN: Documents Section

University of Kentucky
ATTN: Governments Publication Dept
ATTN: Director of Libraries

Kenyon College Library
ATTN: Librarian

Lake Forest College
ATTN: Librarian

Lake Sumter Comm Coll Lib
ATTN: Librarian

Lakeland Public Library
ATTN: Librarian

OTHER (Continued)

Lancaster Regional Library
ATTN: Librarian

Lawrence University
ATTN: Documents Dept

Lee Library, Brigham Young University
ATTN: Documents & Map Section

Library & Statutory Distribution & Svc
2 cy ATTN: Librarian

Little Rock Public Library
ATTN: Librarian

Long Beach Publ Library
ATTN: Librarian

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

Louisiana State University
ATTN: Government Doc Dept
ATTN: Director of Libraries

Louisville Free Pub Lib
ATTN: Librarian

Louisville Univ Library
ATTN: Librarian

Lyndon B. Johnson Sch of Pub Affairs Lib
ATTN: Librarian

Maine Maritime Academy
ATTN: Librarian

Maine University at Oreno
ATTN: Librarian

University of Maine
ATTN: Librarian

Manchester City Library
ATTN: Librarian

Mankato State College
ATTN: Govt Publications

Mantor Library
Univ of Maine at Farmington
ATTN: Director of Libraries

Marathon County Public Library
ATTN: Librarian

Marshall Brooks Library
ATTN: Librarian

University of Maryland
ATTN: McKeldin Libr Docs Div

University of Maryland
ATTN: Librarian

OTHER (Continued)

University of Massachusetts
ATTN: Government Docs College

McNeese State Univ
ATTN: Librarian

Memphis Shelby County Pub Lib & Info Ctr
ATTN: Librarian

Memphis State University
ATTN: Librarian

Mercer University
ATTN: Librarian

Mesa County Public Library
ATTN: Librarian

University of Miami, Library
ATTN: Government Publications

Miami Public Library
ATTN: Documents Division

Miami Univ Library
ATTN: Documents Dept

Michel Orradre Library
University of Santa Clara
ATTN: Documents Div

Michigan State Library
ATTN: Librarian

Michigan State University Library
ATTN: Librarian

Michigan Tech University
ATTN: Library Documents Dept

University of Michigan
ATTN: Acq Sec Documents Unit

Middlebury College Library
ATTN: Librarian

Millersville State Coll
ATTN: Librarian

Milne Library
State University of New York
ATTN: Docs Librn

Milwaukee Pub Lib
ATTN: Librarian

Minneapolis Public Lib
ATTN: Librarian

Minnesota Div of Emergency Svcs
ATTN: Librarian

Minot State College
ATTN: Librarian

Mississippi State University
ATTN: Librarian

OTHER (Continued)

University of Mississippi
ATTN: Director of Libraries

Missouri Univ at Kansas City Gen
ATTN: Librarian

Missouri University Library
ATTN: Government Documents

M.I.T. Libraries
ATTN: Librarian

Mobile Public Library
ATTN: Governmental Info Division

Moffett Library
ATTN: Librarian

Montana State Library
ATTN: Librarian

Montana State University, Library
ATTN: Librarian

University of Montana
ATTN: Documents Div

Moorhead State College
ATTN: Library

Mt Prospect Public Lib
ATTN: Librarian

Murray State Univ Lib
ATTN: Library

Nassau Library System
ATTN: Librarian

Natrona County Public Library
ATTN: Librarian

Nebraska Library Comm
ATTN: Librarian

Univ of Nebraska at Omaha
ATTN: Librarian

Nebraska Western College Library
ATTN: Librarian

Univ of Nebraska at Lincoln
ATTN: Director of Libraries

Univ of Nevada at Reno
ATTN: Governments Pub Dept

Univ of Nevada at Las Vegas
ATTN: Director of Libraries

New Hampshire University Lib
ATTN: Librarian

New Hanover County Public Library
ATTN: Librarian

Nebraska University Library
ATTN: Acq Dept

OTHER (Continued)

New Mexico State Library
ATTN: Librarian

New Mexico State University
ATTN: Lib Documents Div

University of New Mexico
ATTN: Director of Libraries

University of New Orleans Library
ATTN: Govt Documents Div

New Orleans Public Lib
ATTN: Library

New York Public Library
ATTN: Librarian

New York State Library
ATTN: Doc Control, Cultural Ed Ctr

New York State Univ at Stony Brook
ATTN: Main Lib Doc Sect

New York State Univ Col at Cortland
ATTN: Librarian

State Univ of New York
ATTN: Library Documents Sec

State Univ of New York
ATTN: Librarian

New York State University
ATTN: Documents Center

State University of New York
ATTN: Documents Dept

New York University Library
ATTN: Documents Dept

Newark Free Library
ATTN: Librarian

Newark Public Library
ATTN: Librarian

Niagara Falls Pub Lib
ATTN: Librarian

Nicholls State Univ Library
ATTN: Docs Div

Nieves M. Flores Memorial Lib
ATTN: Librarian

Norfolk Public Library
ATTN: R. Parker

North Carolina Agri & Tech State Univ
ATTN: Librarian

Univ of North Carolina at Charlotte
ATTN: Atkins Library Documents Dept

Univ of North Carolina at Greensboro, Library
ATTN: Librarian

OTHER (Continued)

North Carolina Central University
ATTN: Librarian

North Carolina State University
ATTN: Librarian

North Carolina University at Wilmington
ATTN: Librarian

University of North Carolina
ATTN: BA SS Division Documents

North Dakota State University Lib
ATTN: Docs Librarian

University of North Dakota
ATTN: Librarian

North Georgia College
ATTN: Librarian

North Texas State University Library
ATTN: Librarian

Northeast Missouri State University
ATTN: Librarian

Northeastern Illinois University
ATTN: Library

Northeastern Oklahoma State Univ
ATTN: Librarian

Northeastern University
ATTN: Dodge Library

Northern Arizona University Lib
ATTN: Government Documents Dept

Northern Illinois University
ATTN: Librarian

Northern Iowa University
ATTN: Library

Northern Michigan Univ
ATTN: Documents

Northern Montana College Library
ATTN: Librarian

Northwestern Michigan College
ATTN: Librarian

Northwestern State Univ
ATTN: Librarian

Northwestern State Univ Library
ATTN: Librarian

Northwestern University Library
ATTN: Govt Publications Dept

Norwalk Public Library
ATTN: Librarian

OTHER (Continued)

University of Notre Dame
ATTN: Document Center

Oakland Comm College
ATTN: Librarian

Oakland Public Library
ATTN: Librarian

Oberlin College Library
ATTN: Librarian

Ocean County College
ATTN: Librarian

Ohio State Library
ATTN: Librarian

Ohio State University
ATTN: Libraries Documents Division

Ohio University Library
ATTN: Docs Dept

Oklahoma City University Library
ATTN: Librarian

Oklahoma City University Library
ATTN: Librarian

Oklahoma Dept of Libraries
ATTN: U.S. Govt Documents

University of Oklahoma
ATTN: Documents Div

Old Dominion University
ATTN: Doc Dept Univ Library

Olivet College Library
ATTN: Librarian

Omaha Pub Lib Clark Branch
ATTN: Librarian

Oregon State Library
ATTN: Librarian

University of Oregon
ATTN: Documents Section

Ouachita Baptist University
ATTN: Librarian

Pan American University Library
ATTN: Librarian

Passaic Public Library
ATTN: Librarian

Paul Klapper Library
ATTN: Documents Dept

Pennsylvania State Library
ATTN: Government Publications Section

OTHER (Continued)

Pennsylvania State University
ATTN: Library Document Sec

University of Pennsylvania
ATTN: Director of Libraries

Penrose Library
University of Denver
ATTN: Penrose Library

Peoria Public Library
ATTN: Business, Science & Tech Dept

Free Library of Philadelphia
ATTN: Govt Publications Dept

Philipsburg Free Public Library
ATTN: Library

Phoenix Public Library
ATTN: Librarian

University of Pittsburg
ATTN: Documents Office G 8

Plainfield Public Library
ATTN: Librarian

Popular Creek Public Lib District
ATTN: Librarian

Association of Portland Lib
ATTN: Librarian

Portland Public Library
ATTN: Librarian

Portland State University Library
ATTN: Librarian

Prescott Memorial Lib
Louisiana Tech Univ
ATTN: Librarian

Princeton University Library
ATTN: Documents Division

Providence College
ATTN: Physics Dept

Providence Public Library
ATTN: Librarian

Cincinnati & Hamilton County Public Library
ATTN: Librarian

Public Library of Nashville and Davidson County
ATTN: Library

University of Puerto Rico
ATTN: Doc & Maps Room

Purdue University Library
ATTN: Librarian

OTHER (Continued)

Quinebaug Valley Community Col
ATTN: Librarian

Ralph Brown Draughon Lib
Auburn University
ATTN: Microforms & Documents Dept

Rapid City Public Library
ATTN: Librarian

Reading Public Library
ATTN: Librarian

Reed College Library
ATTN: Librarian

Reese Library
Augusta College
ATTN: Librarian

University of Rhode Island Library
ATTN: Govt Publications Office

University of Rhode Island
ATTN: Director of Libraries

Rice University
ATTN: Director of Libraries

Richard W. Norton Mem Lib
Louisiana College
ATTN: Librarian

Richland County Pub Lib
ATTN: Librarian

University of Richmond
ATTN: Library

Riverside Public Library
ATTN: Librarian

University of Rochester Library
ATTN: Documents Section

Rutgers University, Camden Library
ATTN: Librarian

Rutgers State University
ATTN: Librarian

Rutgers University
ATTN: Govt Docs Dept

Rutgers University Law Library
ATTN: Federal Documents Dept

Salem College Library
ATTN: Librarian

Samford University
ATTN: Librarian

San Antonio Public Library
ATTN: Bus Science & Tech Dept

OTHER (Continued)

San Diego County Library
ATTN: C. Jones, Acquisitions

San Diego Public Library
ATTN: Librarian

San Diego State University Library
ATTN: Govt Pubs Dept

San Francisco Public Library
ATTN: Govt Documents Dept

San Francisco State College
ATTN: Govt Pub Collection

San Jose State College Library
ATTN: Documents Dept

San Luis Obispo City-County Library
ATTN: Librarian

Savannah Pub & Effingham Libty Reg Lib
ATTN: Librarian

Scottsbluff Public Library
ATTN: Librarian

Scranton Public Library
ATTN: Librarian

Seattle Public Library
ATTN: Ref Doc Asst

Selby Public Library
ATTN: Librarian

Shawnee Library System
ATTN: Librarian

Shreve Memorial Library
ATTN: Librarian

Silas Bronson Public Library
ATTN: Librarian

Simon Schwob Mem Lib
Columbus College
ATTN: Librarian

Sioux City Public Library
ATTN: Librarian

Skidmore College
ATTN: Librarian

Slippery Rock State College Library
ATTN: Librarian

South Carolina State Library
ATTN: Librarian

University of South Carolina
ATTN: Librarian

OTHER (Continued)

University of South Carolina
ATTN: Government Documents

South Dakota Sch of Mines & Tech
ATTN: Librarian

South Dakota State Library
ATTN: Federal Documents Department

University of South Dakota
ATTN: Documents Librarian

South Florida University Library
ATTN: Librarian

Southdale-Hennepin Area Library
ATTN: Government Documents

Southeast Missouri State University
ATTN: Librarian

Southeastern Massachusetts University Library
ATTN: Documents Sec

University of Southern Alabama
ATTN: Librarian

Southern California University Library
ATTN: Documents Dept

Southern Connecticut State College
ATTN: Library

Southern Illinois University
ATTN: Librarian

Southern Illinois University
ATTN: Documents Ctr

Southern Methodist University
ATTN: Librarian

University of Southern Mississippi
ATTN: Library

Southern Oregon College
ATTN: Library

Southern University in New Orleans, Library
ATTN: Librarian

Southern Utah State College Library
ATTN: Documents Department

Southwest Missouri State College
ATTN: Library

Southwestern University of Louisiana, Libraries
ATTN: Librarian

Southwestern University School of Law Library
ATTN: Librarian

OTHER (Continued)

Spokane Public Library
ATTN: Reference Dept

Springfield City Library
ATTN: Documents Section

St. Bonaventure University
ATTN: Librarian

St. Joseph Public Library
ATTN: Librarian

St. Lawrence University
ATTN: Librarian

St. Louis Public Library
ATTN: Librarian

St. Paul Public Library
ATTN: Librarian

Stanford University Library
ATTN: Govt Documents Dept

State Historical Soc Lib
ATTN: Docs Serials Section

State Library of Massachusetts
ATTN: Librarian

State University of New York
ATTN: Librarian

Stetson Univ
ATTN: Librarian

University of Steubenville
ATTN: Librarian

Stockton & San Joaquin Public Lib
ATTN: Librarian

Stockton State College Library
ATTN: Librarian

Superior Public Library
ATTN: Librarian

Swarthmore College Lib
ATTN: Reference Dept

Syracuse University Library
ATTN: Documents Div

Tacoma Public Library
ATTN: Librarian

Tampa, Hillsborough County Public Lib
ATTN: Librarian

Temple University
ATTN: Librarian

Tennessee Technological University
ATTN: Librarian

OTHER (Continued)

University of Tennessee
ATTN: Dir of Libraries

Terteling Library
College of Idaho
ATTN: Librarian

Texas A & M University Library
ATTN: Librarian

University of Texas at Arlington
ATTN: Library Documents

University of Texas at San Antonio
ATTN: Library

Texas Christian University
ATTN: Librarian

Texas State Library
ATTN: U.S. Documents Sect

Texas Tech University Library
ATTN: Govt Docs Dept

Texas University at Austin
ATTN: Documents Coll

Texas University at El Paso
ATTN: Documents and Maps Lib

University of Toledo Library
ATTN: Librarian

Toledo Public Library
ATTN: Social Science Dept

Torrance Civic Center Library
ATTN: Librarian

Traverse City Public Library
ATTN: Librarian

Trenton Free Public Library
ATTN: Librarian

Trinity College Library
ATTN: Librarian

Trinity University Library
ATTN: Documents Collection

Tufts University Library
ATTN: Documents Dept

Tulane University
ATTN: Documents Dept

University of Tulsa
ATTN: Librarian

UCLA Research Library
ATTN: Public Affairs Svc/US Docs

OTHER (Continued)

Uniformed Svcs Univ of the Hlth Sci
ATTN: LRC Library

University Libraries
ATTN: Dir of Libraries

Upper Iowa College
ATTN: Documents Collection

Utah State University
ATTN: Librarian

University of Utah
ATTN: Special Collections

University of Utah
ATTN: Dept of Pharmacology
ATTN: Director of Libraries

Valencia Library
ATTN: Librarian

Vanderbilt University Library
ATTN: Govt Docs Sect

University of Vermont
ATTN: Director of Libraries

Virginia Commonwealth University
ATTN: Librarian

Virginia Military Institute
ATTN: Librarian

Virginia Polytechnic Inst Lib
ATTN: Docs Dept

Virginia State Library
ATTN: Serials Section

University of Virginia
ATTN: Public Documents

Volusia County Public Libraries
ATTN: Librarian

Washington State Library
ATTN: Documents Section

Washington State University
ATTN: Lib Documents Section

Washington University Libraries
ATTN: Dir of Libraries

University of Washington
ATTN: Documents Div

Wayne State University Library
ATTN: Librarian

Wayne State University Law Library
ATTN: Documents Dept

Weber State College Library
ATTN: Librarian

Wagner College
ATTN: Librarian

OTHER (Continued)

Wesleyan University
ATTN: Documents Librarian

West Chester State Coll
ATTN: Documents Dept

West Covina Library
ATTN: Librarian

University of West Florida
ATTN: Librarian

West Hills Community Coll
ATTN: Library

West Texas State University
ATTN: Library

West Virginia Coll of Grad Studies Lib
ATTN: Librarian

University of West Virginia
ATTN: Dir of Libraries

Westerly Public Library
ATTN: Librarian

Western Carolina University
ATTN: Librarian

Western Illinois University Lib
ATTN: Librarian

Western Washington Univ
ATTN: Librarian

Western Wyoming Community College Lib
ATTN: Librarian

Westmoreland Cty Comm Coll
ATTN: Learning Resource Ctr

Whitman College
ATTN: Librarian

Wichita State Univ Library
ATTN: Librarian

William & Mary College
ATTN: Docs Dept

William Allen White Library
Emporia Kansas State College
ATTN: Govt Documents Div

William College Library
ATTN: Librarian

Willimantic Public Library
ATTN: Librarian

Winthrop College
ATTN: Documents Dept

University of Wisconsin at Whitewater
ATTN: Governments Documents Library

OTHER (Continued)

Wisconsin Milwaukee University
ATTN: Librarian

Wisconsin Oshkosh University
ATTN: Librarian

Wisconsin Platteville University
ATTN: Librarian

Wisconsin University at Stevens Point
ATTN: Docs Section

University of Wisconsin
ATTN: Govt Pubs Dept

University of Wisconsin
ATTN: Acquisitions Dept

Worcester Public Library
ATTN: Librarian

OTHER (Continued)

Yale University
ATTN: Director of Libraries

Yeshiva University
ATTN: Librarian

Yuma City County Library
ATTN: Librarian

Wright State Univ Library
ATTN: Govts Documents Dept

Wyoming State Library
ATTN: Librarian

University of Wyoming
ATTN: Documents Div

University of Alaska
ATTN: Govt Publication Librarian