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OPERATION CROSSROADS

1946

United States Atmospheric Nuclear Weapons Tests
Nuclear Test Personnel Review

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BAKER Emerges From Bikini Lagoon Amid Target Fleet

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Crossroads was the first peacetime nuclear weapons test series. It was conducted at Bikini Atoll in 1946.

Report emphasis is on the radiological safety of the personnel. Available records on personnel exposure are summarized.

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FACT SHEET

Operation CROSSROADS was an atmospheric nuclear weapon test series conducted in the summer of 1946. The series consisted of two detonations, each with a yield of 23 KT:

- ABLE -- detonated at an altitude of 520 feet (158 meters) on 1 July
- BAKER -- detonated 90 feet (27 meters) underwater on 25 July.

It was the first nuclear test held in the Marshall Islands.

The series was to study the effects of nuclear weapons on ships, equipment, and material. A fleet of more than 90 vessels was assembled in Bikini Lagoon as a target. This target fleet consisted of older U.S. capital ships, three captured German and Japanese ships, surplus U.S. cruisers, destroyers and submarines, and a large number of auxiliary and amphibious vessels. Military equipment was arrayed on some of the ships as well as amphibious craft that were beached on Bikini Island. Technical experiments were also conducted to study nuclear weapon explosion phenomena. Some experiments included the use of live animals.

The support fleet of more than 150 ships provided quarters, experimental stations, and workshops for most of the 42,000 men (more than 37,000 of whom were Navy personnel) of Joint Task Force 1 (JTF 1), the organization that conducted the tests. Additional personnel were located on nearby atolls such as Enewetak and Kwajalein. The islands of the Bikini Atoll were used primarily as recreation and instrumentation sites.

Before the first test, all personnel were evacuated from the target fleet and Bikini Atoll. These men were placed on units of the support fleet, which sortied from Bikini Lagoon and took safe positions at least 10 nmi (18.5 km) east of the atoll.

In the ABLE test, the weapon was dropped from a B-29 and burst over the target fleet. In BAKER, the weapon was suspended beneath an auxiliary craft anchored in the midst of the target fleet.

ABLE operations went smoothly except that the test weapon was dropped between 1,500 and 2,000 feet (457 and 610 meters) off target. The radioactivity created by the burst had only a transient effect, and within a day nearly all the surviving target ships had been safely reboarded. The ship inspections, instrument recoveries, and remooring necessary for the BAKER test proceeded on schedule. Five ships were sunk as a result of the test.

The crews of the target ships that had been remanned following ABLE were evacuated before BAKER to the support fleet east of the atoll. BAKER sank

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eight ships and damaged more ships than ABLE. The detonation caused most of the target fleet to be bathed in radioactive water spray and radioactive debris from the lagoon bottom. With the exception of 12 target vessels anchored in the array and the landing craft beached on Bikini Island, the target fleet remained too radiologically contaminated for several weeks for more than brief on-board activities.

The inability to complete inspections on much of the target fleet threatened the success of the operation after BAKER. A program of target vessel decontamination was begun in earnest about 1 August. This involved washing the ships' exteriors using work crews drawn from the target ships' companies under radiological supervision of monitors equipped with radiation detection and measurement devices. Initially, decontamination was slow as the safe time aboard some of the target ships was measured only in minutes. As time progressed, the support fleet itself had become contaminated by low-level radioactivity in marine growth on the ships' hulls and seawater piping systems.

By 10 August, a decision was made to stop work in Bikini and tow the surviving target fleet to Kwajalein Atoll where the work could be done in uncontaminated water. The move was accomplished during the remainder of August and September. A major task at Kwajalein was to offload ammunition stored aboard the target ships. This work continued into the fall of 1946. Personnel continued to work on target ships at Kwajalein into 1947.

Eight of the major ships and two submarines were towed back to the United States and Hawaii for radiological inspection. Twelve target ships were so lightly contaminated that they were remanned and sailed back to the United States by their crews. The remaining target ships were destroyed by sinking off Bikini Atoll, off Kwajalein Atoll, or near the Hawaiian Islands during 1946-1948.

The support ships were decontaminated as necessary and received a radiological clearance before they could return to the fleet. This decontamination and clearance process required a great deal of experimentation and learning at Navy shipyards in the United States, primarily at San Francisco.

Finally, a formal resurvey of Bikini Atoll was conducted in the summer of 1947 to study long-term effects of the CROSSROADS tests.

All CROSSROADS operations were undertaken under radiological supervision intended to keep personnel from being exposed to more than 0.1 roentgen (R) per day. At the time, this was considered to be an amount of radiation that could be tolerated for long periods without any harmful effects on health.

Radiological supervision included predicting areas of possible danger, providing trained personnel equipped with radiation survey instruments to act as guides during operations involving potential exposure, and elaboration of rules and regulations governing conduct in these operations. Personnel were removed for one or more days from areas and activities of possible exposure if their badges showed more than 0.1 R/day exposure.

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About 15 percent of the JTF 1 personnel was issued at least one of the 18,875 film-badge dosimeters during CROSSROADS. Approximately 6,596 personnel were on islands or ships that had no potential for radiation exposure. Personnel anticipated to be at greatest radiological risk were badged, and a percentage of each group working in less contaminated areas was badged. The maximum accumulated exposure recorded was 3.72 R, received by a radiation safety monitor.

Lacking complete radiation exposure data, reconstructions have been made of personnel exposures for unbadged crewmembers of the ships involved. These calculations have considered the several sources of radiation at work in Bikini, such as the low-level contamination in the lagoon water, living aboard support ships, and boarding the contaminated target ships. The calculations relied upon radiation measurements recorded by radiation safety personnel in 1946. This data was used in a computer model that includes such factors as the radiation-shielding properties of ships' hulls and realistic patterns of daily personnel activity on weather decks and below. The actual movements of each ship were then used to reconstruct a dose for the crew. Calculated exposures range from 0 to 2.5 rem (gamma) for support ships. Exposures for target ship crews that reboarded their ships after BAKER were higher than those for support ship crews. A summary of film badge readings (in roentgens) for July and August, when the largest number of personnel was involved, is listed below:

Actual Film Badge Readings:
(R gamma)

	Total	0	0.001-0.1	0.101-1.0	1.001-10.0
July	3,767	2,843	689	232	3
%	100	75	18	6	<0.1
August	6,664	3,947	2,139	570	8
%	100	59	32	9	0.1

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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 205,000 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 Centers 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 CROSSROADS is one of a series of 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 1 (JTF 1) 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.

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For CROSSROADS, the most important archival source is the National Archive and Record Center, Modern Military Branch, Washington, D.C. The Naval Archives at the Washington Navy Yard also were helpful, as was the collection of documents in the AFWL Technical Library at Kirtland Air Force Base, Albuquerque, New Mexico, and the Stafford L. Warren Papers at the University of California, Los Angeles. 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 I exposure records 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, were also useful.

Primary documentation of personnel movement in areas of potential radiation exposure is limited. 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 099 QMXMK 506-09 M2590D for the Defense Nuclear Agency by personnel from Kaman Tempo. Guidance was provided by Mr. Paul W. Boren of the Defense Nuclear Agency Biomedical Effects Directorate.

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of 1946, and its contracts, facilities, and management responsibilities were transferred to the newly established Atomic Energy Commission (AEC).

The primary purpose of CROSSROADS was to determine the effects of atomic bombs upon naval vessels. The effects of nuclear weapons on ships was of considerable interest to the U.S. defense establishment. As early as August 1945, the Chairman of the Senate's Special Committee on Atomic Energy proposed that the effectiveness of atomic bombs be demonstrated on captured Japanese ships. In September, the Army Air Forces commanding general put the question of such a test before the Joint Chiefs of Staff (JCS) (Reference A.1, p. 10).

The Navy's response to this proposal was that such a test also should include a few modern U.S. naval units in the target array (Reference A.1, p. 10). In effect, this broadened the test from a mere demonstration of the power of nuclear detonations to a scientific test whose results could be used in designs of naval vessels and naval tactics. In November the JCS established a subcommittee to prepare a detailed proposal. The subcommittee completed its work in 6 weeks.

Secondary purposes of CROSSROADS were to afford training for Army Air Forces personnel in attack techniques using atomic bombs against ships, and to determine atomic bomb effects upon military equipment and installations. Such information was not available from the Trinity test or the Hiroshima and Nagasaki bombings (Reference C.9.189, p. XIII).

On 10 December 1945, the President announced that the United States would further explore the capabilities of atomic energy in the form of scientific atomic bomb tests under JCS jurisdiction. The JCS proposed a joint task force to be composed of Army and Navy personnel and civilian scientists, and on 10 January 1946 the President approved the formation of this task force. On 11 January the JCS created Joint Task Force One (JTF 1) and approved a naval officer who had commanded large Army-Navy operations in the Pacific during the war and who also had been Chief of the Navy's Bureau of Ordnance to serve as Commander JTF 1 (CJTF 1).

CROSSROADS, as proposed, was to have consisted of three nuclear events. In approving the plans, the President approved the detonation of three nuclear weapons, one-third of the U.S. stockpile at the time -- surely a measure of the importance given the operation (Reference A.7).

Among the major problems confronting CJTF 1 after his appointment was the selection of a test site. Several locations were considered in the Atlantic and Pacific oceans and in the Caribbean Sea. The requirements were:

- A protected anchorage (at least 6 nmi [11 km] wide) to hold the target and support fleet
- A site that was nearly uninhabited
- A location at least 300 statute miles (about 483 km) from a city
- Freedom from severe cold and violent storms

- Predictable winds directionally uniform at all altitudes from sea level to 60,000 feet (18 km)
- Predictable water currents of great lateral and vertical dispersion; fast currents avoiding important fishing areas, ocean shipping lanes, and inhabited shores
- Control by the United States.

The location that best satisfied these requirements was Bikini Atoll. Bikini's location in the Central Pacific is shown in Figure 1 and a map of the atoll itself in Figure 2. The final choice of Bikini was announced on 24 January 1946 by the JCS after a slight delay because the fishing industry feared the tests might kill millions of fish, especially tuna and whales. To evaluate any dangers, the Department of Interior's Fish and Wildlife Service conducted surveys. Those surveys concluded that Bikini was not a critical area for tuna fish or other fish of commercial importance and was far from migratory whale routes (Reference A.1, pp. 19 and 20).

CJTF 1 requested that the Bikini native population be evacuated from the atoll by 15 March 1946. Rongerik Atoll was selected as the future home for the Bikinians and on 26 February a group of Navy Construction Battalion personnel (Seabees) began construction of cisterns, water catchments, and 26 house frames there. These frames (Figure 3) were temporarily covered with canvas, but this was replaced by thatch from the pandanus, or screw pine, tree. The thatch was brought to Rongerik by the Bikinians. The cisterns were initially filled with 25,000 gallons (94,785 liters) of water brought from Kwajalein.

Bikini was evacuated on 7 March. Figure 4 shows the Bikinians collecting their belongings, and Figure 5 shows the loading of the LST that transported them. The 167 Bikinians arrived at Rongerik the next day (Figure 6). In an effort to improve the lives of the Bikinians who were unhappy with Rongerik, meetings were held in 1946 and 1947 between the Chief and members of his council and military authorities to find a more suitable island. On 3 November 1948, the Bikinians and their possessions were resettled on the island of Kili, in the southern Marshall Islands, 400 nmi (741 km) southeast of Bikini and 27 nmi (50 km) southeast of Jaluit Atoll (Reference A.8, pp. 507-551).

On 23 March, after preparations for the operation were well underway, the President changed the date of the first test from 15 May to 1 July; the second test was scheduled for 25 July. This allowed certain members of Congress to observe Operation CROSSROADS. On 7 September 1946, the President announced that Test CHARLIE, the third scheduled and a deep underwater test, was indefinitely postponed (Reference C.9.206, p. V-(D)-5). Engineering problems in constructing a bathysphere capable of withstanding the tremendous pressures involved precluded the scheduling of Test CHARLIE before Spring of 1947 (Reference C.9.206, p. V-(A)-5).

REPORT ORGANIZATION

Subsequent sections of this overview chapter discuss the form of weapon effects test programs, with emphasis on potential radiation exposure of participating Navy and War Department personnel. The chapter concludes with a description of JTF 1 and indicates how elements within JTF 1 functioned.

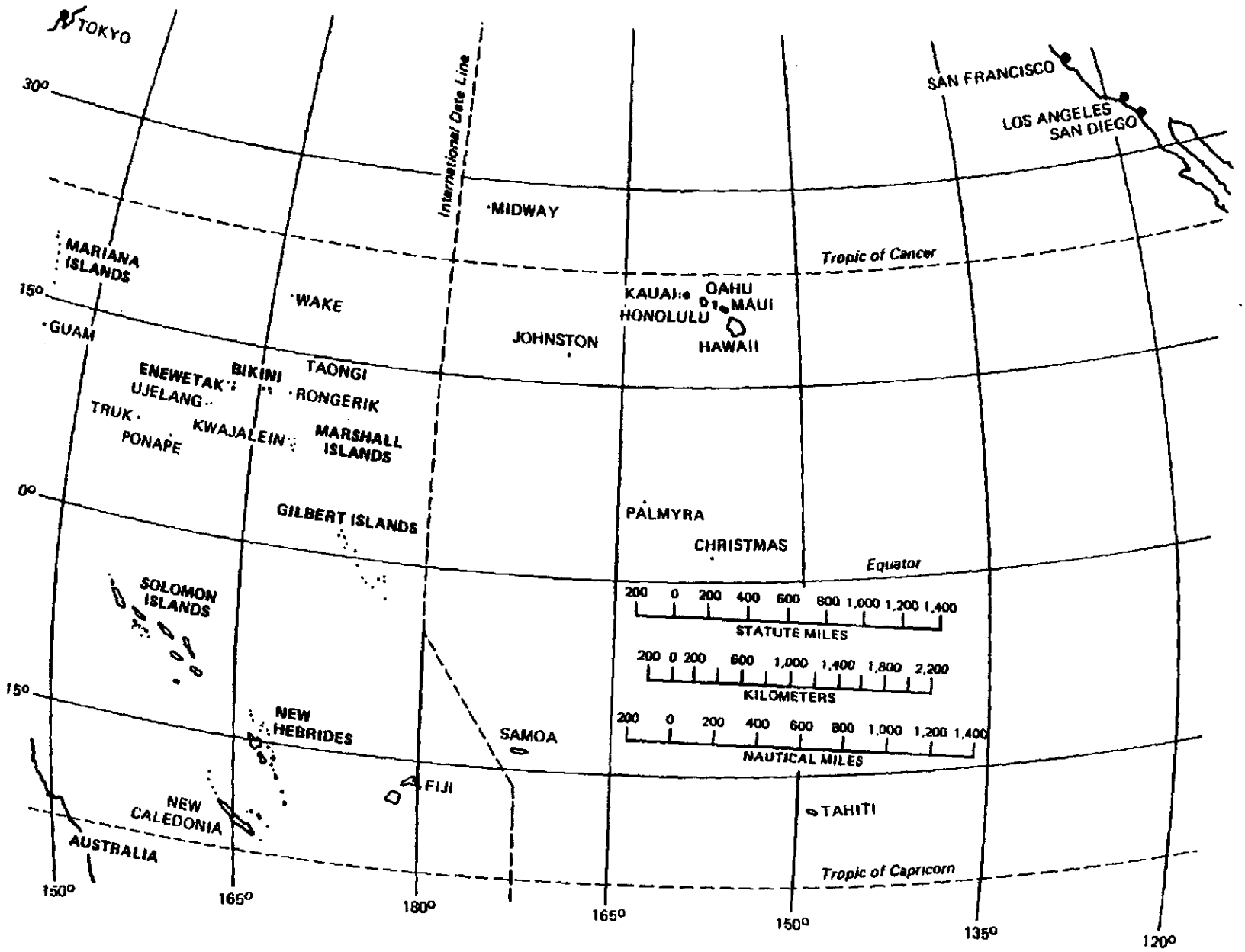

Figure 1. The Central Pacific.

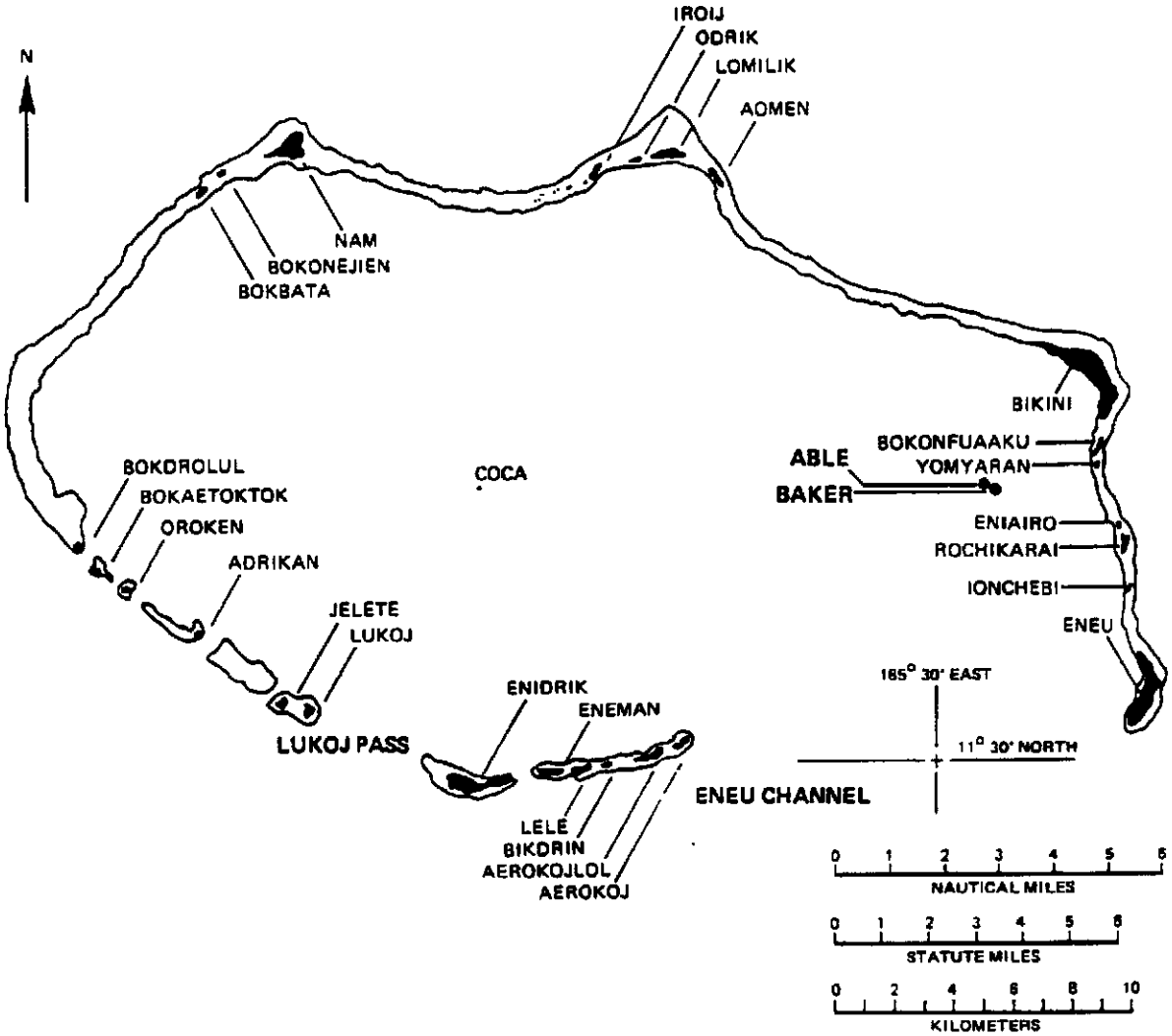

Figure 2. Bikini Atoll, 1946, showing ABLE and BAKER test sites.

Figure 3. Navy Construction Battalion personnel, assisted by Marshallese, construct wooden house frames on Rongerik for Bikinians.

Figure 4. Bikinians collecting their belongings for move to Rongerik.

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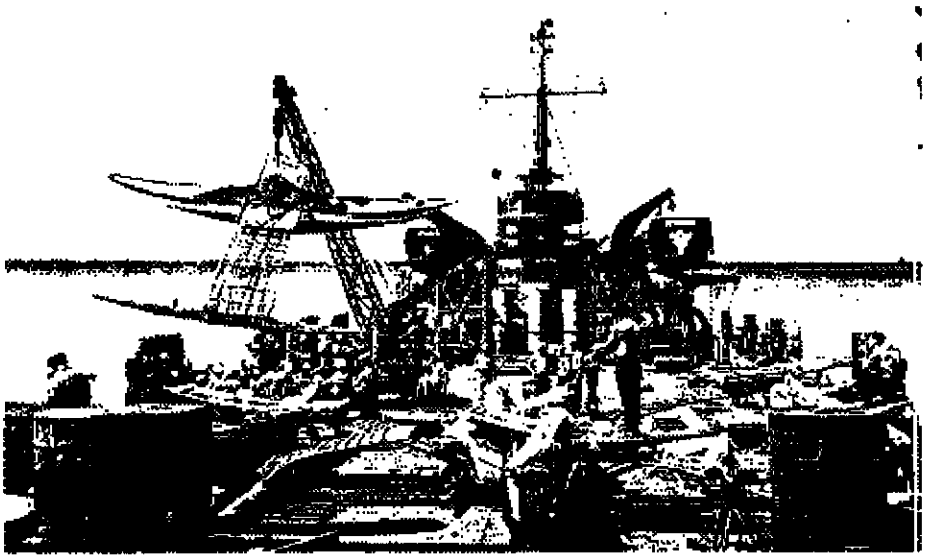

Figure 5. Bikini outrigger swung aboard LST for transport to Rongerik.

Figure 6. USS LST-1108 arrives at Rongerik, 8 March 1946.

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

Chapter 3 discusses the general role of personnel in the weapon effects program in CROSSROADS, leading to a discussion of operations for test events in Chapter 4, and in the post-test operations discussed in Chapters 5 and 6.

Chapters 7 through 10 report participation by the Army Ground Forces, Army Air Forces, Navy, and Marine Corps, respectively. Chapter 11 summarizes participation of other government agencies, contractors, and universities. Personnel exposures are discussed in Chapter 12.

NUCLEAR TESTS AND RADIATION EXPOSURES

In general, nuclear testing before 1961 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 ocean's surface; emplaced on or slightly beneath the Earth's surface; atop a tower; or supported by a balloon, dropped from an airplane, suspended underwater, or fired from cannon or rocket launchers. CROSSROADS employed two operational weapons: one was dropped from an aircraft and detonated in the air; the other was suspended from a ship and detonated underwater.

In theory, personnel can be exposed either to 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.

The neutron component of initial radiation indirectly contributes to the later exposure of personnel. Neutrons are emitted in large numbers by nuclear weapon detonations. They have the property of altering certain nonradioactive materials so that they become radioactive. This process, called activation, works on 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 produced 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, called fission products, releasing energy. When the uranium and plutonium fission, they produce a variety of fission products. Different fission products have different half-lives. In general, the lighter fission products have half-lives that are shorter than the mother elements. The residual radiation produced by these products, given their shorter half-lives, is initially quite high. However, over a period of time, the radioactivity diminishes. The decay of the original fission products produces other, lighter fission products that may (or may not) be radioactive themselves. The net result is that initial decay of fission products produces fairly high levels of radioactivity that dissipate over time. While a radioactive fission product

theoretically continues to exist forever (albeit in diminishing amounts), a point is reached where it is practically undetectable.

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 the 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 a nuclear detonation, 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 radioactive components of the material in the debris cloud. This cloud and its fallout are the primary sources of potential exposure to residual radiation.

In a nuclear airburst, 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 of relatively low yield, 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.9). Areas in which this fallout material will be deposited will appear on maps as bands following the wind's direction. Thus, airbursts result in less potential for residual radiation exposure to personnel at the testing area from the debris, although there may be some residual radiation fission products from rapid settling of large particles 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).

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. This forms 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 detonation yield, or total energy released), the bubble may break the surface of the water near its fully expanded size or smaller. Some radioactive products (including activated salt) are vented into the air as the bubble breaks the surface, but most of the device debris and activation products remain trapped in the volume of water that collapses on the bubble. This volume of water is called the radioactive pool.

When the burst is close enough to the bottom, as in the BAKER shot of CROSSROADS, an underwater crater may be formed, and the material excavated from it will be radioactive and contribute to the residual radiation inventory.

The primary source of personnel exposures from the BAKER shot was not the radioactive pool of water, however, but from contact with the target ships, which had been bathed in the radioactively contaminated water, sand, and coral that rained down upon them from the cloud and from the radioactive mist (base surge) that rolled out from the base of the underwater explosion column.

A nuclear explosion produces three types of radiation that posed a potential hazard to CROSSROADS participants: alpha, beta, and gamma radiation. When any of these encounters living tissue, it transfers some of its energy to the target atoms, tearing off some or all of their electrons. This leaves the atoms with a positive electrical charge. The process is called ionization. This tearing off of the electrons destroys the bonds holding together the complex molecules making up living tissue and leaves the tissue damaged to some extent. At low levels of radiation, the damage is minor and probably does not adversely affect the individual's health or longevity. At higher levels, the reverse is true.

Gamma rays are electromagnetic radiation, differing from the more familiar radio waves and x-rays in that they have higher frequency and shorter wavelength. They are produced in great quantities and with very high energy during a nuclear explosion. They are also given off during the decay of the radioactive isotopes produced by a nuclear explosion. They can travel long distances and can readily penetrate clothing and skin. Because the personnel conducting Operation CROSSROADS were miles from the two detonations, the gamma hazard to them came from radioactive isotopes left in the target area or carried from it by wind or tide or on the participating ships or planes or even on the bodies of the personnel themselves. The radiation detection instruments used during CROSSROADS readily detected gamma rays.

Beta particles are electrons. Like gamma rays, they are given off by a nuclear explosion or by the radioactive isotopes produced by the explosion. Unlike gamma rays, however, beta particles do not travel far and, except at high energies, are stopped by clothing or the outer layers of skin. They are a greater hazard if isotopes emitting them are taken into the body or are left in contact with skin for a long period. Beta radiation was measured fairly well by several types of safety instruments used during CROSSROADS.

Alpha particles are made up of two protons and two neutrons. With the addition of two electrons, each becomes a helium atom. Alpha particles are given off by some radioactive isotopes created in a nuclear explosion and by unfissioned uranium or plutonium. Because alpha particles are relatively massive, they do not travel far, about 1 or 2 inches in air. The skin, clothing, or even a piece of paper will stop them. However, if the material emitting them enters the body and lodges there, the alpha particles can do great harm because they cause a high rate of ionization. The decay time of many alpha emitters is long. Plutonium only loses half of its alpha particles in 24,000 years! As described in detail in Chapter 2, the safety instruments available at CROSSROADS for detecting alpha particles directly were few in number and would not operate

outside the controlled conditions of the laboratory on the ship housing the radiation safety organization. Therefore, the only expedient way to estimate alpha radiation was to assume that some relatively stable ratio existed between alpha emitters and gamma or beta emitters. One could then measure gamma or beta radiation and calculate the alpha hazard. As beta and gamma radiation decreased, however, alpha radiation remained because of the long decay time of the plutonium and other alpha emitters.

EFFECTS EXPERIMENTS

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. CROSSROADS had two experimental programs. The first was to determine the effects of nuclear detonations on animals and on military equipment such as ships, aircraft, and various supplies. The second program was to measure weapon phenomena such as heat, blast, radiation, and wave action. CROSSROADS was not a weapon development operation; the bombs used were of the same design as the one dropped on Nagasaki.

Effects experiments were intended to acquire urgently needed military data. 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 effects 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 to train personnel to survive. Examples of environmental measurements taken at CROSSROADS include static (crushing) and dynamic (blast) pressure, heat generated by the detonation, and fallout radiation. Measurement techniques employed for CROSSROADS varied with the effects being measured, but usually measuring devices were placed at a variety of ranges from surface zero and their measurements recorded in some way. Many types of gauges and data-recording techniques were used. Measuring devices or instruments were airborne, underwater, on shore towers, or on a technical support vessel; the majority were placed on target vessels (Reference C.9.208, p. 2).

Rugged, self-recording gauges were developed for blast and thermal radiation measurements 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, early data recovery was still desirable as the gauges might be thin aluminum foil meters that could be made radioactive by the initial neutrons. Early observation was necessary before the information contained in the induced radiation pattern decayed to undetectable levels.

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; 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 (aircraft parts, ammunition, radar, petroleum, tanks, field stoves, clothing, and medical equipment) was exposed to nuclear detonation effects. Techniques used for these 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 threat to which the system was exposed almost always required measurement to properly understand the response, necessitating an environmental experiment along with each systems response experiment. It was often not enough to know whether the system survived, but rather what the effects were on the component parts and their interactions. This required the placement of extensive instrumentation and recording devices throughout the test area.

While the potential radiological exposure of personnel during these systems response experiments was governed primarily by the proximity of personnel in space or time to the detonation, an additional problem arose. Often, when the exposed object was recovered for closer examination, it could be contaminated by device debris or even be radioactive itself due to neutron activation. Personnel recovering or handling such objects could be exposed to radiation. For this reason, reboarding parties who inspected vessels, aircraft, and equipment after each detonation were given published guidelines and radsafe instructions (see Appendix B).

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 of this area only about 70 mi^2 (180 km^2) is land. Two parallel chains form the islands: Ratak (or Sunrise) to the east, and Ralik (or Sunset) to the west; Bikini is in the Ralik chain at its northern extreme. Figure 1 shows these islands in the Central Pacific; Figure 2 is a map of Bikini Atoll.

A typical atoll, Bikini is a coral cap set on truncated, submerged volcanic peaks that rise to considerable heights from the ocean floor. It consists of 27 small islands that encircle a broad lagoon 25 miles (40.2 km) long and 15 miles (24.1 km) wide, with a maximum depth of about 200 feet (61 meters). The dry land area, 2.72 mi^2 (7 km^2), is covered with low, scrubby brush and coconut and pandanus trees. 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.

Climate 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 the atoll is open ocean for a thousand miles, the only inhabited island being Wake. East of Bikini are

several atolls, with Rongelap at 80 nmi (148 km) the closest. 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 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), 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 Krakatoa easterlies from the tropopause up into the stratosphere. These systems are all basically east-to-west or west-to-east air currents. Day-to-day changes reflect relatively small north-south components, which are markedly variable. Greatest variation occurs in the upper westerlies, particularly during late summer and fall.

Steady northeast trade winds in the lower levels cause water at the surface of the lagoon to flow from northeast to southwest, where it sinks to the bottom and returns along the lower levels of the lagoon, rises to the surface along the eastern arc of the reefs and islands, and is moved by 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 northern and eastern reefs and flows out of the western portion of Eneu Channel. Water exchanges over the western reefs with the tides, ocean water flowing in and mixing with the flood and lagoon water flowing out with the ebb. The net rate of flushing of Bikini waters is such that one-half of the lagoon waters is 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 (Reference C.9.209, p. F-25).

During CROSSROADS, the Marshall Islands were under the jurisdiction of a U.S. military governor who reported to the Chief of Naval Operations and ultimately to the Secretary of the Navy. Since July 1947 these islands have been part of the Trust Territory of the Pacific Islands, a strategic area trusteeship of the United Nations, administered by the United States (Reference A.8, pp. 507-551).

In order to prepare Bikini Atoll for test operations, a considerable amount of work was required in the lagoon and on the principal islands. First, it was necessary to clear the lagoon of Japanese mines. On 10 March a survey unit arrived and began hydrographic and land surveys to augment the data recorded on the available Japanese charts. After the survey several coral heads were blasted out to permit safe navigation of large ships and to permit proper placement of ships in the proposed target arrays. Navigational and mooring buoys were laid in the lagoon and beacons placed on shore. On the islands, photographic towers (Figure 7), recording stations, recreational facilities (Figure 8), and landing facilities were constructed. This work was started on 20 March with the arrival of the 53rd Special Naval Construction Battalion, assisted by elements of the service groups and minesweeping units of the Pacific Fleet (Reference C.9.206, p. V-(B)-4).

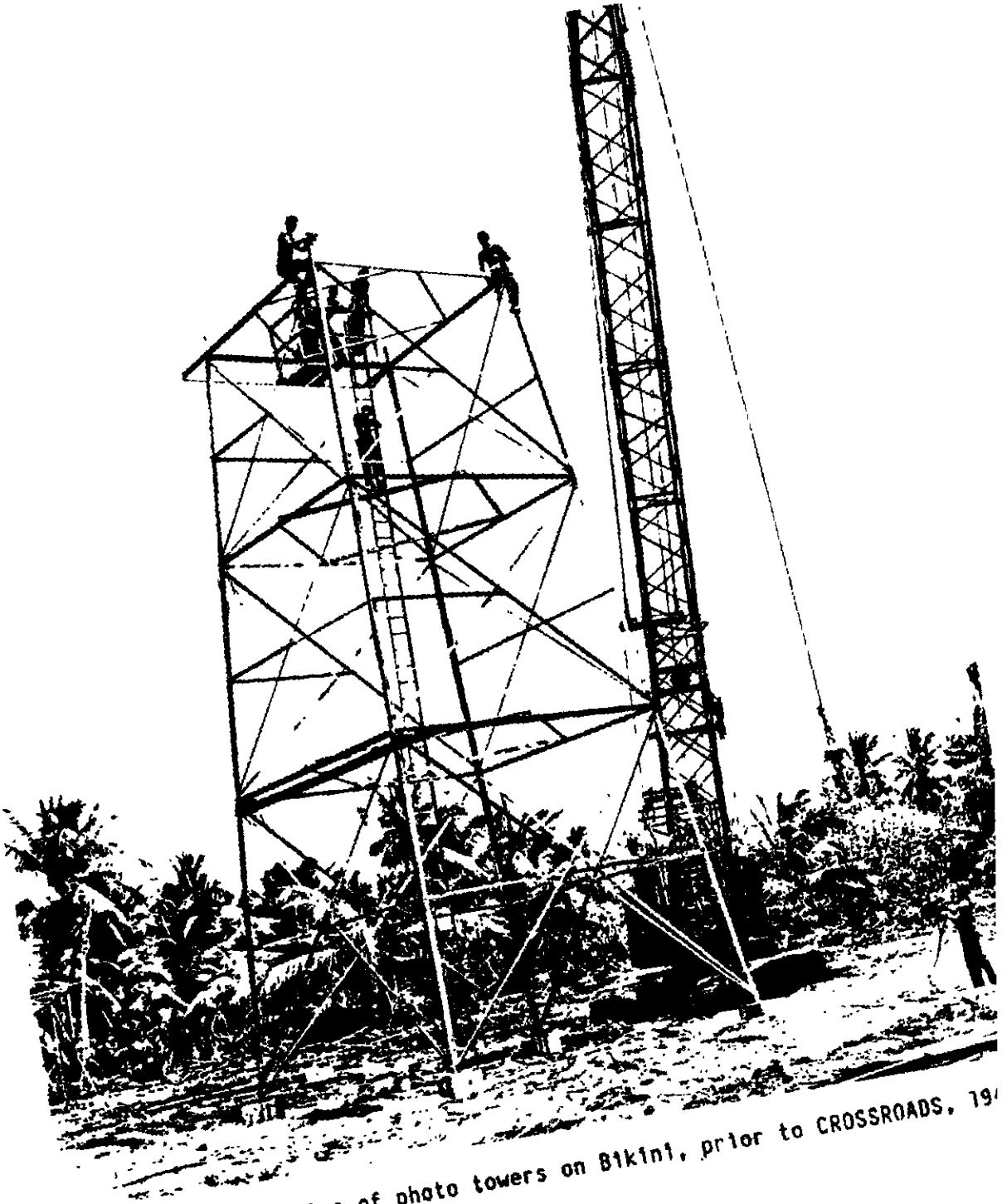

Figure 7. Erection of photo towers on Bikini, prior to CROSSROADS, 19

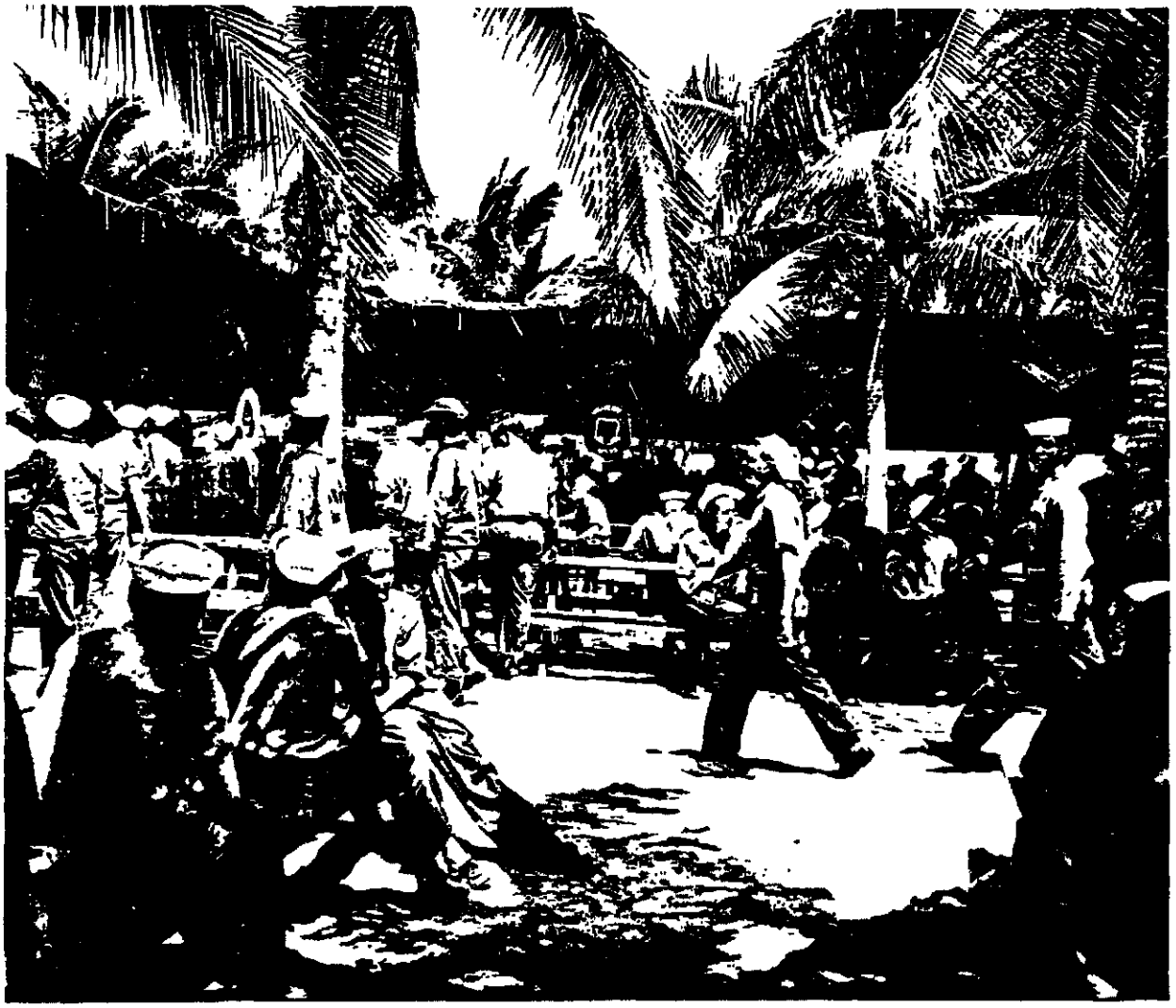

Figure 8. Bikini recreation area during CROSSROADS.

SPECIAL PROBLEMS IN THE CROSSROADS TESTS

The remoteness of Bikini Atoll posed significant logistics problems in procuring and transporting personnel, materials, and supplies to the new test site. Special security arrangements were also required to transport the nuclear weapons from the United States to the test area. However, there were many advantages to testing at Bikini. It offered a large, uninhabited area for test activities and normally steady directional winds to clear the airborne test debris.

Another major problem was design, procurement, and installation of the many scientific instruments required to measure effects of the detonations. These included instruments for observing shock waves, water pressure, airblast, wave action, deformation of structures, and radioactivity. Remotely controlled (drone) boats and aircraft had to be provided to obtain important measurements in radioactive zones without endangering personnel. Laboratories had to be

installed on ships and on shore to repair instruments and carry out test analyses (Reference C.9.206, p. I-(B)-7).

In addition, CROSSROADS posed other problems (Reference A.1, pp. 20 through 23):

- Scientific resources were declining from wartime peaks
- The number of nontechnical Service personnel was diminishing
- Civilian scientists participating from universities were insistent upon returning by early September
- Army and Navy budgets were expected to become smaller after the war
- Obsolete target vessels could not be held available indefinitely.

JOINT TASK FORCE ONE

JTF 1 was organized on 11 January 1946. It followed the basic principles employed during World War II to develop amphibious task forces, but incorporated needs of the scientific program. The joint task force staff comprised Army, Navy, and civilian scientific personnel. This joint staff maintained liaison with the War and Navy Departments, the Manhattan Engineer District, and other government agencies.

CJTF 1 maintained liaison with two boards of special interest, the JCS Evaluation Board and the President's Evaluation Commission. The Evaluation Board was to advise CJTF 1 during preparation for the tests and evaluate test results. The Evaluation Commission was to cooperate with the War and Navy Departments in conducting the tests, and to undertake a study of the tests and to submit its observations to the President along with findings, conclusions, and recommendations (Reference C.9.206, pp. VI-(B)-1 and VI-(B)-2).

JTF 1 was subdivided into eight task groups, each of which performed some specific function. Figure 9 details the structure of JTF 1, which was headquartered on USS Mount McKinley (AGC-7).

Task Group 1.1 (Technical Group)

Task Group (TG) 1.1 was responsible for instrumenting all target ships and target areas. Selected ships assigned to the group were equipped with laboratory facilities to service scientific instruments and record all data. The primary mission of its Drone Boat Unit (Task Unit [TU] 1.1.3) was to obtain early samples of radioactive water after each test and conduct remotely controlled radiological reconnaissances of the lagoon area after shot BAKER. TG 1.1 also did the following:

- Operated and performed technical services
- Observed and measured physical phenomena
- Furnished technical advice and assistance.

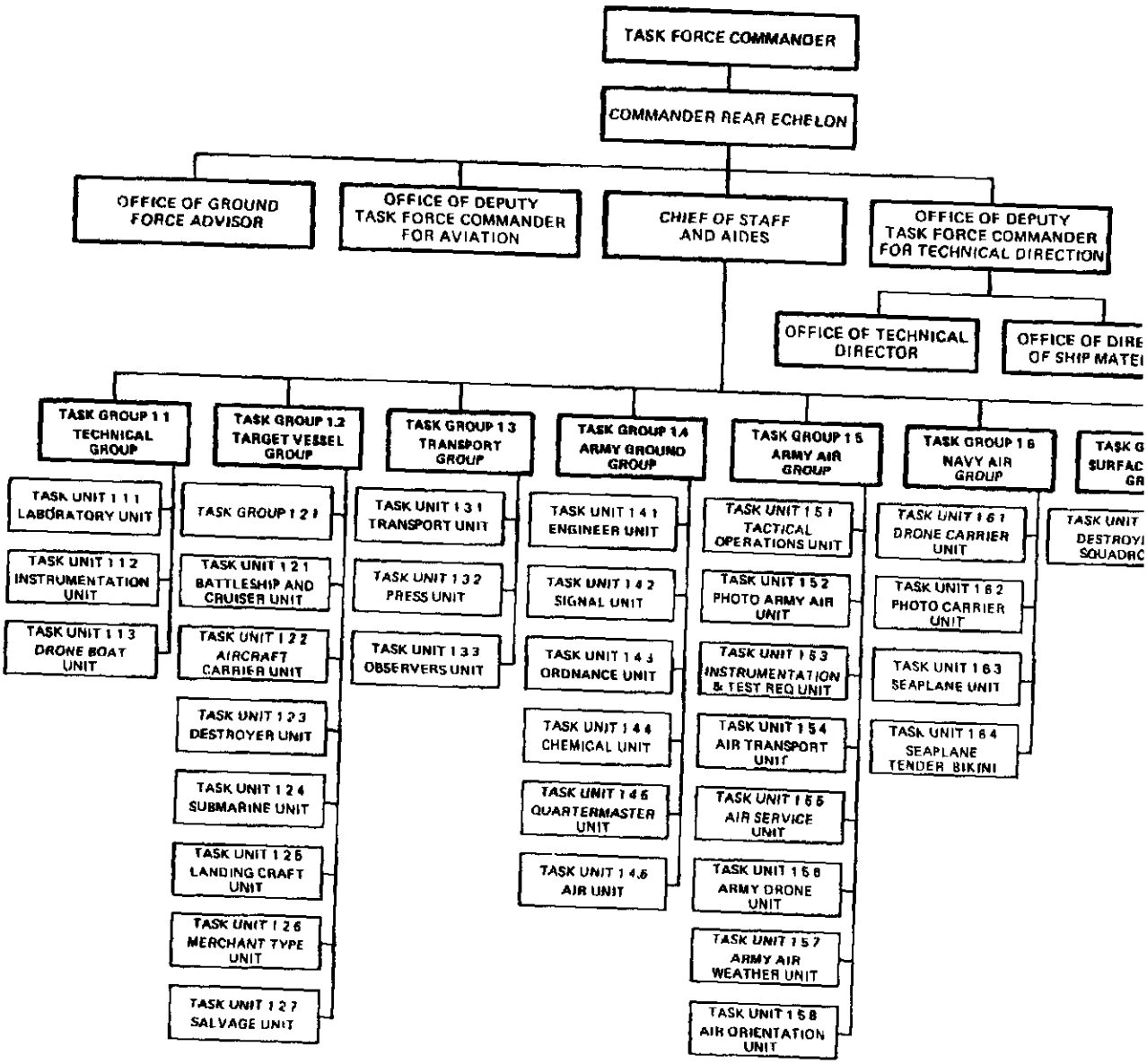

Figure 9. Joint Task Force 1 organization, CROSSROADS.

TG 1.1 had the following three task units, listed below with the ships on which they were based.

- TU 1.1.1 (Laboratory Unit)
  - -- USS Albemarle (AV-5) (Flagship)
  - -- LCT-1359
  - -- LSM-60 (BAKER surface zero vessel)
- TU 1.1.2 (Instrumentation Unit)
  - -- USS Avery Island (AG-76)
  - -- USS Burleson (APA-67)
  - -- USS Cumberland Sound (AV-17)
  - -- USS Haven (AH-12)
  - -- USS Kenneth Whiting (AV-14)
  - -- USS Wharton (AP-7)
- TU 1.1.3 (Drone Boat Unit)
  - -- USS Begor (APD-127)

Task Group 1.2 (Target Vessel Group)

TG 1.2 did the following:

- Prepared and placed target vessels for tests
- Salvaged and provided rescue assistance to damaged, strained, or distressed vessels
- Evacuated ships at time of tests
- Furnished boats and boat crews to the boat pool
- Provided boats from target vessels for radsafe reconnaissance and transport of initial inspection parties.

TG 1.2 was composed of seven task units during the testing period; their respective ships are listed in Table 1. USS Fall River (CA-131) was the flagship for TG 1.2. Not all TG 1.2 ships were target ships, although most were. Nontarget ships listed supported preparation, placement, and salvage of the targets. An eighth task unit, TU 1.2.12 (Kwajalein Maintenance Force), provided radiological decontamination and ammunition removal and disposal services for the JTF 1 ships moved from Bikini to Kwajalein during August and September 1946. Other activities included rollup of operations at Bikini, radiological survey of marine life around Wotho, Rongerik, and Rongelap islands, preparation of ships for movement to other shipyards, and aid in the training of radiological safety school graduates who had been sent to Kwajalein for practical experience. The unit initially consisted of about 1,500 men based ashore and on assorted small craft as well as the following vessels:

Table 1. Task Group 1.2 (Target Vessel Group) ships participating in CROSSROADS.

Task Group 1.2	Task Unit 1.2.3	Task Unit 1.2.4	Task Unit 1.2.5	Task Unit 1.2.6	Task Unit 1.2.7
Flagship	Destroyer Unit	Submarine Unit	Landing Craft Unit	Merchant Type Unit	Salvage Unit
USS Fall River (CA-131)[a]	Destroyer Division 31	Submarine Division 111	LST Group 9	Transport Division 91	ATR-40[a]
	USS Anderson (DD-411)	USS Searaven (SS-196)	USS LST-52	USS Banner (APA-60)	ATR-87[a]
Task Unit 1.2.1	USS Hughes (DD-410) (Flagship)	USS Skate (SS-305)	USS LST-125	USS Brule (APA-66)	ATA-180[a]
Battleship and Cruiser Unit	USS Lamson (DD-367)	USS Skipjack (SS-184)	USS LST-133	USS Carlisle (APA-69)	ATA-185[a]
Battleship Division 7	USS Rhind (DD-404)	USS Tuna (SS-203)	USS LST-220	USS Carteret (APA-70)	ATA-192[a]
USS Arkansas (BB-33) (Flagship)	Destroyer Division 2	Submarine Division 112	USS LST-545	USS Fallon (APA-81)	USS Achomawi[a] (ATF-148)
Nagato (captured Japanese battleship)	USS Ralph Talbot (DD-390)	USS Apogon (SS-308)	USS LST-661	Transport Division 92	USS Chickasaw[a] (ATF-83)
USS New York (BB-34)	USS Stack (DD-406)	USS Dentuda (SS-335)	LCI Group 7	USS Barrow (APA-61)	USS Clamp[a] (ARS-33)
Battleship Division 9	USS Wainwright (DD-419) (Flagship)	USS Parche (SS-384)	LCI-327	USS Butte (APA-68)	USS Conserver[a] (ARS-33)
USS Nevada (BB-36)	USS Wilson (DD-408)	USS Pilotfish (SS-386)	LCI-329	USS Cortland (APA-77)	USS Coucal[a] (ASR-8)
USS Pennsylvania (BB-38) (Flagship)	Destroyer Division 3		LCI-332	USS Crittenden (APA-77)	USS Current[a] (ARS-22)
Cruiser Division 23	USS Conyngham (DD-371)		LCI-620	USS Dawson (APA-79)	USS Deliver[a] (ARS-23)
USS Pensacola (CA-24)	USS Flusser[a] (DD-368)		LCI(L)-549	Transport Division 93	USS Etlan[a] (AN-79)
Prinz Eugen (captured German cruiser)	USS Mugford (DD-389)		LCI(L)-615	USS Bladen (APA-63)	USS Gypsy[a] (ARSD-1)
Sakawa (captured Japanese cruiser)	USS Mustin (DD-413)		*LCT Group 15*	USS Bracken (APA-64)	LCT-581[a]
USS Salt Lake City (CA-25) (Flagship)	Destroyer Division 4		LCT-816	USS Briscoe (APA-65)	LCT-746[a]
	USS Mayrant (DD-402)		LCT-818	USS Catron (APA-71)	LCT-1184[a]
Task Unit 1.2.2	USS Trippe (DD-403)		LCT-874	USS Fillmore (APA-83)	LCT-1420[a]
Aircraft Carrier Unit[b]			LCT-1078	USS Geneva (APA-86)	USS Mender[a] (ARSD-2)
Carrier Division 31			LCT-1112	USS Niagara (APA-87)	USS Oneota[a] (AN-85)
USS Independence (CVL-22)			LCT-1113	Transport Division 94	USS Palmyra[a] (ARST[T]-3)
USS Saratoga (CV-3)			LCT-1114	USS Appling[a] (APA-58)	USS Preserver[a] (ARS-8)
			LCT-1115	USS Artemis[a] (AKA-21)	USS Reclaimer[a] (ARS-42)
			LCT-1116[a]	USS Gasconade (APA-85)	USS Shakamaxon[a] (AN-88)
			LCT-1130[a]		USS Suncock[a] (AN-88)
			LCT-1132[a]		USS Widgeon[a] (ASR-1)
			LCT-1155[a]		
			LCT Group 21		
			LCT-412[c]		
			LCT-414		
			LCT-705		
			LCT-812		
			LCT-1013		
			LCT-1175		
			LCT-1187		
			LCT-1237		
			LCT-1268[a]		
			LCT-1341[a]		
			LCT-1377[a]		
			LCT-1415[a]		
			Miscellaneous		
			ARDC-13		
			YO-160		
			YOG-83		

NOTES:

[a]Nontarget vessels.

[b]Two PB2Y-5H Coronado seaplanes were also moored in the target array. They were not assigned to any task unit.

[c]BAKER target only.

USS Conserver (ARS-39)	APL-27
USS Current (ARS-22)	LCI-329
USS Geneva (APA-86)	LCI(L)-549
USS Haven (AH-12)	LCI(L)-615
	YF-753

Task Group 1.3 (Transport Group)

TG 1.3 transported personnel and equipment to Bikini Atoll as well as evacuating personnel of the Target Vessel Group. It also furnished boats and boat crews to the boat pool, supplied two AKAs and two LSTs for the construction unit, and transported and quartered the press and observers. This task group was composed of three task units; their respective ships are listed below.

TU 1.3.1 (Transport Group)

Transport Division 31

USS Bayfield (APA-33)	USS Ottawa (AKA-101)
USS Bexar (APA-227)	USS Rockbridge (APA-228)
USS Bottineau (APA-235)	USS Rockingham (APA-229)
USS George Clymer (APA-27)	USS Rockwall (APA-230)
USS Henrico (APA-45)	USS Rolette (AKA-99)
USS LST-817	USS Saint Croix (APA-231)
USS LST-881	

TU 1.3.2 (Press Unit)

USS Appalachian (AGC-1)

TU 1.3.3 (Observer Unit)

USS Blue Ridge (AGC-2)

USS Panamint (AGC-13)

An alphabetically arranged list of participating target and support ships, which includes a summary of their activities, forms Appendix A of this report.

Task Group 1.4 (Army Ground Group)

TG 1.4 was responsible for determining damage to selected Army equipment exposed at varying distances from the detonation point and measuring radii of effectiveness for each detonation. Each of the operating task units had Army equipment on certain ships and on Bikini Island for exposure to the nuclear detonations. Figure 10 shows the TG 1.4 organization. Each unit had inspection teams that were assigned to target ships and responsible for loading, securing, maintaining, and inspecting assigned test items. These teams also instructed crews of each target ship concerning exposed test items. Teams were to reboard

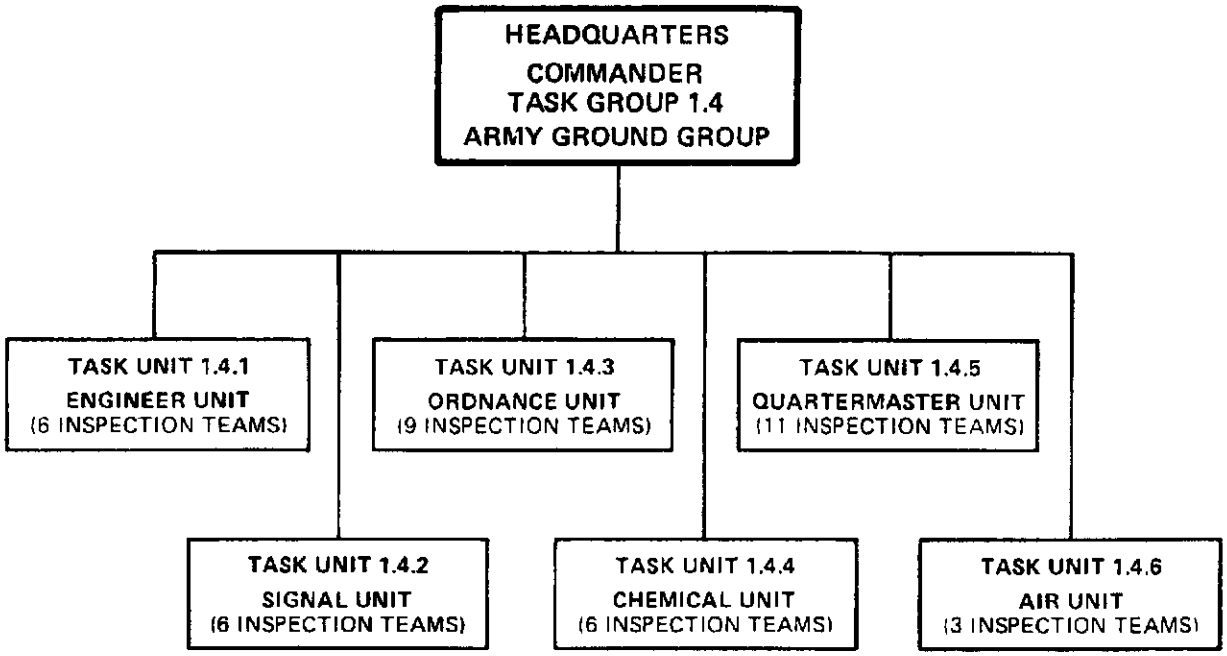

Figure 10. Task Group 1.4 organization, Operation CROSSROADS.

ships after the tests when ships were radiologically cleared and safe for boarding (Reference C.9.149, p. 3). TG 1.4 was composed of a headquarters and the following six operating task units:

- TU 1.4.1 (Engineer Unit)
- TU 1.4.2 (Signal Unit)
- TU 1.4.3 (Ordnance Unit)
- TU 1.4.4 (Chemical Unit)
- TU 1.4.5 (Quartermaster Unit)
- TU 1.4.6 (Air Unit).

Task Group 1.5 (Army Air Group)

TG 1.5, the Army Air Group, composed of provisional Army Air Forces units, was assigned the mission of dropping the ABLE weapon on the target array in Bikini Lagoon. In addition, it furnished aircraft, facilities, and crews for photography, weather reconnaissance, air-sea rescue, cloud sampling, pressure gauge drops, and air transport. Table 2 lists the Army aircraft used during CROSSROADS. B-29s and F-13s, which were modified B-29s, have become intermingled at some points in the historical accounts of Army Air Group operations. The totals for each shown here are correct by most accounts. TG 1.5 was composed of the following 10 task units (as shown in Figure 11).

TASK UNIT 1.5.1 (TACTICAL OPERATIONS UNIT). TU 1.5.1 trained crews, prepared equipment for the tests, airdropped the test ABLE weapon, set up the air search radar in the Bikini area, and provided radar analyses of practice bomb

Table 2. Army aircraft, CROSSROADS.

Task Unit	Type	Quantity	Mission
1.5.1	B-29	1	Command
	B-29	1	Bomb drop
	B-29	2	Pressure gauge drop
	F-13[a]	2	Radiological reconnaissance
	B-29	3	Spare
1.5.2	C-54	2	Photographic
	F-13[b]	8	Photographic
1.5.3	B-17	10	Drone samplers
	B-17	6	Drone controllers
1.5.4	C-46[c]	20	Transport
	C-54[c]	10	Transport
1.5.6	This unit was combined with TU 1.5.3 before ABLE and BAKER tests.		
1.5.7	WB-29	3	Weather reconnaissance
1.5.8	B-29	2	Radio broadcast, press, observation
	C-54[d]	---	
1.5.9	B-17	2	Air-sea rescue

Notes:

[a]Borrowed from TU 1.5.2.

[b]B-29s modified for photography.

[c]Includes those used to carry supplies to and from the continental United States.

[d]Borrowed from TU 1.5.4 on shot days.

Source: Reference C.9.189, p. VII-E, Appendix II.

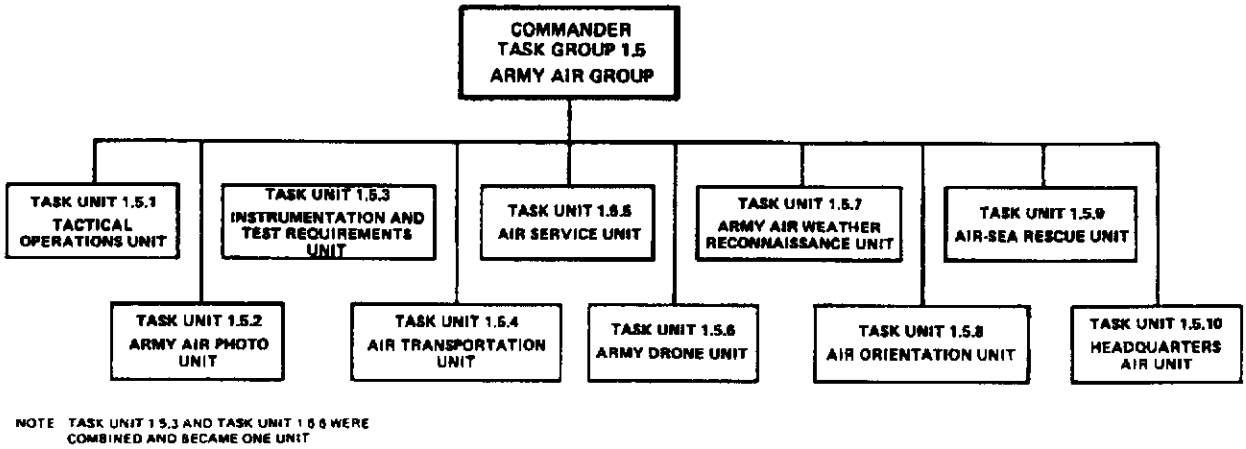

Figure 11. Task Group 1.5 organization, Operation CROSSROADS.

runs. It also operated two B-29s that dropped pressure gauges during each test. In addition, after each detonation it tracked the radioactive clouds and sampled air around the clouds. The unit was based on Kwajalein Island.

TASK UNIT 1.5.2 (ARMY AIR PHOTOGRAPHIC UNIT). TU 1.5.2 conducted air photographic operations and furnished aircraft for radiological reconnaissance flights. It was stationed on Kwajalein Island.

TASK UNIT 1.5.3 (INSTRUMENTATION AND TEST REQUIREMENTS UNIT). TU 1.5.3 and TU 1.5.6 (Army Drone Unit) were combined before the operation began. It was responsible for providing the B-17 drone and B-17 drone-controller aircraft for cloud-sampling operations. The drone mission required that the unit provide and maintain special equipment for sampling and for drone control operations. This included special cameras mounted in the drones. This unit was located on Enewetak Island.

TASK UNIT 1.5.4 (AIR TRANSPORT UNIT). TU 1.5.4 provided airlift for personnel, supplies, and equipment between Roswell Army Air Field, New Mexico, and the Pacific Test Area. It also provided air shuttle service among Kwajalein, Bikini, and Enewetak islands. Both C-46s and C-54s were available. This unit, stationed on Kwajalein Island, was responsible to assist in evacuating Enewetak Island in case of radiological danger to personnel on that island.

TASK UNIT 1.5.5 (AIR SERVICE UNIT). TU 1.5.5 serviced and maintained Army aircraft at Kwajalein Island. In addition to service and maintenance personnel, the task unit had engineers, military policemen, and weather-forecasting personnel.

TASK UNIT 1.5.7 (ARMY AIR WEATHER RECONNAISSANCE UNIT). TU 1.5.7 had three WB-29 aircraft with crews trained in weather reconnaissance. It flew long-range weather reconnaissance missions before each test. This unit was located on Kwajalein Island.

TASK UNIT 1.5.8 (AIR ORIENTATION UNIT). TU 1.5.8, based on Kwajalein Island, was responsible for accommodating visitors, observers, the press, and

news broadcasters. It flew these groups in two B-29s and two borrowed C-54s to witness CROSSROADS detonations.

TASK UNIT 1.5.9 (AIR-SEA RESCUE UNIT). TU 1.5.9 was initially part of TU 1.5.3 but was made a separate unit before testing started. It had two B-17 aircraft (called "Dumbos") for air-sea rescue and provided coverage between Enewetak and Bikini. The unit was based on Enewetak Island.

TASK UNIT 1.5.10 (HEADQUARTERS, AIR UNIT). TU 1.5.10 contained the command and staff elements of TG 1.5. It was based on Kwajalein Island and operated the task group headquarters. It was also known as Hq TG 1.5 (Reference B.5.1).

Task Group 1.6 (Navy Air Group)

TG 1.6 had three different functions: drone plane and drone boat control, aerial photography, and seaplane transportation. TG 1.6 was composed of four task units:

TU 1.6.1 (Drone Carrier Unit)

TE 1.6.11

USS Shangri-La (CV-38)

TE 1.6.12

USS Charles P. Cecil (DD-835)

USS Furse (DD-882)

USS Newman K. Perry (DD-883)

USS Turner (DD-834)

TE 1.6.13 (Navy Field Recovery Subunit, NAB Roi-Namur, Kwajalein)

TE 1.6.14

Air Development Squadron 2 (VX-2)

TU 1.6.2 (Photo Carrier Unit)

USS Saidor (CVE-117)

Plane guard destroyers from TE 1.6.12 as assigned.

TU 1.6.3 (Seaplane Unit, NAB Ebeye Island, Kwajalein)

Patrol Seaplane Squadron 32 (VPB-32)

Air-Rescue Squadron 4 (VH-4)

Carrier Aircraft Service Unit (Fleet) 34 (CASU[F]-34)

TU 1.6.4 (Seaplane Tender, Bikini)

USS Orca (AVP-49).

Shangri-La carried drone aircraft and operated off Roi Island, Kwajalein, where an airfield was used for landing and experimenting with drone planes.

Between tests, Saidor operated from Bikini Lagoon with drone boat control and photographic unit personnel on board. Except on ABLE and BAKER days, Orca was stationed at Bikini as a terminal and service unit for transport seaplanes. The ship maintained seaplane runways and furnished overhaul servicing required for all planes on turn-around service (Reference C.9.206, p. V-B-10).

Task Group 1.7 (Destroyer Surface Patrol Group)

TG 1.7 performed the following tasks during CROSSROADS:

- Furnished radsafe patrols
- Anchored one ship at Bikini Atoll lagoon entrance, except when it was evacuated, and supplied arrival information to incoming vessels
- Advised the Senior Officer Present Afloat (SOPA) about each arrival and departure from Bikini Lagoon
- Deployed two destroyers to act as approach markers for the bombing aircraft in test ABLE.

TG 1.7 was composed of only one task unit, TU 1.7.1 (Destroyer Squadron Unit), and contained the following ships.

Destroyer Division 71

USS Barton (DD-722) (Flagship) USS O'Brien (DD-725)

USS Laffey (DD-724) USS Walke (DD-723)

USS Lowry (DD-770)

Destroyer Division 72

USS Allen M. Sumner (DD-692) USS Moale (DD-693)

USS Ingraham (DD-694) USS Robert K. Huntington (DD-781)

Task Group 1.8 (Service Group)

This task group had the following responsibilties:

- Base facilities and services including repair, fuel, water, mail service (USS LST-861); general supply, provisions, hospital, and recreation (USS LST-388)
- Island commander functions for land areas of Bikini Atoll, such as policing recreational areas, conducting shore patrol, and controlling boat traffic at landings
- Boat services
- Medical and hospital services
- Quarters and laboratory facilities on USS Fulton (AS-11) for the Oceanographic Wave Measurement Group
- Surveys in accordance with the Oceanographic Survey Plan
- Construction in accordance with Logistic Plan

- LCI shuttle service between Bikini and Kwajalein atolls
- Evacuation of Rongerik Atoll population if necessary.

TG 1.8 was composed of the following six task units (Reference B.0.1, pp. 5 and 6).

TU 1.8.1 (Repair and Service Unit)

USS Ajax (AR-6)
ARD-29
ATA-124
ATA-187
USS Cebu (ARG-6)
USS Chikaskia (AO-54)
USS Chowanoc (ATF-100)
USS Coasters Harbor (AG-74)
USS Creon (ARL-11)
USS Dixie (AD-14) (Flagship)
USS Enoree (AO-69)
USS Fulton (AS-11)
USS Hesperia (AKS-13)
USS Limestone (IX-158)
USS LST-388
USS LST-861
USS Munsee (ATF-107)
USS Phaon (ARB-3)
USS Pollux (AKS-4)
USS Quartz (IX-150)
USS Severn (AO-61)
USS Sioux (ATF-75)
USS Sphinx (ARL-24)
USS Telamon (ARB-8)
USS Tombigbee (AOG-11)
USS Wenatchee (ATF-118)
USS Wildcat (AW-2)
YC-1009
YF-385
YF-733
YF-734
YF-735
YF-752
YF-753
YF-754
YF-990
YF-991
YF-992
YO-132
YO-199
YOG-63
YOG-70
YW-92

TU 1.8.2 -- No units assigned

TU 1.8.3 (Dispatch Boat and Boat Pool)

USS Gunston Hall (LSD-5)
LCI(L)-977
LCI(L)-1091
LCI(L)-1062
LCI(L)-1067
LCT-1361
LCT-1461
PGM-23
PGM-24
PGM-25
PGM-29
PGM-31
PGM-32
USS Presque Isle (APB-44)
USS San Marcos (LSD-25)

TU 1.8.4 (Medical Unit)

USS Benevolence (AH-13)

USS Bountiful (AH-9)

TU 1.8.5 (Survey Unit)

USS Bowditch (AGS-4)

USS James M. Gillis (AGS-13)

USS John Blish (AGS-10)

YMS-354

YMS-358

YMS-413

YP-636

TU 1.8.6 (Construction Unit)

53rd Construction Battalion (later, Construction Battalion Detachment 1156)

TU 1.8.7 (Rongerik Evacuation Unit)

USS LST-871

USS LST-989

POST-OPERATION ORGANIZATION AND ACTIVITIES

After 7 September all survey and construction activites at Bikini were rapidly brought to a close, and the atoll was evacuated by 26 September 1946. Following a meeting on the West Coast from 17 to 20 September concerning decontamination procedures, some officers from JTF 1 were ordered to temporary duty under Commander Western Sea Frontier to follow up and coordinate the decontamination, monitoring, and clearance of exposed ships. On 24 September, in a joint speedletter, the Bureau of Ships and the Bureau of Medicine and Surgery assumed responsibility for giving final radiological ship clearances and prescribed detailed decontamination and clearance procedures. JTF 1 was formally dissolved on 1 November; its successor was a JCS committee, the Joint CROSSROADS Committee, whose task was to oversee the final test activities, publish the final reports, and supervise the Bikini Resurvey Operation of summer 1947, described in Chapter 6 (Reference C.9.206, pp. V-(D)-5 through V-(D)-7).

CHAPTER 2
RADIOLOGICAL SAFETY

PLANNING

Proposals to test atomic weapon effects on ships were made at the end of World War II, but the first discussion of radiological safety appears to have occurred at a meeting held 8 December 1945. Among those attending were the commanding general of the Manhattan Engineer District, the chief of the District's Medical section, and a Navy officer closely associated with the atomic bomb project and trained in chemical warfare technology. This officer became Safety Advisor to Commander Joint Task Force 1 (CJTF 1) and headed the task force safety organization. The chief of the medical section, an Army medical officer, became Radiological Safety Advisor to CJTF 1 and headed the task force Radiological Safety Section within the safety organization (Reference A.1, pp. 9, 48, and 49; Reference B.0.1; Reference C.9.206, pp. VII-(C)-1 and VII-(C)-2).

During the next several months, training of radiological safety (radsafe) personnel, organization of the radsafe unit, and writing of the radsafe plan went forward. By 15 December medical officers from the Army, Navy, and Public Health Service had been selected for training in radiological safety. The Manhattan Engineer District took responsibility for radiological safety as the result of a meeting on 7 January 1946 between the joint task force commander designate and the commanding general of the Manhattan Engineering District. The Safety Advisor, the Radiological Safety Advisor, and the Radiological Safety Section were part of the joint task force from the time of its formal establishment on 11 January 1946. By April 15 a radsafe plan was submitted to CJTF 1. The plan was approved with revisions on 28 April. The plan underwent no significant revisions until after shot ABLE (Reference C.9.206, pp. VII-(C)-1 and VII-(C)-2). Relevant portions are reproduced in Appendix B.

Radiological safety, however, was only part of the task force's comprehensive safety program. It also included protecting personnel from fire, explosions, and toxic material. By exposing a fleet of warships, many loaded with ammunition, fuel, and lubricants, to nuclear explosions, the task force added nuclear safety to the many concerns damage control officers had faced for years.

The radsafe plan emphasized detection and avoidance of radiation to protect personnel. Systematic reconnaissance was to begin shortly after each detonation. Navy patrol seaplanes (PBMs) were to conduct aerial surveys over the lagoon and destroyers were to patrol the open ocean upwind and downwind of the atoll. Drone patrol boats were to enter the lagoon first to take water samples. Radsafe monitors aboard gunboats (PGMs) and landing craft (LCPLs) were to measure the lagoon's radioactivity. B-29s were to track the nuclear cloud. Radsafe monitors were to accompany all units and working parties reentering the target area to recover data or work on the target vessels.

RADIOLOGICAL SAFETY RESPONSIBILITY AND ORGANIZATION

Although the Manhattan Engineer District had taken responsibility for radiological safety at CROSSROADS, the District's role actually consisted of providing radsafe equipment and senior radsafe personnel. CJTF 1 was in command at Bikini and major radsafe orders were issued in his name. A Radiological Safety Section was established to advise CJTF 1 in this area and to implement his orders. Its chief was also CJTF 1's Radiological Safety Advisor. During test operations the section operated directly under the JTF 1 Assistant Chief of Staff for Operations. For the purposes of technical advice and instrumentation, the Radiological Safety Section reported to the Technical Director. This dual chain of command caused no difficulty during CROSSROADS (Reference C.9.206, p. VII-(C)-2).

The mission of the Radiological Safety Section was (Reference B.0.1, p. E-II-1):

> . . . to protect personnel from the hazards peculiar to the use of the atomic bomb during Operation CROSSROADS and to enable personnel to return safely to the target area at the earliest possible moment.

The task force operation plan specified the following elements for the Radiological Safety Section (Reference B.0.1, p. E-II-1):

1. Radiological Safety Control Unit
2. Radiological Safety Advisory Board
3. Radiological Safety Reconnaissance Units
4. Radiological Safety Monitor-Advisors
5. Radiological Safety Technical Service Units.

Documents written during CROSSROADS provide additional details on the section's organization. Figure 12 gives a composite picture based on information from the available sources.

The section chief, his staff, and supporting personnel, such as clerks and radiomen, made up the Radiological Safety Control Unit, based aboard USS Mount McKinley (AGC-7), the task force flagship. They were to (1) receive, plot, and analyze radiological data from all sources, (2) control the radsafe reconnaissance units, and (3) advise CJTF 1 on the l ation and amount of radioactivity. They were also to predict the path of the radioactive cloud and the pool of radioactive water.

The Committee for Review of Radiological Safety Measures functioned during most of its existence at Bikini under the title of Medico-Legal Board. It was convened on 15 June 1946 by the chief of the Radsafe Section, after which it met irregularly at his call or when one of more of its members felt a matter required its attention. Initially, it served to evaluate the regulations and safety measures adopted to protect personnel from radiological hazards. Later the board initiated a number of investigations, believing itself warranted in defining its own field of action. A total of 14 men served on the board at one time or another. All were medical doctors, specializing in radiology or with

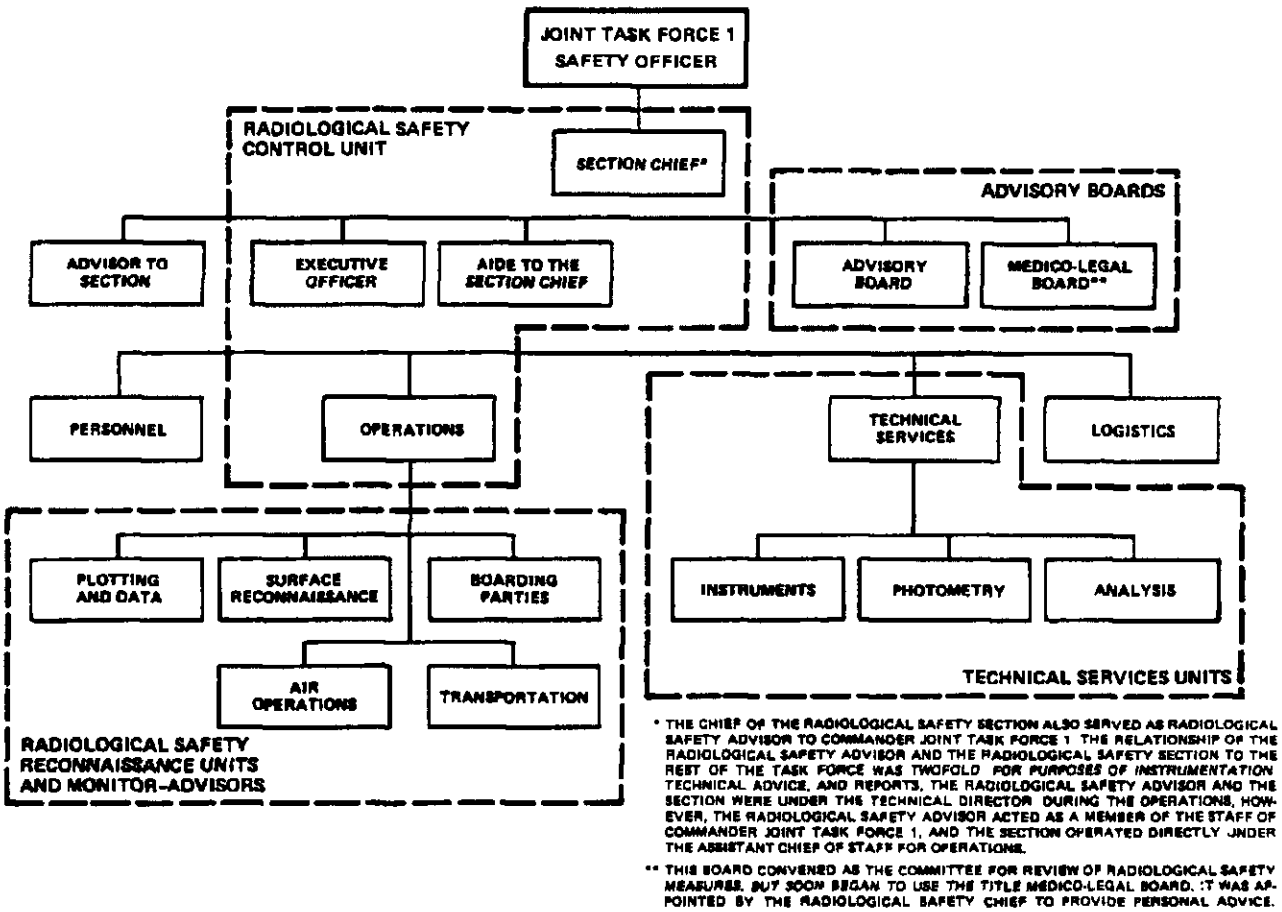

Figure 12. Organization of the Radiological Safety Section, CROSSROADS (sources: References C.9.206, B.0.2, B.0.4, and B.0.7).

radiation safety experience. The board held 14 meetings and considered such topics as the plutonium hazard, permissible beta exposure, fission products in the air, decontamination of personnel, control of overdoses, urinalyses, blood counts, monitoring procedures, and removal of equipment from target vessels (References B.0.7, C.0.5, C.0.6, C.0.7, C.0.8, and C.0.9b).

Planning called for each radsafe reconnaissance unit to consist of a monitor and one or more assistants. Initially, units were assigned as follows: two for PBMs, two for HSO-1 helicopters, nine for destroyers, six for PGMs on lagoon patrol, twenty for LCPLs on lagoon patrol, six for cloud-tracking aircraft, and two for drone boat operations (Reference B.0.1, p. E-II-1). However, as ABLE shot approached it became clear that many more monitors would be needed; in fact, over 225 monitors were used for each of the two shots (Reference C.9.206, p. VII-C-5).

Radsafe monitor-advisors were assigned to commands and aircraft likely to encounter radioactivity. The major function of these monitors was to advise their commands and pilots on radiological safety. In addition, they had a reconnaissance function. Thus, they could quickly communicate with the radsafe control unit to report radiation levels and receive advice on safety measures (Reference B.0.1, p. E-II-8).

The Radiological Safety Technical Service Units were composed of instrument repair personnel, photometrists, and analysts. The instrument repair personnel maintained, repaired, and calibrated all instruments used by the radsafe section. They supplied monitoring equipment to all aircraft operating in the test area that did not carry monitors, and they trained pilots in use of that equipment. The photometrists (dosimetry technicians) calibrated film dosimetry badges, prepared casualty and personnel badges, processed film from badges that had been worn, calculated exposure from film data, and recorded the results. Analysts collected and analyzed samples of water, soil, and marine life for radioactivity (Reference B.0.1, p. E-II-8; Reference B.0.4).

PERSONNEL PROTECTION

Tolerance Exposure

The Operation Plan set the maximum allowable dose or tolerance for exposure over a long period at 0.1 roentgen (R) per 24 hours (Reference B.0.1, p. E-I-3). The National Bureau of Standards had established that limit in 1934, and it was used in manufacturing plants in the United States (Reference B.0.8). The Chief of the Radsafe Section stated that this dosage was based on 2 to 2-1/2 years of experiments with dogs, mice, and fruit flies, and on experience with a workforce of 8,000 people (Reference B.0.9). The Operation Plan also stated that an individual was not to have a total exposure of over 50 or 60 R in 2 weeks. If an individual received 10 R in 1 day or 60 R in 2 weeks he was to be withdrawn from active participation in the operation (Reference B.0.1, p. E-I-3). Such action was never required. The highest accumulated recorded exposure for the operation was 3.72 R, which was received by an Army assistant radsafe monitor badged for 6 days. The highest number of badges issued to a single individual was 19. He also was a radsafe monitor and his cumulative exposure was 2.48 R.

Provision was made for special situations (Reference B.0.1, p. E-II-9) that might:

> . . . permit the assuming of a calculated risk in order to let certain key personnel enter a hazardous area to make highly desirable observations when the total amount of radiation to be received is less than 10 roentgen units. This may be permitted only on direct instructions from Radiological Safety Control. Details of the situation and clearance therefore will be carefully logged by the accompanying monitor and at Radiological Safety Control.

There is no record that this special provision was invoked during the operation.

On 5 August the Medico-Legal Board recommended that three monitors refrain from monitoring for 1 or 2 days because of badge readings in excess of 0.1 R (Reference C.0.10). Later, monitors who exceeded the tolerance were removed from work on USS Salt Lake City (CA-25) (Reference C.0.11).

Film Badges

Two types of film badges were used at CROSSROADS. One type, called a personnel or mission badge, had a range from 0 to 2 R. Badges were issued to some of the men about to enter possibly radioactive areas and most badges were collected after the men returned, usually the same day. Some badges were worn for 2 or 3 days, and a few worn for as long as 9 days have been noted. Each badge contained a piece of Kodak Type K double-coat film in a dental film packet holder. Strips of lead were crossed over the film at right angles, leaving the film's corners without lead covering. Each badge was sealed in a tropical weather-proof envelope to protect it against the hot, humid Bikini climate (Reference C.0.5, p. 2-2).

The badges were designed to measure both beta and gamma exposure, but the beta readings obtained and recorded are now considered questionable (Reference C.13.2). There are several reasons for this. One is that the response of the double-coated film dosimeter emulsions depends on the energy of the beta particles they are exposed to. Unless additional thin metal foils are used over the films to filter or sort the beta radiation into known energy groups, or unless the energy distribution of the beta radiation is otherwise known, very large errors in interpreting the film darkening can result. There also appear to have been some incorrect assumptions made concerning whether gamma as well as beta would darken the unfiltered areas (Reference C.13.2). Despite the doubtfulness of the validity of the beta readings, the values as originally assigned have been accepted and used in total dose assignment in the NTPR program (Reference C.13.2).

After a badge was returned to the Radsafe Section, the photometrists of the Radiological Safety Technical Service Units developed the film in it and measured the film's optical density. This was a measure of the amount of radiation to which the film had been exposed. The film number, the wearer's last name, and the exposure date and time were written on a line on the left-hand page of an open ledger book of the type then widely used by Federal agencies. Sometimes the individual's first name, initials, or rank were written in. Sometimes the name of the ship where he was quartered or, more often, the target ship on which he had worked that day was entered. If the badge had been used on an island or ship as a radiation recorder, the location information was recorded instead of a person's name. Optical densities under the lead cross and on the corners of the badge were entered on the right-hand page. The radiation exposure was calculated from these densities and recorded as the final beta and gamma readings at the page's far right. Years later, the pages were removed from the ledgers and microfilmed. Information from badges worn during September, October, November, and December of 1946 was recorded on large (5- x 8-inch) cards for each individual.

Neither the detached pages nor the microfilm is easy to work with. The penmanship of the radsafe staff is not always legible, and incomplete identification of the badge wearers and inconsistent ship identifiers are additional problems. In 1968 the Reynolds Electrical and Engineering Company (REECo) transferred the information from the ledgers to a computer data base, allowing easier manipulation and analysis of the material. The REECo list is used as the basis of the personnel exposures in this report.

Multifilm badges, called casualty badges, were used to record high-range exposures. They were placed aboard a small number of ships and aircraft that might enter areas of high radiation. Casualty badges were also placed aboard target ships as part of the scientific program to determine exposure from the detonations.

Radiological Safety Instruments

CROSSROADS requirements for radsafe instruments turned out to be far greater than had been expected when planning for the operation began. No comprehensive program existed for development and manufacture of rugged instruments for use under field conditions; thus, the head of the Radsafe Section had to make do with what the Manhattan Engineer District could provide from its inventory and what the Victoreen Instrument Company could manufacture quickly (Reference C.11.1; Reference C.0.12, p. 18).

Each monitor unit or monitor-advisor was equipped with a Geiger-Mueller counter (X-263 Survey Meter) and an ionization meter (Model 247 Survey Meter), as well as other equipment, depending on the nature of the mission (Reference B.0.1, pp. E-II-2 through E-II-8).

The X-263 measured beta and gamma radiation from about 0.001 R/24 hours to about 0.4 R/24 hours (References B.0.10 and C.0.13). This range made the meter too sensitive for some radiation fields encountered during CROSSROADS (Reference A.2, pp. 7 and 8). The X-263 proved too delicate to function consistently under field conditions (Reference C.0.14, p. 3). Three hundred twenty of these instruments were available 2 days before BAKER (Reference C.0.12, p. 9). Every monitor tried to have three or four of them to assure that at least one would be working when he reached his post (Reference C.0.15, p. 3).

The 263 G.M. Set, an older version of the same instrument, also was used at Bikini, but information is lacking on the number available. Experienced monitors preferred it whenever accurate and reliable data were required (Reference C.0.12, p. 18).

The 247 Survey Meter measured gamma radiation only. Its range was from 0.5 to 200 R/24 hours, and it was often used for measuring intensities beyond the range of the X-263. It was rugged, spray resistant, and held its calibration well (Reference A.2, pp. 7 and 8; Reference C.0.12, p. 23). Twenty of these were available for monitoring after the BAKER detonation (Reference C.0.14, p. 3).

Pocket dosimeters were designed to measure cumulative gamma dose up to about 0.3 R. About 160 were issued for the BAKER test. They were relatively rugged and easy to repair. Apparently they were often issued to divers (Reference C.0.12, pp. 27 and 28).

Several other instruments were available to the monitors, although in numbers smaller than the X-263, the 247, and the pocket dosimeter. The L&W survey meter measured between 0.001 and 25 R/24 hours. Twelve were in service following BAKER. They were used mostly by boarding parties and by special groups, such as the target monitor group. The head of the monitor group wrote

that the L&W meter was the most reliable instrument for these measurements because it was energy-independent and insensitive to temperature and humidity changes (Reference C.0.16). Six assault meters, brought out by individual monitors, were used during the operation. They were very rugged and ideal for quick and rough determination of radiation levels from 0.1 to 10 R/24 hours. They proved useful for boarding ships and similar operations (Reference C.0.12, p. 31). The "cutie pie" survey meter was a small instrument capable of measuring beta and gamma radiation up to 100 R/24 hours. Few of these were available for CROSSROADS, but a monitor aboard PGM-32 after BAKER used one and decided it was an excellent portable rate meter (Reference C.0.15, p. 4).

The task force had several instruments for measuring alpha contamination. None, however, proved reliable for field surveys. Photographs of task force activities show the Zeus counting meter, the Zeuto, and the X-323. These three instruments were mentioned in training lectures for monitors (References C.0.17 and B.0.11). One or all may have been the Poppy or Walkie Poppy referred to in radsafe reports after BAKER. The three devices appear to have been small, and each had a carrying handle, but apparently they did not work well outside of USS Haven's (AH-12) air-conditioned laboratories in the hot, humid Bikini climate (Reference C.0.14, p. 4). In addition, the Radsafe Section had five Filter Queen Air Samplers. Basically, these were tank-type vacuum cleaners with an alpha detector and filter paper mounted in the intake tube. Samples collected in the filter papers aboard the target ships had to be returned to Haven where alpha counts were made. Initially, the alpha detectors worked well, but humidity, along with personnel opening the detectors improperly, caused them to fail (Reference C.0.12, pp. 8 and 9).

Personnel Decontamination

Personnel working in radioactive areas sometimes picked up radioactive particles on their bodies and their clothing. Procedures were established to minimize the spread of this contamination and potential internal and external exposure from these radioactive sources. The procedures spelled out for the USS Ajax (AR-6) crew working on repair of Salt Lake City following BAKER were typical and are summarized in the following paragraphs.

Ajax crewmembers slated for work on Salt Lake City left their own compartments wearing only their own shoes. These shoes were removed and left in a compartment adjacent to a designated head (bathroom) where the men donned work clothing. They then left Ajax via a Jacobs ladder into a small boat while carrying canvas gloves and shoe covers. The gloves and shoe covers were put on immediately before boarding the target ship for work and were taken off just before leaving.

Upon return to Ajax, the men boarded by Jacobs ladder and went to the upper deck where they were monitored. They walked only on a deck covering, which presumably was disposed of after use. The men first washed their hands and forearms with hot water and salt-water soap. Then each man washed his own clothing. These were first scrubbed in hot water and salt-water soap and then rinsed in a special hot rinse and rinsed again in plain hot water. The clothes were hung on lines to dry on the upper deck.

Clothing so contaminated that it read more than 0.10 R/24 hours (gamma) was placed in paper bags, and radiation was allowed to decay for a period of time before the clothing was washed. If the radiation did not decrease to less than 0.10 R/24 hours, the clothing was disposed of at sea.

After the clothing had been washed or put aside to cool, the men took a shower in the decontamination head in a designated stall with hot water, thoroughly soaping themselves with salt-water soap. They then proceeded to a second stall where they again showered with ordinary soap. The men were monitored again and if free of contamination could return to their own compartments; otherwise they continued showering (Reference B.0.12).

Commander Task Group (CTG) 1.2 set a slightly lower radiation level, 0.05 R/24 hours, above which the clothing was to be disposed of at sea. The contaminated clothing was to be bundled and weighted and the Radsafe Section was to be notified. An LCT picked up the bundles the next day and dumped them 10 nmi (18.5 km) from Bikini at sea.

Clothing in small lots was laundered in separate buckets (like the Ajax procedure above) or done in the ships' laundry if in large lots. If the ships' laundry were used, however, the clothing had to be separately done and the laundry machinery had to be specially cleaned after use (Reference C.10.8).

Urine Testing

The discovery of alpha emitters, including plutonium, led to urine tests for personnel thought to have been exposed to determine whether any had taken these substances into their bodies. The water-testing laboratory on Haven was converted for testing urine. By 15 August, 2,600 samples had been tested. The men doing the work had to use instruments that were on hand and develop techniques as they worked. The widespread presence of radioactive material led to high background counts and made it difficult to determine whether an individual had low levels of alpha emitters in his urine. On 15 August the Radsafe Section reported slight beta activity had been found in the urine of 2,600 men checked (Reference A.2, pp. 117, 118, and 121 through 125; Reference C.10.9; Reference C.10.15). Despite all the concern and discussion about it, there is no indication in CROSSROADS documentation that positive alpha counts were found in any urine samples.

Eye Protection

Eye protection from the ABLE flash was a major concern. Approved darkened goggles were provided to personnel on ships 25 nmi (46 km) or less from the ABLE detonation and to all observers on the press and observer ships. Men without goggles within 30 nmi (56 km) were to turn away from surface zero, look down at the deck, close their eyes, and cover their eyes with their arm (Reference B.0.1, pp. E-I-1, E-I-2, and E-IV-2). Pilots airborne at the time of the detonation were to wear approved goggles and turn their heads away from the detonation. In addition, each copilot was to close his eyes and cover them with his arm so that he would be ready to fly the aircraft if the pilot was flashblinded (Reference B.0.1, p. F-XII-5).

EXCLUSION AREAS AND OPERATIONS LIMITS

Surface Operations

To reduce the chance of exposing task force personnel to radiation, several surface areas were defined by the Operation Plan to which access was forbidden or restricted (Reference C.9.206, p. VII-(C)-9):

1. Surface Survey Sector. This was a forbidden surface area outside the lagoon. It was bounded by two bearings drawn from the detonation point and by a radius that increased with time after the detonation.

2. Red Line. This line surrounded the lagoon area within which the radiation level was 1 R/24 hours or higher. This boundary was separate from the Red Arc that defined airspace limits.

3. Blue Line. This line marked the boundary between the lagoon area with a radiation level more than 0.1 R/24 hours and the area with a lower level. Vessels could operate in the lagoon area between the Blue and Red Lines only for specified periods of time with permission from the Radiological Safety Control Unit. Vessel movement outside of the Blue Line was governed only by regular Navy rules.

4. Anchorage Area Able. Ships could anchor in this area, provided they were ready to get underway on 1 hour notice.

5. Anchorage Area Baker. An unrestricted anchorage area.

In addition, certain operational limits were specified. No manned ships were to be closer than 10 nmi (18.5 km) from the ABLE detonation, and most were to be 20 nmi (37 km) away (Reference B.0.1, p. E-IV-1). In case of fallout on the ships, nonessential personnel were to be sent below decks, the ship closed up, and exposed personnel were to strip off their outer clothing before taking cover. If necessary, men in coveralls and gas masks were to decontaminate contaminated areas of the ship after fallout ended (Reference B.0.1, p. E-IV-7).

Before each test all ships were to have full freshwater tanks. Distilling plants and heat exchangers were not to be operated until the Radiological Safety Section had declared the saltwater to be used was radiologically safe. If the equipment had to be operated before radiological clearance had been given, special monitoring attention was required (Reference B.0.1, p. E-IV-10).

In order to gain access to classified or radioactive areas, the leader of a work party was required to present an identification card and a letter of authority. There were letters for damage control, instrumentation, observer, press, and radsafe parties, among others (Reference B.0.3).

Aerial Operations

Initially Joint Task Force One Operation Plan 1-46 (OpPlan 1-46) prescribed certain general safety precautions for air operations. It specified that all aircraft aloft from H-2 hours to H+30 minutes carry a radiation monitor with monitoring equipment. Exceptions were the bomb-drop and pressure-gauge-drop

B-29s, single-seated aircraft, and those other aircraft so designated by CJTF 1 as exempt. The crewmembers of all aircraft aloft during that period were to wear film badges, and each aircraft was to carry at least one casualty badge capable of recording radiation much higher than personnel film badges. In actuality, these plans were modified somewhat for both shots. For shot ABLE, radiation monitors were aboard all photographic aircraft, reconnaissance aircraft, drone control aircraft (except the Navy F6Fs), air-sea rescue aircraft, and press/observer aircraft. The F6Fs were single-seated, fighter-type aircraft in which radiation monitoring equipment was installed for the pilot's protection. On shot BAKER, radiation monitors were aboard all photographic aircraft, reconnaissance aircraft, and press/observer aircraft (Reference C.9.206, pp. VII-(C)-10 and VII-(C)-19).

The prohibited airspace for aircraft was defined separately for each of the two tests and was a function of time and range. For the first 6 minutes after detonation, no aircraft was to approach closer than 10 nmi (18.5 km) to surface zero. From H+6 to H+30 minutes, a radiation danger sector (radex) was defined, consisting of two bearings drawn from surface zero, e.g., 320° clockwise to 120°. From H+6 to H+18 minutes, the aircraft exclusion area consisted of all space in this sector within the Red Arc. From H+18 to H+30 minutes, the exclusion area was all space in this sector within the Blue Arc. The Red and Blue Arcs were decided upon based on wind speeds the morning of each detonation. The morning of each shot, the radex sector was updated from the one predicted the previous evening. The Red Arc was, by definition, nearer surface zero than the Blue Arc. Specific values for radex sectors and the Red and Blue Arcs for the ABLE and BAKER shots are discussed in Chapter 4 (Reference B.0.6). In addition, no aircraft without radiation detection instrumentation was to approach closer than 20 nmi (37 km) to the visible column or downwind clouds. From H+30 minutes to H+30 hours, no aircraft was to be within 30 nmi (56 km) of surface zero unless engaged in radsafe work or cleared by the Deputy Commander for Aviation (Reference B.0.1, p. F-XII-3).

All aircraft, manned and drone, airborne from H-hour until H+30 were to be monitored upon landing. Aircraft oil filters and any surface oil spots were to receive special monitoring attention. All drones were considered heavily contaminated until proven otherwise (Reference B.0.1, pp. E-IV-3 and E-IV-4).

STAFFING AND TRAINING

Selection of Personnel

When the Radiological Safety Section was established in January 1946, it was believed that 50 to 60 monitors would be needed. Between 20 and 30 were to be experienced radsafe practitioners from the Manhattan Engineer District and thirty were to be doctors from the Army, Navy, and U.S. Public Health Service. The latter group, including a chemical warfare officer, reported to Oak Ridge National Laboratory on 15 January for an intensive 11-week course. The course included the physics of radioactivity, nuclear safety techniques, biological effects of radioactivity, field training, and hazards of ingested radionuclides. Experts from Oak Ridge and Los Alamos laboratories and from the universities of Rochester, Chicago, and California at Berkeley provided instruction (Reference C.9.206, p. VII-(C)-4).

As the Chief of the Radiological Safety Section and his staff continued work on the radsafe plan, they realized that a much larger group of monitors and other experts would be required than would be available from the Manhattan Engineer District. To fill this gap, the section chief called on a number of scientists who had already returned to civilian life from wartime service with the government. Few were eager for another extended period of government service, and they and the universities or laboratories employing them demanded, and received, promises of strict limits on the duration of their CROSSROADS service. Apparently, all were to be back in the United States by late August or early September (Reference C.9.206, p. VII-(C)-4).

On 23 March 1946, efforts to staff the Radiological Safety Section were dealt a major setback when the President announced that the first test was to be postponed from 15 May to 1 July (Reference B.12.1, p. 1), with the result that the second test also was delayed. This change raised the prospect that personnel from colleges and universities would not be back on campus for the start of the fall semester. The Chief of the Radiological Safety Section struggled to hold his civilian recruits, but many resigned and he was forced to search for replacements. He asked for more military officers and was supplied with 55 from the Navy and 15 from the Army, almost all of whom were reservists. He also was able to obtain some additional civilians (Reference C.9.206, p. VII-(C)-5; Reference B.0.5).

Bikini Activities

Most of the Radiological Safety Section reached Bikini on 12 June aboard Haven (Reference A.2, p. 11). Some personnel, however, did not arrive until after the ABLE shot or the BAKER rehearsal, and some civilians left Bikini before the BAKER detonation. The Radiological Safety Section was able to muster over 300 personnel for ABLE. Over 225 monitors were available for each of the two shots, but they were stretched thin. During ABLE there were more monitors than during BAKER (Reference A.1, p. 31; Reference C.9.206, p. VII-(C)-5).

Training of Radiological Safety Section personnel had three phases. First, intensive training for the original group of military and public health personnel at Oak Ridge and other locations beginning in mid-January; second, training of the entire section aboard Haven on the way to Bikini; and, third, additional training for the section and for later arrivals once at Bikini.

One of the monitors, a medical doctor drafted into the Army late in the war and assigned to CROSSROADS, characterized the group aboard Haven as follows (Reference A.2, p. 5):

> Most are older men, some are well-known scientists. Some have worked with radiation in the Manhattan District, but the majority come with little more than a scientific background. Test ABLE is only one month away. Since this group is to have the responsibility for protecting task force personnel from the invisible dangers of radioactivity, the problem of briefing them on the fundamentals and the practical aspects of radiation is acute.

Training for the entire section began aboard Haven on 31 May as the ship steamed for Bikini. It consisted of lectures and work with radiation detection

instruments. The 12-day curriculum is shown in Table 3. On the seventh day, personnel were divided into groups by job: destroyer monitors, aircraft monitors, PGM monitors, etc. They were issued instruments, and radium sources in lead "pigs" (containers) were used to give the men experience calibrating and reading their instruments under a semblance of field conditions (Reference A.2, p. 7; Reference C.9.206, pp. VII-(C)-6 and VII-(C)-7).

Haven arrived at Bikini on 12 June, and a task-force-wide rehearsal, called Queen Day, was held on 14 June. Two problems for the radsafe section became immediately apparent. First, because of a shortage of electronics technicians, radios on Mount McKinley used by the Radiological Safety Control Unit could not be kept operating adequately under the heavy load put upon them. Second, the 24 landing craft assigned to the Radiological Safety Section were in very poor repair and their radios were even worse. Only six of the twenty-four landing craft could participate in this first exercise, and four of them broke down within 3 hours. Neither Mount McKinley's radios nor the landing craft were fully ready for the ABLE rehearsal. Their first completely satisfactory performance was on ABLE day (Reference C.9.206, p. VII-(C)-8).

Task force personnel had various means of learning about the upcoming operation and the safety procedures and the problems that might be encountered. Ships' newspapers and Plans of the Day carried many articles on CROSSROADS. The Operation Plan was available on each ship and formed the basis for indoctrination of the ship's force about what to expect and what safety precautions were to be taken. A bulletin addressed to the officers and men of USS Wharton (AP-7) and signed by the Director of Ship Materials (DSM) gave a description of the projected detonation and the arrangement of the target fleet. The bulletin also included the statement that from time to time members of the staff would give lectures on various aspects of the bomb tests that would be of general interest (Reference B.0.14). This bulletin probably was typical of the briefing materials used throughout the task force. In addition, there was a full-scale rehearsal stressing safety before each test. Most of the scientific personnel collecting data on phenomenology and blast effects were probably fairly well-versed in radiation safety from their service with the Manhattan Engineer District. Units designated to enter possibly radioactive areas received briefings from members of the radsafe staff, usually the unit's assigned monitor, on radsafe procedures needed for their particular assignment (for example, see Reference B.0.1, p. F-XII-3). The radsafe monitors were responsible for the safety of personnel reboarding target ships. Task force personnel received general indoctrination on radiation safety and nuclear effects.

Continuing Need for Radiological Safety Personnel

Even after ABLE and BAKER had been detonated and the first phase of CROSSROADS drew to a close, the need for radsafe monitors and other radsafe personnel continued. The contaminated target and support ships presented a relatively long-term problem, and CHARLIE, the third test in the CROSSROADS Series, was still planned. Moreover, the series' first phase had brought home to the military leadership the need for a substantial military radsafe organization.

August saw the beginnings of activity designed to begin meeting these long-term needs. On 5 August, CJTF 1 asked the Navy Bureau of Ships for 100 naval

Table 3. Basic intensive courses for CROSSROADS radiological safety monitors.

Day	Time	Course Title
1	0830-0920	Introduction: Mission of the Radiological Safety Section
	0930-1020	Mechanics, Force, and Energy
	1030-1120	Electricity
	1300-1400	The Atom Speaks
	1430-1520	Casualties at Hiroshima
	1530-1620	Conference
	1900	Physical Damage at Hiroshima
2	0830-0920	Atomic Structure
	0930-1020	The Bohr Theory
	1030-1120	Ionization and Quantum Concepts
	1300-1520	Group Seminar
	1530-1620	Instruments Demonstration
	1900	Radioactivity
3	0830-0920	X-rays; Alpha, Beta, and Gamma Rays
	0930-1020	Mass and Energy
	1030-1120	Nuclear Composition
	1300-1520	Demonstration and Group Seminar
	1530-1620	Demonstration of the X-263
	1900	Thermal Radiation
4	0830-0920	Artificial Radioactivity
	0930-1020	Fission Process
	1030-1120	Fission Products
	1300-1520	Demonstration and Group Seminar
	1530-1620	Demonstration of the 247
	1900	Effect of Radiation on the Human Body: Radiation Sickness and Other Pathology
5	0830-0920	Chemistry of Plutonium, Uranium, and Fission Products
	0930-1020	Nuclear Cross-Section and the Production of Plutonium
	1030-1120	Mesons and the Synchro- or Frequency-Modulated Cyclotron
	1300-1520	Demonstration and Group Seminar
	1530-1620	Demonstration of the Pocket Dosimeter
	1900	Physical Damage to the Principal Hospitals and First-Aid Stations in Nagasaki

(continued)

Table 3. Basic intensive courses for CROSSROADS radiological safety monitors (continued).

Day	Time	Course Title
6	0830-0920	Ionization Chamber and Geiger-Mueller Counter
	0930-1020	Tolerance Dose
	1030-1120	Radiobiology
	1300-1520	Practical Problems of Radiation Exposure
	1530-1620	Proteximeters [radiation detectors used in aircraft]
	1900	Physical Damage at Nagasaki
7	0830-1120	Calibration of the X-263 and the Pocket Dosimeter
	1300-1620	Practical Exercise with the X-263
	1900	Thermal Radiation
8	0830-1120	Calibration of the 247 and the Pocket Dosimeter
	1300-1620	Practical Exercise with the 247
	1900	Radioactivity from a Nuclear Blast
9	0830-1020	Principles of Radiological Survey
	1030-1120	Radiological Operations
	1300-1400	Air Monitoring
	1430-1520	Sea Monitoring
	1530-1620	Land Monitoring
	1900	Biological Studies
10	0830-0920	Initial Boarding Party Monitoring
	0930-1020	Target Ship Clearance
	1030-1120	Analysis of Radioactive Water
	1300-1520	Laboratory Analysis of Radioactive Water
	1530-1620	Instrument Repair
	1900	Biological Studies
11	0830-0920	Principles of Health Physics
	0930-1020	Protection Against Radioactive Hazards
	1030-1120	Analysis of Radioactive Solids
	1300-1520	Laboratory Analysis of Radioactive Solids
	1530-1620	Instrument Repair
12	0830-0920	Ventilation Clearance
	0930-1020	Evaporator Clearance
	1030-1120	Ship Clearance
	1300-1620	Field Exercise

officers with technical or scientific backgrounds to be assigned to radsafe work. The officers were to be available by 1 September to begin intensive training designed to prepare them to replace the existing monitor personnel no later than 1 November so that study of the BAKER results and decontamination of the ships for test CHARLIE would not be delayed (Reference C.10.10). On 10 August, CJTF 1 ordered his rear echelon element in Washington to secure approval from the Chief of Naval Operations, Navy Bureau of Personnel, and the Navy Surgeon-General for a program to be set up by JTF 1 to train 100 new monitors. He also indicated that these new radsafe personnel might be needed to help monitor the drydocking of task force ships returning to the United States (Reference C.10.12). Most radsafe personnel left Bikini for the United States on 16 August aboard USS Henrico (APA-45), leaving a much reduced radsafe organization on Haven to continue radsafe work at Bikini (Reference C.9.206, p. VII-(C)-24). Personnel traveling on Henrico probably were mostly civilians returning to their campuses and laboratories or military officers at the end of their terms of service. Under discussion by 20 August was a proposal to add 25 members from West Point's class of 1946 to the group to undergo monitor training (Reference C.10.13). The training program was to start on 9 September at the Navy Department in Washington, with field work at Alamogordo and on the target ships at Kwajalein or Bikini. After their training, the new monitors would be assigned to JTF 1 (Reference C.0.2). One attendee wrote he received 4 weeks of instruction in "basic radiology" in Washington, D.C., and did laboratory work at the Radiation Safety Laboratory, San Francisco Naval Shipyard, Hunters Point, California, before reporting to the Radiological Safety Section at Kwajalein (Reference B.0.8).

The potential radsafe needs created by Test CHARLIE disappeared, however, when President Truman cancelled that test on 7 September.

OCEANOGRAPHIC SURVEY

While radsafe planning and organization of the Radiological Safety Section went forward in the United States, important radsafe preparations also took place at Bikini. Beginning on 10 March 1946, civilian and military scientists at Bikini aboard USS Bowditch (AGS-4) conducted detailed oceanographic, biological, and geological surveys of the atoll. From the radsafe perspective, their most important work was an effort to chart the currents in the atoll's lagoon. This information was needed to estimate what might happen after BAKER when a large amount of radioactive contamination would be dispersed in the lagoon and perhaps into the surrounding ocean. The safety of the task force and the ability of its recovery teams to reenter the target area were involved (Reference A.1, p. 92).

After the shots, the radsafe section monitored the radiation level in the lagoon water through the use of drone boats, PGMs, and LCPLs (Reference A.2, p. 100). Monitors accompanied scientists collecting fish, coral, and samples of the bottom. On 9 August, a monitor with a collection party found the first bottom sample so radioactive he ordered it pitched over the side (Reference A.2, p. 108). Highest recorded activity on a bottom core sample was 0.292 microcuries/gram in newly deposited sand and mud from the first 6 inches of the core (Reference C.9.209, Annex J, Figure 7).

WEATHER PREDICTION

Accurate weather predictions at least 24 hours in advance were needed to allow the task force to complete the complex final preparations for a detonation and to give reasonable assurance that radiological safety could be maintained. Cloud cover had to be at a minimum for the ABLE airdrop to allow the bombardier to see the target ship. Wind direction, not only near the surface but up to 60,000 feet (18.3 km), had to be such that it would not carry fallout over the task force. Moreover, wind direction had to be fairly steady so that fallout areas would be predictable. Tropical meteorology was not well developed at that time, and detailed data of past weather patterns at Bikini were lacking. The exacting forecasting requirements for CROSSROADS posed a major challenge.

The official forecast issued the day before a planned detonation and used as a major element in the decision to proceed included: the amount, in tenths of sky coverage, of low, middle, and high clouds; the altitude of the base and top of the low clouds and the altitude of other cloud layers; precipitation (if expected); the wind direction and velocity in 5,000-foot (1.5-km) increments from the surface to 60,000 feet (18.3 km); height of the tropopause; and visibility, temperature, and relative humidity (Reference C.9.207, p. VII-(O)-17).

Responsibility for furnishing weather forecasts or weather advice for task force operations was vested in the Staff Aerological Unit located on Mount McKinley. The unit was to prepare special forecasts for the Radiological Safety Unit to help anticipate movement of the radioactive cloud (Reference B.0.1, p. T-2). Because of lack of space on Mount Mckinley, a significant portion of the personnel doing weather data analysis was stationed on Kwajalein at the Weather Central. To supply upper air and surface data, aerological units of from four to six personnel were stationed on USS Shangri-La (CV-38), USS Saidor (CVE-117), USS Fall River (CA-131), and USS Albemarle (AV-5). These personnel also provided weather briefings to task group commanders and aircrews. To gather surface data, one-man aerological units were stationed aboard USS Orca (AVP-49), Bowditch, USS Kenneth Whiting (AV-14), USS Blue Ridge (AGC-2), and USS Appalachian (AGC-1). Weather Central received reports daily or more often from weather stations on Wake, Enewetak, Tarawa, Majuro, Kwajalein, and Marcus islands and from two weather ships northeast and northwest of the Marshall Islands at 12°45'N, 180°0'W and 12°0'N, 153°40'E, respectively (Reference C.9.207, p. VII-(O)-22). Data from more distant U.S. and foreign weather stations funneled through Fleet Weather Central in Hawaii were also used.

At least one B-29 and one PB4Y-2 flew out of Kwajalein each day for weather reconnaissance, the B-29s usually toward the east and the PB4Y-2s toward the west. More flights were scheduled as necessary. On ABLE and BAKER days, three flights passed through the Bikini area.

The weather forecast for the following day was presented to CJTF 1 each day at 0830. From that he decided if the weather would allow the next day's planned operations. A second briefing for the commander was held daily at 2200. On the basis of this briefing, he decided whether to hold to the morning's decision or alter it. Continued weather input was provided the commander (Reference C.9.207, pp. VII-(O)-9, through VII-(O)-19).

RADIOLOGICAL SAFETY PREPARATIONS FOR BAKER

Because BAKER was the first underwater detonation of a nuclear weapon, neither the participating scientists nor the task force leadership could predict with certainty how the lagoon water would react to and modify the explosion cloud. Spread of radioactive contamination and creation of damaging waves were major concerns. Simulation using conventional explosive charges was one approach to estimate the effects. In one effort to predict the spread of radioactivity, 1,000-lb charges of TNT were detonated and the results extrapolated upward to the expected 20-KT yield of the BAKER device (Reference B.0.15, pp. 13 through 16).

During the period March to May 1946, several organizations under the supervision of a professor from the University of California carried out experiments for the task force on wave action in shallow water (Reference C.0.18; Reference C.0.12.3, p. 6). In 1946, computer simulations were still in the future, but various scientists applied their slide rules and scientific imagination to the forecasting problem. One study analyzed the possibilities largely on the basis of the height to which the column of contaminated water might rise. A rise of only 10,000 feet (3.1 km) would present the greatest hazard because most of the contamination would fall on the target ships or back into the lagoon. Reboarding some target ships within 1,000 yards (9.1 meters) of the detonation might be dangerous for weeks because of the contamination deposited from the water column (Reference C.0.19, pp. 5 and 9).

In an early overview of the operation, CJTF 1 offered the opinion that following BAKER (Reference B.0.16, p. 7)

> It will be undoubtedly be some weeks before the lagoon and target ships are again habitable. During this period, some of the task force ships may be sent to anchor at Kwajalein. If it should turn out that the target ships will not be habitable for months, other arrangments will be made.

On 18 June, an appendix was added to the Operation Plan that gave a description of the underwater detonation's expected effects (Reference B.0.1, pp. E-X-1 through E-X-17 and E-IX-1 through E-IX-4). The ball of fire or steam caused by the detonation was predicted to rise to an altitude of from 10,000 to 60,000 feet (3.1 to 18.2 km). The most likely altitude was predicted to be 30,000 feet (9.1 km) (Reference B.0.1, p. E-IX-1, Change No. 6). However, a postoperation document indicates that planning was based on a prediction of maximum altitude of 15,000 feet (4.6 km) (Reference C.9.206, p. VII-(C)-18).

The appendix further predicted that a plume of water might rise, extend for several thousand feet above the surface, and then fall back into the lagoon. Radioactive material would be deposited initially in the lagoon within boundaries represented by a cylinder several hundred yards in diameter and extending from the surface to the bottom of the lagoon. The trail of water and steam following the ball of fire would be heavily contaminated. Distribution of radioactivity in the water was anticipated to be more widespread than following ABLE and would persist for a longer period. Target ships within 1,500 yards (1.4 km) of the explosion would be seriously contaminated. Downwind serious contamination would occur beyond 1,500 yards (1.4 km). It was expected that

some target ships might be so heavily contaminated they could not be boarded safely for an indefinite period (Reference B.0.1, pp. E-IX-1 and E-IX-2).

Following conferences attended by senior radsafe personnel, a new appendix to the CJTF 1 Operation Plan radsafe annex was issued in 15 July. Under the revised radsafe plan, the Radiological Safety Section retained its five major elements. Since radioactivity from the underwater explosion was expected to be last longer and be more intense than from ABLE, personnel were added to the Radiological Safety Control Unit for around-the-clock operation (Reference C.9.206, p. XII-(C)-16). Some additions and subtractions were made to the radsafe reconnaissance units. A third PBM unit and one upwind destroyer unit were added to improve lagoon reconnaissance. Three cloud-tracking units were dropped, presumably because the underwater explosion was not expected to create a cloud as high and far-reaching as ABLE (Reference B.0.1, pp. E-X-1 and E-X-5).

The total number of civilians and military officers in the Radiological Safety Section changed between ABLE and BAKER as follows (Reference C.9.206, p. VII-(C)-5):

	ABLE	BAKER
Civilians	130	93
Navy Officers	77	102
Army officers	96	63
Total	303	258

The number of monitors probably decreased, but more than 225 were available for BAKER (Reference A.1, p. 31).

The distribution of radsafe monitors was changed for BAKER: fewer were put on LCPLs and more were assigned to the DSM. Sixty-one were placed under the control of the DSM with duties as follows (Reference B.0.1, pp. E-X-14 and E-X-15):

1. The DSM and his deputy each were to have a monitor acting as his technical advisor and administrative assistant on radsafe matters
2. Six monitors were to have radsafe duties in support of emergency firefighting and salvage operations as directed by the DSM or his radsafe advisor
3. Two monitors were to accompany each of the ten initial boarding teams and to act as radsafe advisors to the team captains
4. Thirty-three personnel were to act as monitors for the target ship crews when they reboarded their ships and as radsafe advisors to the ships' captains

Monitor duties were basically the same for ABLE and BAKER. For BAKER, however, monitors were admonished to (Reference B.0.1, p. E-X-16):

> . . . frequently check radioactivity of various parts of their own ship or craft including underwater hull and all intakes, particularly condensers, boilers and other places where there may be a concentration from contaminated water.

Definitions of the radex area and surface survey sector were changed so that no real difference between them existed (Reference B.0.1, p. E-X-3). Both names were retained, however, since operational personnel were familiar with them. The definitions of the Red and Blue Lines remained the same, but a few special salvage vessels with senior monitors aboard were allowed to operate independently between the Red and Blue Lines. The definitions of the anchorage areas remained unchanged, but a boating area was established where unrestricted movement of small boats was allowed. By implication, small boat traffic beyond that area was more strictly controlled (Reference C.9.206, p. VII-(C)-18).

As before ABLE, training was an important feature of the radsafe organization's activities. Newly arrived monitors were given instuction by experienced personnel. Daily communication drills were held by the Radiological Safety Control Unit using the PGM, LCPL, and drone boat circuits. On 16 July the Radiological Safety Control Unit held a drill on Mount McKinley to train new members of its expanded staff. On 19 July the entire radsafe organization participated in William Day, the joint task force rehearsal for BAKER. So that radsafe personnel would not be caught unaware by major new hazards, they met on several occasions with scientists in charge of the BAKER test and were briefed on the expected results (Reference C.9.206, p. VII-(C)-17). The monitors met with the commanders of the LCPLs and PGMs between William and BAKER days. Two more communications drills were held and by 22 July all radsafe personnel and equipment were considered ready (Reference C.9.206, p. VII-(C)-18).

Radsafe operations immediately before and after the BAKER detonation are described in Chapter 4, "Test Operations." Chapter 5, "Post-BAKER Operations: Bikini, Kwajalein, and the United States," continues the discussion of radsafe operations as the contaminated target ships are moved to Kwajalein Atoll and, later, as some of them are returned to the United States for final examination and disposition.

CHAPTER 3
CROSSROADS EXPERIMENTAL PROGRAM

INTRODUCTION

In late 1945 and early 1946 several conferences were held by the Manhattan Engineer District Project with the military services. It was agreed that the CROSSROADS program should gather data:

- On the nature, range, and duration of radiation danger
- On bomb efficiency, burst location, wave formation, and ship movement
- For ship designers and ordnance designers to aid in assessing damage from and designing protection against nuclear weapons
- That would be helpful in learning to detect nuclear detonations.

As a result, CROSSROADS had two experimental programs. The first was to determine nuclear weapon effects on military equipment, such as ships, planes, and supplies, and on animals. The second was to measure weapon phenomena such as blast, heat, radiation, and wave action. The ABLE and BAKER tests were not weapon development tests; in fact, the bombs used were of the same design as the one dropped on Nagasaki, Japan.

The Deputy Task Force Commander for Technical Direction had responsibility for both experimental programs. To accomplish this mission he had two organizations under his control. The first was the Ship Material and Inspection Division, headed by the Director of Ship Material (DSM), and the second was the Instrumentation Division, headed by the Technical Director.

EFFECTS ON MILITARY EQUIPMENT

The Ship Material and Inspection Division was responsible for determining weapon effects on military equipment. The organization of the Ship Material and Inspection Division contained both Army and Navy elements (see Figure 13). Responsibilities included preparing the ships, aircraft, equipment, supplies, and animals for each test and determining the exact cause and extent of damage. Decontaminating ships and material after the second test also became a responsibility of this group. Duties included distinguishing between damage caused by the direct effects of the explosion and damage caused by indirect effects such as fires and flooding. Table 4 shows the exposures received by personnel in each of the groups under the DSM.

The DSM set up a two-phase program to accomplish his mission. The first phase was readying the target ships, aircraft, and equipment and included conditioning, loading, instrumenting, and preparing specific equipment, and

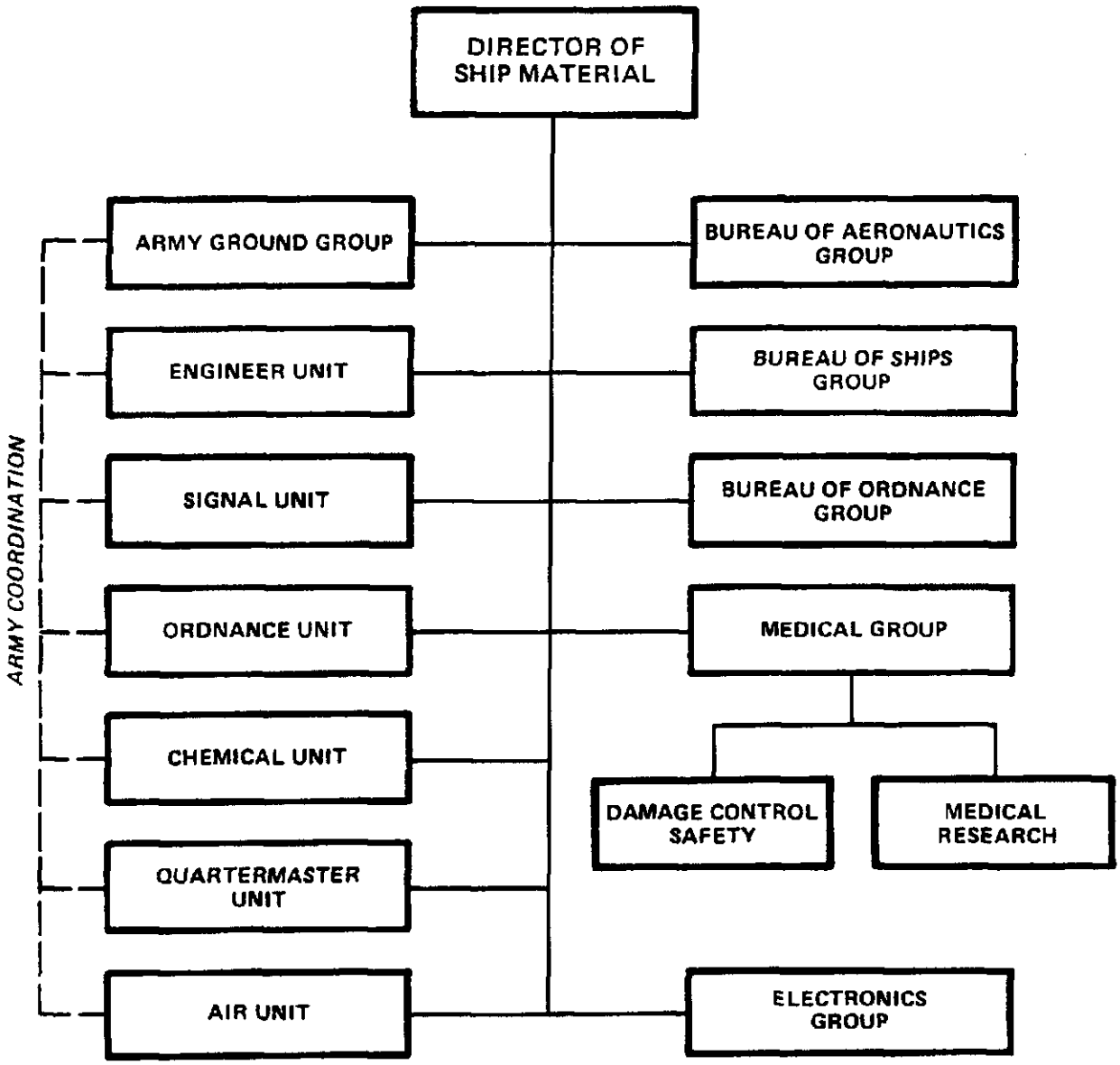

Figure 13. Organization of Ship Material and Inspection Division, Operation CROSSROADS (source: Reference C.9.206).

Table 4. Ship Material and Inspection Division recorded personnel exposures, CROSSROADS.

Element	No. of Persons Listed	No. of Persons Badged	Exposure Ranges (R)			High (R)
			0	0.001-0.5	0.5-1	
Office of the Director	31	9	3	5	1	0.590
Army Group	322	7	1	6		0.310
Bureau of Aeronautics Group	15	11	2	9		0.230
Bureau of Ships Group	113	55	12	40	3	0.650
Bureau of Ordnance Group	116	68	20	48		0.420
Medical Group						
Damage Control Safety Section	17	11	5	6		0.220
Medical Research Section	117	71	44	27		0.340
Electronics Group	411	56	23	32	1	0.600

Note:

[a]Data taken from Reynolds Electrical and Engineering Company exposure list. Since personnel were not badged all the time, these figures should be recognized as a partial statement of potential total exposure for these groups.

Sources: References C.13.4 and B.0.17.

inspecting, mooring, and anchoring the target ships before each test. The second phase of his program was the inspection of ships, aircraft, and equipment after each detonation. Detailed instructions were published to provide the necessary guidance to boarding parties who were to inspect the equipment after each shot. Extensive use was made of photography to permanently record "before" and "after" conditions of the ships, aircraft, and equipment. Most of the equipment was packed and shipped to continental U.S. locations for further analysis after Test BAKER (Reference C.9.208, p. 7.3). Six subordinate groups under the DSM were responsible for carrying out the details of the experimental program.

Army Ground Group

The exposure of Army equipment was a mission of Commander, Army Ground Group. Under his command were engineer, signal, ordnance, chemical warfare, quartermaster, and air units. Personnel from these units were berthed on USS Wharton (AP-7). They exposed a wide variety of equipment on both tests ranging from ammunition, radar, trucks, petroleum, and tanks, to field stoves, clothing, and medical equipment. Figure 14 shows armored vehicles and other equipment on board USS Saratoga (CV-3) before the test. While most equipment was positioned on board the target vessels, some was placed on nearby islands of Bikini Atoll to provide a better range of effects. Members of the Army Ground Group were evacuated from the Bikini Lagoon on Wharton the day before each test and planned to return the afternoon of each test day. Inspection of equipment after ABLE began on 2 July and was completed by 12 July. The heavy concentration of radioactivity in the lagoon after BAKER slowed inspection efforts. Inspections were not begun until 30 July and were not completed until 10 August. Items on USS Nevada (BB-36) and the concrete drydock, ARDC-13, remained too contaminated to be inspected. The drydock was finally scuttled with all equipment.

Engineer equipment was exposed on three attack transports (APAs). Signal equipment was exposed aboard ships and on nearby islands. Several different items of ordnance equipment were on the decks of four target battleships and on four tank landing ships and one oil barge. Chemical equipment was exposed

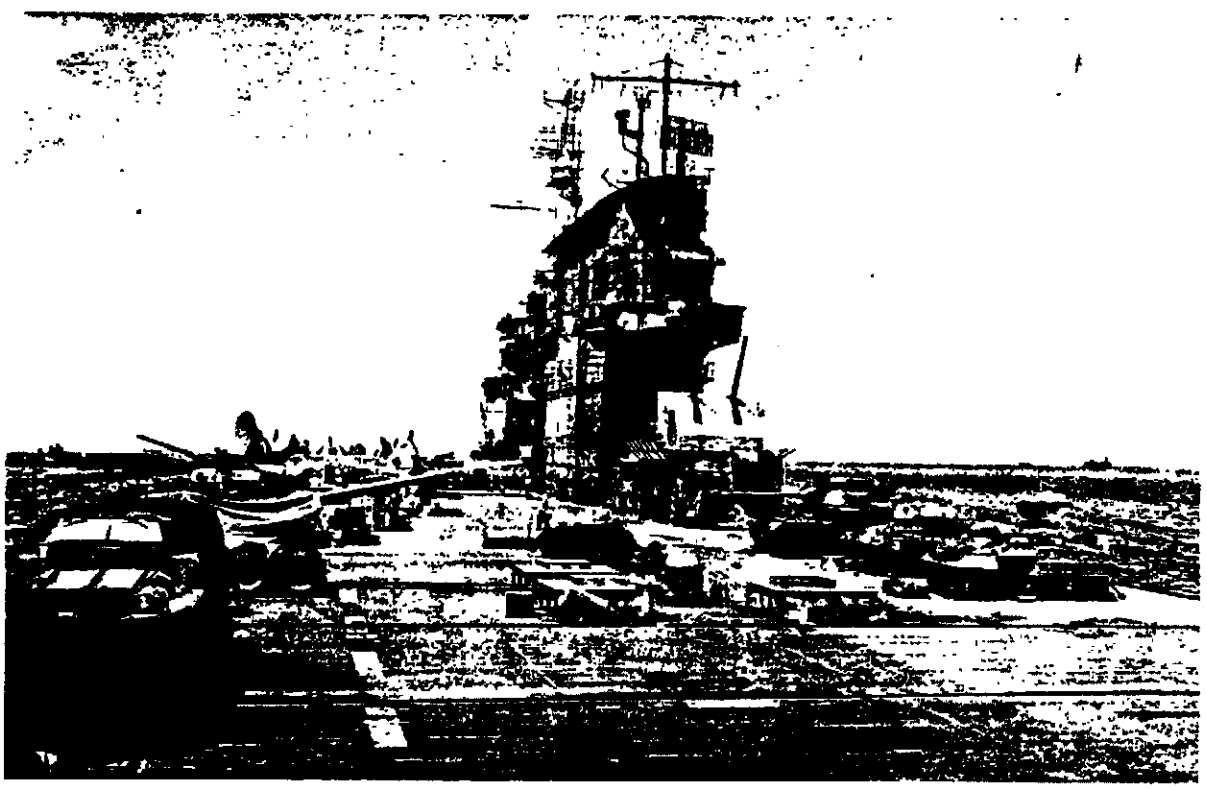

Figure 14. Armored vehicles and other Army equipment aboard USS Saratoga (CV-3), ready for exposure to atom bomb, CROSSROADS.

only on shot ABLE. Sample kits of food and clothing were stored in normal storage spaces aboard Nevada, USS Arkansas (BB-33), USS Carteret (APA-70), and Saratoga. Test lots of over 150 items of food and clothing were exposed on the decks of 11 target vessels. Field equipment, lubricants, and fuels were exposed on four tank landing craft and on the concrete drydock, ARDC-13.

Aircraft parts were placed on the decks of target ships. Several types of wing panels made of various materials were secured to the decks. In addition, wing tanks, stabilizers, a P-47 fuselage, an altimeter, and several fire extinguishers were exposed. No aircraft parts were exposed on BAKER test (Reference C.9.208, p. 7.10).

Bureau of Aeronautics Group

The Navy Bureau of Aeronautics (BuAer) Group was responsible for providing, exposing, and inspecting Navy aircraft and aeronautical equipment. It also provided special instruments to be placed in the Navy F6F aircraft drones to determine radiation intensities and blast effects. Velocity and acceleration gauges were installed on various target aircraft located on the target ships. The BuAer group, berthed on Wharton and USS Avery Island (AG-76), was evacuated with the ships the day before each shot and planned to return to the lagoon the afternoon after each shot. Inspection of equipment commenced on 2 July for ABLE and 30 July for BAKER. Records of F6F drone aircraft reaction to the detonations were removed from the aircraft after they landed at Roi Island, Kwajalein, and aircraft were inspected for damage (Reference C.9.208, pp. 3.51 and 7.8).

Bureau of Ships Group

This group was responsible for preparing target ships (and certain non-target ships) to determine effects of the detonations on the ships and carrying out decontamination activities. The group prepared Op Plan 1-46 Annexes W and X entitled "Ship Preparation Plan" and "Reboarding and Inspection Plan," respectively. Readying the target ships for the tests took place initially in shipyards at Philadelphia; Terminal Island, Long Beach, California; San Francisco, California; Mare Island, Vallejo, California; Bremerton, Washington; and Pearl Harbor, Hawaii. Target ship crews did much of this work, both at Pearl Harbor and on site at Bikini.

Members of the Bureau of Ships (BuShips) Group were berthed on Wharton. They were aboard that ship when it sortied from Bikini the day before each test and returned after each test. Ship inspection began on 2 July after ABLE and on 26 July after BAKER. Interim repairs after ABLE to prepare ships for BAKER were completed by 5 July; however, ship inspections continued for several more days. The ship inspection program was broken down into six categories: hull, ship stability, machinery, electrical, electronics equipment, and measurement of any change in magnetic fields within the ship. Inspection of ships after BAKER was hampered by radioactivity on the ships and in the lagoon. Five attack transports, one destroyer, two infantry landing craft, and four submarines were reboarded and manned in August and September and were sailed back to U.S. ports. The remaining target ships, however, were too contaminated to be boarded except for short visits and were towed to Kwajalein during August

and September. By 26 September, Bikini Atoll was cleared of the target fleet and all personnel were evacuated. Eight target ships and two target submarines were subsequently towed from Kwajalein to Pearl Harbor. Six of these were towed to U.S. west coast ports in 1946 and 1947 for further radiological examination (Reference C.9.208, pp. 3.51 and 7.5). The disposition of the target fleet is summarized in Chapter 9.

Bureau of Ordnance Group

The Bureau of Ordnance (BuOrd) Group was responsible for obtaining and exposing naval ordnance equipment and for appraising the damage after each detonation. The group was organized into six sections: fire control, gun mounts, explosives, aviation ordnance, underwater ordnance, and armor metallurgy. The group was berthed on Wharton.

Its personnel left Bikini Lagoon the day before each shot and reentered after each shot. Inspection of equipment after ABLE shot was easily and quickly accomplished, but high levels of radioactivity after BAKER severely restricted activities (Reference C.9.208, pp. 3.52 and 7.10).

Medical Group

The Medical Group was comprised of two sections: Damage Control Safety Section and Medical Research Section. Personnel of the Damage Control Safety Section were to reboard target ships with the initial boarding party and evaluate and reduce nonradiological hazards to boarding parties. Hazards that had to be addressed included falling objects, slippery decks, weak ladders, drowning, fires, steam, electrical shock, chemical hazards, and ammunition hazards. The personnel trained extensively, and in turn trained members of designated boarding parties both on the U.S. west coast and at Bikini. There were no incidents on either test day. This section was berthed on USS Haven (AH-12) (Reference C.9.208, p. 3.52).

The Medical Research Section was responsible for the biological research program, which involved exposing animals, seeds, bacteria, and medical and dental materials, and for studying the resulting damage and injury. Principal animals used were pigs, goats, guinea pigs, rats, and mice.

For ABLE, the animals and other biological samples were placed on USS Geneva (APA-86), USS Niagara (APA-87), USS LST-133, LCI-327, and LCI-329. Goats in exposure position are shown in Figure 15. They were retrieved by section personnel operating from USS Burleson (APA-67) at approximately 1600 on 1 July.

For BAKER, the animals and samples were on USS Gasconade (APA-85), USS Briscoe (APA-65), USS Catron (APA-71), and USS Bracken (APA-64). Section personnel could not retrieve animals and samples from Bracken until 1351 on 28 July (D+3). At 1447 the same day, about one-half the animals were removed from Catron. Daily radiation tolerances prohibited the personnel from continuing to work on Catron. On 29 July, animals and samples remaining on Catron and on Briscoe were recovered. On 30 July, animals and samples on Gasconade were recovered (Reference C.9.206, pp. VI-B-12 and VI-D-30 through D-44; Reference C.9.208, pp. 3.54 and 25.3).

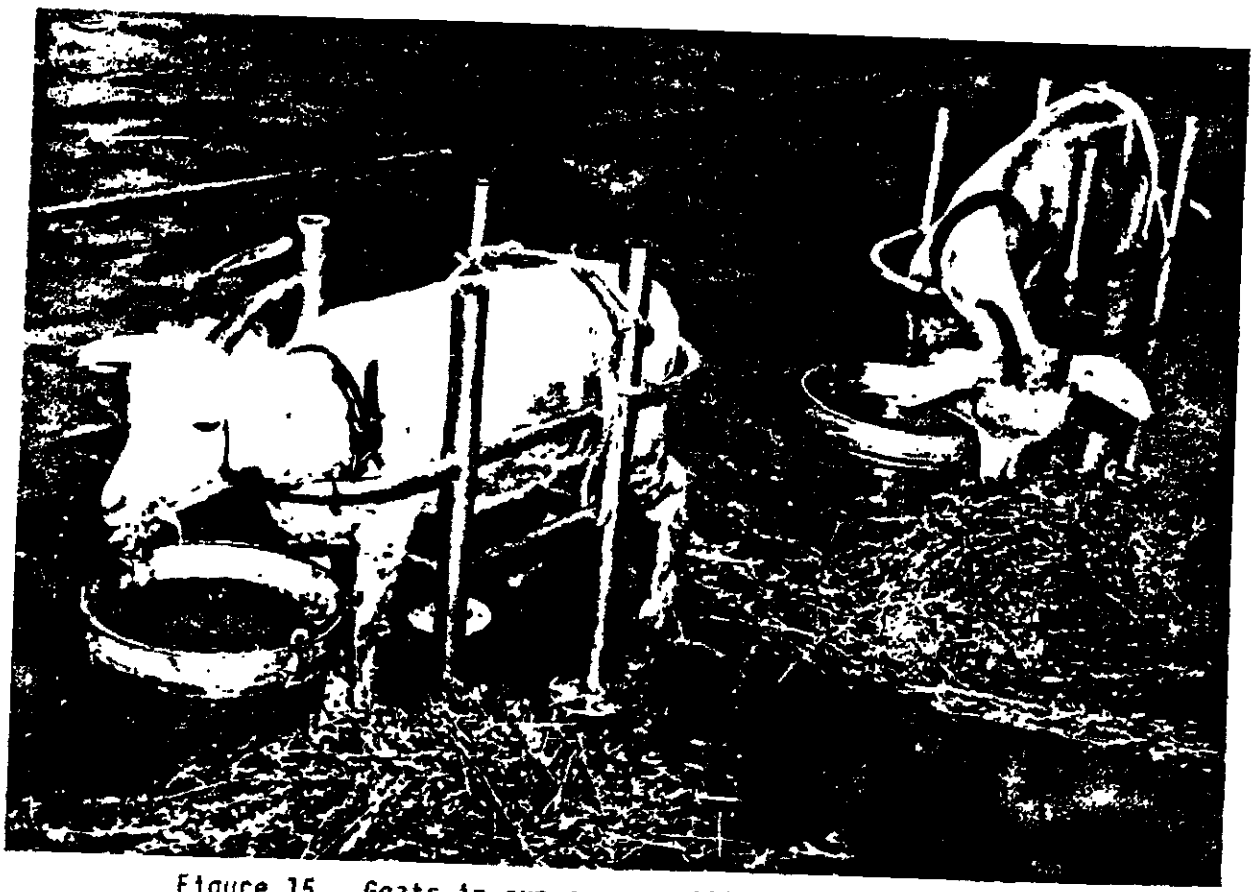

Figure 15. Goats in exposure position on target ship deck during CROSSROADS.

Electronics Group

This group and the 013D Electronics Group in the Technical Director's organization (see the section on Nuclear Weapon Phenomena below) were one and the same. They performed a dual function in working for both the DSM and the Technical Director.

As planned initially in January 1946, this group's primary responsibility was to determine the damage to electronic equipment aboard ships after exposure to each detonation. After a series of meetings in February 1946, the group's responsibilities were significantly expanded. It took over electronic equipment responsibilities from BuAer and the Army Signal Corps. It assumed full responsibility for execution of electronics instrumentation projects as specified in the Instrumentation Plan (Annex G, Op Plan 1-46) and the Communications and Electronic Plan (Annex C, Op Plan 1-46). It carried out most of the studies associated with the electromagnetic propagation program and provided support to wave motion, blast pressure, shock, drone boat, and telemetering projects. As a result of all these added responsibilities, the size of the group was expanded and liaison officers from several other groups were assigned. Also because of these added responsibilities, the group became accountable to the Technical Director, although it maintained close liaison with the DSM.

Specific projects included preparation and inspection of shipboard electronic equipment; provision of technical communications for the flagship USS Mount McKinley (AGC-7), press ships, and instrumentation ships; electromagnetic propagation studies and provision of sonobuoys for pressure recording; telemetering technical data from certain target ships; television recording of wave motion and wave heights; provision of timing signals for most projects (excluding bomb detonation timing signals); and provision of electronics equipment necessary for operation of the drone boats. The types of shipboard electronic equipment that had to be prepared and inspected included radios, radiosondes, radars, Identification Friend or Foe (IFF) systems, sonars, radar repeaters, homing devices, radar beacons, and interior communications systems.

The Electronics Group was berthed aboard Avery Island. USS Coasters Harbor (AG-74) was designated as an electronics repair ship for this group. Group personnel were evacuated from Bikini Lagoon the day before each shot and returned to the lagoon after each shot. For ABLE, group members were not part of initial boarding teams, but began their inspections when general reboarding was authorized. After BAKER, radioactivity delayed most inspections until mid-August. In fact, on 7 August the Target Inspection Section of the Electronics Group was reberthed aboard USS Fulton (AS-11), and Avery Island returned to the United States with most of the Electronics Group personnel. The Instrument Repair Unit also remained behind aboard Wharton and Haven to repair and maintain radiac instruments (Reference C.9.208, p. 3.43; Reference C.9.190, pp. 192-225).

Army Air Group (Task Group 1.5)

Although not under the control of the DSM, Task Group (TG) 1.5 assisted the DSM in determining the bombs' effects on in-flight aircraft. In addition to its several missions as TG 1.5, this group carried out blast and radiation experiments using B-17 drone and B-29 and F-13 aircraft. The drones were equipped with flight analyzers that recorded acceleration, airspeed, and overpressure. Some data were telemetered by a television arrangement. Upon landing at Enewetak, the instrumentation was removed for analysis. The drones were monitored for radiation and inspected for damage. The B-29 and F-13 aircraft had similar instrumentation except for the television system. Additional information on TG 1.5 is found in Chapter 8.

Table 4 is a tabulation of badging and exposures of personnel in the various groups of the Ship Material and Inspection Division. Since personnel were not badged all the time, these figures should be recognized as a partial statement of potential total exposure for these groups. Dose reconstruction techniques, discussed in Chapter 12, provide a way of estimating total dose figures.

NUCLEAR WEAPON PHENOMENA

The program to measure and record the various effects produced by the ABLE and BAKER nuclear detonations was the responsibility of the Technical Director, who headed the Instrumentation Division. The Instrumentation Division was responsible for measuring and recording weapon diagnostic data (blast, heat, radiation, etc.). The plan to measure and record the weapons' effects

was broken down into numbered programs, categorized and described in Table 5. For control reasons, the Technical Director set up an administrative organization (see Figure 16) and a functional organization (Figure 17). The administrative organization was used for personnel assignments. Personnel rosters were maintained using this organizational breakdown. The functional organization was used for grouping experimental projects. Table 5 and the functional organization in Figure 16 show the similarity between the programs. Over 130

Table 5. Instrumentation Division programs and responsible groups, CROSSROADS.

Program	Title	Responsible Groups
I	Bomb Preparation	Los Alamos Laboratory
II	Blast Pressure and Shock	Navy Bureau of Ordnance Los Alamos Laboratory Navy Bureau of Ships Army Air Forces Navy Air Group
III	Wave Motion Oceanography	Smithsonian Institution U.S. Geodetic Survey U.S. Fish and Wildlife Service Woods Hole Oceanographic Institution
IV	Propagation of Electromagnetic Waves	Navy Bureau of Ships Army Air Forces Los Alamos Laboratory National Bureau of Standards Federal Communications Commission
V	Radiological Safety	Los Alamos Laboratory
VI	Radiometry	Army Air Forces Navy Bureau of Ordnance
VII	Radiation Measurements	Los Alamos Laboratory
VIII	Remote Measurements	U.S. Geodetic Survey Carnegie Institute National Bureau of Standards Naval Research Laboratory David Taylor Model Basin U.S. Weather Bureau
IX	Technical Photography	Army Air Forces U.S. Navy Los Alamos Laboratory

Source: References C.9.209 and C.9.210.

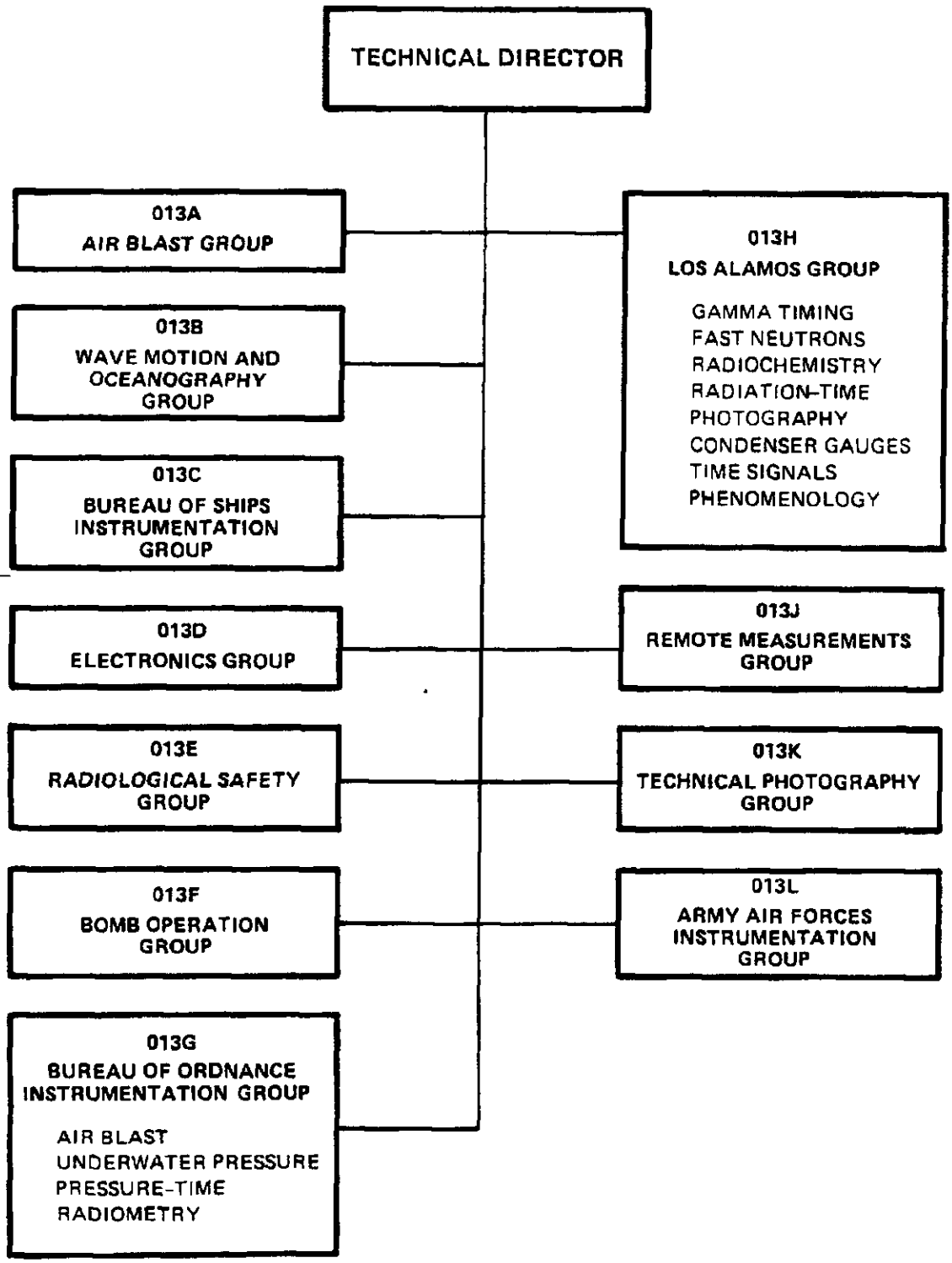

Figure 16. Instrumentation Division (administrative organization), CROSSROADS (source: Reference C.9.210, N 138A).

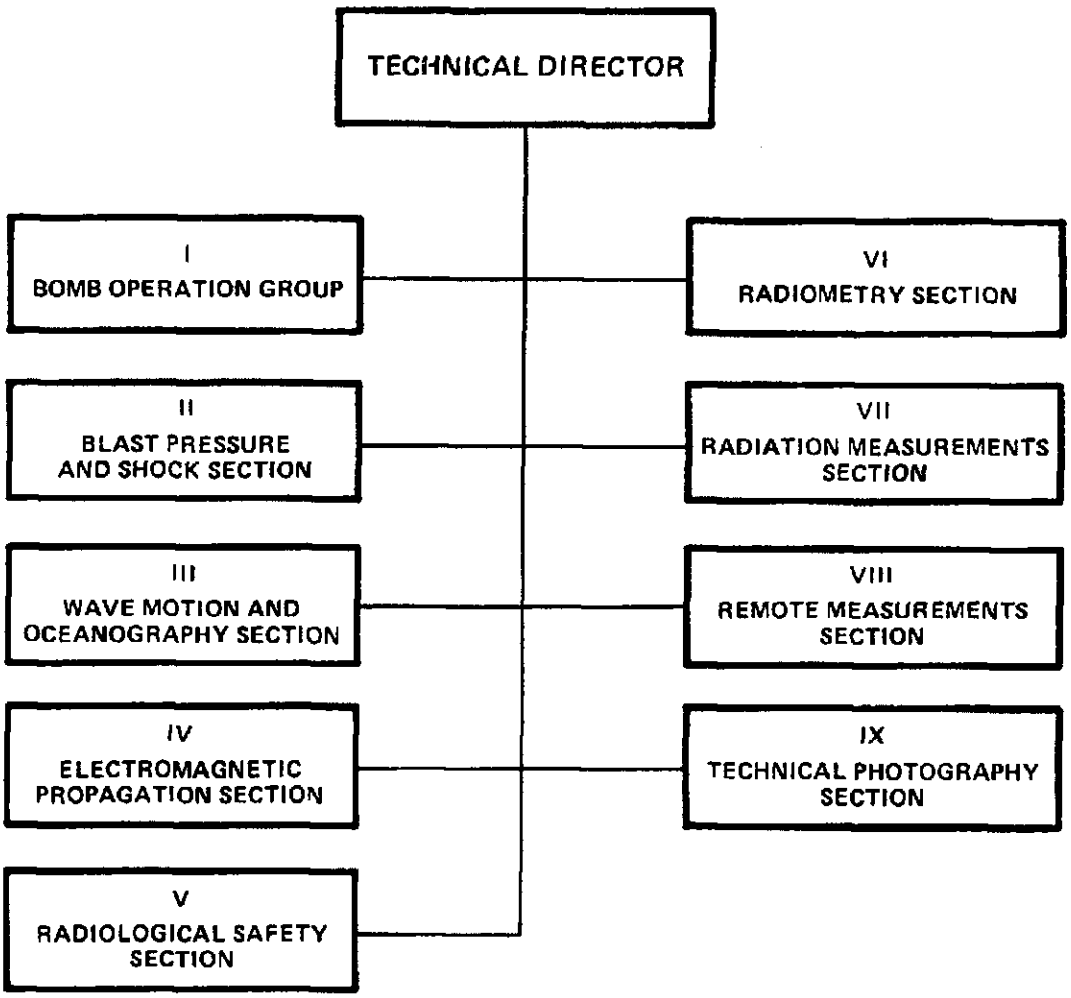

Figure 17. Instrumentation Division (functional organization), CROSSROADS (source: Reference C.9.210, N 138B).

projects were associated with Programs II through IX. Appendix C lists these projects by title and shows which group in the Instrumentation Division was responsible.

Table 6 presents exposure information for the groups in the Instrumentation Division. The Remote Measurements Group is not shown in the table because its personnel were not present in the Bikini area and had no one badged during CROSSROADS. The highest exposures recorded were for personnel in the Radiological Safety Group. These personnel monitored the contaminated ships and other areas to determine dangerous radiation levels. The accumulated high individual exposure in this group was 3.720 R. This monitor was badged six days.*

* Since personnel were not badged all the time, these figures reflect only a part of the total potential exposure. Dose reconstruction techniques discussed in Chapter 12 can be used to produce an estimate of total dose.

Table 6. Instrumentation Division personnel exposure, CROSSROADS.[a]

Element	No. of Persons Listed	No. of Persons Badged	Exposure Ranges (R)					High (R)
			0	0.001-0.5	0.5-1	1-1.5	Over 1.5	
Office of the Director	3	1		1				0.050
Air Blast Group	9	3	1	2				0.120
Wave Motion and Oceanography Group	93	30	19	11				0.180
BuShips Instrumentation Group	58	36	3	27	6			0.990
Electronics Group[b]	411	56	23	32	1			0.600
Radiological Safety Group	436	316	88	181	33	7	7	3.720
Bomb Operation Group	70	3	3					0
Bureau of Ordnance Instrumentation Group	208	47	24	23				0.470
Los Alamos Laboratory Group	70	12	6	6				0.330
Tech Photo Group	36	9	6	2	1			0.820
Army Air Forces Instrumentation Group[c]	1							0

Notes:

[a]Data taken from Reynolds Electrical and Engineering Company List. Since personnel were not badged all the time, these figures should be recognized as a partial statement of potential exposure for these groups.

[b]Same as the Electronics Group in Ship Material and Inspection Division.

[c]Personnel almost entirely supplied by Army Air Group, Task Group 1.5.

Sources: References C.13.4 and B.0.17.

The nine programs managed by the Instrumentation Division are discussed in the following paragraphs. Where appropriate, individual projects within each program are discussed.

Program I -- Bomb Preparation

Agency:

Los Alamos Laboratory

Operations: The bomb for ABLE was prepared at Kwajalein and loaded onto the B-29 drop aircraft at Kwajalein airfield. The bomb for BAKER was prepared on Kwajalein and on medium landing ship LSM-60 in Bikini Lagoon. It was placed in a waterproof caisson and lowered 90 feet (27 meters) under the LSM.

Staffing: Seventy Los Alamos Laboratory employees worked on this program. The radioactivity of the nuclear components of the bombs presented a very low risk of exposure. Personnel in this program were not required for reentry operations so they should not have been exposed to significant amounts of radiation. According to exposure records only three individuals were badged (see Table 6).

Program II -- Blast, Pressure, and Shock

Agencies: Los Alamos Laboratory
Navy Bureau of Ordnance (BuOrd)
Navy Bureau of Ships (BuShips)
Army Air Force
Navy Air Group
Air Blast Group (013A)

Operations: This program had 28 projects, some with several subprojects (see Appendix C). Except for Project II-12, which measured fireball growth using cameras, all these projects were associated with pressure, blast, and shock measurements. A variety of self-recording airblast gauges were placed on Bikini islands, in the lagoon, on target ships, and on aircraft aloft in the area above the target area. Condenser gauges were dropped from two B-29 aircraft just before each detonation and they transmitted readings to recorders in the two B-29 aircraft. Water-shock gauges were also used. All B-29, F-13, and B-17 aircraft participating in either shot carried instrumentation also.

Staffing: Personnel from the Air Blast Group, Los Alamos Laboratory Group, Electronics Group, and the BuOrd Instrumentation Group worked on projects in Program II. Although there were probably more, 51 personnel have been identified with this project from existing records, 35 of whom were badged. The highest exposure of these 35 was 0.99 R for an individual working on Project II-18 who got all of his exposure the first week in August.

Placement of gauges in aircraft, target ships, islands, etc. should have provided little or no exposure to project personnel. Removal of gauges after ABLE should have been relatively easy as radioactivity was limited to a few target ships and decayed rapidly. BAKER, however, contaminated islands due north of the detonation, the lagoon, and most of the target

ships. Gauge removal was closely monitored by radiological safety (radsafe) personnel.

Project Report: Reference C.9.209, Enclosure C.

Program III -- Wave Motion Oceanography

Agencies Smithsonian Institution
U.S. Geodetic Survey
U.S. Fish and Wildlife Service
Woods Hole Oceanographic Institution

Operations: This program had 20 separate projects to measure and record wave motion and to study detonation effects in the area of Bikini Lagoon. Some instrumentation was placed on the bottom of the lagoon, some suspended in the water from target ships, and some on nearby islands.

Staffing: Program III personnel were from the Wave Motion and Oceanography Group of the Instrumentation Division. Ninety-three personnel were assigned, 30 of whom were badged. Recorded exposures during the periods they were badged were all less than 0.5 R.

Removal of instrumentation from target ships, particularly after BAKER, exposed personnel to radioactivity on the ships. Removal of instrumentation from the lagoon bottom also exposed recovery personnel to some radiation after BAKER since the water in some areas of the lagoon was radioactive. However, recovery times apparently were relatively short and this minimized radiation exposure. Some islands were also contaminated after BAKER and instrument recovery there created exposure potential depending on recovery date and stay time.

Project Report: Reference C.9.209, Enclosure F.

Program IV -- Propagation of Electromagnetic Waves

Agencies: Los Alamos Laboratory
Army Air Forces (AAF)
Electronics Group
National Bureau of Standards (NBS)
Federal Communications Commission (FCC)

Operations: There were 18 separate projects in Program IV. Radars and radios, some operating at detonation time, were placed on selected islands at Enewetak, Kwajalein, Bikini, and on selected target ships. Television cameras were installed on B-17 drones and controllers. Two projects provided timing and firing signals for BAKER. Four projects measured electromagnetic properties from remote locations in Hawaii, Germany, Manila, Alaska, and the United States. One project telemetered air- and water-pressure readings from target ships to receivers on Avery Island.

Staffing: Personnel from the Electronics Group of the Instrumentation Division accomplished all the projects in this program except for IV-9 through IV-13, which were done by Los Alamos Laboratory and the Army Air Forces.

NBS and FCC personnel involved were not in the Bikini area. This Electronics Group was the same as that in the Ship Material and Inspection Division under the DSM. The highest recorded exposure in the Electronics Group was 0.6 R.

Since the experiments measured interference with electromagnetic waves at and after detonation time there was no urgency to recover equipment in radioactive areas such as the Bikini islands and target ships.

Project Report: Reference C.9.209, Enclosure G.

Program V -- Radiological Safety

Agency: Radiological Safety Group

Operations: There were 12 projects in this program (see Appendix C). The first eight involved radsafe monitors who measured radioactivity in the air, water, and on ships to obtain data on radiation in order to protect personnel. The eight monitor groups were: destroyer, seaplane, boat, boarding party, fixed base, gunboat, Bikini Lagoon channels, and airborne. Monitoring instruments used were: 275 Victoreen Geiger counters (Model No. 263), 150 Victoreen ionization chambers (Model No. 247), 12 alpha meters, and an unknown quantity of self-reading dosimeters. All monitors also wore film badges whenever there was a probability of encountering radioactivity. Film badges were normally exchanged daily. All monitor groups had Geiger counters and ionization chambers except the Bikini Lagoon Channel Group, which used battery-operated, deep-channel counters with submersible probes. Project 9 (Photometric Film Badges) measured radiation at various locations in the target array and recorded radiation received by all who wore film badges. They used 5,000 sulfur and calcium triphosphate capsules in addition to a large number of film badges. Projects 10 and 11 measured gamma radiation over a period of time on several target ships. Project 12 personnel measured total gamma intensity on several target ships.

Staffing: As shown in Table 6, 436 personnel of the Radsafe Group have been identified (Reference B.0.19). Of these 316 were badged at least one time (see Table 21 for badging summary). Personnel in all 12 projects on the Radsafe Program had a high potential for exposure because of their assigned duties. Monitors who reboarded ships with boarding parties (Project 4) after Test BAKER accumulated the highest exposures. The highest individual accumulated recorded exposure was 3.720 R. Most of those badged in Program V were military personnel performing monitoring duties.

Project Report: Reference C.9.209, Enclosure J.

Program VI -- Radiometry

Agencies: Navy Bureau of Ordnance (BuOrd)
Army Air Forces (AAF)

Operations: Measurement of the bombs' radiant energy was attempted from several locations. For ABLE, instruments were installed on one ship 18 nmi

(33 km) from the detonation and on an aircraft flying 18 nmi (33 km) from the detonation. For BAKER, instruments were installed on a ship positioned 10.9 nmi (20 km) from the detonation and spectroscopes were placed on an aircraft flying 7.2 nmi (13 km) from the burst.

Staffing: BuOrd Instrumentation Group personnel manned the projects in this program with some help from AAF. Potential for exposure of Program VI personnel was quite low. Aircraft and ships involved remained clear of radioactive areas in and downwind of the Bikini Lagoon. BuOrd Instrumentation Group personnel had low exposures as can be seen from Table 6. Most personnel working in Program VI were not badged and those that were had readings less than 1.0 R.

Project Report: Reference C.9.209, Enclosure H.

Program VII -- Radiation Measurements

Agency: Los Alamos Laboratory

Operations: The first of the three projects in this program was the measurement of fast neutrons on ABLE test by placing sulfur samples on several target ships.

The second was measurement of gamma-ray emissions from BAKER detonation. During this project, gamma-ray measurement signals were transmitted from the bomb case to USS Cumberland Sound (AV-17) just before the transmitters were destroyed.

The third project was collection and measurement of air and water samples to determine the efficiency of the detonations. This included the use of drone aircraft (B-17 and F6F) and drone boats to obtain radioactive air and water samples.

The Army B-17 drones were guided from Enewetak to Bikini by B-17 controller aircraft. On ABLE they sampled at 12,000, 18,000, 24,000, and 30,000 feet (3.66, 5.49, 7.32, and 9.14 km) between 6 and 15 minutes after the detonation. On BAKER they sampled at 6,000 and 10,000 feet (1.83 and 3.05 km) between 5 and 10 minutes after the detonation. Each B-17 drone aircraft had a filter box mounted in place of its top turret and a large inflatable rubber bag in its bomb bay. The air filter unit with its special filter paper was designed to filter 90 cubic feet (7.5 cubic meters) of air in 30 seconds. The rubber bag was opened on command of the controller in the B-17 control aircraft when the drone entered the cloud. It automatically closed 30 seconds later, capturing 90 cubic feet (7.5 cubic meters) of air. The drones were guided back to Enewetak where they were landed by ground controllers. Los Alamos Report No. 613 (Reference C.1.1) describes removal of the filter unit:

> The AAF filter unit was fixed to the top turret of a drone B-17. A lanyard ran from the unit down along the outside fuselage and ended in a handle fixed near the door of the plane. One sharp pull on the lanyard brought the filter unit tumbling down. Each door of the unit itself was fitted with a short lanyard. One sharp pull of this lanyard, and the door leaped

off in an amazing shower of springs and bolts. The filter papers sandwiched between their screens could then be picked up, a few wires snipped to separate the screens, and the paper removed.

Figure 18 shows a drone B-17 landed at Enewetak after shot ABLE. A monitor is shown walking away from the rubber bag in the background. The bag had been dropped from the bomb bay into a wheeled contrivance and was pulled away from the B-17 with long ropes. The top filter unit is visible on the top of the B-17 fuselage. Los Alamos personnel removed the filter papers from the boxes and flew to Kwajalein on the waiting C-54 with the filter papers and the large rubber bags filled with air samples. The samples were analyzed at Kwajalein.

Navy F6F drones were guided to Bikini from the carrier USS Shangri-La (CV-38) by drone control F6Fs. For ABLE, three drones sampled at 10,000, 15,000, and 20,000 feet (3.05, 4.57, and 6.1 km) approximately 8 to 15 minutes after the detonation. For BAKER, three drones sampled at 5,000, 9,000, and 14,000 feet (1.52, 2.74, and 4.27 km) 5 to 10 minutes after the detonation. After the sampling was complete they were guided to the island of Roi-Namur in Kwajalein Atoll and were landed there by ground control pilots. The F6F drones had a single unit with filter paper mounted under the left wing. A 10-foot (3.05-meter) pole with a hook was used to unhook and drop the unit from the wing. Six bolts were then removed on the doors

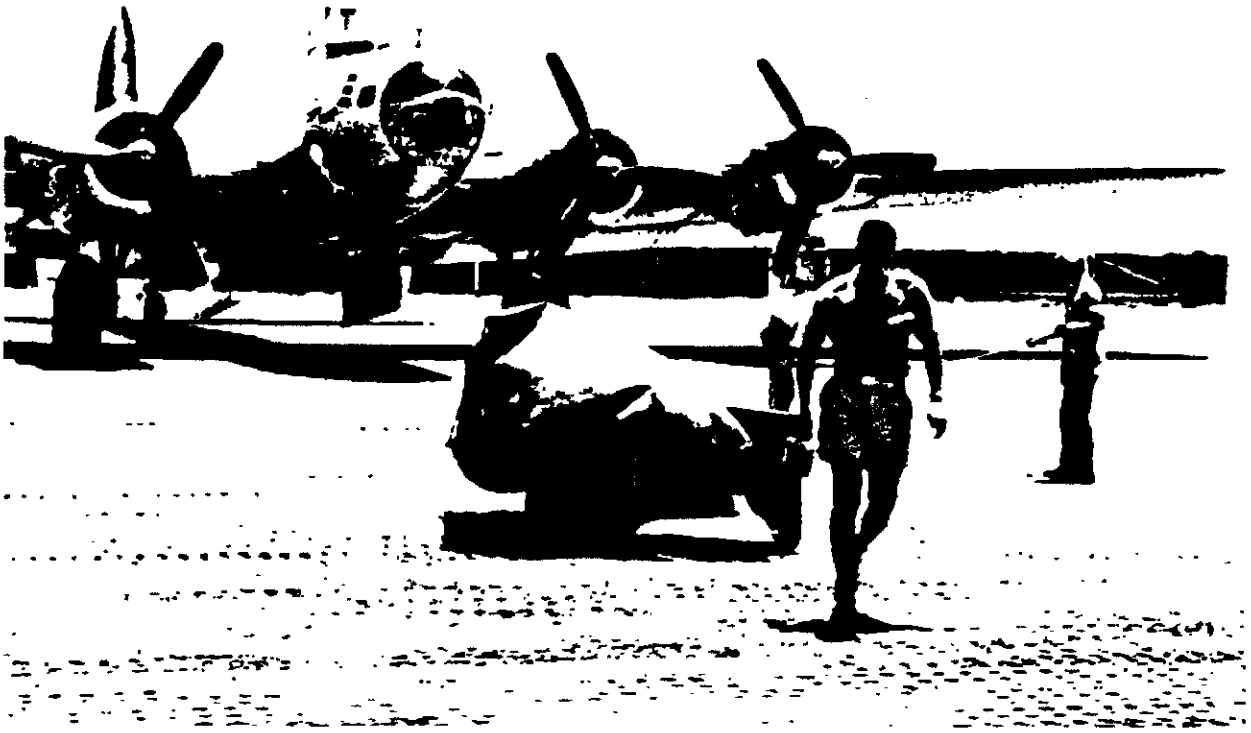

Figure 18. Air sampling gas bag and drone B-17 at Enewetak Island following shot ABLE, CROSSROADS.

by specially adapted 10-foot (3.05-meter) poles. The doors were then pulled off with another special 10-foot (3.05-meter) pole. The filter paper and securing screens were attached to the doors and came out of the unit with the doors. The filter papers were picked up with long-handled tongs (Figure 19) and placed in special lead receptacles. They were then flown by C-54 to Kwajalein for analysis.

Drone boats from USS Begor (APD-127) collected radioactive water samples throughout the target array. Radioactive samples were taken from Begor to Kwajalein and then to Los Alamos Laboratory for analysis.

Staffing: Los Alamos Laboratory supplied the personnel for the projects in this program. Removal of sulfur samples from target ships on ABLE test would have exposed men to low-level radiation on those ships that were near surface zero, viz. Sakawa (a captured Japanese cruiser), USS Crittenden (APA-77), USS Carlisle (APA-69), and USS Arkansas (BB-33) (Reference C.9.210, p. N-212). Measurement of gamma rays at detonation time for BAKER should not have created any radiation exposure to personnel. Removal of radioactive air and water samples from planes and boats was a very sensitive operation with a high exposure potential. Only 12 of 70 personnel in

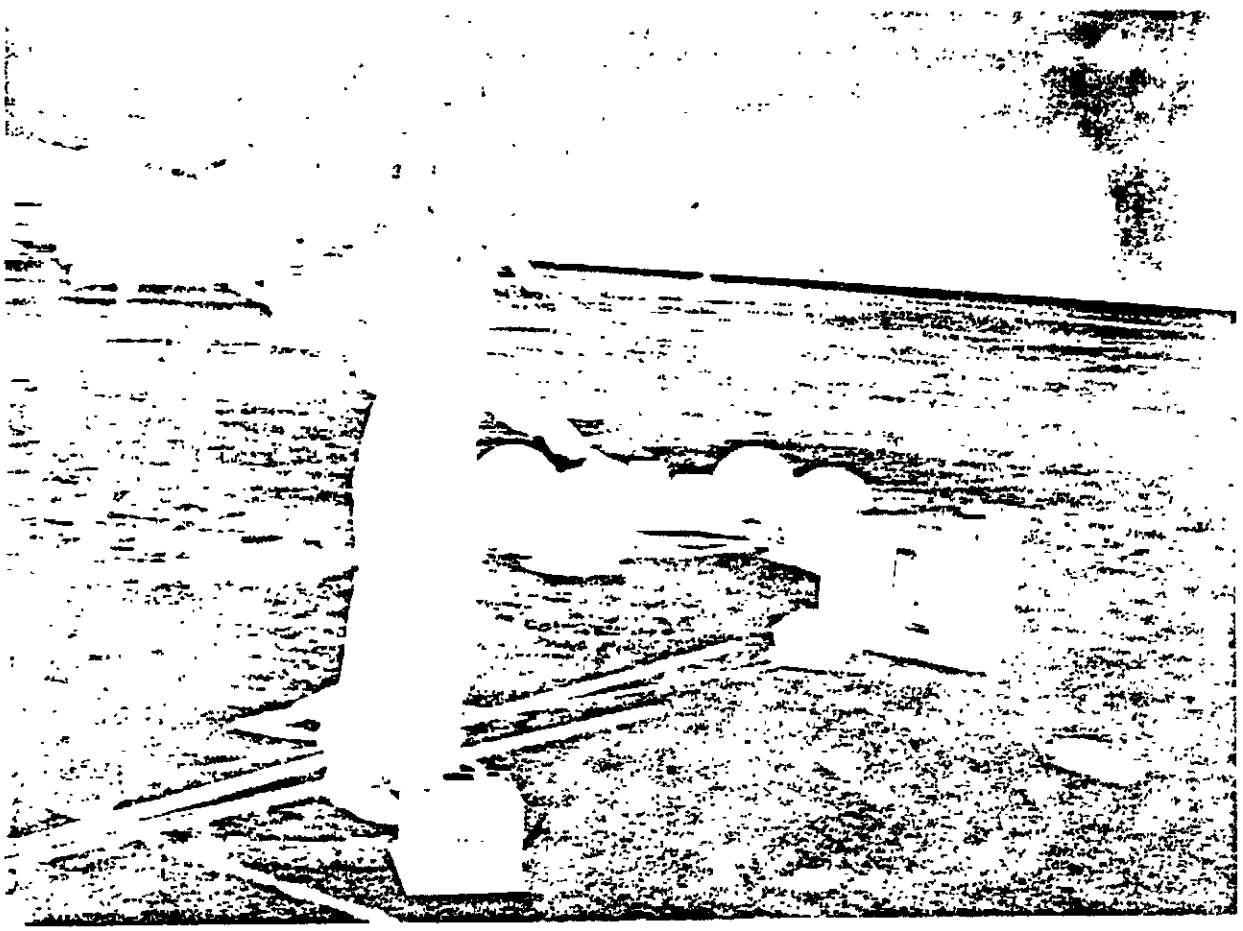

Figure 19. Removal of filter papers from the F6F filter units at Roi-Namur Island following shot ABLE, CROSSROADS.

the Los Alamos Laboratory Group were badged and their exposures were very low (see Table 6).

Project Report: Reference C.1.1 (Los Alamos Laboratory Report No. 613, November 1946).

Program VIII -- Remote Measurements

Agencies:

U.S. Coast & Geodetic Survey	University of Texas
Carnegie Institute	Bartol Foundation
National Bureau of Standards	Mt. Wilson Observatory
Naval Research Laboratory	Evans Signal Laboratory
David Taylor Model Basin	Federal Communications Commission
U.S. Weather Bureau	Puget Sound Naval Shipyard
University of Washington	Army Air Forces (AAF)

Operations: This program consisted of 18 projects. Experiments were conducted at sites around the world to measure changes produced by the detonations. Measurements were made of tides, wave action, atmospheric reflectivity, atmospheric pressure, atmospheric ionization, atmospheric noise, radioactivity, and long-range radio waves. Only Project 14 used locations in the Bikini area, specifically Eneu Island and USS Kenneth Whiting (AV-14).

Staffing: Organizations involved in each of the projects are listed above. Names of individuals associated with these organizations cannot be separately identified. Except for Project 14, which had instrumentation on Eneu Island and Whiting, exposure potential was extremely low for everyone working with this program. The Eneu site was not contaminated after ABLE but the beach was contaminated after BAKER. Eneu was visited on 25 July (BAKER day) and all experiments removed during the afternoon. Three days later it was radiologically cleared and reopened for troop use.

Project Report: Reference C.9.209, Enclosure K.

Program IX -- Technical Photography

Agencies: Los Alamos Laboratory
Army Air Forces (AAF)
U.S. Navy
Technical Photography Group

Operations: There were 19 projects in Program IX associated with technical photography. Project 1, operated by Los Alamos Laboratory, used high-speed cameras to record the growth rate of the ABLE fireball. Half of the cameras were in a tower on Bikini Island and half in a tower on Eneu Island. Projects 2 through 7 used cameras mounted in six camera towers to observe water waves, ship motion, burst location, light intensity, and record damage. There were two camera towers each on Bikini, Eneu, and Aomen islands. These six projects were operated by the Technical Photography Group of the Instrumentation Division. Projects 8, 9, and 10 consisted of technical photography from AAF planes. Cameras were mounted in B-17 drones, C-54s,

and F-13s. Pictures were taken of fireball development, nuclear cloud formation, the target area, and radar scopes inside the aircraft. Projects 11 through 14 consisted of technical photography from U.S. Navy aircraft. A variety of cameras were installed in PBMs, TBMs, F6Fs, and F6F drones to photograph wave motion, target array, target damage, and detonation effects on ships in real time. Project 15 used 20 cameras placed on target ships and nearby islands for shot ABLE and 24 cameras on target ships and nearby islands for shot BAKER to observe ship reaction to the detonation. Project 16 consisted of mounting high-speed cameras in a C-54 to measure the ABLE fireball growth. Project 17 consisted of mounting 50 icaroscopes on nine observer ships to observe bomb flash intensities (Reference C.9.190, p. 207). Project 18 mounted two drum spectographs in a camera tower on Eneu to record the light's spectrum as a function of time. Projects 15 through 18 were conducted by the Technical Photography Group of the Instrumentation Division. Project 19 used a high-speed camera on Bikini to photograph ABLE fireball development. This project was accomplished by the BuOrd Group of the Instrumentation Division.

Staffing: Personnel in the Technical Photography Group consisted of officers and enlisted men from the U.S. Navy and civilians. Of the civilians assigned, at least one was from Los Alamos Laboratory. The Navy Photographic Unit was aboard USS Saidor (CVE-117). In addition to the Technical Photo Group, the Army Air Task Group, TG 1.5, had one task unit devoted completely to photography. Army Air Photo Unit, TU 1.5.2, with several photographic aircraft, provided substantial support to this program.

For ABLE there was little chance for exposure on any of the projects except for Projects 8, 13, and 15, where cameras had to be recovered from B-17 and F6F drones and target ships. The drones were contaminated; however, none of the target ships with cameras were contaminated on shot ABLE. For BAKER, recovery of several projects created an exposure potential. Projects 2 through 7 required recovery of film from contaminated islands around the lagoon after BAKER. Projects 8 and 13 required recovery of film from contaminated B-17 and F6F drones. Project 15 required recovery of film from contaminated target ships after BAKER. Projects 18 and 19 required recovery of film from Eneu and Bikini, the beaches of which were contaminated after BAKER.

CHAPTER 4
TEST OPERATIONS

CROSSROADS was primarily a sea-based operation. The islands of Bikini Atoll* were used as sites for instrument locations and as recreation areas. However, a Navy Construction Battalion had quarters for its men on Bikini Island. Joint Task Force 1 (JTF 1) personnel lived at Kwajalein, Enewetak, and aboard ships in Bikini Lagoon. They commuted to their work sites in the target array or at island-based measurement sites.

In Test ABLE, the weapon was dropped from an Army Air Forces B-29 (nicknamed "Dave's Dream") based at Kwajalein. The bomb burst in the air 520 feet (158 meters) over the target ships. In the BAKER test the weapon was suspended in a waterproof container 90 feet (27 meters) below LSM-60, anchored at the center of the target fleet. A third test, to have been called CHARLIE, would have been a deep underwater test, but it was cancelled after Test BAKER.

The target fleet was unmanned for both tests and was anchored in the northeastern area of Bikini Lagoon off Bikini Island. For ABLE 22 landing craft and for BAKER 24 landing craft were beached on the lagoon side of this island, simulating boats in an amphibious operation. Military equipment (including airplanes), animals, and scientific instruments were aboard the target ships. Two anchored seaplanes were also part of the target fleet.

The manned JTF 1 support ships withdrew from the lagoon before the tests and remained east of the atoll or were at other atolls until it was safe to reenter the lagoon. Nontarget small craft were moored (unmanned) in the lagoon off Eneu Island about 5 nmi (9.3 km) south of the test area. Among these were several drone boats equipped to be remotely controlled. After each detonation the drones were guided by aircraft and USS Begor (APD-127) to areas in the target array to collect water samples and take radiation readings. After the water samples were collected, the drones were guided back to Begor where they were hosed down to remove radioactive contamination (Figure 20) and the samples removed. After each test the drones were followed by six patrol motor gunboats (PGMs) and twenty landing craft (LCPLs) with radiation monitors aboard. Radiation intensity measurements were sent by radio to the Radsafe Control Center. From this information and that gathered from aircraft equipped with radiation detectors, it was determined when a safe reentry to the lagoon by the main body of the fleet could be made.

PRE-TEST OPERATIONS

Preparation for the tests began in January 1946 when the atoll was surveyed by USS Allen M. Sumner (DD-692) and USS Bowditch (AGS-4). The survey was finished in April.

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* The islands of Bikini Atoll and their various transliterations and synonyms are listed in Appendix D.

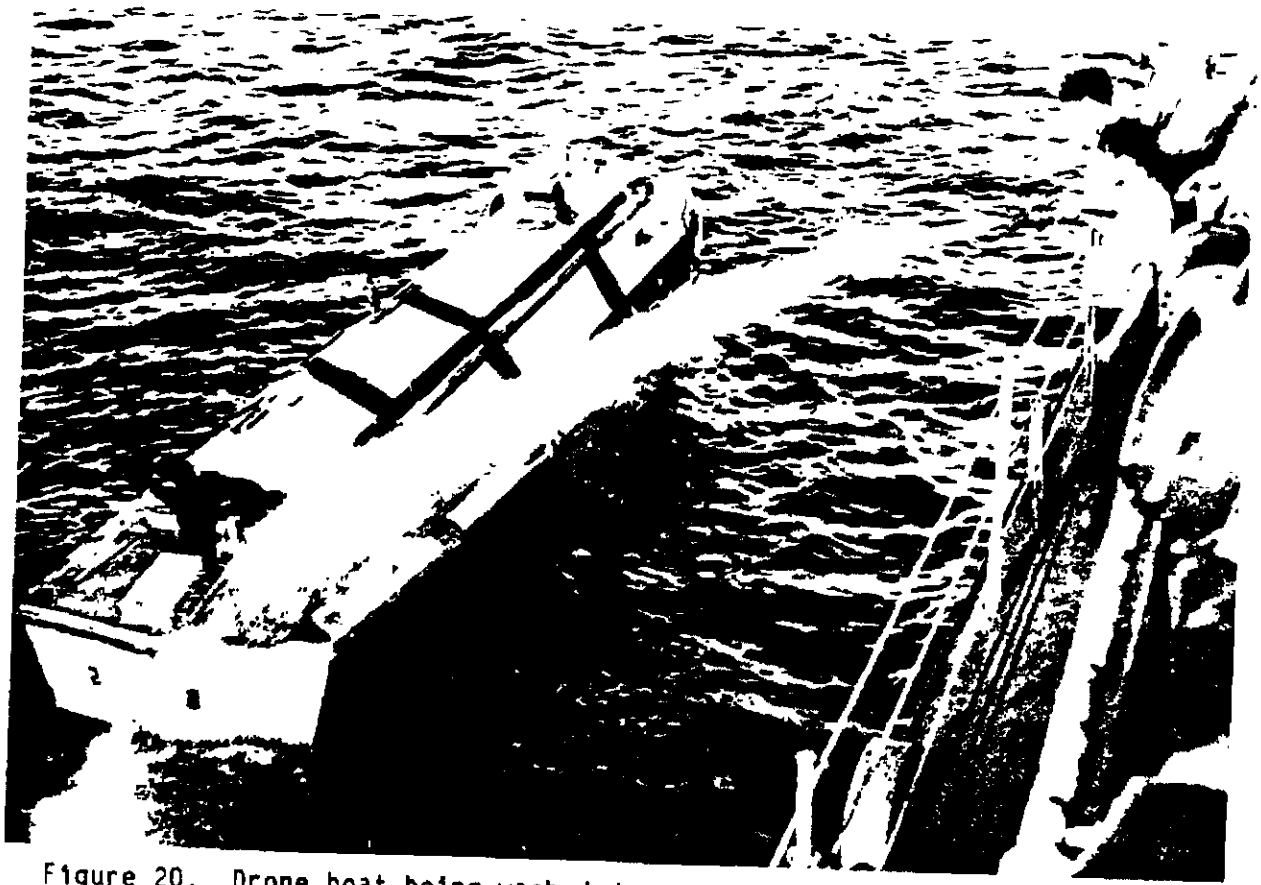

Figure 20. Drone boat being washed down before radioactive water samples were removed, CROSSROADS.

On 7 March 1946, 167 Bikinians embarked aboard USS LST-1108 and were taken to Rongerik Atoll. At the same time the Navy 53rd Construction Battalion began arriving to build the various phototowers, instrumentation sites, workshops, and recreation facilities on the islands of the atoll. One hundred tons of dynamite were used to clear coral heads in the lagoon. Five naval mines were discovered and disposed of during March.

Movement of participating ships from eastern U.S. shipyards and ports toward Bikini also began in March. Movement from closer ports began later, and by mid-May there were over 100 CROSSROADS-bound ships stopping over in Pearl Harbor on their way to Bikini. Interior spaces of some support ships were modified as laboratories or machine shops, and USS Burleson (APA-67) was being converted to a "great dirtless farm" (Reference A.1), a living place for the experimental animals that were used during CROSSROADS.

The target ships also required special preparation. For Test ABLE, 93 target vessels were assembled. For Test BAKER, 92 target vessels were arrayed. The target fleet was led by older U.S. capital ships like the famous USS Saratoga (CV-3) and the old battleships USS Nevada (BB-36), USS Pennsylvania (BB-38), and USS New York (BB-34). The German battle cruiser Prinz Eugen and two major captured Japanese ships, the battleship Nagato and the cruiser Sakawa, were also targets. All target vessels were accurately moored and made ready for the

tests. This involved a great deal of work by Task Group (TG) 1.2 in making the ships watertight so that pumping would not be required to keep them afloat. Many of the target ships could be classed as "war weary," making this task difficult. For the sake of the experiment, the ships were to be in as near to fighting condition as was reasonable, which included loading them with ammunition, torpedoes, fuel, radar equipment, etc.

The target ships also required close pretest inspection since the aim of the tests was to measure the effects of the nuclear detonations. This was done by inspection teams of the Ship Material and Inspection Division and ships' crews and was documented extensively with photographs. Instrument placement aboard these vessels also was extensive. Compartments in nearly every target vessel were inspected and the condition recorded before and after each test. An aerial view of the target array is shown in Figure 21.

ABLE OPERATIONS

By mid-June the task force was in place. Burleson, with its cargo of experimental animals, was one of the last arrivals (14 June). Several small-scale rehearsals and one major rehearsal on 24 June 1946 (Queen Day) preceded the test. For the Queen Day rehearsal a number of non-self-propelled or slow-moving vessels were evacuated to Kwajalein, some not to return to Bikini until after ABLE. Projected ABLE Day remained 1 July.

At the morning weather conference on 30 June 1946, favorable weather was forecast for the following day, so Commander JTF 1 (CJTF 1) set 0830, 1 July, as shot time. At the evening weather conference, conditions still appeared

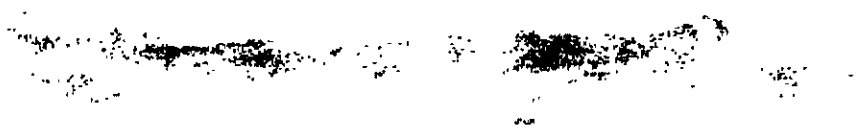

Figure 21. CROSSROADS, ABLE target array in Bikini Lagoon. View is looking south.

favorable. However, fairly heavy cloud cover was reported early on the morning of 1 July, and shot time was changed to 0900.

Evacuation of task force support ships began soon after CJTF 1 set the hour for ABLE. All destroyers except USS Moale (DD-693) got underway and were clear of the lagoon by early afternoon on 30 June. Most of the support ships of TG 1.2 were out of the lagoon shortly thereafter, except for the TG 1.2 flagship USS Fall River (CA-131) and three small support ships. Throughout the afternoon the vessels of TG 1.8 cleared the lagoon. Three tugs towed barges to Kwajalein and USS Chowanoc (ATF-100) towed YO-130 to the open sea, more than 20 nmi (37 km) northeast of Bikini Atoll. Small craft had evacuated task force personnel from Enidrik and Eneman islands and transferred them to Fall River, which then left the lagoon along with the smaller ships of TG 1.2. Ten ships remained in the lagoon after 1800 hours.

Preparations ashore had included removal of the roofs of buildings to prevent blast damage and removal of the pontoon-supported docks and causeways that had been installed on the islands. Machinery such as refrigerators, generators, and water-distilling units had been covered by tarpaulins.

USS Chilton (APA-38) evacuated 691 nonessential U.S. personnel and natives from Enewetak before the test. Provision had been made to evacuate essential U.S. personnel on Enewetak if necessary, and five C-54 air transports were at Enewetak for this purpose. The Marshallese on Rongerik to the east had been taken aboard USS LST-989 in case evacuation was necessary there.

Two additional C-54s were sent from their Kwajalein base on 30 June, one to Enewetak and one to Roi Island. These were scheduled to receive the radioactive cloud samples to be collected by the B-17 drone samplers based at Enewetak and the F6F drone samplers returning to Roi following the shot.

At 0512 on 1 July, PGM-23 had all task force personnel from Iroij, Nam, and Aomen islands embarked and was underway for the fleet assembly area. At 0524 USS Kenneth Whiting (AV-14) had all personnel from Bikini and Eneu islands aboard and was underway. The last ship out of the lagoon was USS Mount McKinley (AGC-7). These ships joined the other JTF 1 ships in operating areas east of Bikini. These operating areas were designated by the names of automobile manufacturers.

The first airborne aircraft were three B-29s that had made weather reconnaissance flights in the shot area and northeast and northwest of Bikini Atoll. At 0540 CJTF 1 ordered the drop aircraft to take off from Kwajalein. This was a specially modified B-29 on which the bomb had been loaded about midnight (Figure 22). At 0555 the bomber was reported as being airborne. The four F6F drones and sixteen F6F controllers from USS Shangri-La (CV-38) were airborne shortly after 0700. In all, 79 aircraft were airborne on the morning of ABLE. By 0800 all aircraft and ships were on station. One F6F drone went out of control and crashed in the sea just as the B-29 began its live run at 0850. The bombing aircraft had made one practice run before the live run. Aircraft participation in Test ABLE is summarized in Table 7, and Table 8 summarizes the designated orbiting points for these aircraft.

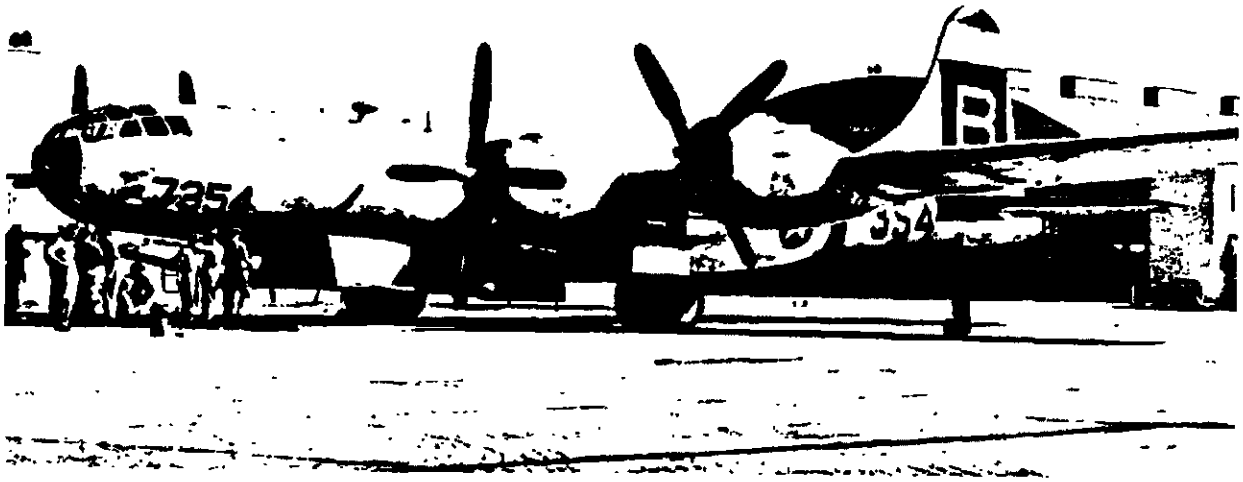

Figure 22. "Dave's Dream," the B-29 from which the CROSSROADS, ABLE weapon was dropped.

All other air operations within 500 nmi (927 km) had been suspended 12 hours before the shot.

Observers included Congressmen, the President's Evaluation Commission, the Joint Chiefs of Staff (JCS) Evaluation Board, United Nations representatives, and media correspondents. The live run was made at 28,000 feet (8.5 km). The bomb was released at 0859 and detonated with a yield of 23 KT 15 seconds before 0900, 1,500 to 2,000 feet (457 to 610 meters) west of the planned surface zero (Figure 23).

An Army doctor trained as a radiological safety (radsafe) monitor made the following observation from a PBM aircraft 20 nmi (37 km) away (Reference A.2, p. 55):

> At 20 miles it gave us no sound or flash or shock wave. . . . Then, suddenly we saw it -- a huge column of clouds, dense, white, boiling up through the strato-cumulus, looking much like any other thunderhead but climbing as no storm cloud ever could. The evil mushrooming head soon began to blossom out. It climbed rapidly to 30,000 or 40,000 feet, growing a tawny-pink from oxides of nitrogen, and seemed to be reaching out in an expanding umbrella overhead. . . . For minutes the cloud stood solid and impressive, like some gigantic monument over Bikini. Then finally the shearing of the winds at different altitudes began to tear it up into a weird zigzag pattern.

An aerial view of the cloud from the southeast is shown in Figure 24.

The radiological danger sector (radex) designated for aircraft at 0730 on the shot day predicted the downwind danger area to be between 325° clockwise

Table 7. Aircraft participation, Test ABLE, CROSSROADS.

Type	Quantity	Mission
Army		
B-17	3	Air-sea rescue
B-17	4	Drone samplers
B-17	6	Drone controllers
B-29	1	Command
B-29	1	Bomb drop
B-29	1	Radio broadcast
B-29	1	Press and newsmen
B-29	2	Pressure-gauge drop
B-29	2	Radiological reconnaissance
WB-29	3	Weather reconnaissance
C-54	2	Photography
C-54	2	Observers
F-13[a]	8	Photography
Navy		
F6F[b]	4	Drone samplers
F6F	16	Drone controllers
F6F	6	Photography
PBM	2	Radiological reconaissance
PBM	3	Air-sea rescue
PBM	4	Photo-radiometry
TBM	2	Air-sea rescue
TBM	2	Photography
TBM	4	Drone boat control

Notes:

[a]A B-29 modified for photography.

[b]One F6F drone crashed in the ocean 10 minutes before the shot.

Source: Reference C.9.206, Part VII, p. F1.

Table 8. CROSSROADS, Test ABLE aircraft orbit points.

Orbit Designation	Bearing From Surface Zero (°)	Horizontal Range[a] from Surface Zero (nmi)	(km)
Able	50	20	37
Charlie	170	15	28
Dog	80	15	28
Easy	90	25	46
King	125	15	28
Love	315	30	56
Nan	0	20	37
Peter	240	35	65
Sugar	135	20	37
Tare	135	40	74
Uncle	40	30	56
Victor	315	20	37
William	270	20	37
Yoke	45	20	37
Zebra	0	40	74
I.P.	225	30	56

Note:

[a]Slant ranges of aircraft vary with aircraft-orbiting altitude. Orbiting altitudes were from 1,000 feet (305 meters) to 31,000 feet (9.5 km).

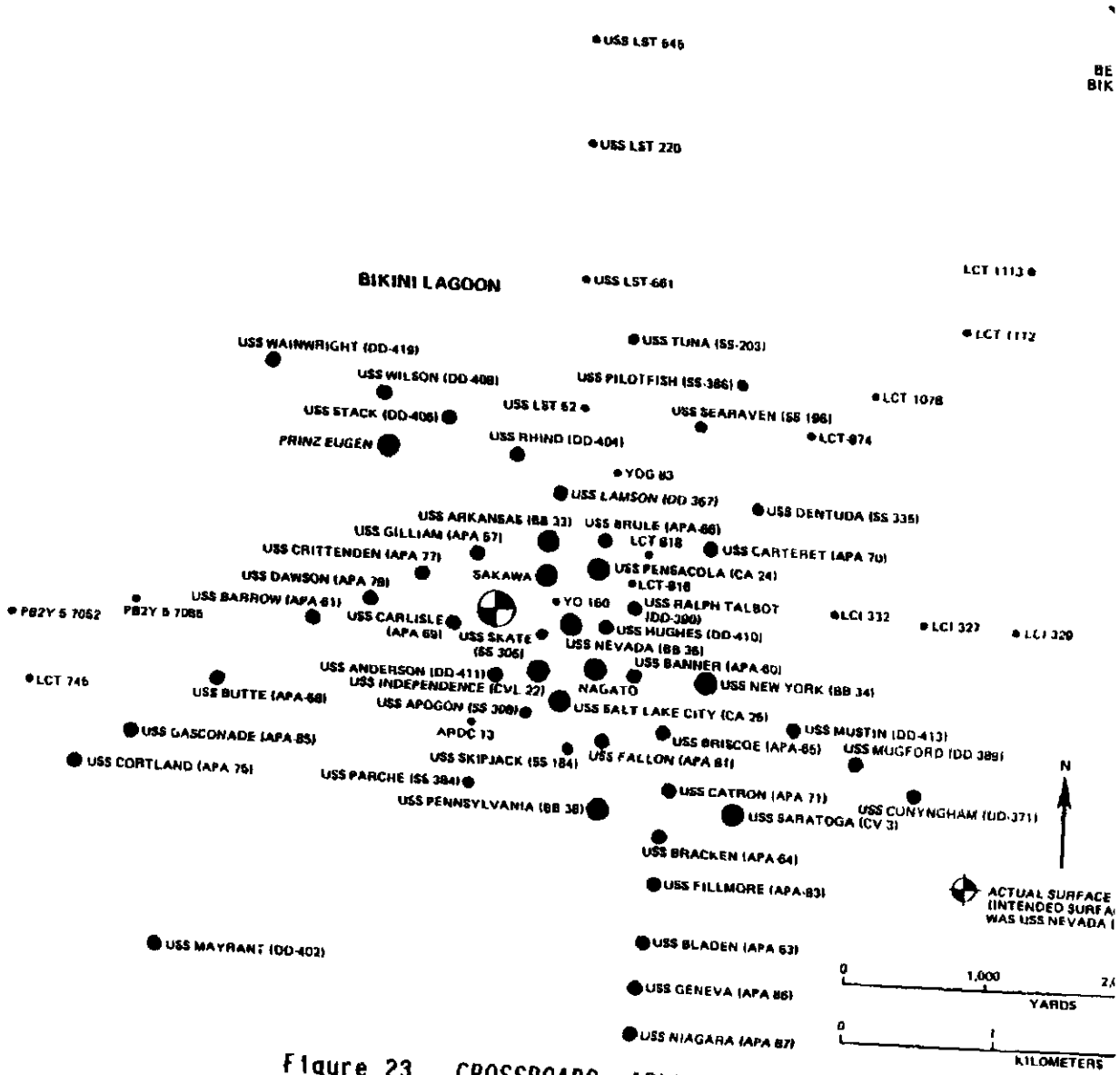

Figure 23. CROSSROADS, ABLE target ship locations.

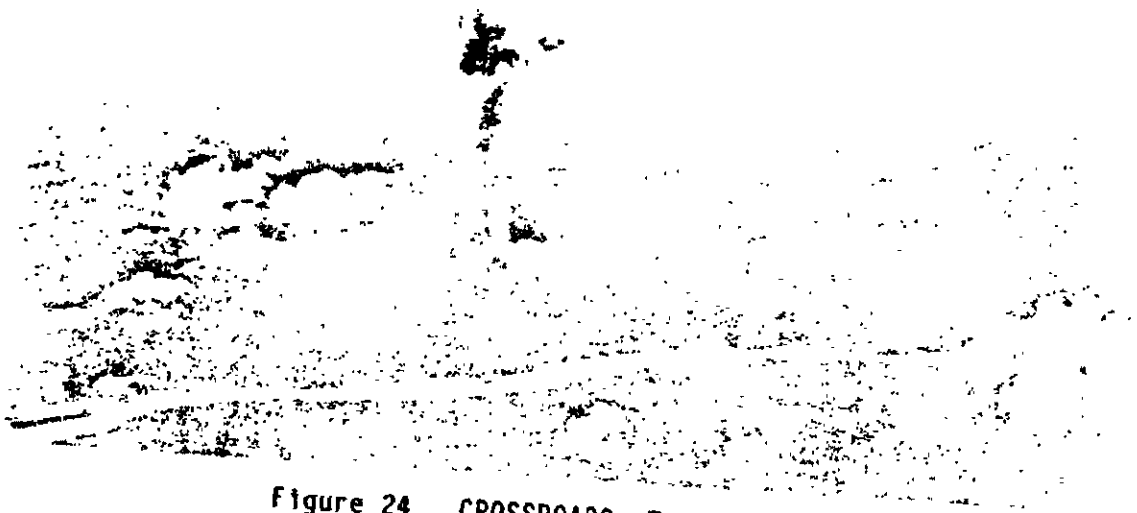

Figure 24. CROSSROADS, Test ABLE cloud.

to 125° from surface zero. At 1000 it was changed to 350° clockwise t 180°. The Red Arc was set 16 nmi (30 km) downwind from surface zero, and th Blue Arc 22 nmi (41 km) downwind from surface zero. Radsafe monitors wer placed aboard all aircraft airborne in the vicinity of Bikini at shot tim except in the single-seat F6Fs. The F6F pilots had Geiger counters whose click ing signals were fed into their earphones to warn of increasing radioactivit (Reference C.9.206, Part VII, p. C10).

Two radiological reconnaissance PBMs began making passes over the target area at 0952, starting at an altitude of 2,000 feet (610 meters) and working down to 500 feet (152 meters). They continued until 1427 and then returned to Ebeye Island, Kwajalein. The two radiological reconnaissance B-29s began track- ing and photographing the cloud at 1000 and were relieved during the day by two other B-29s. Four TBM aircraft were launched from USS Saidor (CVE-117) be- tween 0910 and 0918. Two developed engine trouble and returned; the remaining two took stations upwind from the drone boats and transmitted boat locations to Begor, which was controlling the drone boats. They completed their mission and departed the area for Saidor at 1238.

Army and Navy aircraft involved with photography and cloud sampling accom- plished their missions before 1000. B-17 sampler drones penetrated the cloud at altitudes of 13,000, 18,000, 24,000, and 30,000 feet (3.96, 5.49, 7.32, and 9.14 km) about 20 minutes after the detonation, obtained their samples, and were guided back to Enewetak Island. Three remaining Navy F6F drones sampled the radioactive cloud between 0906 and 0920 at altitudes of 10,000, 15,000 and 20,000 feet (3.05, 4.57 and 6.10 km). All three drones were guided back to Roi and were landed without incident. C-54 aircraft waiting at Enewetak and Roi transported the cloud samples in airbags and filters to Kwajalein. The samples were analyzed as soon as they were removed from the drones by Los Alamos

- 9 ships moderately damaged
- 43 ships negligible damage
- 22 landing craft beached at Bikini Island, no damage
- 14 aircraft destroyed
- 30 aircraft seriously damaged
- 10 aircraft lightly damaged
- 19 aircraft no damage.

In general all target vessels within 500 yards (457 meters) of actual surface zero were sunk or seriously damaged. Those beyond 1,500 yards (1.37 km) received minor damage (Reference C.9.206, Part V, p. C6). Those ships beyond 750 yards (686 meters) had little induced activity or contamination; they were reboarded on 1 July and were used for crew quarters beginning on 2 and 3 July. Figure 25 shows a group of VIPs and CJTF 1 inspecting New York after ABLE. By 5 July all target vessels (except those sunk) had been rehabilitated to the extent necessary for the upcoming BAKER event.

More than 50 percent of the test animals within 1,000 yards (914 meters) died, between 15 and 30 percent died between 1,000 and 2,000 yards (0.91 and 1.83 km), and between 5 and 15 percent died outside 2,000 yards (1.83 km). Airblast was the principal cause of injury and death. However, radiation exposure was the principal cause of death for those animals who died after the first few hours.

During Test ABLE, 200 cameras, 300 5-gallon (18.93-liter) cans, 400 photographic radiation badges, 5,000 sulfur capsules, 850 ball-crusher gauges, and over 5,000 other gauges of various types were used to measure and record the detonation effects (blast, heat, and radiation). The timing signal relied on to start a number of instruments was sent out about 10 seconds late because of errors by the timing signal operator. The following instruments obtained no data as a result of this 10-second delay: free-piston gauges, shock wave velocity cameras, O'Brien and Bowden cameras on Bikini, Fastex cameras on Bikini and Eneu, and the drum spectrograph.

PREPARATION FOR BAKER

As soon as the extent of damage from ABLE had been determined, CJTF 1 tentatively set 25 July for BAKER. The news media ship USS Appalachian (AGC-1) returned to Pearl Harbor to allow some media people to depart and others to join the group. Some observers were taken on a cruise to Ponape, Truk, Majuro, and Guam islands while the task force prepared for BAKER (Reference C.9.206, Part V, p. C7).

Several target ships had sustained boiler and/or stack damage. Wreckage was cleared and repairs made so that every target ship (except those sunk) was able to steam under its own power on at least one boiler. USS Independence (CVL-22) needed considerable work to ensure watertight integrity. The submarine Skate needed superstructure repairs, including a temporary bridge (Figure 26). One by one the target ships were moved to their positions in the new target

Figure 25. VIPs and Commander Joint Task Force 1 inspect USS New York (BB-34) following Test ABLE.

Figure 26. Damaged USS Skate (SS-305) on 3 July following Test ABLE.

array for BAKER. Test ABLE blast damage inspections were completed (Figure 27), and new instrumentation and new experiments were set up on these target ships in preparation for Test BAKER (Reference C.9.206, Part VII, p. A73).

Some turnover of task force personnel occurred following ABLE. A continuous training program was in effect after ABLE to train new personnel in preparation for BAKER. A large quantity of radiac instruments was received during this period, alleviating a minor shortage experienced during ABLE. The underwater BAKER shot was expected to create a much larger radsafe problem and require more radiac meters than did ABLE (Reference C.9.206, Part VII, p. C17).

The Army Air Forces conducted a major rehearsal on 14 July. All Army air units participated. Locations, communications, and coordination were tested,

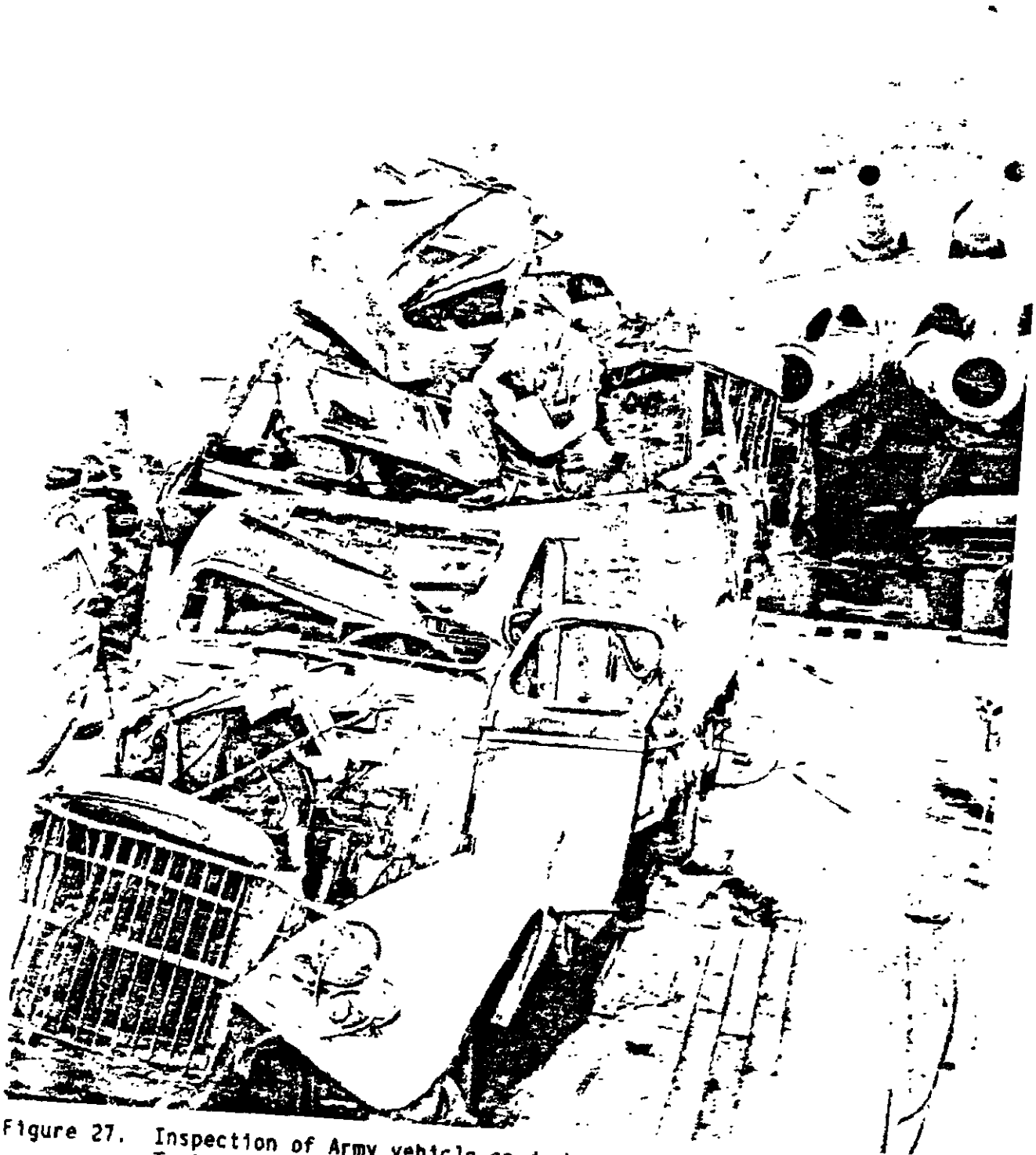

Figure 27. Inspection of Army vehicle on deck of USS Nevada (BB-36) following Test ABLE, CROSSROADS.

checked, and rechecked. Then on 19 July, JTF 1 conducted a full-scale dress rehearsal, dubbed "William Day." All units of the task force participated fully except the air task units. Heavy cloud cover and rain limited aircraft participation in the rehearsal (Reference C.9.206, Part VII, p. E180).

On D-1 (24 July) CJTF 1 confirmed BAKER Day as 25 July and designated shot time for 0835. Weather forecasts indicated that there would be favorable weather on that day. Evacuation of task force ships and personnel began immediately. Personnel and ships not needed immediately after the shot were evacuated to Rongelap Atoll instead of Kwajalein because it was closer to Bikini. USS Saint Croix (APA-231) evacuated 607 U.S. personnel and natives from Enewetak on 21 July.

The day before BAKER, two C-54s were again sent to Enewetak and Roi islands to transport the cloud samples to Kwajalein on 25 July. Five C-54s were again positioned at Enewetak in case evacuation of essential personnel was necessary. Except for minor changes, the aircraft missions were similar to the ABLE shot missions. Table 9 shows the aircraft that participated in BAKER, and Table 10 summarizes their orbit areas.

By 1735 on 24 July all but 13 support ships were clear of the lagoon. These cleared the lagoon by 0700 the following morning. Task force personnel on the islands at Bikini were evacuated by 1555 on 24 July. Three sailors on USS Gasconade (APA-85), a target ship, were somehow overlooked. They filled the yardarms with bunting (the signal that they needed evacuation) and were picked up by USS Conserver (ARS-39) at 0530 on 25 July (Reference C.9.206, Part VII, pp. H5-H7).

The bomb was suspended 90 feet (27.4 meters) beneath the surface of the lagoon from medium landing ship LSM-60. The LSM had been extensively modified to provide rigging facilities, a laboratory, and special radio receivers and transmitters. The bomb was encased in a strong, watertight, steel caisson and had a coaxial cable running from it to the LSM. The TG 1.1 laboratory personnel associated with the bomb arming were evacuated from LSM-60 at 0545 on 25 July (Reference C.9.206, p. 5.12).

There were 68 target vessels in the array for Test BAKER. Twenty-four small craft were beached on Bikini Island. Their positions are shown in Figure 28. The submarine USS Searaven (SS-196), which had been submerged on 24 July, partially surfaced later in the day. It was finally resubmerged by 2300 on 24 July. Of the eight target submarines, six were submerged and two were on the surface for the test (Reference C.9.206, Part VII, p. F10).

Weather was not quite as important for BAKER as for ABLE because the underwater detonation was expected to limit the cloud height and thus localize the radioactivity. Good visibility, however, was important for photography (Reference C.9.206, Part IV, p. C7).

BAKER TEST

BAKER was detonated on schedule at 0835 on 25 July 1946. The detonation command was sent by radio using coded signals. The weapon yield was 23 KT.

Table 9. Aircraft participation, CROSSROADS, Test BAKER[a].

Type	Quantity	Mission
Army		
B-17	3	Air-sea rescue
B-17	4	Drone samplers
B-17	6	Drone controllers
B-29	1	Radio broadcast
B-29	1	Press and newsmen
B-29	2	Command
B-29	2	Pressure-gauge drop
B-29	2	Radiological reconnaissance
WB-29	3	Weather reconnaissance
C-54	1	Observers
C-54	2	Photography
F-13[b]	8	Photography
Navy		
F6F	3	Drone samplers
F6F	12	Drone controllers
F6F	6	Photography
PBM	3	Radiological reconnaissance
PBM	5	Air-sea rescue
PBM	5	Photo-radiometry
TBM	2	Photography
TBM	4	Drone boat control

Notes:

[a]Does not include aircraft taking off after 1200, 25 July.

[b]A B-29 modified for photography.

Source: Reference C.9.206, VII 5, Encl. 9.

Table 10. CROSSROADS, Test BAKER aircraft orbit points.

Orbit Designation	Bearing from Surface Zero (°)	Horizontal Range[a] from Surface Zero (nmi)	(km)
Able	45	20	37
Charlie	180	10	19
Dog	330	9	17
Easy	90	20	37
King	225	10	19
Love	315	30	56
Sugar	135	20	37
Tare	135	40	74
Victor	315	20	37
William	270	20	37
Yoke	45	7	13

Note:

[a]Slant ranges of aircraft vary with orbit altitude. Orbit altitudes were from 500 feet (152 meters) to 30,000 feet (9.1 km).

Source: Reference C.9.206, p. VII-(E)-194.

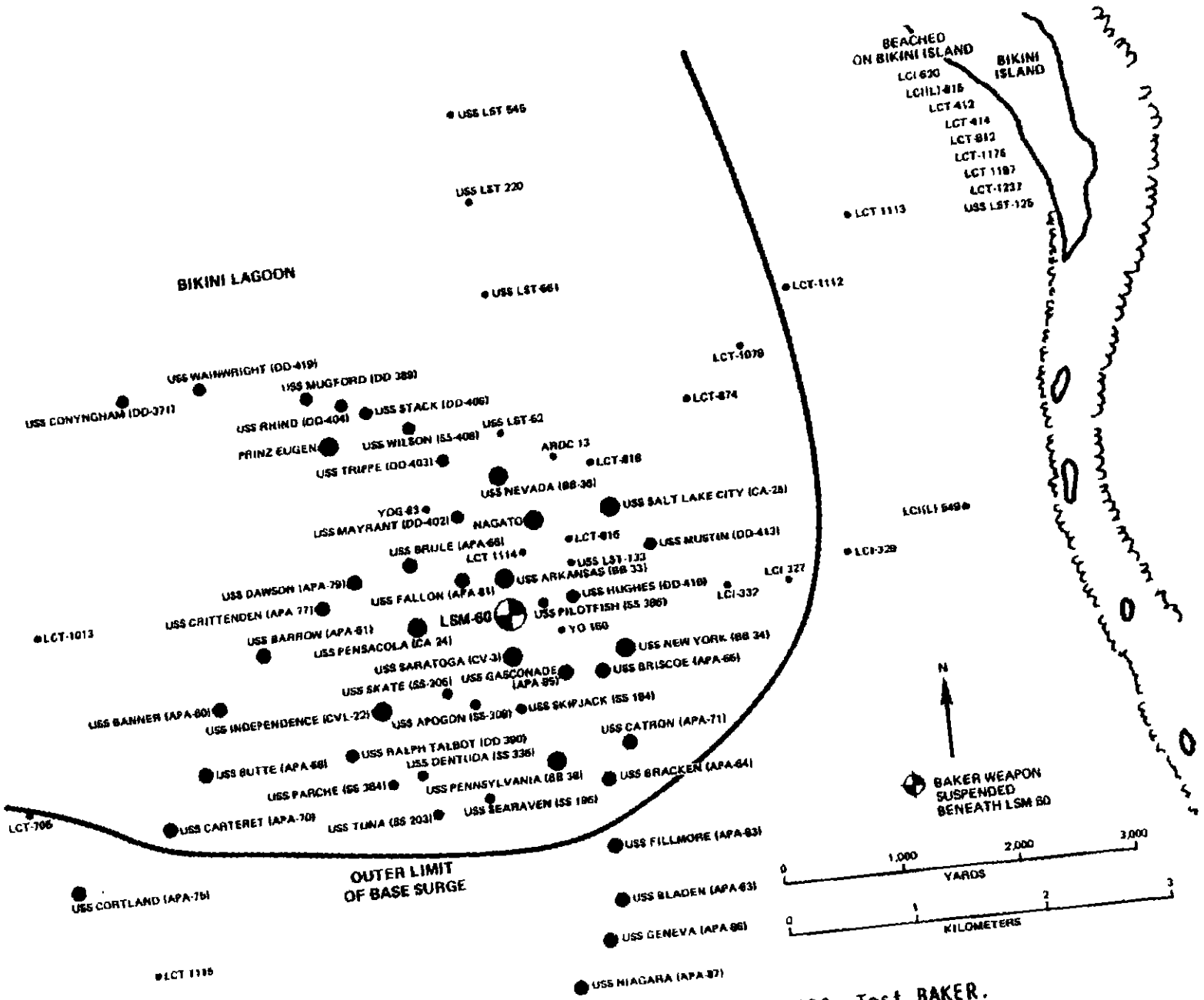

Figure 28. Target ship locations for CROSSROADS, Test BAKER.

Observers included United Nations representatives, Congressmen, the President's Evaluation Commmission, the JCS Evaluation Board, and media representatives (Reference C.9.206, Part V, p. C8).

The Army radsafe monitor previously quoted was again aboard a Navy PBM about 15 nmi (28 km) away and described the visual effects as follows (Reference A.2, p. 93):

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

Another aircraft observer reported seeing a major ship "on [its] nose" before it sank and saw a water wave pass over one of the small islands between Bikini and Eneu islands about 2 minutes after the detonation (Reference C.9.206, Part VI, p. D9). Figure 29 shows the BAKER detonation wave as it lifted the stern of Saratoga some 43 feet (13.1 meters). The dark area to the left of Saratoga is believed to be a cavity in the column formed by the hull of USS Arkansas (BB-33). When the air over the fleet cleared, Arkansas, LSM-60, and four LCTs were not in sight. Saratoga was listing to starboard and her stern was low. Figure 30 shows the BAKER cloud as viewed from the manned support ships in their operating areas.

The underwater burst inflicted heavy damage on the target fleet. Eight ships were sunk or capsized (See Table 11). Eight ships were immobilized or seriously damaged. Generally, ships beyond 1,500 yards (1.37 km) were undamaged. Those between 1,100 and 1,500 yards (1.01 and 1.37 km) susustained only slight damage. Those between 900 and 1,100 yards (0.82 and 1.01 km) suffered moderate damage. Those inside 900 yards (823 meters) were seriously damaged or were sunk (Reference C.9.208, p. 23.3).

At 0912, the drone control ship, Begor, began moving two drone boats from the lee of Eneu towards the target array using directions from the orbiting drone control TBMs as in Test ABLE. Each boat took ten 5-gallon (18.93-liter) samples of lagoon water and by 1030 was en route back to its anchorage. The drone boats were so radiologically contaminated that boarding parties from Begor could not go aboard. The drone boats were taken to USS Albemarle (AV-5) where the water samples were finally removed about 1430. Two additional drone boats were guided into the target area the same afternoon using the same combination of TBMs and Begor. Each took 10 samples of water, which were transferred to Albemale about 1800. Albemarle then headed for Kwajalein with the samples. Four more runs were made on 26 July and two more on 27 July using the same control procedures. The radiation intensities had lessened somewhat, allowing boarding parties from Begor to remove these samples and transfer them to USS Haven (AH-12) (Reference C.9.206, Part VII, p. R28-34).

Figure 29. CROSSROADS, Test BAKER column at about 10 seconds, photographed by remote-control camera on Eneu Island.

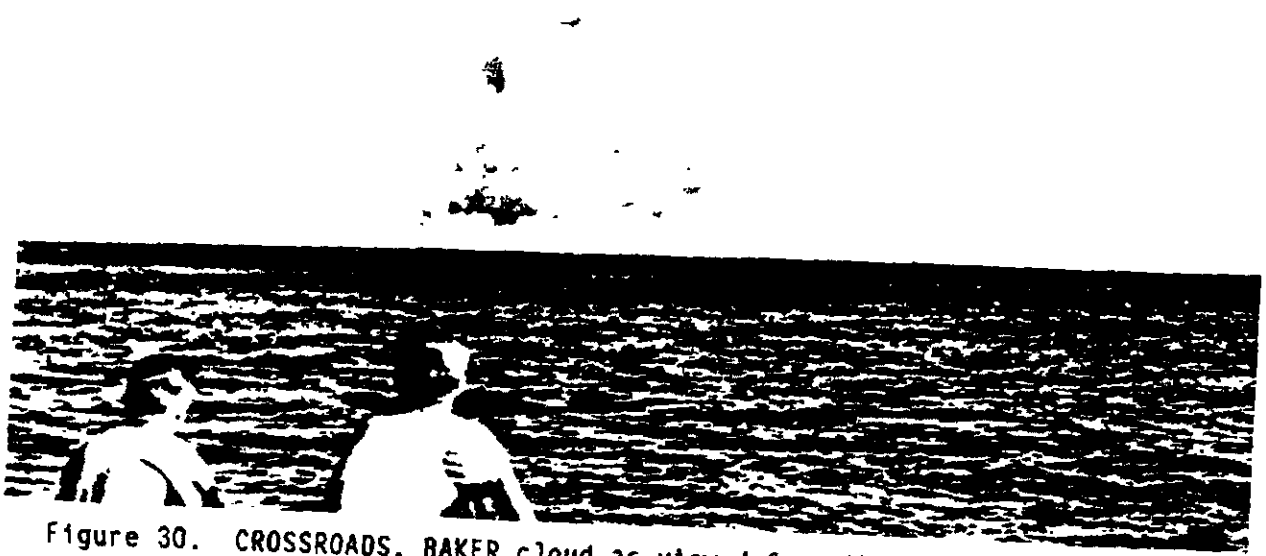

Figure 30. CROSSROADS, BAKER cloud as viewed from the manned support ships in their operating areas.

Table 11. Target ships sunk at CROSSROADS[a].

ABLE	BAKER	
USS Anderson (DD-411)	USS Arkansas (BB-33)	ARDC-13
USS Carlisle (APA-69)	LSM-60[b]	USS Apogon (SS-308)
USS Gilliam (APA-57)	USS Pilotfish (SS-386)	Nagato
USS Lamson (DD-367)	YO-160	USS Saratoga (CV-3)
Sakawa		

Notes:

[a]USS Dentuda (SS-335), submerged for test, flooded and sank; later it was raised and taken to Pearl Harbor and is not included in the ship sunk category. Six LCTs were sunk at Bikini after Test BAKER.

[b]Surface zero ship.

Sources: Reference A.1, pp. 130-132; Reference C.9.2, pp. 32-33.

Three air-sea rescue B-17s patrolled the area between Enewetak and Bikini to protect the six drone-control B-17 crews. Four drone-sampler B-17s took part in the test. Two were flown over surface zero at detonation time, one at 6,000 feet (1.83 km) and one at 16,000 feet (4.88 km). The one at 6,000 feet (1.83 km) had its bomb bay doors warped, its inspection plates blown open, the tail gunners hatch blown inside the aircraft, the canvas cover over the tail wheel split, and the standard aircraft cushions inside split open. The other B-17 drone jumped 300 feet (91 meters) in altitude but sustained no damage. The third B-17 drone sampled in the cloud at 7,000 feet (2.13 km) 5 minutes after the burst, and the fourth B-17 drone sampled above the cloud at 11,000 feet (3.35 km) 7-1/2 minutes after the burst. Three Navy F6F drones and their twelve F6F controllers took off from Shangri-La and sampled at altitudes of 14,000, 9,000, and 5,000 feet (4.27, 2.74, and 1.52 km). Only the drone at 5,000 feet (1.52 km) passed through the cloud. Sampling was completed by 0850 and all aircraft returned safely to base (Enewetak for the B-17s and Roi for the F6Fs). The airbags and filters were removed by Los Alamos Laboratory personnel and transported in the waiting C-54s to Kwajalein for analysis.

Eight B-29s and three WB-29s participated in shot BAKER. The radio broadcast, press, and command B-29s orbited the area accomplishing their missions at a safe distance. The two pressure-gauge drop B-29s dropped their gauges from 24,000 and 25,000 feet (7.32 and 7.62 km) just before the detonation. The two radiological reconnaissance B-29s tracked and photographed the remnants of the cloud until almost 1400 when they were relieved by two other B-29s. The three WB-29s were airborne by 0231 the morning of the detonation to report on cloud cover and other weather phenomena north and east of Bikini until 0500, when they returned to Bikini to provide current weather reports at that location. The three C-54 and eight F-13 Army aircraft were involved with transporting observers and photography (Reference C.9.206, Part VII, p. E195 through E207). All aircraft except the F6F had radsafe monitors aboard. As at Test

ABLE, the F6F pilots used earphones connected to Geiger counters to monitor radioactivity.

Early reports from radiological reconnaissance PBMs and drone boats indicated that the lagoon and surrounding atmosphere were intensely radioactive. A drone boat recorded about 730 R/24 hours near the center of the target array. The three PBMs made several passes over the lagoon on 25 July, starting at 4,000 feet (1.22 km), then at 3,000, 2,000, 1,000 and 500 feet (914, 610, 305, and 152 meters); the first pass was made at 0915 and the last at 1615. The preshot radex sector bearings of 360° clockwise to 220° were modified slightly at 0940 to 360° to 270°. The Red Arc was set at 9 nmi (17 km) from surface zero and the Blue Arc at 11 nmi (20 km) from surface zero (Reference C.9.206, Part VII, p. C-19).

Reentry into the lagoon commenced at 0916 when the PGM and LCPL radiological patrol boats with monitors aboard entered. They were closely followed by TU 1.2.8 and Kenneth Whiting. Fall River took up its position at the lagoon entrance at 0947 to control entry and exit. The Salvage Unit (TU 1.2.7) entered the lagoon at 1015 and began checking and boarding target vessels. A total of 49 support ships with 14,920 personnel entered the lagoon by the end of 25 July.

For BAKER, ten initial boarding teams were established, a total of 86 men, including one monitor for each team. These teams were the first groups to return to the target vessels, although five of the firefighting officers may not have actually reboarded unless there was a fire to fight (Reference B.0.1, pp. X-X-1 through X-X-17). In addition, representatives of the groups responsible for the scientific experiments and tests of military equipment returned to retrieve data and materials when given permission by the monitors. Film and other data were recovered from Bikini and Eneu islands during the afternoon. Twelve target ships were temporarily boarded, ten of which were declared radiologically safe (no radiation measured above 0.1 R/24 hours) before nightfall on 25 July (Reference C.9.206, p. VII-C-53). The remaining target ships were too radioactive to board and the water near the detonation site remained radioactive as well (Reference C.9.206, p. VII-C-54).

The radioactive cloud had apparently moved north of the burst. Radiological reconnaissance F-13s discovered weak radioactivity while flying 43 nmi (80 km) north of the lagoon at 1318 and a highly radioactive cloud at 80 nmi (148 km) almost directly north of Eneu Channel at 1610 (Reference C.9.206, Part VI, p. D13). An F-13 due west of Bikini at 50 nmi (93 km) made no contact with radioactivity by 1415. Apparently based on this information, the alert at Enewetak Atoll west of Bikini was dropped at 1418 and clearance was given to return evacuees there (Reference C.9.206, Part VI, p. D13).

At about 1608 Saratoga sank (Figure 31). Until that time it had been the oldest U.S. aircraft carrier afloat. Saratoga was laid down as a battle cruiser in 1920, but was completed as an aircraft carrier. Radiological conditions prevented any attempt to save the ship.

The radioactivity persisted through 26 July. Films from cameras on Aomen Island were recovered using helicopters. An oil slick with radioactive debris

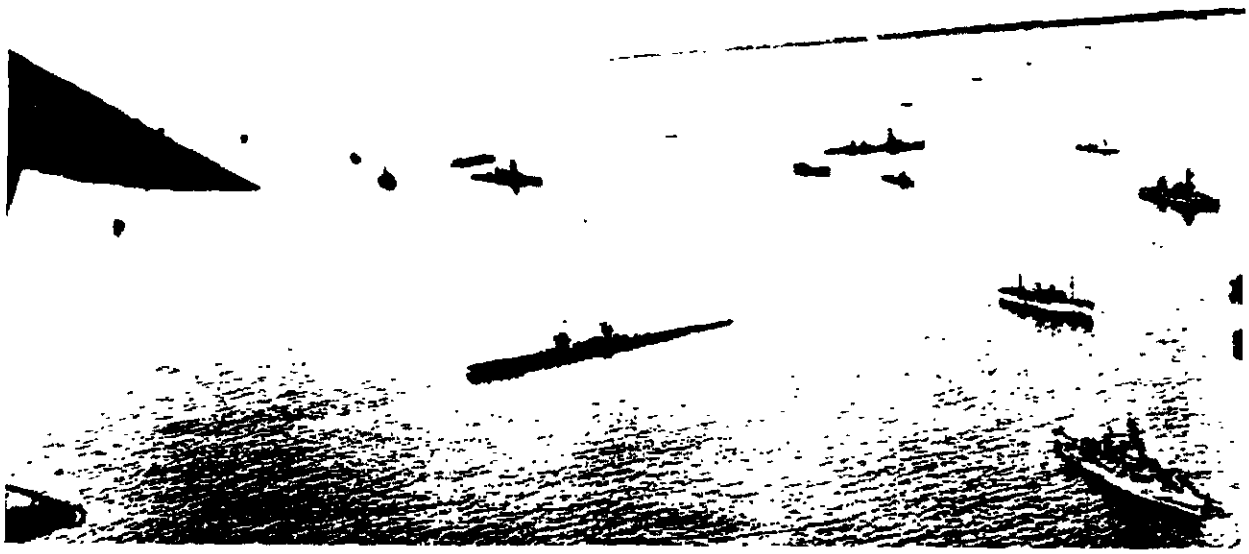

Figure 31. USS Saratoga (CV-3) sinks following CROSSROADS, Test BAKER.

was observed north of Nam Island (outside the lagoon). Task force ships in the lagoon stayed in the southeast sector near the entrance in order to keep clear of the radioactive water. Their evaporators were allowed to be used on 26 July. The target ship USS Hughes (DD-410) was towed to Eneu and beached by USS Reclaimer (ARS-42) to prevent sinking. Figure 32 shows a welder aboard Hughes during preparations for towing. Note the respiratory protection device being worn and the nearby monitor. The same situation persisted on 27 July; however, some instrumentation was recovered from the target ships. USS Preserver (ARS-9) attempted to get a line aboard the damaged and heavily contaminated USS Fallon (APA-81) so that it could also be beached beside Hughes. This could not be accomplished until the following day, however.

Because of the persistent radiation in the lagoon, several radiological reconnaissance flights took place over the next few days. Eight missions were flown on 26 July and two on 27 July. Five photography flights were made on 26 July and four on 27 July. Six drone boat control TBMs flew on 26 July and two on 27 July. Photo and radiological reconnaissance flights continued through 30 July, while drone boat control flights were not needed after 28 July (Reference C.9.206, Part VII, S, Encl 13-14).

On 28 July, radioactive water in the lagoon spread southeast to some of the task force ship anchorage areas, forcing some ships to relocate to uncontaminated areas. However, the Red Line (1 R/24 hours) was eliminated at 1455 on 28 July. On 28 July at 2352, Sumner reported readings of 0.156 R/24 hours on outboard bunks and 0.204 R/24 hours at the evaporators. On 29 July it was sent out of the lagoon and into the open sea in an attempt to decontaminate the hull. PGM-24 and PGM-29 had become contaminated earlier, reading 1.56 R/24 hours amidships. Their crews were evacuated to USS Appling (APA-58) and Haven.

CHAPTER 5

POST-BAKER OPERATIONS: BIKINI, KWAJALEIN, AND THE UNITED STATES

In early August it became apparent that while the radiation levels in the water and on the land areas were below tolerance levels, the accumulation of radioactivity in the remaining ships' evaporators, saltwater piping, and marine growth on their hulls presented an increasing problem. Consequently, the base of operation of the task force had to be moved from Bikini. Kwajalein Atoll was selected for the new base (Reference C.0.22, p. 1). On 19 August 1946, movement of all remaining ships to Kwajalein was initiated, and by 26 September 1946 Bikini Atoll was completely evacuated. Subsequently, a large number of them were sunk, others were returned to naval shipyards in the United States for inspection and additional decontamination.

The experience, problems, and solutions associated with ship decontamination at Bikini and in naval shipyards and a discussion of radiological and other problems associated with off-loading ammunition from target ships and securing them at Kwajalein are addressed in this chapter.

REMANNING LIGHTLY CONTAMINATED TARGET SHIPS AT BIKINI

Five target vessels, attack transports USS Bladen (APA-63), USS Cortland (APA-75), USS Fillmore (APA-83), USS Geneva (APA-86), and USS Niagara (APA-87), were on the outer fringes of the target array and were not heavily contaminated by the rainout or the base surge (see Figure 28, Chapter 4). The crews of Bladen, Fillmore, Geneva, and Niagara returned to their ships on 29 July, and Cortland's crew returned on 30 July (Reference A.3, Bladen, Cortland, Fillmore, Geneva, and Niagara).

The ships needed some decontamination work (Reference C.9.185, pp. 4 and 10). Although the radioactivity on these ships' weather surfaces was not sufficient to prevent reboarding and cleanup work, they were found to have radioactivity on the outside of their hulls at the waterline, apparently because marine growth there was taking up radioactive isotopes from the lagoon water. Radioactivity was 0.4 R/24 hours on the inner surface of Niagara's hull, decreasing to 0.1 R/24 hours 5 feet (1.5 meters) toward the center of the ship (Reference C.2.1). After the waterline areas of the five ships were scraped, they steamed in the open ocean for 24 hours in an effort to reduce contamination. Niagara steamed alone on 1 and 2 August and the other four steamed as a group on 4 and 5 August (Reference A.3, Bladen, Cortland, Fillmore and Geneva). In addition, Geneva's entire bottom was scraped by passing wires under the hull from one side to the other and pulling them toward the stern (Reference C.9.185, p. 18). Upon reaching Pearl Harbor, the small boats of both Cortland and Fillmore were found to be radioactive (References C.2.4 and C.2.5).

DECONTAMINATION OF HEAVILY CONTAMINATED TARGET VESSELS AT BIKINI

Decreasing lagoon radioactivity by 27 and 28 July allowed the Director of Ship Material (DSM) aboard USS Reclaimer (ARS-42) to survey other target ships from a distance of 50 to 100 feet (15 to 30 meters). Of the 92 target vessels, only 10 ships in the target array and 20 landing craft beached on Bikini islands had readings less than 0.1 R/24 hours by 2000 on 3 August (Reference C.11.19). Since "the nature and extent of contamination of the targets was completely unexpected, no plans had been prepared for organized decontamination measures" (Reference C.9.185, p. 4). As a result, the Technical Director and the DSM could not complete their programs in a timely way unless a means could be found to decontaminate the target vessels.

Washdown of Target Ships

After conferring with members of the Radiological Safety Section, the DSM took the lead in trying to remove contamination from the target vessels with materials and equipment immediately available to the task force at Bikini. First, task force firefighting equipment was used. Use of firefighting equipment is shown in Figure 34 as USS Achomawi (ATF-148) uses its forward monitor to wash down USS New York (BB-34).

Firefighting vessels of Task Unit (TU) 1.2.7, the Salvage Unit, twice attempted to wash down the heavily contaminated USS Hughes (DD-410) with saltwater on 27 July. The first effort produced a 50 percent reduction in radiation levels, but the second did not lower the radiation level. Next, foamite, a foam-like preparation used for smothering fires, was tried. Foamite was plentiful and was hoped to have a detergent action on the contamination adhering to Hughes. Fireboats sprayed Hughes with foamite and then with saltwater. Figure 35 shows the beached Hughes whitened by the foamite as two Salvage Unit ships stand by.

The reduction in radioactivity led to a decision to use foamite and saltwater until a better method was devised. The foamite and saltwater method, however, could be used only after waiting for the lagoon water to become virtually free of contamination. Radioactivity from the lagoon would itself contaminate both target and firefighting ships. Moreover, because the foamite and saltwater method was not totally effective, a search for better methods continued (Reference C.9.185, pp. 5 and 6).

Early Experiments in Decontamination

At a meeting on 27 July, attended by the DSM and members of the Radiological Safety Section, the radiological safety (radsafe) group was directed to study the decontamination problem. It selected pieces of contaminated equipment and blasted them with ground corncobs, coconut shells, barley, rice, ground coffee, rice hulls, and sand. Sandblasting worked best, but it was not suitable for general decontamination of the more than 60 contaminated vessels of the target fleet (Reference C.9.185, pp. 6 and 7).

Observation had revealed that most radioactivity stemmed from radioactive material collecting on painted or rusty surfaces, or on exposed organic materials, such as canvas, life rafts, manila lines, swabs, brooms, wood decks,

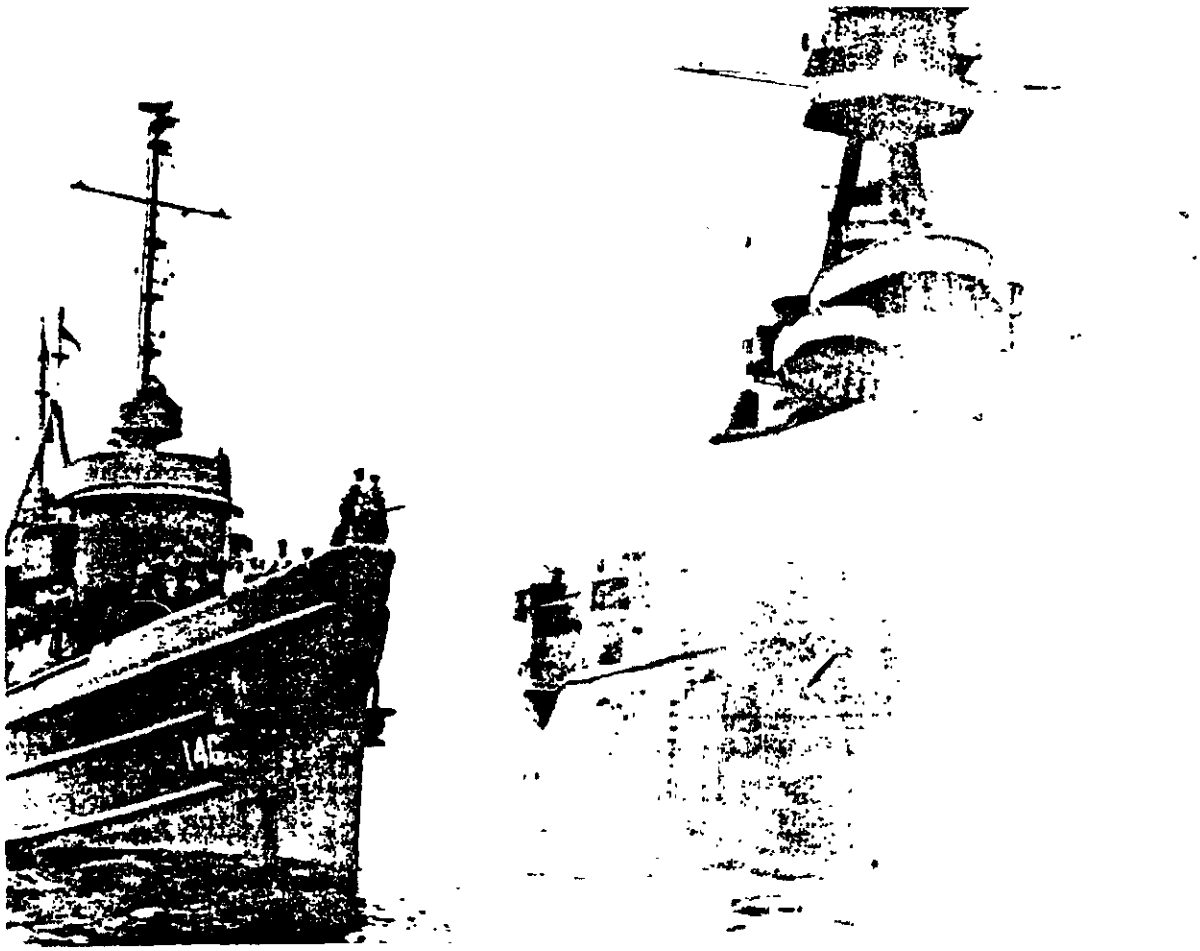

Figure 34. USS Achomawi (ATF-148) spraying USS New York (BB-34) with saltwater after BAKER, CROSSROADS.

Figure 35. USS Hughes (DD-410) beached off Eneu Island, covered with foamite following BAKER, CROSSROADS (two Salvage Unit ships are to the right).

2. Other target vessels, such as USS Independence (CVL-22) and USS Pensacola (CA-24), be declared hopelessly contaminated and beached to let their radioactivity decrease by natural decay

3. Scientific equipment be retrieved where it was safe to do so.

Decontamination Operations

Decontamination operations encountered the same basic obstacle that had been encountered during the program to develop decontamination methods. The radioactive particles were firmly attached. Initial efforts produced significant results by removing lightly attached radioactive particles, but more deeply embedded radioactivity could be reduced only slowly by additional hosing and scrubbing. The exact number of men involved in the decontamination effort cannot now be determined, but 41 percent of the task force personnel was assigned to units involved in decontamination, inspection, towing, or salvaging. Many of these personnel, because of their skills or occupations however, were not directly involved in that work. The brunt of the reboarding and decontamination effort was borne by the 8,463 target ship crewmembers, although it appears that only a portion of them actually worked on contaminated ships. See Chapter 12 for a discussion of personnel exposures.

On 7 August, in another memorandum to CJTF 1, the Chief of the Radsafe Section argued that under the conditions at Bikini it was not possible to decontaminate the target vessels without exposing personnel to a serious radiation hazard. Safety measures on target vessels were deteriorating, and adequate monitoring personnel and instruments were no longer available. Contamination was erratically distributed so that an individual's exposure could not be estimated. The potential of inhalation of contamination was a major concern. Furthermore, the untrained men doing the decontamination work could not be expected to follow safety precautions consistently (Reference C.0.14).

On 8 August, CJTF 1 asked the Chief of Naval Operations (CNO) to allow him to decommission, or place out of service at Bikini, 39 target vessels because with the resources at hand (Reference C.10.11):

> They cannot all be made absolutely safe to board in the near future for sufficiently long periods to either prepare them for movement to Pearl [Harbor] or to assess fully in all cases the damage sustained.

During this period, problems developed in strict enforcement of radsafe regulations. Inadequate supervision of men doing decontamination work on Prinz Eugen and New York was reported (References C.0.11, C.2.2, and C.2.3). Monitors visiting Prinz Eugen noted an apparent indifference among the ship's officers to the 0.1 R/24 hours standard, and the monitors suspected some men had been on the ship overnight (Reference C.2.2). As a result there was concern that unbadged working parties aboard the target ships might have overexposures similar to those recorded by their monitors (Reference C.0.8). No substantiation of these serious allegations about activities on Prinz Eugen can be found in the ship's deck log or that of USS Rockingham (APA-229) where its evacuated

crew was berthed. The decontamination report (Reference C.2.54) written by Prinz Eugen's commanding officer on 13 August appears to indicate a definite concern for radsafe matters.

The officer in charge of target ship monitors complained that work on the target ships had increased to the point where his men could not adequately protect the decontamination crews. As an example, he described the situation on USS Salt Lake City (CA-25), where from 3 to 7 August four of six monitors received exposures in excess of 0.1 R/24 hours, along with twenty other personnel of the ship's working teams (Reference C.0.11). On 10 August, the Medico-Legal Board recommended that work cease on Salt Lake City until 20 September, and the board's chairman in a minority report called for the ratio of monitors to decontamination personnel be increased from one to sixteen to one to ten and for all personnel working on target ships to be badged (References C.0.8 and C.0.21).

Discovery of Plutonium Contamination

Into this situation a new element was introduced (Reference C.9.185, p. 13):

> On 9 August, The Director of Ship Material requested the Radiological Safety Officer and the Commander Target Group to visit ships on which ship's forces were employing the detailed decontamination procedures. During that inspection, samples of materials were obtained from areas of the wardroom of PRINZ EUGEN for which geiger counter readings showed radiation intensities sufficiently low to permit extended personnel exposure [8 hours] without danger of injury. An analysis of the samples revealed the presence of alpha emitters which were not detectable with monitoring instruments in use at Bikini. Further investigation showed probable widespread presence of the alpha emitter [plutonium] in the target area even in spaces not obviously contaminated.

It is unfortunate that this discovery, which so markedly affected subsequent CROSSROADS operations, is so poorly reported in the surviving documents. The only direct reference is the quotation above from the DSM report. It is not mentioned in the portion of the Technical Director's Report devoted to nuclear radiation (Reference C.9.209, Enclosure J), and although allusions to the existence of plutonium contamination and reports of laboratory determinations of the presence of plutonium can be found in the voluminous collection of papers of the Radsafe Section Chief, these do not appear to directly relate to Prinz Eugen.

The Chief of the Radsafe Section and his staff probably did not directly detect alpha emitters on Prinz Eugen. Instead, indirect evidence convinced them the hazard existed.

The difficulty of directly measuring alpha emissions with the field instruments of 1946 has been discussed earlier. The Radsafe Chief in a speech in 1947 said that beta activity was measured and then a ratio used to calculate alpha activity (Reference C.12.4, p. 23). Direct determination of alpha

contamination were made by removing samples to laboratories where analyses could be made. Field assessments were made by assuming that the alpha emitter plutonium was mixed with the other weapon debris, made up of fission products and activated materials. The ratio of this mixture was apparently assumed to be constant so that there was a ratio between the measurable radiations, gamma and beta, emitted by the fission products and activated materials and the unmeasurable alphas from the unfissioned plutonium. Since the emissions from the beta and gamma emitters decayed while the alpha emissions remained nearly constant, this ratio changed with the passage of time -- but in a way that was predictable.

The laboratory on Kwajalein operated by Los Alamos informed the Radsafe Advisor that on BAKER day + 13 (7 August) 4.5 alpha counts [per minute] per square centimeter of contaminated area could be expected when a survey meter gave a reading of 1 R/24 hours (presumably gamma) (Reference C.10.16). This theoretical determination was made in conjunction with samples that had been taken on 7 August from the forward lookout platform of New York. These samples had been collected by using concentrated hydrochloric acid to dissolve the paint and surface material, which were then collected for analysis. The result was forwarded by teletype to the Chief of the Radsafe Section on 10 August and stated that the reading in the collected material was 25 alpha counts [per minute] per square centimeter [of the contaminated platform] for a [gamma] reading of 3 R/24 hours. The laboratory said that this count was twice as high as expected due to "washing." By this it is presumed the laboratory meant that the fission and activation products had been more easily washed away during decontamination activities before 7 August than had the plutonium particles. It should be noted that this anaysis took three days from sample collection to report.

The account from the DSM report continues (Reference C.9.185, p. 13):

> A conference was called by the Task Force Commander on 10 August to discuss the matter [Prinz Eugen contamination]. As a result of this conference, continuation of detailed decontamination was considered unsafe under the existing conditions, and all further decontamination work on the targets by ship's force was ordered discontinued. Subsequently, all further work on these vessels by Task Force Personnel was limited to recovery of instruments, limited surveys, salvage work and preparations for towing from the area.

Judging from the time required to analyze and report the New York samples, it does not appear that the samples from Prinz Eugen taken on 9 August could have been analyzed by the next day.

There is a further difficulty with this sole surviving account of the discovery. It appears in the last sentence of the first quotation wherein "widespread presence . . . in spaces not obviously contaminated" is deemed "probable." If "not obviously contaminated" means not easily measured with existing field survey meters, then the statement is not confirmed by surviving records of the measurements that were taken of alpha contamination. Reports available after 4 September on alpha contamination in samples taken from the target vessels and sent back to Los Alamos for analysis show that alpha emissions were always reported in conjunction with gamma and beta emissions.

It seems more reasonable to assume that the phrase "not obviously contaminated" refers to more obvious criteria such as visible deposit of coral sand or presence of blast damage. What had actually been discovered was radioactivity in places that, because they were below decks or closed, were not expected to be contaminated. This probably was announced in an undated memorandum from the "Pill Counting Lab" (presumably the laboratory on USS Haven [AH-12] set up to analyze Program VII activation samples) to the Radsafe Advisor. The subject was "Dust Samples Taken in Crew Spaces on Prinz Eugen 9 August 1946." The memo states that B counts (the typewriter perhaps lacked Greek characters and this refers to beta counts) on four dust samples taken from certain given crew spaces were made and the results were from 0.00005 to 0.68 mc (perhaps microcuries) per gram of dust. This memo further states that the background radiation measured in these spaces by an X-263 meter was 0.10 R/24 hours (Reference C.11.31).

This discovery, along with the assumption of the presence of plutonium wherever there was any radioactive material, led to the inference that plutonium had been discovered. This assumption was perhaps reinforced by the New York data that showed that plutonium was actually present in paint on the lookout platform. That information became available the same day as the CJTF 1 conference.

This interpretation of the events is strengthened by a telegram sent by the Radsafe Section Chief to the United States on 13 August and probably intended for the Oak Ridge Laboratory of the Manhattan Engineer District (Reference C.11.29).

> UPON USING RATIONAL [sic] ALPHA BETAS FURNISHED BY YOU FIND INNER COMPARTMENTS ALL TARGET SHIPS HIGHLY CONTAMINATED BY ALPHAS.

The reference to the ratio provided may refer to the results of analysis of ABLE or BAKER cloud samples done at Oak Ridge and made available at some time before 9 August.

In the light of what the surviving records show to be the actual knowledge of the degree of plutonium contamination, the decision to halt all further decontamination work appears to have been prudent and conservative. As the Medico-Legal Board recorded at their 13 August meeting at 1300 (Reference C.0.9.a):

> For safe guidance of the Operations from this time onwards, we need to know:
>
> a. The number of alpha particles per second per square centimeter
>
> b. The alpha tolerance for different types of surfaces.

Furthermore, special clothing and intensive training would have been required if major work on the target ships was to continue. According to a senior radsafe official (Reference C.11.4, p. 2):

> In the laboratory, radioactive material was handled by remote controls. At Bikini, it was scattered over the decks of the ships. Men walked through it, tracked it around, and got it on their clothing and hands and faces. There was some tendency on the part of the men to disregard a danger which they could not see, nor touch, nor smell. It was known that the men could not taste the radioactive material. But they could eat it! The situation was fraught with grave danger if the enlisted men could not be trusted to do exactly as he was told. It became apparent that it would be necessary to subject these men to long periods of training before they could be expected to abide by the precautions which are commonplace in a nuclear laboratory.

On 4 September, Los Alamos reported by message an analysis of samples taken from target ships that showed measured levels of alpha contamination. The maximum alpha reading came from USS Skate (SS-305) periscope mast sample, reportedly taken on 19 July. This pre-BAKER test date conflicts with the DSM final report of late 1946, which states that no extensive deposits of alpha emitters were found following Test ABLE (Reference C.9.185, p. 3). This fact, plus additional circumstantial evidence, suggests that the date was a typographical error, and should have read 19 August (Reference C.13.12). The periscope mast sample read 1,830 alpha disintegrations (assumed to be disintegrations per minute per gram [dpm/gm]) and 9,100,000 beta disintegrations for a beta-to-alpha ratio of 5,000 to 1. Other Skate readings were:

> Bow -- 28 alpha dpm/gm, 93,400 beta dpm/gm, ratio 3,500
>
> Frame 120 -- 0 alpha dpm/gm, beta 9,160 dpm/gm
>
> Base of 5-inch gun -- 50 alpha dpm/gm, 115,000 beta dpm/gm, ratio 2,300.

Four samples from USS Wainwright (DD-419) collected on 18 August show alpha counts of 263 (beta-to-alpha ratio 3,500), 12 (ratio 2,500), and two zero alpha counts, but both of the latter with beta.

Three samples of unknown collection date, two from USS Searaven (SS-196) and one from USS Parche (SS-384), show alpha counts of 38 (beta-to-alpha ratio 1,400), 28 (beta-to-alpha ratio 66,000), and 23 (beta-to-alpha ratio 5,600) (Reference C.11.2).

A later analysis of 31 samples from 23 target ships all indicated the presence of alpha radiation. All but six of the samples had less than 10 dpm/cm^2. Nine of the samples were 1 dpm/cm^2 or less. The highest reading was a sample from USS LST-52, at 183 dpm/cm^2 and a beta-to-alpha ratio of 677. After Test BAKER, it was calculated that LST-52 received one of the highest radiation exposures from deposition of material in the rainout and base surge (Reference C.11.28).

There were also some later determinations at the San Francisco Naval Shipyard of alpha contamination of support ships. These are discussed later in this chapter.

Cessation of Bikini Decontamination Efforts

As a result of the 10 August conference, decontamination efforts stopped but apparently someone proposed at a 12 August conference that the capital ships be entered for the purpose of starting their engines and machinery to pump them out and thoroughly inspecting their internal structures. The reply was a staff CJTF 1 memorandum to Commander Task Group (CTG 1.2), dated 13 August and signed by the Chief of the Radsafe Section. The tone of this document can only described as stern and didactic. It dismisses the argument that the low gamma readings would permit such operations with a terse, "This is not the case," and continues, "The widespread presence of an alpha emitter has been demonstrated." The memorandum then catalogs the sources of possible exposure of personnel on the target ships, introducing the list with the statement, "The following facts have been observed in these vessels." It concludes with several "uncontestable conclusions." These conclusions amounted to a denial of the request to enter the ships on a large scale (Reference C.11.30).

It was directed that no one go aboard ships after 14 August without a badge. However, while the percentage of badging does increase after 14 August, 100 percent badging was not achieved. Only recovery of instruments, limited surveys, salvage work, and preparations for towing were allowed (Reference C.9.185, p. 13; Reference C.11.3). Virtually no target ships were boarded on 11 August, and only a few on 12 August. Beginning on 13 August some limited decontamination was done as part of the effort to ready the ships for towing. Inspections of target ships were conducted between 13 and 19 August.

CTG 1.2, however, requested that restoration work on USS Carteret (APA-70), USS Conyngham (DD-371) and Wainwright be continued. All surfaces of spaces to be occupied by personnel for working, berthing, or messing were to be painted, presumably to prevent alpha emitters from becoming airborne or being picked up on the men's clothing or skin (Reference C.10.2). In the end, however, only Conyngham was decontaminated sufficiently to be remanned. On 28 August, it departed Kwajalein for Pearl Harbor under its own power, arriving there on 6 September (Reference C.0.3, p. 3; Reference C.9.206, p. V-(D)-6). On advice from the Radsafe Section, all work on Carteret and Wainwright ceased on 18 August. The crews of both ships were transported home on 20 August because of possible overexposure to radiation (Reference C.0.3, p. 3).

Although radiation levels in the lagoon and on the atoll's islands were below tolerance levels, the accumulation of radioactivity in the support ships' evaporators and saltwater piping and in the marine growth and rust on their hulls below the waterline presented an increasing problem. The base of operation had to be moved from Bikini, and Kwajalein was selected (Reference C.10.4).

Contamination made it difficult to prepare most target ships for movement to Pearl Harbor or to systematically study the damage they had sustained. A series of decisions resulted in towing target ships to Kwajalein beginning 19

August. By 5 September the last of the target ships afloat had left Bikini (Reference C.10.11; Reference C.0.3, p. 1; Reference C.0.4, p. 1). By 26 September 1946, Bikini Atoll was completely evacuated.

All survey and construction activities at Bikini were rapidly brought to a close, and the atoll was completely evacuated. For safety and security reasons, a recommendation was made to CNO to declare Bikini Lagoon a defensive sea area. CNO ordered continued surveillance of this area to restrict entry of foreign, merchant, or private shipping that had not been duly authorized. This restriction was promulgated through a Notice to Mariners declaring the area bounded by latitudes 11°28'N and 11°43'N and longitudes 165°10'E and 165°35'E dangerous to shipping and personnel, and restricting entry except to those duly authorized by proper authority. (Reference C.0.31, p. 6).

TARGET VESSEL OPERATIONS AT KWAJALEIN

All target vessels at Bikini had some ammunition on board to serve as test material. Some ships had a great deal, placed there to determine the effects of the atomic bomb on warships having different loading conditions. For example, USS Nevada (BB-36) had more than 1,100 tons of ammunition. Most of the ammunition was service type and highly stable, but some experimental ammunition and some obtained from foreign navies was included. Some service ammunition had been flooded. There was a presumption that ammunition on certain ships was, or would soon become, unstable from the heat and pose a considerable and growing hazard. Its removal would be necessary, and the longer such operations were deferred the more dangerous the work would become. After careful consideration, it was decided that the total hazard would be less if the work were accomplished in 1946 than if it were deferred to a later year when the radioactivity would be reduced but the explosive hazard increased (Reference C.11.4). Because the ships were contaminated, work parties had to wear special clothes and were accompanied by radsafe monitors when aboard them. When working below deck, the men were required to wear rescue breathing apparatus.

For work on the target vessels, the Kwajalein Maintenance Force, Task Unit (TU) 1.2.12 was formed on 28 August 1946 (Reference C.11.5). The flagship was Haven, on which the radsafe unit had its headquarters and laboratories. Geneva was the hotel ship and APL-27 was the change ship, where working party members donned their protective clothing before going aboard target vessels and where they removed that clothing and showered after their work was done. In addition, the unit consisted of USS Conserver (ARS-39), USS Current (ARS-22), LCI-329, LCI(L)-549, LCI(L)-615, YF-753, and assorted small craft for towing, ammunition disposal, and personnel transportation (Reference C.0.22, pp. 4 and 5). At its peak, the total manpower of the unit was approximately 1,500 officers and enlisted men. Haven departed Kwajalein on 10 October, Geneva on 13 October, and Current departed on 2 December; Conserver remained until February 1947.

On 29 August, CTG 1.2 (Target Vessel Group) directed the removal of the approximately 2,700 tons of unstable ammunition from target ships by personnel of the Ammunition Disposal Unit of JTF 1 (Reference C.11.6). Actual unloading commenced on 4 September. The unit consisted of about 10 officers and 275 enlisted personnel (Reference C.10.18). Its personnel were divided into six working teams (one initial boarding team and five ammunition disposal teams),

each consisting of one or two officers and about 40 enlisted personnel. The duties of the initial boarding team were to board, make initial inspection for flooding and other hazardous conditions, obtain current radiological data with the assistance of radsafe monitors, and obtain information pertinent to ammunition inspection and removal as required. When conditions were satisfactory for working on a vessel, the initial boarding team proceeded with opening up, ventilating as necessary, and rigging hoists and other equipment required to proceed with ammunition removal. Then an assigned ammunition team or teams would remove and transfer the ammunition to the lighter YF-753 for disposal at sea or, in certain cases, would leave the ammunition topside and tow the vessel itself to sea and dump the ammunition directly into the sea (Reference C.11.5, p. 2).

Ammunition was removed from each target ship without using any of its own facilities or equipment. Sufficient equipment was obtained to undertake five ammunition-handling operations at one time, which might be on one to five ships. The basic plan was to use pneumatic hoists to lift the ammunition topside on the ship. Portable lighting was used in the magazines and handling rooms. Spaces containing concentrated ether fumes or other explosive gases were ventilated before commencing ammunition removal. Flooded spaces were pumped out sufficiently so that men wearing rubber boots could work in them. Wood chutes were used to transfer the ammunition from the ships' topside to YF-753. To minimize carrying the ammunition across the decks of the ship and barge, roller sections were used where practicable.

Personnel were transported to and from work in LCMs. Five of these were each equipped with a gasoline-engine-driven air compressor and generator. These were connected, respectively, to the portable hoists and the portable lights. A gasoline drum in each equipment boat held a reserve fuel supply.

Working party members entered the change ship, APL-27, from the clean side. Each was issued freshly laundered fatigues, canvas or rubber gloves, rubber boots or field boots with removable canvas covers, and a rescue breathing apparatus, intended to prevent inhalation of radioactive particles. Members of the working party then boarded an LCM from the contaminated side of the change ship for their trip to the target vessel. Upon return to the change ship, each man showered twice, was checked with a Geiger counter to make sure he had removed all contamination, and then changed into his regular clothing. Used canvas gloves and canvas boot covers were thrown overboard. Fatigues were laundered for reuse. The rescue breathing apparatus was checked for contamination and sterilized. Rubber boots and gloves probably were washed (Reference A.2, pp. 143 and 144; Reference C.11.5, pp. 1 and 2).

Ammunition removal was exhausting and potentially dangerous work. Personnel suffered considerably from being required to work fully clothed and wearing the breathing apparatus in the hot, humid Kwajalein climate. Under these trying conditions a man could work only about 30 minutes below decks without a topside break for air. The breathing apparatus restricted their vision, and lighting inside of the ships was poor. The belief, however, at the command level apparently was that the rate of ammunition deterioration required immediate action if an even greater overall hazard was to be avoided (Reference C.11.4, p. 3).

obtaining surveillance powder samples from target ships) were completed. Approximately 1,036 tons of ammunition had been removed from about 35 ships in about 45 days with no serious injuries (Reference C.11.5, p. 1). In the process, 145 rescue breathing apparatus, 900 green fatigue shirts, 900 pairs of green fatigue trousers, 660 pairs of undershorts, 1,500 undershirts, 500 pairs of field shoes, 1,700 towels, 6,180 pairs of canvas work gloves, and 12,500 canvas shoe covers had been discarded. In addition, 150 rescue breathing apparatus were usable but contaminated, as were air compressors, generators, air hoists, and portable blowers used in the operation (Reference C.11.5, pp. 3-4). Exposures for the Ammunition Disposal Unit are discussed in Chapter 12.

In mid-October Commander Marianas requested Commander Service Force, Pacific (ComServPac), to transfer the Ammunition Disposal Unit intact to Guam to dispose of surplus ammunition. In view of the task they were just completing and the length of time they had been in the forward area, Commander Navy Task Group (CNTG) JTF 1 strongly advised against such a transfer and recommended that the entire unit be given leave before reassignment. ComServPac concurred (Reference C.0.24, p. 2).

Concurrent with the completion of this disposal, CNO ordered USS Gasconade (APA-85), USS Fallon (APA-81), USS Crittenden (APA-77), USS Brule (APA-66), Independence, and USS Mayrant (DD-402) towed to San Francisco and Hughes, Pensacola, Salt Lake City, New York, USS Rhind (DD-404), and Nevada towed to the Puget Sound area for examination. The towing was to be in the order listed, with one ship arriving in each area every 2 months. Only six of these twelve ships were ultimately towed to the United States. Brule, Fallon, Rhind, and Mayrant were eventually sunk in the vicinity of Kwajalein. New York and Nevada were towed to Pearl Harbor for inspection and were later sunk off Oahu.

In connection with this, CNO directed that CNTG insure, insofar as practical in the forward area, the removal of all ammunition, including projectiles, before the vessels' arrival at the mainland. This, of course, called for a radical change of plans for the Ammunition Disposal Unit at Kwajalein. The rollup orders already issued for its dissolution on 23 October were cancelled and action was initiated to transfer the entire unit to Atoll Command Kwajalein (AtComKwaj) on 23 October at the same time that the target ship maintenance unit was transferred.

When the rollup plans were cancelled, the officer in charge of the disposal unit flew to Pearl Harbor to confer with CNTG. As a result of this conference, it was decided that removal of powder and small-caliber projectiles before the vessels' departure from Kwajalein would be practical and could be done well within the time limits imposed by the towing schedule. Removal of the large-caliber projectiles however, especially the 14-inch projectiles in New York and Nevada and the 8-inch projectiles in Pensacola, would present a very difficult, if not impossible, problem in view of the limited facilities at Kwajalein, but the task was initiated (Reference C.0.25, p. 1). All unstable ammunition and all pyrotechnics, catapult charges, igniters, detonators, boosters, torpedo expelling charges, and bulk black powder were removed from all target vessels at Kwajalein.

The status of ammunition in the eight target ships that were finally towed from Kwajelein was (Reference C.0.25, p. 12):

USS Crittenden (APA-77)	No ammunition aboard
USS Gasconade (APA-85)	No ammunition aboard
USS Hughes (DD-410)	No ammunition aboard
USS Independence (CVL-22)	No ammunition except two-thirds of the unfuzed normal bomb allowance remained aboard
USS Nevada (BB-33)	Two-thirds of the normal allowance remained aboard
USS New York (BB-36)	Ten percent of the 14-inch projectiles and eight percent of the remaining normal allowance remained aboard
USS Pensacola (CA-24)	No ammunition except two-thirds of the 8-inch projectile allowance and two-thirds of the unfuzed bomb allowance remained aboard
USS Salt Lake City (CA-25)	Ten percent of the normal allowance remained aboard.

When the initial phase of the ammunition disposal was completed, the last of the experienced radiological monitors departed Kwajalein. When work was resumed to unload the target ships due for transfer to the continental United States, the only available monitors were still receiving additional training at Kwajalein after intensive instruction in Washington, D.C. In addition, serious morale problems were developing in the Ammunition Disposal Unit due to doubts and unanswered fears about the effects of radiation and fatigue due to the long, uninterrupted arduous and hazardous duty.

The officer-in-charge dispatched a letter dated 11 November 1946 to the Chief, Navy Bureau of Medicine and Surgery (BuMed) (Reference C.11.7) detailing the concerns of personnel in his unit regarding radiation hazards. He described the problems in the use of the rescue breathing apparatus and the added hazards in handling heavy ammunition when wearing the apparatus in confined dangerous spaces. He recommended better indoctrination and training for those working under similiar conditions, suitable limitation on the length of continuous duty, and -- if it was determined that a protective mask was required -- discontinuance of all unloading until a suitable mask could be developed.

On 29 November the officer-in-charge was advised by the Safety Advisor to JTF 1 (Reference C.11.8) that the answers to some of the questions asked by the men were classified and, in any event, the officer in charge of the Ammunition Disposal Unit should discuss these questions with the Radsafe Advisor and then disseminate the proper information to his personnel. He was further informed that the rescue breathing apparatus was considered necessary by senior radsafe experts and would continue to be worn and that if all safety regulations were complied with no hazard to health was involved in the work. Hence, BuMed did not feel it was necessary to limit the time spent in this type of work (Reference C.11.8).

Clearly, operations at Kwajalein were intense during the early months of the target fleet's presence. The order from CNO to remove additional ammunition prevented the dissolution of the Ammunition Disposal Unit and forced work to continue, apparently with the same personnel (Reference C.0.26). From 1 September 1946 to 31 December 1946, 5,734 badges were issued to personnel of this unit. The period of heaviest issue was September and October; thereafter, very few badges were issued (Reference C.13.4).

The deck logs of Conserver and Current indicate that these ships were extremely busy during this period in mooring, diving, towing, and housekeeping operations on the target fleet at Kwajalein. Between 31 August and 30 November 1946, 14,532 personnel decontaminations (similar to those described in Chapter 2) were carried out aboard the change ship APL-27, an average of 158 each day (Reference C.13.7).

In October the preliminary examination and securing of target ships at Kwajalein was completed. On 1 October, CNO directed that upon dissolving JTF 1, these ships and their caretaking unit be turned over to CINCPAC.

TARGET SHIP ACTIVITIES AFTER JOINT TASK FORCE 1 DISSOLUTION

In accordance with directives of the Joint Chiefs of Staff (JCS), steps were carried out rapidly to complete the work of the task force and to turn over operational control of all units to appropriate commands. As of 24 October no ships or units remained under the operational control of the CJTF 1, and only staff activities were left. The task force was formally dissolved on 1 November 1946 (Reference C.9.206, pp. V-(D)-5 and V-(D)-6).

In all, 63 target ships (12 were remanned after CROSSROADS) passed through Kwajalein. Of these, 41 remained at Kwajalein until sunk. These ships were radiologically contaminated and could not be disposed of until cleared by CNO and Radiological Section BuShips.

On 31 January 1947, Chief BuMed issued additional safety regulations for work on the target ships. The potential internal radiation hazard was emphasized. The exposure of persons boarding ships was to be kept to a minimum, and their exposure was to be appropriately interrupted to reduce the chance of injurious effects. All persons who were to board target ships and who might encounter radiation were to have a preduty physical examination. All personnel connected with work on target ships were to have monthly physical examinations with special attention to their hands. Each individual was to have a weekly urinalysis, including a gross beta count.

Various measures were to be taken to protect the men while at work. A change house was to be provided where the men would dress in hard hats, coveralls fastened at the neck, canvas or rubber gloves, canvas booties over their boots or work shoes, appropriate breathing apparatus, and goggles. Each man was to have a film badge pinned on the left breast of his coveralls. The tolerance limit was 0.1 R per 8-hour day. A work party could not board target vessels without the permission of the radsafe unit and each party had to be accompanied by a monitor. While aboard a target vessel, the men were not to

eat, drink, smoke, or to chew gum or tobacco. They were to avoid pools of water, dust clouds, and piles of rust, paint chips, or the like since each might be a radiation source. When below decks, the men were to wear the rescue breathing apparatus at all times. Upon returning to the change house they were to turn in their film badges, disrobe, and wash thoroughly. The regulations appear to have broken little new ground but instead codified existing CROSSROADS practice (Reference C.11.9, pp. 1 through 8).

On 3 March 1947, Navy Bureau of Personnel reduced the Kwajalein ships' security detail to 5 officers and 127 enlisted men. Both CINCPAC and AtComKwaj considered this to be a minimum number. However, on 31 March there were only 27 men in the unit. The attempt by Kwajalein personnel to keep up with the towing schedule in spite of the manpower shortage operated to contravene the requirement for radiological safety (Reference C.11.10, p. 2).

In a letter to AtComKwaj dated 9 April 1947, the senior monitor assigned to the radsafe section at Kwajalein on 23 January described violations of radsafe procedures he had seen or had good reason to suspect during his time there. Upon arrival he had been given some instructions about radsafe procedures to be followed in working on the target ships, but he had been shown no written regulations. In his work, this Navy ensign observed men smoking and lounging about the decks of target ships and boarding parties going aboard Pensacola without first passing through the change ship. He believed that personnel sometimes ate aboard the target vessels and that work parties unaccompanied by a monitor sometimes boarded them. He believed looting was common. The monitor was also very concerned that men were not wearing rescue breathing apparatus while on the decks of the target vessels, but the BuMed regulations of 31 January did not make it mandatory in all circumstances (Reference C.0.27, pp. 7 and 8).

When the ensign reported his observations and suspicions to the Medical Radsafe Officer at Kwajalein, the doctor showed him a list of safety precautions for boarding target vessels sent by BuMed. From the monitor's letter it cannot be determined, however, whether these were the regulations of 31 January as amended or some other document. The doctor apparently had not been aware of the violations of BuMed's rules. On 13 March the monitor showed the safety precautions to the officer in charge of the change ship. Together they checked fatigues and found "numerous" high readings. The monitor's letter gives the impression that the officer in charge of the change ship had not previously seen the list of safety precautions.

The senior monitor also showed the precautions to the captain of the salvage vessel from which work parties had boarded Pensacola without passing first through the change ship. The captain visited the radsafe officer to discuss the precautions. The monitor's revelations led to a meeting on 20 March attended by the Medical Radsafe Officer, the captains of Conserver and Current, AtComKwaj, the monitors, and another official. Greater efforts to follow BuMed's guidelines apparently followed. The monitor also had been concerned about the unreliability of the radiation detection instruments, but the meeting did not produce actions that relieved his apprehension. He wrote that "our instruments are still very unreliable and I felt unsafe in boarding without proper equipment. I told [the radsafe officer] that I thought operations should cease

because we knew so little about the dangers we were dealing with" (Reference C.0.28).

The complaints of the senior monitor to AtComKwaj were passed to higher authorities. CINCPAC, in a letter endorsement to Chief BuMed, stated that AtComKwaj had been instructed on 10 April to fully comply with existing safety regulations at the cost of curtailing security measures and, if necessary, falling behind in towing schedules. He noted that a serious health hazard existed if safety regulations were not strictly maintained (Reference C.11.22).

The problem was essentially one of manpower, as less than 200 personnel were assigned to the ship's security detail. This was too few personnel to maintain the desired schedule of preparing ships for tow back to Navy shipyards. This fact and its consequences were acknowledged in a letter from CNO to Chief of Naval Personnel dated 15 July 1947. The letter observed that in many instances certain recognized safety precautions were violated, attributable to the towing schedule, inadequate indoctrination of men, and insufficient supervisory personnel. It stated, however, that in the opinion of responsible persons experienced in the subject that, in fact, no individual actually was subjected to danger. In order to substantiate that opinion, the letter stated that a broad survey of all persons involved had been instituted (Reference C.0.33).

The results of this broad survey have not been located. The survey may refer to the blood tests administered to all Navy CROSSROADS participants (Reference C.11.23). There is evidence that action at Kwajalein in this regard was underway at least by April 1947. A 17 May message from AtComKwaj to BuMed advised that blood tests given at Kwajalein established that exposed personnel were disqualified from additional work detail. He noted that the results had urgent medical implications and impacted on personnel rotation policies (Reference C.11.24).

A standard gamma source to calibrate instruments was provided by 5 June 1947, and the hope was voiced that a suitable alpha counter could be provided "eventually." Moreover, the bureaus concerned were going to supply "essential technical help," apparently meaning more personnel (Reference B.11.1). This last effort probably was related to the monitor shortage at Kwajalein. During April 1947, the radsafe unit was down to one monitor; hence only one working party at a time could enter radiologically suspect areas (Reference C.0.29).

Commencing in June 1947, Kwajalein and all shipyards where target ships were located began monthly reports of personnel film badge exposures. These monthly reports to BuMed continued until November 1948. Until at least July 1948, a ship's security detail existed at Kwajalein to care for the target ships. Protective clothing was apparently worn by U.S. shipyard personnel when working with the CROSSROADS target ships, judging from an inspection photo (Figure 38) of the engine room of Hughes at Puget Sound in April 1948.

CONTAMINATION OF SUPPORT SHIPS

The majority of the support ships did not reenter Bikini Lagoon until after 31 July when the lagoon water was below 0.1 R/24 hours. Within 3 days,

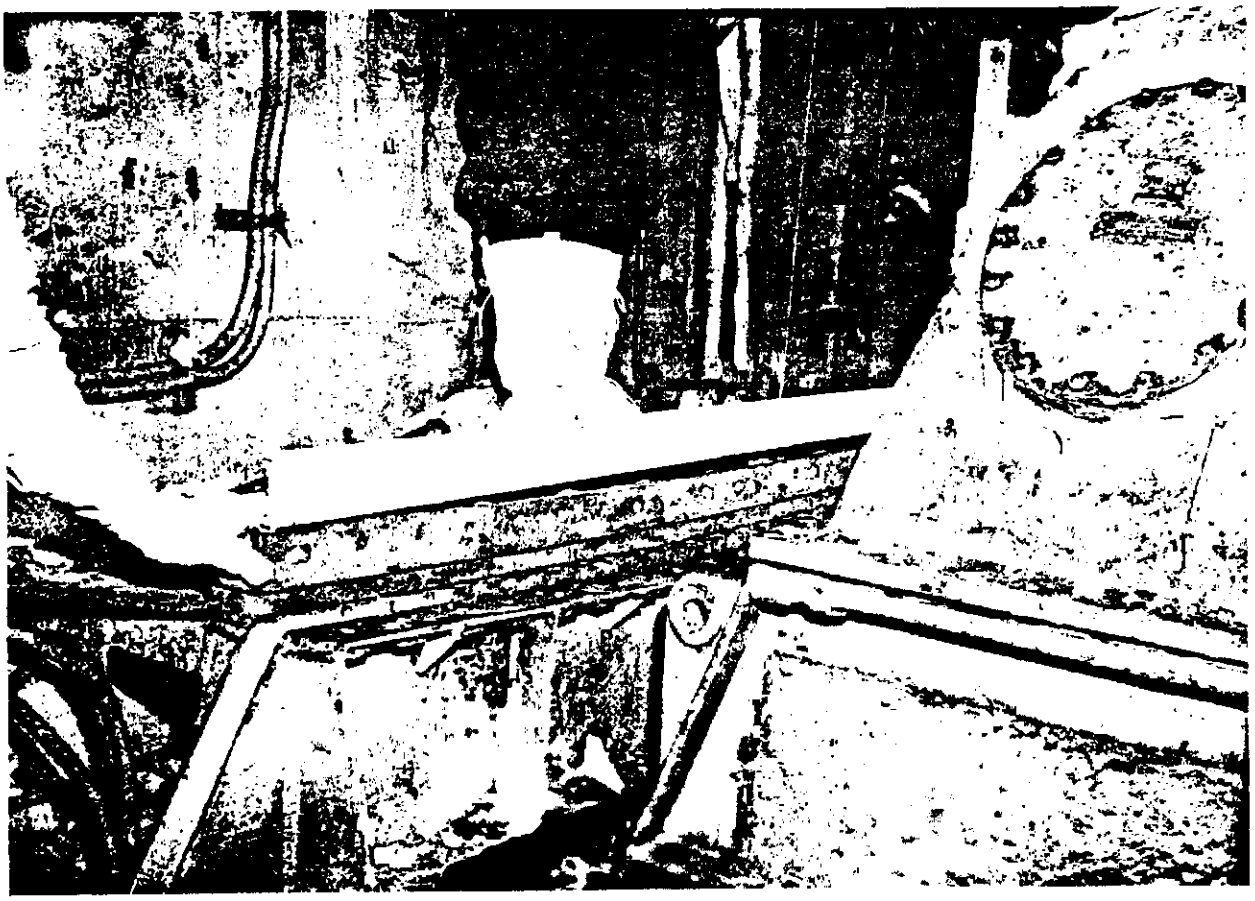

Figure 38. Inspection of USS Hughes (DD-410) at Puget Sound Naval Shipyard in 1948 showing workers wearing protective shoe covers and gloves.

concentrations of radioactive contamination were observed in the marine growth and rust on their hull exteriors at the waterline. Even though the water in which the ships were anchored showed a radiation intensity of only about 0.01 R/24 hours, the radioactivity collected on the hulls to such an extent that several ships had interior readings in the vicinity of the waterline exceeding 0.1 R/24 hours (Reference C.9.185, p. 18).

Decontamination at Bikini

On 29 July, faced with increasing radioactivity in the water where the ships were anchored and hoping to deal with problems of contamination, the support ships and the target ships that had been cleared as radiologically safe were moved to a new anchorage in the southeast portion of the lagoon (Reference C.9.185, p. 19; Reference A.2, p. 101). All ships were ordered to list ship, that is, change ballast, causing them to list and expose portions of their hulls below the waterline for scraping (Reference C.9.185, p. 19). Rather than immerse themselves in the lagoon water, personnel were to use long-handled scrapers (Reference C.10.7). Because the ships' evaporators used to distill freshwater concentrated radiation from the lagoon water in the scale on the inner surfaces of their shells and tubing, radiation levels near some of them exceeded the 0.1 R/24 hours limit.

Orders were issued not to open evaporators without specific authorization of the radsafe section and then only with a monitor present (Reference C.10.3). Experiments showed that the evaporators would not pass radioactivity over into distilled water if they were operated at somewhat reduced rates. Orders to operate at reduced rates were issued, although sources available disagree on whether the approved rate was 75 or 80 percent (Reference C.9.185, p. 19; Reference C.10.6). To remove some of the contaminated scale, ships were to use the "cold-shock" treatment; that is, cold water was run through the hot evaporator tubes that had accumulated radioactive scale. The pipes' rapid contraction caused the scale to flake off and be flushed out (Reference C.10.6). To decrease the formation of new scale, ships were ordered to use a standard scale reduction technique of introducing a mixture of boiler compound and cornstarch continuously into the evaporators (Reference C.10.1). In an effort to reduce contamination on hulls and in evaporators, a number of support ships left the lagoon for one-day trips in the open ocean to flush the sides and interior systems with clear saltwater.

These measures reduced the radiation level inside most ships to 0.1 R/24 hours (gamma) or less. To keep radiation levels down, the ships, where possible, were kept in water indicating 0.001 R/24 hours (gamma) or less. Numerous exceptions to this were necessary, however, to carry out the duties of the task force. Ships used for salvage, radsafe, and survey work sometimes needed to enter waters with higher levels of radioactivity. One source indicated that in some cases a ship's crew was evacuated and the ship was allowed to stand idle, presumably in water with low radioactivity levels, until the readings inside fell below the 0.1 R/24 hours level (Reference C.9.185, p. 20). The source does not indicate the number of ships in this category.

Shift to Kwajalein

On 11 August, CJTF 1 asked the CNO for permission to shift the task force's base to Kwajalein, asserting that the tendency of ships to accumulate radioactivity, especially in their evaporators and in the marine growth on their hulls, mandated leaving Bikini. He emphasized that no hazard to Kwajalein would result and that preparations for CHARLIE (the anticipated third CROSSROADS shot) would not be compromised (Reference C.10.4).

On 19 August the task force was ordered to shift base to Kwajalein. Nontarget ships that had reentered the lagoon were monitored before departure and given conditional operational clearances, subject to employing safety procedures to meet each ship's condition. Most were restricted on the amount of time personnel could spend in certain compartments and near certain pieces of equipment (Reference C.9.206, p. V-(D)-4; Reference C.9.185, p. 20).

Commander Joint Task Force 1 Letter of 19 August 1946

Although it was hoped that natural decay and steaming in the open ocean would minimize radioactive expoure of personnel, the Chief of Staff of JTF 1 sent a letter on 19 August to commanding officers of all ships that had been in the lagoon between 25 July and 10 August and hence were radiologically suspect. He wrote that before these ships could be considered completely clear, further monitoring would be needed, especially to ensure the safety of personnel

scraping ships' bottoms or working on their evaporators. Arrangments were being made for radiological monitors to be available at naval shipyards and principal ports on the U.S. west coast and Pearl Harbor. Commanding officers of the ships involved were to request these monitors before having evaporators opened, having work done on other contaminated machinery, or entering drydock (Reference C.9.185, pp. 144 and 145).

After further study, the task force radsafe and safety advisors decided the precautions set forth in the letter of 19 August were inadequate to protect personnel from alpha emitters associated with the detected radiation. Moreover, considerable cleaning would be required to eliminate radioactivity, and the cleaning itself and the wastes created would pose yet another problem. After a conference with the safety advisors, the ComServPac on 29 August issued special precautions to be applied to all vessels that had spent more than 10 days in Bikini Lagoon after 25 July (Reference C.9.185, p. 21). In summary, the precautions were as follows:

1. Avoid drydocking until further notice
2. Avoid opening saltwater plumbing
3. Avoid exposing the external surface of the hull below the waterline
4. Avoid exposing personnel to fumes or dust from welding, cutting, or other work on contaminated saltwater surfaces.

He also recommended the ships be examined at San Francisco or Pearl Harbor to determine their exact radiological status and to indoctrinate crews in proper radsafe procedures (Reference C.10.5).

CJTF 1 concurred with ComServPac, but argued that ships in the western Pacific should return to Guam for radiological monitoring. He advised that JTF 1 was organizing a monitoring group for use at San Francisco, Pearl Harbor, and other ports as required. He recommended that docking or yard work on the affected ships be avoided until they had been monitored and declared radiologically safe. Finally, he suggested that the precautions applied to the ships also be applied to the small boats they carried (Reference C.9.185, p. 22). On 28 August CNO directed compliance with these recommendations and two days later ordered all small boats found radiologically unsafe sunk in deep water (Reference C.9.185, pp. 22 and 23; Reference C.10.4, p. 1).

RADIOLOGICAL CLEARANCE OF NONTARGET SHIPS

CJTF 1 dispatched his Chief Medical Officer to head the program for giving radiological clearance to nontarget vessels. On 26 August the medical officer established his headquarters in the offices of the 12th District Medical Officer at San Francisco Naval Shipyard. He encountered immediate difficulties. Radsafe monitors were not available at San Francisco in numbers sufficient to check the many ships expected to arrive during the coming weeks. Monitors were drawn from the ranks of those who had served during CROSSROADS and from the radsafe organization at Kwajalein, but at some cost to operations there. The first graduates of the JTF 1 radsafe school became available for duty by mid-October. Although some were assigned to Kwajalein, most were assigned to

shipyards or laboratories on the west coast or in Hawaii where they worked on problems presented by the contaminated nontarget vessels. Because no safe and effective methods had yet been developed for removing the known or suspected contamination on the nontarget ships, only a list of precautionary measures could be given to ships' captains. These measures were principally as follows (Reference C.9.185, p. 24):

1. Treat evaporators using starch and boiler compound, cold shocking, or, in the case of vapor compression stills, standard cleaning
2. Sink at sea all radiologically hazardous equipment made from wood and plant fibers, such as lines, fenders, nets, camels, and swabs
3. Prohibit burning, welding, chipping or wire-brushing of saltwater lines or exposed saltwater surfaces except under the supervision of a monitor. Scraping is permitted on surfaces provided they are kept wet at all times.
4. When dropping anchor avoid the dust raised from the outgoing chain, keep the anchor wet, use gloves when handling the anchor and chain, and discard the gloves after use
5. Sink small boats with readings greater than 0.1 R/24 hours
6. Scrub urinals and head troughs with abrasive cleaner or acid solution.

In an effort to determine accurately the contamination level on nontarget ships exposed at Bikini, Commander Western Sea Frontier (ComWestSeaFron) on 30 August ordered Commander 12th Naval District to drydock one of the destroyers from the joint task force at the San Francisco Naval Shipyard. USS Laffey (DD-724) was drydocked and inspected on 5 September under supervision of the JTF 1 Chief Medical Officer. The underwater portion of the hull and portions of the saltwater plumbing were monitored. Shipyard workers in protective clothing and breathing apparatus chipped off samples of rust, paint, and scale. Radiation levels detectable with hand-held instruments were found to be below the accepted tolerance level. Samples were also taken from USS Whiting (AV-14), USS Henrico (APA-45), and USS Mount McKinley (AGC-7). The samples were sent to the University of California's Crocker Radiation Laboratory for further analysis, especially for the presence of alpha emitters. Encouraged by the low readings, the medical officer gave permission for overhaul work on USS Walke (DD-723), USS Barton (DD-722), USS Lowry (DD-770), and Laffey, except that work involving the exterior of the hull below the waterline or the saltwater plumbing had to await the arrival of sufficient monitors. A decontamination center was established for yard employees working on the ships (Reference C.9.185, pp. 28 and 32; Reference C.12.2, pp. 84 and 85).

In late August and early September, however, concern increased in command circles that unless a means could be found to service the underwater hulls and saltwater plumbing of the nontarget vessels, they would eventually be rendered useless.

On 9 September 1946, CJTF 1 sent a letter (Serial 079) to commanding officers of all nontarget ships suspected of being contaminated. His purpose was

to make them aware of the discussion in progress, to summarize safety precautions, and to give information on the clearance procedure under development (Reference C.9.185, pp. 125 and 145). His letter, however, did not (Reference C.9.185, pp. 25 and 26):

1. Establish adequate decontamination procedures or a plan for developing them
2. Establish the final tolerance level for alpha emitters, the alleged principal hazard
3. Assign responsibility for decontamination and final clearance.

During the next several months the Navy put considerable effort into filling these gaps.

ComWestSeaFron on 11 September recommended to CNO that highest priority be given to providing staff for the JTF 1 Medical Officer, that BuShips have the responsibility for developing decontamination methods, and that the DSM be dispatched to the west coast as BuShips' representative. On 13 September CNO advised that ComWestSeaFron and BuShips had been assigned the responsibility and that the DSM was on his way, to arrive on 17 September (Reference C.9.185, pp. 26 and 27).

Decontamination Experiments at San Francisco Naval Shipyard

Meanwhile, efforts to measure contamination continued. On 12, 13, and 19 September portions of Laffey's hull were sandblasted and particle samples collected in filter devices set up nearby. A section of contaminated saltwater pipe was burned through in a small, closed compartment and particulate samples collected in a filter device (Reference C.9.185, p. 29). The samples were taken to the University of California Crocker Radiation Laboratory for analysis.

Methods for cleaning contaminated saltwater lines were tested. On 13 and 17 September various acid solutions were pumped into sections of Laffey's saltwater plumbing and then the sections were flushed a number of times. The result was a considerable reduction in radiation levels. These experiments were judged completely successful. Also on 17 September preparations were made to test acid solutions on the saltwater plumbing of a second ship, Henrico (Reference C.9.185, pp. 30 and 32).

The DSM arrived on 17 September, and during the next few days, he conferred with officials supervising contamination measurement and decontamination experiments. He inspected the work being done on Laffey and USS Benevolence (AH-13) (Reference C.9.185, pp. 30 through 33).

On 20 September, laboratory assays of rust, evaporator and condenser scale, saltwater lines, algae from the hull, and other samples from Laffey, Kenneth Whiting, Henrico, and Mount McKinley were completed. They indicated that the amount of plutonium (an alpha emitter) associated with fission products (beta and gamma emitters) was quite constant. Thus -- the plutonium concentration -- could therefore be estimated from the fission product activity with a Geiger counter (Reference C.11.17).

Taking samples for laboratory analysis was unnecessary, since analysis of the filter samples taken while sandblasting portions of Laffey's hull showed no detectable plutonium. Using the ratio of plutonium to fission products to calculate the amount of plutonium present led to an estimate that a worker using a respirator would have to spend 100 million days of wet-sandblasting to inhale a dangerous amount of plutonium. From this came the conclusion that ships up to 100 times as contaminated as Laffey could be sandblasted without exposing shipyard personnel to a lung hazard. Filter samples collected during welding of contaminated saltwater lines also revealed no plutonium. Calculations using the plutonium-fission products ratio indicated an individual would need to weld for 1,000 days to accumulate a dangerous amount of plutonium in his body (Reference C.9.185, pp. 32 and 33). The findings of the laboratory assays appeared to show that nontarget ships of JTF 1 could be decontaminated and overhauled without radiological hazard to personnel, but, as discussed below, that work did not go forward immediately because of fears among the experts that hard-to-detect dangers were still present (Reference C.9.185, pp. 32 and 33).

The Question of Clearance Standards

About 20 September, the DSM left San Francisco for Washington, D.C., to present the findings from the decontamination experiments to higher authority. In Washington he prepared a directive setting forth the decontamination procedures established up to that point. Issued on 24 September as a joint BuShips-BuMed speedletter, it included authority and direction for decontamination of evaporators, heat-transfer apparatus (except condensers*), hulls beneath the waterline, and ships' boats of all contaminated ships scheduled to remain in the active fleet. Members of each ship's crew were to clean the evaporators and heat-transfer apparatus as soon as practical. Hulls were to be cleaned below the waterline using standard wet sandblasting methods at the time of a ship's next scheduled drydock period. Debris from cleaning evaporators and heat-transfer devices and sand from sandblasting were to be kept wet until dumped at sea. Monitors were desirable but not essential for this work. Saltwater lines could be cut and welded without hazard, but sections removed were to be dumped at sea. All zinc plates used to retard electrolytic action were to be removed from main and auxiliary condensers and discarded at sea. Different rules were being developed to cover ships scheduled for disposal or deactivation (Reference C.9.187, pp. 16 and 19).

The DSM's directive was greeted with great enthusiasm by all commands concerned. The message from CJTF 1 on 9 September had led to fears that a great and indeterminant hazard to personnel was present. Now the hazard had been found to be minimal if the indicated safety precautions were taken. The methods to remove contamination were not too complicated, and regular maintenance could proceed more or less on schedule. BuShips representatives taking part in the work at San Francisco visited the 11th, 13th, and 14th Naval Districts at San Diego, Seattle, and Pearl Harbor, respectively, to brief shipyard management

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* A condenser is a low-pressure heat-transfer device for changing steam to water in a propulsion or similiar closed-cycle system. It should not be confused with the evaporators used to distill freshwater.

on the decontamination procedures (Reference C.9.185, p. 36). Meanwhile, a vigorous program of decontamination experiments went on at the San Francisco Naval Shipyard in an effort to develop better methods.

However, considerable uncertainty persisted about whether the 0.1 R/24 hours standard, as measured with a Geiger counter or similiar device, could be used for determining when a vessel required decontamination and when it could be considered safe and given clearance. No reliable instrument was available for determining the presence or absence of alpha contamination in the field. Analyses of the samples taken from Laffey, Whiting, Henrico, and Mount McKinley had provided an approximate ratio of plutonium to fission products, but no radsafe expert of recognized reputation was ready to declare that a Geiger reading of 0.1 R/24 hours or less assured protection from the total alpha hazard, that is, from plutonium or any other alpha emitters (Reference C.9.185, p. 41).

Consequently, BuShips called a conference in San Francisco on 1 October to grapple with the problem. The decision was made to study contamination of USS Rockbridge (APA-228). At that time it was considered the most heavily contaminated ship to arrive in the area, and it was of a size and type judged suitable for a detailed study of wide implications. The hope was not only to improve the accuracy of the plutonium ratio, but particularly to determine the total amount of plutonium on the ship. The figure could then be used as the basis for the needed standards. Numerous samples were taken from the ship and sent to the University of California for analysis, but the University's facilities for radiochemical analysis were sufficiently limited that weeks passed before the results were available (Reference C.9.185, pp. 41, 45 and 46).

While awaiting the results of the work on Rockbridge, BuShips in Washington, D.C., on 10 October proposed a set of contamination limits. After discussions between naval and civilian radsafe experts on the west coast and BuShips and BuMed in Washington, the final clearance standard for all ships was set at 0.001 R/24 hours (gamma) from shielded sources and 0.005 R/24 hours (combined beta and gamma) from exposed surfaces, subject to change if required by new information. These limits required decontamination of almost all nontarget ships that spent more than one day in the Bikini Lagoon after BAKER (Reference C.9.185, p. 49). Twelve ships were found to be within radiological limits. These ships were associated with CROSSROADS, but either had never entered Bikini after Baker or had been in the lagoon following BAKER for 1 to 3 days. They were USS Charles P. Cecil (DD-835), USS Limestone (IX-158), USS LST-871, USS LST-989, USS Albemarle (AV-5), USS Panamint (AGC-13), USS Appalachian (AGC-1), USS Blue Ridge (AGC-2), USS Furse (DD-882), USS Turner (DD-834), USS Shangri-La (CV-38), and USS Bountiful (AH-9).

Decontamination work on a large scale apparently started after 14 October, when BuShips authorized crews of all nontarget ships, including those scheduled for disposal and deactivation, immediately to go forward with acid cleaning of evaporators and of firefighting, flushing, cooling, and drainage systems. At least 55 nontarget ships that had arrived at one of the west coast naval districts were involved. CINCPAC and ComWestSeaFron were to see that the work was done. The final clearance limits recently agreed upon by BuShips and other interested parties were used, however, only as a temporary standard for

"operational, conditional, or preliminary" clearance, pending the analysis and availability of Rockbridge data (Reference C.9.185, pp. 50 through 52).

Results of the assay of fission products and plutonium on Rockbridge were available on 25 October 1946 from the University of California. At the time of the collection of the samples, radsafe monitors reported the external hull readings were 0.009 to 0.010 R/24 hours (beta plus gamma). The total activity calculated to be present on Rockbridge was 376 millicuries of fission product activity and 2.020 milligrams of plutonium. This material was distributed inside 23,207 ft^2 (2.16 km^2) of saltwater piping, inside 12,780 ft^2 (1.18 km^2) of condenser and evaporator interiors, and the entire underwater hull. The hull contamination when removed was contained in the 125 tons of sand used to sandblast the external hull. Although about two tolerance doses of plutonium were detected, these and the fission products were spread over an extremely large area and in locations that greatly reduced the potential exposure to personnel (Reference C.11.18; Reference C.9.185, p. 56).

In addition to continuing uncertainty about final clearance standards, the decontamination regulations promulgated up to that time had two gaps: (1) how to determine contamination of a ship's hull without time-consuming and expensive drydocking, and (2) how to remove contamination from condensers. At that point BuMed appointed a special medical board to advise the Navy's Surgeon General, who was Chief of BuMed, on radiological matters presented to it for study. It was chaired by the Medical Officer dispatched to San Francisco in late August by CJTF 1 and included the Radsafe Advisor to CJTF 1 and radiation experts from the University of California (Reference C.9.185, p. 54).

The medical board held its first general meeting on 4 November to consider results of analysis of Rockbridge samples. After much discussion, the members of the board suggested a set of final clearance standards, but these were not acceptable either to BuMed or BuShips. BuShips sent a representative to the west coast, and after consultation with the BuShips representative and additional study, the board proposed a new set of final radiological clearance standards as follows (Reference C.9.185, p. 56):

1. Habitually closed saltwater systems were not to have exterior readings exceeding:
   a. 0.001 R/24 hours (gamma) for 94 percent of the system
   b. 0.005 R/24 hours (gamma) for 5 percent of the system
   c. 0.01 R/24 hours (gamma) for 1 percent of the system.
2. Open systems were not to exceed an average of 0.001 R/24 hours (gamma) and 0.005 R/24 hours (gamma plus beta)
3. Underwater portions of the hull exposed by listing and trimming were not to exceed an average of 0.02 R/24 hours (gamma plus beta) wet or dry.

BuShips accepted these standards for final clearance. For operational or preliminary clearance, the bureau took the standards the board had originally set for active ships, namely (Reference C.9.185, pp. 54 and 55):

1. For shielded systems -- 0.01 R/24 hours (gamma)
2. For unshielded systems and surfaces -- 0.05 R/24 hours (gamma plus beta)
3. For underwater body -- 0.05 R/24 hours (gamma plus beta).

During the development of clearance standards, work had continued at the San Francisco Naval Shipyard on removing radioactivity from condensers and satisfactory methods had been worked out.

Clearance Standards Adopted

On 22 November, BuMed, and BuShips jointly issued a letter giving agreed-upon decontamination methods and clearance standards (Reference C.9.187, pp. 30 through 51), which superseded all previous directives (Reference C.9.185, pp. 57 and 58).

The criteria for clearance are:

(1) The existence of any areas of radioactivity with readings in excess of 0.1r (gamma) or 0.5r (beta) combined will be considered as above safety tolerance for external radiation and will be immediately decontaminated or disposed of, and there will be taken such other precautions as are required to insure safety of personnel. Serious radioactive hazard, not involving external radiation, will exist in enclosed salt water systems which give a reading of 0.1r (gamma) through the metal of the system. All areas of contamination within closed saltwater systems with readings between 0.1 and 0.01 gamma on external reading will be decontaminated immediately.

(2) Operational Clearance MAY be granted for urgent reasons when readings are:

(a) Maximum, shielded, between 0.1 and 0.001r gamma

(b) Maximum, unshielded, between 0.5 and 0.005r beta gamma combined except underwater bodies with surface readings having statistical averages between 0.5 and 0.02 beta gamma combined.

Operational Clearance WILL be granted when readings are:

(a) Maximum, shielded, between 0.01 and 0.001r gamma

(b) Maximum, unshielded, between 0.05 and 0.005r gamma beta combined except hulls of external surface readings having statistical averages between 0.05 and 0.02 R beta gamma combined.

(3) Final Clearance will be granted when readings are:

(a) Maximum, shielded, not above 0.001r gamma

(b) Maximum, unshielded, not above 0.005r gamma beta combined.

> Exception (a) Underwater body, readings statistically averaged not above 0.02r beta gamma combined and with no single localized area in excess of 0.1r beta gamma combined
>
> Exception (b) salt water systems having external readings ninety-four (94) per cent of which are not above 0.001r gamma, five (5) per cent not above 0.005r (gamma) and, one (1) per cent not above 0.01r gamma.

The letter also stated:

> All of the ships involved (target vessels not included) have low radiation intensities and small amounts of contaminating materials. They present no danger from external radiation. Any danger to personnel which may exist involves the introduction of contaminating toxic materials into the body . . . . Considering the relatively small quantities of toxic material present in any one ship and the great amount of gross material with which it is mixed (marine growth, scale, rust) and the quantities of this gross material necessary to gain access to the body in order to produce physical injury due to radioactive effects it is NOT LIKELY that personnel engaged in routine operations or maintenance of these vessels will suffer injury. It is CERTAIN they will not suffer injury if the precautions directed are followed, and the established clearance procedures complied with. The Bureau of Medicine and Surgery has established certain tolerance limits on the basis of recommendations made by an advisory board of experts in this field of toxicology. These are in conformity with nationally accepted standards for safety in regard to external radiation and to radioactive hazards within the body.

On 27 November at a conference on radiological safety convened by Buships in Washington D.C., a University of California scientist speaking to the question of dangers from scraping CROSSROADS nontarget ships took much the same position. He stated that much authoritative information indicated the insoluble form of plutonium used in nuclear weapons was not absorbed in the digestive tract or the lungs unless quantities as large as a gram were present. He argued that the health hazards from long-lived fission products, such as strontium and cesium, were far greater than from plutonium. The amount of such fission products would be on the order of 50 millicuries in many tons of scrap. This quantity of radioactive material was equivalent to the amount of radium found in ordinary rock. Therefore, he was willing to state positively that there was absolutely no possibility of physical injury from the amounts of radioactive material present on the nontarget ships (Reference C.9.187, pp. 112 and 113).

On 18 December, results from tests at the University of California indicated that decay rates of gamma emitters were much greater than had been realized. This led to some revision of the clearance instructions, and a reestimation that all nontarget ships would receive final clearance by 15 March 1947 (Reference C.9.185, pp. 60 and 61).

Activities at Other Shipyards

In order to avoid overtaxing the facilities at San Francisco, ComServPac, CJTF 1, and CNO issued orders that established decontamination and clearance centers at San Francisco, Pearl Harbor, Guam, and other selected shipyards (Reference C.9.185, p. 22). This culminated in the ultimate dispersal of ships to the various shipyards as follows (target ships are noted with an asterisk (Reference C.13.3):

SAN FRANCISCO

USS Achomawi (ATF-148)
USS Appalachian (AGC-1)
USS Appling (APA-58)
USS Artemis (AKA-21)
ATR-40
ATA-187
ATA-192
USS Avery Island (AG-76)
USS Barton (DD-722)
USS Benevolence (AH-13)
*USS Bladen (APA-63)
USS Bottineau (APA-235)
USS Bowditch (AGS-4)
USS Cebu (ARG-6)
USS Chickasaw (ATF-83)
*USS Conyngham (DD-371)
*USS Cortland (APA-75)
*USS Crittenden (APA-77)
USS Deliver (ARS-23)
USS Dixie (AD-14)
USS Enoree (AO-69)
*USS Fillmore (APA-83)
USS Gasconade (APA-85)
*USS Geneva (APA-86)
USS Henrico (APA-45)
*USS Independence (CVL-22)
USS James M. Gillis (AGS-13)
USS John Blish (AGS-10)
USS Laffey (DD-724)
*LCI(L)-549
*LCI(L)-615
USS Lowry (DD-770)
USS LST-338
USS LST-817
USS LST-861
USS LST-871
USS LST-881
USS LST-989
USS Moale (DD-693)
USS Munsee (ATF-107)
*USS Niagara (APA-87)
USS O'Brien (DD-725)
USS Palmyra (ARS[T]-3)
USS Rockbridge (APA-228)
USS Rockingham (APA-229)
USS Rockwall (APA-230)
USS San Marcos (LSD-25)
USS Walke (DD-723)
USS Widgeon (ASR-1)

MARE ISLAND

*USS Dentuda (SS-335)
USS Fulton (AS-11)
*USS Parche (SS-384)
*USS Searaven (SS-196)
*USS Skate (SS-305)
*USS Skipjack (SS-189)
*USS Tuna (SS-203)

PEARL HARBOR

ARD-29
USCG Bramble (WAGL-392)
USS Chowanoc (ATF-100)
USS Current (ARS-22)
USS Flusser (DD-368)
USS Hesperia (AKA-13)
LCI(L)-1062
*USS Nevada (BB-36)
*USS New York (BB-34)
USS Oneota (AN-85)
USS Orca (AVP-49)
USS Ottowa (AKA-101)
PGM-23
PGM-24
PGM-31
USS Shakamaxon (AN-88)

PUGET SOUND

USS Allen M. Sumner (DD-692)
ATR-87
ATA-124
ATA-180
USS Bayfield (APA-33)
USS Chikaskia (AO-54)
USS Etlah (AN-79)
USS Ingraham (DD-654)
*USS Hughes (DD-410)
USS Robert K. Huntington (DD-781)
*USS Pensacola (CA-24)
USS Pollux (AKS-4)
USS Quartz (IX-150)
*USS Salt Lake City (CA-25)
USS Suncock (AN-80)
USS Wharton (AP-7)
USS Wildcat (AW-2)

GUAM, MARIANAS

LCI(L)-977
LCI(L)-1067
LCI(L)-1091
LCT-1130
LCT-1155
LCT-1184
LCT-1341
LCT-1361
LCT-1377
LCT-1420
LCT-1461
YF-990
YMS-354
YMS-358
YMS-413
YMS-463
YO-132

SAN DIEGO

USS Ajax (AR-6)
ATA-185
USS Begor (APD-127)
USS Bexar (APA-237)
USS Coucal (ASR-8)
USS George Clymer (APA-27)
USS Mount McKinley (AGC-7)
USS Newman K. Perry (DD-883)
USS Rolette (AKA-99)
USS Saidor (CVE-117)
USS Saint Croix (APA-231)

LOS ANGELES

USS Albemarle (AV-5)
USS Blue Ridge (AGC-2)
USS Clamp (ARS-33)
USS Coasters Harbor (AG-74)
USS Creon (ARL-11)
USS Cumberland Sound (AV-17)
USS Dutton (AGS-8)
USS Fall River (CA-131)
USS Furse (DD-882)
USS Gunston Hall (LSD-5)
USS Haven (AH-12)
USS Kenneth Whiting (AV-14)
USS Mender (ARSD-2)
USS Panamint (AGC-13)
USS Phaon (ARB-3)
USS Preserver (ARS-8)
USS Presque Isle (APB-44)
USS Reclaimer (ARS-42)
USS Severn (AO-61)
USS Sioux (ATF-75)
USS Sphinx (ARL-24)
USS Telamon (ARB-8)
USS Tombigbee (AOG-11)

KWAJALEIN

APL-27

PHILIPPINES

PGM-32

NORFOLK, VIRGINIA

USS Burleson (APA-67)

NEW ORLEANS, LOUISIANA

PGM-25
PGM-29

Information is lacking on decontamination procedures used at shipyards other than San Fransisco. San Francisco was, however, the center of research and expertise on the problem and decontamination is considered to have been standard at all naval yards. Moreover, warnings and instructions flowed at a fairly brisk rate from CJTF 1, BuMed, and BuShips. In dealing with such a new and unfamiliar problem, responsible officials at other shipyards had little to depend on except the procedures developed at San Francisco and ordered by central naval authorities.

By 1 January 1947, 80 nontarget ships had been granted final radiological clearance (Reference C.9.185, p. 59). On 28 February, the status of nontarget ship clearance was as follows (Reference C.0.1, p. 3):

Ships with final clearance, including 12 not exposed	128
Ships with operational clearance and recommended for final clearance	4
Ships with operational clearance but requiring more work for final clearance	3
Ships without either clearance	22
Nontarget ships destroyed since BAKER	2

Disposal of Sand and Acid Used in Decontamination

Cleaning ships' hulls using wet sandblasting and cleaning saltwater piping using various acid solution began early in the effort to decontaminate nontarget CROSSROADS vessels. Until 4 December 1946, the sand and acid solution used in decontamination was segregated and disposed of at sea.

The problem of disposal was discussed at the Washington BuShips conference on 27 November. The conferees concluded that (Reference C.9.187, pp. 108 and 109):

1. Special disposal of sand used in sandblasting underwater bodies of radioactively contaminated nontarget ships is not required, provided marine growth is removed first and disposed of.
2. Solutions used in removal of radioactivity from saltwater systems of nontarget ships may be discharged into harbors, preferably at a slow rate or after dilution, without security or health hazard.

Based on experience at the San Franciso Naval Shipyard and the discussion at the conference, CJTF 1 issued a message on 4 December stating, in part, that (Reference C.9.187, p. 53):

1. Special disposal of sand used in wet sandblasting of underwater bodies of CROSSROADS nontarget vessels is not required.
2. Marine growth and scale removed from vessels at first drydocking shall be segregated and sunk at sea as previously prescribed.

3. Acid and other decontaminating solutions used in cleaning saltwater systems may be discharged into the harbor. Solutions should be discharged at slow rate or by providing a flow of water along with the discharge so as to dilute the solution by about one-fourth. Discharge should be made well clear of docks and shorelines during ebb tide.

4. Scales and marine growth removed manually from evaporators and saltwater systems shall be segregated and sunk at sea.

Of the approximately 54 ships decontaminated at San Francisco only 9 were decontaminated after 4 December. In a 1982 letter from the U.S. Navy to the mayor of San Francisco regarding her concern of radiation contamination of San Francisco Bay, the issue was readdressed (Reference C.13.3):

> Records of the quantities of radioactive fission products which were discharged into San Francisco Bay could not be located. As a result of the Navy's current review, it is estimated that a maximum of 1 curie of fission products of the most highly contaminated ship could have been disposed of in this manner. It is concluded that the total quantity of fission products which could have been disposed of in San Francisco Bay as a result of all nine ships decontaminated after 4 December 1946, could also be discharged today from a commercial nuclear facility and meet the requirements of the Nuclear Regulatory Commission.

The procedures used in 1946 to dispose of sand and acid solutions produced no greater concentrations of radioactivity than are currently acceptable from commercial nuclear reactor operations.

CHAPTER 6

BIKINI SCIENTIFIC RESURVEY

BACKGROUND

Following the conclusion of Operation CROSSROADS, the Joint CROSSROADS Committee gave preliminary consideration to the possibility of a Bikini Scientific Resurvey. Members of the Joint Committee carried out feasibility assessments and consulted with scientists from Joint Task Force 1 on potential studies and the logistics support that would be required for the operation. A subcommittee was formed to analyze proposed operational details and make recommendations (Reference C.8.1, p. 1).

Acting in response to recommendations from the Joint CROSSROADS Committee, on 16 May 1947 the Joint Chiefs of Staff (JCS) issued a memorandum to the Secretary of the Navy requesting that the Joint CROSSROADS Committee and its successor organization, the Armed Forces Special Weapons Project, undertake technical supervision of the Bikini Scientific Resurvey. The operation was to be conducted by the Navy in cooperation with the War Department and with the participation of the U.S. Geological Survey, the Fish and Wildlife Service of the Department of Interior, and the Smithsonian Institution. A target date of 15 July 1947 was proposed (Reference C.8.1, p. 75).

The objectives of the Bikini Scientific Resurvey, as formulated by JCS, were to (Reference C.8.1, p. 75):

- Collect biological samples
- Carry out diving operations to recover instrumentation from target ships and conduct structural examinations of these vessels
- Collect water, bottom samples, and cores
- Conduct radiological studies of the lagoon, surrounding islands, and organisms, with particular emphasis on the analysis of hazards from alpha radiation and from possibly contaminated food organisms.

Following the issuance of the JCS memorandum, the Joint CROSSROADS Committee immediately began to prepare for the operation. Building on the guidance contained in this memorandum, a number of specific scientific objectives were established (Reference C.8.1, p. 3):

- Analysis of the amount and nature of radioactivity remaining in the lagoon water and on the reef and land structure of the atoll wherever it exceeded normal background levels of radioactivity. Particular attention was to be given to the portion of the reef between Aomen and Bikini islands at a stage of tide as close as possible to that which existed 15 minutes after Test BAKER. These investigations

would include charting the exposed portion of the reef through aerial photography.

- Examination of the concentration and kinds of radioactive materials found in plants and animals in the area and assessment of the effects the radioactivity had on these organisms
- Physiological, geological, and oceanographic studies of organisms and reef-building processes, including the drilling of cores down to 1,000 and perhaps 2,500 feet (305 and 762 meters)
- Detailed observation (including photographic recording) of target ships sunk as a result of Test BAKER, with special attention to be given to USS Saratoga (CV-3), Nagato (captured Japanese battleship), USS Pilotfish (SS-386), USS Apogon (SS-308), and perhaps USS Arkansas (BB-33) and USS Gilliam (APA-57) if time permitted. Detailed structural inspections were to be made to determine the exact cause of sinking and to identify minor structural failures.
- Recovery of four instruments from Nagato -- one ionization gauge, two linear time-pressure recorders, and one diaphragm-type damage gauge. Since these instruments were watertight they would be in good condition and yield recordings of considerable value.
- Attempt to locate a section of LSM-60, believed to have been identified in photographs and to inspect this section for type of rupture, heat effects, and radioactivity.

TASK GROUP 10.12

In a directive issued on 2 June 1947, the Chief of Naval Operations (CNO) ordered that the Bikini Scientific Resurvey be carried out under the operational control of the Commander-in-Chief, Pacific Fleet (CINCPACFLT). On 3 June 1947, CNO sent a dispatch to CINCPACFLT designating three ships for participation in the operation:

- USS Chilton (APA-38) (flagship)
- USS Coucal (ASR-8)
- LCI(L)-615.

The same message ordered Chilton to depart San Diego on 1 July for Bikini Atoll via Pearl Harbor (Reference C.8.1, p. 6). On 12 June CINCPACFLT designated a commander for the task group (TG 10.12) that would conduct the Bikini Scientific Resurvey. CINCPACFLT Operation Order No. 101-47 dated 29 June 1947 (Reference C.8.1, p. 6) detailed the task group's organization.

Commander Task Group (CTG) 10.12 was a Navy captain who had a subordinate Navy officer for a technical director and a staff of 36. One Navy Medical Corps officer on the staff was assigned as Radiological Health Officer and seven officers were assigned duties involving radiological safety (Reference C.8.1,

pp. 6 through 9). In addition, one individual from Scripps Institution of Oceanography was assigned to the radiological safety (radsafe) group as a radiological monitor and three pharmacist's mates were assigned to assist the Radiological Health Officer (Reference C.8.1, p. 13).

Navy Construction Battalion Detachment 1800, consisting of 1 officer and 36 enlisted personnel, was assigned to TG 10.12 to provide engineering support for the resurvey. This unit also operated one amphibian aircraft in support of the operation (Reference C.8.1, p. 6).

The X-Ray Division, commanded by one of the staff officers of TG 10.12, was formed to provide technical support to the resurvey scientific teams. This unit contained 183 Navy enlisted personnel (Reference C.8.1, p. 8).

Primarily for reporting results and findings of the investigations, a scientific group organization was set up, drawing from the military, civilian government employees, and civilian contractor personnel assigned to TG 10.12 (Reference C.8.1, pp. 8 through 14). This organization had ten divisions as listed below (number of personnel shown in parentheses):

- Geology
  - -- Island and Reef Geology (5)
  - -- Submarine Geology (2)
  - -- Contractor Support Team (8)
- Radiobiology -- (11)
- Fisheries
  - -- Reef and Lagoon Fishes (4)
  - -- Pelagic Fishes (6)
  - -- Population and Taxonomic Studies (1)
- Biology
  - - Experimental Biology (6)
  - - Ecology and Morphology (3)
- Radiochemistry and Radiophysics
  - -- Fission Products Chemistry (5)
  - -- Plutonium Chemistry (3)
  - -- Soils Chemistry (1)
  - -- Radiophysics (2)
- Radiological Safety (8 personnel -- 7 were TG 10.12 staff officers)
- Radiological Health (4 personnel drawn from the TG 10.12 staff)

- Diving, Underwater Photgraphy and Television (6)
- Army Engineers (2)
- Aerology (Weather Observation) (1 person from the TG 10.12 staff).

The members of the scientific and military groups came from a large number of organizations -- the Navy (including officers taken from the TG 10.12 staff), the War Department, and (Reference C.8.1, p. 8):

- Atomic Energy Commission
- Clinton Laboratories
- Colorado School of Mines
- Columbia University
- Cornell Aeronautical Laboratory
- Department of Interior Fish and Wildlife Service
- Hanford Engineering Works
- International Pacific Fisheries Halibut Commission
- Ohio State University
- Scripps Institution of Oceanography
- Stanford University (including Stanford Research Institute and Hopkins Marine Station)
- U.S. Geological Survey
- U.S. National Museum, Smithsonian Institute
- University of Hawaii
- University of Minnesota
- University of Tennessee
- University of Washington
- Washington State Department of Game.

PREPARATIONS

Relatively little preparation time was available between the CNO order of 2 June 1947 directing that the Bikini Scientific Resurvey be undertaken and initiation of onsite operations in July 1947 (Reference C.8.1, p. 20).

Chilton, which was to serve as the task group's flagship, had been recently overhauled. The first members of the resurvey team boarded Chilton in San Diego on 17 June 1947. Construction of laboratory facilities was started immediately. Stores were loaded between 23 June 1947 and when the ship departed on 1 July 1947 (Reference C.8.1, p. 17).

Chilton arrived at Pearl Harbor on 7 July. Additional personnel and supplies were taken aboard and Chilton departed Pearl Harbor en route Bikini on 8 July (Reference C.8.1, p. 17).

Coucal departed Pearl Harbor en route Bikini on 7 July 1947. LCI(L)-615 loaded supplies at Kwajalein and arrived on station at Bikini on 17 July (Reference C.8.1, p. 17).

An operation plan was prepared while Chilton was en route from San Diego to Pearl Harbor. This plan generally restated the objectives outlined in the JCS memorandum.

Various annexes of the operation plan covered the operational, scientific, and radsafe aspects of the mission.

The plan (Reference C.8.1, pp. 23 and 24) detailed the procedures to be followed to ensure radiological safety, including the initial radiological reconnaissance of Bikini Atoll. Appendix I of Annex J of the Operation Plan (reproduced in Appendix B) contains these sections:

- Radiological hazards were defined and estimated for the Bikini area.
- Provision was made for special pre- and postoperational medical examinations.
- Provision for the issue of special clothing for personnel working in contaminated areas was made.
- Regulations covering shore operations were established. Restrictions were placed on eating foods and drinking water from the islands, swimming in the area was prohibited (these restrictions subsequently were lifted), and provision made for a radsafe officer to accompany all initial trips to onshore areas.
- Radsafe equipment was specified:
  - -- Type 263 Geiger tube survey meters would be used to detect beta and gamma radiation in the field
  - -- Portable "Zeuto" nylon window ionization chambers would be employed to detect heavy alpha radiation
  - -- Type 235 survey meters with ionization chambers in an extended probe would be used for gamma radiation monitoring on sunken ships
  - -- As dictated by circumstances, pencil-type quartz fiber dosimeters for detection of gamma radiation would be employed by divers and other personnel.
- Provisions were made for the establishment of a photographic dosimetry unit to process film badges.
- All divers and other personnel expected to encounter significant radiation would wear Type K film badges, and an individual would not be allowed to reengage in the same

activity if his total body radiation exceeded 0.1 R/24 hours the previous day.

- Plans were made for the establishment of decontamination stations and decontamination techniques were outlined.
- Rules governing the handling of radiologically active scientific specimens, the conduct of laboratory work, and disposal of laboratory waste were established.
- Procedures for reentry into Bikini Atoll and for offloading of equipment (presupposing favorable results from the initial radiological reconnaissance) were established.

Additional technical support for radsafe operations was available from the two radiochemistry laboratories and the counter room established on Chilton (Reference C.8.1, pp. 27 through 29).

Daily staff conferences were held during the trip to Bikini Atoll. During these meetings, detailed plans and procedures for the implementation of the operation plan were developed (Reference C.8.1, p. 27). A Scientific Advisory Board was established on 2 July 1947. This board provided advice to the project officer on administrative matters, particularly allocation of laboratory space and facilities and implementation of the scientific work program (Reference C.8.1, p. 33).

On the recommendation of the Scientific Advisory Board, a series of seminars was conducted. The purpose of these seminars was to provide scientific personnel with information concerning the background, objectives, and methodologies of the studies to be conducted during the Bikini Scientific Resurvey. Three of the ten seminars in the series covered topics pertaining to radiological safety (Reference C.8.1, pp. 33 through 41). The first, "Effects of Radiation on Man," summarized what was known in this field and identified potential hazards on Bikini Atoll. The remaining two seminars outlined the operation plan for radiological safety at Bikini (Reference C.8.1, pp. 39 and 40).

While Chilton was en route from Pearl Harbor to Bikini Atoll, several series of experiments bearing on radiological safety were conducted. In one group of tests, samples of seawater were analyzed for radioactive content to establish a background figure for comparison with the lagoon water at Bikini Atoll. In a separate test, a container of radium was hidden on board Chilton and monitors with Geiger counters attempted to identify its location. The monitors detected not only the radium container but also x-ray equipment in the dental office. The purpose of this test was to ensure that the Geiger counters were in good operating condition before the initial landing at Bikini Atoll (Reference C.8.1, p. 44).

During the trip to Bikini Atoll, work proceeded on the scientific laboratories. As a consequence, by 15 July 1947 all of the programmed onboard laboratories were ready for use. These facilities included (Reference C.8.1, p. 29):

- Two radiochemistry laboratories and a counting room aboard Chilton that were capable of determining beta, gamma, and alpha radiation levels in samples

- A radiobiology laboratory (aboard Chilton)
- A photography laboratory to support scientific operations, which had an associated activity devoted to photographic dosimetry, including the processing and examination of film badges aboard Chilton.

Subsequently, other laboratories were established on Bikini Island to support the scientific activities of onshore research personnel.

Medical examinations were the final preoperational component of the radsafe program. All TG 10.12 military and civilian personnel who were to be engaged in the resurvey operations were required to complete a special physical examination and detailed laboratory tests. Later, personnel who had been actively engaged in resurvey activities were reexamined following the operation. Appendix E of the operation plan detailed the medical tests and criteria employed (Reference C.8.1, p. 100).

OPERATIONS

Initial landing operations commenced on 15 July 1947. Coucal and Chilton passed through Eneu Channel at 1030. Coucal anchored in the vicinity of the sunken Saratoga; Chilton anchored off Bikini Island (Reference C.8.1, p. 47).

At 1145 a radiological monitoring team landed on Bikini Island to monitor the beach, being the first party ashore. Radsafe officers obtained beta and gamma readings along the beach and at a number of inland locations. Readings inland from the beach were uniformly at the same general levels as normal background. The lagoon side of the beach area had radioactivity concentrated in old life rafts, fenders, and similar materials. It was believed that these items might have washed ashore from target ships sunk during CROSSROADS. Samples were obtained from all areas and returned to Chilton for alpha counts (Reference C.8.1, p. 47 through 51).

All members of the initial landing party were required to wear long-sleeved shirts, full-length trousers, and heavy work shoes. On return to Chilton they were monitored to assure necessary decontamination of personnel (a change station was established for this purpose) and prevent ship contamination. All personnel wore film badges designed to record both beta and gamma radiation and monitors carried pocket dosimeters (Reference C.8.1, p. 51).

Evaluation of the pocket dosimeters and examination of developed film badges indicated that no individuals in the landing party had been exposed to tolerance levels of beta or gamma radiation (Reference C.8.1, p. 51).

Immediately after the initial landing, a second landing team went ashore on Eneman Island where monitoring operations were also carried out (Reference C.8.1, p. 51).

Evidence collected by these two landing parties indicated that landing operations could be safely conducted.

Based on the results of the initial surveys, the Radiological Health Officer reported in a memorandum dated 16 July 1947 (reproduced in Appendix B) that (Reference C.8.1, p. 119):

- The preliminary survey of Bikini Island indicated that radiation intensities were on the order of 0.004 R/24 hours and were well below the established tolerance levels.
- Reconnaissance of Bikini Island indicated that all of the low-intensity radiation encountered in the central sector of the island was confined to the sand beaches along the lagoon side of the island and to debris that had washed up on the beaches.
- The survey of the northwestern tip of the island indicated intensities of approximately 0.03 R/24 hours in algal beds and other scattered locations in that sector. In the remainder of the surveyed areas, only background counts were observed.
- Observed intensities on Eneman Island were not above background, with the exception of scattered pieces of debris that produced readings somewhat above background count.

As soon as the radiological safety of various areas on Bikini Island was assured, offloading of material from Chilton commenced. Working on a dawn-to-dark schedule between 15 July 1947 and 22 July 1947, the offloading schedule specified in Annex K of the operation plan was met (Reference C.8.1, pp. 53 and 54).

Scientific activity commenced on 16 July. On 17 July, diving operations from Coucal were initiated. The initial target was Saratoga, which had been sunk by shot BAKER almost a year before. On the same day, LCI(L)-615 arrived with additional supplies. This vessel was used to support submarine geology studies. On July 18, drilling operations commenced (Reference C.8.1, p. 54).

Radsafe officers accompanied all scientific working parties during the initial landings on islands and reef areas and continued to accompany these groups over the period 15 July to 28 August 1947 until it had been determined that the specific areas to be visited were free from contamination by radioactive materials (Reference C.8.2, p. 94).

Victoreen Model 263 survey meters were used in all field and personnel monitoring operations. These devices were capable of detecting both gamma and beta-plus-gamma radiation through the approximate range of 0.001 to 0.6 R/24 hours. Model 356 alpha meters were also included in the equipment of the Radiological Safety Section but proved to be of no value in general terrain monitoring and of only limited value in the monitoring of underwater samples because of their comparatively low sensitivity (Reference C.8.2, p. 94).

While no major problems were encountered with the Victoreen Model 263 survey meters, these devices were a continuous repair and maintenance problem. They also proved to be too heavy and cumbersome to transport by hand over long distances. Hence, web straps were improvised. Canvas cases were also improvised

to protect the meters from water damage during rubber boat landings (Reference C.8.2, p. 95).

Between 15 July and 28 August, two members of the Radiological Safety Section were assigned to Coucal on a full-time basis. Duties included monitoring of divers, diving dress, and associated gear immediately following return aboard the ship after a dive: preliminary monitoring of all samples brought to the surface by the divers; and periodic monitoring of the ship itself to ensure that no unnecessary accumulation of radioactive materials occurred (Reference C.8.2, p. 95).

Two types of underwater survey meters/probes were tested during deep-water diving operations conducted from Coucal (Reference C.8.2, p. 94).

The initial equipment set consisted of a brass-cased Geiger tube, approximately 120 feet (37.6 meters) of shielded extension cable, and a Victoreen Model X-325 counting rate meter. Tests conducted before the initial dive on Saratoga showed that this equipment was inadequate because the survey cable was too short to survey the bottom in the vicinity of the target ship's position. Hence, the probe could not be used throughout the target area (Reference C.8.2, p. 94).

On 28 July, an experimental underwater radiological survey meter probe was received aboard Chilton from the Naval Research Laboratory. It consisted of a brass cylinder containing seven Geiger tubes, electrical circuitry and recording meters, and 225 feet (69 meters) of shielded extension cable. This device had a sensitivity range between (approximately) 0.00005 and 0.005 R/24 hours for gamma radiation only. Limited tests of this equipment were made during the latter part of August (Reference C.8.2, pp. 94 and 95).

Both probes were of limited utility because of their high sensitivities and because they required alternating current (Reference C.8.2, p. 95).

In addition to radiological reconnaissance, one of the missions of the original landing parties was to search for signs of human activity on Bikini following the conclusion of CROSSROADS. During both the initial survey and subsequent operations, no indications of human occupation before the arrival of the resurvey team were found (Reference C.8.1, p. 59).

The operation plan prohibited the consumption of fish, fruits or other materials grown in or around Bikini Lagoon, the drinking of water from any island source, and swimming. On 19 July CTG 10.12 opened limited recreation areas on Bikini Island. Certain beach areas were opened to swimming on 21 July, and the ban on consumption of edible fruits was lifted on 24 July. The prohibition of the consumption of fish and other marine organisms remained in effect and all personnel were cautioned to avoid unnecessary contact with barges and other objects in Bikini Lagoon and with the debris found on the beaches. CTG 10.12 initiated these actions on the advice of the Radiological Health Advisory Board established by Annex J of the operation plan (Reference C.8.1, p. 59; Reference C.8.2, p. 95). This annex is reproduced in Appendix B.

After it had been determined that the general level of radiation throughout Bikini Atoll was well within the tolerance limit of 0.1 R/24 hours, all members

of the Radiological Safety Section, except the radsafe officer and the two officers assigned to Coucal, were assigned collateral duties as planning officers for the major scientific groups of the resurvey staff. These reassigned officers continued to be primarily responsible for monitoring and for protecting personnel from radiation. One officer served as both radsafe officer and planning officer for LCI(L)-615 throughout the period of bottom sampling and coring operations. Another officer acted in the same capacity during shallow diving operations conducted from an LCM (Reference C.8.2, p. 95).

Monitoring data were collected by radsafe officers accompanying scientific teams and by independent radiological reconnaissance teams between 15 July and 28 August from all of the major islands and from representative islands in each group except the sector at the western end of Bikini Lagoon (Bokdrolul, Bokaetoktok, and Oroken islands). A complete reconnaissance of the latter islands was regarded as unnecessary because of their distance from the anchorage of Chilton and their lack of significance for the resurvey operation (Reference C.8.2, p. 96).

The survey indicated that while certain isolated areas and accumulations of waterborne debris found on the lagoon beaches continued to produce beta and gamma radiation in excess of the established tolerance limit of 0.1 R/24 hours, the general level of beta and gamma radiation throughout the atoll was well below this limit. Debris along the beach that continued to produce radiation was almost entirely material that was assumed to have been blown overboard from target ships during CROSSROADS or thrown into the lagoon by reboarding and damage control teams following BAKER (Reference C.8.2, p. 96).

On 25 July, CTG 10.12 forwarded two requests to CINCPACFLT, asking that LCI(L)-615 be retained for the duration of the resurvey and that an LSM be assigned for use in resurvey operations and for the transport of scientific specimens to San Diego. On 30 July, Commander Service Force, Pacific, ordered LSM-382 to report to CTG 10.12 as soon as practicable. LSM-382 reported to Bikini Lagoon on 5 August (Reference C.8.1, pp. 59 through 61).

On 11 August, LSM-382 with a number of scientific staff members on board visited Rongerik Atoll. This radiologically uncontaminated atoll was studied to obtain comparative data for the Bikini analyses (Reference C.8.1, p. 62).

OTHER UNITS AND PERSONNEL

Other personnel and units, not formally or originally assigned to TG 10.12, visited Bikini during the resurvey.

The first of these contacts occurred on 15 and 16 July when two Navy Catalina (PBY) aircraft flew up from Kwajalein. The Atoll Commander, Kwajalein, arrived to confer with CTG 10.12 on 16 July. Courier aircraft operated on the Kwajalein-Bikini route throughout the operation (Reference C.8.1, p. 51).

On 28 July USS Latona (AF-35) arrived in Bikini Lagoon. It transferred supplies to Chilton and departed the same day (Reference C.8.1, p. 59).

Between 31 July and 2 August, three technical specialists from Cornell Aeronautical Laboratory joined the resurvey to assist in the installation and operation of underwater television equipment (Reference C.8.1, p. 59).

From 6 to 8 August, a representative from the Office of the Secretary of the Navy arrived via courier plane. He visited the sites ashore at which resurvey operations were being conducted (Reference C.8.1, pp. 61 and 62).

From 6 to 11 August, four natives of Bikini Atoll were returned by courier plane. They toured the atoll to observe changes. The only change detected was the presence of a new species of fruit-bearing plant -- the papaya. The seeds of this plant apparently reached Bikini during CROSSROADS. This group departed by aircraft (Reference C.8.1, p. 61).

One representative from Geo-Technical Corporation joined the scientific team on 15 August to assist in seismographic research (Reference C.8.1, p. 62).

A representative from the Navy Hydrographic Office reached the survey site on 20 August to participate in analyses of seawater chemistry. Two additional Navy officers joined the task group on August 25 to assist in scientific experiments (Reference C.8.1, pp. 62 and 63).

ROLLUP OPERATIONS

In a dispatch to CINCPACFLT on 13 August, CTG 10.12 recommended that operations be terminated on 30 August 1947. An affirmative response from CINCPACFLT directing that operations cease on that date was received by CTG 10.12 on 14 August (Reference C.8.1, p. 62).

Active preparations for the end of the resurvey operation began on 22 August 1947 (Reference C.8.1, p. 71). Before leaving Bikini Lagoon, all ships in TG 10.12 were instructed to dispose of all lines and other equipment exhibiting radiation in excess of the final clearance limits specified by the Bureau of Ships and the Bureau of Medicine. In the absence of specific directives covering the final clearance limits established for diving dress and associated gear, Coucal was instructed to retain all such equipment pending return to Pearl Harbor, since monitoring had indicated that the contamination present was of a low order and presented no significant radiation hazard (Reference C.8.2, p. 96).

On 25 August, the securing of shore establishments and loading of ships was begun. LSM-382 completed operations and departed for Kwajalein, Pearl Harbor, and San Francisco on 26 August. Coucal was scheduled to complete diving operations on 27 August and, after offloading some special equipment to Chilton, departed Bikini. LCI(L)-615 departed for Kwajalein on 29 August (Reference C.8.1, p. 63).

Monitoring of Chilton's hull at the waterline immediately before departure from Bikini Lagoon on 29 August resulted in readings of background and slightly above background level. Monitoring of Chilton's small boats and deck gear between 29 and 31 August failed to indicate radiation levels above background. Samples of scale taken from Chilton's No. 2 evaporator on 1 September showed a

beta plus gamma count of 1.7 times background and a gamma count of 1.25 times background in scale taken from the second stage of the evaporator, and a beta plus gamma count of 2.3 times background and a gamma count of 1.3 times background in scale taken from the first stage. External monitoring of Chilton's evaporators, condensers, and other saltwater systems produced no evidence of radiation above normal background levels (Reference C.8.2, p. 96 and 98).

Chilton was loaded and ready for sea at 1000 on 29 August. A final inspection of secured installations ashore was made and ship musters were held to ensure that all personnel were properly accounted for. The last courier plane for Kwajalein embarked passengers and loaded mail. Chilton then departed for Pearl Harbor, arriving there on 3 September 1947 (Reference C.8.1, p. 63).

TG 10.12 was dissolved at Pearl Harbor on 4 September 1947 (Reference C.8.1, p. 73).

During the concluding phase of the operation, the Medical Legal Board submitted a report to the project officer. The report began by summarizing the radiological situation. Consistent with the foregoing account, only certain isolated areas and accumulations of debris were found to produce beta and gamma radiation in excess of the tolerance limit of 0.1 R/24 hours (Reference C.8.1, p. 123).

The maximum radioactivity observed during the resurvey was found on a deposit of tar or oil residue on a ledge of rock on a sandspit extending west of Bikini Island. This area produced a beta plus gamma reading of 0.6 R/24 hours and a gamma reading of 0.18 R/24 hours (Reference C.8.1, p. 123).

Concerning the operational phase of the resurvey, the report noted that (Reference C.8.1, pp. 123 and 124):

- Radsafe and health procedures specified in the operation plan were observed throughout the operation.
- Radsafe officers accompanied all scientific work parties during initial landings and continued to accompany these parties until it had been determined that the area in question was free from any hazardous concentrations of radioactive materials.
- Each diver returning to Coucal was initially hosed down with seawater while still on the stage and before being taken aboard. Following removal of the diving suit, divers and gear were monitored with Model 263 survey meters to detect any gamma and beta radiation.
- Personnel monitoring was carried out aboard Chilton until it was determined that this procedure was no longer required.
- Personnel decontamination stations were established on both Chilton and Coucal in the event that monitoring indicated presence of excessive radiation on either individuals or clothing.

- All members of the scientific teams wore individual film badges during the initial stages of the operation and until such time as it had been determined that this procedure could be modified or dispensed with entirely in areas that presented no radiological hazards.

- Since deep diving and underwater inspection operations were considered to pose the greatest potential hazard, film badges and pocket dosimeters were carried by each diver throughout the course of the underwater work. Three film badges, each enclosed in a waterproof covering, were attached to the inner clothing of the diver before descent -- one at waist height, one at chest height, and one in a shoe. During the early phases of the operation, these film badges were delivered to the Photodosimetry Unit for developing and analysis at the conclusion of each dive. Later, when it had been determined that hazardous concentrations of radioactive materials were not being encountered, badges were analyzed at weekly intervals.

- A total of 517 film badges were processed by the Photodosimetry Unit of the Radiological Health Section. No badge carried during the course of the operation gave evidence of exposure to beta or gamma radiation in excess of the daily specified tolerance limit of 0.1 R/24 hours.

- Biological analyses conducted during the resurvey indicated the presence of varying amounts of radioactivity in marine life in Bikini Lagoon, though not in sufficient concentrations to pose an external radiation hazard. Instructions issued by the task group commander on the recommendation of the Radiological Health Advisory Board directed that no marine life would be consumed by personnel involved in the operation.

- Recreational swimming at designated beaches on Bikini Island was allowed only after chemical analysis of lagoon water indicated a plutonium content of less than 10^{-11} grams per liter of water. A gross analysis of the fission products present in the water indicated a content of less than 10^{-12} curies per liter of water.

- On the basis of radiochemical analysis of edible fruits, the original ban on the consumption of such fruits was lifted on 24 July by the task group commander acting on the recommendation of the Radiological Health Advisory Board.

The Statement of Findings of the Medical Legal Board noted that (Reference C.8.1, p. 124):

> In view of the data obtained and the observations made during the period 15 July 1947 through 26 August 1947, the undersigned members of the Medical Legal Board, Bikini Scientific Resurvey, attest, that to the best of their knowledge and belief, no individual assigned to, attached to, or participating

in the Bikini Scientific Resurvey during the same period of time was exposed to radiation in excess of the established standards.

PERSONNEL EXPOSURE LEVELS

The photographic dosimetric equipment that was employed consisted of (Reference C.8.2, p. 101):

- An Ansco-Sweet densitometer for reading densities of films exposed in film badges
- Type K film badges (500) obtained from the Radiation Laboratory, San Francisco Naval Shipyard
- Holders and DuPont film packets obtained from the Atomic Energy Commission at Oak Ridge, Tennessee (300 holders and 5,000 packets).

Both types of film badges were exposed to a standard radium source for calibration. Each type had an approximate sensitivity range of 0.02 to 2 R.

Project reports differ as to the number of badges used during the operation. The Report of Findings of the Medical Legal Board stated (Reference C.8.1, p. 124):

> Of the total of 517 [emphasis added] film badges processed by the Photodosimetry Unit of the Radiological Health Section, no badge carried during the course of the Resurvey Operations gave evidence of exposure to beta or gamma radiation in excess of the tolerance limits referred to in Paragraph A.1., above.

On the other hand, the section entitled "Radiological Health at Bikini" presented in Volume II of the Report of the Technical Director states (Reference C.8.2, p. 101):

> During the period from 15 July to 29 August 1947, a total of 572 [emphasis added] film badges were developed, and the exposures interpreted. None of these badges was found to have been exposed to sufficient radiation to acquire computable density. From film-badge data it was determined that there were no personnel exposures in excess of the daily tolerance limit of 0.1R, beta plus gamma. All developed badges were alphabetically filed, and will be permanently stored at the Radiation Laboratory, San Francisco Naval Shipyard, as a permanent exposure record for personnel connected with this Resurvey Operation.

While these two sources differ as to the number of badges examined, both reach the same conclusion regarding badge readings -- no personnel exposures in excess of specified daily tolerance limits occurred; however, neither the badges nor any listing of the readings have been located.

RESURVEY CONCLUSIONS

The Bikini resurvey concluded that the atomic detonations caused only minor, transient disturbance to the plant and animal populations in the area. Some plants and animals in the immediate area of the underwater detonation were killed and some highly radioactive plants, fish, and invertebrates of impaired vitality were found during the 3 weeks following Test BAKER. One year later, a careful search of the islands, reefs, and lagoon revealed no changes in populations, number, or composition. No physiological damage could definitely be attributed to the detonation. Some dying coral on a reef between Bikini and Aomen islands provided the closest case of damage from the test. The corals (Heliopora) were in fine condition a few weeks before Test BAKER. At the time of the detonation, the tops of the coral clumps were about [illegible] (0.3 meter) underwater and the tide was rising. They may have been [illegible] the radioactive fission products that washed over the reef after raining [illegible] from the radioactive cloud. More probable causes of the corals' death were contamination from oil from the sunken ships or by heavy rain during one of the low tides. The question of what caused the death of the corals remained unsolved (Reference A.4, pp. 74 and 75).

One of the most discussed effects of the radioactivity was the possibility of producing genetic changes. At Bikini, more than 1,000 species of organisms were exposed to radioactivity, and many of them had reproduced at least once. A careful search of tens of thousands of specimens in the area failed to show definite evidence of aberrant forms. Since mutations produced by radiation almost invariably do not survive, the result was not unexpected (Reference A.4, p. 76). No scientific investigations found evidence of radiation-induced genetic effects during the 6 weeks of work in the atoll (Reference A.4, p. 77).

The Radiological Safety Section, which monitored most of the islands, found few places where beta-gamma readings exceeded the tolerance limit of 0.1 R/24 hours. The studies of sea urchins and other invertebrates led to the observation that the specimens examined in the shipboard laboratories were healthy, abundant, and reproducing normally.

Occasionally there were reports of situations in which radioactivity may have played a part in generating ecological anomalies, although other, non-radiological, factors could have been present. The Technical Director of the resurvey stated that the level of residual radioactivity was low and not dangerous (Reference A.4, p. 61). While there was no doubt that decay and dilution had reduced residual radioactivity to a low level, questions persisted (Reference A.4, p. 67).

For example, there remained the question of the unexplained turbidity of the eastern lagoon waters near Bikini Island and the target area. Before Test BAKER, the waters had been clear and transparent. However, in 1947 Chilton noted the lagoon waters were opaque. The most likely cause for the increased opacity was an increase in plankton (Reference A.4, pp. 66 and 67). Hypotheses for the increased plankton growth included seasonal effects (later rejected) and the discharge of untreated sewage by personnel at CROSSROADS in 1946. While the scientists agreed the turbidity was unique, they were unwilling to conclude that the atomic detonations had set up conditions that would encourage an increase in plankton (Reference A.4, p. 68).

Studies of radioactivity made in the vicinity of the target ships indicated that there were "large amounts of radioactive material" on the lagoon bottom, particularly in the vicinity of the target array (Reference A.4, p. 70). The radioactivity made its way into the food chain as sea cucumbers and worms ingested and excreted the mud. The plants took up some of the excreted radioactivity. The plants were eaten by small fish, which were preyed upon by larger fish. While the animals excreted most of the radioactive material, a small amount was retained, particularly by the liver, spleen, kidneys, and gonads. Furthermore, the ingestion of radioactive material resulted in a very widespread distribution of radioactivity in the lagoon. The radioactivity detected at Bikini was low, yet it was traceable in food chains. Fission products were found occurring in fish and invertebrates such as clams, snails, oysters, corals, sponges, octopods, crabs, sea urchins, sea cucumbers, spiny lobsters, and shrimp. They were also represented in the algae found in the lagoon (Reference A.4, p. 73).

CHAPTER 7

U.S. ARMY GROUND FORCES PARTICIPATION

INTRODUCTION

Approximately 3,300 Army personnel were assigned to Operation CROSSROADS (Reference C.9.206, p. III-(A)-3). Of the total number of Army personnel, approximately 350 were assigned to Task Group (TG) 1.4 (Army Ground Group) and 2,500 to TG 1.5 (Army Air Group). The forces that were to become the U.S. Air Force in 1947 were still part of the Army in 1946. A summary of Army Air Forces participation is discussed in Chapter 8. In addition to the 71 Army officers assigned to TG 1.4, another 70 Army ground officers have been identified on the Joint Task Force 1 (JTF 1) Officer Roster. Fifty of these were assigned to the Radiological Safety Section. Approximately 380 Army ground personnel remain without positive unit identification. Some of these probably were assigned to JTF 1 Hq staff. Others were probably assigned to TU 1.5.5 (Air Service Unit) at Kwajalein as engineers and military police.

TASK GROUP 1.4 (ARMY GROUND GROUP)

TG 1.4 had two assigned missions: to determine damage to selected Army equipment exposed at varying distances from the point of detonation and to measure the bombs' radii of effectiveness. CTG 1.4 maintained close liaison with various agencies operating under the Director of Ship Material and was assigned the operating code designation 014B. Senior representatives of each of the technical services under TG 1.4 were at the same time in command of a task unit and also a member of the technical staff (Reference C.9.149, p. 3).

TG 1.4 was berthed aboard the support ship USS Wharton (AP-7) and consisted of a headquarters and the following six operating task units (TU):

- TU 1.4.1 (Engineer Unit)
- TU 1.4.2 (Signal Unit)
- TU 1.4.3 (Ordnance Unit)
- TU 1.4.4 (Chemical Unit)
- TU 1.4.5 (Quartermaster Unit)
- TU 1.4.6 (Air Unit).

Headquarters was composed of Command, Technical, and Administrative sections. The functions of Command and Administrative sections were the normal ones implied by their respective designations. The Technical Section was composed of representatives of six branches, i.e., Corps of Engineers, Chemical Warfare Service, etc. Its members planned, correlated, and supervised test procedures; prepared reports covering test items; and assisted the commanding officer in preparation of the test. The provisional headquarters was activated on 22 March 1946 with an operating strength of five officers and eighteen

enlisted personnel. Four officers and nine enlisted headquarters personnel have been identified, none of whom were badged.

Each operating task unit was under the command of a technical staff officer and was composed of a staff and a group of inspection teams. These teams were assigned to target ships and were responsible for loading, securing, maintaining, and inspecting test items. Teams were to reboard target ships after each detonation after the ships had been radiologically cleared and declared safe for boarding.

Task Unit 1.4.1 (Engineer Unit)

TU 1.4.1 conducted tests to determine the radii of damage to typical items of Corps of Engineers equipment and to discover weaknesses that might be corrected by improved design. Items such as construction tractors, crawlers, caterpillars, floating bridges, and firefighting and water-supply equipment were exposed aboard the target attack transports USS Gilliam (APA-57) at 800 yards (732 meters), USS Dawson (APA-79) at 1,500 yards (1.37 km), and USS Butte (APA-66) at 2,200 yards (2.01 km) for Test ABLE. During Test BAKER, water purification units and other equipment were exposed aboard USS LST-545 4,100 yards (3.75 km), and USS LST-125 and LCM-5 5,700 yards (5.21 km) away on Bikini Island (Reference C.9.150, p. 15). TU 1.4.1 operating strength called for 12 officers, 53 enlisted personnel, and 2 civilians (Reference C.9.150, Appendix E, p. 1). Six officers, four enlisted personnel, and one civilian have been identified, but none can be positively identified as badged.

Task Unit 1.4.2 (Signal Unit)

Signal Corps participation in Tests ABLE and BAKER was to determine the effects of damage versus distance on Signal Corps equipment such as switchboards, generators, batteries, wires, and installations. Equipment was exposed aboard USS Nevada (BB-36), USS Arkansas (BB-33), USS Independence (CVL-22), Prinz Eugen, USS Saratoga (CV-3), USS New York (BB-34), USS Gasconade (APA-85), and on Bikini Island for Test ABLE. For Test BAKER, items were exposed aboard Arkansas, Nevada, Saratoga, and Prinz Eugen. The unit operating strength called for nine officers and twenty-seven enlisted personnel as well as nine civilians from Signal Corps Engineer Laboratory. Seven officers, twenty-six enlisted men, and nine civilians have been identified. Two individuals can be identified as having been badged. One had a badge he carried from 30 June to 7 July 1946; it read zero. The other was badged on 19 August, and his badge read 0.130 R (gamma). He may also have had a badge showing zero exposure on 14 August.

Task Unit 1.4.3 (Ordnance Unit)

To facilitate control and preclude duplication it was agreed that the Ordnance Unit would handle all explosives and demolition materials for the Corps of Engineers. Objectives of the TU 1.4.3 tests were to determine whether changes in design of ordnance materials, ammunition, and packaging were necessary to minimize the effects of a nuclear detonation and to collect technical data that might aid in future designs. Items were placed on Arkansas, Nevada, USS Pennsylvania (BB-38), Saratoga, YOG-83, USS LST-52, USS LST-661, USS LST-220, and LST-545 for both tests; some test items were also located on Bikini Island. Operating strength called for 17 officers and 72 enlisted personnel.

Only 15 officers and 38 enlisted personnel have been identified and none were badged. It was not until 31 July that ordnance inspection teams were allowed to inspect the Army equipment after Test BAKER (Reference B.5.3; Reference C.9.155, p. 1).

Task Unit 1.4.4 (Chemical Unit)

Chemical Warfare Service personnel conducted tests to expose selected items of chemical warfare equipment and fillings to the effects of a nuclear detonation. The tests had two objectives: first, to determine the effects of heat, blast, and radiation on packaging, chemical composition, and functioning; second, to determine whether changes in design and chemical composition of these items were necessary to ensure their effective use during and after exposure. Items were displayed during Test ABLE on the following six target ships (distances from Nevada, center of target array, in parentheses): YMS-[illegible] (1,000 yards [914 meters]), LCT-818 (1,200 yards [1.10 km]), LST-52 (1,6[illegible] yards [1.37 km]), LCT-874 (2,000 yards [1.83 km]), LST-661 (2,300 yards [2.1[illegible] km]), and LST-220 (3,200 yards [2.93 km]). The Chemical Warfare Service did not participate in Test BAKER. The operating strength of this unit called for six officers, seventeen enlisted personnel, and one civilian. Except for one enlisted man, all have been identified. Only one person was badged and he had a zero reading (Reference B.5.3; Reference C.9.151, p. 1-2, Appendix F).

Task Unit 1.4.5 (Quartermaster Unit)

The objectives for TU 1.4.5 tests were to determine the effects of a nuclear detonation on quartermaster supplies and prepare recommendations for future implementation. This unit was composed of a technical staff of four officers and five enlisted men and 11 test teams consisting of one officer and six enlisted men each. TU 1.4.5 was activated from 1 February through 10 August 1946. Test ABLE tested the effects on quartermaster supplies in open storage from an airburst, and Test BAKER tested the effects on quartermaster supplies in various stages of an amphibious invasion operation from an underwater explosion.

Test items for ABLE were displayed on the following 13 target ships: New York, Arkansas, Nevada, Pennsylvania, USS Pensacola (CA-24), Saratoga, USS Carteret (APA-70), USS Fallon (APA-81), USS Cortland (APA-75), USS Bladen (APA-63), USS Niagara (APA-87), USS Catron (APA-71), and ARDC-13. USS Rockwall (APA-230) was used as a supply ship. After each target vessel was declared radiologically safe, test teams reboarded their assigned vessels and prepared inspection reports on damage sustained by test items.

After Test ABLE, TU 1.4.5 was divided into three groups. The first group consisted of three officers, three enlisted personnel, three test teams, and a security detachment to guard supply dumps on Bikini. Each test team had one officer and fourteen enlisted personnel, and the security detachment consisted of one officer and twelve enlisted personnel. The second group was composed of chemists and chemical engineers who departed for Honolulu before BAKER to compile data from ABLE. Members of the third group were relieved from further duty with TU 1.4.5 and proceeded to their normal duty stations. The latter two groups departed Bikini on 13 July aboard USS Chilton (APA-38) for Hawaii and the mainland.

Three displays were used for Test BAKER: aboard LST-545, 4,000 yards (3.66 km) from the blast, LST-125, beached on shore of Bikini, and Bikini Island beachhead. On BAKER D+6, TU 1.4.5, accompanied by radsafe monitors, inspected three displays. In all, 16 officers and 78 enlisted personnel have been identified from this unit, but only 7 were badged; the highest badge reading was 0.21 R (References B.5.3, C.9.155, and C.9.154).

Task Unit 1.4.6 (Air Unit)

The objectives of TU 1.4.6 were to test nuclear effects on representative items of Army Air Forces equipment at varying distances from Test ABLE. Navy target ships used to expose items were Nevada, Independence, and New York. After radsafe personnel declared each target ship safe, Army Air Forces inspection teams went aboard. Reboarding was as follows:

	Time	Date	Hours after Detonation
New York	1145	2 July	25
Nevada	0830	4 July	71
Independence	0930	5 July	93

The operating strength of this unit called for seven officers and nine enlisted personnel. Reboarding teams were composed of ships' personnel and Army personnel. Seven officers and six enlisted personnel have been identified; none were badged (Reference B.5.3; Reference C.9.156, p. 218).

CHAPTER 8

U.S. ARMY AIR FORCES PARTCIPATION

About 2,500 U.S. Army personnel in the Army Air Forces* served in CROSSROADS and were assigned to Task Group (TG) 1.5, Army Air Group. The air units of TG 1.5 operated from Kwajalein and Enewetak islands. A small number of personnel (13 have been identified) were assigned to Task Unit (TU) 1.4.6 (Air Unit). This unit is discussed in Chapter 7, "U.S. Army Ground Forces Participation."

In January 1946, the 58th Bombardment Wing of the U.S. Army Fourth Air Force was designated TG 1.5 for CROSSROADS activities. Roswell Army Air Field, New Mexico, was selected as the center for preparations in the continental United States. The 509th Composite Group at Roswell formed the nucleus of the various task units needed for the tests. A large part of the headquarters staff of the 58th Wing at March Army Air Field, California, was transferred to Roswell to form Headquarters, TG 1.5. (Reference C.9.206, Part VIIE). Other units that furnished significant manpower included the 320th Troop Carrier Squadron, 329th Bomb Squadron, 330th Bomb Squadron, 393rd Bomb Squadron, and 1027th Air Materiel Squadron. Table 12 lists all units known to have supplied personnel to TG 1.5.

Functions performed by TG 1.5 included airdropping the shot ABLE nuclear weapon, collecting samples of nuclear debris from the radioactive clouds, weather reconnaissance and prediction, communications support, operation of the airbase at Enewetak Island, photography and air transport support for men and material. It also assisted in some effects experiments associated with measuring blast, heat, and radiation aboard aircraft.

Table 13 lists the task units in TG 1.5. The table shows number of persons in each unit, number badged, and dosimetry breakdown. The information was obtained using May 1946 task unit rosters and the Reynolds Electrical and Engineering Company's (REECo) printout of radiation exposure by name. Rosters for June and July 1946 could not be located, and there is some evidence that more personnel were assigned to the various task units during June and July. An undated chart showing task unit totals for Hq TG 1.5 and TU 1.5.1 through TU 1.5.5 was located at Brooks AFB, Texas. Totals for Hq TG 1.5, TU 1.5.1, TU 1.5.2, and TU 1.5.3 are quite close to those on the May rosters (as shown in Table 13). However, the total for TU 1.5.4 is 309 versus 55 in Table 13; and for TU 1.5.5 it is 995 versus 686 in Table 13. Since TU 1.5.4 included personnel who ferried men and equipment to the Pacific, the roster may have included only those assigned on Kwajalein. However, no such explanation is available for the difference in TU 1.5.5.

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*In 1946 the Air Forces were still part of the U.S. Army.

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Table 12. Participating Army Air Forces units, Operation CROSSROADS.

Unit	Home Station	Task Unit
1st Ordnance Squadron	Roswell AAF, New Mexico	1.5.1
61h Aircraft Repair Unit (Floating)	SS Brig. Gen. Alfred J. Lyon	Unknown
40th Bomb Group (VH)	Davis Monthan AAF, Arizona	1.5.8
44th Bomb Group	Smoky Hill AAF, Kansas	1.5.2
58th Bomb Wing	March AAF, California	Hq 3G 1.5
59th Weather Recon Squadron	Castle AAF, California	1.5.7
71st AACS Group	Hickam AAF, Hawaii	1.5.5
93rd Bomb Group	Clovis AAF, New Mexico	1.5.3
107th AACS Squadron	Robins AAF, Georgia	1.5.5
110th Army Air Force Base Unit	Mitchel AAF, New York	1.5.5
112th Army Air Force Base Unit	Grenier AAF, New Hampshire	3.5.2
123d Army Air Force Base Unit	Seymour-Johnson AAF, North Carolina	3.5.3
136th Army Air Force Base Unit	Myrtle Beach AAF, South Carolina	3.5.2
139th Army Air Force Base Unit	Shaw AAF, South Carolina	3.5.5
146th Army Air Force Base Unit	Selfridge AAF, Michigan	3.5.5
291st Army Air Force Base Unit	Peterson AAF, Colorado	1.5.5
233d Army Air Force Base Unit	Ft. Worth AAF, Texas	1.5.3
234th Army Air Force Base Unit	Clovis AAF, New Mexico	1.5.3
243rd Army Air Force Base Unit	Great Bend AAF, Kansas	1.5.2
245th Army Air Force Base Unit	McCook AAF, Nebraska	1.5.5
247th Army Air Force Base Unit	Smoky Hill AAF, Kansas	1.5.5
263rd Army Air Force Base Unit	Peterson AAF, Colorado	1.5.5
311th Reconnaissance Wing	Buckley AAF, Colorado	1.5.7
316th Troop Carrier Squadron	Pope AAF, North Carolina	1.5.1
320th Troop Carrier Squadron	Roswell AAF, New Mexico	1.5.4
326th Army Air Force Base Unit	MacDill AAF, Florida	1.5.5
329th Bomb Squadron	Clovis AAF, New Mexico	3.5.3
330th Bomb Squadron	Clovis AAF, New Mexico	3.5.3
337th Army Air Force Base Unit	Venice AAF, Florida	3.5.5
390th Air Service Group	Roswell AAF, New Mexico	1.5.5

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Table 12. Participating Army Air Forces units, Operation CROSSROADS.

Unit	Home Station	Task Unit
1st Ordnance Squadron	Roswell AAF, New Mexico	1.5.1
61h Aircraft Repair Unit (Floating)	SS Brig. Gen. Alfred J. Lyon	Unknown
40th Bomb Group (VH)	Davis Monthan AAF, Arizona	1.5.6
44th Bomb Group	Smoky Hill AAF, Kansas	1.5.2
58th Bomb Wing	March AAF, California	Hq TG 1.5
59th Weather Recon Squadron	Castle AAF, California	1.5.7
71st AACS Group	Hickam AAF, Hawaii	1.5.5
93rd Bomb Group	Clovis AAF, New Mexico	1.5.3
107th AACS Squadron	Robins AAF, Georgia	1.5.5
110th Army Air Force Base Unit	Mitchel AAF, New York	1.5.5
112th Army Air Force Base Unit	Grenier AAF, New Hampshire	1.5.2
123d Army Air Force Base Unit	Seymour-Johnson AAF, North Carolina	1.5.3
136th Army Air Force Base Unit	Myrtle Beach AAF, South Carolina	1.5.2
139th Army Air Force Base Unit	Shaw AAF, South Carolina	1.5.5
146th Army Air Force Base Unit	Selfridge AAF, Michigan	1.5.5
201st Army Air Force Base Unit	Peterson AAF, Colorado	1.5.5
233d Army Air Force Base Unit	Ft. Worth AAF, Texas	1.5.3
234th Army Air Force Base Unit	Clovis AAF, New Mexico	1.5.3
240rd Army Air Force Base Unit	Great Bend AAF, Kansas	1.5.2
245th Army Air Force Base Unit	McCook AAF, Nebraska	1.5.5
247th Army Air Force Base Unit	Smoky Hill AAF, Kansas	1.5.5
263rd Army Air Force Base Unit	Peterson AAF, Colorado	1.5.5
311th Reconnaissance Wing	Buckley AAF, Colorado	1.5.7
316th Troop Carrier Squadron	Pope AAF, North Carolina	1.5.1
320th Troop Carrier Squadron	Roswell AAF, New Mexico	1.5.4
326th Army Air Force Base Unit	MacDill AAF, Florida	1.5.5
329th Bomb Squadron	Clovis AAF, New Mexico	1.5.3
330th Bomb Squadron	Clovis AAF, New Mexico	1.5.3
337th Army Air Force Base Unit	Venice AAF, Florida	1.5.5
390th Air Service Group	Roswell AAF, New Mexico	1.5.5

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Table 12. Participating Army Air Forces units, Operation CROSSROADS.

Unit	Home Station	Task Unit
1st Ordnance Squadron	Roswell AAF, New Mexico	1.5.1
6th Aircraft Repair Unit (Floating)	SS Brig. Gen. Alfred J. Lyon	Unknown
40th Bomb Group (VH)	Davis Monthan AAF, Arizona	1.5.8
44th Bomb Group	Smoky Hill AAF, Kansas	1.5.2
58th Bomb Wing	March AAF, California	Hq TG 1.5
59th Weather Recon Squadron	Castle AAF, California	1.5.7
71st AACS Group	Hickam AAF, Hawaii	1.5.5
93rd Bomb Group	Clovis AAF, New Mexico	1.5.3
107th AACS Squadron	Robins AAF, Georgia	1.5.5
110th Army Air Force Base Unit	Mitchel AAF, New York	1.5.5
112th Army Air Force Base Unit	Grenier AAF, New Hampshire	1.5.2
123d Army Air Force Base Unit	Seymour-Johnson AAF, North Carolina	1.5.3
136th Army Air Force Base Unit	Myrtle Beach AAF, South Carolina	1.5.2
139th Army Air Force Base Unit	Shaw AAF, South Carolina	1.5.5
146th Army Air Force Base Unit	Selfridge AAF, Michigan	1.5.5
201st Army Air Force Base Unit	Peterson AAF, Colorado	1.5.5
233d Army Air Force Base Unit	Ft. Worth AAF, Texas	1.5.3
234th Army Air Force Base Unit	Clovis AAF, New Mexico	1.5.3
243rd Army Air Force Base Unit	Great Bend AAF, Kansas	1.5.2
245th Army Air Force Base Unit	McCook AAF, Nebraska	1.5.5
247th Army Air Force Base Unit	Smoky Hill AAF, Kansas	1.5.5
263rd Army Air Force Base Unit	Peterson AAF, Colorado	1.5.5
311th Reconnaissance Wing	Buckley AAF, Colorado	1.5.7
316th Troop Carrier Squadron	Pope AAF, North Carolina	1.5.1
320th Troop Carrier Squadron	Roswell AAF, New Mexico	1.5.4
326th Army Air Force Base Unit	MacDill AAF, Florida	1.5.5
329th Bomb Squadron	Clovis AAF, New Mexico	1.5.3
330th Bomb Squadron	Clovis AAF, New Mexico	1.5.3
337th Army Air Force Base Unit	Venice AAF, Florida	1.5.5
390th Air Service Group	Roswell AAF, New Mexico	1.5.5

(continued)

Table 12. Participating Army Air Forces units, Operation CROSSROADS (continued).

Unit	Home Station	Task Unit
393d Bomb Squadron	Roswell AAF, New Mexico	1.5.1
400th Army Air Force Base Unit	San Francisco AAF, California	1.5.2
420th Army Air Force Base Unit	March AAF, California	1.5.2
427th Army Air Force Base Unit	Roswell AAF, New Mexico	1.5.2
439th Troop Carrier Squadron	Roswell AAF, New Mexico	1.5.4
444th Bomb Group	Davis-Monthan AAF, Arizona	1.5.3
448th Bomb Group	Ft. Worth AAF, Texas	1.5.2
462d Bomb Group	MacDill AAF, Florida	1.5.2
466th Air Service Group	Sedalia AAF, Missouri	1.5.5
466th Army Air Force Base Unit	Sedalia AAF, Missouri	1.5.5
467th Army Air Force Base Unit	Salt Lake City AAF, Kearns, Utah	1.5.5
468th Bomb Group	Roswell AAF, New Mexico	Hq TG 1.5
477th Air Service Group	Pope AAF, North Carolina	1.5.5
509th Composite Group	Roswell AAF, New Mexico	Hq TG 1.5
519th Air Services Group	Smoky Hill AAF, Kansas	1.5.2
603d Air Engineering Squadron	Roswell AAF, New Mexico	1.5.5
702d Army Air Force Base Unit	Mitchel AAF, New York	1.5.5
719th Air Materiel Squadron	Pope AAF, North Carolina	1.5.5
454th Army Air Force Base Unit	McCord AAF, Washington	1.5.5
775th Army Air Force Base Unit	Hickam AAF, Hawaii	1.5.5
789th Bomb Squadron	Clovis AAF, New Mexico	1.5.3
790th Bomb Squadron	Clovis AAF, New Mexico	1.5.3
804th Army Air Force Base Unit	Greenville AAF, South Carolina	1.5.5
811th AAB FU	Ft. Benning, Georgia	1.5.5
812th Army Air Force Base Unit	Pope AAF, North Carolina	1.5.5
902d Army Air Force Base Unit	Orlando AAF, Florida	1.5.2
1027th Air Materiel Squadron	Roswell AAF, New Mexico	1.5.5
1395th Military Police Squadron	Roswell AAF, New Mexico	1.5.5
1503rd Army Air Force Base Unit	Hamilton AAF, California	1.5.5
2135th Army Air Force Base Unit	Tyndall AAF, Florida	1.5.2
2140th Army Air Force Base Unit	Smyrna AAF, Tennessee	1.5.2

(continued)

Table 12. Participating Army Air Forces units, Operation CROSSROADS (continued).

Unit	Home Station	Task Unit
2530th Army Air Force Base Unit	Selman AAF, Louisiana	1.5.2
2533th Army Air Force Base Unit	Goodfellow AAF, Texas	1.5.2
2621st Army Air Force Base Unit	Barksdale AAF, Louisana	1.5.2
2622th Army Air Force Base Unit	Mather AAF, California	1.5.2
3010th Army Air Force Base Unit	Williams AAF, Arizona	1.5.2
3501st Army Air Force Base Unit	Boca Raton AAF, Florida	1.5.2
3705th Army Air Force Base Unit	Lowry AAF, Colorado	1.5.2
4000th Army Air Force Base Unit	Patterson AAF, Ohio	1.5.2
4121st Army Air Force Base Unit	Kelly AAF, Texas	1.5.2
4135th Army Air Force Base Unit	Hill AAF, Utah	1.5.4
4136th Army Air Force Base Unit	Tinker AAF, Oklahoma	1.5.2
Air Material Command	Wright AAF, Ohio	1.5.2 1.5.3 1.5.8

Source: Reference C.13.5.

Table 13. U.S. Army Air Forces personnel exposure, CROSSROADS.

Element	No. of Persons Listed	No. of Persons Badged	Exposure Ranges (R)		
			0	0.001-0.5	0.5-1
Hq TG 1.5	139	20	17	3	
TU 1.5.1	367	48	42	6	
1.5.2	412	149	143	6	
1.5.3	450	117	30	87	
1.5.4	55	8	8		
1.5.5	686	2	0	2	
1.5.7	56	0			
1.5.8	27	15	14	1	
1.5.9	48	8	2	5	1
Others	249	0			

Sources: References C.13.4, B.5.3, and B.5.4.

Eleven personnel listed in the REECo exposure data as being on Enewetak on 25 July are not on any TG 1.5 roster. Five of these have sequential badge numbers. This strongly implies that they were an aircraft crew in TU 1.5.3. Since there were no other units on Enewetak, these 11 individuals have been counted with TU 1.5.3. It is not possible to arbitrarily group otherwise unidentified personnel on Kwajalein since numerous units were there besides Army Air Forces units.

The REECo data (taken from original source documents) shows last name only (no first name or initials) in about 60 percent of the listings, so for the more common names such as Smith, Jones, and Williams it is very difficult to match the right name. In some cases, e.g., aircraft crews, men were given sequential badge numbers and it was possible to match common names positively. In general, however, whenever there was doubt it was assumed that there was no match. In addition to name, the REECO list shows badge number, location (Enewetak, Kwajalein, ships by name, etc.), badge dates, and badge exposure. It does not identify an individual with a particular organization, only his location. Thus the task unit rosters have to be used along with the dosimetry list.

TU 1.5.6 and TU 1.5.10 are not shown in Table 13. TU 1.5.6 was consolidated with TU 1.5.3 in June 1946. TU 1.5.3 totals reflect personnel from both units. TU 1.5.10 is synonymous with Hq TG 1.5 and the latter designation is used in Table 13.

HEADQUARTERS TASK GROUP 1.5

This group was made up primarily of personnel from Hq 58th Wing and Hq 509th Group. The listing in Table 13 includes personnel assigned to Hq TG 1.5 and Hq 509th Composite Group on Kwajalein. Why these two units are listed separately is unknown. It may be that the personnel in Hq 509th Composite Group were recent arrivals at Kwajalein and were pending assignment to one of the task units. Only 20 of 139 personnel were badged and no exposures exceeded 0.5 R. Three civilians are included in the totals.

Task Unit 1.5.1 (Tactical Operations Unit)

Personnel from the 393rd Bombardment Squadron of the 509th Group Roswell AAF, New Mexico, made up the majority of TU 1.5.1. This unit operated seven B-29 aircraft from Kwajalein including the bomb drop aircraft, two command-and-control aircraft, two pressure-gauge drop aircraft, and two spare aircraft. Of 367 personnel associated with TU 1.5.1, 48 were badged, and all exposures were less than 0.5 R. Almost all the badged personnel were aircraft crews; 27 of the 48 were officers. There were no civilians in this task unit.

Task Unit 1.5.2 (Army Air Photographic Unit)

Personnel drawn from several units in the Air Materiel Command formed this task unit. This unit was responsible for a large part of the technical photography program during CROSSROADS. It operated two C-54s and eight F-13s (modified B-29s) from Kwajalein, which were equipped with very-high-speed and normal-speed motion picture cameras and 35-mm still cameras. Table 13 provides dosimetry information for the 149 personnel out of 412 who were badged. All

but 15 of the badged personnel were aircraft crewmembers. This unit had 55 civilians assigned, several of whom were cameramen on the aircraft and were badged. The highest exposure, 0.05 R, was recorded by a civilian.

Task Unit 1.5.3 (Instrumentation and Test Requirements Unit)

Personnel drawn from several units within the Air Materiel Command made up this task unit. TU 1.5.3 was consolidated with the Drone Aircraft Unit, TU 1.5.6, and was one of two organizations based on Enewetak Island for the CROSSROADS operation. The aircrews that flew the B-17 drones came from the 329th and 330th Bomb Squadrons, Clovis AAF, New Mexico. TU 1.5.3 operated the airfield and flew and maintained the seven B-17 drone controllers and ten B-17 drone aircraft used for cloud sampling. It also operated all base support functions at Enewetak including mess facilities, post exchange, special services, rations, fuel, signal and engineer support, and the message center (Reference B.5.1). There were 117 personnel badged out of a total of 450. All recorded exposures were less than 0.5 R. The vast majority of those badged were members of aircraft crews flying the B-17 controller aircraft. However, several firefighters and sheetmetal workers were also badged. The badging of firefighters is understandable since they may have had to fight a fire on contaminated aircraft. Perhaps the sheetmetal workers performed duties associated with the gaseous or particulate filter boxes on the drone B-17s, which were of sheetmetal construction.

Task Unit 1.5.4 (Air Transport Unit)

Personnel for TU 1.5.4 came primarily from the 320th Troop Carrier Squadron of the 509th Composite Group at Roswell Army Air Field, New Mexico. This unit provided airlift to and from the United States to Enewetak-Kwajalein, and performed air support missions in the Enewetak-Kwajalein-Bikini area. Although documents reflect TU 1.5.4 had 20 C-46s and 10 C-54s, there were not sufficient personnel for this many aircraft. In fact, the 20 C-46s were manned by the 439th Troop Carrier Squadron, Roswell Army Air Field, New Mexico, and were used to ferry men and materiel to and from the Pacific area. These personnel were never assigned to the joint task force. Only eight personnel were badged, four of whom were officers. None of the eight recorded any exposure.

Task Unit 1.5.5 (Air Service Unit)

Personnel for this unit came primarily from the 603rd Air Engineering Squadron, 1027th Materiel Squadron, 1395th Military Police Squadron, and the 390th Headquarters and Service Squadron. All were part of the 509th Composite Group at Roswell, New Mexico. TU 1.5.5 provided the supply and maintenance functions to Army Air Forces units on Kwajalein. In addition, it operated a mess facility, the special services office, a post exchange, rations breakdown point, fuel dump, signal and engineer supply point, and a message center for the Army Air Forces needs. It also had weather forecasting personnel and military policemen assigned to it. Of 686 personnel on the roster only 2 were badged. Their exposures were less than 0.10 R.

Task Unit 1.5.6 (Army Drone Unit)

This unit was combined with TU 1.5.3 before ABLE and BAKER tests.

Task Unit 1.5.7 (Army Air Weather Reconnaissance Unit)

Personnel for this task unit came primarily from the 59th Reconnaissance Squadron at Castle Army Air Field, California. This unit operated three WB-29s from Kwajalein to monitor weather around Bikini before the tests. On days before each shot, its planes monitored the weather at long ranges. Just after midnight the morning of each shot, its planes took off and monitored the weather in the Bikini area. Records indicate that none of these personnel were badged.

Task Unit 1.5.8 (Air Orientation Unit)

Personnel and aircraft for TU 1.5.8 came from units in the Air Materiel Command. Stationed at Kwajalein, it was responsible for aiding and transporting observers, visitors, news broadcasters, and the press. It furnished facilities for broadcasting and news releases on Kwajalein and provided two B-29s and two borrowed C-54s for media representatives to view the detonations and their results. Although no roster could be located for TU 1.5.8, a Letter Order from the 40th Bomb Group provided the names of 27 personnel assigned to TU 1.5.8. More personnel were probably in this unit, but they cannot be identified. Of the 27 personnel identified, 15 were badged and only one recorded any exposure, 0.06 R.

Task Unit 1.5.9 (Air-Sea Rescue Unit)

This unit was stationed on Enewetak with TU 1.5.3, and, in fact, was part of TU 1.5.3 until June 1946. It was made a separate task unit by Change No. 4 to the JTF 1 Op Plan 1-46 dated 30 May 1946. It operated two B-17 air-sea rescue aircraft equipped to support air-sea rescue operations for downed aircraft crews. It patrolled the area between Enewetak and Bikini, which was the flight path of the B-17 drones and B-17 controllers flying out of Enewetak. Although no roster for TU 1.5.9 personnel could be located, a set of orders marked "VOCG Mid Pac, eff 6 May 46" (Verbal Order Commanding General Mid-Pacific, effective 6 May 1946) was located, assigning 40 personnel from the 4th Emergency Rescue Squadron, APO 244, to TG 1.5. The remaining eight on Table 13 were identified from a TU 1.5.3 roster made up before TU 1.5.9 broke away from TU 1.5.3. Only eight personnel were badged, all of whom were officers. Four of these eight are also listed as radsafe monitors in the Radsafe Group of the Instrumentation Division (see Chapter 3). They were badged and received exposures in August as well as on both shot days. Two other officers in TU 1.5.9 appear to have performed radsafe monitoring duties as well since they were also badged and received exposures in August and on both shot days. These latter two may have been assigned to radsafe duties after the 20 April 1946 edition of the Instrumentation Division roster was formulated.

It is unusual that six officers from this unit received exposures on 1 July and 25 July (shot days), while no one else in the unit did. Furthermore, the location for all six on both dates is shown as "Eniwetok." They obviously were not members of a B-17 air-sea rescue crew since no one else was badged. They may have monitored returning drones for radiation at Enewetak on those dates and then went on to other radsafe monitoring duties in August. The highest exposure of the six was 0.77 R, recorded by an Army Air Forces captain. He was badged three times in August for a total of 0.47 R and on both shot days when

he recorded a total of 0.30 R. As mentioned above, his location on shot days was "Eniwetok;" however, his locations in August were target ships in Bikini Lagoon. His name is so unusual that it is unlikely that these were two different individuals, although it remains a possibility since the REECo exposure list shows no initials for this name.

OTHERS

Unit orders were located that identify the 6th Aircraft Repair Unit (Floating) as being aboard SS Brigadier General Alfred J. Lyon at Kwajalein during CROSSROADS. Lyon was a U.S. Army aircraft repair ship. Names of assigned personnel do not appear on other TG 1.5 rosters. None of the personnel assigned this unit has a record of being badged during CROSSROADS.

CHAPTER 9
U.S. NAVY PARTICIPATION

Operation CROSSROADS was popularly perceived as a Navy operation. The Deputy Task Force Commander for Aviation, an Army Air Forces officer, observed that (Reference C.9.206, pp. II-(B)-3 and II-(B)-4):

> Despite all efforts to the contrary on the part of the Task Force Commander and his officers in charge of public relations, news releases and publicity in the majority of cases tended to create, in the mind of the public, the impression that the tests were primarily a naval activity rather than a joint effort in which all services were participating and in which they were equally entitled to praise or censure.

That this was the case is not surprising. From every point of view except the organizational, CROSSROADS was predominantly a U.S. Navy operation. The primary mission of the test was to determine the effects of nuclear detonations on naval vessels. Commander Joint Task Force 1 (CJTF 1) was a Navy officer, and the majority of his joint staff were Navy personnel. In all, over 37,000 Navy personnel participated in CROSSROADS, approximately 90 percent of the total combined military and civilian population of the operation. There were 45 Navy aircraft and 237 Navy ships involved as full-time participants.

The ships were in two categories: support ships and target ships. In the support group were 153 large and small ships, which provided the berthing, messing, laboratory, and office space for the task force. In the target group were 93 vessels for Test ABLE and 92 vessels for Test BAKER, ranging from battleships to small amphibious craft. Of the target ships only 12 were remanned by their crews after the tests, 13 were sunk after ABLE or BAKER, 8 were towed to Pearl Harbor or the United States for inspection, and the remainder were sunk at Bikini or Kwajalein. The target ships that were later remanned were those with low radioactive contamination and no significant structural damage. Support ships evacuated the lagoon before each shot and took all personnel, including target ship crews, to a safe distance outside Bikini Lagoon. Tables 14 and 15 summarize the Navy vessels' participation in CROSSROADS. Ship histories, largely extracted from the ships' deck logs, which present information pertinent to potential personnel exposure, make up Appendix A to this report.

In the remainder of this chapter, the other Navy components of JTF 1 are discussed. For each unit, except small support ships, detailed information is given on the events in which they were involved during CROSSROADS. Discussed are Navy air units, diving units, and other Navy units that had some potential for radiological exposure.

Table 14. CROSSROADS target vessels and their disposition.

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure[a]	Destination and Arrival[a]	Decontamination Location	Disposition/Remarks	
						Date	Location
USS Anderson (DD-411)						1 Jul 46	Sunk at Bikini, shot ABLE
USS Apogon (SS-308)						25 Jul 46	Sunk at Bikini, shot BAKER
ARDC-13						6 Aug 46	Sunk at Bikini, shot BAKER
USS Arkansas (BB-33)						25 Jul 46	Sunk at Bikini, shot BAKER
USS Banner (APA-60)	27 Aug 46	29 Aug 46				16 Feb 48	Scuttled off Kwajalein
USS Barrow (APA-61)	26 Aug 46	27 Aug 46				11 May 48	Scuttled off Kwajalein
USS Bladen (APA-63)	20 Aug 46	21 Aug 46[b]	30 Aug 46	Pearl Harbor San Francisco 13 Sep 46	San Francisco	3 Aug 53	Remanned; transferred to Maritime Commission[c]
USS Bracken (APA-64)	19 Aug 46	21 Aug 46				10 Mar 48	Scuttled off Kwajalein
USS Briscoe (APA-65)	20 Aug 46	22 Aug 46[b]				6 May 48	Scuttled off Kwajalein
USS Brule (APA-66)	28 Aug 46	29 Aug 46				11 May 48	Scuttled off Kwajalein (8°47'N, 167°18'E)
USS Butte (APA-68)	28 Aug 46	30 Aug 46[c]				12 May 48	Scuttled off Kwajalein (8°40'N, 167°15'E)
USS Carlisle (APA-69)						1 Jul 46	Sunk at Bikini, shot ABLE
USS Carteret (APA-70)	25 Aug 46	27 Aug 46				19 Apr 48	Sunk by gunfire, Kwajalein (8°42'N, 167°5'E)
USS Catron (APA-71)	26 Aug 46	28 Aug 46				6 May 48	Sunk at Kwajalein (9°2'N, 167°17'E)
USS Conyngham (DD-371)	22 Aug 46	23 Aug 46	28 Aug 46	Pearl Harbor San Francisco 17 Oct 46	San Francisco	July 1948	Remanned; scuttled, southern California (31°33.5'N, 118°27'W)[c]
USS Cortland (APA-75)	19 Aug 46	20 Aug 46	30 Aug 46	Pearl Harbor San Francisco Norfolk December 1946	San Francisco	31 Mar 48	Remanned; transferred to Maritime Commission[c]

Notes:

[a]Target vessels that were sunk or scuttled at Kwajalein have no entry in this column.

[b]Inferred from various sources.

[c]Operational and Final radiological clearance dates for remanned target vessels can be found in Appendix A.

(continued)

Table 14. CROSSROADS target vessels and their disposition (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure[a]	Destination and Arrival[a]	Decontamination Location	Disposition/Remarks	
						Date	Location
USS Crittenden (APA-77)	24 Aug 46	26 Aug 46	1 Dec 46	San Francisco 1 Jan 47	San Francisco	5 Oct 48	Sunk off southern California (32°05'N, 115°05'E)
USS Dawson (APA-79)	19 Aug 46	21 Aug 46				19 Apr 48	Sunk by gunfire, Kwajalein (8°47'N, 167°20'E)
USS Dentuda (SS-335)	22 Aug 46	23 Aug 46	28 Aug 46	Pearl Harbor San Francisco October 1946	Mare Island Naval Shipyard	20 Jan 69	Remanned; sold for scrap[b]
USS Fallon (APA-81)	1 Sep 46	3 Sep 46				10 Mar 48	Scuttled near Kwajalein
USS Fillmore (APA-83)	22 Aug 46	23 Aug 46	28 Aug 46	Pearl Harbor Norfolk January 1947	San Francisco	1 Apr 48	Remanned; transferred to Maritime Commission[b]
USS Gasconade (APA-85)	24 Aug 46	26 Aug 46	Jan 47[c]	San Francisco 27 Jan 47	San Francisco	21 Jul 48	Sunk off southern California (31°35'N, 118°33'W)
USS Geneva (APA-86)	24 Aug 46	25 Aug 46	13 Oct 46	Pearl Harbor Norfolk January 1947	San Francisco	2 Nov 66	Remanned; transferred to Maritime Commission[b]
USS Gilliam (APA-57)						1 Jul 46	Sunk at Bikini, shot ABLE
USS Hughes (DD-410)	26 Aug 46	28 Aug 46	May 47[c]	Bremerton 31 May 47	Bremerton	16 Oct 48	Sunk off southern California (31°47'N, 118°40'W)
USS Independence (CVL-22)	25 Aug 46	27 Aug 46[c]	Jun 47	San Francisco 16 Jun 47	San Francisco	26 Jan 51	Sunk off southern California (37°20'N, 123°04'W)
USS Lamson (DD-367)						1 Jul 46	Sunk at Bikini, shot ABLE
LCI-327	1 Sep 46	3 Sep 46				30 Oct 47	Destroyed at Kwajalein
LCI-329	24 Aug 46	25 Aug 46				16 Mar 48	Sunk at Kwajalein
LCI-332	1 Sep 46	3 Sep 46				30 Sep 47	Sunk at Kwajalein
LCI-620						10 Aug 46	Sunk at sea off Bikini

Notes:

[a] Target vessels that were sunk or scuttled at Kwajalein have no entry in this column.

[b] Operational and final radiological clearance dates for remanned target vessels can be found in Appendix A.

[c] Inferred from various sources.

(continued)

Table 14. CROSSROADS target vessels and their disposition (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure[a]	Destination and Arrival[a]	Decontamination Location	Disposition/Remarks	
						Date	Location
LCI(L)-549	24 Aug 46	25 Aug 46	June 1948	San Francisco	San Francisco	19 Aug 49	Remanned; sold to private purchaser[b]
LCI(L)-615	4 Sep 46	5 Sep 46	June 1948	San Francisco	San Francisco	19 Aug 49	Remanned; sold to private purchaser[b]
LCT-412[c]	4 Sep 46	6 Sep 46				Sept 1947	Sunk at Kwajalein
LCT-414						After 25 Jul 46	Sunk at Bikini, demolition
LCT-705	2 Sep 46	4 Sep 46				Sept 1947	Sunk at Kwajalein
LCT-812						30 Aug 46	Sunk at Bikini, demolition
LCT-816	Unknown	Unknown				June 1947	Sunk at Kwajalein
LCT-818	1 Sep 46	3 Sep 46				Sept 1947	Sunk at Kwajalein
LCT-874	4 Sep 46	6 Sep 46				Sept 1947	Sunk at Kwajalein
LCT-1013	2 Sep 46	4 Sep 46				Sept 1947	Sunk at Kwajalein
LCT-1078	4 Sep 46	6 Sep 46				Sept 1947	Sunk at Kwajalein
LCT-1112	1 Sep 46	3 Sep 46				Sept 1947	Sunk at Kwajalein
LCT-1113	Unknown	Unknown				June 1947	Sunk at Kwajalein
LCT-1114						30 Jul 46	Sunk at Bikini, demolition
LCT-1115	Unknown	Unknown				Sept 1947	Sunk at Kwajalein
LCT-1175						After 25 Jul 46	Sunk at Bikini, shot BAKER
LCT-1187						29 Aug 46	Sunk at Bikini, shot BAKER
LCT-1237						After 25 Jul 46	Sunk at Bikini, shot BAKER
LSM-60						25 Jul 46	Sunk at Bikini, shot BAKER

Notes:

[a]Target vessels that were sunk or scuttled at Kwajalein have no entry in this column.

[b]Operational and final radiological clearance dates for remanned target vessels can be found in Appendix A.

[c]*Shot BAKER target only.*

(continued)

Table 14. CROSSROADS target vessels and their disposition (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure[a]	Destination and Arrival[a]	Decontamination Location	Disposition/Remarks	
						Date	Location
USS LSI-52	26 Aug 46	27 Aug 46				Apr 1948	Sunk by gunfire, Kwajalein (8°47'N, 167°25'E)
USS LST-125[b]						11 Aug 46	Sunk at sea off Bikini (11°25'N, 165°25'E)
USS LST-133	29 Aug 46	30 Aug 46				11 May 48	Sunk at Kwajalein (8°48'N, 167°10'E)
USS LST-220	28 Aug 46	30 Aug 46				12 May 48	Sunk at Kwajalein (8°44'N, 167°25'E)
USS LST-545	28 Aug 46	30 Aug 46				12 May 48	Sunk at Kwajalein (8°48'N, 167°21'E)
USS LST-661	25 Aug 46	27 Aug 46				25 Jul 48	Sunk at Kwajalein (8°51'N, 167°20.3'E)
USS Mayrant (DD-402)	28 Aug 46	29 Aug 46				4 Apr 48	Sunk by gunfire, Kwajalein (8°49'N, 167°23'E)
USS Mugford (DD-389)	19 Aug 46	21 Aug 46				22 Mar 48	Scuttled, Kwajalein
USS Mustin (DD 413)	28 Aug 46	30 Aug 46				28 Apr 48	Sunk by gunfire, Kwajalein (8°47.8'N, 167°11.5'E)
Nagato (Japanese battleship)						30 Jul 46	Sunk at Bikini, shot BAKER
USS Nevada (BB 36)	19 Aug 46	22 Aug 46	May 1947[c]	Pearl Harbor 15 May 1947	Pearl Harbor	31 Jul 48	Sunk by gunfire, near Pearl Harbor (20°58'N, 159°17'W)
USS New York (BB-34)	22 Aug 46	24 Aug 46	March 1947[c]	Pearl Harbor 15 Mar 1947	Pearl Harbor	8 Jul 48	Sunk 40 nmi (74 km) southwest of Pearl Harbor
USS Niagara (APA-87)	21 Aug 46	23 Aug 46	30 Aug 46	Pearl Harbor San Francisco Norfolk	San Francisco	1950	Remanned; sold for scrap to Northern Metals Co., Philadelphia[d]
USS Parche (SS-384)	22 Aug 46	23 Aug 46	28 Aug 46	Pearl Harbor San Francisco 14 Oct 46	Mare Island Naval Shipyard, San Francisco	July 1970	Remanned; sold for scrap[d]
USS Pennsylvania (BB-38)	21 Aug 46	24 Aug 46				10 Feb 48	Sunk at Kwajalein

Notes:

[a]Target vessels that were sunk or scuttled at Kwajalein have no entry in this column.

[b]Shot BAKER target only.

[c]Inferred from various sources.

[d]Operational and radiological clearance dates for remanned target vessels can be found in Appendix A.

(continued)

Table 14. CROSSROADS target vessels and their disposition (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure[a]	Destination and Arrival[a]	Decontamination Location	Disposition/Remarks	
						Date	Location
USS Pensacola (CA-24)	24 Aug 46	27 Aug 46[b]	April 1947[b]	Bremerton 21 Apr 1947	Bremerton	10 Nov 48	Sunk off Washington coast (48°12'N, 127°01'W)
USS Pilotfish (SS-386)						25 Jul 46 16 Oct 48	Sunk, shot BAKER; raised and inspected; resunk at Bikini
Prinz Eugen (German cruiser)	20 Aug 46	22 Aug 46				22 Dec 46	Sank at Kwajalein
USS Ralph Talbot (DD-390)	26 Aug 46	29 Aug 46				March 48	Sunk at Kwajalein
USS Rhind (DD-404)	30 Aug 46	1 Sep 46				22 Mar 48	Scuttled, Kwajalein
Sakawa (Japanese cruiser)						2 Jul 46	Sunk at Bikini, shot ABLE
USS Salt Lake City (CA-25)	23 Aug 46	25 Aug 46	July 1947[b]	Bremerton 28 Jul 47	Bremerton	25 May 48	Sunk off southern California (31°57'N, 119°54'W)
USS Saratoga (CV-3)						25 Jul 46	Sunk at Bikini, shot BAKER
USS Searaven (SS-196)	22 Aug 46	23 Aug 46	28 Aug 46	Pearl Harbor San Francisco 14 Oct 46	Mare Island Naval Shipyard, San Francisco	11 Sep 48	Remanned; sunk off southern California (31°42.3N, 118°26.4'W)[c]
USS Skate (SS-305)	23 Aug 46	24 Aug 46	28 Aug 46	San Francisco 22 Oct 46	Mare Island Naval Shipyard, San Francisco	1948	Sunk off southern California (32°00'N, 119°04'W)[c]
USS Skipjack (SS-184)	5 Sep 46	7 Sep 46	11 Sep 46	San Francisco	Mare Island Naval Shipyard, San Francisco	11 Aug 48	Sunk off southern California (32°22'N, 118°53'W)
USS Stack (DD-406)	19 Aug 46	20 Aug 46				24 Apr 48	Sunk at Kwajalein
USS Trippe (DD-403)	20 Aug 46	22 Aug 46				3 Feb 48	Sunk at Kwajalein
USS Tuna (SS-203)	22 Aug 46	23 Aug 46	28 Aug 46	Pearl Harbor	Mare Island Naval Shipyard, San Francisco October 1946	24 Sep 46	Remanned; sunk off southern California (31°40'N, 118°30'W)[c]
USS Wainwright (DD-419)	23 Aug 46	25 Aug 46[b]				5 Jul 48	Sunk at Kwajalein
USS Wilson (DD-408)	19 Aug 46	21 Aug 46				8 Mar 48	Scuttled, Kwajalein
YO-160						25 Jul 46	Sunk at Bikini, shot BAKER
YOG-83	5 Sep 46	7 Sep 46				16 Sep 48	Sunk at Kwajalein

Notes:

[a]Target vessels that were sunk or scuttled at Kwajalein have no entry in this column.

[b]Operational and final radiological clearance dates for remanned target vessels can be found in Appendix A.

[c]Inferred from various sources.

Table 15. CROSSROADS support ships and decontamination locations.

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
USS Achomawi (ATF-148)	29 Aug 46	30 Aug 46	1 Sep 46	Pearl Harbor San Francisco 4 Oct 46	San Francisco	6 Dec 46	13 Dec 46
USS Ajax (AR-6)	23 Aug 46	24 Aug 46	28 Aug 46	Pearl Harbor San Pedro 27 Sep 46	San Diego	By 1 Jan 47	Unknown
USS Albemarle (AV-5)[a,b]	25 Jul 46	26 Jul 46	30 Jul 46	Pearl Harbor San Pedro 12 Aug 46	Not required		By 22 Nov 46
USS Allen M. Sumner (DD-692)	10 Aug 46			Pearl Harbor San Diego San Francisco Puget Sound 30 Oct 46	Puget Sound	19 Nov 46	10 Jan 47
APL-27	24 Aug 46	26 Aug 46	July 1947	Los Angeles	Kwajalein	25 Feb 47	10 Mar 47[c]
USS Appalachian (AGC-1)[a]	29 Jul 46	30 Jul 46	30 Jul 46	Pearl Harbor San Francisco 16 Aug 46	Not required	2 Oct 46	3 Oct 46
USS Appling (APA-58)	8 Aug 46			Pearl Harbor San Francisco 22 Aug 46	San Francisco	By 22 Nov 46	13 Dec 46
ARD-29	25 Aug 46	26 Aug 46	16 Sep 46	Pearl Harbor 3 Oct 46	Pearl Harbor	18 Feb 47	18 Feb 47
USS Artemis (AKA-21)	18 Aug 46			Pearl Harbor 24 Aug 46	San Francisco	20 Nov 46	27 Dec 46
ATA-124[b]	25 Aug 46	26 Aug 46	9 Sep 46	Pearl Harbor Puget Sound 25 Nov 46	Puget Sound	Unknown	18 Dec 46

Notes:

[a]Ship not present at Bikini for sufficient period after BAKER test to be radiologically suspect.

[b]Shot BAKER only

[c]Inferred from various sources.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
ATA-180	1 Sep 46	3 Sep 46	8 Sep 46	Pearl Harbor Puget Sound 25 Nov 46	Puget Sound	24 Feb 47	Unknown
ATA-185	5 Sep 46	7 Sep 46	8 Sep 46	Pearl Harbor 20 Sep 46	Pearl Harbor San Diego	13 Dec 46	18 Jan 47
ATA-187	24 Aug 46	25 Aug 46	11 Sep 46	Pearl Harbor San Francisco 9 Oct 46	San Diego	6 Nov 46	By 22 Nov 46
ATA-192	2 Sep 46	4 Sep 46	8 Sep 46	Pearl Harbor San Francisco 12 Oct 46	San Francisco	14 Nov 46	10 Feb 47
ATR-40	23 Aug 46	25 Aug 46	8 Sep 46	Pearl Harbor 21 Sep 46	San Francisco	17 Dec 46	21 Dec 46
ATR-87	1 Sep 46	3 Sep 46	8 Sep 46	Johnston Island Pearl Harbor Bremerton 27 Nov 46	Puget Sound	13 Dec 46	By 4 Jan 47
USS Avery Island (AG-76)	7 Aug 46			San Francisco 21 Aug 46	San Francisco	3 Dec 46	By 4 Jan 47
USS Barton (DD-722)	10 Aug 46			Pearl Harbor San Diego 22 Aug 46	San Francisco	2 Nov 46	18 Dec 46
USS Bayfield (APA-33)	3 Aug 46	4 Aug 46	8 Aug 46	Pearl Harbor San Francisco Puget Sound August 1946	Puget Sound	7 Dec 46	10 Feb 47
USS Begor (APD-127)	3 Aug 46			Pearl Harbor 8 Aug 46	San Diego	30 Sep 46	25 Jan 47
USS Benevolence (AH-13)	25 Aug 46	26 Aug 46	29 Aug 46	Pearl Harbor San Francisco 8 Sep 46	San Francisco	24 Sep 46	April 1947
USS Bexar (APA-237)	23 Aug 46	24 Aug 46	29 Aug 46	Pearl Harbor San Pedro 10 Sep 46	San Diego	24 Jan 47	1 Feb 47

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
USS Blue Ridge (AGC-2)[a]	30 Jul 46			Pearl Harbor 6 Aug 46	Not required		By 22 Nov 46
USS Bottineau (APA-235)	10 Aug 46			Pearl Harbor San Francisco 21 Aug 46	San Francisco	19 Dec 46	27 Dec 46
USS Bountiful (AH-9)[a]	27 Jul 46			Pearl Harbor 4 Aug 46	Not required	27 Sep 46	27 Sep 46
USS Bowditch (AGS-4)[b]	27 Sep 46	28 Sep 46	30 Sep 46	Pearl Harbor 8 Oct 46	San Francisco	20 Nov 46	20 Nov 46
USCG Bramble (WAGL-392)	24 Aug 46	25 Aug 46	Unknown	Pearl Harbor[c]	Pearl Harbor	Unknown	By 22 Nov 46
USS Burleson (APA-67)	5 Aug 46			Pearl Harbor San Pedro 22 Aug 46	Norfolk	Unknown	By 14 Oct 46
USS Cebu (ARG-6)	23 Aug 46	24 Aug 46	29 Aug 46	Pearl Harbor San Diego[c]	San Francisco	16 Dec 46	21 Dec 46
USS Charles P. Cecil (DD-835)[a]	25 Jul 46	25 Jul 46	28 Jul 46	Pearl Harbor San Diego 9 Aug 46	Not required	Unknown	By 22 Nov 46
USS Chickasaw (ATF-83)	26 Aug 46	28 Aug 46	7 Sep 46	Guam	San Francisco	13 Jan 47	18 Jan 47
USS Chikaskia (AO-54)	23 Aug 46	24 Aug 46	24 Aug 46	Pearl Harbor San Francisco 17 Sep 46	Puget Sound	31 Dec 46	4 Jan 47
USS Chowanoc (ATF-100)	28 Aug 46	30 Aug 46	16 Sep 46	Pearl Harbor 3 Oct 46	Pearl Harbor	Unknown	1 Feb 47
USS Clamp (ARS-33)	28 Aug 46	30 Aug 46	5 Sep 46	Pearl Harbor San Francisco 22 Oct 46	Los Angeles	Unknown	By 22 Nov 46

Notes:

[a]Ship not present at Bikini for sufficient period after BAKER test to be radiologically suspect.

[b]Shot BAKER only

[c]Inferred from various sources.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
USS Coasters Harbor (AG-74)	15 Aug 46	16 Aug 46	17 Aug 46	Pearl Harbor San Diego	Los Angeles	7 Dec 46	13 Dec 46
USS Conserver (ARS-39)	5 Sep 46	7 Sep 46	12 Feb 47	Wake Island Pearl Harbor 22 Feb 47	Pearl Harbor	4 May 47	11 May 47
USS Coucal (ASR-8)	4 Sep 46	6 Sep 46	11 Sep 46	Pearl Harbor 22 Sep 46	San Diego	10 Jan 47	18 Jan 47
USS Creon (ARL-11)	21 Aug 46	23 Aug 46	11 Sep 46	Pearl Harbor San Pedro	Los Angeles	23 Jan 47	1 Feb 47
USS Cumberland Sound (AV-17)	1 Aug 46			San Pedro	Los Angeles	3 Dec 46	13 Dec 46
USS Current (ARS-22)	25 Aug 46	27 Aug 46	2 Dec 46	Pearl Harbor 18 Dec 46	Pearl Harbor	6 Feb 47	17 Feb 47
USS Deliver (ARS-23)	20 Aug 46	22 Aug 46	8 Sep 46	Pearl Harbor 23 Sep 46	San Francisco	20 Dec 46	27 Dec 46
USS Dixie (AD-14)	25 Aug 46	26 Aug 46	9 Sep 46	Pearl Harbor San Francisco 22 Sep 46	San Francisco	2 Oct 46	By 22 Nov 46
USS Dutton (AGS-8)	14 Sep 46	15 Sep 46	25 Sep 46	Pearl Harbor 4 Oct 46	Los Angeles	18 Dec 46	10 Jan 47
USS Enoree (AO-69)	24 Aug 46	25 Aug 46[a]	7 Sep 46	San Francisco 20 Sep 46	San Francisco	3 Dec 46	Unknown
USS Etlah (AN-79)	27 Aug 46	29 Aug 46[a]	2 Sep 46	Pearl Harbor 12 Sep 46	Puget Sound	18 Dec 46	21 Dec 46
USS Fall River (CA-131)	4 Sep 46	5 sep 46	9 Sep 46	Pearl Harbor 14 Sep 46	Los Angeles	23 Dec 46	27 Dec 46
USS Flusser (DD-368)	4 Sep 46	5 Sep 46	9 Sep 46	Pearl Harbor 14 Sep 46	Pearl Harbor	By 22 Nov 46	13 Dec 46
USS Fulton (AS-11)	25 Aug 46	26 Aug 46	28 Aug 46	Pearl Harbor San Francisco	San Francisco	24 Dec 46	10 Jan 47

Notes:
[a]Inferred from various sources.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
USS Coasters Harbor (AG-74)	15 Aug 46	16 Aug 46	17 Aug 46	Pearl Harbor San Diego	Los Angeles	7 Dec 46	13 Dec 46
USS Conserver (ARS-39)	5 Sep 46	7 Sep 46	12 Feb 47	Wake Island Pearl Harbor 22 Feb 47	Pearl Harbor	4 May 47	11 May 47
USS Coucal (ASR-8)	4 Sep 46	6 Sep 46	11 Sep 46	Pearl Harbor 22 Sep 46	San Diego	10 Jan 47	18 Jan 47
USS Creon (ARL-11)	21 Aug 46	23 Aug 46	11 Sep 46	Pearl Harbor San Pedro	Los Angeles	23 Jan 47	1 Feb 47
USS Cumberland Sound (AV-17)	1 Aug 46			San Pedro	Los Angeles	3 Dec 46	13 Dec 46
USS Current (ARS-22)	25 Aug 46	27 Aug 46	2 Dec 46	Pearl Harbor 18 Dec 46	Pearl Harbor	6 Feb 47	17 Feb 47
USS Deliver (ARS-23)	20 Aug 46	22 Aug 46	8 Sep 46	Pearl Harbor 23 Sep 46	San Francisco	20 Dec 46	27 Dec 46
USS Dixie (AD-14)	25 Aug 46	26 Aug 46	9 Sep 46	Pearl Harbor San Francisco 22 Sep 46	San Francisco	2 Oct 46	By 22 Nov 46
USS Dutton (AGS-8)	14 Sep 46	15 Sep 46	25 Sep 46	Pearl Harbor 4 Oct 46	Los Angeles	18 Dec 46	10 Jan 47
USS Enoree (AO-69)	24 Aug 46	25 Aug 46[a]	7 Sep 46	San Francisco 20 Sep 46	San Francisco	3 Dec 46	Unknown
USS Etlah (AN-79)	27 Aug 46	29 Aug 46[a]	2 Sep 46	Pearl Harbor 12 Sep 46	Puget Sound	18 Dec 46	21 Dec 46
USS Fall River (CA-131)	4 Sep 46	5 sep 46	9 Sep 46	Pearl Harbor 14 Sep 46	Los Angeles	23 Dec 46	27 Dec 46
USS Flusser (DD-368)	4 Sep 46	5 Sep 46	9 Sep 46	Pearl Harbor 14 Sep 46	Pearl Harbor	By 22 Nov 46	13 Dec 46
USS Fulton (AS-11)	25 Aug 46	26 Aug 46	28 Aug 46	Pearl Harbor San Francisco	San Francisco	24 Dec 46	10 Jan 47

Notes:
[a]Inferred from various sources.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
USS Furse (DD-882)[a]	28 Jul 46	29 Jul 46	30 Jul 46	Pearl Harbor San Pedro	Not required	Unknown	By 22 Nov 46
USS George Clymer (APA-27)	20 Aug 46			Pearl Harbor San Pedro 3 Sep 46	San Diego	By 22 Nov 46	7 Feb 47
USS Gunston Hall (LSD-5)	25 Aug 46	26 Aug 46	2 Sep 46	Pearl Harbor 1 Sep 46	Los Angeles	8 Jan 47	10 Jan 47
USS Gypsy (ARSD-1)	5 Sep 46	7 Sep 46	10 Sep 46	Pearl Harbor 16 Sep 46	Pearl Harbor Los Angeles	9 Jan 47	19 Jan 47
USS Haven (AH-12)	25 Aug 46	26 Aug 46	10 Oct 46	Pearl Harbor 15 Oct 46	Los Angeles	14 Feb 47	Unknown
USS Henrico (APA-45)	16 Aug 46			Pearl Harbor San Francisco 27 Aug 46	San Francisco	28 Jan 47	1 Feb 47
USS Hesperia (AKS-13)	23 Aug 46	24 Aug 46	31 Aug 46	Pearl Harbor 12 Sep 46	Pearl Harbor	28 Dec 46	4 Jan 47
USS James M. Gilliss (AGS-13)	20 Aug 46			Pearl Harbor 1 Sep 46	San Francisco	13 Nov 46	13 Nov 46
USS John Bish (AGS-10)	20 Aug 46			Pearl Harbor 1 Sep 46	San Francisco	15 Oct 46	22 Nov 46
USS Ingraham (DD-694)	10 Aug 46			Pearl Harbor San Diego	Puget Sound	19 Nov 46	21 Nov 46
USS Kenneth Whiting (AV-14)	14 Aug 46			Pearl Harbor 19 Aug 46	Los Angeles	11 Dec 46	21 Dec 46
USS Laffey (DD-724)	10 Aug 46			Pearl Harbor San Diego 22 Aug 46	San Francisco	2 Nov 46	18 Dec 46
LCI(L)-977	22 Aug 46	23 Aug 46	11 Sep 46	Guam	Guam/Marianas	Unknown	7 Mar 47

Note:

[a]Ship not present at Bikini for sufficient period after BAKER test to be radiologically suspect.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
LCI(L)-1062	22 Aug 46	23 Aug 46	11 Oct 46	Guam Pearl Harbor	Pearl Harbor	Unknown	By 4 Jan 47
LCI(L)-1067	22 Aug 46	23 Aug 46	9 Sep 46	Guam 16 Sep 46	Guam	24 Feb 47	Unknown
LCI(L)-1091	25 Aug 46	26 Aug 46	9 Sep 46	Guam 16 Sep 46	Guam	Unknown	11 Dec 46[a]
USS Limestone (IX-158)[b]		15 Apr 46	8 Sep 46	Pearl Harbor 23 Sep 46	Not required	Unknown	By 22 Nov 46
USS Lowry (DD-770)	10 Aug 46			Pearl Harbor San Diego 22 Aug 46	San Francisco	6 Nov 46	By 4 Jan 1947
USS LST-388	25 Aug 46	26 Aug 46	Unknown	Caroline Islands	San Francisco	5 Dec 46	13 Dec 46
USS LST-817	23 Aug 46	24 Aug 46	31 Aug 46	Pearl Harbor Port Hueneme 5 Oct 46	San Francisco	21 Nov 46	22 Nov 46
USS LST-861	24 Aug 46	25 Aug 46	2 Sep 46	Pearl Harbor 12 Sep 46	San Francisco	6 Dec 46	13 Dec 46
USS LST-871[b]	25 Jul 46	27 Jul 46	9 Aug 46	Pearl Harbor 30 Aug 46	Not required	Unknown	By 22 Nov 46
USS LST-881	22 Aug 46	27 Aug 46	31 Aug 46	Pearl Harbor 10 Sep 46	San Francisco	13 Dec 46	23 Dec 46
USS LST-989[b]	25 Jul 46	9 Aug 46[c]	9 Aug 46	Pearl Harbor 20 Aug 46[a]	Not required	19 Nov 46	22 Nov 46
USS Mender (ARSD-2)[d]	4 Sep 46	6 Sep 46	8 Sep 46	Pearl Harbor 19 Sep 46[a]	Los Angeles	3 Jan 47	Unknown

Notes:

[a]Inferred from various sources.

[b]Ship not present at Bikini for sufficient period after BAKER test to be radiologically suspect.

[c]From Enewetak.

[d]Shot BAKER only.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
USS Moale (DD-693)	10 Aug 46			Pearl Harbor San Diego 22 Aug 46	San Francisco	19 Nov 46	11 Dec 46
USS Mount McKinley (AGC-7)	10 Aug 46			Pearl Harbor 16 Aug 46	San Diego	20 Dec 46	29 Jan 47
USS Munsee (ATF-107)	28 Aug 46	30 Aug 46	2 Sep 46	Pearl Harbor	San Francisco	18 Nov 46	April 1947
USS Newman K. Perry (DD-883)	4 Aug			Pearl Harbor 9 Aug 46	San Diego	17 Jan 47	25 Jan 47
USS O'Brien (DD 725)	8 Aug 46			Pearl Harbor 15 Aug 46	San Francisco	6 Nov 46	19 Dec 46
USS Oneota (AN-85)	26 Aug 46	29 Aug 46	6 Sep 46	Guam 13 Sep 46	Pearl Harbor	11 Dec 46	Unknown
USS Orca (AVP-49)	12 Aug 46	13 Aug 46	14 Aug 46	Guam	Pearl Harbor	11 Dec 46	13 Dec 46
USS Ottawa (AKA-101)	2 Aug 46			Port Hueneme 14 Aug 46	Pearl Harbor	13 Sep 46	13 Sep 46
USS Palmyra (ARS[T]-3)	5 Sep 46	6 Sep 46	11 Sep 46	Pearl Harbor San Francisco 9 Oct 46	San Francisco	By 22 Nov 46	By 4 Jan 47
USS Panamint (AGC-13)[a]	27 Jul 46	28 Jul 46	29 Jul 46	Honolulu San Francisco 12 Aug 46	Not required	22 Nov 46	22 Nov 46
PGM-23	25 Aug 46	26 Aug 46	9 Sep 46	Pearl Harbor 16 Sep 46	Pearl Harbor	Unknown	Unknown
PGM-24	25 Aug 46	26 Aug 46	9 Sep 46	Pearl Harbor 16 Sep 46	Pearl Harbor	13 Feb 47	Decommissioned 13 Mar 47
PGM-25	10 Aug 46	11 Aug 46	12 Aug 46	Guam 17 Aug 46	New Orleans	Unknown	28 May 47

Note:

[a]Ship not present at Bikini for sufficient period after BAKER test to be radiologically suspect.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
PGM-29	10 Aug 46	11 Aug 46	12 Aug 46	Guam 17 Aug 46	New Orleans	Unknown	28 May 47
PGM-31	10 Aug 46	11 Aug 46	12 Aug 46	Guam 17 Aug 46	Pearl Harbor	17 Jan 47	25 Jan 47
PGM-32	10 Aug 46	11 Aug 46	12 Aug 46	Guam 17 Aug 46	Philippines	10 Oct 46	10 Oct 46
USS Phaon (ARB-3)[a]	23 Aug 46	24 Aug 46	3 Sep 46	Pearl Harbor 12 Sep 46	Los Angles	26 Dec 46	4 Jan 47
USS Pollux (AKS-4)	19 Aug 46	20 Aug 46	20 Aug 46	Pearl Harbor 29 Aug 46	Puget Sound	29 Nov 46	25 Jan 47
USS Preserver (ARS-8)	28 Aug 46	30 Aug 46	1 Sep 46	Pearl Harbor	Los Angeles	8 Dec 46	4 Jan 47
USS Presque Isle (APB-44)	19 Aug 46	20 Aug 46	2 Sep 46	Pearl Harbor 12 Sep 46	Los Angeles	12 Dec 46	21 Dec 46
USS Quartz (IX-150)	22 Aug 46	23 Aug 46	3 Sep 46	Pearl Harbor 15 Sep 46	Puget Sound	12 Dec 46	13 Dec 46
USS Reclaimer (ARS-42)	1 Sep 46	3 Sep 46	6 Sep 46	Pearl Harbor 25 Sep 46	Los Angeles	24 Dec 46	By 4 Jan 47
USS Robert K. Huntington (DD-781)	10 Aug 46			Pearl Harbor San Diego 27 Aug 46	Puget Sound	19 Nov 46	4 Jan 47
USS Rockbridge (APA-228)	23 Aug 46	24 Aug 46	29 Aug 46	Pearl Harbor San Francisco 12 Sep 46	San Francisco	6 Dec 46	13 Dec 46
USS Rockingham (APA-229)	24 Aug 46	25 Aug 46	29 Aug 46	Pearl Harbor San Francisco 12 Sep 46	San Francisco	4 Dec 46	18 Dec 46
USS Rockwall (APA-230)	19 Aug 46			Pearl Harbor Port Hueneme 13 Sep 46	San Francisco	17 Dec 46	27 Dec 46

Notes:

[a]Shot BAKER only.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
USS Rolette (AKA-99)	26 Aug 46			Enewetak Port Hueneme 13 Sep 46	San Diego	28 Jan 47	1 Feb 47
USS Saidor (CVE-117)	4 Aug 46			Pearl Harbor 9 Aug 46	San Diego	28 Jan 47	1 Feb 47
USS Saint Croix (APA-231)	2 Aug 46			Pearl Harbor Port Hueneme	San Diego	22 Nov 46	10 Jan 47
USS San Marcos (LSD-25)	25 Aug 46	26 Aug 46	30 Aug 46	Pearl Harbor 6 Sep 46	San Francisco	24 Oct 46	18 Jan 47
USS Severn (AO-61)[a]	24 Aug 46			Pearl Harbor	Los Angeles	Unknown	3 Nov 46
USS Shakamaxon (AN-88)	27 Aug 46	28 Aug 46	6 Sep 46	Guam	Pearl Harbor	12 Dec 46	4 Jan 47
USS Shangri-La (CV-38)[a]	25 Jul 46	25 Jul 46	28 Jul 46	Pearl Harbor San Diego	Not required	Unknown	By 22 Nov 46
USS Sioux (ATF-75)	25 Aug 46	26 Aug 46	3 Sep 46	Pearl Harbor	Los Angeles	28 Nov 46	4 Dec 46
USS Sphinx (ARL-24)	19 Aug 46	20 Aug 46	14 Dec 46	Wake Island Pearl Harbor	Los Angeles	14 Feb 47	23 Apr 47
USS Suncock (AN-80)	30 Aug 46	1 Sep 46	2 Sep 46	Pearl Harbor 12 Sep 46	Puget Sound	12 Dec 46	13 Dec 46
USS Sylvania (AKA-44)	25 Aug 46	26 Aug 46	27 Aug 46	Pearl Harbor 7 Sep 46	Puget Sound	7 Dec 46	Unknown
USS Telamon (ARB-8)[b]	15 Aug 46			Pearl Harbor San Francisco 7 Sep 46	Los Angeles	12 Dec 46	21 Dec 46
USS Tombigbee (AOG-11)[c]	21 Aug 46	22 Aug 46	5 Sep 46	Pearl Harbor	Los Angeles	31 Dec 46	4 Jan 47
USS Turner (DD-834)[a]	25 Jul 46			Pearl Harbor 30 Aug 46	Not required	Unknown	By 22 Nov 46

Notes:

[a]Ship not present at Bikini for sufficient period after BAKER test to be radiologically suspect.

[b]Shot BAKER only.

[c]Shot ABLE only.

(continued)

Table 15. CROSSROADS support ships and decontamination locations (continued).

Vessel	Bikini Departure	Kwajalein Arrival	Kwajalein Departure	Destination and Arrival	Decontamination Location	Operational Clearance	Final Clearance
USS Walke (DD-723)	10 Aug 46			Pearl Harbor San Diego 22 Aug 46	San Francisco	Unknown	23 Oct 46
USS Wenatchee (ATF-118)	18 Aug 46	19 Aug 46	28 Aug 46	Pearl Harbor 5 Sep 46	San Francisco	13 Nov 46	13 Nov 46
USS Wharton (AP-7)	25 Aug 46	26 Aug 46	28 Aug 46	San Francisco After 3 Sep 46	Puget Sound	10 Feb 47	Unknown
USS Widgeon (ASR-1)	5 Sep 46	7 Sep 46	11 Sep 46	Pearl Harbor 22 Sep 46	San Francisco	13 Dec 46	10 Jan 47
USS Wildcat (AW-2)	19 Aug 46	20 Aug 46	28 Aug 46	Pearl Harbor 9 Sep 46	Puget Sound	9 Jan 47	10 Jan 47
YMS-354	14 Sep 46	15 Sep 46	21 Oct 46	Guam/Subic Bay	Guam/Marianas	20 Dec 46	10 Feb 47
YMS-358	14 Sep 46	15 Sep 46	21 Sep 46	Guam/Subic Bay	Guam/Marianas	20 Dec 46	10 Feb 47
YMS-413	14 Sep 46	15 Sep 46	21 Oct 46	Guam/Subic Bay	Guam/Marianas	20 Dec 46	10 Feb 47
YMS-463	14 Sep 46	15 Sep 46	21 Oct 46	Guam/Subic Bay	Guam/Marianas	20 Dec 46	10 Feb 47

Sources: References A.3, A.5, C.0.23, A.13.9, C.13.10, C.13.11, C.11.27.

JOINT TASK FORCE 1 STAFF

The Joint Chiefs of Staff (JCS) directive establishing JTF 1 stated that it would be organized with adequate representation of land, sea, and air forces, and that it would include civilian scientists. Implementation of adequate representation reflected the dominant naval flavor of the operation. The JTF 1 roster of officers dated 1 July 1946 shows 501 Navy officers, 8 Marine Corps officers, 141 Army ground officers, and 21 Army Air Forces officers. Of the 501 Navy officers, 444 were assigned to various ships at Bikini. The remainder filled billets in other locations: 39 were in the JTF 1 rear echelon at Washington, D.C.; 1 each was at Pearl Harbor and Oak Ridge, Tennessee; and 16 were assigned to Kwajalein Atoll.

DISPATCH BOAT AND BOAT POOL

The Dispatch Boat and Boat Pool was designated Task Unit (TU) 1.8.3 (Dispatch Boat and Boat Pool) under Task Group (TG) 1.8 (Service Group). The mission of TU 1.8.3 was to provide dispatch and mail service, interatoll freight and passenger service, and general boat pool services, e.g., ship-to-ship and ship-to-shore. Special boat operations were also a mission, which included operating a flag pool as required for use of distinguished persons and visiting flag and general officers and providing craft for radiological safety (radsafe) work and boats for the target array.

A large number of personnel, ships, and boats were assigned to TU 1.8.3. These totals varied throughout the operation as personnel were discharged from the naval service or transferred to other task force activities, and as boats were damaged or sunk, or released for special missions. Originally 313 personnel were assigned to operate and maintain the boat pool. By 10 June this number had been reduced to 228 due to discharges and transfers. Some replacements were obtained from TG 1.7 (Surface Patrol Group) and from new personnel arrivals. However, personnel deficiencies were never made up. The loss of personnel, as enlistments from World War II lapsed, continued to be a problem throughout CROSSROADS. For the most part, replacement personnel were untrained and great difficulty was experienced in keeping boats operating. For example, a maximum number of boats assigned to TU 1.8.3, 152, was reached on 19 June. By 31 July, a time of high boat pool need, only 93 boats were in operating condition.

Units assigned to TU 1.8.3 were two dock landing ships, USS San Marcos (LSD-25) and USS Gunston Hall (LSD-5), one self-propelled barracks ship, USS Presque Isle (APB-44), and a variety of small boats. The two LSDs provided boat maintenance facilities and along with the APB quartered and messed boat pool personnel. A landing craft repair ship, USS Sphinx (ARL-24), from TG 1.8 also assisted in boat repairs. The number and types of boats assigned varied. On 19 June there were six motor gunboat patrol vessels (PGM-23, PGM-24, PGM-25, PGM-29, PGM-31, and PGM-32), used almost exclusively for by the Radiological Safety Group; four large infantry landing craft (LCI(L)-1062, LCI(L)-1067, and LCI(L)-1091 at Bikini and LCI(L)-977 at Kwajalein; 38 LCMs (mechanized landing craft); 34 LCVPs (vehicle and personnel landing craft); 44 LCP(R)s (ramped personnel landing craft); 1 LCP(L) (large personnel landing craft); 30 PPBs (24-foot boats); 3 PBs (45-foot boats); 1 LCC (control landing craft); and 1 MB (35-foot boat).

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All ships and most of the boats of TU 1.8.3 cleared the lagoon for both tests. San Marcos and the six PGMs used for radiological monitoring soon after both shots were stationed about 12 nmi (22 km) from the lagoon entrance. The remainder of the task unit evacuated to Rongelap Atoll for shot BAKER (Reference C.9.206, pp. VII-(A)-77 and VII-(F)-29 through VII-(F)-31).

In order to meet pressing demands, the boat pool was augmented by boats and personnel from various ships and TU 1.3.1 (Transport Unit) and TG 1.2 (Target Vessel Group). Despite these arrangements, at no time during the course of the operation did the boat pool have sufficient operable boats to meet all requirements. The situation was very much aggravated by the damage, beaching, and sinking of 42 boats in the vicinity of Aomen Island during Queen Day (ABLE shot rehearsal) evacuation. The loss was caused by a combination of heavy weather, inadequate moorings, and an LCT breaking loose and drifting through the boat moorings (Reference C.9.206, p. VII-(A)-79).

DIVERS

Following both tests, experienced salvage and diving officers took teams of divers down to inspect wrecks and to obtain comprehensive descriptions of conditions encountered (Reference C.9.207, pp. VII-(I)-87-B and VII-(I)-75-B; Reference A.2, p. 75; Reference C.2.9). The ships sunk during the operation carried with them precisely the type of information CROSSROADS was set up to obtain, the type and degree of damage caused by a nuclear detonation. Divers communicated information to the surface and took many underwater photographs. The Technical Director requested services of divers to recover instrumentation from a number of target ships. These operations were carried out when it was radiologically safe. Diving operations included recovery of (Reference C.9.207, p. VII-(I)-83-B):

- Nine vertical stations
- Pressure-time recorders from USS Arkansas (BB-33), USS Saratoga (CV-3), and USS Pilotfish (SS-386)
- Two hydrophones
- Diaphragm gauge and 5-gallon (18.93-liter) cans attached to raft on Nagato
- Radiation intensity film on Arkansas, Nagato, Saratoga, USS Apogon (SS-308), and Pilotfish
- Underwater pressure gauges on USS Bracken (APA-64) and USS Briscoe (APA-65)
- Bottom pressure recorders and possibly gamma meters attached to a cable near the center of BAKER detonation site.

Divers from the submarine rescue vessel USS Coucal (ASR-8) reported on 2 August (eight days after shot BAKER) that it was moored over the target submarine USS Skipjack (SS-184) and ready to start diving operations as soon as radiological conditions permitted. Inspection dives in preparation to salvage Skipjack were done that day (Reference C.9.207, p. VII-(I)-75-B).

In order to alert divers to radiation exposure levels, a long watertight Geiger tube was carried by them on dives when radiological conditions were uncertain. This instrument transmitted to a counter aboard the tending diving ship. When high radiation levels were detected, the crew on board communicated to the divers to stand clear (Reference A.2, p. 75).

UNDERWATER DEMOLITION TEAM 3 (UDT-3)

In March, Los Alamos scientists decided that the analysis of a sample of water from the immediate vicinity of the nuclear detonation was essential if the tests were to be properly evaluated. After consideration of several proposals to accomplish this, it was finally decided to employ drone boats of the type used in World War II by Naval Combat Demolition Units in southern France. In April, the Drone Boat Unit was designated TU 1.1.3, composed of USS Begor (APD-127), Underwater Demolition Team Easy (later renamed UDT-3), 6 LCVP drone boats (with 2 boats in reserve), and control TBM-3Es from TG 1.6 (when assigned) stationed aboard USS Saidor (CVE-117). On 27 April, Begor reported that 7 officers and 51 enlisted men boarded for transfer from Port Hueneme to Bikini for UDT operations (Reference A.3, Begor, 27 April). It is assumed that this was the composition of UDT-3. UDT-3 personnel were responsible for operation and maintenance of the drone boats and provided airborne control officers for the TBM flights. The LCVP drones were directed to desired sample areas and, when an adequate Geiger reading was transmitted back to the controllers, a water sample was taken. Upon completion of the mission, each drone was directed back to Begor where it was washed down with hoses from Begor and boarded by a safety officer. After being declared safe, a UDT-3 boat crew took over and a radiochemist boarded to transfer the collected water samples.

Successful sample operations were carried out for both shots. On BAKER day, two LCVP drones were monitored by boarding parties and were found to be highly radioactive. Water samples were left in the drones and were recovered 2-1/2 hours later (Reference C.9.207, p. VII-(R)-30). Forty 5-gallon (18.93-liter) water samples were collected on BAKER day (Reference C.9.207, p. VII-(R)-39).

53rd NAVAL CONSTRUCTION BATTALION (53rd NCB)

An advance contingent of the 53rd NCB (Seabees) arrived at Bikini Atoll on 5 March 1946 aboard USS Saint Croix (APA-231) for an initial survey by Seabees to plan the construction of facilities for CROSSROADS. On 13 March, 550 personnel of the 53rd NCB arrived at Bikini Atoll from Guam on USS Randall (APA-224). They were later transferred to Saint Croix, where most of the Seabees were berthed throughout the operation. On 14 March, USS LST-881 delivered 175 stevedores from Pearl Harbor who were to be responsible for handling cargo, assembling moorings for the target array, assisting in the installation of instruments, and assembling sonobuoys and life rafts. During CROSSROADS, the stevedores were berthed on Saint Croix, USS Ottawa (AKA-101) and USS Rolette (AKA-99). On 19 March, USS LST-817 arrived with 75 Seabees. On 20 March, Rolette and Ottawa brought 200 more Seabees from Port Hueneme (Reference C.9.206, pp. VII-(A)-20 and VII-(A)-91). The maximum strength of the battalion from 20 March to mid-May was 1,006 (Reference C.9.206, p. VII-(A)-92(d)).

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Construction on Bikini Atoll was limited to that necessary for essential test instrumentation and recreational facilities. The structures built were instrument towers, radio beacons, magazines, photo reference crosses, observation towers, seismic huts, bombing targets, and a recreational area for 7,000 personnel. All of this was to be completed by 1 May 1946 (Reference C.9.206, pp. VII-(A)-2, VII-(A)-42, and VII-(A)-43).

Early in May, 200 men were released from the 53rd NCB, and an additional 522 were released early in June when all originally planned construction was essentially complete. Twenty-one officers were released late in May. They were replaced by six ensigns. By 19 June all remaining naval reserve personnel were released and replaced by regular enlisted personnel. During July, 6 officers and 240 enlisted men remained in the battalion to maintain installations at Bikini Atoll (Reference C.9.206, pp. VII-(A)-93 and VII-(A)-94).

For shot ABLE, the Seabees evacuated part of their construction equipment by LST. The equipment that remained ashore was not damaged by Test ABLE. For shot BAKER most of the equipment was left; again, there was no damage (Reference C.9.206, pp. VII-(A)-50 through VII-(A)-52).

On 3 August, the 53rd NCB was dissolved and personnel were transferred to Construction Battalion Detachment 1156 (CBD-1156), which was activated the same date, for the rollup phase at Bikini Atoll (Reference C.9.206, p. VII-(A)-99).

The majority of the 53rd NCB had completed their construction tasks and departed Bikini before shot ABLE. Those who remained were evacuated from Bikini prior to both shots.

CONSTRUCTION BATTALION DETACHMENT 1156

CBD-1156 was activated on 3 August 1946 when the 53rd NCB was dissolved. Two hundred forty enlisted men were transferred directly from the 53rd NCB to CBD-1156. Two officers were then assigned to take command (Reference C.9.206, p. VII-(A)-99). CBD-1156 prepared Bikini Atoll for rollup operations. The fleet recreation area was closed, dynamite disposed of, and security measures taken to protect equipment left behind. A complete survey and report on the conditions of Bikini Atoll was taken before its departure to Enewetak aboard Rolette. One ensign remained at Bikini and made reports on the condition of the equipment (Reference C.11.13). On 26 August, the battalion transferred from Bikini Atoll to Enewetak Atoll after closing off areas in the atoll. On 11 September, 30 Seabees flew to Bikini from Enewetak to assist in the transportation of usable and repairable equipment on board USS LST-388. This equipment went to Pearl Harbor for further evaluations (Reference C.9.206, p. VII-(A)-99). The ensign then completed another survey and reported on the condition of the equipment left behind on 27 September (Reference C.11.13). It is unknown when CBD-1156 left Enewetak Atoll.

TRANSIENT SHIPS

Several transient ships visited Bikini Atoll during CROSSROADS. All of them were stores ships (AF) or attack transports (APA). These ships and their dates at Bikini Atoll are listed below:

USS Pickaway (APA-222) -- 2 July, 21 July

USS Chilton (APA-38) -- 10-15 July

USS Graffias (AF-29) -- 15-16 July and 21-23 July

USS Hyades (AF-28) -- 19-22 August

USS Lavaca (APA-180) -- 23 August.

NAVY AIR GROUP (TASK GROUP 1.6)

Composed of ships and aircraft, TG 1.6 was involved in a variety of support missions during CROSSROADS. Elements of the task group were operated from two aircraft carriers and from two island bases, Roi and Ebeye at Kwajalein. Table 16 gives TG 1.6 composition.

Task Unit 1.6.1 (Drone Carrier Unit)

This unit was based on USS Shangri-La (CV-38). It was responsible for training personnel, preparing equipment for atomic bomb tests, conducting aircraft operations for drones engaged in collecting air and water samples in target areas on ABLE and BAKER days. It operated the carrier and plane guard destroyers as necessary to carry out air operations of embarked units (Chapter 4) (Reference C.9.206, p. VII-(E)-14).

Personnel and equipment of the Drone Carrier Unit (TU 1.6.14), the Drone Boat Control Unit (TU 1.6.15), and the Field Recovery Unit (TU 1.6.13) were transported overseas aboard Shangri-La. An extensive program of takeoffs and recoveries was initiated while en route from Hawaii to Roi Island, Kwajalein. The units arrived at Dyess Field, NAB Roi, on 5 June. Training was given en route in navigation, homing, fighter direction, general communications, and the ABLE day Air Operation Plan (Reference C.9.206, p. VII-(E)-118).

Practice for ABLE day using the drones occurred on 10, 20, and 24 June. The practices included all Navy and Army aircraft. For each of these joint rehearsals, 4 drone F6Fs, 16 control F6Fs, and 2 air-sea rescue TBMs were launched from Shangri-La near Orbit Point Tare (40 nmi [74 km] from the center of Bikini Island). Orbit points for ABLE are summarized in Table 8. During each rehearsal, the carrier drones operated as follows (Reference C.9.206, pp. VII-(E)-119 and VII-(E)-120):

- Four primary drone-control flights (Red, White, Blue, Yellow) of two F6Fs each were launched and rendezvoused over Shangri-La to await the launching of four F6F drones (Red, White, Blue, Yellow)
- As each of the four F6F drones were launched (each carrying a safety pilot for the rehearsals only), the corresponding color-coded flight of the primary drone-control aircraft assumed control of the aircraft and directed it to its station over Bikini Lagoon.
- Four secondary drone-control flights (Red, White, Blue, Yellow) of two F6Fs each then took off and proceeded to their stations opposite the point where it was expected

Table 16. Units in Task Group 1.6, CROSSROADS.

Task Unit 1.6.1 -- Drone Carrier Unit

- Task Unit 1.6.11 -- USS Shangri-La (CV-38)
- Task Unit 1.6.12 -- Commander Destroyer Division 5
- Destroyer Division 51
  - USS Turner (DD-834)
  - USS Charles P. Cecil (DD-835)
- Task Unit 1.6.13 -- Field Recovery Unit (NAB Roi)
- Task Unit 1.6.14 -- Carrier Drone Air Unit (detachment from Air Development Squadron-2 (VX-2)
  - 26 F6F-3K drones
  - 31 F6F-5 drone control planes
- Task Unit 1.6.15 -- Drone Boat Control Air Unit[a]
  - 6 TBM-3E

Task Unit 1.6.2 -- Photographic Carrier Unit

- Task Unit 1.6.21 -- USS Saidor (CVE-117)
- Task Unit 1.6.22 -- Photographic carrier plane guard destroyers
  - USS Furse (DD-882)
  - USS Newman K. Perry (DD-883)
- Task Unit 1.6.23 -- 5 F6F-5P photo aircraft
- Task Unit 1.6.24 -- 5 TBM-3P photo aircraft
- Task Unit 1.6.25 -- 4 HOS-1 helicopters

Task Unit 1.6.3 -- Seaplane Unit

- Task Unit 1.6.31 -- Naval Air Base (Ebeye)
- Task Unit 1.6.32 -- Patrol Seaplane Squadron 32 (VPB-32) (9 PBM-5s)
- Task Unit 1.6.33 -- Air-Sea Rescue Squadron 4 (VH-4) (6 PBM-5s)

Task Unit 1.6.4 -- Seaplane Tender, Bikini

- Task Unit 1.6.41 -- USS Orca (AVP-49)

Note:

[a]Transferred to Saidor on 10 June.

Source: Reference C.9.206, p. VII-E-Appendix III.

Some safety restrictions were relaxed since airborne radiation from the underwater shot would be less than for ABLE, and the control group was brought closer to the target area. One flight in each group was positioned to be in sight contact of the drone at all times. The amber shield over the cockpit greenhouse and the blue goggles were discarded (Reference C.9.206, p. VII-(E)-187). The White drone had been modified to include the installation of a Mitchell camera, and a K-17 type aerial camera had been installed on the Red drone.

On 13 July all drones and drone-control airplanes were transported by barge from Roi to Shangri-La, which then proceeded to Bikini to participate in the first air rehearsal on 14 July. A second air rehearsal on 19 July was cancelled because of foul weather (Reference C.9.206, p. VII-(E)-188).

At 1610 on 24 July, Shangri-La, accompanied by destroyers Turner and Cecil, left Roi Island to assume their positions 40 nmi (74 km) from the center of Bikini Island (Reference C.9.206, p. VII-(E)-208). On 25 July at 0723, launching of the three F6F drones and twelve F6F drone-control aircraft began. By 0814, the three drone groups were on station. First the two F6Fs of each primary drone-control flight were launched, followed by the drones and the secondary drone-control flights. All aircraft rendezvoused over Shangri-La before proceeding to their assigned stations. At H-hour the primary drone-control flights were orbiting with their drones at Orbit Point Victor, bearing 315°T, 20 nmi (37 km) from the target center at the following altitudes: Red at 14,000 feet (4.3 km), White at 9,000 feet (2.7 km), and Blue at 5,000 feet (1.5 km). The secondary drone-control flights took up their positions on the opposite side of the target axis at Orbit Point Sugar, bearing 135°T, 20 nmi (37 km) from the target center, at altitudes corresponding to the other elements of their respective groups (Reference C.9.206, pp. VII-(E)-212 and VII-(E)-213). Orbit points for BAKER are summarized in Table 10 (Chapter 4).

The primary drone-control flights and the drones moved toward the target array after the detonation. The Red drone entered the cloud column at 0841 from 14,000 feet (4.3 km), the White drone at 0845 from 9,000 feet (2.7 km), and the Blue drone at 0847 from 5,000 feet (1.5 km). The secondary drone-control flight reported the drones at approximately the same altitudes as follows: Red at 0850, White at 0847, and Blue at 0849. Since the cloud of water and steam did not reach the altitude expected, the Red and White drones at the higher altitudes passed over the top of the cloud, and the Blue drone at 5,000 feet (1.5 km) flew through the upper portion of the column (Reference C.9.206, p. VII-(E)-216). Radioactivity was detected on the Blue drone only. Maximum reading was 7 R/24 hours (Reference C.7.6). All drones were guided to Roi Island and landed without damage between 0950 and 1006. All air filters, cameras, and other special installations operated satisfactorily except the camera installation in the Red drone (Reference C.9.206, p. VII-(E)-217). All pilots wore film badges. The 12 badges averaged 0.05 R (gamma) and the maximum was 0.08 R (gamma).

At detonation, the four drone boat control TBMs (Bucko-1, Bucko-2, Bucko-3, and Bucko-4) were standing by aboard Saidor ready for launching. All four took off between 0846 and 0849. Bucko-2 and Bucko-4 stood by in the air over the carrier as replacements while Bucko-1 and Bucko-3 proceeded to a position upwind from drone boats Factory-1 and Factory-3. Remaining approximately 5 nmi

that the drones would be directed into the atomic cloud on ABLE day by the correspondingly color-coded primary control aircraft

- Each of the secondary drone-control flights then took control its drone after its passage through the area of the expected cloud column and guided it approximately 175 nmi (324 km) to Roi Island, where the drones were landed by the Field Recovery Unit
- The primary control aircraft returned to the carrier, and the secondary control aircraft landed on Roi Island.

The drone unit was not successful in carrying out all the details of the plan for the first two rehearsals, but the Queen Day rehearsal was almost perfect (Reference C.9.206, p. VII-(E)-120). The control aircraft were equipped with Geiger counters to enable the pilot to detect the presence of radiation.

SHOT ABLE. On 30 June at 1625 Shangri-La, accompanied by plane guard destroyers USS Turner (DD-834) and USS Charles P. Cecil (DD-835), departed Roi Island to take station within 15 nmi (28 km) of reference Point Tare (bearing 135°T, 40 nmi [74 km] from the center of Bikini Island) (Reference C.9.206, p VII-(E)-162). Earlier, final inspection of aircraft and special equipment had been initiated. At 1005, the drone unit in Shangri-La began a deck checkout of each drone and drone-control aircraft and bench checkouts of all identification, friend or foe (IFF) equipment on them. In addition, all special equipment on the aircraft, such as Geiger-Mueller counters, air filters, cameras, and recording devices, was given final tests. By 2130 all aircraft to be launched the next morning for ABLE were on the deck ready to be launched (Reference C.9.206, p. VII-(E)-163).

Between 0714 and 0717 on 1 July, two F6Fs from each of the four primary drone-control flights took off from Shangri-La. The eight primary control F6Fs rendezvoused over the carrier in position to intercept the drones. The Red, White, Blue and Yellow drones took off, in that order, between 0725 and 0745. The primary control flight established control over each airborne drone. By 0828 all drones were at their respective stations, bearing 312°T, 20 nmi (37 km) from target center, flying at the following altitudes: Red at 28,000 feet (8.5 km), White at 20,000 feet (6.1 km), Blue at 15,000 feet (4.6 km), and Yellow at 10,000 feet (3.0 km). Meanwhile, the four secondary drone-control flights of two F6Fs each were launched between 0747 and 0750. By 0830 all were on station, bearing 135°T, 20 nmi (37 km) from the target center at altitudes corresponding to the drones and primary drone-control flights across the center of the target axis (Reference C.9.206, p. VII-(E)-167). Two air-sea rescue TBMs (Dagger-1 and Dagger-2) were launched at 0757 from Shangri-La and stood by over the carrier until 1150 (Reference C.9.206, pp. VII-(E)-167 and VII-(E)-168).

No problems in launching the drones or in controlling them to station occurred. However, after the Red drone arrived on station, a stuck aileron caused it to go out of control and it crashed in the sea at 0850. Consequently, the Red primary and secondary drone-control flights were ordered to return to base at 0900 (Reference C.9.206, pp. VII-(E)-167 and VII-(E)-168).

All pilots in the controlling planes had adjusted their darkened goggles to shield their eyes from the blinding flash of light at the instant of detonation. Since the pilots had expected a much stronger flash than actually occurred, they were momentarily unsure whether the burst had occurred on schedule. However, no serious delay resulted. The primary control flights commenced controlling the drones toward the cloud column, entering as follows: at 0906 the Yellow drone at 10,000 feet (3.0 km), at 0909 the White drone at 20,000 feet (6.1 km), and at 0910 the Blue drone at 15,000 feet (4.6 km). As the drones passed through the cloud column, the White drone increased altitude from 20,000 feet to 26,000 feet (6.1 to 7.9 km), probably due both to the strong upward currents within the cloud and to the White drone having a slight nose-up altitude when the primary drone-control flight released it. The secondary drone-control flights successfully completed the interceptions as follows: Yellow at 0923, Blue at 0924, and White at 0953. The control aircraft recaptured the White drone over Wotho Atoll and returned it to Roi without damage. All drones landed safely at Roi between 1028 and 1046, and all control aircraft returned to the base aboard Shangri-La or to Roi between 0957 and 1056 (Reference C.9.206, pp. VII-(E)-171 and VII-(E)-172). All 16 pilots wore film badges, and 16 were readable. The average exposure was 0.02 R (gamma), with a maximum of 0.03 R (gamma).

Following completion of drone flight operations, radiological samples were removed from the F6F drones after they landed at Roi. Soon after, all other drone and drone-control aircraft from Shangri-La were flown to Roi Island where they were later checked and flight-tested. On 9 July one drone and its safety pilot were lost on a routine test flight off Roi Island when the drone, under the control of the field unit, rolled over at a very low altitude and spun into the sea (Reference C.9.206, p. VII-(E)-188).

Between 0910 and 0918 four drone boat control TBMs (Bucko-1, Bucko-2, Bucko-3, and Bucko-4) of TU 1.6.15 were launched from Saidor. Immediately after takeoff, Bucko-1 and Bucko-3 proceeded to their stations 5 nmi (9.3 km) upwind from the drone boats Factory-1 and Factory-3. Bucko-2 and Bucko-4 stood by circling the carrier as replacements. When Bucko-1 reported a hydraulic leak shortly after takeoff, Bucko-2 replaced it. At 1015 Bucko-4 replaced Bucko-3, which had developed generator trouble. The TBMs remained about 5 nmi (9.3 km) upwind from the drone boats. The TBMs controlled the drone boats' courses as they moved through the radioactive target area. The TBMs also reported on the levels of radiation in the area in which they were flying. Bucko-2 and Bucko-4 completed their missions and were out of the area by 1238 (Reference C.9.206, p. VII-(E)-172).

SHOT BAKER. The air operation plan for shot BAKER provided for the active use of only three drones with twelve control aircraft: Red drone at 14,000 feet (4.3 km) at B+6 minutes, White drone at 9,000 feet (2.7 km) at B+10 minutes, and Blue drone at 5,000 feet (1.5 km) at B+12 minutes. The Yellow control flight remained in readiness as a replacement in case any control flights developed trouble. The primary drone-control aircraft were at Orbit Point Victor, bearing 315°T, 20 nmi (37 km) from the target center. The secondary drone control aircraft were at Orbit Point Sugar, bearing 135°T, 20 nmi (37) from target center (Reference C.9.206, p. VII-(E)-213).

Some safety restrictions were relaxed since airborne radiation from the underwater shot would be less than for ABLE, and the control group was brought closer to the target area. One flight in each group was positioned to be in sight contact of the drone at all times. The amber shield over the cockpit greenhouse and the blue goggles were discarded (Reference C.9.206, p. VII-(E)-187). The White drone had been modified to include the installation of a Mitchell camera, and a K-17 type aerial camera had been installed on the Red drone.

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(9.3 km) upwind of the drone boats, Bucko-1 at 2,300 feet (701 meters) and Bucko-3 at 2,600 feet (792 meters) conned the courses of Factory-1 and Factory-3 by voice radio as the boats moved through the radioactive waters near the target area (Reference C.9.206, pp. VII-(E)-217 and VII-(E)-218). Bucko-1 completed its conning assignment at 1055 and Bucko-3 at 1105. In the afternoon between 1508 and 1574, similar conning assignments were carried out by Bucko-2 and Bucko-4. Bucko-3 stood by in the air over Saidor as a replacement (Reference C.9.206, p. VII-(E)-218). The three F6F drones and half the control aircraft landed at Roi after the test and radiological samples were removed. On 26 July, two drones were returned by barge to Shangri-La. The following day the remaining F6Fs were transferred to Shangri-La.

Task Unit 1.6.2 (Photographic Carrier Unit)

TU 1.6.2 was based on Saidor. Its mission was to train crews and prepare equipment for atomic bomb tests during ABLE and BAKER and:

- Conduct photographic operations
- Operate helicopter aircraft for radiological reconnaissance, photography, and photographic utility flights
- Conduct conning of drone boats
- Operate photographic carrier and plane guard destroyers as necessary to carry out air operations of embarked units
- Provide pre- and postshot mapping and other photography.

The F6F photographic aircraft were equipped with cameras to provide stills, sonne-strip photos, and a limited amount of motion-picture coverage. Their primary duty was to obtain photographs of the target array just before the detonation. In addition, they were to make mosaics of the target area and strip photos of Bikini Beach before and after the tests (Reference C.9.206, p. VII-(E)-38). One F6F was to obtain motion pictures of the target array and cloud phenomenology after detonation.

Personnel and equipment of the F6F Photo Unit (TU 1.6.23), the TBM Photo Unit (TU 1.6.24), and the Helicopter Unit (TU 1.6.25) were transported overseas in Saidor. The Drone Boat Control Unit (TU 1.6.15) also joined the carrier on 10 June at Bikini (Reference C.9.206, p. VII-(E)-122). TU 1.6.23 had eight F6F and seven F6F-5P pilots. TU 1.6.24 had five TBM and five TBM-3E pilots (Reference C.9.206, p. VII-(G)-22).

After the photographic units arrived at Bikini, the training of the two photographic carrier units (TU 1.6.23 and TU 1.6.24) consisted primarily of three air rehearsals on 10, 20, and 24 June. In addition, they completed various preshot photographic assignments (Reference C.9.206, p. VII-(E)-123).

At Bikini, the Helicopter Unit (TU 1.6.25) observed the target array and inspected target installations. Considerable difficulty was experienced in operating the HOS-1 helicopters. One helicopter was irreparably damaged on a test landing on 30 May and another force-landed in Bikini Lagoon on 3 June (Reference C.9.206, pp. VII-(E)-123, and VII-(E)-124).

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SHOT ABLE. The aircraft carrier was the first element of the group to begin moving to ABLE day stations. At 1400 on 30 June, Saidor, accompanied by destroyers USS Furse (DD-882) and USS Newman K. Perry (DD-883), left Bikini Lagoon for its position bearing 0°T, 40 nmi (74 km) from the center of Bikini Island (Point Auto) (Reference C.9.206, p. VII-(E)-162).

On 1 July between 0712 and 0715, six F6Fs (Queen flight of four and Sugar and Roger flights) were launched from Saidor to obtain still photographs of the Bikini target area immediately before detonation. The F6Fs flew directly from the carrier to positions 5 nmi (9.3 km) east of Bikini Atoll. All reported on station at 0725, but the first photographic run was delayed to allow time for the dissipation of the low stratus and cumulus clouds. After making photographic runs at 0747 and 0826, the Queen flight left the target area and landed aboard Saidor by 0840 (Reference C.9.206, p. VII-(E)-165).

Meanwhile, F6F Sugar had made a calibration run over Bikini Atoll at 0725 from 3,500 feet (1.1 km) and then returned to make three photo flights over the target array at 0742, 0750, and 0800, maintaining an altitude of 3,500 feet (1.1 km) for each run. Sugar made a final calibration run at 0810 before returning to Saidor at 0839. F6F Roger, meanwhile, had made a calibration run at 0729 and a photo run over the target array. F6F Roger then proceeded to its assigned station at Orbit Point Able, 20 nmi (37 km) from the target center and was in position at 0827 (Reference C.9.206, pp. VII-(E)-165 and VII-(E)-166).

Two TBMs, Nan and Oboe, of the photographic unit were launched from Saidor at 0734 and 0736. At 0800 they were on station, 20 nmi (37 km) from the target center. At h-hour TBM Nan was orbiting at 9,000 feet (2.7 km), and Oboe orbited at 4,000 feet (1.2 km) (Reference C.9.206, p. VII-(E)-166).

By H-hour, five photographic F6Fs had completed preshot photography of the target array and returned to Saidor (Reference C.9.206, p. VII-(E)-168). Roger was the only photography F6F still airborne at detonation, approximately 12 nmi (22 km) away and flying directly toward the target center at 10,000 feet (3.0 km). Roger took motion pictures of the burst and other photographs of the cloud column and the target ships until 0927 (Reference C.9.206, p. VII-(E)-70).

TBM Oboe was orbiting at 4,000 feet (1.2 km), 20 nmi (37 km) from the target center at H-hour. It moved in as close as 8 nmi (15 km) during the first 6 minutes following the burst, made oblique angle photographs of the cloud column, and at 0906 returned to its carrier base. TBM Nan was approximately 12 nmi (22 km) from target center at 0900. Immediately following the burst, it began circling the cloud column counterclockwise and took photographs of the cloud and of other aircraft in the area. Six minutes after the detonation, Nan began to fly a 270° arc at a minimum radius of 8 nmi (15 km) from the target, reversing its direction away from the area whenever necessary to avoid radioactivity. Motion picture photography had been started immediately preceding the burst and continued until 0933 when Nan left the area (Reference C.9.206, p. VII-(E)-170).

At 1013 the photographic carrier unit was directed to prepare two F6F photographic aircraft for a special oceanographic survey in Bikini Lagoon. The F6Fs, Sonar-1 and Sonar-2, were launched from Saidor at 1615 and proceeded

immediately over the lagoon. They made their strip color photographic runs from bearings 180° and 0° between 250 and 400 feet (76 and 176 meters) altitude over the target area. The aircraft landed on Saidor by 1715 (Reference C.9.206, p. VII-(E)-175).

Although not actually employed on ABLE day, the Helicopter Unit (TU 1.6.25) was standing by for air-sea rescue and miscellaneous missions as they arose. Moreover, its employment on D-1, when a helicopter delivered repair parts to Aomen Island, ensured operation of the photographic towers there on D-day (Reference C.9.206, p. VII-(E)-175). The ABLE Air Operation Plan called for a TU 1.6.25 helicopter to recover dirt samples from Bikini Island (Reference B.0.1, p. F-II-14), but there is no evidence that this mission took place.

SHOT BAKER. The mission of the units aboard the photographic carrier Saidor remained almost unchanged for BAKER. Seven F6Fs and four TBMs carried out special photographic missions over the Bikini target area on 5 July. Four TBM drone boat control aircraft practiced their BAKER assignments with Begor on the same day. The aircraft rehearsed successfully on 14 July. Two F6Fs were involved in accidents between 2 July and 24 July. One plane and its pilot were lost on 5 July when it spun into the sea while approaching the carrier. Another plane was badly damaged on 19 July when the tail wheel gave way in landing (Reference C.9.206, p. VII-(E)-189).

The first elements of the Navy air group to begin movement to BAKER stations were the aircraft carrier and its plane guard destroyers. At 0930 on 24 July, Saidor, accompanied by destroyers Furse and Perry, departed Bikini Lagoon to take up position in area Paige. Six F6F photographic aircraft were launched from Saidor between 0655 and 0704. The mission of the group was primarily to obtain still photographs of the target array immediately before the detonation. All six F6Fs flew directly from the photographic carrier to positions 5 nmi (9.3 km) east of Bikini Atoll, reporting on station between 0710 and 0716. One flight made photomapping runs of the target array at 0742 and 0820 and left the target area at 0825 to return to Saidor. At 0710, F6F Sugar made a camera calibration run over Bikini Island at 500 feet (152 meters), then climbed to 3,500 feet (1.1 km). It made photography runs of the target array beginning at 0725 before returning to Saidor at 0835. F6F Roger made a pass over Bikini Island from 600 feet (183 meters) at 0750 and took up station 10 nmi (18.5 km) northeast of the target array while awaiting the detonation (Reference C.9.206, pp. VII-(E)-211 and VII-(E)-212).

Three TBMs (Nan-1, Nan-2, and Oboe) were launched from Saidor between 0650 and 0710. By 0745 all were on station. The Nan TBMs were 7 nmi (13 km) from the target center at 10,500 feet (3.2 km). Oboe, however, proceeded first to Nam Island at Bikini Atoll and flew counterclockwise around the target center at 4,000 feet (1.2 km) so the turret photographer could make oblique angle photographs of the target array. At 0745 Oboe was on station 1 nmi (1.9 km) southeast of the south tip of Eneu Island. At H-hour, Oboe was again circling the target center at 4,000 feet (1.2 km) (Reference C.9.206, p. VII-(E)-212).

Roger, the only photographic F6F still airborne at detonation, was orbiting at 11,000 feet (3.4 km), 10 nmi (18.5 km) northeast of the target center. It immediately approached within 5 nmi (9.3 km) of the cloud column, taking motion

pictures and other photographs of the cloud column and aircraft in the vicinity. The mission was completed by 0900 when Roger returned to the photographic carrier (Reference C.9.206, p. VII-(E)-215).

Nan-1 and Nan-2 were orbiting in loose formation 7 nmi (13 km) from the target center at H-hour. After detonation, they circled the cloud column counterclockwise at approximately 5 nmi (9.3 km) from its center and photographed the cloud and the aircraft. Oboe moved from the southeast of the south tip of Eneu Island to within approximately 5 nmi (9.3 km) of the cloud column, where it took photographs of the cloud and the aircraft in the vicinity. Their missions were completed between 0905 and 0908 and the three planes returned to Saidor (Reference C.9.206, p. VII-(E)-215).

Helicopters flew to some of the islands after BAKER to recover instruments (Reference C.9.206, p. VII-(E)-222).

Task Unit 1.6.3 (Seaplane Unit)

Based at Ebeye, Kwajalein Atoll, the seaplane unit conducted (Reference C.9.206, p. VII-(E)-14):

- Photographic, radiological reconnaissance, air-sea rescue, and patrol operations
- Provided air shuttle service between Ebeye and Bikini
- Provided air facilities
- Serviced and maintained seaplanes of the Navy air group.

Carrier Aircraft Service Unit (Fleet) 34 performed maintenance on the unit.

TU 1.6.3 was composed of patrol bombers (PBM-5), converted to transport and air-sea rescue aircraft, from Patrol Seaplane Squadron 32 (VPB-32) and Air-Sea Rescue Squadron 4 (VH-4). Six VH-4 aircraft arrived at Ebeye Island from Saipan, Marianas Islands, on 10 March, and nine VPB-32 aircraft arrived between 16 and 22 March. On 20 March, elements of both squadrons reported to CTG 1.6 as TU 1.6.3 (Reference C.9.206, p. VII-(E)-25).

One PBM carried radiometric equipment to measure intensity of radiant energy as a function of time. The two PBM radiological reconnaissance aircraft carried equipment to determine the safe time for reentry into the lagoon. All aircraft carried normal communications equipment (Reference C.9.206, p. VII-(E)-39).

Two PBM radiological reconnaissance aircraft also carried equipment to record the observations made by the ship observer, photographic equipment, special gas masks, and other equipment. The PBMs for photographic wave measurement also carried special transmitters for actuation of cameras, sonobuoy receivers with scope cameras, and television receivers (Reference C.9.206, p. VII-(E)-39). Two PBM photographic aircraft took high-angle oblique photographs before, during, and after the blast for documentary purposes and for possible radio phototransmission. Three PBM photographic aircraft were specially equipped to obtain motion pictures of the blast for blast analysis and to obtain still

photos for photogrammetric analysis, documentary records, and possible radio phototransmission (Reference C.9.206, p. VII-(E)-38).

TU 1.6.3 training was carried out at Ebeye Naval Air Base (TU 1.6.31). Since the Patrol Seaplane Squadron (TU 1.6.32) was actively engaged in flight operations, its training for ABLE was limited almost exclusively to the three rehearsals. The unit was responsible for a minimum of one roundtrip flight daily from Ebeye to Bikini. Including the three rehearsals, the nine PBMs of TU 1.6.32 flew 1,139.8 hours during the period from 16 March to 30 June, transporting 1,521 passengers, 184,104 pounds of mail, and 73,469 pounds of freight (Reference C.9.206, p. VII-(E)-125).

VH-4 (TU 1.6.33) was also actively engaged in flight operations. It was directed to maintain one PBM each on the water at Ebeye and Bikini for air-sea rescue missions from 2 hours after sunrise to 2 hours before sunset. The unit assisted the patrol seaplane unit with overflow CROSSROADS passengers and freight transportation. A total of 714.3 hours was flown by the six PBMs of TU 1.6.33 between 11 March and 30 June (Reference C.9.206, p. VII-(E)-126).

SHOT ABLE. On 30 June the last seaplane cleared Bikini Lagoon at 1534. The first group of Navy aircraft to be airborne on ABLE day were nine seaplanes from Ebeye. They took off between 0503 and 0620 and reported at their respective stations off Bikini Lagoon between 0639 and 0730 (Reference C.9.206, p. VII-(E)-163). Each plane carried a radsafe officer with a Geiger counter.

The radiometry seaplane took off at 0503. It was the first Navy aircraft to depart, and at 0710 it was on its ABLE day station 15 nmi (28 km) bearing 15° from the target center. Two radiological reconnaissance seaplanes Charlie and Dog took off at 0514 and 0515 and reported on station at 0730, 30 nmi (56 km) from the target center. Three photographic seaplanes (Tare, Uncle, and William) were next off the water between 0519 and 0529. By 0658 all had reported on station, 15 nmi (28 km) from the target center at orbit points Charlie, King, and Dog (Reference C.9.206, p. VII-(E)-164).

The first air-sea rescue seaplane (Dumbo-2) of TU 1.6.33 was airborne at 0505 and at 0639 arrived at its station at Orbit Point Uncle. Dumbo-1 was off the water next at 0510 and at 0642 was on station at Orbit Point Love. Both seaplanes were stationed 30 nmi (56 km) from the target center. Dumbo-3 was the last to take off at 0620 and at 0710 reported on station at 7,000 feet (2.1 km) over Wotho Atoll, 90 nmi (167 km) from the target center (Reference C.9.206, pp. VII-(E)-164 and VII-(E)-165).

The radiometry seaplane was orbiting 15 nmi (28 km) northeast of the target center at the time of detonation. Equipped with special radiometry instruments to photograph and measure the infrared and visible electromagnetic radiation of the blast, the plane remained on station only 6 minutes making its recording of blast phenomena (Reference C.9.206, p. VII-(E)-168).

Three TU 1.6.32 seaplanes (Tare, Uncle, and William) measured the waves resulting from the burst. They were also instructed to monitor readings of the sonobuoys placed in the target array and to obtain the receiver scope photographs. These attempts were unsuccessful because of the distance away from

The three Dumbo seaplanes of TU 1.6.33 continued to stand by for air-sea rescue calls. At 0806, Dumbo-3 reported its Geiger-Mueller counter was out of order. When Dumbo-4, the standby PBM at Ebeye, was ordered as a replacement, it reported having no counter. Nonetheless, Dumbo-3 was ordered to return to Ebeye. Dumbo-2 was shifted to the position over Wotho, and Dumbo-1 was transferred to Orbit Point Uncle. The seaplanes remained on station until 1425 at Uncle and 1455 over Wotho (Reference C.9.206, p. VII-(E)-174).

In addition to providing air transportation between Ebeye and Bikini in the period between the two tests, TU 1.6.32 prepared six PBMs to perform assignments similar to those executed on ABLE day. It also prepared two new seaplanes for participation in shot BAKER, namely Charlie-2 (a radiological reconnaissance PBM) and Eagle Eye (a special observation PBM) (Reference C.9.206, VII-(E)-190).

TU 1.6.33 continued its air-sea rescue and transportation mission between the two tests. For BAKER its mission was altered to provide two PBM air-sea rescue standby aircraft, Dumbo-4 and Dumbo-5, in addition to the three air-sea rescue seaplanes that had participated in ABLE (Reference C.9.206, p. VII-(E)-190).

SHOT BAKER. On 24 July the final seaplane from Bikini landed at Ebeye at 1614 (Reference C.9.206, p. VII-(E)-208).

A VPB-32 radiological reconnaissance seaplane (Dog) taking off at 0501 was the first Navy aircraft to depart from Ebeye for Bikini on 25 July for BAKER operations. It was followed at 0516 by a second radiological reconnaissance seaplane (Charlie-1). By 0655 both Dog and Charlie-1 were orbiting on their assigned stations at Orbit Point Able, bearing 45°T, 20 nmi (37 km) from the target center. Meanwhile three photographic seaplanes (Tare, Uncle, and William) were airborne between 0527 and 0542. By 0705 all had reported on station at Orbit Points Charlie, King, and Dog, respectively, each 9 nmi (17 km) from the target center. Tare and Uncle orbited in loose formation at 12,000 feet (3.7 km) bearing 180° and 215°, respectively, and William at 3,000 feet (914 meters) bearing 325°. The radiometry seaplane departed at 0505 and at 0645 was on station at Orbit Point Yoke bearing 45°T, 7 nmi (13 km) from the target center. The observation PBM (Eagle Eye) had replaced one of the Army C-54s that had performed a similar mission in shot ABLE. Eagle Eye was off the water at 0545 and at 0713 was at its station approximately 10 nmi (18.5 km) from the target center, bearing 285°T at 8,000 feet (2.4 km) (Reference C.9.206, p. VII-(E)-20).

Three air-sea rescue seaplanes also took off from the lagoon at Ebeye during the same interval. Dumbo-1 was airborne at 0510 and at 0646 arrived at its station at Orbit Point Love, bearing 315°T, 30 nmi (56 km) from the target center at 3,000 feet (914 meters). Dumbo-2 departed at 0513 and at 0647 assumed its position at Orbit Point Able, bearing 45°T, 20 nmi (37 km) from the target center at 3,000 feet (914 meters). Dumbo-3 departed last at 0617 and at 0709 was on station at 7,000 feet (2.1 km) over Wotho Atoll, 90 nmi (167 km) from the target center (Reference C.9.206, p. VII-(E)-210).

The radiometry seaplane at 0833, from its orbit point at 9,500 feet (2.9 km), 7 nmi (13 km) from the target center, took up a course heading 335°T so that the point of detonation was within 5° of the bore-sighted axis of the radiometric equipment. Remaining at the same altitude, successful operation of the radiometric, photometric, and spectrographic equipment was accomplished before its departure from the area at 0852 (Reference C.9.206, p. VII-(E)-214).

One minute before the detonation, three seaplanes (Tare, Uncle, and William) moved from their orbit points to positions tangent to a circle approximately 8 nmi (15 km) from the target center. Tare and Uncle then flew a counterclockwise course from 12,000 feet (3.7 km), generally along the periphery of the circle. Each plane flew at approximately 135 knots (250 km/hr) taking synchronized photographs of the waves and water column thrown up by the explosion. Seaplane Tare at 0834 and 0845 also transmitted synchronized signals in order to induce simultaneous operation of the airborne and ground tower cameras. The three PBMs completed their runs by 0907 and immediately departed for Ebeye (Reference C.9.206, p. VII-(E)-214).

The observation seaplane (Eagle Eye) was on course 285°T at 7,900 feet (2.4 km), approximately 10 nmi (18.5 km) from the target center at the time of detonation. It orbited the same general position until 0908 when it returned to Ebeye (Reference C.9.206, p. VII-(E)-216).

Two radiological reconnaissance seaplanes (Charlie-1 and Dog) were orbiting at 2,000 feet (610 meters), 20 nmi (37 km) from the target center at H-hour. Immediately after the explosion, Charlie-1 proceeded to a position 5 nmi (9.3 km) upwind from the target center and then approached within approximately 3 nmi (5.6 km) at 4,000 feet (1.2 km). At 0915 it began traversing the radioactive area in a series of sweeps along parallel tracks normal to the wind direction, covering a rectangle roughly 6 by 5 nmi (11 by 9 km). The paths of the sweeps were not regular because the course was shifted each time a radioactive area was encountered. Charlie-1 made sweeps at 3,000, 2,000, 1,000, and 500 feet (914, 610, 305, and 152 meters). It then orbited the target array at 500 feet (152 meters) from 4 nmi (7.4 km) before departing for Ebeye at 1304 after being relieved by Charlie-2 (Reference C.9.206, p. VII-(E)-218).

PBM Dog in the meantime had first made sweeps over the area occupied by the JTF 1 vessels northeast of Bikini Atoll and reported on the radioactivity encountered. As Charlie-1 reported completing each sweep over the target area, Dog came in at 1008 and flew four similar flight patterns at the same altitudes. After completing its radiological sweeps at 1214, Dog orbited over the target area and photographed the damaged and sinking Saratoga between 1215 and 1319 and then departed for Ebeye. Charlie-2 relieved Charlie-1 at 1258. At 1330 and 1334 it made photographic runs over Saratoga and at 1400 began the first of two photographic runs over the target array at 1,500 feet (457 meters). After descending to 1,000 feet (305 meters), Charlie-2 made eight radiological reconnaissance surveys over the radioactive area between 1425 and 1506. It executed a sonar run 2 nmi (3.7 km) west of the target area between 1535 and 1545 at 400 feet (122 meters). From 1,000 feet (305 meters), photographs of the sinking of Saratoga were taken between 1552 and 1610. Charlie-2 departed for Ebeye at 1615 (Reference C.9.206, p. VII-(E)-219).

No rescues were necessary. The air-sea rescue seaplanes left the area as follows: Dumbo-3 at 0952, Dumbo-2 at 1120, and Dumbo-1 at 1243. Dumbo-4, which relieved Dumbo-1 at 1243, remained on station until 1619 (Reference C.9.206, p. VII-(E)-219).

Task Unit 1.6.4 (Seaplane Tender Unit, Bikini)

The mission of TU 1.6.4 was to provide tender and air transport terminal services for seaplanes at Bikini Atoll. It was based from the seaplane tender USS Orca (AVP-49).

Orca arrived at Bikini Lagoon on 7 May 1946 to assume its assigned duties. It was felt, however, that provision should be made for air-sea rescue units both at Bikini and Kwajalein in case of takeoff accidents. By 15 June an AVR air-sea rescue boat had been obtained for Bikini Lagoon. During operating hours the boat was stationed at the seaplane runway. Once in the morning and again in the late afternoon it made sweeps of the area to be sure the takeoff space was clear. About this time Commander, Marianas, requested Commander in Chief, Pacific (CINCPAC) to furnish two destroyers for air-sea rescue service at Kwajalein, one to be stationed within the lagoon and the other in the ocean near the runway. CINCPAC replied that the destroyers were not available in the Pacific Fleet. It was necessary to assign vessels from JTF 1 to patrol the entrance to Kwajalein Lagoon for air-sea rescue duty (Reference C.9.206, p. VII-(E)-26). LCI(L)-977 from TU 1.8.3 (Dispatch and Boat Pool Unit) was assigned this duty.

SHOT ABLE. On 30 June the last seaplane cleared Bikini Lagoon at 1534. At 1648 Orca moved from the lagoon to its station in area Paige near reference Point Nan, bearing 0°T, 20 nmi (37 km) from the center of Bikini Island.

SHOT BAKER. On 24 July the last seaplane from Bikini Island landed at Ebeye at 1614 (Reference C.9.206, p. VII-(E)-208).

Other Navy Air Groups

Carrier Aircraft Service Unit (Fleet) 34 (CASU[F]-34). Located on Ebeye, CASU(F)-34 performed maintenance for aircraft of the Seaplane Unit (TU 1.6.3) (Reference C.9.206, p. VII-(E)-190).

VPW-1. This unit sent at least four Navy PB4Y-2s under Commander, Kwajalein Atoll, to assist in weather reconnaissance and air-sea rescue missions (Reference C.9.206, p. VII-(E)-190). The detachment at Kwajalein was recalled to Agana, Guam, on 12 August 1946. This unit was airborne on shot days, but flew weather reconnaissance flights well away from the test area.

VPB-116. With VPW-1, VPB-116 assisted in weather reconnaissance and air-sea rescue missions using 12 PB4Y-2 aircraft under Commander, Kwajalein Atoll (Reference C.9.206, p. VII-(E)-190). This unit was not airborne on shot days.

Carrier Aircraft Service Unit 8 (CASU-8). This unit performed aircraft maintenance on the PB4Y-2s from VPW-1 and VPB-116 at NAB Kwajalein (Reference C.9.206, p. VII-(E)-190).

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CHAPTER 10

U.S. MARINE CORPS PARTICIPATION

Approximately 580 Marines participated at Bikini and Kwajalein during Operation CROSSROADS. Participation by the U.S. Marine Corps primarily involved photographic duties and security guard duties. They provided security on Aomen, Bikini, and Eneu islands at Bikini Atoll, on Kwajalein Island, and aboard certain task force ships. Approximately 155 Marines were aboard USS Saidor (CVE-117). According to a CROSSROADS participant there were three different Marine units/groups aboard the ship (Reference C.12.5):

- A detachment of Marine Fighter Squadron (VMF-513), based out of San Diego, California. Primarily, this was an aircraft maintenance detachment that was responsible for the aircraft of a Navy photographic detachment aboard Saidor.
- Marines who were part of the ship's air department.
- Twenty-eight enlisted Marines who were listed as Marine photographic personnel and who were transported by Saidor. Some were administratively assigned to VMF-513 and some to USS Wharton (AP-7).

Saidor was part of Task Unit 1.6.2 (Photo Carrier Unit), which trained air crews for the bomb tests. This unit conducted aerial photo operations, operated helicopters for radiological reconnaissance, conducted aerial control of drone boats, and operated a photo laboratory on board (Reference C.9.206, p. VII-(E)-14; Reference C.12.5). Movie crews aboard Saidor also filmed the target array and provided documentary coverage of the fleet and the visit of Commander Joint Task Force 1 to Rongerik Atoll (Reference B.7.1).

A Marine guard detachment at Bikini Atoll was furnished by Marine Ground Forces. A total of 36 Marine guards were stationed on Bikini Island, 6 each were on Aomen and Eneu islands.

A provisional Marine detachment at Enewetak had a total of 107 Marines. This unit was a heavy antiaircraft detachment whose duties were not directly related to CROSSROADS (Reference C.11.14).

Provisional detachments and normal Marine detachments were on a number of task force ships (Table 17) (Reference C.13.8). Duties primarily involved ship security.

Badge readings have not been located for Marine Corps personnel who participated in Operation CROSSROADS.

APPENDIX B

RADIOLOGICAL SAFETY DOCUMENTS

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3.(x)(14). An official report of scientific and operational data will be submitted, through Technical Staff channels, to CJTF-1. The usual operation report will be submitted through channels. See Annex BB.

3.(x)(15). Historical data will be prepared as directed by Deputy Task Force Commander for Technical Direction (Annex BB).

3.(x)(16). For movements of MT. MCKINLEY and HAVEN see Annex A.

4. Logistics in accordance with Annex B and Appendix VII to this Annex.

5. Communications in accordance with Annex C and Appendix VI to this Annex. Chief of Section in HAVEN except when in MT. MCKINLEY between Queen minus one day and about ABLE plus five days and during similar period at time of Test "B."

APPENDIX IV

SAFETY PRECAUTIONS

1. SAFETY OF PERSONNEL ABOARD SHIP AT TIME OF DETONATION

(a) Protection at Time of Detonation

(1) General. CJTF-1 will direct the operations of ships and aircraft in such a manner as will assure a maximum degree of safety to all personnel involved.

(2) Ships at time of detonation

(aa) No ships will be permitted closer than ten (10) nautical miles to the point of detonation at the time of detonation.

(bb) Most of the ships of the Force will be 20 nautical miles or more from the point of detonation at the time of the detonation.

(cc) Ships and personnel essential to the safe and expeditious accomplishment of the technical mission will be approximately 18 nautical miles from the point of detonation at time of detonation. Three ships will be 10 nautical miles at time of detonation.

(dd) The position of the SECTOR AXIS (Annex I, Reentry Plan) will be established on the basis of wind direction at intended time of detonation.

(ee) The ships of the Force will be directed to operate in designated areas upwind of a line through Point Auto, normal to the SECTOR AXIS.

(3) Individuals at time of detonation

(aa) Individuals on board ships of the Force will be protected collectively by the operation of the ships from the hazards of blast, heat, and radioactivity. This protection is a primary consideration in establishing the distances ships will be from point of detonation at time of detonation.

(bb) Individuals on board ships of the Force will be required to take individual action in the protection of their own eyes at the time of the detonation. The required action is given. The responsibility for carrying out this action is that of the individual himself. This fact will be made known properly to all individuals concerned by those having proper responsibility therefor.

(cc) All Commanding Officers of ships shall observe the following safety regulations in regard to personnel who are not provided with goggles.

1. At How hour minus 10 minutes, Commanding Officers of all ships within 30 nautical miles of Bikini Atoll will assemble topside all hands not otherwise required below decks, to observe phenomena of the bomb explosion.

2. At How hour minus 5 minutes, commanders will have read clearly over the loud speaker system the safety regulations that have been specifically prepared by CJTF-1. The instructions read to ships' personnel will include what to do and how and where to face between the time the command is given to look away and the occurrence of the bomb flash. Commanding officers shall clearly indicate direction in which to look.

3. At the signal "RELEASE MINUS TWO MINUTES" Commanding Officers shall order all hands (a) to face in a direction properly indicated by him as being away from Bikini Atoll, (b) to look down at the deck, (c) to shut their eyes, and (d) to cover their closed eyes with the bent arm against the face. Personnel will remain in this position until after the flash, at which time they may "carry on." It is safe to view with the naked eye the incandescent column that follows the flash.

(dd) All Commanding Officers of the ships shall observe the following safety regulations in regard to personnel who are provided with approved goggles:

1. The Commanding Officers shall add "ADJUST GOGGLES" to his command at the time of "RELEASE MINUS TWO MINUTES."

2. Those with approved goggles may look directly at the flash or otherwise as they desire.

3. They must not remove goggles until after the flash. The flash may be taken as the signal to remove the eye protection and observe the phenomena that follow the explosion.

(ee) Approved goggles (Navy All Purpose Goggles, 4.5 Neutral Density Filter Replacement) will be provided for all personnel on ships nearer than 20 nautical miles at time of intended detonation (H hour) and for observers (not ships' personnel) on Press and Observer ships.

(ff) Emphasis, throughout, will be placed by responsible leaders on the fact that, while no serious damage can result from looking at the flash at a distance of 20 nautical miles or more, the flash is so blinding it will prevent the individual from seeing the beautiful display of colors in the incandescent column of cloud and the gigantic clouds that follow the explosion.

(b) By direction of CJTF-1, these instructions pertaining to individual protection of the eyes are included in the operations plan and will further form the basis of suitable instructions to be issued separately to (a) commanding officers, and (b) press and observers.

(c) There need be no concern on the part of individuals for their personal safety if they will (a) follow the commands of their respective commanding officers, (b) observe the intent of the instructions as to safety for the eyes, and in the case of participating observers, monitors, operational and technical personnel intimately participating in the operation, <u>if they observe all requirements of this annex</u>.

2. <u>DANGER FROM RADIOACTIVE OBJECTS ON TARGET SHIPS</u>

On target ships and possibly on the islands of the lagoon, certain objects may become dangerous to handle due to the effects of radiation, or to contamination with radioactive material. Because of this subtle hazard no personnel of the Force will handle objects on target ships unnecessarily. Under no circumstances will souvenirs be taken from target ships. This is particularly important as far as scrap metal is concerned. Commanding Officers will disseminate the required information to personnel within their command, and will enforce this safety regulation. This regulation will apply not only to service personnel but to civilian technical observers and to official visiting observers, as well.

3. SAFETY OF PLANES AND AIRBORNE PERSONNEL

(a) <u>General Safety Precautions Applicable to All Air Operations</u>

(1) With the exception of the bomb-carrying and pressure-drop aircraft and such other aircraft that CJTF-1 may direct, all planes airborne between How minus 2 hours and Mike plus 30 hours will be equipped with a Geiger counter or will carry a monitor with a portable counter.

(2) Personnel in planes airborne between How minus 2 hours and Mike plus 30 hours, including the bomb-carrying and pressure-drop aircraft, will wear on each person a personnel badge (supplied by the Radiological Safety Section through the Air Monitors) to indicate whether or not they have been exposed to radioactivity. In each aircraft there will be a minimum of one casualty badge to record possible higher intensities of radiation.

(3) At MIKE hour no aircraft will be within twenty (20) nautical miles radius of the Target, except that certain aircraft whose missions so require may be fifteen (15) nautical miles radius from the Target (Appendix II to Annex F); and the bomb-carrying airplane and pressure-drop aircraft, which must be 10 nautical miles (slant range) from the point of detonation, going away, at Mike hour plus 40 seconds. Between Mike hour and Mike plus six minutes, no aircraft will approach closer than 8 nautical miles to the cloud column. Between Mike plus six minutes and Mike plus thirty minutes, all aircraft will maintain a minimum distance of 8 nautical miles from the point of detonation and will keep clear of the Radiological Danger Sector, which is defined as an atmospheric and surface area of radioactive contamination that commences at the center of the target array and spreads leeward with the prevailing winds. The Radiological Danger Sector will be announced from Flag Headquarters and will be bounded by true bearings from the center of the target array.

(4) No plane will approach closer than 8 nautical miles to the rising column or the visible cloud, or within 10 nautical miles of a visible "downwind" cloud mass, even if equipped with instruments for detecting and measuring radioactivity.

(5) In the column that follows the ball of fire (Mike hour to Mike hour plus 6 minutes), the radioactive hazard will be pretty well confined to the visible column and to the air within 2 to 3 miles of it. If approached, it should be upwind or crosswind. In the "downwind" areas, the visible clouds will probably be surrounded by an invisible envelope beyond the visible cloud. The downwind "fallout" of radioactive particles will also be invisible. It is to detect these invisible hazards that radiological instruments and monitors are provided.

(6) Between Mike hour plus 6 minutes and Mike plus 30 hours, no planes will be airborne in any of the areas occupied or traversed by the cloud and its fallout except (1) those required by the Radiological Safety Section in the execution of the Safety Plan, (2) those specifically cleared by the Deputy Commander for Aviation, or (3) unless Radiological Safety Control, based on reconnaissance, declares the air safe earlier than Mike plus 30 hours. Included in (1) would be planes required for safety reconnaissance and those for air-sea rescue and safety patrol.

(7) [Deleted]

(8) All planes equipped with monitors or radiological instruments, except pilots in single-seated planes, will, while airborne, maintain a two-way communications contact, on a specially allocated frequency, with Radiological Safety Control, Flag Headquarters, CJTF-1. They will be subject to the safety requirements of this control. Pilots in single-seated planes will maintain such contact with the Force Fighter Director as safety demands.

(9) During all air operations, the Commander Joint Task Force One will be continuously advised from Radiological Safety Control,

Flag Headquarters, JTF-1, as to the safety of operating planes and personnel in order that he may terminate the operation or direct such changes in operations as the situation may require for the safety of operating personnel.

(10) CJTF-1, on advice of the officer in charge of Radiological Safety Control, will direct when and where planes may be airborne, as soon as reconnaissance indicates area of hazard and areas free from hazards due to radioactivity.

(11) Radiological measurement instruments will be provided by Radiological Safety Section for all manned planes during the air operations except the bomb-carrying and pressure-drop aircraft and others specifically excepted by CJTF-1 above.

(12) Personnel from Radiological Safety Section will be assigned to units participating in air operations in order to provide required briefing and indoctrination of personnel for these specific operations, and to provide technical advice and monitoring services essential to safe conduct of the operation. The senior representative of the Radiological Safety Section so assigned will be responsible for getting required instruments and approved goggles to the operating unit and will see that the instruments are properly installed in the plane. He will issue "casualty badges" and "personnel badges" (film) to personnel before flights.

(13) All operational planes, including drones, which have been airborne between Mike hour and Mike plus 30 hours, will be monitored for radioactivity on landing. This will be the responsibility of the monitor assigned to the air unit for this specific purpose and will not be the responsibility of the monitor within the particular plane. In monitoring planes, the monitor will pay special attention to the oil filter and to oil splashes on the exterior of the plane where radioactive particles will be held, if at all, on the plane. It is believed that, excepting the drones, no other planes will collect enough radioactive materials to be a hazard to ground crews. In the case of the oil splashes or oil filters that are contaminated, the hazard will have little range (a few feet at the most). Risk will be incurred only by (a) prolonged exposure within a few feet of the contaminated part or parts of the plane (hours, not minutes) and/or (b) direct touch or handling of the oil filter or oil splash. Most radioactive particles will not adhere to the clean skin of the plane. Greasy spots and oil splashes will collect radioactive particles. Hosing down with water would remove most of the loosely attached radioactive particles if there were any there. Air movement (wind) would have the same influence. This would occur (a) naturally in flight, (b) standing in the open (weathering).

(aa) "Drones" will be considered as being heavily contaminated until proven otherwise by the monitor specifically assigned to the drone landing site. He will be prepared to keep personnel away from the immediate vicinity of the drone until he has monitored it and advised the local commander of its safety or hazard. He will then advise the local commander as

to the necessity for posting sentries, delimiting areas of hazard, and such other actions as are required to protect personnel locally. Ground crews and personnel approaching drones that have been exposed will wear "personnel" badges as provided by, and in accordance with the instructions of, the monitor assigned to the landing site.

(bb) In the event that seaplanes are forced to land in contaminated waters, it will be the responsibility of the monitor specifically assigned to the seaplane base, or other landing place, to apply such measures as are required for detection of hazard on return of the aircraft to base and make recommendation to the local commander as to actions desirable to protect personnel locally.

(cc) The above considerations (bb) apply to PBMs engaged in reconnaissance of the air over the lagoon.

(14) [Deleted]

(15) [Deleted]

(16) Except for certain missions especially authorized by Radiological Safety Control, the pilot of any airplane, upon finding radioactivity, will take immediate evasive action, leaving the area in such a manner as to put the area of contamination directly on his stern as quickly as possible.

(17) When a pilot encounters a situation such as that described in paragraph (16), he will take the necessary action at once and report the observations and his actions, including position and altitude, to Radiological Safety Control, Flag Headquarters, CJTF-1 as promptly as practicable.

(18) The action described in paragraphs (16) and (17) is a "MUST" as life shall not be risked beyond this point.

(19) If planes do not encounter conditions depicted in paragraph (16), they will continue with the operation as planned.

(20) All monitors, and all personnel employing radiological measuring instruments, will keep a log of observations if at all practicable. These logs should confirm the information reported to the Radiological Safety Control, Flag Headquarters, CJTF-1.

(21) Any air operation may be terminated at any time by the Commander Joint Task Force One on advice from the Chief of the Radiological Safety Section, if it appears that continuation of the operation entails an unwarranted risk. Meteorological conditions may alter the behavior of the radioactively contaminated column, or of the downwind clouds in such a manner as to present an unpredictable hazard. This is unlikely to occur before Mike hour plus 6 minutes. Likelihood increases progressively after this time, requiring that the initial phase of the air operations be concluded by Mike hour plus 30 minutes.

(22) "Casualty badges" (films) and "personnel badges" (films) used in air operations will be collected by personnel of Radiological

Safety Section upon completion of the operation. These devices will be suitably labelled and as promptly as possible returned to Photometric Division, Radiological Safety Section on board HAVEN for processing.

(23) Personnel and planes engaged in these air operations will be monitored by personnel of the Radiological Safety Section immediately after landing. Observations will be logged and where significant readings are found, reported at once to Radiological Safety Control, Flag Headquarters, CJTF-1.

(24) If planes for press, radio, nonparticipating observer, or photographic purposes are airborne during the period of the air operations, or thereafter, they will comply with the requirements of this appendix.

(25) Should any plane be unable to maintain contact with the Force Fighter Director, and hence be unable to get directions relative to hazardous areas, the pilot will take such action as will take him at once toward safer upwind areas and withdraw from the operation until communications are reestablished.

(b) Protection of Eyes at "H" Hour

(1) General-purpose goggles fitted with ND 4.5 Filter Replacements will be provided all personnel airborne at "H" hour. An exception is in the case of the Navy Drone Unit (Task Unit 1.6.1), which will employ a special blue-amber combination of light filters specified by dispatch. No other unit will deviate from the use of ND 4.5 goggles unless so authorized by CJTF-1. Senior radiological monitor attached to air operation units will see to it that they are available and will check to see that all personnel airborne at this time are so equipped before taking to the air. He will also see to it that they have had previous instructions in the proper use of the goggles and in eye protection.

(2) The bombardier on the bomb-carrying aircraft will announce a warning to put on goggles at two minutes before the time of bomb release. At start of the automatic tone signal (one minute before bomb release), all personnel will adjust the goggles over their eyes. (Note exception as to copilots in para. 3.(b)(4) below.) Immediately after announcing "bomb away" for the last time, the bombardier will issue his final warning to put on goggles.

(3) At signal for bomb release ("bomb away," stop of tone signal), as an extra precaution all personnel will turn their faces away from the target until after the flash of light and heat occurs, after which time they may immediately remove the goggles and observe the rise of the incandescent column or cloud.

(4) Copilots in planes with copilots will take extra precautions to ensure greater safety. They will attempt to protect eyes completely. Copilots will have goggles adjusted by Release minus 5 minutes. At start of automatic tone signal (one minute before bomb release) copilots will cover goggles and eyes with bent arm in order to completely protect the eyes. After the flash, arm and

goggles may be removed and the column observed. This will permit copilots to take over in case pilot is temporarily blinded.

(5) The chances that a pilot will be partially blinded while using these goggles are remote, particularly if the pilot's position is such that he cannot, or does not, view the explosion directly.

4. The Chief of the Radiological Safety Section will issue to the force such additional safety precautions as are necessary.

APPENDIX IX

GENERAL CONSIDERATIONS
RADIOLOGICAL SAFETY
TEST BAKER

1. PHENOMENA ACCOMPANYING THE EXPLOSION

In Test BAKER, the mechanism of the nuclear reaction will be identical with that in Test ABLE. However, since the explosion in Test BAKER will occur in a water rather than in a gaseous medium, the phenomena that will be observed as a result of this explosion will be quite different from those that were seen in Test ABLE.

In Test ABLE, the sphere of hot gases formed by the nuclear reaction has been aptly described as a "ball of fire" that rises rapidly toward the stratosphere. In Test BAKER, the hot gases will take the form of a rapidly expanding "bubble" below the surface of the water of the lagoon. This "bubble" quickly rises to the surface of the water. It is the interaction of the "bubble" with the water that is responsible for the new or modified phenomena that are described below.

A. RADIATION

The water that encloses the "bubble" is much more effective in absorbing radiation (both gamma rays and neutrons) than is air. Hence, the primary radiations produced by the nuclear reaction will have a much smaller range than they did in the ABLE shot.

B. HEAT AND LIGHT

The water will cool the hot gases much more rapidly than did the air. Hence, the temperature of the "bubble" when it reaches the surface of the lagoon will be low as compared with the initial temperature. This means that heat and light will not be emitted in intensities that will injure persons nearby. Observers in the air and in surface vessels will see an illumination of the water and overlying clouds but will not be conscious of a "ball of fire" rising from the surface of the lagoon.

C. WATER BLAST

The water will accept a certain portion of the energy of the "bubble." This energy will then be propagated in the water outwards from the explosion in the form of a shock wave. This water blast will be more damaging to ships' hulls than was the airblast (the analogue of the water blast in the previous test). Probably, various reflections may either enhance or diminish the forces exerted in different locations so that the damage may not be uniformly or symmetrically distributed about the center. This has its analogue in airblast also.

D. MOVEMENT OF THE WATER

The rapid expansion of the "bubble" will cause a number of different types of responses in the surrounding water: (a) A mound of water and steam in the "dome" above the expanding gas bubble will be thrown upward from the surface of the water. This water will rise to a height estimated to be 5,000 to 8,000 feet and before breaking up into spray will have a calculated diameter of about 2,500 feet. (b) After the water from the "dome" has ceased rising, its summit will be pierced by a jet of water forced up from the bottom of the lagoon with the collapse of the gas bubble. This jet of water, called the "plume," may extend vertically two or three miles into the air in a matter of 10 to 15 seconds. Most of the water will fall to the lagoon in a matter of minutes. A small fraction of the water may remain suspended in the air as vapor. This column of vapor has been called the "ghost plume." Some of the gaseous detonation products in the "bubble" may escape up the ascending water and spray mass and collect about the top of the plume. These will be radioactive.

E. WAVE FORMATION

As a result of the movement of the huge masses of water described under section D, waves will be produced on the surface of the lagoon. These waves will spread out from the point of detonation in a concentric fashion. The waves will probably not be greater than 50 to 75 feet in height and 500 yards in length. At a radius of 4,000 feet the wave height will decrease rapidly as the waves move outward.

F. DISPOSITION OF FISSION PRODUCTS

As the bubble disappears, the fission products formed by the nuclear reaction will be dispersed in the water of the lagoon, as well as in the water of the dome and the plume. It is estimated that fifty percent or more of the fission products will be present in a circumscribed area in the lagoon within a few minutes after the explosion. Water vapor containing fission products will remain in the vicinity of the plume as a "ghost plume." The upper portion of this ghost plume may eventually form a low-lying cloud that will be carried off by the prevailing winds. It is possible that such a cloud may draw in the fission products from a wide area and concentrate them in the form of rain. The high-level mushroom-shaped cloud so characteristic of nuclear explosions in air will

not occur in this test, although a small cap of vapor may develop at the top of the plume.

2. HAZARDS RESULTING FROM THE EXPLOSION

The hazards resulting from Test BAKER can be divided into two types according to the time at which they make their appearance.

A. IMMEDIATE HAZARDS

(1) LIGHT AND HEAT

The water will shield the observers from the initial intense flash of light and heat and will rapidly cool the bubble so that these factors will not present a serious hazard to observers. Thus, the explosion can be viewed with safety by the naked eye from a distance of 7 or more miles.

(2) WATER AND AIR BLASTS

The blast waves will not be strong enough to affect ships at a distance of ten or more miles from the point of detonation, particularly because of the interposition of the reef.

(3) FRAGMENTS

It is possible that large fragments may be accelerated to high speeds in the air and that their trajectories may extend for considerable distances. It is extremely unlikely that these fragments will cover a distance of ten miles.

(4) WAVES

A series of waves on the surface of the lagoon will be formed by the explosion. These waves may have an initial height of 50 to 75 feet, but will rapidly expend their energy and probably not wash over Bikini Atoll. The waves will not endanger ships at a distance of 10 miles.

(5) RADIATION

The range of the gamma rays and neutrons produced by the nuclear reaction should be much less than that in Test ABLE because of the radiation-absorbing properties of the water surrounding the "bubble" as it is formed. The fission products present in the "bubble" then will be mixed intimately with the water in the plume and lagoon. Those fission products in the plume should emit intense radiation over a small distance in the air because there is considerable absorption of radiation by the water in the plume. Hence, there is no reason to believe that there is a hazard from radiation at the points of observation.

B. DELAYED HAZARDS

(1) DELAYED HAZARDS OF THE WATER OF THE LAGOON AND TARGET VESSELS DUE TO RADIOACTIVITY

It is estimated that the greater part of the fission products will be present in the lagoon after the water in the plume has returned to the surface. Most of the radioactivity that has not

gone up in the air will be uniformly distributed throughout the volume of a cylinder of water whose central axis will be formed by a line drawn upward to the surface of the water from the point of detonation. Most of the radioactive fission products in the water and spray that return to the lagoon from the plume will probably fall around and over this cylinder and shortly thereafter form a tongue on the surface extending several miles in the downwind direction from the contaminated cylinder described above. All ships in the area accupied by the tongue thus will be heavily contaminated by radioactive materials falling from above. Thus, it is the hazard from the radiation emitted by the fission products present in the large volume of water in the target area that present the greatest hazard to personnel returning to the lagoon. The hazardous radiation will be primarily gamma and beta in character. Beta rays are dangerous only if the radioactive materials are kept in contact with the skin for a long period of time or if the materials are taken into the body in appreciable quantities. The danger to personnel from inhalation or ingestion of radioactive materials is nonexistent when the radiation hazard in the cleared area is below 0.1 R/24 hours.

(2) DELAYED HAZARDS OF THE WATER OF THE AIR IN THE REGION OF THE "GHOST PLUME" DUE TO RADIOACTIVITY

The residual radioactive materials that have been left in the air with water droplets in the ghost plume should be rapidly carried away by the prevailing winds within thirty minutes after the explosion so that there should be no danger from these materials except in the downwind region.

(3) DELAYED HAZARDS OF THE CLOUD DUE TO RADIOACTIVITY

As mentioned above, it is possible that the upper portion of the plume may form a low-lying cloud, the radioactivity of which may be precipitated in the form of rain in the downwind area. This hazard may be greater in Test BAKER than in Test ABLE since the airborne radioactive material will be concentrated in the lower altitudes. However, for the same reason, the danger sector will be narrower in the BAKER Test.

3. PROTECTION

A. Against the primary effects of radiation, distance will provide necessary protection.

B. Against the secondary effects due to excessive waves, airblast and underwater shock, distance will provide necessary protection.

C. Against the secondary hazards due to radioactivity, detection and avoidance provide the best means of protection. This will form the basis of the Safety Plan as far as radiological hazards are concerned.

4. DETECTION AND MEASUREMENT OF RADIOACTIVITY

Suitable instruments will indicate both the presence and intensity of the radioactivity at a given place. The methods successfully employed in Test ABLE will be used. Instruments will include Geiger counters, protexi-meters, pencil elctrometers, ionization chambers, personnel badges (film), casualty badges (film), surface rate meters, underwater counters, "probe" meters, etc.

5. AVOIDANCE AND MEASUREMENTS

Area reconnaissance, maintenance of "contamination situation maps," designation of contamination areas by suitable means to JTF-1, and the posting of dangerous areas in ships or on land surfaces will constitute the active measures of avoidance. Exposures in excess of 0.1 roentgen per day will be avoided and this will be the limit of tolerance acceptable during the operation. This can be effectively measured by the methods employed in Test ABLE. This is well within the safety limits. In Test BAKER, due to the greater intensities of residual radioactivity anticipated, it will be particularly necessary to observe this limitation of exposure.

6. ANTICIPATED HAZARDOUS AREAS

A. IN THE AIR

(1) Air immediately over the surface of the lagoon, particularly directly over the center of the target array, may be dangerous due to: (a) radiation from surface of the water of the lagoon and from the target ships, and (b) to fallout of mist containing radioactive materials.

(2) The most serious radiation hazard will exist in the air within 3 feet of the surface of contaminated water. This will be particularly serious in the surface water initially in the central target area and particularly during BAKER Day. The intensity of gamma radiation from the target area water will be great enough to be hazardous for vertical distances of from 500 to 4,000 feet. These hazards due to water contamination may persist for several days and decrease in intensity with time and dilution with clean lagoon water. It is likely that the air for some distance above the surface of the water of the lagoon and downwind of the explosion may present a relatively high content of radioactive materials in mist or vapor that will be hazardous to planes flying at altitudes of 500 to 1,500 feet for several hours.

(3) Beyond the lagoon and downwind there will be an airborne hazard due to radioactive mist or particles. In some instances this may be held up in a low-level cloud, which may present a serious hazard. This may travel downwind for a distance of 100 to 150 miles or more. At a distance of 200 to 300 miles, it is unlikely that any air hazard may exist for air operations. Airlanes at a distance of over 400 miles will be endangered at no time.

B. IN THE LAGOON

(1) WATER HAZARDS

(A) SURFACE WATER

The surface water (to a depth of 40 feet) will contain radioactive particles that are initially deposited in the central area of the target array and will tend to move down current at a rate of approximately 0.5 knot. Downwind of this central area, there will be additional contamination of surface water as a result of water falling from the "plume." This will make surface operations dangerous downwind and down current from the central area for an unpredictable time since the exact pattern of the contaminated surface area cannot be predicted, since much of it will depend upon the character of the surface winds and waves and the height and characteristics of the "plume" arising from the explosion.

(B) Subsequently, the surface water will receive an additional contamination. This may arise from contaminated water that has formerly been in the lower layers of the lagoon and moves in the opposite direction to the surface layers; thus, this deep layer can come up to the surface (upswell) upwind to the target area. Following this upswelling the deep water mixes its contamination with the surface water and moves downcurrent with it. It is anticipated that many subtle hazards difficult to forecast may arise in the water of the lagoon during the first three or four days. Later, the distribution of the radioactive material within the water of the lagoon may tend to be more homogeneous. Brisk surface winds will tend to favor mixing and dilution. Some surface water will leave the lagoon and will carry with it some radioactive material. Some entrances to the lagoon may be hazardous as a result of this. Winds, tides, and length of time decay following a detonation will exert important influences in this respect.

(C) SUBSURFACE WATER

Subsurface water (below 40 feet) will be contaminated with radioactive material initially in the region of the central target area. This will tend to move generally to the east "upwind" at a rate of approximately 0.1 knot (while the surface moves to the west at approximately 0.3 knot). Mixing and diffusion of the radioactive material within the water may be so slow as to prolong the persistence of very hazardous undiluted masses of water with high radioactivity. This may give rise to irregular areas or patches both below the surface and on the surface of the water of the lagoon.

(2) HAZARDS IN TARGET SHIPS

(A) TOPSIDE SURFACES

Topside surfaces will become contaminated with water containing radioactive materials. This will arise from water falling

from the "plume" and from contaminated water of the lagoon being splashed on the target ships. In general, there will be negligible induced radioactivity in the metals of the ship. Evaporation of the water will tend to leave radioactive fission products dried on the exposed surfaces of the ships.

(B) BELOW DECKS

Below decks and in compartments of the target ships, radioactive hazards will be found due to some exent to radioactivity in the water outside the compartment or radioactive material on the surface of the ship. In the main, the more serious hazards will arise from water initially highly contaminated and trapped within the compartment. Due to the fact that this water will usually not be diluted by water from without the compartment, the benefits of dilution, mixing, and dispersion will be lacking. This will result in localized hazards of relatively high intensity and probably with greatly increased persistence.

(C) HAZARDS ON THE ISLANDS OF THE ATOLL

If waves of contaminated water roll over the land surfaces, radioactivity may be found in these areas. It is likely this will not occur during the early phases following the explosion as the contamination within the water is well localized. Later, land surfaces downwind may be contaminated by water or mist settling out from the air. Later, also contamination within the water of the lagoon may extend into such areas as may wash up on the sandy beaches of the islands. Lesser contamination may be found at variable distances from the beach, depending on how far the wind may carry contaminated spray and droplets in from the beach. Serious hazards will hardly be developed in this manner.

(D) HAZARDS AT A DISTANCE

Airlanes beyond 400 miles will not be endangered at any time. It is probable that no hazard will exist for planes operating at distances beyond 300 miles. Special monitoring is desirable for islands within 200 miles downwind. Contaminated water leaving the lagoon will not set up hazards at a distance beyond 50 miles. It is believed that projectiles will not create a hazard beyond a distance of 10 miles from point of detonation.

7. ESTIMATE OF RADIOACTIVE HAZARDS IN RELATION TO OPERATIONS

A. SELECTION OF A DAY TO SHOOT

If the winds at all altitudes below 25,000 feet are within a sector no greater than 5°, and if this sector lies within 45° and 135°T, the most suitable conditions will exist with regard to radiological safety. Winds from the southeast will not be as desirable as those from the east or northeast due to the greater likelihood of upwelling of contaminated water in the lagoon near the entrance to Enyu Channel.

B. SAFETY OF SHIPS OF FORCE

(1) If at the time of detonation all ships of the Force are stationed upwind of the detonation and not closer than 10 nautical miles to the central target area, they will be safe from any effects of the explosion.

(2) Subsequent to the detonation the radioactivity that is airborne will be carried downwind and away from the areas to which the ships have been assigned. By the time reentry can be attempted, no danger from particles falling out of the air will exist within the lagoon.

(3) During reentry, it will be necessary for the radiological reconnaissance of the lagoon to establish the distribution and characteristics of the radioactive contamination within the lagoon before any ships may be permitted more than limited entry. It may be possible to have ships essential to the early reentry and safety reconnaissance operations approach within the entrance to the lagoon where they may be safe until the termination of that working day. This possibility seems likely due to the fact that diffusion and dispersion of the radioactive products within the water is expected to be slow enough on BAKER Day to safely permit essential ships to enter just inside the lagoon, but prepared to withdraw on an hours notice and planning to withdraw from the lagoon before dark. By BAKER plus one day, it is expected that the contamination within the water may have spread in such a manner as to constitute a hazard that can be determined only by radiological safety reconnaissance. During the first few days following BAKER Day it will be necessary each day to conduct a cautious safety reconnaissance and limited reentry operation. It is likely that ships not essential to the early reentry phase and to the safety reconnaissance cannot reenter the lagoon for five or more days. Hazards that may be anticipated in connection with boating and with the operation of the ships may make such reentry of other ships impracticable if not actually unsafe.

C. AIR OPERATIONS

(1) PERIOD MIKE TO MIKE PLUS 30 minutes

There is strong evidence to indicate that the hazard from blast, heat, and light will be essentially negligible. There is also good evidence to believe that during the first six minutes that the radiological hazard will be confined to a cylinder not to exceed 5 miles in radius and extending vertically upward. After 6 minutes the hazard tends to move downwind as the spray and mist are carried by the wind. Operations outside the prescribed RADEX will be safe provided that the visible cloud of mist or shower of water (if any) is avoided at a minimum distance of 5 nautical miles and that the intensity of radioactivity does not exceed 0.1 roentgen per 24 hours. While the intensity of the radioactivity during this period is believed to be high, its distribution will probably be quite localized and limited to the area to be designated as RADEX. Operations within this area would be dangerous during this 30-minute period.

(2) PERIOD AFTER MIKE PLUS 30 minutes

(a) PBM CHARLIE

It is unlikely that there will be any hazard from mist or fallout after Mike plus 30 minutes, but it must be anticipated as the central target array is approached. The contours of radioactivity from the surface of the lagoon will be approached cautiously in the same manner as in Test ABLE. It is not known whether this will be observed at greater altitudes. This information will be ascertained by this reconnaissance. The intensity of the radiation given off from the water surface will be greater at lower levels, i.e., from surface up to 4,000 feet.

(b) PBM DOG

It is unlikely that any radioactivity will be encountered in the air over the ships of the force. Reconnaissance of the air over the lagoon will be detected as in Test ABLE.

(c) Personnel in helicopters, if operating over contaminated areas of the lagoon, would be in danger of falling into dangerous water in case of engine failure.

(e) Planes operating in the air over the lagoon will be exposed to radioactive effects, if they enter those areas that PBM Charlie and PBM Dog ascertain to present a radioactive hazard. The day-to-day changes in these areas can be determined only by the reconnaissance of these areas on successive days by PBM Charlie and PBM Dog. Surface reconnaissance may assist in localization of these hazards in the air over the lagoon. This hazard may not be important after BAKER plus one day.

(e) Planes operating near the lagoon after Mike plus 30 minutes will not be exposed to radioactive hazard if they avoid the downwind sector provided by an extension of the radial boundaries of the RADEX. In general, this area in Test BAKER will be similar to the Surface Survey Sector. It will extend for 150 miles from the central target area.

(f) Air-sea rescue planes cannot operate within the lagoon until the water is safe radiologically.

(g) PBM planes of Bikini-Kwajalein air shuttle will not be able to operate from the lagoon until a suitably safe anchorage for the seaplane tender can be provided. This is unliekly before Mike plus 5 days.

D. DRONE BOAT OPERATIONS

The operation of BEGOR and the TBM planes will be in safe areas. The hazard of this operation lies in the handling of the radioactive water samples. Adequate protection can be provided in the manner planned. This may be accomplished by using several persons for short times, i.e., still within the period required to give no more exposure than 0.1 roentgen.

E. LAGOON PATROL

The PGMs and LCPLs will commence operations within the lagoon at a time when there is no danger of fallout from the air. Initially they will probably be able to advance well within the entrance to the lagoon and with safety detect and outline the contaminated surface layers and the deeper layer, which may upwell in unexpected places. It appears to be likely that this phase of the operation can be successfully conducted on BAKER Day. The operation on BAKER Day plus one will have to be initiated more cautiously than on BAKER Day due to this uncertainty of the spread of the contamination within the water of the lagoon. It is possible that the reconnaissance of the waters of the surface layers of the lagoon and of the lower layers may be required beyond five days. During this operation the air within 3 feet of the surface of the water will contain the most significant radioactivity. The methods of protection employed in Test ABLE will be equally successful in Test BAKER. "Hot" areas that upwell may "trap" PGMs or LCPLs, so this hazard will be anticipated. Destroyers operating within the lagoon would anticipate similar hazards as the small craft.

F. DESTROYERS

The likelihood of a serious radioactive hazard within 50 miles of the lagoon on the downwind side will be much more likely than in Test ABLE. Within 20 miles of the lagoon, this will probably be confined to the Surface Safety Sector. The intensity of the contamination due to fallout on the surface of the ocean cannot be predicted with accuracy, but it is probable that it would fall quickly due to dilution and dispersion within the water. A cautious approach to the boundaries of the Surface Safety Sector will be required. The methods employed in Test ABLE will provide ample protection to personnel in the destroyers. Instructions from Radiological Safety Control will assist, during the operation, the destroyer units in locating and avoiding dangerous areas. Contaminated water from the lagoon will probably not be found until BAKER Day plus one. The movement from the lagoon can be tracked with safety, employing methods employed by the Destroyers on ABLE day.

G. REBOARDING OF TARGET SHIPS

(1) It is likely that the water of the lagoon may be radiologically safe for Initial Boarding Teams to traverse prior to the time that they may attempt to board the ships.

(2) Initial Boarding Teams will encounter a variety of hazards of radioactivity. While this is due primarily to the high intensity of radiological contamination of the water of the lagoon, the next important factor will be the probable irregularities of areas of hazard within the target ships. This will require a more cautious and probably slower topside reconnaissance than in Test ABLE. Exterior surfaces may be contaminated with radioactive particles that adhere to the surface after contaminated water evaporates and leave a persistent deposit.

(3) Inspection Teams A and B will encounter hazards not encountered in Test ABLE. Compartments that are flooded or to which radioactive water gains access may be hazardous. The prevention of

dilution and the retention of highly contaminated water in this manner will constitute a serious hazard. The intensity and the duration of this form of hazard cannot be predicted. The special preparation and training of monitors in this aspect of the operation will facilitate the movement within the ships and provide adequate safety.

(4) Instrument Teams reboarding target ships will encounter the hazards characteristic of the phase at which they board the target ship, namely Initial Boarding Team or Inspection Team phase.

H. FIREFIGHTING AND SALVAGE

Firefighting and salvage operations will be limited in the early phases by the intensity and distribution of the contamination of the water and by the radioactivity of the target ship, or ships, involved. It is unlikely that such operations can be conducted prior to BAKER Day plus two, probably later. Monitors specially trained to assist in the conduct of such operations will be necessary.

I. DIVING OPERATIONS

Diving operations will be hazardous as long as the water in the lagoon is radioactive. Water at all depths must be monitored. It is impossible to predict just what radioactive hazards may exist in or near sunken ships. Methods employed in later phases of Test ABLE will be equally successful in ascertaining the presence, intensity, and distribution of such hazards.

J. REENTRY OF SHIPS OF THE FORCE

Reentry of ships of the Force will probably be delayed beyond BAKER Day plus four. Until the water of the lagoon is radiologically safe from the standpoint of small boating and from the standpoint of operating evaporators and condensers it will probably be impracticable to have the ships of the Force reenter the lagoon and take up permanent anchorages.

K. REOCCUPATION OF TARGET SHIPS BY SHIPS' CREWS

Reoccupation of target ships by ships' crews will be delayed. The time at which this may take place can only be determined by the situations encountered by the Reboarding Teams. Careful monitoring will be required until it can be shown that habitation within the ship is safe and the conditions required for the normal operation of the ships are known to be safe.

8. FACTORS TENDING TO REDUCE DANGERS FROM PREDICTED RADIOACTIVE HAZARDS

A. FROM GAMMA RADIATION

Despite the fact that enormous quantities of high-energy radiations may emanate from the contaminated water and cloud there are certain physical facts that will make it possible ', approach and delineate such areas without excessive danger. They may be listed as follows:

(1) The intensity of radiation will diminish with the distance from the source.

(2) There will be considerable absorption in the intervening air between observer and source.

(3) The geometric consideration will also influence the distance of approach to the contaminated area. Since the source will be spread over a wide area. Flights over the area will be subject to radiation at various angles from the entire source. On the surface, however, the subtended angle will be so small, an individual will be affected only by material on the near side of the contaminated area.

B. FROM BETA RADIATION

To receive excessive amounts of beta radiation in a situation such as Test BAKER, it would be necessary to come in very close contact with the contaminated material. Protection from this will be unnecessary if the gamma radiation intensities are low.

C. The radioactive materials in the air and the water of the lagoon will become less in quantity and concentration with time. The factors that tend to bring about this diminution are as follows:

(1) DECAY WITH TIDE

The mixture of fission products is known to decay inversely with time, in hours.

(2) DILUTION AND DISPERSION

There will be slow but appreciable dilution with the surrounding media (air and water). Mixing will occur in both vertical and horizontal planes.

(3) TRANSFERRENCE

There will be gradual transfer of materials away from the test site by wind movement in the air and by currents in the water.

Serial: 019 30 August 1946

From: Commander Task Group One Point Two, JTF-1

To: All CROSSROADS Activities on Kwajalein -- Bikini Area

Subject: Safety Precautions Incident to Boarding Target Vessels Laid-Up at Kwajalein and Bikini

1. Boarding of the target vessels now laid up at Kwajalein and Bikini will be necessary from time to time during the coming months in connection with such work as ammunition inspection and disposal, scientific investigation, inspection and maintenance of watertight integrity and structural safety, etc. These vessels, in addition to the hazards which are inherent in any uninhabited ship which has been closed up and laid up for a long period of time, present certain other peculiar hazards which are the direct consequences of the participation of the ships as targets in the two atomic bomb tests of the past summer. These hazards, to which all personnel boarding these ships will be subjected, fall into four general categories as follows:

(a) Radiological hazards

(b) Explosive hazards

(c) Hazards due to concentration of poisonous or noxious gases and vapors in enclosed spaces

(d) Structural hazards.

2. The purpose of this letter is to summarize in convenient form the hazards to be expected and the safety precautions to be observed when boarding the target ships. It is not intended to be a treatise on the subject. All responsible officers are expected to read and familiarize themselves with [sources of safety information cited but not reproduced herein], and by appropriate instruction and indoctrination of their men, familiarize them with the dangers of the job in hand in order that their own ignorance will not lead them into danger or disaster.

It is emphasized that all possible dangers and emergencies which may arise cannot be covered in this letter, and that responsible officers are expected to exercise prudence and sound judgment in dealing with any situation not specifically covered herein.

3. GENERAL RULES

(a) All target ships, regardless of their previous radiological history, or the amount of CROSSROADS work previously expended on them must be assumed to be radiologically hazardous. Parties boarding them will invariably be accompanied by radiological monitors, and all radiological safety precautions will be scrupulously observed.

(b) The predominance of one type of hazard in any particular job to be done must not be allowed to prevent consideration of other types of hazards which may be simultaneously present, even though in lesser or supposedly negligible degrees.

(c) Safety of personnel shall be the governing consideration at all times. No job is of sufficient urgency or importance to justify departure from this guiding principle.

(d) The Pensacola, because of the presence on board of dangerously unstable 8-inch powder, is out of bounds to all personnel. No one shall be permitted to board this vessel without the express authority of SOPA in each instance.

Due to the unusual character of the conditions existing in the Pensacola, special instructions with regard to this ship will be issued at a later date.

4. RADIOLOGICAL HAZARDS

(a) [CTG 1.2 Serial 699, 17 Aug 1946] will be the governing directive for radiological safety of personnel working on target vessels. Salient points of this directive, as well as additional precautions pertinent to the nature of the work to be done, are set forth in the following subparagraph.

(b) While on the job, personnel will wear only the work clothing which is specifically issued to them for that purpose on the APL-27.

(c) Despite consideration of physical comfort, sleeves will be rolled down and gloves and proper footgear will be worn while working on target ships.

(d) All individuals while on the job will wear film badges, which will be issued, collected and processed in accordance with existing instructions.

(e) Monitors will invariably be procured and clearance obtained from RadSafe prior to boarding. Required advance notice will be given in so far as practicable.

(f) All personnel will be processed through the APL-27 for issue of clothing and for radiological decontamination on the way to and from work on the target ships. Since this activity is well established and familiar to all concerned, detailed instructions for its operation are not repeated here. The activity will be administered by the Commanding Officer of the Geneva and subsequently by the Commanding Officers of such vessels as may successively relieve and take over the functions of station ship and hotel ship now being performed by the Geneva.

(g) With the decontamination center on the APL-27 in operation and the use of "sour" boats, it is not believed that the prevention of contamination of non-target ships will present a serious problem. RadSafe will make periodic surveys of non-target ships and will issue such instructions from time to time as are deemed necessary.

(h) Boats used for carrying working personnel back and forth between the APL-27 and the target ships will be monitored and scrubbed when necessary as described in [CTG 1.2 Serial 699].

(i) With the possible exception of ammunition disposal, the remaining work to be done on the target vessels will not involve the same degree of intimate contact with sources of contamination as did the earlier decontamination work on these ships. Nevertheless, the same dangers still exist, and the same precautions will be exercised.

(j) Working parties will be kept concentrated as much as possible and men will not be permitted to roam about the ship at random.

(k) All hands should be warned that standing pools of water about the decks, even in supposedly uncontaminated parts of the ship, are potentially serious radiological hazards. The reason for this is that during rain squalls water may wash over a contaminated part of the ship's structure and then be carried through the drainage system and deposited in a clean part of the ship.

(l) Ship's blowers will not be operated except when necessary, and then only when the ventilation system has been checked by RadSafe and cleared for operation.

(m) Due to the danger of inhaling radioactive dust, no dry sweeping or dusting will be done on any part of the target vessel. It is not considered likely that any work of this nature will be required. If accumulation of dirt or trash interferes with efficient working, it will be removed by hosing down, if practicable, otherwise by wet brushing or wet swabbing. Swabs if used will never be wrung out by hand but will be taken topside and placed in a bucket of water, if available, otherwise hung on the life lines to dry.

(n) The danger of ingestion of radioactive material by the mouth must always be borne in mind. All working personnel must be made conscious of this danger and instructed not to eat or smoke or otherwise place contaminated hands in, on, or near the mouth. Lunches will under no circumstances be served to men on the target vessels and working parties will not be fed until thay have been processed through the decontamination center on the APL-27.

(o) No men with open wounds not securely covered and protected by bandages will be permitted to perform work on target vessels, and officers in charge of working parties will be vigilant to detect and eliminate men with such wounds. This precaution particularly applies to wounds on the hands, which should not only be bandaged but also protected by rubber gloves while working. Any wound, however small, received while working aboard target vessels should be immediately scrubbed well with soap and clean water. The injured man will then be processed through the decontamination center and taken to sick bay on the Haven where surgical debridement may be performed.

(p) Handling of objects on board target vessels will be reduced to the minimum required by the nature of the work to be done. The

practice of taking objects as souvenirs from target ships will be vigilantly guarded against and sternly suppressed.

(q) No personnel shall go below decks on target vessels unless wearing oxygen rescue breathing apparatus or positive pressure mask.

(r) An additional inhalation hazard exists in connection with such mechanical operations as cutting and chipping. Personnel performing such work will wear rescue breathing apparatus or positive pressure masks.

(s) If evaporators are opened for any purpose, such as removal of tubes or scale, all personnel on the job will wear rescue breathing apparatus or positive pressure masks. Shirt sleeves will be rolled down and rubber gloves will be worn. A radiological safety monitor will also be in attendance.

(t) Any articles or materials to be removed from target vessels will be monitored in an area where no contamination exists prior to being taken aboard any non-target vessel or sent to any shore installation.

5. EXPLOSIVE HAZARDS [not reproduced]

6. HAZARDS DUE TO NOXIOUS OR POISONOUS GASES OR VAPORS [not reproduced]

7. STRUCTURAL HAZARDS [not reproduced]

TASK GROUP 10.12
OPERATION PLAN
ComBikResurvGroup No. 1-47

ANNEX J

RADIOLOGICAL SAFETY AND HEALTH PLAN

I. ORGANIZATION

A. Radiological Health Section

1. Evaluation of radiological hazards and recommendations for safety procedures

2. Photographic dosimetry

B. Radiological Safety Section

1. Monitoring operations

2. Decontamination "change stations"

C. Radiological Health Advisory Board

1. This Board will consist of the Radiological Health and Safety Officers and such scientific personnel as may be appointed by the Project Officer of the resurvey. It will advise, evaluate, and make recommendations in writing to the Radiological Health Officer in special radiological health matters not covered in BuMed directives; i.e., radiological clearance of questionable areas.

II. STAFF

A. Radiological Health Officer

B. Radiological Safety Officer

C. Radiological Health Advisory Board

III. MISSION

The mission of the Radiological Health and Safety organization will be to protect personnel from radiological health hazards that may be encountered in the Bikini Scientific Resurvey operations.

IV. TASKS

A. The Radiological Health Officer and the Radiological Safety Officer will prepare the Health and Safety Plans to be followed in this operation, and will be responsible for the execution of radiological health and safety directives. They will organize and direct all medical and technical elements of the operation required to execute this plan.

B. The Radiological Health and Radiological Safety Plans are attached hereto as Appendixes I and II, respectively.

Appendix I

Radiological Health Plan

I. RECOGNIZED RADIOLOGICAL HAZARDS

A. Two types of radiological hazards are recognized: "external radiation" and "internal radiation." The former is the type received when standing in the path of a powerful X-ray beam. The latter produces an effect similar to that resulting from the ingestion of radium or the inhalation of radioactive dust.

B. Because of the natural radioactive decay that has taken place since Test A and Test B, the "external radiation" hazard is of lesser importance, but in some localities may prove to be dangerous.

C. The "internal radiation" hazard, however, may still be important. It is characterized by the fact that the injurious material produces damage only when it gains access to the body through ingestion, inhalation, or through breaks in the skin. It may best be visualized on the one hand as comparable to the hazard present in the mining of radioactive materials (inhalation), and on the other to that encountered in the painting of radium dials (ingestion). Even in cases of extreme exposure, characteristic clinical findings may not appear for several years. Even when the exposure is not sufficient to cause death, it may produce tumors in various tissues.

II. ESTIMATE OF CURRENT RADIOLOGICAL HAZARDS

A. General Information

1. The detonation of an atomic bomb liberates an enormous quantity of electromagnetic radiations and neutrons. The electromagnetic radiations include infrared, visible light, ultra-violet light, X-rays, and gamma radiation.

2. Thereafter, the products formed during the fission process emit gamma rays and beta particles, constituting the "external radiation" hazard.

3. The bomb also releases other products that constitute an "internal radiation" hazard.

B. Present Hazards as a Result of Test A (airblast)

1. None.

C. Present Hazards as a Result of Test B (underwater blast)

1. In an underwater burst such as Test B, the radiation resulting from residual radioactive products still may be of considerable magnitude.

2. The products of fission sometimes are absorbed and concentrated in and on ships, corals, algae, and animals. At the present time, radiation hazards of this sort seem remote.

3. However, the highly dangerous unfissioned material producing alpha radiation has a half-life of several thousand years, and will be practically undiminished in intensity due to decay. It was more or less concentrated immediately following Test B, but probably will not be more widely distributed within the atoll area.

4. These unfissioned alpha emitters, together with the fissioned beta- and gamma-radiating products, will occur in greatest concentrations in the area of the coral crater produced by the underwater blast.

5. The sunken ships in this area can be considered contaminated to a relatively high degree, and other areas throughout the lagoon will be considered dangerous until radiologically cleared.

6. Algae, fish, and other marine organisms may contain relatively high concentrations of both fissioned and unfissioned materials.

III. PERSONNEL PRE-EXAMINATION

A. All personnel, both military and civilian, who are to participate in the Bikini Scientific Resurvey will be required to have a special physical examination prior to entering upon such duty.

B. Special medical records, separate from the individual's health records, will be set up under the cognizance of the Radiological Health Officer, and will be classified Confidential.

C. Particular attention will be given to a history of skin sensitivity and respiratory allergy, and it will be necessary to eliminate from contact with radioactive material personnel who have chronic infections or chronic conditions of any nature, particularly skin or respiratory infections, blood dyscrasias, extensive fungus infections of the skin and scalp, precancerous lesions, and all open wounds on the hands.

D. The clinical laboratory examination will include, in addition to a complete blood count, an erythrocyte sedimentation rate, and X-ray of the chest, and a complete urinalysis. Beta counts will be made on the urine when indicated, and if necessary, more extensive radiochemical analysis will be completed. The X-ray of the chest is considered important for future reference, and will be made on full-sized film and filed in the "special medical record."

E. These examinations must be completed before personnel will be given medical clearance to engage in the Bikini Scientific Resurvey.

IV. PERSONNEL FOLLOW-UP EXAMINATIONS

A. All personnel will be given a follow-up medical examination upon completion of the Bikini Scientific Resurvey, even though it is unlikely that any evidence of overexposure will be encountered if safety regulations are followed.

B. Particular attention will be given to the hands for any signs of radiation effects, such as reddening of the skin around the nails or

changes in the fingerprints. These observations will be used as a screening method to select those who should be referred to a Medical Advisory Board for more careful evaluation.

C. The urine will be carefully studied in case of accidental overexposure to radiation or radioactive materials. Beta counts will be made, and if twice background or higher is found in any urine sample, more extensive radiological tests will be carried out.

D. The follow-up examination will include complete blood counts, and an erythrocyte sedimentation rate. All blood samples should be obtained under similar technique, and at the same time of day for each individual. Since a variety of changes is possible in the blood picture after exposure to radiation, all blood counts will require interpretation by a medical officer trained in the special problems of hematology in radiation sickness. In cases suspected of overexposure, or when unexplained laboratory findings occur, total erythrocyte and leucocyte counts will be made, and urine beta counts repeated. Individuals presenting these findings, and individuals known to have received overexposure to external radiation, as shown by photographic dosimetry, will be eliminated from further possible exposure pending the outcome of these studies.

V. PERSONNEL PROTECTION

A. General Information

1. All personnel will be issued protective clothing consisting of caps, green work pants and shirts, canvas gloves, and work shoes.

2. This uniform will be worn by all personnel working at tasks or in areas considered dangerously radiologically contaminated.

3. The wearing of protective clothing and the use of other designated protective measures must be rigidly followed until the radiological situation has been evaluated by the Radiological Safety and Health Sections.

4. Navy Gas Masks with B-2 canisters will be made available for use in situations where radioactive dust is found present in hazardous amounts.

5. The Radiological Health Officer will make recommendations as to changes in safety regulations as the situation may require.

B. Beach Working Parties

1. Initial beach working parties will be accompanied or preceded by a Radiological Safety Officer, and all members of each party will wear the prescribed protective clothing.

2. The Radiological Safety Officer will determine if any contamination exists, and will collect suitable samples of materials for laboratory examination aboard ship.

3. Great care shall be taken to avoid eating or eating with, drinking or drinking with, any materials found on the islands until radiological clearance has been given. In most cases this

clearance will require shipboard laboratory tests of the materials in question. (There shall be no swimming in lagoon waters until clearance has been given by the Radiological Health Officer.)

C. Scientific Expeditions to Beaches and Reefs

1. A Radiological Safety Officer will accompany all initial expeditions to reefs and beaches.

2. All protective measures will be executed until the radiological situation has been fully determined and clearance given by Radiological Health Officer.

3. Care must be exercised to avoid cuts and scratches from sharp coral, as open wounds are extremely hazardous when handling materials contaminated with radioactive fission products and unfissioned materials. If any such wounds occur accidentally, the Radiological Health Officer will be notified immediately.

D. Camps Ashore

1. All new camp sites and existing camps, buildings, and other materials, which may be utilized as a shore-based camp for living purposes, will be checked by monitors before use, and laboratory analyses of samples will be made, when and if indicated.

2. Particular attention will be given to drinking water in tanks and service pipes. Water analysis will be made before such facilities are rehabilitated for use.

3. All gear that is found on Bikini Island associated with the preparation of, and handling of food and drink, must be thoroughly scrubbed clean, and radiologically cleared before being returned to such service.

4. Rusty or corroded materials must not be allowed to come in contact with food or drink.

5. The north end of Bikini Island was the most heavily contaminated, and special precautions must be taken if camp sites are required in this area. Under no circumstances will marine life of any type (found within or about the atoll) be eaten, unless prior radiological health clearance has been given.

E. Diving Operations

1. The deep-water diving operations for the inspection of the sunken target ships probably will constitute the greatest radiological hazard to Resurvey personnel. Most of these operations will be within or about the coral crater formed by the underwater blast. The coral and sediment, as well as the ships in this sector, were highly radioactive following Test B of last year. Allowing for natural decay, there still will be considerable radiation present, together with hazardous quantities of fissioned and unfissioned material.

2. All protective measures will be adhered to by personnel engaged and assisting in those operations.

3. Radiological Safety Officers will determine the extent of the radiation, and safe working period with deep-water survey probes, at the site and prior to the diver's descent.

4. All diving clothing, gear, and associated equipment that has been submerged will be washed off with a stream of water as it is hoisted, carefully monitored, and further decontaminated if necessary.

5. Divers will be monitored, and will proceed through the "change station," if necessary, for decontamination prior to being re-monitored. If any part of the body exceeds twice background count, showering or scrubbing with soap and water must be repeated until this level has been attained.

6. All personnel handling diving gear and associated equipment that comes in contact with radioactive materials will be processed in the same manner as divers.

7. While it is anticipated that radiological hazards in connection with shallow-water diving along atoll reefs will be minor, all diving areas will be initially checked by monitors with underwater probes, and laboratory samples will be taken for analysis if necessary. Based upon the monitoring reports and laboratory findings, and Radiological Health Officer will determine the protective measures necessary.

VI. PROTECTIVE PROCEDURES AND EQUIPMENT

A. Monitoring Instruments

1. For general field and personnel monitoring, the type 263 Geiger tube survey meter will be used. This instrument can detect both beta and gamma radiation in a range from less than 0.001 R/24 hr. In addition, by use of earphones, background counts can be determined.

2. For alpha detection in the field, the portable "Zeuto" nylon window ionization chamber will be used. Since this instrument requires the presence of considerable alpha activity in order to respond, a negative indication does not signify complete absence of alpha emitters. Laboratory analysis of suspected samples will be required.

3. For gamma radiation measurements in the vicinity of sunken ships and bomb crater coral, the Type 235 survey meter with an ionization chamber in an extended probe will be used. This instrument has a gamma range of from 0.001 R/24 hr to 0.6 R/24 hr, but will not detect the presence of alpha or beta radiation.

4. For supplementing film badges, the pencil type quartz fiber dosimeter will be used. This pocket type instrument depends upon the ionizing discharge of gamma radiation. It has a range from 0 to 2.0 R. Pencil dosimeters will be worn by all deep-water divers and by others as conditions indicate.

B. Photographic Dosimetry

1. A photographic dosimetry unit will be set up to issue, receive, and process film badges. The Radiological Health Officer will have cognizance of this unit. The Type K film badges used will totalize the amount of general body radiation received. They have a gamma range from 0 to 2.0 R.

2. Film badges will be worn by all deep-water divers, and all others contacting significant radiation, and will be processed daily for divers, and for others at intervals dictated by the radiation contacted.

3. Complete records will be kept of name, badge numbers, date, and hours of exposure. The exposure will be totalized for each individual concerned, and entered into the total dosage record for the operation.

4. As a general rule, an individual will be permitted to reengage in the same operation the following day only if the tolerance limit of total body radiation of 0.1 R per day has not been exceeded.

C. Decontamination "Change Stations"

1. Personnel decontamination or "change stations" will be established aboard Chilton (APA-38), Coucal (ASR-8), and on LCI(L)-615, if necessary.

2. All personnel returning to these ships who have been engaged in operations resulting in contamination to clothing or body will proceed through the "change station."

3. A special compartment will be provided for the removal of contaminated clothing; handwashing facilities, including brushes for scrubbing the nails, will be provided separate from the showers.

4. After gross dirt and contamination are removed from the hands by repeated scrubbing with soap and water, personnel will proceed to the shower and wash the body, repeatedly soaping and rinsing. They will then dry themselves in the shower room and reenter the noncontaminated dressing room, where they will be completely monitored, with special attention being given to the hair, hands, and feet. A Type 263 survey meter with earphones shall be used for personnel monitoring.

5. If any part of the body reads above twice background count, a second scrubbing and shower must be taken, and the decontamination process repeated until this level is attained, prior to donning clean clothing.

6. Contaminated clothing will be laundered in a special-purpose laundry, which will be used exclusively for such purposes. The wastewater from the portable laundry equipment will be pumped over the side and not connected to the ship's sanitary system. Monitors will inspect the laundry equipment from time to time to make sure that it is not accumulating any contamination. Clothing

that exceeds twice background gamma plus beta after repeated laundering will be discarded and disposed of in a safe manner.

D. Radiological Sample Handling and Storage

1. Care will be exercised in handling and storing radioactive samples to prevent the spilling and spreading of contaminated material about the ship.

2. All samples must be placed in covered bottles or jars wherever practicable before being brought aboard ship and well-packaged or placed in leakproof containers in such a manner that no wet or dry material can escape.

3. Special storage spaces will be designated and properly marked for the storage of "hot" samples. These spaces shall be so located that no personnel can receive more than 0.1 R/24 hours radiation from them.

4. Shelves in sample rooms shall be lined with paper or other suitable disposable material to protect against or pick up any accidental spills.

5. Scientific laboratory work tables used for contaminated material likewise shall be covered with disposable paper to prevent the accumulation of radioactive materials. This is important both as a health measure and as an aid in keeping laboratory background counts low.

6. Suitable, well-marked disposal cans shall be provided in sample sorting rooms and technical laboratories for the disposal of discarded radioactive specimens and wastes. No radioactive wastes will be discarded in the ship's sanitary system, since radioactivity will accumulate and may later present a difficult decontamination problem.

7. Monitors will be assigned to make periodic inspections of sample rooms and technical laboratories.

Appendix II

Radiological Safety Plan

I. ORGANIZATION

Chief of Section and Radiological Safety Officers. The Radiological Safety Section will be based aboard USS Chilton (APA-38).

II. GENERAL INFORMATION

Appendix I to this Annex contains general information relative to the radiological situation expected to be encountered by personnel engaged in the operations to be undertaken by the Bikini Scientific Resurvey.

III. MISSION

To determine the magnitude of the radiological hazards existing within the operational area, and to furnish the Radiological Health Officer with such data and reports as may be required to permit an accurate evaluation of the radiological situation, and the formulation of policies and procedures necessary for the protection of personnel engaged in the operation.

IV. TASKS

A. Monitoring Operations

1. Preliminary Survey of Bikini Island

Radiological Safety Officers will accompany the initial parties ashore on Bikini Island, and will begin a preliminary radiological survey thereof. This preliminary survey will be completed as soon as practicable, and particular emphasis will be placed upon the monitoring of all existent buildings or structures on the island.

2. Diving Operations

a. Deep Water

Two (2) Radiological Safety Officers will be aboard USS Coucal (ASR-8) during all deep-water diving operations conducted from that vessel. One (1) Radiological Safety Officer will operate the deep-water probe during such operations, and one (1) Radiological Safety Officer will be responsible for the monitoring of all divers returning aboard Coucal, together with the monitoring of all samples brought to the surface by the divers.

Detailed instructions as to precautionary measures to be taken in connection with deep-water diving are contained in paragraph V.(E) pf Appendix I to this Annex.

3. Core Sampling

One (1) Radiological Safety Officer will be aboard LCI(L)-615 during all core-sampling operations conducted from that ship. The Radiological Safety Officer will be responsible for the monitoring of all samples and personnel engaged in the work on the vessel.

4. Accompaniment of Beach and Boat Parties

Radiological Safety Officers will accompany all beach and boat parties working within the operational area until such time as specific localities have been determined to be free from radiation hazards and properly cleared by the Radiological Health Officer.

5. Periodic Inspections

Radiological Safety Officers will periodically check various parts of the ships for radioactivity. Such checks will include condensers, evaporators, fire mains, flushing systems, etc. where

there may be a concentration of deposition of radioactive materials from contaminated water.

6. Special Radiological Reconnaissance

Special radiological reconnaissance, not essential to safety, may be conducted by the Radiological Safety Section when safety requirements are not overriding.

V. PROTECTION OF PERSONNEL

A. Film Badges

Radiological Safety Officers will issue film badges daily to individuals entering hazardous areas, and will collect these badges at the end of each day for delivery to the Photographic Dosimetry Unit. This procedure will be followed until such time as radiological reconnaissance indicates that it may be modified in specific instances. All exceptions to this procedure will be cleared and announced by the Radiological Health Officer.

B. Protective Clothing

1. General

Radiological Safety Officers will insure that members of all scientific work parties are equipped with the following items of protective clothing:

Cap, "baseball type"

Shirt, working, green twill

Trousers, working, green twill

Shoes, field

Gloves, canvas (will be issued whenever radiological conditions warrant).

C. Clothing for Divers

Personnel engaged in shallow-diving operations in areas presenting a radiological hazard will be provided with the following items of protective equipment in addition to their normal diving gear:

Gloves, canvas

Coveralls.

D. Decontamination

1. Decontamination, or "change stations," will be established aboard Chilton, Coucal, and LCI(L)-615, if required.

2. Radiological Safety Officers will monitor all personnel upon the completion of personnel decontamination procedures, and each individual will be responsible for reporting to the Radiological Safety Officer in attendance for such monitoring prior to donning his clean clothing.

3. Detailed instructions as to the decontamination procedu followed is contained in paragraph VI.(C) of Appendix I Annex.

E. Technical Reports and Data

1. The Radiological Safety Section will receive and mainta of monitoring reports compiled during the operation, wi tain the "radiological situation map," and will comp additional data as may be required by the Project Office Scientific Resurvey.

2. The Radiological Safety Officer will cooperate with th logical Health Officer, and will submit all data perta the existent radiological situation to him for re evaluation.