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DNA 6033F

OPERATION SANDSTONE

1948



**United States Atmospheric Nuclear Weapons Tests
Nuclear Test Personnel Review**

**Prepared by the Defense Nuclear Agency as Executive Agency
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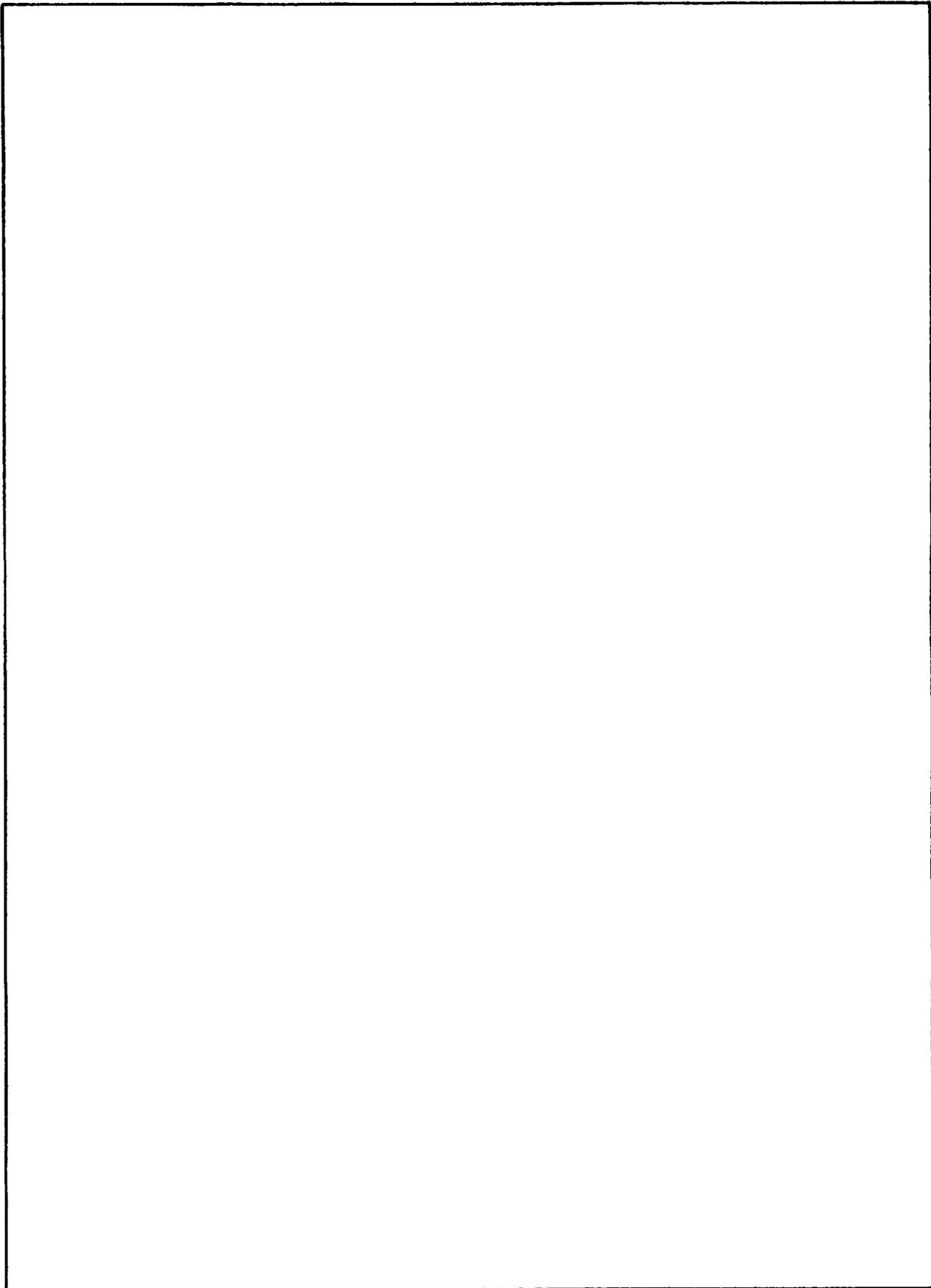
SANDSTONE Shot X-RAY Fireball



REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER DNA 6033F	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) OPERATION SANDSTONE: 1948		5. TYPE OF REPORT & PERIOD COVERED Technical Report
		6. PERFORMING ORG. REPORT NUMBER KT-82-026(R)
7. AUTHOR(s) L.H. Berkhouse J.H. Hallowell F.W. McMullan S.E. Davis C.B. Jones M.J. Osborn F.R. Gladeck E.J. Martin W.E. Rogers		8. CONTRACT OR GRANT NUMBER(s) DNA 001-79-C-0274
9. PERFORMING ORGANIZATION NAME AND ADDRESS Kaman Tempo 816 State Street (P.O. Drawer QQ) Santa Barbara, CA 93102		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Subtask U99QAXMK506-09
11. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, DC 20305		12. REPORT DATE 19 December 1983
		13. NUMBER OF PAGES 222
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A since UNCLASSIFIED
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES This work was sponsored by the Defense Nuclear Agency under RDT&E RMSS Code B350079464 U99QAXMK50609 H2590D. For sale by the National Technical Information Service, Springfield, Virginia 22161.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Nuclear Testing Enewetak JTF-7 Nuclear Test Personnel Review X-Ray SANDSTONE YOKE Pacific Proving Ground ZEBRA		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) SANDSTONE was a three-detonation atmospheric nuclear weapon test series conducted during the spring of 1948 at Enewetak Atoll in the Marshall Islands. Report emphasis is on the radiological safety of the personnel. Available records on personnel exposure are summarized.		

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FACT SHEET

SANDSTONE was a three-detonation nuclear weapon test series held at Enewetak Atoll, the Atomic Energy Commission's (AEC) Pacific Proving Ground (PPG), in the spring of 1948. Located in the Central Pacific Ocean, the PPG consisted principally of Enewetak* and Bikini atolls in the northwestern Marshall Islands.

Assigned Name	Local Date	Location	Yield (KT) ^a
X-RAY	15 April	200-foot (61-meter) tower on Enjebi Island	37
YOKE	1 May	200-foot (61-meter) tower on Aomon Island	49
ZEBRA	15 May	200-foot (61-meter) tower on Runit Island	18

Note:

^aOne kiloton equals the approximate energy release of a one-thousand-ton TNT explosion.

HISTORICAL BACKGROUND

Operation SANDSTONE was the second test series to be held in the Marshall Islands, but it differed from the first series (CROSSROADS in 1946) in that it was primarily an AEC scientific test series with the armed forces serving in a supporting role. Its purpose was to proof-test improved-design atomic weapons, whereas the purpose of CROSSROADS was to test nuclear weapons effects on ships.

The weapons were tested at Enewetak by a joint military and civilian organization designated Joint Task Force 7 (JTF 7). This was a military organization in form, but contained military, civil service, and contractor personnel of the Department of Defense (DOD) and the AEC. The commander of this force was the appointed representative of the AEC and reported to both the Joint Chiefs of Staff and the Commander in Chief, Pacific.

Peak DOD numerical strength at SANDSTONE was approximately as follows:

Uniformed military	9,890
DOD civilians	350
DOD contractors	126
	<u>10,366</u>

* Formerly Eniwetok. A better understanding of the Marshall Islands language has permitted a more accurate transliteration of Marshall Island names into English language spelling.

Numerous technical experiments were carried out in conjunction with each of the three detonations. These experiments measured the yield and efficiency of the devices and attempted to gauge military effects of the explosions. DOD personnel participated in this test operation as individuals whose duty stations were at the AEC weapon design and development laboratories, as units performing separate experiments, and as units performing various support roles.

An extensive radiological safety (radsafe) program with the following objectives was instituted:

1. Keeping personnel radiation exposure at the lowest possible level consistent with medical knowledge of radiation effects and the importance of the test series
2. Avoiding inadvertent contamination of populated islands or transient shipping.

This program established an organization to provide radsafe expertise and services to commanders of the separate components of the task force, who were responsible for personnel safety within their commands. Personnel were trained in radiological safety. Standards governing permissible exposure were established. The standards were 0.1 roentgen (R) per 24-hour period and a maximum exposure of 3 R for certain approved specific missions. Film badges were issued to persons likely to be exposed to radiation, as well as a representative group of the task force. An extensive weather forecasting group was established to predict wind directions and areas of potential fallout. Personnel were evacuated from danger areas before each detonation. Reentry to radioactive areas was restricted to personnel required to retrieve important data, and their radiation exposures were monitored.

TEST OPERATIONS AND EXPOSURES

Each of the SANDSTONE tower shots produced fallout; however, none of the inhabited islands in the area received appreciable fallout. Kwajalein received measureable fallout on 3 May, two days after the YOKE shot. The estimated dose from fallout for persons who were on Kwajalein for the entire test series was calculated to be 0.075 R.

Most task force personnel were on Kwajalein or aboard ships. The remainder were on Enewetak and stayed there for the three shots. The temporary camps on the northern and eastern islands of the atoll near the detonation sites were abandoned and dismantled before the shots. Task force ships evacuated the lagoon, except for USS Albemarle (AV-5), USS Mount McKinley (AGC-7), USS Curtiss (AV-4), and USS Bairoko (CVE-115), which remained in the lagoon near the base islands on the southern side of the atoll.

Highest DOD exposures for both the Army (6.050 R) and the Navy (5.140 R) were accrued by radiation monitors from the Joint Radiological Safety Group. Only eleven personnel (0.6 percent of those badged) received exposures in excess of the imposed standards of 3 R. In fact, radiation exposure for badged JTF 7 personnel at SANDSTONE averaged less than 0.25 R, and approximately 65 percent had zero exposures. Recorded SANDSTONE exposures are summarized in the table on the following page.

SANDSTONE Joint Task Force 7 Personnel Exposures

	Number Badged	Exposure Ranges (roentgens)				High (R)
		0	0.001-1	1-2	Over 2	
Army	327	168	141	10	8	6.050
% of Total		51	43	3	3	
Navy	973	730	233	8	2	5.140
% of Total		75	24	1	<1	
Air Force	350	195	144	8	3	3.060
% of Total		56	41	2	1	
Marines	112	102	9	1	0	1.040
% of Total		91	8	<1	0	
Non-DOD Participants	119	18	83	6	12	17.0
% of Total		15	70	5	10	
Totals	1,881	1,213	610	33	25	17.0
% of Total		65	32	2	1	

PREFACE

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

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

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

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

This report on Operation SANDSTONE is one of many volumes that are the product of the NTPR. The 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 concerning various aspects of each of the tests. Reports of the NTPR provide a public record of the activities and associated radiation exposure of DOD personnel for interested former participants and for use in public health research and Federal policy studies.

Information from which this report was compiled was primarily extracted from planning and after-action reports of Joint Task Force 7 (JTF 7) and its subordinate organizations. Documents were desired that accurately placed personnel at the test sites 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 by discussion or review with participants.

For SANDSTONE, the most important archival source is the National Archives and Record Center, Modern Military Branch, Washington, D.C. The Naval Archives at the Washington Navy Yard also was helpful, as was the collection housed in the Air Force Weapons Laboratory Technical Library at Kirtland Air Force Base, Albuquerque, New Mexico. Other archives searched were the Department of Energy archives at Germantown, Maryland, its Nevada Operations Office archives at Las Vegas, and archives of the Test Division of Los Alamos National Laboratory.

JTF 7 exposure records and an additional file of exposure-related documents (microfilmed by the Reynolds Electrical and Engineering Company, Inc., support contractor for the Department of Energy/Nevada Operations) have also been very useful.

The work was performed under RDT&E RMSS B350079464 U99 QAXMK 506-09 H2590D for the Defense Nuclear Agency by personnel from Kaman Tempo. Guidance was provided by Mr. Kenneth W. Kaye of the Defense Nuclear Agency.

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CHAPTER 1 OVERVIEW

INTRODUCTION

Purpose

SANDSTONE was a test series in which three nuclear fission devices were detonated at the Atomic Energy Commission's (AEC) Pacific Proving Ground (PPG) at Enewetak Atoll* in the spring of 1948. Table 1 lists the detonations.

Table 1. SANDSTONE detonations, Enewetak, 1948.

Assigned Name	Local Date	Location	Yield (KT) ^a
X-RAY	15 April	200-foot (61-meter) tower on Enjebi Island	37
YOKE	1 May	200-foot (61-meter) tower on Aomon Island	49
ZEBRA	15 May	200-foot (61-meter) tower on Runit Island	18

Note:

^aOne kiloton equals the approximate energy release of a one-thousand-ton TNT explosion.

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

Historical Background

Operation SANDSTONE was primarily conducted to proof-test new weapon designs. Interest in weapon effects experiments in these tests was definitely secondary. A proof-test had not been conducted since the TRINITY test in July 1945, in which the design of the weapon used for the Nagasaki attack was

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

proven. Operation CROSSROADS was conducted in 1946, chiefly to test the effects of nuclear detonations on Navy ships.

When the President approved the preliminary SANDSTONE test program on 27 June 1947, the United States apparently had only 13 nuclear weapons in its stockpile. One year later, in spite of heavy emphasis on increased production of fissionable material, the number of weapons was only about 50, far short of the number (estimated at as high as 200) that military planners calculated would be required in a war with the Soviet Union. The more efficient weapon designs proof-tested at SANDSTONE, coupled with the higher production rates of fissionable material, allowed the great expansion in the U.S. stockpile evident by the end of 1949 (Reference D.1).

Meetings were held on 9 July at Los Alamos, New Mexico, to define test responsibilities for SANDSTONE. Los Alamos Scientific Laboratory (LASL), the organization that had developed the wartime atomic weapons and the AEC organization that did research and laboratory development of new nuclear weapon designs, was to provide technical leadership and the military services were to provide supplies and support. Potential test sites in the Marshall Islands were visited in September 1947, and a site was selected on 11 October 1947 (Reference A.8, pp. 140 and 141).

Enewetak Atoll was selected because it was large enough for three shots, and the steady trade winds would carry fallout from the shots over the open ocean to the west. These trade winds, and their orientation with respect to Enewetak Island (the major island of the atoll), made a permanent major airfield possible. This was undoubtedly a factor that made Enewetak more desirable than Bikini Atoll, which had been used for Operation CROSSROADS (Reference A.5). Figure 1 shows the location of the Marshalls in the Central Pacific and Figure 2 is a map of Enewetak Atoll.

Although inhabited by about 140 people, the dri-Enewetak and the dri-Enjebi, who lived on the islands of Bijire and Aomon, Enewetak Atoll was far removed from other inhabited islands. Bijire housed the dri-Enjebi, the people whose normal home was Enjebi in the northern islands of the atoll, and Aomon was occupied by the dri-Enewetak, whose normal home was Enewetak Island on the southern side of the atoll. Both of these islands had been the scene of fierce fighting during World War II and later were major military operating areas, requiring the population's removal. In 1946, these people were moved to Meck Island at Kwajalein Atoll for a short time when Enewetak was considered a possible site for the CROSSROADS test series (References A.9 and A.10).

Ujelang Atoll, 124 nmi (230 km) southwest of Enewetak, was selected as the future home for this group of people, and construction of cisterns, water catchments, latrines, tent frames, and other buildings was begun by a Navy construction battalion group on 22 November 1947. Ujelang had been without permanent inhabitants from the time it had been abandoned in the late nineteenth century by the survivors of a typhoon that swept the atoll.

On 2 December 1947, the United States notified the United Nations Security Council that it was closing Enewetak Atoll in order to conduct necessary experiments relating to nuclear fission. The land area of Enewetak Atoll, its

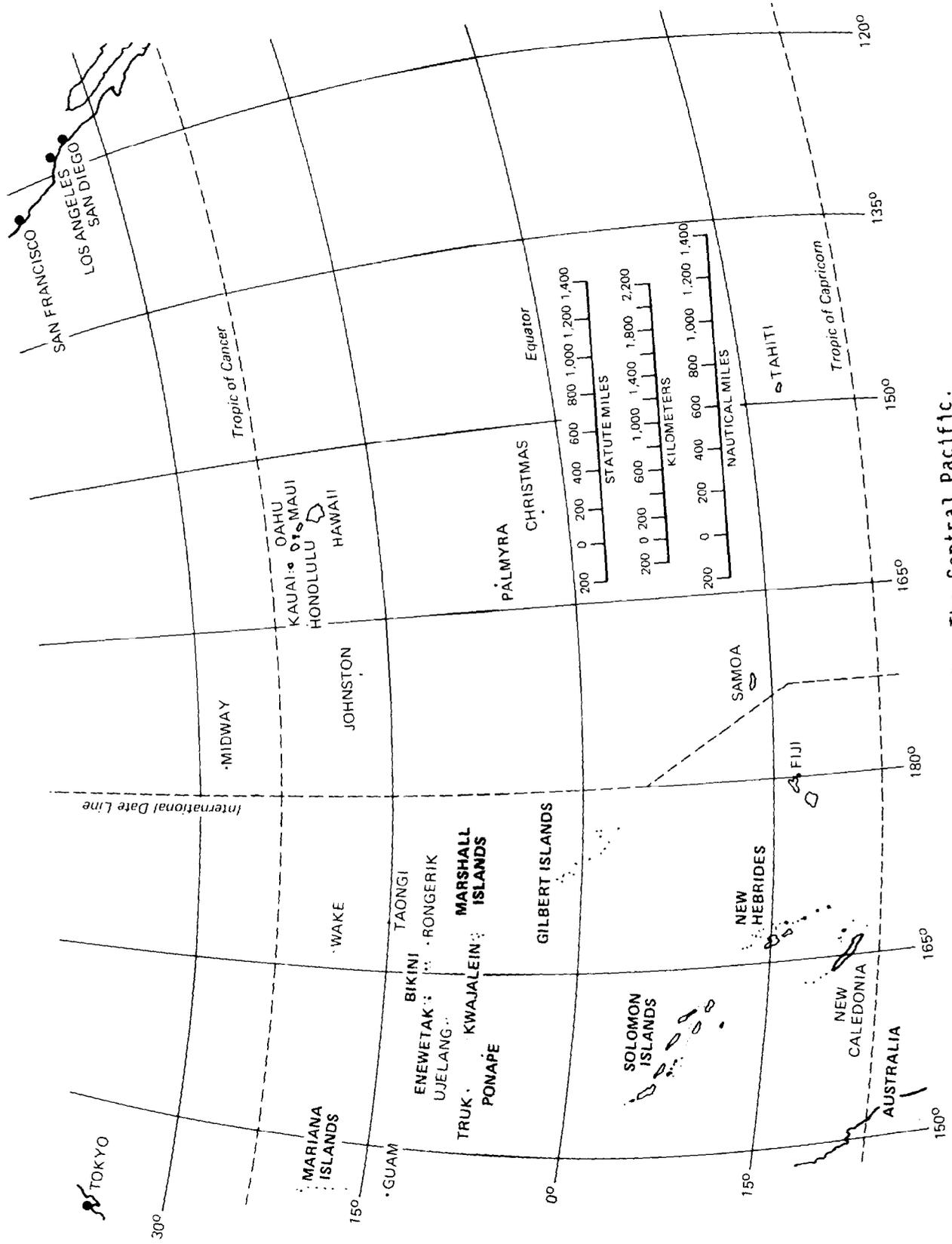


Figure 1. The Central Pacific.

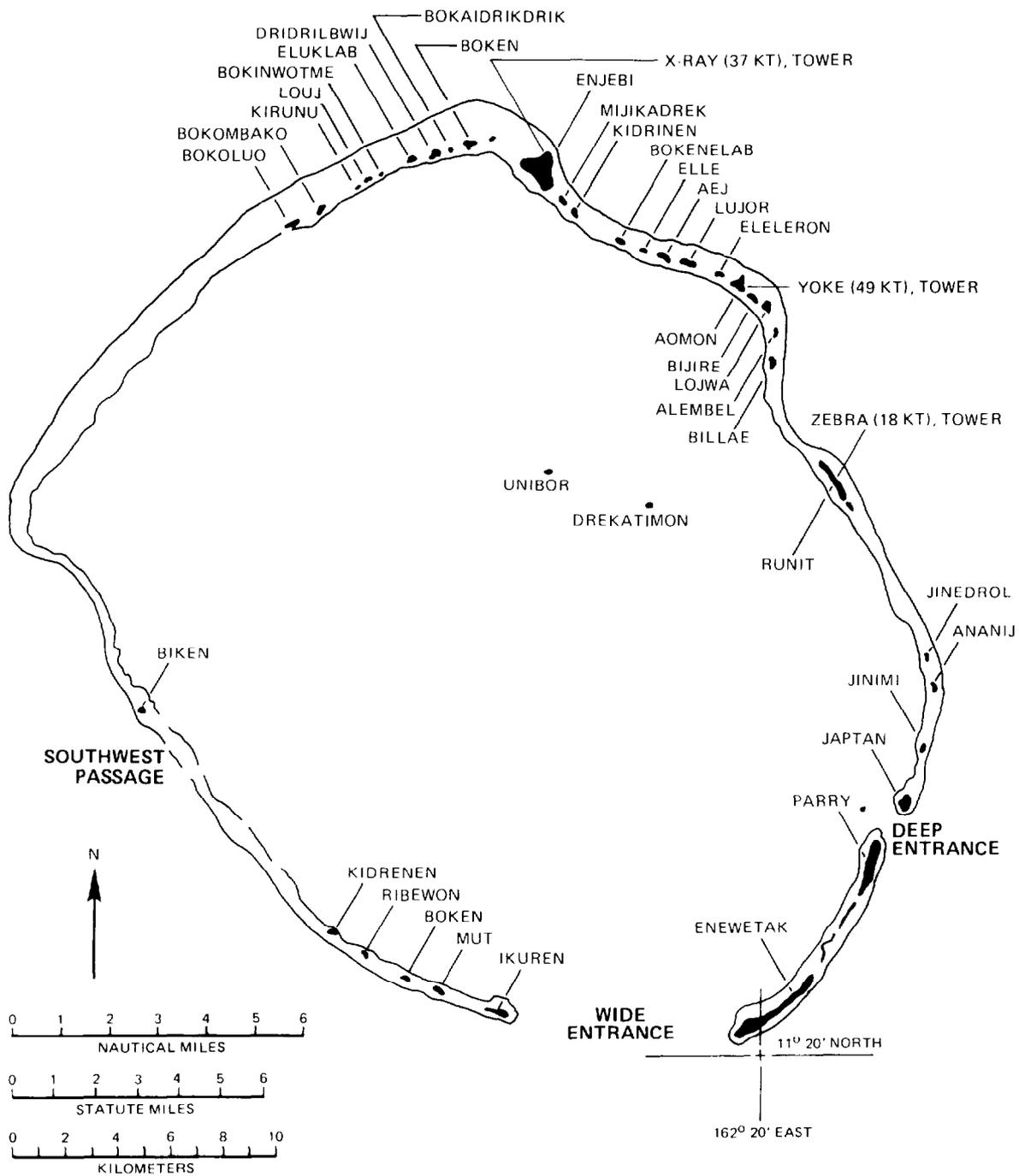


Figure 2. Enewetak Atoll, 1948.

lagoon, and the waters within 3 miles (5 km) of its seaward sides constituted the test area. These islands were part of the Trust Territory of the Pacific Islands, a strategic area trusteeship of the United Nations, administered by the United States. The U.S. agency in charge of the test area itself was the AEC.

On 3 December 1947, military authorities met with the dri-Enewetak and dri-Enjebi to explain the proposed move. Chiefs and members of the councils visited Ujelang on the following day and agreed to move upon their return to Enewetak on 5 December. The move of the people and their belongings was completed by 20 December by USS LST-857 (References A.9 and A.10). The number of people moved is given in contemporary sources as 142, but recent authoritative work cites 136 (Reference A.10).

Report Organization

Subsequent sections of this overview chapter discuss the form of experimental nuclear weapon test programs with emphasis on the potential radiation exposure of participating DOD personnel. The experimental activities are considered first without particular reference to geographic location of the testing and are then related to the geographic limitations on such activities at the PPG. The portion of the experimental program of heaviest DOD participation is emphasized. The chapter concludes with a description of Joint Task Force 7 (JTF 7), the organization that conducted SANDSTONE, and indicates how the DOD elements within JTF 7 functioned.

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

Chapter 3 focuses on the role of the DOD in the experimental program of SANDSTONE in general, leading to a discussion of DOD operations for the test events in Chapter 4.

Chapters 5 through 8 report participation by the Army, Navy, Air Force and Marine Corps. Chapter 9 summarizes participation of other government agencies and contractors. A listing of participating units and a statistical characterization of their personnel exposures are included in these chapters. Personnel exposures are discussed in Chapter 10.

NUCLEAR TESTS AND RADIATION EXPOSURES

Nuclear testing before 1961 usually consisted of the unconfined detonation of nuclear devices (usually not weapons) in the atmosphere. Devices might be placed on a platform or a barge on the surface, placed atop a tower, supported by a balloon, dropped from an airplane, flown on a rocket, or shot from a cannon. A few were detonated underwater or buried in the earth in underground tunnels or shafts. SANDSTONE was the first operation in the Pacific to detonate nuclear devices on towers.

In theory, personnel could be exposed either by the radiation emitted at the time of explosion and for about 1 minute thereafter -- usually referred to

as initial radiation -- or the radiation emitted later (residual radiation). Initial radiation is part of the violent nuclear explosion process itself; to be close enough for initial radiation exposure would place an unprotected observer within the area swept by lethal blast and thermal effects.

The neutron component of initial radiation has 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 nuclear detonation process and contribute to the possibility of personnel exposure as residual radiation.

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

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

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

In a nuclear airburst in which the central core of intensely hot material, or fireball, does not touch the surface, weapon residues (including the fission products, 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 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 winds and weather. If the detonation is small, 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.6). Areas in which this fallout material will be deposited will appear on maps as bands following the wind's direction. Larger detonations (yields equivalent to megatons of TNT) will have cloud stabilization altitudes in the stratosphere (above about 10 miles [16 km] in the tropics); radioactive material from such

altitudes will not return to Earth for many months and its distribution will be much wider. Thus, airbursts contribute little potential for radiation exposure of personnel at the testing area, although some residual and short-lived radioactivity might come from activated surface materials under the burst if burst altitude is sufficiently low for neutrons to reach the surface.

Surface and near-surface bursts pose larger potential radiation exposure problems. These detonations create more radioactive debris because more material is available for activation within range of neutrons generated by the explosion. In such detonations the extreme heat vaporizes device materials and activated earth materials as well. These materials cool in the presence of additional material gouged out of the burst crater. This extra material causes the particles formed as the fireball cools to be larger in size, with radioactivity embedded in them or coating their surfaces. The rising cloud will lift these particles to altitudes that depend on particle size and shape and the power of the rising air currents in the cloud, which in turn depend on yield of the detonation. The largest particles will fall back into the crater or very near the burst area with the next largest falling nearby. It has been estimated that as much as 80 percent of the radioactive debris from a land-surface burst falls out within the first day following the burst (Reference A.6).

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

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

EXPERIMENTAL PROGRAM

Central to the test series was the experimental program. This program and its requirements dictated the form of the test organization and the detail of personnel participation. SANDSTONE's experimental program incorporated two aspects, the most important of which was the development of the weapons themselves; the second aspect was measuring effects of the detonations on equipment and structures.

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

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

Weapon Diagnostic Experiments

LASL was responsible for conducting experiments designed to measure the output of the nuclear devices, specifically radiation, blast, and yield. In testing devices, weapon designers are interested in two classes of measurements: the total energy release of the device, and the rate of release. Total energy release measurements are called yield measurements, and the rate of release measurements are called diagnostic measurements.

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

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

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

Sampling of device debris, however, necessitated exposure to higher levels of radioactivity. The technique used in most atmospheric tests was to fly aircraft with collectors directly through portions of the radioactive (or mushroom) cloud, although for some shots rockets and drone aircraft were used. About 90 percent of the fission debris was usually considered to be in the upper portion of the radioactive cloud (Reference A.6).

For SANDSTONE, cloud debris was collected by eight unmanned B-17 drone aircraft. The drones picked up significant amounts of radioactive material on their surfaces, posing potential radiation exposure to ground crews involved in decontamination. Samples collected were radiologically "hot" and required special handling as they were taken from the aircraft and prepared for shipment to laboratories for analysis.

DIAGNOSTIC MEASUREMENTS. The detonation of a nuclear device is a progressive release of increasing amounts of nuclear radiation, some of which directly escapes the device. The rest of the radiant energy interacts with the associated material of the device itself and is converted into differing forms of

radiation and into the kinetic energy of the remaining materials in a small fraction of a second. The intensely hot core then reradiates, heating the surrounding air and creating a shock wave that propagates outward from the burst point.

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

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

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

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

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

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

Since radiation decays with time, the time lapse between the detonation and exposure is a critical factor in dose assessment. Primary recording media for weapon diagnostic experiments were photographic films from oscilloscope, streak, or framing cameras located in survivable bunkers near the detonation point. Because radiation fogs film in time, these films and other time-sensitive data were removed from the bunkers by helicopter-borne personnel within hours of the detonation to minimize damage by fogging. This recovery constituted the main potential for exposure of weapon diagnostics participants.

Service Tests

These experiments were designed to measure the effects of detonations on equipment and structures. They were requested by the military services, approved by the AEC, and conducted by a variety of task force organizations.

The potential for radiation exposure of personnel responsible for recovery depended in general upon the proximity of the instruments to the device and the elapsed time between detonation and instrument recovery. If the recovery was not time-sensitive, the exposure was very low.

OCEANIC TESTING OPERATIONS

Nuclear test operations in the Pacific posed problems in logistics and in the management of radioactive contamination because of the limited land area and the remoteness of Enewetak Atoll.

Marshall Islands Setting

The Marshall Islands are in the easternmost part of the area known as Micronesia ("tiny islands"). The Marshalls are spread over 770 thousand mi^2 (2 million km^2) of the Earth's surface, but the total land area is only about 70 mi^2 (180 km^2). Two parallel chains form the islands: Ratak (or Sunrise) to the east, and Ralik (or Sunset) to the west; Enewetak is in the Ralik chain at its northern extreme (Figures 1 and 2).

A typical atoll, Enewetak is a coral cap set on truncated, submerged volcanic peaks that rise to considerable heights from the ocean floor. Coral and sand have gradually built up narrow islands into a ring-like formation with open ocean on the outside and a relatively sheltered lagoon on the inside. Enewetak has three passages, Southwest Passage, Wide Entrance, and Deep Entrance, that permit access to its lagoon from the sea. All the islands are low-lying, with elevations seldom over 20 feet (6 meters) above high tide.

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

Elliptically shaped, Enewetak Atoll is approximately 550 nmi (about 1,020 km) southwest of Wake Island and 2,380 nmi (4,410 km) southwest of Honolulu. It encloses a lagoon 17 by 23 miles (27 by 37 km) and has a total land area of 2.75 mi^2 (7.12 km^2), with elevations averaging 10 feet (3 meters) above mean sea level. The support section of Enewetak (Enewetak, Parry, and Japtan islands) constitutes about 34 percent of the atoll's land surface. The string of islands from Runit to Bokoluo, the detonation area, constitutes about 32 percent. The various names used for the islands of the atoll are listed in Appendix C, "Island Synonyms."

The climate of Enewetak Atoll 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 Enewetak is

open ocean for over a thousand miles, with the only inhabited island being Wake. East of Enewetak are several atolls including Bikini, Rongelap, Rongerik, Ailinginae, and Utirik. Rongelap, the nearest inhabited atoll, is a little over 260 nmi (about 480 km) from Enewetak. 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. Much cumulus cloud cover exists in the area.

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

The steady northeast trade winds in the lower levels cause the water at the surface of the 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 the winds to the southwest again. The lagoon waters moving in this closed loop also mix with those of the open ocean, resulting in a flushing action. Flushing is rapid and has two major routes. The first is directly through the eastern reefs to the western reefs; the second is in through Deep Entrance between Japtan and Parry and out Wide Entrance west of Enewetak Island. These two routes also function to keep the waters of the northern part of the lagoon separate from the southern waters.

The islands of Enewetak Atoll had been used for growing coconuts from the time of their German possession in the nineteenth century, but during the 1944 assault and capture of the atoll by American forces, the coconut stands had been destroyed on the islands of Enjebi, Enewetak, and Parry. On those islands on which the coconut stands had not been destroyed, the lack of normal care was evident (Figure 3) as the low-growing native shrubbery advanced.

After the fighting, an airstrip was built on Enewetak Island, but little attempt was made to clear battle debris (Reference A.10). Facilities and structures on the islands were in poor condition in the fall of 1947. In addition, surplus American property purchased by the Chinese had to be removed from the island. Many of the islands had short piers that were in poor repair. Airstrips had to be built and submarine cable laid. The overall construction plan for the proving ground required three test-firing sites, a 200-foot (61-meter) tower on each site, and instrument stations. Photographic towers also had to be erected and a control station built.

By Christmas 1947, construction was progressing on schedule, and the rehabilitation of living and messing facilities at Enewetak was well underway. A causeway between Aomon and Bijire was constructed by a private company.



Figure 3. Aerial view of Anani Island, Enewetak Atoll, in 1948. Instrument tower is visible.

Special Problems in Testing in the Marshalls

The remoteness of Enewetak Atoll posed significant logistics problems in procuring and transporting personnel, materials, and supplies to the test site. Special security arrangements were also required for transport of the nuclear devices from laboratories in the United States to the test area. Radioactive cloud samples had to be expeditiously transported back to several U.S. laboratories for analysis.

The limited land area at Enewetak Atoll was also a problem. The two inhabited islands at the southern end — Enewetak and Parry — were overcrowded during testing. Buildings on Enewetak and Parry were originally constructed to accommodate approximately 2,100 men. Aerial views of these base islands are shown in Figures 4 and 5.

Lack of a land bridge to the northern islands required a major effort to transport men and materiel to the test islands. Navy landing craft were used extensively for this task.

Testing at Enewetak, however, also had some advantages besides the large open ocean area that surrounds the atoll. Separation between the northern and southern islands created a natural safety barrier from the detonations. The separate islands also made control of personnel movement easier.



Figure 4. Enewetak Island, 1948, showing upwind (northeast) end of runway with junk revetments and B-17 samplers in foreground.



Figure 5. Parry Island, 1948. Joint Task Force 7 ships are in the lagoon in the background.

JOINT TASK FORCE 7

On 18 October 1947, JTF 7 was activated and assigned the code name, "Switchman." Incorporated into its organization were elements of the four military services, other government agencies including the AEC, and civilian organizations under contract. The AEC, charged with responsibility for nuclear energy development by the Atomic Energy Act of 1946, designated Commander JTF 7 (CJTF 7) as its representative. JTF 7 was also subordinate to the Joint Chiefs of Staff (JCS). These relationships are illustrated in Figure 6.

The resulting organization, though complex, worked well enough, as it conformed with the realities of the situation. The realities were that the tests were being conducted to develop nuclear weapons, an activity limited by law to a civilian agency, the AEC. The tests were mainly being conducted in an area that came under the jurisdiction of the AEC (in the sense that the AEC was the U.S. government agency primarily responsible for the islands that were included in the test area). Furthermore, the territory was remote from the United States and required special supply and security arrangements appropriate to military operations. Finally, the organization for which the weapons were being developed was the U.S. military establishment. The mission of the task force was to, "construct a proving ground, under the scientific direction of the AEC, and conduct proof testing of atomic weapons on the Enewetak Atoll" (Reference C.5, p. 2-6). Any military service tests or experiments were to be conducted on a noninterference basis.

The Armed Forces Special Weapons Project (AFSWP) was the tri-service military organization formed to manage the receipt, storage, safety, security, and inspection of atomic weapons, if and when the military was required to use them. It was most interested in participating in the SANDSTONE tests and coordinated with LASL early in the planning. AFSWP was to provide military personnel to be integrated into Task Group (TG) 7.1 (AEC Proving Ground Group), and 116 personnel were assigned to this organization.

The armed services furnished personnel, equipment, and services necessary to ensure security, proper operation, and logistic support. The joint task force was divided into functional and service-branch oriented task groups.

The test director of TG 7.1 was responsible to the AEC for direction of technical test activities and policies. All military experiments were under his direction. TG 7.2 (Army Task Group) was commanded by an Army general officer who was also Commander, Enewetak Atoll. He was responsible for construction and security on the atoll as well as billeting, transportation, sanitation, recreation, medical facilities, and utilities maintenance for all units. TG 7.3 (Naval Task Group), commanded by a Navy flag officer, was responsible for the operational control of all TG 7.3 units, augmenting air-sea rescue by available aircraft and ships as required, offshore patrol of a circular area from the center of Enewetak Atoll commensurate with available aircraft and surface craft, operation of a boat pool, ship security, helicopter operations except when attached to the Air Force, and laying of submarine cable. TG 7.4 (Air Task Group) commanded by an Air Force general officer, was responsible for all air operations, meteorological services, interisland air transportation, air-sea rescue, and aerial photography. TG 7.5 (Joint Security Group) was responsible for advising appropriate commanders relative to security

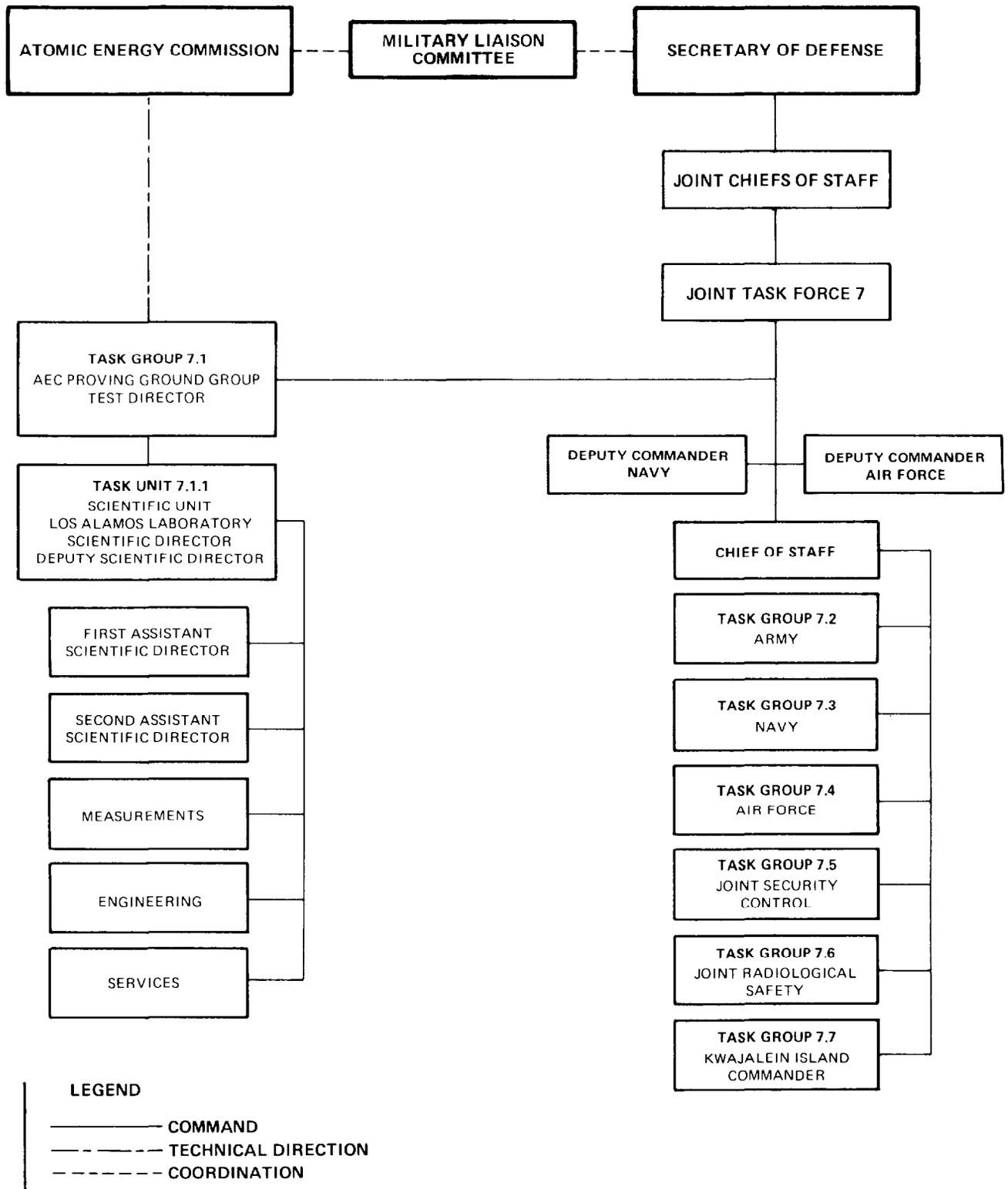


Figure 6. Organization of Joint Task Force 7, SANDSTONE.

control measures, for safeguarding classified information, for security of the instrumentation islands, and for providing couriers. TG 7.6 (Joint Radiological Safety Group) was responsible for the operational detection and determination of intensities and types of radioactivity. This group furnished monitors to accompany all parties returning to an area of possible radioactivity. TG 7.7 (Kwajalein Island Group) was responsible for billeting, transportation, sanitation, recreation, medical facilities, and utilities maintenance for all JTF 7 units on Kwajalein, for the military security of the island, and for construction on Kwajalein. A radsafe officer from the staff of CJTF 7 was assigned to TG 7.7 to determine radiological exposure potential for all personnel, including precautions necessary to protect personnel against exposure and detection and determination of intensities and types of radioactivity. TG 7.8 (Observer Escort Group) was responsible for escorting observers in the test area. Thirty spaces each were allocated to the AEC and the armed forces for observers.

During peak manning periods the Army provided approximately 2,124 personnel for SANDSTONE, the Navy 5,850, the Air Force 1,800, and AFSWP 116. Approximately 350 nonservice civilians from LASL, DOD, and various other contractor organizations participated. The Navy provided a total of 28 Navy ships, 11 small craft, 6 helicopters, 6 patrol seaplanes, 3 large land-based patrol aircraft, and 2 small aircraft. The Air Force supported SANDSTONE operations with over 60 other aircraft.

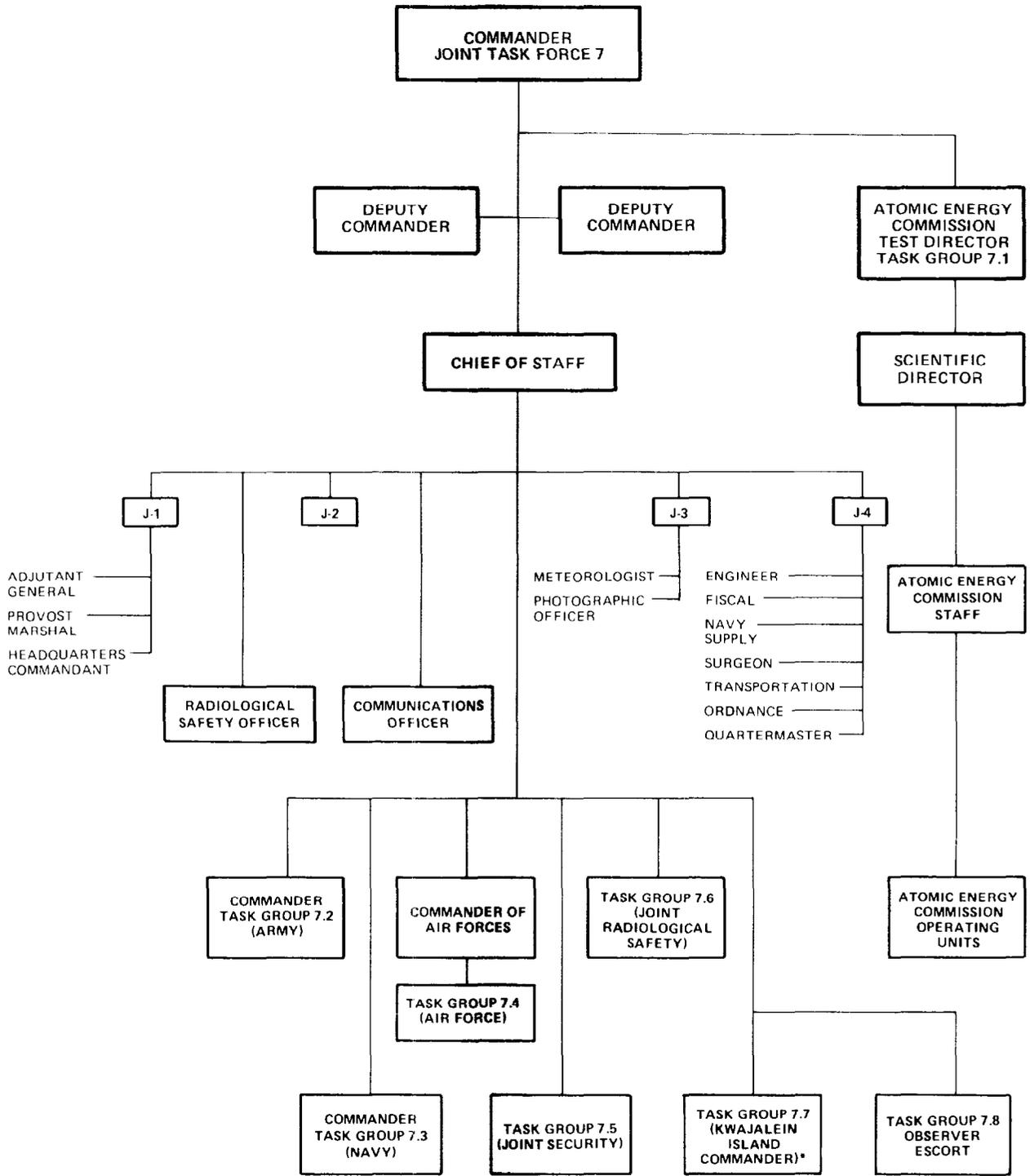
Joint Task Force 7 Headquarters

Figure 7 shows the organization of Hq JTF 7. CJTF 7 had three principal deputies, one of whom was the Test Director and in charge of TG 7.1. The joint staff and the comptroller were patterned after other military organizations. During test operations, Hq JTF 7 was located on USS Mount McKinley (AGC-7); some staff members were also on USS Albemarle (AV-5), USS Curtiss (AV-4), and USS Bairoko (CVE-115). Total strength of Hq JTF 7 during April and May was approximately 175 personnel, with approximately 96 stationed on Mount McKinley (Reference C.5, p. 3-A9).

Task Group 7.1 (Atomic Energy Commission Proving Ground Group)

Figure 8 shows the organization of TG 7.1, which was the heart of the task force. It was responsible for preparing and firing the three nuclear devices, preparing and conducting all experimental programs, and operating and maintaining all atoll base facilities except those on Enewetak Island, which were manned by TG 7.2. TG 7.1 contained both scientific and military civilian personnel. Subordinate task units are discussed subsequently. In the forward area, TG 7.1 was composed of 283 personnel from LASL; AFSWP; Naval Research Laboratory; Naval Ordnance Laboratory; Argonne National Laboratory; Edgerton, Germeshausen & Grier, Inc.; Aberdeen Proving Ground; AEC; Navy Bureau of Personnel; David Taylor Model Basin; and the Military Liaison Committee. Table 2 lists task group strength figures.

TASK UNIT 7.1.1 (SCIENTIFIC). Task Unit (TU) 7.1.1 was staffed primarily with scientists from LASL who were assisted by military personnel as well as scientists from other AEC installations and outside agencies. Its nucleus of



*RESPONSIBLE TO COMMANDER JOINT TASK FORCE 7 ONLY FOR SUPPORT OF THIS OPERATION

Figure 7. Organization of Headquarters, Joint Task Force 7, SANDSTONE.

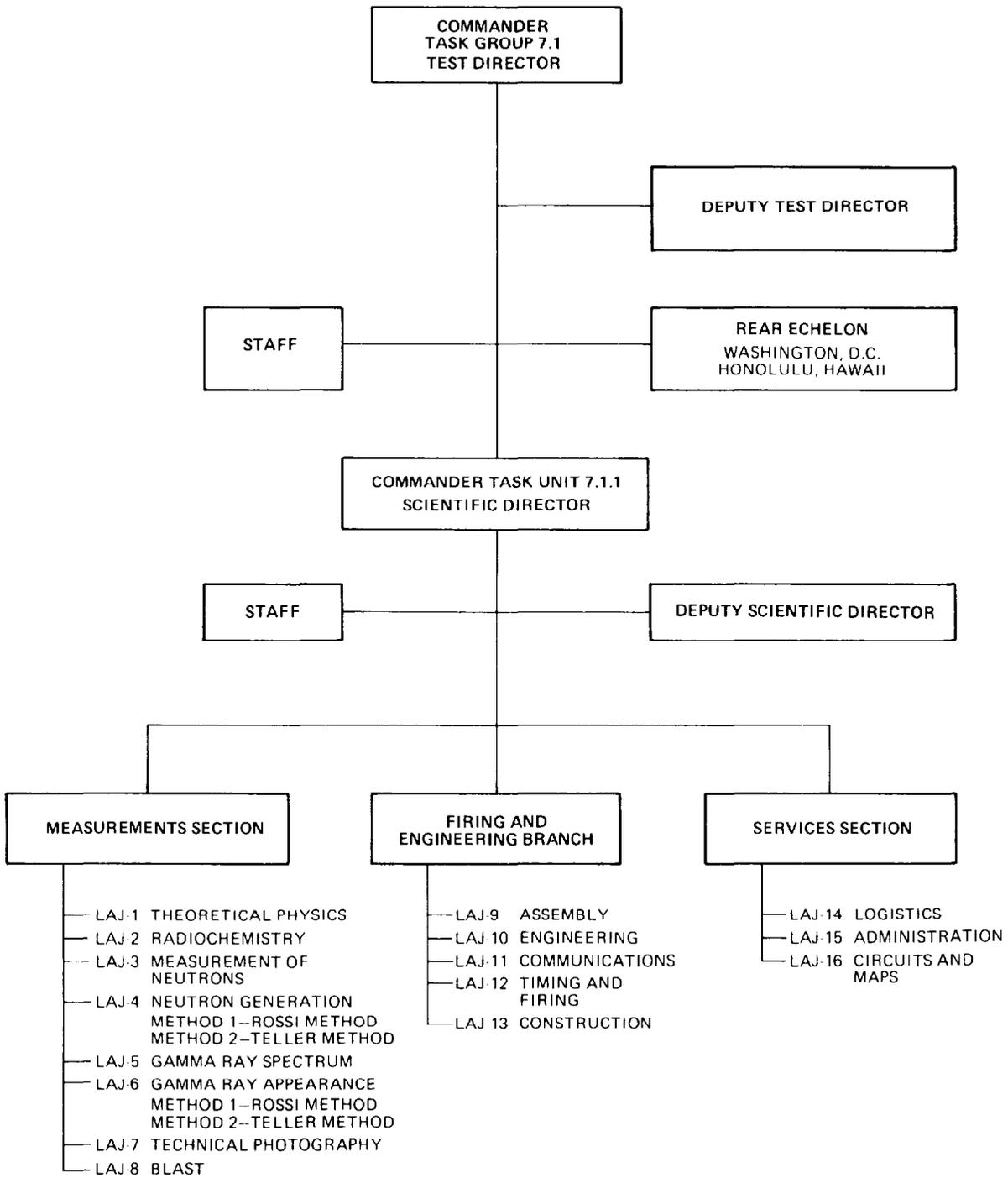


Figure 8. Organization of Task Group 7.1, Operation SANDSTONE.

Table 2. Task Group 7.1 personnel strength, SANDSTONE.

Agency	Number of Personnel
Los Alamos Scientific Laboratory	77
Armed Forces Special Weapons Project	116
Naval Research Laboratory	23
Naval Ordnance Laboratory	20
Argonne National Laboratory	6
Edgerton, Germeshausen & Grier, Inc.	12
Aberdeen Proving Ground, Army	8
Atomic Energy Commission	12
Bureau of Personnel, Department of the Navy	6
David Taylor Model Basin, Navy	2
Military Liaison Committee, Atomic Energy Commission	<u>1</u>
Total	283

Source: Reference C.5, p. 1-24.

LASL personnel was assigned to LASL's newly created J-Division, and personnel from other divisions were also transferred to J-Division (Reference C.5, p. 1-24).

The mission of the scientific task unit was to provide equipment and personnel and to prepare detailed plans for and to conduct the scientific and technical phases of the proof-tests. It fired the devices and made necessary observations. TU 7.1.1 was divided into Measurements Section, Firing and Engineering Branch, and Services Section.

Measurements Section. The responsibilities of this section were divided into four phases: (1) planning experiments, (2) preparing an experiments handbook, (3) consulting with experimenters at Enewetak, and (4) interpreting results of the experiments. The nucleus of the group consisted of three civilians from LASL. This section included J-1 through J-8, which conducted experiments in theoretical physics, radiochemistry, neutron measurements, neutron generation, gamma-ray spectrum, gamma-ray appearance, technical photography, and blast.

Firing and Engineering Branch. An assistant Scientific Director was responsible for the engineering and firing work. He selected a staff of engineers from Sandia Branch of LASL to carry out his duties. This branch was responsible for the following activities:

- Weapon assembly and handling
- Ships' modifications and installations
- Engineering
- Communications liaison
- Firing circuitry liaison
- Construction liaison
- Industrial safety.

Services Section. Services Section included J-14 through J-16 -- Logistics, Administration, and Circuits and Maps. Logistics (J-14) was a service group in charge of procurement, shipping, and property control.

J-15 (Administration) was primarily concerned with personnel matters, including employment of personnel at LASL, preparation of all personnel under the Scientific Director for overseas travel, arrangements for travel to and from the test area, and multiple problems arising from maintaining personnel at the forward base. Other minor responsibilities included provision of office space, equipment and services, housing at LASL, and similar functions overseas.

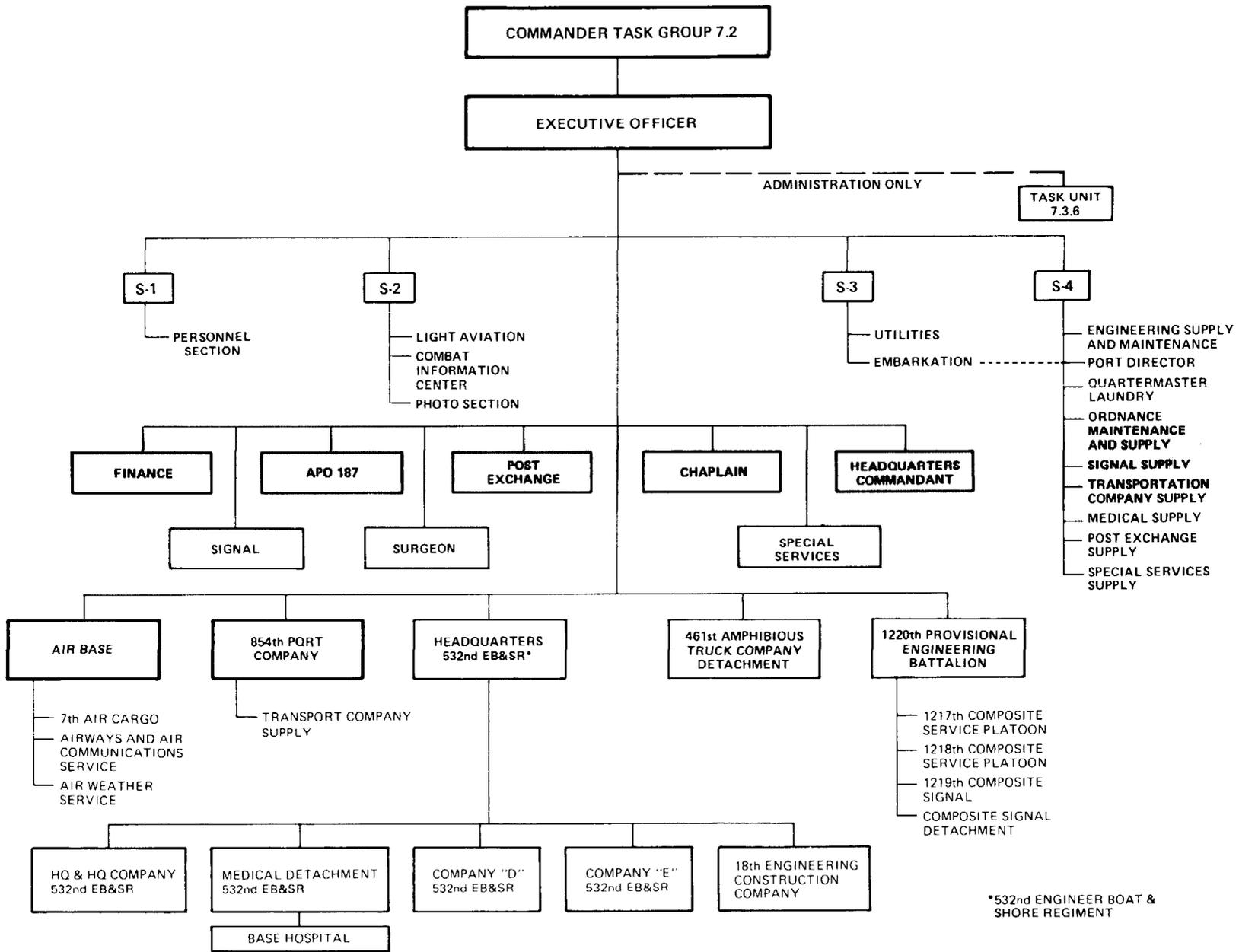
J-16 (Circuits and Maps) was responsible for preparing maps and plans indicating the location of all experimental installations and underground cables and wires. This group was also responsible for coordinating cable-laying during the construction period (Reference C.40, pp. 33, 115, 129).

Task Group 7.2 (Army)

Most Army personnel in JTF 7 were assigned to TG 7.2. The group was activated on 15 October 1947. CTG 7.2 was also Atoll Commander for JTF 7. Figure 9 shows the TG 7.2 organization. Table 3 lists units involved and enumerates the personnel at Enewetak. This task group was engaged in construction throughout the atoll and operated base facilities at Enewetak Island and the atoll.

During the operational shot phase, TG 7.2 personnel provided the following services for all units ashore on the atoll:

- Construction
- Maintenance of ordnance wheeled vehicles
- Atoll ground defense and general security
- Operation of transient billeting
- Bakery and messing
- Repair and maintenance services for utilities and facilities
- Operation and maintenance of off-island radio communications
- Transportation
- Counterintelligence



*532nd ENGINEER BOAT & SHORE REGIMENT

Figure 9. Organization of Task Group 7.2, SANDSTONE.

Table 3. Task Group 7.2 operating strength at Enewetak, SANDSTONE.

Unit	Strength
1220th Provisional Engineer Battalion (1217th, 1218th Composite Service Platoons; Hq & Hq Detachment, 18th Engineer Construction Company; 1219th Signal Service Platoon with attached Composite Signal Detachment)	26 officers 2 warrant officers 468 enlisted men
2nd Engineer Special Brigade (532nd EB&SR, Hq & Hq Company D, Company E, and Medical Detachment)	49 officers 4 warrant officers 566 enlisted men
461st Transportation Amphibious Truck Company	1 officer 26 enlisted men
Hq 854th Transportation Port Company	8 officers 272 enlisted men
Naval Shore Base Detachment, with Navy Signal Team	7 officers 110 enlisted men
Photo Team No. 7	2 officers 4 enlisted men
401st CIC Detachment	2 officers 50 enlisted men
Sources: Personnel Rosters TG 7.2, 31 March 1948; SANDSTONE Reports 3 and 4)	

- Sanitation
- Operation of port and port headquarters
- Special services (recreation) facilities
- Medical and dental services
- Financial services.

Task Group 7.3 (Navy)

The Navy task group provided support at Enewetak Atoll for the scientific programs and carried out surface and air operations in and around the atoll. The main tasks of TG 7.3 were to:

- Deliver nuclear components to Enewetak Atoll
- Provide mobile facilities for devices at the test site
- Conduct surface and air security measures in the Enewetak Danger Area

- Provide intra-atoll water transport
- Plan for evacuation of all personnel from the atoll
- Transport personnel and scientific and naval equipment to and from the atoll
- Provide living accommodations for task group personnel
- Lay cable
- Provide offshore patrol.

In order to carry out these tasks, TG 7.3 was organized into eight functional task units.

Most of the naval vessels stayed at Enewetak during the test series except for the destroyers, which routinely were on surveillance patrols of the area. The flagship, Mount McKinley, was anchored off Parry Island for all three shots. USS Comstock (LSD-19) was the mother ship for the boat pool, which provided water transportation for all task units during SANDSTONE. Most TG 7.3 personnel remained on board ships except for those involved in scientific operations. Table 4 provides the personnel strength for TG 7.3.

Task Group 7.4 (Air Force)

The SANDSTONE TG 7.4 mission was local air transport, cloud sampling, weather data, communications, search and rescue, and photographic support. Specific missions were to:

- Provide and operate aircraft for experimental programs and cloud sampling operations
- Provide and operate aircraft to gather weather data
- Provide and operate weather observation posts at Enewetak, Rongerik, Majuro, Kwajalein, and Wake
- Provide and operate JTF 7 Weather Central on Mount McKinley
- Provide and operate liaison-type aircraft for intra-atoll transportation at Enewetak
- Provide and operate aircraft for search and rescue operations within 300 nmi (556 km) of Enewetak
- Provide photographic coverage of Operation SANDSTONE.

Air Force personnel in SANDSTONE were in many task force organizations in addition to manning TG 7.4. Within Hq JTF 7, there were 55 Air Force personnel, 22 on the JTF 7 staff and 33 working for Commander Air Forces. Commander Air Forces was also a deputy to the task force commander and had his own staff and command authority for TG 7.4. TG 7.4 was organized as shown in Figure 10. Table 5 shows GF 7.4 personnel distributed by task unit.

Providing and operating aircraft in support of SANDSTONE was the primary function of TG 7.4. Table 6 shows types and numbers of aircraft used at SANDSTONE by TG 7.3 and TG 7.4.

Table 4. Task Group 7.3 organization and personnel strength, SANDSTONE.

Task Unit/Designation	Strength
7.3.1 -- Flagship <u>USS Mounl McKinley</u> (AGC-7)	578
7.3.2 -- Main Naval Task Unit, Enewetak	
<u>USS Pickaway</u> (APA-222)	290
<u>USS Warrick</u> (AKA-89)	167
<u>USS Curtiss</u> (AV-4)	555
<u>USS Yancey</u> (AKA-93)	148
<u>USS Albemarle</u> (AV-5)	537
<u>USS LST 45</u>	66
<u>USS LST-219</u>	60
<u>USS LST-611</u>	53
7.3.3 -- Off-Shore Patrol	
<u>USS Gardiners Bay</u> (AVP-39)	273
<u>USS Henry W. Tucker</u> (DDR-875)	233
<u>USS Rogers</u> (DDR-876)	234
<u>USS Perkins</u> (DDR-877)	223
<u>USS Spangler</u> (DE-696)	135
<u>USS George</u> (DE-697)	141
<u>USS Raby</u> (DE-698)	143
<u>USS Marsh</u> (DE-699)	138
<u>USS Currier</u> (DE-700)	136
Patrol Squadron (MS) 6 Detachment	153
Developmental Squadron 4 Detachment	54
AVR #C-26638	6
AVR #C-26653	6
7.3.4 -- Helicopter Unit	
<u>USS Bairoko</u> (CVE-115) with 4 HO3S and 2 HTL helicopters	770
7.3.5 -- Services Unit	
<u>USS Arequipa</u> (AF-31)	76
<u>USS Pasig</u> (AW-3)	164
YOG-64	11
YW-94 ^a	
7.3.6 -- Cable Unit	
LSM-250	61
LSM-378	43
Naval Signal Unit No. 1	54
7.3.7 -- Boat Pool Unit	
<u>USS Comstock</u> (LSD-19)	252
<u>USS Askari</u> (ARL-30)	164
LCI 549	18
LCI(L)-1054	21
LCI(L)-1090	21
LCI-472 ^a	
LCI-494 ^a	
LCI-1194 ^a	
LCI-1345 ^a	
Various small boats: 4 LCTs, 2 AVRs, 28 LCMs, 32 LCVPs, 1 LCPR, 6 LCPLs, 2 PPBs, 2 50-foot MLs, 2 35-foot MBs, 1 MWB.	
7.3.8 -- Evacuation and Reentry Unit	
Units from other task units as assigned	
Total	5,984

Note:

^aNo data available.

Sources: Data from CNO OP 981-TD Aug 82 and Reference C.4, p. XVII-34.

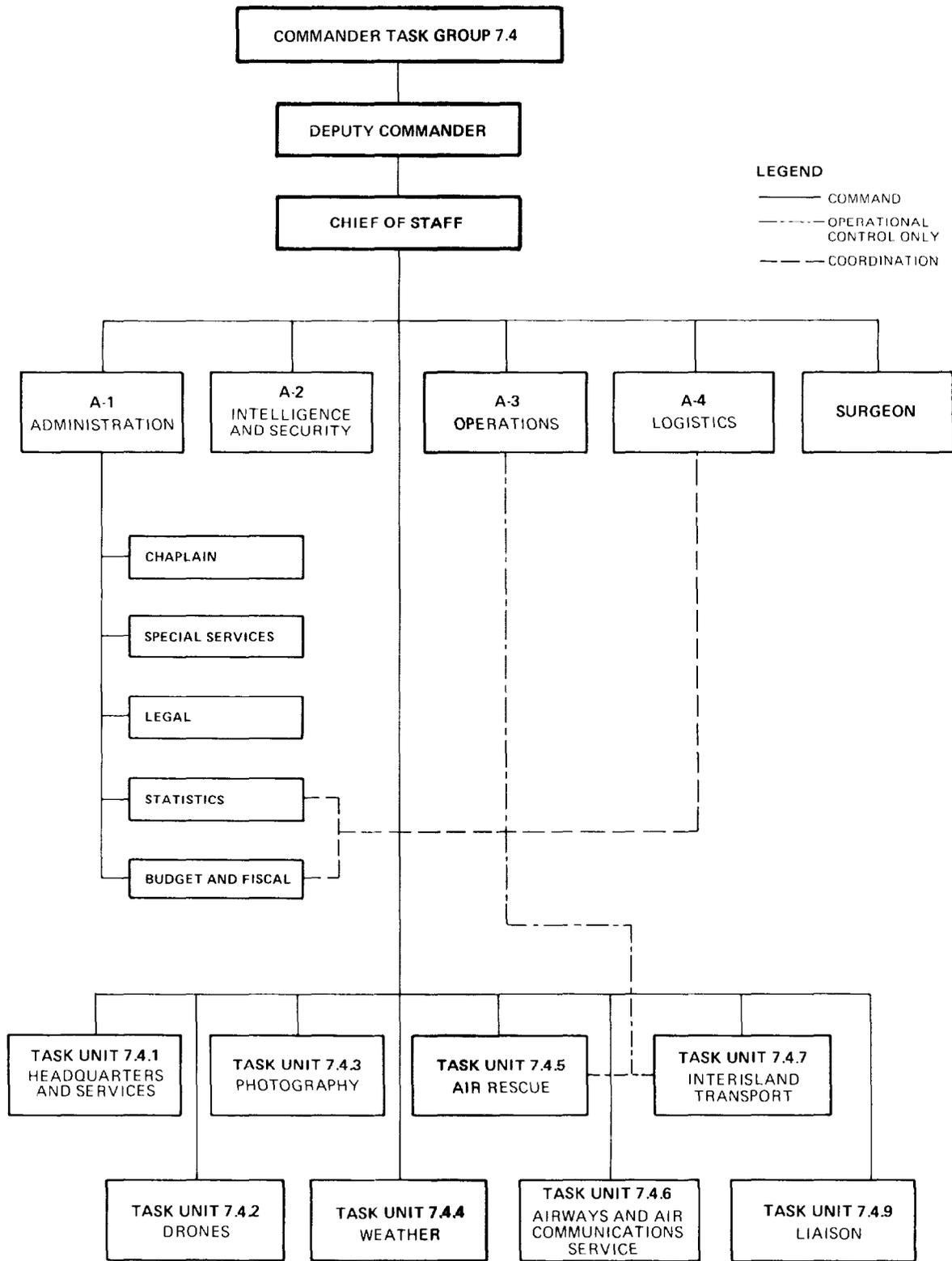


Figure 10. Organization of Task Group 7.4, SANDSTONE.

Table 5. Task Group 7.4 SANDSTONE personnel distribution
(26 January 1948).

Unit	Command	Officers	Airmen	Civilians	Totals
Hq JTF 7	Mixed	17	5	--	22 ^a
Commander Air Forces, JTF 7	SAC	12	10	--	22 ^a
TU 7.4.1	APG	66	518	--	584
TU 7.4.2	APG	105	376	--	481
TU 7.4.3	APG	43	102	19	164
TU 7.4.4	ATC	47	185	--	232
TU 7.4.5	ATC	13	20	--	33
TU 7.4.6	ATC	4	109	--	113
TU 7.4.7	ATC	12	35	--	47
TU 7.4.9	Mixed	2	11	--	13

Notes:

^aU.S. Air Force strength only, does not include other services.

SAC -- Strategic Air Command

APG -- Air Proving Ground

ATC -- Air Transport Command

Source: Reference C.5, p. 3-A-12.

Table 6. SANDSTONE aircraft.

Type	Quantity	Task Unit	Mission
PBM-5	6	7.3.3	Offshore air patrol
PB-1W (B-17G)	3	7.3.3	Offshore air patrol
DB-17G	12	7.4.2	Drone controllers
QB-17G	12	7.4.2	Drone samplers
C-54	2	7.4.3	Photography
F-13 ^a	3	7.4.3	Photography
WB-29	8	7.4.4	Weather reconnaissance
SB-17	2	7.4.5	Search and rescue
OA-10	2	7.4.5	Search and rescue
H03S	4	7.4.5	Search and rescue ^b
HTL	2	7.4.5	Search and rescue ^b
PBM-5	2	7.4.5	Search and rescue ^b
C-54	11	7.4.7	Interatoll transport and sample return
C-47	3	7.4.7	Interatoll transport
L-4	2	7.4.9	Liaison
L-5	11	7.4.9	Liaison

Notes:

^aAn F-13 was a B-29 modified for photography.

^bNavy supplied two PBM seaplanes for search and rescue on shot days only and four H03S and two HTL helicopters. The helicopters were used for scientific support on shot days and for high-priority interisland transportation on nonshot days.

Sources: Reference C.3, pp. VIII-5, 26, 32, 60; Reference C.4, pp. XVII-35).

TASK UNIT 7.4.1 (HEADQUARTERS AND SERVICE UNIT). This unit formed Hq TG 7.4 and provided TG 7.4 aircraft with supply and maintenance support. It also performed most of the base housekeeping services for Air Force units on Kwajalein, where it was stationed.

TASK UNIT 7.4.2 (DRONE UNIT). This unit was made up of 460 men from the 1st Experimental Guided Missiles Group at Eglin Field, Florida. Men from this task unit operated 24 B-17s, 12 of which were drone control aircraft and 12 were unmanned cloud sampling aircraft. Contaminated drones were landed at Enewetak, where the radioactive cloud sample filters were removed by LASL personnel. The

drones were decontaminated at Enewetak and then returned to Kwajalein where the unit was stationed.

TASK UNIT 7.4.3 (PHOTOGRAPHY UNIT). This unit had separate suborganizations to accomplish its diverse missions. Aerial photography was done by the 311th Air Division using C-54s and F-13s. Documentary photography was done by seven teams on various ships and attached to various task groups. Tower photography was done by another team. A film processing laboratory was also set up on board Curtiss. Additional personnel for TU 7.4.3 came from Lookout Mountain Laboratory, LASL, Army, Navy, and Marine Corps.

TASK UNIT 7.4.4 (WEATHER UNIT). This unit was composed of two separate groups that collected weather data. Weather reconnaissance was done by the 514th Weather Reconnaissance Squadron operating eight WB-29s out of Kwajalein. These aircraft were also used to track the radioactive cloud after each shot for up to 5 days. For cloud-tracking operations a monitor from TG 7.6 was aboard each aircraft. Cloud-tracking aircraft always returned with exterior contamination, requiring monitoring and personnel decontamination operations (Reference C.43, p. 91). The second group was the weather reporting portion of the task unit. Two persons were stationed aboard Mount McKinley. One of these was in charge of JTF 7 Weather Central. Weather reports from several other atolls were furnished daily to Weather Central.

TASK UNIT 7.4.5 (AIR RESCUE UNIT). This task unit was made up of personnel of the 5th Air Rescue Squadron from MacDill AFB, Florida, who flew two OA-10 and two SB-17 rescue aircraft. They were stationed at Kwajalein but were at Enewetak on shot days. The Navy provided six helicopters from Bairoko and two PBMs on shot days.

TASK UNIT 7.4.6 (AIRWAYS AND AIR COMMUNICATIONS SERVICE [AACS] UNIT). This unit was responsible for TG 7.4 communications and for airbase navigational aids at Enewetak and Kwajalein. The 71st AACS Group, Hickam Field, Hawaii, provided 27 men; 86 more came from several units in the United States.

TASK UNIT 7.4.7 (INTERISLAND TRANSPORT UNIT). This unit operated 11 C-54 and 3 C-47 aircraft from the Kwajalein Air Base, ferried personnel and equipment to and from Enewetak, and conducted aerial radiological surveys of ground-level radiation at shot sites. The C-54s also flew radioactive cloud samples and exposed film to the United States. This task unit, which consisted of 47 men, also borrowed personnel and aircraft from the 1535th Air Force Base Unit, which was permanently stationed on Kwajalein.

TASK UNIT 7.4.8. This unit was used only to control the movement of TG 7.4 personnel to and from the PPG.

TASK UNIT 7.4.9 (LIAISON UNIT). This unit operated 13 fixed-wing light aircraft and 6 helicopters to transport men and equipment to the various islands of Enewetak Atoll. Thirteen Air Force personnel were assigned to this unit along with Navy pilots who flew the helicopters off Bairoko.

Task Group 7.5 (Joint Security Group)

The missions assigned to TG 7.5 were:

- Travel control (air and water)
- Protection of technical installations
- Security survey of the atoll
- Dissemination of security information
- Establishment and implementation of security clearances in the forward area.

In addition, TG 7.5 personnel guarded the drones when they landed at Enewetak. Five TG 7.5 courier teams escorted the radioactive cloud sample filters and film back to the United States. Approximately 30 AFSWP personnel from the 38th Engineer Battalion were sent to TG 7.5 as special guards (Reference C.5, p. 5-1). On 24 January 1948, two officers and thirty-three enlisted military police arrived to strengthen units on Enjebi, Aomon, Runit, and Parry.

Task Group 7.6 (Joint Radiological Safety Group)

On 29 February 1948, TG 7.6 was divided into the following units for operational purposes (Reference C.35, p. 37):

- TU 7.6.1 Air Monitor Unit (based on Kwajalein)
- TU 7.6.2 Staff Unit
- TU 7.6.3 Operations Unit
- TU 7.6.4 Laboratory Unit
- TU 7.6.5 Radiological Records Unit
- TU 7.6.6 Technical Measurements Unit
- TU 7.6.7 Monitor Unit
- TU 7.6.8 Advisory Unit
- TU 7.6.9 Rear Echelon Unit.

The primary responsibility of the Air Monitor Unit was to ensure the radiological safety of TG 7.4 and also to obtain, compile, and evaluate data likely to be of value to the AEC or DOD. It consisted of 24 Air Force officers (Reference C.35, p. 86).

The Staff Unit administered services such as communications, logistics, historical records, photographic liaison, and athletics. It was also concerned with personnel morale. This unit consisted of six officers and eight enlisted men.

The Operations Unit supported CJTF 7 and CTG 7.6 planning and radSAFE operations. It maintained current information on all radioactive areas and on the location of all monitors and parties engaged in radiological operations. It controlled operations of all radSAFE missions. The unit consisted of seven officers.

The Laboratory Unit performed all laboratory work required to support radSAFE operations including: repair and calibration of instruments; developing, reading, and calibrating personnel film badges; measurement of decay rates of radioactive samples; and determination of the radiation exposure potential from radioactive materials. It also prepared comparative records of instrument performance. The unit consisted of two officers, eight enlisted men, and two civilians.

The Radiological Records Unit calculated exposures of all personnel who entered radioactive areas and submitted its findings. It prepared all necessary reports concerning exposures and overexposures and made recommendations to CTG 7.6. The unit also established a medical review board to consider and comment on all findings of radiological overexposure. It consisted of one officer, one enlisted man, and one civilian.

The Technical Measurements Unit supervised and coordinated all technical measurement projects assigned to TG 7.6. It consisted of five officers, four enlisted men, and two civilians.

The Monitor Unit provided monitors and equipment for all radSAFE missions, including decontamination operations. This unit consisted of nine Army officers, twelve Navy officers, one Public Health Service officer, and four Army enlisted men.

The Advisory Unit acted in an advisory capacity to the task force radSAFE officer on medical and technical matters. It consisted of three civilians.

The Rear Echelon Unit consisted of one officer. He maintained liaison with supporting activities in the continental United States.

TG 7.6 arrived on Enewetak Atoll by 16 March 1948. In addition to its radSAFE duties, TG 7.6 also conducted several experiments, which are described in Chapter 3 (References C.35 and B.6.1).

Task Group 7.7 (Kwajalein Island Command)

A permanent garrison of Army, Navy, and Air Force personnel existed on Kwajalein Island at the time of SANDSTONE. Most of TG 7.4 was stationed on Kwajalein. Commander Navy Base Kwajalein was designated as CTG 7.7 to facilitate integration of Kwajalein into the planning and operation of SANDSTONE. He was responsible for billeting, transportation, sanitation, recreation, medical facilities, and utilities maintenance for all task force units ashore on Kwajalein. He was also responsible for military security and all construction at Kwajalein. TU 7.7.3 was the Joint Control and Liaison Office. TU 7.7.4 was the Aviation Engineer Unit (926th Aviation Engineer Battalion) and did all construction in preparation for TG 7.4.

The Kwajalein Island Command had two Air Force units assigned to assist during SANDSTONE. One, the 1535th Air Force Base Unit, supplied personnel and aircraft for TU 7.4.7. The other was the 31-8 Air Weather Service Detachment, which had 23 men on Kwajalein to support SANDSTONE with air weather information.

Task Group 7.8 (Observer Escort Group)

TG 7.8 was organized to escort official observers and was assisted by personnel and facilities of TG 7.2. TG 7.2 arranged for observers' accommodations, transportation, and activities ashore. Five or six officers of TG 7.2 were assigned to observer parties to provide information (Reference C.3, p. VI, C-8-9).

CHAPTER 2 RADIOLOGICAL SAFETY

Radiological safety (radsafe) for Operation SANDSTONE was defined as a command responsibility in Joint Task Force 7 Field Order 1. One task group, TG 7.6, was given primary responsibility for ensuring the health and safety of the task force in the face of potential exposure to radioactivity (Reference C.43, Appendix B-1). Activities of TG 7.6 had the following objectives (Reference C.43, Appendix B, Annex A):

1. Inform Commander Joint Task Force 7 (CJTF 7) regarding safe employment of personnel in radioactive areas
2. Inform CJTF 7 about radiological hazards that might cause injury or sickness
3. Prepare instructions outlining precautions necessary to protect personnel from radiation exposure
4. Reevaluate the hazards of radioactive areas as radiological work progressed
5. Advise the Task Force Surgeon on diagnosis and treatment of illness or injury resulting from, or associated with, exposure to radioactivity.

The radsafe plan for TG 7.6 was derived primarily from the Joint Task Force Field Orders. It detailed the application of safety criteria during operations and included procedures for training, installing equipment aboard task force ships, monitoring, and decontaminating personnel and equipment.

ORGANIZATION AND RESPONSIBILITIES

Overall organization planning and authority for radiological safety rested with CJTF 7. The commander's staff, specifically the Staff Radiological Safety Officer, was responsible for radsafe planning. The Staff Radiological Safety Officer coordinated radsafe information during shot operations and maintained liaison with the Commander-in-Chief of the Pacific (CINCPAC) regarding radiological contamination outside the Pacific Proving Ground (PPG) (Reference C.43, p. 4). Elements of control existed at all command levels, and operational control was implemented through normal command channels. For example, party leaders in radioactive areas were responsible for the radiological safety of their personnel.

CTG 7.6 exercised control of a functional group composed of Army, Navy, Air Force, U.S. Public Health Service (USPHS), and various civilian personnel. Carrying out the safety policy within a separate activity allowed coordination of effort without impeding the overall operation (Reference C.43, p. 4). CTG 7.6 performed the following tasks (Reference C.43, Appendix B-1):

1. Organization and command of a joint radsafe group composed of radsafe monitors and supporting personnel

2. Support of all operations in radioactive areas by supplying radiological monitors and equipment
3. Promulgation of radsafe regulations and reporting their infractions
4. Detection and determination of the intensity and types of radioactivity encountered in all radioactive areas
5. Organization and supervision of personnel decontamination as necessary.

TG 7.6 was divided into the task units shown in Figure 11. Descriptions of major functions of the task units follow.

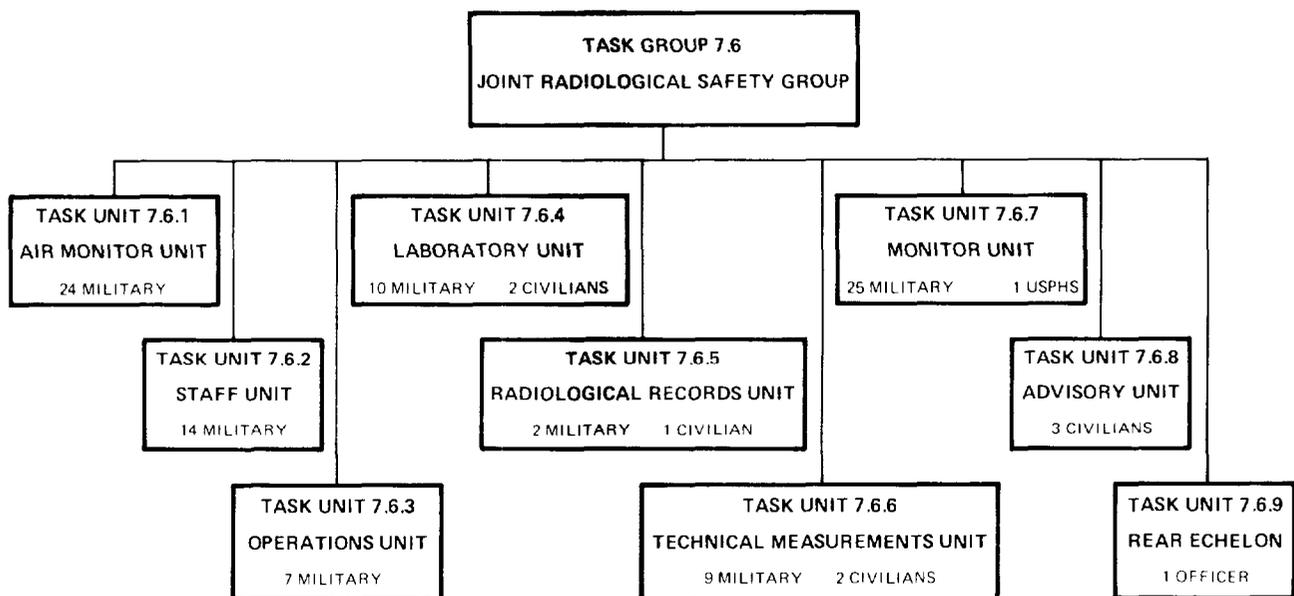


Figure 11. Task Group 7.6 (Joint Radiological Safety Group), Operation SANDSTONE.

Task Unit 7.6.1 (Air Monitoring Unit)

Task Unit (TU) 7.6.1 was composed of 24 Air Force officer monitors. It operated from Kwajalein Atoll, supporting the mission of Commander Air Forces, JTF 7, and had responsibilities for instrument repair, calibration, and photometry (Reference C.43, Appendix B-2).

During the period from 1 November to 15 December 1947, personnel requirements for the radsafe group were estimated at 50 officers, 17 enlisted men, and 5 civilians. Ten officers were air monitors, whose chief duty was to advise airborne crews about radioactive intensities at shot time, indicate paths of least intensity for entry and exit, distribute film badges to aircrews before takeoff, and collect film badges upon completion of the mission (Reference C.43, p. 7). About 22 January 1948, planners realized that the number of air monitors needed had been underestimated. As a result, nine officers of the Medical Service Corps, USAF, were added (Reference C.43, p. 8).

On 17 March personnel from TU 7.6.1 departed for Kwajalein from Enewetak to begin operations with TG 7.4 (Reference C.43, p. 50). Projects undertaken immediately included publication of operational memoranda, assignment of monitors to mission aircraft, indoctrination and ground training of monitors for flying operations, construction of personnel decontamination and instrument calibration facilities, orientation and indoctrination of TG 7.4 personnel, evaluation of instrument performance at high altitudes, photographic documentation, detailed operational planning for shot days, and monitoring indoctrination flights (Reference C.43, pp. 86-87).

A TU 7.6.1 air monitor was aboard each manned aircraft in the test area on shot days to prevent aircraft from entering areas where the radiation intensity exceeded 0.100 R/hr. Radiation detection equipment used by air monitors is listed in Table 7. The unit monitored drone aircraft after landing and engaged in decontamination operations at Enewetak. It also participated in aircraft monitoring and personnel decontamination operations on Kwajalein, including cloud-tracking operations until H+108. TU 7.6.1 personnel also repaired and calibrated instruments, prepared medical exposure records, and compiled mission reports (Reference C.43, pp. 87-88).

Each monitor averaged two training flights with his assigned crew before the X-RAY rehearsal. These practice flights permitted monitors to develop radsafe procedures that minimized interference with the primary mission. Instrument performance data were accumulated and analyzed. As a result of these data, instrumentation procedures were changed for better operations (Reference C.43, p. 88).

By the day of the X-RAY rehearsal, the unit had mapped out radsafe procedures aboard aircraft, completed operational plans for test days, and was plotting radiological exclusion (radex) areas daily. In addition, the personnel decontamination center at Kwajalein for TG 7.4 and TG 7.6 was being readied for operation. TU 7.6.1 also indoctrinated TG 7.4 personnel (Reference C.43, pp. 88-89).

The radiological procedure aboard aircraft during the X-RAY rehearsal and X-RAY test consisted of the following (Reference C.43, p. 90):

- At H-30 minutes instruments were turned on
- At H-5 minutes cabin heaters were shut off and all crewmembers turned on 100 percent oxygen
- At H-10 seconds all crewmembers adjusted high-density goggles
- After detonation, goggles were removed to observe burst phenomena and monitor instruments
- After leaving the area the interior of aircraft was monitored
- Upon landing the crew and the aircraft exterior were monitored.

Table 7. Radiological safety equipment distribution, SANDSTONE.

Group	Equipment	Monitor	Party Member
Scientific Group	Film badge	X	X
	Dosimeters	X	X
	Protective clothing	X	X
	Gas masks ^a	X	X
Air Group	Ion-chamber survey instrument	X	
	Geiger-Mueller counter	X	
	1 or 2 proteximeters	X	
	1 pocket dosimeter (0.2 R)	X	
	1 or 2 high-range dosimeter(s) (10 R or 50 R)	X	
	1 casualty film badge	X	
	Film badge	X	X
Disaster Group	Casualty film badge	X	
	Film badge	X	
	Pocket dosimeter (0.2 R)	X	
	Pocket dosimeter (10 R)	X	
	Pocket dosimeter (50 R)	X	
	Gas mask, hood	X	
	High-range ion survey meter	X	
	Alpha meter	X	
Zero Day Ashore Group	Film badges	X	X
	0.2 R pocket dosimeter	X	X
	10 R pocket dosimeter ^a	X	X
	Casualty film badge ^a	X	X
Enewetak, Parry, Ujelang	Geiger-Mueller counter	X	
	Ion chamber instrument	X	
	0.2 R pocket dosimeter	X	
	Film badges ^b	X	X

Notes:

^aUrgent work. The casualty film badges originally were planned to contain high-range film (above 10 R), but there is no evidence that they were used. The high-range film may have been incorporated in the normal film badge.

^bParry and Enewetak personnel only.

Source: Reference C.43, Annex J-3 to Field Order 1.

Task Unit 7.6.2 (Staff Unit)

The Staff Unit of TG 7.6 was established by Special Order Number 2 to administer services to the task group. The kinds of services ranged from communications to athletic programs (Reference C.43, p. Appendix B-2). Six officers and eight enlisted men were assigned to this task unit on 29 February 1948 (Reference C.43, Appendix B, Annex I, Part II-1).

Task Unit 7.6.3 (Operations Unit)

The Operations Unit, composed of seven officers, supported CJTF 7 and CTG 7.6 planning and radsafe operations. It maintained current information on location of all monitors and parties engaged in radiological operations. It also maintained current information on all radioactive areas and controlled operations of all radsafe missions (Reference C.43, p. Appendix B-2). The plotting room located on the flag bridge of USS Mount McKinley (AGC-7) was used and maintained only for shot days unless otherwise directed by the JTF 7 Radsafe Officer. Data were recorded on a chart of the atoll and on detailed maps of each island involved in the test. The unit also maintained current air and surface radex area information. The Radsafe Center on Mount McKinley furnished systematic information to the plotting room and the JTF 7 Radsafe Officer. The Radsafe Center communicated directly with monitors in the field on test days.

Task Unit 7.6.4 (Laboratory Unit)

TU 7.6.4, established by Special Order 2, was composed of two civilians, two officers, and eight enlisted men (Reference C.43, Appendix B, Annex I, Part II-2). This unit performed all laboratory work required to support radsafe operations, including repair and calibration of instruments; development, reading, and calibration of personnel film badges; and measurements of the decay rates of radioactive samples (Reference C.43, Appendix B-2). Laboratories were established on Enewetak (specifically for crater sample recovery) and aboard USS Bairoko (CVE-115). These laboratories plotted isointensity lines (or contours) and monitored biological samples (Reference C.43, p. 60). All samples were brought to the instrument issue area, never directly to the laboratory (Reference C.43, Appendix B, Annex C-1&2).

TU 7.6.4 was responsible for maintaining an adequate stock of health physics survey instruments; for the repair, servicing, and calibration of the instruments; and for an evaluation of the various types of health physics survey instruments. It processed and read the photographic personnel film badges. Laboratory facilities were also made available to TU 7.6.6 (Technical Measurements Unit) for any measurements necessary in connection with its projects (Reference C.43, Appendix B, Annex C-1).

The Laboratory Unit maintained a stock of calibrated ionization chamber and Geiger-Mueller (GM) survey instruments and pocket dosimeters in the after ready room of Bairoko for reentry surveys. Instruments were issued on the hangar deck of Bairoko upon recommendation of the Operations Officer and were returned there after use. Photographic film badges were issued to each party in sufficient numbers to badge all members. Instruments were checked for contamination (Reference C.43, Appendix B, Annex C). Film badges and pocket dosimeters were returned to the issue room where they were processed, read, and recorded on forms supplied by the Radiological Records Unit. Records were kept on repair and replacement of each survey instrument. In addition, a series of tests was conducted on the various instruments, and the monitors were surveyed to evaluate instrument design features.

Task Unit 7.6.5 (Radiological Records Unit)

This unit was composed of a civilian, an officer, and an enlisted man (Reference C.43, Special Order 2). TU 7.6.5 calculated and recorded the exposures for all personnel who entered radioactive areas and prepared regular exposure reports as well as special reports of any overexposures. The Radiological Record Unit's Medical Review Board considered and commented on all overexposures (Reference C.43, Appendix B-2). All pocket dosimeters and film badges were read and the results recorded when work in radioactive areas was completed. CTG 7.6 sent the results to CJTF 7, with copies to the Test Director and Scientific Director. The report gave the names of all individuals receiving exposures exceeding 0.1 R on any day of operations and indicated total accumulated radiation received by the individuals to date (Reference C.43, Appendix B, Annex A).

Task Unit 7.6.6 (Technical Measurements Unit)

The Technical Measurements Unit was composed of 11 men, including civilians and military. The unit supervised all technical measurement projects assigned to CTG 7.6 (Reference C.43, Appendix B-2). Projects were suggested by the Armed Forces Special Weapons Project (AFSWP), Navy Bureau of Medicine and Surgery (BuMed), Navy Bureau of Ships (BuShips), Navy Bureau of Aeronautics, and Army Chemical Corps. These projects, discussed further in Chapter 3, involved studies of nuclear and optical radiation effects of nuclear detonations (Reference C.43, Appendix B, p. G-1-2).

Task Unit 7.6.7 (Monitor Unit)

The monitor unit, composed of 26 officers, provided monitors and equipment for all radsafe missions. It also decontaminated personnel as necessary.

Because of the number of operations using monitors and the necessity for locating each member of TG 7.6, a detailed operation schedule for each day throughout the test periods was prepared. Each radsafe party was given a number, its time of movement noted, monitors' names given, type of transportation cited, and a brief summary of the specific mission stated. Mission priority was also designated as routine or urgent. A rough draft of the schedule was thoroughly studied, and shortly before X-RAY it was mimeographed in final form and distributed to all personnel concerned. Beginning 2 days after X-RAY (X-RAY D+2), a schedule was published each night for the following day. A new, abbreviated schedule gave the radsafe party number, a brief description of the mission, names of the monitors, type and number of instruments involved, number of film badges provided, and times of issue and departure. Monitor assignments were regulated in accordance with previous exposure (Reference C.43, pp. 56-56a).

The basic plans for YOKE and ZEBRA operations followed the same pattern as X-RAY. Radsafe activities were a repetition of those of X-RAY. Whenever possible, however, personnel were reassigned from one group to another, so broad experience in various aspects of radiological safety could be gained (Reference C.43, pp. 62, 64).

Task Unit 7.6.8 (Advisory Unit)

This unit was established by Special Order 2 to advise the task force Radsafe Officer on medical and technical matters. TU 7.6.8 was staffed by three civilians (Reference C.43, Appendixes B-1 and B-2).

Task Unit 7.6.9 (Rear Echelon Unit)

The Rear Echelon Unit maintained liaison with supporting activities in the United States. It was established by Special Order 2 (Reference C.43, Appendix B-2) and consisted of one officer based in Washington, D.C., who was affiliated with AFSWP (Reference C.43, Appendix B, Annex I, Part II-3).

TRAINING

Considerable staffing problems had to be resolved before assembling the necessary TG 7.6 "primary duty" technicians, most of whom were military personnel affiliated with AFSWP or the Atomic Energy Commission (AEC) and were graduates of the radsafe schools at Treasure Island (Navy) and Edgewood Arsenal (Army) (Reference C.43, p. 5).

Before CROSSROADS, a special JTF 1 Radiological Safety School was established by the Navy. One of the lessons learned by the Navy from CROSSROADS was that a full radiological safety program was required. Accordingly, in October 1946, the Chief of Naval Operations directed that such a program be established with the least practicable delay (Reference B.3.0.1). The Bureau of Naval Personnel Special Committee outlined the goals of a radsafe training program on 3 December 1946. The basic premises (Reference B.3.0.2) in instituting the Navy's training program were:

1. Navy damage control procedures should be able to handle multiple effects of atomic bombs
2. Shore establishments were the most important target of an atomic attack
3. The Navy's radsafe training program should supplement courses given at the damage control schools
4. Personnel should be trained at several levels of qualification
5. Instruments for the classes should be provided through a BuShips development program
6. The primary source of basic radiological information should come from the Radiological Safety Manual Project of the Joint CROSSROADS Committee.

Among the training programs were a nuclear physics correspondence course (functioning by 20 December 1946 at New York, New Orleans, San Francisco, and Great Lakes naval installations); the Radiological Safety Officer and Meter Operator Training Program (a 6-week course at the damage control schools to qualify radiological safety officers); the Radiological Safety Engineer Training Program (being formulated at the U.S. Navy Postgraduate School from the Postgraduate Physics-Electronics-Radar Group for a limited number of officers);

and the radiological safety courses at damage control schools (Reference B.3.0.2).

Of these five, the last was among the most important. Two courses were set up to cover radiological safety at damage control schools in Philadelphia, Pennsylvania, and Treasure Island, California. Instructors selected had thorough knowledge of physics, radiological decontamination, and had instructional experience. In instructing radiological meter operators, at least one ensign or lieutenant, three chief petty officers and one electronics technician were assigned per fifty students (Reference B.3.0.2).

Of the two damage control schools, the one at Treasure Island was perceived as better suited for setting up a radiological safety course, partially because the nearby Hunters Point and Mare Island Naval Shipyards had been used in the decontamination work following CROSSROADS. Furthermore, use of radiological experts from the University of California at Berkeley could be arranged. All instructors participating in the Philadelphia Radsafe Training School assisted in establishing the first courses at Treasure Island. This ensured that the courses at Philadelphia would be similar.

The target date for the opening of the radsafe course was established as 1 March. All instructors were to be present at the Treasure Island Damage Control School on 1 February to prepare all of its officers and instructors and to have all instructional materials on hand before the opening date (Reference B.3.0.2).

The Radiological Safety School actually opened on 17 March 1947 with 40 officers (24 Navy and Marine Corps, 15 Army, and 1 USPHS). The most serious problem associated with the first class in the radsafe training program was in the selection of attendees. After the first day, it was apparent that many students were unable to handle even rudimentary mathematical concepts. A voluntary, supplementary course designed to facilitate mathematics training did not completely eliminate the problem. Significantly, fifteen people, more than one-third of the class, regularly attended the extra sessions. As a result of the lack of mathematically sophisticated students, restriction of future classes to individuals who had the equivalent of Naval Academy training, or at least to those who had had at least one college course in science or mathematics, was recommended (Reference B.3.0.3).

The Army implemented a similar program. The Joint Radiological Safety Training Committee authorized the program. The committee (Reference B.2) determined the:

1. Types of radsafe billets required by the armed services
2. Types and ranks or rates of personnel required to fill the billets
3. Types of training required to fill each billet and approximate length of training periods
4. Types and numbers of instructors required per hundred students and their availability

5. Training organization required and recommended relationship between such an organization and the War and Navy Departments and the Joint Chiefs of Staff (JCS).

Edgewood Arsenal was a desirable location to provide radsafe training on the East Coast, and the Chemical Corps recommended beginning the first class about 8 September 1947. AFSWP determined student qualifications, curricula, length and nature of courses, and types, numbers and availability of instructors (Reference B.2).

Criteria were established to ensure the quality of instruction. Six weeks appeared to be the optimum training period. If the course were extended to eight weeks, as had been suggested, augmenting the material presented or decreasing the tempo of presentation would be required. Additionally, further increase in material would have required the students to have greater mathematical knowledge.

A joint indoctrination lecture-syllabus was prepared and offered to the schools for inclusion in their curricula. The Joint Radiological Safety Training Committee recommended that it be closely coordinated with indoctrination lectures, primarily on radiological safety, plus movies and one demonstration (Reference B.6.2).

The proposed radsafe indoctrination course (Reference B.6.2, Encl. A) given in the schools was to include the following material:

- Security lecture using the Army, Navy Screen Magazine #86 "What is Radsafe?"
- Atomic energy film/types of radiation lecture
- CROSSROADS film/atomic bomb explosion phenomena lecture
- Biological effects lecture (blast and radiation)
- Instruments lecture/demonstration
- Radsafe film/decontamination lecture
- Organization and training lecture
- Tactical and strategic implications lecture.

On 29 February 1948 Bairoko departed Long Beach, California, with TG 7.6 embarked, for Pearl Harbor and Enewetak. On the day of embarkation, further indoctrination of TG 7.6 personnel began. CTG 7.6 gave two orientation lectures in which all aspects of the mission were covered. Immediately upon sailing for Pearl Harbor, detailed operational planning and a comprehensive study of expected problems began (Reference C.43, p. 35, 36).

The School Director at the Radiological Safety School, Treasure Island, California, had been designated the School Officer for TG 7.6. He outlined a schedule of classes to be conducted en route to the test site. These classes began on 1 March and were conducted daily. In addition to scheduled lectures, a daily afternoon period was established for calibration of the various instruments used in monitoring operations (Reference C.43, p. 39). Figure 12 shows



Figure 12. Monitors calibrating Victoreen Model 247A instruments on board USS Bairoko (CVE-115) before SANDSTONE as the instructor observes.

monitors calibrating Victoreen Model 247A instruments on the Bairoko deck as the instructor observes.

Physical conditioning was deemed advisable, particularly for monitors, who would be involved in strenuous operational activities. Accordingly, a period of physical training was scheduled each afternoon (Reference C.43, p. 39).

SAFETY CRITERIA

Radsafe criteria in general followed the standards set forth by the National Committee on Radiation Protection: 0.1 R per day; 0.5 R per week. Operational rules for radiological situations were disseminated throughout JTF 7 as Annex J to JTF 7 Field Order 1.

Radiation Safety Standards

The permissible radiological exposure was established at 0.1 R per 24-hour period. In the event that anyone exceeded 3 R (total), he would be denied access to radioactive areas for 30 days and was not to be further exposed unless specifically cleared by CJTF 7 on advice from the Radsafe Officer.

All individuals scheduled to enter radioactive areas or to work with radioactive materials received a complete physical examination, including chest X-ray, blood count, and urinalysis, before leaving the United States.

Radiation Exposure Waivers

Absolute adherence to the radiological standards prescribed for routine laboratory or industrial use was recognized as unrealistic for the special conditions of a field test (Reference C.43, Appendix B, Annex A). A definition of overexposure, standard operating procedures for exposures, and rest periods required after overexposures were established by the JTF 7 Staff Radsafe Officer and TG 7.6 staff. The basic formula of 0.1 R per 24-hour period was set as the maximum, except for certain specific missions where exposures of 3 R were permitted. All missions involving 3 R exposure were to be approved by the Test Scientific Director and the Staff Radsafe Officer. No exposure over 3 R would be permitted unless approved by CJTF 7 (Reference C.43, p. 9).

Radiation exposure records were maintained by the Radiological Records Unit (TU 7.6.5). TG 7.6 and the task force Medical Officer exchanged medical data required for evaluating an individual's radiation health record.

The Medical Review Board considered an individual's medical file, his group exposure record, and his radiation exposure record and rendered decisions on his availability for future work in radioactive areas. An individual was reported to the board if he received over 0.1 R per 24-hour period or approached the authorized limit of 3 R. Personnel receiving 3 R had the data included on their medical charts, along with the expected date they could resume activity in a radioactive area. The board also maintained records on any instrument suspected of giving an erroneous reading and evidence of such was entered on a group exposure record for future evaluation as well as for medical-legal purposes (Reference C.43, Appendix B, Annex H).

Radiation Exposure Records

In recording exposures, JTF 7 used a definition of "overexposure" that requires a note of explanation. Exposures of 0.1 R or less per day were not considered overexposures. Exposures greater than 0.1 R/day were considered overexposures, and if a man's cumulated total reached 3.0 R he was withdrawn from activity that would involve the possibility of additional exposure for a period of 30 days. This overexposure cumulation, however, could be lessened by 0.1 R for each day the man received no exposure. For example, if an individual received 0.1 R per day for four days, his overexposure was zero. If on the fifth day he received 2.4 R, his overexposure was 2.3 R. If on the sixth day his exposure was 0.8 R, his overexposure for that day was 0.7 R. The 0.7 R was added to the 2.3 R of day five for a total overexposure of 3 R, the prescribed limit for overexposure, and he was not permitted any activities involving the potential presence of radioactivity for 30 days to allow him to recover from his overexposure at a rate of 0.1 R per day. Had he only received 0.2 R on the sixth day instead of 0.8 R, his overexposure would have been 0.1 R for that day, which would have been added to the fifth day's reading of 2.3 R for an exposure total of 2.4 R. If he then received no radiation exposure for 5 days, his total overexposure would then drop to 1.9 R on the basis of a recovery factor of 0.1 R per day. If however, he received 0.1 R each day, the total overexposure would remain 2.4 R until the day of no overexposure. This overexposure total was kept on a radiation exposure record (Reference C.43, Appendix B, Annex H).

Group Exposure Record

The group exposure record included names of all individuals assigned to each work party, the organization to which they belonged, the general nature of the mission, and the times of departure and return. The monitor collected film badges and other instruments and entered film badge and pocket dosimeter numbers issued for each man on the form. He also entered pocket dosimeter readings opposite the man's name after the mission. If any members of the party required decontamination or if any unusual event relating to safety occurred, the monitor entered the remarks on the group exposure record. He also entered any appropriate remarks concerning the instruments. He returned the form to the instrument issue desk immediately upon return to Bairoko. The record was then sent to the Radiological Records Unit (TU 7.6.5) for entry of the film badge readings. This unit dispatched the completed record to the Medical Review Board if an overexposure was indicated. When the review was completed, the group exposure record was returned to TU 7.6.5. After exposures were transcribed from the group exposure record, the record was then filed (Reference C.43, Appendix B, Annex H).

RADIOLOGICAL SAFETY INSTRUMENTATION

The major radsafe instruments were the 247-A ion chamber and the 263-A Geiger-Mueller (GM) instruments manufactured by Victoreen Instrument Company. On 22 September 1947, a group of radsafe specialists recommended to the JTF 7 radsafe advisors that the following instruments be procured: 150 GM counters (from a variety of manufacturers), 100 ion-chamber survey instruments, 600 direct-reading dosimeters (pocket electrometers), and 900 direct-reading dosimeters (vacuum-tube integration) (Reference C.43, p. 10-11). Table 7 lists radsafe equipment for all task force groups expected to be exposed to radiation.

The quantities of survey instruments recommended included allowances for only six aircraft. If more aircraft were to be involved it was recommended that the following quantities and types of instruments be procured for each aircraft: one ion-chamber survey meter, two GM survey meters, and one proteximeter (Reference C.43, p. 13). During the test series, each air group monitor was furnished with an ion-chamber survey instrument, one GM counter, one or two proteximeters, one 0.2 R pocket dosimeter, one or two high-range pocket dosimeters (10 R or 50 R), and one casualty badge (a film badge capable of registering high- or casualty-range exposures) (Reference C.43, Appendix B, Annex B-2).

In addition to recommendations made by the instruments committee, others suggested the addition of 40 alpha-measuring instruments, 20 additional (unmodified) Rauland-Zeus Alpha-Beta-Gamma meters, and 20 AEC-designed Pluto meters (Reference C.43, p. 13). AEC was responsible for procuring the radsafe instruments and spare parts (Reference C.43, p. 13).

Among the instruments available for the technical measurements portion were film badges, crystal dosimeters, activation samples, filter collection units, rate-meters, and recorders (Reference C.43, Appendix B, Annex G).

The three manufacturers of gamma-recording pocket dosimeters, (Beckman, Cambridge, and Kelly-Koett) all designed rather rugged instruments. They included the following models: Kelly-Koett Models K-100, K-150, K-160; Cambridge (no model number, AEC catalog number PIC-9A); and Beckman Model MX-7 (AEC catalog numbers PIC-11A and PIC-12A) (Reference C.43).

An AN/PDR-1 (X-1) was sent by Admiral Electronics and Raytheon for SANDSTONE. This experimental model differed from the AN/PDR-1 contracted for by the Navy (OP-36) later in the year. By 3 November 1948 the AN/PDR-1 was identical to the AN/PDR-8 except for power supply (Reference B.3.0.4).

All instrument calibration presumably utilized radium sources (Reference C.43, p. 39). The radium standards procured from BuShips were 25-, 50-, 100-, and 250-mg sources in containers of 0.5 mm of platinum or its equivalent (Reference C.43, Appendix A-4).

PERSONNEL FILM BADGES AND RECORDS

On 5 November 1947, a memorandum was issued stating that 10,000 film badges with a range of 0 to 10 R were to be supplied by Eastman Kodak Company (Reference C.43, p. 15). These were to be of two types -- Type A and Type K, the latter distinguished by a lead cross-shield.

On 3 March, the first calibration of personnel film badges was run, using a 48.7-mg radium source. A second calibration was completed on 6 March. The films were then developed and read on a Western densitometer, model number 877 (Reference C.43, p. 46). Several men from TG 7.6 received low exposures during the eight instrument calibration sessions. Many of these exposures were detected only on the direct-reading dosimeters and not by film badges. The exposures recorded by the film badges were typically 0.005 R for each calibration session, although at one session a badge recorded 0.040 R (Reference E.1). These readings are typical for detection instrument calibration laboratories and were largely derived from removing the radium sources from their shields and placing them in calibration position. The readings were recorded in a Kardex file for radiological records. This served as a dry run of the record system. (Reference C.43, p. 45).

Only men who were expected to be exposed to radioactivity were badged. Before leaving for a potentially radioactive mission, all personnel were checked against the control list by a monitor and issued appropriate equipment, including film badges, pocket dosimeters, and any necessary protective clothing. After the radioactivity on the shot islands had decayed for several days, the issue of the badges and equipment was handled at a checkpoint manned by TU 7.6 personnel on the shot island. An example of the task force's perception of the expectation of exposure to these personnel may be found in the instructions. In the 24 April (X-RAY D+9) instructions for the checkpoint on Enjebi, the monitors are instructed to issue badges to anyone expected to come closer than 550 yards (503 meters) to the surface zero. The instructions for the following 2 days use the same distance as a criterion. (Reference C.43, Monitor Instructions, pp. 26-28). When work was completed in the radioactive area, all film badges and pocket dosimeters were returned to the monitor (Reference C.43, Appendix B, Annex A-3).

One film badge was furnished for each aircraft crewmember. Film badges and pocket dosimeter readings were returned by air from Kwajalein to Bairoko (Reference C.43, Appendix B, Annex B-2).

At first, film badges were apparently processed and read in order of receipt. On X-RAY day, for example, film badges and monitor cards began to come in at 1200. By 2300, 250 had been received. All film badges were processed and overexposures reported to CJTF 7 the next day (Reference C.43, p. 84). Beginning on the night of X-RAY D+2, the system of film processing was accelerated by segregating all darkened badges and reading them first. This allowed completion of the overexposure report by midnight of X-RAY D+2. This procedure was continued throughout the series (Reference C.43, p. 84).

On YOKE D+4, permission was obtained from CJTF 7 to change the method of submitting overexposure reports. Up to that time, all individual exposures exceeding 0.1 R/day had been reported daily. Thereafter, no individual was reported by dispatch unless he received more than 0.3 R in 3 days (Reference C.43, p. 84).

Procedures used throughout the first two tests were continued for ZEBRA. On ZEBRA D+1, a dispatch was received by CJTF 7 concerning entries on the physical records of all Navy and Marine Corps personnel. A conference of medical officers and CTG 7.6 devised a report form that would supply all task group commanders with the necessary exposure data (Reference C.43, p. 85).

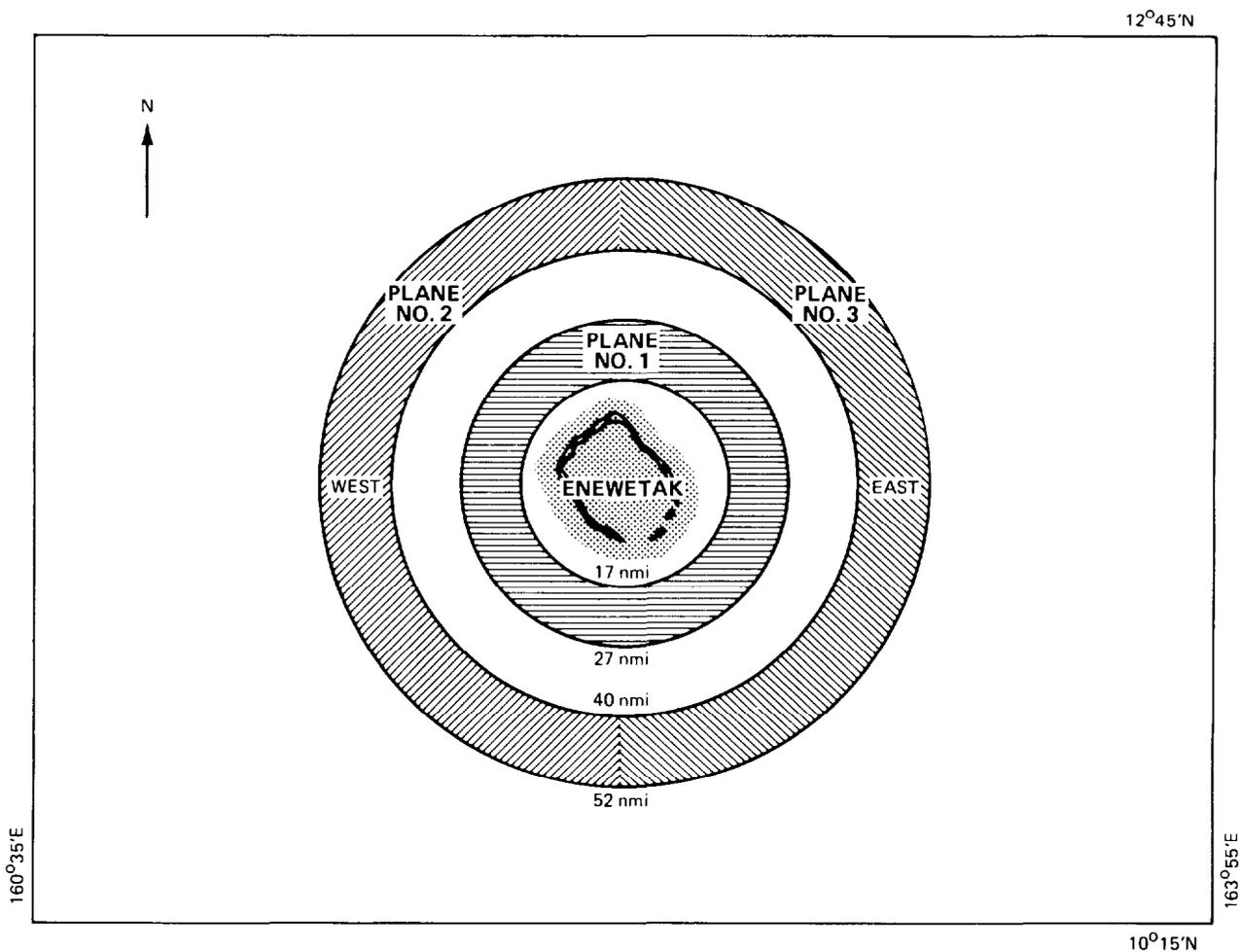
A Kardex file system was set up to maintain individual records. On X-RAY D+5, the Kardex file was rechecked and all overexposures were recorded. The final information on overexposure was submitted on X-RAY D+13 in the postshot report (Reference C.43, p. 84). The records created in this file consist of 3- by 5-inch preprinted cards, noted as a JTF 7 form and labeled "Individual Exposure Record." The cards had the man's name entered as well as the date(s) of badge issue, the exposure(s) (in milliroentgens) from the badge(s), and usually the exposure recorded from a pocket dosimeter. A column was reserved for entering the calculated overexposure. This file of cards, along with film badge log sheets, is the basic dosimetric record for SANDSTONE personnel exposure (References A.3 and E.1).

After ZEBRA, CJTF 7 recommended that the radiological medical records with medical-legal supporting data be delivered to the Test Director for incorporation in AEC records on D+25 (Reference C.43, Field Order 2). Copies of the records of all military personnel were forwarded to AFSWP for distribution among the armed services (Reference C.43, p. 52).

PRE-EVENT SAFETY MEASURES

Danger Area

On 30 December 1947, the AEC issued a press release announcing that from 31 January 1948 through 31 December 1948, a Danger Area would exist around Enewetak Atoll as a result of the planned weapon tests. The Danger Area was defined as laying between 10°15'N and 12°45'N and between 160°35'E and 163°55'E (see Figure 13). This notice was also published through routine air and maritime channels (Reference C.5, p. 1-A6). Entry into the Danger Area was not prohibited, although Enewetak itself was a Closed Area.



- Plan A. One plane patrols inner ring (between 17 and 27 nmi) (32 and 50 km) in a six-leg (hexagonal) flight path with total circuit length of 132 nmi (245 km).
- Plan B. Two planes: one flies Plan A, and a second patrols outer ring (between 40 and 52 nmi) (74 and 96 km) in a six-leg (hexagonal) flight path with total circuit length of 276 nmi (456 km).
- Plan C. Three planes: one flies Plan A, Plane 2 patrols western half of outer ring, and Plane 3 patrols eastern half.

Figure 13. Air patrol plans A, B, and C, Operation SANDSTONE

The Danger Area was patrolled both with surface ships and aircraft under TG 7.3. The surface patrol worked outside of Enewetak Lagoon. TG 7.3 maintained a plot of individuals, vessels, and aircraft authorized to operate in the Closed Area and the Danger Area.

The Air Patrol Unit (TU 7.3.3) flew a variety of search patterns in the Danger Area. It was composed of Navy Medium Seaplane Patrol Squadron 6 (VP[MS]-6) and Navy Air Development Squadron 4 (VX-4) (Reference B.3.2).

To prevent inadvertent contamination or unauthorized surveillance, the greatest attention was paid to the area 40 nmi (74 km) offshore from Enewetak Atoll, particularly to the north and east. During patrols, all vessels discovered within the Danger Area were identified and warned to leave immediately. Immediate reports of all such incidents were made to Hq JTF 7. Contact surveillance of any vessel in the area was maintained until further instructions were received. CTG 7.3 had to be prepared to use the maximum patrol force patrol during the period H-48 and H+24 (patrol plan F) (Reference B.3.1, Annex A-2).

Figures 13 to 16 show the proposed methods of patrolling the Closed and Danger Areas.

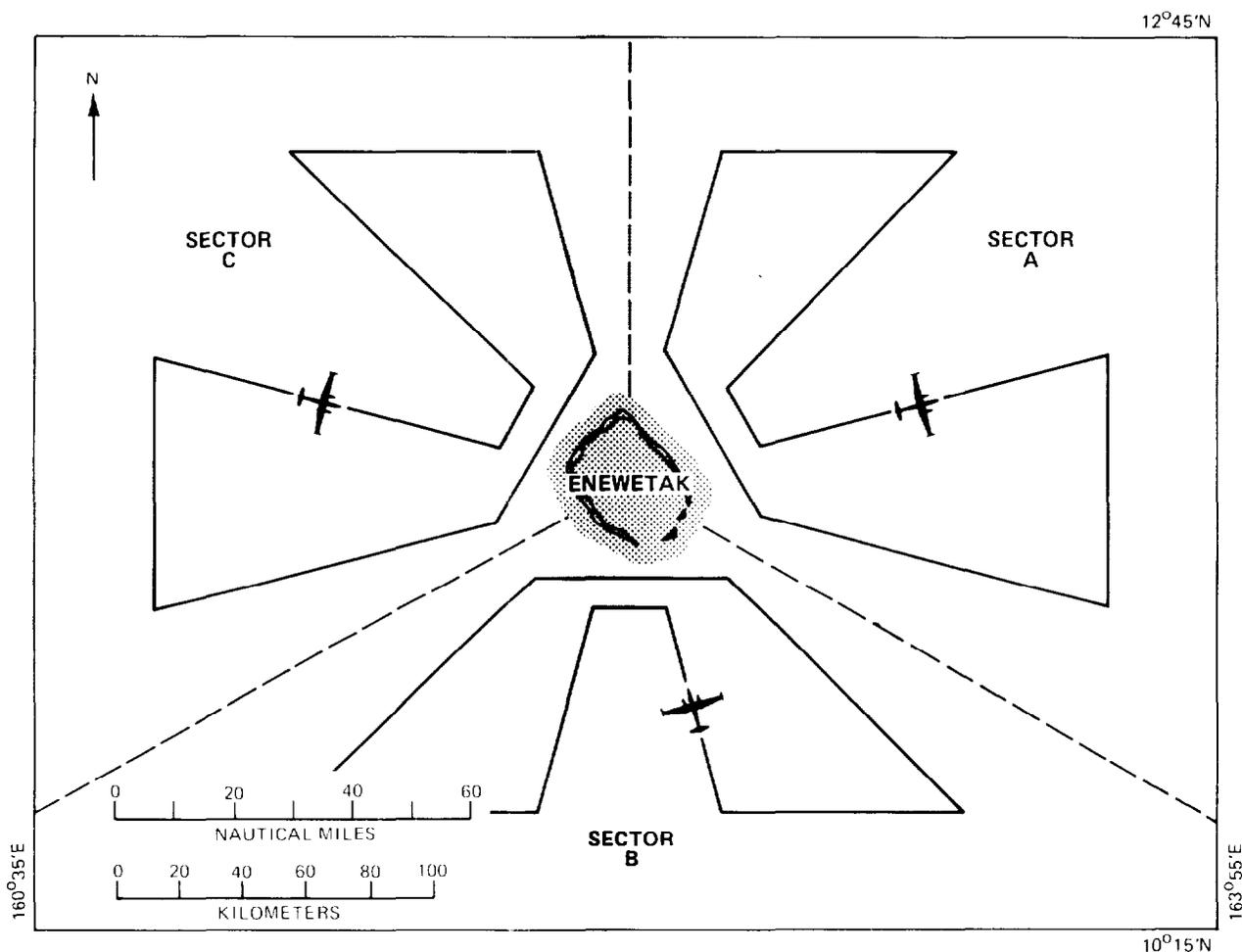


Figure 14. Air patrol plan D, Operation SANDSTONE. (Four planes: plane 1 flies patrol plan A; planes 2-4 patrol sectors A through C in accordance with the diagram.)

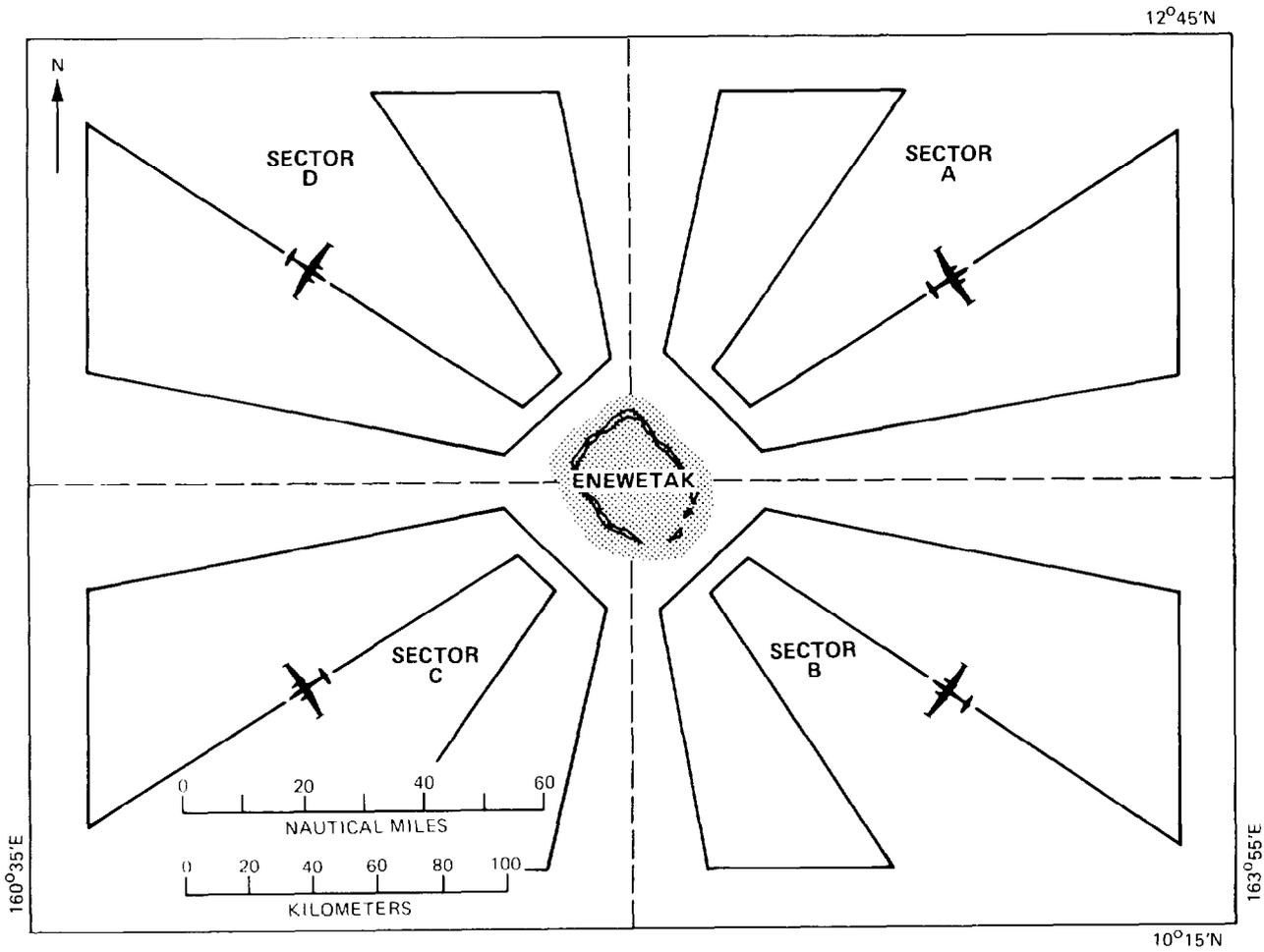


Figure 15. Air patrol plan E, Operation SANDSTONE. (Five planes: plane 1 flies patrol plan A; planes 2-5 patrol sectors A through D in accordance with the diagram.)

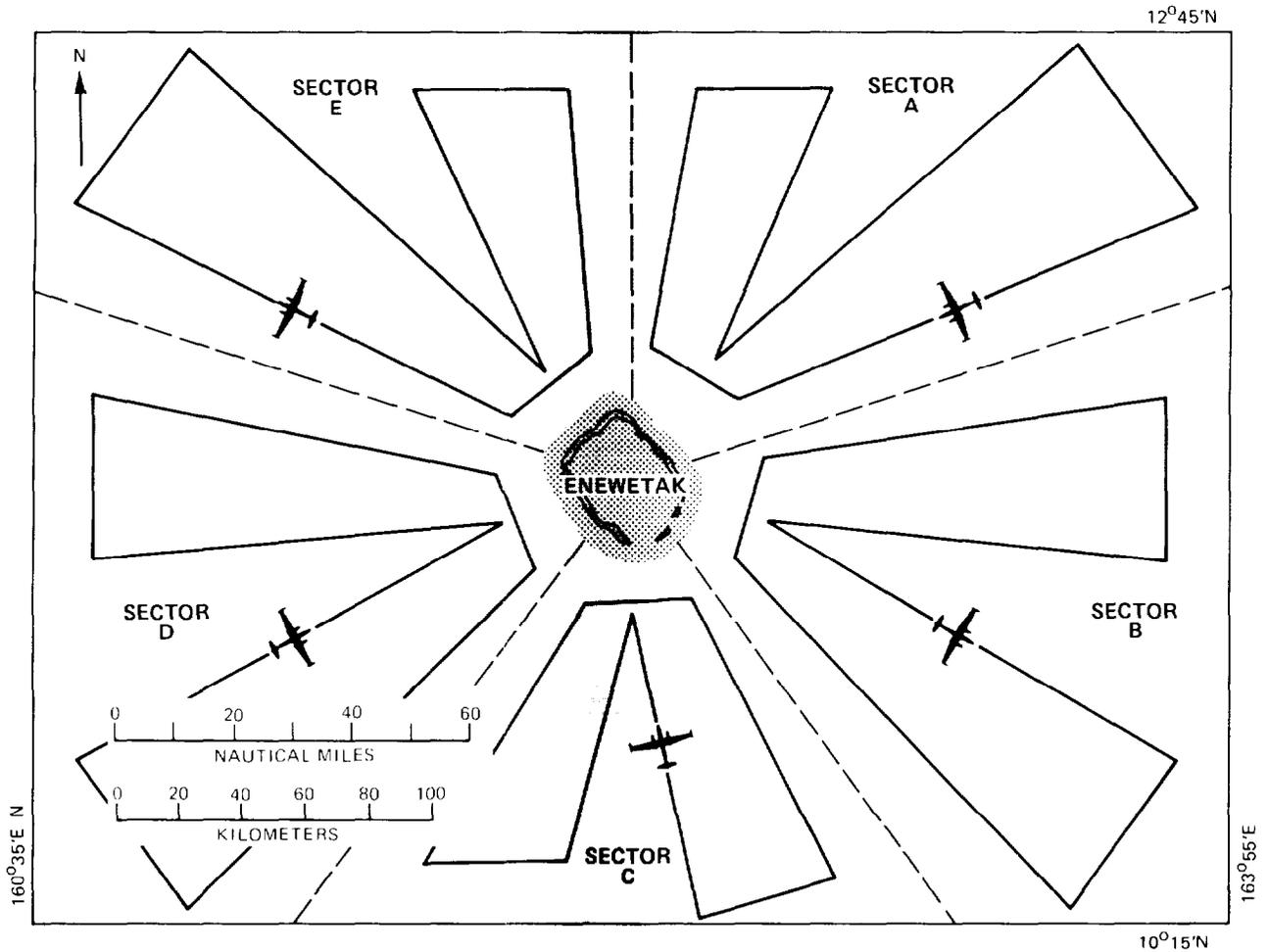


Figure 16. Air patrol plan F, Operation SANDSTONE. (Six planes: plane 1 flies patrol plan A; planes 2-6 patrol sectors A through E in accordance with the diagram.)

Fallout and Lagoon Contamination Prediction

The Radsafe Office prepared fallout predictions, delineated radiological exclusion (radex) areas (showing where radioactivity and fallout were expected to be present in the air and on surfaces), and presented the predictions at command briefings before each shot. Radex plotting used vector analysis of wind patterns. Fallout patterns were predicted for the surface, 15,000, 20,000, 25,000 and 30,000 feet (4.6, 6.1, 7.6, and 9.1 km). The surface radex area, designated between two bearings from zero point, was determined from the predicted fallout patterns.

Fallout predictions were based on weather observations. If fallout from 45,000 feet (13.7 km) or below was predicted to occur outside the sector bounded by 90°T and 170°T from zero point, the day was considered as a possible shot day. If fallout from 45,000 feet (13.7 km) was predicted on the bearings of Enewetak-Parry islands (150° - 160°T), the day was judged questionable with moderate hazard. If fallout from 35,000 feet (10.7 km) or below was predicted on these islands, the day was ruled a nonshot day (Reference C.43, Appendix I, Annex I-3 and I-4).

Three days preceding the test, a forecast for a test day was made, and on the day before the test day the latest weather forecast was presented at 1800. Actual wind data was plotted at intervals from this time to 0300 at which time the last balloon sounding was made and the data was prepared for the briefing.

At Ujelang, a monitor aboard the designated evacuation ship furnished radiological data to the ship's commanding officer. The monitor was to advise the commanding officer of any necessary action if radioactive rainout occurred on Ujelang.

A special study of currents around Enjebi was made. This study was conducted to anticipate the direction and spread of any possible radioactivity from the explosion. The drift of partially submerged floating objects was also observed by helicopter and small boat patrols. The study indicated that currents were generally from east-northeast and that no radioactivity would be expected south of a line bearing 240°T from the southern tip of Enjebi. Results of the lagoon survey following X-RAY bore out the accuracy of these predictions (Reference C.43, p. 53).

Command Briefing

CJTF 7 decided whether to go ahead with a test firing on the basis of four meetings. The first of these meetings was held at 1500 on D-3. At this meeting meteorologists gave a weather briefing, including a 4-day forecast. Based on this forecast, he decided whether to proceed with the firing procedure for D-2 and the morning of D-1. Each task group reported on its state of readiness during this meeting. The meeting was attended by CJTF 7 and his deputies, the Chief of Staff, Test and Scientific Directors, Commander TG 7.2, Commander TG 7.3, Commander Air Forces, staff meteorologist, Radsafe Officer, staff photographer, and representatives of J-2 and J-3.

A second meeting was held at 1100 on D-1. At this meeting CJTF 7 decided if the weather would be satisfactory for the shot, determined how the operation was proceeding, and if all ships, aircraft, equipment, instruments, and personnel were ready for the test. If he decided to proceed with the test, he notified the AEC.

A third meeting was held at 1800 on D-1. In addition to the latest weather forecast, the Radsafe Officer presented his forecast of the movement of the radioactive cloud. A meeting was sometimes held at H-4 to determine if takeoff of the drone control planes from Kwajalein was acceptable. The last meeting was held at H-1. Any changes in weather or cloud travel forecasts were given, and a final decision was made.

A postponement of the test after the D-3 meeting involved little repetition of firing sequence operations. During the 1800 meeting on D-1, the decision was made whether ships should leave their anchorages and whether the firing party should proceed to the shot island to complete the firing circuits. At the last meeting it was decided whether to fire the weapon. The meetings were not closely scheduled with meteorological operations. At some meetings decisions were made with much poorer meteorological information than would have been available a few hours later. However, the last meeting was held at H-1 when the final firing decision was made based upon the latest weather data. (Reference C.7, pp. 157-159).

Weather Prediction

Because fallout forecasts depend primarily on forecasts of wind speed and direction, the accuracy of SANDSTONE fallout predictions was related to the accuracy of the weather predictions. CTG 7.3 and CTG 7.4 administered and supported weather elements to provide meteorological data in conjunction with the SANDSTONE tests. (Reference C.5, pp. 3-A195 ff).

The meteorological organization provided information to JTF 7, including cloud-cover forecasts for all air and photographic operations, wind information to heights of 60,000 feet (18.3 km) or higher for radiological studies and safety procedures, climatological information, and severe storm warnings. Weather detachments were located at Kwajalein, Majuro, Enewetak, Rongerik, and Wake islands.

Commander Air Forces, JTF 7, established and operated the weather stations at these islands except Kwajalein and Wake. He resupplied the weather detachments with assistance from TG 7.3 for Rongerik, TG 7.7 for Majuro, and Pan American Airlines for Wake. The weather stations provided complete weather observation service, including a minimum of four rawinsondes (instrumented balloons) per 24-hour period, a forecast and briefing service for crews of transient and JTF 7 aircraft, and a relaying service to disseminate all weather information (including flight reports and flight summaries). In addition to the outlying weather stations, Joint Task Force Weather Central was located aboard Mount McKinley.

The JTF 7 Staff Weather Officer recommended flight paths for the two weather reconnaissance flights each day. The 43rd Weather Wing maintained weather facilities at Enewetak until CTG 7.4 meteorological facilities were in place. The 43rd Weather Wing transferred control of eight WB-29 aircraft and crews,

plus one additional officer and seventy enlisted men, to Commander Air Forces for weather reconnaissance and cloud-tracking duties. It also lent additional support by ferrying meteorological equipment and personnel to weather stations. Bairoko, USS Albemarle, (AV-5) and USS Curtiss (AV-4) also served as weather ships. These ships gathered and disseminated information from four rawinsonde and two radiosonde observations per day as well as information from complete shipboard surface observations. A small number of 2,000-gm balloons for high-altitude ascents (100,000 feet [30.5 km]) were included in the weather equipment (Reference C.5, p. 3-A 198).

Eye Protection

Individuals looking directly at a blast at H-hour wore high-density goggles. They were issued to all airborne personnel. The special goggles were put on at H-2 minutes. Copilots attempted to protect their eyes completely (for an extra margin of safety) by covering their eyes with bent arms until after the flash. A copilot could then take over if the pilot were temporarily blinded (Reference C.43, Appendix B, Annex A, II-3).

Evacuation and Reentry Plans

JTF 7 issued an evacuation plan to ensure that all personnel were removed from danger of the explosion or radioactivity at test time. Two days before each test, CTG 7.2 made a detailed, physical search of all islands in Enewetak Atoll (except for Enewetak and Parry) to ensure that no unauthorized personnel were ashore. Color-coded badges, coupled with access lists, facilitated identification of authorized personnel.

On D-1, CJTF 7 alone authorized movement into and within a 40-nmi (74-km) radius from the center of Enewetak Atoll. On the same day, authorized ships entered Enewetak Lagoon only after being passed by CTG 7.3 control. Similarly, CTG 7.4 prohibited any unauthorized JTF 7 aircraft from leaving Kwajalein or Enewetak islands.

All personnel, except those authorized to be at Enewetak, Parry, and the shot islands, evacuated the atoll by H-1. They moved aboard the ships of TU 7.3.8, which were east of the atoll during shot operations. Individuals ashore consisted of the minimum number of CTG 7.1 personnel at Enewetak, Parry, and the shot islands to carry out the scientific operations plan. CTG 7.2 maintained a mobile reserve of three officers and eighteen enlisted men on Enewetak Island during the test, as well as minimum security guards and communications personnel on Enewetak and Parry islands. A minimum boatcrew under CTG 7.3 remained at Enewetak or Parry Island. Minimum aircrews and operations personnel, including air communications, photographic, and weather personnel, remained at Enewetak Island. CTG 7.5 maintained one officer and nine enlisted men as security guards who remained on the shot islands until returning with the firing crew to Parry Island. Other TG 7.5 guards remained on the unused shot islands until 1215 on D-1. They were evacuated to Enewetak Island, remaining there during the test. CTG 7.6 kept required radsafe monitors at Enewetak and Parry islands. CTG 7.3 evacuated the remaining personnel from the shot island. They arrived at Parry Island between H-3 and H-1. The shot island thus was completely evacuated and preparations on Parry Island complete.

In addition to general Enewetak evacuation, CTG 7.3 was prepared to evacuate personnel from Ujelang. CTG 7.2 planned to give suitable warning to all personnel on Enewetak and Parry islands to assemble in a designated area if the radsafe monitor indicated that this was appropriate. CTG 7.3 maintained sufficient craft to evacuate the individuals in an emergency. CTG 7.4 was to be evacuated with Air Force personnel to Kwajalein by air (Reference C.7, pp. 3-A-144 ff).

The reentry plan dictated that only personnel with "urgent" duties return to radioactive areas on shot day. CTG 7.6 conducted a radiological survey of the shot island and surrounding islands. After they were cleared, experiment personnel would be allowed to conduct "routine" work. Ships and aircraft landed only at Enewetak and Parry islands in accordance with CJTF 7 or the reentry plan. Following the shot, no aircraft flew within 2 nmi (3.7 km) of the shot islands except in accordance with the reentry plan or on orders of CJTF 7. These restrictions were in effect throughout SANDSTONE (Reference C.7, pp. 3-A153 ff).

POSTEVENT SAFETY MEASURES

Mount McKinley Radsafe Center issued radex area information where significant fallout was predicted to occur within 6 hours after detonation. Task units were denied entry into radex areas except with specific authorization.

Data were recorded on shot days on a chart of the atoll and on detailed maps of the shot islands maintained on board Mount McKinley. Air and surface radex area information was available there.

All communications from radsafe missions were directed to Mount McKinley Radsafe Center and monitored by the Radsafe Center on Bairoko. This provided immediate, first-hand information for the radsafe officer aboard Mount McKinley. On days after a shot the plan called for direct communications with the Radsafe Center on Bairoko. Mount McKinley Radsafe Center plotted fallout patterns based on weather forecasts for the radsafe officer and maintained daily surface and air radex area plots. Information from TU 7.6.1 monitors and from the cloud-tracking aircraft was also plotted in the Radsafe Center (Reference C.43, p. 58).

Mount McKinley Radsafe Center furnished systematic information to CJTF 7 and the JTF 7 Radsafe Officer. Radiological situation maps were updated based on information received there. Air and surface radex areas were changed after the shots when warranted by weather conditions. Isointensity lines of 0.1 R per day in the lagoon water were plotted, as were fallout data from Kwajalein and Ujelang (Reference C.43, Appendix B, Annex E-9 and E-10).

All islands north of Runit were considered radioactive until cleared by TG 7.6. Enewetak postshot control and decontamination activities were centered at Enewetak Island. Parties recovering scientific data soon after the shot operated from naval vessels in the lagoon until early radiological surveys determined whether it was safe to move data-recovery operations ashore.

All personnel entering radioactive areas were badged. Radsafe checkpoints strictly controlled entry into and exit from these areas. Protective clothing

was required in radioactive areas. The radsafe monitors accompanying the scientific parties determined the amount of protective clothing necessary, including whether gas masks were advisable. Instructions were given to the monitors in some cases so that they did not themselves decide on the degree of protection required. Instructions for 24 April on Enjebi, for example, stated that personnel coming closer than 550 yards (503 meters) to the X-RAY surface zero would wear gas masks if they were doing anything to raise dust (Reference C-43, Monitor Instructions, p. 26).

The Radiological Records Unit (TU 7.6.5) maintained cumulative personnel exposure records aboard Bairoko. When work parties returned to Bairoko, they turned in their clothing, pocket dosimeters, and personnel film badges.

Transport of radioactive materials out of the test area complied with AEC regulations for shipping radioactive materials (AEC Regulations, Safety No. 3, Standard Safety Requirements, Part 14). All radioactive materials were monitored by TG 7.6 before transport. Authority to remove samples of radioactive material from the test area was obtained from the Test Director and such removals complied with security requirements (Reference C.43, Appendix B, Annex A-4).

Cloud Tracking

Tracking debris with WB-29 weather reconnaissance aircraft was the primary method planned to verify radioactive cloud travel in the predicted direction. An aerial survey determined radiation intensities and fallout occurring at varying altitudes in the vicinity of the shot island. TU 7.6.1 plotted the cloud-tracking information aboard Mount McKinley. (Reference C.43, p. 58).

Major areas of concern were:

1. Downwind, especially Enewetak and Ujelang
2. Upwind
3. Upwind of the native populated atolls to the southeast
4. Air and surface transportation routes through Wake Island and the Marshall Islands.

Sample Recovery Techniques

Unmanned drone B-17s were used to collect samples of particles from the radioactive shot clouds. These samples were collected on filter papers placed in sheet-metal boxes mounted in the normal position of the top and chin turrets of the B-17 (see Figure 17). Three flights were made through the weapon cloud by each of several drones, after which the planes were landed at Enewetak.

After the drone B-17s had stopped rolling, their tails were checked for radioactivity and a tow bar attached to each drone's tail. The drones were then towed into an area at the eastern end of the runway on the lagoon side of the island (see Figure 4). An area there had been isolated by rows of junked heavy construction equipment, trucks, steel landing mats, etc. These rows were meant primarily to protect the landed samplers from any other drones that might



Figure 17. Drone B-17 at Enewetak after shot ZEBRA, Operation SANDSTONE, approached by truck with forklift with extension arm to grasp top sampler box. Lower sampler box is under nose.

go out-of-control during their landing. They also served to attenuate radiation emanating from the contaminated drone aircraft.

The first step in recovering the samples was releasing the filter boxes. This was done by a man running in and pulling a release lanyard under the trailing edge of the B-17 wing at its root. The top filter box was then removed by a modified forklift in the bed of a 2-1/2-ton truck (Figure 18). Two men took the filter box from the forklift (Figure 19) and placed it on the ground well away from the B-17. The filter papers themselves were then removed from the box in their holders. Lanyards were available to pull the filter holders free, one from each side of the box. Figures 20, 21, and 22 show a man freeing the filter holders using only the lanyard. The filter holders, however, apparently did not always come free easily. Figure 23 shows a man using his free hand on the box and exerting considerable pull to remove the filter holder.

The lower filter box was dropped to the ground and the filter holders were then removed. By the third shot it was observed that it was quicker to simply have men run in and remove the filter holders from the lower boxes while the boxes were still attached to the B-17. Figure 24 shows this being done after ZEBRA.

When all the filter holders for a drone were freed, they were moved away from the drones, opened, and the filter papers removed, marked, and placed in lead containers on the back of a jeep. Figure 25 shows the transfer of the lead container to the aircraft that transported the filter papers to Los Alamos.



Figure 18. Forklift extension arm lifts top filter from drone B-17 following shot ZEBRA, Operation SANDSTONE.



Figure 19. Two men take top filter box from forklift and place it on the ground following shot ZEBRA, Operation SANDSTONE.



Figure 20. Man pulls lanyard to remove one of two filter-paper holders from top filter unit following shot ZEBRA, Operation SANDSTONE.



Figure 21. Lanyard pulls filter-paper holder free from top filter unit following shot ZEBRA, Operation SANDSTONE.



Figure 22. Second filter holder comes free from top filter. Man in background tilts top filter unit from another drone. Junk revetment is at right, SANDSTONE.



Figure 23. Hard pull and both hands are required to free filter-paper holder, Operation SANDSTONE.



Figure 24. Two men run in to pull filter holders from lower sampler on B-17 drone following shot ZEBRA, Operation SANDSTONE. Junk revetment is in background.



Figure 25. Filter papers in lead box handed up to C-54 preparing for flight to United States following shot ZEBRA, Operation SANDSTONE.

Four-foot (1.2-meter) tongs were available to handle the papers, although they were not always used as they were unwieldy. All the men wore gloves, some wearing rubber gloves under cotton ones. The filter papers were identified by drone aircraft number, which was stapled to the papers when they were removed from the filter holders.

Generally, the filters were divided into two equal groups and flown directly to Albuquerque for radiochemical analysis at LASL, the aircraft making one stop at Honolulu en route to Albuquerque.

Samples were also collected from the ground surface near the detonation point with a radio-controlled drone tank. These were taken to Bairoko by LCVP boat or helicopters and were returned to Los Alamos later. The techniques and protective measures used in handling these samples are not documented. The samples themselves were not as intensely radioactive as the samples collected by the aircraft.

Protective Clothing

Personnel working in areas likely to be contaminated or working with contaminated objects wore clothing to avoid contaminating skin, hair, and personal clothing. This protective clothing usually consisted of coveralls or fatigues with a head covering, gloves, and shoe covers. The function of this clothing was to trap radioactive particles in the cloth. This made personnel decontamination much easier and also prevented inadvertent transport of the radioactive materials to uncontaminated areas. A gas mask was also worn where airborne contamination was suspected. Personnel shown in Figures 18 through 24 are shown wearing the usual protective clothing. Figure 26 shows the shoe coverings or booties, and Figure 27 shows personnel wearing masks during an inspection of a timing station after shot X-RAY.

Personnel Decontamination

The basic method used for personnel decontamination was removal of contaminated clothing, radiation monitoring, showering, radiation monitoring with additional washing, and additional monitoring as required before donning fresh clothes. Shower and change facilities were set up near worksites where personnel contamination was likely. Figures 28 and 29 show the shower near the drone decontamination area in Enewetak with personnel who had been working on the drones passing through after their shift. Special attention was paid to hands. They were frequently rewashed and remonitored (Figures 30 and 31).

Any personnel caught in radioactive fallout or rainout were to take cover immediately in as airtight a location as was available. Gas masks were to be worn if senior monitors present advised. Any person actually contaminated by radioactive rain was to remove his clothing and wash himself. No eating, drinking, or smoking were allowed while the rainout continued or before decontamination was complete.

On Enewetak and Parry islands, all personnel were to take cover in buildings previously selected by monitors and remain there until danger from fallout or radioactive rain ended. Monitors were to check the area surrounding the shelter to determine when it was safe to resume normal operations in the open.



Figure 26. Booties or shoe covers used in Operation SANDSTONE.



Figure 27. Personnel leave Enjebi timing station several days following shot X-RAY, Operation SANDSTONE.



Figure 28. Decontamination truck and drone B-17 viewed through clothesline at shower station on Enewetak Island, Operation SANDSTONE.



Figure 29. Shower station on Enewetak, Operation SANDSTONE. Personnel are being monitored before dressing in clean clothes.



Figure 30. Drone maintenance man rewrites hands following work on drone B-17, Operation SANDSTONE.



Figure 31. Hands are remonitored, Operation SANDSTONE.

If task force ships were involved in a radioactive rainstorm, all personnel were to go below deck and all hatches were to be closed. The ship was to follow a course predicted to take it out of the rain as rapidly as possible. As soon as the rain ended, the monitor was to check exposed surfaces and, if necessary, recommend hosing down to remove contamination (Reference C.43, Appendix B, Annex J-2, pp. 3-4).

Ujelang was considered unlikely to receive fallout. However, plans were made that upon warning from CJTF 7 that it lay in a possible fallout zone, the Enewetak people living there would board an LST for possible evacuation.

Fallout typically occurred at Enewetak on the uninhabited islands northwest of the shot islands. Two days after YOKE, fallout was reported on Bairoko (off Aomon Island) and at Kwajalein. Chapter 4 has a more thorough discussion of the fallout and its consequences.

On D+1 a beach radsafe center on the shot island was set up near the landing point in an area of low radioactivity. Radiation monitors from it accompanied all parties entering the shot island. It also served as a communication and information center.

When background radiation was less than 0.0001 R/hr (gamma), a person was considered contaminated if any part of his body gave a reading greater than 0.0001 R/hr above background. If background was greater than 0.0001 R/hr (gamma), personnel were not checked until taken to an area where it was less than 0.0001 R/hr (gamma) (Reference C.43, Appendix E, Annex I-1 and I-2).

When personnel were contaminated on the shot island, they returned after the mission to the beach radsafe center and removed their clothing, including cloth booties and gloves. Clothing was considered contaminated if it measured more than 0.0001 R/hr (gamma) above background, if background itself was less than 0.0001 R/hr. If background was higher than 0.0001 R/hr, all clothing worn in the radioactive area was placed in containers that were later weighted and dumped at sea in deep water.

Personnel who had removed their gloves in the radioactive area were required to wash their hands. The monitor checked everyone in his party for radioactivity. Fresh clothing from the beach radsafe center was issued after the individual was monitored. If removing clothing failed to complete personnel decontamination, the monitor escorted any remaining contaminated personnel to Bairoko, rechecked them, and they undertook necessary additional decontamination for complete clearance.

Personnel were advised not to bring valuable personal items ashore. If, however, any valuable item (such as a watch or ring) became contaminated in excess of 0.0001 R/hr above background, it was put in a clean container and stored on Bairoko until the item was radiologically cleared.

If a person was contaminated somewhere other than on the shot island, monitors checked him to ensure that he was decontaminated at the completion of the mission during which he was exposed. Procedures similar to those on the shot islands were carried out. If rainout or fallout contaminated inhabited

islands, the monitor reported the circumstances to CJTF 7 and CTG 7.6. Walking in radioactive areas and handling contaminated materials were kept to a minimum (Reference C.43, Appendix B, Annex D).

A portside section of Bairoko's hangar deck was set up as a decontamination center, supply section, and issue point. As monitors prepared to leave the ship, they reported to this area and drew instruments, booties, gloves, and any other equipment required for the mission. When the mission was completed, they came aboard portside and passed into a restricted zone roped off on the deck. Here they were monitored for contamination, decontaminated if required, drew new clothing, and turned in their equipment, film badges, pocket dosimeters, and monitor report cards. This procedure was an established routine and prevented personnel in contaminated clothing from spreading radioactivity throughout the ship (Reference C.43, pp. 55-56).

A personnel decontamination center was constructed on Kwajalein and placed in operation before X-RAY (Reference C.43, p. 88). After fallout occurred on Kwajalein following YOKE, a radiological control center was established there. Surveys were made and water samples collected for radiation counts.

Ship Decontamination

Ship decontamination had been a great concern to the Navy before SANDSTONE. BuShips was responsible for developing ship decontamination measures, and a project was designed to provide information about the contaminability and relative ease of decontamination for a variety of materials used as protective coatings on naval equipment and structures. Although high levels of contamination were not expected at SANDSTONE, the operation provided an opportunity to gain information. These materials were exposed as part of the TG 7.6 experimental activity discussed in Chapter 3 (Reference C.43, pp. 30-31).

On an operational level, one ship, USS Rogers (DDR-876), reported that decontamination was necessary. It probably was done using firehoses. An LCM was deliberately sunk rather than decontaminated. Four days after the last shot, all ships present were surveyed for their radiological clearances before they left for the United States. Areas monitored on the ships included evaporators, auxiliary condensers, weather decks, berth decks, intake screens of high-capacity supply blowers, and ventilation duct elbows. Hull scrapings near the waterline were taken from ships that had anchored within 5 nmi (9.3 km) of the test area. CTG 7.6 noted in a memo to CTG 7.3 that the radiological inspection of the ships was generally satisfactory, except for intake screens of the blowers. He suggested that the screens be removed and scrubbed with soap and water on the following day. The monitor then rechecked the screens (Reference C.43, Appendix I, Annex IV, 18 May 1948).

Mount McKinley, Albemarle, Curtiss, Bairoko, USS Comstock (LSD-19), USS Gardiners Bay (AVP-39), USS Pickaway (APA-222), USS Mispillion, USS Askari (ARL-30), USS Henry W. Tucker (DDR-875), Rogers, USS Spangler (DE-696), USS Yancey (AKA-93), USS Raby (DE-698), USS Pasig (AW-3), LSM-378, LSM-250, USS LST-45, and LCI(L)-1054 had spot readings greater than 0.0002 R/hr above background. All of the above-named ships with high- and intermediate-capacity supply blowers showed readings above 0.0002 R/hr on intake screens after scrubbing. Contamination above 0.0002 R/hr persisted also on the No. 1 five-inch gun

on Spanqler and three air-conditioning units on Curtiss. As a result, CTG 7.6 suggested that the intake supply screens of the ships' blowers be scraped to bare metal, repainted, and monitored on arrival at a Navy yard. He recommended that shipyard workers wear respirators when wire-brushing or sand-blasting these screens and that workers with cuts on their hands not participate (Reference C.43, Appendix I, Annex IV, 18 May 1948).

USS Perkins (DDR-877), USS George (DE-697), USS Marsh (DE-699), USS Currier (DE-700), USATS FS-370, YW-94, YOG-64, LCI(L)-1090, LCI(L)-1540, AVR-26653, and AVR-26638 had no readings greater than 0.0002 R/hr above background. BuShips and BuMed therefore immediately issued final radiological clearance (Reference C.43, Appendix I, Annex IV, CTG 7.6 to CTG 7.3, May 20, 1948).

Equipment Decontamination

Radiac instruments were often wrapped in plastic (Figure 32) to avoid contamination of the instrument itself. However, when radiac instruments were contaminated, the issue officer aboard Bairoko was informed when they were returned. If scientific instruments showed less than 0.0001 R/hr (gamma), they were considered uncontaminated. For more heavily contaminated instruments, CTG 7.6 cleared specific items for removal to task force ships. Otherwise they were left at the measurement site to allow the radioactivity to decay. If background exceeded 0.0001 R/hr (gamma) and if the scientific instruments were urgently needed, they were removed to a site having a background less than 0.0001 R/hr (gamma) so that their level of radioactivity could be determined and final disposition arranged.

The drone tanks used in collecting radioactive samples near the shot craters became contaminated, but were sunk in the lagoon rather than being decontaminated. The project personnel felt that such an effort was not worthwhile as better equipment would be available in any future tests. (Reference C.10, p. 55 and Appendix C).

Aircraft Decontamination

The drone cloud sampler B-17s required decontamination after each shot before they could be serviced and necessary maintenance performed. This was done after the planes had sat undisturbed in the sample removal area at Enewetak for several days to allow radiation on the planes to lessen due to natural decay processes.

Just before decontamination, the aircraft were moved to another area of the island, but this location is not documented. In later test series held at Enewetak, a decontamination area was set up at the downwind end of the runway next to the lagoon to minimize the hazards from contaminated runoff water and spray. Possibly this area was also used during SANDSTONE.

The drone B-17s were moved under their own power. The two outboard engines were started and the planes were taxied by a pilot from the upwind corner of the airfield to the decontamination area. After ZEBRA, 3 days elapsed before this took place, but the intensity of the drones' radioactivity is not known.



Figure 32. Monitor checks radioactivity following SANDSTONE shot with plastic-wrapped Geiger-Mueller instrument.

A motion picture film exists (19 RMF 153) that shows ZEBRA drone 7 being taxied into position for decontamination. The film shows the pilot drop from a hatch after the propellers had stopped and sprint from the stopped plane. The photographer's notes describe him "running to a safe area" where he was monitored to see if he had picked up any radioactive particles while moving the drone (Figure 33). The pilot wore standard fatigues and his hands were gloved. No film badge was visible on his uniform, but a fountain-pen-like object, probably an electroscopic dosimeter, may be observed in his left chest pocket.



Figure 33. Pilot who had just moved drone B-17 into position for decontamination is monitored for radioactive contamination, Operation SANDSTONE.

Decontamination of the drones themselves consisted of monitoring, washing, rinsing, and remonitoring. Figures 34 through 36 show these operations. The engines were the most contaminated parts because oil and grease in their many narrow passages trapped and retained radioactive particles.

Decontamination personnel wore protective clothing and were monitored (Figure 37). Shower and change facilities were located close by the drone contamination area.

After decontamination the drones were still radioactive, but radiation had decayed enough to allow some maintenance work. At this time maintenance work was limited to 90 minutes for any man. Access to the decontaminated drones was controlled (Figure 38).

Some TG 7.6 personnel were assigned to TG 7.4 in time to provide the required briefing and indoctrination of personnel for these decontamination operations. Early assignment also allowed them to provide technical advice and monitoring services essential for safe conduct of the operation (Reference C.43, Appendix B, Annex A).



Figure 34. Monitors record radioactivity of SANDSTONE drone sampler before decontamination.



Figure 35. Decontamination of SANDSTONE B-17 drone sampler.



Figure 36. Decontamination of SANDSTONE B-17 drone sampler.



Figure 37. Enlisted man is monitored for radioactivity following decontamination of SANDSTONE drone sampler.



Figure 38. Military policeman prevents access to SANDSTONE drone B-17 following its decontamination.

The first member of the TG 7.6 party arrived at Enewetak Island on 30 March 1948. A radsafe center was established in the radiochemistry laboratory, close to the drone parking area. The drone planes were not parked together, however, following the first shot. This caused some confusion, since the monitor was unable to keep track easily of all his men. Complete rehearsals, including drone landings, were held for X-RAY. It was estimated from the rehearsal that two monitors could handle filter-removal operations (Reference C.43, Annex I-1).

The air monitor unit monitored drone aircraft and decontamination operations at Enewetak, aircraft and personnel decontamination operations at Kwajalein, and cloud-tracking operations until H+108. It also maintained and recalibrated instruments, prepared medical dosimetry records, and compiled mission reports (Reference C.43, pp. 87-88). Monitors from the air monitor unit also accompanied each manned aircraft on shot days to prevent them from entering areas where radiation intensity was greater than 0.1 R/hr (Reference C.43, pp. 87-88). If the aircraft encountered an intensity of 0.1 R/hr, the monitor advised the pilot to take immediate evasive action to avoid the radioactive area (Reference C.43, Appendix I, Annex I-1 and I-2).

Following the detonations, drone aircraft returned to Enewetak. All other aircraft involved in the tests returned to Kwajalein. Cloud-tracking missions were flown until D+5. Aircraft used for these missions following X-RAY returned with exterior contamination, necessitating monitoring and aircraft and personnel decontamination. Six monitors supervised drone aircraft decontamination operations at Enewetak. All ground crews and personnel working on the contaminated drones wore film badges provided by the monitor assigned to the landing site (Reference C.43, Appendix B, Annex A, Part II-2). Two monitors were sent to Guam to assist in weather reconnaissance aircraft decontamination.

Additional TG 7.6 monitoring operations consisted of postshot photography aircraft missions, compilation of mission data, and monitoring drone aircraft ground maintenance operations following the return of drone aircraft to Kwajalein (Reference C.43, p. 91).

Aircraft were cleared to return to the United States after the radioactive contamination had decayed below 0.016 R/hr. Four monitors from TU 7.6.1 accompanied these aircraft back to Eglin Field, Florida (Reference C.43, p. 93).

CHAPTER 3

DEPARTMENT OF DEFENSE EXPERIMENTAL PROGRAM

EXPERIMENTAL PARTICIPATION

SANDSTONE was a proof-test of second-generation nuclear devices. The two weapons detonated at CROSSROADS (1946) were the same type weapon dropped on Nagasaki. On 3 April 1947, the General Advisory Committee to the Atomic Energy Commission (AEC) recommended development and testing of new weapons. Los Alamos Scientific Laboratory (LASL) had developed the SANDSTONE weapons and was charged with the responsibility for measuring their outputs as well. Measurement of weapon output (X-rays, gamma rays, neutrons, heat, blast, etc.) was a new science, and in October 1947 LASL created a new division, called J-Division, to manage the nuclear testing program. J-Division contracted with selected military service laboratories and private contractors to assist it. Naval Ordnance Laboratory (NOL) was tasked to prepare and conduct experiments to measure blast overpressures. Naval Research Laboratory (NRL) was similarly tasked to prepare and conduct radiation measurement experiments. Argonne National Laboratory was tasked to measure gamma-ray output. Edgerton, Germeshausen & Grier, Inc. (EG&G) was contracted to design and install timing and firing systems to trigger the nuclear devices and to activate the many experiments at precisely the right time (Reference C.7, p. 105).

The military services were eager to participate in the testing to determine the effects of blast, heat, and radiation on biological specimens, equipment, and structures. They proposed many experiments and 15 were finally approved. These experiments were not to interfere with the basic mission of testing the new weapons and were under the technical control of Commander Task Group (CTG) 7.1 (Reference C.1, p. 37).

Armed Forces Special Weapons Project (AFSWP) assisted the AEC in the weapon diagnostics experiments that measured nuclear device outputs. AFSWP also supervised the proposed effects experiments from the military services and assisted the services in gaining AEC approval. Approximately 116 AFSWP personnel were integrated into Task Group (TG) 7.1 (AEC Proving Ground Group), where they assisted in almost every area of effort (Reference C.43, p. 21).

Table 8 lists the weapon diagnostics and service test experiments. The table also lists the six experiments of a special operation, associated with long-range detection of the detonations, which were conducted independently of SANDSTONE by the Air Force with assistance from the U.S. Coast and Geodetic Survey (USC&GS), the Navy, and NRL. No radiation exposure potential existed for these six experiments as the operations were far removed from the test site. No task force personnel participated in these experiments.

Table 9 contains exposure information for personnel who could be associated with a particular experiment. Information for individuals associated with weapon diagnostics experiments is complete. Not everyone associated with the

Table 8. SANDSTONE experiments.

Experiment	Responsible Organization
Weapon Diagnostics Experiments	
Radiochemistry	Los Alamos Scientific Laboratory
Neutron Measurement	Los Alamos Scientific Laboratory
Neutron Generation -- Rossi Method	Naval Research Laboratory
Neutron Generation -- Teller Method	Edgerton, Germeshausen & Grier, Inc.
Gamma-Ray Spectrum	Argonne National Laboratory
Gamma-Ray Appearance -- Rossi Method	Naval Research Laboratory
Gamma-Ray Appearance -- Teller Method	Edgerton, Germeshausen & Grier, Inc.
Technical Photography	Task Group 7.4
Blast Measurements	Naval Ordnance Laboratory
Service Tests	
Reinforced Concrete Structures	Task Group 7.2
Blast Resistance of Structures	Task Group 7.3
Aircraft Blast Acceleration	Task Group 7.4
Exposure of Biological Material	Task Group 7.6
Exposure of Material to Radiation	Task Group 7.6
Evaluation of New Radiological Instruments	Task Group 7.6
Radiation Shielding by Materials	Task Group 7.6
Evaluation of Collective Protectors	Task Group 7.6
Residual Crater Contamination	Task Group 7.6
Aerial Survey of Ground Contamination	Task Group 7.6
Aerial Survey of Cloud Intensity	Task Group 7.6
Survey of Cloud Particle Size	Task Group 7.6
Special Operations	
Observation of the Moon	Air Force
Magnetic Effects	Air Force; Naval Ordnance Laboratory
Seismic Observations	U.S. Coast and Geodetic Survey
Acoustic Observations	Navy
Remote Detection by Airborne Filters	Air Force
Remote Detection by Ground Observation	Air Force

Table 9. SANDSTONE scientific personnel radiation exposures.

Experiment Title/Organization	No. of Persons	No. of Persons Badged	Exposure Ranges (roentgens)							
			0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	Over 3 ^a
Weapon Diagnostics Experiments										
Radiochemistry										
Los Alamos Scientific Laboratory	8	8	0	0	0	2	1	0	0	5
Aberdeen Proving Ground	5	5	0	1	3	1	0	0	0	0
Neutron Measurement										
Los Alamos Scientific Laboratory	26	26	2	13	1	1	3	3	1	2
Neutron Generation -- Rossi Method										
Naval Research Laboratory	38	19	11	8	0	0	0	0	0	0
Neutron Generation -- Teller Method										
Edgerton, Germeshausen & Grier, Inc.	23	23	19	4	0	0	0	0	0	0
Gamma-Ray Spectrum										
Argonne National Laboratory	8	8	2	6	0	0	0	0	0	0
Gamma-Ray Appearance -- Rossi Method										
Naval Research Laboratory	38	19	11	8	0	0	0	0	0	0
Gamma-Ray Appearance -- Teller Method										
Edgerton, Germeshausen, & Grier, Inc.	23	23	19	4	0	0	0	0	0	0
Technical Photography										
Task Unit 7.4.3	175	166	122	43	1	0	0	0	0	0
Blast Measurements										
Naval Ordnance Laboratory	38	38	14	21	0	2	1	0	0	0
Service Tests										
Reinforced Concrete Structures										
Task Group 7.2	2	2	0	2	0	0	0	0	0	0
Structural Shapes										
Task Group 7.3	1	1	0	0	1	0	0	0	0	0
Aircraft Blast Acceleration										
Task Group 7.4	1	1	0	1	0	0	0	0	0	0
Exposure of Biological Material										
Task Group 7.6	1	1	0	1	0	0	0	0	0	0
Exposure of Material to Radiation										
Task Group 7.6	5	5	0	1	2	2	0	0	0	0
Evaluation of New Radiological Instruments										
Task Group 7.6	2	2	0	1	1	0	0	0	0	0
Radiation Shielding by Materials										
Task Group 7.6	4	3	0	0	1	2	0	0	0	0
Evaluation of Collective Protectors										
Task Group 7.6	3	3	0	2	1	0	0	0	0	0
Aerial Survey of Ground Contamination										
Task Group 7.6	1	1	0	0	0	1	0	0	0	0
Aerial Survey of Cloud Intensity										
Task Group 7.6	3	3	0	1	0	2	0	0	0	0
Survey of Cloud Particle Size										
Task Group 7.6	3	3	0	2	1	0	0	0	0	0

Note:

^a Permissible exposure was 0.1 R/day. Overexposure, over 0.1 R/day, to a maximum of 3 R was allowed before removing an individual from additional exposure for a period of 30 days.

service tests could be identified, however, so this information is based on personnel who could be identified with a particular test. Some individuals worked on more than one service test. Wherever this occurred, the individual has been counted under each service test in which he participated. The table omits the special long-range detection operation, since task force personnel did not participate.

WEAPON DIAGNOSTICS EXPERIMENTS

These experiments were designed to measure the output of the nuclear devices, specifically yield, radiation, and blast. LASL was responsible for these experiments and accomplished them with its own personnel or with personnel from other organizations (see Table 8).

Radiochemistry

Agency: Los Alamos Scientific Laboratory (LASL)

Operations: Radioactive cloud samples were collected by eight remotely controlled drone B-17s on two shots by seven drones on one shot. Each drone, controlled by a manned B-17 flying clear of the weapon, made two or three passes through the radioactive cloud shortly after detonation to collect cloud debris on filter paper in special boxes mounted on top of and under the fuselage. Personnel from LASL removed the highly radioactive papers at Enewetak Island and these were flown to Los Alamos, New Mexico, for analysis. The techniques used in handling these samples are discussed in Chapter 2.

Soil samples were collected by a modified light tank with a digging device installed and the turret removed (Figure 39). The tank was unmanned and was controlled from a hovering helicopter. The tank was placed in a protective shelter on the shot island (Figure 40) before the shot. Several hours after the shot it was driven out of its shelter by personnel landed on the island by LCM or helicopter. After the tank was started it was turned over to the controller in the helicopter for sampling runs into the crater area. The craters formed by the SANDSTONE shots were slightly depressed areas on the surface under the burst point, not deep holes in the ground. The concrete bases of the towers survived. A second drone tank was available in the LCM that brought personnel to the island in case the first tank failed. The soil samples retrieved by the tanks were then split, with one part analyzed locally and the other sent to LASL for analysis.

Staffing: LASL (LAJ-2) provided eight men and Aberdeen Proving Ground five men for this experiment. In addition, the entire Drone Unit of 460 men in TG 7.4 participated. LASL civilians performed various tasks, including removal of filters from the drone aircraft. LASL personnel also directed the ground-sample, drone tank operation. This operation was delayed until the filters from the aircraft drones had been removed so that the LASL scientist who supervised that operation could be flown by helicopter from Enewetak Island to the shot island.

The actual operation of the drone tanks involved an officer, an NCO, and three civilians from Aberdeen Proving Ground (Army). The officer acted



Figure 39. Drone tank used for soil sampling operation, Operation SANDSTONE.



Figure 40. Drone tank in revetment; helicopter hovers overhead to control tank after it has been started, Operation SANDSTONE.

as controller in the helicopter on shot days. He was also involved in recovering the tank that stalled after X-RAY and YOKE shots.

The Navy provided the helicopter and pilot for the drone tank operation as well as the LCM and crew for the backup tank. A second helicopter was also involved and was positioned to help the tank-control helicopter keep its position away from the radioactive area. The particular Navy personnel involved cannot be identified.

Participants in this experiment, particularly those handling the samples from the drone aircraft, had relatively high exposures.

Project Reports: References C.3, C.5, and C.10.

Neutron Measurement

Agency: Los Alamos Scientific Laboratory (LASL)

Operations: On all three shots, neutron measurements were made with two strings of samples, a land string and a water string. Samples were placed on the water string from 100 to 1,000 yards (91.4 to 914 meters) at 100-yard (91.4-meter) intervals from surface zero and on the land string from 200 to 1,000 yards (183 to 914 meters) at 200-yard (183-meter) intervals from surface zero. Samples consisted of a variety of elements. Both strings were designed for retrieval of samples by pulling them in from a safe distance.

Staffing: LASL provided 10 men including the LAJ-3 section leader, and AFSWP provided 16 military personnel for this experiment. Exposures of one LASL and one military worker exceeded the 3-R limit (see Table 9). Exposures were generally higher than for other experiments because the samples were retrieved shortly after each detonation.

Project Reports: References C.18 and C.19.

Neutron Generation -- Rossi Method

Agency: Naval Research Laboratory (NRL)

Operations: Instrumentation was placed at three to four stations (depending on the shot) at varying distances from surface zero. In addition, one test station was located at the base of each shot tower, one station 300 meters from each shot tower, and one station located over 1,000 meters from each shot tower. Data and films were recovered from the various stations 7 hours after the X-RAY detonation and 4 hours after the YOKE and ZEBRA detonations.

Staffing: NRL provided 22 men including the project leader, and AFSWP initially provided 16 military personnel for this experiment. After X-RAY about one-third of the military participants were released to AFSWP, and after YOKE all but one of the remaining military were released to AFSWP. All personnel were billeted on USS Albemarle (AV-5). Exposures were low, as reflected in Table 9.

Project Reports: References C.11, C.12, and C.13.

Neutron Generation -- Teller Method

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

Operations: Measurement of early neutrons was attempted by detecting visible light variations. A mirror optical system was used with photomultipliers.

Staffing: EG&G provided 11 technicians including the project leader, and AFSWP provided 12 personnel. Since return to the shot island for recovery operations was unnecessary, exposures were quite low (see Table 9).

Project Reports: References C.15, C.16, and C.17.

Gamma-Ray Spectrum

Agency: Argonne National Laboratory

Operations: Argonne was charged with measuring gamma rays as a function of time. "Gamma shelters" were constructed on or near each shot island: Shelters A and B for X-RAY, and Shelters A, B and C for YOKE and ZEBRA. The shelters were located 750, 1,300 and 1,800 yards (0.69, 1.19, and 1.65 km) from surface zero. Personnel were required to return to the shelters after each shot to retrieve data; however, because of distances to surface zero, radiation at recovery time was at an acceptable level.

Staffing: Eight Argonne staff members managed and executed this experiment. Their exposures are shown in Table 9.

Project Report: Reference C.29.

Gamma-Ray Appearance -- Rossi Method

Agency: Naval Research Laboratory

Operations: The experiment was essentially identical to the Neutron Generation -- Rossi Method experiment. Gamma output was calculated from measured neutron production.

Staffing: Staffing was the same as for the Neutron Generation -- Rossi Method experiment.

Project Reports: References C.11, C.12, and C.13.

Gamma-Ray Appearance -- Teller Method

Agency: Edgerton, Germeshausen & Grier, Inc.

Operations: The experiment was essentially identical to the Neutron Generation -- Teller Method experiment. Gamma output was calculated from measured neutron production.

Staffing: Staffing was the same as for the Neutron Generation -- Teller Method experiment.

Project Reports: References C.15, C.16, and C.17.

Technical Photography

Agency: Task Group 7.4 (TG 7.4)

Operations: Fireball growth can be used for a variety of nuclear device diagnostic measurements if good photographs are collected. Four large towers were constructed for photography at locations that allowed use of two towers on each shot. A tower constructed on a coral head in the lagoon was used for all three shots. Towers were also built on Ananij, Aomon, and Runit; one was used for each of the three shots. Film was placed in cameras the day before each shot and retrieved from the Coral Head Photo Tower by personnel in small boats (LCM) and from the island towers by personnel flown over in L-5 aircraft the morning of the shots. In addition to tower photography, LASL also required airborne photography of the fireball growth. TG 7.4 (Air Force) furnished two OA-10 and two F-13 aircraft for technical photography on each shot. These aircraft circled the surface zero island at a safe distance, at altitudes ranging from 12,000 feet (3.7 km) to over 30,000 feet (9.1 km).

Staffing: LASL furnished 19 photographers and 3 other men to assist TG 7.4, which managed the entire photography program. The Air Force Photography Unit (Task Unit [TU] 7.4.3) had 175 personnel assigned, including the 19 LASL civilian photographers and 12 Army, 5 Navy, 1 Marine, and 138 Air Force personnel. This group is discussed further under TU 7.4.3 (Photography Unit) in Chapter 7. Those in TU 7.4.3 involved with technical photography cannot be distinguished from those involved with documentary photography; therefore, Table 9 lists everyone in TU 7.4.3.

Project Reports: References C.27 and C.28.

Blast Measurements

Agency: Naval Ordnance Laboratory (NOL)

Operations: To measure peak overpressure at various distances, variation of pressure with time, and shock arrival time, concrete piers 1.5 feet (0.46 meter) high were set in the ground from 220 to 2,921 yards (0.20 to 2.67 km) to hold blast gauges on each of the three shots. The gauges were primarily self-recording and consisted of empty beer cans, foil-meters, pipes, 5-gallon (19-liter) cans, indenter gauges, velocity switches, harps, and free-piston gauges, but some strain-gauge data were telemetered. Gauges were retrieved the afternoon of D+1. Recovery crews were accompanied by a monitor and wore film badges, pocket dosimeters, booties, caps, and gloves.

Staffing: NOL provided 21 men including the project leader, AFSWP provided 12, Army Ballistics Research Laboratories provided 3, David Taylor Model

Basin provided 1, and LASL provided 1 this experiment. All 38 were badged; most exposures ranged from zero to 0.5 R (see Table 9).

Project Reports: References C.20, C.21, and C.22.

SERVICE TESTS

These experiments were designed to measure effects of the detonations on equipment and structures. They were requested by the military services, approved by the AEC, and conducted by a variety of task force organizations.

Reinforced Concrete Structures

Agency: Task Group 7.2 for Office, Chief of Engineers (Army).

Operations: To determine the protection afforded by structures and earth barricades against blast and radiation from an atomic detonation, four reinforced concrete structures and one earth barricade were constructed on Enjebi Island and subjected to the effects of the X-RAY detonation. The structures were 12 by 24 feet (3.7 by 7.3 meters). Two had walls 1 foot (0.30 meter) thick and two had walls 2 feet (0.61 meter) thick; the former were located at 1,500 and 2,500 feet (457 and 762 meters) from surface zero and the latter located at 1,000 and 1,500 feet (305 and 457 meters) from surface zero. The earth barricade was 10 feet (3 meters) high and located 2,500 feet (762 meters) from surface zero. Navy Bureau of Ships (BuShips) personnel (TG 7.3) placed gamma-reading film badges and AFSWP placed neutron detectors in the structures. BuShips personnel also placed test samples on the exterior of the structures for thermal radiation studies. Photographs were taken of the structures before and after the shot to record the effects.

Staffing: Two TG 7.2 personnel have been identified with this experiment, an Army major and a civilian employed by the Army. Exposures were less than 0.5 R for both (see Table 9).

Project Report: Reference C.24.

Blast Resistance of Structures

Agency: Task Group 7.3 for Navy Bureau of Yards and Docks

Operations: To determine blast damage to a variety of structural shapes made of concrete, steel, and wood, 79 specimens were exposed on X-RAY and 92 specimens were exposed on YOKE. Structural shapes included cubes, prisms, cylinders, spheres, half-cylinders, pyramids, and domes, all with varying thicknesses. Figure 41 shows these shapes on Aomon after the YOKE shot. The specimens were placed between 1,000 and 5,000 feet (0.31 to 1.52 km) from surface zero. To record and evaluate the damage, pre- and postshot photographs were taken, visual examinations were made and recorded, and the contours of all steel specimens were measured and recorded.

Staffing: Most specimens were designed and constructed at locations in the United States. Army engineers built a few on site; however, they departed



Figure 41. Navy Bureau of Yards & Docks experimental structural shapes after shot YOKE, Operation SANDSTONE.

the forward area before the test series began. An onsite Navy lieutenant commander was the manager of the experiment and received less than 1 R during the series (see Table 9).

Project Report: Reference C.25.

Aircraft Blast Acceleration

Agency: Task Group 7.4

Operations: Four of the 12 B-17 drones used for cloud sampling were instrumented with accelerometers, strain gauges, and pressure gauges to measure and record the initial blast effects and buffeting they received when they penetrated the radioactive cloud. This instrumentation was removed by TG 7.6 air monitors when the drones landed at Enewetak, shortly after completing their cloud sampling missions.

Staffing: An Air Force colonel was the onsite manager for this experiment. Drone Unit (TU 7.4.2) and TG 7.6 personnel assisted in preparing the instrumentation in the drones and in removing the recorded data. The colonel's exposure is listed in Table 9.

Project Report: Reference C.23.

Exposure of Biological Materials

Agency: Task Group 7.6 for Navy Bureau of Medicine and Surgery (BuMed).

Operations: Selected biological materials, including seeds, grain, insects, fungi, and bacteria, were exposed to ionizing radiation during the first

two shots. These came from the Department of Agriculture, California Institute of Technology, Army Chemical Corps, and Naval Medical Research Institute. The materials were placed in 20 separate packets and located at distances from 250 to 1,000 yards (229 to 914 meters) from surface zero.

A second part of this experiment consisted of placing four empty animal containers between 350 and 1,500 yards (0.32 and 1.37 km) from the X-RAY and YOKE detonations. The purpose was to determine their suitability for use in future irradiation testing of larger animals, such as dogs and pigs.

Staffing: A Navy captain from TG 7.6 managed this experiment. Recovery after detonation was not time-sensitive so exposure to radiation was low (see Table 9).

Project Report: Reference C.33.

Exposure of Materials to Radiation

Agency: Task Group 7.6 for Navy Bureau of Ships (BuShips)

Operations: Small samples of several materials were exposed at 12 separate stations on each of the three SANDSTONE shots to determine the effects of radiation from fission products. Some of the materials had special coatings.

Staffing: Five TG 7.6 personnel managed this experiment for BuShips. Their exposures are listed in Table 9.

Project Report: Reference C.5.

Evaluation of New Radiological Instruments

Agency: Task Group 7.6 for Navy Bureau of Ships

Operations: Several new types of radiac meters were tested and evaluated under field conditions. Twelve types of beta-gamma instruments were tested, some of which were also designed to measure alpha activity. Seven types of pocket dosimeters were tested along with newly designed dosimeter chargers and new concepts in alpha meters. A total of over 300 gamma-beta instruments and over 1,000 pocket dosimeters were available for field testing by TG 7.6.

Staffing: Two TG 7.6 personnel were assigned to test these instruments under field conditions. Their exposures are included in Table 9.

Project Report: Reference C.31.

Radiation Shielding by Materials

Agency: Task Group 7.6 for Navy Bureau of Ships

Operations: Film badges were placed behind concrete, steel, and other samples to determine relative radiation protection. Samples varied in thickness and in distance from surface zero.

Staffing: Four TG 7.6 personnel were assigned to this experiment (see Table 9).

Project Reports: References C.5 and C.43.

Evaluation of Collective Protectors

Agency: Task Group 7.6 for Army Chemical Corps

Operations: To determine the efficiency of a system for the removal of airborne radioactive materials, field collective protectors were installed before X-RAY, one in the reinforced-concrete structure at 1,500 feet (457 meters) from surface zero and one in an LCVP 2,500 yards (2.29 km) downwind from surface zero. The LCVP sank before the detonation and a second collective protector was installed on an LCM downwind of the YOKE surface zero. Recovery soon after the burst was unnecessary and exposures were low, although the LCM was highly radioactive and was scuttled rather than decontaminated.

Staffing: Three TG 7.6 personnel have been identified with this experiment. Their exposures are listed in Table 9.

Project Reports: References C.24, C.30, and C.43.

Residual Crater Contamination

Agency: Task Group 7.6

Operations: The Technical Measurements Unit (TU 7.6.6) was responsible for this experiment. Unit personnel carried out studies of residual radiation in the craters by measuring radiation in soil samples collected by remotely controlled tanks on shot day and several succeeding days.

Staffing: Two U.S. Public Health Service personnel in TG 7.6 have been identified with this experiment. Personnel from the Aberdeen Proving Ground operated the drone tank and their exposures are listed under TG 7.1 in Table 9.

Project Report: Reference C.43.

Aerial Survey of Ground Contamination

Agency: Task Group 7.6

Operations: The concept of this test was to determine if an aerial radiation survey could be used to determine levels of radioactivity on the ground. A C-47 aircraft flew over the contaminated islands shortly after each detonation at altitudes varying from 1,000 to 7,000 feet (0.31 to 2.13 km) taking readings of gamma intensity. This procedure was repeated on D+1 for each detonation and again on D+6 (except for the ZEBRA shot).

Staffing: The C-47 was flown by a crew from TG 7.4. A TG 7.6 monitor conducted the experiment. His exposure is included in Table 9.

Project Report: Reference C.43.

Aerial Survey of Cloud Intensity

Agency: Task Group 7.6

Operations: Film badges were placed in each drone that conducted sampling operations on all three shots. Since each drone sampled the radioactive cloud at an assigned altitude, this assisted in determining distribution of intensity within the cloud. Badges were removed by TG 7.6 personnel when the drones landed at Enewetak.

Staffing: Three individuals from TG 7.6 have been identified with this experiment. Two had exposures in excess of 1 R (see Table 9).

Project Report: References C.30 and C.43.

Survey of Cloud Particle Size

Agency: Task Group 7.6 for Army Chemical Corps

Operations: Cascade impactors, which collect particles in the air, were placed in all four reinforced concrete shelters for X-RAY. For ZEBRA, a cascade impactor was in one of the drones. For YOKE and ZEBRA a cascade impactor was in operation on board an LCM, 2,500 yards (2.29 km) downwind of surface zero. Recovery was on D+1.

Staffing: Three TG 7.6 personnel have been identified with this experiment. Their exposures are listed in Table 9.

Project Report: Reference C.30.

CHAPTER 4

TEST OPERATIONS

Each SANDSTONE nuclear device was placed on a 200-foot (61-meter) tower, allowing clear lines of sight from instrument stations to the burst point. The islands used -- Enjebi, Aomon, and Runit -- were stripped of vegetation and graded level to facilitate instrument placement and test activities. On Enjebi, the 1944 World War II bombardment had destroyed the coconut palms, and only shrubby brush on the island remained before SANDSTONE. Aomon, nearby Bijire, and Runit, however, had to be cleared of these trees, although one section of Aomon was left untouched.

A causeway was built between Aomon and Bijire in preparation for SANDSTONE. The causeway allowed underground instrument cable runs from the test tower to an instrument station on Bijire. It was also a roadway for a radio-controlled tank used to collect samples of soil in the burst area, and allowed freer movement of construction and test personnel on the small islands before the shot. Details of instrument placement and experimental activities are in Chapter 3.

The succession of shots was from Enjebi, the most northern and western of the test islands, to Runit, the most southern and eastern. Winds at Enewetak are usually such that the area of potential contamination by radioactive fallout would lie north of a line running west-southwest to east-northeast, passing just south of the burst point. Moving the shot points progressively from northwest to southeast minimized the possibility of personnel working in areas contaminated by prior shots.

Operations for each of the three test shots were similar but were carried out more precisely with YOKE and ZEBRA as collective experience grew (Reference C.3, p. IX-70). Operations were rehearsed from 4 to 8 April, with the latter the date of the X-RAY shot rehearsal.

Test operations began about a week before each shot, when various samples of materials to be exposed were set out in or near test structures and at other measurement sites.

On D-3, a meeting of all commanders and principal staff officers was held to determine if all preparations were sufficiently advanced to permit proceeding according to schedule. Upon receiving Commander Joint Task Force 7 (CJTF 7) approval to proceed, orders were issued to execute the Evacuation Plan.

On D-2, movements within and into the atoll were restricted to last-minute essentials; all islands except Enewetak and Parry were searched to ensure that everyone had been evacuated.

On D-1, a personnel muster took place to ensure an accurate check of all personnel; last-minute preparations of all scientific equipment were carried out; and Enewetak Atoll was evacuated completely except for the personnel and equipment essential for the test.

Throughout test preparation days, the weather watch continued to ensure that the day selected for the test would have favorable weather.

Wind direction and velocity at all altitudes were critical to minimize the possibility of fallout from the radioactive cloud on task force ships and any inhabited islands. Light, variable winds, which made forecasting more difficult, and winds with a northerly component presented unfavorable conditions for firing. Clouds that would interfere with visual direction of drone aircraft through the radioactive cloud also made firing conditions unfavorable. Additionally, heavy cloud cover would interfere with aerial photography, but since this was not essential to scientific recording, this condition could be tolerated if other criteria were favorable. Rainshowers that could be predicted as "few and scattered" were acceptable, but predicted "heavy showers" were not acceptable because of possible interference with surface photography, which was essential to scientific recording. Keeping the drone aircraft away from all rainshowers to avoid wetting their filters was also essential.

During periods of normal trade wind conditions, weather forecasts could be made with a high degree of certainty, but during periods of little weather movement, forecasts were very uncertain (Reference C.2, pp. III-24 and III-25).

Three musters were held on the day before each shot. The first, at 0600, was to account for everyone who was in the Enewetak area before personnel left for their assigned shot-hour stations. The second, at 1330, was to ensure that personnel were at their assigned stations before the departure of the boats and ships. The third, at 1800, was to determine the whereabouts of everyone in the task force (Reference C.7, p. 157).

Task force personnel on Enewetak were evacuated to ships the day before the shot, except for a small group that remained on Enewetak and Parry islands for the three shots. The temporary camps on Enjebi, Runit, and Aomon were abandoned and dismantled for each shot on those islands. Evacuation of Enjebi before X-RAY was photographed and is shown in Figure 42. The shot tower is in the background. Task force ships evacuated the lagoon except for USS Albemarle (AV-5), USS Mount McKinley (AGC-7), USS Curtiss (AV-4), USS Bairoko (CVE-115), AVR C-26638, and AVR C-26653 (air-sea rescue boats), which were off Parry Island.

Plans were made to evacuate Ujelang (the atoll to which the Enewetak people had been moved before Operation SANDSTONE began) if fallout from any of the three shots occurred there. An LST was dispatched to Ujelang on D-3 for each shot to stand by if needed for evacuation. Four C-54 aircraft were on standby at Kwajalein to assist in evacuating the skeleton force on Enewetak if fallout occurred. Neither contingency plan had to be used for any of the three shots.

Cloud sampling was conducted by directing unmanned B-17 drones through the cloud. These drones were controlled by manned B-17 controller aircraft on a one-to-one basis. The drones were landed at Enewetak where the "hot" filter papers were removed and flown to Los Alamos Scientific Laboratory (LASL) for analysis. Analyses of the bomb debris collected by these filters were used to determine device yields and other technical data.



Figure 42. Evacuation of Enjebi before shot X-RAY, Operation SANDSTONE. Shot tower in background.

Choice of the shot hour was a compromise that resolved conflicting requirements. The experiment to measure gamma output by the Teller method needed darkness to record visible light emission. However, Task Group (TG) 7.4 (Air Force) needed daylight for the B-17 control aircraft to properly guide the B-17 drone sampling runs. Several early morning practices were held by TG 7.4 to determine the earliest possible time it could fly the drones, and a shot time that was dark enough for the gamma measurement and light enough shortly thereafter for sampler control was chosen.

The Air Force also operated C-54 and F-13 aircraft for photography, SB-17 and OA-10 aircraft for search and rescue, and WB-29 aircraft for weather reconnaissance and cloud tracking. Eleven other C-54s were available for courier service and emergency evacuation. Five were designated for transport of filter papers, soil samples, and film to the United States. Four of these aircraft were at Enewetak on shot days. Four C-54s were on standby at Kwajalein for emergency evacuation of Enewetak. One was used to ferry B-17 drone spare parts between Kwajalein and Enewetak and another ferried photo equipment from Kwajalein to the United States. Table 6 contains a list of the aircraft available to support SANDSTONE.

X-RAY

The X-RAY nuclear device was detonated with a yield of 37 KT at 0617 on 15 April 1948 just before sunrise on a tower on Enjebi. Figure 43 shows ship positions at burst time. The detonation produced a brilliant flash, and observers felt radiant heat on their faces for an instant. The fireball was immediately obscured by a condensation (Wilson) cloud that moved out behind the advancing shock wave and formed a hemispherical shape with a diameter of about 5 nmi (9.3 km), which was illuminated from within by the fireball. This cloud disappeared after a few seconds, and the incandescent fireball changed from nearly white, to yellow, to orange, and finally to red in about 20 seconds. In 45 to 50 seconds, the sound of the shot -- like that of heavy thunder -- reached the observers on the ships in the lagoon.

The radioactive cloud pushed through the deck of broken cumulus shortly after the first minute. When its top reached 40,000 feet (12.2 km) in approximately 5 minutes, an ice cap was seen to form. The darkness prevented careful observations, and not all observers reported this ice-cap phenomenon. After 6 minutes, the cloud top was at approximately 44,000 feet (13.4 km). The cloud consisted of two major portions: the mushroom with its tapering stem, and a large cumulus-type cloud from which the stem appeared to extend. This lower cloud portion reached up to an estimated height of 15,000 feet (4.6 km) and was mingled with the other lower clouds so that it was mostly obscured. As the mushroom continued to rise, it began to move eastward with the prevailing southwesterly winds. This eastward drift had begun between 3 and 4 minutes after the detonation, when the cloud had reached approximately 30,000 feet (9.1 km). Meanwhile, the lower portion was drifting westward, and the stem was elongating and becoming smaller in diameter.

At 9-1/2 minutes, Albemarle observers recorded a clean break, or shear, between the upper and lower cloud masses that was estimated to occur at 20,000 feet (6.1 km). The stem of the cloud rapidly dispersed in this wind shear region during the following 3 or 4 minutes, leaving an irregular patch of dust or smoke that separated itself from both the upper and lower portions of the cloud. This shear point was at about the altitude that measured winds showed a direction change from predominantly northwest to predominantly northeast.

Between 12 and 13 minutes after detonation, the mushroom reached its highest altitude. The upper portion of the cloud was estimated to be approximately 5.5 nmi (10.2 km) in diameter at this time, and its center was 19 nmi (35.2 km) from the observing ships. After reaching maximum altitude, the upper cloud was moved by a wind from 230° at approximately 25 knots (46 km/hr).

The lower cumulus-type portion of the cloud remained visible for about 20 minutes, when it was obscured by other clouds. The stem of the mushroom, which formed a broad, irregularly shaped area of fine dust and smoke, appeared to disperse in the region of wind shear and disappeared after about 2 hours. The primary portion maintained its general shape but appeared to become thin and sheet-like so that it closely resembled cirrocumulus. Finally, in approximately 3 hours even this most prominent part of the cloud could not be distinguished by surface observers (Reference C.35, pp. 9 and 10).

At H-hour plus 20 minutes a helicopter left Bairoko to go to Enjebi to check on the cable winch, which was there to retrieve samples from near the

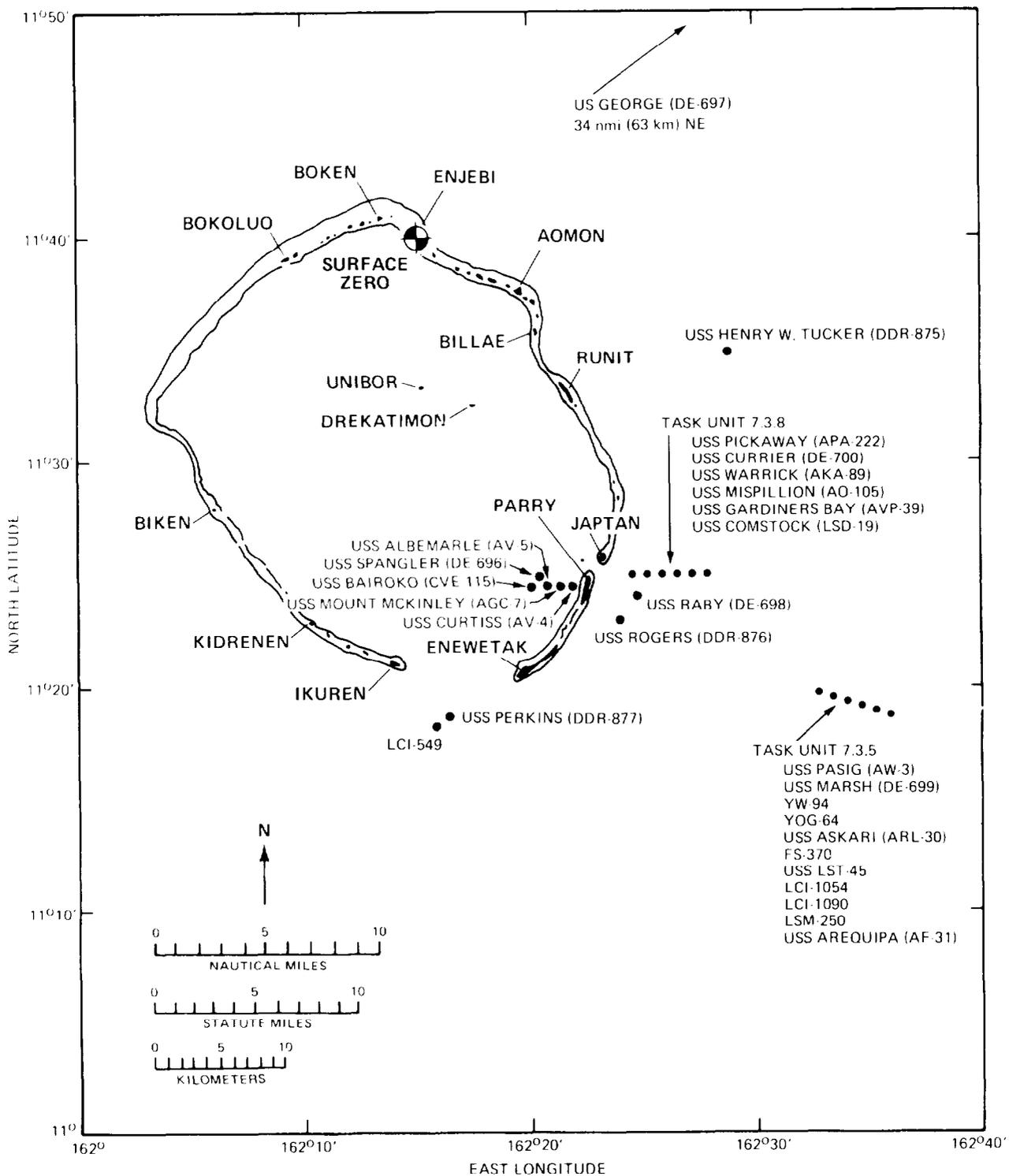


Figure 43. Ship positions at shot time, SANDSTONE, X-RAY.

burst point, and the feasibility of other data-recovery work in that area. Ten minutes earlier an AVR had left Parry for Enjebi in case a helicopter in the shot area required assistance. Another AVR with a group of radsafe monitors, who were to be set ashore on Enjebi, also left Parry at this time. These men were monitors for high-priority data-recovery missions (Reference C.3, p. IX-67).

At H-hour plus 45 minutes, Bairoko got underway from the anchorage and moved toward Enjebi. When the ship was about 5 nmi (9.3 km) from Enjebi two small boats were lowered. These were manned by TG 7.6 personnel and preceded Bairoko, surveying the lagoon waters for radioactivity. After Bairoko was anchored off Enjebi, these boats continued this survey activity in the lagoon (Reference C.3, p. IX-68).

The B-17 drones had been flown to Enewetak Island the day before and the B-17 controllers arrived from Kwajalein early enough on the morning of 15 April to have all eight drones in position before the detonation. One B-17 drone became unmanageable and crashed in the ocean a few minutes before the detonation. Five drones made three cloud penetrations and the remaining two drones made two cloud penetrations to collect cloud debris. These seven drones were landed at Enewetak and the filter papers removed. Filters from the top of the fuselage were removed, placed in flat lead boxes by 0900, and were en route to LASL aboard a C-54 by 0945. Filters from the under-fuselage box were en route by 1040 (Reference C.23, p. 28). The drones were washed down with kerosene and distilled water by TG 7.6 personnel and returned to Kwajalein 5 days later (Reference C.3, pp. VIII-68 and 70, IX-113).

A light tank had been modified at Aberdeen Proving Ground to scoop up soil samples in the craters formed by the detonations. The character of this crater is shown in Figure 44. It was merely a slightly depressed area surrounding the remains of the shot tower. The tank had been parked on Enjebi in a specially



Figure 44. Monitor in SANDSTONE, X-RAY crater, probably 6 days after the shot. Stumps of the shot tower are shown.

built protective revetment in preparation for the X-RAY shot. After the filters had been pulled from the drone aircraft, the Rad-Chem section chief flew to Enjebi in a helicopter to supervise soil sample collection. He first advanced toward the crater to set out a row of red flags indicating the limit of safe approach. The antenna of the revetted tank had been sheared off by the blast. After the antenna of the backup tank was used as a replacement, the tank was started. A helicopter, hovering at a safe distance, was used to guide the tank into the crater by radio control. On the third attempt the tank mired in the soft soil and could not be restarted. Since the backup tank in an LCM in the lagoon lacked a radio antenna, it could not be used (Reference C.43, Annex I).

The C-47 for aerial radsafe survey left Enewetak at H-hour plus 30 minutes and flew to a position 10 nmi (18.5 km) upwind of the shot point, where it began its survey at H-hour plus 69 minutes. Almost immediately the monitor observed a reading of 0.12 R/hr and ordered a change of course. The plane had apparently come under a fringe of the upper portion of the cloud. The background in the plane remained at 0.008 R/hr for 1 hour, but had decreased to 0.001 R/hr by landing time. Flights at altitudes from 5,000 feet (1.52 km) down to 1,000 feet (0.30 km) over the crater followed; peak rate readings of 3.5 R/hr (uncorrected) were recorded. Later flights over the islands west of Enjebi indicated that, as expected, they had been contaminated by fallout. Readings of 0.5 R/hr were recorded 200 feet (61 meters) over Boken, Bokaidrik-drik, and Dridrilbwij (Reference C.30, Rpt 2, p. 17).

The diagnostic experiments fielded by LASL (LAJ-3) were attached to a land cable and a water cable. LAJ-3 personnel, accompanied by a monitor, were flown by helicopter to the land cable that was attached to a winch situated in a relatively safe position. This cable was successfully winched in and most samples were recovered. The water-cable samples suffered appreciable blast damage, and 2 days were required to recover those that could be located. Exposures for the land-cable sample recovery personnel were less than 0.200 R for the 2-hour mission. A survey of the water cable locations took a second party nearer to the shot point. Exposures were higher, but "well within the tolerance established." The "tolerance established" is not cited in the source document, but must refer to the up-to-3 R exposure allowed for "specific urgent missions." The monitor for both the first and second parties was the same person and was, in fact, also the project leader for the experiments. His total exposure for the day was 0.75 R (Reference C.43, Appendix I, Annex I, p. 3, and Appendix I, Annex I, Appendix 1, p. 5; and Reference E.1).

Five hours after detonation, personnel from LAJ-4 and LAJ-5 were helicoptered to Enjebi. They recovered instruments and film from the timing station and Gamma B station. Jeeps left on the island were used for transportation (Reference C.5, p. 3-22).

Photo personnel recovered film from the Coral Head Photo Tower by LCM from Enewetak and from the Aomon Photo Tower by L-5 aircraft. Blast records were recovered from Enjebi by LAJ-8 personnel on D+1 (Reference C.5, p. 3-22).

Two C-54 and two F-13 aircraft photographed the detonation. Two were at 12,000 feet (3.66 km), one at 30,000 feet (9.14 km), and one above 30,000 feet (9.14 km). They flew from Kwajalein and circled Enjebi from a safe distance while taking pictures (Reference C.7, p. IV-19).

One weather reconnaissance WB-29 flew over Enewetak from midnight to 0530 the morning of the shot. The WB-29 on this mission lost a propeller and aborted the mission; however, it was replaced by a second WB-29. After the detonation, the WB-29s were used in 12-hour shifts for 5 days to track the radioactive cloud. All of these aircraft returned contaminated and the aircraft crews required decontamination (Reference C.3, p. IX-102). In fact, the filters from one WB-29 were too radioactive to analyze initially (Reference A.4, p. 22).

Albemarle, Mount McKinley, and Curtiss steamed to Aomon from Parry after sunrise on D-day (15 April) to begin preparations for the next shot. Bairoko steamed to Enjebi to set up radiation controls and monitor personnel and equipment for radioactivity (Reference C.5, p. 3-21).

A fallout chart of Enewetak, Kwajalein, and Ujelang atolls was maintained on board Bairoko. The Enewetak chart included daily surface and air radex areas. Fallout patterns for surface, 15,000, 20,000, 25,000, and 30,000 feet (4.6, 6.1, 7.6, and 9.1 km) were plotted (Reference C.43, Annex 1).

The unpopulated islands west of Enjebi were heavily contaminated; however, the rest of the islands were relatively free of any radioactivity. On D+5, CTU 7.6 recommended closing the islands from Elle around to Southwest Passage because of radioactivity along the beaches and evidence of fallout. Temporary clearance of the other islands and their beaches for swimming was also recommended (Reference C.43, p I-4).

Evidently, monitors from TG 7.6 were in heavy demand, for on 19 April the task force commander sent a dispatch to all task groups as follows:

19 April 1948

From: CJTF-7

Action: All Task Group Commanders

Personnel of Task Group 7.1 will be allowed to work on Enjebi in the area in which radiation intensity is less than 12.5 mR/hr for a period of 8 hours unaccompanied by a monitor in accordance with the following procedures: CTG 7.1 will be notified daily by CTG 7.6 as to the extent of this area and CTG 7.1 will inform all TG 7.1 working parties, who can accomplish their work in this area, of the extent of the area. CTG 7.6 will insure that there will be at least one monitor in this area to advise all individuals working under the above provisions. CTG 7.6 will provide for issue of film badges, pocket dosimeters and clothing as necessary at the landing area on Enjebi. Upon returning all working parties will stop at the Bairoko as it is not feasible to monitor personnel for contamination on Enjebi due to high background.

The bogged tank that was to collect soil samples was recovered on 25 April, 10 days after the shot (Reference C. 43, Annex I, p. 27). This recovery was done by attaching a cable to the tank and pulling it free of the loose sand with another vehicle, after which the tank was driven out by an Aberdeen Proving Ground (APG) technician. The cable could not be hooked to any substantial

point on the top of the tank's hull, although attempts were made. Finally, the cable was hooked to a towing point on the underside of the tank's hull. According to the Army officer from APG who did the hook up, this required considerable time crawling under the tank. The LASL radiochemist who was in charge of the project and was at the recovery acting as the monitor recollects that the hookup required little more than bending at the waist to accomplish (Reference D.5). A recent analysis was made of this incident using the conservative (and incorrect) assumption that the incident took place 5 days after X-RAY shot. Assuming that extensive crawling was required, the results of this analysis were that the whole-body gamma dose would have been between 4.4 and 7.2 rem. All personnel were badged for the incident and the APG officer's badge recorded 0.140 R for the day. The film badges of the four monitors on this mission recorded between 0.150 and 0.180 R for the day (Reference E.1).

Engineers destroyed the remains of the test structures on Enjebi in order to prevent unauthorized persons from obtaining any information on the effects of the test. Nine days after the shot, Bairoko had shifted its anchorage to a location near the YOKE test site, joining the test support ships that had moved there earlier. Eleven days after the shot, Enjebi was closed to all personnel.

YOKE

YOKE was detonated at 0609, just before sunrise on 1 May 1948 on a tower on Aomon. It had been postponed 1 day because of unfavorable winds. Its yield was 49 KT, the largest nuclear detonation to that time. Figure 45 shows ship positions at shot time. Observers noted the same brilliant flash and heat as from X-RAY, but the condensation cloud was larger, about 6 nmi (11.1 km) across. The sound of the YOKE detonation was perceived as a "resounding pop . . . similar to . . . [but] considerably magnified . . . a paper bag which is forcefully burst in a small room" (Reference C.35, p. 9).

When the condensation cloud vanished, the fireball was seen. The base of the fireball seemed to spread out over the island and appeared to linger momentarily before rising. In about 10 seconds the fireball had grown to a diameter of 1 mile (1.6 km). The brilliant yellows and oranges changed to red as the incandescent gases cooled in about 20 seconds. In one minute, the mushroom top was estimated at about 2 miles (3.2 km) in diameter. From about 2 to 5 minutes, the cloud rose as a large, spherical mass on a broad stem, leaving a relatively thick trail of dust and smoke in its wake.

After 5 minutes, the mushroom stem bent to the east, as strong westerly winds took effect. The cloud reached a maximum altitude of 56,000 feet (17.1 km). At this time, it consisted, from the surface upward, of (1) a thick vertical mass estimated to be 1-1/2 miles (2.4 km) in diameter extending to 15,000 feet (4.6 km); (2) a slanting column, tilted toward the east, of irregular patches of reddish-brown smoke and dust; and (3) an upper, dominant mass that was about 5 miles (8 km) in diameter and 3 miles (4.8 km) thick. All parts of the cloud remained connected.

At H-hour plus 16 minutes, the highest portion of the cloud resembled an anvil top, similar to that found on a cumulonimbus cloud, assumed to have been caused by its top spreading out as it flattened against the stratospheric

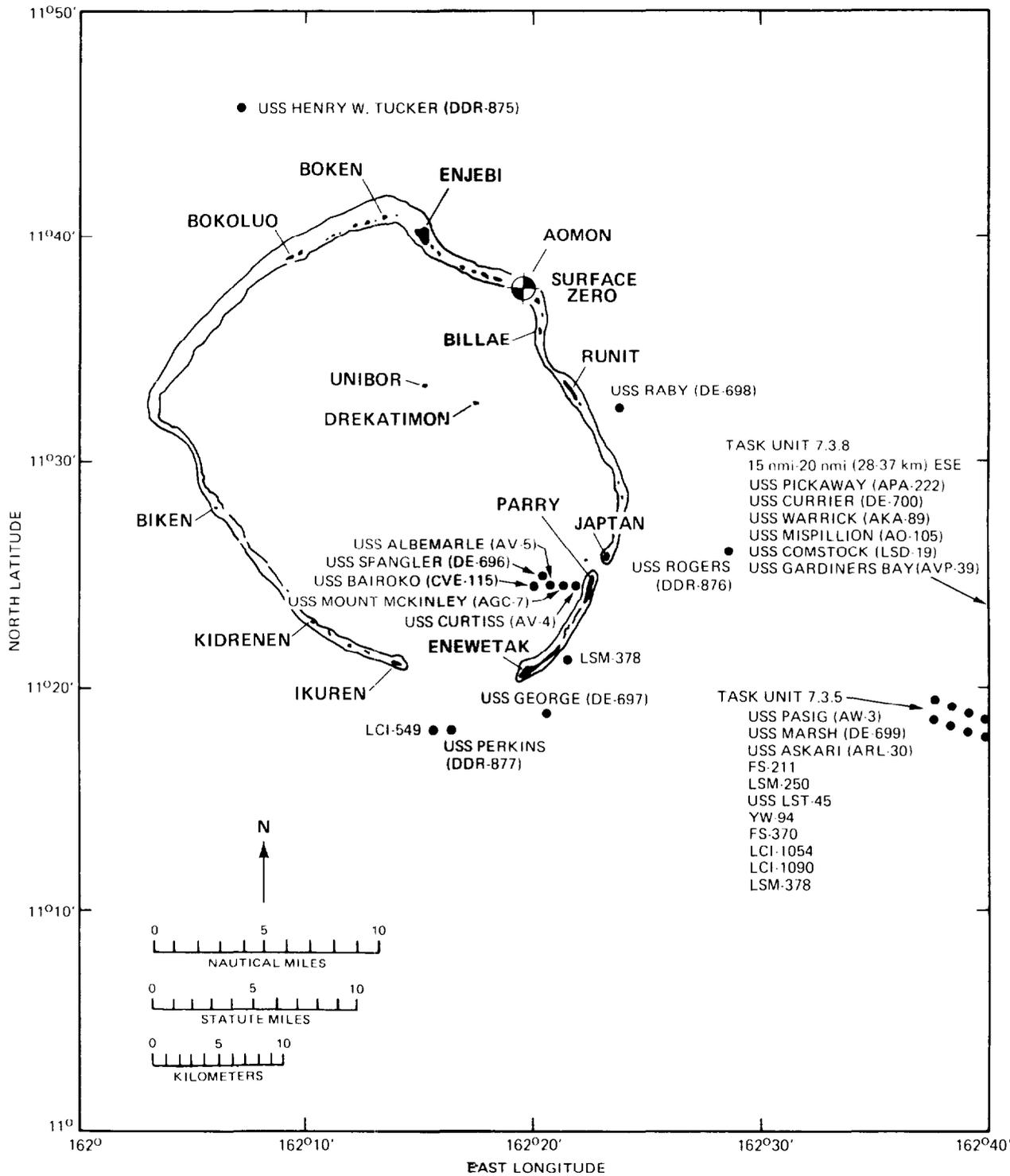


Figure 45. Ship positions at shot time, SANDSTONE, YOKE.

inversion. After 1 hour, the highest portion of the former anvil seemed to contain the only moisture in the entire cloud. It appeared to have stretched out into a rectangular patch of cirrocumulus; whereas the remainder of the cloud maintained its reddish-brown color and smoky, dusty appearance. The cloud had been drawn out by the upper winds into a ribbon whose extremities were about 50 miles (80 km) apart. This ribbon varied in width and density, but remained unbroken. It generally zig-zagged downward in a slanting line from east to west and reached completely across the northern sky. The cloud had moved away until it was less than 10° above the horizon. After 2 hours, it appeared at such a low angle, and was so dispersed, that its general form could not be determined (Reference C.35, pp. 10-11).

Four helicopters landed on Aomon at H+20 minutes to retrieve the land cable with attached samples using a powered winch. A jeep was also used to assist in retrieving the samples. The cable closest to the detonation measured 15 R/hr at a distance of 6 inches (15 cm) when it was reeled in. Two members of the party approached the crater until readings reached 20 R/hr, then retreated. One of these two was the TG 7.6 monitor. His exposure for this mission was 1.450 R (Reference C.43, Annex I).

LAJ-4 and LAJ-5 personnel arrived at Aomon-Bijire by an LCVP at about H+1. They recovered instrumentation from the Gamma A and B stations, which was flown by helicopter to Albemarle. All personnel returned via Bairoko for monitoring and decontamination (Reference C.43, Annex I). The TG 7.6 monitor with this party received 0.800 R during the operation (Reference C.29).

Mount McKinley, Albemarle and Curtiss left the Parry Island anchorage after the shot and steamed for Runit, site of the next shot. Bairoko headed for Aomon to control entry to radex areas and to monitor personnel and equipment from the YOKE shot island. It encountered an increase in background radiation (amount not given) on the bridge even before it departed Parry Island; however, it was not sufficient to be of concern. This same increase was noted on Parry Island (Reference C.43, Annex I).

Fallout charts were maintained for Enewetak, Kwajalein, and Ujelang atolls; again the Enewetak chart included air as well as ground radexes. The unpopulated islands northwest of Aomon were heavily contaminated by shot YOKE (Reference C.43, Annex I).

As they had been for X-RAY, the drones were prepositioned at Enewetak the day before the shot. B-17 controllers departed from Kwajalein early enough on shot day to guide the drones to the target area well before shot time. One drone made a simulated bomb run over the target area at H-hour and took pictures of the detonation. It flew at 20,000 feet (6.10 km) and experienced severe buffeting but returned safely. It did not perform any sampling as the radiation might have damaged the exposed photographic film. It was one of four B-17 drones instrumented to measure blast effects. LASL personnel removed the filters from all sampler drones after they landed at Enewetak and by 0940 had placed them aboard awaiting C-54s for flights to LASL. Drones were again decontaminated by TG 7.6 personnel and flown back to Kwajalein after a few days (Reference C.3, p. VIII-71; Reference C.23, p. 55).

The radio-controlled tank intended to collect soil samples from the YOKE crater was started after 1130. It stalled, and the LCM landed the backup tank and it obtained usable samples. These were shipped back to LASL via Enewetak, being dispatched by air from there after 1510 (Reference C.3, p. VIII-73).

The C-47 was dispatched from Enewetak shortly after the detonation to conduct a radiological survey of Aomon and surrounding islands. It encountered fallout at about 1 hour and 15 minutes and readings inside the aircraft rose to 0.150 R/hr. The intensity did not drop rapidly despite flying through rain clouds to flush its exterior, and the mission was terminated at 0728 when the reading was 0.048 R/hr, only 3 minutes after the fallout was encountered. The C-47 landed at Enewetak at 0805 with a reading of 0.025 R/hr. It was allowed to sit and "cool" until 1310, when the intensity had dropped to 0.004 R/hr. The aircraft then resumed its mission. This later mission was considered quite successful, and several low passes were made over the crater at 500- and 600-foot (152- and 183-meter) altitudes. Intensity readings on one of these passes rose to 25 R/hr. The TG 7.6 monitor on board the C-47 received an exposure of 0.280 R during this mission (Reference C.30, p. 2-20; Reference E.1).

Film recovery personnel were taken to the Coral Reef Photo Tower by an LCM from Enewetak and to the Runit Photo Tower by L-5 aircraft. Monitors accompanied both parties; however, neither tower was radioactive (Reference C.27, p. 40).

Blast records were recovered from Aomon-Bijire the afternoon of D+1 by Naval Ordnance Laboratory (NOL) personnel (LAJ-8) accompanied by a TG 7.6 monitor. All personnel wore booties, caps, and gloves and had pocket dosimeters as well as film badges (Reference C.20, p. 148).

The two C-54 and two F-13 photography aircraft circled the shot island at the same altitudes as for X-RAY -- two at 12,000 feet (3.66 km), one at 30,000 feet (9.14 km), and one above 30,000 feet (9.14 km). They took extensive pictures of the development of the cloud from a safe distance. They flew from and returned to Kwajalein (Reference C.7, p. IV-19).

A WB-29 weather aircraft patrolled the Enewetak Atoll area reporting on cloud conditions from midnight until almost 0600 the morning of the shot. WB-29s were again used to track the radioactive cloud in 12-hour shifts for 5 days (Reference C.4, p. XII-42). Most returned with some radioactivity (Reference C.3, p. XII-102).

Two days after YOKE, Bairoko (anchored off Aomon) experienced fallout. The maximum intensity recorded was 0.0017 R/hr. At about the same time Kwajalein was also experiencing fallout. Intensities on Kwajalein exceeded 0.002 R/hr, and the total lifetime exposure for persons remaining in the open was calculated to be 0.770 R (Reference D.6). Because of concern that inhabited islands might have experienced fallout, drinking-water samples were taken from Majuro, Likiep, Rongelap, Ujelang, and Ujae as well as Kwajalein. All samples were found to be completely safe (Reference C.43, Annex I, Annex IV).

According to the Monitor Schedule, the stalled drone tank was recovered 2 days after the shot. Four days after the shot, a regular monitor station was

set up on Aomon to control access to the island, on which by that time radioactivity had decreased enough to begin destruction of surviving test structures. The island was closed and declared a restricted area 11 days after YOKE (Reference C.43, Appendix I, Annex I, Appendix 1, p. 8).

ZEBRA

The third and last shot of the SANDSTONE series was detonated atop a tower on Runit at 0604 just before sunrise on 15 May 1948. Its yield was 18 KT. Figure 46 shows ship positions at shot time. Observers saw the brilliant flash and felt the heat, as during the two previous shots. The sound was described as like the "bang of an eight inch gun" heard at a distance of several hundred feet. The condensation cloud formed as before, but the base was at an altitude of about 2,000 feet (610 meters), allowing direct observation of the fireball.

Because of its relative nearness and the unobstructed view, the fireball seemed brighter and appeared to last longer than those of previous shots. During the first 2 minutes, the cloud rose almost straight up. After 3 minutes, the upper part of the cloud began to move toward the east. Between 10 and 11 minutes, the top of the cloud moved to the east of the broad stem, and observers on Bairoko were able to look up into the base of what had been the rising mushroom head. These observers stated that the cloud, viewed from the bottom, had a hollow appearance and looked somewhat like a smoke ring.

After H+1, the edges of the cloud became indistinct, and it began to blend with the thin cirrus clouds that almost completely covered the sky. By 90 minutes, the outline of the cloud was indefinite; and at 2 hours, only a light tan patch remained of the primary cloud mass; no other parts of it could be seen.

Eight B-17 drones were directed through the cloud for sampling operations, each aircraft making three passes. One drone was to make a simulated bomb run at 20,000 feet (6.1 km) at H-hour; however, the control B-17 had trouble with this drone, so the bomb run was cancelled. Four of the drones were equipped to measure blast effects. The drones and samples were noticeably more radioactive than on the previous two shots.

As on the previous two shots, five LASL personnel were assigned to remove the filter papers from the aircraft. Three of the five had performed this operation on both the earlier shots. On this shot, however, three of the men received serious beta radiation burns on their hands. Overall gamma exposure for the five ranged from 2 R to 17 R during ZEBRA. This was accumulated as they removed the wire-mesh filter-paper holders from the large filter boxes on the aircraft. After removing these they took the filter papers from the holders and stapled an identifying tag (aircraft number) to each filter paper. Four-foot- (1.2-meter-) long tongs were available to hold the paper, but these were difficult to manipulate in the brisk trade winds and were apparently seldom used. The papers were then placed in flat lead boxes (called "pigs") and transported to two awaiting C-54 aircraft.

The three men who received the radiation burns showered thoroughly and flew back to LASL on the two C-54 aircraft. Even before arriving at LASL their

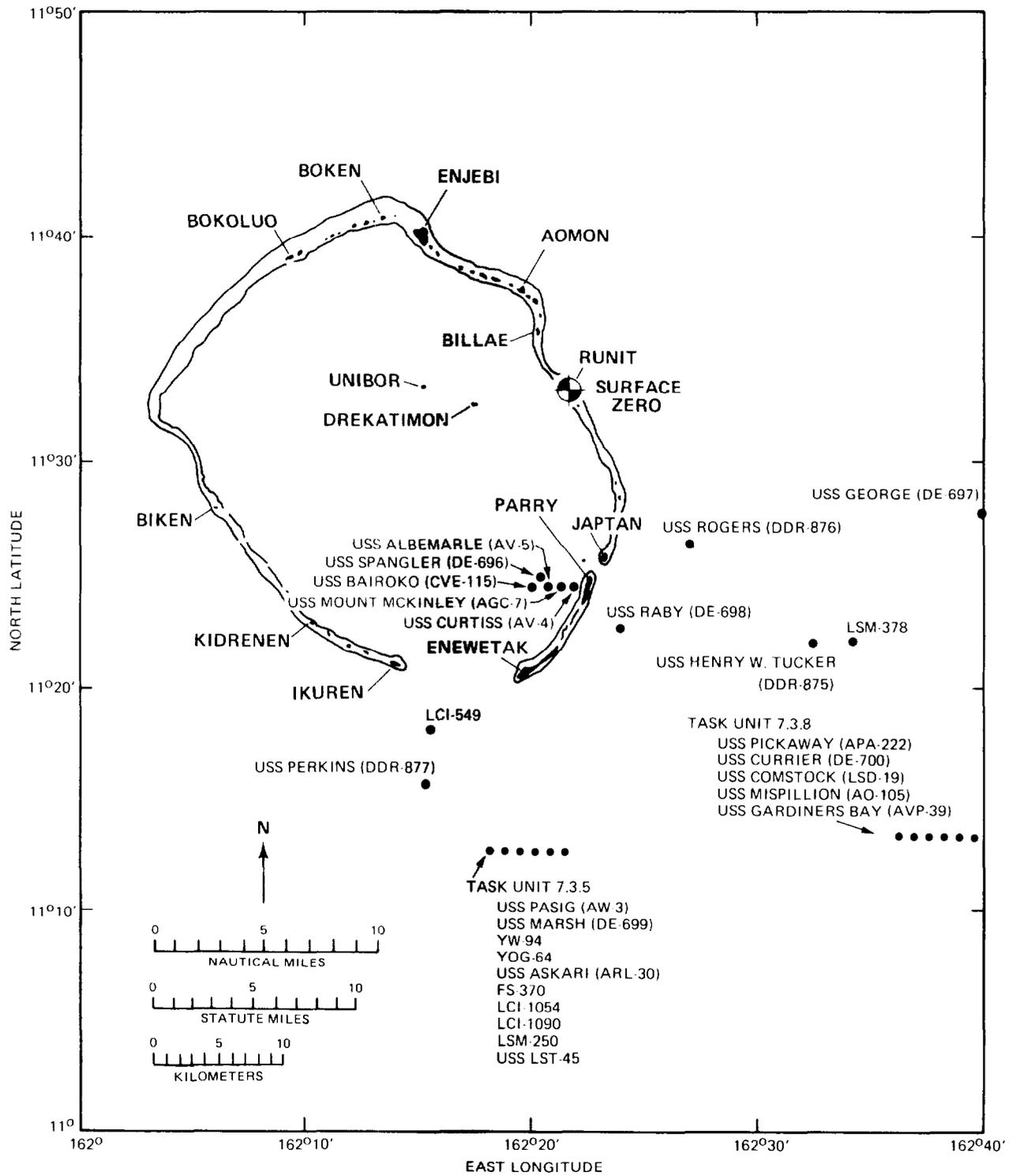


Figure 46. Ship positions at shot time, SANDSTONE, ZEBRA.

hands had become red, swollen, and itching. At LASL their injuries were quickly diagnosed as beta burns and all three were hospitalized. An individual who had done this job for YOKE also had complained of sore hands upon his return to LASL. He was called to the hospital and diagnosed as having beta burns also. He was hospitalized at this time, but was released on 28 May as his burns were minor. The other three men had badly burned hands that required skin grafts (Reference D.2).

TG 7.6 personnel decontaminated the drones during the following few days, and Drone Unit personnel flew them back to Kwajalein (Reference C.3, p. VIII-74). They were cleared for flight back to Eglin AFB when the intensity levels had dropped to 0.016 R/hr, but were required to stay at least 24 hours at Hickam AFB, Hawaii, and 24 hours at Fairfield-Suisun AFB, California, during their flight to Eglin (Reference C.43, p. 93; Reference C.43, "Messages," p. 4).

LAJ-3 personnel and a TG 7.6 monitor were ferried to Runit after the detonation to retrieve the samples attached to the land cable and winch. The cable snagged, however, and the samples had to be removed by driving a jeep down alongside the cable, exposing the party to somewhat higher radiation intensities than encountered on the previous shots. Blast gauges were retrieved by NOL (LAJ-8) the afternoon of D+1.

The neutron- and gamma-ray diagnosticians (LAJ-4 and LAJ-5) were helicoptered to Runit the morning of the detonation to recover instruments and film from the gamma stations and the timing station. Jeeps were again used on the shot island (Reference C.5, p. 3-22).

The radio-controlled tank on Runit stalled in the ZEBRA crater, but the backup tank was successfully employed to obtain soil samples from the crater. The samples were not sent to LASL but were analyzed locally aboard Albamarle (Reference C.3, p. VIII-75). The two tanks used for the three shots were disposed of in the ocean after ZEBRA.

The aerial radsafe survey C-47 took off on schedule from Enewetak shortly after the detonation and surveyed Runit and the surrounding islands. Heavy fallout on the islands north of Runit was discovered. The C-47 also conducted a radsafe survey on D+1 to determine the extent of contamination (Reference C.30, pp. 2-25, 2-26).

Photo personnel recovered their film from the Coral Head Photo Tower and the photo tower on Ananij. Light fallout was detected at the Coral Head Photo Tower, but it decayed rapidly (Reference C.43, Annex I).

The two C-54 and two F-13 photography aircraft again flew from Kwajalein and took high-speed photographs of the detonation and cloud development from a safe distance. Altitudes were the same as for X-RAY and YOKE (Reference C.7, p. IV-19).

One WB-29 flew weather reconnaissance in the Enewetak area from midnight until 0500 the morning of the shot to ensure that cloud cover was not too heavy for the shot. After the detonation, WB-29s were used in 12-hour relays to track

the radioactive cloud for 5 days. At about H plus 3 hours, a WB-29 inadvertently passed through a finger of the cloud and became contaminated. After another 40 minutes, the air monitor on board indicated that the WB-29 should return to its base at Kwajalein because of the contamination. The pilot flew through several rain squalls to reduce the radioactivity. The rain washed the radiating particles from the surface of the airplane and the radioactivity was reduced within (Reference A.4, pp. 22-24). The pilot was apparently not badged. A review of all air monitor records (air monitors were always badged) shows that none received an exposure exceeding 1 R for the SANDSTONE series (Reference E.1, p. E2.6).

On ZEBRA D+3, TG 7.6 monitors inspected the task force ships. Particular attention was paid to blower intake screens, open decks, lifeboats, evaporators, and auxiliary condensers. Blower screens that were found to be contaminated were removed and scrubbed with soap and water. When this did not reduce contamination of the blowers to acceptable levels on 23 ships, TG 7.6 recommended removal of intakes, scraping to bare metal, and repainting. Monitoring when they arrived at a Navy yard was also recommended.

On 19 May the island of Runit was closed and no further operations were permitted there. The crater areas on all three shot islands were posted with danger signs in various languages. No attempt was made to fill the craters (Reference C.6, p. 16-6). On 20 May all but one person in TG 7.6 departed the test area and all monitoring operations ceased. This individual remained as Radsafe Officer for Enewetak. The JTF 7 Radsafe Officer provided the radiological status of the Enewetak islands in a 20 May 1948 letter, which is reproduced as Appendix A.

CHAPTER 5
U.S. ARMY PARTICIPATION IN OPERATION SANDSTONE

The Chief of Staff of the Army was the executive agent for the Joint Chiefs of Staff (JCS) in executing SANDSTONE. Commander Joint Task Force 7 (CJTF 7) was an Army general officer and other Army personnel were represented in Hq JTF 7 and in all the task groups. Army units constructed scientific test structures, airstrips, and base facilities at Enewetak. Support services included activities such as supply shipments, communications, stevedoring, laundry, small boat support, and security for Army personnel and for other elements of the task force. Personnel from Army laboratory and research agencies and Army personnel serving in the Armed Forces Special Weapons Project (AFSWP) participated in the experimental program. More than 1,300 Army personnel were at SANDSTONE during the testing period.

Units supplying Army personnel are discussed below, arranged by the element of the task force the units' men were in. Available radiological exposure information for the units is summarized in Table 10.

HEADQUARTERS JOINT TASK FORCE 7

A total of 88 Army personnel served in Hq JTF 7, and 11 (10 officers and 1 enlisted man) were badged.

TASK GROUP 7.1 (ATOMIC ENERGY COMMISSION PROVING GROUND GROUP)

Over 100 personnel from the following Army organizations participated in Task Group (TG) 7.1 scientific activities.

Aberdeen Proving Ground, Research Department, Maryland. Three civilians, one officer and one noncommissioned officer participated in radiochemistry drone tank operations conducted by Los Alamos Scientific Laboratory (LASL). All were badged. High exposure was 1.070 R (Reference C.5, p. 6-3).

Ballistic Research Laboratories, Aberdeen, Maryland. Three civilians participated in blast measurements with the Naval Ordnance Laboratory (NOL). Three were badged with the high exposure being 1.295 R.

Chemical Corps. The Chemical Corps sponsored the project on the evaluation of protective field collectors. This experiment was conducted by TG 7.6 personnel with no apparent on-site Chemical Corps participation.

Corps of Engineers. This organization sponsored the tests of blast effects on concrete structures. Manning was by Army personnel in TG 7.2.

Signal Corps. The Signal Corps participated in an attempt to detect the atomic explosion by reflection of its light from the moon on YOKE day as part of the Air-Force-sponsored experiments. Four were badged with the Signal Corps; all received zero readings.

Table 10. SANDSTONE personnel exposures, U.S. Army organizations.

Organization	No. of Persons Badged	Exposure Ranges (roentgens)						
		0	0.001-0.5	0.5-1.0	1.0-1.5	1.5-2	Over 2	High
Hq Joint Task Force 7	11	6	5	0	0	0	0	0.380
Task Group 7.1								
Aberdeen Proving Ground	5	0	1	3	1	0	0	1.070
Ballistics Research Laboratories	3	0	2	0	1	0	0	1.295
Signal Corps	4	4	0	0	0	0	0	0
38th Engineer Battalion	75	43	29	0	0	1	2	5.085
Other	1	1	0	0	0	0	0	0
Total Army in TG 7.1	88	48	32	3	2	1	2	5.085
Task Group 7.2								
Hq 1220th Provisional Engineer Battalion	8	4	4	0	0	0	0	0.050
Hq 1220th Provisional Engineer Battalion, Medical Detachment	1	1	0	0	0	0	0	0
1219th Signal Service Platoon	3	1	2	0	0	0	0	0.010
Hq 532nd Engineer Boat & Shore Regiment	30	23	7	0	0	0	0	0.175
532nd Engineer Boat & Shore Regiment, Co D	12	2	10	0	0	0	0	0.443
532nd Engineer Boat & Shore Regiment, Co E, Med	16	8	8	0	0	0	0	0.080
461st Transportation Amphibious Truck Co	2	0	2	0	0	0	0	0.200
Unidentified units	27	1	26	0	0	0	0	0.305
Total Army in TG 7.2	99	40	59	0	0	0	0	0.443
Task Group 7.4								
Task Unit 7.4.2	1	0	1	0	0	0	0	0.5
Task Unit 7.4.3	12	10	2	0	0	0	0	0.150
Total in TG 7.4	13	10	3	0	0	0	0	0.5
Task Group 7.5								
369th CIC Detachment	18	11	7	0	0	0	0	0.230
401st CIC Detachment	9	8	1	0	0	0	0	0.090
8456th Military Police Co.	54	41	12	1	0	0	0	0.580
Total Army in TG 7.5	81	60	20	1	0	0	0	0.580
Task Group 7.6	35	4	9	9	3	4	6	6.050
Totals	327 ^a	168	128	13	5	5	8	6.050

^aMean total of those badged was 0.271 R.

38th Engineer Battalion, Armed Forces Special Weapons Project (AFSWP). A total of 42 officers (mostly engineers) and 61 enlisted men from this battalion (an AFSWP organization) were assigned to various task units of TG 7.1. The battalion did not participate in SANDSTONE as a whole; rather, individuals from this unit reported for temporary duty for AFSWP activities. Altogether, 75 personnel were badged. The highest exposure, 5.085 R, was probably incurred in recovering samples.

Five men were assigned to USS Albemarle (AV-5) to help assemble and anchor rafts. They assisted in posttest sample recovery and counting samples. A total of 15 men were assigned to the Neutron Generation and Gamma-Ray Appearance experiments. They procured, tested, packaged, and shipped copper conductors, built a nitrogen supply system, and constructed lead shields.

Twelve personnel (four officers and eight enlisted men) participated with Edgerton, Germeshausen & Grier, Inc. (EG&G) in studies of control, power, and monitoring circuits in the Timing and Firing Section. Altogether, 13 personnel (3 officers and 10 enlisted men) worked in the Blast Measurements Section. They assembled, checked, and maintained blast gauges. Five personnel (one officer and four enlisted men) participated in the Mechanical Assembly Section. The Pit Assembly Section consisted of 12 officers (divided into four teams); Teams 2 and 3 monitored nuclear materials and the other two teams counted neutron samples.

One officer and two enlisted men worked in the Engineering Section. The officer escorted official observers, and the enlisted men maintained the tower hoists. One officer worked in the Communications Section as liaison between TG 7.1 and the task force Communications Officer. Five officers and nine enlisted men were in the Firing Section, checking and testing firing-cone assemblies. They formed three teams; each team participated in one shot. Three officers and four enlisted men worked in the Logistics Section; they operated warehouses on Enewetak and stockrooms aboard Albemarle. Two officers were assigned to the Circuit Diagrams and Map Section (Reference C.5, p. 4-1 ff). Apparently this AFSWP unit also provided 25 men for special guard assignments under TG 7.5 (Reference C.5, p. 5-2). However, this was, at least for some, additional to their assignment in TG 7.1 (Reference C.5, p. 3-C8).

In addition, an Army NCO served in the office of CTG 7.1. He was badged with zero exposure. His home station is not known (Reference C.5, p. 3-C3).

TASK GROUP 7.2 (ARMY)

Most Army personnel in the task force were in TG 7.2. TG 7.2 was composed primarily of service units and teams, and was activated by Hq JTF 7 on 15 October 1947. TG 7.2 was responsible for construction at Enewetak test site and for military security of the atoll. This task group was also responsible for housing, medical care, local transportation, and general housekeeping for all units ashore on the atoll (Reference C.1, p. 18). TG 7.2 population reached a peak of 2,124, including 40 observers and a naval signal unit of approximately 100 men stationed on Parry Island; however, this was before actual testing began (Reference C.1, p. 60). In general, the main body of TG 7.2 was in place on Enewetak by 29 December 1947. Discussions of participating Army units follow.

1220th Provisional Engineer Battalion. This battalion, consisting of service units and teams, was organized on 22 October 1947 and arrived on Enewetak Atoll on 29 November 1947 from Oahu. The 1220th included the following service units and teams: Battalion Headquarters, 1219th Composite Service Platoon with attached Composite Signal Detachment, 1218th and 1217th Composite Service Platoons, and the 18th Engineer Construction Company with attachments. The Medical Detachment was part of Headquarters. The mission of the 1220th was to rehabilitate Enewetak Island as a base of operation before arrival of the main body of troops by 25 December. The 18th Engineer Construction Company constructed facilities on Enjebi Island and also provided housing and housekeeping facilities for civilian workers engaged in Atomic Energy Commission (AEC) work. Personnel strengths of the components of this battalion were (Reference E.2.2.1):

- Battalion Headquarters (included mess, supply, medical, postal, finance, and chaplain): 11 officers, 2 warrant officers, and 89 enlisted men (including 6 from JTF 7 Engineer and 13 from 18th Engineer Construction Company). Eight men were badged with Headquarters; the highest exposure of this group was 0.050 R. Another individual badged with the 12-man Headquarters Medical Detachment had a zero reading (Reference C.3, p. 27 ff).
- 1219th Signal Service Platoon: 5 officers, 2 warrant officers, 60 enlisted men; Composite Signal Detachment: 2 officers, 100 enlisted men. This unit also included personnel from several other units. One officer, designated as commanding officer of the 1219th Composite Signal Detachment, was from 4th Army Headquarters. One first lieutenant from the 51st Signal Battalion, Ft. Meade, Maryland, was assigned to the 1219th Composite Signal Detachment. A total of 43 enlisted men from the 9400th TSU, Ft. Monmouth, New Jersey, unit were assigned to the 1219th Composite Signal Detachment. Six enlisted men from the 17th Signal Service Company, Ft. Myer, Virginia, were assigned to the 1219th Composite Signal Detachment. Three individuals were badged according to individual exposure records (Reference E.1); one man had a zero reading, another recorded an exposure of 0.005, and the third recorded 0.010 R.
- 1218th Composite Service Platoon: 4 officers and 62 enlisted men.
- 1217th Composite Service Platoon: 2 officers and 50 enlisted men.
- 18th Engineer Construction Company (with attachments): 2 officers and 107 enlisted men.

532nd Engineer Boat and Shore Regiment (EB&SR) of the 2nd Engineer Special Brigade. The 532nd EB&SR arrived for Operation SANDSTONE on 9 October 1947. The operating strength of this brigade was 46 officers, 4 warrant officers, and 566 enlisted men for construction activities during SANDSTONE. The following units of the 532nd EB&SR were committed for this operation:

- Hq Company: 28 officers, 4 warrant officers, and 187 enlisted men
- Company D: 7 officers, 180 enlisted men
- Company E: 6 officers, 180 enlisted men
- Medical Detachment: 5 officers, 19 enlisted men

The officers were attached directly to the 2nd Engineer Special Brigade (Reference E.2.2.1).

Headquarters Company, stationed on Enewetak, performed construction on Parry and Enewetak islands (Reference C.4, p. XVI-53). This company was installed on Enewetak Island to function as a service unit and provided personnel to assist other allied headquarters on the island. According to the individual exposure records, 30 individuals were badged. The highest exposure was 0.175 R.

Company D began construction activities on Aomon, Lojwa, and Bijire islands by 5 January 1948. It also assisted civilian contractors on the lagoon and Ananij photo tower projects and the causeway adjoining Aomon with Bijire Island. The maximum number of personnel present for duty was 180, with normal strength averaging 156 (Reference C.4, p. XVI-32). According to the individual exposure records, 12 personnel were badged with Company D. The highest exposure was 0.443 R.

Company E landed on Runit on 29 December 1947 as part of an advance echelon that had arrived on 24 December aboard USS Yancey (AKA-93). It constructed showers, latrines, mess halls, quarters, and installations on Runit Island. According to the company commander, the average daily strength was 115 enlisted men and 4 officers (Reference C.3, p. XIII-1 ff). Company E also used two pioneer platoons, consisting of 2 officers and 35 enlisted men, for construction work and a heavy-equipment platoon of 1 officer and 25 enlisted men (Reference C.3, p. IV-6). According to the individual exposure records, 16 personnel were badged with the 532nd EB&SR, Company E, Med. The highest exposure was 0.080 R.

The first part of the Medical Detachment (one officer and three enlisted men) arrived on Runit Island on 8 January 1948 and set up a field dispensary. It is not possible to tell if the 16 men badged with the 532nd (above, E Company) were from Company E or the Medical Detachment.

461st Transportation Amphibious Truck Company. Composed of one officer and twenty-six enlisted men, this unit operated and maintained amphibious troop trucks (DUKWs) for Company D, 532nd EB&SR (Reference C.3, p. 75; Reference E.2.2.1). Two personnel were badged. The highest exposure was 0.200 R.

854th Transportation Port Company. This unit loaded and unloaded ships at Enewetak. Its operating strength was 8 officers and 272 enlisted men, including 1 officer and 45 enlisted men from the 447th Transportation Port Company and 1 officer and 17 enlisted men from the 863rd Transportation Port Company (Reference C.4). None were badged according to the individual exposure records.

TASK GROUP 7.3 (NAVY)

Ships of the U.S. Army Transportation Service supported SANDSTONE operations during which time they came under the control of CTG 7.3. The units were:

USATS FS-211. This ship arrived at Enewetak on 19 March transporting dry stores. It left on 22 March and stopped at Ujea, Ailinglapalap, Jaliut, Majuro, and Mili and twice at Kwajalein before returning to Enewetak on 7 April. On 10 April, the ship left Enewetak for a reprovioning trip to Rongerik and Bikini (Reference C.3, p. VII-80 to 82). FS-211 was in the vicinity of Bikini Atoll for X-RAY. For YOKE, FS-211 was steaming with TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of surface zero on Aomon. Between 6 and 10 May, the ship left Enewetak for a resupply run to Rongerik and Bikini. On 12 May, the ship left Enewetak for Mili to assist in the rollup of a station there and remained there for ZEBRA. The day after ZEBRA the ship left Mili for Ailinglapalap and returned to Kwajalein on 17 May. FS-211 was monitored for contamination at Pearl Harbor in early June. The usual crew size for this class of ship was 26 men.

USATS FS-234. On 25 November 1947, this ship reported to CJTF 7 for operational control. It arrived at Kwajalein on 1 December. From then until late January 1948, it was the dry stores shuttle between Enewetak and Kwajalein. On 11 February 1948, FS-234 left Enewetak for Pearl Harbor and returned to control of U.S. Army Pacific (C.3, pp. VII-14, -15, -22, and -24). The usual crew size for this class of ship was 26 men. The ship was not in the operation area for any of the test shots.

USATS FS-370. This ship arrived at Enewetak on 8 December 1947. Operating under CTG 7.3, it served as a refrigerator ship. It left Enewetak for Kwajalein on 3 January 1948 and returned on 11 January (Reference C.3). During X-RAY it was underway as part of TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. During YOKE it was underway with TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of surface zero on Aomon. For ZEBRA it was also with TU 7.3.5 about 20 nmi (37 km) south of Runit, the shot island.

The radsafe inspection on 20 May revealed no radioactivity on FS-370 (Reference D.4, p. 6). The date of the ship's departure from Enewetak after SANDSTONE cannot be determined from available documents. The usual crew size for this class of ship was 26 men.

TASK GROUP 7.4 (AIR FORCE)

Army personnel served in several elements of this predominantly Air Force unit.

Task Unit 7.4.1 (Hq and Service Unit)

Twenty-three Army personnel were in this service unit. None were badged.

Task Unit 7.4.2 (Drone Unit)

Five Army personnel were with this TG 7.4 unit, which operated the drone B-17s that collected radioactive cloud samples. The unit, like most of TG 7.4,

was based on Kwajalein but the unmanned flights originated at Enewetak where the sample collection and aircraft decontamination took place. One of the five Army personnel was badged; his exposure was 0.5 R.

Task Unit 7.4.3 (Photography Unit)

Twelve Army personnel were in the photo teams of this unit. All were badged and the exposures were low.

TASK GROUP 7.5 (JOINT SECURITY GROUP)

The Army primarily provided a provisional military police company and two CIC detachments for security of the atoll.

369th CIC Detachment. This detachment consisted of five officers and thirteen personnel who were assigned various security duties. A total of 18 personnel were badged according to the individual exposure records. The highest exposure was 0.230 R (Reference E.2.0.4).

401st CIC Detachment. This detachment was the nucleus of the security force for JTF 7 and was attached to TG 7.5. By 13 December 1947, the detachment was assigned the following missions:

- Travel control (air and water)
- Protection of technical installations
- Security survey of the atoll
- Dissemination of security information
- Security clearances.

A total of 13 personnel (including 2 officers and 1 warrant officer, and 10 enlisted men) comprised this detachment. Four of these conducted the initial security survey, and the remaining were assigned as resident CIC agents on Enjebi, Aomon, Runit, and Parry islands. A total of nine personnel were badged according to the individual exposure records. The highest exposure was 0.090 R (Reference C.3, p. 32, and Reference E.2.0.4).

8456th Military Police Company. This company consisted of 6 officers and 99 enlisted personnel who were assigned security duties. A total of 54 personnel were badged according to the individual exposure records. The highest exposure was 0.580 R (Reference E.2.0.4).

TASK GROUP 7.6 (JOINT RADIOLOGICAL SAFETY GROUP)

A total of 35 Army personnel (31 officers and 4 enlisted men) performed various tasks for TG 7.6. All were badged. An officer in TU 7.6.3 (Operations Unit) had the highest reading with a 6.050 R exposure according to individual exposure records. The operations unit planned and controlled radiation safety missions. The second highest exposure was 5.085 R and belonged to an enlisted man who was part of TU 7.6.7 (Monitor Unit). He was probably a monitor (Reference E.2.0.3).

CHAPTER 6

U.S. NAVY PARTICIPATION IN SANDSTONE

Eight thousand, thirty-four naval personnel have been identified as having participated in SANDSTONE. Most were in crews of ships operating in the Enewetak area under command of Commander Task Group (CTG) 7.3. The Navy operated about 40 ships in the area to support SANDSTONE. Roughly two-thirds of the 10,000-man task force were stationed aboard ship. Most personnel in Hq Joint Task Force 7 (JTF 7), TG 7.1, and TG 7.6 were billeted and worked aboard ship.

Naval air units flew out of both Enewetak and Kwajalein in support of the test series. Several naval units were ashore under command of CTG 7.2. Kwajalein Air Station and various attached naval units supported SANDSTONE in addition to their regular duties.

Civilian and military personnel from naval technical bureaus and laboratories worked on the experimental program as part of TG 7.1 and TG 7.6. Naval personnel also participated in the radiological safety (radsafe) activities of TG 7.6. Naval personnel held many positions in the Headquarters of JTF 7.

USS Albemarle (AV-5), a seaplane tender, was modified to be a laboratory ship for TG 7.1. Alterations included installation of work benches, racks, bins, darkrooms, power outlets, test panels, and instruments. Albemarle was used to transport the nuclear devices to the test area. The devices, less the nuclear components, were stored aboard USS Curtiss (AV-4). USS Mount McKinley (AGC-7) was used as the command ship and also had the Weather Center and Air Operations Office on board. USS Bairoko (CVE-115) was used by the radsafe personnel (TG 7.6). Navy ships also patrolled the Danger Area to keep unauthorized ships out and conducted weather-reporting operations to supplement other weather data. Both confirmed and unconfirmed reports of submarine sightings were recorded during SANDSTONE, all quite close to Enewetak Atoll.

Not all Navy personnel who served with the joint task force were badged; however, exposure records of those badged are available, along with rosters of most ships and other naval organizations involved. From these sources, a detailed picture of naval participation can be constructed. Available exposure information is tabulated in Table 11.

HEADQUARTERS JOINT TASK FORCE 7

As of 31 March 1948, 52 uniformed Navy personnel were assigned to the headquarters (Reference E.2.0.2). It is not clear, however, whether all of these were at the Pacific Proving Ground (PPG) because even during the operational period the joint task force maintained small offices in Hawaii and Washington. Badged personnel can be assumed to have been at Enewetak, but the location of unbadged personnel is uncertain.

Table 11. SANDSTONE personnel exposures, U.S. Navy organizations.

Organization	No. of Persons Badged	Exposure Ranges (roentgens)					
		0	0.001-0.5	0.5-1	1-1.5	Over 1.5	High
Hq Joint Task Force 7	13	6	6	1	0	0	0.620
Task Group 7.1							
David Taylor Model Basin	1	0	1	0	0	0	0.010
Naval Ordnance Laboratory	21	5	15	0	1	0	1.180
Naval Research Laboratory	14	9	5	0	0	0	0.030
Other	17	12	5	0	0	0	0.250
Navy Total in TG 7.1	53	26	26	0	1	0	1.180
Task Group 7.2							
Enewetak Shore Detachment	17	6	11	0	0	0	0.090
Signal Unit 1	6	5	1	0	0	0	0.002
Navy Total in TG 7.2	23	11	12	0	0	0	0.090
Task Group 7.3							
Commander Task Group 7.3	7	4	3	0	0	0	0.140
<u>USS Albemarle (AV-5)</u>	137	125	12	0	0	0	0.248
<u>USS Arequipa (AF-31)</u>	3	3	0	0	0	0	0
<u>USS Askari (ARL-30)</u>	44	44	0	0	0	0	0
AVR C-26638	6	4	2	0	0	0	0.110
AVR C-26653	5	1	4	0	0	0	0.130
<u>USS Bairoko (CVE-115)</u>	56	32	22	2	0	0	0.780
<u>USS Comstock (LSD-19)</u>	2	1	1	0	0	0	0.020
Boat Pool	34	14	20	0	0	0	0.370
<u>USS Currier (DE-700)</u>	105	103	2	0	0	0	0.050
<u>USS Curtiss (AV-4)</u>	39	34	5	0	0	0	0.373
<u>USS Gardiners Bay (AVP-39)</u>	2	0	2	0	0	0	0.110
Sonobuoy Monitor Unit	7	5	2	0	0	0	0.030
<u>USS Henry W. Tucker (DDR-875)</u>	22	3	19	0	0	0	0.070
LCI(L)-1090	16	16	0	0	0	0	0
LSM-250	1	1	0	0	0	0	0
LSM-378	3	3	0	0	0	0	0
<u>USS LST-45</u>	4	4	0	0	0	0	0
<u>USS LST-219</u>	7	7	0	0	0	0	0

(continued)

Table 11. SANDSTONE personnel exposures, U.S. Navy organizations (continued).

Organization	No. of Persons Badged	Exposure Ranges (roentgens)					
		0	0.001-0.5	0.5-1	1-1.5	Over 1.5	High
Task Group 7.3 (continued)							
<u>USS Marsh</u> (DE-699)	1	1	0	0	0	0	0
<u>USS Mount McKinley</u> (AGC-7)	23	17	6	0	0	0	0.080
<u>USS Pasig</u> (AW-3)	11	9	2	0	0	0	0.360
<u>USS Pickaway</u> (APA-222)	12	7	4	1	0	0	0.826
<u>USS Raby</u> (DE-698)	1	1	0	0	0	0	0
<u>USS Rogers</u> (DDR-876)	178	178	0	0	0	0	0
<u>USS Spangler</u> (DE-696)	9	8	1	0	0	0	0.005
<u>USS Warrick</u> (AKA-89)	40	40	0	0	0	0	0
Medium Seaplane Patrol Sqdrn 6	11	1	10	0	0	0	0.370
Navy Total in TG 7.3	786	666	117	3	0	0	0.826
Task Group 7.4 Total Navy	6	2	4	0	0	0	0.100
Task Group 7.5 Total Navy	1	1	0	0	0	0	0
Task Group 7.6							
Bureau of Medicine & Surgery	3	0	1	1	1	0	1.340
Bureau of Ships	1	0	0	1	0	0	0.780
Bureau of Yards & Docks	1	0	0	1	0	0	0.735
Other	41	6	23	4	5	3	5.140
Total Navy in TG 7.6	46	6	24	7	6	3	5.140
Task Group 7.7							
Construction Battalion 1509	5	0	5	0	0	0	0.020
Naval Air Station, Kwajalein	13	0	13	0	0	0	0.305
Naval Station, Kwajalein	4	0	4	0	0	0	0.010
Naval Station, Kwajalein Ship Security Detachment	18	12	6	0	0	0	0.180
Total Navy in TG 7.7	40	12	28	0	0	0	0.305
Task Group 7.8 Navy Observers	5	0	4	1	0	0	0.760
Total Navy Badged	973 ^a	730	221	12	7	3	5.140

Note:

^aMean of those badged was 0.085 R.

Office of the Deputies. Six naval officers and two enlisted men were listed as assigned to this office on 1 April 1948. By the end of the operation only three had been badged. One badged and one unbadged officer also served for some period of time with TG 7.1 (Reference E.2.0.4; Reference C.5, p. 3-C11).

Office of the Chief of Staff. One naval officer is listed. He was not badged.

J-1 Section. An officer and an enlisted man were assigned to this office. Neither was badged.

J-2 Section. Seven Navy personnel were listed. Three were badged.

J-3 Section. A badged Navy captain served in this section.

J-4 Section. Five Navy men were listed, two of whom were badged.

Communications Section. As of 1 April 1948, this section had 22 Navy officers and enlisted men; only two were badged.

Fiscal Section. Two unbadged Navy officers were assigned to this section.

Meteorological Section. Of two officers assigned, one was badged.

Photographic Section. One unbadged Navy officer was assigned.

Surgeon. The surgeon was a Navy captain who was badged (Reference E.2.0.4)

TASK GROUP 7.1 (ATOMIC ENERGY COMMISSION PROVING GROUND GROUP)

Most of the 64 Navy personnel in this task group were drawn from Naval Ordnance Laboratory (NOL) and Naval Research Laboratory (NRL), although other Navy organizations contributed. The organizations were:

Bureau of Personnel. Six personnel from this bureau were noted as being in TG 7.1 in the forward area, but their SANDSTONE activities have not been identified. They were probably among the Navy personnel in the office force of either CTG 7.1 or CTU 7.1.1 (see below).

David Taylor Model Basin (DTMB). The Test Director's report indicates that two DTMB personnel were in TG 7.1. One DTMB staff member was badged as part of the blast measurement program (Reference C.5, pp. 1-24 and 3C-7).

Naval Ordnance Laboratory (NOL). Altogether 21 civilian employees of this organization were badged and worked in LAJ-8 Section -- Blast (see Chapter 3 for a discussion of these sections). Another NOL man was also aboard USS Pelican (AMS-32), but he was not badged (Reference C.5, pp. 1-23 and 3-C7; References E.2.0.3, E.2.0.5, and E.2.3.3).

Naval Research Laboratory (NRL). A total of 23 personnel from this organization served in TG 7.1, but only 20 can be identified by name. Of these, 14 were badged and based on Albemarle. NRL personnel made up the majority of the

personnel in Subsection A of the task group's LAJ-4 and LAJ-6 Sections (Reference C.5, pp. 1-23 and 3-C5; Reference E.2.0.5).

The home organization for 20 other Navy personnel in TG 7.1 is not clear, although it is likely that the six from Bureau of Personnel mentioned above were among the CTG 7.1 or CTU 7.1.1 office personnel. TG 7.1 organizations indicated as having Navy personnel for whom home station information is not available follow.

Office of Commander Task Group 7.1. A Navy captain headed the task group with a Navy lieutenant commander as his chief staff officer. The office was on Albemarle. Nine Navy enlisted men were members of the clerical staff (Reference C.5, p. 3-C3; Reference E.2.3.3, pp. 2594-2595). The commander of the task group, the chief staff officer, and seven of the nine Navy enlisted men were badged.

Office of Commander Task Unit 7.1.1. Stationed on Curtiss, the unit's six-man clerical staff apparently included five Navy enlisted men, all of whom were badged (Reference C.5, p. 3-C4).

LAJ-10 Section -- Engineering. A Navy commander was a member of this group, but he was not badged (Reference C.5, p. 3-C9; Reference E.2.3.3, p. 2596).

LAJ-11 Section -- Communications. A Navy commander was technical advisor to this section. He was badged (Reference C.5, p. 3-C9).

LAJ-16 Section -- Circuit Diagrams and Maps. A badged Navy lieutenant commander served in this section (Reference C.5, p. 3-C10).

Two additional Navy officers have been identified by name as serving with TG 7.1, but information is lacking on which task group components they worked in. Before their work in TG 7.1, they were assigned to the Office of the Deputies in the Hq JTF 7. One was badged and had a reading of 0.100 R. The other was not badged.

TASK GROUP 7.2 (ARMY)

Two units manned by 95 Navy personnel served in SANDSTONE under the operational control of TG 7.2.

Enewetak Shore Detachment. This detachment consisted of 5 officers and 37 enlisted men. According to individual exposure records, 17 personnel were badged. The highest exposure was 0.090 R (Reference E.1).

Signal Unit 1. This unit, attached to the Enewetak Shore Detachment, maintained and operated the shore station on Parry Island. It was manned by 1 Navy officer and 52 Navy enlisted men. They assembled at Port Hueneme, California, and sailed to Enewetak aboard USS Pickaway (APA-222), arriving by 6 December 1947 (Reference E.2.0.3, p. 29). They were attached to the 1220th Provisional Engineer Battalion for movement purposes. According to the individual exposure records, six personnel from Signal Unit 1 were badged. The highest exposure was 0.010 R.

TASK GROUP 7.3 (NAVY)

Most Navy personnel were in TG 7.3, which totaled 6,788 personnel. Most were assigned to ships or smaller surface craft. Total numbers of badged personnel are listed by unit in Table 11. Unless otherwise indicated, information on ship movements is drawn from the deck logs of the ships discussed.

Following the last test at SANDSTONE, all but seven task force ships were monitored for radiation at least once, and in many cases twice, by JTF 7 radsafe personnel. All ships that were inspected were cleared of any radiological hazard to personnel; in no case did readings reach accepted human tolerance levels. Since some shipboard machinery was not opened for inspection, however, and the standard Commander Western Sea Frontier inspection form was not used, CJTF 7 recommended that all ships be monitored again when they arrived at Pearl Harbor, San Francisco, or Puget Sound. The radiological readings listed in this chapter for the task force ships were, in general, the highest readings on the ship and were obtained on high- and intermediate-capacity air-supply blower screens, where a buildup could be expected from the large volumes of air passing over the screens. In the few cases where screens approached tolerance, they were removed and destroyed or cleaned. Very few readings were noted on other shipboard surfaces.

Fallout was only recorded aboard task force ships following YOKE and this was low level, but it must have been enough to cause the contamination later detected. Eighteen ships and one infantry landing craft were found to have low levels of contamination, as did one maritime patrol bomber and a number of small boats on USS Comstock (LSD-19). When checked, five ships, two infantry landing craft, two service craft, two aircraft rescue vessels, and a number of other small boats on Comstock were found to be free of significant contamination (Reference D.4, pp. 1-6).

Staff Organizations

Staff of Commander Task Group 7.3. This organization included 54 personnel and was based aboard Mount McKinley. They provided support to CTG 7.3. Seven were badged (Reference E.2.3.3, p. 2594; Reference C.3, p. VII-4).

Commander of Escort Division 1 and Staff. The escort division was made up of USS Spangler (DE-696), USS George (DE-697), USS Raby (DE-698), USS Marsh (DE-699), and USS Currier (DE-700). The commander and his four-man staff were aboard George. All can be identified by name, but none were badged (Reference C.3, pp. VII-4 and VII-5; Reference E.2.3.3, p. 2594).

Commander Destroyer Division 52 and Staff. Destroyer Division 52 was made up of USS Henry W. Tucker (DDR-875), USS Rogers (DDR-876), and USS Perkins (DDR-877). The commander and his staff were aboard Tucker, but neither the commander nor his staff can be identified by name. Apparently they were not badged (Reference C.3, p. VII-4).

Ship Units

USS Albemarle (AV-5). This seaplane tender was part of TU 7.3.2, the Main Naval Task Unit. Albemarle arrived at the proving ground on 16 March 1948. The

ship had the major laboratories for analysis of test samples and instruments (Reference C.5, pp. 2-3). It served as the center for TG 7.1 operations (Reference C.6, p. 7-13). After each shot, samples were brought to Albemarle (Reference C.1, p. 137). Of its 537 crewmembers, 137 were badged.

- X-RAY (15 April). At shot time moored about 3,520 yards (3.2 km) west of Parry, 16.5 nmi (30.6 km) south-southeast of the shot island. At 0715 the ship got underway and at 0925 it anchored about 2,750 yards (2.5 km) south-southwest of Aomon.
- YOKE (1 May). At shot time moored about 3,520 yards (3.2 km) west of Parry, 13.5 nmi (25 km) south of the shot island. At 0811 the ship got underway and at 0934 it anchored about 2,030 yards (1.9 km) west of the south end of Runit.
- ZEBRA (15 May). At shot time moored about 3,520 yards (3.2 km) west of Parry, 8.5 nmi (15.8 km), south of the shot island. Underway at 0834, the ship anchored 3,890 yards (3.6 km) west-southwest of Ananij at 0916.

On 18 May, Albemarle was underway for refueling at sea, later anchoring in the lagoon near Enewetak Island. On 20 May, radsafe monitors found readings of 0.0005 to 0.0007 R/hr on four air intakes on the ship (Reference D.4, p. 1). The ship left the proving ground for Pearl Harbor on 21 May.

USS Arequipa (AF-31). This stores ship arrived at Enewetak Atoll on 11 April and anchored in the lagoon off Enewetak Island. The ship participated only for X-RAY, supplying provisions to other task force ships. At shot time on 15 April, it was steaming with TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. At 1050, the ship anchored in the lagoon off Enewetak Island. Arequipa left Enewetak Atoll for Pearl Harbor on 20 April before YOKE. Three of its seventy-six crewmembers were badged.

USS Askari (ARL-30). This landing craft repair ship arrived at Enewetak Atoll on 11 January 1948 and was attached to TU 7.3.7, the Boat Pool Unit. It assisted Comstock in keeping boat pool and other boats in running order, and it provided repair services to forces ashore and afloat. Of its 164 crewmembers, 44 were badged.

- X-RAY (15 April). At shot time, underway with TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. At 1053, the ship anchored in the lagoon about 1,780 yards (1.6 km) west-northwest of the northern tip of Enewetak Island.
- YOKE (1 May). At shot time, steaming with TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of the shot island. At 1212, the ship anchored in the lagoon about 1,780 yards (1.6 km) west-northwest of the northern tip of Enewetak Island.
- ZEBRA (15 May). At shot time, underway with TU 7.3.5 about 20 nmi (37 km) south of the shot island. At 1100, the ship anchored in the lagoon in its post-X-RAY and post-YOKE location.

Radsafe monitors came aboard Askari on 18 and 20 May. They detected radiation in two locations, the highest reading being 0.001 R/hr in a vent set (Reference D.4, p. 2). The ship departed Enewetak Atoll on 29 May bound for Kwajalein Atoll.

AVR C-26638 and AVR C-26653. These aviation rescue vessels were assigned to TU 7.3.3 (Off-Shore Patrol Unit) (Reference C.3, p. VII-4). Before each detonation they transported the firing party from the shot island to Parry. Immediately following each detonation, they transported scientific recovery parties, radsafe monitors, and DUKW and LCVP crews to the shot island. Thereafter they moved personnel, delivered samples to the ships, and acted as search and rescue vessels in the lagoon (Reference C.3, p. VII-71-72). Neither vessel was found to be radioactive during the radsafe check of 20 May (Reference D.4, p. 6). Each boat had a crew of six, of which all but one of the twelve were badged.

USS Bairoko (CVE-115). This escort aircraft carrier carried personnel and equipment of TG 7.6. Bairoko arrived at Enewetak Island with its 770-man crew on 16 March. During the test series it was part of TU 7.3.4, the Helicopter Unit (Reference C.3, pp. VII-4 and 25). It served as the base for the helicopter unit and TG 7.6. The helicopter unit provided four HO3S-1s and two HTL-2s and was manned by five officers and thirteen enlisted men.

- X-RAY (15 April). At shot time, anchored about 4,600 yards (4.2 km) west of Parry in Enewetak Lagoon, about 16.5 nmi (30.6 km) south-southeast of surface zero on Enjebi (Reference C.3, p. VII-70). At 0700, the ship got underway for an anchorage off Enjebi. About 5 nmi (9.3 km) from the island, two small boats were lowered into the water. They preceded Bairoko up the lagoon, and TG 7.6 personnel aboard them monitored radiation levels and reported their findings to the ship (Reference C.43, p. 59). At 0843, it anchored 3,480 yards (3.2 km) southwest of the southern tip of Enjebi. Thereafter, it supported recovery operations, especially the radsafe activities of TG 7.6 (Reference C.43, p. 71).
- YOKE (1 May). At shot time, anchored about 4,600 yards (4.2 km) west of Parry in Enewetak Lagoon and about 13.5 nmi (25 km) from the shot tower on Aomon. At 0700, the ship got underway for a berth off Aomon. It anchored about 6,000 yards (5.5 km) south-southwest of the southern tip of the island at 0825. It was preceded during the entire trip by four small boats checking for radioactivity (Reference C.3, p. VII-72; Reference C.43, p. 63). Two days after YOKE, Bairoko was still anchored in the same location. About 1000, apparently as the result of fallout, the background count on the ship's flight and hangar decks began to rise, reaching 0.0017 R/hr. The fallout ceased in the early afternoon (Reference C.43, Annex I, p. 6).
- ZEBRA (15 May). At shot time, anchored about 4,600 yards (4.2 km) west of Parry and 8.5 nmi (15.8 km) from the shot tower on Runit (Reference C.3, pp. VII-73 and VII-74). At 0703, the ship was underway for a location off Runit. At 0815, the ship anchored about 6,330 yards (5.8 km) south-southeast of Runit's northern tip to support recovery operations.

Radsafe monitors checked Bairoko on 20 May. The highest radiation level detected was 0.0014 R/hr, probably at an air intake on the portside (Reference D.4, p. 5). Badges were issued to 56 crewmembers.

USS Comstock (LSD-19). This dock landing ship arrived at the proving ground on 29 November 1947, left on 12 January 1948, and returned on 1 February (Reference C.3, pp. VII-14 and VII-19). It served as the flagship for TU 7.3.7, the Boat Pool Unit. The ship's large well provided a protected environment for loading, unloading, and repairing boat pool vessels.

- X-RAY (15 April). At shot time, steaming in formation with TU 7.3.8 in the open sea between 18 and 23 nmi (33 and 43 km) south-southeast of the shot island. At 0916, the ship anchored in Enewetak Lagoon.
- YOKE (1 May). At shot time, steaming in formation with TU 7.3.8 between 15 and 20 nmi (28 and 37 km) southeast of Aomon, the shot island. The ship anchored in the lagoon at 1032.
- ZEBRA (15 May). At shot time, underway with TU 7.3.8 between 25 and 30 nmi (46 and 56 km) southeast of the shot island. At 1019, the ship anchored in the lagoon.

A radiation check of the ship on 20 May showed a maximum reading of 0.0015 R/hr on two vent screens. Comstock boat contamination is discussed under Boat Pool (see below) (Reference D.4, pp. 2 and 5). In late May, Comstock left Enewetak Atoll for Kwajalein Atoll, returning a few days later. On 31 May, the ship left Enewetak Atoll bound for Pearl Harbor. Badges were issued to 2 of its 152 crewmembers.

Boat Pool. This unit was augmented by an Army unit, the Boat Detachment of the 2nd Engineer Special Brigade (discussed in Chapter 5). Both units were based on Comstock, and they provided water transportation in the lagoon for JTF 7 elements. Between them, there were approximately 80 boats (Reference C.4, XVII-34). During the radsafe check of 20 May, 12 boats were found to be radioactive and 15 boats had no significant readings. The highest level of contamination was 0.0013 R/hr on LCVP No. 3. Eight of the boats had readings less than 0.001 R/hr. Information is lacking, however, on which boats belonged to each of the two units (Reference D.4, pp. 5-6). The Navy component was made up of 184 officers and enlisted men, of whom 34 were badged (Reference E.2.3.3, p. 23).

USS Currier (DE-700). This destroyer escort arrived at Enewetak Atoll on 30 March, where it served as part of TU 7.3.3, the Off-Shore Patrol Unit, which was to prevent intrusion into the test area by unauthorized planes or vessels. Badges were issued to 105 of its 136 crewmembers.

- X-RAY (15 April). At shot time, underway with TU 7.3.8 a few miles east of Parry and between 18 and 23 nmi (33 and 43 km) south-southeast of the shot island. At 0805, the ship began steaming independently for patrol duty.
- YOKE (1 May). At shot time, screening for TU 7.3.8 between 15 and 20 nmi (28 and 37 km) east-southeast of the shot island. At 0826, the task unit entered the lagoon. By 1308, the ship had left the lagoon for patrol.

- ZEBRA (15 May). At shot time, underway with TU 7.3.8 between 25 and 30 nmi (46 and 56 km) southeast of the shot island. By about 0930, the ship was near the lagoon entrance between Parry and Japtan. The ship entered the lagoon at 1225 and departed at 1330.

The radiation check of 20 May revealed no radioactivity (Reference D.4, p. 6). Currier sailed for Pearl Harbor on 31 May.

USS Curtiss (AV-4). This seaplane tender arrived at Enewetak Atoll on 16 March with the nuclear devices, less the nuclear material. It was part of TU 7.3.2, the Main Naval Task Unit. Before each test, the device was assembled on Curtiss and then moved ashore (Reference C.5, p. 3).

- X-RAY (15 April). At shot time, anchored in Enewetak Lagoon about 1,360 yards (1.2 km) west of Parry and about 17 nmi (32 km) from the shot island. At 0745, Curtiss was underway for a berth off Aomon. At 0920, the ship anchored about 2,200 yards (2 km) south-southwest of Aomon.
- YOKE (1 May). At shot time, anchored 1,360 yards (1.2 km) west of Parry in Enewetak Lagoon about 13.5 nmi (25 km) from the shot island. At 0838 the ship proceeded to Runit and anchored about 1,740 yards (1.6 km) south-southwest of the northern tip of Runit at 1020.
- ZEBRA (15 May). At shot time, anchored 1,360 yards (1.2 km) west of Parry in Enewetak Lagoon, 8.5 nmi (15.8 km) from the shot island. At 0903, the ship moved to an anchorage about 3,550 yards (3.2 km) west of the northern tip of Enewetak Island.

On 20 May, Curtiss was checked for contamination. The highest readings were 0.006 and 0.0055 R/hr on two vent duct screens amidships on the boat deck. These screens were removed. Other duct screens read from 0.00025 to 0.0013 R/hr (Reference D.4, p. 3). Curtiss departed for Pearl Harbor on 21 May. Of the 555 crewmembers, 39 were badged.

USS Davison (DMS-37). This high-speed minesweeper arrived at Kwajalein on 24 March from Pearl Harbor. It was under the operational control of CTG 7.3 for support of a balloon-launching team from NRL (Reference C.3, pp. VII-58 and VII-81). Davison arrived at Enewetak Island on 10 April and left on 12 April to take up its station for X-RAY.

- X-RAY (15 April). On station at approximately 12°25'N, 172°25'E about 600 nmi (1,112 km) east of the test site. At 0802 on 19 April it moored in Kwajalein Lagoon. On 27 April it was underway to take up its station for YOKE.
- YOKE (1 May). On station at 14°40'N, 171°61'E, about 660 nmi (1,223 km) east of the detonation. On 3 May it anchored at Kwajalein. On 12 May it was underway to take up its station for ZEBRA.
- ZEBRA (15 May). On station at 11°25'N, 172°54'E. Later the same day, the ship headed for Majuro Atoll to pick up an NRL group. This ship was back at Kwajalein on 19 May, and it left for Pearl Harbor on 21 May.

Davison was not exposed to radiological contamination and none of its 170-man crew was badged.

USS Gardiners Bay (AVP-39). This small seaplane tender arrived at the proving ground with a crew of 265 on 29 January. It served as flagship of TU 7.3.3, the Off-Shore Patrol Unit, and acted as tender for its seaplanes. Gardiners Bay provided the eight personnel of the Sonobuoy Monitor unit. In Table 11, these are shown separately.

- X-RAY (15 April). Underway with TU 7.3.8 in the open sea just east of Jinimi, between 18 and 23 nmi (33 and 43 km) south-southeast of the shot island. At 0933, the ship anchored in Enewetak Lagoon west of Parry Island.
- YOKE (1 May). Underway between 15 and 20 nmi (28 and 37 km) south-east of the shot island with TU 7.3.8. At 1011, the ship anchored in the lagoon west of Parry.
- ZEBRA (15 May). Steaming as part of TU 7.3.8 between about 25 and 30 nmi (46 and 56 km) southeast of the shot island. The ship anchored in the lagoon west of Parry at 0959.

Gardiners Bay was checked for radiological contamination on 20 May. The highest level, 0.001 R/hr, was detected on the portside main air intake (Reference D.4, p. 1). On 22 May, the ship left the proving ground for Pearl Harbor.

Sonobuoy Monitor Unit No. 1. By 24 April, strings of sonobuoys had been laid across both Deep Entrance and Wide Entrance at Enewetak Atoll. Stations to monitor the buoys on Parry and Enewetak islands were manned continuously during the rest of the operation (Reference C.3, p. VII-68). Eight men from Gardiners Bay were assigned to man this temporary unit.

USS George (DE-697). On 2 April, this destroyer escort reached Enewetak Atoll for duty as part of TU 7.3.3, the Off-Shore Patrol Unit.

- X-RAY (15 April). On patrol roughly northeast of the atoll. At 1200, the ship was about 34 nmi (63 km) east-northeast of the shot island.
- YOKE (1 May). Steaming independently about 2.2 nmi (4 km) south-southeast of the southern end of Enewetak Island, 19 nmi (35 km) south of the shot island.
- ZEBRA (15 May). On patrol about 19 nmi (35 km) east-southeast of the shot island.

The radiation check of 20 May revealed no significant contamination on George. The ship left for Pearl Harbor on 25 May. None of its 141 crew-members was badged.

USS Gull (AMS-16). This small minesweeper was under the operational control of CTG 7.3. On 16 March, the ship arrived under escort at Kwajalein. After replenishment there, it sailed, again under escort by USS LST-219, to Mili, about 660 nmi (1,223 km) southeast of Enewetak Atoll, to act as

support ship for the balloon station there. It arrived at Mili on 3 April. On 15 May, it departed Mili bound for Ailinglapalap (Reference C.3, pp. VII-80, VII-81, and VII-85; LST-45 deck log). On 26 May, the ship left the area bound for Pearl Harbor. Gull was not exposed to radiological contamination and none of its 24-man crew was badged.

USS Henry W. Tucker (DDR-875). On 18 March, this radar picket destroyer arrived at Enewetak Atoll, where it became part of TU 7.3.3, the Off-Shore Patrol Unit.

- X-RAY (15 April). On patrol about 14.5 nmi (27 km) southeast of the shot island. At 1735 on 16 April, it moored in Enewetak Lagoon off Enewetak Island.
- YOKE (1 May). On patrol about 14.5 nmi (27 km) northwest of the shot island. It returned to Enewetak Lagoon in the late afternoon of 4 May and moored off Enewetak Island.
- ZEBRA (15 May). On patrol about 15 nmi (28 km) southeast of the southern tip of Runit. At 1447, the ship anchored in Enewetak Lagoon about 5,040 yards (4.6 km) west-southwest of the southern tip of Parry.

A radiation check on 20 May revealed a maximum level of 0.0001 R/hr at three locations (Reference D.4, p. 1). Of its 233 crewmembers, 22 were badged. Tucker left the proving ground for Pearl Harbor on 21 March.

LCI(L)-549. This large infantry landing craft arrived at Enewetak Atoll on 1 January 1948 to serve as part of TU 7.3.7, the Boat Pool Unit.

- X-RAY (15 April). On station as a point of reference for drone aircraft operations, about 4.3 nmi (8 km) roughly west-southwest of Enewetak Island and 22 nmi (41 km) south of the shot island. At 1236 on 15 April it anchored in the lagoon, apparently off Enewetak Island.
- YOKE (1 May). On station as a drone aircraft reference vessel, positioned about as it had been for X-RAY and about 20 nmi (37 km) south of the shot island. At 1403 the same day, it anchored in Enewetak Lagoon.
- ZEBRA (15 May). On station as drone aircraft reference vessel, about 4.5 nmi (8.3 km) southwest of the southern end of Enewetak Island and 16 nmi (30 km) from the shot island. At 1305, it anchored in the lagoon about 2,690 yards (2.5 km) west of the northern tip of Enewetak Island.

The report of the radsafe inspection of 20 May indicates no radioactivity on LCI(L)-549 (Reference D.4, p. 6). None of its 18 crewmembers was badged. On 24 May, it sailed for Kwajalein Atoll and then to Pearl Harbor.

LCI(L)-1054. This large infantry landing craft arrived at Enewetak Atoll on 18 January. It became part of TU 7.3.7, the Boat Pool Unit.

- X-RAY (15 April). Steaming with TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. At 1144, it anchored in Anchorage A in Enewetak Lagoon west of Parry and Enewetak Island.
- YOKE (1 May). Underway with TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of the shot island. At 0615, it left the formation to return to the lagoon, anchoring west of Parry and Enewetak at Anchorage A at 1205. It began a ferry run to Runit at 1603. It anchored off Runit at 1709, and remained there overnight.
- ZEBRA (15 May). Underway with TU 7.3.5 about 20 nmi (37 km) south of the shot island. At 0610, it left the formation to proceed to the vicinity of Wide Entrance. It left the vicinity of Wide Entrance at 1230 to reenter the lagoon through Deep Entrance. It anchored in Anchorage A in the lagoon west of Enewetak and Parry Island at 1405.

During the inspection on 20 May, a 0.0014 R/hr reading was found on one air vent (Reference D.4, p. 4). LCI(L)-1054 left Enewetak Atoll on 24 May and visited various islands and atolls in the area, returning to Enewetak briefly in July and September. None of its 21 crewmembers was badged. On 20 November, it left Kwajalein Atoll bound for Pearl Harbor and Long Beach, California.

LCI(L)-1090. On 1 March, this large infantry landing craft reached Enewetak Atoll, where it was assigned to TU 7.3.7, the Boat Pool Unit.

- X-RAY (15 April). Underway with TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. It anchored in Enewetak Lagoon at 1126, and at 1525 it got underway for a ferry run first to Runit and then to Aomon. It anchored off Aomon at 1702. The next morning the vessel was at Enjebi, the shot island, for about 15 minutes. It spent the rest of the day on ferry runs between Aomon and Runit.
- YOKE (1 May). Steaming with TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of the shot island. At 1209, it anchored in the southeast portion of the lagoon.
- ZEBRA (15 May). Underway with TU 7.3.5 about 20 nmi (37 km) south of the shot island. At 1405, it anchored in the southeast portion of Enewetak Lagoon.

The radsafe monitor checked LCI(L)-1090 for about an hour on 20 May, but found no contamination (Reference D.4, p. 6). Sixteen of its twenty-one crewmembers were badged. On 24 May, it left Enewetak bound for Kwajalein Atoll.

LCTs 472, 494, 1194, and 1345. All were assigned to TU 7.3.7, the Boat Pool Unit. No other information is available.

LSM-250. This medium landing ship arrived in the proving ground on 1 January 1948. It was assigned to TU 7.3.6, the Cable Unit and helped lay and maintain the extensive system of underwater cables required during the operation.

- X-RAY (15 April). Steaming with TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. At 1125, it anchored about 2,220 yards (2 km) west-northwest of the northern end of Enewetak Island.
- YOKE (1 May). Underway with TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of the shot island. At 1219, it anchored in its post-X-RAY location.
- ZEBRA (15 May). Underway with TU 7.3.5, about 20 nmi (37 km) south of the shot island. At 1352 it anchored in its post-X-RAY location.

On 20 May, LSM-250 was found to have slight contamination in three locations, with the highest level being less than 0.001 R/hr on the aft weather deck (Reference D.4, p. 4). One of its sixty-one crewmembers was badged. On 24 May, it left for Pearl Harbor.

LSM-378. This vessel was part of TU 7.3.6, the Cable Unit, which laid and maintained the cable network. It arrived at Enewetak Atoll on 1 January 1948 and departed for Kwajalein on 30 March, arriving there on 1 April. On 14 April it began the return trip to Enewetak.

- X-RAY (15 April). Underway from Kwajalein to Enewetak; at 0800 it was about 200 nmi (370 km) east-southeast of Enewetak Island. It reached Enewetak the next day, anchoring at 0811 about 2,200 yards (2 km) northwest of the northern tip of Enewetak Island.
- YOKE (1 May). Underway less than 1 nmi (1.9 km) south-southeast of the northern portion of Enewetak Island about 16.5 nmi (31 km) from the detonation. At 1220, it anchored about 2,040 yards (1.9 km) north of the southern end of Enewetak Island.
- ZEBRA (15 May). Underway about 12 nmi (22 km) east-southeast of the northern end of Parry Island and about 16.5 nmi (31 km) from the detonation. At 1222, it anchored in its post-YOKE location.

On 20 May, LSM-378 was monitored and found to have a reading of 0.0017 R/hr on one air intake amidships on the starboard side (Reference D.4, p. 4). Three of the forty-three crewmembers were badged. It left the proving ground for Pearl Harbor on 24 May.

USS LST-45. This tank landing ship arrived at Enewetak Atoll on 29 November 1947, part of the first group of TG 7.3 ships. It joined TU 7.3.2, the Main Naval Task Unit (Reference C.3, pp. VII-4 and VII-14). Before X-RAY and after X-RAY and YOKE the ship provided forward logistical support for operations on the shot islands.

- X-RAY (15 April). Steaming with TU 7.3.5 between 27 and 36 nmi (50 and 67 km) from the shot island. At 1152, the ship anchored about 4,150 yards (3.8 km) south-southwest of the southern tip of Aomon Island.
- YOKE (1 May). Steaming in formation with TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of the shot island. The ship anchored about 3,150 yards (2.9 km) south-southwest of the northern end of Runit at 1320.

- ZEBRA (15 May). Underway with TU 7.3.5 about 20 nmi (37 km) south of the shot island. At 1213, the ship anchored about 1,260 yards (1.2 km) north of the southern end of Enewetak Island.

Contamination of 0.0012 R/hr was detected in the generator room escape trunk vent set on 20 May (Reference D.4, p. 4). Four of its sixty-six crewmembers were badged. LST-45 left the proving ground for Pearl Harbor on 24 May.

USS LST-219. This tank landing ship arrived at Enewetak Atoll with its 60-man crew on 29 November 1947 and left for Pearl Harbor on 2 February 1948. It returned to Enewetak on 21 March after stopovers at Pearl Harbor and Kwajalein Atoll. At the proving ground, it was part of TU 7.3.2, the Main Naval Task Unit.

Under orders from CTG 7.3, the ship left Enewetak Atoll on 6 April for Ujelang Atoll, to stand by for evacuation of the inhabitants if fallout occurred on the island. Evacuation was not required. It remained there through all three tests and departed on 16 May for Kwajalein.

After leaving Kwajalein, LST-219 sailed to Rongerik Atoll, arriving on 19 May, back to Kwajalein Atoll, arriving 22 May, to Majuro, arriving 24 May, then back to Kwajalein Atoll, arriving 27 May, and on 30 May it reached Enewetak Atoll. It left for Pearl Harbor on 31 May.

USS LST-611. This tank landing ship was among the first group of ships to arrive at Enewetak (29 November 1947) in support of the SANDSTONE test series. Thereafter, it made several trips between Enewetak Atoll and Pearl Harbor. It served as part of TU 7.3.2, the Main Naval Task Unit, but it does not appear to have been in the vicinity of Enewetak Atoll for any of the detonations. On 10 April, it left Pearl Harbor for Enewetak, but it probably had not reached the atoll by 15 April, the day of X-RAY. On 26 April, the ship left Enewetak for Hawaii, arriving there on 7 May; hence it was not in the proving ground for YOKE on 1 May. The ship left Hawaii for Enewetak on 12 May, but probably would not have reached the atoll in time for ZEBRA (Reference C.3, pp. VII-4, -14 and -15, -18 and -19, -21, -23, -80, and -84). The ship's log are unavailable, so its movements cannot be followed in detail. Its crew numbered 53.

USS Marsh (DE-699). This destroyer escort arrived at Enewetak Atoll on 30 March. It served as part of TU 7.3.3, the Off-Shore Patrol Unit.

- X-RAY (15 April). Underway as antisubmarine screening vessel for TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island.
- YOKE (1 May). Underway as antisubmarine screening vessel for TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of the shot island. On 7 May at 1528, it anchored about 3 nmi (5.6 km) southwest of the south end of Runit. A radSAFE monitor boarded Marsh on the afternoon of 2 May and remained aboard until the afternoon of 5 May.
- ZEBRA (15 May). Underway as antisubmarine screening vessel for TU 7.3.5 about 20 nmi (37 km) south of the shot island. Shortly after

1245, the ship entered the lagoon to pick up a radsafe monitor, who came aboard from Tucker. After the monitor boarded Marsh at 1309, the ship left the lagoon for antisubmarine patrol around Enewetak Atoll. At 1028 on 18 May, the ship reentered the lagoon and then lay to, awaiting a radsafe party. The party came aboard at 1130. The ship then anchored about 3,960 yards (3.6 km) west of the northern end of Enewetak Island. The monitor, who had come aboard on 15 May, and the radsafe party left the ship at 1343. There is no information on the radiation levels detected.

No contamination was found during a check by radsafe monitors on 20 May (Reference D.4, p. 6). Only 1 of its 138 crewmembers was badged. Marsh left for Pearl Harbor on 3 June.

USS Mispillion (AO-105). This oiler arrived at Enewetak on 10 April. It belonged to TU 7.3.5, the Service Unit, and served as tanker to the task group.

- X-RAY (15 April). Steaming as part of TU 7.3.8 between 18 and 23 nmi (33 and 43 km) south-southeast of the shot island. At 0858, Mispillion anchored in the lagoon about 3,960 yards (3.6 km) west of the northern end of Enewetak Island.
- YOKE (1 May). Underway with TU 7.3.8 between 15 and 20 nmi (28 and 37 km) east-southeast of the shot island. At 1019, the ship anchored in its post-X-RAY location. On 5 May, the ship left for Guam, returning to Enewetak Atoll on 12 May.
- ZEBRA (15 May). Underway with TU 7.3.8 between 25 and 30 nmi (46 and 56 km) southeast of the shot island. At 1015, the ship anchored in its post-X-RAY location.

On 20 May, Mispillion was found slightly contaminated at several locations. The highest level was 0.002 R/hr in the portside engine-room supply vents (Reference D.4, p. 3). All other readings were less than 0.001 R/hr. Its crew totaled 173. The next day the ship left Enewetak Atoll for Kwajalein Atoll en route to the U.S. mainland.

USS Mount McKinley (AGC-7). On 16 March, this amphibious force flagship with a crew of 578 arrived at Enewetak. It was the only ship in TU 7.3.1, the Flagship Unit.

- X-RAY (15 April). Anchored in the lagoon about 2,400 yards (2.2 km) west of Parry, about 17 nmi (32 km) from surface zero. At 0730, the ship got underway to an anchorage about 3,260 yards (3 km) southwest of Aomon Island. It arrived there at 0937.
- YOKE (1 May). Anchored in its pre-X-RAY location, about 13.5 nmi (25 km) from the shot island. The ship got underway at 0825, and at 0946 it anchored about 2,480 yards (2.3 km) southwest of the northern end of Runit.
- ZEBRA (15 May). Anchored as for the first two shots and about 8.5 nmi (15.8 km) south of surface zero on Runit. At 0939, moved to a berth about 2,400 yards (2.2 km) west of the northern end of Enewetak Island.

On 20 May, radsafe monitors found slight contamination at two locations on the ship. The readings were 0.0006 R/hr and 0.0003 R/hr (Reference D.4, p. 2). Mount McKinley left the proving ground for Pearl Harbor on 21 May.

USS Pasiq (AW-3). This water distillation ship was in the proving ground twice in February and twice in March, arriving the second time on 28 March. During this 2-month period, it also was at Kwajalein, Rongerik, and Bikini atolls. Pasiq served as flagship for TU 7.3.5 and provided freshwater.

- X-RAY (15 April). Leading TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. At 1257, the ship anchored in the southeast portion of Enewetak Lagoon.
- YOKE (1 May). Leading TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of the shot island. At 1206, the ship anchored in the lagoon about 2,740 yards (2.5 km) west-northwest of the northern end of Enewetak Island.
- ZEBRA (15 May). Leading TU 7.3.5 about 20 nmi (37 km) south of the shot island. At 1140, the ship anchored in its post-YOKE location. At 1502, Pasiq departed for Bikini Atoll and then Kwajalein Atoll, returning to Enewetak Atoll on 19 May.

On 20 May, Pasiq was found to have radioactive contamination at several locations. The highest radiation level was 0.0017 R/hr in one of the intakes on the starboard side (Reference D.4, p. 4). Of its 164 crewmembers, 11 were badged. On 24 May, the ship departed for Pearl Harbor.

USS Pelican (AMS-32). This motor minesweeper was under operational control of TG 7.3. On 3 March, Pelican sailed under escort to Kwajalein Atoll. After replenishment there, it was escorted to Ailinglapalap about 470 nmi (870 km) southeast of Enewetak Atoll. Apparently it was there for all three shots. It departed Ailinglapalap for Kwajalein Atoll on 16 May (Reference C.5, pp. VII-58, 84&85). Pelican was not exposed to radiological contamination, and none of its 25-man crew was badged.

USS Perkins (DDR-877). On 29 January, this radar picket destroyer arrived at Enewetak Atoll, where it served as part of TU 7.3.3, the Off-Shore Patrol Unit. Its crew size was 223.

- X-RAY (15 April). Patrolling south of Wide Entrance, about 3.8 nmi (7 km) southwest of the southern end of Enewetak Island and 21.25 nmi (39.4 km) south-southeast of the shot island. On 27 April at 1500, as the ship continued to patrol south of Wide Entrance, a radsafe monitor came aboard. About an hour later he transferred to George.
- YOKE (1 May). Patrolling in approximately the same location as for X-RAY, about 20 nmi (37 km) from surface zero. On 3 May at 1751 it moored beside Mispillion to take on fuel; at 2015 it anchored west of Enewetak Island.
- ZEBRA (15 May). Patrolling south of Wide Entrance, about 6 nmi (11 km) southwest of the southern end of Enewetak Island and about 18.5

nmi (34.3 km) south-southwest of surface zero on Runit. On 15 May at 1418 it returned to Enewetak Lagoon; at 1736, after refueling from Mispillion, it anchored about 3,300 yards (3 km) northwest of the northern end of Enewetak Island.

During the radsafe inspection on 20 May, no contamination was found on Perkins (Reference D.4, p. 6). The ship left for Pearl Harbor on 21 May.

USS Pickaway (APA-222). This attack transport ship served as a troop evacuation vessel. Dates of arrival at and departure from Enewetak Atoll before SANDSTONE by this ship are:

<u>Arrival</u>	<u>Departure</u>
28 December 1947	1 January 1948
26 February 1948	14 March 1948
1 April 1948	

During SANDSTONE the ship was part of TU 7.3.2, the Main Naval Task Unit.

- X-RAY (15 April). Steaming with TU 7.3.8 a few miles east of Parry and between 18 and 23 nmi (33 and 43 km) south-southeast of the shot island. At 0834, the ship anchored in the lagoon about 2,370 yards (2.2 km) west of the northern end of Enewetak Island.
- YOKE (1 May). Underway with TU 7.3.8 between 15 and 20 nmi (28 and 37 km) southeast of the shot island. The ship anchored in the lagoon at 1005 at its post-X-RAY location.
- ZEBRA (15 May). Underway with TU 7.3.8 between 25 and 30 nmi (46 and 56 km) southeast of the shot island. At 1019, the ship anchored about 3,070 yards (2.8 km) west-southwest of the northern end of Enewetak Island.

The radsafe inspection on 20 May revealed several contaminated locations on Pickaway. The highest level of radioactivity was 0.0015 R/hr in the main engine-room blower at Frame 86 and in a porthole fan in the officer's mess (Reference D.4, p. 2). Badges were issued to 12 of its 290 crewmembers. On 27 May, the ship left Enewetak Atoll for Pearl Harbor via Kwajalein Atoll.

USS Quick (DMS-37). On 24 March, this high-speed minesweeper arrived at Kwajalein. It was under the operational control of CTG 7.3. On 10 April it arrived at Enewetak Atoll and departed for its station on 12 April.

- X-RAY (15 April). On station within a 50-nmi (93-km) radius of 15°0'N, 171°45'E. On 18 April the ship anchored at Kwajalein. On 27 April it left Kwajalein for its station.
- YOKE (1 May). On station in the area of 13°0'W, 172°20'E. On 3 May the ship moored at Kwajalein Atoll. On 12 May the ship left to take up its station for ZEBRA.
- ZEBRA (15 May). On station in the area of 12°30'N, 172°20'E. The ship returned to Kwajalein on 16 May and left for Pearl Harbor on 21 May.

For each shot the ship was about 600 nmi (1,112 km) from Enewetak Atoll. The ship arrived at Kwajalein on the morning of 3 May, approximately 4 hours after the radiological rainout from YOKE had fallen on the atoll for 10 hours. The ship was not exposed to radiological contamination, and none of its 167 crewmembers was badged.

USS Raby (DE-698). For SANDSTONE, destroyer escort was part of TU 7.3.3, the Off-Shore Patrol Unit. It arrived at Enewetak Atoll with its 143 crewmembers on 1 January.

- X-RAY (15 April). Steaming near the southern end of Parry, about 19.5 nmi (36.1 km) south-southeast of the shot island. On 18 April at 1848 it entered Enewetak Lagoon; at 1904 moored to Mispillion. On 19 April at 0710 it anchored in the lagoon west of Enewetak Island.
- YOKE (1 May). Steaming in the open sea off Enewetak Atoll, about 7 nmi (13 km) southeast of the shot island. At 0846, the ship entered the lagoon through Deep Entrance and then steamed to Northern Anchorage near Mount McKinley, which was anchored about 2,480 yards (2.3 km) southwest of the northern end of Runit. By 0955, Raby hove to near Mount McKinley. From Mount McKinley, Raby took aboard two officers and a ten-man U.S. Marine Corps detachment for transportation to Bikini Atoll where it was to investigate a report of footprints and tampering with experimental equipment on Enidrik Island (Reference C.3, p. VII-73). Raby was underway for Bikini Atoll at 1022. It returned to Enewetak Atoll on 3 May, following the investigation at Bikini Atoll.
- ZEBRA (15 May). Underway about 1.8 nmi (3.3 km) southeast of the southern end of Parry and about 10 nmi (18.5 km) south-southeast of the shot island. At 1443, the ship moored alongside Spangler, about 4,630 yards (4.2 km) west of the northern end of Parry, for refueling. At 1650, it anchored about 8,070 yards (7.4 km) west of the northern end of Enewetak Island.

The radsafe check on 20 May indicated slight contamination at less than 0.001 R/hr on two air intakes on Raby (Reference D.4, p. 5). The ship left for Pearl Harbor on 21 May.

USS Rogers (DDR-876). This radar picket destroyer reached Enewetak Atoll on 8 March, where it became part of TU 7.3.3, the Off-Shore Patrol Unit.

- X-RAY (15 April). On patrol about 2.1 nmi (3.9 km) east-southeast of the northern tip of Enewetak Island, about 19 nmi (35 km) from surface zero.
- YOKE (1 May). On patrol about 5.3 nmi (9.8 km) east of Japtan and about 15 nmi (28 km) southeast of the shot island. Between 0844 and 0855, the ship first entered and then left Deep Entrance channel. On 2 May at 1030 anchored about 3 nmi (5.6 km) southwest of the southern tip of Runit.
- ZEBRA (15 May). On patrol about 8 nmi (15 km) southeast of the shot island and about 4.7 nmi (8.7 km) east-northeast of the northern

end of Enewetak Island. At 1643, the ship anchored in the lagoon about 2,370 yards (2.2 km) northwest of the southern tip of Enewetak Island. Between 1315 and 1345 on 18 May, a radsafe party checked the ship for radioactivity. The radsafe party left the ship at 1345 after finding various items excessively radioactive.

Between 0915 and 0945 on 20 May, a radiological party again came aboard and found contamination in 18 vent-duct screens. The highest level of radioactivity was 0.0039 R/hr in the vent duct at Frame 150 on the starboard side (Reference D.4, p. 4). Later the same day, the ship left Enewetak Atoll for Rongerik Atoll en route to Pearl Harbor. Rogers was again inspected by radsafe personnel when it arrived at San Diego on 4 June and was declared safe. Of its 234 crewmembers, 178 were badged -- all with zero exposure.

USS Spangler (DE-696). This destroyer escort arrived in the proving ground on 15 January. It participated in operations as part of TU 7.3.3, the Off-Shore Patrol Unit.

- X-RAY (15 April). Anchored in the lagoon about 4,630 yards (4.2 km) west of the northern end of Parry about 16 nmi (30 km) south-southeast of surface zero. Assigned as plane guard for Bairoko, Spangler steamed toward the northern part of the lagoon at 0705. It was released from plane guard duty at 0802 and returned to the southeast portion of the lagoon, where it anchored about 2,330 yards (2.1 km) northwest of the northern end of Enewetak Island at 0915.
- YOKE (1 May). Anchored as for X-RAY, 13 nmi (24 km) south of the shot island. At 0710, the ship was underway as plane guard for Bairoko. Released from plane guard duty at 0805, Spangler anchored 2.4 nmi (4.4 km) west of the northern end of Parry Island. At 1405 the ship got underway for patrol off the atoll. On 4 May the ship returned to the lagoon for refueling from Mispillion, resuming patrol the same day. On 8 May, after refueling from Comstock, Spangler anchored 2,860 (2.6 km) west-northwest of the northern end of Enewetak Island. At 0653 on 12 May, the ship was underway to patrol the Wide Passage. At 1412, a radsafe monitor came aboard the ship. On 14 May it anchored 2.4 nmi (4.4 km) west of the northern end of Parry Island.
- ZEBRA (15 May). Anchored in the same postshot location as for the two previous detonations, about 8 nmi (15 km) south of the ZEBRA surface zero. At 1320, the radsafe monitor transferred to Currier.

The radiation check of 20 May revealed contamination of 0.0055 R/hr in the starboard vent duct screen at Frame 70 on the port side. The screen was jettisoned. This left the highest reading as 0.004 R/hr on the starboard vent duct screen at Frame 50 (Reference D.4, p. 4). Of its 135 crewmembers, 9 were badged. Spangler left for Pearl Harbor on 21 May.

USS Swallow (AMS-36). This motor minesweeper arrived at Kwajalein Atoll with 23 crewmembers sometime after 5 March. It was under the operational control of CTG 7.3. Its crew was 23. On 23 March, it left Kwajalein Atoll to

take up its station at Bikini Atoll, where it arrived on 27 March. Apparently it was at Bikini Atoll for all three detonations of Operation SANDSTONE, arriving back at Kwajalein Atoll on 17 May (Reference C.3, pp. VII-58, -73, -81, and -85; Raby deck log, Pasig deck log).

USS Warrick (AKA-89). This attack transport first arrived at Enewetak Atoll in connection with SANDSTONE on 28 December 1947. It departed for Pearl Harbor on 25 January and returned to Enewetak Atoll on 29 March. It evacuated troops before the shots. During the test series, the ship was part of TU 7.3.2, the Main Naval Task Unit. Badges were issued to 40 of its 167 crewmembers.

- X-RAY (15 April). Steaming with TU 7.3.8 in the open sea a few miles east of Parry, between 18 and 23 nmi (33 and 43 km) south-southeast of the shot island. At 0842, it anchored about 3,900 yards (3.6 km) west of the northern end of Enewetak Island.
- YOKE (1 May). Underway with TU 7.3.8 between 15 and 20 nmi (28 and 37 km) southeast of the shot island. At 1014, the ship anchored at its post-X-RAY location. On 9 May, the ship left Enewetak Atoll for Kwajalein Atoll.
- ZEBRA (15 May). Anchored at Kwajalein Atoll.

After a trip to Wake Island between 18 and 22 May, Warrick left Kwajalein Atoll for Pearl Harbor on 1 June.

USS Yancey (AKA-93). This attack transport, with 148 crewmembers, was part of TU 7.3.2, the Main Naval Task Unit. The ship was present at Enewetak Atoll from 24 December 1947 to 6 January 1948, from 4 to 30 March 1948, and from 16 to 26 May 1948. It was not, however, in the proving ground for any of the detonations, being in Pearl Harbor for X-RAY, en route to Pearl Harbor from San Francisco for YOKE, and en route to Enewetak Atoll for ZEBRA. On 16 May it anchored in the lagoon a short distance west of Enewetak Island. Nevertheless, during the radsafe inspection of 20 May, contamination of 0.001 R/hr was found in the deck vent at Frame 92 (Reference D.4, p. 5).

YOG-64. No information is available on when this gasoline barge arrived in the proving ground. During the test series it served as part of TU 7.3.5, the Service Unit (Reference C.3, p. VII-4). Its crew numbered 11.

- X-RAY (15 April). Underway as part of TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. It returned to Enewetak Lagoon at 1233 on 15 April.
- YOKE (1 May). The barge was probably moored in Enewetak Lagoon during YOKE. Its crew was transferred to Askari on 30 April. YOG-64 was reboarded about 9 hours after YOKE.
- ZEBRA (15 May). Underway as part of TU 7.3.5 about 20 nmi (37 km) south of surface zero on Runit.

During the radsafe inspection on 20 May, no contamination was detected on YOG-64 (Reference D.4, p. 6). The date of its departure from the proving ground is not known.

YW-94. This water barge arrived in the proving ground on 29 November 1947. It became part of TU 7.3.5, the Service Unit (Reference C.3, pp. VII-4 and -14).

- X-RAY (15 April). Steaming with TU 7.3.5 between 27 and 32 nmi (50 and 59 km) southeast of the shot island. It returned to Enewetak Lagoon on 15 April. On 16 April it moored by Pasig 2,860 yards (2.6 km) west-northwest of the northern end of Enewetak Island.
- YOKE (1 May). Underway with TU 7.3.5 between 17 and 22 nmi (32 and 41 km) southeast of surface zero on Aomon. It returned to Enewetak Lagoon on 1 May by 1230, when it was alongside the Pasig in the same location as following X-RAY.
- ZEBRA (15 May). Underway with TU 7.3.5 about 20 nmi (37 km) south of the shot island. It returned to Enewetak Lagoon by 1243, when it came alongside Pasig to take on water. It was located as following X-RAY.

The radsafe inspection on 20 May found YW-94 free of contamination (Reference D.4, 6). No record of its departure from Enewetak has been located.

Air Units

Air Development Squadron 4 (VX-4) Detachment. Assigned to TU 7.3.3 (Off-Shore Patrol), the VX-4 Detachment reported for duty on 20 March and was based on Kwajalein. The detachment had 54 personnel, none badged. It flew nightly patrols using one of its three PB-1W (B-17G) patrol aircraft (Reference E.2.3.3, p. 24; Reference C.3, p. VIII-67). Aircraft and personnel were detached from VX-4 on 1 April and reassigned to Air Early Warning Squadron 1 (VPW-1). Its SANDSTONE mission was not affected by this change.

Fleet Aircraft Service Squadron 119 Detachment (FASRON-119). This unit was stationed aboard Gardiners Bay and maintained the six PBM-5 patrol planes of the Medium Seaplane Patrol Squadron 6 (VS[MS]-6) Detachment in the proving ground. FASRON-119 had 33 personnel, none of whom appear to have been badged (Reference E.1).

Medium Seaplane Patrol Squadron 6 (VP[MS]-6) Detachment. The detachment reported for operational control on 21 January 1948. Equipped with six PBM-5 patrol aircraft, the detachment had 153 personnel, 11 of whom were badged. It began patrolling the proving ground on 1 February 1948. Single aircraft daylight searches were flown six days per week; the seventh day a five aircraft search was flown. Gardiners Bay was the detachment seaplane tender (Reference C.3, p. VII-4; E.2.3.3, p. 24). During a radsafe check on 20 May, PBM-59250 was found to have radioactivity levels between 0.0003 and 0.0013 R/hr on the top of the wing (Reference D.4, p. 1). PBMs 50155, 84602, and 84623 did not show significant readings (Reference D.4, pp. 1 and 4). Records are lacking on the two other aircraft.

TASK GROUP 7.4 (AIR FORCE)

Staff of the Air Force Commander. One badged Navy officer served in this organization.

Task Unit 7.4.3 (Photography Unit). Five Navy personnel participated in the several photographic teams. All were badged with a high of 0.1 R.

TASK GROUP 7.5 (JOINT SECURITY GROUP)

A manning report dated 31 March 1948 indicates 116 Navy personnel were in TG 7.5, but the monthly roster of TG 7.5 personnel of the same date (Reference E.2.0.2, p. 15) lists only one Navy man, an officer who was badged, working in task group headquarters (Reference E.2.5.2, p. 1). In the manning report, the figures are divided into three categories: Army, Navy, and Air Force. No Marines were enumerated. However, there were 115 Marines in TG 7.5 (see Chapter 8), and therefore 115 of the 116 Navy personnel referred to in the manning report are these Marines.

TASK GROUP 7.6 (JOINT RADIOLOGICAL SAFETY GROUP)

Fifty Navy personnel were in this task group including its commander, a badged Navy officer.

Bureau of Medicine and Surgery (BuMed). In conjunction with Bureau of Ships, this organization led the service tests of biological material, pocket dosimeters, samples of cloth and other material, and animal containers at various distances from the detonations. These activities involved exposure to radioactivity (Reference C.5, p. 3-10). Three Navy officers from BuMed can be identified with this test. During the operation they worked as part of TU 7.6.6 (Reference E.2.6; Reference C.3, pp. VIII-11 and IX-55).

Bureau of Ships (BuShips). A Navy officer from BuShips, working as part of TU 7.6.6, conducted the material sample exposure tests at stations on Enjebi, Aomon, Bijire, and Lojwa. In addition, radiation detection and exposure recording instruments were tested during radsafe operations (Reference C.5, pp. 3-10 and -11). The officer was badged (Reference C.3, p. IX-54).

Bureau of Yards and Docks (BuDocks). This organization led the service test of prefabricated structures set out on Enjebi for X-RAY and on Aomon, Bijire, and Lojwa for YOKE. Men from TG 7.3 apparently did most of that work (Reference C.5, p. 3-4). Only one officer from BuDocks, a badged Navy commander, can be identified with this effort. On 24 April, following X-RAY, he inspected the structures on Enjebi and gathered data. On 7 May, following YOKE, he inspected the structures on Aomon, Bijire, and Lojwa and gathered data (Reference C.3, p. VII-78).

Thirty-seven Navy personnel whose home stations are not known were also in TG 7.6, having the following assignments.

Task Unit 7.6.2 (Staff Unit). Eight Navy enlisted men, all badged, served in this unit (Reference C.43, Special Order No. 1, p. 1; Reference E.2.3.3, p. 2596).

Task Unit 7.6.3 (Operations Unit). Three badged Navy officers were in this task unit (Reference C.43, Special Order No. 1, p. 1; Reference E.2.3.3, p. 2596).

Task Unit 7.6.4 (Laboratory Unit). Eight badged Navy enlisted men were in this unit (Reference C.43, Special Order No. 2, p. 1; Reference E.2.3.3, p. 2596).

Task Unit 7.6.5 (Radiological Records Unit). One badged Navy enlisted man was in this unit (Reference C.43, Special Order No. 2, p. 2; Reference E.2.3.3, p. 2597).

Task Unit 7.6.6 (Technical Measurements Unit). Five Navy officers and four enlisted men, all badged, served in this unit (Reference C.43, Special Order No. 2, p. 2; Reference E.2.3.3, pp. 2596-97). Four of the officers were from BuM and BuShips (above).

Task Unit 7.6.7 (Monitor Unit). Including its commander, the unit had eleven Navy officers, all of whom were badged (Reference C.43, Special Order No. 2, p. 2; Reference E.2.3.3, p. 2596-7).

Task Unit 7.6.9 (Rear Echelon Unit). Based in Washington, D.C., this unit was headed by a Navy officer. He was badged, probably when he visited the proving ground as a TG 7.8 observer. No other information is available on Navy participation in this unit (Reference C.43, Special Order No. 2, p. 3).

Seven other Navy personnel have been identified as serving with TG 7.6, but their home stations and task unit affiliation are unknown. Three were badged; four were not. (Reference E.2.3.3, pp. 2596-97).

TASK GROUP 7.7 (KWAJALEIN ISLAND COMMAND)

Nine hundred seventy-one Navy personnel have been identified with this task group. The following organizations contributed.

Amphibious Patrol Squadron 2 (VPAM-2) Detachment. This unit had 18 officers and men, none badged (Reference E.2.3.3, p. 2180).

Civil Administration Unit, Kwajalein. This unit had 34 Navy personnel, none badged (Reference E.2.3.3, pp. 2588-2589).

Construction Battalion 1509 Detachment. Badges were issued to 5 of the 215 officers and men of this detachment (Reference E.2.3.3, pp. 2589-2594; Reference E.2.3.2).

Heavy Lift Patrol Squadron 8 (VPHL-8) Detachment. Two officers and six enlisted men made up this unit, none badged (Reference E.2.3.3, p. 2680; Reference E.2.3.4).

Naval Air Station, Kwajalein. This unit had 427 personnel, of whom 13 were badged (Reference E.2.3.3, pp. 2664-2674).

Naval Station, Kwajalein. One hundred and fifteen personnel were in this unit; four were badged (Reference E.2.3.3, pp. 2674-6).

Naval Station, Kwajalein, In-Service Craft. This served as the Kwajalein Boat Pool. Twenty-eight personnel have been identified with this unit (Reference

E.2.3.3, p. 2676). Enlisted personnel in the four lowest ranks have not been identified.

Naval Station, Kwajalein, Ship Security Detachment. This unit had a total of 93 officers and men; 18 were badged (Reference E.2.3.3, pp. 2676-2678). The unit was the responsible for maintaining the target ships towed to Kwajalein Atoll from Bikini Atoll after Operation CROSSROADS in 1946.

Transport Squadron 8 (VR-8) Detachment. The 26 personnel of this detachment were unbadged (Reference E.2.3.3, p. 24).

Utility Transport Squadron 3 (VRU-3) Detachment. The seven personnel in this detachment were not badged (Reference E.2.3.3, p. 2687).

TASK GROUP 7.8 (OBSERVER ESCORT GROUP)

Individuals escorting observers typically were drawn from other task groups. Assignments to this duty were temporary and in addition to other duties. No information is available on Navy participation in escort work.

Seven Navy officers visited the proving ground as observers. Three were attached to the Armed Forces Special Weapons Project (AFSWP); one of the three also served as commander of TU 7.6.9. Two of the officers were from the staff of Commander-in-Chief, Pacific. One was from AEC, and one had no recorded affiliation beyond the Navy. Five were badged (Reference C.1, pp. 147-148).

NON-TASK-FORCE SHIPS

A number of other ships were in the area of the proving ground during the operational or rollup stages of Operation SANDSTONE. They were not part of JTF 7, and their operations did not take them into radioactive areas.

USS Ashtabula (AO-51). On 1 April, this oiler was at Enewetak Atoll, and on 2 April, it was at Kwajalein Atoll. On 3 April at 0745 it left Kwajalein Atoll (Curtiss deck log, Yancey deck log).

USS Chehalis (AOG-48). This gasoline tanker arrived at Enewetak Atoll on 3 May and departed on 7 May (Reference C.3, p. VII-83).

USS Cimarron (AO-22). On 1 May, this oiler was underway from Kwajalein Atoll on a southwesterly course (Pasig deck log). It was also present at Kwajalein from 15 May to 17 May (Warrick log).

USS Kerstin (AF-34). On 1 April, this reefer was at Enewetak Atoll (Gardiners Bay deck log). It left on 1 April at 1815.

USS Klickitat (AOG-64). This gasoline tanker was at Enewetak Atoll on 19 May and refueled from Mispiration (Curtiss deck log). It left that day.

USS Latona (AF-35). This reefer arrived in the area on 9 April 1948. No information on its location at the time of X-RAY has been found, but the ship does not appear to have been at Enewetak Atoll. For YOKE, Latona was at

Kwajalein Atoll and left for Enewetak Atoll that day to reprovision vessels there, arriving on 3 May. The ship left Enewetak Atoll on 12 May (Reference C.3, pp. VII-83 and -85).

LCI-615. For all three shots this infantry landing craft was at Ujelang Atoll (LST-219 deck log), acting as tender vessel for a Navy detachment putting up buildings on the island (Reference C.3, p. VII-64).

USS Nemasket (AOG-10). On 1 December 1947 this gasoline tanker was at Enewetak as a station tanker. In February it delivered aviation gasoline to Enewetak.

USS Ryer (AG-138). On 1 April, this ship was in the vicinity Kwajalein Atoll (Yancey deck log). On 17 April, two days after X-RAY, it was at Ujelang Atoll (LST-219 deck log).

CHAPTER 7

U. S. AIR FORCE PARTICIPATION IN OPERATION SANDSTONE

SANDSTONE was the first test series in which the newly created U.S. Air Force played a role. Over 2,000 Air Force personnel with approximately 60 aircraft participated in the operation. Most Air Force personnel were stationed on Kwajalein; however, others were stationed on ships, on Enewetak, Rongerik, and Majuro atolls, and on Wake Island.

Air Force personnel for SANDSTONE were in several task force organizations. In addition to Task Group (TG) 7.4, 55 Air Force personnel served in Hq Joint Task Force 7 (JTF 7) (22 on the JTF 7 staff and 33 on the staff of Commander Air Forces, who was a Deputy to Commander JTF 7 [CJTF 7]). Commander Air Forces had command authority over CTG 7.4. Although the entire airbase operation at Enewetak Island was under the control of CTG 7.2, several Air Force personnel at Enewetak provided essential runway control, communications, and navigation services for aircraft using the Enewetak airbase. Over 200 Air Force personnel in the 1535th Air Force Base Unit, permanently based on Kwajalein Atoll, were assigned to TG 7.7. An Air Force security unit, the 700-X Counter Intelligence Corps (CIC) Detachment, was also assigned to TG 7.5.

TG 7.4 established weather stations on Enewetak, Rongerik, and Majuro atolls and supplemented existing weather facilities at Kwajalein Atoll and Wake Island as part of Task Unit (TU) 7.4.4. Few, if any, weather and communications personnel at these weather stations were badged. Authorized strength was 35 for Enewetak, 20 each for Rongerik and Majuro, and 15 for Wake including 5 permanent U.S. Weather Bureau personnel. The remaining 155 persons authorized for TU 7.4.4 were stationed on Kwajalein (Reference B.4.1, Annex K).

Of the 2,012 Air Force participants, only 350 were badged. The exposure recording program was in its infancy, and no comprehensive program existed for badging all participants for the duration of the series. Information on those who were badged is very limited. Normally only the individual's name and rank were posted to badge records. In some cases the first name (or initial) is not available, and in some cases the rank is not available. Some orders for Air Force personnel have been located that, along with clearance rosters, have allowed identification of most Air Force participants. Only personnel who entered potentially radioactive areas were issued badges. Generally, badges were issued and turned in daily during this series. Within TG 7.4 this included most aircrews and photographers. Winds were favorable for all three shots, and fallout drifted away from TG 7.3 ships and the inhabited islands of Parry and Enewetak at Enewetak Atoll. Fallout from shot YOKE on 1 May 1948, however, drifted over Kwajalein on 3 May. Calculations indicate that the total exposure for persons remaining in the open would have been 0.770 R from this fallout (Reference D.6). Table 12 reflects personnel exposure for Air Force personnel by task force functional organization and is derived from film badge readings. Overall exposures were low and only one person (in the Drone Unit) exceeded 3 R. Discussion of each organization listed Table 12 follows.

Table 12. SANDSTONE personnel exposures, U.S. Air Force organizations.

Organization	No. of Persons Badged	Exposure Ranges (roentgens)								
		0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	High
Hq Joint Task Force 7	6	4	2	0	0	0	0	0	0	0.380
Commander Air Forces	31	18	13	0	0	0	0	0	0	0.405
Task Group 7.1	2	0	1	1	0	0	0	0	0	0.890
Task Group 7.4										
Task Unit 7.4.1	4	2	1	0	1	0	0	0	0	1.052
Task Unit 7.4.2	99	21	57	14	3	2	0	1	1	3.060
Task Unit 7.4.3	148	110	37	1	0	0	0	0	0	0.530
Task Unit 7.4.4 Reconnaissance	4	4	0	0	0	0	0	0	0	0
Task Unit 7.4.4 Reporting	1	1	0	0	0	0	0	0	0	0
Task Unit 7.4.9	5	1	4	0	0	0	0	0	0	0.060
Task Group 7.5	15	15	0	0	0	0	0	0	0	0
Task Group 7.6	13	3	7	3	0	0	0	0	0	0.880
Task Group 7.7										
1535th Air Force Base Unit	16	11	1	1	1	1	1	0	0	2.29
Official Observers	6	5	1	0	0	0	0	0	0	0.290
Total Air Force personnel	350 ^a	195	124	20	5	3	1	1	1	3.060

Note:

^aMean exposure was 0.187 R.

HEADQUARTERS JOINT TASK FORCE 7

Altogether, 22 Air Force personnel have been identified as working in Hq JTF 7 within the various staff sections. Six of these individuals were badged and their exposures are listed in Table 12.

HEADQUARTERS AIR FORCES, JOINT TASK FORCE 7

This special command organization in Hq JTF 7 was formed to manage air operations within the test area. This headquarters had a staff of 35 personnel, all of whom were located aboard USS Mount McKinley (AGC-7). One Navy, one Army, and 33 Air Force personnel made up this staff. Exposures for the 31 badged Air Force personnel are given in Table 12.

TASK GROUP 7.1 (ATOMIC ENERGY COMMISSION PROVING GROUND GROUP)

TG 7.1 rosters show one Air Force colonel and one Air Force major assigned during SANDSTONE. The colonel was Deputy Director, TG 7.1; the major's duties are not specified. Both were badged (see Table 12).

TASK GROUP 7.4 (AIR FORCE)

Most Air Force personnel in SANDSTONE served in this task group. Personnel identified with this group total 1,699.

Task Unit 7.4.1 (Hq and Service Unit)

This unit staffed Hq TG 7.4, provided third echelon supply and maintenance to TG 7.4 units, and was responsible for base housekeeping on Kwajalein for Air Force personnel and equipment. It operated a dispensary on Kwajalein Island and had 12 medical specialists assigned to the hospital on Kwajalein. All were stationed on Kwajalein, although some certainly traveled to Enewetak. Only 4 of 605 personnel assigned to Task Unit (TU) 7.4.1 were badged (see Table 12). The 605 assigned to this unit included 23 Army personnel and 4 commissioned women Air Force nurses who were on Kwajalein. The Army personnel and nurses were not badged (Reference C.3, p. VIII-5) (Reference C.4, p. IV-7).

Task Unit 7.4.2 (Drone Unit)

This unit consisted of personnel from the 1st Experimental Guided Missiles Group at Eglin Field, Florida. They operated 24 B-17s, of which 12 were unmanned drones used for cloud sampling and 12 were manned drone control aircraft. The manned B-17 control aircraft flew close to the radioactive cloud to control the drones, but only the drones penetrated the cloud. The radioactive drones were landed at Enewetak where the samples were removed by LASL personnel. Drones were decontaminated while at Enewetak and returned to Kwajalein. Table 12 shows exposures for TU 7.4.2. The 460 participants included five Army personnel (one of whom was badged and whose exposure was 0.050 R) as well as five civilians (all of whom were badged). The Army personnel are not included in Table 12, but are in Table 10. The one person who received an exposure greater than 3 R was a staff sergeant in this task unit. His exposure was 3.060 R, almost all of which was received in the 7 days following shot ZEBRA. He probably was involved in decontamination or maintenance of the radioactive B-17 drones. This unit was stationed on Kwajalein Island, but unit personnel frequently traveled to Enewetak Atoll in support of drone operations (Reference C.3, pp. VIII-5, -73, and -75).

Task Unit 7.4.3 (Photography Unit)

This unit with 173 Air Force personnel had separate suborganizations to conduct its several diverse missions. Aerial photography was done by the 311th Air Division using C-54s and F-13s. Documentary photography was done by seven teams on various ships and ashore at Enewetak and Kwajalein. Tower photography, using four specially constructed photo towers, was done by yet another team. Also, a film-processing laboratory was set up on USS Curtiss (AV-4) (Reference C.3, p. VIII-5&31; Reference C.4, p. XVIII-5). Personnel for TU 7.4.3 came from several organizations in addition to the 311th Air Division. Lookout Mountain Laboratory and Los Alamos Scientific Laboratory (LASL) furnished some personnel, and LASL hired 19 civilian photographers for the SANDSTONE tests. In addition, 12 Army, 5 Navy, and 1 Marine Corps personnel were assigned to TU 7.4.3. All except nine personnel in this unit were badged at one time or another during SANDSTONE. All exposures were low (see Table 12). The exposures of the non-Air-Force personnel in this unit are shown in Table 10 for Army personnel, Table 11 for Navy personnel, and Table 13 for Marine Corps personnel.

Task Unit 7.4.4 (Weather Unit)

This unit contained two separate groups that collected weather data: weather reconnaissance (173 personnel) and weather reporting (112 personnel).

The 514th Weather Reconnaissance Squadron operated eight weather reconnaissance WB-29s out of Kwajalein. These aircraft were also used to track the nuclear cloud for up to 5 days after each detonation. For cloud-tracking operations, a monitor from CTG 7.6 was aboard. A dispatch from TG 7.6 to TU 7.6.1 (Air Monitor Unit) on 11 April 1948 allowed contact with the cloud during tracking as long as total exposure did not exceed 0.100 R. Cloud-tracking aircraft returned after shot X-RAY with exterior contamination that required aircraft monitoring and personnel decontamination operations (Reference C.43, p. 91). Reconnaissance personnel in TU 7.4.4 are reported separately from TU 7.4.4 weather reporting personnel in Table 12. Even though cloud-tracking aircraft flew through radioactive material, records reflect badge readings for only four persons in the 514th Weather Reconnaissance Squadron. A check of TG 7.6 air monitors who flew with crews of the WB-29s shows that none received an exposure in excess of 1 R during SANDSTONE.

Weather reporting personnel were trained at Tinker AFB, Oklahoma, which was probably home station for many of these individuals. During SANDSTONE they were stationed at several locations in the Pacific test area. Two were aboard Mount McKinley and staffed JTF 7 Weather Central; 27 on Enewetak, 7 on Kwajalein, 27 on Majuro, 30 on Rongerik, and 19 on Wake furnished daily weather reports to Weather Central. Only one person in this group was badged and his exposure was zero (see Table 12) (Reference C.3, pp. VIII-6 and -58; Reference C.4, p. XII-7).

Task Unit 7.4.5 (Air Rescue Unit)

This task unit consisted of 33 personnel primarily from the 5th Air Rescue Squadron at MacDill AFB, Florida. It operated two OA-10 and two SB-17 rescue aircraft. Stationed on Kwajalein, its rescue aircraft were in the Enewetak area on test days. None of the 33 was badged. Its personnel approached the detonations no closer than 10 nmi (18.5 km).

Task Unit 7.4.6 (Airways and Air Communications Services Unit)

This unit with 127 personnel was responsible for TG 7.4 communications and airbase navigational aids at Enewetak and Kwajalein. The 71st Airways and Air Communications Services (AACS) Group, Hickam Field, Hawaii, provided 25 personnel and the remaining 102 came from several units in the United States. Seventy-nine personnel from this task unit were on Enewetak, 20 on Kwajalein, 10 each on Rongerik and Majuro, and 8 on Wake. All were unbadged (Reference C.44, p. V-15). Of these locations, only Kwajalein received any fallout.

Task Unit 7.4.7 (Interisland Transport Unit)

This unit operated eleven C-54 and three C-47 aircraft from Kwajalein Air Base. It ferried personnel and equipment to and from Enewetak and conducted aerial radiological surveys of ground-level radiation at shot sites. The C-54s were used for returning radioactive cloud samples and exposed film to the

United States. The 47 individuals in this task unit were assisted by personnel and equipment of the 1535th Air Force Base Unit (AFBU) permanently assigned to Kwajalein Island. The 1535th AFBU activities are discussed under TG 7.7. None of the 47 assigned to TU 7.4.7 was badged during SANDSTONE (Reference C.2, p. V-63; Reference C.3, pp. VIII-5 and -26).

Task Unit 7.4.9 (Liaison Unit)

This unit operated 13 fixed-wing light aircraft to transport men and equipment to the various islands at Enewetak Atoll. Of the 13 assigned Air Force personnel, 5 were badged (see Table 12). According to historical references, Army and Navy personnel were in this unit also, but specific numbers or names could not be identified (Reference C.3, p. VIII-7).

TASK GROUP 7.5 (JOINT SECURITY GROUP)

Among other duties, TG 7.5 guarded the TU 7.4.2 drones when they were landed at Enewetak Island and used five courier teams to escort the radioactive cloud samples and film back to the United States from Enewetak. The 700-X CIC Detachment with 14 Air Force personnel was assigned to TG 7.5. One Air Force man was assigned to the 369th CIC Detachment, an Army security unit. All 15 were badged and all badges recorded zero (see Table 12) (Reference C.2, p. II-52; Reference E.2.0.3).

TASK GROUP 7.6 (JOINT RADIOLOGICAL SAFETY GROUP)

This group of 103 men provided qualified monitors to accompany personnel and aircraft on missions where radiation exposure was possible. It also conducted several experiments (described in Chapter 3). The Air Force assigned 13 to this task group, all badged. Of the 13, 12 were assigned to TU 7.6.1 (Air Monitor Unit), which provided one monitor for each manned TG 7.4 aircraft on shot days and on postshot cloud-tracking missions. None of the 13 Air Force personnel in TG 7.6 received more than 1 R exposure (see Table 12) (Reference C.43, Annex H).

TASK GROUP 7.7 (KWAJALEIN ISLAND COMMAND)

The commander of Kwajalein Island was also designated Commander TG 7.7 for SANDSTONE. His SANDSTONE missions are described in Chapter 1. Substantial engineering work was done on Kwajalein from December 1947 to March 1948 in preparation for the arrival of TG 7.4. The 2307th Aviation Engineer Company from Wheeler Field, Oahu, Hawaii, assisted the 2308th Aviation Engineer Company that was permanently stationed on Kwajalein. The 2307th returned to Oahu before the first SANDSTONE shot. The population on Kwajalein increased from 320 on 1 December 1947 to 1,988 on 1 May 1948. Two Air Force units assigned to Kwajalein to assist in SANDSTONE, but not part of TG 7.4, were the 1535th Air Force Base Unit and the 31-8 Air Weather Service Detachment. Discussions of units follow.

1535th Air Force Base Unit

This unit was the Air Transport Command (ATC) Unit stationed on Kwajalein to support normal ATC trans-Pacific operations. During SANDSTONE it also

supported test operations. A roster of personnel supporting SANDSTONE exists with the names of 190 officers and senior noncommissioned officers. Enlisted personnel in the lower grades probably supported SANDSTONE as well, but no data are available for them. This unit supported TU 7.4.7 (Interisland Transport Unit) in operating eleven C-54s and three C-47s. Sixteen of the 190 personnel who can be identified were badged. Five crewmembers received measurable exposures, the highest of which was 2.29 R. Table 12 lists the exposures (Reference E.2.0.3, 1535th Roster).

31-8 Air Weather Service Detachment

This Air Force detachment was also stationed on Kwajalein at the time of the SANDSTONE tests. Its mission was to provide weather data for the Kwajalein area. A roster of 23 personnel in the unit who supported test operations exists, but total strength of the unit is not known. None of these 23 were badged (Reference E.2.0.3, 31-8 Det. Roster).

OFFICIAL OBSERVERS

Fifteen Air Force officers have been identified from the official observer rosters for X-RAY, YOKE, and ZEBRA. Six were badged; one had an exposure of 0.290 R (see Table 12).

CHAPTER 8
U.S. MARINE CORPS PARTICIPATION IN OPERATION SANDSTONE

Participation of U.S. Marine Corps personnel in SANDSTONE primarily involved security responsibilities, although some of the 224 Marine personnel also contributed to JTF 7 communications, radiological safety (radsafe) activities, and photography. Marines were assigned to JTF 7 staff and Task Groups (TG) 7.3, 7.4, 7.5, 7.6, and 7.7. Each task force element with Marine participation is discussed below and Table 13 lists the exposures for Marine Corps participants in SANDSTONE.

JOINT TASK FORCE 7 STAFF

Four marines were assigned to the communications section. Two were badged; one had zero exposure and the other had 0.020 R (Reference E.2.0.6, p. 4).

TASK GROUP 7.3 (NAVY)

Marines were aboard several TG 7.3 ships as the Marine Detachment of the ship's company or in other capacities.

USS Albemarle (AV-5). Twenty-nine Marines assigned to TG 7.5 provided security aboard this ship. All were badged, but only two had exposures, neither of which exceeded 0.1 R.

USS Bairoko (CVE-1154). The Marine Detachment on this ship had 24 Marines, one of whom was badged with a reading of 0.020 R. In addition to the Marine Detachment there were two Marines aboard who appear on the TG 7.5 roster. Both were badged, one recording zero exposure and the other less than 0.1 R.

USS Curtiss (AV-4). The security of the weapon assembly work done on this ship was assumed by 29 Marines assigned to TG 7.5. All were badged with zero exposure.

USS Mount McKinley (AGC-7). Muster rolls show that 25 Marines made up the Marine Detachment on Mount McKinley. Nine of these were badged and all of these had zero exposure. There was also a Marine Security Detachment (MSD) of 18 personnel aboard Mount McKinley, none of whom were badged. An MSD is considered an expeditionary force and is not expected to function aboard ship as the regular Marine Detachment does. No documentation has been located indicating the assignment of this MSD on Mount McKinley. In addition to the regular Marine Detachment and the MSD, there were four badged Marines from TG 7.5 aboard Mount McKinley. All had zero exposures.

USS Pickaway (APA-222). There was a two-man Marine Detachment aboard Pickaway. One of these Marines was badged with a zero exposure.

Table 13. SANDSTONE personnel exposures, U.S. Marine Corps organizations.

Organization	No. of Persons Badged	Exposure Ranges (roentgens)					High
		0	0.001-0.5	0.5-1	Over 3		
Hq Joint Task Force 7	2	1	1	0	0	0.020	
Task Group 7.3							
<u>USS Albemarle (AV-5)</u>							
TG 7.4 Detachment	29	27	2	0	0	0.090	
<u>USS Bairoko (CVE-115)</u>							
Marine Detachment	1	0	1	0	0	0.02	
TG 7.5 Detachment	2	1	1	0	0	0.90	
<u>USS Curtiss (AV-4)</u>							
TG 7.5 Detachment	29	29	0	0	0	0	
<u>USS Mount McKinley (AGC-7)</u>							
Marine Detachment	9	9	0	0	0	0	
TG 7.5 Detachment	4	4	0	0	0	0	
<u>USS Pickaway (APA-222)</u>							
TG 7.5 Detachment	1	1	0	0	0	0	
Task Group 7.4							
Task Group 7.5 (see also TG 7.3 for shipboard detachments)							
Enewetak Detachment	32	30	2	0	0	0.90	
Task Group 7.6							
Task Group 7.7							
Totals	112a	102	8	1	1	1.04	

Note:

^aMean exposure was 0.018 R.

TASK GROUP 7.4 (AIR FORCE)

A Marine NCO was in one of the photo teams of TU 7.4.3. He was badged with a zero exposure.

TASK GROUP 7.5 (JOINT SECURITY GROUP)

TG 7.5 had 115 personnel including detachments on four ships (above) and at Enewetak Atoll (Reference E.2.0.3, pp. 4-6; Reference C.2, pp. 69 and 70). The Enewetak detachment had 51 of the 115, 32 of which were badged. Of the 32 badged only two showed exposures and these were less than 0.1 R.

TASK GROUP 7.6 (JOINT RADIOLOGICAL SAFETY GROUP)

Two Marines participated and were badged in this unit. Responsibilities are unknown. The high reading was 1.04 R and the low was 0.559 R. The person with the higher reading was scheduled to be on USS Gardiners Bay (AVP-39) at Kwajalein on ZEBRA D-1. The other person was scheduled to be on Parry Island (Reference E.2.6)

TASK GROUP 7.7 (KWAJALEIN ISLAND COMMAND)

Out of a total of 89 Marines assigned to the Marine Barracks, Kwajalein, one Marine appears on the exposure list under TG 7.7. His responsibilities are unknown. It is not known whether the Marine Barracks formally was part of TG 7.7, or just this one individual.

CHAPTER 9

JOINT DEFENSE, ATOMIC ENERGY COMMISSION, OTHER GOVERNMENT AGENCIES, AND CONTRACTOR PARTICIPATION IN OPERATION SANDSTONE

JOINT DEFENSE AGENCIES

Joint defense agencies were a new type of organization in 1948. The Department of Defense (DOD) was created in 1947, absorbing the War Department, which became the Department of the Army, and the Navy Department, which became the Department of the Navy. Created also as a branch of the DOD was the Department of the Air Force. This was the executive agent for a new service, the United States Air Force, which consisted of men and materiel of the former Army Air Forces.

Triservice agencies of DOD were few in number in 1947, but two were involved in SANDSTONE activities.

Joint Chiefs of Staff (JCS). This organization was one of the most important and controversial organizations resulting from the 1947 military reorganization. JCS was active in outlining the requirements for the military development of atomic energy in general and the proposed SANDSTONE testing in particular.

The joint task force conducting SANDSTONE was a subordinate command of JCS. The early stages of planning were done by the Joint Proof Test Committee established by JCS. Personnel of this committee were military officers who later became the leadership of Joint Task Force 7 (JTF 7). Except for the command relationship, direct JCS participation in SANDSTONE was limited to a field-grade officer who acted as an observer and was not badged (Reference C.1, p. 47).

Armed Forces Special Weapons Project (AFSWP). AFSWP was created in 1946 to be the military successor to the Manhattan Engineering District, which had developed the atomic bomb for the War Department during World War II. In 1947, its commanding officer was the same Army general officer who had commanded the Manhattan District throughout its life. AFSWP was to handle military aspects of atomic energy not handled by the Atomic Energy Commission (AEC), which was activated at the same time as AFSWP. AFSWP (and its successors) is probably the oldest of the joint defense agencies, predating formation of the DOD itself.

AFSWP was anxious to have as many of its technical personnel participate in SANDSTONE as was possible in order to increase their knowledge and background in the development and use of atomic weapons. Because of this, AFSWP made available to the task force about 130 of its personnel, primarily from Sandia Base with a few from Washington, D.C. The unit providing most of these was the 38th Engineering Battalion (SP), an AFSWP unit made up of Army personnel. As befits the objective of their participation, AFSWP personnel were in almost all areas in the scientific measurements program described in Chapter 3 of this report, although AFSWP also provided

guard personnel (apparently as an additional duty assignment), clerical support, labor, and "working observers." Rotation of teams for separate shots was also used to increase the number of AFSWP participants and the collective AFSWP experience.

Although the AFSWP contingent was primarily Army personnel, there were several Navy officers from AFSWP who served in Hq JTF 7 or Hq Task Group (TG) 7.1 and one civilian who headed the Technical Measurements Unit (TU 7.6.6). Exposure information for badged AFSWP personnel from the military services is included in Tables 10 and 11. Table 14 shows only the exposure of the civilian CTU 7.6.6.

Table 14. SANDSTONE personnel exposures, civilians from joint defense and other government agencies and contractors.

Organization	No. of Persons Badged	Exposure Ranges (roentgens)								High
		0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	Over 3	
Joint Defense Agency										
Armed Forces Special Weapons Project	1	0	0	0	1	0	0	0	0	1.23
Atomic Energy Commission	62	4	44	3	2	1	2	3	3	5.215
Contractors to Atomic Energy Commission										
Argonne National Laboratory	4	1	3	0	0	0	0	0	0	0.035
Edgerton, Germeshausen & Grier, Inc.	12	9	3	0	0	0	0	0	0	0.070
Los Alamos Scientific Laboratory	26	1	18	1	0	2	1	0	3	17
Los Alamos Z-Division (Sandia)	3	0	3	0	0	0	0	0	0	0.140
Oak Ridge National Laboratory	1	1	0	0	0	0	0	0	0	0
University of California	7	1	6	0	0	0	0	0	0	0.26
Other Government Agencies										
U.S. Public Health Service	2	0	0	2	0	0	0	0	0	0.949
Department of Defense Contractors										
Philco Technology Corporation	1	1	0	0	0	0	0	0	0	0
Total	119	18	77	6	3	3	3	3	6	17

ATOMIC ENERGY COMMISSION

This federal executive agency was charged with the development and control of atomic energy by the Atomic Energy Act of 1946. The AEC operated a

laboratory (Los Alamos Scientific Laboratory [LASL]) at Los Alamos, New Mexico, with a branch at Sandia Base in Albuquerque, whose function was the design and development of atomic weapons. LASL developed the first atomic bombs. It had been operated since its inception by the University of California, first under contract with the Manhattan Engineer District of the War Department, and then with the newly formed AEC. The AEC also contracted for operation of a laboratory at Oak Ridge, Tennessee, where uranium was processed. This laboratory had been operated by the Manhattan Engineering District during World War II as the Clinton Engineer Works. The University of Chicago operated the Argonne National Laboratory for the AEC. All these laboratories had personnel at SANDSTONE.

Liaison between the AEC and the JCS was handled by the Military Liaison Committee (MLC). The MLC sent six military officers as observers to increase their knowledge and background in the development and use of atomic weapons by working with civilians and scientists (Reference C.5, p. 5-1; Reference C.1, p. 147). None of these was badged.

The total number of AEC participants (as opposed to contractor personnel) was 111. This total, however, may have included University of California contract personnel from LASL, as some of the observers listed as "AEC from Los Alamos" in Reference C.1 (p. 147) were clearly scientific observers from the laboratory itself. The 111 participants included 104 civilians, 4 Navy officers, 2 Army officers, and 1 officer with an unknown military affiliation. The military officers were from the AEC Division of Military Application. AEC personnel participated in various parts of the task group organization, including Hq JTF 7 (6 men), TG 7.1 (74 men), and TG 7.6 (24 men) and included 17 official observers (Reference C.1, p. 1; Reference C.3; and Reference C.40).

The individual exposure records (Reference E.1) show that out of the AEC total of 111, 69 were badged (63 civilians, 4 Navy officers, and 2 Army officers). The distribution of the badge readings for the AEC civilians is shown in Table 14. The military exposures are included in tables in their respective chapters.

CONTRACTORS TO THE ATOMIC ENERGY COMMISSION

Argonne National Laboratory. This laboratory participated mostly in the gamma-ray experiments. Four were badged.

Edgerton, Germeshausen, and Grier, Inc. (EG&G). This organization worked for Los Alamos Scientific Laboratory in the establishment of timing and firing. Twelve were badged.

Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico. A total of 30 LASL personnel participated in SANDSTONE, including 1 Army major from the Health Division of LASL (Reference C.1, p. 147, Reference C.3, pp. 18, 40).

The individual exposure records show 26 badged personnel, including the Army officer who worked in TG 7.6 and whose exposure was 1.7 R. The highest LASL exposure was 17 R, the highest experienced during SANDSTONE. This exposure involved contact with radioactive filters (discussed in Chapter 4) extracted from the B-17 drone samplers.

LASL operations at Sandia Base were conducted by its Z-Division (Reference A.8), which soon after SANDSTONE emerged as a separate laboratory, the Sandia Laboratory, operated under contract by the Sandia Corporation, a subsidiary of Western Electric. Sandia participation in SANDSTONE involved two Army officers and four civilians (Reference C.3).

Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. One badged civilian from ORNL participated.

University of California. Seven were badged. Their role in SANDSTONE has not been determined. The University operated LASL and it is likely that these personnel were at the test site because of this connection.

Exposure for the badged civilians from the AEC contractors is shown in Table 14.

OTHER GOVERNMENT AGENCIES

Other Federal government groups participated directly or indirectly.

Department of Agriculture (DOA). DOA handled biological materials from the atoll area.

National Bureau of Standards (NBS). NBS calibrated and read film badges (Reference C.30, p. 22; Reference C.31, p. IX-4).

U.S. Coast and Geodetic Survey (C&GS). C&GS took part in the seismic measurements after each shot (Reference C.5, p. 3-10). C&GS also sent a party to survey the general layout of the islands before Operation SANDSTONE. One Navy lieutenant commander, one lieutenant colonel (either Army or Air Force), and seven civilians were involved. None of them appear on the individual exposure records.

U.S. Coast Guard (USCG). USCG participated in task force communications. Two military personnel are listed in Hq JTF 7. Neither appears on the individual exposure records.

U.S. Public Health Service (USPHS). Two badged officers from USPHS participated in the neutron absorption measurements, the residual contamination in craters measurements, particle size of material in the cloud, evaluation of radioactivity survey, and field collective protector instruments as part of TG 7.6 (Reference C.43).

U.S. House of Representatives. Two unbadged congressmen were present at SANDSTONE as observers (Reference C.1, p. 147).

DEPARTMENT OF DEFENSE CONTRACTORS

Philco Technology Corporation. This corporation worked on the radio-link telephone and teletype equipment. Of five civilians identified, one appears to have been badged.

A large group of contractors manufactured instrumentation used during the tests. It is possible, but not likely, that some may have had representatives at Enewetak during the testing period. Other contractors apparently did off-site analytical work for the testing agencies. Contractors in these categories include:

Air Reduction and Sales Company	Mine Safety Appliance Company
A.O. Beckman Company	Mole Richardson Company
Cambridge Instrument Company	MSA Company
Cornell Aeronautical Laboratory	National Technical Laboratories
Designers for Industry	North American Philips Company
Dumont Company	Nuclear Instrument and Chemical Company
Eastman-Kodak Company	Rauland Radio Company
Electronics Company, Inc.	RCA
Esterline-Angus	Simpson
General Radio	Spencer
Geophysical Instrument Company	Sun Company
Instrument Development Labs	Sylvania Electric Products
Kelly-Koett Manufacturing Company	Tracer Laboratory
Lansverk Electrometer Company	Victoreen Instrument Company
Lear Company	Watson Laboratories
Massachusetts Institute of Technology	Weston

CHAPTER 10
SUMMARY OF PERSONNEL EXPOSURES

In SANDSTONE, fewer than one in five participants was badged. Those selected to be badged were personnel whose activities were expected to bring them into areas of radioactivity. Some badges, however, may have been issued to individuals on a ship, for example, to represent larger groups of personnel. Results of the badging are shown in Table 15. The distribution of exposures for Department of Defense (DOD) personnel, uniformed and civilian, is arranged by task group. Shown separately in Table 15 are non-DOD exposures. These were almost exclusively Atomic Energy Commission (AEC) personnel and their contractors, and their exposures would primarily be associated with Task Group (TG) 7.1 and secondarily with TG 7.6 activities.

Table 15. Exposures by task group for the entire SANDSTONE series.

Organization	Number Badged	Exposure Ranges (roentgens)						Over 2	High (R)
		0	0-0.5	0.5-1.0	1.0-1.5	1.5-2			
Hq Joint Task Force 7	32	17	14	1	0	0	0	0.120	
Task Group 7.1	143	74	59	4	3	1	2	5.085	
Task Group 7.2	122	51	71	0	0	0	0	0.443	
Task Group 7.3	796	675	118	3	0	0	0	0.826	
Task Group 7.4	312	170	119	15	4	2	2	3.06	
Task Group 7.5	165	139	25	1	0	0	0	0.580	
Task Group 7.6	97	13	40	20	11	5	8	6.050	
Task Group 7.7	57	24	29	1	1	1	1	2.29	
Task Group 7.8	11	5	5	1	0	0	0	0.76	
Non-DOD	119	18	77	6	3	3	12	17.0	

Table 15 indicates that task force personnel exposed to nuclear radiation during the SANDSTONE series were primarily involved in operations such as handling radioactive cloud samples, data recovery (TG 7.1), and radiological safety (radsafe) monitoring and technical measurements (TG 7.6), where exposures were expected to occur. Only low-level exposure of support personnel appears to have occurred.

Only 25 men exceeded an exposure of 2 R. Five of these were LASL personnel who were exposed while handling cloud sampling filter papers covered with radioactive cloud particulates. One of these incidents resulted in the highest SANDSTONE reading for whole-body exposure (17 R).

The single incident in which unbadged personnel came into contact with radioactivity was an incident at Kwajalein, which affected TG 7.4 and TG 7.7. Two days after YOKE shot, fallout occurred at Kwajalein. The maximum estimated total lifetime dose from this fallout for personnel who were on Kwajalein for the entire test series was calculated to be 0.770 R. This figure assumes that personnel were in the open 24 hours a day (Reference D.6).

The Kwajalein exposures (TG 7.7) also contain a small group of personnel who were apparently badged because of their potential exposure to radioactivity in their activities in pumping and otherwise maintaining target ships from the 1946 nuclear test series, CROSSROADS, and not from any SANDSTONE activities (see Table 11, "Ship Security Detachment" under "Naval Station Kwajalein"). The exposures of two-thirds of this 18-man group were zero; the high was 0.180 R.

BIBLIOGRAPHY AND REFERENCES

The sources consulted for this report are listed on the following pages. They are organized into sections based upon their relationship to the body of nuclear testing information.

The first section (A) contains basic references pertinent to nuclear weapons development and effects and to all or several atmospheric nuclear tests. These are generally monographs published and distributed through regular trade channels and are available in bookstores and libraries with the exceptions noted.

The second and third sections are documents generated by Joint Task Force 7 (JTF 7) and its subordinate organizations. The second section (B) contains planning and related documents for SANDSTONE, and the third (C) after-action reports. These JTF 7 references are arranged in order of their SANDSTONE report number (styled either SS, OS, or SR, depending upon a particular library's bibliographic practices).

The fourth section (D) lists other reports concerning SANDSTONE by non-task-force organizations concerning SANDSTONE.

The fifth section (E) consists of various rosters and personnel lists used.

Footnoted availability codes appear at the end of many reference citations for those who wish to read or obtain copies. Availability status was correct at the time the reference list was prepared. Many documents indicated as unavailable will become available during the declassification review process. The Department of Energy Coordination and Information Center (DOE CIC) and NTIS will be provided future DNA-WT documents bearing an "EX" after the report number.

Source documents with an availability code of DOE CIC may be reviewed at the following address:

Department of Energy
Coordination and Information Center
(Operated by Reynolds Electrical & Engineering Co., Inc)
2753 S. Highland
P.O. Box 14100
Las Vegas, Nevada 89114
Telephone: (702) 734-3194; FTS: 598-3194.

Source documents bearing an NTIS availability code may be purchased at the following address:

- A.5 Proving Ground: An Account of Radiobiological Studies in the Pacific 1946-1961
N.O. Hines
University of Washington Press, Seattle
1962
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April 1975
- A.10 The Radiological Cleanup of Enewetak Atoll
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1981
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B. SANDSTONE PLANNING DOCUMENTS

- B.1.1 Operations Order 1-48***
Test Directorate
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- B.2 Training in Protection Against Radioactivity***
Memo for the Director of Organization and Training
Maj. Gen. L.R. Groves (Army)
21 May 1947 374-21-11

*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

***Not available.

- B.3.0.1 Establishment of a Radiological Safety Program for the Navy***
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- B.3.0.3 Report on Opening of Radiological Safety School, Treasure Island***
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- B.3.2 Operations Order 2-48***
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- B.4.1 Operations Plan 1-48***
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- B.6.2 Third Interim Report of the Joint Radiological Safety Training Com-
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- C.3 Atomic Weapons Tests. Operation SANDSTONE. 1948. Report to the Joint Chiefs of Staff. Part 2 of Annex 1 to Volume 1
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- C.12 Operation SANDSTONE Measurements by the Naval Research Laboratory, Annex 2, Part II***
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- C.14 Slowly Varying Light from an Atomic Explosion as Measured with a Photocell, Annex 2, Part IV of the Scientific Directors Report***
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- C.15 Operation SANDSTONE Report by Groups LAJ-4B, LAJ-12A, Annex 3, Part I of the Scientific Directors Report***
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- C.21 Blast -- Measurement of Peak Pressure, Annex 5, Part II of the Scientific Directors Report***
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- C.22 Blast Measurements of Pressure as a Function of Time***
JTF 7
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- C.23 Blast -- Airplane Shock Wave Measurements (Service Test No. 5)***
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- C.24 Blast Protection Afforded by Structures -- OCE (Service Tests Nos. 1, 2, and 3), Annex b***
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- C.25 Blast Resistance of Structures -- Bureau of Yards and Docks (Service Test No. 4)***
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- C.31 Radiological Safety Instruments, Annex 10, Parts I, II, and III of the Scientific Directors Report
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- C.37 LAJ-9B Activities, Annex 15, Part II of the Scientific Directors Report***
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- C.38 LAJ-12B Activities, Annex 15, Part III of the Scientific Directors Report***
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- C.39 Planning and Construction, Annex 16, Parts I and II of the Scientific Directors Report***
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- C.40 Operation SANDSTONE -- J-Division History, Annex 17, Part I of the Scientific Directors Report (extracted version)
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- C.44 Technical Report of the Communications and Electronics Section of the Special Staff of the Commander, Joint Task Force Seven***
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- D.1 "U.S. Nuclear Stockpile, 1945 to 1950" Bulletin of the Atomic Scientists, Vol 38, No. 5, p. 25
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May 1982
- D.2 Operation SANDSTONE Radiation Injuries***
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- D.4 Monitor Reports of SANDSTONE Vessels***
10 June 1948 374-75-82
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E. ROSTERS

- E.1 Individual Exposure Records***
(File of cards arranged alphabetically by name and microfilmed. A list summarizing the total exposures from this file was prepared by Reynolds Electrical and Engineering Co., Inc. (REECO) in 1967. REECO also prepared the microfilm in 1978. The pertinent cartridge for SANDSTONE is Roll 2)
JTG 7.6
1948
- E.2.0.1 JTF 7 Personnel Roster***
19 December 1947

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**Available at DOE CIC.

***Not available.

- E.2.0.2 Strength Report by Task Group***
 JTF 7
 31 March 1948 374-70A-56
- E.2.0.3 Roster of Personnel Attached to TG 7.6***
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- E.2.0.4 Monthly Roster of Task Group 7.5 Personnel***
 31 March 1948 374-70A-45
- E.2.0.5 Request for Issuance of U.S. Navy Identification Cards (M. Nav 546) to Certain Civilians Traveling to Central Pacific Areas in Connection with Operation SANDSTONE***
 JTF 7
 15 January 1948 374-70A-15
- E.2.0.6 "Q" Clearance Roster***
 JTF 7
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- E.2.2.1 Personnel Roster***
 TG 7.2
 31 March 1948
- E.2.2.2 Roster Photo Team 7***
 31 March 1948
- E.2.2.3 Roster Enewetak Shore Detachment with Signal Unit 1***
 31 March 1948
- E.2.3.1 Roster USS Pelican (AMS-32)***
 7 April 1948
- E.2.3.2 Roster Construction Battalion Det. 1509***
 n.d.
- E.2.3.3 Rosters, Dose Averages, and Summaries***
 CNO OP 982-TD
 10 March -10 June 1982
- E.2.3.4 Roster of Officers and Men Attached***
 VPHL-8 Detachment
 1948
- E.2.5.1 Monthly Roster TG 7.5***
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- E.2.5.2 Monthly Roster TG 7.5***
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*Available from NTIS; order number appears before the asterisk.

**Available at DOE CIC.

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APPENDIX A
RADIOLOGICAL STATUS REPORT OF ENEWETAK ATOLL
20 May 1948

APPENDIX A

JOINT TASK FORCE SEVEN
USS MT McKINLEY (AGC-7)
Fleet Post Office
San Francisco, California

20 May 1948

SUBJECT: Eniwetok Atoll - Radiological Status Report.

TO: Commander, Joint Task Force SEVEN.

1. All islands of Eniwetok Atoll were surveyed for radioactivity during the period 17 to 19 May 1948. During Operation SANDSTONE much of the land mass of the Atoll was contaminated with significant amount of radioactivity. For practical purposes the degree of contamination is divided into four classes.

A. Class I - Zero Islands.

These are islands on which tests were conducted and consequently have highly contaminated craters. The crater is defined as a disk shaped area, radius 400 yards, centered at the zero tower base. The three islands should be considered as uninhabitable for a period of years. Radiochemical analyses of dirt samples would be required before considering any extensive re-use of these islands. Monitors should accompany any parties working in these craters.

Class I Islands are as follows: Engebi, Aoman, Runit.

B. Class II - Islands Heavily Contaminated from Fall-out.

Several islands downwind of the zero islands were heavily contaminated by fall-out of radioactive materials following the various tests. Until final clearance, every group re-entering these islands should be accompanied by a monitor. There should be no extensive re-use or occupation until a thorough and satisfactory re-survey and radiochemical analysis has been conducted.

Class II Islands:

Piiraai	Yeiri
Aaraanbiru	Bokonaarappu
Rojoa	Kirinian
Bijiri	Muzinbaarikku
Eberiru	Bogon
Rujoru	Engebi (outside of crater)
Aitsu	Aoman (outside of crater)

C. Class III - Islands lightly Contaminated from Fall-out.

Several islands in the northwest section of the atoll were contaminated from fall-out to a lesser degree than those listed under Class II. Only limited operations should be permitted for the next few weeks. For

such operations a monitor would not be necessary unless dust producing operations were conducted. Extensive re-survey and radiochemical analysis should be conducted before any of these islands were opened for permanent occupancy.

Class III Islands:

Bogairikk	Ruchi
Teiteiripucchi	Bogombogo
Elugelab	Bogallum
Beacon "N"	Runit (outside of crater)

D. Class IV - Uncontaminated Islands.

The islands of the southern half of Eniwetok Atoll received no fall-out or other contamination and should be considered as cleared for all types of operations and permanent occupancy if desired.

Class IV Islands:

Chinicero	Igurin
Aniyaanii	Mui
Chinimi	Pokon
Japtan	Ribaion
Parry	Giriinian
Eniwetok	Rigili

2. For the use of the radiological safety officer of the Eniwetok Garrison Command, AEC material was transferred on 17 May 1948 to Supply Officer, Task Group 7.2 as follows:

Silica Gel Bags	1 Box
Personnel Film Badges	216 Each
Instruction Books for:	
263A counters	
Dosimeters	2 Each
Vacuum Tubes:	
VX-41A	10 Each
2E35	4 Each
2532	4 Each
GM Tubes	15 Each
Flashlite Batteries 1.5 v	96 each
No. 467 67.5 v batteries	50 each
No. 493 300 v batteries	50 each
No. 4F 1.5 v batteries	20 each
Minimax, 22.5 v batteries	96 each
B2BP 3 v batteries	18 each
Charging Kit batteries	
Minimax	9 each
Simpson Test Meter	
plus leads (Model 260)	1 each
Radium buttons	2 each
Crystal headsets	5 each

Keleket Charging Units	2 each
Keleket .2 r dosimeters	20 each
MX-6 Ion Chambers	2 each
263A survey instruments	5 each
MX-6 (Zeus) covers	6 each
263A covers	15 each

One calibration source (Cobalt) will be delivered prior to departure of U.S.S. BAIROKO. This should be kept in a safe and should be shielded by three inches of lead.

3. Captain Meredith Mallory, Jr., MC, USA, of TF-7.6 will remain at Eniwetok on temporary duty until 1 June 1948 to monitor any necessary operations during the turn-over period. Major Butkus, MC, USA, has been ordered from AFSWP to Eniwetok as Radiological Safety Officer and Post Surgeon to arrive about 1 June 1948.

4. It is recommended that gas masks be worn for all dust producing operations on all islands listed under Classes I, II and III.

5. It is further recommended that upon completion of any operations or visit to any island except those listed under Class IV all personnel and equipment involved be monitored for contamination.

JAMES P. COONEY
Colonel, MC
Radiological Safety Officer
Joint Task Force SEVEN

Copies to:
Eniwetok Garrison Commander
Garrison RadSafe Officer
TG-7.6 file (2)

APPENDIX B

GLOSSARY OF TERMS

Many of the definitions in this glossary relating to nuclear device and radiation phenomena have been quoted or extracted from The Effects of Nuclear Weapons (3rd edition), S. Glasstone and P.J. Dolan, 1977.

AACS. Airways and Air Communication Service (Air Force).

ACSW. Aircraft Control and Warning (Air Force).

AAU. Administrative Area Unit (Army).

ACC. Army Chemical Center, Edgewood Arsenal, Maryland.

accelerometer. An instrument for determining the acceleration of the system with which it moves.

activation products. Radioactive nuclides produced by the irradiation of a stable nuclide, usually with neutrons.

AD. Destroyer tender (Navy).

AEC. Atomic Energy Commission, Washington, D.C. Independent agency of the Federal government with statutory responsibilities for atomic energy matters. No longer exists; its functions have been assumed by the Department of Energy and the Nuclear Regulatory Commission.

AF. Store ship (Navy); also Air Force.

AFB. Air Force Base.

AFBU. Air Force Base Unit.

AFSWC. Air Force Special Weapons Center, Kirtland AFB, New Mexico.

AFSWP. Armed Forces Special Weapons Project.

AGC. Amphibious force flagship (Navy).

airburst. The detonation of a nuclear device in the air at a height such that the expanding fireball does not touch the Earth's surface when the luminosity (emission of light) is at a maximum.

air particle trajectory. The velocity and rate of descent of windblown radioactive particles.

AK. Cargo ship (Navy).

AKA. Attack cargo ship (Navy).

allowable dose. See MPL.

alpha emitter. A radionuclide that undergoes transformation by alpha-particle emission.

alpha particle. A charged particle emitted spontaneously from the nuclei of some radioactive elements. It is identical with a helium nucleus, having a mass of 4 units and an electric charge of 2 positive units. See also radioactivity.

alpha rays. A stream of alpha particles. Loosely, a synonym for alpha particles.

AMN. Airman; enlisted Air Force personnel.

AMS. Army Map Service, Washington, D.C.

AMS. Small minesweeper (wooden hull) (Navy).

AO. Oiler (Navy).

AOC. Air Operations Center.

AOG. Gasoline tanker (Navy).

AP. Transport ship (Navy).

APA. Attack transport (Navy).

APG. Aberdeen Proving Ground, Maryland.

APO. Army Post Office.

ARL. Landing craft repair ship (Navy).

arming. The changing of a nuclear device from a safe condition (that is, a condition in which it cannot be accidentally detonated) to a state of readiness for detonation.

ARS. Salvage ship (Navy).

ARSD. Salvage lifting ship (Navy).

ASA. Army Security Agency.

ASU. Army Support Unit.

ASW. Anti-Submarine Warfare.

ATA. Auxiliary ocean tug (Navy).

ATC. Air Transport Command.

ATF. Fleet ocean tug (Navy).

atoll. A ring of coral reefs, usually with small islets, that surrounds a lagoon. Most are isolated reefs rising from the deep sea that have built up on submerged volcanoes. They vary considerably in size; the largest atoll, Kwajalein in the Marshall Islands, has an irregular shape that extends for 84 miles (135 km). See also coral reef.

atomic bomb (or weapon). A term sometimes applied to a nuclear weapon utilizing fission energy only. See also fission, nuclear device.

atomic explosion. See nuclear explosion.

attenuation. The process by which radiation is reduced in intensity when passing through some material. It is due to absorption or scattering or both, but it excludes the decrease of intensity with distance from the source (inverse square law, which see).

AU. Army Unit.

AV. Seaplane tender (Navy).

AVP. Small seaplane tender (Navy).

AVR. Aircraft rescue vessel (Navy).

AW. Distilling ship (Navy).

B-17. Four-engine, propeller-driven bomber developed by Boeing Airplane Company and widely used in World War II. Used as radio-controlled, unmanned drone cloud sampler in atmospheric nuclear weapon tests.

B-29. A 4-engine, propeller-driven bomber developed by Boeing, used for weather reconnaissance, cloud tracking, aerial sampling and photography, and aerial refueling at the PPG. These versions designated RB-29, WB-29, and KB-29.

background radiation. The radiation of man's natural environment, consisting of that which comes from cosmic rays and from the naturally radioactive elements of the Earth, including that from within man's body. The term may also mean radiation extraneous to an experiment.

base surge. The particulate dust cloud that rolls out from the bottom of the cloud column produced by the detonation of a nuclear device. For underwater bursts, the base surge is a cloud of water droplets, and the flowing properties are those of a homogeneous liquid.

bathythermograph (B/T). A device for obtaining a record of temperature with depth in the upper 1,000 feet (300 meters) of the ocean from a ship underway.

becquerel (Bq). See curie (Ci).

beta burns. Beta-emitting particles that come into contact with the skin and remain for an

appreciable time can cause a form of radiation injury sometimes referred to as "beta burn." In an area of extensive early fallout, the whole surface of the body may be exposed to beta particles.

beta emitter. A radionuclide that disintegrates by beta particle emission. All beta-active elements existing in nature expel negative particles, i.e., electrons or, more exactly, negatrons. Beta-emitting particles are harmful if inhaled or ingested or remain on the skin.

beta particle (ray). A charged particle of very small mass emitted spontaneously from the nuclei of certain radioactive elements. Most, if not all, of the direct fission products emit negative beta particles (negatrons). Physically, the beta particle is identical to an electron moving at high velocity.

bhangmeter. A device that measures bomb yield based on light generated by the explosion.

blast. The detonation of a nuclear device, like the detonation of a high explosive such as TNT, results in the sudden formation of a pressure or shock wave, called a blast wave in the air and a shock wave when the energy is imparted to water or Earth.

blast wave. An air pulse in which the pressure increases sharply at the front followed by winds propagated from an explosion.

blast yield. That portion of the total energy of a nuclear explosion that manifests itself as blast and shock waves.

bomb debris. See weapon debris.

BRL. Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland (Army).

BuAer. Bureau of Aeronautics (Navy).

BuDocks. Bureau of Yards and Docks (Navy).

BuMed. Bureau of Medicine and Surgery (Navy).

burst. Explosion; or detonation. See also air-burst, high-altitude burst, surface burst.

BuShips. Bureau of Ships (Navy).

C-47. A twin-engine transport aircraft manufactured by Douglas Aircraft Company (Air Force version of the DC-3).

C-54. A 4-engine military cargo and personnel transport manufactured by Douglas Aircraft Company (Air Force version of the DC-4).

cab. The shelter that covers a nuclear device being prepared for test. May be located on a tower, on the Earth's surface, or on a barge.

cathode-ray tube. A vacuum tube in which cathode rays (electrons) are beamed upon a fluorescent

screen to produce a luminous image. The character of this image is related to, and controlled by, one or more electrical signals applied to the cathode-ray beam as input information. The tubes are used in measuring instruments such as oscilloscopes and in radar and television displays.

cave. A heavily shielded enclosure in which radioactive materials can be remotely manipulated to avoid radiation exposure of personnel.

CDC. Center for Disease Control.

Ci; c. Abbreviation for curie, which see. Ci is preferred now but c was the abbreviation used in the 1950s.

CIC. Counter-Intelligence Corps (Army); Combat Information Center (Navy).

CINCPAC. Commander in Chief, Pacific.

Circle William fittings. The closing of certain closures, designated "Circle William" fittings, hinders the movement of outside air into the interior spaces of naval ships. This sealed state is also called Circle William condition.

CJTF 7. Commander, Joint Task Force 7.

closed area. The land areas of Bikini and Enewetak and the water areas within 3 miles of them that the United States closed to unauthorized persons.

cloud chamber effect. See Wilson cloud.

cloud column (funnel). The visible column of weapon debris (and possibly dust or water droplets) extending upward from the point of a nuclear burst.

cloud phenomena. See fallout, fireball, radioactive cloud.

CNO. Chief of Naval Operations.

collimate. To align nuclear weapon radiant outputs within an assigned solid angle through the use of baffles in order to enhance measurements.

Co. Chemical symbol for cobalt.

cobalt. Metallic element with radionuclide ^{60}Co used as a calibration source for gamma instruments.

ComAirPac. Commander Naval Air Forces Pacific (Navy).

ComServPac. Commander Service Forces Pacific (Navy).

Condition "Purple". See Purple conditions.

contamination. The deposit of radioactive materials on the surfaces of structures, areas,

objects, and personnel following a nuclear detonation. This material generally consists of fallout in which fission products and other device debris have become incorporated with particles of dust, vaporized components of device platforms, etc. Contamination can also arise from the radioactivity induced in certain substances by the action of neutrons from a nuclear explosion. See also decontamination, fallout, weapon debris.

coral reef. A complex ecological association of bottom-living and attached shelled marine animal fossils that form fringing reefs, barrier reefs, and atolls. The lagoons of barrier reefs and atolls are important places for the deposition of fine-grained calcium carbonate mud.

CPM. Counts per minute, a measure of radioactive material disintegration.

crater. The depression formed on the surface of the Earth by a surface or underground explosion. Crater formation can occur by vaporization of the surface material, by the scouring effect of airblast, by throwout of disturbed material, or by subsidence.

Cs. Chemical symbol for cesium.

C/S. Chief of Staff.

CTG. Commander, Task Group.

curie (Ci). A unit of radioactivity; it is the activity of a quantity of any radioactive species in which 3.700×10^{10} (37 billion) nuclear disintegrations occur per second (approximately the radioactivity of 1 gram of radium). The gamma curie is sometimes defined correspondingly as the activity of material in which this number of gamma-ray photons is emitted per second. This unit is being replaced by the becquerel (Bq), which is equal to one disintegration per second.

cutie pie. A portable beta-gamma survey meter using an ionization chamber as the detector volume to measure radiation exposure rates. Usually used at higher radiation levels for both detecting and measuring ionizing radiation. A removable end-cap acts as a shield for the detector, allowing the instrument to indicate combined beta and gamma radiation when the cap is removed, or gamma radiation only when the cap is in place.

CVE. Escort aircraft carrier (Navy).

CW net. Continuous wave network. An organization of stations capable of direct radio communications on a common channel or frequency.

D-day. The term used to designate the unnamed day on which a test takes place. The equivalent rule applies to H-hour (which see). Time in plans is indicated by a letter which shows the unit of time employed in figures, with a

minus or plus sign to indicate the amount of time before or after the reference event, e.g., D+7 means 7 days after D-day, H+2 means 2 hours after H-hour.

DDE. Escort destroyer (Navy).

DE. Destroyer escort (Navy).

debris (radioactive). See weapon debris.

decay (radioactive). The decrease in activity of any radioactive material with the passage of time due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, sometimes accompanied by gamma radiation, or by gamma photons alone. Every decay process has a definite half-life.

decontamination. The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of natural decay; and (3) covering the contamination in order to attenuate the radiation emitted.

device. Nuclear fission and fusion materials, together with their arming, fuzing, firing, chemical-explosive, and effects-measuring components, that have not reached the development status of an operational weapon.

diagnostic measurements or experiments. Experiments whose purpose is to study the explosive disassembly of a nuclear device as opposed to effects measurements (which see).

DMS. Minesweeper destroyer (Navy). Converted destroyer designed to conduct high-speed minesweeping operations.

DOD. Department of Defense. The Federal executive agency responsible for the defense of the United States. Includes the four services and special joint defense agencies. Reports to the President through the Secretary of Defense.

dose. A general term denoting the quantity of ionizing radiation absorbed. The unit of absorbed dose is the rad (which see). In soft body tissue the absorbed dose in rads is essentially equal to the exposure in roentgens. The biological dose (also called the RBE dose) in rems is a measure of biological effectiveness of the absorbed radiation. Dosage is used in older literature as well as exposure dose and simply exposure, and care should be exercised in their use. See also exposure.

dose rate. As a general rule, the amount of ionizing (or nuclear) radiation that an individual or material would receive per unit of time. It is usually expressed as rads (or rems) per hour or multiples or divisions of these units such as millirads per hour. The dose rate is commonly used to indicate the level of radioactivity in a radioactive area. See survey meter.

dosimeter. An instrument for measuring and registering the total accumulated dose of (or exposure to) ionizing radiation. Instruments worn or carried by individuals are called personnel dosimeters.

dosimetry. The measurement and recording of radiation doses and dose rates. It is concerned with the use of various types of radiation instruments with which measurements are made. See also dosimeter, survey meter.

DPM. Disintegrations per minute, a measure of radioactivity, literally atoms disintegrating per minute. Difficult to directly compare with roentgens per hour for mixtures of radio-nuclides.

DTMB. David Taylor Model Basin, Carderock, Maryland (Navy).

DUKW. Two-and-one-half-ton amphibious truck (Navy).

dynamic pressure. Air pressure that results from the mass air flow (or wind) behind the shock front of a blast wave.

effects measurements or experiments. Experiments whose purpose is to study what a nuclear explosion does to material, equipment and systems. Includes also measurement of the changes in the environment caused by the detonation such as increased air pressures (blast), thermal and nuclear radiation, cratering, water waves, etc.

EG&G. Edgerton, Germeshausen & Grier, Boston, Massachusetts (now EG&G, Inc.). An AEC contractor. Provided timing and firing electronics.

electromagnetic radiation. Electromagnetic radiations range from X-rays and gamma rays of short wavelength (high frequency), through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength.

electron. A particle of very small mass and electrically charged. As usually defined, the electron's charge is negative. The term negatron is also used for the negative electron and the positively charged form is called a positron. See also beta particles.

exposure. A measure expressed in roentgens of the ionization produced by gamma rays (or X-rays) in air. The exposure rate is the exposure per unit time (e.g., roentgens per hour). See dose, dose rate, roentgen.

exposure rate contours. Lines joining points that have the same radiation intensity that define a fallout pattern, represented in terms of roentgens per hour.

fallout. The process or phenomenon of the descent to the Earth's surface of particles contaminated with radioactive material from the radioactive cloud. The term is also applied in a

collective sense to the contaminated particulate matter itself. The early (or local) fallout is defined, somewhat arbitrarily, as particles reaching the Earth within 24 hours after a nuclear explosion. The delayed (or worldwide) fallout consists of the smaller particles, which ascend into the upper troposphere and stratosphere and are carried by winds to all parts of the Earth. The delayed fallout is brought to Earth, mainly by rain and snow, over extended periods ranging from months to years.

fathometer. A depth-sounding instrument. The depth of water is measured by noting the time the echo of a sound takes to return from the bottom.

film badges. Used for the indirect measurement of ionizing radiation. Generally contain two or three pieces of film of different radiation sensitivities. They are wrapped in paper (or other thin material) that blocks light but is readily penetrated by gamma rays. The films are developed and the degree of fogging (or blackening) observed is a measure of the gamma-ray exposure, from which the absorbed dose is calculated. Film badges can also measure beta and neutron radiation.

fireball. The luminous sphere of hot gases that forms a few millionths of a second after a nuclear explosion as the result of the absorption by the surrounding medium of the thermal X-rays emitted by the extremely hot (several tens of millions of degrees) device residues. The exterior of the fireball in air is initially sharply defined by the luminous shock front and later by the limits of the hot gases themselves.

fission. The process of the nucleus of a particular heavy element splitting into two nuclei of lighter elements, with the release of substantial amounts of energy. The most important fissionable materials are uranium-235 and plutonium-239; fission is caused by the absorption of neutrons.

fission detectors. Radiation pulse detector of the proportional counter type in which a foil or film of fissionable materials is incorporated to make it respond to neutrons.

fission products. A general term for the complex mixture of substances produced as a result of nuclear fission. A distinction should be made between these and the direct fission products or fission fragments that are formed by the actual splitting of the heavy-element nuclei into nuclei of medium atomic weight. Approximately 80 different fission fragments result from roughly 40 different modes of fission of a given nuclear species (e.g., uranium-235 or plutonium-239). The fission fragments, being radioactive, immediately begin to decay, forming additional (daughter) products, with the result that the complex mixture of fission products so formed contains over 300 different radionuclides of 36 elements.

fixed alpha. Alpha radioactivity that cannot be easily removed as evidenced by no activity removed on a swipe of a 100-cm² area.

fluorescence. The emission of light (electromagnetic radiation) by a material as a result of the absorption of energy from radiation. The term may refer to the radiation emitted, as well as to the emission process.

forward area. The PPG and adjoining areas (e.g., Kwajalein).

FPO. Fleet Post Office (Navy).

fusion. The combination of two light nuclei to form a heavier nucleus, with the release of the difference of the nuclear binding energy of the fusion products and the sum of the binding energies of the two light nuclei.

gamma rays. Electromagnetic radiations of high photon energy originating in atomic nuclei and accompanying many nuclear reactions (e.g., fission, radioactivity, and neutron capture). Physically, gamma rays are identical with X-rays of high energy; the only essential difference is that X-rays do not originate from atomic nuclei of high energy. Gamma rays can travel great distances through air and can penetrate considerable thickness of material, although they can neither be seen nor felt by human beings except at very high intensities, which cause an itching and tingling sensation of the skin. They can produce harmful effects even at a long distance from their source.

Geiger-Mueller (GM) counter. A gas discharge pulse counter for ionizing radiation. See also ion-chamber-type survey meter.

GMT. Greenwich Mean Time.

gray (Gy). A recently introduced ICRP term; 1 Gy equals 100 rad.

ground zero (GZ). See surface zero.

gunk. A viscous commercial preparation that is soluble both in water and petroleum derivatives. It acts as a wetting agent in removing grease and particulate matter from metal and other nonporous surfaces.

H-hour. Time zero, or time of detonation. When used in connection with planning operations it is the specific time at which the operation event commences. H-1 indicates 1 hour before the detonation, and H+1 indicates 1 hour after detonation, etc. Minutes and seconds may also be indicated using this system, but the units used must then be shown, e.g., H-30 minutes, H+55 seconds. See also D-day.

half-life. The time required for a radioactive material to lose half of its radioactivity due to decay. Each radionuclide has a unique half-life.

HE. High explosive.

high-altitude burst. Defined, somewhat arbitrarily, as a detonation in or above the stratosphere. The distribution of the energy of the explosion between blast and thermal radiation changes appreciably with increasing altitude.

hodograph. A common hodograph in meteorology represents the speed and direction of winds at different altitude increments.

hot; hot spot. Commonly used colloquial term meaning a spot or area related more radioactive than some adjacent area.

ICRP. International Commission on Radiological Protection.

initial radiation. Electromagnetic radiations of high energy emitted from both the fireball and the radioactive cloud within the first minute after a detonation. It includes neutrons and gamma rays given off almost instantaneously (usually defined as prompt radiation, which see), as well as the gamma rays emitted by the fission products and other radioactive species in the rising cloud. Initial neutrons from ground or near-ground bursts react with both earth materials and device debris to create activation products.

inverse square law. The decrease in radiation intensity with distance from a single-point source is proportional to the square of the distance removed.

ion-chamber-type survey meter. A device for measuring the amount of ionizing radiation. Consists of a gas-filled chamber containing two electrodes (one of which may be the chamber wall) between which a potential difference is maintained. The radiation ionizes gas in the chamber and an instrument connected to one electrode measures the ionization current produced.

ionization. The process of adding electrons to, or knocking electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, and nuclear radiation can cause ionization.

ionizing radiation. Any particulate or electromagnetic radiation capable of producing ions, directly or indirectly, in its passage through matter. Alpha and beta particles produce ion pairs directly, while gamma rays and X-rays liberate electrons as they traverse matter, which in turn produce ionization in their paths.

ionosphere. The region of the atmosphere, extending from roughly 40 to 250 miles (about 64 to 400 km) above the Earth, in which there is appreciable ionization. The presence of charged particles in this region profoundly affects the propagation of radio and radar waves.

irradiation. Exposure of matter to radiation.

isodose lines. Dose or dose-rate contours. In fallout, contours plotted on a radiation field at which the dose rate or the total accumulated dose is the same.

isotopes. Atoms with the same atomic number (same chemical element) but different atomic weight; i.e., the nuclei have the same number of protons but a different number of neutrons.

JCS. Joint Chiefs of Staff.

JTF 7. Joint Task Force 7 was a combined force of personnel of the Department of Defense (Air Force, Army, Marine Corps, Navy), the AEC, and their contractors. JTF 7 was responsible for all aspects of nuclear weapon tests in the Pacific during 1948.

kiloton convention. Relates nuclear explosion energy to TNT explosion energy by using the approximate energy release of 1,000 tons of TNT as the measuring unit.

kinetic energy. Energy associated with the motion of matter.

L-5, L-13. Single-engine, propeller-driven light planes.

LASL. Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

LCI(L). Infantry landing craft (large) (Navy).

LCM. Mechanized landing craft (Navy).

LCP(L). Personnel landing craft (large) (Navy).

LCP(R). Personnel landing craft (ramp) (Navy).

LCT. Tank landing craft (Navy).

LCU. Utility landing craft (Navy).

LCVP. Vehicle and personnel landing craft (Navy).

LML. Lookout Mountain Laboratory, Hollywood, California (Air Force).

Loran. Long-range aid to navigation system. Loran stations were maintained by the U.S. Coast Guard Station on Enewetak Island and Johnston Atoll.

LSD. Dock landing ship (Navy).

LSIL. Infantry landing ship (large) (Navy).

LST. Tank landing ship (Navy).

LSU. Utility landing ship (Navy).

magnetometer. An instrument for measuring changes in the geomagnetic field.

megaton (energy). Approximately the amount of energy that would be released by the explosion of one million tons of TNT.

microcurie. One-millionth of a curie.

micron. One-millionth of a meter (i.e., 10^{-6} meter or 10^{-4} centimeter); it is roughly four one-hundred-thousandths (4×10^{-5}) of an inch.

milliroentgen. One-thousandth of a roentgen.

MPL. Maximum Permissible Limit. That amount of radioactive material in air, water, foodstuffs, etc. that is established by authorities as the maximum that would not create undue risk to human health.

mR; mR. Abbreviation for milliroentgen.

mushroom cap. Top of the cloud formed from the fireball of a nuclear detonation.

MV. Motor vessel.

NADC. Naval Air Development Center.

NAS. Naval Air Station.

NBS. National Bureau of Standards.

NCO. Noncommissioned officer.

NCRP. National Committee on Radiation Protection and Measurements. Before 1956 simply the National Committee on Radiation Protection.

NEL. Naval Electronics Laboratory.

neutron. A neutral elementary particle (i.e., with neutral electrical charge) of approximately unit mass (i.e., the mass of a proton) that is present in all atomic nuclei, except those of ordinary (light) hydrogen. Neutrons are required to initiate the fission process, and large numbers of neutrons are produced by both fission and fusion reactions in nuclear explosions.

neutron flux. The intensity of neutron radiation. It is expressed as the number of neutrons passing through 1 cm^2 in 1 second.

NML. Naval Materials Laboratory.

NMRI. Naval Medical Research Institute.

NOB. Naval Operating Base.

NOL. Naval Ordnance Laboratory.

NPG. Nevada Proving Ground, now the Nevada Test Site (NTS).

NRDL. Naval Radiological Defense Laboratory.

NRL. Naval Research Laboratory.

NTPR. Nuclear Test Personnel Review.

NTS. Nevada Test Site.

nuclear device (or weapon or bomb). Any device in which the explosion results from the energy released by reactions involving atomic nuclei, either fission or fusion, or both. Thus, the A- (or atomic) bomb and the H- (or hydrogen) bomb are both nuclear weapons. It would be equally true to call them atomic weapons, since the energy of atomic nuclei is involved in each case. However, it has become more or less customary, although it is not strictly accurate, to refer to weapons in which all the energy results from fission as A-bombs. In order to make a distinction, those weapons in which part of the energy results from thermonuclear (fusion) reactions of the isotopes of hydrogen have been called H-bombs or hydrogen bombs.

nuclear explosion. Explosive release of energy due to the splitting, or joining, of atoms. The explosion is observable by a violent emission of ultraviolet, visible, and infrared (heat) radiation, gamma rays, neutrons, and other particles. This is accompanied by the formation of a fireball. A large part of the energy from the explosion is emitted as blast and shock waves when detonated at the Earth's surface or in the atmosphere. The fireball produces a mushroom-shaped mass of hot gases and debris, the top of which rises rapidly. See also radiation, gamma rays, fireball, nuclear weapon, fission, fusion, blast.

nuclear fusion. See thermonuclear fusion.

nuclear radiation. Particulate and electromagnetic radiation emitted from atomic nuclei in various nuclear processes. The important nuclear radiations, from the weapons standpoint, are alpha and beta particles, gamma rays, and neutrons. All nuclear radiations are ionizing radiations, but the reverse is not true; X-rays, for example, are included among ionizing radiations, but they are not nuclear radiations since they do not originate from atomic nuclei.

nuclear tests. Tests carried out to supply information required for the design and improvement of nuclear weapons and to study the phenomena and effects associated with nuclear explosions.

nuclide. Any species of atom that exists for a measurable length of time. The term nuclide is used to describe any atomic species distinguished by the composition of its nucleus; i.e., by the number of protons and the number of neutrons. Isotopes of a given element are nuclides having the normal number of protons but different numbers of neutrons in these nuclei. A radionuclide is a radioactive nuclide.

off-scale. Radiation (or other physical phenomena) greater than the capacity of a measuring device to measure.

ONR. Office of Naval Research, Washington, D.C.

ORNL. Oak Ridge National Laboratory, Tennessee.

oscilloscope. The name generally applied to a cathode-ray device.

overpressure. The transient pressure, usually expressed in pounds per square inch, exceeding the ambient pressure, manifested in the shock (or blast) wave from an explosion.

PBM. Twin-engine, patrol-bomber flying boat, developed by Martin for the U.S. Navy.

PC. Patrol craft (Navy).

peak overpressure. The maximum value of the overpressure (which see) at a given location.

permissible dose. That dose of ionizing radiation that is not expected to cause appreciable bodily injury to a person at any time during his lifetime. See also MPL.

phantom. A volume of material closely approximating the density and effective atomic number of tissue. The phantom absorbs ionizing radiation in the same manner as tissue, thus radiation dose measurements made within the phantom provide a means of approximating the radiation dose within a human or animal body under similar exposure conditions. Materials commonly used for phantoms are water, masonite, pressed wood, beeswax, and plexiglas.

plg. A heavily shielded container (usually lead) used to ship or store radioactive materials.

POL. Petroleum, oil, and lubricants. The storage area for these products is referred to as a POL farm.

PPG. Pacific Proving Ground (after 1956 designated the Eniwetok Proving Ground, or EPG).

prompt radiation. Neutrons and gamma rays emitted almost instantaneously following a nuclear fission or fusion.

proton. A particle carrying a positive charge and physically identical to the nucleus of the ordinary hydrogen atom.

Purple conditions. A shipboard warning system used in radiological defense. Various numbered conditions were sounded when radioactive fallout was to be encountered. Responses to the sounded warnings included closing of various hatches and fittings, turning off parts of the ventilation system, and removing personnel from a ship's open decks. The higher the Purple condition number, the more severe the radiological situation.

QB-17. Radio-controlled version of the B-17.

"Q"-clearance. A security clearance granted by the Atomic Energy Commission, based upon a background investigation.

R; r. Symbol for roentgen.

Ra. Chemical symbol for radium.

rad. Radiation absorbed dose. A unit of absorbed dose of radiation; it represents the absorption of 100 ergs of ionizing radiation per gram (or 0.01 J/kg) of absorbing material, such as body tissue. This unit is presently being replaced in scientific literature by the Gray (Gy), numerical equal to the absorption of 1 joule of energy per kilogram of matter.

RadDefense. Radiological defense. Defense against the effects of radioactivity from atomic weapons. It includes the detection and measurement of radioactivity, the protection of persons from radioactivity, and decontamination of areas, places, and equipment. See also radSAFE.

radex area. Radiological exclusion area. Following each detonation there were areas of surface radioactivity and areas of air radioactivity. These areas were designated as radex areas. Radex areas were used to chart actual or predicted fallout and also used for control of entry and exit.

radiac. Radiation detection, indication, and computation.

radiation. The emission of any rays, electromagnetic waves, or particles (e.g., gamma rays, alpha particles, beta particles, neutrons) from a source.

radiation decay. See decay (radioactive).

radiation detectors. Any of a wide variety of materials or instruments that provide a signal or indication when stimulated by the passage of ionizing radiation; the sensitive element in radiation detection instruments. The most widely used media for the detection of ionizing radiation are photographic film and ionization of gases in detectors (e.g., Geiger counters), followed by materials in which radiation induces scintillation.

radiation exposure. Exposure to radiation may be described and modified by a number of terms. The type of radiation is important: alpha and beta particles, neutrons, gamma rays and X-rays, and cosmic radiation. Radiation exposure may be from an external radiation source, such as gamma rays, X-rays, or neutrons, or it may be from radionuclides retained within the body emitting alpha, beta, or gamma radiation. The exposure may result from penetrating or nonpenetrating radiation in relation to its ability to enter and pass through matter -- alpha and beta particles being considered as nonpenetrating and other types of radiation as penetrating. Exposure may be related to a part of the body or to the whole body. See also whole body irradiation.

radiation intensity. Radiation rate. Measured and reported in roentgens (R), rads, rems, and multiples and divisions of these units as a

function of exposure time (per hour, day, etc.).

radioactive cloud. An all-inclusive term for the cloud of hot gases, smoke, dust, and other particulate matter from the weapon itself and from the environment, which is carried aloft in conjunction with the rising fireball produced by the detonation of a nuclear device.

radioactive nuclide. See radionuclide.

radioactive particles. See radioactivity.

radioactivity. The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nuclei of an (unstable) nuclide. As a result of this emission the radioactive nuclide is converted (decays) into the isotope of a different (daughter) element, which may (or may not) also be radioactive. Ultimately, as a result of one or more stages of radioactive decay, a stable (nonradioactive) end product is formed.

radiological survey. The directed effort to determine the distribution and exposure rate of radiation in an area.

radionuclide. A radioactive nuclide (or radioactive atomic species).

radiosonde. A balloon-borne instrument for the simultaneous measurement and transmission of meteorological data, consisting of transducers for the measurement of pressure, temperature, and humidity; a modulator for the conversion of the output of the transducers to a quantity that controls a property of the radiofrequency signal; a selector switch, which determines the sequence in which the parameters are to be transmitted; and a transmitter, which generates the radiofrequency carrier.

radiosonde balloon. A balloon used to carry a radiosonde aloft. These balloons have daytime bursting altitudes of about 80,000 feet (25 km) above sea level. The balloon measures about 5 feet (1.5 meters) in diameter when first inflated and may expand to 20 feet (6 meters) or more before bursting at high altitude.

radium. An intensely radioactive metallic element. In nature, radium is found associated with uranium, which decays to radium by a series of alpha and beta emissions. Radium is used as a radiation source for instrument calibration.

radSAFE. Radiological safety. General term used to cover the training, operations, and equipment used to protect personnel from unnecessary exposures to ionizing radiation.

rainout. Removal of radioactive particles from a nuclear cloud by rain.

rawin. Radar wind sounding tests that determine the winds aloft patterns by radar observation of a balloon.

rawinsonde. Radar wind sounding and radiosonde (combined).

RB-29. Reconnaissance version of the B-29.

RBE. Relative biological effectiveness. A factor used to compare the biological effectiveness of absorbed radiation doses (i.e., rads) due to different types of ionizing radiation. For radiation protection the term has been superseded by Quality Factor.

rem. A special unit of biological radiation dose equivalent; the name is derived from the initial letters of the term "roentgen equivalent man (or mammal)." The number of rems of radiation is equal to the number of rads absorbed multiplied by the RBE of the given radiation (for a specified effect). The rem is also the unit of dose equivalent, which is equal to the product of the number of rads absorbed multiplied by the "quality factor" and distribution factor for the radiation. The unit is presently being replaced by the sievert (Sv).

rep. An obsolete special unit of absorbed dose.

residual nuclear radiation. Nuclear radiation, chiefly beta particles and gamma rays, that persists after 1 minute following a nuclear explosion. The radiation is emitted mainly by the fission products and other bomb residues in the fallout, and to some extent by Earth and water constituents, and other materials, in which radioactivity has been induced by the capture of neutrons.

R-hour. Recovery or reentry hour.

roentgen. (R; r) A special unit of exposure to gamma (or X-) radiation. It is defined precisely as the quantity of gamma (or X-) rays that will produce electrons (in ion pairs) with a total charge of 2.58×10^{-4} coulomb in 1 kilogram of dry air under standard conditions. An exposure of 1 roentgen results in the deposition of about 94 ergs of energy in 1 gram of soft body tissue. Hence, an exposure of 1 roentgen is approximately equivalent to an absorbed dose of 1 rad in soft tissue.

roll-up. The process for orderly dismantling of facilities no longer required for nuclear test operations and their transfer to other areas.

sampler aircraft. Aircraft used for collection of gaseous and particulate samples from nuclear clouds to determine the level of radioactivity or the presence of radioactive substances.

SAR. Search and rescue operations.

SB-17. SAR version of the B-17.

SC. Sandia Corporation, Albuquerque, New Mexico.

scattering. The diversion of radiation (thermal, electromagnetic and nuclear) from its original path as a result of interactions (or collisions) with atoms, molecules, or larger

particles in the atmosphere or other media between the source of the radiations (e.g., a nuclear explosion) and a point some distance away. As a result of scattering, radiations (especially gamma rays and neutrons) will be received at such a point from many directions instead of only from the direction of the source. See also skyshine.

SCEL. Signal Corps Engineering Laboratories, Ft. Monmouth, New Jersey (Army).

scintillation. A flash of light produced by ionizing radiation in a fluor or a phosphor, which may be crystal, plastic, gas, or liquid.

seamount. A submarine mountain rising above the deep sea floor, commonly from 3,000 to 10,000 feet (1 to 3 km) and having the summit 1,000 to 6,000 feet (0.3 to 1.8 km) below sea level.

shear (wind). Refers to differences in direction (directional shear) of wind at different altitudes.

shielding. Any material or obstruction that absorbs (or attenuates) radiation and thus tends to protect personnel or equipment from the effects of a nuclear explosion. A moderately thick layer of any opaque material will provide satisfactory shielding from thermal radiation, but a considerable thickness of material of high density may be needed for gamma radiation shielding. See also attenuation.

shock. Term used to describe a destructive force moving in air, water, or earth caused by detonation of a nuclear detonation.

shock wave. A continuously propagated pressure pulse (or wave) in the surrounding medium, which may be air, water, or earth, initiated by the expansion of the hot gases produced in an explosion.

sievert (Sv). A recently introduced ICRP measure of "dose equivalent" that takes into account the "quality factor" of different sources of ionizing radiation. One sievert equals 100 rem.

skyshine. Radiation, particularly gamma rays from a nuclear detonation, reaching a target from many directions as a result of scattering by the oxygen and nitrogen in the intervening atmosphere.

slant range. The straight-line distance of an aircraft at any altitude from ground zero or the distance from an airburst to a location on the ground.

stratosphere. Upper portion of the atmosphere, approximately 7 to 40 miles (11 to 64 km) above the Earth's surface, in which temperature changes but little with altitude and cloud formations are rare.

streamline. In meteorology, the direction of the wind at any given time.

surface burst. A nuclear explosion on the land surface, an island surface or reef, or on a barge.

surface zero. The point on the ground or water surface directly above or below the detonation point of a nuclear device.

survey meters. Portable radiation detection instruments especially adapted for surveying or inspecting an area to establish the existence and amount of radiation present, usually from the standpoint of radiological protection. Survey instruments are customarily powered by self-contained batteries and are designed to respond quickly and to indicate directly the exposure rate conditions at the point of interest. See Geiger-Mueller counter, and ion-chamber-type survey meter.

survey, radiation. Evaluation of the radiation levels associated with radioactive materials or areas.

TDY. Temporary duty assignment.

TG. Task Group. Subordinate unit of Task Force.

TD. Task Detachment.

thermal radiation. Electromagnetic radiation emitted in two pulses from a surface or airburst from the fireball as a consequence of its very high temperature; it consists essentially of ultraviolet, visible, and infrared radiation. In the first pulse, when the temperature of the fireball is extremely high, ultraviolet radiation predominates; in the second pulse, the temperatures are lower and most of the thermal radiation lies in the visible and infrared regions of the spectrum.

thermonuclear fusion. Refers to the processes in which a very high temperature and pressure is used to bring about the fusion of light nuclei, such as those of the hydrogen isotopes (deuterium and tritium), with the accompanying liberation of energy. The high temperature and pressure required to initiate the fusion reaction are obtained by means of a fission explosion. See also fusion.

TNT equivalent. A measure of the energy released as the result of the detonation of a nuclear device or weapon, expressed in terms of the mass of TNT that would release the same amount of energy when exploded. The TNT equivalent is usually stated in kilotons (1,000 tons) or megatons (1 million tons). The basis of the TNT equivalence is that the explosion of 1 ton of TNT is assumed to release 1 billion calories of energy. See also megaton, yield.

trapped radiation. Electrically charged particles moving back and forth in spirals along the north-south orientation of the Earth's magnetic field between mirror points, called conjugate points. Negatively charged particles drift eastward as they bounce between northern and southern conjugate points and positively

charged particles drift westward, thus forming shells or belts of radiation above the Earth. The source of the charged particles may be natural, from solar activity (often called Van Allen belts), or artificial, resulting from high-altitude nuclear detonations.

tropopause. The boundary dividing the stratosphere from the lower part of the atmosphere, the troposphere. The tropopause normally occurs at an altitude of about 25,000 to 45,000 feet (7.6 to 13.7 km) in polar and temperate zones, and at 55,000 feet (16.8 km) in the tropics. See also stratosphere, troposphere.

troposphere. The region of the atmosphere, immediately above the Earth's surface and up to the tropopause, in which the temperature falls fairly regularly with increasing altitude, clouds form, convection is active, and mixing is continuous and more or less complete.

Trust Territory. The Marshall Islands were included in the Trust Territory of the Pacific Islands under the jurisdiction of the United Nations. Assigned by the United Nations to the United States in trust for administration, development, and training.

TU. Task Unit. Subordinate unit of Task Group.

type commander. The officer or agency having cognizance over all Navy ships of a given type. This is in addition to the particular ship's operational assignment in a task force, fleet, or other tactical subdivision.

UCLA. University of California, Los Angeles.

UCRL. University of California Radiation Laboratory, Livermore, California.

ultraviolet. Electromagnetic radiation of wavelengths between the shortest visible violet (about 3,850 angstroms) and soft X-rays (about 100 angstroms).

USFS. U.S. Forest Service.

USNS. United States Navy Ship; vessels of this designation are manned by civilian crews.

VA. Veterans' Administration.

VC. Fleet composite squadron (formerly VU).

Versene. A detergent.

VR. Naval air transport squadron.

WADC. Wright Air Development Center, Wright-Patterson AFB, Ohio (Air Force).

warhead. The portion of the missile or bomb containing the nuclear device.

WB-29. Weather reconnaissance version of B-29 used for cloud tracking and sampling.

weapon debris. The radioactive residue of a nuclear device after it has been detonated, consisting of fission products, various products of neutron capture, weapon casing and other components, and uranium or plutonium that has escaped fission.

whole body irradiation. Exposure of the body to ionizing radiation from external radiation sources. Critical organs for the whole body are the lens of the eye, the gonads, and the red-blood-forming marrow. As little as only 1 cm³ of bone marrow constitutes a whole-body exposure. Thus, the entire body need not be exposed to be classed as a whole-body exposure.

Wilson cloud. A mist or fog of minute water droplets that temporarily surrounds a fireball following a nuclear detonation in a humid atmosphere. This is caused by a sudden lowering of the pressure (and temperature) after the passing of the shock wave (cloud chamber effect) and quickly dissipates as temperatures and pressures return to normal.

worldwide fallout. Consists of the smaller radioactive nuclear detonation particles that ascend into the upper troposphere and the stratosphere and are carried by winds to all parts of the Earth. The delayed (or worldwide) fallout is brought to Earth, mainly by rain and snow, over extended periods ranging from months to years.

YC. Open lighter (nonself-propelled; Navy).

YFN. Covered lighter (nonself-propelled; Navy).

yield. The total effective energy released in a nuclear detonation. It is usually expressed in terms of the equivalent tonnage of TNT required to produce the same energy release in an explosion. The total energy yield is manifested as nuclear radiation (including residual radiation), thermal radiation, and blast and shock energy, the actual distribution depending upon the medium in which the explosion occurs and also upon the type of weapon. See TNT equivalent.

yield (blast). That portion of the total energy of a nuclear detonation that is identified as the blast or shock wave.

yield (fission). That portion of the total energy released by a nuclear explosion attributable to nuclear fission, as opposed to fusion. The interest in fission yield stems from the interest in fission product formation and its relationship to radioactive fallout.

YQ. Fuel oil barge; self-propelled (Navy).

YOG. Gasoline barge; self-propelled (Navy).

YOGN. Gasoline barge; nonself-propelled (Navy).

YW. Self-propelled water barge (Navy).

ZI. Zone of Interior (conterminous United States).

APPENDIX C
ISLAND SYNONYMS
ENEWETAK ATOLL

CAPITALIZED entries are the code names used by the joint task force for the islands. Underscored entries are the names of the islands as used in this report. All other entries are spellings of the islands that may appear in other literature.

Aaraanbiru	VERA - <u>Alembel</u> - Arambiru
<u>Aej</u>	OLIVE - Aitsu
Aitsu	OLIVE - <u>Aej</u>
<u>Alembel</u>	VERA - Aaraanbiru - Arambiru
ALICE	<u>Bokoluo</u> - Bogallua
ALVIN	<u>Jinedrol</u> - Chinieero
<u>Ananij</u>	BRUCE - Aniyaanii
Anerowij	TOM - <u>Munjor</u> - Munjur
Aniyaanii	BRUCE - <u>Ananij</u>
<u>Aomon</u>	SALLY
Arambiru	VERA - <u>Alembel</u> - Aaraanbiru
BELLE	<u>Bokombako</u> - Bogombogo
Bijjiri	TILDA - <u>Bijire</u> - <u>Bijile</u> - Bikile
Bijile	TILDA - <u>Bijire</u> - <u>Bijjiri</u> - Bikile
<u>Bijire</u>	TILDA - <u>Bijile</u> - <u>Bijjiri</u> - Bikile
<u>Biken</u>	LEROY - <u>Rigile</u> - <u>Rigili</u>
Bikile	TILDA - <u>Bijire</u> - <u>Bijile</u> - <u>Bijjiri</u>
<u>Billae</u>	WILMA - <u>Piiraa</u> - <u>Piirai</u>
Billee	LUCY - <u>Kidrinen</u> - Kirinian
Bogairikk	HELEN - <u>Bokaidrikdrik</u> - Bogeirik - Bokaidrik
Bogallua	ALICE - <u>Bokoluo</u>
Bogan	IRWIN - <u>Boken</u> - Pokon
Bogeirik	HELEN - <u>Bokaidrikdrik</u> - Bogairikk - Bokaidrik
Bogen	REX - <u>Jedrol</u> - <u>Jieroru</u>
Bogombogo	BELLE - <u>Bokombako</u>
Bogon	IRENE - <u>Boken</u>
Bokaidrik	HELEN - <u>Bokaidrikdrik</u> - Bogairikk - Bogeirik
<u>Bokaidrikdrik</u>	HELEN - Bogairikk - Bogeirik - Bokaidrik
<u>Bokandretok</u>	WALT
<u>Boken</u>	IRENE - Bogon
<u>Boken</u>	IRWIN - Pokon - Bogan
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Bokonarppu	MARY - <u>Bokenelab</u> - Bokonaarappu
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Buganegan	HENRY - <u>Mut</u> - Mui

Chinieero	ALVIN - <u>Jinedrol</u>
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Cochita	DAISY - <u>Louj</u> - Lidilbut
DAISY	<u>Louj</u> - Cochita - Lidilbut
DAVID	<u>Japtan</u> - Muti
<u>Drekatimon</u>	OSCAR
<u>Dridrilbwij</u>	GENE - Teiteiripucchi
Eberiru	RUBY - <u>Eleleron</u>
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ELMER	<u>Parry</u> - Medren
Elugelab	FLORA - <u>Eluklab</u>
<u>Eluklab</u>	FLORA - Elugelab
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Eybbiyae	CLARA - <u>Kirunu</u> - Ruchi
FLORA	<u>Eluklab</u> - Elugelab
FRED	<u>Enewetak</u> - Eniwetok
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Igurin	GLENN - <u>Ikuren</u>
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Jieroru	REX - <u>Jedrol</u> - Bogen
<u>Jinedrol</u>	ALVIN - Chinieero
<u>Jinimi</u>	CLYDE - Chinimi
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KEITH	<u>Kidrenen</u> - Giriinien - Grinem
<u>Kidrenen</u>	KEITH - Giriinien - Grinem

<u>Kidrinen</u>	LUCY - Billee - Kirinian
<u>Kirinian</u>	LUCY - <u>Kidrinen</u> - Billee
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LEROY	<u>Biken</u> - Rigile - <u>Rigili</u>
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<u>Lojwa</u>	URSULA - Rojoa
<u>Louj</u>	DAISY - Cochita - <u>Lidilbut</u>
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Medren	ELMER - <u>Parry</u>
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Munjur	TOM - <u>Munjor</u> - <u>Anerowij</u>
<u>Mut</u>	HENRY - Buganegan - <u>Mui</u>
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<u>Parry</u>	ELMER - Medren
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PERCY	<u>Taiwel</u>
Piiraai	WILMA - <u>Billae</u> - <u>Piirai</u>
Piirai	WILMA - <u>Billae</u> - <u>Piiraai</u>
Pokon	IRWIN - <u>Boken</u> - Bogan
REX	<u>Jedrol</u> - Bogen - <u>Jieroru</u>
Ribaion	JAMES - <u>Ribewon</u> - <u>Libiron</u>
<u>Ribewon</u>	JAMES - <u>Libiron</u> - <u>Ribaion</u>
Rigile	LEROY - <u>Biken</u> - <u>Rigili</u>
Rigili	LEROY - <u>Biken</u> - <u>Rigile</u>
Rojoa	URSULA - <u>Lojwa</u>
RUBY	<u>Eleleron</u> - Eberiru
Ruchi	CLARA - <u>Kirunu</u> - <u>Eybbiyae</u>
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Rujoru	PEARL - <u>Lujor</u> - <u>Rujiyoru</u>
<u>Runit</u>	YVONNE
SALLY	<u>Aomon</u>
SAM	<u>Boko</u>
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<u>Taiwel</u>	PERCY
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TOM	<u>Munjor</u> - Anerowij - Munjur
<u>Unibor</u>	MACK
URIAH	<u>Inedral</u>
URSULA	<u>Lojwa</u> - Rojoa
VAN	Enewetak Atoll
VERA	<u>Alembel</u> - Aaraanbiru - Arambiru
WALT	<u>Bokandretok</u>
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Detroit Public Library
ATTN: Librarian

Dickinson State College
ATTN: Librarian

Drake Memorial Learning Resource Ctr
ATTN: Librarian

Drake University
ATTN: Cowles Library

Drew University
ATTN: Librarian

Duke University
ATTN: Public Docs Dept

Duluth Public Library
ATTN: Documents Section

Earlham College
ATTN: Librarian

East Carolina University
ATTN: Library Docs Dept

East Central University
ATTN: Librarian

East Islip Public Library
ATTN: Librarian

East Orange Public Lib
ATTN: Librarian

East Tennessee State Univ Sherrod Lib
ATTN: Documents Dept

OTHER (Continued)

East Texas State University
ATTN: Library

Eastern Branch
ATTN: Librarian

Eastern Illinois University
ATTN: Librarian

Eastern Kentucky University
ATTN: Librarian

Eastern Michigan University Lib
ATTN: Documents Libn

Eastern Montana College Library
ATTN: Documents Dept

Eastern New Mexico Univ
ATTN: Librarian

Eastern Oregon College Library
ATTN: Librarian

Eastern Washington Univ
ATTN: Librarian

El Paso Public Library
ATTN: Documents & Geneology Dept

Elko County Library
ATTN: Librarian

Elmira College
ATTN: Librarian

Elon College Library
ATTN: Librarian

Enoch Pratt Free Library
ATTN: Documents Office

Emory University
ATTN: Librarian

Evansville & Vanderburgh County Pub Lib
ATTN: Librarian

Everett Public Library
ATTN: Librarian

Fairleigh Dickinson Univ
ATTN: Depository Dept

Florida A & M Univ
ATTN: Librarian

Florida Atlantic Univ Lib
ATTN: Div of Public Documents

Florida Institute of Tech Lib
ATTN: Federal Documents Dept

Florida Intl Univ Library
ATTN: Docs Section

OTHER (Continued)

Florida State Library
ATTN: Documents Section

Florida State University
ATTN: Librarian

Fond Du Lac Public Lib
ATTN: Librarian

Fort Hays State University
ATTN: Librarian

Fort Worth Public Library
ATTN: Librarian

Free Pub Lib of Elizabeth
ATTN: Librarian

Free Public Library
ATTN: Librarian

Freeport Public Library
ATTN: Librarian

Fresno County Free Library
ATTN: Librarian

Gadsden Public Library
ATTN: Librarian

Garden Public Library
ATTN: Librarian

Gardner Webb College
ATTN: Documents Librn

Gary Public Library
ATTN: Librarian

Georgetown Univ Library
ATTN: Govt Docs Room

Georgia Inst of Tech
ATTN: Librarian

Georgia Southern College
ATTN: Librarian

Georgia Southwestern College
ATTN: Director of Libraries

Georgia State Univ Lib
ATTN: Librarian

University of Georgia
ATTN: Dir of Libraries

Glassboro State College
ATTN: Librarian

Gleeson Library
ATTN: Librarian

OTHER (Continued)

Government Publications Library-M
ATTN: Director of Libraries

Graceland College
ATTN: Librarian

Grand Forks Public City-County Library
ATTN: Librarian

Grand Rapids Public Library
ATTN: Director of Libraries

Greenville County Library
ATTN: Librarian

Guam RFK Memorial University Lib
ATTN: Fed Depository Collection

University of Guam
ATTN: Librarian

Gustavus Adolphus College
ATTN: Library

Hardin-Simmons University Library
ATTN: Librarian

Hartford Public Library
ATTN: Librarian

Harvard College Library
ATTN: Director of Libraries

University of Hawaii
ATTN: Government Docs Collection

Hawaii State Library
ATTN: Federal Documents Unit

University of Hawaii at Monoa
ATTN: Director of Libraries

University of Hawaii
ATTN: Librarian

Haydon Burns Library
ATTN: Librarian

Henry Ford Comm College Lib
ATTN: Librarian

Herbert H. Lehman College
ATTN: Library Documents Division

Hofstra Univ Library
ATTN: Documents Dept

Hollins College
ATTN: Librarian

Hoover Institution
ATTN: J. Bingham

OTHER (Continued)

Hopkinsville Comm College
ATTN: Librarian

University of Houston, Library
ATTN: Documents Div

Houston Public Library
ATTN: Librarian

Hoyt Public Library
ATTN: Librarian

Humboldt State College Library
ATTN: Documents Dept

Huntington Park Library
ATTN: Librarian

Hutchinson Public Library
ATTN: Librarian

Idaho Public Lib & Info Center
ATTN: Librarian

Idaho State Library
ATTN: Librarian

Idaho State University Library
ATTN: Documents Dept

University of Idaho
ATTN: Documents Sect
ATTN: Dir of Libraries

University of Illinois, Library
ATTN: Documents Section

Illinois State Library
ATTN: Government Documents Branch

Illinois Univ at Urbana Champaign
ATTN: P. Watson, Documents Library

Illinois Valley Comm Coll
ATTN: Library

Indiana State Library
ATTN: Serial Section

Indiana State University
ATTN: Documents Libraries

Indiana University Library
ATTN: Documents Department

Indianapolis Marion Cty Pub Library
ATTN: Social Science Div

Iowa State University Library
ATTN: Govt Documents Dept

Iowa University Library
ATTN: Government Documents Dept

OTHER (Continued)

Butler University, Irwin Library
ATTN: Librarian

Isaac Delchdo College
ATTN: Librarian

James Madison University
ATTN: Librarian

Jefferson County Public Lib
ATTN: Librarian

Jersey City State College
ATTN: Librarian

Johns Hopkins University
ATTN: Documents Library

John J. Wright Library, La Roche College
ATTN: Librarian

Johnson Free Public Lib
ATTN: Librarian

Kahului Library
ATTN: Librarian

Kalamazoo Public Library
ATTN: Librarian

Kansas City Public Library
ATTN: Documents Div

Kansas State Library
ATTN: Librarian

Kansas State Univ Library
ATTN: Documents Dept

University of Kansas
ATTN: Director of Libraries

Kent State University Library
ATTN: Documents Div

Kentucky Dept of Library & Archives
ATTN: Documents Section

University of Kentucky
ATTN: Governments Publication Dept
ATTN: Director of Libraries

Kenyon College Library
ATTN: Librarian

Lake Forest College
ATTN: Librarian

Lake Sumter Comm Coll Lib
ATTN: Librarian

Lakeland Public Library
ATTN: Librarian

OTHER (Continued)

Lancaster Regional Library
ATTN: Librarian

Lawrence University
ATTN: Documents Dept

Lee Library, Brigham Young University
ATTN: Documents & Map Section

Library & Statutory Distribution & Svc
2 cy ATTN: Librarian

Little Rock Public Library
ATTN: Librarian

Long Beach Publ Library
ATTN: Librarian

Los Angeles Public Library
ATTN: Serials Div U.S. Documents

Louisiana State University
ATTN: Government Doc Dept
ATTN: Director of Libraries

Louisville Free Pub Lib
ATTN: Librarian

Louisville Univ Library
ATTN: Librarian

Lyndon B. Johnson Sch of Pub Affairs Lib
ATTN: Librarian

Maine Maritime Academy
ATTN: Librarian

Maine University at Orono
ATTN: Librarian

University of Maine
ATTN: Librarian

Manchester City Library
ATTN: Librarian

Mankato State College
ATTN: Govt Publications

Mantor Library
Univ of Maine at Farmington
ATTN: Director of Libraries

Marathon County Public Library
ATTN: Librarian

Marshall Brooks Library
ATTN: Librarian

University of Maryland
ATTN: McKeldin Libr Docs Div

University of Maryland
ATTN: Librarian

OTHER (Continued)

University of Massachusetts
ATTN: Government Docs College

McNeese State Univ
ATTN: Librarian

Memphis Shelby County Pub Lib & Info Ctr
ATTN: Librarian

Memphis State University
ATTN: Librarian

Mercer University
ATTN: Librarian

Mesa County Public Library
ATTN: Librarian

University of Miami, Library
ATTN: Government Publications

Miami Public Library
ATTN: Documents Division

Miami Univ Library
ATTN: Documents Dept

Michel Orradre Library
University of Santa Clara
ATTN: Documents Div

Michigan State Library
ATTN: Librarian

Michigan State University Library
ATTN: Librarian

Michigan Tech University
ATTN: Library Documents Dept

University of Michigan
ATTN: Acq Sec Documents Unit

Middlebury College Library
ATTN: Librarian

Millersville State Coll
ATTN: Librarian

Milne Library
State University of New York
ATTN: Docs Librn

Milwaukee Pub Lib
ATTN: Librarian

Minneapolis Public Lib
ATTN: Librarian

Minnesota Div of Emergency Svcs
ATTN: Librarian

Minot State College
ATTN: Librarian

Mississippi State University
ATTN: Librarian

OTHER (Continued)

University of Mississippi
ATTN: Director of Libraries

Missouri Univ at Kansas City Gen
ATTN: Librarian

Missouri University Library
ATTN: Government Documents

M.I.T. Libraries
ATTN: Librarian

Mobile Public Library
ATTN: Governmental Info Division

Moffett Library
ATTN: Librarian

Montana State Library
ATTN: Librarian

Montana State University, Library
ATTN: Librarian

University of Montana
ATTN: Documents Div

Moorhead State College
ATTN: Library

Mt Prospect Public Lib
ATTN: Librarian

Murray State Univ Lib
ATTN: Library

Nassau Library System
ATTN: Librarian

Natrona County Public Library
ATTN: Librarian

Nebraska Library Comm
ATTN: Librarian

Univ of Nebraska at Omaha
ATTN: Librarian

Nebraska Western College Library
ATTN: Librarian

Univ of Nebraska at Lincoln
ATTN: Acquisitions Dept

Univ of Nevada at Reno
ATTN: Governments Pub Dept

Univ of Nevada at Las Vegas
ATTN: Director of Libraries

New Hampshire University Lib
ATTN: Librarian

New Hanover County Public Library
ATTN: Librarian

Nebraska University
ATTN: Director of Libraries

OTHER (Continued)

New Mexico State Library
ATTN: Librarian

New Mexico State University
ATTN: Lib Documents Div

University of New Mexico
ATTN: Director of Libraries

University of New Orleans Library
ATTN: Govt Documents Div

New Orleans Public Lib
ATTN: Library

New York Public Library
ATTN: Librarian

New York State Library
ATTN: Doc Control, Cultural Ed Ctr

New York State Univ at Stony Brook
ATTN: Main Lib Doc Sect

New York State Univ Col at Cortland
ATTN: Librarian

State Univ of New York
ATTN: Library Documents Sec

State Univ of New York
ATTN: Librarian

New York State University
ATTN: Documents Center

State University of New York
ATTN: Documents Dept

New York University Library
ATTN: Documents Dept

Newark Free Library
ATTN: Librarian

Newark Public Library
ATTN: Librarian

Niagara Falls Pub Lib
ATTN: Librarian

Nicholls State Univ Library
ATTN: Docs Div

Nieves M. Flores Memorial Lib
ATTN: Librarian

Norfolk Public Library
ATTN: R. Parker

North Carolina Agri & Tech State Univ
ATTN: Librarian

Univ of North Carolina at Charlotte
ATTN: Atkins Library Documents Dept

Univ of North Carolina at Greensboro, Library
ATTN: Librarian

OTHER (Continued)

North Carolina Central University
ATTN: Librarian

North Carolina State University
ATTN: Librarian

North Carolina University at Wilmington
ATTN: Librarian

University of North Carolina
ATTN: BA SS Division Documents

North Dakota State University Lib
ATTN: Docs Librarian

University of North Dakota
ATTN: Librarian

North Georgia College
ATTN: Librarian

North Texas State University Library
ATTN: Librarian

Northeast Missouri State University
ATTN: Librarian

Northeastern Illinois University
ATTN: Library

Northeastern Oklahoma State Univ
ATTN: Librarian

Northeastern University
ATTN: Dodge Library

Northern Arizona University Lib
ATTN: Government Documents Dept

Northern Illinois University
ATTN: Librarian

Northern Iowa University
ATTN: Library

Northern Michigan Univ
ATTN: Documents

Northern Montana College Library
ATTN: Librarian

Northwestern Michigan College
ATTN: Librarian

Northwestern State Univ
ATTN: Librarian

Northwestern State Univ Library
ATTN: Librarian

Northwestern University Library
ATTN: Govt Publications Dept

Norwalk Public Library
ATTN: Librarian

OTHER (Continued)

University of Notre Dame
ATTN: Document Center

Oakland Comm College
ATTN: Librarian

Oakland Public Library
ATTN: Librarian

Oberlin College Library
ATTN: Librarian

Ocean County College
ATTN: Librarian

Ohio State University
ATTN: Libraries Documents Division

Ohio University Library
ATTN: Docs Dept

Oklahoma City University Library
ATTN: Librarian

Oklahoma City University Library
ATTN: Librarian

Oklahoma Dept of Libraries
ATTN: U.S. Govt Documents

University of Oklahoma, Library
ATTN: Govt Doc Collection

Old Dominion University
ATTN: Doc Dept Univ Library

Olivet College Library
ATTN: Librarian

Omaha Pub Lib Clark Branch
ATTN: Librarian

Oregon State Library
ATTN: Librarian

University of Oregon
ATTN: Documents Section

Ouachita Baptist University
ATTN: Librarian

Pan American University Library
ATTN: Librarian

Passaic Public Library
ATTN: Librarian

Paul Klapper Library
ATTN: Documents Dept

Pennsylvania State Library
ATTN: Government Publications Section

OTHER (Continued)

Pennsylvania State University
ATTN: Library Document Sec

University of Pennsylvania
ATTN: Director of Libraries

Penrose Library
University of Denver
ATTN: Penrose Library

Peoria Public Library
ATTN: Business, Science & Tech Dept

Free Library of Philadelphia
ATTN: Govt Publications Dept

Philipsburg Free Public Library
ATTN: Librarian

Phoenix Public Library
ATTN: Librarian

University of Pittsburg
ATTN: Documents Office G 8

Plainfield Public Library
ATTN: Librarian

Popular Creek Public Lib District
ATTN: Librarian

Association of Portland Lib
ATTN: Librarian

Portland Public Library
ATTN: Librarian

Portland State University Library
ATTN: Librarian

Prescott Memorial Lib
Louisiana Tech Univ
ATTN: Librarian

Princeton University Library
ATTN: Documents Division

Providence College
ATTN: Librarian

Providence Public Library
ATTN: Librarian

Cincinnati & Hamilton County Public Library
ATTN: Librarian

Public Library of Nashville and Davidson County
ATTN: Librarian

University of Puerto Rico
ATTN: Doc & Maps Room

Purdue University Library
ATTN: Librarian

OTHER (Continued)

Quinebaug Valley Community Col
ATTN: Librarian

Ralph Brown Draughton Lib
Auburn University
ATTN: Microforms & Documents Dept

Rapid City Public Library
ATTN: Librarian

Reading Public Library
ATTN: Librarian

Reed College Library
ATTN: Librarian

Reese Library
Augusta College
ATTN: Librarian

University of Rhode Island Library
ATTN: Govt Publications Office

University of Rhode Island
ATTN: Director of Libraries

Rice University
ATTN: Director of Libraries

Richard W. Norton Mem Lib
Louisiana College
ATTN: Librarian

Richland County Pub Lib
ATTN: Librarian

University of Richmond
ATTN: Librarian

Riverside Public Library
ATTN: Librarian

University of Rochester Library
ATTN: Documents Section

Rutgers University, Camden Library
ATTN: Librarian

Rutgers State University
ATTN: Librarian

Rutgers University, Library of Sci & Medicine
ATTN: Govt Docs Dept

Rutgers University Law Library
ATTN: Federal Documents Dept

Salem College Library
ATTN: Librarian

Samford University
ATTN: Librarian

San Antonio Public Library
ATTN: Bus Science & Tech Dept

OTHER (Continued)

San Diego County Library
ATTN: C. Jones, Acquisitions

San Diego Public Library
ATTN: Librarian

San Diego State University Library
ATTN: Govt Pubs Dept

San Francisco Public Library
ATTN: Govt Documents Dept

San Francisco State College
ATTN: Govt Pub Collection

San Jose State College Library
ATTN: Documents Dept

San Luis Obispo City-County Library
ATTN: Librarian

Savannah Pub & Effingham Libty Reg Lib
ATTN: Librarian

Scottsbluff Public Library
ATTN: Librarian

Scranton Public Library
ATTN: Librarian

Seattle Public Library
ATTN: Ref Doc Asst

Selby Public Library
ATTN: Librarian

Shawnee Library System
ATTN: Librarian

Shreve Memorial Library
ATTN: Librarian

Silas Bronson Public Library
ATTN: Librarian

Simon Schwob Mem Lib
Columbus College
ATTN: Librarian

Sioux City Public Library
ATTN: Librarian

Skidmore College
ATTN: Librarian

Slippery Rock State College Library
ATTN: Librarian

South Carolina State Library
ATTN: Librarian

University of South Carolina
ATTN: Librarian

OTHER (Continued)

University of South Carolina
ATTN: Government Documents

South Dakota Sch of Mines & Tech
ATTN: Librarian

South Dakota State Library
ATTN: Federal Documents Department

University of South Dakota
ATTN: Documents Librarian

South Florida University Library
ATTN: Librarian

Southdale-Hennepin Area Library
ATTN: Government Documents

Southeast Missouri State University
ATTN: Librarian

Southeastern Massachusetts University Library
ATTN: Documents Sec

University of Southern Alabama
ATTN: Librarian

Southern California University Library
ATTN: Documents Dept

Southern Connecticut State College
ATTN: Library

Southern Illinois University
ATTN: Librarian

Southern Illinois University
ATTN: Documents Ctr

Southern Methodist University
ATTN: Librarian

University of Southern Mississippi
ATTN: Library

Southern Oregon College
ATTN: Library

Southern University in New Orleans, Library
ATTN: Librarian

Southern Utah State College Library
ATTN: Documents Department

Southwest Missouri State College
ATTN: Library

Southwestern University of Louisiana, Libraries
ATTN: Librarian

Southwestern University School of Law Library
ATTN: Librarian

OTHER (Continued)

Spokane Public Library
ATTN: Reference Dept

Springfield City Library
ATTN: Documents Section

St. Bonaventure University
ATTN: Librarian

St. Joseph Public Library
ATTN: Librarian

St. Lawrence University
ATTN: Librarian

St. Louis Public Library
ATTN: Librarian

St. Paul Public Library
ATTN: Librarian

Stanford University Library
ATTN: Govt Documents Dept

State Historical Soc Lib
ATTN: Docs Serials Section

State Library of Massachusetts
ATTN: Librarian

State University of New York
ATTN: Librarian

Stetson Univ
ATTN: Librarian

University of Steubenville
ATTN: Librarian

Stockton & San Joaquin Public Lib
ATTN: Librarian

Stockton State College Library
ATTN: Librarian

Superior Public Library
ATTN: Librarian

Swarthmore College Lib
ATTN: Reference Dept

Syracuse University Library
ATTN: Documents Div

Tacoma Public Library
ATTN: Librarian

Tampa, Hillsborough County Public Lib
ATTN: Librarian

Temple University
ATTN: Librarian

Tennessee Technological University
ATTN: Librarian

OTHER (Continued)

University of Tennessee
ATTN: Dir of Libraries

Terteling Library
College of Idaho
ATTN: Librarian

Texas A & M University Library
ATTN: Librarian

University of Texas at Arlington
ATTN: Library Documents

University of Texas at San Antonio
ATTN: Library

Texas Christian University
ATTN: Librarian

Texas State Library
ATTN: U.S. Documents Sect

Texas Tech University Library
ATTN: Govt Docs Dept

Texas University at Austin
ATTN: Documents Coll

Texas University at El Paso
ATTN: Documents and Maps Lib

University of Toledo Library
ATTN: Librarian

Toledo Public Library
ATTN: Social Science Dept

Torrance Civic Center Library
ATTN: Librarian

Traverse City Public Library
ATTN: Librarian

Trenton Free Public Library
ATTN: Librarian

Trinity College Library
ATTN: Librarian

Trinity University Library
ATTN: Documents Collection

Tufts University Library
ATTN: Documents Dept

Tulane University
ATTN: Documents Dept

University of Tulsa
ATTN: Librarian

UCLA Research Library
ATTN: Public Affairs Svc/US Docs

OTHER (Continued)

Uniformed Svcs Univ of the Hlth Sci
ATTN: LRC Library

University Libraries
ATTN: Dir of Libraries

Upper Iowa College
ATTN: Documents Collection

Utah State University
ATTN: Librarian

University of Utah
ATTN: Special Collections

University of Utah
ATTN: Dept of Pharmacology
ATTN: Director of Libraries

Valencia Library
ATTN: Librarian

Vanderbilt University Library
ATTN: Govt Docs Sect

University of Vermont
ATTN: Director of Libraries

Virginia Commonwealth University
ATTN: Librarian

Virginia Military Institute
ATTN: Librarian

Virginia Polytechnic Inst Lib
ATTN: Docs Dept

Virginia State Library
ATTN: Serials Section

University of Virginia
ATTN: Public Documents

Volusia County Public Libraries
ATTN: Librarian

Washington State Library
ATTN: Documents Section

Washington State University
ATTN: Lib Documents Section

Washington University Libraries
ATTN: Dir of Libraries

University of Washington
ATTN: Documents Div

Wayne State University Library
ATTN: Librarian

Wayne State University Law Library
ATTN: Documents Dept

Weber State College Library
ATTN: Librarian

Wagner College
ATTN: Librarian

OTHER (Continued)

Wesleyan University
ATTN: Documents Librarian

West Chester State Coll
ATTN: Documents Dept

West Covina Library
ATTN: Librarian

University of West Florida
ATTN: Librarian

West Hills Community Coll
ATTN: Library

West Texas State University
ATTN: Library

West Virginia Coll of Grad Studies Lib
ATTN: Librarian

University of West Virginia
ATTN: Dir of Libraries

Westerly Public Library
ATTN: Librarian

Western Carolina University
ATTN: Librarian

Western Illinois University Lib
ATTN: Librarian

Western Washington Univ
ATTN: Librarian

Western Wyoming Community College Lib
ATTN: Librarian

Westmoreland Cty Comm Coll
ATTN: Learning Resource Ctr

Whitman College
ATTN: Librarian

Wichita State Univ Library
ATTN: Librarian

William & Mary College
ATTN: Docs Dept

William Allen White Library
Emporia Kansas State College
ATTN: Govt Documents Div

William College Library
ATTN: Librarian

Willimantic Public Library
ATTN: Librarian

Winthrop College
ATTN: Documents Dept

University of Wisconsin at Whitewater
ATTN: Government Documents Library

OTHER (Continued)

Wisconsin Milwaukee University
ATTN: Librarian

Wisconsin Oshkosh University
ATTN: Librarian

Wisconsin Platteville University
ATTN: Librarian

Wisconsin University at Stevens Point
ATTN: Docs Section

University of Wisconsin
ATTN: Govt Pubs Dept

University of Wisconsin
ATTN: Acquisitions Dept

Worcester Public Library
ATTN: Librarian

OTHER (Continued)

Yale University
ATTN: Director of Libraries

Yeshiva University
ATTN: Librarian

Yuma City County Library
ATTN: Librarian

Wright State Univ Library
ATTN: Govts Documents Dept

Wyoming State Library
ATTN: Librarian

University of Wyoming
ATTN: Documents Div

State Library of Ohio
ATTN: Librarian

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