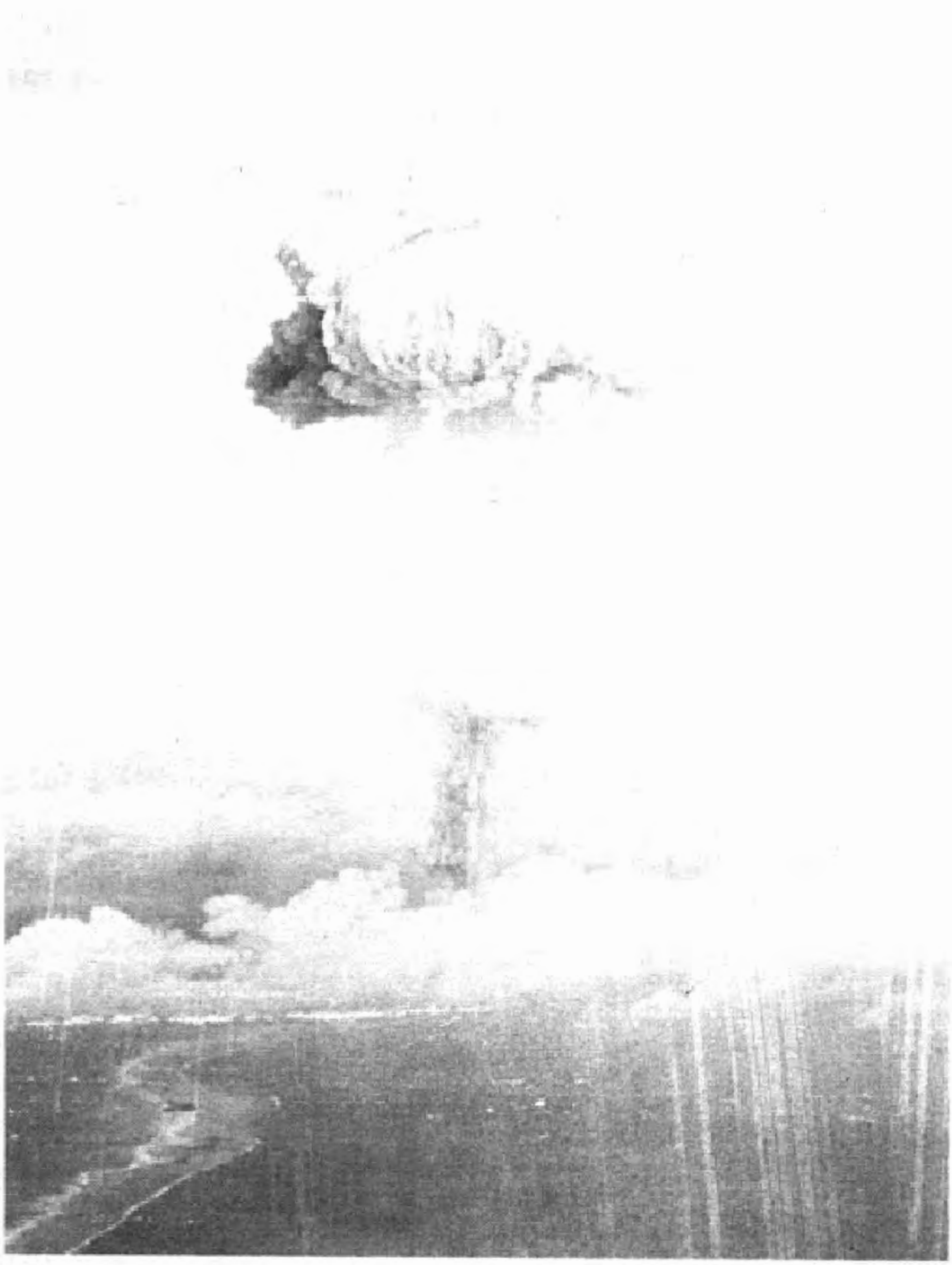
HAROLD L. BRODE

DNA 6034F

OPERATION GREENHOUSE
1951

United States Atmospheric Nuclear Weapons Tests
Nuclear Test Personnel Review

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



Shot GEORGE Cloud

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GREENHOUSE was a four-detonation atmospheric nuclear weapon's test series conducted in the Marshall Islands at Enewetak Atoll in April and May 1951. This is a report of DOD personnel in GREENHOUSE with an emphasis on operational radiological safety.

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GREENHOUSE FACT SHEET

GREENHOUSE, the fourth postwar atmospheric nuclear weapon test series, was conducted by the United States during April and May 1951. CROSSROADS took place at Bikini in 1946; SANDSTONE was held at Enewetak in 1948; and RANGER was conducted at the Nevada Test Site in early 1951. In GREENHOUSE, four nuclear devices were detonated on the islands of Enjebi, Eleleron, and Runit on Enewetak Atoll. All four were detonated on towers. These detonations resulted in significant downwind fallout.

GREENHOUSE detonations, Enewetak, 1951

Detonation	Date	Time	Location	Type Burst
DOG	8 April	0634	Runit	300-foot (91.4-meter) tower shot
EASY	21 April	0627	Enjebi	300-foot (91.4-meter) tower shot
GEORGE	9 May	0930	Eleleron	200-foot (61.5-meter) tower shot
ITEM	25 May	0617	Enjebi	200-foot (61.5-meter) tower shot

Remarks: Dates and times are local dates and times at Enewetak. Only the yield of shot EASY, 47 kilotons (KT), has been announced. One kiloton equals the approximate energy release of the explosion of one thousand tons of TNT.

Tests were conducted by a joint military-civilian organization designated Joint Task Force Three (JTF 3). JTF 3 was patterned generally after military organizations but was made up of military personnel from the Army, Navy, Air Force and Marine Corps, as well as civilians from the Department of Defense (DOD), Atomic Energy Commission (AEC), and contractors. The commander, an Air Force general, was an appointed representative of the AEC but reported to the Joint Chiefs of Staff as well as to the AEC. This appointment was important because, by law, development of atomic weapons was vested in the AEC.

Army, Navy, and Air Force were about equally represented in numbers of personnel during GREENHOUSE. The Navy had provided the bulk of personnel for the earlier Pacific nuclear test series. During GREENHOUSE, the Army provided an estimated 1,615 men, the Navy 2,952, the Air Force 2,621, and the Marine Corps 134. Civilians numbered 2,049. Most of the civilians were affiliated with the AEC.

The purpose of the four tests in the GREENHOUSE series was to continue development of nuclear weapons for defense. Work was proceeding at this time on development of thermonuclear weapons, and the GREENHOUSE tests were part of this process. DOD was interested in the physical and biological effects of nuclear weapons, so its various branches participated in several experimental programs to measure them. One of the important programs used unmanned, radio-controlled drone aircraft to measure blast and thermal effects and to collect radioactive cloud samples.

A separate organization within JTF 3 provided radiological safety (radsafe) expertise and services to the task force. This organization was responsible for defining radioactive areas after each shot, accompanying reentry parties to radioactive areas to retrieve experimental data, monitoring removal, packaging, and shipment of radioactive cloud samples, and other radiation monitoring duties. It also procured all radiation detection film badges, developed and interpreted exposed film badges, and kept cumulative radiation exposure records on each person who was badged.

Film badges were issued to individuals who possibly could have been exposed to radiation while performing their duties; such as those visiting any of the islands made radioactive by the shots, boat pool crews, radiation monitors, aircrews, aircraft decontamination personnel, and runway crash crews. In addition, over 75 film badges for each test were distributed among the six participating ships, to be worn from the day of the test and 7 days thereafter. Of the approximately 9,350 men in the test area during all or part of the testing operations, 2,416 were badged one or more times. Film badges for personnel entering radioactive areas normally were issued and turned in daily. Boat pool, air crew, and ship badges generally were issued for a week.

The overall average exposure recorded by these badges was less than 0.5 roentgen (R). A number of individuals, however, had recorded exposures between 5 and 8 R. Some, with these higher exposures were affiliated with the AEC and some were involved with the Air Force long-range radioactive cloud-tracking and -sampling program. Most of these Air Force personnel were in the Experimental Aircraft Unit. This unit flew the B-17s used as drones and drone controllers and operated the personnel and aircraft decontamination stations on Enewetak Island. The following table summarizes the recorded film badge exposures.

GREENHOUSE Badge Exposures (R)

	Number Badged	0	0-1	1-3	Over 3	High (R)
U.S. Army	195	6	143	35	11	5.430
U.S. Navy	813	134	458	187	34	8.080
U.S. Air Force	849	86	516	146	101	8.475
U.S. Marine Corps	8	3	3	0	2	3.805
Other Participants	551	110	325	82	34	8.575

Fallout occurred on the islands of Japtan, Parry, and Enewetak and the six task force ships after three of the four shots in this series. The fallout from the first two shots was heaviest on Japtan and lightest on Enewetak. Enewetak was a base island where personnel from JTF 3 lived throughout the series. Japtan was an island used for recreation, but it also had an Army communication station and a Navy medical research unit. The fallout from shot ITEM, the last shot in this series, was much heavier than the first two. Enewetak Island received heavier fallout from ITEM than Japtan and Parry. Personnel who remained on Enewetak Island for 4 days after ITEM received over 2.45 R. Those who remained for 14 days received over 2.8 R. Most people, however, departed the test area within a week after the shot.

The amount of fallout received by the six ships varied with their locations and decontamination procedures. Nearly all crewmembers on five of these ships were assigned a fallout exposure immediately after GREENHOUSE, and these exposures were recorded in Navy medical records. The assigned exposures ranged from 0.334 R on USS LST-859 to 1.1 R on USS Cabildo (LSD-16) and USS Sproston (DDE-577). Boat pool exposures ranged from 0.700 to 2.1 R. The fallout exposure was lower aboard ship than on the islands due to water washdown and decontamination of external surfaces.

The fallout exposure is in addition to those film badge exposure readings accrued by individuals during daily missions. Fallout exposure can be calculated for all individuals based upon their location and length of stay at Enewetak Atoll.

PREFACE

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

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

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

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

This report on Operation GREENHOUSE 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 reporting various aspects of each of the tests. Reports of the NTPR provide a public record of the activities and associated radiation exposure risks 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 Three (JTF 3) and its subordinate organizations. What was desired were documents 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 some discussion or review with participants.

For GREENHOUSE, the most important archival source is the Modern Military Branch of the National Archives in Washington, D.C. The Naval Archives at the Washington Naval Yard also were helpful. Other archives searched were those of the Department of Energy (DOE) at Germantown, Maryland, its Nevada Operations Office (DOE/NV) at Las Vegas, and the records center at the Los Alamos National Laboratory (LANL).

JTF 3 exposure records were retrieved from LANL and from the Reynolds Electrical and Engineering Company, Inc. (REECo), Las Vegas, Nevada, support contractor for DOE/NV. Those available at REECo are microfilm records of source documents in archives.

Documentation of individual fallout exposure during GREENHOUSE is incomplete. Each individual's arrival date, ship or island station, and departure date must be obtained to determine fallout exposures because not all participants exposed to fallout were wearing film badges.

The work was performed under RDT&E RMSS B3500079464 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

GREENHOUSE was the fourth series of nuclear tests conducted by the United States following World War II. CROSSROADS, in 1946, was the first, consisting of an air and an underwater detonation at Bikini using an array of target ships. SANDSTONE, in 1948, consisted of three tower detonations at Enewetak.* The third, designated RANGER, consisted of five airdrops in January and February 1951 at the Nevada Proving Grounds north of Las Vegas, Nevada.

GREENHOUSE consisted of four detonations in April and May 1951 on the northeast islands of Enewetak Atoll. Task force personnel were stationed either on the southern islands of Enewetak Atoll, on ships, or at Kwajalein Atoll about 350 nmi (650 km) southeast, depending on their mission. Table 1 lists the four shots, their dates, and locations. Figure 1 shows the locations of the GREENHOUSE shots at Enewetak Atoll and the three earlier SANDSTONE shots.

This report documents the participation of Department of Defense (DOD) personnel who were active in this test series. Its purpose is to bring together the available information about this atmospheric nuclear test series pertinent to the radiation exposure of DOD personnel, both uniformed and civilian employees. The report lists the DOD organizations represented and describes their

Table 1. GREENHOUSE detonations, 1951.

Detonation	Date	Time	Location	Type Burst
DOG	8 April	0634	Runit	300-foot (91.4-meter) tower shot
EASY	21 April	0627	Enjebi	300-foot (91.4-meter) tower shot
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Remarks:

Dates and times are local dates and times at Enewetak. Only the yield of shot EASY, 47 kilotons (KT), has been announced. One kiloton equals the approximate energy release of the explosion of one thousand tons of TNT.

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

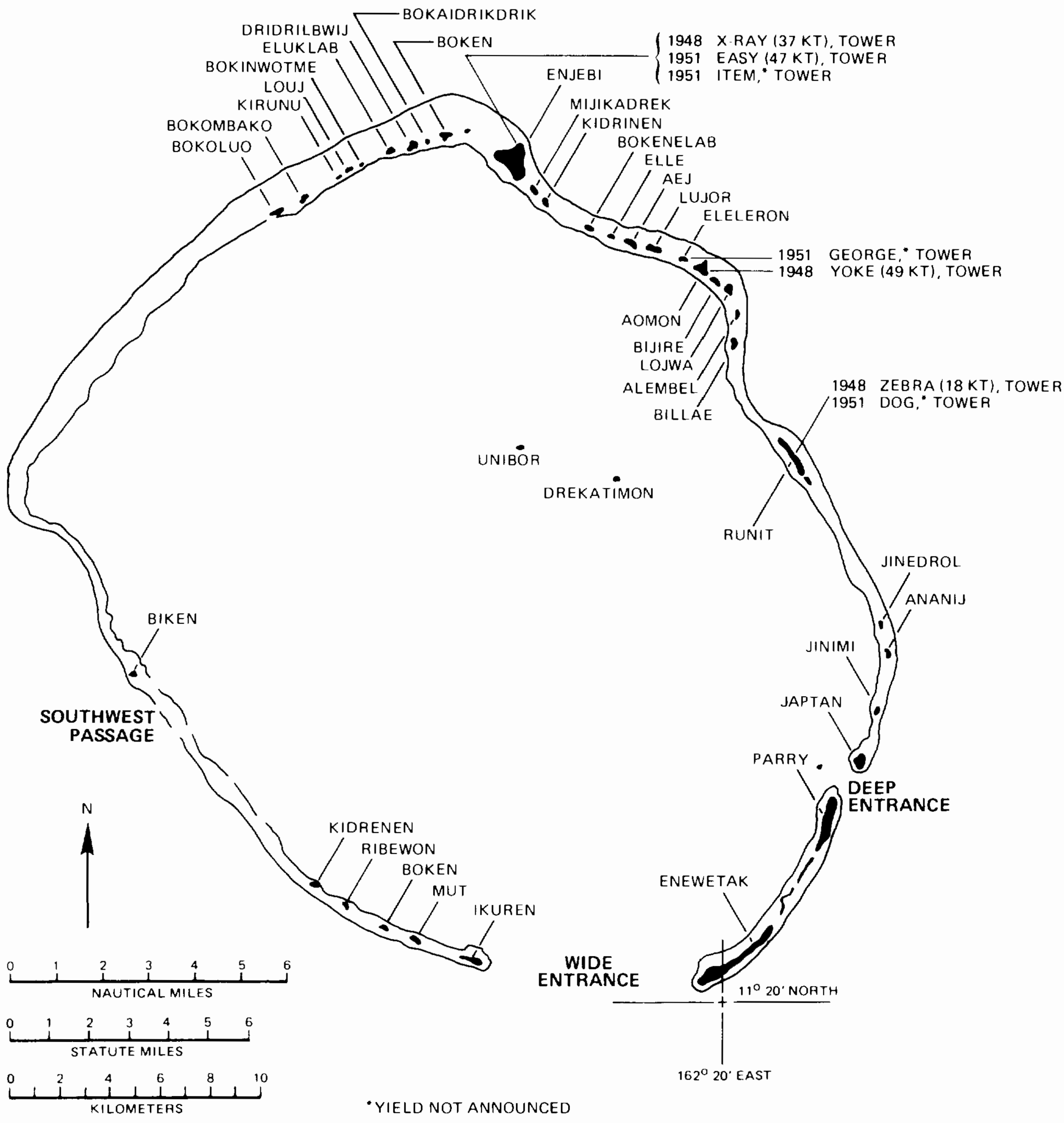


Figure 1. Enewetak Atoll showing SANDSTONE and GREENHOUSE detonation sites.

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

In 1949, the Soviet Union detonated its first atomic bomb (Reference 1, p. 114), providing the impetus for the United States to proceed with development of a bomb whose energy would come from the fusion, or joining, of light elements. These are also called thermonuclear, or hydrogen, bombs. The Atomic Energy Commission (AEC), the civilian executive agency empowered by the Atomic Energy Act of 1946 to develop nuclear weapons, received the go-ahead from the President in January 1950 after a long, hard debate in high defense circles over the advisability of developing such weapons.

Although GREENHOUSE nuclear devices were not thermonuclear devices, two of them involved thermonuclear experiments, and one test, GEORGE, was an important way station on the path to development of thermonuclear devices.

According to the published account (Reference 2) of one of the leaders in nuclear weapon development of the period, GEORGE demonstrated the initiation of a sustained thermonuclear reaction by use of a fission reaction. This led directly to the first successful thermonuclear test, MIKE (Operation IVY), some 16 months later. The same account notes that the fourth test of the series, ITEM, involved boosting the efficiency of fission explosions. Development of this experiment had been planned before the Soviet test in 1949.

GREENHOUSE was conceived even as the SANDSTONE tests were being completed. Planning began in the summer of 1948 at the AEC's Los Alamos Scientific Laboratory (LASL). In July 1948, LASL created J-Division to assume responsibility for planning and conducting nuclear tests. The civilian in charge of this division would become GREENHOUSE director of scientific activities. An Air Force officer was designated as GREENHOUSE Task Force Commander in May 1949, and a Joint Proof Test Committee (JPTC) was set up in June 1949. JPTC was given the missions of determining task force organization, outlining service participation, and recommending necessary actions that affected the services. In July 1949, the test organization was designated Joint Task Force Three (JTF 3). In August 1949, the name "Operation GREENHOUSE" was approved. JTF 3 was activated in November 1949 to coordinate the detailed planning between LASL and the armed services. Meetings were held with JPTC members, service representatives, and JTF 3 staff members in late 1949. JPTC was dissolved 7 January 1950, when the JTF 3 staff took complete control of all activities associated with GREENHOUSE (Reference 3, pp. 3 through 16).

A major construction program began at Enewetak in 1949, and it became necessary for an Army Engineer Construction Battalion to assist the civilian contractor in preparing the test site. Therefore, Army Task Group (TG) 3.2, was activated on 12 January 1950. Commander JTF 3 assumed overall military responsibility for the Enewetak area on 1 February 1951 (Reference 3, p. 39). The Korean War started in June 1950, and the Army quickly became hard-pressed to supply troops for action in Korea. The Army tentatively planned to move two units - Hq 7th Engineer Brigade and 79th Engineer Construction Battalion --

from Enewetak to Korea, but this was contingent on the tests being moved to a stateside location (Reference 3, pp. 34 through 37).

Report Organization

Subsequent sections of this chapter discuss the form of experimental nuclear weapon test programs with emphasis on the potential radiation exposure of participating DOD personnel. Experimental activities are considered first without particular reference to the geographic location of the testing, and are then related to the geographic limitations at Enewetak Atoll. The portion of the experimental program of heaviest DOD participation is emphasized. The chapter concludes with a description of JTF 3, the organization that conducted Operation GREENHOUSE, and indicates how DOD elements within JTF 3 functioned.

Chapter 2 is concerned with radiological safety (radsafe) aspects of the tests. This chapter documents procedures, training, and equipment used to protect participants from the radiation exposure inherent in the test operations. It also addresses safety measures that were employed to minimize hazards associated with nuclear detonations. Discussions include both predetonation and postdetonation safety measures that were taken, primarily to avoid unnecessary radiation exposure.

Chapter 3 discusses GREENHOUSE test operations. Chapter 4 expands on the DOD role in the GREENHOUSE experimental program.

Chapters 5 through 8 report on participation by the Army, Navy, Air Force, and Marine Corps, respectively. Chapter 9 summarizes participation of other government agencies and contractors. Participating units are listed and personnel exposures are statistically characterized in these chapters. Personnel exposures are discussed in Chapter 10.

NUCLEAR TESTS AND RADIATION EXPOSURES

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

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

The neutron component of initial radiation did indirectly contribute to the possibility of personnel exposure. Neutrons are emitted in large numbers by nuclear weapon detonations. Neutrons have the property of altering certain nonradioactive materials to make them radioactive. This process, called activation, works on sodium, silicon, calcium, manganese, and iron, as well as other common materials. The process affects the metal casing of the device, the test tower, and earth materials. Activation products thus formed are added to the inventory of the radioactive products produced in the detonation process. The radiation emitted by this inventory is referred to as residual radiation.

The potential for personnel exposure to residual radiation was much greater than the potential for exposure to initial radiation. In the nuclear detonation 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.

The overall radioactivity of all the fission products formed decays at a rate that is closely approximated by a rule that states that for each sevenfold increase in time the intensity of the radiation will decrease by a factor of ten. Thus, a radiation rate of 1 roentgen per hour (R/hr) at 1 hour after the burst would be expected to be 0.1 R/hr after 7 hours and 0.01 R/hr after 49 hours. This rule seems to be valid for about 6 months following an explosion, after which the observed decay 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, constitute the radioactive material in the debris cloud, and this cloud and its fallout are the primary sources of the 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, the device residues (including the fission products, the activation products resulting from neutron interaction with device materials, and unfissioned uranium and/or plutonium) are vaporized. These vapors condense as the fireball rises and cools, and the particles formed by the condensation are small and smoke-like. They are carried up with the cloud to the altitude at which its rise stops, usually called the cloud stabilization altitude. The spread of this material then depends on the winds and weather. If the burst size is small, the cloud stabilization altitude will be in the lower atmosphere and the material will act like dust and return to the Earth's surface in a matter of weeks. Essentially all debris from bursts with yields equivalent to kilotons of TNT will be down within 2 months. The areas in which this fallout material will be deposited will appear on maps as bands following the wind's direction. Larger bursts (yields equivalent to megatons of TNT) will have cloud stabilization altitudes in the stratosphere (above about 10 miles [16 km] in the tropics); the radioactive material from such altitudes will not return to Earth for many months and its distribution will be much wider. Thus, airbursts contribute little potential for radiation exposure to personnel at the testing area, although there may be some residual and short-lived radiation coming from activated surface materials under the burst if the burst altitude is sufficiently low for neutrons to reach the surface.

Surface and near-surface bursts pose larger potential radiation exposure problems. These bursts create more radioactive debris because more material is available for activation within range of the neutrons generated by the explosion. In such explosions the extreme heat vaporizes device materials and activated earth materials as well. These materials cool in the presence of additional material gouged out of the burst crater. This extra material causes the particles formed as the fireball cools to be larger in size, with radioactivity embedded in them or coating their surfaces. The rising cloud will lift these particles to altitudes that will depend on the particle size and shape and the power of the rising air currents in the cloud, which in turn depend on the energy of the burst. 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.

Bursts on the surface of seawater generate particles consisting mainly of salt and water droplets that are smaller and lighter than the fallout particles from a land-surface burst. As a consequence, water-surface bursts produce less early fallout than similar devices detonated on land. The large-yield surface bursts in the Pacific Proving Ground (PPG) over relatively shallow lagoon waters or on the very little truly dry land probably formed a complex combination of land-surface- and water-surface-burst particle-size characteristics.

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 an equal height tower not only because of the additional fission products and weapon debris, but also because it will pull up more earth materials, or even form a crater. In addition, the materials of the tower itself are a source of easily activated materials. The particles of the tower material may also act as centers for the debris vapors to condense on to form the larger particles that lead to heavier early fallout. Devices that fission uranium or plutonium inefficiently will cause more of these radioactive components of the device residue to be dispersed.

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. GREENHOUSE's experimental program incorporated two aspects. The more important aspect was diagnostic measurements of the detonations; the secondary experiments involved the measurement of the explosive and radiation effects.

These two aspects can serve as a rough measure of differentiation of interest between the major participants: the AEC interest in weapon development, and the DOD interest in the military application of the effects of the detonations. In GREENHOUSE, however, the AEC was interested in experiments in areas that later became of DOD interest exclusively. These were measurements of airblast and thermal radiation, for example, that were termed "field variable" measurements. These measurements were used to construct the hostile environment for studies of the response of military systems and have been termed "environmental measurements" in this report.

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

Weapon Development Experiments

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

YIELD MEASUREMENTS. Device yield was usually 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 were 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.

The best direct measurement of yield is by collecting and analyzing representative samples of device debris. Yield is then determined by measuring the radioactivity of these samples.

Construction, instrumentation placement, and data recovery for the photo-optical yield determinations did not usually 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 device debris, however, necessitated exposure to radioactivity. The technique used in most atmospheric tests was to fly aircraft with collectors directly through portions of the radioactive (or "mushroom") cloud. About 90 percent of the device debris was usually considered to be in the upper, or cap, portion of the mushroom cloud. Several aircraft were used to obtain a representative sample. For GREENHOUSE, unmanned drone B-17 aircraft were used to collect most of the cloud samples. Aircraft flying these sampling missions picked up significant amounts of radioactive material on their surfaces, and this was a potential source of radiation exposure to the ground crews who decontaminated and maintained the aircraft. Manned aircraft sampled the air under and very close to the cloud, which created some low-level exposure to aircraft crews. 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 explosion of a nuclear device is a progressive release of increasing amounts of nuclear radiation, some of which directly escapes the device. The rest of the radiant energy interacts with the associated material of the device itself and is converted into differing forms of radiation and into the kinetic energy of the remaining materials in a small fraction of a second. The intensely hot core then reradiates, heating the surrounding air and creating a shock wave that propagates outward from the burst point.

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

Radiation measurements are based upon the effects that result from the interaction of the radiation with matter. Fluorescence is one such effect. Materials that fluoresce when exposed to radiation 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 soil materials, water, and other substances. These materials are also used to baffle or collimate radiation to ensure that radiation is directed toward the detecting instrument.

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

Preshot preparation included hazards normally associated with heavy construction. At times workers were exposed to residual radiation from previous tests; however, this was not a problem during GREENHOUSE tests.

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

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

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

Effects Experiments

All four GREENHOUSE shots tested new weapon developments. Priorities of time and space and go or no-go considerations on shot day favored weapon development experiments over the effects experiments. Although the effects experiments were clearly secondary, they directly involved a relatively large number of DOD organizations and individuals and are therefore of prime importance for this report.

Effects experiments were intended to acquire urgently needed military data. These experiments may be classed into two general kinds. The first class of measurements was made to document the hostile environment created by the nuclear detonation. The second class of effects experiments documented the response of systems to the hostile environment; these measurements are termed systems response experiments.

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

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

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

SYSTEMS RESPONSE EXPERIMENTS. To document the response of systems to the hostile environment, military structures and hardware (aircraft, tanks, etc.) were exposed to the effects of nuclear detonations.

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

While the potential radiological exposure for these systems response experiments was governed primarily by the closeness in space or time, an additional problem often arose. When the exposed system was recovered for closer examination, it might be contaminated by device debris or even be radioactive because of the activating effects of the device's neutron output.

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 cover about 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 of atolls 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. Figure 2 shows these islands in the Central Pacific.

A typical atoll (see Figure 1), 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 larger islands in the south and southeast areas of the atoll. Devices were detonated on the northern islands. The western sections of the atoll were not involved in test activities except for limited use as instrumentation sites.

Elliptically shaped, Enewetak is approximately 550 nmi (1,020 km) southwest of Wake Island and 2,380 nmi (4,410 km) southwest of Hawaii. It encloses a lagoon 17 by 23 nmi (32 by 43 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 Atoll (Enewetak, Parry, and Japtan islands) constitutes about 34 percent of its land surface. The string of islands from Runit to Enjebi, the detonation area, constitutes about 32 percent. The various names used for the islands of the atoll are listed in Appendix C, "Island Synonyms."

North of Enewetak is open ocean for over a thousand miles, with the only inhabited island being Wake. Enewetak Atoll's inhabitants had been voluntarily moved to Ujelang Atoll in 1948, approximately 110 nmi (200 km) southwest of

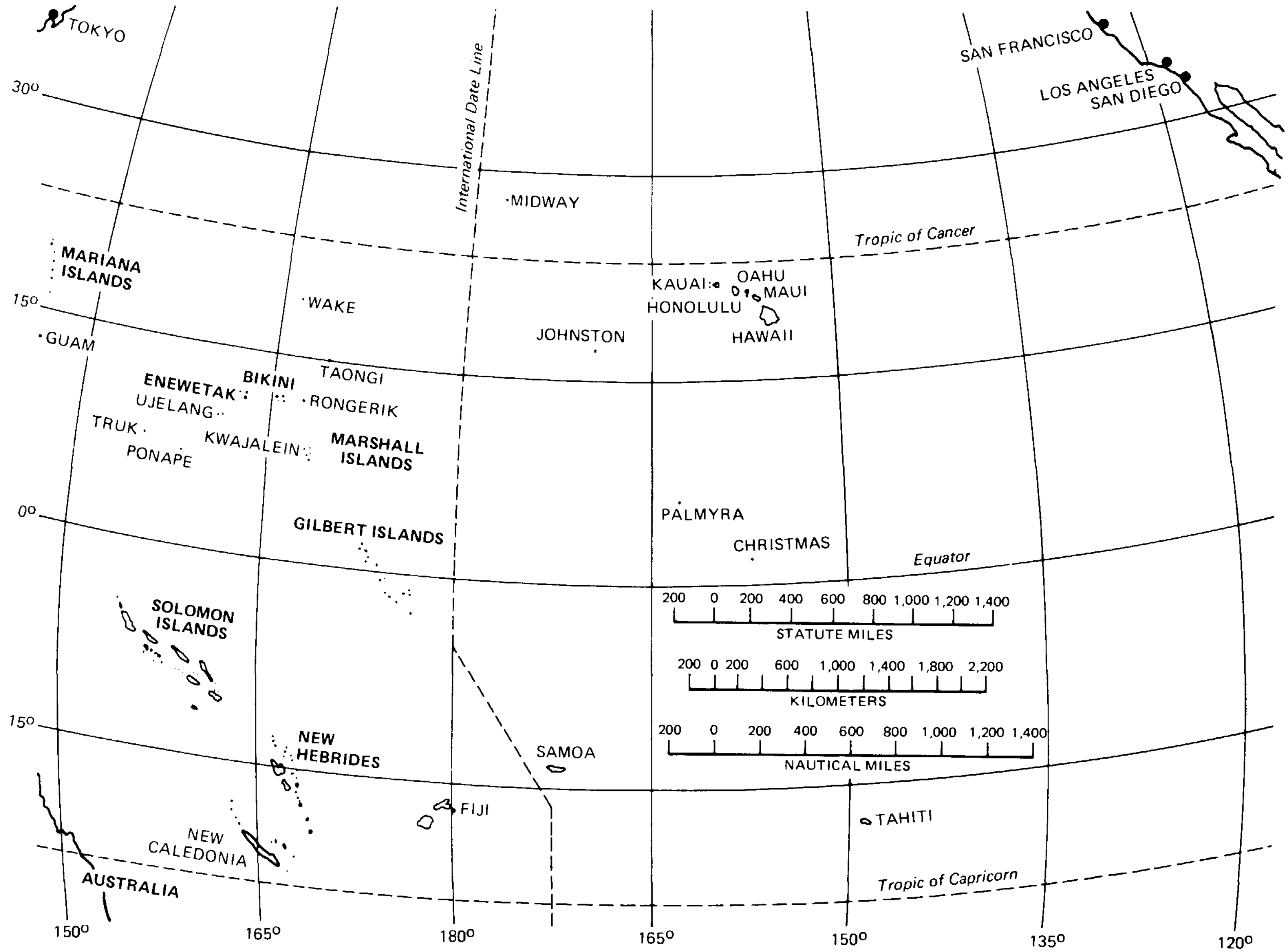


Figure 2. The Central Pacific.

Enewetak, as a precaution against fallout exposure. East of Enewetak are several atolls including Bikini, Rongelap, Rongerik, Ailinginae, and Utirik. Rongelap, the nearest inhabited atoll in this direction, is a little over 260 nmi (480 km) from Enewetak.

The climate of Enewetak 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. Storms are infrequent, although typhoons sometimes occur. Although possible at any time, most tropical storms occur from September to December. Both wind and sea are continuous erosional agents.

Much cumulus cloud cover exists in the Enewetak region, which incorporates three basic wind systems. The northeast trade winds extend from the surface to 25,000 to 30,000 feet (7.6 to 9.1 km), the upper westerlies from the top of the trades to the base of the tropopause at 55,000 to 60,000 feet (16.8 to 18.3 km), and the Krakatoa easterlies from the tropopause 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.

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. Lagoon waters moving in this closed loop also mix with those of the open ocean, resulting in a flushing action. The flushing is rapid and has two major routes. The first is directly through the eastern reefs to the western reefs; the second is through Deep Entrance between Japtan and Parry and out Wide Entrance west of Enewetak. These two routes keep the water of the northern part of the lagoon separate from the southern waters.

On 2 December 1947, the United States closed Enewetak in order to test nuclear weapons there. The land area of Enewetak Atoll, its 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 (Reference 4, p. 23).

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

PHYSICAL CONDITIONS BEFORE GREENHOUSE. Enewetak had been the site of nuclear testing in 1948: the islands in the southeast quadrant served as the base for the task force, and the islands from north through east-northeast were used for the tests themselves. The principal base islands were Enewetak, which bordered Wide Entrance, and Japtan and Parry, northeast of Enewetak, which bordered Deep Entrance.

Facilities and structures on the islands were primarily from World War II, and most were in very poor condition in 1948. Many of the islands had short stub piers that were in poor repair. There was no deep water pier. There were six airstrips, of which only the airstrip at Enewetak was in serviceable condition. It was 6,400 feet (2 km) long and paved with crushed coral. There was underwater communications cable to several islands that was in good shape (Reference 4, pp. 5 through 7).

In late 1948 H&N was charged with the complete rehabilitation of the operational islands at Enewetak Atoll. The first half of 1949 was needed for surveys, planning, preparing drawings, and obtaining necessary approvals from the AEC. By the time the construction program was completed in July 1951, the cost had reached $25 million. Construction included barracks for 708 men on Parry and for 600 on Enewetak, mess halls, laboratories, medical areas, theaters, barber shops, chapels, experimental structures, and many other facilities to support a semipermanent workforce. All construction on Enewetak Island was done by the Army's 79th Engineer Construction Battalion, and H&N worked on Parry and the shot islands. The runway at Enewetak was lengthened to 7,000 feet (2.1 km) and paved. More taxiways and parking areas were added. Three piers were built, including a deepwater pier at Parry Island. Utilities were completely refurbished, including sewers, saltwater and freshwater systems, telephones, and electric power (Reference 1, p. 117; Reference 4, p. 16).

The islands in the northeastern section of the atoll had been denuded of most vegetation during World War II and in 1949 after the SANDSTONE shots, when extensive grading was done to reduce radioactivity. Japtan, just north of Parry, had escaped this action and still had a good stand of coconut trees and other vegetation. The islands in the northwestern section still bore the lower-growing native trees. Figure 3 shows Dridrilbwij and Bokaidrikdrik mainly covered with native plants. Figure 4 shows the coconut palms on Japtan, and Figure 5 shows Parry Island.

A causeway had been built between Aomon and Bijire islands during SANDSTONE. In preparation for GREENHOUSE, another was built between Eleleron and Aomon. Temporary camps were constructed on three islands in the shot area in preparation for GREENHOUSE. A tent camp capable of billeting 610 was constructed on Enjebi. Similar camps for 320 men on Bijire and 240 on Runit were also constructed and used during GREENHOUSE (Reference 4, p. 15).

RADIOLOGICAL CONDITIONS BEFORE GREENHOUSE. The SANDSTONE shots on Enjebi, Aomon, and Runit were detonated on 200-foot (61-meter) towers and contaminated the island surfaces because of the relatively low heights of their bursts. In July 1948, 2 months after SANDSTONE, a radiobiology team from the Applied Fisheries Laboratory, University of Washington, visited Enewetak to examine effects on plant and animal life and returned in August 1949 to further study these effects. The Korean War forced cancellation of a planned trip in 1950. Results indicated that radioactivity was passed up the food chain among fish in the lagoon and that some plant life was destroyed or stunted by radioactivity near the detonations. Radioactivity persisted in plants, particularly in older, dead tissue (Reference 1, p. 105).

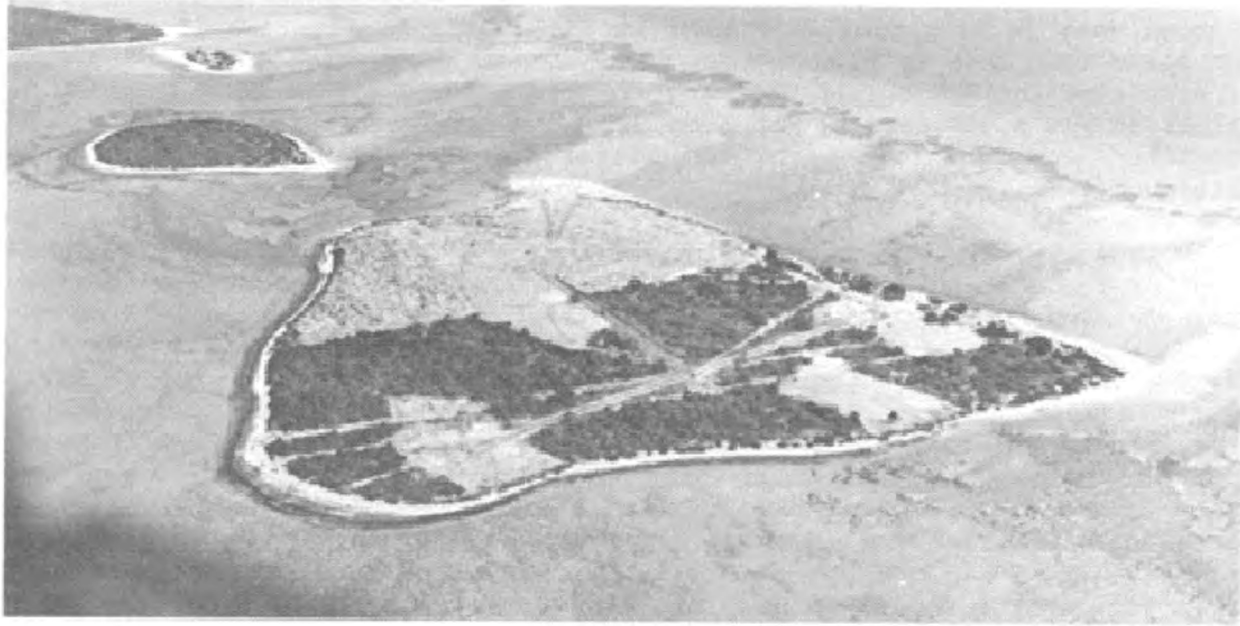


Figure 3. Aerial view of Dridrilbwij and Bokaidrikdrik islands, 1951.

Figure 4. Coconut stands on Japtan Island, 1951.

Figure 5. Parry Island buildings, 1951.

In February 1949, the AEC sent a survey and decontamination team to Enewetak under the command of an Army officer who later headed the Radsafe Unit during GREENHOUSE. Enjebi was surveyed in detail, while Aomon, Bijire, Runit, and Lojwa were surveyed in general. Radioactivity was found in most locations; however, the three crater areas on Enjebi, Aomon, and Runit were the most radioactive.

Cleanup was begun in March 1949, and all persons working on radioactive islands wore dosimetry badges. Radioactive metal was gathered up and dumped at sea. The top 4 to 6 inches (10 to 15 cm) of soil in radioactive areas was bulldozed into the three shot craters and covered with uncontaminated live coral scooped from the lagoon. This covering was 1 foot (0.3 meter) thick to a radius of 1,000 feet (305 meters) and 6 inches (15 cm) thick from 1,000 to 1,500 feet (305 to 457 meters). No radiological cleanup work was considered necessary for Parry, Enewetak, or Ananij. Because of the possibility of inhaling dust containing radioactive material, a sprinkling system to wet down the unstabilized soil was considered. Later research indicated that this system was unncessary. It was, nevertheless, purchased and used. By 22 November 1949, the shot islands had been regraded to the point that no radiological problem existed on most of them.

A survey in March 1950 showed that Lojwa had no radioactivity and Enjebi and Aomon were down to 0.001 R/hr maximum, whereas Eleleron showed readings as high as 0.002 to 0.004 R/hr and Runit averaged 0.0015 R/hr. SANDSTONE shot

ZEBRA tower footings on Runit measured between 0.005 and 0.0012 R/hr, and work there was limited to 25 hours per week per worker. A final survey from 5 to 11 May 1950, after cleanup was complete, showed no possibility of overexposure to gamma radiation anywhere on the atoll (Reference 5, p. 42). Use of dosimetry badges and other radsafe procedures was discontinued on 11 May 1950.

Special Problems in Testing in the Marshalls

The remoteness of the Enewetak location posed significant logistic problems for GREENHOUSE, especially considering the major construction program undertaken to prepare for GREENHOUSE. The remoteness also required special security arrangements in transporting the nuclear devices from laboratories in the United States to the test area. The radioactive cloud samples required expeditious transport by the Military Air Transport Service (MATS) to several U.S. laboratories for analysis.

The limited land area at Enewetak Atoll was also a problem. The three inhabited islands at the southern end -- Enewetak, Parry, and Japtan -- were overcrowded during testing. For example, for shot GEORGE over 3,000 personnel were on Enewetak and over 1,000 on Parry. In addition, 700 men who were evacuated from the tent camps on the northern islands had to be billeted aboard several ships (Reference 5, p. 89).

The lack of a land bridge to the northern islands required a major effort to transport men and material to the test islands. Navy landing craft were used extensively for this task. Three temporary tent camps were built on the northern islands to minimize the commuting time. Figure 6 shows the camp at Enjebi.

There were also some advantages, however, in testing at Enewetak besides the large open ocean area. The 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, and the task force devised a color-coded security badge system to show access authorization to the several islands.

JOINT TASK FORCE THREE

JTF 3 was formally established by the Joint Chiefs of Staff (JCS) on 23 June 1949, and was organized similarly to the earlier JTF 7 organization used for SANDSTONE. It incorporated 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 3 (CJTF 3) as its representative. CJTF 3 was also subordinate to JCS and reported to the Chief of Staff of the U.S. Air Force who was the JCS executive agent for the series. These relationships are illustrated in Figure 7.

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 conducted in the Pacific Proving

Figure 6. Enjebi camp, GREENHOUSE.

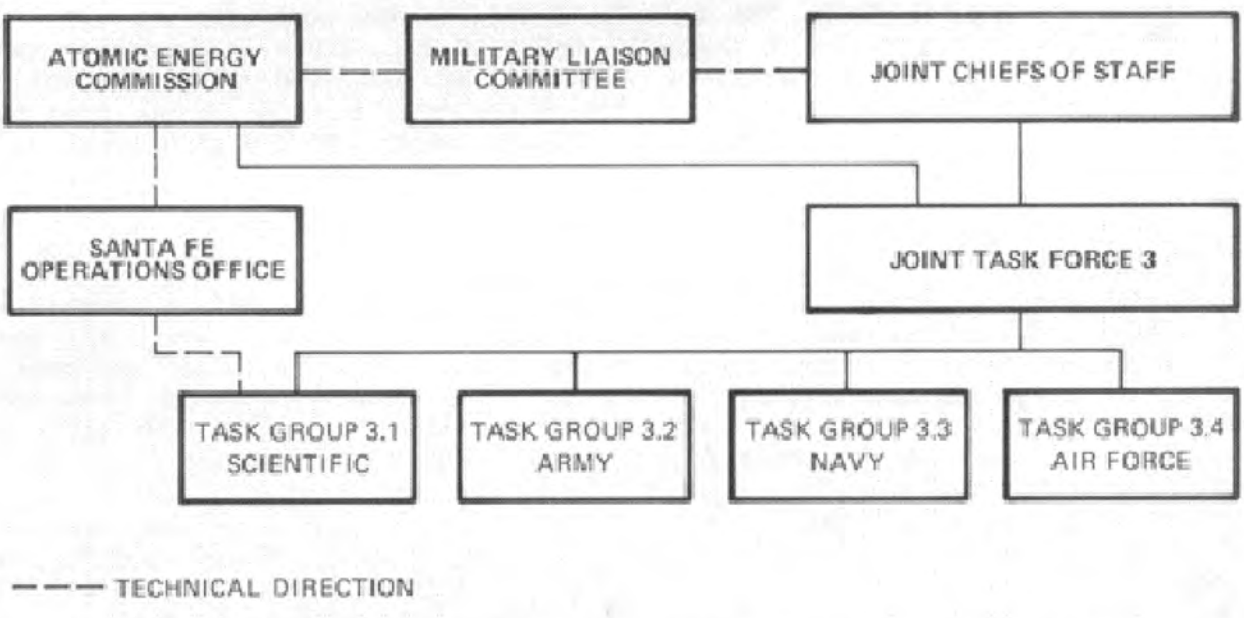


Figure 7. Organization of Joint Task Force 3, GREENHOUSE.

Ground in an area that came under the jurisdiction of the AEC. Further, the test area was remote from the United States and the special supply and security arrangements required military operations. Finally, the organization for which the weapons were being developed was the Department of Defense.

The joint task force was divided into functional and service-branch oriented task groups. The JTF 3 Scientific Deputy actually directed the testing and CJTF 3 managed the overall program. TG 3.1, directed by a civilian scientist from LASL, conducted all the experimental programs and managed the facilities contractor for the test area. TG 3.2, commanded by an Army brigadier general, provided military security for the test area and logistic support to Air Force units. TG 3.3, commanded by a Navy flag officer, provided off-shore air patrols and general logistic support, surface defense, local water transport for men and equipment, and floating fuel storage. TG 3.4, commanded by an Air Force major general, provided air weather reconnaissance, search and rescue (SAR), air taxi service, aircraft flight control, and air defense. This task group also operated the drone aircraft used for cloud sampling and measurement of blast effects.

During GREENHOUSE the Army provided 1,615 personnel, the Navy 2,951, the Air Force 2,604, and the Marine Corps 134. There were also 2,049 civilians from DOD, LASL, and various contractor organizations. Not included in these totals is the Army's 79th Engineer Construction Battalion, which was employed in construction work on Enewetak Atoll in preparation for GREENHOUSE but was transferred from the area before the test period (Reference 6, p. 1). A total of six ships and one hundred ten small boats, mostly landing craft and DUKWs, participated in GREENHOUSE. The Air Force provided 103 aircraft and the Navy 10 to support GREENHOUSE operations (Reference 6, p. 3).

Commander JTF 3 had three principal deputies, one of whom was also the civilian scientist in charge of TG 3.1. The joint staff was patterned after other military organizations. The Radsafe Advisor to the commander was also in charge of Task Unit (TU) 3.1.5 (Radsafe) under TG 3.1. JTF 3 Headquarters was located on Parry Island and assigned personnel were billeted there. Evidently the staff had some duties on Enewetak Island as well, because 60 men from Hq JTF 3 were there for shot GEORGE. Total strength of Hq JTF 3 during April and May was 320 (Reference 5, p. 89).

Task Group 3.1 (Scientific)

TG 3.1 was the heart of the task force. It was responsible for preparing and firing the four nuclear devices, preparing and conducting almost all the various experimental programs, executing the entire radsafe program, and operating and maintaining all atoll base facilities except those on Enewetak Island, which were managed by TG 3.2 (Army) (Reference 7, p. B1). TG 3.1 was formed at LASL and most of its key people, including its commander, were from LASL's newly formed J-Division. Figure 8 shows the organization of TG 3.1. Descriptions of its seven subordinate task units follow. Personnel strength of TG 3.1 in the test area, not including H&N employees, increased from 99 on 1 February 1951 to 521 on 1 March, and to 871 on 1 April, decreasing to 817 on 1 May, 67 on 1 June, and 2 on 1 July 1951. H&N employees made up the bulk of TU 3.1.7.

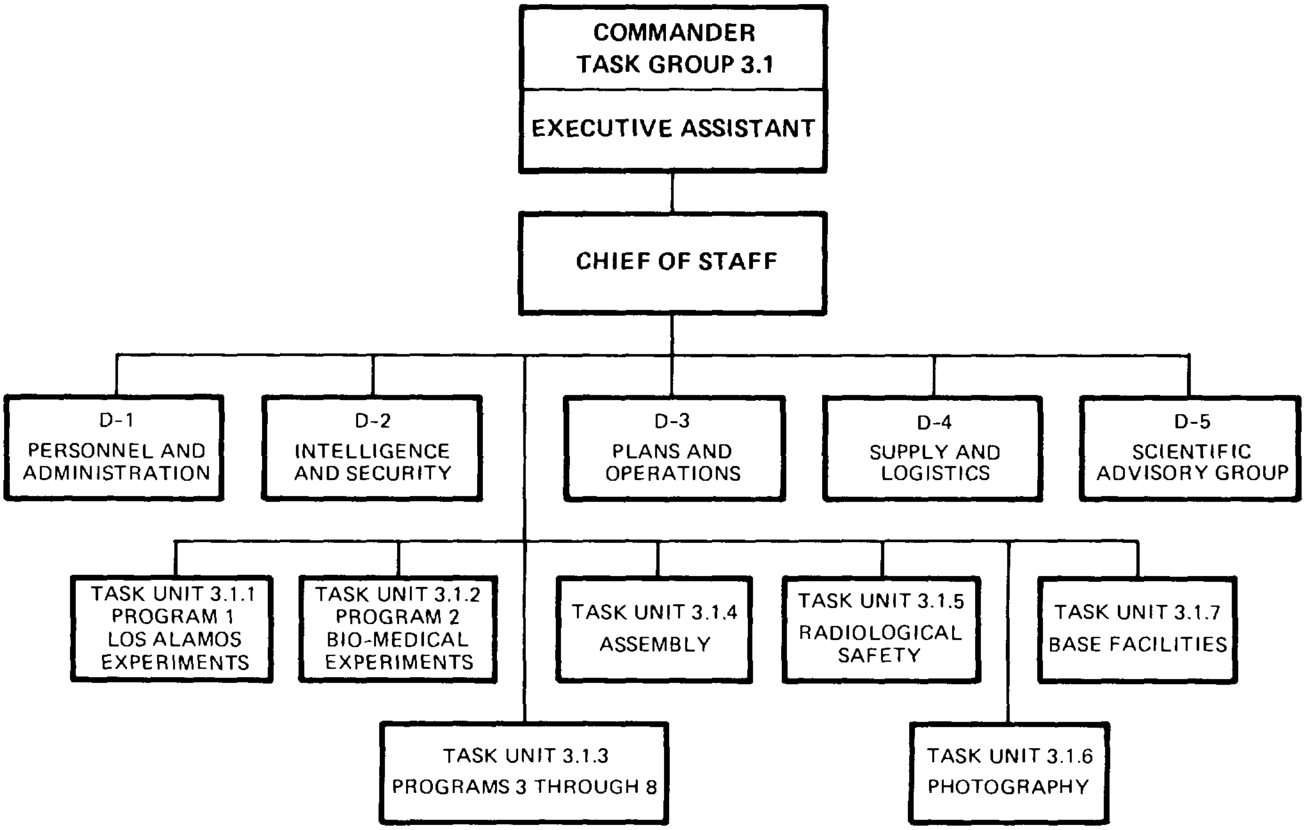


Figure 8. Organization of Task Group 3.1, GREENHOUSE.

TASK UNIT 3.1.1 -- LOS ALAMOS EXPERIMENTS. This task unit was responsible for all Program 1 experiments, the diagnostic experiments associated with the four nuclear devices. Most of its personnel were from LASL. On 2 February 1951, 335 men in the test area were in TU 3.1.1 (Reference 8).

TASK UNIT 3.1.2 -- BIOMEDICAL EXPERIMENTS. This task unit was responsible for Program 2 experiments, which encompassed the entire biomedical program of 18 separate projects. There were 100 men in TU 3.1.2; 23 of them civilians and 77 military personnel. The majority of the Navy personnel were assigned to BuMed Unit One. This unit was formed specifically for the GREENHOUSE operation by the Navy Bureau of Medicine and Surgery. Tests were conducted on dogs, pigs, mice, corn seed, and mold. The animals were kept and Program 2 personnel were billeted on Japtan Island (Reference 8; Reference 9, p. 88; Reference 10, p. 6). Facilities on Japtan consisted of a laboratory, a shop, living quarters for scientific and custodial personnel, a mess hall, storage bunkers, and pens and cages for dogs, pigs, and mice. The maximum number of personnel on the island was 145 in mid-April including 52 from BuMed Unit One in TU 3.1.2, 47 others in TU 3.1.2, 18 H&N employees, 13 military police, 7 monitors from the Radsafe Unit, 5 consultants or observers, and 3 men from TU 3.1.4 (Reference 11, pp. 1 through 9).

TASK UNIT 3.1.3 -- PROGRAMS 3 THROUGH 8. This task unit was responsible for a wide variety of service-oriented experiments. Altogether 327 men worked on the five various programs in TU 3.1.3 (Reference 12 p. 17; Reference 8).

Program 3 experiments tested nuclear effects on structures. Participants were the Army Corps of Engineers, Navy Bureau of Yards and Docks, the Air Force, and the Public Building Service, an element of the General Services Administration. Sandia Corporation measured pressure, acceleration, and displacement on the various structures. H&N built the structures.

Program 4 experiments investigated nuclear cloud physics. Air Force aircraft carried out these experiments.

Program 5 experiments tested the effectiveness of new airborne and ground-based radiac equipment. Airborne testing was done with two aircraft, a P2V and a B-17, equipped with a variety of proven and new radiac instruments.

Program 6 experiments were physical tests requiring a variety of measurements, including cloud sampling, thermal radiation, fallout pattern, testing of decontamination equipment, and testing of protective clothing. Equipment such as tanks was also tested.

Although not formally a part of TG 3.1, Program 7 experiments were monitored by TG 3.1. Program 7 experiments were conducted by Hq USAF, whose personnel were in TG 3.4. These experiments included air conductivity measurements (Project 7.4) and cloud sampling (Project 7.8). Project 7.4 used two L-13s and two B-50As, and Project 7.8 used several aircraft, including the B-17 drones, B-50As and B-50Ds, and WB-29s. Another project in Program 7 was the Long Distance Measurement of Energy Yield of an Atomic Explosion, which used a C-54 aircraft from the 54th Weather Reconnaissance Squadron on Guam. This project took measurements in the Guam area only (Reference 13; Reference 14, p. 15).

Program 8 experiments measured nuclear effects on specially instrumented aircraft. Altogether, 327 personnel worked on the six projects in TU 3.1.3.

TASK UNIT 3.1.4 -- ASSEMBLY. This task unit was reponsible for preparing, emplacing, and firing the nuclear devices. Fifty-five men were in this task unit (Reference 43).

TASK UNIT 3.1.5 -- RADIOLOGICAL SAFETY. Radiological safety was a command responsibility for each of the task groups, but this task unit was responsible for providing technical assistance to CJTF 3 in radsafe matters. TU 3.1.5 provided radsafe monitors to conduct radiation surveys of islands, to accompany reentry teams, to monitor sample removal from aircraft, and to perform a variety of other monitoring. TU 3.1.5 also was responsible for procuring all film badges, developing and interpreting exposed film badges, and keeping updated exposure records for all badged individuals (Reference 7, p. H2). As of 2 February 1951, 77 men were in this unit (Reference 8).

TASK UNIT 3.1.6 -- PHOTOGRAPHY. This task unit was formed from LASL employees, averaging about 15 people in the test area. TU 3.1.6 had four primary responsibilities:

- Taking documentary photographs for scientific units
- Storing and providing security control for sensitized material used during tests (spectroscopic plates, recording paper, etc., as well as film used in still photos)
- Staffing darkrooms, when needed, to process scientific photographic records, and supplying chemicals, solutions, and aid to those who wished to process their own records
- Providing file prints during the operation and finished report prints after the operation.

The unit took over 11,000 photographs, 3,500 before the tests began and 7,500 during the tests. The emphasis was on supporting Programs 2 through 8 (Reference 15, pp. 87 and 88). Evidently its mission had little overlap in the test area with that of the Air Force photography unit from the Air Force Lookout Mountain Laboratory (TU 3.4.8).

TASK UNIT 3.1.7 -- BASE FACILITIES. The facilities on all islands of Enewetak Atoll except Enewetak Island were managed by H&N. H&N personnel operated the electrical systems, water systems, sewage systems, telephone systems, and various others.

Task Group 3.2 (Army)

Most Army personnel in JTF 3 were assigned to TG 3.2. TG 3.2 was the first task group activated by CJTF 3 when General Order #1 was promulgated on 12 January 1950. Composed entirely of service units, the first components of TG 3.2 arrived at Enewetak Atoll on 16 March 1950. Table 2 lists units involved and

Table 2. Organizations in Task Group 3.2, March 1950, GREENHOUSE.

Unit	Officers	Enlisted Men
Hq and Hq Company 7th Engineering Brigade	41	154
79th Engineering Construction Battalion	29	693
QM Detachment #6, 6135th TSU	4	101
70th Auto Maintenance Ordnance Detachment	1	28
9470th TSU Signal Detachment	2	13
3rd Mobile Surgical Hospital	4	22
Hq 18th Transportation Battalion	2	8
511th Transportation Port Company	4	204
Finance Detachment	2	5
Totals	89	1,228

Source: Reference 3, p. 143.

enumerates the men at Enewetak in March 1950. The task group was a self-sufficient base development organization engaged in construction and operation of base facilities at Enewetak Island and the atoll. The onset of the Korean War in June 1950 had a large impact upon composition and manning levels of TG 7.2. Significant unit and personnel changes occurred before the first GREENHOUSE detonation in April 1951.

During the operational shot phase, TG 3.2 personnel provided the following services:

- Operation of transient billets
- Maintenance and supervision of all officer quarters and mess
- Repair and maintenance services for utilities and facilities
- Bakery and mess support
- Heavy field maintenance for ordnance wheeled vehicles
- Operation and maintenance of off-island radio communications
- Medical and dental services
- Operation of the port and port headquarters
- Financial services
- Special services (recreation) facilities
- Counterintelligence
- Atoll ground defense and general security
- Emergency ground transportation.

In addition, some TG 3.2 personnel participated in the operational phase in support of scientific projects of Army interest. Figure 9 illustrates the TG 3.2 organization.

Task Group 3.3 (Navy)

The Navy task group supported scientific programs at Enewetak Atoll and carried out surface and air operations in and around the atoll.

The main tasks of TG 3.3 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
- Establish Air Force special project and weather stations at outlying atolls
- Conduct radiological surveys of inhabited islands

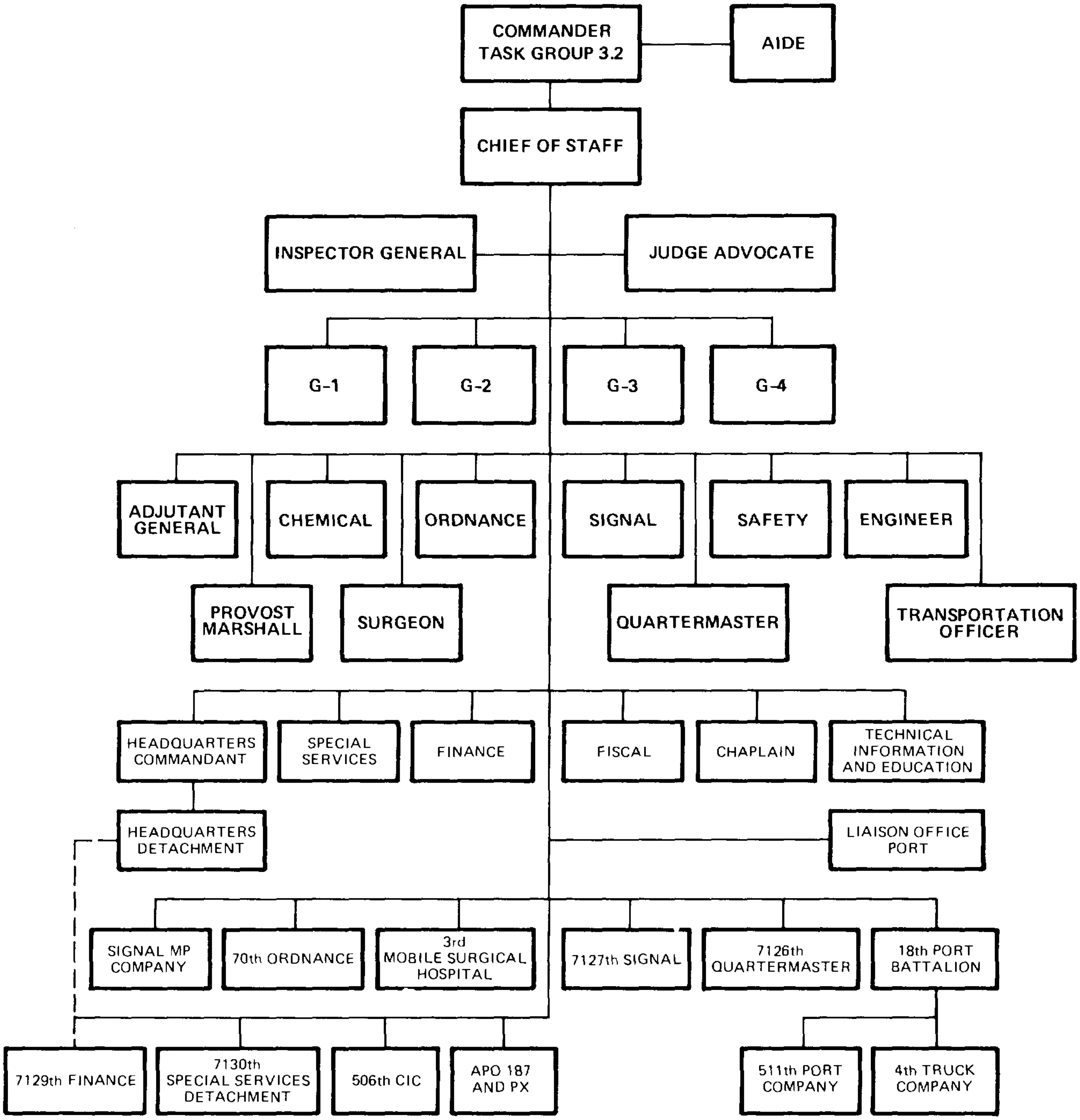
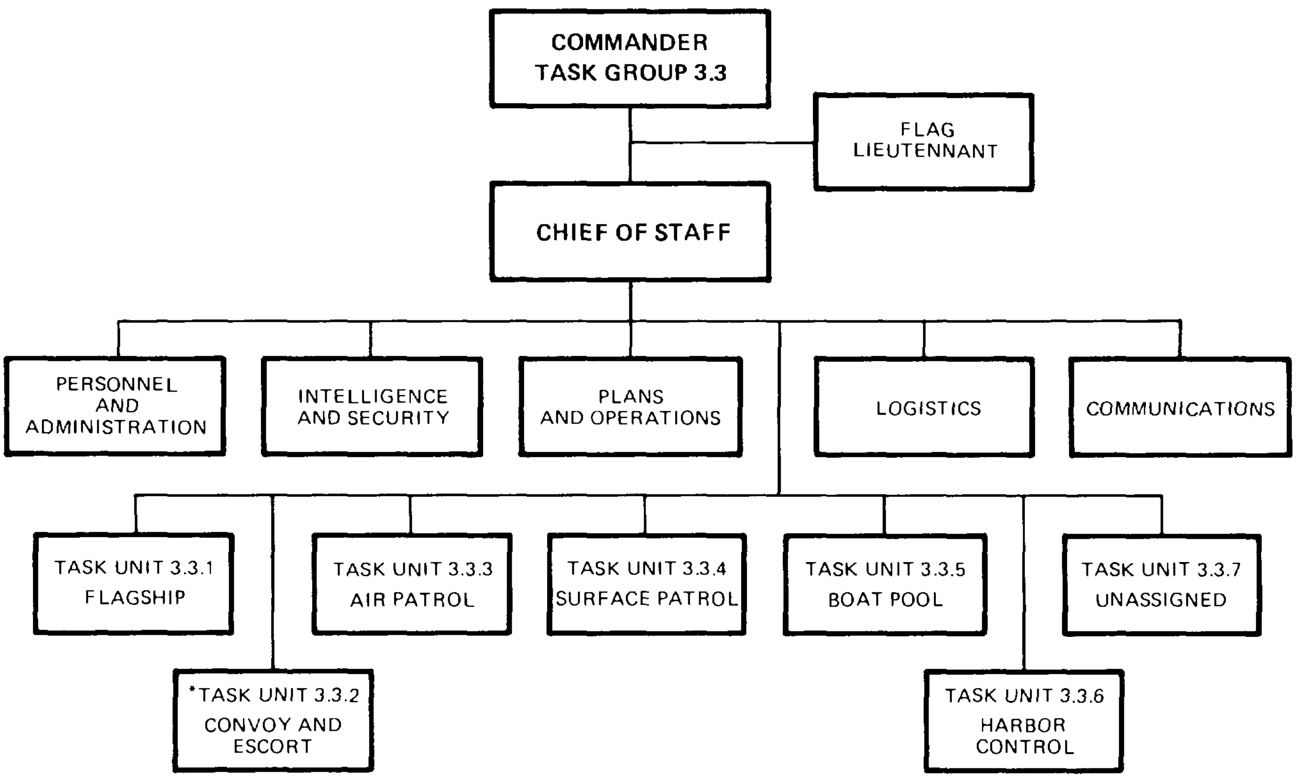


Figure 9. Task Group 3.2 organization, GREENHOUSE.

- Provide interatoll 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.

TG 3.3 was organized into functional task units as shown in Figure 10. These task units with their names, forces assigned, and functions are listed in Table 3.

Most of the naval vessels stayed at Enewetak during the test series except for the two destroyers, which constantly patrolled the area. The flagship, USS Curtiss (AV-4), was anchored off Parry Island during all the shots. USS Cabildo (LSD-16) was the mother ship for the boat pool, which provided water transportation for all task units during GREENHOUSE. Living accommodations were provided by the Military Sea Transportation Service (MSTS) troop transport, USNS Sgt. Charles E. Mower (T-AP-186). USS LST-859 supplied all outlying stations and, when at Enewetak Atoll, housed TG 3.1 personnel. Security was reinforced by the Harbor Control Unit, which monitored the entrances to the atoll lagoon. Most TG 3.3 personnel remained on board ships except for naval personnel involved in the scientific operations and recreation parties. Table 4 lists task group strength figures for three different weeks during the operation.



*OPERATIONAL ONLY DURING MOVEMENT TO AND FROM ENEWETAK

Figure 10. Organization of Task Group 3.3, GREENHOUSE.

Table 3. Functions and complements of Task Group 3.3, GREENHOUSE.

Task Element/Unit		Ship Name or Unit	Reported Strength[a]			Functions
Number	Name		Officers	Enlisted Men	Civilians	
3.3.1	Flagship	USS Curtiss (AV-4)	40	612		Transported nuclear components to Enewetak Atoll. Headquarters for TG 3.3. Provided weapon assembly facilities.
	Staff CTG 3.3		15	44		
3.3.2	Convoy & Escort	USS Curtiss (AV-4) USS Sproston (DDE-577) USS Walker (DDE-517)	See TU 3.3.1 16 17	 264 285		While en route to and from Enewetak Atoll, Curtiss was escorted by Sproston and Walker. This unit activated only during movement to and from Enewetak Atoll.
3.3.3	Air Patrol Squadron	VP-931 5 P2V-2 4 P2V-3W 1 PBM-5A	52	336	1	Provided air search and antisubmarine capability with 5 P2V-2s and 4 P2V-3Ws. The PBM-5A collected water samples for the Radsafe Unit.
3.3.4	Surface Patrol	USS Sproston (DDE-577) USS Walker (DDE-517)	See TU 3.3.2 See TU 3.3.2			Provided surface search and antisubmarine surveillance capability.
3.3.5	Mobile Boat Pool	USS Cabildo (LSD-16)	23	517		Mother ship for boat pool. Provided water transportation, controlled all boat movements, maintained of boats.
		30 LCMs, 8 LCPs, 3 LCVPs, 3 LSUs, 3 launches, 3 AVRs, 8 DUKWs				Ship-to-shore transport of personnel, equipment, vehicles, and weapons. Evacuation of personnel from islands. Search and rescue operations within the atoll. Security sweeps of islands.
3.3.6	Harbor Control	No ships	2	57		Harbor entrance control.
3.3.7	Unassigned Unit	USNS Sgt C.E. Mower (T-AP-186)	4	12	178	Hotel ship for TG 3.1 personnel.
		USS LST-859	5	65		Established Air Force and Weather Stations at outlying atolls, supplied these stations during test series. Hotel ship, transport for scientific personnel.

Note:

[a]Sources: References 16 and 17.

Table 4. Task Group 3.3 strength, GREENHOUSE.

	Enewetak			Kwajalein			
Date	Officers	Enlisted	Civilians	Officers	Enlisted	Civilians	Total
6 Apr 51	123	1,853	177	52	339	1	2,545
20 Apr 51	122	1,856	178	52	336	1	2,545
4 May 51	121	1,833	177	52	333	1	2,517

Source: Reference 17.

Task Group 3.4 (Air Force)

The Air Force task group mission for GREENHOUSE was to provide local air transport, atomic cloud sampling, weather data, air operations control, search and rescue, and photographic support. Specific missions were to (Reference 7, pp. 1 through 9):

- Operate an airbase at Enewetak
- Provide and operate aircraft to conduct experimental programs and cloud sampling, long-range detection, and airborne structural blast tests
- Provide and operate aircraft to provide weather data and detect and track the atomic cloud
- Provide and operate decontamination facilities for TG 3.4 aircraft and personnel at Enewetak and Kwajalein
- Provide and operate weather observation posts at Kusaie, Nauru, Bikati, and Majuro
- Provide and operate JTF 3 Weather Central at Enewetak
- 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 documentary motion picture and still photographic coverage of Operation GREENHOUSE.

To implement these functions TG 3.4 was organized as shown in Figure 11 (Reference 9, p. 4). Headquarters, U.S. Air Force, tasked its major commands to provide men and equipment to staff TG 3.4. Figure 12 shows the parent commands of the different elements of TG 3.4 (Reference 9, p. 3). Personnel strength of TG 3.4 on site increased from 637 on 31 January 1951 to a high of 2,409 on 12 April 1951, slowly decreasing to 1,854 on 24 May 1951, the date of the last shot (Reference 3, p. 114; Reference 18, p. 3; Reference 19, p. 3). Table 5 shows TG 3.4 personnel distribution by task unit (Reference 20, p. 69).

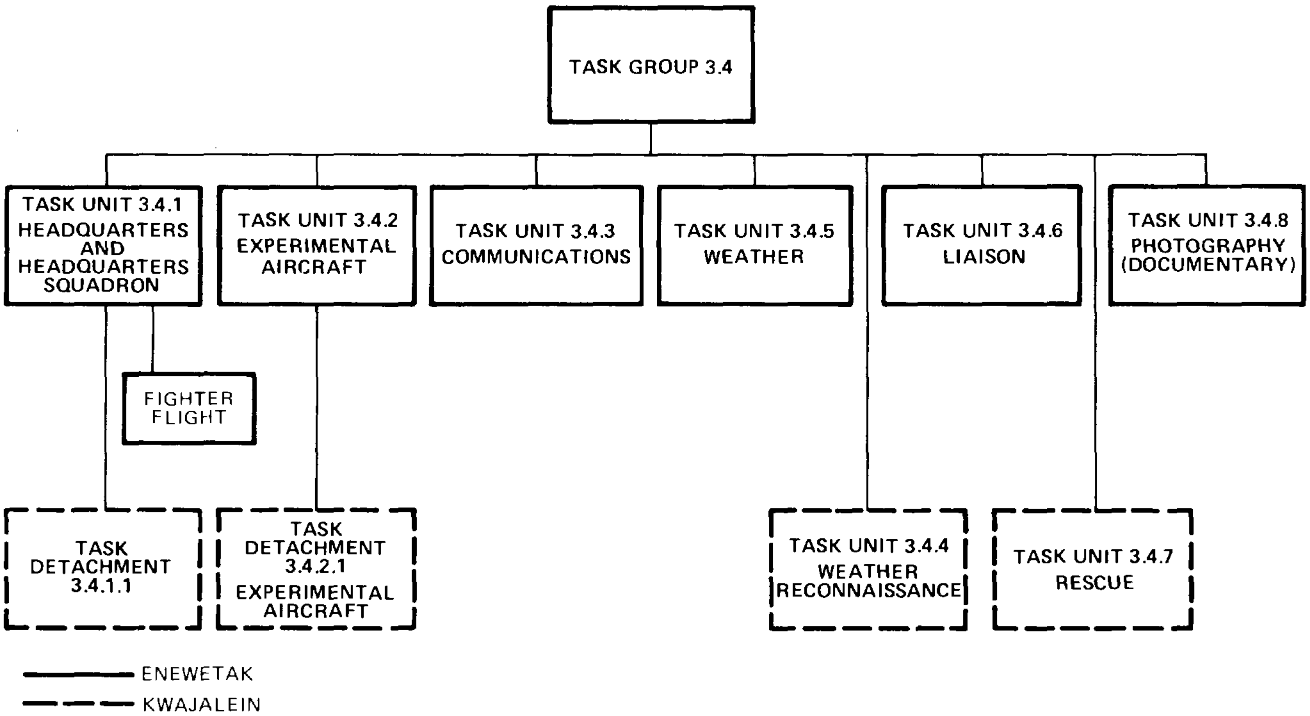


Figure 11. Organization of Task Group 3.4, GREENHOUSE.

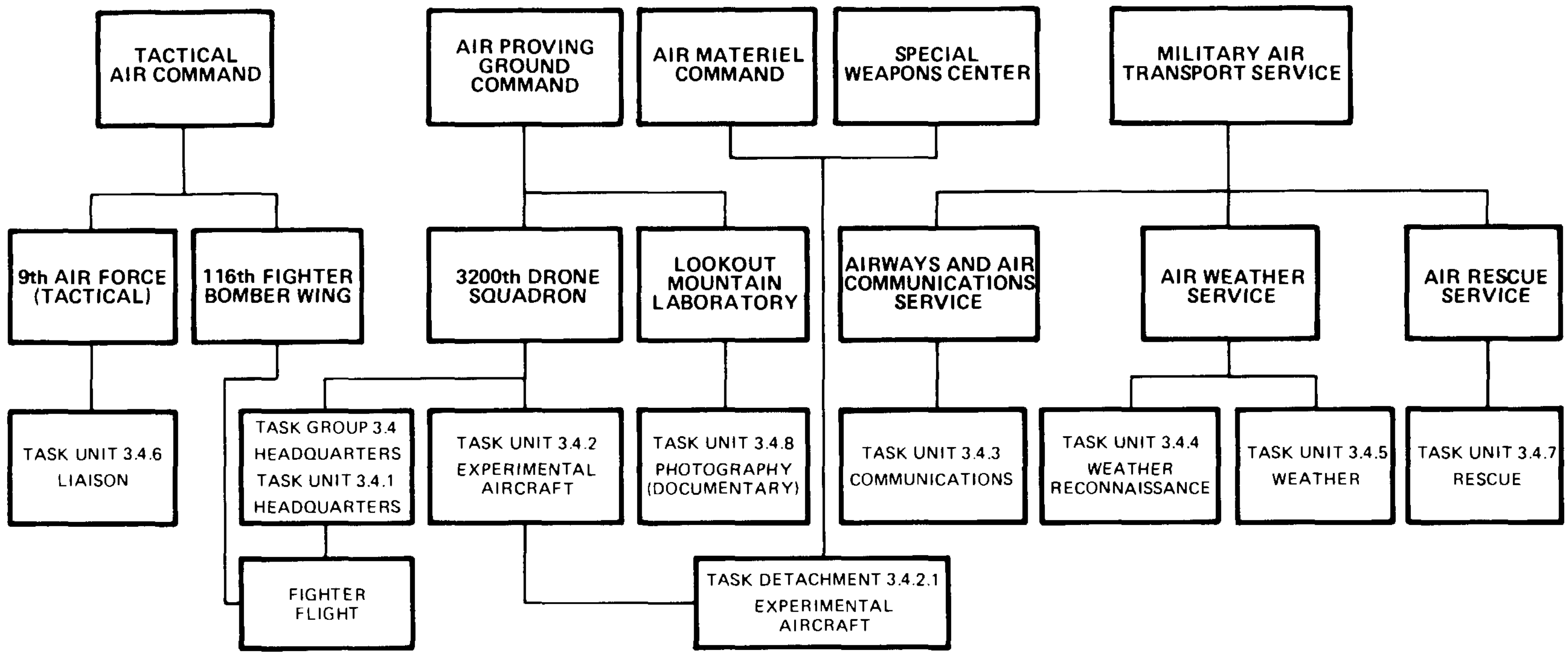


Figure 12. Parent commands of Task Group 3.4 task units, GREENHOUSE.

Table 5. Personnel distribution Task Group 3.4, GREENHOUSE.

Unit	Parent Command[a]	Officers	Airmen	Civilians	Totals
TU 3.4.1	APG	94	798	0	892
TU 3.4.2	APG	137	512	0	649
TD 3.4.2.1	AMC	18	27	53	98
TU 3.4.3	MATS	4	135	0	139
TU 3.4.4	MATS	69	254	0	323
TU 3.4.5	MATS	20	99	0	119
TU 3.4.6	TAC	30	77	0	107
TU 3.4.7	MATS	15	37	0	52
TU 3.4.8	APG	9	3	18	30
Total	396	1,942	71	2,409	

Note:

[a]AMC -- Air Materiel Command; APG -- Air Proving Ground; MATS -- Military Air Transport Service; TAC -- Tactical Air Command.

Source: Reference 20, p. 69.

Providing and operating aircraft in support of GREENHOUSE was the primary function of TG 3.4. Table 6 shows the types and numbers of aircraft used within TG 3.4 and their functions. Chapter 7 discusses the units that supplied personnel to each of the eight task units in TG 3.4. The F-80C interceptors were added at the last minute to provide air defense of Enewetak.

TASK UNIT 3.4.1 -- HEADQUARTERS AND HEADQUARTERS SQUADRON. Stationed on Enewetak Island with a maximum strength of 660 men during GREENHOUSE (Reference 20, p. 69), TU 3.4.1 operated the airbase at Enewetak Island and maintained and supplied all aircraft located on Enewetak. Personnel from TU 3.4.1 assisted TU 3.4.2 in aircraft decontamination operations. The flight of six F-80C interceptors was a late addition to TU 3.4.1. TU 3.4.1 established a detachment on Kwajalein (Task Detachment [TD] 3.4.1.1) consisting of 232 personnel who maintained and supplied aircraft for task force elements on that island (Reference 7, p. 3; Reference 27, p. 40).

TASK UNIT 3.4.2 -- EXPERIMENTAL AIRCRAFT. This task unit, comprised of personnel from the 3200th Drone Squadron, Eglin AFB, Florida, was stationed on Enewetak Island and had a maximum strength of 649. TU 3.4.2 operated the B-17 and T-33 drones and B-17 and T-33 controller aircraft. The B-17 drones were used in cloud sampling, and both types of aircraft were used in effects testing. TU 3.4.2 also operated aircraft and personnel decontamination facilities on Enewetak Island for TG 3.4 personnel and equipment, and two aircraft, a B-17

Table 6. GREENHOUSE aircraft.

Type Aircraft	Mission	Task Unit	Tail and Identification Numbers
SA-16	Search and rescue	3.4.7	9087, 9091
SB-17G	Search and rescue	3.4.7	83754, 83791
P2V	Radiac	3.4.2	368
B-17	Radiac	3.4.2	246
DB-17G	Manned controllers for QB-17 drones	3.4.2	514, 525, 542, 559, 636, 654, 657, 680, 683, 684, 687, 689, 690, 694, 715
QB-17G[a]	Cloud sampling and effects testing (unmanned)	3.4.2	537, 549, 565, 566, 617, 644, 649, 652, 656, 658, 666, 669, 674, 679, 692, 697, 738, (remaining one tail number is unknown)
WB-29	Weather and sampling	3.4.4	44-27300, 44-27343, 44-27335, 44-27269, 44-87740, 44-62202, 44-85399, 44-86399, 44-62220, 45-21816, 45-21819, 45-21872
RB-29[b]	Film fogging test	3.4.2	1762
XB-47	Blast effects	3.4.2	46-066
B-50A	Tracking/sampling	3.4.2	46-017, 46-023
B-50D	Blast effects	3.4.2	49-290, 49-340
C-47	Photography	3.4.1	408 (remaining four tail numbers are unknown)
C-54	Photography	3.4.1	082
DT-33A	Manned controllers for QT-33 drones	3.4.2	920, 930, 950, 951, 959
QT-33A[c]	Effects testing, unmanned drones	3.4.2	927, 928, 929, 939, 940
L-5	Liaison	3.4.6	7 light planes
L-13	Liaison	3.4.6	15 light planes
H-5	Liaison	3.4.6	4 helicopters
F-80C	Interceptors	3.4.1	6 jet fighters
P2V	Ocean surveillance	3.3.3	9 Navy patrol planes
PBM	Radsafe water sampling	3.3.3	1 Navy amphibious patrol plane

Notes:

[a] QB-17G #666 lost on ITEM shot.

[b] RB-29 (SAC) arrived in the test area shortly before shot GEORGE and departed two days after participating in GEORGE.

[c] QT-33A #928 lost on DOG shot and QT-33A #929 and #940 lost on EASY shot.

Sources: Reference 21, p. 75; Reference 22, p. 17; Reference 23, 16; Reference 24, p. 37; Reference 25, p. 8; Reference 20, pp. 57 through 63 and Appendix E; Reference 26, p. 25.

and a P2V, which tested new radiac instrumentation and equipment. The Air Materiel Command established a detachment of men on Kwajalein, designated TD 3.4.2.1, Experimental Aircraft Detachment, under operational control of TU 3.4.2 for the duration of GREENHOUSE. TD 3.4.2.1 had a maximum of 98 men in the test area, some of whom moved to Enewetak Island when the two B-50Ds were transferred there before the first shot of the series. In addition to the two B-50Ds, this detachment operated two B-50As and one B-47. The B-50As and B-50Ds collected radioactive air samples near the nuclear cloud and conducted other experiments. The B-47 was used for airborne structural blast tests.

TASK UNIT 3.4.3 -- COMMUNICATIONS. This task unit provided and operated the airways communications facilities at Enewetak, which included the control tower, aircraft liaison net, weather reporting net, point-to-point communications, aircraft homing beacons, and other navigation aids. TU 3.4.3 also had a detachment at Kwajalein that provided similar services to task force aircraft in that area. This task unit had a peak strength of 139 personnel. The specific breakdown between Enewetak and Kwajalein is not known (Reference 7, p. 6; Reference 20, p. 69).

TASK UNIT 3.4.4 -- WEATHER RECONNAISSANCE. This task unit provided and operated 12 WB-29s that were used for long-range weather reconnaissance and for sampling and tracking the radioactive clouds. The unit had a maximum of 323 personnel in early April, of whom all but 6, who remained on Enewetak Island, were stationed on Kwajalein. TU 3.4.4 also operated aircraft and personnel decontamination facilities for TG 3.4 aircraft and personnel on Kwajalein (Reference 7, p. 6; Reference 20, p. 69).

TASK UNIT 3.4.5 -- WEATHER. This task unit manned JTF 3 Weather Central on Parry Island and operated remote weather stations on Nauru, Bikati, Majuro, and Kusaie islands. This unit had 119 personnel scattered around the Pacific: 70 total on the remote islands, 3 on Kwajalein who did radiological exclusion (radex) area plotting for TU 3.4.4, and 46 who ran the Weather Central on Parry Island. The 46 men, 12 of whom were Navy personnel, lived on Enewetak Island and commuted to and from Parry daily. Most of the Air Force personnel in this task unit were from the 2060th Mobile Weather Squadron at Tinker AFB, Oklahoma.

TASK UNIT 3.4.6 -- LIAISON. This task unit operated and maintained the light aircraft (L-5s and L-13s) of the 4th Liaison Flight and helicopters (H-5s) of the 5th Helicopter Flight used for intra-atoll airlift. These aircraft were also used for security sweeps of the islands before and after shots and for spraying insecticides on the islands. The light aircraft were used to assist Hq USAF by taking air conductivity measurements in conjunction with Program 7 experiments. Maximum strength of this unit was 107 in early April, most of whom were from the 2600th Air Base Squadron at Pope AFB, North Carolina. All TU 3.4.6 personnel were stationed at Enewetak Island (Reference 7, p. 7; Reference 28, p. 3).

TASK UNIT 3.4.7 -- RESCUE. This SAR unit, comprised of 52 men from the 4th and 5th Air Rescue Squadrons and 4 aircraft (2 SA-16s and 2 SB-17s), served all task force activities within 300 nmi (556 km) of Enewetak Atoll (Reference 7, p. 8). Most of this unit was stationed on Kwajalein; however, at least one SA-16 and one SB-17 were retained at Enewetak Island and aircrews were rotated about every 2 weeks (Reference 27, p. 74). At times two SA-16s and one SB-17 were at Enewetak. In addition, at least one person from this task unit was assigned to the 11th Air Rescue Squadron, Hickam AFB, Hawaii.

TASK UNIT 3.4.8 -- PHOTOGRAPHY. This documentary photography unit produced two films as well as a large collection of still photographs. Personnel in this unit were from Air Force Lookout Mountain Laboratory, California; its maximum strength was 30, all of whom were stationed on Enewetak Island. A few worked at Parry Island, however, and commuted daily.

CHAPTER 2

RADIOLOGICAL SAFETY

During Operation GREENHOUSE, radiological safety (radsafe) was based on adapting current safety principles and procedures to the field operation. Protective regulations issued by Commander Joint Task Force 3 (CJTF 3) were based on national and international advisory bodies' recommendations concerning radiation exposure limits, and administrative rules and controls implemented the regulations.

Methods to limit human exposure to radiation included both physical safeguards (barriers to restrict access to radiological exclusion [radex] areas) and indoctrination and training to acquaint personnel with the problem of radiation. This chapter explains the regulations, administrative rules, and procedures used by JTF 3 to limit exposure and measure the effectiveness of the controls.

The concept of radiological safety for Operation GREENHOUSE required each task unit to provide for its own safety under directives issued by CJTF 3. Each task unit was delegated support functions for the benefit of the task force as a whole, but task units were basically self-sufficient in manpower, maintenance, and training (Reference 29, Annex D-1). CJTF 3 radsafe directives (Reference 30) had the following underlying objectives:

- Collect and disseminate information on potential radiological problems that might cause injury and sickness to personnel
- Ensure the safety of all personnel employed in radioactive areas
- Prepare information detailing necessary precautions for protecting personnel
- Reevaluate the hazards of a radiological area as survey work progressed
- Maintain records of any illness or injury resulting from exposure to radioactivity.

RADIOLOGICAL SAFETY PLANNING

In autumn 1948, Los Alamos Scientific Laboratory (LASL) gave serious consideration to radsafe control and organization during the tests planned for 1951. In December 1948, the Scientific Director of the task force presented his philosophy regarding conduct of the program, stating that he had a moral responsibility for the radiological safety of all personnel engaged in work under his direction and urging that the radsafe section be placed under the Scientific Director rather than the task force commander (Reference 5, p. 39). Throughout spring and early summer of 1949, this issue was discussed.

J-Division of LASL was directed to establish radsafe regulations and train monitors to ensure radiological safety of all personnel conducting the tests under the commander of the scientific task group (Task Group [TG] 3.1). J-Division was also willing to assist the task force commander in establishing radsafe regulations for all personnel and equipment within Enewetak Atoll, and even outside the atoll to some reasonable limit. The great advantage to such a plan, the Scientific Director argued, was that he could authorize the monitors under his control to stop any operation they considered unsafe. The Scientific Director felt that since Enewetak was an Atomic Energy Commission (AEC) installation, monitoring was J-Division's responsibility (Reference 5, p. 39).

To give the Scientific Director, who was also commander of TG 3.1, control over radsafe activities in other task groups, however, was contrary to normal military operations. The task force commander decided in August 1949 that despite possible duplication of efforts and instruments for training and organizational purposes, it was critical that he have final radsafe responsibility (Reference 5, p. 39). This responsibility would, in turn, be delegated to task group and task unit commanders through regular command channels. Each commander was responsible for personnel in his command (Reference 5, pp. 39 and 40).

In its report to the Joint Chiefs of Staff (JCS), the Joint Proof Test Committee (JPTC) set forth provisions for radiological safety. Radiological safety was declared to be a command responsibility at all levels in matters pertaining to hazards that might result in injury or death to personnel (Reference 5, p. 40). The report defined specific task group missions and responsibilities.

Preliminary plans for the JTF 3 radsafe program were completed by April 1950. The TG 3.1 Radsafe Officer, who would command the Radsafe Unit (Task Unit [TU] 3.1.5), was made responsible for the safety of personnel assigned to TG 3.1. The military task group responsibilities were also assigned. Full-time task group radsafe officers were assigned only to each task group staff (Reference 5, p. 40).

The radsafe plan of each task group was based on the JTF 3 radsafe plan. The most extensive radsafe instructions were detailed for TG 3.1 and TG 3.4. The Army task group (TG 3.2) had few detailed instructions concerning radiological safety, and the Navy task group (TG 3.3) had more. JTF Field Order 2-50 (1 Dec. 1950) established radsafe command responsibility, regulations, operations, handling of radioactive material, and radsafe responsibilities of each task group and discussed hazards from atomic bomb explosions. Field Order 2-50 is reproduced in Appendix A of this report and is cited as Reference 29.

ORGANIZATION AND RESPONSIBILITIES

Overall organizational planning and authority for radiological safety rested with CJTF 3. The commander's staff coordinated radsafe information collected before and during shot operations. Elements of control existed at all command levels, and operational control was applied through normal command channels. A decentralized system of operational control employing elements of the CJTF 3 staff and units within each task group was established for the operation. A Radsafe Section established in J-3 of the task force staff had ultimate responsibility for advising CJTF 3 regarding the health and safe employment of all personnel. The Radsafe Section informed CJTF 3 of anticipated and current radiological hazards. It prepared radsafe rules and regulations pertaining to radiological health examinations and employment of personnel in contaminated areas, prepared training standards for monitoring personnel, and delineated the various task group areas of radsafe responsibility. While CJTF 3 determined whether a shot was go or no-go, CTG 3.1 determined at any time after that whether it should be cancelled or postponed.

Each task group established a self-sufficient radsafe unit. In addition to routine task group radsafe matters, each task group radsafe unit provided some general support to the joint task force. In summary, these support functions were:

- Task Group 3.1 (Scientific)
  - -- Perform all monitoring services associated with experimental projects
  - -- Conduct all laboratory functions associated with radiological safety, except for TG 3.3, including film badge processing, laboratory services, exposure record maintenance, instrument repairs and maintenance, sample packaging, and ground radex area plotting
  - -- Monitor water supplies on outlying inhabited islands for possible fallout
- Task Group 3.2 (Army)
  - -- Assume responsibility for the radiological safety of Enewetak base facilities, except for air operations activities
- Task Group 3.3 (Navy) (Reference 31, p. 2)
  - -- Develop all necessary shipboard radsafe procedures
  - -- Provide radsafe officers, instruments, clothing, monitors, decontamination crews and aircraft monitors
- Task Group 3.4 (Air Force) (Reference 5, pp. 40 and 41)
  - -- Assume responsibility for the safety of all military and civilian personnel assigned to TG 3.4 and instruct all TG 3.4 personnel in radsafe problems
  - -- Provide necessary radsafe instruments and clothing
  - -- Plot air radex areas
  - -- Provide one radsafe monitor for each manned aircraft within 20 nmi (37 km) of the test at time of detonation or collecting radiological information after detonation
  - -- Provide aircraft ground monitors
  - -- Provide decontamination crews.

With the exception of TU 3.1.5 (Radsafe), radsafe assignment was for most personnel an additional duty. Permanent positions existed for only a few primary duty staff and supervisory personnel. Each task group was assigned at least one fully trained radiological defense engineer who supervised the activities of the task group. Thus, the Army task group trained radsafe personnel from each activity in its task group; the Navy task group placed radiological safety under its damage control organization in accordance with normal shipboard practices; and the Air Force task group used flight crewmembers as monitors and ground personnel for aircraft decontamination. The one exception, TU 3.1.5, was designated the major radsafe unit for onsite operations and given the responsibility for specific centralized and highly technical radsafe services. Considerable staffing problems had to be resolved before assembling the necessary TU 3.1.5 primary duty technicians, most of whom were military personnel on temporary duty assignments.

Task Group 3.1 (Scientific)

This group, through its radsafe unit, was a technical service group that assisted the supervisory personnel of each scientific project by providing the necessary technical advice and training for project personnel designated as monitors.

CTG 3.1 was responsible for radiological protection of TG 3.1, maintaining operational efficiency for TG 3.1, and technical assistance to other JTF 3 elements on nonmedical matters pertaining to radiological safety.

Under CTG 3.1 Op Plan 1-51 (Reference 32, p. L-1), TU 3.1.5 provided:

- All ground monitoring services associated with experimental projects
- Surface radex area plots to operating agencies of JTF 3
- Protective (disposable) clothing and film badges or personnel dosimetry devices to personnel working in contaminated areas or with radioactive materials
- Protective goggles for individuals of JTF 3 requiring visual protection
- Records of individual exposure to radioactivity
- Radiation detection survey instruments for TG 3.1
- Instrument repair and maintenance for JTF 3
- Technical personnel to inspect all samples and radiologically contaminated objects.

As a service to the task force as a whole, TU 3.1.5 issued a safety bulletin to be read by all personnel, including visitors, at the Pacific Proving Ground (PPG).

TU 3.1.5 had three sections: Staff, Laboratory and Instrumentation, and Monitoring.

The Monitoring Section provided monitors for missions in radioactive areas and for personnel working with radioactive materials. The assignment of monitors was handled by the Operations Officer in Staff Section J-3. All operations were generally considered routine except for "special" operations specifically designated by CJTF 3. Special operations were urgent work missions on shot islands (Reference 32, pp. 1 and 2). Radiation monitoring units from TG 3.1 were established at Enewetak, Parry, and Japtan islands to monitor the handling of test materials (Reference 29, p. D-3).

The Laboratory and Instrumentation Section, termed the Radsafe Laboratory, was responsible for procurement and maintenance of an adequate supply of radsafe instruments, and for repair, servicing, and calibration of the instruments to be used by TU 3.1.5. All other groups of JTF 3 procured their own radsafe instruments and appropriate spare parts used in operations. The Radsafe Laboratory was responsible for maintenance, repair, and servicing of all radsafe instruments used by JTF 3. Finally, it maintained the personnel exposure records of all JTF 3 personnel.

TU 3.1.5 maintained a stock of ionization chambers, Geiger-Mueller counter survey instruments, personnel dosimeters, and pocket ionization chambers at the Radsafe Laboratory on Parry Island. The laboratory issued survey instruments to the monitors, which were retained throughout the operation as long as the instruments worked and had an adequate range for the missions in which the monitors were engaged. The laboratory gave each monitor sufficient photographic film badges and personnel dosimeters for all party members before each mission, which were returned to the Radsafe Laboratory at the end of the mission. Radiation sources used in instrument calibration were kept at the laboratory. The laboratory also checked and repaired any broken instrument returned by JTF 3 personnel. It processed, read, and maintained all photographic film badges and pocket chambers. It also determined radioactive decay curves on crater material and other samples (Reference 32, p. C-2).

The Radsafe Center was established by TU 3.1.5 on Parry Island as an operations headquarters for all radsafe activities. All radsafe data were gathered at the headquarters, and any information needed by other groups was distributed from the center as memoranda or situation maps.

The center supported CTU 3.1.5 radsafe planning operations. It tracked the locations of all monitors engaged in operations and maintained an operations table detailing all scheduled missions into contaminated areas. This table included the monitors' names, destinations, kinds of missions, and times of arrivals and departures. Three officers and six enlisted men handled these responsibilities.

The Radsafe Center plotted surface radex areas and maintained radiological situation data on all islands of the atoll based on monitor and survey data obtained by specific monitoring missions (Reference 32, p. C-18). It was tied by a communications net to all shot islands and other vital installations throughout the atoll, including CTG 3.1, CJTF 3, Enewetak Island, Parry Island, and boat dispatchers (Reference 32, p. C-11).

Radiation control centers were used for radiological protection of personnel entering radioactive areas. There were several operations stations for all radsafe activities at the centers. At the stations, radiological situation data were gathered and information required by monitors was maintained in memoranda and situation maps. These maps delineated areas cleared by radsafe personnel, as well as areas requiring monitor escort.

Task Group 3.2 (Army)

TG 3.2 performed all radsafe monitoring and decontamination services for Enewetak Island, except air operations and TG 3.1 activities. The TG 3.2 Radsafe Officer advised CTG 3.2 of the presence and location of radiation areas on Enewetak Island, the safe employment of personnel in these areas, and the necessary precautions to minimize radiation exposures. The radiation areas on Enewetak Island were delineated by the TG 3.2 Radsafe Officer and placed off limits to all personnel not authorized to enter them.

The TG 3.2 Radsafe Officer and his staff (Reference 33):

- Rechecked the radioactive areas, submitting to CTG 3.2 periodic reports on the changing radiological conditions
- Advised the task group surgeon of effects of ionizing radiation on personnel
- Supervised all TG 3.2 personnel entering a radioactive area and prevented anyone not physically qualified as the result of previous exposure from entering such areas
- Provided radiological physical examinations by the task group surgeon for personnel scheduled to enter radioactive areas
- Evaluated, analyzed, synthesized, and used information and equipment from the Special Assistant for Radiological Safety, CJTF 3
- Monitored personnel in TG 3.2 working in radioactive areas
- Reported daily to TG 3.2 surgeon on the daily amount of radiation received by individuals
- Submitted individual dosimeters and film badges to the TG 3.1 Radsafe Officer
- Informed the task group surgeon of any personnel who might encounter radioactivity
- Submitted to CTG 3.1 the names of all TG 3.2 personnel who were to enter a radioactive area 2 weeks before their entry into the area.

Task Group 3.3 (Navy)

Responsibility for overall coordination of TG 3.3 radsafe activities lay with the task group commander aboard USS Curtiss (AV-4). In addition, the Department of Navy was requested to assign six men to the TU 3.1.5 Radsafe Laboratory and ten men as TU 3.1.5 monitors.

TG 3.3 was responsible for the following (Reference 31, p. 2):

- Designating the TG 3.3 Radsafe Officer, who was responsible for the safety of all military and civilian personnel assigned or attached to TG 3.3
- Procuring and issuing necessary radsafe instruments, equipment, and protective clothing
- Providing monitors and decontamination crews aboard each ship within the task group
- Providing aircraft monitors for air units of the task group
- Ensuring that all TG 3.3 personnel were instructed in the radsafe matters involved in the operation.

Each ship had its own radsafe monitor. The monitors typically were part of damage control teams and had radsafe responsibilities as additional duties. Radiac (radioactivity detection, identification, and computation) instrumentation was provided to each ship. Curtiss had radiac instrument repair facilities for all TG 3.3 instrument repair.

Task Group 3.4 (Air Force)

Commander TG 3.4 was responsible for the following general radsafe functions (Reference 7, p. H-1):

- Procuring and issuing radiac instruments, protective clothing, and equipment within TG 3.4
- Training radsafe monitors for aircraft flying within 20 nmi (37 km) of the detonation and for aircraft collecting radiological data after detonation
- Providing and operating personnel and aircraft decontamination facilities at Kwajalein and Enewetak for TG 3.4 personnel and aircraft
- Plotting the air radex area and controlling all aircraft in the vicinity of the detonation cloud.

Each of the task units in TG 3.4 had specific radsafe missions.

TU 3.4.1 (Headquarters and Headquarters Squadron) had the following missions (Reference 7, H-3):

- Radsafe training
- Aircraft decontamination assistance
- Procurement and storage of radiac and decontamination equipment for TG 3.4.

TU 3.4.2 (Experimental Aircraft) had the following missions (Reference 7, p. H-3):

- Radsafe training
- Airborne monitoring in TU 3.4.2 aircraft
- Procurement and storage of radiac and decontamination equipment for TG 3.4 units on Enewetak
- Decontamination of assigned aircraft
- Operation of the TG 3.4 personnel decontamination center at Enewetak
- Plotting ground and air radex areas
- Coordinating the film badge program and radiac equipment maintenance with TU 3.1.5
- Overall responsibility for TG 3.4 radsafe program at Enewetak.

Task Detachment (TD) 3.4.2.1 (Experimental Aircraft) was part of TU 3.4.2 but was located at Kwajalein. Its responsibilities were radsafe training, airborne monitoring, decontamination operations with the aid of TU 3.4.4, assisting TU 3.4.4 in operating the personnel decontamination center at Kwajalein, and obtaining radiac equipment from TU 3.4.4 (Reference 7, p. H-5).

TU 3.4.3 (Communications) had the mission of providing radsafe training for its personnel (Reference 7, p. H-4).

TU 3.4.4 (Weather Reconnaissance) had the following missions (Reference 7, p. H-4):

- Radsafe training
- Airborne monitoring in TU 3.4.4 aircraft
- Procurement, issuance, and control of radiac and decontamination equipment for TG 3.4 units on Kwajalein
- Decontamination of assigned aircraft
- Operation of the TG 3.4 personnel decontamination center at Kwajalein
- Plotting ground and air radex areas
- Overall responsibility for TG 3.4 radsafe program at Kwajalein.

TU 3.4.5 (Weather) was responsible for radsafe training and decontamination operations as required (Reference 7, p. H-4).

TU 3.4.6 (Liaison) was responsible for radsafe training, airborne monitoring in its aircraft, decontamination operations as required, and obtaining necessary radiac equipment from TU 3.4.2 (Reference 7, p. H-5).

TU 3.4.7 (Rescue) was responsible for radsafe training, obtaining radiac equipment from 3.4.4 as required, and decontamination operations with the aid of TU 3.4.4 (Reference 7, p. H-5).

TU 3.4.8 (Documentary Photo) was responsible for radsafe training and for decontamination operations with the aid of TU 3.4.2 (Reference 7, p. H-5).

TRAINING

In Field Order 2-50 (Reference 29), CJTF 3 ordered two levels of training -- basic indoctrination and technical -- but allowed each task group to vary the scope of instruction according to the group's operational requirements. Basic indoctrination included nontechnical instruction in radiological matters and techniques. Such instruction was to be given to all task force personnel to encourage efficient performance of duties within allowable radiological exposure levels. Technical training was required of all personnel who were to staff the task force radsafe organizations and perform monitoring and other technical operations, such as decontamination and instrument repair. Technical instruction was to be obtained through existing service courses and training sessions established at the task group level.

Task Group 3.1 (Scientific)

The technical radsafe group depended on obtaining from AEC, LASL, and the services personnel who had formal and specialized training. Sources for technically qualified health physics personnel during the decontamination period were the Health Physics Division of Oak Ridge National Laboratory (ORNL), LASL, and special military organizations. In the period between SANDSTONE and GREENHOUSE, the need to decontaminate the shot islands became apparent. Early in 1949, a series of regulations were issued for Holmes & Narver, Inc. (H&N) workmen on the shot islands (Reference 34). These regulations remained in effect until the SANDSTONE crater on Enjebi had been covered.

In a conference on 17 May 1950 regarding TU 3.1.5 orientation, it was agreed that TU 3.1.5 monitors, totalling some 30 men, would meet at LASL about 15 September. Orientation was necessary to assure CTG 3.1 of the adequacy of the radsafe plan, to familiarize monitors with the work of scientific groups requiring monitor services, and to allow time to adjust monitor plans if conditions warranted (Reference 35).

The radsafe information meeting was held at LASL from 2 to 7 October 1950. Program directors and project officers briefed the monitors on operational plans of the projects. Monitors were assigned duty with the various scientific programs and were briefed on radsafe instruments to be used. At the conference, it was decided to establish a radsafe center on Parry Island to serve as an operations headquarters for all radsafe activities. All radsafe data were to be gathered at this headquarters and information required by other groups would be distributed in the form of memoranda and/or situation maps (Reference 36, p. 2). When the radsafe monitor requirements had been analyzed, it became obvious that additional monitors would be required. TG 3.1 established requirements for 11 additional monitors, and replacement was requested for 5 who could not be used (1 from illness, 2 unavailable, 2 unqualified) (Reference 37, pp. 38 and 39).

Training of monitors began shortly after their arrival at Enewetak Atoll. Instruments were issued at once, and familiarization with them was emphasized in the training program. Monitors began to work with the project directors on their assigned projects about 10 March. Assigning monitors well in advance of shot time was an innovation and was reported as a definite improvement over previous methods (Reference 38, p. 5). Weekly meetings were held for critiques, orientation, and education, and lectures were given by CTU 3.1.5 and members of his staff. By 6 April, the TG 3.1 radsafe unit was ready to begin its GREENHOUSE monitoring tasks.

Task Group 3.2 (Army)

While TG 3.1 was generally composed of scientists, TG 3.2 was manned almost entirely by personnel whose knowledge of nuclear matters was gained by on-the-job training (Reference 5, p. 93).

On 30 June 1950, CJTF 3 sent a letter to CTG 3.2 directing that training be conducted in accordance with policies set forth in the training circular, Number 1, Department of the Army, 27 February 1950. The letter declared that units assigned or attached to TG 3.2 should be considered as employed on operational duties and should conduct maximum training on a balanced program, emphasizing proper physical training, and indoctrination in security, hygiene, radiological safety, and military courtesy. Plans and training were also required for physical safety of the atoll area and for emergency evacuation (Reference 5, p. 94).

On 12 December 1950 Annex H, Training, Op Plan 1-50 was issued. The directive continued the provisions of the 1 November 1950 Training Memo Number 1 and expanded the requirements to include such subjects as radiological safety, supply discipline, defense against chemical attacks, and recognition of aircraft. This program was in effect until 26 January 1951. On this date, CTG 3.2 suspended all training indefinitely, except that related to the GREENHOUSE operation and troop information program. This action was necessary because of continued interference with the increased construction program and logistic activities (Reference 39, p. 4).

Task Group 3.3 (Navy)

Like TG 3.2, TG 3.3 was generally composed of personnel whose knowledge of nuclear matters was gained by on-the-job training (Reference 5, p. 93). On 9 March 1951 CTG 3.3 sent to TG 3.3 information on radsafe training and organization, which included enclosures pertaining to the radsafe training program, operating procedures for radiac equipment, shipboard radsafe organization chart, and shipboard radsafe organization and billet descriptions. Radsafe training course topics covered development of nuclear weapons, detection of radiation, and decontamination. The detailed training syllabus is presented in Appendix A of this report.

Training also included detailed operating instructions for the AN/PDR-5, AN/PDR-8B, AN/PDR-T1B, IM-3/PD; general information; range and controls; operating procedures; calibration and checking procedures; and security procedures.

Each ship and air unit underwent some basic training before arriving in the PPG. However, the level of training varied from one organization to another.

Patrol Squadron 931 (VP-931) had 24 officers and 18 enlisted men trained in radsafe schools at San Diego, Treasure Island, and Pearl Harbor. This training provided, in most cases, two trained officers and one trained enlisted man (the designated monitor) in each crew, and two ground monitoring and decontamination teams. These men constituted a nucleus for training within the squadron through lectures, demonstrations, and operational use of equipment. The commanding officer of VP-931 added that it would be desirable in future operations to have at least one AN/PDR-8B, one AN/PDR-T1B, and three pocket dosimeters assigned to the squadron for training purposes (Reference 40).

The commanding officers of USS Walker (DDE-517) and USS Sproston (DDE-577) (TU 3.3.4) complained of receiving little basic training to prepare their crews for participation in GREENHOUSE. Both ships had been recommissioned in September 1950 from the reserve fleet and were manned largely with crews of recalled reservists. The commanding officers generally considered both radiological and general preoperational training inadequate and that a paucity of training aids and materials existed. They recommended that ships participating in future operations be designated in sufficient time to allow for preoperational training, especially in fleet schools. They maintained that radiological training aids, equipment, and information should have been made available (Reference 41).

In contrast to Walker and Sproston, Curtiss reported extensive radsafe training. Before arriving at Enewetak, 32 men attended and satisfactorily completed the 5-day practical radsafe course at the Fleet Training Center, San Diego, California. In addition, one officer on board was a graduate of the 6-week radsafe course at the Damage Control Training Center, San Francisco, California. Training was also conducted at Enewetak. Training in radsafe and defense techniques was integrated into the ship's regular damage control organization. The training program included exercises at battle stations at least once weekly. This permitted rehearsals of individual damage control problems by each repair party, with radiological defense drills and techniques comprising an important part. All members of the damage control repair parties were instructed in the use of radiac equipment aboard ship to detect radiological hazards, use of various decontamination processes, establishment of isodose lines, use of change stations, and personnel decontamination. Aside from the specialized instruction of the damage repair parties, general indoctrination lectures were given to all hands on the following subjects:

- Nature of the radiological hazards
- Detection of radiation, including capabilities and limitations of instruments
- Decontamination techniques and procedures.

The training was tested when, during the operation, Curtiss received fallout. The commanding officer noted: "Due to the contamination of the ships from fallout, detection of the hazards became more realistic and monitors displayed a keener interest in determining the extent and intensity of the contamination. All hands became aware of the hazard and received training in the actual decontamination of the ship. Errors in Radsafe methods and techniques were discovered and corrected" (Reference 42, p. 2).

While radiological defense training aboard Curtiss was generally satisfactory, the commanding officer felt that insufficient time precluded an efficient organization to combat any radiological hazard (Reference 42).

Two members of the naval complement and two members of the ship's crew of the Military Sea Transportation Service (MSTS) ship, USNS Sgt. Charles E. Mower (T-AP-186), took indoctrination courses in radiological safety before arrival at the forward area. The Executive Officer (Military) participated in an indoctrination course at Treasure Island, and the medical officer took an indoctrination course at Edgewood, Maryland. The second officer and the boatswain received indoctrination at San Diego. The training programs were described as adequate in the theory presented but somewhat lacking in the practical application of shipboard monitoring and decontamination. Before arriving in the forward area, the Commanding Officer (Military) conducted a series of short orientation lectures for the entire crew. Once in the forward area, a brief and practical period of training was given to the monitoring teams, supplemented by drills conducted by the radsafe officer and the medical officer. This training was considered quite adequate. During the operational period, the ship's monitoring teams gained experience in monitoring, zoning contaminated areas, marking isodose lines, and in conducting simple decontamination procedures. No persistent radioactivity was encountered, although Mower was in slight fallout following shot DOG, and the ship was effectively decontaminated by hosing with saltwater spray. Personnel monitoring teams gained limited experience in personnel monitoring, but effective monitoring, decontamination, and disposal of contaminated clothing ashore eliminated all personnel contamination. Showers and sinks installed on the main topside deck were never used. Embarking personnel were monitored for a limited period, but no contamination was discovered (Reference 37).

Task Group 3.4 (Air Force)

Radsafe training procedures for TG 3.1, TG 3.2, and TG 3.3 were not as extensive or detailed as they were for TG 3.4. Although TG 3.1 expected to face a certain amount of radioactive contamination, most members of TG 3.1 were sufficiently familiar with radsafe procedures that additional extended training was not considered necessary. TG 3.4 was operationally involved in shot-day activities, for which extensive radsafe training was a prerequisite. TG 3.4 training was therefore undertaken relatively early in the preoperational phase of GREENHOUSE. Indeed, the importance of TG 3.4 training was foreseen by those who organized the task group.

On 13 March 1950, Chief of Staff, U.S. Air Force, addressed a directive to Commanding General, Air Proving Ground (APG), Eglin AFB, Florida, to organize, man, equip, and train TG 3.4, Provisional, and its task units for support of JTF 3 (Reference 5, p. 94). Specifically, he was ordered to thoroughly indoctrinate all personnel in radsafe matters. Special instruction, including knowledge in and proper use of radsafe instruments, equipment, and protective clothing, was given to crews charged with handling and washing down contaminated aircraft. Personnel designated as airborne radsafe monitors in manned aircraft and monitors charged with supervising and handling contaminated aircraft on the ground were required to complete a formal course of instruction at a radsafe school (Reference 30).

A CTG 3.4 directive placed responsibility upon task unit commanders for training essential to success of the operational mission. Training was to be directly supervised by the parent command during the initial phase, and directly supervised by CTG 3.4 during the operational phase. Emphasis was placed on dissemination of proper instructions relating to atomic energy information, radiological safety, security, and personal hygiene. The task group commander and his staff frequently visited task units to determine the degree of readiness and training for the operational role.

Experimental Aircraft Unit (TU 3.4.2) training was conducted to ensure its capability to deploy 17 drone B-17s, 15 controller B-17s, 5 drone T-33s, and 5 controller T-33s; to man and operate one B-17 radiac aircraft for Project 5.2; and to assume operational control of one B-47, two B-50Ds, and two B-50As of TD 3.4.2.1 at Kwajalein. TU 3.4.2 also assumed operational control of one B-50D aircraft for the Air Force Special Weapons Center, performed organizational maintenance, conducted radiological decontamination operations on unit aircraft as required, and operated a radiological decontamination center for all units of TG 3.4 located on Enewetak Island (Reference 5, p. 97).

After each field exercise at Eglin AFB, radsafe measures were tested by the radsafe personnel assigned to the unit. Before takeoff, airborne monitors plotted air radex areas, briefed aircrews, and issued articles that simulated radsafe devices. All manned aircraft and crews were monitored immediately after landing, and drone recovery crews removed the simulated contaminated planes from the runway. Also, personnel decontamination was practiced by all aircraft crews at Eglin auxiliary field, who passed through a decontamination center set up for instruction in this portion of the mission (Reference 5, p. 99).

The Weather Reconnaissance Unit (TU 3.4.4) conducted basic training at Tinker AFB to ensure its capability to deploy 12 B-29s for weather reconnaissance missions within a radius of 1,200 nmi (2,224 km) of Enewetak. The unit was also trained for radioactive-cloud-tracking and -sampling missions in conjunction with an Air Force experimental program, and for the TG 3.4 radsafe program at Kwajalein. Training conformed to Military Air Transport Service (MATS) and Air Weather Service (AWS) standard directives and procedures for weather reconnaissance squadrons (Reference 5, p. 100).

SAFETY CRITERIA

Commander Joint Task Force 3 disseminated operational rules for radiological situations as an annex to JTF 3 Field Order No. 2-50. Each task group supplemented the annex with its own orders or plans.

Radiation Exposure Measurement Units

Radiation measurement units were the roentgen (R) and the rem. The roentgen, a measure of radiation in air, denotes an exposure intensity. The rem is a unit of radiation dose, i.e., a measure of radiation energy deposited within the body that takes into account its capability to cause an effect in human tissue. Both units can be written as fractions. For example, a milliroentgen (mR) is 1/1,000th of a roentgen. For radiation such as X-rays and gamma rays, the rem dose is somewhat less than the roentgen exposure, for not all of the energy measurable in air penetrates body tissue. Another unit often used in discussing radiation dose is the rad. The rad is a measure of radiation energy deposited in any material. For biological tissue, a rad of radiation such as from gamma- or X-rays essentially equals a rem.

At the time of GREENHOUSE series the distinction was usually not made between exposure (properly expressed in units of roentgens) and absorbed dose (properly expressed in units of rem, although at the time often expressed in roentgens). Presumably external whole-body exposure and absorbed dose were assumed equivalent. This report expresses the measured data in roentgens. Although the original references often referred to dose, there is no evidence that whole-body energy deposition was determined, nor that dose was indeed measured.

In this report all measurements of exposure intensity are given in roentgen per hour (R/hr) whole units and decimal fractions. This is not the common way these are reported in the source literature. Lower exposure intensities are usually reported in milliroentgens per hour and the higher exposure intensities in roentgens per hour. Some rate-measuring devices could measure both lower and higher intensities with different dial settings. Personnel records show the same sort of differentiation. Lower individual exposures are usually recorded in milliroentgens, but the larger allowed or permitted exposures are given in roentgens. This use of different measuring units for different levels of radiation could cause some confusion to readers who are unfamiliar with the field. Therefore, the whole unit convention was adopted for this report.

Radiological Safety Standards

In accordance with safety criteria established by CJTF 3, a maximum permissible exposure level was set. Maximum Permissible Exposure (MPE) for Operation GREENHOUSE was 0.1 R/day (0.7 R/wk), not to exceed a total of 3.9 R for 13 weeks. CJTF 3 could authorize a total exposure of up to 3 R on any one day in specific cases. When this authorization was made, exposed individuals were to be prohibited from further exposure to more than 0.1 R/day during the remainder of the operation (Reference 43, p. 2).

In all cases, exposure records of personnel working in radioactive areas were scrutinized after each day's operations, and persons who approached or exceeded established tolerance levels were so informed and cautioned not to enter radioactive areas for prescribed lengths of time (Reference 38, p. 25).

For GREENHOUSE a "radiation area" was defined as any area where the level of radioactivity consistently exceeded 0.005 R per 24 hours. In addition, all radiation areas were routinely monitored at intervals prescribed by the commanding officer on recommendation of the radsafe staff.

Before arrival at Enewetak, each person who was to work in areas containing radioactivity or to work with radioactive materials was to have a complete radiological physical examination. Enewetak, Parry, and Japtan islands were not considered to be areas that would contain radioactivity. The examinations included chest X-rays, blood counts, and urinalysis. Reports of the examinations were referred to the radsafe office for review before an individual's departure from the United States (Reference 44).

Because of the duty and locations most Navy personnel were expected to have no, or at most a small, potential for radiological exposure, BuMed stated (Reference 45) that before assignment at Enewetak, special examinations and the use of film badges were to be waived for any individual assigned to duty in areas of low-level radioactivity, where

> . . . under normal working conditions . . . the individual will not receive an exposure of external radiation of more than 100 milliroentgens per week (beta and/or gamma) provided:
>
> a. Prior to this assignment, the individual was not engaged in work involving routine exposure to ionizing radiation (working with radioactive materials or in radiation fields).
>
> b. The individual has not received radiation therapy.
>
> c. The Tour of Duty in such area will not exceed one year.
>
> d. There are no internal radiation hazards present in the area assigned.

Radiation Exposure Waivers

CJTF 3 recognized that instances could arise in a field test in which the MPE would likely need to be exceeded. Provision was made for CJTF 3 to authorize exceeding the MPE when it was determined that successful completion of the operation required a departure from normally acceptable safety standards. Groups for which MPE waivers were issued most frequently were scientific personnel and TG 3.4 aircraft crews (Reference 46, p. 1).

A revision to Field Order Number 2 provided that the MPE (0.7 R/wk) was applicable for a field experimental test of nuclear weapons in peacetime. The standards were recognized as not usable in war or in tactical situations. The field order also provided that if an air-sea rescue occurred within the lagoon following detonation, a radiation monitor from TG 3.1 would accompany the rescue craft (Reference 29, Change No. 2).

On 29 March 1951, the commanding officer of the Air Weather Reconnaissance task unit (TU 3.4.4) requested that CTG 3.1 permit personnel in Program 7 (Long Range Detection), to accumulate a total exposure of 3.0 R in any one 24-hour period. Personnel receiving exposures in excess of 3.0 R were to be restricted to an exposure of 0.1 R/day for the remainder of the program (Reference 46). Permission to exceed 3.0 R for this program (specifically for B-50A crews) was granted on 7 May (Reference 47).

Two other waivers were granted to CTG 3.1 for personnel associated with Programs 5 and 6 (Radiation Instrument Evaluation, and Physical Tests and Measurements). A total of 22 persons, including 7 from TG 3.4, were authorized an exposure of 1.5 R on shots EASY and GEORGE. These two waiver request letters indicated that the MPE normally was 0.7 R per week (Reference 48). Waivers of the 0.7 R limit were also requested during the GEORGE test for the Strategic Air Command (SAC) photo crews.

As the series progressed, it was recognized that expressing daily maximum exposure could cause some confusion. It was concluded that for future operations only an average weekly maximum should be cited rather than a daily limit. This was a direct result of some confusion on the part of the boat pool commander following shot DOG. He took 0.1 R/day as the limit rather than the 0.7 R/week. On the day following DOG, most of his men had received exposures in excess of 0.1 R/day, and he refused to permit these men to go out on the boats, effectively tying up all boat traffic for that day (Reference 49, pp. B-11 and B-12).

Another recommendation made was to raise the one-time exposure of 3.0 R. Many felt that it was too low. CTG 3.3, for example, stated that the one-time limit could easily be changed to 10 R with no serious health risks (Reference 49, pp B-15 and B-16).

RADIOLOGICAL SAFETY MONITORING AND INSTRUMENTATION

A variety of radiac devices were used. Table 7 identifies these instruments and indicates the numbers available.

Two different types of Geiger-Mueller (GM) field survey instruments were supplied to TU 3.1.5: 75 Victoreen 263B beta-gamma survey meters and 35 El-Tronics SGM-18A beta-gamma meters. TU 3.1.5 also serviced other units' GM devices including the AN/PDR-8B.

An electronic repair shop aboard Curtiss was the primary facility for the repair and calibration of TG 3.3 radiac equipment in the Enewetak area. When demands overloaded Curtiss' repair shop, a TU 3.1.5 repair facility on Parry Island was used. Emergency radiac repair and calibration facilities for TG 3.3 and TG 3.4 elements on Kwajalein were available through TU 3.4.4.

Aircraft operating within 20 nmi (37 km) of the detonation or detecting or tracking the radioactive cloud were required to carry a monitor (Reference 27, p. 16). These included all manned B-17 aircraft, all WB-29s, both radiac aircraft (B-17 and P2V), both B-50As, both B-50Ds, one C-47, both SB-17s, and both SA-16s. The monitor issued film badges to all crewmembers, monitored the radiation environment in flight, placed the crew on 100-percent oxygen when radiation was encountered, and issued rubber gloves, dosimeters, and respirators to C-1 filter box operators.* The monitor normally operated the B/31 bottle-filling equipment on those WB-29s so equipped (Reference 52, Incl. 3).†

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* The C-1 filter system was composed of two rectangular boxes mounted on each side of a B-29. Each box contained two filters that could be charged in flight.

† The B/31 system consisted of J-5 oxygen bottles that were filled to 265 psi (1,827 kPa) with air in the vicinity of the radioactive cloud.

Table 7. Radiac equipment used during GREENHOUSE.

ID No. or Manufacturer	Type/Range	No. Available
AN/PDR-5A	Geiger-Mueller survey meter, beta-gamma, 0.020 R/hr	--
AN/PDR-8B	Geiger-Mueller survey meter, beta-gamma, 0.005 R/hr maximum	18
AN/PDR-27A	Geiger-Mueller survey meter	a
AN/PDR-T1B	Ion chamber survey meter, gamma, 0 to 50 R/hr	60[b]
IM3/PD	Ion chamber survey meter, gamma	--
IM4/PD	Ion chamber survey meter, alpha	--
IM50A/PD	Pocket dosimeter, 0 to 0.2 R	29
K-135	Radiac detector charger	2
PP-354C/PD	Dosimeter charger	4
Beckman	Dosimeter charger	8
Beckman	Pocket dosimeter, 0 to 0.2 R	100
El-Tronics SGM-18A	Geiger-Mueller survey meter, beta-gamma	35
Keleket	Dosimeter charger	125
Keleket	Pocket dosimeter, 0 to 10 R	200
Keleket	Pocket dosimeter, 0 to 50 R	144
Kelley-Koett	Pocket dosimeter, 0 to 0.2 R	100
Victoreen 263B	Geiger-Mueller survery meter, beta-gamma, 0 to 0.020 R/hr	75
Victoreen 247A	Ion chamber field survey meter	47
Victoreen 247E	Ion chamber field survey meter	40
Victoreen 247H	Ion chamber field survey meter	10
Victoreen	Minometer charger-reader	4
Victoreen	Pocket dosimeter, 0 to 100 R	200
Victoreen	Pocket dosimeter, 0 to 200 R	25

Notes:

[a]Some received late in GREENHOUSE.

[b]Because of a battery shortage, only 10 usable for shot DOG (Reference 38, p. 4).

Sources: Reference 50, Encl. 1; Reference 51, Part I; Reference 38, p. 35; Reference 43, p. 2.

He also monitored the crew and their equipment upon landing to determine if decontamination was necessary (Reference 53, p. 2). Instruments on board each aircraft varied with the mission. For example, the WB-29 assigned to fly under the radioactive cloud and collect fallout samples had two AN/PDR-T1Bs, one Victoreen 263B, two 0 to 0.2 R dosimeters, one 0 to 10 R dosimeter, and one PP-354C/PD dosimeter charger in addition to film badges for all crewmembers (Reference 54, Part II).

The Air Force had the following radiac equipment on hand before the first shot: 18 AN/PDR-8B radiac meters, 18 AN/PDR-T1B radiac training sets (gamma survey meters), 3 Victoreen model 638B beta-gamma survey meters, 29 IM-50A/PD pocket dosimeters (range 0 to 0.2 R), 17 pocket dosimeters (range 0 to 10 R), 4 PP-354C/PD radiac detector chargers, 2 model K-135 radiac detector chargers, 300 film badges, 15 dustproof respirators, 8 X-ray technician gloves, 45 4.2-neutral density goggles, 12 clear-lens goggles, 225 pairs of rubber gloves and rubberized booties, and miscellaneous clothing.

As a result of shot DOG, TU 3.4.4 reached some conclusions about the radsafe equipment. AN/PDR-8Bs were deemed inappropriate for air monitoring because beta radiation in excess of 0.005 R/hr ran the instrument off-scale. The radiac training set AN/PDR-T1B chamber had to be vented with a 1/8-inch (0.05 cm) hole for use at various altitudes. Venting did not harm the instrument, but inexplicably caused it to read more accurately. The Victoreen beta-gamma survey meter, model 263B, was considered more suitable for the work being carried on than the AN/PDR-8B because of its 0.020-R/hr beta-gamma range. Because there were only two operable Victoreen meters on hand, all the demands placed for them could not be met.

TG 3.4 discovered that the IM-50A/PD pocket dosimeter (0 to 0.2 R range) sometimes gave aircraft decontamination crews inconsistent results. Because of this, film badges were issued to decontamination crewmembers as an additional precaution. In contrast, the 0 to 10 R pocket dosimeter appeared to work satisfactorily. However, aircraft generally encountered few high-intensity readings. In spite of its inconsistency, the IM-50A/PD dosimeter appeared adequate for most tasks. The PP-354C/PD radiac detector charger, while slightly unwieldy at times, was generally considered very practical. The model K-135 radiac detector charger was suitable for charging pocket dosimeters, but was larger than the PP-354C/PD and could not conveniently be carried around by air or ground monitors.

Aircraft decontamination operations required extensive monitoring. Aircraft were monitored when they first returned from their missions to determine if they were contaminated and to what general extent. Those contaminated were then given more detailed monitoring checks before, during, and after decontamination operations. Ground monitors working with aircraft usually used the AN/PDR-T1B for the initial, detailed contamination surveys and used the Victoreen 263B (GM type) for postdecontamination survey work since it was more sensitive (Reference 52, Incl. 1). Each aircraft had specified locations that were monitored for radiation. An example for the drone B-17 is shown in Figure 13.

Personnel decontamination operations also required extensive monitoring with radiac equipment. Two personnel decontamination stations were operated by

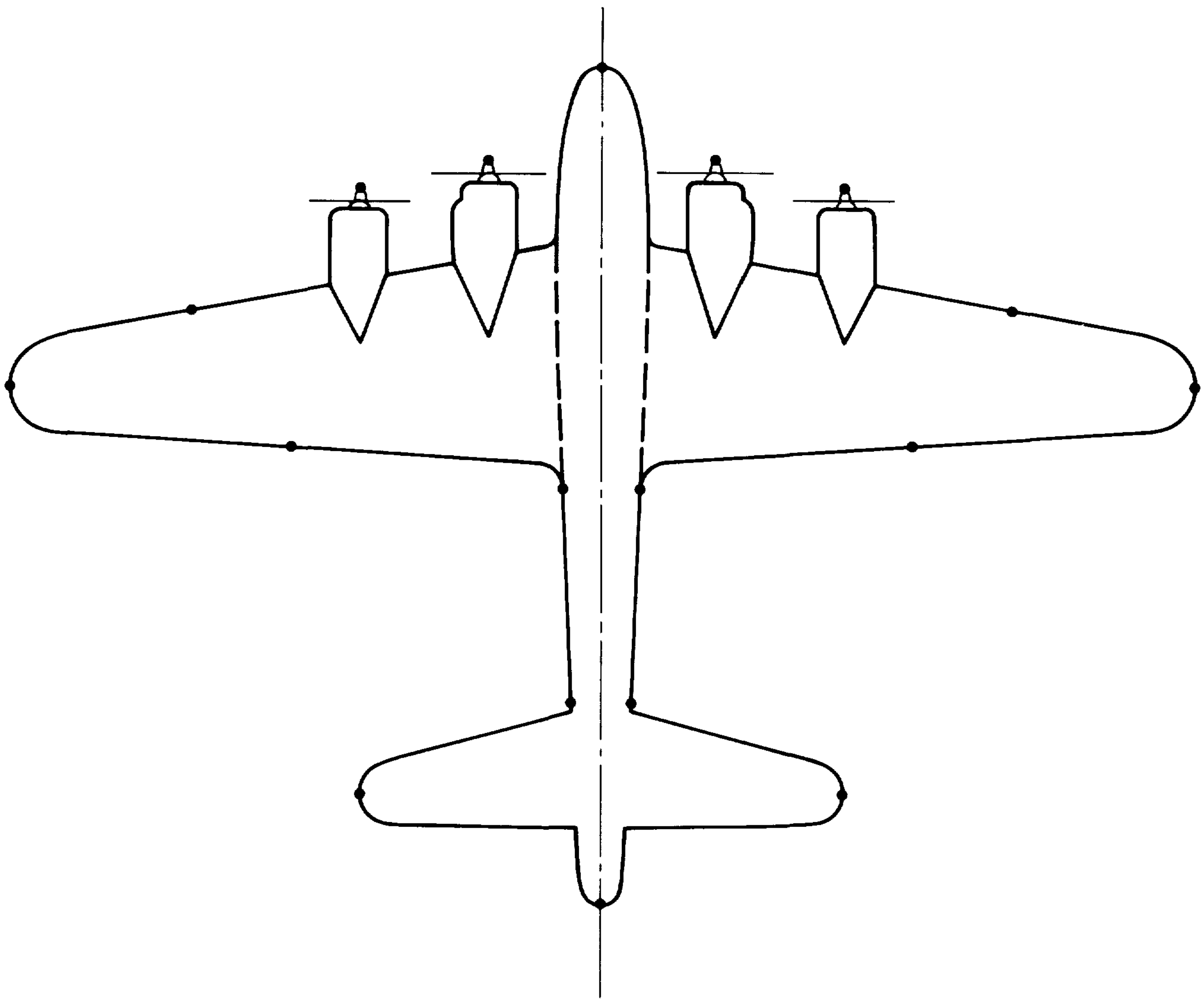

Figure 13. GREENHOUSE drone B-17 aircraft decontamination monitor points.

TG 3.4, one at Enewetak and one at Kwajalein. In addition to monitoring individuals before, during, and after they were processed through these facilities, monitors checked clothing and equipment to determine whether it was contaminated. The AN/PDR-T1B, AN/PDR-27A, AN/PDR-8B, AN/PDR-5A, and Victoreen 263B were available for this monitoring (Reference 50, Part I).

Radiation on personnel and equipment was measured with a side-window type Geiger counter. These instruments were used with their shield open to permit detection of beta radiation, holding the surface of the probe from 1 to 6 inches (2.5 to 15 cm) from the item in question. This caused the mica window on some probes to become contaminated. Thus, the equipment calibration and repair service had to decontaminate the radiac instruments. They had varied success in this effort.

Generally, TG 3.4 found the AN/PDR-T1B ion chamber instrument to be the most useful for its activities. It had a good range (0 to 50 R/hr), and was described as reliable and superior to the other types of instruments. The AN/PDR-8B was of little use as its highest beta reading was only 0.005 R/hr. The AN/PDR-5A instruments (0 to 0.020 R/hr) were useful for personnel monitoring since they monitored a higher range of beta-gamma, but they required excessive maintenance. The AN/PDR-27A instruments were received late in the program and could not be properly evaluated. The Victoreen 263Bs gave reliable measurements and were well-received by the monitors (Reference 51, Incl. 1).

Of the pocket dosimeters, the 0.200-R range instruments were more reliable than those used at SANDSTONE. These were calibrated against a radium reference source. Of the 200 pocket dosimeters, however, 24 were eventually set aside because of excessive charge leakage across their electrodes. Both calibration and leakage changed with time as the dosimeters were used, and considerable differences were noted in readings of film badges and dosimeters used by monitors in the field. These may have been caused by a variety of factors, including defective films, energy dependence, or a monitor's technique. When compared against a radium source, the results were within normal limits of accuracy. Other dosimeters were plagued with calibration and leakage problems (Reference 38, pp. 33 and 35).

FILM BADGES

Exposure records were kept carefully for all JTF 3 personnel who were issued film badges based upon the possibility of exposure to radiation. The permanent record of such exposure for Operation GREENHOUSE was the photographic film badge. Its importance for planning purposes of future test operations and as documentation that might be used in possible litigation was recognized (Reference 49). The 15,000 film badges requested were received on schedule. Upon calibration, however, the film packs were found to leak light around the perforations that formed the identifying numbers of the badges. This was overcome by wrapping the film badges in black photographic masking tape. Because large quantities of the tape were required, shortages developed, necessitating special air shipments from the United States (Reference 38, p. 33).

The film badge used at GREENHOUSE was a DuPont 553 film pack with a range of 0.1 to 250 R. It had two constituent parts: the 502 film, which was sensitive between 0.1 R and 10 R, and the 606 film, which was sensitive between 10 and 250 R. Film badges were stored in refrigerators (Reference 55) and were issued by TU 3.1.5. They were processed in the Radsafe Building at Parry Island. The TG 3.1 Radsafe Laboratory did all processing and recording and task group commanders received copies of the exposure records, although not always expeditiously.

CTU 3.4.4, based at Kwajalein, complained about the radsafe monitoring of his aircrews. Film badges from shots DOG and EASY were forwarded from Kwajalein to the Parry Island Radsafe Center via Enewetak Island. He stated, "As far as this unit is concerned, the film badge service provided this unit has been worthless, since no data has been received to date." He was particularly concerned because pocket dosimeters had yielded inconsistent data. Since CTU 3.4.4 had no idea as to the correlation between film badges and pocket dosimeter data, he was unaware whether crewmembers had exceeded their maximum allowable exposure during the operation (Reference 56, Incl. V).

In response, the TG 3.4 Radsafe Officer stated (Reference 57):

> The processing of film badges is accomplished by Task Unit 3.1.5 for the primary purpose of compiling permanent records of exposure of all personnel assigned to Joint Task Force 3. The policy established by Joint Task Force 3 is that only those personnel receiving exposures exceeding the authorized tolerance dosages will be advised of such exposure. Since no reports have been received from JTF-3, it may be assumed that none of TU 3.4.4 personnel have exceeded their tolerance dosages."

Two methods of film badging were used. The first was area badging, which involved placing film badges in key living and working areas to provide coverage. Some examples of this include the film badges placed outside of Building 69 following shot DOG and the placement of various film badges aboard ship. The second method was personnel badging. Film badges were issued only to persons engaged in recovery operations on shot islands or in aerial sampling and aircraft decontamination, and on a representative basis in TG 3.3.

Some types of activities required badging each member of a group. For example, film badges were worn by all crewmembers of the boat pool (TU 3.3.3) on shot days because they transported scientific experiment recovery parties to the shot islands immediately after detonation.

Badges were issued at the Radsafe Center at Parry Island or Kwajalein (for TU 3.4.4) to parties entering radex areas, or at least this was the intent. While most members of parties entering radex areas were badged, a cross-check of badged personnel and names of personnel assigned to experiments and interviews with a participant (Reference 127) indicate that some personnel entering these areas were not badged.

PERSONNEL EXPOSURE RECORDS

All film badge processing and maintenance of exposure records for all personnel was done by TU 3.1.5. Personnel Contamination-Decontamination Report Forms (441) were kept for personnel, particularly those of the boat pool and other Navy units. This form included the individual's name, location and time when contaminated, the intensity (beta and gamma) on his clothing and body, his film badge (and pocket dosimeter reading if available) accumulated exposure, and the method by which he was decontaminated.

In addition to this form, a Material Contamination-Decontamination Report Form (442) was developed. This was used when ships or other craft were exposed to radioactivity. It gave the ship's location when it received contamination, the distance from and type of detonation, the time the survey began, amount of time required to decontaminate the vessel, means and effectiveness of decontamination, and intensity of the contamination on vessel surface areas, and was accompanied by an exposed area monitoring sheet.

Film badge data, including that of special mission badges worn by personnel entering a radioactive area or handling radioactive material, were transferred to 5- x 8-inch cards for each individual. The form had two columns, one for film badges and another for pocket dosimeters. Each column had headings of date (presumably of return), badge (or dosimeter) number, reading in milliroentgens, and accumulated exposure. At the bottom of the card was the participant's name. The person's organization was also usually given, but for some no organization assignment is noted.

In all cases, exposure records of personnel working in radiation areas were scrutinized after each day's operation, and those who approached or exceeded established tolerance levels were so informed and cautioned not to enter radiation areas for prescribed lengths of time. In general, cooperation of test personnel with radsafe instructions was excellent (Reference 38, p. 25). A notable exception was the problem between CTU 3.4.4 and the TG 3.4 Radsafe Officer previously discussed.

Apparently no single list, or group of related lists, summarizing and consolidating information from all 5x8 cards was made by the task force, or at least such a list has not been discovered. In later nuclear test series in the Pacific, task forces were directed to compile such a list (or related lists) in their operations orders, and the resulting Consolidated List of Exposures for each of the subsequent test series can be found in archives.

A list consolidating the exposure information for LASL personnel in TG 3.1 was compiled and is located in the files of the Los Alamos National Laboratory (Reference 58). In this file also are lists covering personnel from the Naval Radiological Defense Laboratory (NRDL) and the Naval Research Laboratory (NRL) who participated in TG 3.1. These lists are apparently based on information recorded on edge-punched cards. The cards record individual identification information including task force affiliation, business and home addresses, next-of-kin, and date of required pre-GREENHOUSE physical examination. Added to these cards were dates that each person was at Enewetak and the total exposure recorded by his film badges.

This file of edge-punched cards has been microfilmed along with the 5x8 cards by the Reynolds Electrical & Engineering Co., Inc. (REECo), the contractor that operates the Nevada Test Site for the Department of Energy (Reference 59).

A list of GREENHOUSE exposures for all badged GREENHOUSE participants does exist (Reference 60), but this is based on the total badge accumulation on the 5x8 cards and additional amounts assessed for "fallout." This list was reconstructed some 17 years after the series by REECo, working with the Air Force with funds supplied to the AEC by the Defense Atomic Support Agency (now the Defense Nuclear Agency).

The magnitudes of the assessments were based only on fallout received at Parry Island and did not take into consideration the actual location of a person's duties. For some records, fallout computation did not consider the actual length of a person's stay in the Pacific Proving Ground. Therefore, that list is no longer considered useful.

Fallout assessments were made for 1,690 Navy personnel serving on the ships at Enewetak, and these were entered on their medical records in 1951. These assessments were probably made using representative badging and knowledge of particular personnel assignments and are useful as estimates for fallout exposure for those ships.

The contribution to personnel exposures from GREENHOUSE fallout and estimates of its magnitude are discussed in Chapter 10.

PRE-EVENT SAFETY MEASURES

Hazard Zones

A security zone (Danger Area) was established around Enewetak before GREENHOUSE. It was 200 by 150 nmi (371 by 278 km), bounded by coordinates 160°30'E to 163°55'E and 10°15'N to 12°45'N, and is shown in Figure 14 (Reference 49). The area was patrolled by aircraft and two destroyers to direct unauthorized vessels. Two unauthorized vessels entered the Danger Area during GREENHOUSE -- a Japanese fishing ship, Kuroshio Maru, and a tug, Eugenia M. Moran. Kuroshio Maru was sighted on 5 April and escorted from the area. Eugenia M. Moran was sighted on 27 April and was escorted from the area by Sproston (Reference 61).

VP-931 flew day and night reconnaissance patrols over the Enewetak Danger Area, covering a radius of 100 nmi (185 km) from Enewetak. Immediately preceding and following a shot, additional flights were made to increase coverage of the area (Reference 16, p. 4). Three search planes were employed, all centered on a point approximately equidistant from the various test sites. An outer search pattern (Able) was flown about a square 200 nmi (371 km) on a side. An intermediate search pattern (Baker) followed an octagonal track 66 nmi (122 km) on each leg at a mean distance of 84 nmi (156 km) from its center. An inner search pattern (Charlie) comprising parallel sweeps 10 nmi (18.5 km) apart and covering a square area 90 nmi (167 km) on a side, had two forms, sweeps running north-south and east-west. During periods between tests, one Able patrol plus either a Baker or a Charlie patrol were flown every 24 hours by search units consisting of a single aircraft. Beginning 5 days before each test, the patrols were gradually drawn in and search units were increased to two-aircraft teams. From 24 hours before until 10 hours after each test, only Charlie patterns were flown. At the end of this critical period, patrols were progressively expanded and single-aircraft searches resumed (Reference 16, p. A-7). Surface patrols were also conducted immediately preceding and following shots. The aerial search patterns and the surface patrol area is shown in Figure 15.

Fallout Prediction

CTG 3.1 was responsible for plotting surface radex areas and issuing instructions to operating agencies of JTF 3, while CTG 3.4 plotted air radex

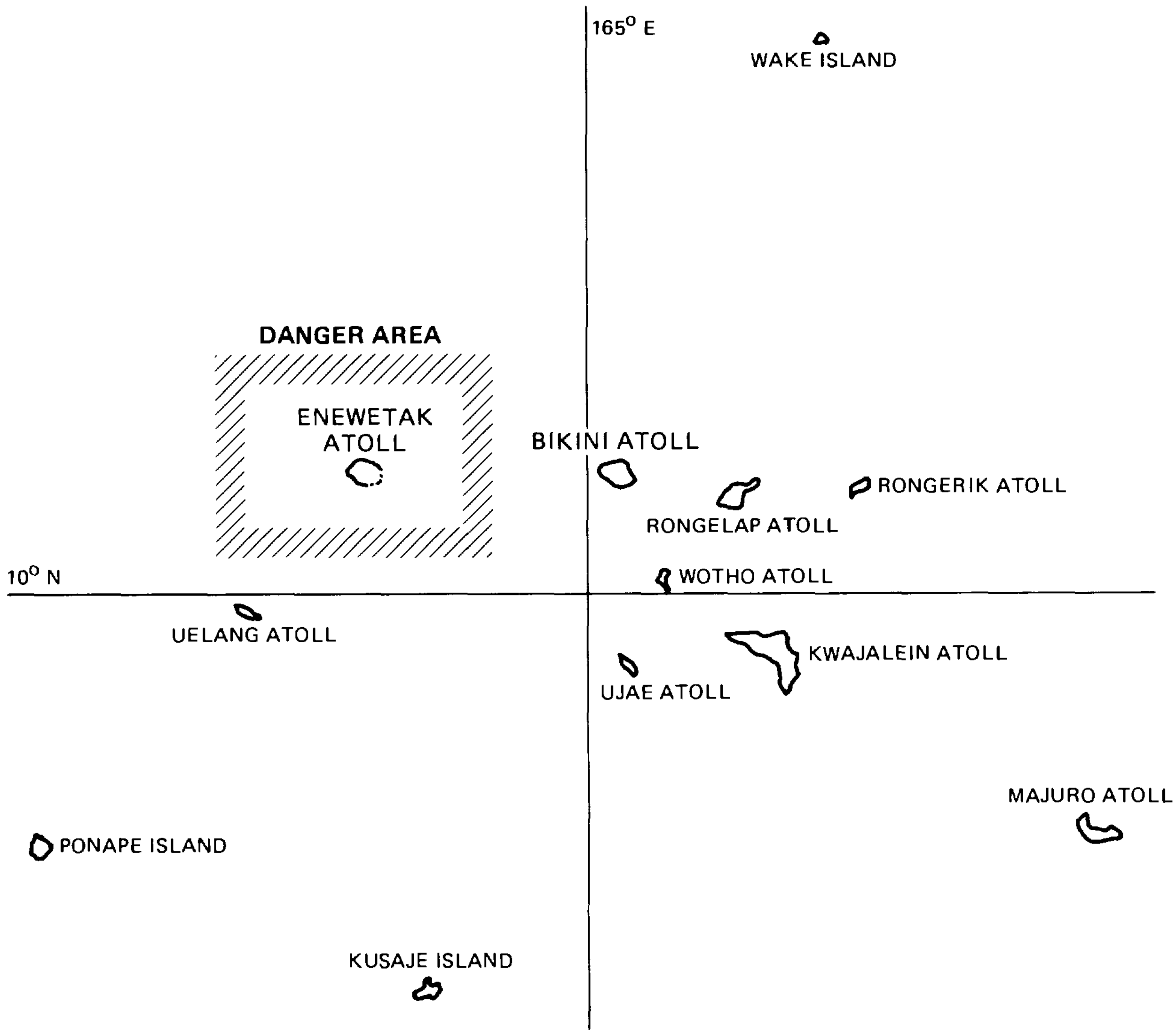

Figure 14. GREENHOUSE Danger Area around Enewetak.

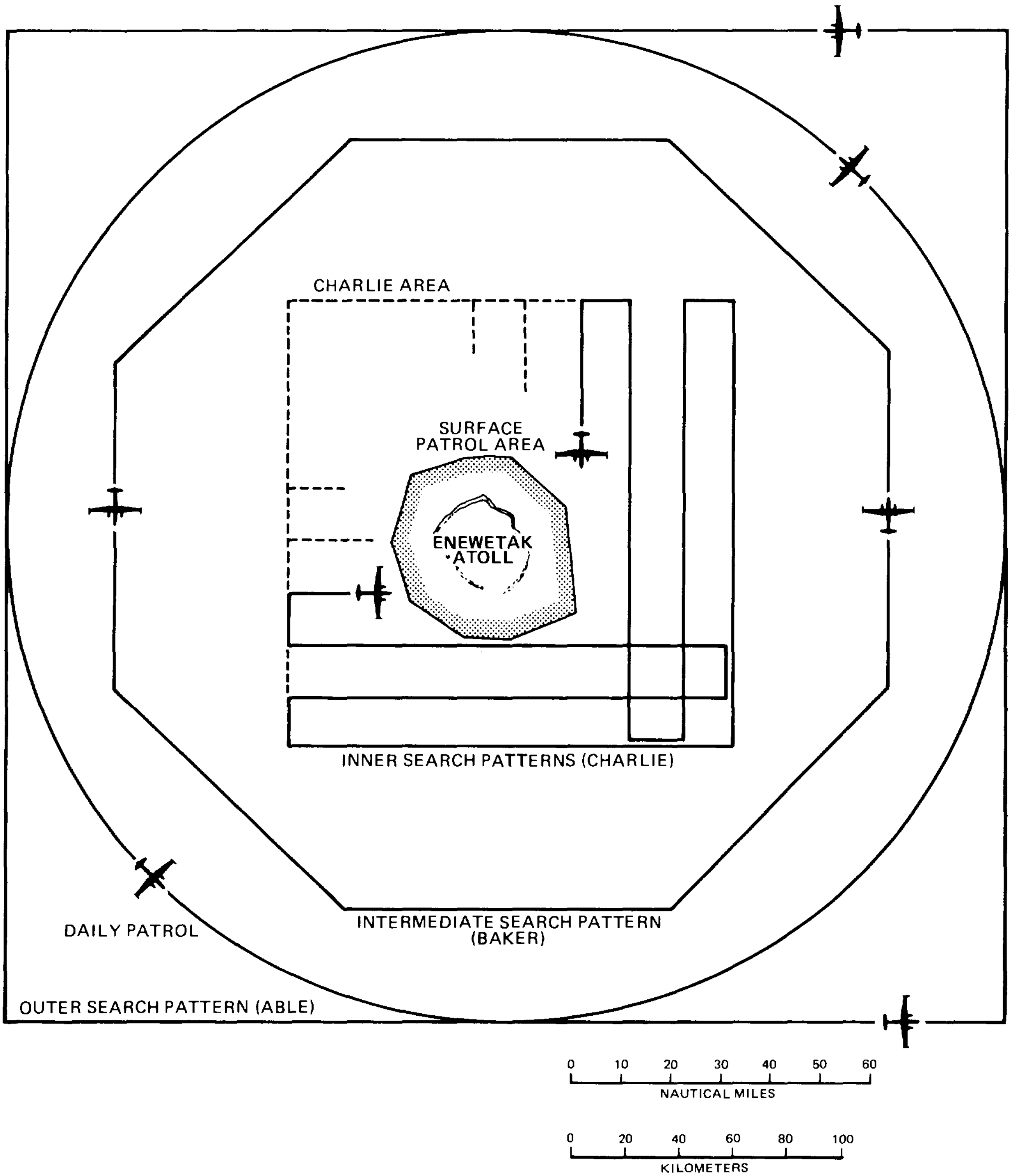

Figure 15. Aerial search patterns and surface patrol area, GREENHOUSE.

areas and issued instructions to all aircraft operating in the vicinity. Fallout predictions were based on weather observations and results of previous operations, including information from recently completed Nevada operations.

Two types of analyses of wind-weather data were used in preparing the fallout predictions: hodographs and trajectory forecasts of the paths of particles falling from a given altitude through the various wind layers.

A hodograph is a diagram representing the projection on the Earth's surface of the path of a wind-sounding balloon rising in the atmosphere at a constant rate. The projection points on the surface represent the locations where the particles would land if they had originated over surface zero at a given altitude.

Maps of the paths that particles at a given altitude would take due to winds were known as particle trajectory forecasts. Cloud trajectory forecasts were developed from these using Air Force meteorological data, and the model assumed that particles descended at a constant velocity without turbulence. Fallout particles were assumed to originate from various altitudes over surface zero, and the particles were assumed to drop with varying velocities. Using these assumptions, a series of points on the ground was obtained, each the product of an assumed initial altitude, assumed fall rate, and predicted wind. These series were formed into curves representing the path along which fallout could occur (Reference 62, p. 17).

Scientists at GREENHOUSE were satisfied with their cloud trajectory and fallout forecasting techniques, but the extent and location of the actual fallout sometimes came as a surprise (Reference 38, pp. 6 and 11; Reference 16, p. B-1). The forecast rate and amount of fallout had been predicated in part on results of previous experiments, including the 1951 RANGER tests in Nevada. When the results for DOG and ITEM were not as predicted, one explanation given was that the soil type at Nevada differed sufficiently from the stabilized coral soil at Enewetak to have significantly altered particle size, type, and the rate of fall. Because of the unknown factors of weather and fallout mechanisms, predicting times and locations of fallout was a difficult problem.

Weather Reconnaissance, Reporting, and Prediction

Weather information was important to radsafe operations and was used to make accurate predictions of detonation cloud movement and fallout. TG 3.4 was assigned three weather missions. One was to establish and operate four remote weather stations on the islands of Majuro, Kusaie, Nauru, and Bikati. Another was operation of a fleet of 12 WB-29s to make daily long-range weather flights starting at D-4 of each shot. The third mission was to operate the Weather Central at Hq JTF 3, where air and ground radex areas were forecast before each detonation (Reference 7, p. 1-9).

TU 3.4.5 (Weather) was responsible for manning and operating the four remote stations and JTF 3 Weather Central (Reference 7, p. 7). This task unit was formed at Tinker AFB, Oklahoma, and departed for the Pacific on 20 December 1950 (Reference 3, p. 113).

The four remote-island weather stations were occupied in early February by TU 3.4.5 detachments. Each remote island weather detachment was authorized one officer and eighteen airmen (Reference 63, p. 24). A permanent Navy station on Majuro and a Coast Guard station on Bikati assisted the detachments on these islands in setting up and operating. These island detachments used balloons (three per day) for upper air observations and monitored barometric pressure, wind speed, and wind direction at ground level.

JTF 3 Weather Central was manned by 12 officers and 18 enlisted men. Six officers and 12 enlisted men were from the Navy; the remainder were Air Force personnel from TU 3.4.5. There were two radex area plotting units, one with 12 personnel located with Weather Central at Enewetak and one located at Kwajalein. These two units were staffed by personnel from TU 3.4.5 (Reference 64, App. 14). Air and ground radex area plots predicting the movement of the cloud and accompanying fallout were made before H-hour. After H-hour, new plots were made at H+6 minutes, H+1, and H+6. Air radex areas were also plotted by altitude (Reference 27, p. 19). Weather Central had a full complement of communications equipment for collecting data, including radio, radioteletype, and facsimile receivers. Data were received from Tokyo; Townsville (Australia); Guam, Fiji, Wake, Ponape, Truk, and Yap islands; Washington, D.C.; and Hawaii (Reference 5, p. 7; Reference 29, Annex E). Tokyo, Washington, and Honolulu data included facsimile weather maps.

One of the Weather Central's more critical functions was weather briefings for interested JTF 3 organizations. These organizations included JTF 3 Radsafe, TG 3.1, TG 3.3, TG 3.4, TU 3.4.2, and the JTF 3 Staff Weather Officer (Reference 64, p. 11). Charts plotted and analyzed daily included (Reference 66, p. 11):

- Surface weather maps (2 per day)
- 700-mB (0.7 MPa) constant pressure charts (2 per day)
- Logs of 3-hourly surface weather at 18 stations
- Upper wind tabulations for 6 stations
- Wind-time section graphs for 4 stations
- Upper air soundings for 4 stations.

The Weather Reconnaissance Unit, TU 3.4.4 supported Weather Central with WB-29 flights to obtain current local weather information. Most of the unit left Tinker AFB, Oklahoma, on 3 February 1951 and arrived at Kwajalein on 9 February with aircraft, men, and equipment. The remainder arrived on 21 February (Reference 21, p. 6). By 1 March the unit was flying daily missions on predesignated routes called "gooney tracks." Eleven separate tracks averaged 1,500 to 2,000 nmi (2,780 to 3,706 km) each. Normally, Charlie track and George track were flown daily to the northeast and northwest, respectively. Most tracks were triangular; however, a few were rectangular. The average flight time for a track was 12 hours. Normally, on each track one AN/AMT-3 radiosonde was dropped to obtain weather data at lower altitudes. The unit flew 158 weather missions during GREENHOUSE; 7 in February, 48 in March, 56 in April, an 47 in May 1951 (Reference 67, Incl. 2). In addition to weather missions, it flew radioactive cloud tracking and sampling missions. Other aerial weather observations were obtained from TG 3.3's patrol squadron (VP-931).

Weather information allowed delineation of radex areas. Radex areas were determined by both TU 3.1.5 (surface radex) and TU 3.4.4 (air radex). Radex areas were usually defined as locations where significant fallout would occur within 6 hours after detonation.

Weather information was also valuable for other command-level decisions concerning the tests. Minimum cloud cover was desirable for the important photographic projects, and predictions of heavy cloud cover did cause shot postponements. Last-minute postponements were undesirable. One experimental program used small animals as test subjects. They were transported from Japtan to the shot islands anesthetized so they would remain motionless during the detonation. To return the animals because of a needless detonation delay could have resulted in their loss. Hence, accurate forecasts were important (Reference 5, p. 6).

Command Briefings

The decision to conduct a test shot was made during a series of command briefings beginning at H-30. Fallout exposure evaluation was critical to the shot/no-shot decisions. Evaluations were presented by a senior representative of the Radsafe Office. The radsafe briefing included:

- Forecast winds for H-hour, hodographs, and resultant wind diagrams. For each briefing, hodographs were constructed with the latest wind information at different altitudes in order to show the development of the wind pattern.
- Surface radex areas and long-range fallout plots. The surface radex area was drawn using the hodograph to forecast H-hour winds. A long-range (24-hour) fallout plot also was drawn to show its location relative to inhabited atolls and was presented in conjunction with the surface radex area.
- Seventy-two hour airborne particle trajectory forecast. The airborne particle trajectory forecast was used to evaluate contamination on air routes and to extend the surface radex area beyond H+6.
- Air radex area. The air radex area was plotted at Kwajalein, primarily for the benefit of the aircrews there. Since the air radex area normally did not affect the shot decision, it was not directly used at briefings unless requested.
- Radiation hazard outlooks. Specific potential problems evaluated at each briefing were:
  - -- Enewetak. The outlook was determined from the forecast hodograph on the shot atoll.
  - -- Inhabited atolls. Both the shot atoll hodograph and the long-range fallout plot were used to evaluate the outlook for these atolls.

-- Air routes through Wake and Kwajalein. The impact on the air routes was determined by the 72-hour airborne particle trajectory forecast and by the air radex area. The trajectories at 10,000, 20,000, and 30,000 feet (3.05, 6.1, and 9.14 km) were considered to have the major impact on these routes between H-hour and H+24.

-- Surface routes inside 500 nmi (927 km), or about one day of cloud travel. A display of all known transient shipping was presented in conjunction with the surface radex area and the long-range fallout plot.

-- Position of task force ships. Recommended positioning of surface ships was based on the surface radex area.

-- Cloud-tracking plan. The plan was reviewed as necessary to adjust to changes in forecast wind patterns.

A general overall statement of favorability or unfavorability of the radsafe shot conditions summarized and concluded the radsafe briefing.

Radiation Protection Modifications

Special radiation protection measures were available to TG 3.4 cloud-tracking aircrews. The JTF 3 Radsafe Officer stated that a vigorous effort should be made to develop abdominal shielding for crewmembers, since the physiological effects of radiation were greater in the abdomen than elsewhere. At a meeting with the radsafe officers, doctors from the Air Force and from the Armed Forces Special Weapons Project (AFSWP) recommended that 50 pounds (22.7 kg) of shielding per crewmember be used (Reference 68). Whether the shielding was available by the beginning of the series is uncertain.

Pilots flying toward the cloud were issued 4.0 neutral density goggles to prevent temporary flashblindness. Other radsafe clothing allotments to cloud trackers included rubber gloves, booties, and special filtering equipment. The individuals who changed the filters aboard were also required to wear special respirators. Aircraft crewmembers were required to breathe 100-percent oxygen during and after sampling missions to reduce the possibility of inhaling radioactive particles.

In 1951, Navy ships were not equipped with washdown system such as those used in later test series. Instead, Navy ships participating in nuclear tests relied on firefighting-system hoses. Each ship participated in an atomic defense inspection at Enewetak. The inspection included a drill to simulate actions to be taken if the ship encountered radioactivity. During training drills, inspectors uncovered some minor problems that were readily corrected. When ships actually encountered fallout, they were prepared to handle it (Reference 42).

Washing down ships during fallout naturally exposed some personnel to radioactivity. Personnel were required to hose down and, if necessary, scrub down exposed surfaces. Complete water-resistant decontamination outfits protected the damage control parties who had to work on contaminated sections of the ship. Decontamination suits consisted of waterproof and windproof rubberized cotton fabric (Navy foul weather gear), an anti-splash eyeshield, anti-splash gauntlets, rubber gloves, rubber boots or overshoes, a standard gas mask or respirator, and a film badge dosimeter. When possible, hosing was done from upwind to avoid spray drifting back on the workers (Reference 69, H).

Standard shipboard procedure when radioactivity was encountered was to shut off all ventilation systems and close appropriate hatches to prevent the entrance of radioactivity. Nonessential personnel went below to minimize the number exposed. However, the case of USS LST-859 disclosed a problem with this procedure. When the monitor realized that the ship was passing through radioactive fallout, all personnel were ordered below deck and the ship sealed, but it soon became evident that the ship's interior had become contaminated from personnel tracking radioactive particles. Cleaning interior spaces was a major problem. This problem was addressed by the commanding officer of Curtiss, who suggested decontamination areas at entrances to the ships to prevent the spread of fallout below deck.

CTG 3.3 recommended that ships in the future use a modified Condition Able setup. This setup requires closing all windward doors and hatches during fallout and leaving open all interior hatches not required for ordinary safe steaming. He reasoned that it was nearly impossible to close up a ship tightly for long periods of time in the tropics and still maintain below-deck efficiency. If enough time were available, gauze pads over critical ventilator intakes would allow limited ventilation below decks, improving the general situation, especially in engine rooms (Reference 16, p. B-17).

Evacuation

Light planes (L-5 and L-13) were used to survey uninhabited islands of the atoll 4 days, and again 3 days, before each scheduled shot. The islands north of Japtan were evacuated, and all task force personnel were mustered and accounted for 2 days before each shot (Reference 70, p. 8). Accountability for all transient aircraft crews was the responsibility of CTG 3.4. Accountability for all other transient personnel not specifically assigned to a group was Hq JTF 3's responsibility. On D-1, TG 3.1, as well as TG 3.2 and TG 3.3, were given specific duties in evacuating all personnel from the islands north of Japtan during the afternoon of the day before the shot. A second physical muster was required at 1900 on D-1. Periodic reports were to be made to CJTF 3 during these shot preparations.

Shot times varied from predawn to midmorning and all personnel were awakened at least 1 hour before each shot. Task force ships generally remained in the lagoon off Enewetak and Parry for the tests. The number of men evacuated from the camps in the northern islands was about 700 for shot GEORGE, and this may be typical of the magnitude of the normal preshot evacuation operations. These men were carried to the lower islands or to task force ships in LCMs and other small craft. In addition, 429 TG 3.4 personnel were evacuated by air from Enewetak to Kwajalein before shot GEORGE.

A plan for evacuation of the entire atoll existed for shot GEORGE. Two contingencies were planned for. One presumed limited fallout, requiring personnel to remain under cover unless they had essential duties outside. The second was for fallout sufficiently intense to require evacuation from Parry, Japtan, and Enewetak, except for communications and radiological crews at Enewetak. If an extreme emergency occurred, these personnel would have a helicopter and a C-47 at their disposal for evacuation to Kwajalein.

Ships to be used in case the evacuation became necessary and personnel assignments are listed in Table 8.

Table 8. Joint Task Force 3 evacuation assignments for GREENHOUSE, GEORGE.

Ship	Location	Unit	No. of Personnel
USS Curtiss (AV-4)	Parry	Headquarters	236
USS Curtiss (AV-4)	Parry	TG 3.1	857
USS Curtiss (AV-4)	Japtan	TG 3.1, TG 3.2	133
USNS Sgt. Charles E. Mower (T-AP-186)	Enewetak	Headquarters	60
USNS Sgt. Charles E. Mower (T-AP-186)	Enewetak	TG 3.1	118
USNS Sgt. Charles E. Mower (T-AP-186)	Enewetak	TG 3.2	500
USS Cabildo (LSD-16)	Enewetak	TG 3.2	751
USS-LST-859	Enewetak	TG 3.4	1,172

Source: Reference 71.

POSTEVENT SAFETY MEASURES

Reentry to the shot islands and the upper lagoon was controlled by a schedule that assumed, from experience at SANDSTONE and RANGER, that radioactivity on the shot island would be low enough to permit "quick reconnaissance parties landing . . . for short periods of time . . . to rescue . . . data . . . [also] that the surface RADEX could be lifted approximately one hour after H-hour" (Reference 5, p. 118). After the first two shots of the series a "new procedure was initiated . . . in that recovery operations were delayed until a radiological safety survey of the shot island was conducted" (Reference 38, p. 7). This survey began about 1-1/2 hours after the shot.

Parry Island was the postshot control center. Both Parry and Enewetak islands had decontamination facilities. Parties recovering scientific data soon after the shots operated from Navy craft in the lagoon until early radiological surveys determined that the atoll environment was safe enough to move data-recovery operations ashore.

Entry to and exit from radioactive areas was strictly controlled through radsafe checkpoints. All personnel entering moderately or highly radioactive areas were to be badged and accompanied by a radsafe monitor. Cumulative personnel exposure records were maintained at the checkpoints. Each center maintained current radiological situation maps of the atoll so the accompanying monitor could advise the party leader of allowable stay-time in any area.

Personnel traveling in a radioactive area were advised to wear radsafe protective clothing. The clothing had tight wrist and ankle closures and a tight neck closure as well if it did not cover the head (Reference 72, pp. 7 and 8). The chief function of the clothing was to prevent contamination of the skin, hair, and personal clothing, thus facilitating personnel decontamination. It also prevented personnel from inadvertently transporting and spreading radioactive particles to the base islands because it was left at decontamination stations. Particles less than 10 microns in size were viewed as constituting an inhalation hazard (Reference 62, p. 10). Personnel who anticipated working in an environment that might contain 10-micron or smaller particles were to wear respirators to minimize the inhalation hazard (Reference 32).

Cloud Tracking

Two B-50A aircraft operating out of Kwajalein were used to locate and track radioactive clouds.

The first B-50A took off from Kwajalein approximately 2 hours after each shot and located the radioactive cloud using airborne radiological detection instruments, since it was no longer visible. After finding it, a cloverleaf pattern was flown around the cloud. The cloud trackers headed into the radioactive area until the detection instruments indicated a limiting reading, after which the cloud tracker turned and flew out of the radioactive area. The series of successive inbound and outbound headings fixed the position of the radioactive area.

The second B-50A took off from Kwajalein approximately 24 hours after the detonation to continue tracking the cloud. If the cloud location was not known, its location was estimated from available meteorological information and an expanding area search was flown. Once radioactive traces were detected, the cloverleaf pattern was again flown. Cloud-tracking missions averaged 12 hours (Reference 20).

As an adjunct to cloud tracking, WB-29 aircraft were used to obtain air samples and make air conductivity observations for 36 hours after detonation. The WB-29s operated out of Kwajalein. One WB-29 orbited east of the detonation point at 5,000 feet (1.52 km) and after the detonation tracked the radioactive cloud and collected air samples for 12 hours.

Twelve hours after a detonation, two WB-29s took off from Kwajalein and flew a 600-nmi (1,112-km) north-south track along the Kwajalein meridian at altitudes varying from 5,000 to 30,000 feet (1.52 to 9.14 km). When the first two WB-29s landed two more took off and flew the same track, thereby observing a cloud for up to 36 hours after the detonation. These aircraft staged through Enewetak for initial decontamination before returning to Kwajalein (Reference 20, p. 18).

Cloud Sampling

Cloud-sampling, sample recovery, and sample return were operations of critical importance for radsafe operations. Sampling was undertaken to obtain data needed for evaluation of nuclear explosions. Both gas samples and particle samples were obtained from the debris clouds. This cloud sampling relied heavily on unmanned, remotely controlled, drone aircraft operations.

Different kinds of planes were involved in sampling activity. Eight B-17 drones were used to penetrate the radioactive cloud to obtain readings and to make measurements and collect samples for the AEC. Manned WB-29s, B-50As, and B-50Ds tracked and sampled around the edges of the cloud in areas of relatively light radiation.

Airborne monitors and weather observers on the manned sampler aircraft normally were responsible for collecting various samples. Monitors were responsible for the aircrews' radiological safety. Normal procedure during sampling operations was for monitors to use the low scale on their GM counters during the flight. This allowed detection of low levels of radiation. For filter sampling missions, before the aircraft reached 2,000 feet (610 meters), two air filters were installed in the air filter device. The air filter on the right device was removed and replaced every 10 minutes and attached to its data sheet. Dust-proof respirators were issued to filter device operators not breathing 100-percent oxygen while changing filters. Contamination found on the heads and shoulders of operators indicated that particle fallout occurred during removal and replacement of filters. Personnel decontamination is discussed below.

Monitors continued to check the crewmembers' exposure to radioactivity while samples were being collected. Samplers were scheduled to fly for 12 hours or until the crew's radiation exposure to radiation approached 3.0 R. At the 3.0 R level, aircrews, regardless of the time they had been airborne, were ordered to curtail their sampling missions and return to Kwajalein. Both sets of air filters were removed just before the aircraft descended to 2,000 feet (610 meters), as the aircraft returned to base when the mission was over.

Sample-Recovery Techniques

Responsibility for removing and handling experimental equipment from drones rested solely with TG 3.1. Drone samples were removed as soon as the aircraft were parked. Removal time normally was not more than 5 to 10 minutes per drone. Figure 16 shows a motorized and shielded conveyance being used to remove one of the sampling devices from under the nose of a drone B-17. Figure 17 shows the filter being removed from the device by personnel with long-sleeves, gloves, and long-handled tools. Figure 18 shows the conveyance removing a sample of gaseous radioactive debris through a probe.

To minimize delay in analyzing the samples, TG 3.1 personnel packaged the samples immediately after removal from the various aircraft, and placed them aboard waiting C-54 aircraft at Enewetak. The radiological section monitored the B/31 bottles before shipment and posted intensity readings and safe distances (Reference 73). Samples were packaged to keep radiation readings below 1 R/hr, 1 foot from the container. The sample containers were placed in the aircraft such that no personnel would be exposed to more than 0.1 R/day (Reference 74). Project personnel served as radsafe monitors on sample-return flights. The radsafe monitors' advice concerning radiological safety and safe distances from the samples was final and binding on the courier. Further, all

Figure 16. Motorized, shielded conveyance used to remove sampling debris beneath nose of drone B-17, GREENHOUSE.

Figure 17. Filter being removed from sampling device by personnel wearing gloves and using long-handled tongs, GREENHOUSE.

Figure 18. Removing gas sample from B-17 drone on Enewetak during GREENHOUSE.

passengers aboard the aircraft were to be issued film badges that were submitted at the point of debarkation to a JTF 3 liaison officer. The badges were subsequently returned to CTU 3.1.5 (Reference 75).

Couriers were instructed to advise airfield commanders of the time-sensitive nature of the samples to ensure that the short-lived radionuclides arrived at appropriate laboratories (NRDL, Army Chemical Center [ACC], and LASL) as soon as possible (Reference 75).

Personnel Decontamination

TG 3.1.5 organized operations to protect personnel against the effects of radiological contamination by reducing the amounts of radioactive material carried into nonradioactive areas. Checkpoint personnel controlled all entries and exits, and directed personnel leaving radioactive areas to a decontamination center if required.

Personnel decontamination areas were established on Kwajalein Atoll (Figure 19), Enewetak Island, and aboard ships. The description of the personnel decontamination center at Kwajalein is the most detailed. Located near the aircraft runway, it included an instrument storage area, "hot" clothing removal areas, showers, a drying room, and a "clean" dressing room.

Flight crews would leave the aircraft on the advice of the airborne monitor, who estimated the extent of the contamination on the plane. The crewmen

Figure 19. Personnel decontamination area at Kwajalein, GREENHOUSE.

brought with them all radiological equipment, including film badges, instruments, and filters, which was collected. They then went to the showers where each was monitored. Personnel with readings well above background were decontaminated to background in the decontamination center and their clothing was held. The showers were planned to drain away from other areas. Similarly, the floors of any spot where contaminated individuals were likely to walk were painted to expedite removal of contaminants (Reference 76, Annex H, App. I). Personnel with lower readings were advised to air their clothing for 48 hours before its reuse.

The shower facilities accommodated 12 men at a time, approximately 50 men per day for up to 10 days after each detonation. If a man was contaminated, the preferred decontamination method was showering and shampooing. Each man was monitored in a drying room next to the showers. If he had decontaminated himself to a safe degree, he was given a towel. If he was not sufficiently decontaminated, he returned to the showers until he was.

A partition was installed to prevent contaminated personnel from needlessly tracking radioactivity into the general latrine facilities. It was near the contaminated clothing removal area, where personnel entered, had their clothing monitored, and discarded the clothing in large, covered cans.

All groundcrews were required to report to the decontamination shower center both before and after aircraft decontamination activities. On reporting they were issued protective work clothing including footwear covering (booties), fatigues, caps, and rubber gloves. They used the clean dressing room of the center to change into work clothing before attempting to decontaminate aircraft. On completion of decontamination operations, personnel were monitored on the spot. They then removed their protective outer clothing, gloves, and booties and put them into covered containers. They were then remonitored and sent to the personnel decontamination center if necessary. All contaminated personnel were monitored at the change house entrance, where they were told the extent of their contamination. They were also advised of where to dispose of clothing. Some items might require laundering, others permanent disposal. Other items, such as shoes, might be worn without laundering after natural decay lowered the amount of radioactivity. After personnel were monitored (clothed and unclothed) and personnel dosimeters were collected, they showered until decontaminated (Reference 77, Incl. V).

Personnel Contamination-Decontamination Form 441, used when Navy personnel were contaminated, recorded the extent of contamination on hair, armpits, hands, feet, body, crotch, and clothing. It also recorded the method and amount of time necessary to decontaminate the person. If repeated decontamination efforts were necessary, it explained why (such as lingering contamination on hair).

When a TG 3.4 radiological mission aircraft landed, it was parked adjacent to the radiological personnel decontamination center. The crewmembers immediately left the aircraft and were directed to the personnel monitoring center. The aircraft was quickly surveyed by the aircraft decontamination crew and towed away as soon as practicable to avoid increasing the background count in the personnel monitoring area. Personnel monitors noted that it was impossible to obtain actual beta-plus-gamma-intensity recordings when personnel were contaminated in excess of 0.005 R/hr, beta plus gamma.

Naval Vessel Decontamination

CTG 3.3 Op Plan 1-51 (Reference 69) prescribed the standard operating procedure for ship decontamination. It stated that:

- The topside of the ship was to be wetted before unavoidable exposure to radioactive particles in the fallout area to minimize the decontamination effort. The interior of the ship was to maintain its clean status by sealing the ship by closing appropriate hatches and ventilation fittings.
- If the ship required decontamination, damage control parties were to wear complete water-resistant decontamination outfits. Specific hosing techniques were to be used to control contaminated spray from hosing operations. If possible, hosing was to be done from upwind to minimize drifting back on crewmembers. If possible, objects were to be sprayed from 15 to 20 feet (4.6 to 6.1 meters) away. Water was to be directed to strike vertical surfaces at an angle of 30^{o} to 45^{o}. If a contaminated area were large, it was to be hosed down at a rate of 4 ft^2/min. In all cases, drainage was to be such that contaminated water flowed directly over the sides.
- If hosing was insufficient, the vessel was to be scrubbed.

- If exposed painted or metal surfaces of the ship remained contaminated after hosing and scrubbing, if practicable, surface contamination could be allowed to decay naturally. Contamination could be sealed in by repainting while it decayed to prescribed tolerances.

- Wooden surfaces, if contaminated, were to be decontaminated under general boat decontamination procedures. Like shipboard decontamination, the preferred method in decontaminating boats was prevention by wetting surfaces before exposure to radioactive particles. Boats, however, had a greater potential for retaining contamination. If the boat's interior became contaminated, it could be hosed down and the contaminants pumped over the side, but frequent use of this method would concentrate contaminants in the bilge pumps.

Ship commanders discovered, particularly as a result of actual fallout, that the recommendation they had received in CTG 3.3 Op Plan 1-51 to wet the topside of the ship before the detonation greatly reduced decontamination efforts.

Contamination inside the boats could be introduced by contaminated passengers, radioactive fallout, or seepage of contaminated water into the bilges. A particularly difficult source of shipboard decontamination was unpainted wood. If the contamination proved to be resistant to hosing, scrubbing, or scraping, a coat of varnish, shellac, or paint would contain radioactivity and seal the surface until radioactivity decayed to a permissible level.

Both ships and boats were expected to be decontaminated in the open sea, where drainage and dispersal of low-level contamination presented no problem (Reference 49, Annex H-II, pp. 3 and 4). Table 9 summarizes the effectiveness of ship and boat decontamination techniques in GREENHOUSE.

Equipment Decontamination

Decontamination of radioactive clothing was handled by the Army Quartermaster. Development of special monitoring instruments was found necessary to measure both initial degree of contamination and effectiveness of the decontamination process. Clothing collected from personnel working in radioactive areas was first monitored by this system, then washed using quartermaster laundry procedures. The clothing was then remonitored to determine the degree of contamination remaining. (In some cases, clothing could be decontaminated simply by airing it. In other cases, if clothing were too contaminated or threatened to overtax laundry facilities, it was disposed of in the ocean.)

Location of contamination on clothing was spotty. Radioactivity was generally found on cuffs, trouser legs, and pockets. A monitoring device that could be easily maneuvered to precisely measure contamination was desirable. Several instruments used for detection of contamination on clothing are compared in Table 10. Because contamination was spotty, it was difficult to assess the overall level of contamination an individual encountered (Reference 78, p. 201).

Table 9. Ship and boat decontamination effectiveness.

Vessel	Date	Hour	Highest Contamination[a] (R/hr)	Techniques[b]	Effectiveness (percent)
AVR-P-645	8 Apr	1045	0.010-0.022	FS, SB	50
	8 Apr	1445	0.006-0.012	FS, SB	75
	8 Apr	1800	0.005-0.008	FS, SB	87
	9 Apr	0900	0.0019-0.0037	FS, SB	95
	25 May	1530	0.002-0.0036	FS, SB	87
	25 May	1700	0.020-0.047	FS, SB	--
	26 May	0800	0.014-0.042	FS, SB	30
	26 May	0930	0.008-0.022	FS, SB	50
	26 May	1100	0.008-0.016	FS, SB	60
AVR-20987	8 Apr	1230	0.012-0.050	FS	85
	9 Apr	1230	0.002	FS	98
	21 Apr	0828	0.002-1.000	FS, SB	96
	9 May	1520	0.044		96
	9 May	1800	0.005		99
	25 May	0717	NA		NA
	25 May	1330	0.005-0.016	FS, SB	10
AVR-20967	25 May	1530	0.012-0.021	FS, SB	--
	26 May	1000	0.003-0.007	FS, SB	75
AVR-26656	8 Apr	1400	0.040	FS, SB	75
	9 Apr	1500	0.0021-0.0042	FS, SB	93
	10 Apr	0800	0.0007-0.0018	FS, SB	98
	21 Apr	0737	0.210	FS, SB	50
	21 Apr	1300	0.012-0.060	FS, SB	95
	22 Apr	1200	0.038	FS, SB	98
	25 May	0800	0.009-0.020	FS, SB	
	25 May	1010	0.010-0.020	FS, SB	20
	25 May	1300	0.0013-0.004	FS, SB	92
	26 May	0952	0-0.019	FS, SB	50
<u>USS Cabildo</u> (LSD-16)	8 Apr	1300	0.002-0.026	FS, SB	70
	8 Apr	1800	0.002-0.021	FS, SB	70
	9 Apr	0400	0.002-0.018	FS, SB	90
	9 Apr	1030	0.0001-0.027	FS, SB	95
	9 Apr	1500	0.0005-0.010	FS, SB	96
	10 Apr	1000	0-0.010	FS, SB	98
	11 Apr	0900	0-0.0052	FS, SB	99
	20 Apr	1500	0-0.0003	FS, SB	100
	25 May	1400	0.002-0.023	FS	50
	25 May	1630	0.004-0.130	FS	--
	25 May	1900	0.004-0.135	FS	10
	25 May	2130	0.004-0.075	FS	50
	26 May	0415	0.004-0.050	FS	73
	26 May	0730	0.002-0.040	FS	85
	26 May	1700	0.001-0.022	FS, SB	97
LCM-9	8 Apr	1200	0.003-0.009	FS	95

(continued)

Table 9. Ship and boat decontamination effectiveness (continued).

Vessel	Date	Hour	Highest Contamination[a] (R/hr)	Techniques[b]	Effectiveness (percent)
LCM-10	8 Apr	1200	0.005-0.010	FS	95
LCM-18	21 Apr	1100	0.003-0.008	FS	96
LCM-20	8 Apr	1200	0.004-0.015	FS	95
LCM 23	21 Apr	1200	0.002-0.007	FS	97
LSU-1194	8 Apr	1710	0.008-0.028	FS, SB	70
	9 Apr	1000	0.001-0.009	FS, SB	92
	10 Apr	1000	0.008-0.028	FS, SB	98
	25 May	1135	0.006-0.033	FS, SB	10
	25 May	1730	0.040-0.090	FS, SB	--
	25 May	0730	0.007-0.040	FS, SB	80
LSU-1249	8 Apr	1808	0.0012-0.008	FS, SB	80
	9 Apr	1230	0.0001-0.0003	FS, SB	98
	21 Apr	1648	0.010-0.092	FS, SB	75
	21 Apr	1900	0.004-0.018	FS, SB	95
	22 Apr	1200	0.003	FS, SB	98
	25 May	1125	0.008-0.075	FS, SB	50
	25 May	1200	0.006-0.012	FS, SB	75
	25 May	1910	0.006-0.023	FS, SB	75
	26 May	0730	0.008-0.075	FS, SB	50
LSU-1345	8 Apr	1400	0.008-0.021	FS	0
	8 Apr	1600	0.005-0.018	FS	25
	9 Apr	0800	0.002-0.006	FS	80
	10 Apr	0800	0.0003-0.0012	FS	97
	11 May	1715	0.040-0.105	FS, D	100
	25 May	1158	0.0004-0.015	FS, SB	50
	25 May	1900	0.037-0.060	FS, SB	10
	26 May	0658	0.016-0.045	FS, SB	--
USS Sproston (DDE-577)	8 Apr	0630		S&W, FS	90
	21 Apr	0630		FS, D	33
USS Walker (DDE-517)	8 Apr	0745		FS	100
	26 May	0630		FS	95
USS Curtiss (AV-4)	8 Apr	1300		FS, SB, S&W	40-60
	25 May	1030		FS	75
USNS Charles E. Mower (T-AP-186)	8 Apr	0945		FS	50
USS LST-859	8 Apr	0649		FS, SB, D	85

Notes:

[a] Sources: References 79 through 94.

[b] FS -- Flush with saltwater; SB -- scrubbed with scrub brush; D -- departed fallout area; S&W -- soap and water.

Table 10. Comparison of laundry monitoring instrumentation.

Factor	AN/PDR-27A	Signal Corps Table-Top System	Chemical Corps Suitcase System
Sensitivity (low-level contamination)		Poor at moderate backgrounds	Can detect in moderate background
Sensitivity (high-level contamination)	Limited to 0.0005 and 0.005 R/hr scales	Rate-meter upper limit insufficient; good with scaler; has linear characteristics	Good with scaler, although counting-rate-true intensity relation becomes nonlinear
Operation with background contamination	Impossible with background greater than 0.005 R/hr	Good at low background only; no operation at fallout background	Good for low and moderate backgrounds; no operation at fallout background
Rate response	Too slow	Rate meter satisfactory	Limited to minimum scaler count time
Geometry	Single detector; varies with position	Very good; counting rate independent of clothing position within 10 percent	Poor; very critical to clothing position
Geiger-tube operation	No trouble reported	Poor; frequent tube failures	Poor; frequent tube failures
Electronic-circuit performance	No trouble reported	Humidity causes high-voltage-circuit breakdowns on rate meters, scalers, and Geiger-tube connections	Humidity causes high-voltage breakdown of scaler; vacuum-tube failures frequent
Contamination problems	None	Decontamination by dusting top and tubes required after 20 garments; removal of paper covering on top effective in reducing contamination	Paper taped to top and bottom sections effective in eliminating contamination of parts and tubes; however, periodic replacement of paper was very time-consuming
Ease of operation	Small-area probe, slow meter-response time, and lack of a fixed geometry made monitoring laborious and time-consuming	Principle of operation desirable for field use; recording and replacement time for a garment is 45 seconds using a 30-second scaler count; when used vertically with rate meter for sorting, time is 10 seconds	Operating technique not feasible for rapid field operation; folding of garments, proper placement on sections, and closing of lid time-consuming and laborious
Ruggedness	Very good	Very good, except for Geiger tubes	Poor
Comparative instrument readings taken 6 inches from sample (corrected for background)	0.0005 R/hr 0.001 R/hr 0.0018 R/hr 0.0023 R/hr 0.003 R/hr	23,000 CPM[a] 47,000 CPM 97,000 CPM 137,000 CPM No reading taken	130,000 CPM 270,000 CPM 441,000 CPM 455,000 CPM 537,000 CPM

Note:

[a]CPM = counts per minute.

Source: Reference 78.

Aircraft Decontamination

In addition to TG 3.4 cloud-tracking and sampler aircraft, P2Vs and drone aircraft required decontamination. Typically, drone aircraft were exposed to higher amounts of radioactivity than manned Navy and Air Force aircraft. Manned TG 3.4 aircraft were decontaminated at Kwajalein by TG 3.4 groundcrews. They were also responsible for decontaminating TG 3.3 VP-931 aircraft based at Kwajalein.

TU 3.4.4 constructed a personnel decontamination center and an aircraft decontamination area at Kwajalein. The hardstand site stored 2,400 gallons (9,084 liters) of freshwater for washing down the aircraft during decontamination. The aircraft decontamination area was 110 by 300 feet (33.4 by 91.4 meters), and was marked off with a double line of red and yellow and placards warning of radiological hazard.

Many subunits of TG 3.4 organized their own radsafe operations personnel. TU 3.4.2 had 20 monitors (12 ground supervisor monitors and 8 crewmembers trained as airborne monitors). The 12 ground monitors conducted aircraft and personnel decontamination operations. Twenty ground maintenance crews (five men each) decontaminated aircraft. TU 3.4.4 had one crewmember per aircrew who was trained for airborne monitoring. These monitors also supervised any decontamination operations required by their unit. In addition, the senior monitor performed additional duty as a staff radsafe officer for the unit. TU 3.4.4 ground maintenance crews also decontaminated their own aircraft. TU 3.4.6 had four persons qualified for airborne monitoring. Monitors supervised decontamination operations of detachments (Reference 70, H).

Typically, except following shot EASY, when an experimental cleaning technique was used, decontamination techniques closely followed those established during Operation SANDSTONE. The most common agents used in TG 3.4 decontamination operations were the water- and kerosene-soluble cleaning compound, "gunk," kerosene, laundry detergent, and freshwater. The solution used consisted of gunk and kerosene in a one-to-three ratio (25 gallons [94.6 liters] of gunk to 75 gallons [284 liters] of kerosene). About 1,200 gallons (4,542 liters) of water were required to rinse a B-17.

As the radioactive drones completed their landing rolls, a crew equipped with a tug and an extended towbar to separate the drones from the tug driver towed the drones to a restricted parking area (Figure 20). Radiological monitors then removed the radioactive samples and test equipment from the drones. If samples and equipment were sufficiently radioactive, samples were removed using long hooks (Figure 17). After all samples and test equipment had been removed from the drones, they were towed to the drone decontamination area.

With manned aircraft, once the radsafe monitor deemed it safe, the aircrew deplaned carrying instruments and equipment. If the aircraft was highly contaminated the crew left without the samples and equipment, but the goal was to retrieve material left aboard in less than 15 minutes.

Once the aircraft were in the decontamination area (Figure 21), the crews attempted to decontaminate them as safely and expeditiously as possible. The first step was to thoroughly flush the external surfaces with water under high

Figure 20. Drone B-17 being towed from runway following GREENHOUSE, GEORGE.

Figure 21. Aircraft decontamination area, Enewetak, GREENHOUSE.

pressure. This was done to remove as many radioactive particles in loose contact with the surface as possible. The aircraft were then monitored, and the time required to decontaminate them was estimated. If the aircrafts' radioactivity exceeded the MPL, they were flushed with gunk solution under high pressure. The cleaning solution was allowed to stand as long as possible without drying. The aircraft were then flushed again with water. Figure 22 shows a drone B-17 being washed down. The engine cowlings have been removed.

Following this, the aircraft were remonitored. Usually the first gunk treatment removed 50 percent of the contamination. If the radiation levels still exceeded the MPL, they would undergo the gunk treatment a second time. The second application usually removed another 12 percent. Further applications were deemed of negligible value.

When metal parts were contaminated and there was no danger of damaging a porous fabric, straight gunk proved effective. In contrast to flushing the aircraft with a gunk solution, additional applications of pure gunk were beneficial.

Initial contaminants sealed in by paint were treated with a solution of 5 pounds (2.27 kg) of lye, 5 pounds (2.27 kg) of boiler compound, 1 pound (0.45 kg) of cornstarch, and 10 gallons (37.9 liters) of water. This was applied to a painted surface using a wire brush and scraping to remove all paint. After the paint had been stripped and the surface thoroughly scrubbed with gunk and flushed with water, the aircraft was remonitored (Reference 7).

Figure 22. Drone B-17 being washed at Enewetak 2 days after GREENHOUSE, EASY.

The method of decontamination used for Operation RANGER was tried following shot EASY. RANGER personnel had indicated a high degree of success using 1 pound (0.45 kg) of trisodium phosphate (TSP) dissolved in 100 gallons (379 liters) of water. The solution was applied until decontamination was complete. For EASY, WB-29 #202 was decontaminated using the RANGER method. Two engines were flushed with TSP solution. After using 400 gallons (1,514 liters) of the solution, radioactivity dropped from 0.060 R/hr to about 0.050 R/hr. In contrast, the remaining two engines were treated with the 1:4 gunk-kerosene solution and rinsed with 200 gallons (757 liters) of freshwater. As a result, these engines read 0.030 R/hr (down from 0.060 R/hr). While the RANGER method had worked well in Nevada, it was abandoned because of the large amounts of water required.

Although WB-29 #202 had been subjected to two decontaminations at Enewetak before returning to Kwajalein, the readings remained high. Even after three washings of the aircraft engines and one of its skin, the engines still read 0.018 R/hr and could be reduced no further.

After the second shot, gunk-kerosene solution was applied using long-handled brushes for the initial decontamination instead of simply flushing the aircraft. It was generally conceded that this was very effective for loose parts like engine cowlings. For large-scale operations such as the entire aircraft, however, three to four times more manhours were used than flushing with gunk and kerosene and rinsing with freshwater.

During shot DOG, a decontamination crew consisted of six men and two equipment operators. Equipment used included one chemical decontamination truck, a steam jenny, a gunk machine, and aircraft-washing brushes. A number of solutions were used. During DOG, the decontamination truck was used primarily for rinse water. The steam jenny used a solution of 100 gallons (379 liters) of water mixed with 1 pound (0.45 kg) of TSP for the initial washing. While the method was effective, it was extremely slow. It was decided to continue use of the jenny in other tests, but not as the primary washing method. The gunk machine used a mixture of one part gunk to three parts kerosene for greasy or oily surfaces.

Heavily contaminated WB-29s required about 3,300 gallons (12,492 liters) of water each for decontamination, B-50s about 2,000 gallons (7,571 liters) each, and the P2V required 200 gallons (757 liters) of water. Lightly contaminated WB-29s required 1,100 gallons (4,164 liters). On the average, eight men per aircraft were involved in decontamination. The amount of time needed to decontaminate the aircraft had dropped by the second shot, in part due to experience gained, but also due to initially scrubbing aircraft with brushes.

Decontamination procedures used by TG 3.4 were generally very effective. Nevertheless, a complicating factor arose. While most decontamination measures reduced radioactivity to within permissible limits for personnel, radioactivity of some of the very sensitive debris-sampling equipment and filters still remained high. Standard decontamination methods could not lower the activity to the point desired.

An ion chamber was used to survey the planes before decontamination began. Decontamination crews used a GM counter (Victoreen model 263B) as the primary instrument for postdecontamination survey work. All decontamination crewmembers were issued booties, clean overalls, hats, and rubber gloves. Personnel operating spray equipment were also given clean goggles. In almost all cases, decontamination crewmembers accumulated contamination during the course of their work and required a trip through the personnel decontamination center.

After shot GEORGE, all aircraft were decontaminated with a mixture of four parts kerosene to one part gunk, with the exception of RB-29 #1762, which was partially washed with a mixture of water and TSP. WB-29 #2202 and RB-29 #1762 had been partially decontaminated at Enewetak before returning to Kwajalein. As usual at Kwajalein, the cowling was removed before washing. Considerable scrubbing was necessary on some parts of the cowling, particularly the movable vents around the circumference of the engine, which had strips of rubber attached, to remove the major portion of the contamination. Highest concentrations of radioactive materials invariably were found on engines, with above-average intensities on deicer boots, turrets (on the RB-29), and on C-1 airfoils.

Carburetor airscreens were not normally touched during decontamination operations because of their inaccessibility. The unit did check carburetor air screens for radioactivity at the time of the next major inspection of the aircraft when the screens were normally removed for cleaning. Even though considerable periods of time elapsed between exposure of the aircraft and the next major inspection, contamination was invariably found on the screens at the time of removal after all other radioactivity had decayed.

In a memorandum dated 17 March 1951, CTG 3.3 (Navy) wrote that it was his understanding that TG 3.4 would furnish personnel and limited material decontamination facilities at Kwajalein. CTU 3.4.4 agreed to furnish personnel and aircraft decontamination facilities for both WB-29 and VP-931 aircraft when required. While the Kwajalein facility was ample and trained personnel were available, VP-931 personnel were to assist in decontamination efforts if necessary. CTU 3.4.4 however, did not want to land any of his planes at Enewetak, primarily because of maintenance requirements. Further, Enewetak decontamination facilities were set up largely to decontaminate drones. Because of this, the CTG 3.3 radsafe officer felt that as long as intensity inside any VP-931 aircraft did not exceed 0.004 R/hr above background, it should continue normal patrols and return to Kwajalein on completion. At Kwajalein it would be decontaminated if necessary, and the crew checked. Like other aircraft, VP-931 was routinely checked for contamination upon completing all patrols after shot day (Reference 96).

CTG 3.3 Op Plan 1-51, Appendix II to Annex H, included general aircraft decontamination procedures. In general, aircraft decontamination procedures for Navy aircraft were the same as for Air Force aircraft. However, the Op Plan did state that no aircraft or personnel would be permitted within 4 nmi (7.4 km) of the rising column or visible radioactive cloud unless specifically directed to do so for tactical reasons. TU 3.3.3 aircraft in the air at H-hour carried radsafe monitors to determine the length of time personnel flying in an air radex area could remain without exceeding prescribed or tactical tolerances. During shots, TU 3.3.3 aircraft at cruising altitude made background counts with survey meters and continuously monitored the course during flights in the vicinity of suspected zones of radioactive contamination. The plan called for each aircrew member to be issued a film badge that was to be worn throughout the flights for specific periods. When aircrews encountered sufficiently intense radioactivity, the monitor advised the aircraft commander who ordered the crew and passengers to wear standard Navy gas masks or respirators to prevent inhalation of airborne radioactive particles. Masks and respirators were to be worn until readings returned to normal and until the aircraft was flushed with clean air.

Standard operating procedure in the event an aircraft entered a highly radioactive airspace was to take evasive action by making a 180° turn and seeking a nonradioactive flight path.

At the end of any flights the first day after a shot, even though no radioactivity was reported by the aircraft commander, crews were held until an engine was monitored. If the engine showed radioactivity, the crew had to be monitored (Reference 69, Annex H).

Offsite Monitoring

Detonating a nuclear device posed the possibility of radioactive fallout exposure not only to persons in the vicinity of Enewetak Atoll but also on inhabited outlying islands. Surveys were conducted of neighboring atolls. VP-931 had operational control of one Navy PBM-5A aircraft. The PBM was used, among other things, for post-test collection of water samples at Ujelang, Rongelap, Rongerik, Ailingae, Lae, Ujae, Wotho, and Ponape (Reference 49, Annex A). Only a small amount of documentation has been located that provides results of these offsite surveys. One survey made during the week of 7 to 14 May (after shot GEORGE) on Ujelang, Ponape, Bikini, Rongelap, Lae, Ujae, and Kwajalein showed no significant contamination. Water samples that were collected showed no significant activity (Reference 38, p. 7).

Program 7 (Long Range Detection) had three other projects that sought to collect device debris. One method of doing this was launching balloon-borne instruments at Johnston Island in the Pacific and Swan Island in the Caribbean 350 nmi (about 650 km) south of Cuba. In addition, debris was collected at ground level at seventeen stations by filter papers, rainwater (if possible), electrostatic precipitation, direct fallout, and roof-scrubbing. Finally, seven aircraft from Kwajalein, seven from Hickam AFB, Hawaii, and four from McClellan AFB, California, were equipped with instruments for instantaneous debris recovery encountered at great distances from the burst (Reference 5, p. 73).

CHAPTER 3

GREENHOUSE TEST OPERATIONS

After the extensive construction program had been completed and personnel assembled and rehearsed, actual test operations could begin. These were divided into three overlapping phases (Reference 5, p. 89).

The first phase began 3 days before the planned shot hour and lasted for 48 hours. During this phase aerial and surface surveillance of the Danger Area was intensified, and task force personnel were withdrawn from the camps near the shot islands and their whereabouts verified.

The second phase began at midnight the day before the shot and continued through shot day. During this period, the device assembly was finished and it was moved from the workshop aboard USS Curtiss (AV-4) and hoisted to the cab atop the shot tower. Experimental teams made final instrument adjustments and calibrations and experimental animals were placed at their exposure stations.

The third phase began with the first efforts to recover recorded data following the detonation and lasted through the days immediately following a shot. During this phase, the predominant activities were surveying shot sites and recovering data.

Although all four shots were weapon development experiments, the objectives, associated experiments, and required instrumentation for each were different. Shot EASY had associated with it an extensive Department of Defense (DOD) structures program, which involved building a number of test structures at various ranges from the shot point. This required the test to be on the largest of the upper islands, Enjebi, which had room for the placement of the structures. The nearby islet of Mijikadrek also allowed placement of structures at longer ranges for this program.

Construction for EASY, which began in 1950 and was over 75 percent completed by the end of that year, required the device to be predictably in the desired yield range. The EASY test array also meant that any tests occurring before EASY had to be at a range from Enjebi that would not disturb the structures. Therefore, shot DOG was fired on Runit, which is about as far (10 nmi [18.5 km]) from Enjebi as it is from Parry, the center of the base islands.

The time of day selected for each shot and its flexibility also was a function of the types of measurements planned. Shot time for DOG was fixed at 30 minutes before dawn. If, for some reason, it could not have been fired then, it would have had to be delayed for several days.

Shot EASY could have had one 15-minute delay if a rainshower appeared over Enjebi, but it would have had to be called before H-20 minutes to allow restarting the extensive test instrumentation; otherwise, the test would have had to be postponed for several days.

Shot GEORGE could have been held up until late afternoon (1730) of the shot day, but this would have had to be known at least 7 hours before the scheduled early morning time. If this condition could not have been met, the shot would have had to be delayed for at least 48 hours (Reference 5, p. 89).

For shot ITEM, the acceptable shot-time tolerances are not reported. The shot was not confirmed as even being in the schedule until 28 April 1951, although some preparations had been made for it, and it consequently had fewer experiments with exacting time requirements (Reference 5, p. 84).

SHOT DOG

Preparations

Months of effort, both in the United States and in the proving ground, including a rehearsal on 3 April 1951, brought Joint Task Force 3 (JTF 3) to the point where shot operations could formally begin. Following receipt of readiness reports from his four task group commanders and conferences with the scientific director and the weather forecasters, Commander JTF 3 (CJTF 3) initiated shot DOG operations at 0200 on 5 April 1951 (D-3) (Reference 97, p. 1). A 24-hour postponement was later approved by CJTF 3 and H-hour was changed from 7 April at 0634 to 8 April at 0634 because adverse weather resulting from typhoon George slowed instrument placement.

A number of important tasks still had to be performed before detonation could take place (Reference 20, p. 57; Reference 98, p. 16):

1. The area around the atoll had to be carefully patrolled to make sure no unauthorized ships or aircraft were present, both for their own safety and to restrict access to information on the U.S. nuclear program
2. All personnel and much equipment had to be evacuated from the northern islands of the atoll
3. The weather had to be monitored to detect any deterioration in conditions requiring postponement of the test
4. On the basis of the latest weather analysis, radiological exclusion (radex) area boundaries had to be established and fallout areas predicted for protection of all units and personnel
5. The device had to be moved from Curtiss and placed on the shot tower
6. Final preparations for the many experiments had to be made, including positioning of 49 aircraft and 1,170 mice.

P2V patrol planes from Navy Patrol Squadron 931 (VP-931), based on Kwajalein, searched for unauthorized vessels in the ocean around Enewetak Atoll beginning 1 March 1951. Until 3 April, two missions were flown each 24-hour period, using a single aircraft for each mission. Beginning on 3 April the number of missions was increased and two aircraft, a P2V-3W and a P2V-2, flew together on each mission. Shortly before 0800 on that day, they sighted an unidentified vessel bearing 231°T, 76 nmi (141 km) from Enewetak Island. Apparently it was directed out of the area. The maximum number of missions planned for a 24-hour period was five on 7 April, the day before the test. For DOG D-day, 8 April, four missions were planned, two before the detonation and two after. Three missions were planned for 9 April. Single-aircraft missions were reinstituted on 10 April (Reference 61, p. 11-2; Reference 16; Reference 99, pp. CII-I and CII-2; Reference 76).

To prevent unauthorized personnel from viewing the detonation or obtaining fallout samples, the atoll's uninhabited islands were periodically inspected. On 5 April, Task Group (TG) 3.4 liaison planes made a final air sweep of the uninhabited islands. The next day, military police from TG 3.2, in amphibious DUKWs from Task Unit (TU) 3.3.5, conducted a final ground sweep of these islands (Reference 97, p. 1).

A complete task force personnel muster was begun at 1900 on D-2. On 6 April, equipment was evacuated from Runit, and the island was declared an exclusion area that could be entered only by personnel on a special access list (Reference 97, p. 3). By midday on 7 April, all personnel left Runit, except those responsible for placing the nuclear device on the tower and arming it, plus a military police (MP) security group and Holmes & Narver, Inc. (H&N) maintenance men. Figure 23 shows the device being lifted to the cab atop the tower. Later the same day, all but a small group of MPs and H&N maintenance men were evacuated from Enjebi and Lowja (Reference 97, p. 5). On D-day at 0530, personnel were mustered on Parry.

At 1100 on D-1, all personnel were evacuated from the northern islands of the atoll aboard Curtiss, USNS Sgt. Charles E. Mower (T-AP-186), and USS LST-859. These ships anchored in the lagoon off Parry Island and awaited H-hour. All tents and aluminum buildings had been removed from Runit. Only the power plant, instrument stations, a tethered balloon of one experiment, and the shot tower remained on the island at shot time. Even construction debris and waste of every sort had been gathered and burned to avoid scattering by the explosion.

Several times each day WB-29s from TU 3.4.4 flew weather reconnaissance missions. Beginning at midnight on 4 April, the task force commander and his key staff members received weather briefings twice daily.

On the morning of 7 April, the surface radex forecast was issued. From the DOG surface zero, it extended outward for 25 nmi (46.3 km) between 245°T and 275°T, and was in effect until H-1 (Reference 16, p. B-3).

On D-day this radex area was replaced by more detailed ones:

- Ground-air composite radex areas -- surface to 15,000 feet (4.6 km) altitude, H+6, bearing from 235°T to 263°T, radial distance 76 nmi (141 km) minimum, 123 nmi (228 km) maximum (from surface-zero point)
- Air radex area -- 20,000 to 60,000 feet (6.1 to 18.3 km), H+6, bearing from 66°T clockwise to 131°T, radial distance55 nmi (102 km) minimum , 147 nmi (272 km) maximum

Figure 23. GREENHOUSE, DOG test device being hoisted in its tower.

- Ground-air composite radex areas -- surface to 60,000 feet (18.3 km), H+1, bearing from 73°T to 272°T, radial distance 21 nmi (38.9 km) maximum and 25 nmi (46.3 km) minimum (from surface zero).

Locations of the surface ships and the H+6 ground-air composite radex area are shown in Figure 24.

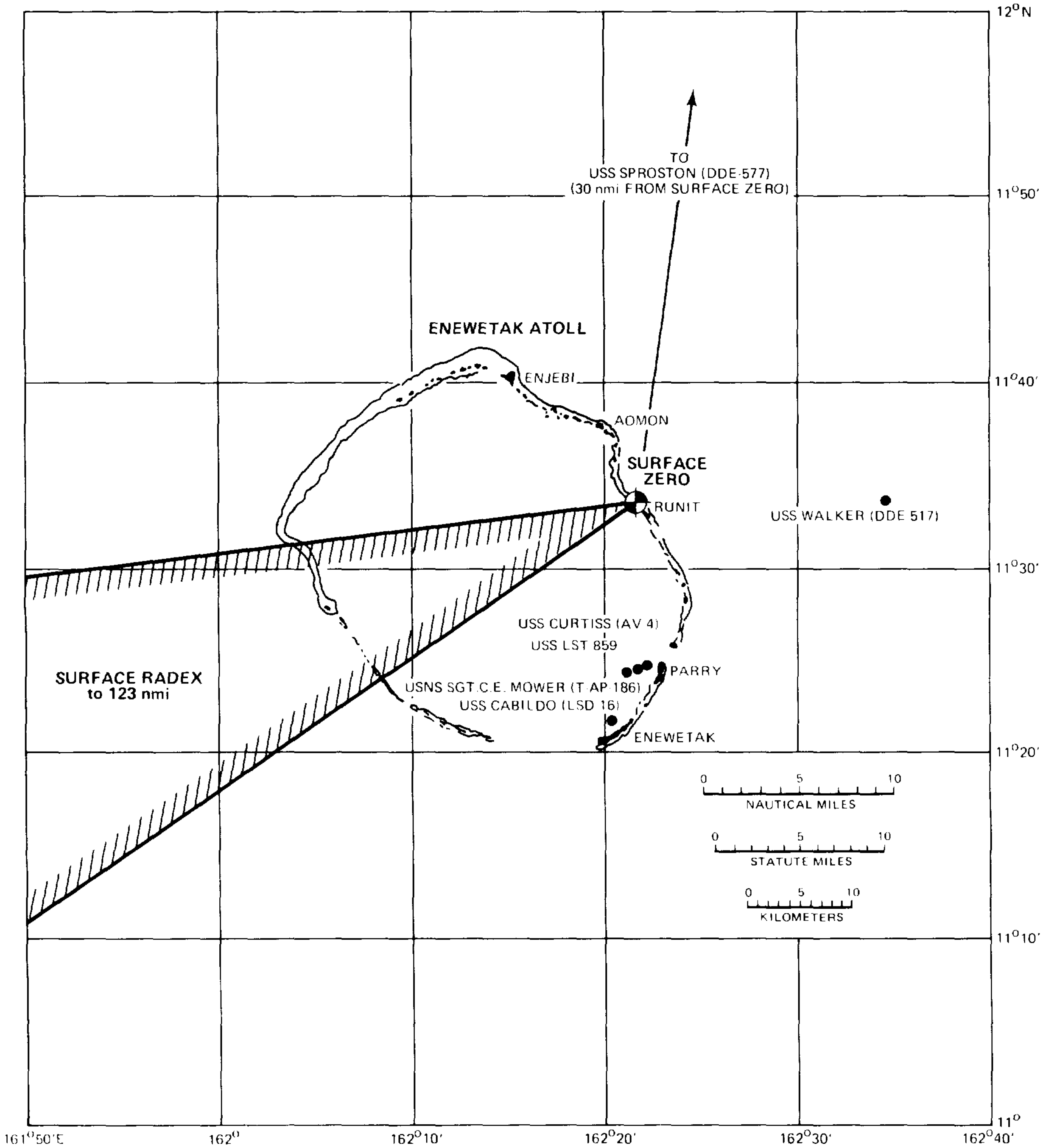

Figure 24. Radex area and ship locations during GREENHOUSE, DOG.

Experimental Activities

The test program for DOG included 57 experiments or projects conducted by TU 3.1.1, TU 3.1.2, and TU 3.1.3. Twenty-seven of these experiments measured device performance, airblast, and nuclear radiation output. A biomedical experiment used mice. Six experiments studied nuclear cloud physics, eight evaluated nuclear radiation instrumentation, nine studied surface blast effects, two were on test detection, and four experiments measured blast effects on aircraft. These experiments were based on instrumentation and test objects placed on the shot island, on surrounding islands, and on manned and radio-controlled drone aircraft. For many experiments, recovery of recorded data had potential for radiation exposure. These experimental projects and the part DOD organizations played in them are discussed in Chapter 4.

The Test

Weather conditions were not optimal due to an overcast sky and low cloud formations from approximately 4,000 to 8,000 feet (1.2 to 2.4 km) (Reference 16, p. B-2). The winds predicted from the surface to 20,000 feet (6.1 km) were from the east and east-northeast with velocities greater than 15 knots (28 km/hr). Above 20,000 feet (6.1 km), winds gradually shifted from north to west. Based on SANDSTONE experience, no fallout problem was foreseen (Reference 38, p. 5).

At 0634, on 8 April, the device was detonated at the north end of Runit atop the 300-foot (91.4-meter) tower. All ships, except USS Sproston (DDE-577), USS Walker (DDE-517), and USNS Lt. Robert Craig (T-AK-252) were anchored off Parry and Enewetak islands, with Curtiss closest to surface zero, bearing 354° to the shot point at a distance of 8.8 nmi (16.3 km). Sproston was on station bearing 187°T at a distance of 30 nmi (56 km) to surface zero. Walker was on station bearing 270°T 15 nmi (28 km) to surface zero. Craig was about 100 nmi (185 km) east of surface zero en route to Enewetak Atoll.

At Parry Island where a group of VIPs observed the shot from the Officer's Beach Club patio (Figure 25), the shock wave arrived about 45 seconds after

Figure 25. VIP visitors view GREENHOUSE, DOG from Officer's Beach Club Patio.

the explosion. At H+1 minute, B-17 drone aircraft began sampling runs through the radioactive cloud at various altitudes. At approximately 0730, the drones began landing, some having been aloft since about 0130. The drones and their controller planes were down by 0900. Cloud samples were transferred to special flights scheduled to return to various laboratories in the United States (Reference 16, p. B-3). In all, 32 aircraft took part in DOG. Their flight patterns are shown in Figure 26. One of the two QT-33 drone aircraft, used to measure blast and thermal effects, crashed at sea when control was lost.

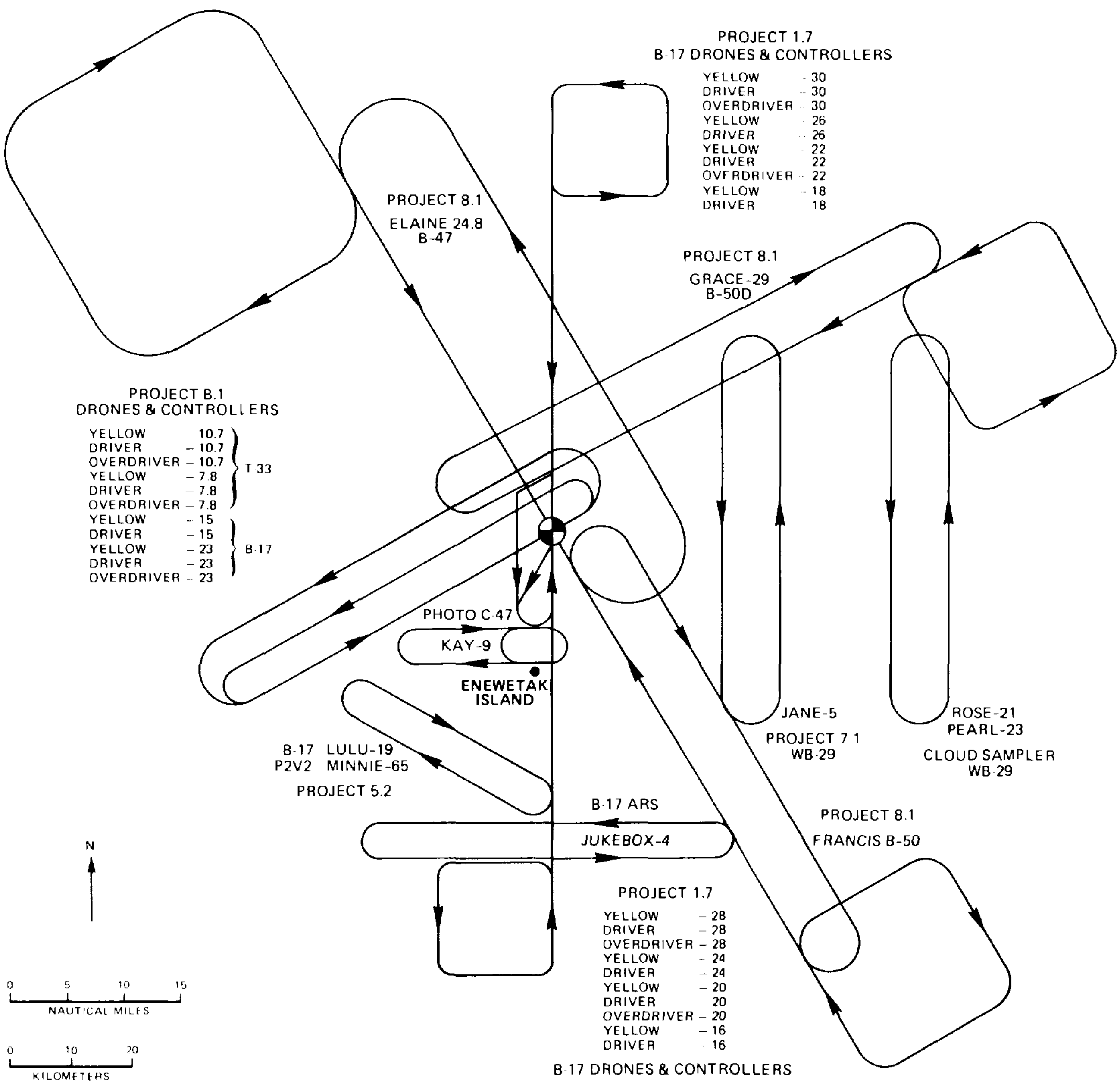

Figure 26. GREENHOUSE, DOG flight patterns (source: Reference 5).

At 0640 a helicopter and an L-5 took off from Parry to check for radioactivity on the northern part of the atoll (Reference 16, p. B-3). The helicopter also carried a radioman who was to reestablish communications between Parry and Runit. Communications were reestablished at 0706 (Reference 5, p. 118).

At 0700, a radsafe escort boat with a monitoring team departed for the Enjebi anchorage. By 0710 initial survey reports for TG 3.3 indicated negative readings. At 0810, after the surface radex requirement had been lifted, Mower and LST-859 proceeded to their assigned berths at Enjebi and Lojwa carrying construction personnel to complete work for shots EASY and GEORGE. At first it appeared that the expected patterns of radioactivity had been found. The shot site was intensely radioactive, but this decreased toward the southern end of the island. The other islands showed only slight radioactivity (Reference 5, p. 118).

By 0823, the senior monitor of the escort boat reported radiation levels ranging from 0.010 to 0.025 R/hr. At 0907, the escort boat was directed to return to Curtiss because the crew, monitors, and instruments had become contaminated. This contamination apparently came from radioactive lagoon water and airborne radioactivity. All pocket dosimeters indicated readings from 0.180 R to off-scale (0.2 R) when they returned by 1030. At the same time or shortly thereafter, Japtan, Parry, and Curtiss recorded fallout varying in intensity from 0.020 to 0.070 R/hr.

There was evidence of two distinct waves of fallout. The first occurred between 0900 and 1100 and the second between 1200 and 1400. Apparently the actual shot-time winds were somewhat different than predicted. Winds below 17,000 feet (5.2 km) altitude were from the east, but at higher altitudes were from the west. The lower winds moved the cloud west, but the upper winds brought it back a short time later (Reference 16, p. B2). All trips to the northern islands were cancelled except for small parties of monitors and scientists who continued reconnaissance in radioactive areas. Conditions began to approach normal by noon of 9 April (Reference 5, p. 118).

Table 11 indicates radiation intensities on the task force ships at various times and positions.

The average radiation intensity was probably low because of a continuous film of water flowing on all weather decks, washing the particles overboard and preventing a buildup of radiation (Reference 16, p. B-5).

At 1400, the following readings were reported from several ships (Reference 100, p. 2):

> Curtiss -- Maximum levels at belt height on horizontal surfaces 0.100 R/hr (topside readings ranged from 0.010 R/hr to 0.100 R/hr). Boat deck and fantail isolated with decontamination in progress.
>
> Cabildo -- From 0.010 to 0.040 R/hr topside.
>
> LST-859 -- At anchor (Lojwa), mean level 0.050 R/hr with a maximum of 0.380 R/hr. Most personnel exceeded 0.100 R/hr (maximum permissible exposure).

Table 11. GREENHOUSE, DOG D-day average radiation readings on ships.

Ship	Intensity (R/hr)	Time	Position
USS Walker (DDE-517)	0.010	1010	2,000 yards (1.83 km), 090° Runit
LSU-1345[a]	2.500	1010	1,000 yards (914 meters), 270° Runit
USS Curtiss (AV-4)	0.035	1010	Parry anchorage
USS Sproston (DDE-577)	0.005	1015	2,500 yards (2.29 km), southwest of Enewetak Island
USNS Sgt. Charles E. Mower (T-AP-186)	0.020	1215	Enjebi anchorage
USS Cabildo (LSD-16)	0.020	1315	Enewetak Island anchorage
USS LST-859	0.050	1328	Lojwa anchorage

Note:

[a]Reading taken over lagoon waters, not on the LSU.

Source: Reference 16, p. B-5.

Sproston -- Average 0.005 R/hr readings. Decontamination began at 1600.

Mower -- 0.010 to 0.040 R/hr and decontaminating.

A midafternoon (1500) survey of the islands was made; the results are given in Table 12. This table also shows the levels on successive days. The situation at Parry Island is shown in Figure 27. Intensity readings for Parry are not available for the DOG fallout period except for a few times and the available information (Figure 27) is in units of radioactive disintegrations counted per minute. How this relates to intensity units of roentgens per hour is not straightforward and Figure 27 is presented to show only the relative shape of the fallout buildup and decay with time. The radsafe organization reports that a survey at 1000 showed a few small areas of "relatively high activity (1 R/hr) [but] the island as a whole showed a rather uniform level of contamination" (Reference 38, p. 13). The fallout project reports 0.1 R/hr at 1410 and 0.018 R/hr 24 hours later (Reference 62, p. 7). The radiological situation at Runit for D+1 and D+2 is shown on Figure 28.

A D+1 ship radiation survey report indicated the following levels:

Curtiss -- 1130, all areas below 0.0125 R/hr except an isolated area on fantail at 0.025 R/hr

Walker -- 1208, 0.010 R/hr in spots only

Cabildo -- 1238, 0.005 R/hr average

Table 12. Radiation intensities (R/hr) on various islands following GREENHOUSE, DOG.

	8 April	9 April	10 April	11 April	12 April	13 April
Enewetak	0.025	0.007		0.002	0.002	0.001
Parry	0.060	0.015		0.006	0.005	0.003
Ananij	0.050	0.015	0.005	0.003	0.002	0.001
Enjebi	0.002	0.0002	0.0001	0.0001	0.00003	0.00003
Bokoluo	0.001	0.0002	0.0001	0.0001	0.00003	0.00003
Biken	0.400	0.180	0.080	0.045	0.030	0.024
Kidrenen	0.500	0.160	0.048	0.029	0.018	0.012
Ikuren	0.150	0.040	0.012	0.007	0.009	0.005

Source: Reference 38, p. 6.

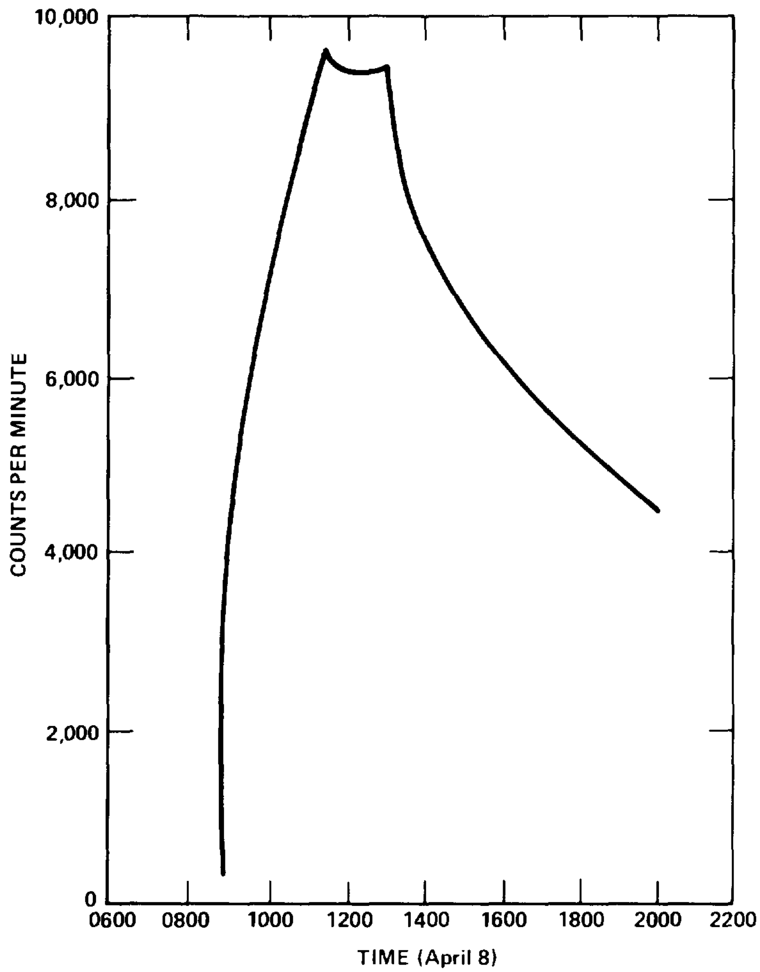

Figure 27. Parry Island radiation levels following GREENHOUSE, DOG (source: Reference 38).

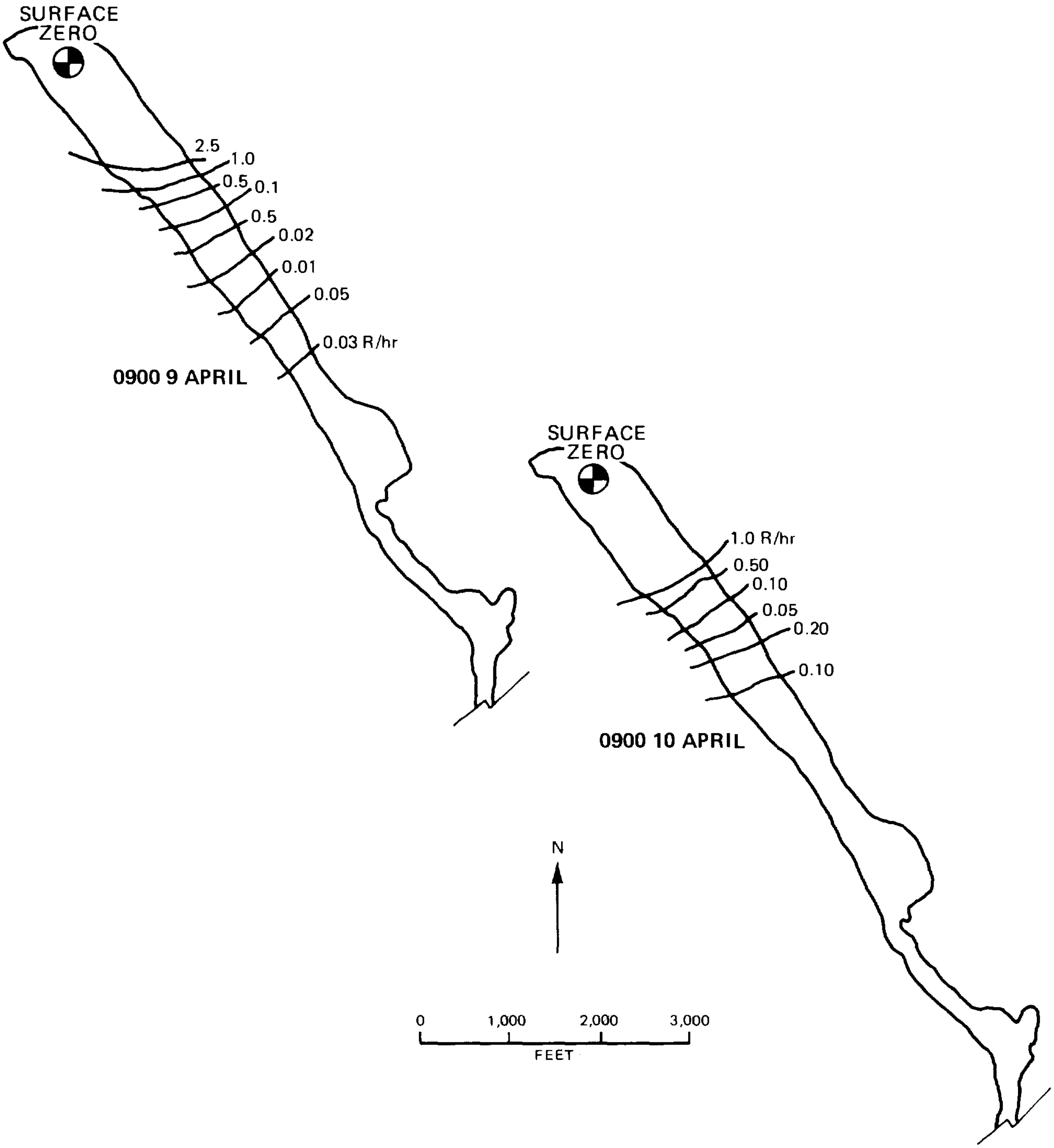

Figure 28. Runit Island radiological safety survey results following GREENHOUSE, DOG (source: Reference 38).

Mower -- 1330, 0.002 R/hr average

LST-859 -- 1757, all areas below 0.005 R/hr.

All other units and subunits showed barely significant levels at the close of D+1 (Reference 16, p. B-4-4).

Decontamination Activities

At 1415 on D-day all ships were directed to carry out thorough decontamination, and all personnel not required topside were directed to remain under cover with all doors and hatches closed. Contamination levels decreased rapidly toward the end of the day (Reference 16, p. B-4-6).

Two WB-29 aircrews required decontamination, as did the personnel who decontaminated the aircraft. Also requiring decontamination at Kwajalein were two B-50As of TU 3.4.4 and one Navy P2V patrol plane. Initial readings (R/hr) taken on these aircraft 12 hours after they landed and final readings after decontamination were (Reference 14):

	Initial	Final
WB-29	0.300	0.018
WB-29	0.150	0.010
B-50A	0.150	0.020
B-50A	0.150	0.018
P2V	0.040	0.005.

The ten QB-17 drones were heavily contaminated from flying through the radioactive cloud soon after the burst. Four days of decontamination effort were required before aircraft maintenance could be safely conducted.

Personnel Exposure

Information on activities of base-island personnel not directly involved with the tests is mixed. A GREENHOUSE radsafe monitor recalls that "non-test personnel" were "supposed to be confined to their quarters" (Reference 55), which would have had the effect of lowering their exposure. However, the former Radsafe Operations Officer is quite definite in his recollection that at a meeting held after DOG fallout began the Radsafe Task Unit (TU 3.1.5) decided that "there would be no disruption of living island routine," and personnel not on duty were not restricted in their activities (Reference 103). An attempt was made to estimate the maximum radiological exposure possible from DOG fallout. When fallout was detected, film badges were exposed outside of buildings on Parry; these were replaced daily and were supplemented by information from pocket dosimeters. Results are shown in Figure 29.

Badges were also issued to TU 3.1.5 personnel that were not to be worn on missions but only during activities on the base island. After 3 days and 10 hours the badges showed a mean exposure of 0.89 R, with a minimum of 0.56 R

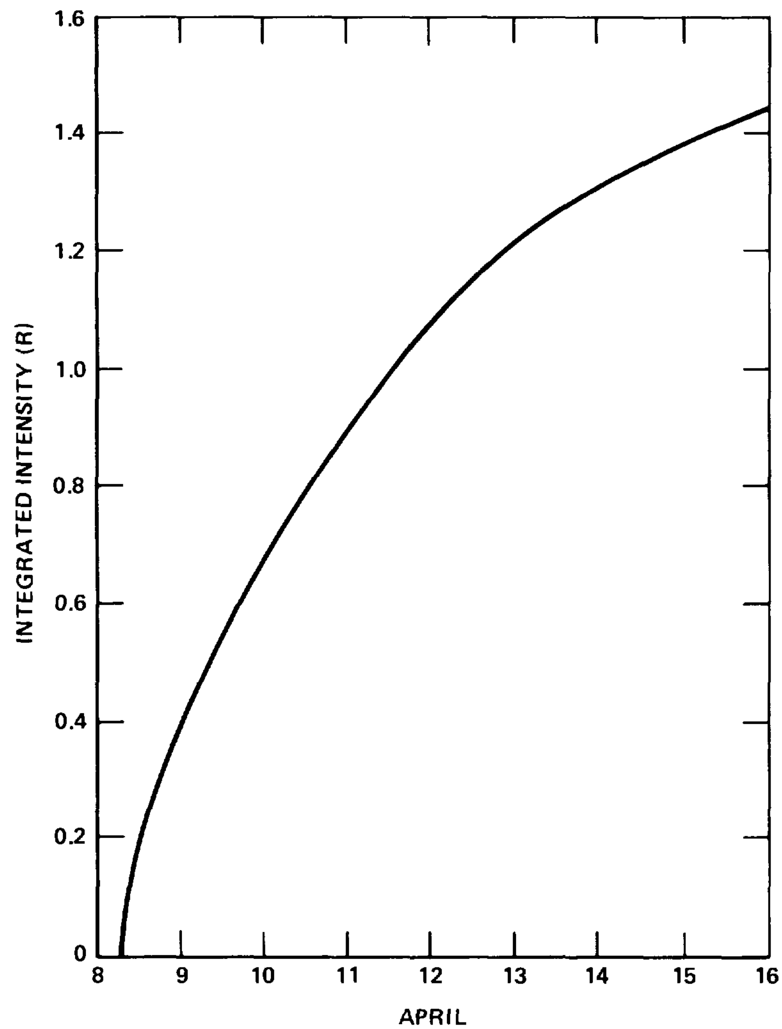

Figure 29. Estimate of maximum possible exposure at Parry Island following GREENHOUSE, DOG (source: Reference 38).

and a maximum of 1.4 R, versus the 1.19 R predicted in Figure 29. Badges worn by Japtan-based personnel during the same experiment showed a low of 0.825 R, a high of 1.6 R, and a mean of 1.04 R. The estimate made by the radsafe authorities who plotted Figure 29 was about 1.3 R for Japtan. The same authorities stated that the intensity on Enewetak was about two-thirds of that on Parry (Reference 38, p. 25).

Shipboard personnel would, of course, have had lower cumulative exposures because decontamination activities removed the radioactive particles from the ships, washing them overboard. Medical record entries indicated fallout doses ranging from 0.334 R on LST-859 to 1.1 R on USS Cabildo (LSD-16). Personnel in buildings were shielded by the buildings. Levels inside the buildings were observed to be one-third to one-half those outside (Reference 38, p. 25).

SHOT EASY

Preparations

A typhoon, which caused the postponement of DOG, also delayed EASY. A one-day rehearsal was held on 17 April. The rehearsal consisted of a modified partial aircraft schedule, one destroyer proceeding to shot station, and one boat evacuation trip scheduled for training. Previous midnight and noon briefings, 5 days before D-day, were eliminated. After receiving reports from all task groups indicating complete readiness on 17 April, CJTF 3 formally declared 21 April at 0627 as H-hour after favorable meteorological conditions developed. By 1800 on D-1, air and ground security sweeps of the atoll were completed with negative results. Scheduled weather conferences confirmed earlier forecasts of weather conditions at H-hour and no modification of the shot schedule was necessary (Reference 5, p. 121).

The first formal weather briefing was held on 20 April at H-3:25. Rainshower activity near Enjebi was of particular concern. Special air and surface weather reconnaissance determined that H-hour readjustments would be necessary. At H-25 minutes, all weather conditions seemed favorable and the original schedule was observed (Reference 5, p. 123).

Approximately 22 hours before H-hour, the TG 3.1 Arming Party had departed Parry for Enjebi Island to prepare for the detonation. The device was removed from Curtiss and taken to the tower. By 1430 on D-1, personnel were evacuated from Enjebi to Curtiss and Mower and personnel musters were completed at 2225. MPs made a final security sweep of the islands, and by 0300 on D-day they and the Arming Party departed for Parry. By 0430, the Arming Party returned to the control station on Parry (Reference 5, p. 125).

Debris from the lower levels of the detonation cloud stem (0 to 15,000 feet [4.6 km]) was predicted to fall in a surface radex area, with a drift sector of 200^{o}T to 260^{o}T and a radial distance 20 nmi (37 km). Significant fallout was also predicted for islands west of Enjebi, and possible fallout for Parry and Japtan islands.

Radex area and locations of the task force ships are shown in Figure 30.

Experimental Activities

The test program for EASY included 69 experiments or projects conducted by TU 3.1.1, TU 3.1.2, and TU 3.1.3. These repeated most, if not all, of the experiments conducted for DOG, but in addition the heavily instrumented experiments of the structural response program were included. These experiments involved full-size and scaled down structures built at various ranges from the shot tower on Enjebi. The nearby island of Mijikadrek also had test structures. Dridrilbwij, at greater range to the west, was used for lower-level blast testing of aircraft structures. Figures 31, 32, and 33 show various aspects of this test array.

Chapter 4 contains a detailed description of these projects, as well as a description of DOD participation in GREENHOUSE experimental programs.

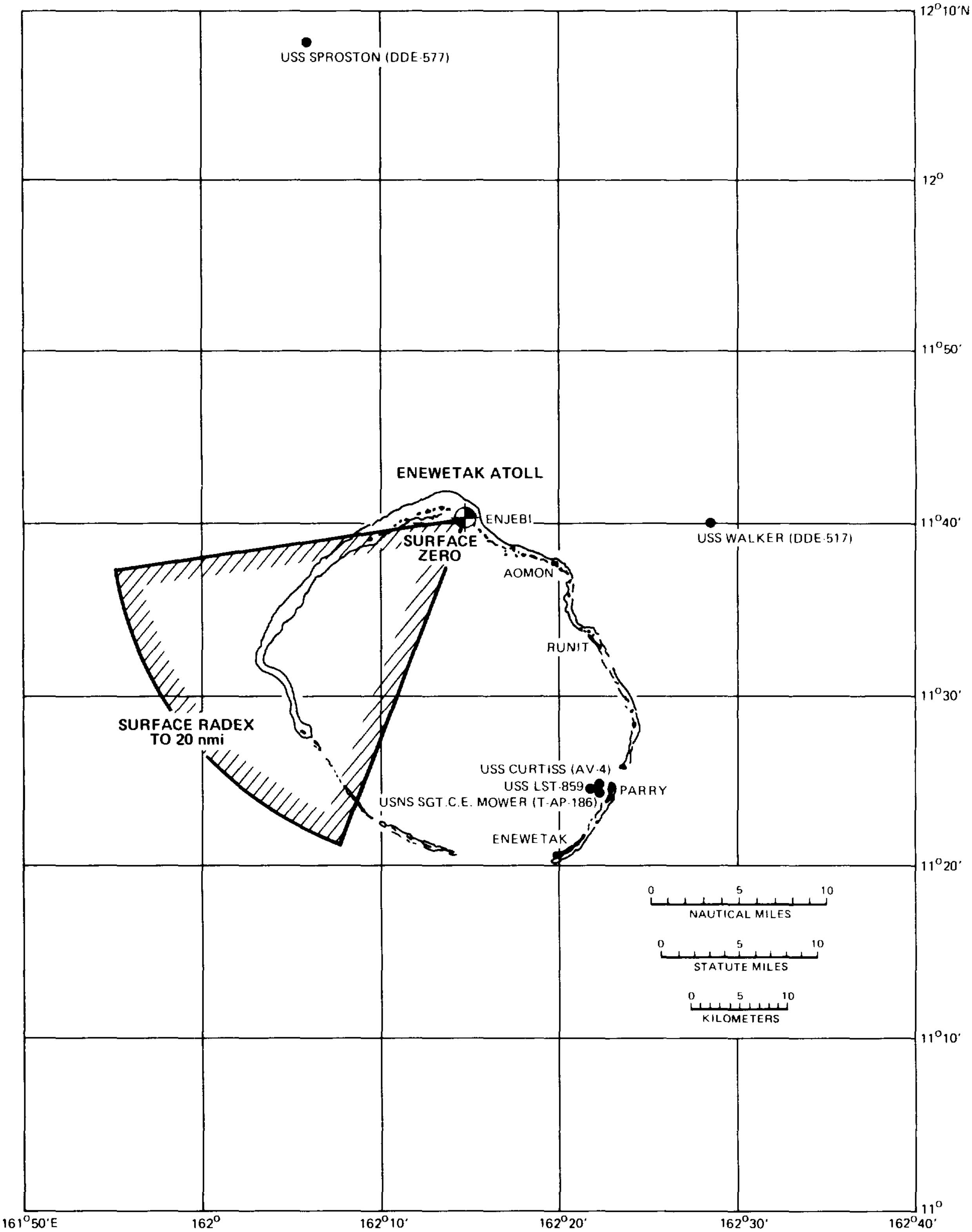

Figure 30. Surface radex areas and ship positions during GREENHOUSE, EASY.

Figure 31. View from GREENHOUSE, EASY shot tower looking southeast toward Program 3 military structures. Tents and other temporary structures are also shown.

Figure 32. Aerial view showing Program 3 test structures on islet of Mijikadrek in foreground and Enjebi with more test structures and GREENHOUSE, EASY tower in background.

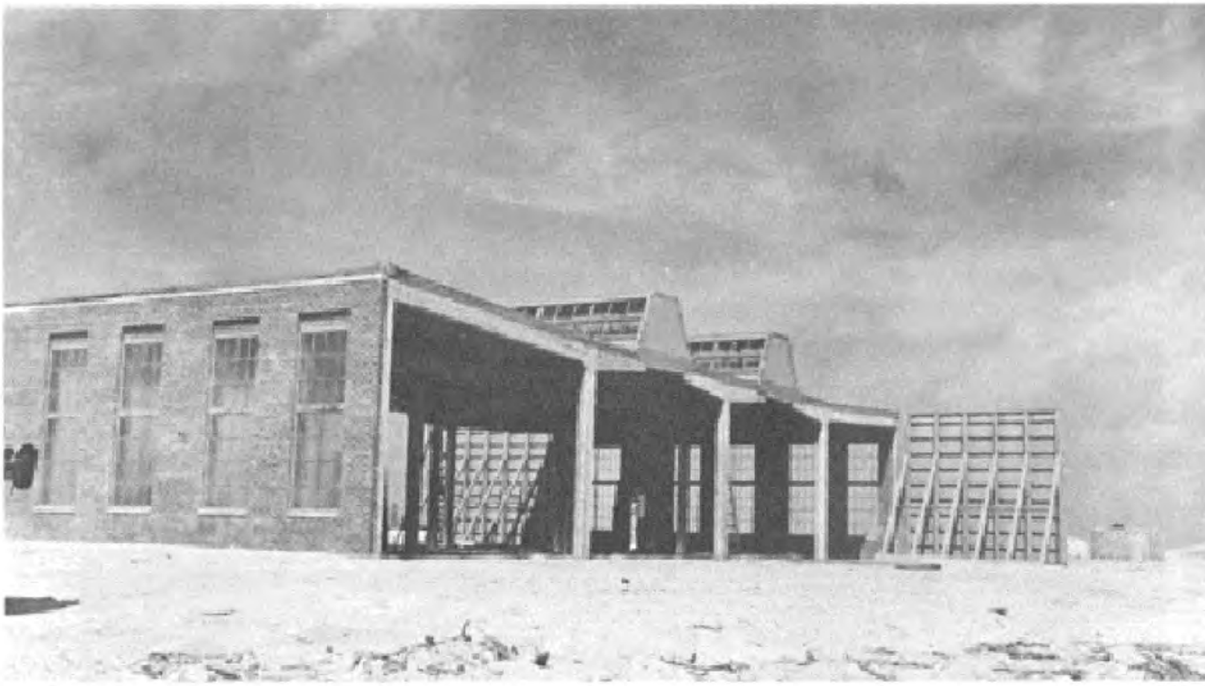

Figure 33. View of test structure on Mijikadrek, GREENHOUSE, EASY.

The Test

Because of instrumentation requirements for structures response, biological, and radiation experiments, the Scientific Director required that Enjebi Island be free of precipitation at shot time. Best weather conditions (little cloud precipitation) accompanied typical trade winds (westerly over northeasterly) and ideal fallout conditions existed with a southerly component in the winds aloft. Fortunately, all weather requirements were realized. The final forecast from 2300, 20 April, to 1000, 21 April, was (Reference 101, pp. 38 and 44):

- One-tenth to three-tenths cumulus base at 2,000 feet (0.6 km), at 3,500 feet (1.1 km), with a few tops to 5,000 feet (1.5 km)
- Five-tenths cirrus at 40,000 feet (12.2 km)
- No showers or precipitation
- Visibility 12 nmi (22 km)
- Surface winds from northeast, 12 to 18 knots (22 to 33 km/hr)
- A height of tropopause 53,000 feet (16.2 km).

Detonation occurred on 21 April at 0627 as planned, with a yield of 47 KT. Fallout was essentially as forecast; however, some light fallout reached inhabited islands. Some radiation was detected on Billae Island to the south. The top of the mushroom cloud reached 41,000 feet (12.5 km), the bottom 30,000 feet (9.1 km), with wind shearing the stem at approximately 15,000 feet (4.6

km). The cloud moved in an westerly direction. At approximately H+15 minutes, recovery groups departed Parry for reentry of Enjebi. By 0815 Project 1.5.2 recovery crews reached Enjebi Pier. The radsafe group reported 2 R/hr radiation readings at Enjebi Pier, and 30 R/hr at Bokoluo as of 0825. At 0830, the radiation level 400 yards (366 meters) from surface zero on Enjebi was 35 R/hr (Reference 71). Results of later surveys on D+1 through D+3 are shown in Figure 34. Radiation on the other islands is shown in Table 13 for 6 days following the shot.

Immediately after the detonation, drone aircraft started sampling missions. Two QT-33 drone aircraft, measuring blast and heat effects, were lost; one crashed into the sea and one crash-landed on Bokoluo. The QB-17 drones landed at Enewetak by 0925 (Reference 5, p. 127). Flight patterns during the test period are shown in Figure 35.

Experimental animals exposed on Enjebi had to be recovered on shot day. This was apparently finished by 1700. Preliminary damage surveys of the test structures on Enjebi were also done on shot day. However, detailed damage surveys were conducted for over 2 weeks following the test. During this post-test activity on Enjebi, H&N personnel watered the roadways and work areas to eliminate dust-borne radioactivity (Reference 5, p. 172).

Decontamination Activities

Sixteen crewmembers of the WB-29s were contaminated above background, with readings varying between 0.002 R/hr and 0.008 R/hr. Persons with readings of 0.005 R/hr or more were decontaminated and monitored again. Two TU 3.4.4 B-50As as well as two Navy P2Vs had to be decontaminated at Kwajalein. Initial and final readings (R/hr) of aircraft at Kwajalein were:

Aircraft	Initial	Final
WB-29	0.070	0.012
WB-29	0.065*	0.018
WB-29	0.015	0.012
B-50A	0.050	0.015
B-50A	0.080	0.015
P2V	0.020	0.010
P2V	0.040	0.012

The B-17 drones that penetrated the radioactive cloud shortly after detonation had gamma intensity readings on the aircraft in excess of 100 R/hr.

While on patrol at 2300 on EASY day, Sproston reported a 0.01275 R/hr reading on a bearing of 32°T, 25 nmi (46 km) from surface zero. The maximum

* This reading was taken 24 hours after the mission and after two decontamination washings at Enewetak. Other initial readings were taken 12 hours after missions were completed (Reference 54).

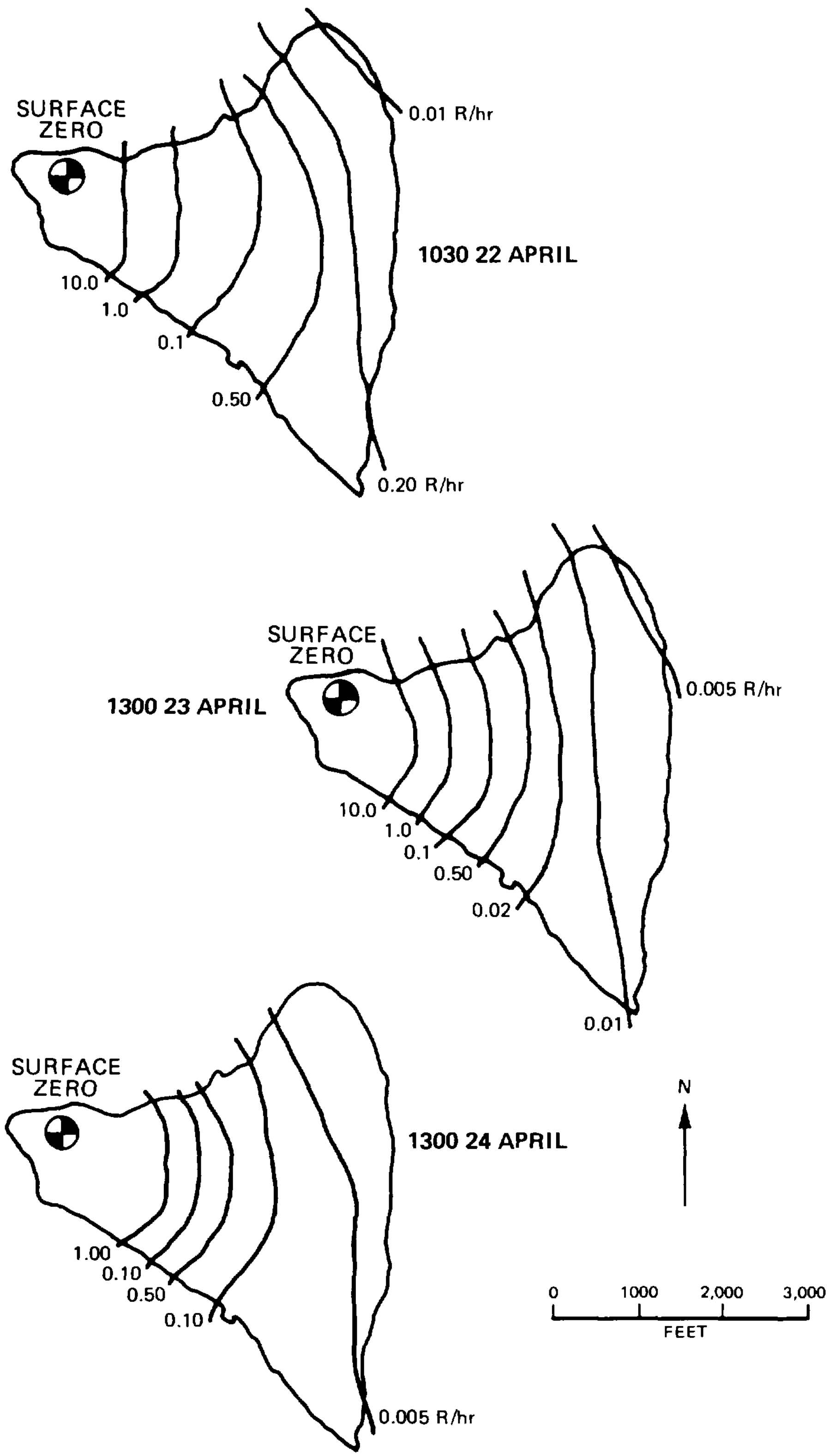

Figure 34. Enjebi Island radiological safety survey results following GREENHOUSE, EASY (source: Reference 38).

Table 13. Radiation intensities (R/hr) on various islands following GREENHOUSE, EASY.

	21 April	22 April	23 April	24 April	25 April	26 April	27 April
Enewetak	0.0005	0.0					
Parry	0.0005	0.0	0.0008	0.0006	0.0006		
Ananij	0.0005	0.001	0.001	0.0006	0.0005	0.0005	0.0005
Runit	0.00003	0.004	0.0028	0.0016	0.0011	0.0005	0.0005
Billae	0.001	0.029	0.015	0.007	0.003	0.001	0.002
Bijire	0.00005	0.040	0.020	0.012	0.007	0.005	0.004
Eleleron	0.00005	0.060	0.030	0.015	0.012		
Bokenelab	2.00	0.080	0.040	0.025	0.017	0.10	0.12
Kidrinen	1.00	0.050	0.028	0.014	0.010	0.006	0.007
Mijikadrek	1.10	0.032	0.018	0.010	0.006	0.001	0.003
Dridrilbwij	3.20	0.100	0.050	0.028	0.016	0.009	0.010
Bokombako	25.0		0.900	0.450	0.320	0.220	0.180
Bokoluo	32.0	1.00	0.900	0.600	0.350	0.200	0.150
Biken	0.001	0.0	0.0016				

Source: Reference 38, p. 6.

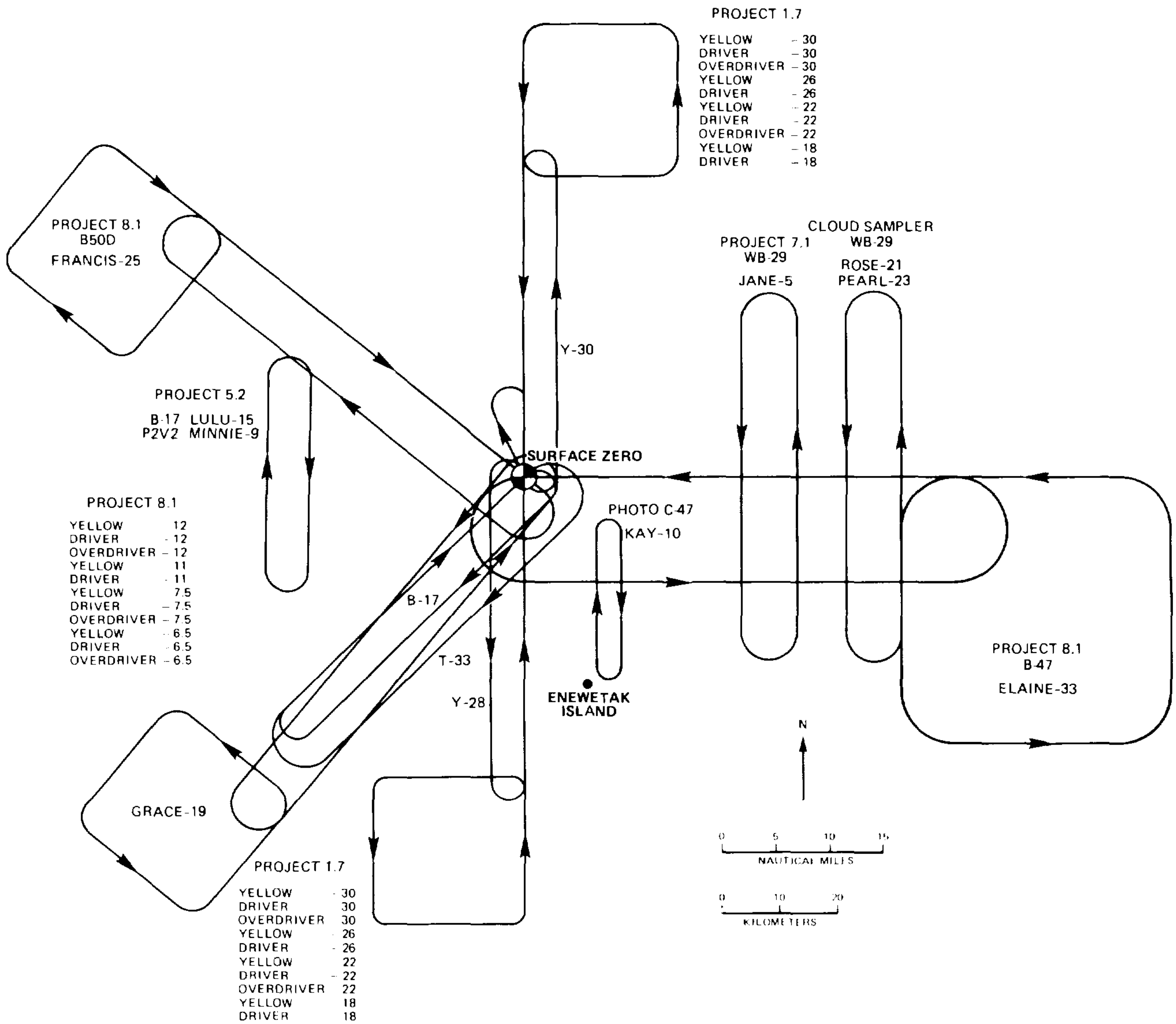

Figure 35. GREENHOUSE, EASY flight patterns (source: Reference 5).

contamination picked up by TG 3.3 units was that reported by AVR-20987 and LSU-1249 while in close proximity to Enjebi Island (Reference 17).

Personnel Exposure

One boat pool crew, consisting of four men operating from Cabildo, wore film badges that showed a cumulative beta exposure range of 12 to 32 R and a gamma range of 8.5 to 20 R. All other radiation intensity and cumulative exposure measurement methods, including readings from Geiger-Mueller counters and pocket dosimeters, failed to support exposures of the magnitude indicated by the boat crew's film badges. The four men were given complete radiological physical examinations with negative findings (Reference 16, p. B-9).

SHOT GEORGE

Preparations

A rehearsal on 5 May 1951 tested airborne and ground electronic equipment of TU 3.4.2. Aircraft from Kwajalein did not participate. TG 3.3 conducted an intensive air search and a simulated evacuation of MPs from Enjebi by the boat pool.

The first formal weather briefing was held at H-30, on 8 May. A tropical storm, north of Enewetak Atoll, was of great concern; however, favorable upper winds from the south were forecast and 12 hours later surface wind direction was 180° from the normal trade flow. These favorable winds, however, were usually accompanied by showers at Enewetak. Because of the desire to ensure that the cloud and any radioactive fallout be carried away from the populated islands of the atoll, it was decided to forego the usual requirements for minimum cloud cover to take advantage of the favorable upper wind direction for airborne detonation debris dispersal.

H-hour was postponed until 0930, a delay of 3 hours and 11 minutes from the original schedule to allow more daylight for drone aircraft operations to compensate for the probable cloud cover.

The third and fourth formal weather briefings were held at 2230 on 8 May and at 0145 on 9 May. Previous forecasts were reaffirmed. The greatest fallout was predicted for the northeast quadrant, clear of populated areas. Fallout was forecast in a 50-nmi (93-km) area, bearing 015°T to 085°T from surface zero. Delayed fallout was also predicted between 2 and 4 hours after detonation, which would cover the sector from surface zero between the same bearings at a radial distance up to 120 nmi (222 km).

The device was removed from Curtiss by 0615 on D-1. At 0800, the Firing Party began inspecting the control station on Parry, and after completing the inspection by 1040, the group departed for Eleleron, the shot island. Later in the afternoon Curtiss, LST-859, and Mower left their berths and anchored off Parry Island. A personnel muster was completed by 2310, with all personnel accounted for. Military personnel of TG 3.2 made a final sweep of the atoll and four P2Vs patrolled the danger area. Sproston and Walker patrolled the waters approximately 15 nmi (28 km) east of the shot island. On D-day, the firing party arrived at the control station by 0820 (Reference 5, pp. 135 through 142). Locations of the ships and radex area are shown in Figure 36.

Experimental Activities

The test program for GEORGE included 47 experiments or projects by TU 3.1.1, TU 3.1.2, and TU 3.1.3. The experiments were many of the same that had been conducted for shot DOG. Chapter 4 contains a detailed description of these projects, as well as a description of DOD participation in other portions of GREENHOUSE experimental programs.

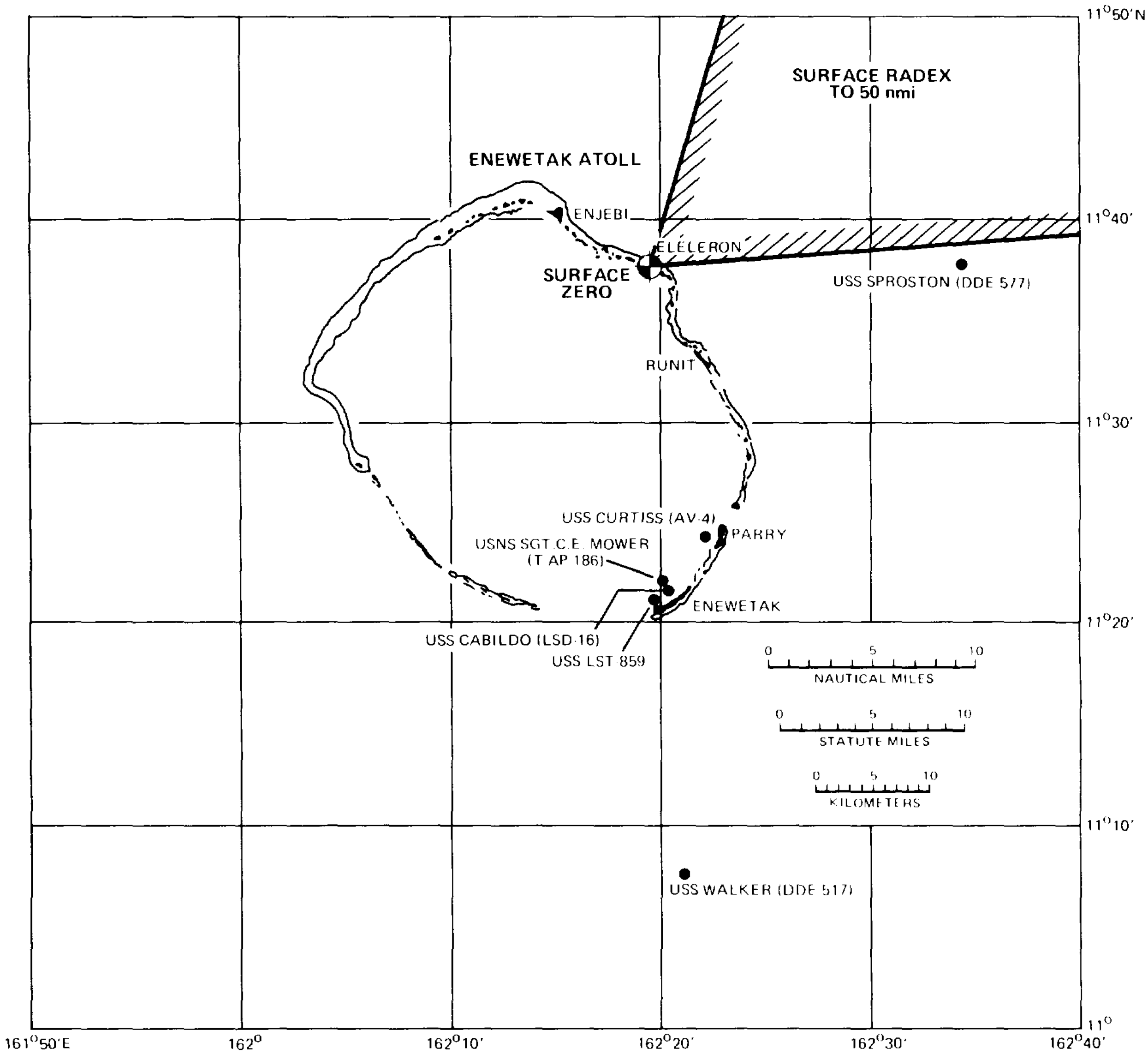

Figure 36. Surface radex area and ship positions during GREENHOUSE, GEORGE.

The Test

The expected yield of shot GEORGE demanded absolutely safe fallout conditions -- southerly winds aloft at all levels, the stronger the better. Typhoon Joan developed and moved as if it were part of the operation. Excellent local weather conditions prevailed with strong, southerly winds at all levels to 50,000 feet (15.2 km). Weather conditions from 0400 through 1200 on 9 May were (Reference 101, pp. 38 and 46):

Broken low clouds at 1,800 feet with broken to overcast middle clouds at 1,400 feet prevailed. After 0700 low and middle clouds became scattered and a high overcast was clearly visible. Light rain showers occurred after 0500. Visibility averaged 8 miles except in rain showers and then was reduced to 5 miles and 1 mile depending on the shower. The surface winds blew between south-southwest and west-southwest at 17 knots.

The detonation occurred on 9 May at 0930 as planned. The top of the mushroom cloud reached 56,000 feet (17.1 km), with a bottom of 41,000 feet (12.5 km). Wind conditions were ideal for the shot, eliminating any immediate downwind fallout on the atoll. No secondary fallout on the atoll occurred.

A new procedure was used for recovery operations. At 1120 a radiological survey helicopter took off to survey the islands in the vicinity of the shot island. By 1315, recovery operations were authorized and reentry hour was declared. All possible recovery operations on D-day were completed by 1745 (Reference 5, p. 140).

At H-hour, project aircraft began their missions. Figure 37 shows preshot and shot-time flight paths. The B-47 mission was cancelled at 0808 because of steady rain at Kwajalein and extensive shower activity in the local area. One B-50 (blast acceleration measurement aircraft at 33,000 feet [10.1 km]) navigational radar became inoperative en route to the target area from Kwajalein, and it flew to the target under guidance from ground-based radars. The aircraft lost one engine at H-30 minutes and landed at Enewetak. Control of a QT-33 drone was lost at 29,000 feet (8.8 km) and its mission was aborted before H-hour, although a successful landing was made after the detonation (Reference 102).

Decontamination Activities

Eighteen personnel from the WB-29s were contaminated beyond 0.020 R/hr. All were decontaminated and their clothing disposed of. Initial readings (R/hr) taken on these aircraft 12 hours after they landed and final readings after decontamination were:

	Initial	Final
WB-29	0.200	0.015
WB-29	0.250	0.090
WB-29	0.600	0.040.

Data for decontamination of the B-17 drones at Enewetak are not available. Figure 38 shows radiological survey results on the shot island and those nearby. Table 14 gives radiation levels throughout the atoll for nearly 2 weeks following the shot.

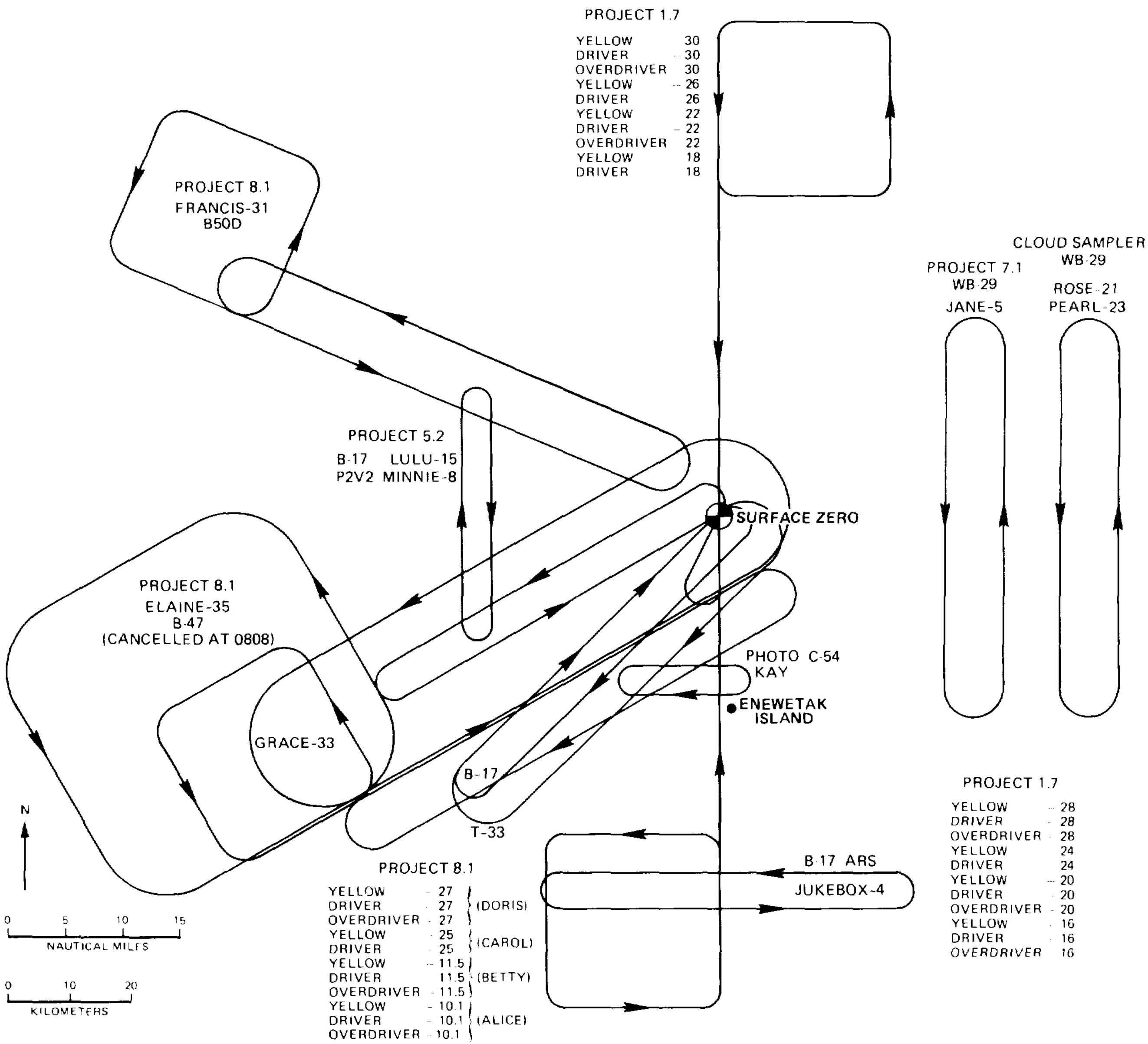

Figure 37. GREENHOUSE, GEORGE flight patterns (source: Reference 5).

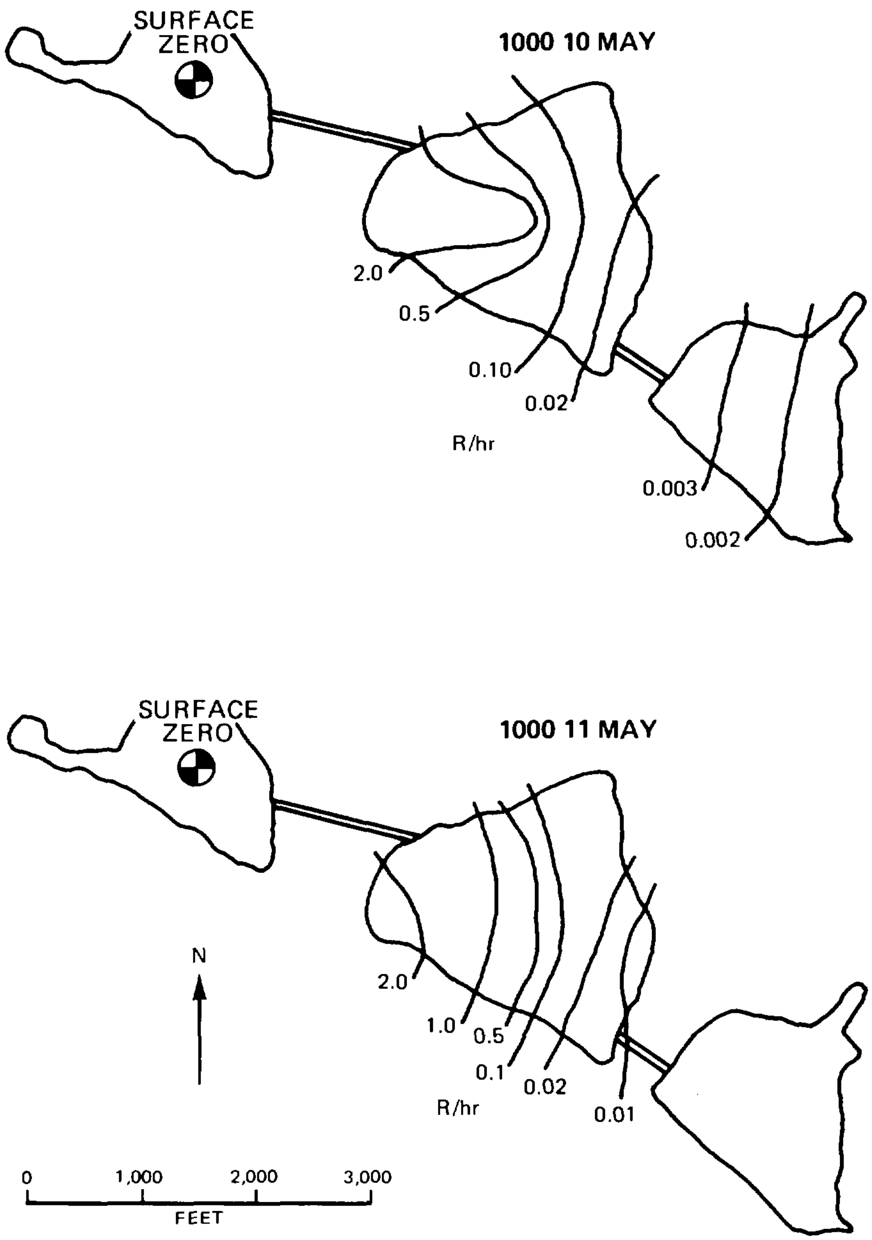

Figure 38. Eleleron, Aomon, and Bijire island radiological safety survey results following GREENHOUSE, GEORGE (source: Reference 38).

Table 14. Radiation intensities (R/hr) on various islands following GREENHOUSE, GEORGE.

	9 May	10 May	11 May	12 May	15 May	22 May
Ananij	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Runit	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Billae	0.00003	0.0003				0.0004
Bokenelab	0.0032	0.006				0.0001
Enjebi	0.0004	0.0004	0.0003	0.0003	0.0004	0.0004
Dridrilbwij	0.0024	0.010				0.001
Bokoluo	0.030	0.030	0.029	0.028	0.026	0.014
Kidrinen	0.001	0.001				0.0008
Ikuren	0.0004	0.0002				0.0003

Source: Reference 38, p. 9.

SHOT ITEM

Preparations

As soon as the radsafe monitors cleared Enjebi after shot EASY on 23 April, Mower moved into the anchorage to provide living quarters for H&N construction crews to erect the shot tower for ITEM. This arrangement lasted about 2 days since the radioactivity levels were low enough to set up a new construction camp within 1,100 yards (1 km) of the EASY surface zero (Reference 103). This job began before shot ITEM was actually approved for inclusion in the schedule by CJTF 3 on 28 April. The tower foundations and a run of coaxial cable that were expected to, and did, survive the EASY test were completed in March in anticipation of ITEM. The tower was completed on 16 May, 9 days before the scheduled detonation (Reference 3, p. 174).

Following receipt of readiness reports from the four task group commanders and conferences with his staff weather officer, CTG 3.1, for technical reasons, selected 0930 on 25 May 1951 as H-hour. A modified rehearsal was conducted on 20 May by the Weapon Assembly Team and Firing Party. TG 3.3 participation was reduced to intensified aerial searches (Reference 5, pp. 143 ff).

The first formal weather briefing was at 2330 on 23 May 1951, and normal trade winds were forecast. During the second formal weather briefing at 1205 on 24 May, it was decided that the upper winds were not as favorable for avoiding fallout as forecast. Due to the rapid deterioration of the weather, the weather officer suggested that H-hour be moved up to 0617, which was approved by CTG 3.1 and CJTF 3. The final weather briefing was 0002 on 25 May. Although the upper winds were changing, H-hour would not be affected (Reference 5, pp. 143 ff).

Meanwhile, the usual security precautions were continued on the atoll. TG 3.2 conducted land sweeps, TG 3.3 performed air and security searches, and TG 3.4 carried out air and radar searches. Negative reports were submitted on all searches.

The MP strength at the shot tower was doubled by 0600 on 23 May, and 30 minutes later the device was removed from Curtiss. The Arming Team command post was opened by 1125.

Curtiss and Mower were underway by 1400 on D-1 day to their stations off Parry Island. Enewetak air facilities were closed to transient aircraft at 1630, and at 1900 control of all intra-atoll movement of boats and aircraft was shifted to CJTF 3. By 1900 all TG 3.1 personnel from all islands north of Japtan, except Enjebi, were evacuated.

At 0315 on D-day the MPs, the Arming Team, and four H&N utility personnel were evacuated from the shot island by two AVRs. At 0445, the Firing Team took position and personnel began to gather along the beaches of the lagoon at 0605 to watch the detonation.

Fallout was forecast downwind in a sector 220°T to 280°T to a radial distance of 40 nmi (74 km), with the heaviest concentration from the upper levels southwest from surface zero. The surface radex area and locations of fleet units at burst time are shown in Figure 39.

Experimental Activities

The test program for ITEM included 19 experiments and projects by TU 3.1.1, TU 3.1.2, and TU 3.1.3. Most of the experimental projects were concerned with weapon development, although a few biomedical, cloud physics, and test detection experiments were included. Chapter 4 contains a detailed description of these experiments and a description of DOD participation in other portions of the GREENHOUSE experimental programs.

Because the drones in the blast effects program were not flown, the total number of aircraft was only 26, fewer than for the earlier shots. Flight patterns of the aircraft involved are shown in Figure 40. Control was lost on one QB-17 drone and it crashed at sea.

The Test

Special requirements for ITEM did not approach the stringent demands for the previous two shots. Very light fallout on inhabited islands was predicted (Reference 101, p. 38). However, as discussed below, significant fallout was received on all the inhabited islands.

Weather conditions from 0000 through 1000 on 25 May were as follows (Reference p. 12):

> Prevailing cloud cover was scattered low clouds at 1,800 feet with a few scattered middle clouds at 16,000 feet and scattered to broken high clouds about 30,000 feet. One light shower occurred at the start of the period, giving only a

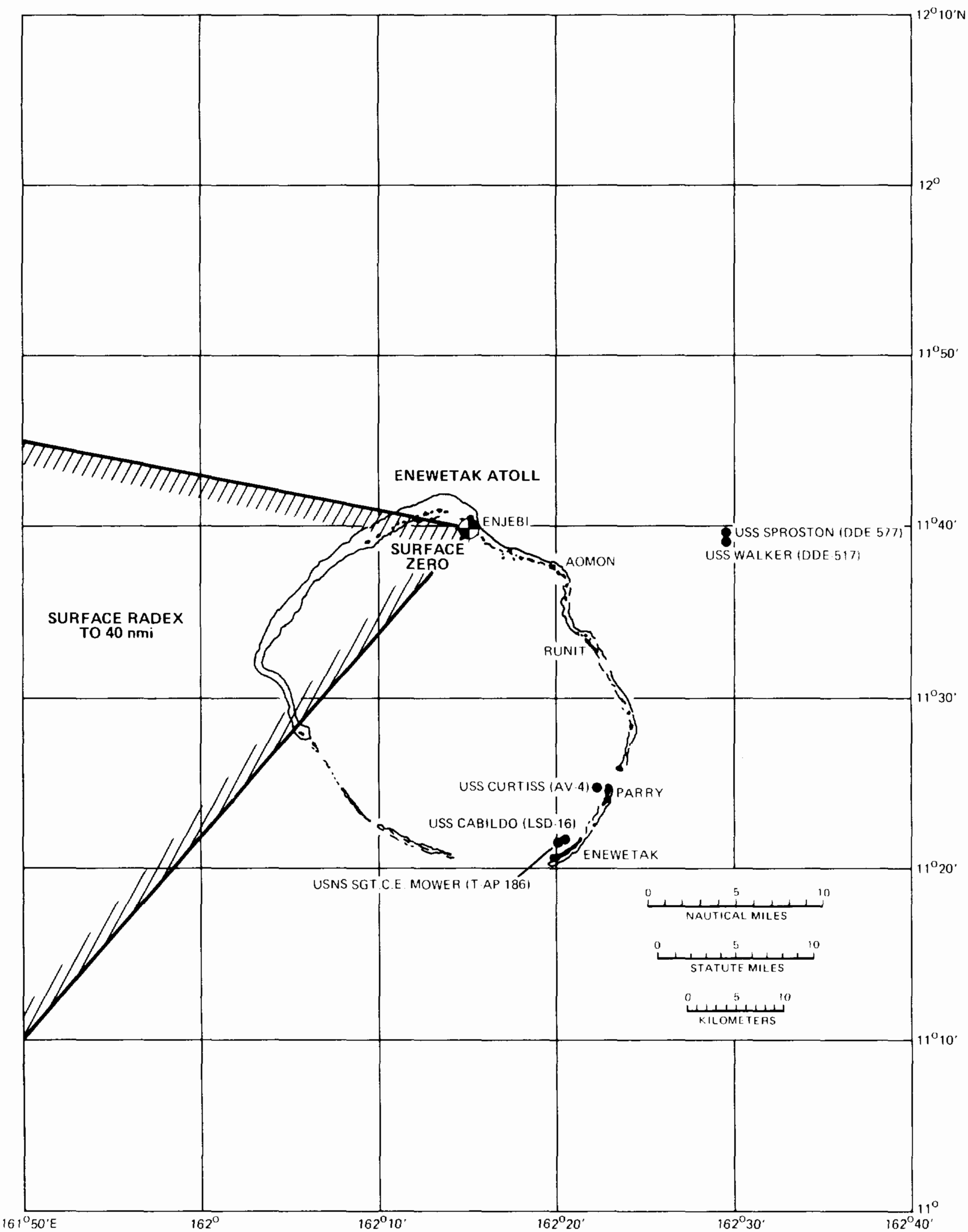

Figure 39. Surface radex area and ship positions during GREENHOUSE, ITEM.

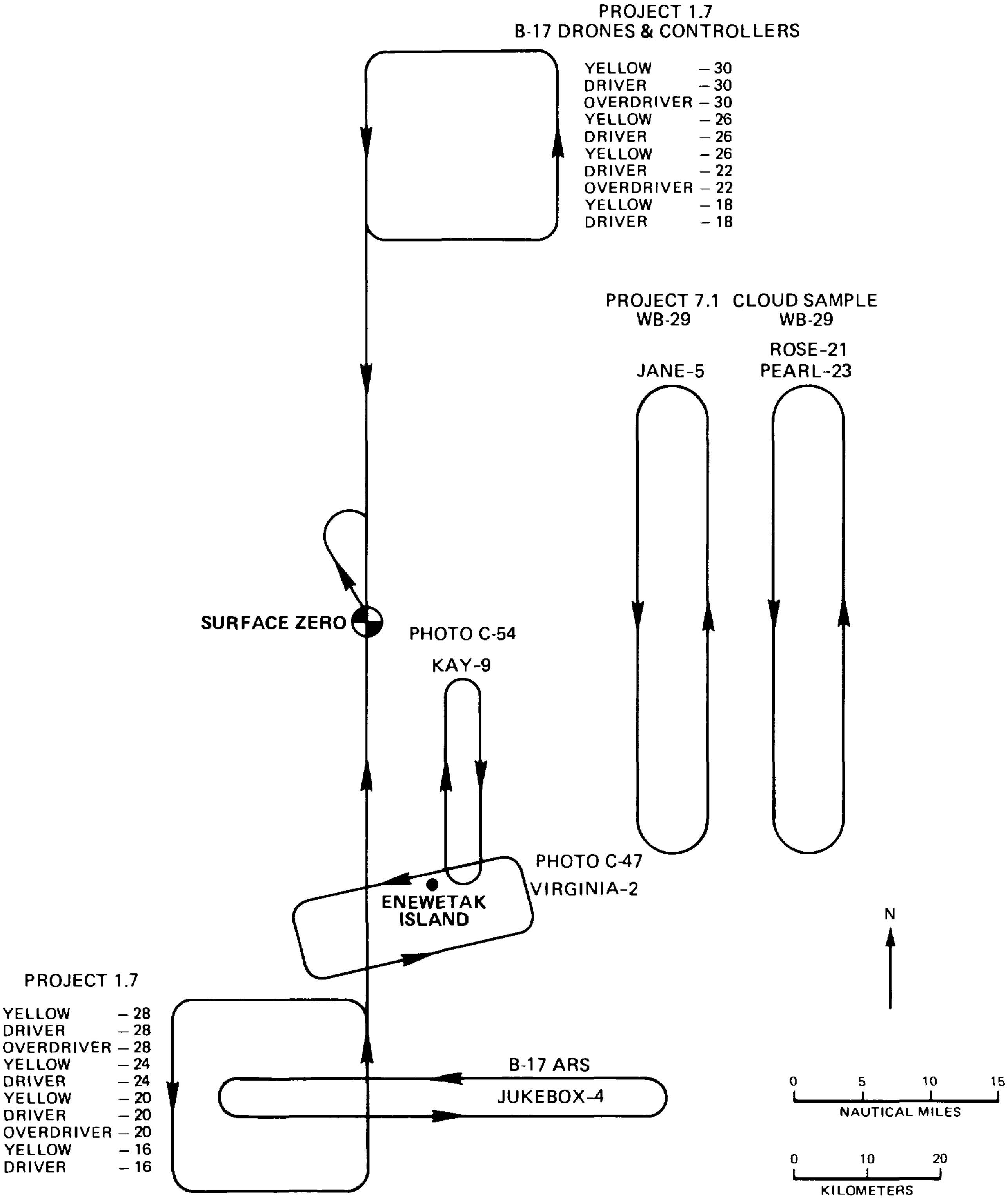

Figure 40. GREENHOUSE, ITEM flight patterns (source: Reference 5).

trace of precipitation. Visibility averaged 12 miles. The surface winds averaged east-northeasterly at 16 knots.

ITEM was detonated as scheduled at 0617 on 25 May 1951. The mushroom cloud reached 40,000 feet (12.2 km). At 0645, a radsafe party left to survey the islands in the vicinity of the shot. Initial reports from the radsafe team arriving at the site by helicopter about 1 hour after the detonation indicated relatively high radioactivity. These reports were confirmed by the team on an AVR anchored 1 nmi (1.85 km) southwest of Enjebi about one-half hour later. Particles from this fallout were large enough to be felt on the hands and faces of personnel. Fallout on the populated islands of the atoll and anchorages in the southern portion of the lagoon was detected on radsafe instruments beginning between 3 to 4 hours after the detonation. Rates rose to 0.40 R/hr before noon and began to decay until a second wave of fallout began in the afternoon, which peaked in the evening. The possibility of this had been indicated earlier by an analysis of the wind. It was the reason for the decision on D-1 to advance H-hour. Had the shot been fired at 0930 as originally planned, higher fallout readings would have resulted. Spot readings on Enewetak Island reached 0.100 R/hr, but a general level of 0.040 R/hr prevailed (References 17 and 104).

Recovery operations were authorized at 0950, and by 1618 all operations were closed out on Enjebi. By 1310, the radiological situation stabilized, and most of the islands from Enewetak to Bokenlab were cleared (including all of the populated ones) for unrestricted movement by authorized personnel, although unmonitored vessels continued to be limited to trips in the Japtan-Parry-Enewetak area. By 2000, the second wave of fallout had stopped (Reference 105; Reference 5, pp. 143 ff). The gamma dose rate at the Radsafe Building at Parry is shown in Figure 41.

Deposited fallout continued to decay, exposing personnel on the base islands until heavy rains set in at the end of May. These rains apparently effectively scoured the islands of the fallout particles and ended the episode (Reference 38, p. 10).

Decontamination Activities

The following survey reports indicated the time and readings of the ships:

<u>Curtiss</u>	H+3.5	Fallout detected
	1045	0.004 to 0.006 R/hr
	1200	Readings normal
	1530-1900	0.025 R/hr
	D+1, 1200	Readings at acceptable levels
<u>Cabildo</u>	1045	0.004 to 0.006 R/hr
<u>Mower</u>	1045	0.004 to 0.006 R/hr.

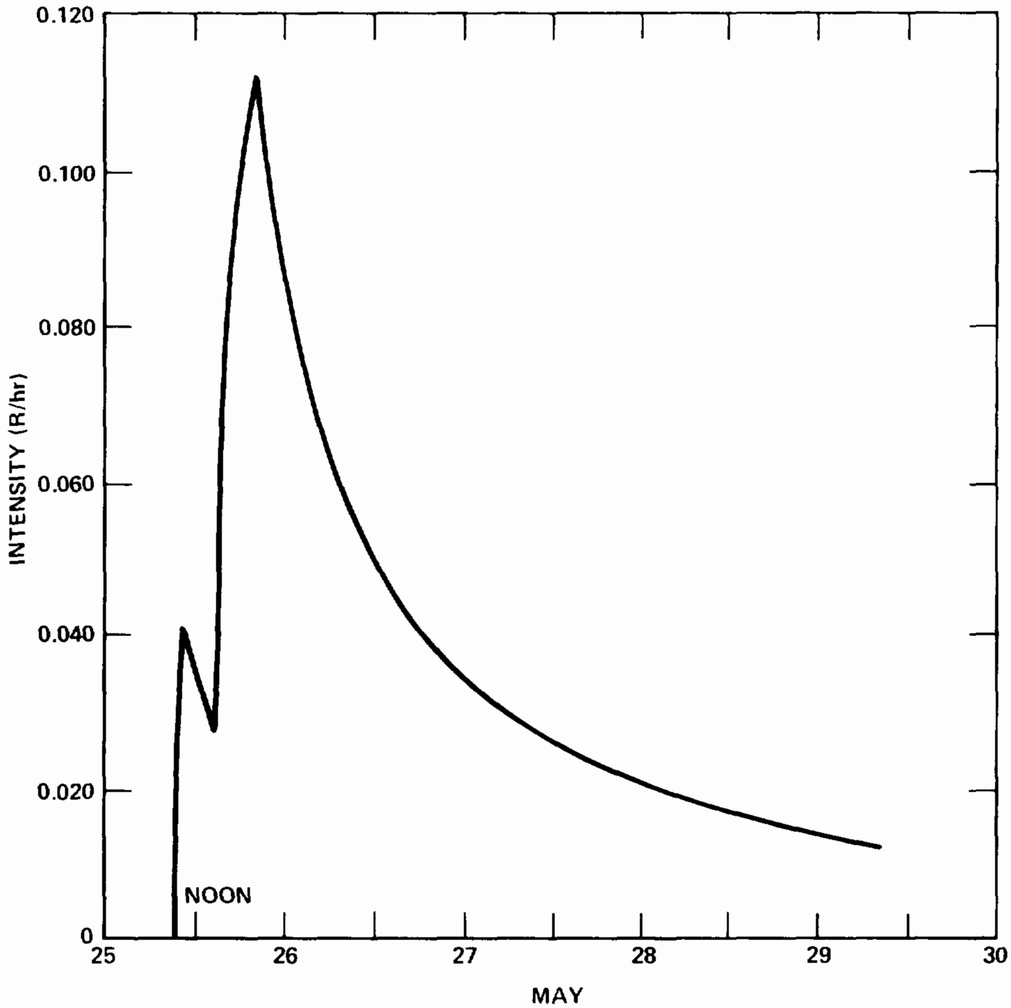

Figure 41. GREENHOUSE, ITEM fallout radiation at Parry Island, Enewetak Atoll (plotted in local time).

Decontamination procedures were initiated. All unnecessary personnel were cleared from decks, ports, and doors, and hatches were closed (Reference 17).

Presumably B-17 drones were contaminated during ITEM and had to be decontaminated at Enewetak, but details are lacking. Two or three WB-29s were partially decontaminated at Enewetak, when they landed to have filter and gas samples removed. At Kwajalein, WB-29s were decontaminated, but no information is available on what other aircraft may have been decontaminated there after ITEM.

CHAPTER 4

GREENHOUSE EXPERIMENTAL PROGRAM

Scientific experiments during GREENHOUSE were organized into eight programs:

- Program 1 -- Atomic Energy Commission (Phenomena of Nuclear Detonations)
- Program 2 -- Biomedical Experiments
- Program 3 -- Structures
- Program 4 -- Cloud Physics
- Program 5 -- Radiation Instrument Evaluation
- Program 6 -- Physical Tests and Measurements
- Program 7 -- Long Range Detection
- Program 8 -- Blast Effects on Aircraft.

Experiments for GREENHOUSE had been proposed by Army, Navy, Air Force, Atomic Energy Commission (AEC), and Armed Forces Special Weapons Project (AFSWP) personnel. By November 1949, the Working Group of the Joint Proof Test Committee had arranged them, as projects, into eight programs. Although the AEC projects were grouped in a single program, the eight programs were seen by the end of 1949 as a unified whole, in which the Department of Defense (DOD) and the AEC had equal interest (Reference 5, p. 59).

Task Group (TG) 3.1 of the joint task force was charged with conducting the overall experimental program. Task Unit (TU) 3.1.1 and TU 3.1.2 were responsible for Programs 1 and 2, respectively, and TU 3.1.3 was responsible for the remaining six. Commander TG (CTG) 3.1 appointed a director for each program (Reference 5, p. 61).

The programs were of three types: those dealing with the chemistry and physics of atomic explosions; those dealing with the effects of such explosions on the natural environment, on manmade objects, and on various plants and animals; and those (Program 7) designed to help develop means to detect nuclear detonations at great distances so that U.S. authorities could monitor nuclear developments in other countries (Reference 5, p. 61).

PROGRAM 1 -- ATOMIC ENERGY COMMISSION (PHENOMENA OF NUCLEAR DETONATIONS)

The numerous projects and subprojects making up this program were designed primarily to increase understanding of the process of nuclear explosions. In addition, however, data gathered were needed to assist in interpreting results of the other programs. The program was headed by a scientist from Los Alamos Scientific Laboratory (LASL).

Project 1.1 -- Prompt Gamma Ray Measurements

Project 1.1.1 -- The Measurement of Alpha by Prompt Gamma Rays

Agency: Naval Research Laboratory, Group H (NRL)

Operations: Detectors mounted on the shot tower and along a radial line outward from surface zero for each shot were connected to a buried cable terminating in one of two bunkered recording stations. The recording stations were located 3,975 feet (1.21 km) southeast of DOG tower on Runit; 4,000 feet (1.22 km) southeast of EASY tower on Enjebi; 6,000 feet (1.83 km) from GEORGE tower on Bijire; and 3,975 feet (1.21 km) south of ITEM tower on Enjebi (Reference 106, pp. 19 and 20; Reference 107, pp. 134 through 137; Reference 108, pp. 44 and 53).

Shortly after each shot Group H, NRL(H) personnel recovered the data on films and tape from the recording bunkers. Departure times from Parry were H+1:45 for shot DOG, H+0:30 for shot EASY, and, H+7 for shot GEORGE. For ITEM, departure was scheduled for H+3 (Reference 97, No. 45; Reference 109, p. E-I-25; Reference 102, p. G-I-22; Reference 110, p. I-I-12).

Project 1.1.1 shared its recording and data-recovery operations with Projects 1.1.2 and 1.1.3.

Estimated radiation intensity in the vicinity of Project 1.1.1 recording stations 1 hour after each shot was (Reference 111, pp. 28, 34, 40, and 45):

- DOG -- 0.17 R/hr
- EASY -- Between 3.0 and 1.0 R/hr
- GEORGE -- 0.1 R/hr
- ITEM -- Between 1.0 and 0.5 R/hr.

Staffing: Counting the apparent project leader, 13 men were assigned to this project, 12 from NRL(H) and 1 from NRL, Group K (NRL[K]). They were assisted by 21 others. It is not clear, however, if all those assisting were from NRL (Reference 112, p. v). Nine personnel assigned to or assisting with the project were not badged. Some of the unbadged may not have been at the proving ground. The highest badge exposure among the 13 assigned to the project was 3.970 R, for a NRL(H) man.

Project Report: WT-66 (Reference 112).

Project 1.1.2 -- Prompt Gamma Ray Intensity as a Function of Time

Agency: Naval Research Laboratory, Group H (NRL)

Operations: Same as for Project 1.1.1.

Staffing: Thirteen men, twelve of whom came from the same group that worked on Project 1.1.1 (above). Some unnamed LASL personnel also assisted (Reference 113, p. v).

Project Report: WT-36 (Reference 113).

Project 1.1.3 -- Measurement of Transit Time

Agency: Naval Research Laboratory, Group H (NRL)

Operations: Same as for Project 1.1.1.

Staffing: Thirteen NRL(H) personnel from the same group that conducted Project 1.1.1 (Reference 114, p. v). All were badged. Highest recorded exposure was 3.970 R.

Project Report: WT-14 (Reference 114).

Project 1.2 -- Delayed Gamma-Ray Measurements

Project 1.2.1 -- Gamma-Ray Spectrum Measurements

Agency: Radiation Physics Laboratory, National Bureau of Standards (RPL/NBS)

Operations: Detector stations were built at 610 and 2,185 feet (186 and 666 meters) from DOG and EASY surface zeroes, respectively (Reference 115, p. 2). Apparently the recording stations were about 3,600 feet (1.10 km) from DOG tower and about 4,800 feet (1.46 km) from EASY tower (Reference 115, pp. 5 and 36). The distances from GEORGE tower to both the detectors and recording stations are not explicitly stated in the available documents, but the recording stations probably were on Bijire. The project did not participate in ITEM.

- DOG. One hour and forty-five minutes after the detonation, six RPL/NBS personnel went by boat to Runit to recover records and equipment from the recording stations. Recovery was expected to take 6 hours. Five hours after the detonation, two of the RPL/NBS personnel returned to Parry. At 1530, the other four left Runit for Enjebi with equipment, presumably to prepare for EASY (Reference 97, Nos. 46, 56, and 68).
- EASY. At 0800 on the shot day, a 4-man RPL/NBS recovery team left Parry by LSU for Enjebi, departing at 1230 for Parry (Reference 109, pp. E-I-28 and E-I-33).
- GEORGE. An RPL/NBS recovery team left Parry by boat for Bijire at 1300 on D+1. Recovery took about 2 hours (Reference 102, p. G-I-26).

Radiation levels in the probable locations of the recording stations on Runit and Enjebi used for Project 1.2.1 were estimated to be 0.3 R/hr and 3 R/hr, respectively, 1 hour after the shot (Reference 111, pp. 28 and 36). The radiation level in the center of Bijire at 1000 the day after GEORGE was between 0.002 and 0.003 R/hr (Reference 38, p. 63).

Staffing: The project report for this experiment was authored by five RPL/NBS personnel and mentions eleven other participants. Of this latter group, five were military (Reference 115, pp. v and vii). One of the authors and five of the group of eleven were not badged. An RPL/NBS civilian had the highest badge exposure (2.750 R).

Project Report: WT-76 (Reference 115).

Project 1.2.2 -- Measurement of Total Gamma-Ray Intensity vs. Time After One Millisecond

Agency: Radiation Physics Laboratory, National Bureau of Standards (RPL/NBS)

Operations: Various types of instruments were set up 600, 610, 1,200, 2,185, and 3,900 feet (0.183, 0.186, 0.366, 0.666, and 1.19 km) from each of the three surface zeroes and near the NRL(H) recording stations (Reference 130, pp. 2 and 60). Apparently there were no remote recording stations; thus data had to be retrieved from the instrument locations after the shots. The project did not participate in ITEM.

Some Project 1.2.2 recovery could have been done by the RPL/NBS groups. Radiation levels close to the three surface zeroes were too high, however, to allow recovery of close-in instruments on DOG- or EASY-day or on GEORGE D+1.

Staffing: The project report was authored by five personnel, and at least two others, including one military officer, were acknowledged to have assisted. All were badged (Reference 116, pp. iii and v). The highest badge exposure -- 5.600 R -- was for one of the civilians.

Project Report: WT-77 (Reference 116).

Project 1.2.3 -- Film Dosimeter Measurements

Agency: Radiation Physics Laboratory, National Bureau of Standards (RPL/NBS)

Operations: Film badges were set out at various distances from the four surface zeroes. The badge station nearest to surface zero (distance approximate) in each case was:

DOG -- 2,250 feet (686 meters)　　GEORGE -- 4,500 feet (1.37 km)

EASY -- 1,950 feet (594 meters)　　ITEM -- 3,000 feet (914 meters)

Badges were also placed inside Building 311 on Enjebi, presumably for EASY and ITEM only. The building was about 2,900 feet (884 meters) from both EASY and ITEM surface zeroes (Reference 117, pp. 45 and 48). To be read, the badges had to be recovered.

Available records do not specify when these badges were retrieved. But, as already noted, RPL/NBS teams returned to the DOG and EASY shot islands on the respective shot days. Initial RPL/NBS reentry following GEORGE was at 1300 on D+1. The operation order does not mention RPL/NBS reentry following ITEM.

Staffing: Presumably the four authors of the project report were civilian employees of RPL/NBS. Four other persons are acknowledged as having assisted, one of whom was a LASL employee. The LASL employee and four of the others were badged. The recorded exposure of the LASL employee was 2.262 R, and the highest among the others was 1.260 R.

Project Report: WT-81 (Reference 117).

Project 1.2.4 -- Measurements under Collimated Conditions

Agency: Radiation Physics Laboratory, National Bureau of Standards (RPL/NBS)

Operations: Two instrument stations and a recording station were built on both Runit and Enjebi. The instrument stations were connected to their respective recording stations by buried cable (Reference 118, pp. 28 and 29). Station 55 on Runit was about 4,800 feet (1.46 km) from DOG surface zero (Reference 110, p. D-I-15). Station 55 on Enjebi was about 3,570 feet (1.09 km) from EASY surface zero (Reference 119, p. 69). Data had to be recovered from both recording stations.

At DOG H+1, the estimated exposure rate in the vicinity of Station 55 was less than 0.17 R/hr (Reference 111, p. 28). The estimated exposure rate in the vicinity of Station 55 on Enjebi at EASY H+1 was between 1.0 and 3.0 R/hr (Reference 111, p. 34).

Staffing: The project report was authored by five persons and acknowledges six others, including one from LASL. One author and one of the others were not badged. Presumably all but the LASL staff member were civilians from RPL/NBS. Highest recorded exposure was 2.750 R.

Project Report: WT-41 (Reference 118).

Project 1.3 -- Thermal Radiation Measurements

Agency: Radiometry Branch, Optics Division, Naval Research Laboratory (NRL)

Operations: A light source was mounted on the DOG shot cab, and a transmissometer -- a device measuring the amount of light received from the source -- was mounted 10 feet (3 meters) above lagoon level on an artificial island on the reef south-southeast of Runit. The distance between the source at the shot point and transmissometer was 2.27 nmi (4.21 km). Apparently data had to be recovered from the transmissometer site.

For shot EASY, the transmissometer was placed on Bokenelab, 3.17 nmi (5.88 km) from the source, which was mounted in the cab of the shot tower.

Data from the transmissometer were relayed by cable back to Parry (Reference 120, p. 18).

Thermal radiation measurements were made at the DOG and EASY transmissometer sites and at Billae and Bokenelab for GEORGE and ITEM. Additional thermal instrumentation was located at Parry for all four shots. Data and equipment had to be recovered from the artificial island, Bokenelab, and Billae. The project was under the general direction of the leader of the NRL(H) group, and it appears that project recovery was scheduled as part of NRL(H) recovery operations.

- DOG. A recovery party left Parry for Runit and the artificial island at 0900 on D+1. At 1300 it left Runit for Bokenelab with a spectrograph and other equipment (Reference 97, Nos. 5 and 10).
- EASY. A mixed Edgerton, Germeshausen & Grier, Inc. (EG&G) and NRL(H) recovery party left Parry at 0700 on D-day. Ten NRL(H) personnel were dropped off at Bokenelab. At 0730 on D+2, an NRL(H) party was to go to Bokenelab to retrieve equipment, including a spectrograph for transfer to Billae (Reference 109, pp. E-I-25 and E-I-45).
- GEORGE. At H+7, an NRL(H) recovery team visited Billae and Bokenelab for recovery of records. There is no indication when the spectrograph was moved (Reference 110, p. G-I-22).
- ITEM. At H+6, the chief of Project 1.3 was to helicopter to Bokenelab to recover data (Reference 110, p. I-I-14).

Project personnel manning instruments on Parry were not exposed to radioactivity from the tests except that from the fallout on these islands following DOG, EASY, and ITEM. Radiation levels on the artificial island, Bokenelab, and Billae, as measured at the times closest to data recovery or equipment movement, were as follows (Reference 38, pp. 8 through 10; Reference 111, p. 28:

- Artificial island. No reading is available, but the radiation level probably was low, considering the low level on the nearest portion of Runit.
- Bokenelab. At 0730 on EASY day, the exposure rate was 2 R/hr, decreasing to 0.040 R/hr at 0900 on D+2. No post-ITEM radiation reading is available.
- Billae. At 1400 on GEORGE day, about 3-1/2 hours after the detonation, the radiation level was 0.0003 R/hr.

Staffing: Seven personnel mentioned in the project report appear to have been badged. One was an Army Signal Corps officer and the rest were probably civilian employees of NRL. The highest badge reading was 2.115 R. (Reference 120, pp. 12 and 32). Project personnel operating equipment on Enewetak and Perry were not badged.

Project Report: WT-120 (Reference 120).

Project 1.4 -- Ball of Fire Observations

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

Operations: Cameras were mounted on photographic towers to record fireball development. Towers were located as follows for each shot (Reference 121, pp. 145 through 148):

DOG --	Billae Artificial island on reef south-southeast of Runit	EASY -	Dridrilbwij Bokenelab
		GEORGE --	Bokenelab Billae
		ITEM --	Bokenelab.

Film was recovered and cameras moved after each shot. The recovery schedule does not mention this project by name; nevertheless, the record shows various activities planned or carried out by EG&G crews following the shots:

- DOG. At H+4, six EG&G personnel went by boat to the artificial island and Billae for film recovery (Reference 97, No. 52). The next day at 0745, six EG&G personnel were to begin moving cameras to Dridrilbwij (Reference 97, No. 52; Reference 110, pp. D-I-17 and D-I-20).
- EASY. At 0700 on the shot day, two EG&G personnel went to Bokenelab by boat. At 0730, an 11-man EG&G party left Parry for Dridrilbwij and other islands (Reference 109, pp. E-I-25 and E-I-27).
- GEORGE. AT H+5:45, EG&G teams helicoptered to Billae and Bokenelab. Two other EG&G recovery groups helicoptered to Bokenelab, one at H+12, and another on D+2 (Reference 102, pp. G-I-21, G-I-23, and G-I-28).
- ITEM. If radiation safety permitted, two EG&G personnel were to go to Bokenelab by helicopter at H+3 to recover film. A second mission was to be flown at 1800 (Reference 110, pp. I-I-13 and I-I-14). Dismantling of the photo stations was to begin on D+1.

Staffing: At least 11 EG&G personnel were present.

Project Report: WT-101 (Reference 121).

Project 1.5 -- Neutron Measurements

Project 1.5.1 -- Diagnostic Neutron Experiments (Sections 1 and 2)

Agency: Naval Research Laboratory, Group K (NRL)

Operations: Various neutron detectors were placed within 465 feet (142 meters) or less of the EASY, ITEM, and GEORGE shot towers. For EASY and

ITEM, detectors were connected by buried cable with the NRL(K) recording station on Enjebi, 2,400 feet (732 meters) from the EASY surface zero and 2,780 feet (848 meters) from the ITEM surface zero. For GEORGE, detectors were connected by buried cable to the NRL(K)-University of California Radiation Laboratory (UCRL) recording station on Aomon, 2,400 feet (732 meters) from surface zero (Reference 108, pp. 46 and 53). Recovery was as follows:

- EASY. At 0800 on shot day the project leader and three men went by boat to Enjebi to recover film from the NRL(K) recording station. At 1230 they started back to Parry. On D+2, an NRL(K) crew moved equipment from the recording station on Enjebi to the NRL(K)-UCRL recording station on Aomon (Reference 109, pp. E-I-28, E-I-33, and E-I-44).
- GEORGE. The detonation threw a great deal of water on the area around the recording station. Flowing into low spots, the water concentrated widely scattered radioactive material, leading to high radiation rates. Recovery was delayed until H+30 (Reference 108, p. 29). On D+2, an NRL(K) crew left Parry, apparently to move equipment back to Enjebi for ITEM, although the record does not specify that the equipment was for this experiment (Reference 102, p. G-I-28).
- ITEM. AT H+3, six NRL(K) personnel were to leave Parry by boat for recovery on Enjebi and return 4 hours later. The next day an NRL(K) crew of ten was to retrieve the equipment (Reference 110, p. I-I-14 and I-I-15).

Radiation levels near recording stations were as follows (Reference 108, p. 23):

	Maximum Radiation Intensity near Station (R/hr)		Residual Radiation Intensity (R/hr)	
Shot	At H+6	At H+30	At H+6	At H+30
EASY	0.3		0.150	
GEORGE	50	20	6-10	0.5-2
ITEM	0.5		0.3	

Staffing: Twenty-two NRL civilian employees and one LASL civilian employee appear to have worked on this experiment in the field (Reference 122, pp. v and vii). Nineteen NRL employees and the LASL employee were badged. Highest exposure was 3.880 R.

Project Reports: WT-96 (Reference 122), WT-97 (Reference 108).

Project 1.5.2.1 -- External Neutron and Gamma Flux Measurements by Sample Activation

Agency: Los Alamos Scientific Laboratory (LASL)

Operations: For all shots, samples of four elements were attached to one or two cables beginning 300 or 600 feet (92 or 183 meters) from surface zero and extending for over 4,500 feet (1.37 km). The cable was to be recovered by winch and the samples removed for analysis. Apparently, each detonation broke the cable near the winch, and a tractor had to be used to draw in the cable (Reference 38, p. 9). The location of this activity is not specifically mentioned, but it probably was somewhere beyond the sample most distant from each surface zero. At each of the four shots, the most distant sample was (Reference 123, pp. 12 through 15):

- DOG -- 5,400 feet (1.65 km) southeast of surface zero
- EASY -- 4,500 feet (1.37 km) southeast of surface zero
- GEORGE -- 6,300 feet (1.92 km) from surface zero on Bijire
- ITEM -- 4,500 feet (1.37 km) south of surface zero.

In addition, the same types of samples were attached to the cables of one or more balloons anchored 4,500 feet (1.37 km) from the EASY surface zero (Reference 108, p. 26; Reference 123, p. 19). Biological samples were set out in stations for DOG, EASY, and GEORGE at about the same ranges.

Ten minutes after DOG, the recovery party left Parry for Runit by AVR. In the group were one military policeman (MP), six H&N employees, and fourteen other personnel of whom thirteen were listed by name. Among the 13 named were the 2 authors of the project report. The group left Runit 2 hours later (Reference 97, Nos. 33 and 46).

At EASY H+2 minutes, several boats left Parry for Enjebi via Japtan. Apparently this activity was associated in part with the sample activation experiment, but the association is not described. At H+10 minutes, three recovery parties in two AVRs left Parry for Enjebi. Upon arriving there, the monitors ordered the boats to lay off Enjebi for an hour, and the parties went ashore about 0755. One group recovered activated samples and equipment not related to this experiment. Some personnel from the original group left Enjebi about 1200. Departure times for the others are unknown (Reference 109, pp. E-I-22, E-I-23, E-I-31).

Post-GEORGE recovery began 5-1/2 hours after the detonation when nine scientific personnel, accompanied by MPs, monitors, and H&N employees, left Parry for Enjebi by boat. Information on their time of departure from Enjebi is unavailable (Reference 102, p. G-I-19).

Recovery after ITEM was scheduled to begin at H+3 and probably began only about 5 minutes late (Reference 110, p. I-I-13; Reference 104, p. 3). Several recovery parties are mentioned, but it is not clear which one retrieved samples for this experiment.

At H+1 on the respective shot days, the estimated radiation rate at the sample attached to the cable at the farthest point from surface zero was less than 0.17 R/hr for DOG, less than 1.0 R/hr for EASY, less than 0.1 R/hr for GEORGE, and less than 0.5 R/hr for ITEM. At the individual sample station nearest to surface zero, the radiation rate was between 60 and 600 R/hr for DOG, about 600 R/hr for EASY, and about 200 R/hr for ITEM. Attempts at recovery from these stations until some later date seems unlikely. At the biological station nearest surface zero, the radiation rate was between 1 and 3 R/hr for DOG, between 3 and 6 R/hr for EASY, and between 25 and 100 R/hr for GEORGE (Reference 111, pp. 28, 34, 40, and 45).

Staffing: The highest recorded exposure among the 13 personnel listed by name as part of the recovery team was 6.280 R for a member of TU 3.1.5. He was probably the radsafe monitor. Among the other 12 men, who probably were LASL employees, the highest exposure was 5.710 R.

Project Report: WT-114 (Reference 123).

Project 1.5.2.2 -- Spectrum and Air Attenuation Static Measurements (Neutron Spectra Measurements)

Agency: Los Alamos Scientific Laboratory (LASL)

Operations: For each shot the instruments were placed at distances of 600, 1,200, 1,800, 2,400, 3,000, and 3,600 feet (0.183, 0.366, 0.549, 0.732, 0.914, and 1.10 km) from surface zero (Reference 107, p. 9). Photographic plates had to be recovered from each instrumentation station.

DOG recovery began at about H+10 or 15 minutes when a recovery party of nine left Parry by LCM for Runit. They were divided into two teams, one of which stayed by the winch house, while the other attempted to recover the photographic plates. The location of the winch house is not known. Maximum exposure rate was set at 2 R/hr. First recovery was from the 2,400-foot (732-meter) station at about 0830. The other crew recovered the plates from the 3,000-foot (914-meter) station. In both cases, the trip from the winch house to the instrument station, removal of the photographic plates, and return to the winch house took about 15 minutes (Reference 107, p. 64). The entire group probably left the island by AVR promptly after the recovery from the 3,000-foot (914-meter) station (Reference 97, No. 46). At 1415 the same group left Parry for another recovery effort. At 1515 one crew went to the 1,800-foot (549-meter) station, where the exposure rate was between 1 and 1.5 R/hr. The other crew retrieved the plates from the 3,600-foot (1.10-km) station. With the radiation level at 0.020 R/hr, the recovery party left for Runit (Reference 107, p. 64). Recovery from the 1,200-foot (366-meter) station took place the next day. Recovery from the 600-foot (183-meter) station was on D+2 (Reference 97, Nos. 3, 9 and 13).

EASY recovery began at H+10 minutes, but landing on Enjebi was delayed until 0755 due to high radiation. Photographic plates were recovered from the 1,200- and 600-foot (366- and 183-meter) stations on the next 2 days, respectively (Reference 109, pp. E-I-40 and E-I-45).

GEORGE recovery started at H+5:45, with later efforts not mentioned in the record (Reference 102, p. G-I-20). ITEM recovery was to begin at H+3 (Reference 110, p. I-I-13). For these shots, recoveries near surface zero were probably 48 hours after the shot at the 1,800-foot (549-meter) station, and about 10 days after the shot at the 1,200- and 600-foot (366- and 183-meter) station (Reference 107, p. 64).

Staffing: The DOG recovery party consisted of three LASL civilian scientists, four H&N personnel, and two Army radiation monitors. One of the H&N

personnel was not badged. Highest recorded exposure in the group was 5.840 R for one of the LASL scientists.

Project Report: WT-68 (Reference 107).

Project 1.5.3 -- High-Energy Spectrum

Agency: Naval Research Laboratory, Group H (NRL)

Operations: For GEORGE and ITEM, two detector stations were used, one 600 feet (183 meters) and the other 3,000 feet (914 meters) from surface zero. Apparently, the detector stations were connected by buried cable to the appropriate NRL(H) recording station. The NRL(H) recording stations on Bijire used for shot GEORGE were about 6,000 feet (1.8 km) from surface zero. The NRL(H) recording stations on Enjebi used for ITEM were about 3,975 feet (1.2 km) south of surface zero. This project did not participate in DOG and EASY. See Project 1.1.1 for the recovery schedule from these stations.

Staffing: The project report indicates that 11 NRL(H) civilian personnel worked on this project (Reference 124, p. v). All were badged and also participated in Project 1.1.

Project Report: WT-37 (Reference 124).

Project 1.6 -- Blast Measurements

At least 45 personnel worked on this project, which consisted of several subprojects: 17 from Naval Ordnance Laboratory (NOL), 9 from Ballistic Research Laboratories (BRL), 6 from LASL, and 13 from the Armed Forces Special Weapons Project (AFSWP). Of this group, 18 were members of the armed services (Reference 125, pp. 174 and 175; Reference 126, pp. vii and 69).

Project 1.6.1.1 -- Free-Air Peak-Pressure Measurements Using Smoke Rocket Photography

Agency: Naval Ordnance Laboratory (NOL)

Operations: A vertical grid was established with rocket smoke trails a few seconds before each shot. The shock front caused a change in air density and refraction of light as it spread outward from the blast. The result was distortion of the grid's image when photographed. Rocket-launching tubes were located several thousand feet from each surface zero. Cameras were mounted on one or more of the photography towers. Film from the cameras had to be recovered. Rocket-launch tubes and timing equipment for firing the launchers were also recovered (Reference 127). Locations of the towers and the launching tubes were (Reference 128, pp. 10, 14 and 15):

- DOG: Photography towers on Billae

  Rocket launchers on Runit between 5,879 and 8,210 feet (1.79 and 2.50 km) from surface zero

- EASY: Photography towers on Dridrilbwij

  Rocket launchers on Enjebi between 2,937 and 4,600 feet (0.896 and 1.40 km) from surface zero

- GEORGE: Photography tower on Bokenelab

  Rocket launchers on Bijire between 5,897 and 6,724 feet (1.79 and 2.05 km) from surface zero.

Location of the bunkers that held the timing equipment and the times of attempted recovery cannot be determined from the available documents.

Staffing: Three NOL personnel from the Project 1.6 group were assigned primarily to this experiment. Only one was badged, and this badge recorded zero exposure. The project leader recollects, however, also being badged and reentering to retrieve equipment (Reference 127).

Project Reports: WT-54 (Reference 128); WT-64 (Reference 125).

Project 1.6.1.2 -- Free-air Peak-pressure Measurements: Telemetering from Moored Balloons

Agencies: Armed Forces Special Weapons Project (AFSWP)

Applied Physics Laboratory, Johns Hopkins University (APL/JHU)

Operations: One or more balloons were tethered within several hundred feet of the base of the shot towers. Various instruments and flash bulbs were attached along the balloon mooring cables to measure blast pressure and facilitate photography. Signals from the pressure gauges were transmitted back to Parry Island. For DOG, one balloon was used. The anchor point appears to have been about 600 feet (183 meters) from the base of the shot tower. The camera tower on the artificial island and one of the camera towers on Billae were used for photography. Two balloons were tethered for EASY, one anchored about 400 feet (122 meters) west of surface zero and the other 600 feet (183 meters) southeast of surface zero. A camera tower on Dridrilbwij and one on Bokenelab were used for photography (Reference 129, pp. 94 through 95, 117 through 118, 132, and 142). No information is available on recovery of this experiment. The project was not included in GEORGE and ITEM.

Staffing: Thirteen personnel can be identified by name as having worked on this experiment. All but one were military personnel from AFSWP. The lone civilian was from APL/JHU (Reference 125, pp. 174 and 175). Only four were badged, with the highest exposure being 0.345 R.

Project Reports: WT-20 (Reference 129); WT-64 (Reference 125).

Project 1.6.3.1 -- Pressure Near Ground Level from Shock-Velocity Measurements

Agency: Ballistic Research Laboratories (BRL)

Operations: For DOG and GEORGE a line of instrument stations extended a few hundred yards from surface zero and outward to a blast hut. Various instruments were connected by cable to experiment data recorders inside the blast hut. Apparently, recovery was from the huts. The distance of each from surface zero was (Reference 130, pp. 38, 44 and 45):

- DOG -- 5,340 feet (1.63 km)
- EASY -- about 3,750 feet and 5,100 feet (1.14 and 1.55 km)
- GEORGE -- 6,600 feet (2.01 km).

Available records give no indication of when recoveries for this experiment were conducted.

Staffing: BRL supplied all six personnel assigned to this experiment. One of the team was from the Air Force (Reference 125, p. 174). They were aided by an advance party of other Project 1.6 personnel (Reference 130, p. 3). Highest recorded exposure among the BRL personnel was 0.378 R.

Project Reports: WT-55 (Reference 130); WT-64 (Reference 125).

Project 1.6.3.2 -- Pressure Near Ground Level with Foil Meters

Agency: Ballistic Research Laboratories (BRL)

Operations: The foil meters for DOG were set out in stations roughly in a line from the surface zero, southeast along Runit Island. Distances from surface zero were from 1,950 to 6,000 feet (0.594 to 1.83 km). Two lines of foil meter stations were established on Enjebi for EASY. One, with six stations, ran southeast from surface zero from 1,380 to 4,650 feet (0.421 to 1.42 km), and the other, with three stations, ran roughly eastward from surface zero from 2,700 to 3,700 feet (0.823 to 1.13 km). Meters had to be read at the stations after the shots, but no information is available on when this was done.

Staffing: One BRL civilian employee is the only person named as assigned to this experiment (Reference 125, pp. 174 and 175). His recorded exposure was 0.438 R.

Project Reports: WT-55 (Reference 130); WT-64 (Reference 125).

Project 1.6.3.3 -- Pressure Near Ground Level by Means of Copper Indenter Gauges

Agency: Naval Ordnance Laboratory (NOL)

Operations: For shot DOG gauges were placed on Runit in stations between 1,650 and 7,500 feet (0.503 and 2.29 km) from surface zero. Billae and Alembel or Lojwa also had stations.

Most gauges used for shot EASY were in stations on Enjebi. Three stations along an easterly line were between 1,800 and 3,699 feet (0.549 and

1.12 km) from the center, and six stations along a southeasterly line were between 1,380 and 4,650 feet (0.421 and 1.42 km) from the center. In addition, Mijikadrek and Kidrinen each had a station (Reference 131, p. 10). The gauges had to be recovered for reading but did not require prompt retrieval.

Staffing: Only the author of the project report, an NOL civilian, can be positively associated with experimental work at the testing ground (Reference 125, p. 174). He was badged and showed a reading of 2.450 R.

Project Report: WT-78 (Reference 131).

Project 1.6.3.4 -- Pressure Near Ground Level: Blast Asymmetry from Aerial Photographs

Agencies: Naval Ordnance Laboratory (NOL)

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

Operations: Cameras on several TG 3.4 aircraft were used in an effort to record asymmetries in the fireball and blast wave. Photography was started a few seconds before and continued a few seconds after the shots. The planes used were manned B-50Ds and drone B-17s. The drones were used to study blast effects. The B-50Ds also participated in Projects 8.3A (Radar Scope Photography), 8.3C (Photographic Bomb Damage Assessment), and 8.1 (Blast Effects on Aircraft in Flight). Once these activities were completed, both B-52D aircraft flew counterclockwise around the nuclear cloud for about 2 hours taking pictures for Project 4.1B, Development of Atomic Clouds. Finally, both participated in an atmospheric conductivity experiment for Project 7.8.

The work of the B-50Ds in all projects, except possibly Project 7.8, should not have exposed the aircraft or crews to much radiation. Moreover, there is no record of them being contaminated. The drones collecting samples were heavily contaminated, as described under Project 1.7. The drones used in Project 1.6.3.4, however, probably had little chance for contamination, and hence posed no potential exposure to ground crews or scientific personnel.

Staffing: The project report had two authors, one the senior EG&G man at the test range and the other an NOL civilian technical assistant to the Project 1.6 director (Reference 132, p. 1; Reference 125, p. 174). Information is lacking on whether EG&G or NOL personnel were aboard the aircraft.

The B-50Ds were part of Task Detachment (TD) 3.4.2.1. Although the task detachment was stationed on Kwajalein, the B-50Ds were moved to Enewetak on 27 March and remained there until shortly after GEORGE.

Project Report: WT-58 (Reference 132).

Project 1.6.3.5 -- Pressure Near Ground Level: Ball-Crusher-Gauge Measurements

Agency: Naval Ordnance Laboratory (NOL)

Operations: For shot DOG, the gauges were set out in stations along two segments of a line through surface zero and oriented about 80°T. Along the segment in the southwest quadrant, gauges were between 12 and 400 feet (3.7 and 122 meters) from the tower's base; along the segment in the northeast quadrant gauges were between about 275 and 369 feet (84 and 112 meters) from the tower (Reference 132, p. 47). For EASY, gauges were on both land and water. The most distant water station was 737 feet (225 meters) from surface zero. Land stations were in two lines roughly southeast of the tower's base. The closest was 12 feet (3.7 meters) from surface zero and the farthest 429 feet (131 meters) (Reference 132, pp. 42 and 48). The gauges had to be recovered for analysis. Because of high radiation levels, recovery was delayed for about 2 weeks in each case.

The party recovering DOG gauges consisted of one each from NOL and H&N and a monitor, all traveling on a weapons carrier. Recovery took about 30 minutes. Gauges in the area of the EASY detonation were first located by an observer flying over the area in a helicopter at an altitude of about 10 feet (3 meters). Then a recovery party of two NOL personnel, two monitors, and four H&N personnel entered the radioactive area, probably by truck, for recovery. They were there for about 30 minutes (Reference 132, p. 44).

Two weeks after shot DOG, the radiation level in the tower area probably was between 0.5 and 1 R/hr. Two weeks after shot EASY, the radiation level in the tower area probably was less than 1 R/hr (Reference 38, p. 49 through 50, 59).

Staffing: The project report has two authors, both NOL civilians, one with an exposure of 1.435 R and the other with an exposure of 2.450 R. The personnel who formed the recovery teams cannot be identified by name.

Project Report: WT-58 (Reference 132).

Project 1.6.4.1 -- Pressure-Time Measurements in the Mach Region: Measurement with Diaphragm-Type Variable-Inductance Gauge

Agency: Naval Ordnance Laboratory (NOL)

Operations: For DOG, gauges were set out in six stations on Runit between 1,950 and 6,000 feet (0.594 and 1.83 km) from surface zero. For EASY, two lines of gauges were established on Enjebi between 1,300 and 4,650 feet (0.396 and 1.42 km) (Reference 128, pp. 96 and 97). Each line of stations apparently had an associated blast hut containing data recorders. Data were transmitted from the stations to the blast hut by cable (Reference 133, p. 26). Data recovery was from the blast huts. The Runit blast hut was 5,450 feet (1.66 km) from surface zero. On Enjebi, blast huts were 3,490 and 4,715 feet (1.06 and 1.44 km) from surface zero. Information on the time of recovery is lacking.

Staffing: Six NOL personnel were assigned to this project in the field (Reference 125, p. 174), one of whom was a Navy officer. One appears not to have been badged. Highest exposure was 2.640 R.

Project Report: WT-53 (Reference 133).

Project 1.6.4.2 -- Pressure-Time Measurements in the Mach Region: Measurement with Spring-Piston Gauge

Agency: Naval Ordnance Laboratory (NOL)

Operations: Gauges were placed in the same stations used for Project 1.6.3.2 (Reference 130, pp. 92 and 93; Reference 133, pp. 51 through 53). The recording devices were with the gauges and they had to be recovered for analysis. There is no indication of when the gauges were recovered.

Staffing: Four NOL employees, one of them a Navy officer, appear to have been associated with this experiment (Reference 133, pp. v and 27). Two apparently were not badged. The Navy officer's exposure was 0.415 R. The badged civilian's exposure was 0.118 R.

Project Report: WT-53 (Reference 133).

Project 1.6.5 -- Measurement of Density, Temperature, and Material Velocity in an Air Shock Produced by a Nuclear Explosion

Agency: Los Alamos Scientific Laboratory (LASL)

Operations: Instruments were set out as follows (Reference 126, p. 104):

Shot	Location	Distance from Ground Zero in feet (km)
DOG	Runit	7,500 (2.29)
EASY	Enjebi	2,850 (0.869)
EASY	Mijikadrek	6,783 (2.07).

A recovery team with a monitor went to the Runit station at 1200 on DOG D-day (Reference 97, D-Day, No. 60). Between D+2 and D+5, films were to be recovered from the Runit station and its equipment moved to the two stations on Enjebi. A monitor was to accompany the group and recovery time was estimated at 2 hours (Reference 97, D+2, No. 12). At 1230 on EASY D-day, a 4-man team with a monitor and a jeep went from Parry to Enjebi and Mijikadrek by boat to recover recording film from the two stations. Two days later, dismantling of the experimental apparatus was to start (Reference 109, pp. E-I-33 and E-I-48).

Radioactivity in the vicinity of the station on Runit appears to have been nil. One hour after the shot EASY the radiation level in the vicinity of the Enjebi station was about 3 R/hr (Reference 111, p. 34), and on Mijikadrek it was 1.1 R/hr (Reference 38, pp. 54 and 8).

Staffing: The project report had two authors, and the report acknowledges another five people who took part. All apparently were LASL personnel, one of whom was a naval officer. All were badged, with the highest exposure recorded being 0.365 R.

Project Report: WT-110 (Reference 126).

Project 1.6.6.1 -- Ground Shock Measurements: Measurements of Ground Motion.

Agency: Ballistic Research Laboratories

Operations: For EASY, ground motion gauges were mounted in six stations roughly southeast of the shot site between 1,080 and 4,501 feet (0.329 and 1.37 km) from surface zero (Reference 134, pp. 16 and 28). Cables conveyed data from the gauges to a blast hut near the extreme southern end of Enjebi, about 5,100 feet (1.55 km) from surface zero (Reference 4, p. 69; Reference 134, p. 7). For GEORGE, five instrument stations were spaced between 1,860 and 6,474 feet (0.567 and 1.97 km) southeast of surface zero. The associated blast hut was 6,600 feet (2.01 km) from surface zero near the southern tip of Bijire (Reference 134, pp. 8 and 31). Data were recovered from the blast huts, but no recovery information is available.

Staffing: Two men, one a civilian and the other an Army reservist, can be identified with this project. The civilian's exposure was 3.085 R and the reservist's was 2.775 R.

Project Report: WT-69 (Reference 134).

Project 1.6.6.2 -- Ground-Shock Measurements: Crater Survey

Agency: Los Alamos Scientific Laboratory (LASL)

Operations: Before DOG, EASY, and possibly GEORGE, steel stakes were driven flush with the ground at various locations near the surface zeroes. For DOG and EASY the stakes were driven between 25 and 500 feet (7.6 and 152 meters) from the base of each tower. Plans called for the GEORGE stakes to be between 300 and 1,150 feet (91 and 351 meters) from surface zero. Five to ten days after each shot, two to four H&N personnel with monitors were to work in relays marking stakes at the point where they were exposed by the blast. This was expected to take 1-1/2 hours in each case. Complete crater surveys were expected to require 5 days work by a 4-man H&N survey team accompanied by monitors and laborers (Reference 135, pp. 23 through 25). The surveying was done on 17 July 1951, and the stakes were removed in March 1952 (Reference 135, p. 26). Information does not appear to be available on radiation levels at the three shot sites as late as July 1951.

Staffing: Although the scientific report was authored by a LASL employee, the postshot work apparently was done entirely by H&N personnel and radiation monitors of unknown affiliation.

Project Report: WT-109 (Reference 135).

Project 1.7 -- Radiochemical Yield and Efficiency Measurements

Agency: Los Alamos Scientific Laboratory (LASL)

Operations: Radio-controlled B-17 drones were flown through all the shot clouds to collect samples for analysis. Some or all of the drones also participated in Projects 4.1, 6.1, 6.5, 6.8, and 8.1. Each drone was controlled by personnel aboard a B-17 controller aircraft. One or more of the drones and their controllers were supervised by personnel aboard another B-17, the master-controller. For this experiment each drone was to make one pass through the shot cloud. Each drone entered the cloud at a different altitude. The manned B-17s -- the controllers and master controllers -- did not enter the cloud. After each shot, drones, controllers, and master controllers returned to Enewetak airfield. Samples were removed from the aircraft (Figure 17) and they were decontaminated as required.

Readings of gamma intensity in drones penetrating the cloud were over 1,000 R/hr. In drones penetrating the cloud stem, gamma readings exceeded 100 R/hr. The average contamination on the drones immediately after passing through the cloud was between 10 and 20 R/hr (Reference 136, p. 1). The highest reading recorded on the outside of a drone after landing was 20 R/hr beta plus gamma, the gamma being only 6 R/hr (Reference 137, p. 106). Several days of waiting for contamination levels to decay naturally and vigorous decontamination efforts were required before the drones were safe to service. Drones were not considered safe for maintenance until 4 days after shot DOG. Available records do not indicate radiation levels encountered by the controllers and master controllers or the degree to which they may have been contaminated. Aircrews, ground crews, and personnel retrieving samples were all in positions for possible radiation exposure in this experiment, as were personnel accompanying samples back to the United States (Reference 97, D-Day, No. 50). Samples were packaged to keep radiation readings below 1 R/hr measured 1 foot from the container (Figure 42) and were placed in the C-54 air transports so that no personnel in the plane would be exposed to more than 0.1 R/day (Reference 5, p. 90).

Staffing: The project report was authored by two LASL civilian scientists, who acknowledged the work of twenty-six other LASL civilians. The work described, however, appears to have been done at LASL in New Mexico. The report does not indicate which of the personnel actually were at Enewetak helping with the experiment. Both authors and four other personnel were badged, with the highest exposure being 3.785 R. Drones, controllers, and master-controllers and their respective aircrews and ground crews were part of TU 3.4.2, based on Enewetak Island and formed from the 3200th Drone Squadron from Eglin AFB, Florida. The unit's peak strength was 649, and 421 men were badged at one time or another. Fifty-two had badge exposures of over 3 R. However, since most of the exposures were received just after ITEM, between 25 and 29 May, they may have been received from fallout rather than from test operations.

Project Report: WT-113 (Reference 138).

Project 1.8 -- Measurement of X-Rays

Agency: University of California Radiation Laboratory (UCRL)

Operations: Detectors for the EASY portion of this experiment were in a blockhouse near the base of the tower and were joined by cable to a recording station 2,400 feet (732 meters) southeast of surface zero. For GEORGE

Figure 42. Monitor checks GREENHOUSE radioactive sample package for radiation before loading on C-54.

the detectors were at the base of the shot tower. Buried cable carried the signals from them to a recording station that UCRL shared with NRL on Aomon about 2,400 feet (732 meters) southeast of the tower (Reference 139, pp. 18 through 19; Reference 108, pp. 46 and 53).

Following shot EASY, five UCRL personnel left Parry at 0800 by LSU to recover film from recording stations. At 1230 they left Enjebi by LSU to go to Bijire. The purpose of this latter activity is unknown (Reference 109, pp. E-I-28 and E-I-33). Six hours after the shot a UCRL party of seven men accompanied by a monitor started for Lojwa from Parry by LCM. There they boarded a weapons carrier to retrieve the film from the recording station on Aomon. Apparently they were to stay at least 30 minutes (Reference 102, p. G-I-21). At EASY H+1 the estimated radiation level in the vicinity of the recording station on Enjebi was between 3 and 6 R/hr. On Bijire it was 0.00005 R/hr (Reference 38, p. 8; Reference 111, p. 34).

At GEORGE H+1, the estimated radiation level was between 25 and 100 R/hr in the vicinity of the recording station on Aomon (Reference 111, p. 40). By 1000 the next day the radiation level was down to between 0.5 and 2 R/hr (Reference 38, p. 63).

The project did not participate in DOG and ITEM.

Staffing: The project report lists 54 UCRL personnel as having had a role in planning and executing the experiment (Reference 139, p. vii). Forty-nine personnel were civilians and the rest were military -- three Navy, one Air Force, and one Army (Reference 110, p. E-I-28). Sixteen civilians and two Navy personnel were badged. Highest exposure was 3.330 R recorded by a UCRL staff member mentioned in the TG 3.1 Operation Order as a member of the EASY recovery party.

Project Reports: WT-79 (Reference 139); WT-80 (Reference 140); and WT-51 (Reference 141).

Project 1.9 -- Air Drop Instrumentation

The three parts of this project were designed to further development of instruments that could be used in aircraft for quick estimation of nuclear weapon yield. None of the test instruments were mounted in aircraft.

Project 1.9.1 -- Bhangmeter Measurements

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

Operations: Devices were set out at Parry for all shots, with additional devices at Ananij for DOG and at Billae for EASY. Recorders were attached to the bhangmeters; thus recovery teams were sent to Ananij and Billae to retrieve the data (Reference 142, pp. 17 and 19). No information is available, however, on when recovery occurred.

Staffing: The number and affiliation of persons working on this experiment are unavailable although they probably were EG&G civilians. The author of the project report was the only person who can be identified by name. He apparently was the senior EG&G representative at the test range. His exposure was 0.100 R.

Project Report: WT-92 (Reference 142).

Project 1.9.2 -- Measurement of Teller-Alpha

Agency: Edgerton, Germeshausen & Grier

Operations: For DOG, equipment was placed on the Ananij photo tower, 34,590 feet (10.54 km) from surface zero. Equipment for EASY was mounted on the Billae photo tower, 44,560 feet (13.58 km) from surface zero (Reference 143, p. 20). The equipment location for shot GEORGE may have been Parry. The project did not participate in ITEM. Because recording devices were attached directly to the detectors, recovery parties had to visit the photo towers to recover the data, but no information on recovery is available.

Staffing: Same as Project 1.9.1.

Project Report: WT-108 (Reference 143).

Project 1.9.3 -- Disc Camera

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

Operations: Disc cameras were placed on the Ananij and Billae photo towers for the same shots (DOG, EASY, and GEORGE) as used in Project 1.9.2. Film had to be recovered from the cameras, but information on recovery is not available.

Staffing: The project probably was staffed by EG&G civilians, but their number cannot be determined. None can be identified by name.

Project Report: WT-112 (Reference 144).

Project 1.10 -- Cryogenics

Agency: Los Alamos Scientific Laboratories (LASL)

Operations: Work on this special project was done before shots GEORGE and ITEM, mostly on Parry Island and around the respective shot towers. Locations and times of project activity were such that personnel should have been exposed to little radiation.

Staffing: The project report lists 17 men as having worked on the project in the field. Their affiliations were as follows: LASL, 11; UCRL, 2; Army, 1; H&N, 3. One of the LASL personnel was also an Army officer. One UCRL employee, three LASL employees, and all of the H&N employees appear to have been unbadged. Highest exposure in the group was 2.200 R for a LASL civilian.

Project Report: WT-50 (Reference 145).

Project 1.11 -- Timing and Firing and Fiducial Markers

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

Operations: A central station on Parry sent signals via submarine cables to a timer station on the shot island for all shots. The timer station controlled signals to the test device and to experimental equipment on the shot island and elsewhere. In some applications, light-sensitive triggering devices (called "blue boxes") provided the signal to start experimental equipment.

Staffing: This project was manned entirely by EG&G personnel.

Project Report: WT-99 (Reference 146).

Project 1.12 -- Long-distance Measurement of Energy Yield of an Atomic Explosion

Agency: University of California Radiation Laboratory

Operations: Devices for detecting light from DOG were set out on Wake and Saipan islands. For EASY, detectors on Saipan were used again, and others were carried aloft by a Guam-based C-54 of the 2143rd Air Wing. At shot time the plane was about 630 nmi (1,168 km) northeast of Enewetak. The detectors were so far from the detonations that personnel operating them and the crew of the aircraft could not have been exposed to radiation.

Staffing: A number of men are listed in the project report, but it is not clear how many were at the detector locations.

Project Report: WT-106 (Reference 14).

PROGRAM 2 -- BIOMEDICAL

Projects making up this program can be divided into two groups: first, those investigating effects of nuclear detonations on mice, dogs, and swine; and, second, those investigating the characteristics of various organisms and substances (biological dosimeters) that were believed to have the capability to measure radiation exposure. Results of the animal experiments were used to estimate injuries that might be caused in a human population exposed to a nuclear detonation. At each shot animals often played a role in several projects. Moreover, animals often were in the same experimental stations with the biological dosimeters. The biomedical program is described as a whole on a shot-by-shot basis, rather than on a project-by-project basis as was done for Program 1.

The program was based on Japtan Island, where H&N had built staff living quarters, laboratories, and animal pens. To ensure that the test animals were acclimated, adult animals were shipped from the United States well in advance, and the animals used in the test were bred on Japtan. *Tradescantia*, a flowering plant used in the experiments, was grown on Japtan.

The program was headed by a LASL consultant, and his deputy was a LASL employee. Program 2 was staffed by 99 personnel drawn from various organizations as shown in Table 15.

Project reports for Program 2 are WT-8 (Reference 147), WT-9 (Reference 148), WT-13 (Reference 149), WT-21 (Reference 10), WT-22 (Reference 150), and WT-43 (Reference 151).

Test animals were removed from their pens and placed in cylindrical containers on Japtan. These containers (Figure 43) facilitated easy handling and quick retrieval from radioactive areas. The animals were taken by small boat and then by truck (Figures 44 and 45) to test stations at various ranges from surface zero and the carrying containers placed inside the pipe-like test stations (Figure 46), which offered protection against overpressure and thermal effects. After the shot, the containers with the test animals were retrieved and returned to Japtan. Figure 47 shows recovery of containers after shot EASY.

Shot DOG

Mice were placed in 16 stations between 2,700 and 6,300 feet (0.823 and 1.92 km) from surface zero on Runit. *Tradescantia* flowers were added in eight of the stations. They were also put aboard each of three B-17 drones that flew twice through the shot cloud at altitudes of 16,000, 18,000, and 20,000 feet

Table 15. Sources of personnel for Program 2, GREENHOUSE.

Organization	Enlisted Men	Officers	Civilians
Unit One, Navy Bureau of Medicine	50	1	0
Other Navy	7	12	2
Army	0	4	0
Air Force	0	4	0
Marine Corps	1	0	0
Los Alamos Scientific Laboratory	0	0	7
Oak Ridge National Laboratory	0	0	2
Brookhaven National Laboratory	0	0	1
University of Rochester	0	0	6
University of California, Los Angeles[a]	0	0	1
Northwestern University[a]	0	0	1

Note:

[a]Also affiliated with the Veterans' Administration.

Source: Reference 98.

Figure 43. Containers for animal exposure experiments in GREENHOUSE.

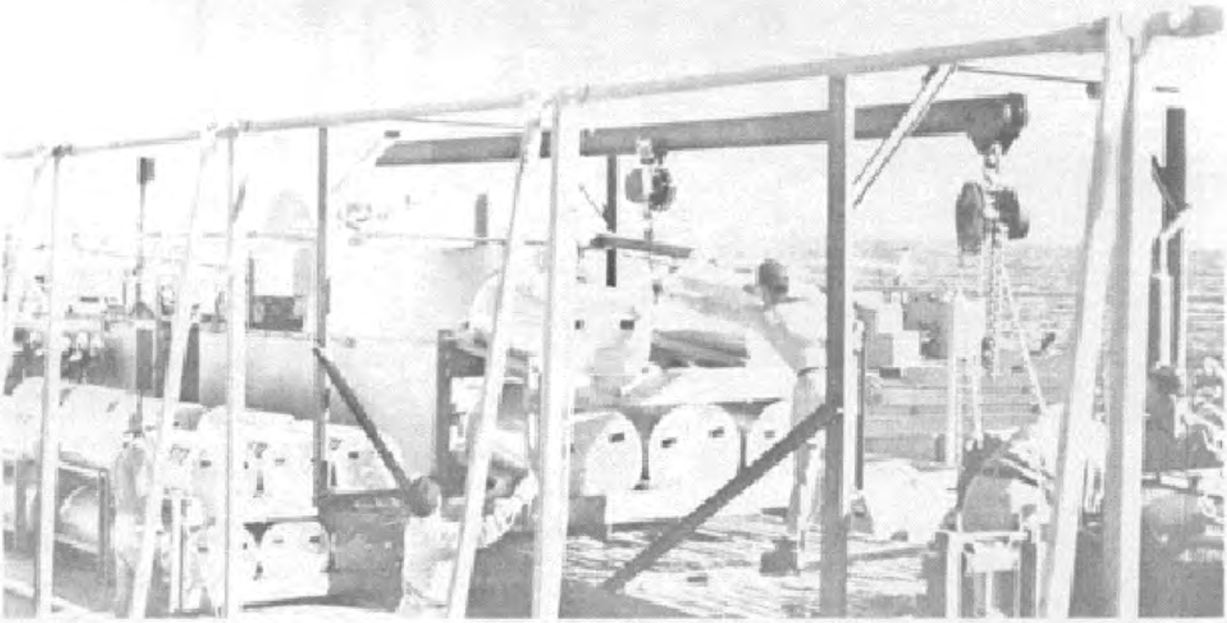

Figure 44. Animal container being loaded on trucks from boat, GREENHOUSE.

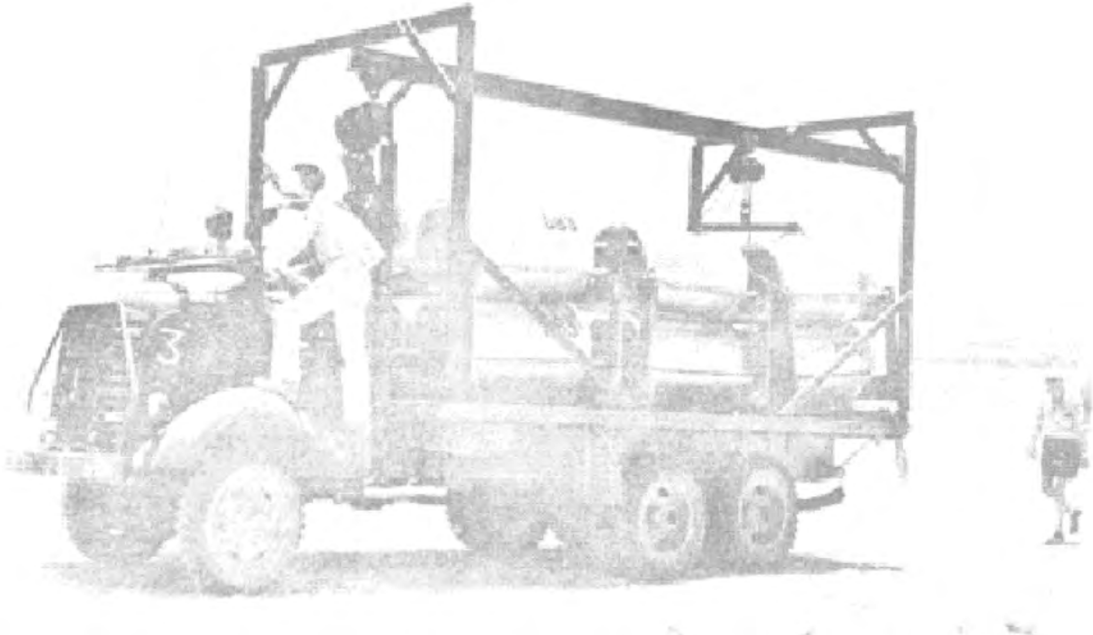

Figure 45. Truck with special equipment for handling animal exposure containers, GREENHOUSE.

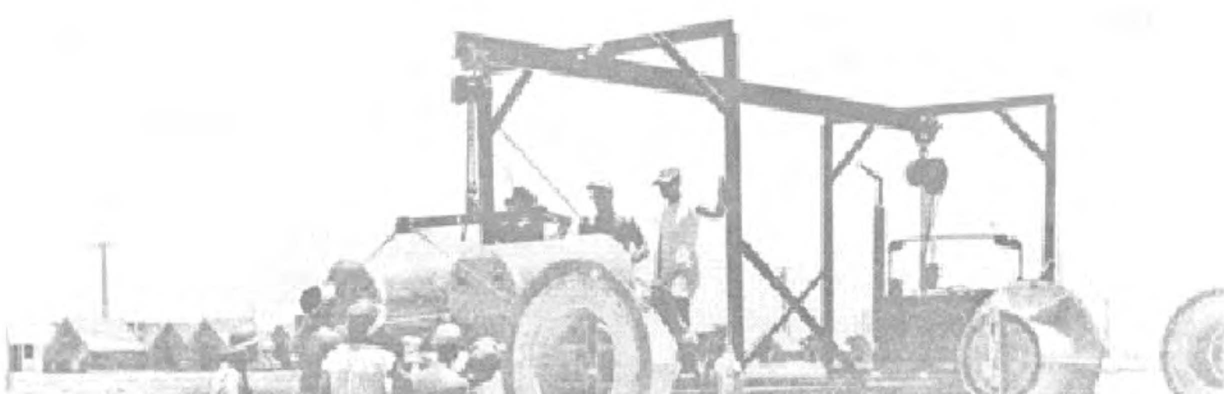

Figure 46. Animal exposure containers being placed within test stations, GREENHOUSE.

Figure 47. Pickup of animals after exposure, GREENHOUSE.

(4.88, 5.49, and 6.10 km), respectively (Reference 10, p. 48; Reference 151, pp. 17, 57, 93, and 139). Recovery crews of TU 3.1.2 left for Runit at about H+30 minutes and returned to Japtan about 2 hours later. Other personnel from the task unit collected the specimens from the drones when they were landed (Reference 97, D-Day, Nos. 38a, 43, and 69).

The animal stations nearest surface zero were in an area with a radiation level estimated between 1 and 3 R/hr at H+1 (Reference 111, p. 28). Drone contamination and radiation exposure potential are discussed under Project 1.7.

Shot EASY

Mice, dogs, and swine were set out in stations roughly along the zero line southeast of surface zero on Enjebi. Beginning 2,025 feet (617 meters) from surface zero, the line of stations stretched to the island's southeastern shore (Reference 151, p. 57). Additional stations were on Mijikadrek, Kidrinen, and Bokenelab. The most distant station, on Bokenelab, was 16,992 feet (5.18 km) from surface zero (Reference 10, p. 50).

Phantoms were set out in various stations. These were plastic or Masonite devices constructed to simulate radiation absorption characteristics of human beings and experimental animals. The human phantoms, simulating tank crews, were placed in tanks, the closest 2,250 feet (686 meters) from surface zero.

As before, Tradescantia was placed at many of the stations (Reference 151, pp. 114 and 140 through 142).

Various materials considered as dosimeters were exposed to radiation from the blast. A species of mold, corn kernels, and glass samples were put in stations between 900 and 2,400 feet (274 and 732 meters) from the tower along the zero line. Potassium bromide crystals and luminescent glass were placed in some of the more distant Enjebi stations (Reference 149, pp. 1, 14, and 21). Mice and Tradescantia were placed aboard drones and exposed in the same way as for DOG (Reference 151, p. 139).

EASY recovery for the biomedical program started a few minutes after the shot when two LSUs, five LCMs, and a water taxi left Parry for Enjebi via Japtan. The recovery teams, at least those after the dogs, arrived at Enjebi at 0900 (Reference 150, p. 90). At about 0830 a group from TU 3.1.2 retrieved the specimens from the three drone B-17s (Reference 109, p. E-I-29). Dogs and their handlers were back at Japtan by 1700, and probably the other personnel, animals and samples were also. Two days after the shot, TU 3.1.2 parties visited Enjebi, Mijikadrek, Kidrinen, and Bokenelab to recover batteries (Reference 109, p. E-I-43).

In the area of the station 900 feet (274 meters) from surface zero, the estimated radiation level at EASY H+1 was 1,400 R/hr. The animal station closest to surface zero was in an area with a radiation level of between 16 and 29 R/hr (Reference 111, p. 28). D-day recovery attempts appeared doubtful in view of the high radiation levels, yet the project reports give the impression that all animals were recovered the first day. Recovery from the stations with the dosimetry material between 900 and 2,400 feet (274 and 732 meters) from surface zero is not specifically mentioned in the available records. Two days after the shot, radiation levels were as low as 0.005 R/hr on the western edge of Enjebi and were 0.018 R/hr on Mijikadrek, 0.028 R/hr on Kidrinen, and 0.040 R/hr on Bokenelab (Reference 38, p. 6). Drone contamination is discussed under Project 1.7.

Shot GEORGE

Mice, dogs, swine, and Tradescantia were used for the GEORGE biomedical experiments. They were placed in stations along the zero line between 3,000 feet and 14,355 feet (0.914 and 4.38 km) southeast of surface zero. Stations were on Aomon, Bijire, Lojwa, Alembel, and Billae (Reference 10, p. 52; Reference 147, pp. 9 and 16; Reference 151, pp. 20, 57, and 141). Phantoms were placed in one station. As with DOG and EASY, mice and Tradescantia were placed aboard three drones that penetrated the cloud twice (Reference 151, pp. 93 and 117).

Recovery began at about H+5:45 when a part of TU 3.1.2, consisting of one LSU and three LCMs, departed Japtan for Lojwa, Alembel, and Billae. They were expected to return about 3-1/2 hours later (Reference 102, p. G-I-21). No information is available on when the mice and plants were removed from the drones, but they were returned to Japtan about 10 hours after the shot (Reference 102, p. G-I-23).

At H+1, the estimated radiation level on Aomon in the neighborhood of animal stations nearest to surface zero was between 25 and 100 R/hr. On the portion of Bijire farthest from surface zero, it was estimated at less than 0.10 R/hr (Reference 111, p. 40). The levels on Lojwa and Alembel are not available. The level on Billae at 1400 on GEORGE day was 0.0003 R/hr (Reference 38, p. 9). Drone contamination is discussed under Project 1.7.

Shot ITEM

Dogs were put in nine foxholes between 1,200 and 4,500 feet (0.366 and 1.37 km), roughly south of the ITEM surface zero on Enjebi. They were recovered at about H+6:30 (Reference 147, pp. 1, 7, and 29). Two foxholes 1,200 feet (366 meters) from surface zero were in an area where the estimated exposure rate 1 hour after the detonation was about 200 R/hr (Reference 111, p. 45).

PROGRAM 3 -- STRUCTURES

This program, sponsored by AFSWP, investigated nuclear blast effects on various types of civilian and military structures. The AEC and the services all had an interest in the program, which was headed by a civilian from AFSWP. The program participated in shot EASY only.

Twenty-seven structures were erected, two for the Army, twelve for the Navy, twelve for the Air Force, and one for the Public Building Service of the Government Services Administration (GSA) (Reference 5, p. 66). Various instrument stations were near the test structures. Project 3.1 was responsible for the two Army structures, which were on Enjebi, one 1,710 feet (521 meters) and the other 2,970 feet (905 meters) from surface zero. Project 3.2 was responsible for the 12 Navy structures. Eleven were on Enjebi: two only 250 feet (76 meters) from surface zero and the rest between 2,400 and 3,630 feet (0.732 and 1.11 km) from surface zero. One was on Mijikadrek. The 12 Air Force structures were the responsibility of Project 3.3. Seven of these structures were on Enjebi, between 3,520 and 4,200 feet (1.07 and 1.28 km) from surface zero, and the rest were on Mijikadrek. Sandia Corporation was in charge of instrumenting the buildings, and the personnel working on this part of the program were organized as Project 3.4. A representative of the Public Building Service, operating as Project 3.5, used a structure on Kidrinen for that organization's portion of the program (Reference 152, pp. 26 and 27, 60 through 62).

At 1230 on shot day, two groups of program personnel left Parry by boat to begin recovery operations. Aboard an LSU bound for Enjebi were one person each from Projects 3.1, 3.2, and 3.3, accompanied by radiation monitors and H&N personnel. They did a preliminary damage survey. Three Project 3.4 personnel with radiation monitors and a photographer were aboard an LCM bound for Mijikadrek and Enjebi. They recovered instruments on Mijikadrek. One Project 3.3 man, accompanied by a photographer, a radiation monitor, and an H&N supervisor, made a preliminary damage survey on Mijikadrek. The program director and his deputy inspected both islands. The various groups returned to Parry at about 1700 (Reference 109, p. E-I-35). A detailed examination of blast damage was begun 2 days after the detonation. At that time radsafe requirements allowed only brief entry into the Army structure 1,710 feet (521 meters) from surface zero. The date when this building was studied is not available. The two Navy structures 250 feet (76 meters) from surface zero could not be inspected until a week after the shot. Photographing and documenting the damage took 16 working days. Photographers from TU 3.1.6 played a major role in this work (Reference 152, p. 68).

Estimated radiation levels on Enjebi at H+1 were from one to several hundred roentgens per hour (Reference 111, p. 34). By 1300 on D+2, they had decreased considerably so that only the two Navy buildings 250 feet (76 meters) from surface zero were within the 1 R/hr zone. Exposure rates on Mijikadrek and Kidrinen were about 1 R/hr on shot day and about 0.5 R/hr on D+1.

Just before the start of testing, 125 personnel were assigned to Program 3 as follows (Reference 152, pp. 61 through 63; Reference 153):

Program Headquarters

- 1 AFSWP civilian
- 1 Navy officer assigned to LASL
- 1 AFSWP colonel (unspecified service)
- 1 Air Force civilian
- 1 government civilian
- 1 Massachusetts Institute of Technology civilian
- 1 Army corporal

Project 3.1

- 1 government civilian
- 1 MIT civilian
- 8 civilians of unspecified affiliation

Project 3.2

- 3 Navy officers
- 1 Navy civilian

Project 3.3

- 1 Air Force officer
- 1 Air Force civilian
- 2 Armour Research Foundation civilians
- 1 civilian of unspecified affiliation
- 9 other persons

Project 3.4

- 4 Sandia civilians
- 1 Holmes & Narver civilian
- 2 Navy officers assigned to LASL
- 1 University of California civilian
- 1 Princeton University civilian
- 1 Stanford University civilian
- 1 University of Illinois civilian
- 42 enlisted men
- 37 civilians of unspecified affiliation.

PROGRAM 4 -- CLOUD PHYSICS

This program was designed to gather information on tropical meteorology and on various properties of nuclear clouds: size, appearance, electrical and radioactive characteristics, temperature, turbulence, moisture content, wind velocity, vertical and horizontal mixing, rate of growth, and dispersion characteristics (Reference 111, p. 6). It was headed by a civilian from Air Force Cambridge Research Center (AFCRC) (Reference 5, p. 61). Apparently he was not badged.

Project 4.1 -- Atomic Cloud Documentation

This project was headed by an unbadged civilian from AFCRC. The project consisted of three experiments: Projects 4.1A, 4.1B, and 4.1C.

Project 4.1A -- Cloud Physics

Agency: Air Force Cambridge Research Center, Atmospheric Physics Laboratory (AFCRC)

Operations: Instruments measuring pressure, temperature, and relative humidity were installed in drones, and data were recorded as the drones flew through three shot clouds. Eight drones participated in each shot and attempted two penetrations of the cloud. Nominal penetration heights were every 2,000 feet (610 meters) from 16,000 through 30,000 feet (4.88 through 9.14 km). Data were recovered from the recorders on each drone after landing. The project did not participate in ITEM.

Staffing: The two authors of the portion of the project report dealing with this experiment were AFCRC civilians. Both appear on an early roster of TG 3.1, but neither appear to have been badged. A third AFCRC employee who was badged was associated with this experiment. On Enewetak the instruments carried by the drones were maintained by a group of one officer and four enlisted men from the 3200th Drone Squadron, 550th G.M. Wing, Eglin AFB, Florida, assigned to TU 3.4.2. One of the enlisted men had an exposure of 4.170 R. An unbadged field representative of the Kollsman Instrument Corporation assisted in maintaining the instruments (Reference 154, pp. 2 and 3).

Project Report: WT-115, Part I (Reference 154).

Project 4.1B -- Development of Atomic Clouds

Agency: Institute of Geophysics, University of California at Los Angeles

Operations: For the first three shots, data were collected from four ground stations:

- Biken -- Unmanned but with an automatic camera
- Japtan -- Two observers
- Enewetak Island -- Two stations, one at each end of the island with observers.

Also for the first three shots, a man aboard each of the two B-50Ds (49-340 and 49-290) took pictures of the shot cloud with a hand-held camera. The activities of the B-50Ds are discussed under Project 1.6.3.4. For ITEM, one of the ground stations on Enewetak Island was manned by two observers (Reference 154, pp. 73 through 76; Reference 20, pp. 57, 59, and 61). No record is available of when film was recovered from the camera on Biken. The camera and related equipment were recovered from the island on GEORGE D+2 (Reference 102, p. G-I-17).

Staffing: An Air Force officer attached to TU 3.1.3 supervised the photography. An Air Force enlisted man and a civilian, also attached to TU 3.1.3, are named as helping with the photography from Enewetak. EG&G personnel may have made up the rest of the crew manning the Enewetak cameras. Two Air Force officers, one from TU 3.4.2 and the other of unspecified affiliation, are named as the B-50Ds photographers. The Air Force enlisted man was not badged, and EG&G personnel cannot be identified. A civilian and two Air Force officers authored the portion of the project report dealing with this experiment (Reference 154, pp. 65 and 67). The affiliation of one of the Air Force officers is unknown, and neither was badged. The other Air Force author was attached to TU 3.4.2. He had the highest listed exposure -- 3.525 R -- of any person identified with this experiment.

Project Report: WT-115, Part II (Reference 154).

Project 4.1C -- Cloud Tracking

Agency: Edgerton, Germeshausen & Grier

Operations: Apparently data for this experiment consisted of photographs taken between about 20 minutes and 1 hour after the detonation by cameras at the two camera stations on Enewetak and the one on Biken. This project did not participate in ITEM.

For the camera crews and those recovering film and photographic equipment from Biken, the exposure potential was the same as for Project 4.1B.

Staffing: It probably was the same as for Project 4.1B, except that the personnel in B-50Ds were not involved.

Project Report: WT-115, Part III (Reference 154).

Project 4.2 -- Measurement of Surface-Air Movements Associated with Atomic Blasts

Agency: Air Force Cambridge Research Center, Atmospheric Physics Laboratory (APL/AFCRC)

Operations: DOG instrument stations were located on Runit (8 stations from 2,400 to 4,500 feet [0.732 to 1.37 km] from surface zero), Billae (1 station), Alembel (1 station), Eleleron (6 stations), Bokenelab (1 station), Kidrinen (1 station), Mijikadrek (4 stations), Enjebi (3 stations), and on Dridrilbwij (2 stations) (Reference 4, p. 64; Reference 155, p. 16). For EASY, the stations were on Enjebi (8 stations 1,500 to 4,668 feet [0.457 to 1.42 km] from surface zero), Mijikadrek (4 stations), Kidrinen (1 station), Dridrilbwij (2 stations), Bokenelab (1 station), Eleleron (6 stations), Alembel (1 station), and Billae (1 station) (Reference 4, p. 64; Reference 155, p. 19). For GEORGE, the stations were on Eleleron (1 station 1,950 feet [594 meters] from surface zero), Aomon (2 stations 2,400 to 3,780 feet [0.732 to 1.15 km] from surface zero), Bijire (4 stations 5,700 feet [1.74 km] from surface zero), Alembel (1 station), Bokenelab (1 station), Billae (1 station), Kidrinen (1 station), Mijikadrek (3 stations), Enjebi (2 stations), and Runit (2 stations) (Reference 4, p. 64; Reference 155, p. 22). Data recordings had to be recovered from each station. At shot DOG H+6, two teams returned to Runit and recovered records from the eight stations. Recovery took about 12 minutes per station. Records from the other stations were retrieved on D+2 (Reference 155, p. 15). At EASY H+6, three teams recovered records from stations on Enjebi and Mijikadrek, except for the Enjebi station 1,500 feet (457 meters) from surface zero, which was too radioactive. Records from that station and from those on the other islands were recovered on D+2 (Reference 155, p. 18). One project team recovered records from stations on Eleleron, Aomon, and Bijire at GEORGE H+10. Three days later records were recovered from the other stations. At the same time, all equipment from the stations was recovered, except that from the two stations on Eleleron 1,950 and 2,400 feet (594 and 732 meters) from surface zero, respectively. Equipment from the second station was recovered 5 days postshot, and from the first 10 days postshot (Reference 155, p. 21).

Staffing: Ten men manned this project. One was a civilian engineer from the Bendix-Friez Corporation, and the other nine appear to have been attached to APL/AFCRC. One, the project leader, was a civilian; the others were Air Force personnel, two officers and six enlisted men (Reference 155, p. 14). All were badged; the highest recorded exposure was 1.555 R.

Project Report: WT-105 (Reference 155).

Project 4.5 -- The Precipitation and Formation Movement of Clouds in the Central Pacific

Agency: Institute of Geophysics, University of California at Los Angeles (UCLA)

Operations: An elaborate system was organized for collecting and analyzing weather data to produce needed forecasts. The core of the forecasting effort was Joint Task Force 3 (JTF 3) Weather Central, part of TU 3.4.5 and located on Enewetak Island. Information entered the system from several sources:

1. Weather stations in the Pacific region not under operational control of Commander JTF 3 (CJTF 3) (Reference 156, p. 26).

2. Weather stations under control of TU 3.4.5. These included existing stations on Kwajalein and Enewetak and others established for GREENHOUSE on Majuro, Bikati, Kusaie, and Nauru (Reference 156, pp. 19 and 20).

3. The Kwajalein-based 57th Strategic Reconnaissance Squadron (Medium), Weather, assigned to TU 3.4.4 and flying various tracks out of Kwajalein. Aircrews recorded and transmitted data to Weather Central.

4. Patrol Squadron (VP-931), a Navy P2V patrol squadron based on Kwajalein, was given the additional duty of transmitting weather data while on patrol (Reference 101, p. 17).

Data supplied from these sources were used not only for weather forecasting but also for Program 4.5. Moreover, personnel at the weather stations, except Enewetak and Bikati, and personnel on the WB-29s of TU 3.4.4 took photographs of weather conditions, which were used in the Program 4.5 analytical effort (Reference 156, pp. 58, 59).

Personnel at Weather Central, personnel at the weather stations, WB-29 aircrews, and P2V aircrews participated in this project as part of their work providing the weather forecasts required for testing.

Both WB-29s and P2Vs were contaminated. The potential radiation exposure arising from the work of the WB-29s is described under Project 7.4. During DOG operations one P2V was contaminated, and two were contaminated during EASY operations. Twelve hours after DOG, radiation on the engines of the contaminated P2V was measured at 0.040 R/hr. Twelve hours after EASY, engine radiation on the two contaminated P2Vs was 0.020 and 0.040 R/hr, respectively.

The project staff, the aircrews, and Weather Central personnel could have been exposed as the result of their work (Reference 156, p. 5). For example, staff members flew aboard the WB-29s, taking weather photographs for the project (Reference 156, p. 59). The weather tracks flown by the WB-29s were such that they probably encountered no radiation, and no record of such an encounter was found (Reference 156, pp. 23 through 26).

Staffing: Project 4.5 staff had at least three personnel, a civilian and two Air Force officers, all apparently associated with UCLA (Reference 156, p. 5; Reference 110). None of them was badged. TU 3.4.4 was made up of personnel from the 55th and 57th Strategic Reconnaissance Squadrons. At peak strength it had 323 personnel, 162 of whom were badged at one time or another. Highest recorded exposure was 7.030 R.

Weather Central on Enewetak Island (TU 3.4.5) had about 32 personnel, including 12 Navy personnel from TG 3.3, and 3 Air Force personnel from TU 3.4.4. Other members of TU 3.4.5 were all Air Force personnel assigned to weather stations on Majuro, Bikati, Kusaie, Nauru, and Kwajalein. Apparently, none of these was badged. Chapter 7 discusses the parent units of Air Force personnel in TU 3.4.5. VP-931 had 386 personnel, of whom 102 were badged (Reference 157).

Project Reports: WT-40 (Reference 156).

Project 4.6 -- Atmospheric Conductivity

Agency: Air Force Cambridge Research Center (AFCRC)

Operations: Four aircraft were assigned to this experiment: two B-50As (nos. 023 and 017) and two L-13s. The B-50As were equipped to measure the atmospheric conductivity and to collect particulate and gaseous samples in or near the radioactive cloud. During daylight hours, one B-50A followed the cloud, taking conductivity readings and collecting samples. Its purpose was to get information on cloud composition and movements, and on the effectiveness of the two sample-collecting systems. After DOG, one B-50A followed and sampled the cloud from H+2 to H+11; the other took up the task from H+24 to H+30; and the first returned to duty from H+52 to H+60. After EASY the aircraft again followed the cloud during daylight hours, one from H+2 to H+9, and the other from H+26 to H+32. The same pattern was followed after GEORGE, but the exact tracking times are not available. The project did not participate in ITEM. The B-50As also participated in Programs 7.4 and 7.8.

The L-13s flew over the atoll's islands beginning at about DOG H+10. Succeeding flights were made on D+1 through D+4 and on D+10 and D+12. Most flights were at 1,000 feet (305 meters), but some were at 200 and 500 feet (61 and 152 meters). The first flight over the crater area on Runit was made at 500 feet (152 meters) on D+3. Islands for which readings are available are Biken, Kidrenen, Ribewon, Boken, Mut, Ikuren, Parry, Japtan, and Runit. The L-13 resumed conductivity studies at EASY H+10, with flights at 500 and 1,000 feet (152 and 305 meters). Flights apparently were made more or less daily for 10 days. The first L-13 conductivity flights for GEORGE began at H+6 and included passes over the shot island initially at 3,000 feet (914 meters) and dropping to 1,000 feet (305 meters). Flights were made daily until the seventh day after GEORGE.

The B-50As were not to penetrate cloud regions of high radiation, but information is lacking on the radiation level that was to prompt evasive action. Filters on the B-50As particle collection systems had to be changed every 30 minutes by personnel aboard the aircraft. Twelve hours after DOG, engine contamination was 0.150 R/hr. Twelve hours after EASY one aircraft's engines were contaminated to a level of 0.080 R/hr and those of the other to a level of 0.050 R/hr. Aircraft skin contamination was about one-tenth of the engine contamination.

There is no record of the L-13s being contaminated, but as they surveyed the atoll's islands, they passed over some areas of relatively high radioactivity. Readings of the conductivity instruments probably were not readily convertible to radiation readings, and they may not have been available to the flight crews. Apparently, concern developed that the L-13s might be exposed to unacceptable levels of radiation. Data were collected after GEORGE by aircraft fitted with standard radiation detectors.

<u>Staffing</u>: The project report had three principal authors, and they acknowledged the assistance of four others. Two of the principal authors were associated with the Geophysics Research Division of AFCRC. Neither was badged. The third principal author was associated with Carnegie Institute. His recorded exposure was 0.030 R. Two civilians and two military officers who assisted the principal authors were from the Atmospheric Electricity Section, Atmospheric Physics Laboratory, AFCRC. All four were badged; the highest reading was 1.640 R.

The two B-50As were from TD 3.4.2.1. The detachment's personnel and aircraft had come from the 3151st Electronic Group and 3171st Electronic R&D Group at Griffiss AFB, New York. All flight crewmen should have been badged when tracking a cloud but some were not (for example, the pilot of the B-50A flight that tracked the DOG cloud on 8 and 10 April) (Reference 24, pp. 32-33).

The two L-13s were from the Liaison Unit, TU 3.4.6. This task unit in turn was made up of personnel from the 2600th Air Base Squadron, the 4th

Liaison Flight, and the 5th Helicopter Flight, all from Pope AFB, North Carolina. A few personnel were from the 4910th Air Base Group at Kirtland AFB, New Mexico. Only one person in TU 3.4.6 received more than 1 R (Reference 59)

Project Report: WT-71 (Reference 158).

PROGRAM 5 -- RADIATION INSTRUMENT EVALUATION

Program 5 was designed to test newly developed equipment to detect and measure radiation, under conditions not too different than what might be encountered during combat. It was headed by a naval officer assigned to LASL. His exposure was given as 0.990 R.

Project 5.1 -- Evaluation of Ground Radiac

The Army Signal Corps Engineering Laboratories (SCEL) had the leading role in this effort. Work was organized as follows:

- Project 5.1.1 -- Dosimeters
- Project 5.1.2 -- Survey Meters
  - Project 5.1.2.1 -- Shot Island Survey
  - Project 5.1.2.2 -- Drone Survey
  - Project 5.1.2.3 -- Aerial Survey
  - Project 5.1.2.4 -- Personnel Monitoring
- Project 5.1.3 -- Mobile Radiological Laboratory
- Project 5.1.4 -- Landing Monitors.

Project 5.1 staff and their exposures (in roentgens) were (Reference 137, p. 209; Reference 59):

SCEL personnel:

Officers		Civilians		Enlisted	
Project Officer	0.430	Project Scientist	0.310	Clerk	1.360
Supply Officer	0.200	Dosimeter Unit	0.570	Field Lab Unit	1.100
Dosimeter Unit	0.400	Dosimeter Unit	1.410		
Survey MMeter Engineer	2.590	Survey Meter Maintenance	0.540		
Field Lab Unit	1.230	Survey Meter Maintenance	0.040		
Field Lab Unit	1.880	Survey Meter Maintenance	1.285		
		Field Lab Unit	2.035		

Chemical Corp Personnel:

Enlisted		Civilian	
Field Lab Unit	1.450	Dosimeter Unit	1.660

Other civilian participants in Project 5.1 were from Federal Civil Defense Agency (Survey Meter Unit) (2.174 R) and TracerLab, an SCEL contractor that participated in the Field Lab Unit. Highest TracerLab exposure was 1.180 R. The amount of assistance by Project 5.1 to the subprojects is not clear. At a minimum, however, the dosimeter personnel probably retrieved samples of drone contamination for the field laboratory, and the survey meter group had to be supplemented by other members of the project staff for shot-island surveys (for example, see Reference 97, D-Day, No. 43b and D+1 Day, No. 1). Project reports are contained in WT-3 (Reference 159), WT-62 (Reference 78), and WT-63 (Reference 137).

Project 5.1.1 -- Dosimeters

During DOG and EASY, dosimeters were carried by each of the eight B-17 drones involved. During EASY, dosimeters were set out in 23 ground stations. The location of stations is not clear from available information. Those closest to surface zero, however, were placed so as to receive an expected exposure of 2,000 R. Some figures in the project report show the closest station about 3,000 feet (914 meters) from surface zero and the farthest somewhat more than 8,000 feet (2.44 km). Besides Enjebi, stations were on Mijikadrek and Boken. Dosimeters were also placed in the Program 6 tanks "close to ground zero." Apparently, at least the tanks 1,500 and 2,250 feet (457 and 686 meters) from surface zero had Project 5.1 dosimeters in them (Reference 137, pp. 23, 27; Reference 5, p. 70). At 0900 on EASY day a group of four project personnel left Parry by LCM to recover dosimeters from stations on Enjebi, Mijikadrek, and Boken. On D+2, a 4-man party from Project 5.1 again visited Enjebi, Mijikadrek, and Boken (Reference 109, pp. E-I-29, E-I-38, and E-I-45). The record is silent on recovery of Project 5.1 dosimeters from Project 6 tanks. On DOG D+1, a 6-man party went from Parry to Enewetak to retrieve the dosimeters from the B-17 drones, and on EASY D+1 a 2-man party went on the same mission. Project 6.1 personnel, however, may have actually boarded the aircraft to get the dosimeters (Reference 97, D+1 Day, No. 6a; Reference 109, pp. E-I-39; Reference 74, p. 83). The project did not participate in GEORGE and ITEM.

Highest reading observed on shot day by a Project 5.1 team surveying the drones was 6 R/hr, so radiation levels when the Project 5.1 dosimeter group was in or near them must have been less (Reference 137, p. 106). One source gives the radiation level as 0.3 R/wk or less (Reference 74, p. 83). Dosimeters aboard the drone were in canvas cases, which in turn were in plastic envelopes. At least some of the plastic envelopes became radioactive, although the level of this radioactivity is not recorded (Reference 137, p. 16).

Project 5.1.2 -- Survey Meters

Project 5.1.2.1 -- Shot Island Survey

Radsafe monitors from TU 3.1.5 were scheduled to conduct a detailed radiation survey of the shot island the day after each of the first two shots. The day after GEORGE, they were to survey the Eleleron-Aomon-Bijire island chain (Reference 137, p. 104). Each TU 3.1.5 monitor was accompanied by at least one person from Project 5.1 or from among the TG 3.3 monitors assigned to assist with Project 5.1. Each of these personnel carried one of the survey meters being tested and took readings as simultaneously as possible with those taken by his TU 3.1.5 companion.

High radiation levels may have prevented a survey of Eleleron, the GEORGE shot island, on the day following the detonation, but apparently the Project 5.1 group took radiation readings on Aomon. The project report also carries readings for Runit and Enjebi for DOG and EASY shot days, respectively (Reference 137, p. 109).

Working in a 4-man team independently of TU 3.1.5, personnel testing survey meters made additional radiation surveys of shot islands as follows: Runit, 19 days after DOG; Enjebi, 3, 4, and 13 days after EASY; and Bijire, 3 days after GEORGE. Apparently they also surveyed Aomon 13 days after GEORGE. Because of decreased radiation, the men were able to go closer to surface zero than during surveys conducted with TU 3.1.5. Some readings were taken in the detonation craters (Reference 137, pp. 104 and 110). There was no ITEM participation.

Project 5.1.2.2 -- Drone Survey

On the shot days except for ITEM, a 4-man team from Project 5.1 went to the airfield on Enewetak. Using the survey meters being tested, the team took readings from the most contaminated drones. The highest reading was 20 R/hr (beta plus gamma) (Reference 137, p. 106).

Project 5.1.2.3 -- Aerial Survey

On 1 May, 23 days after DOG and 10 days after EASY, Project 5.1 personnel conducted an aerial survey of the atoll. Because the instruments used were quite sensitive, the survey aircraft flew relatively high to avoid driving the instruments off-scale. Readings were taken from altitudes between 100 and 2,500 feet (30 and 762 meters), depending on the amount of residual radiation on the island being surveyed. Given the length of time elapsed since the two shots and the fact that measurements were taken from 100-foot (30-meter) or higher altitudes, the potential radiological exposure to Project 5.1 personnel and the survey aircraft crew probably was minimal (Reference 137, pp. 106 and 114).

Project 5.1.2.4 -- Personnel Monitoring

Personnel monitoring was not part of the plan for Program 5.1, but unexpected fallout from DOG offered an opportunity to further test some of the survey meters. One of the Project 5.1 personnel, with several of the test meters, worked alongside the regular radiation monitors to check personnel for contamination. During this work, personnel from Project 5.1 observed readings of from 0.070 to 0.250 R/hr.

Project 5.1.3 -- Mobile Radiological Laboratory

A small laboratory for testing radioactive samples was installed in a military trailer. Project 5.1 personnel working in the laboratory analyzed radioactive samples from a wide range of sources in the proving ground to test the laboratory, its equipment, and the then accepted analytical procedures under field conditions. Samples were collected in filters at the trailer and from the skins of contaminated drone B-17s. Soil samples were collected from the shot islands. Projects 6.1, 6.4, and 6.9 also collected samples used in this experiment (Reference 137, p. 175).

Collection of samples from drone skins apparently lasted for 2 days. At 0800 on DOG D-day a 2-man party of project personnel departed Parry for Enewetak to pick up samples. The next morning one person went on the same mission (Reference 97, D Day, No. 43b, D+1 Day, No. 2a). The pattern for EASY was the same, except that the initial party had six people (Reference 109, p. E-I-28 and E-I-39). For GEORGE, the first trip for samples was made the afternoon of the shot day by one person, with the second trip the morning of the next day (Reference 102, pp. G-I-22 and G-I-24).

The exposure potential in laboratory work was high. Many samples had to be analyzed and many of the procedures were very time-consuming. However, the highest reading among Project 5.1.3 personnel was 2.035 R (Reference 137, p. 209, Reference 59).

Project 5.1.4 -- Laundry Monitors

Four devices for measuring radioactive contamination of clothing were built and tested on clothing collected by Project 6.9 personnel as part of that project. Highest levels of contamination encountered were somewhat in excess of 0.020 R/hr, beta plus gamma, on booties worn on the shot islands. For other clothing, highest level was 0.065 R/hr on test rain suits worn by aircraft decontamination crews (Reference 72, pp. 73 and 74).

Project 5.2 -- Evaluation of Air-Borne Radiac Equipment

Agencies: Navy, Bureau of Aeronautics (BuAer)

Air Force Air Research and Development Command

Operations: A Navy P2V-2 (No. 368) and Air Force B-17 (No. 339246) were similarly equipped with equipment to track radioactive clouds, to map surface radioactivity from the air, and to receive data on surface radiation transmitted by detectors on the ground (Reference 160, pp. 1, 6, and 8). The project did not participate in ITEM. Before H-hour, the P2V-2 was on station at about 8,000 feet (2.44 km) and about 20 nmi (37 km) from surface zero. Immediately following the detonation, it began to fly toward the radioactive cloud. The pilot was under orders not to penetrate the cloud to any significant degree. The P2V-2 followed the cloud for about 2 hours after each shot. Next, it attempted to take measurements of radiation intensity at various altitudes over surface zero. Passes were made at 500-foot (152-meter) intervals, beginning at about 6,000 feet (1.83 km) and working down to about 500 feet (152 meters). Finally, radiation distribution in the area of surface zero was surveyed. Starting at about H+4 after DOG and EASY, the aircraft flew a pattern of four passes over surface zero, with passes separated from each other by about 45°. The pattern was flown at both 1,000 and 500 feet (305 and 152 meters). In addition, about eight radiation detection units were dropped to transmit readings by radio. For shot GEORGE, the same pattern was flown and the radiation detection units dropped, but these activities were not started until D+1.

At H-hour, the B-17 was on station at about 18,000 feet (5.49 km) and 20 nmi (37 km) from surface zero. Immediately after the shot, the plane flew gradually toward the cloud, and tracked it until its instruments no longer gave good readings. The next day it measured radiation intensity versus altitude and surveyed the distribution of radiation on the ground around surface zero in the same way as the P2V-2. The B-17 also recorded signals from the radiation detectors dropped by the P2V-2 (Reference 160, pp. 37 and 38).

Cloud tracking had potential for exposure to radiation, but data are lacking on radiation levels encountered during that activity. Available records do not indicate that either of the Project 5.2 aircraft was contaminated. During the survey of radiation on the shot island, the aircraft's instruments indicated radiation levels of more than 1,000 R/hr on the ground. The radiation levels at their operating altitudes are not indicated in the records (Reference 160, pp. 76 and 78) but would be much lower.

The operations detailed above enabled the test and evaluation of newly designed airborne radiac equipment.

Staffing: The authors of the project report were a civilian and a Navy officer, both probably from BuAer. Their exposures were recorded as 2.150 R and 1.170 R, respectively. The P2V-2 and the B-17 were based on Enewetak and attached to TU 3.4.2. The B-17's parent unit probably was the 3200th Drone Squadron from Eglin AFB in Florida. Available records do not indicate the parent unit of the P2V-2, but it may have been from the Johnsville Air Development Center at Johnsville, Pennsylvania (Reference 160, p. 6). A crew of five manned the B-17. Five men also crewed the P2V-2. Highest recorded aircrew exposure was 1.630 R. For shot GEORGE, four additional personnel were aboard one of the planes: the two authors of the project report, a Navy officer, and an unbadged person. The Navy officer, who was from AFSWP, had the highest exposure, 2.140 R.

Project Report: WT-104 (Reference 160).

PROGRAM 6 -- PHYSICAL TESTS AND MEASUREMENTS

Program 6 was designed to study a wide range of blast effects and to aid in devising defensive measures. The program was headed by the naval officer who headed Program 5.

Project 6.1 -- Cloud Phenomena: Study of Particulate and Gaseous Matter

Agencies: Army Chemical Corps (Chemical Corps)

Army Chemical and Radiological Laboratories (CRL)

Army Chemical Center (ACC)

Naval Radiological Defense Laboratory (NRDL)

Operations: Four types of sampling devices were installed in twelve of the drone B-17s. Eight B-17s were airborne for each shot except ITEM, passing through the shot cloud at 16,000, 18,000, 20,000, 22,000, 24,000, 26,000, 28,000, and 30,000 feet (4.88, 5.49, 6.10, 6.71, 7.32, 7.92, 8.53, and 9.14 km). They collected these samples while participating in Projects 4.1, 6.5, 6.8 and 8.1. Samples were removed after the drones were landed. Sample removal from some of the devices required entering the B-17 drone. Information is lacking on removal of samples from all four types of collectors, but samples from two types were removed by two-man teams, each consisting of a person from Project 6.1 and a radiation monitor. Two teams were used on each shot and each team entered an average of four B-17s. These teams also removed Project 6.6 filter material samples and badged dosimeters for Project 5.1. Removal times were between H+28 and H+36 for shots DOG and EASY, and between H+5 and H+9 for GEORGE (Reference 74, p. 83). The project did not participate in ITEM.

Highest shot-day drone radiation level for which there is a record was 20 R/hr (beta plus gamma) (Reference 137, p. 106).

Staffing: The project staff included personnel from the Chemical Corps, CRL, ACC, NRDL, and TracerLab, Inc. Highest radiation exposure of the two-man removal teams was less than 0.3 R/wk (Reference 74, p. 83). Highest exposure recorded among the personnel from the Army organizations, all civilians, was 2.525 R; one person was not badged. The NRDL group consisted of five civilians and one naval officer. Highest exposure recorded was 0.944 R, with one person not badged. Four civilians represented TracerLab, Inc. One was not badged, and highest exposure recorded was 1.360 R. Staffing and exposures of the drone group are discussed under Program 1.7.

Project Report: WT-72 (Reference 74).

Project 6.2 -- Effect of Thermal Radiation on Material

Agencies: Naval Radiological Defense Laboratory (NRDL)

Naval Material Laboratory (NML)

Operations: Samples were placed in ten stations: five on Mijikadrek, four on Kidrinen, and one probably on Bokenelab. These stations were near the Program 3 structures. In addition, two camera stations on Mijikadrek and four camera stations on Kidrinen were set up to record the response of test materials to shot EASY. Recovery was as follows (Reference 109, pp. E-I-32, E-I-38, and E-I-44):

- EASY Day at 1000
  - -- Two Project 6.2 personnel, one TU 3.1.6 photographer, and one radsafe monitor left Parry by boat for Mijikadrek, Kidrinen, and Bokenelab to inspect and photograph sample stations
  - -- A group of seven project personnel left for the three islands, probably to recover samples
- EASY D+1 at 0730
  - -- Ten project personnel departed Parry for the islands and stayed until about 1330
- EASY D+2 at 0730
  - -- Twelve project personnel departed Parry for the three islands and stayed until about 1430.

Staffing: The project staff consisted of seven NRDL personnel and two NML personnel. Highest recorded exposure for the group was 0.890 R (Reference 161, p. 97). Camera stations were the responsibility of EG&G. The photographer from TU 3.1.6 and the radiation monitor cannot be identified.

Project Report: WT-70 (Reference 161).

Project 6.3 -- Combat Vehicle Exposure

Agency: Army Ballistic Research Laboratories (BRL)

Operations: Pairs of tanks were placed 1,500, 2,250, 3,000, 3,699, and 4,200 feet (0.457, 0.686, 0.914, 1.13, and 1.28 km) from the EASY surface zero (Reference 162, p. 1). Recovery preparations began at 0800 on shot day with the transportation of two vehicles to Enjebi for later use by Project 6.3 personnel. Later the same morning, two project personnel and a radsafe monitor surveyed Enjebi from an L-13. On D+2, at 0815, six project personnel went to Enjebi by boat. At 0930 they were followed by a party of ten with two monitors. Apparently these two groups went to the tanks to recover gauges. Figure 48 shows two men inspecting a tank, which had lost its turret, at the 1,500-foot (457-meter) station (Reference 109, pp. E-I-28, E-I-32, and E-I-47).

Staffing:

- One military officer, probably from the Army but attached to the Supply Division, Headquarters Air Material Command, Wright-Patterson AFB
- Four civilians from BRL
- One civilian from the Department of Physics, Ohio State University
- One civilian and two enlisted men from the Automotive Division, Development and Proof Services, Aberdeen Proving Ground

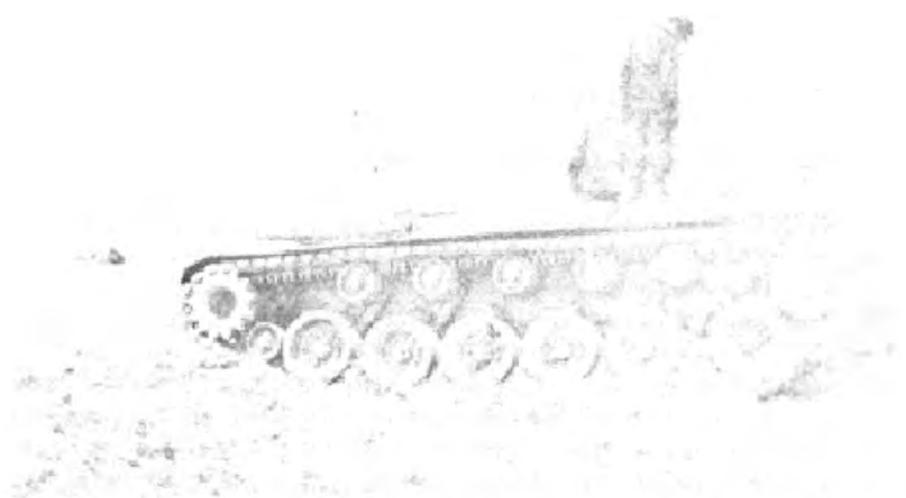

Figure 48. Inspection team on tank 1,500 feet (457 meters) from GREENHOUSE, EASY surface zero.

- One civilian from Melpar, Inc.
- One civilian from NOL
- One Army officer from Fort Richardson, Alaska
- One civilian from Sandia Corporation.

Highest exposure recorded for this group was 0.662 R.

Project Report: WT-90 (Reference 162).

Project 6.4 -- Fallout Phenomenology

Agency: Naval Radiological Defense Laboratory (NRDL)

Operations: Ten holders for greased sample-collecting plates were set out on each of the following islands: Bokoluo, Kidrinen, Billae, Ananij, Parry, Enewetak, Ikuren, Kidrenen, and Biken. The day before each shot, sample-collecting plates were placed in the holders. A few hours after shot DOG, project personnel visited each island and removed plates that had received fallout. For the next 6 days, staff members checked plates on Bokoluo, Parry, and Enewetak for indications of secondary fallout. Probably the same procedure was followed for EASY and GEORGE, but available records mention recovery efforts only for the first 2 days after these shots. The project did not participate in ITEM. Staff members traveled to the islands other than Enewetak and Parry by helicopter or L-13 aircraft.

Staffing: Two civilians from NRDL and a naval officer, probably from Sandia Corporation, comprised the proving ground staff. Highest recorded exposure among the three was 1.110 R. Helicopters and L-13s were supplied by TU 3.4.6.

Project Report: WT-4 (Reference 62).

Project 6.5 -- Interpretation of Survey-meter Data

Agency: Naval Radiological Defense Laboratory (NRDL)

Operations: Fission products were collected on plates carried through the shot clouds by the drones. After the drones were landed, plates were removed, and at about H+40 they were flown back to NRDL for analysis (Reference 163, p. 7). In addition, residual radiation was measured near DOG and EASY surface zeroes (Reference 163, p. 1). At 1200 on DOG day, one of the project personnel, accompanied by a radsafe monitor, left Parry for Runit by boat. The plan was to place dosimeters 2,100 feet (640 meters) from surface zero if radiological conditions permitted (Reference 97, D-Day, No. 60). On D+2, one project staff member with a monitor visited Runit to place a second set of dosimeters (Reference 97, D+2, No. 3a). At 0800 on EASY day, two staff members left Parry by boat for Enjebi, probably to set out dosimeters. On D+2, two members of the project staff went to Enjebi to set out dosimeters (Reference 109, pp. E-I-28 and E-I-46).

Staffing: Three personnel can be identified by name with this program, a naval officer from BuShips, a civilian from AEC, and a naval officer of unknown affiliation who recorded the highest exposure of the three -- 3.280 R. Staffing of the drone unit is discussed under Project 1.7.

Project Report: WT-26 (Reference 163).

Project 6.6 -- Evaluation of Filter Material

Agencies: Army Chemical and Radiological Laboratories (CRL)

Army Chemical Center (ACC)

Operations: Following the first three shots, filter materials were carried through the shot clouds by B-17 drones. The Project 6.6 samples were removed by Project 6.1 personnel from the drones at DOG D+6 and on the morning of GEORGE D+1 (Reference 97, D-Day, No. 62; Reference 102, p. G-I-25). No information on removal after EASY is available. Extensive sample analysis was conducted at the test site following DOG, more limited analysis followed EASY, and none followed GEORGE. Samples were returned to CRL/ACC for further analysis (Reference 165, p. 14).

Staffing: Several individuals are named in the project report, but some probably were not at the proving ground (Reference 165, pp. iii-iv). Four men were badged; the highest exposure was 2.525 R. All were civilian employees of CRL/ACC.

Project Report: WT-19 (Reference 165).

Project 6.7 -- Contamination-Decontamination Studies

Agencies: Naval Radiological Defense Laboratory (NRDL)

Army Chemical Center (ACC)

Operations: Forty panels coated with various materials were taped to the wings and horizontal stabilizers of several B-17 drones and then carried through the shot clouds. For DOG and EASY, all eight drones carried panels; for GEORGE, four drones carried panels, but one of the drones had to be landed before it went through the cloud; and for ITEM, seven drones carried test panels (Reference 166, pp. 7, 123 through 126). A few hours after the shots, panels were removed from the drones. To remove the panels, a man carrying a hooked pole walked to the drone from a truck positioned about 100 feet (30 meters) upwind. He used the hook to engage a loop hanging from each panel and pulled the panel off of the plane. Figure 49 shows such a recovery after GEORGE. Other panels are taped to the underside of the wing just behind the leading edge. Holding the panel at the end of the pole, he returned to the truck, where a second man grasped the panel with tongs and put it in a box. After a number of panels were collected, they were taken by truck to another location where a crew of four men with tongs and poles tipped with scalpels stripped off the remaining tape. They then re-boxed the panels. Some panels were flown to NRDL and ACC about 10 hours after the shots; others were kept in the proving ground for initial study and flown to the laboratories 2 days after the shot (Reference 166, pp. 7 and 8).

Fallout on Enewetak offered an unexpected opportunity to study contamination of building materials. Beginning on DOG D+1, project personnel, using radiation survey instruments, measured contamination on various buildings, in the soil, in the drone decontamination area, and on the roads.

Handling of the samples and the project staff's initial study of them also presented some potential for exposure, but there is no available record of the radiation levels involved.

Figure 49. Contaminated panel recovery following GREENHOUSE, GEORGE. Arrow points to test panels taped on the underside of the wing.

Staffing: The project staff in the proving ground consisted of nine civilians working for NRDL and three Army officers assigned to ACC (Reference 166, pp. 119 and 120). Highest recorded exposure among the NRDL personnel was 2.105 R; among the ACC personnel it was 2.315 R.

Project Report: WT-27 (Reference 166).

Project 6.8 -- Cloud Radiation Field

Agency: Naval Radiological Defense Laboratory

Operations: The B-17 drones were used to carry radiation intensity meters through the shot cloud after each of the first three detonations. For both DOG and EASY, data records were removed from the drones beginning about 0800 on D+1. No information is available on when data recovery for this experiment was conducted after GEORGE (Reference 97, D+1, No. 3; Reference 109, p. E-I-39). The project did not participate in ITEM.

Staffing: A number of personnel are named in the project report, but it is not clear which of them were in the proving ground. Of those listed, five were badged, with the highest exposure -- 1.550 R -- belonging to the author of the project report. TU 3.4.2 supplied the drones and their supporting personnel.

Project Report: WT-11 (Reference 136).

Project 6.9 -- Protective Clothing, Clothing Decontamination and Personnel Decontamination

Agency: Army, Office of the Quartermaster General

Staffing: Fifteen men were on the project staff: two Army officers from the Office of the Quartermaster General, Washington, D.C.; five Army officers and five enlisted men from Quartermaster Detachment 7, 9135th Tactical Support Unit, Fort Lee, Virginia; one civilian from the Quartermaster Research and Development Laboratories, Philadelphia Quartermaster Depot, Philadelphia, Pennsylvania; and two enlisted men from Evans Signal Laboratory, Belmar, New Jersey. Highest recorded exposure -- 1.955 R -- was that of an enlisted man from the 9135th TSU who worked in the laundry.

Project Report: WT-12 (Reference 72).

Project 6.9.1 -- Protective Clothing

Protective clothing was deliberately contaminated in various ways. Test trousers and booties were issued to radsafe monitors and program personnel entering contaminated areas after DOG and EASY. Test trousers and rainsuits were issued to drone decontamination crews of TU 3.4.2 after at least the first three shots (Reference 72, pp. 9 and 10). On EASY D+6, 13 personnel from Project 6.9 and 17 personnel from TG 3.2 went by boat to Bokombako. These teams made five trips across the island and back, mostly walking but crawling some of the way. Each round trip took about 15 minutes and was made in a different set of test trousers (Reference 72, p. 10).

This experiment also included efforts to contaminate cloth samples. On DOG D+3, swatches of test cloth were dragged along the ground on Runit and Biken. The degree of contamination was not high enough for project programs and varied a great deal. Moreover, the dragging operation required a number of persons to be in the contaminated area for an extended period. Consequently, it was decided to tumble the cloth samples in a drum with contaminated soil from Runit and Biken, but information is lacking on when the soil was collected. Thirty swatches were sewn together and staked out on Bokoluo. They were recovered on EASY D+1. Cloth samples were also tumbled with contaminated soil collected from Bokombako on EASY D+6 (Reference 72, pp. 11 and 12). The project did not participate in ITEM.

Six days after EASY, the general background on Bokombako, where the groups from Project 6.9 and TG 3.2 went to contaminate test trousers, was 0.200 R/hr. The highest skin contamination was 0.010 R/hr. The effort on Runit to contaminate swatches of test cloth by dragging was conducted in an area where the radiation level was about 0.060 R/hr. During a similar effort on Biken, the radiation level was about 0.025 R/hr (Reference 72, pp. 10, 11, and 75). The blanket of cloth swatches retrieved from Bokoluo could not be handled until 4 days after EASY because of its high radiation level (Reference 72, p. 20).

Project 6.9.2 -- Clothing Decontamination

The test clothing and the test swatches were washed in a standard, World-War-II-type mobile field laundry, using various cleaning agents and laundry procedures. Test swatches exposed for EASY were laundered 8 and 9 days postshot (Reference 72, p. 12). In addition, program personnel used the mobile laundry to wash hundreds of contaminated garments worn by TU 3.1.5 radsafe personnel and TU 3.4.2 decontamination crews to establish procedures for efficient, large-scale operations and determine the laundry's capacity (Reference 72, p. 52).

Handling contaminated clothing probably exposed project personnel to some radiation. Although records of radiation levels encountered in the washing operation are not available, some clothing checked as part of Project 6.9 was contaminated to a level of 0.010 R/hr (Reference 72, p. 74).

Project 6.9.3 -- Personnel Decontamination

The project report gives a detailed description of how personnel returning from the shot islands and the TU 3.4.2 decontamination crews were checked for contamination. Only one person from Project 6.9 can clearly be identified with that work; however, the number of returning personnel checked leads to the conclusion that several Project 6.9 personnel were taking readings following DOG and EASY (Reference 72, pp. 70 through 71, 73, 75, and 87). With the approval of the commander of the scientific task group (TG 3.1) and the commander of the radsafe task unit (TU 3.1.5), all project personnel took part in a controlled decontamination effort: the men rubbed contaminated soil on their hands and forearms, then tried to wash off the contamination using various cleaning agents (Reference 72, pp. 85 through 86).

In the radsafe building on Parry where personnel returning from the shot islands were checked, the background radiation level at DOG H+4 was about 0.100 R/hr. The level may have been higher after EASY (Reference 72, pp. 70 through 74). Project personnel participating in the controlled decontamination effort contaminated their hands and forearms to a level of about 0.015 R/hr (Reference 72, pp. 70 through 74).

Project 6.10 -- Evaluation of Collective Protector Equipment

Agency: Army Chemical Center (ACC)

Operations: A reinforced concrete blast shelter was installed 1,710 feet (521 meters) from EASY surface zero on Enjebi. The shelter contained equipment to filter air and collect samples. In addition, instrument stations were placed at distances of 900, 1,710, 2,400, 3,450, and 7,500 feet (0.274, 0.521, 0.732, 1.05, and 2.29 km) from surface zero. The last station probably was on Mijikadrek. No information is available on recovery.

Staffing: The staff consisted of two civilians from ACC with recorded exposures of 0.625 and 0.955 R.

Project Report: WT-42 (Reference 167).

PROGRAM 7 -- LONG RANGE DETECTION

Sponsored by the Air Force, this program was designed for developing means to detect and measure atomic explosions at great distances. To supply required data, infrasonic (low-frequency) and seismic signals were recorded and radioactive samples were collected. An Air Force civilian scientist headed the program, but he does not appear to have been badged (Reference 5, pp. 61, 72 through 74). Infrasonic and seismic detection stations were remote and did not involve personnel at the test site. Part of the program did involve test site operations and are discussed subsequently.

No WTs were issued for Program 7 projects.

Project 7.4 -- Collection of Bomb Debris by Airborne Filters

Agency: Hq USAF

Operations: Two B-50As and five WB-29s tracked the shot clouds and collected samples. Flights of the B-50As are described under Project 4.6. The B-50As returned to the United States before ITEM. In addition to their weather duties, five WB-29s tracked the nuclear clouds and collected samples. For the first three shots, one of these aircraft performed this activity from H-hour to H+12, two others took over from H+12 to H+24, and two more from H+24 to H+36 (Reference 9, p. 25; Reference 20, p. 18). For ITEM, four WB-29s tracked the cloud and collected samples during the first 12 hours or so of the shot day, and another WB-29 performed that function at unspecified times between H+12 and H+36 (Reference 22, p. 30). Apparently aircraft from Hickam AFB, Hawaii, and McClellan AFB, California, also took part in this project, but details of their participation are lacking (Reference 5, p. 73).

WB-29s were contaminated following the first three shots. The highest reading at each aircraft's engines 12 hours after its mission were (R/hr):

DOG	0.300	GEORGE	0.200	EASY	0.070
	0.150		0.250		0.150
			0.600		

A third WB-29 also was contaminated during EASY operations. Twenty-four hours after the end of its mission and following two decontamination washings, the highest reading on its engines was 0.650 R/hr.

WB-29 crews became contaminated. After DOG, members of two crews had to be decontaminated. Following EASY, 16 crewmembers from five aircraft were contaminated between 0.0002 and 0.008 R/hr above background. Following GEORGE, 18 men from four crews were contaminated above 0.020 R/hr. Records are lacking for the situation after ITEM. (Reference 52, Incl. 5; Reference 54, Part I; Reference 51, Part I).

All of the WB-29s carried the C-1 box filter system for sample collection. One of the system's two filters was to be changed every 10 minutes when the aircraft was above 2,000 feet (610 meters). Figures are lacking on the radioactivity of the filters, but the person changing the filters wore gloves, a respirator or oxygen mask, a dosimeter, and a film badge (Reference 73, p. 1). Although the WB-29s were stationed at Kwajalein, they stopped first at Enewetak to have filters and gaseous samples removed. Preliminary decontamination work was done if needed, and on all four shots it was required on two or three of the aircraft.

<u>Staffing</u>: A civilian scientist headed the project, but he was not badged and his affiliation cannot be determined. Affiliation and badging of the B-50A crew is discussed under Project 4.6.

The WB-29s were part of TU 3.4.4 (Weather Reconnaissance), made up of personnel from the 55th and 57th Strategic Reconnaissance Squadrons, the former from McClellan AFB, California, and the latter from Hickam AFB, Hawaii.

On Enewetak, samples were removed by personnel from TU 3.1, including personnel assigned to Project 1.7. Preliminary decontamination of the WB-29s while they were on the ground at Enewetak was performed by personnel from TU 3.4.2, assisted by 18 to 24 men from TU 3.4.1.

Bomb debris also was collected at ground level in filter papers, rainwater collectors, electrostatic precipitators, and by roof scrubbing. Seventeen stations participated in this portion of the program, but no information is available on the location (Reference 5, p. 73). The filter papers, however, may have been at the mobile field laboratory used in Project 5.1.3.

Project 7.8 -- Detection of Bomb Debris by Atmospheric Conductivity

Agency: Hq, USAF

Operations: Two B-50As tracked the clouds of the first three detonations using devices measuring atmospheric conductivity caused by bomb debris. Five WB-29s performed the same task following all four shots. Two B-50Ds also participated in this experiment following DOG, EASY, and GEORGE, but details of their activities are lacking. For Project 1.6.3.4, these same B-50Ds took aerial photographs for study of asymmetries in the propagation of the bombs' blast waves, and for Project 4.1B, they photographed the development of the nuclear clouds. The B-50As participated in Project 7.8 simultaneously with their participation in Projects 4.6 and 7.4. The WB-29s participated in both Project 7.8 and Project 7.4. Seven aircraft from Hickam AFB, Hawaii, and four from McClellan AFB, California, may have participated in this project (Reference 5, p. 73).

PROGRAM 8 -- BLAST EFFECTS ON AIRCRAFT

The three projects in this program were designed to collect data for the study of effects of nuclear blasts on aircraft and aircraft components. In addition, there were radar, radio, and photographic studies of weapon effects. The program was headed by an Air Force colonel, with a recorded exposure of 1.534 R.

Project 8.1 -- Blast Effects on Aircraft in Flight

Agency: Air Force Wright Air Development Center, Aircraft Laboratory, Aeronautical Division (WADC)

Operations: Both drones and manned aircraft were used to collect data. For the first two shots, two T-33 drones, two B-17 drones, one B-47, and two B-50Ds carried equipment to detect and record blast loading, heat, and aircraft position when struck by the heat and shock waves. For GEORGE a third B-17 was used, and all of the B-17s and the two T-33s were operated as manned aircraft (Reference 168, pp. 104 and 110). Aircraft positions at shot times are given in Table 16.

Drones used for Project 8.1 should have received little or no contamination. There is no record of the T-33 drones or the B-47 becoming contaminated. The B-50Ds also participated in Projects 4.1B, 7.8, and 8.3. Radiological problems associated with of the B-50D missions are discussed under Project 1.6.3.4.

Staffing: Drones were from TU 3.4.2; manning and badging of that unit are discussed under Project 1.7. The B-50Ds and the B-47 were from Task Detachment (TD) 3.4.2.1. The B-50Ds were based on Enewetak and the B-47 on Kwajalein. Manning and badging of this unit are discussed under Project 4.1B.

The project report mentions 16 individuals. Four were Air Force officers, two of whom were badged with exposures of 0.160 and 0.100 R. Four civilians were from WADC, three of whom were badged with a high exposure of 2.845 R. Five civilians were from MIT, with the only one badged recording

Table 16. Program 8 aircraft positions relative to GREENHOUSE, shots DOG, EASY, and GEORGE.

Aircraft Type	True Altitude in feet (km)	Horizontal Range from Blast in feet (km)	Slant Range from Blast in feet (km)
		DOG	
T-33[a]	7,800 (2.38)	4,980 (1.52)	9,260 (2.82)
T-33[a]	10,700 (3.26)	15,260 (4.65)	18,700 (5.70)
B-17[a]	15,000 (4.57)	6,690 (2.04)	16,150 (4.92)
B-17[a]	23,000 (7.01)	5,750 (1.75)	23,700 (7.22)
B-47	24,800 (7.59)	6,800 (2.07)	25,700 (7.83)
B-50D	29,000 (8.84)	43,600 (13.29)	52,100 (15.88)
B-50D	29,000 (8.84)	32,450 (9.89)	43,500 (13.26)
		EASY	
T-33[a]	6,500 (1.98)	866 (0.26)	6,540 (1.99)
T-33[a]	7,500 (2.29)	1,000 (0.30)	7,530 (2.30)
B-17[a]	11,000 (3.35)	1,949 (0.59)	11,160 (3.40)
B-17[a]	12,000 (3.66)	15,400 (4.69)	19,510 (5.95)
B-47	33,000 (10.06)	18,810 (5.73)	38,000 (11.58)
B-50D	25,000 (7.62)	7,940 (2.42)	26,210 (7.99)
B-50D	19,000 (5.79)	20,500 (6.25)	28,000 (8.53)
		GEORGE	
T-33	29,000 (8.84)	58,500 (17.83)	65,300 (19.90)
T-33	32,000 (9.75)	59,580 (18.16)	67,600 (20.60)
B-17	25,000 (7.62)	23,440 (7.14)	34,300 (10.45)
B-17	27,000 (8.23)	21,340 (6.50)	34,500 (10.52)
B-47	35,000 (10.67)	45,500 (13.87)	57,400 (17.49)
B-50D	31,000 (9.45)	59,420 (18.11)	67,000 (20.42)
B-50D	33,000 (10.06)	37,750 (11.51)	50,200 (15.30)
B-17	14,000 (4.27)	74,970 (22.85)	75,400 (22.98)

Note:

[a]Unmanned drones.

Sources: Reference 168, pp. 102, 103, and 108.

0.050 R. Two civilians designated "TG 3.1" (one of whom was badged) and another civilian designated "TG 3.4" (not badged) completed the acknowledged project personnel (Reference 168, p. vii; Reference 169, p. vii).

Project Reports: WT-31 (Reference 168); WT-34 (Reference 169).

Project 8.2A -- Effects of an Atomic Bomb Burst on Aircraft Structures on the Ground

Agency: Air Force Wright Air Development Center, Aircraft Laboratory, Aeronautical Division (WADC)

Operations: Instrumented sections of various aircraft were set out at four stations at various distances from surface zero: on Enjebi 4,020 feet (1.23 km), on Mijikadrek 6,878 feet (2.10 km) (Figure 50), on Dridrilbwij 12,000 feet (3.66 km), and on Bokenelab 16,614 feet (5.06 km). The project recovery party left Parry at 0730 on EASY day and arrived at Bokenelab at about 1000. It was not accompanied by a radsafe monitor because monitors with Program 2 personnel had already visited the island and declared it safe for reentry. About 1045 the Project 8.2A recovery party left Bokenelab for Mijikadrek, again reentering on the basis of reports of Program 2 monitors. Figure 51 shows a monitor taking a reading on one of the project test specimens on Mijikadrek before the return of project personnel. By 1215 the party was on Enjebi. At 1300 the men went to Dridrilbwij, starting their inspection of that station at about 1330 (Reference 170, p. 32). Presumably they returned later to study the test structures in detail.

Figure 50. GREENHOUSE Project 8.2A test specimen with Program 3 structure in background on Mijikadrek.

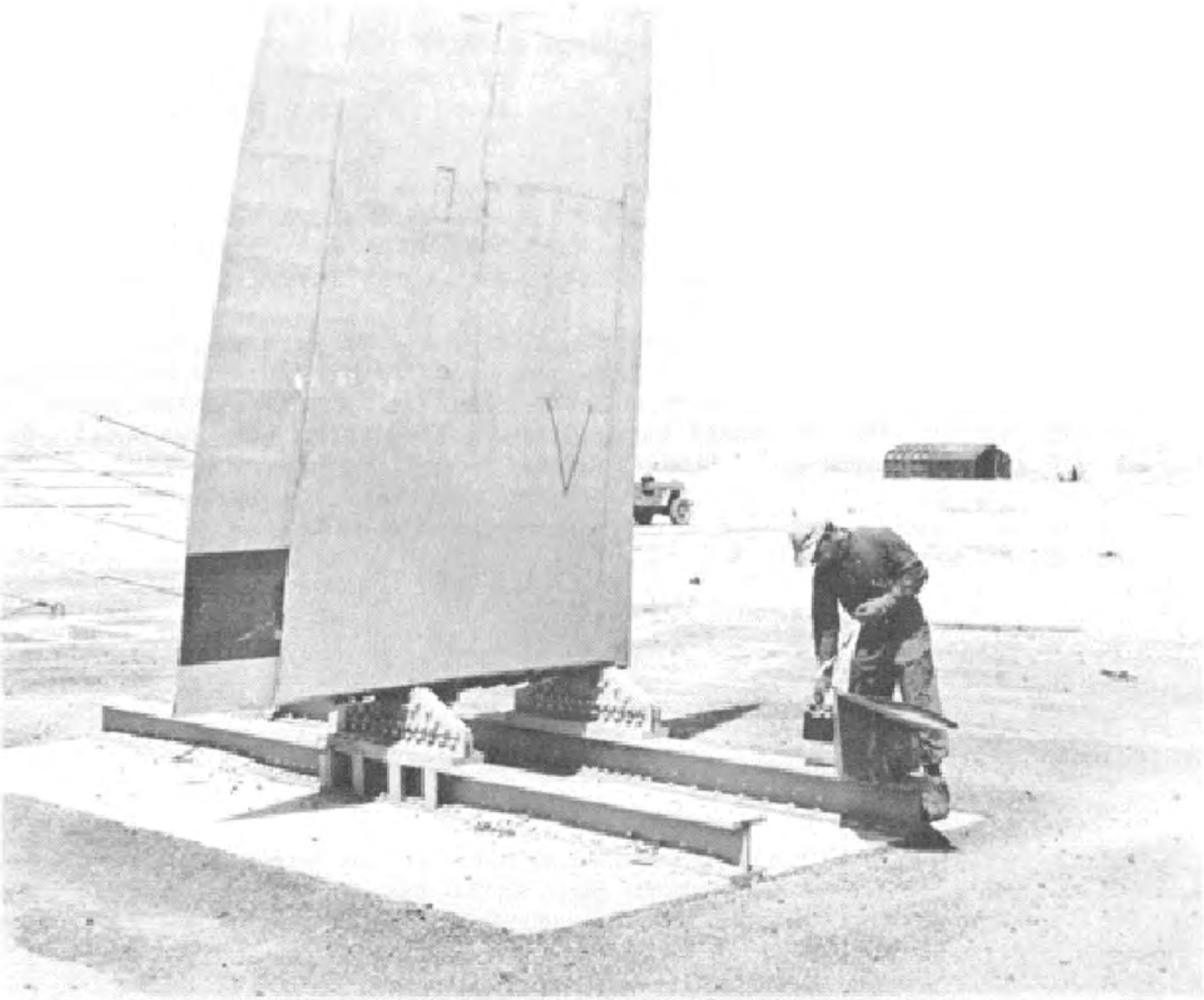

Figure 51. Radsafe monitor checking GREENHOUSE Project 8.2A test specimen before inspection by project personnel.

The monitors with Program 2 personnel reported the radiation level on Mijikadrek to be 0.3 R/hr. The radiation level where the Project 8.2A team reentered Enjebi was 1.0 R/hr; however, at the project station, it was 0.1 R/hr. The radiation level encountered by the Project 8.2A recovery team on Dridrilbwij was 1.2 R/hr (Reference 170, p. 32 and 33).

Staffing: See Project 8.2B.

Project Report: WT-65 (Reference 170).

Project 8.2B -- Interferometer Gauge Pressure-Time Measurements

Agency: Los Alamos Scientific Laboratory (LASL)

Operations: For DOG, gauges were set out in ten stations: eight on Runit between 2,250 and 5,400 feet (0.686 and 1.65 km) from surface zero, and two on Parry. For EASY, ten gauge stations were on Enjebi between 2,850 and 3,945 feet (0.869 and 1.20 km) from surface zero. In addition, stations were on Mijikadrek, Bokenelab, and Dridrilbwij. Finally, four stations were grouped on Lojwa about 6,000 feet (1.83 km) from the GEORGE surface zero (Reference 164, p. 8 through 10).

Two recovery teams of four men each were used on all four shots. One team with a radsafe monitor recovered records from about half the stations; a second team completed recovery. For DOG, EASY and ITEM, records were recovered on shot day. GEORGE recovery was on D+1 (Reference 164, p. 10).

Staffing: The men working on Projects 8.2A and 8.2B were considered as one staff, consisting of seven civilians, three officers, and eighteen enlisted men. In addition, two officers and one civilian were acknowledged as assisting. Most of the personnel probably were from WADC, but one naval officer and two civilians were from LASL (Reference 164, pp. v and 5). Highest exposure was 1.875 R, belonging to a LASL civilian. The three LASL personnel, assisted half-time by four of the enlisted men, worked on Project 8.2B (Reference 164, p. 7).

Project Report: WT-5 (Reference 164).

Project 8.3A -- Radar-Scope Photography

Agency: Air Force Wright Air Development Center, Aircraft Radiation Laboratory

Operations: At shot time radars aboard both B-50Ds were aimed at surface zero. Signals received from shots DOG, EASY, and GEORGE were displayed on oscilliscopes and photographed. The project did not participate in ITEM. The B-50Ds also participated in Projects 1.6.3.4, 4.1B, 7.4, 7.8 and 8.1. Their activities are described under Project 1.6.3.4.

Staffing: The portion of the project report dealing with this experiment was written by an unbadged civilian and an Air Force officer with a listed exposure of 1.575 R.

Project Report: WT-33 (Reference 171).

Project 8.3B -- Effects of Atomic Detonation on Radio Propagation

Agency: Army Signal Corps

Operations: Data for this experiment were from three sources (Reference 171, p. 59 and 91):

1. Ionospheric measurements from Enewetak both before and after the shots.
2. Transmissions from remote locations through the ionosphere over Enewetak to locations beyond the atoll from 5 minutes before to 5 minutes after each of the first three shots. Propagation paths were Okinawa to Kwajalein and Majuro, Yap to Bikini, and Truk to Hawaii.

3. UHF, VHF, HF, and perhaps radar transmissions by USS Sproston (DDE-577) over the surface zero area toward Enewetak Island from 5 minutes before to 5 minutes after each of the first three shots.

Staffing: Personnel from TG 3.2, TG 3.3, and TG 3.4 helped with this experiment in addition to personnel at several stations outside of the proving ground. The project report was written by a Signal Corps officer; he is the only man who can be identified with the project by name. He was not badged.

Project Report: WT-33 (Reference 171).

Project 8.3C -- Photographic Assessment of Bomb Damage

Agency: Air Force Wright Air Development Center, Technical Photographic Service Section

Operations: On 16 and 22 April vertical and oblique photographs of the Air Force Structures on Enjebi were taken from a B-17 at altitudes of 500 feet (152 meters) or higher. On April 21, strike photographs of the same structures were taken from one of the B-50Ds at an altitude of about 25,000 feet (7.62 km), only moments after shot EASY.

The B-17 and B-50D were apparently not exposed to significant radiation from this experiment. The various project activities of the B-50Ds are discussed under Project 1.6.3.4.

Staffing: The B-17 probably was from TU 3.4.2 and the B-50D was from TD 3.4.2.1. A hand-held camera was used for the pictures taken from the B-17, but the photographer is not identified. The author of the section of the project report dealing with this project probably was a civilian employee of the Technical Photographic Service. His exposure is listed as 0.330 R.

Project Report: WT-33 (Reference 171).

Project 8.3D -- Film Fogging Studies

Agency: Los Alamos Scientific Laboratory

Operations: For EASY and GEORGE, film strips were put aboard six of the B-17 drones used in sample collection. For GEORGE, film strips were also put in ground stations, aboard two WB-29s, and aboard an RB-29 from the Strategic Air Command (SAC), flown in specifically to participate in this experiment. The film was removed from the drones following EASY and GEORGE shortly after the aircraft were on the ground and cleared by the radsafe officer in charge. The WB-29s and the RB-29 were flown through portions of the radioactive cloud during the period from GEORGE H+45 minutes to GEORGE H+3 and then landed on Enewetak Island. The film samples were removed within 2 hours of landing. Samples in the ground stations were not removed until GEORGE D+1 because of high radiation levels (Reference 171, p. 373). Locations of the ground stations are not given, but they probably were on

Aomon or Bijire. Apparently, neither of the WB-29s participating in this experiment was the same one that tracked the nuclear cloud for the first 12 hours after GEORGE as part of Projects 7.4 and 7.8. Flying into the nuclear cloud could have exposed both WB-29s and the RB-29 to significant radiation levels. There is no record of the RB-29 being contaminated. After GEORGE, three WB-29s were found contaminated, as discussed under Project 7.4.

Staffing: Staffing of TU 3.4.2, which operated the drones, is discussed under Project 1.7. Staffing of TU 3.4.4, which operated the WB-29s, is discussed under Project 7.4. Further information is unavailable on the SAC RB-29. The author of the report describing this experiment was an Air Force officer with a recorded exposure of 1.854 R.

Project Report: WT-33 (Reference 171).

CHAPTER 5

U.S. ARMY PARTICIPATION IN OPERATION GREENHOUSE

TASK GROUP 3.2 PARTICIPATION

Most Army personnel in the task force were in Task Group (TG) 3.2. TG 3.2 was composed entirely of service units. TG 3.2 was the first task group activated by Headquarters Joint Task Force 3 General Order #1 on 12 January 1950. The first units of this task group arrived at the atoll on 16 March 1950. Their original mission was to construct facilities on Enewetak Island and the atoll. The task group was a self-sufficient base development organization engaged in construction and operation of base facilities at Enewetak and originally consisted of the following units (Reference 172):

- Hq and Hq Company, 7th Engineer Brigade (parent unit of TG 3.2 and replaced by 7126th Army Unit [AU])
- 79th Engineer Construction Battalion -- replaced by 7126th AU
- Quartermaster Detachment (QM Det) #6, 9135th Tactical Support Unit -- later redesignated QM Det 7128th AU
- 70th Automotive Maintenance Ordnance Detachment
- 9470th TSU Signal Detachment -- later redesignated the 7127th AU
- 3rd Mobile Army Surgical Hospital
- Hq, 18th Transportation Corps Port Battalion
- 511th Transportation Corps Port Company
- Finance Detachment, Joint Task Force 3 (JTF 3) -- redesignated Finance Detachment, 7129th AU.

An Army Garrison Force, Enewetak -- 8287th AU, composed of approximately 100 personnel, was administratively closed out on 1 July 1950. It had performed Post Exchange (PX) and postal services. An Air Detachment, Army Garrison Force, was also inactivated on the same date (Reference 172).

Composition and manning levels of TG 3.2 changed significantly before the first detonation of GREENHOUSE on 8 April 1951. Many of the original task group were transferred to the Far Eastern Command on 19 October 1950 for service in Korea. None of these personnel was badged and none was exposed to radiation.

During July and August 1950, Hq 7th Engineer Brigade and 79th Engineer Construction Battalion were relieved for service in Korea. At this time the 7126th AU was activated and designated as the parent unit for TG 3.2. On 10 October 1950 three additional units were assigned to TG 3.2. They arrived at the atoll on 13 October 1950:

- 516th Military Police Service Company
- 506th Counterintelligence Corps (CIC) Detachment
- 4th Transportation Truck Company.

Table 17 shows total TG 3.2 population figures for selected weeks from 1 February to 27 April 1952.

Table 17. Task Group 3.2 population, GREENHOUSE.

	Total Task Group 3.2		Task Group 3.2 on Enewetak	
Week Ending 1951	Enlisted Men	Officers	Enlisted Men	Officers
1 February	1,222	77	1,125	62
31 March	1,311	89	1,061	74
1 April	1,272	86	1,032	70
8 April	1,270	86	1,064	67
13 April	1,087	91	1,070	70
21 April	1,240	84	1,086	70
27 April	1,140	108	1,091	72

Sources: References 173, 174, and 175.

The units at Enewetak during the operational phase and their personnel exposures as recorded by film badges are summarized in Table 18. The majority of all units operated exclusively on Enewetak Island except for the Military Police (MP), the Engineer Construction Battalion, and the Communications Detachment, 7127th AU. Almost all TG 3.2 personnel were affected by the fallout on the base islands during GREENHOUSE and those exposures would not be reflected in the badge readings summarized below. The largest group of Army personnel badged in GREENHOUSE was simply noted as "Task Group 3.2" on their dosimetry records. The high recorded in this group was 2.845 R. Other men were badged as being members of the several TG 3.2 organizations.

Hq and Hq Company, 7th Engineer Brigade. This was the parent unit of TG 3.2. Small units were assigned to the task group and augmented it as work programs progressed. The brigade's mission was to function as Hq TG 3.2. The operational strength called for 41 officers and 154 enlisted men. This unit was replaced by the 7126th AU in late September or early October 1950 because of the Korean war. The 7th Engineer Brigade departed 15 January 1951 with 21 officers and no enlisted men. Enlisted personnel of Hq & Hq Company, 7th Engineer Brigade, were reassigned to the 7126th AU. Five men were badged; the high exposure was 0.845 R (Reference 176).

Table 18. GREENHOUSE personnel exposures, U.S. Army organizations.

Organization	No. of Persons in Unit	No. of Persons Badged	Exposure Ranges (roentgens)[a]								High (R)
			0	0.001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	Over 3	
Task Group 3.2	b	68	2	40	23	1	1		1		2.845
7th Engineer Brigade (assigned to 7126th Army Unit)	b	5	1	3	1						0.845
79th Engineer Construction Battalion	64	1	1								0
7127th Army Unit	146	2		2							0.350
3rd Mobile Army Surgical Hospital	43	2	1		1						0.520
Hq 18th Transportation Corps Port Company	10	2		2							0.080
511th Transportation Corps Port Company	208	3		2	1						0.770
506th Counterintelligence Corps Det	10	3		2	1						0.960
516th Military Police Service Company	228	25	1	16	7	1					1.230
Army Chemical Center	b	25		3	6	6	3	4	2	1	5.430
Ballistic Research Laboratories	b	26		20	3				2	1	3.085
Office of the Quartermaster General	15	11		1			1	1	5	3	3.505
Signal Corps Engineering Laboratories	18	17		5	1		3		4	4	4.135
Other Badged Army Participants	5	5		3						2	3.390
Totals	b	195	6	99	44	8	8	5	14	11	5.430

Notes:

[a] Raw badge data; calculated assigned fallout exposures not included.

[b] Total number of persons in unit cannot be accurately determined.

Hq Commandant. This unit operated transient billets and maintained and supervised all officers' quarters and mess. The unit was also charged with island police, trash and garbage disposal, security, and internal administration and supply for headquarters. It consisted of 1 officer and 23 enlisted men for billeting, 10 enlisted men for police, and 1 officer and 4 enlisted men for messing activities for a total of 39 personnel. The number of personnel badged in the unit is unknown (Reference 39).

79th Engineer Construction Battalion. This unit performed all construction on Enewetak Island such as housing, piers, roads, rehabilitation of existing structures, runway reorientation and extensions, airfield expansion, and utility systems including electricity generation and distribution, cold storage facilities, freshwater distillation and distribution, saltwater pumping and distribution, and sewage. On 19 October 1950, 30 officers and 666 enlisted personnel departed for the Far Eastern Command and a new construction force was organized out of the remaining troops. All but 27 enlisted men departed the island before any detonation. A maintenance engineering section organized immediately upon the departure of the 79th Engineer Construction Battalion included 3 officers and 61 enlisted personnel for repair and maintenance of utilities and facilities. Only one man was badged, with a zero reading (Reference 39).

Quartermaster Detachment, 7128th Army Unit. This unit provided bakery, mess personnel, and food supervision for central mess. It also procured, warehoused, and issued QM rations, and requisitioned property required by TG 3.2. It ran laundry facilities for all personnel on Enewetak Island. Before May 1950 this unit was designated as QM Detachment #6, 9135th TSU. Operational strength called for 4 officers and 101 enlisted men. This unit operated exclusively on Enewetak Island; none was badged (Reference 39).

70th Automotive Maintenance Ordnance Detachment. This unit supported the 7th Engineer Brigade with heavy field maintenance on all ordnance wheeled vehicles and quartermaster materials on Enewetak Island. The unit also procured, stored, and issued all ordnance supplies. In addition, it performed field maintenance on all Air Force general purpose and technical vehicles and furnished units of JTF 3 with ordnance supplies. The unit consisted of 2 officers and 30 enlisted men. It operated exclusively on Enewetak Island; no personnel were badged (Reference 39).

7127th Army Unit Communication Detachment. This detachment operated and maintained the telephone system on Enewetak Island, the Signal Center facilities on Enewetak and Parry islands, and the communication facilities for Hq JTF 3. Before 1 May 1950, it was the 9470th TSU Signal Detachment. Through April and May 1951 unit strength consisted of 8 officers and 138 enlisted men. By the day of the last shot unit strength had decreased to 3 officers and 71 enlisted men. During the rollup phase the unit operated with two officers and 38 enlisted men (Reference 39). Only two men were badged, with a high of 0.350 R.

3rd Mobile Army Surgical Hospital (MASH). This MASH unit operated the hospital and provided medical and dental services to all units on the island as well as sanitation and hygienic supervision. The hospital was originally staffed with 4 officers and 22 enlisted men, but during the series its strength was 7 officers and 36 enlisted men. Three officers and thirteen enlisted men departed the atoll on 29 May 1951 and the remainder of the unit left by 17 June. This unit operated exclusively on Enewetak and only two members were badged. The high badge read 0.520 R (Reference 39).

Hq 18th Transportation Corps Port Company. This company operated and administered the headquarters for the port at Enewetak Atoll. The original organization of the Transportation Section, 7th Engineer Brigade, TG 3.2 was composed of the Hq 18th Transportation Port Battalion (two officers and eight enlisted men). Two men were badged, with a high of 0.080 and a low of 0.035 R (Reference 39).

511th Transportation Corps Port Company. This unit was responsible to the port commander for administration and operation of the port. It loaded and unloaded all cargo except that on Holmes & Narver, Inc. (H&N) boats and barges. Its operational strength was 4 officers and 204 enlisted men (Reference 174, p. 7). Only three people were badged, with a high exposure of 0.770 R and a low of 0.380 R.

7129th Army Unit. This detachment provided financial services on Enewetak Atoll and operated as the central disbursing unit for Army, Air Force, and Navy personnel except those afloat. It was also responsible for providing money to naval disbursing officers afloat and to civilian contractor activities. Before 1 May 1950 this detachment was designated the Finance Detachment. It originally consisted of two officers and four enlisted men and was later increased to eight enlisted men (Reference 39). None was badged.

7130th Army Unit Special Service Detachment. This detachment arrived at the atoll at the end of October 1950. It provided recreational equipment and staffed and operated the library, motion picture theatre, hobby shop and service clubs and organized athletic activities. Its operational strength called for two officers and eight enlisted men. None was badged (Reference 39).

506th Counterintelligence Corps Detachment. This detachment arrived at Enewetak on 13 October 1950 and was assigned to TG 3.2. It assumed counterintelligence responsibilities in the atoll area. It had the following duties:

- Security checks in cooperation with the military police
- Cooperation with the military police in controlling air and water travel
- Security recommendations against sabotage
- Assistance in the discovery of contraband (e.g., weapons, cameras, signalling devices)
- Indoctrination of military personnel in counterintelligence and security.

This detachment consisted of one officer and nine enlisted men, three of whom were badged with readings of 0.960, 0.338, and 0.025 R (Reference 173, Annex D).

516th Military Police Service Company. This company served as the nucleus of the atoll defense, and had the following security missions:

- Enforcement of military laws and regulations
- Security for classified information and critical areas on Enewetak Atoll
- Security patrols of unoccupied islands
- Cooperation and coordination with H&N and AEC security police
- Coordination of interior guard activities.

It consisted of a provost marshal section, traffic section, criminal investigation section, company headquarters, five platoon headquarters and guard and patrol personnel totaling 14 officers and 214 enlisted men. It was responsible for security forces on Enewetak, Parry, Japtan, Runit, Aomon-Eleleron, Bijire-Lojwa, and Enjebi-Mijikadrek islands. On 13 May 1951, an advance detachment of 2 officers and 41 enlisted men departed for the United States. Twenty-five men were badged, with a high reading of 1.230 R (Reference 39).

4th Transportation Truck Company. This company provided emergency ground transportation during the operational phase. It was responsible for operating the Enewetak Motor Pool. This company began to operate as a unit of TG 3.2 on 13 October 1950 with 4 officers and 109 enlisted men. None appear to have been badged (Reference 39).

EXPERIMENTAL PARTICIPATION

Personnel from the following Army organizations participated in the scientific projects of TG 3.1. Their functions are listed in terms of scientific project activity. The projects are further described in Chapter 4. Personnel exposures recorded by film badges for Army participants in the experimental program are presented in Table 18.

Army Chemical Center, Army Chemical and Radiological Laboratories, Edgewood Arsenal, Maryland. Personnel from the Chemical Center participated in Projects 6.1, 6.6, 6.7, and 6.10. Twenty-five were badged and the highest exposure recorded was 5.430 R (References 74, 165, 166, and 167).

Ballistic Research Laboratories (BRL), Aberdeen, Maryland. Nine personnel participated in Project 1.6. All were badged, with a high recorded exposure of 3.085. One civilian who participated in Project 1.6.3.2 had a 0.483 R reading. One civilian and one reservist who participated in Project 1.6.6.1 were not badged. Six men participated in Project 1.6.3.1; the highest recorded exposure was 0.328 R. They were aided by an advance party of three; the highest exposure was 2.640 R. Many of the same personnel from BRL participated in all projects of Project 1.6. Five civilians and two enlisted men participated in Project 6.3; all were badged with a high exposure of 0.622 R (References 125, 126, 130, and 162).

Office of Quartermaster General. Fifteen personnel (five officers from the Quartermaster General, two additional army officers, five enlisted men from 9135th TSU, and one civilian from the Quartermaster Research & Development Laboratory, and two enlisted men from Evans Signal Laboratory), participated in Project 6.9. Eleven persons were badged; the highest exposure recorded was 3.505 R for a man from the 7128th AU (Reference 72, p. 10).

Signal Corps Engineering Laboratories (SCEL), Ft. Monmouth, New Jersey. Eighteen personnel (sixteen from SCEL and two from Army Chemical Center) participated in Project 5.1 -- Evaluation of Ground Radiac. All but one were badged. The highest recorded exposure was 4.135 R for a survey-meter engineer (Reference 137, p. 209). Four also participated in Project 8.3B -- Effects of Atomic Detonation on Radio Propagation; none appear to have been badged (Reference 171).

OTHER ARMY PERSONNEL PARTICIPATION

In addition to Army personnel in the Army task group and the experimental program, an undetermined number served in Hq JTF 3. One of these was badged with a reading of 0.030 R. Four other Army personnel were badged as simply "Joint Task Force 3." High badge reading of this group was 3.390 R.

CHAPTER 6

U.S. NAVY PARTICIPATION IN OPERATION GREENHOUSE

Naval units, naval personnel, and civilians employed by Navy organizations participated in Operation GREENHOUSE in Headquarters Joint Task Force Three (JTF 3), in Task Group (TG) 3.1 (Scientific), in TG 3.3 (Navy), and in TG 3.4 (Air Force). These units and individuals had missions that took them to or near Enewetak Atoll during GREENHOUSE. Most Navy participation was in TG 3.3 operations that were primarily support functions in carrying out the nuclear tests.

Activities of Navy units participating in GREENHOUSE and Navy organizations represented by individuals are discussed in this chapter and personnel involved are enumerated. Most individual participants were not expected to participate in operations involving likelihood of a significant radiation exposure and they were not badged. Table 19 summarizes the exposures recorded by badged Navy personnel.

Task group units were trained for the contingency of fallout, and all six of the major TG 3.3 ships and some of the small craft did receive fallout from shots DOG and EASY. While conducting a recovery mission for TG 3.1 personnel from Enjebi and Lujor islands, USS LST-859, USNS Sgt. Charles E. Mower (T-AP-186), LSU-1345, and LCM-20 received fallout at approximately 0835 on the day of shot DOG. LST-859 had a reading of 0.1 R/hr on its fantail and later, while anchored at Lujor Island, the reading increased to 0.380 R/hr. LSU-1345 reported radiation intensity of 2.5 R/hr. Decontamination procedures were started and were effective. The ships were directed to proceed to and anchor in the northern part of the lagoon (Reference 17, DOG-2; Reference 100).

Fallout from shot ITEM was reported twice, once in the morning at about H+3.5 by USS Curtiss (AV-4), USS Cabildo (LSD-16), USS Sproston (DDE-577), USS Walker (DDE-517), and Mower, and later by the same units in the afternoon. Radiation levels were not as high as those from shot DOG (Reference 17, ITEM-2).

Radiological exposures from these fallout incidents is discussed in Chapter 10.

NAVAL TASK GROUP (TASK GROUP 3.3)

TG 3.3 was the nominal Navy task force organization and contained all the naval units and most Navy personnel involved in GREENHOUSE. The formal organization of TG 3.3 is described in Chapter 1, and its organization is shown in Figure 10. TG 3.3 missions and the units assigned to perform them are discussed below.

The first mission of TG 3.3 was to deliver nuclear device components to Enewetak Atoll and provide mobile facilities at the site for their assembly. This mission was assigned to Curtiss.

Table 19. GREENHOUSE personnel exposures, U.S. Navy organizations.

Element	No. of Navy Persons in Element	No. of Persons Badged	Exposure Ranges (roentgens)										High (R)
			0	0.0001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	Over 5	
Staff, Commander Task Group 3.3	8	5	2	3	0	0	0	0	0	0	0	0	0.340
USS Curtiss (AV-4)	639	38	1	19	11	2	3	0	1	1	0	0	3.990
USS Sproston (DDE-577)	283	10	0	9	1	0	0	0	0	0	0	0	0.580
USS Walker (DDE-517)	317	18	4	10	2	0	0	0	0	1	1	0	4.070
Patrol Squadron 931	386	102	45	55	0	1	0	1	0	0	0	0	2.410
USS Cabildo (LSD-16)	375	84	12	25	32	9	3	3	0	0	0	0	2.380
Boat Pool	213	129	2	33	24	30	17	5	5	7	2	4	20.085[a]
USS Sgt. Charles E. Mower (T-AP-186)	29	10	1	3	3	1	0	2	0	0	0	0	2.380
USS LST-859	113	37	5	10	11	7	4	0	0	0	0	0	1.940
Staff, Commander Joint Task Force 3	88	17	2	6	1	1	1	4	0	1	1	0	4.170
Staff, Commander Task Group 3.1	55	3	0	0	0	0	2	0	1	0	0	0	2.615
Task Unit 3.1.1	105	82	10	22	16	12	6	8	5	2	0	1	5.40
Task Unit 3.1.2	90	68	0	23	11	16	7	4	1	2	3	1	5.19
Task Unit 3.1.3	78	62	4	24	17	8	5	4	0	0	0	0	2.435
Task Unit 3.1.5	19	17	2	3	2	2	2	0	1	3	1	1	5.635
Task Unit 3.1.6	2	2	0	1	0	0	0	0	0	1	0	0	3.240
Air Transport Squadron 3	119	119	44	63	8	1	2	0	0	1	0	0	3.150
Observers	34	9	0	9	0	0	0	0	0	0	0	0	0.165
USNS Lt. Robert Craig (T-AK-252)	12	1	0	1	0	0	0	0	0	0	0	0	0.215
Total Navy	2,952	813	134	319	139	90	52	31	14	19	8	7	20.085[a]

Note:

[a]The three highest exposures include readings of 15, 15, and 20 R from film badges that apparently were left on a contaminated island and are not considered valid. Highest valid individual exposure was 8.080 R.

Surface, antisubmarine, and air security were also missions of forces assigned to TG 3.3. Two escort destroyers, Sproston and Walker, and Patrol Squadron 931 (VP-931), operating out of Naval Operating Base (NOB) Kwajalein, carried out search patrols around the atoll and in the surrounding danger area, seeking out unauthorized surface vessels and submarines close enough for visual or photographic observation of the operations (Reference 179, p. B-2).

Special project and weather stations on outlying atolls were also established by TG 3.3 and the Air Force. TG 3.3 supplied these stations throughout the tests (Reference 99, p. 2).

Radiological surveys of inhabited islands in the area were carried out by the Navy in coordination with the Air Force task group (TG 3.4) (Reference 99, p. 2).

A TG 3.3 boat pool supplied all task groups with interisland water transport (Reference 179, p. 3). This unit was based on Cabildo.

TG 3.3 was responsible for the entry, reentry, and evacuation of all personnel to and from the islands north of Japtan before and after H-hour. In case of total evacuation of the atoll, TG 3.3 would have been responsible for the safe evacuation of all personnel on the islands (Reference 196, Annex A). The units supplying this capability were Mower and LST-859.

A forward echelon unit was established on 24 July 1950 before the boat pool unit arrived at Enewetak Atoll. It consisted of a Forward Echelon Representative, 27 enlisted men, 1 aircraft rescue vessel (AVR), 5 landing craft (LCMs) and a floating drydock, and an auxiliary floating drydock (ARD-28) that provided docking facilities for the small craft. The Forward Echelon Unit was to provide small boat services and safe movement of vessels within the lagoon. USS Deliver (ARS-23), a salvage ship, and USS Elder (AN-20), a net laying ship, were involved in laying a sonobuoy system to detect attempts to enter Enewetak Lagoon. When Cabildo arrived on 23 February, Task Unit (TU) 3.3.5 (Mobile Boat Pool) was established and Forward Echelon Unit 3.33 was dissolved into TU 3.3.6 (Harbor Control) and the Forward Echelon Representative became the Port Director (Reference 16, Annex A).

Preoperational activities of participating ships are summarized in Table 20.

Arrivals and departures of TG 3.3 units during the operational phase of GREENHOUSE are summarized in Table 21. Activities of the individual ships or other Navy units that comprise each unit, largely extracted from the ships logs, are discussed below. Personnel exposures from the film badge information for the units is summarized in Table 19.

Task Unit 3.3.1 -- USS Curtis (AV-4)

The seaplane tender Curtiss participated in TU 3.3.1 as flagship for all shots at Enewetak Atoll and in TU 3.3.2 (Convoy and Escort). The normal complement of Curtiss was 1,195 (References 16, 17, 100, and 180). The first mission of Curtiss was to transport the device elements and personnel from TU 3.1.4

Table 20. Ships participating in the preoperational phase of GREENHOUSE.

Ship Name	Type	Function and Date
USS Alstede (AF-48)	Store Ship	Refrigeration and general supplies, 24-25 March 1951
APL-27	Labor transport or barracks ship	Housed TG 3.2 construction personnel
ARD-28	Auxiliary floating dry dock	Provided docking facilities for small craft; departed 24 February 1951.
Brewster	No data available	Housed TG 3.2 construction personnel and equipment, 16-20 March 1951.
USC&GSS Buttonwood	U.S. Coast and Geodetic Survey ship	Buoyage systems for repair and replacement of navigational aids
USS Deliver (ARS-23)	Salvage ship	Laid 10 sonobuoys; departed 24 February 1951.
USS Elder (AN-20)	Net laying ship	Assisted in laying the sonobuoy detection screens; released 23 February 1951.
USS Elkhorn (AOG-7)	Gasoline tanker	Petroleum supply, 26-28 March 1951.
USNS LST-1010	Tank landing ship	Delivered heavy equipment, 14-25 March 1951.
USNS Joseph F. Merrell (T-AKV-4)	Military Sea Transportation Service ship	Delivered animal food
USNS Sgt. Andrew Miller (T-AK-242)	Military Sea Transportation Service ship	Delivered heavy equipment and general supplies, 17 March to 1 April 1951
USS Tortuga (LSD-26)	Dock landing ship	Delivered small craft and sonobouys

Sources: References 3, 16, and 17.

Table 21. Arrival and departure dates of Task Group 3.3 ships, GREENHOUSE.

Ship	Arrival in PPG	Departure from PPG
USS Curtiss (AV-4)	8 March	27 May
USS Sproston (DDE-577)	8 March	27 May
USS Walker (DDE-517)	8 March	27 May
USS Cabildo (LSD-16)	23 February	30 May
	16 June	18 June
USNS Sgt. Charles E. Mower (T-AP-186)	26 March	5 June
USS LST-859	31 January	12 June[a]

Note:

[a]Underway for Kwajalein Atoll.

Sources: References 180 through 185.

(Weapons Assembly) from San Francisco to Enewetak Atoll. Two destroyers and air coverage escorted Curtiss as TU 3.3.2. The oiler USS Cacapon (AO-52) refueled this task unit off Hawaii on 1 March 1951. Upon arrival at Enewetak, TU 3.3.2 was dissolved and Curtiss became the flagship under TU 3.3.1 (Flag Ship). Curtiss provided weapon assembly facilities and, along with Cabildo, provided maintenance facilities for small craft. Curtiss was in the atoll for all four shots. Thirty-eight men were badged on Curtiss, and their exposures are listed in Table 19. In 1951, Navy medical authorities assigned a dose of 1.043 R to most Curtiss crewmen who were not badged to account for the fallout exposure the ship received. A CTG 3.3 letter (reproduced in Appendix A of this report) specified that twenty men were to be badged to record exposure in various parts of the ship. Badges were to be worn from just before shot time and for 1 week thereafter.

Curtiss activities for the GREENHOUSE shots, summarized from log entries, follow.

- DOG (Runit Island, Enewetak Atoll, 8 April, 0634)

  On 8 March 1951 arrived at Enewetak Atoll and became TU 3.3.1 (Flagship). Moored to buoy 568 north of Japtan Island. At 0615 on 7 April movement of the weapon from Curtiss to the tower began. At 1359 underway for berth B-1 off Parry, 9 nmi (16.7 km) south of shot DOG. Mustered personnel at 2040 on 8 April; all personnel were awake at H-1. At 0600 went to general quarters. At H+45 seconds, shock waves arrived at Parry Island. At 0720 secured from general quarters. At 0730 radiation was detected. A reading of 0.001 R/hr was measured on the island, and at the pier readings were 0.017 to 0.02 R/hr. One-quarter mile (0.4 km) from the pier, the lagoon read 0.01 R/hr. At 0825 the staff radsafe officer was notified of contamination levels between 0.001 and 0.004 R/hr. The crew closed all ventilation systems and washed down all weather decks. At 1010 surveyed the ship. Contamination levels of 0 to 0.035 R/hr were detected. At 1100 the radiological survey reported a high of 0.100 R/hr. Personnel were directed to remain inside the ship (Reference 17, DOG-3). Contamination aboard Curtiss on D-day and D+1 was (References 16 and 80):

Day	Time	Readings (R/hr)
D-Day	0825	0.001-0.004
	1010	0.035
	1100	0.100
	1300	Began decontamination; average reading 0.016, maximum 0.057
	1400	0.010-0.100, 0.040 mean
D+1 Day	1000	0.0125-0.025
	1130	Below 0.0125 with isolated area 0.025 on fantail

On 9 April at 1400 underway for new anchorage and at 1602 moored at berth 768 off Enjebi Island.

- EASY (Enjebi Island, Enewetak Atoll, 21 April, 0627)

  On 20 April at 1410 underway to berth B-1 off Parry. At 1558 moored at B-1. On 21 April at 0600 went to general quarters and set condition Able. At 0659 set condition Baker. At 0708 secured from general quarters.*

- GEORGE (Aomon Island, Enewetak Atoll, 9 May, 0930)

  On 8 May at 1403 underway for new anchorage. At 1727 anchored at berth C-1 off Parry. On 9 May at 0821 set condition Baker. At 0845 went to general quarters. At 0853 set condition Able. At 1017 secured from general quarters. At 1207 set condition Baker throughout ship. At 1257 underway to improve anchorage. At 1305 anchored at berth C-1. No fallout occurred on Curtiss.

- ITEM (Enjebi Island, Enewetak Atoll, 25 May, 0617)

  On 24 May at 1358 underway for new anchorage. At 1535 moored at berth B-1 off Parry. On 25 May at 0510 set condition Able. At 0530 went to general quarters. At 0657 set condition Baker. At 0704 secured from general quarters (Reference 17, ITEM-2). Contamination aboard Curtiss on D-day and D+1 was as follows (Reference 80):

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* A small amount of fallout occurred the night of 21 April and early morning of 22 April. It was either undetected or too light to report.

Day	Time	Readings (R/hr)
D-day	0940	Fallout detected
	1030	Began decontamination; average 0.065, maximum 0.025
	1045	0.004-0.006
	1200	Readings at background
	1230	Decontamination stopped; readings below 0.001
	1530-1930	0.025
D+1	1200	Readings reduced to 0.012.

On 27 May at 1528 underway for Pearl Harbor after loading remainder of weapon elements and personnel from TU 3.1.4 (Weapons Assembly). At 1610 formed TU 3.3.2 (Convoy and Escort) for the trip back to the United States.

Task Unit 3.3.2 -- USS Sproston (DDE-577)

The escort destroyer Sproston participated in TU 3.3.2 (Convoy and Escort) and TU 3.3.4 (Surface Patrol) for all shots (References 16, 17, 99, 100, 183, and 186). As part of TU 3.3.2 (Convoy and Escort Unit), Sproston escorted Curtiss with device components to Enewetak Atoll. Upon arrival, TU 3.3.2 was dissolved and Sproston began operating under TU 3.3.4 (Surface Patrol). Its mission was to maintain an antisubmarine surveillance patrol off the atoll at all times, with one of the two destroyers on duty in the outer atoll area. This patrol was to keep unauthorized vessels from entering the area and to search for any vessels in position to observe the shot sites visually or photographically. Maximum periods for patrolling were four days before the shot and two days after the shot. The patrol area covered by the two destroyers during GREENHOUSE are shown in Figure 15 (Reference 99, p. B-I-1-4). Investigation of contacts made by the sonobuoys in the harbor entrance were also a responsibility of this unit. Sproston participated in Project 8.3, a radar scope photography project under TG 3.1 (Reference 138). At the completion of the test series, Sproston and Walker escorted Curtiss back to the United States. Sproston was in close proximity to the atoll for all shots. Ten men on Sproston were badged, as specified in a CTG 3.3 letter (reproduced in Appendix A of this report). Badges were to be worn from just before shot time and for 1 week thereafter. In 1951, Navy medical authorities assigned most Sproston crewmembers who were not badged a dose of 1.000 R to account for their fallout exposure. Sproston shot activities, summarized from log entries, follow.

- DOG (Runit Island, Enewetak Atoll, 8 April, 0634)

  On 8 March 1951, arrived at Enewetak Atoll and berthed in L-3 off Enewetak Island. On 1 April at 0758 underway for patrol station off Enewetak Atoll. On 2 April at 0815 commenced patrolling around atoll. On 8 April at 0430 proceeded independently to point Able, 30 nmi (56 km) north of Runit Island. At 0600 went to general quarters. At 0634 observed the detonation bearing 187°T, distance 30 nmi (56 km) from Runit Island. At 0704 secured from general quarters. At 0740 resumed normal patrol. At 1045 changed course to investigate surface contact. At 1142 identified surface contact as USNS Lt. Robert Craig (T-AK-252), a Military Sea Transportation Service (MSTS) vessel. Ship encountered fallout 2,500 yards (2.3 km) southwest of Enewetak Island, between 1230 and 1300. Began decontamination at 1600. On 10 April at 1320, anchored at berth L-3 off Enewetak Island (Reference 94).

- EASY (Enjebi Island, Enewetak Atoll, 21 April, 0627)

  On 16 April at 0744 underway for patrol station off atoll. On 18 April at 0852 anchored at berth L-3. On 19 April at 0748 underway for patrol station off atoll. On 21 April at 0558 went to general quarters. At 0627 observed shot EASY bearing 164.5°T, distance 30 nmi (56 km). At 0644 secured from general quarters. At 0833 changed course to investigate an oil slick. At 1000 resumed patrol station. Began decontamination at 2200. At 2300 radiological contamination measured at 0.01275 R/hr while on station (Reference 17, EASY-4). By 1600, 22 April, intensity level reduced to normal. On 23 April at 0715 anchored at berth L-3. On 24 April at 1110 underway for patrol station off atoll. Sproston sighted a tug, Eugenia M. Moran, on 27 April in the danger area. At 0734 on 28 April, Sproston anchored at berth M-3 off Enewetak Island.

- GEORGE (Aomon Island, Enewetak Atoll, 9 May, 0930)

  On 1 May at 0748 underway for patrol station off atoll. On 4 May at 0949 anchored at berth L-3. On 7 May at 0758 underway for patrol station around the atoll. On 9 May at 0855 went to general quarters. At 0930 observed shot GEORGE bearing 270°T, distance 15 nmi (21.2 km). At 1043 secured from general quarters and continued patrol of Wide Entrance. On 12 May at 1012 anchored at berth L-3. On 14 May at 0755 underway for patrol station. At 1438 approaching Deep Entrance and anchorage of Walker. At 1531, LCM-22 cast off with an enlisted man to transfer film badges. At 1555 picked up a motor whale boat with all personnel. At 1556 returned to sea through Deep Entrance. At 1621 commenced patrol off atoll. Sproston was not exposed to GEORGE fallout.

- ITEM (Enjebi Island, Enewetak Atoll, 25 May, 0617)

  Maintaining patrol off atoll. On 18 May at 0940 anchored at berth L-3. On 22 May at 1834 underway for patrol station. On 25 May at 0545 exercised crew at general quarters. Observed ITEM at 0617. At 0704 secured from general quarters and set condition of readiness III, normal cruising. At 0852 continued patrol of atoll. From 1900 to 2300, received minor fallout from ITEM. On 26 May at 1557 anchored in berth L-3. At the completion of GREENHOUSE, Sproston and Walker reformed with Curtiss as TU 3.3.2 (Convoy and Escort). On 27 May at 1200 departed for Pearl Harbor.

Task Unit 3.3.2 -- USS Walker (DDE-517)

The escort destroyer *Walker* participated in TU 3.3.2 (Convoy and Escort) and TU 3.3.4 (Surface Patrol) for all shots at Enewetak Atoll (References 5, 37, 38, 99, 100, 184, and 186). *Walker* participated in TU 3.3.2 (Convoy and Escort) with *Sproston* by escorting *Curtiss* with the weapons elements on board to Enewetak Atoll from San Francisco. The unit was dissolved upon arrival and TU 3.3.4 (Surface Patrol) activated. Patrolling around the atoll began immediately on 11 March. Functions of *Walker* were basically the same as *Sproston* with only a few exceptions. While *Sproston* took part in Project 8.3, *Walker* was equipped with air sampling equipment. In the 50 days spent at sea, each ship intercepted one ship not authorized to be in the test area. When the tests were terminated, *Walker* and *Sproston* reformed as TU 3.3.2 and escorted *Curtiss* back to the United States. *Walker*, like *Sproston*, was in the immediate vicinity of the atoll for each shot. Eighteen men were badged on *Walker*, and their exposures are shown in Table 19. In 1951, Navy medical authorities assigned most crewmembers who were not badged an exposure of 0.433 R to account for the fallout the ship received. *Walker* shot-time activities, summarized from log entries, follow.

- DOG (Runit Island, Enewetak Atoll, 8 April, 0634)

  On 8 March 1951 arrived at Enewetak Atoll and dissolved TU 3.3.2 (Convoy and Escort). TU 3.3.4 (Surface Patrol) was activated and on 11 March at 1829 the ship was underway for antisubmarine warfare (ASW) patrol off the atoll. For the next 3 weeks the ship was in and out of the atoll. On 3 April at 0514 departed for assigned station for rehearsal of shot DOG, which was completed at 0640. At 0816 returned to patrolling the atoll. On 5 April at 0629 changed course to investigate radar contact bearing 219°T, distance 62 nmi (115 km). At 0859 went to general quarters. At 0906 sighted surface target bearing 237°T, distance 7 nmi. At 0934 identified target as *Kuroshio Maru No. 7*, Tokyo, a fishing craft with side markings K-290 (Reference 184). At 1037 secured from general quarters. At 1101 escorted the Japanese ship out of the danger area. At 1507 released the ship and returned to the security patrol area. At 2140 entered the patrol area and resumed patrolling. On 7 April at 0900 went to general quarters to conduct a contamination drill. At 0954 secured from general quarters and returned to ASW patrol. On 8 April at 0500 changed course and proceeded to assigned station. At 0600 went to general quarters and set condition Able. At 0615 ship was on station. At shot time *Walker* was 15 nmi (28 km) bearing 090°T from surface zero. At 0642 secured from general quarters and set antisubmarine condition of readiness III and condition Baker throughout ship. At this time ship commenced irregular random security patrol. At 0745 received minor fallout. At 0930 radiological survey of the ship showed highest level at 0.010 R/hr (Reference 17, DOG-3). Radiological surveys continued and showed the following:

Day	Time	Reading (R/hr)
D-day	0830	Began decontamination
	1010	0.010
	1400	0.010
D+1	1000	0.010, maximum
	1208	0.010.

At 1130 surface contact bearing 120°T, distance 10 nmi (18.5 km) was identified as Craig, an MSTS vessel. At 1132 commenced security patrol off atoll. On 9 April at 0812 anchored at berth O-4 off Enewetak Island. On 12 April at 0758 underway for ASW patrol station.

- EASY (Enjebi Island, Enewetak Atoll, 21 April, 0627)

  On 16 April at 1843 underway for security patrol. At 2230 changed course to take station 15 nmi (28 km) off Enjebi Island for rehearsal of shot EASY. On 17 April at 0115 completed rehearsal of shot EASY and resumed patrol off-shore atoll. On 18 April from 1620 to 1645 ceased ASW patrol and commenced search and rescue (SAR) operations, then resumed ASW patrol. On 20 April at 1457 civilian observers came on board. At 1504 resumed ASW patrol. On 21 April at 0420 changed course to take weather station 10 nmi (18.5 km) upwind bearing 70°T from Enjebi. Maneuvered to remain within 2 nmi (3.7 km) of shot station. At 0600 went to general quarters. At 0627 observed shot EASY bearing 270°T, distance 15 nmi (28 km). At 0640 secured from general quarters and set ASW watch. At 1130 light fallout detected; average readings were 0.004 to 0.005 R/hr. At 1852 maneuvered to investigate disappearing radar contact. At 1934 completed investigation with negative results. At 2010 resumed security patrol. On 22 April at 0843 anchored at berth M-3. By 1200 on 22 April, radioactivity had decayed to 0.001 R/hr. On 28 April at 0800 underway for security patrol. On 29 April at 1700 anchored at berth M-2 off Enewetak Island.

- GEORGE (Aomon Island, Enewetak Atoll, 9 May, 0930)

  On 7 May at 0800 underway for security patrol. On 9 May at 0730 proceeded to shot station 30 nmi (56 km) from Eleleron Island. At 0900 went to general quarters. At 0908 set condition Able. At 0915 arrived on station. At 0930 observed shot GEORGE. At 0936 secured from general quarters and set ASW watch and condition Baker. At 1325 resumed ASW patrol. On 13 May at 0530 sighted surface contact bearing 120°T, distance 15 nmi (28 km). At 1616 contact identified as USS Rio Grande (AOG-3) (Reference 184). On 14 May at 1145 anchored at berth M-2. Walker received no GEORGE fallout.

- ITEM (Enjebi Island, Enewetak Atoll, 25 May, 0617)

  On 22 May at 1757 underway for routine security patrol. On 25 May at 0523 went to general quarters. At 0602 on station. At 0604 set condition Able throughout ship. At 0617 observed shot ITEM bearing 270°T, distance 15 nmi (28 km). At 0629 secured from general quarters and set the regular condition III ASW watch and set condition Baker. At 0850 resumed security patrol near Enjebi Island. From 1600 to 1900 encountered fallout. At 1900 average intensity was 0.030 R/hr. Decontamination was 95 percent effective. On 26 May at 1406 anchored at berth M-2. On 27 May reformed with TU 3.3.2 (Convoy and Escort Unit).

Task Unit 3.3.3 -- Patrol Squadron 931

VP-931 arrived on 19 February 1951 at Kwajalein Atoll where it remained throughout GREENHOUSE as TU 3.3.3 (Air Patrol Unit). According to a weekly roster report the squadron averaged 52 officers, 336 enlisted men, and 1 civilian. The squadron was equipped with nine antisubmarine aircraft, five P2V-2s and four P2V-3Ws. One PBM-5A was also assigned to the squadron and was used to support TU 3.1.5 (Radsafe Unit) by collecting water samples from outlying atolls and supplying weather and special project stations on outlying islands. The mission of TU 3.3.3 was defense of an area within a radius of 100 nmi (185 km) from Enewetak Atoll. This area was surveyed day and night with double coverage at night. Flight missions started on 1 March and continued throughout the test series, totaling 264 missions and 2,656.5 hours flown. On 6 March the squadron flew an antisubmarine escort for the incoming TU 3.3.2 (Convoy and Escort) comprised of Curtiss, Sproston and Walker. A two-aircraft team escorted them into the atoll.

All decontamination washdown procedures were done at Kwajalein as well as all maintenance. Critical periods for air patrols were 5 days before each shot and the day after (Reference 17). Specific flight patterns are shown in Figure 15 (Reference 187, p. C-I-1-5).

On 12 May the PBM-5A, while on a water sampling mission for TU 3.1.5, beached at Ponape Island 370 nmi (686 km) southwest of Enewetak Atoll. Assistance arrived and the damaged aircraft was repaired enough to fly back to Kwajalein on 29 May.

Nonflyable squadron equipment departed Kwajalein on 28 May by MSTS. Four ships aided in the rollup of the task unit: USNS David C. Shanks (T-AP-180), USNS General D.E. Aultman (T-AP-156), Mower, and USNS Sgt. Andrew Miller (T-AK-242). The last ship departed on 14 June with the squadron's equipment (Reference 188, p. 1).

VP-931 had 102 personnel badged. A CTG 3.3 letter (reproduced in Appendix A of this report) specified that 150 badges were to be provided VP-931 for each test. They were to be worn by all crewmembers on all flights airborne from shot time and for one week thereafter. Dosimetry records indicate this was done. The highest exposure received by the squadron was 2.410 R. This was an electronics officer from the Armed Forces Special Weapons Project (AFSWP) at Sandia Base, Albuquerque, New Mexico. AFSWP had special equipment installed on one of the aircraft.

Task Unit 3.3.5 -- USS Cabildo (LSD-16)

The dock landing ship Cabildo participated in TU 3.3.5 (Mobile Boat Pool) for all shots at Enewetak Atoll (Reference 182; Reference 16, p. 5). Cabildo arrived at Enewetak Atoll on 23 February 1951. At the time of arrival TU 3.3.5 was established (Reference 189, p. 1). Cabildo was the mother ship to 55 boat pool craft consisting of 30 LCMs, 3 LSUs, 3 AVRs, 8 DUKWs, 8 LCPs, 3 LCVPs, and 3 launches. These are further described under "Mobile Boat Pool (Task Unit 3.3.5)." The mission of Cabildo and the boat pool was to provide water transport for each of the task groups. All boats were maintained by Cabildo, and the ship also was the center for operating a voice signal system in the lagoon for TU 3.3.6 (Harbor Control Unit). Cabildo was in the lagoon for each of the four shots. There were 84 personnel badged on Cabildo. In 1951, Navy medical authorities assigned a 1.1 R dose to most Cabildo crewmen who were not badged to account for fallout during GREENHOUSE. Cabildo's shot-time activities, summarized from log entries, are as follows:

- DOG (Runit Island, Enewetak Atoll, 8 April 0634)

  On 23 February arrived at Enewetak Atoll and established TU 3.3.5 (Mobile Boat Pool) and moored to buoy N-2 off Enewetak Island. On 8 April at 0600 exercised crew at general quarters. At 0634 observed atomic weapon test. At 0643 secured from general quarters and set special sea detail. At 0745 secured from special sea detail. At 1014 fallout was detected and material condition Able was set. At 1015 all unauthorized persons were ordered below deck as a protection against radioactive fallout; ventilation secured and washdown started (Reference 17, DOG-3). The 2-day summary of DOG fallout readings indicate:

Day	Time	Readings (R/hr)
D-day	1100	0.025 average reading; maximum, 0.040
	1315	0.020
	1400	0.010-0.040, with 0.025 mean topside
D+1	1000	0.020 maximum with 0.005 topside
	1238	0.005
	1500	0.003 average

  On 9 April at 1246 secured from radioactivity precautions, opened topside hatches, ports, and vents, and all hands were allowed topside. Only contaminated areas were off limits.

- EASY (Enjebi Island, Enewetak Atoll, 21 April, 0627)

  Moored to N-2. On 21 April at 0600 went to general quarters. At 0627 observed shot EASY. At 0700 secured from general quarters. Very light fallout received on night of 21 April, less than 0.001 R/hr.

- GEORGE (Aomon Island, Enewetak Atoll, 9 May, 0930)

  Moored to N-2. On 9 May at 0900 went to general quarters and set material condition Able. At 0930 observed shot GEORGE. At 0933 secured from general quarters and set special sea detail. At 1130 secured from special sea detail. At 1303 secured from material condition Able. Cabildo received no GEORGE fallout.

- ITEM (Enjebi Island, Enewetak Atoll, 25 May, 0617)

  Moored to N-2. On 25 May at 0539 exercised crew at general quarters and set material condition Able. At 0617 observed shot ITEM. At 0656 secured from general quarters and set condition Baker. At 1028 set material condition Able and all persons were ordered below deck. Radiation was detected at 1045 with a reading of 0.004 to 0.006 R/hr (Reference 17, ITEM-2). At 1130, reading was 0.012 R/hr. Decontamination started at 1230. At 1245 secured from material condition Able and set material condition Baker. At 1400, reading was 0.007 R/hr. At 1620 set condition Able and all persons were ordered below deck. At 1815 set modified material condition Able. At 1830 set condition Able. At 2140 secured from material condition Able and set condition Baker. On 25 May at 1620 fallout detected again. By 1630, readings were 0.040 R/hr. At 2130, readings were 0.027 R/hr. On 26 May, readings at 0415 were 0.020 R/hr, and at 1700, 0.007 R/hr.

On 30 May, Cabildo started its rollup operation by departing for Pearl Harbor with a load of boat pool personnel and equipment. It later returned with USS Catamount (LSD-17) to transport the remaining boat pool craft and equipment.

Task Unit 3.3.5 -- Mobile Boat Pool

The Mobile Boat Pool was established upon the arrival of Cabildo on 23 February 1951. The pool consisted of 30 LCMs (mechanized landing craft) for ship-to-shore transport of equipment, 3 LSUs (utility landing ships) for weapons transport, 3 AVR (air rescue vessels) to evacuate personnel from islands and to perform SAR operations within the atoll, 8 DUKWs (troop amphibious trucks) to conduct security sweeps of islands, plus 8 LCPs (personnel landing craft), 3 LCVPs (vehicle and personnel landing craft), and 3 launches. A total of 58 boats in this pool were operated by TU 3.3 (Reference 3, p. 123). The boat pool provided ship-to-shore transportation and emergency transportation for special security missions. Schedules were made out principally in view of TG 3.1 needs.

Contamination was reported on some of the boats following shot DOG. On 8 April at 0820 an LSU reported a reading of 0.010 to 0.025 R/hr when it was just north of anchorage N-9 off Enewetak Island. LSU-1345 reported a reading of 2.500 R/hr at 0830 when it was just north of Runit Island (Reference 17, DOG-3). LCM-20 also had radiological contamination while in movement with LST-859 and Mower. On 9 April the boat pool had a reading of below 0.004 R/hr. For shot EASY, AVR-20987 and LSU-1249 were contaminated while near Enjebi Island, but no readings are available.

A group of three boat pool members had very high readings on their film badges of 8.5 to 20 R gamma and 12 to 32 R beta exposures between 21 and 23 April following shot EASY. Another enlisted man in the same boat crew did not wear a film badge. The boat was on a run that included Parry, Enjebi, Mijikadrek, Boken, and Dridrilbwij islands. All four men were given radiological physical examinations including chest X-rays, blood counts, urinalysis, and a red blood cell count. Blood counts and urinalysis were done weekly and a followup examination was conducted. These men were not allowed to enter any contaminated area for the rest of the operation. These men were suspected of obtaining high exposure readings on their badges by deliberately leaving them on the shot island. The men did not admit this, however. No other boat pool member operating under the same conditions received an exposure of such magnitude. The crew party monitor reported that at no time during the trip did the meter read more than 0.040 R/hr. Two civilians on the trip had readings of 0.170 R and 0.185 R. The clothing worn by the four men supported the suspicion as it read only 0.003 R/hr. No evidence to support these high exposures was found following an investigation of the incident (Reference 38, p. 6).

On 30 May, <u>Cabildo</u> started the rollup phase of GREENHOUSE, and TU 3.3.5 organization was dissolved.

There were 129 men badged in the boat pool. A CTG 3.3 letter (reproduced in Appendix A of this report) specified that 215 film badges per test were to be available. Badges were to be worn from just before shot time and for 1 week thereafter. In 1951, Navy medical authorities assigned a dose ranging from 0.7 R to 2.1 R for most personnel who were not badged to account for fallout.

Task Unit 3.3.6 -- Harbor Control Unit

This task unit consisted of two officers and fifty-seven enlisted men (Reference 17). No ships were assigned. The unit operated a Harbor Entrance Control Post and provided Port Director facilities. Control over unauthorized entry was monitored by sonobuoys placed in Wide Entrance and Deep Entrance. Regulations controlling boat movement and personnel were issued upon arrival of each ship into the lagoon (Reference 16, p. 6; Reference 189).

Task Unit 3.3.7 -- <u>USNS Sgt. Charles E. Mower</u> (T-AP-186)

An MSTS vessel, <u>Mower</u> participated in TU 3.3.7 (Logistics) for all shots at Enewetak Atoll (References 16, 17, 100, and 185). <u>Mower</u> arrived on 26 March 1951 at Enewetak Atoll. It was used as a hotel ship anchored off Enjebi Island. The ship provided mobile living accommodations for a large number of personnel. The ship remained anchored near Enewetak or Parry island inside the lagoon at shot time. After H-hour, it headed north to either Enjebi or Lujor Island to support scientific recovery operations. <u>Mower</u> was within the lagoon for all shots. Ten men were badged on <u>Mower</u>. A CTG 3.3 letter (reproduced in Appendix A of this report) specified that 10 men were to be badged to record exposure in various parts of the ship. Badges were to be worn from just before shot time for 1 week.

Shot-time activities for <u>Mower</u>, summarized from log entries, were as follows:

- DOG (Runit Island, Enewetak Atoll, 8 April, 0634)

On 26 March the ship arrived for duty in TU 3.3.7 at Enewetak Atoll and anchored at berth C-1 off Parry Island. On 30 March at 1415 it departed for Enjebi Island. On 2 April at 1515, during a trial run, passengers embarked from Enjebi to Enewetak Island. On 3 April at 1136 they debarked from Enewetak to Enjebi. One day before shot DOG, passengers were removed from Enjebi at 1315. On 8 April at 0757 underway to northern end of lagoon while carrying out radsafe precautions. At various times during shot day and the day after, this ship received fallout (Reference 17, DOG-3). The following is a summary of contamination reports:

Day	Time	Readings (R/hr)
D-Day	0858	0.015 average
	1215	0.020
	1400	0.010-0.040; began saltwater washdown and decontamination procedures
D+1	1000	0.002-0.0041
	1330	0.002.

Even though the ship was receiving fallout, it was ordered to proceed to the anchorage position. At 1037 the ship anchored at berth 765 off Enjebi.

- EASY (Enjebi Island, Enewetak Atoll, 21 April, 0627)

On 20 April at 1410 the ship was underway to anchorage C-1 off Parry Island, where it anchored at 1550. Fallout occurring on <u>Mower</u> is not mentioned, but Parry Island, 1,500 yards (1.4 km) east received a small amount. If <u>Mower</u> received this fallout, the average peak intensity would have been approximately 0.0015 R/hr.

- GEORGE (Aomon Island, Enewetak Atoll, 9 May, 0930)

On 8 May at 1420 started embarking passengers from anchorage near Enjebi. At 1940 anchored in southern area, berth MB off Enewetak Island. On 9 May at 1030 shifted anchorage bearings. On 10 May at 0647 underway and at 0927 anchored at berth 765 off Enjebi. No GEORGE fallout occurred on <u>Mower</u>.

- ITEM, Enjebi Island, Enewetak Atoll, 25 May, 0617)

On 24 May at 1410 underway from anchorage and at 1605 anchored off Enewetak Island. On 25 May at 0530 closed all portholes and set condition Able. At 0659 secured from condition Able. At 1045 reported radiation level at 0.004 to 0.006 R/hr (Reference 17, ITEM-2). On 5 June departed for Kwajalein Atoll. No fallout data are available. Since <u>Mower</u> was only 700 yards (640 meters) from <u>Cabildo</u>, however, nearly identical fallout aboard the two ships was likely.

Task Unit 3.3.7 -- USS LST-859

This tank landing ship participated in TU 3.3.7 (Logistics) for three of the four shots at Enewetak Atoll (References 16, 17, 100, and 181). Its function before arriving at Enewetak Atoll was to establish the Air Force special project and weather stations for scientific research. These stations were located at Majuro and Bikini atolls, and Bikati, Nauru, and Kausie islands. LST-859 reported to TG 3.3 on 24 February 1951. It was used as a barracks ship for TG 3.1 personnel who could not be quartered on shore. During the first three shots, LST-859 functioned the same as Mower. It anchored south of the shot sites at H-hour, then took personnel north to Enjebi and Lujor islands for project recovery operations. There were 37 personnel badged on LST-859, although a CTG 3.3 letter (reproduced in Appendix A of this report) specified that only 5 men were required to be badged to record exposure in various parts of the ship. Badges were to be worn from just before shot time and for 1 week thereafter. In 1951, Navy medical authorities assigned most unbadged LST-859 crewmen a dose of 0.33 R to account for GREENHOUSE fallout. Shot-time activities, summarized from log entries, were as follows:

- DOG (Runit Island, Enewetak Atoll, 8 April, 0634)

  On 7 April at 1831, anchored at berth C-2. On 8 April at 0530 prepared to get underway. At 0600 went to general quarters and set condition Able. At 0735 underway for station. As the ship proceeded toward the northern islands with LCM-20 and Mower, levels of up to 0.025 R/hr were reported on the LCM between 0820 and 0857. At 0835 all engines stopped on station. Readings ranged from 0.180 R/hr to off-scale readings. A reading of 0.100 R/hr was reported on the fantail. All hands were ordered below deck and the ship was sealed (Reference 17, DOG-2, pp. 3 and 4). This procedure brought contamination inside the ship. Decontamination began below decks so that personnel with the highest exposure level could retreat to this area for further decontamination. Decontamination washdown started inside the ship working aft and downwards into the crew's compartment. On topside areas the washdown technique used was scrubbing with hard-bristle brushes using soap, saltwater, and 100 psi of water pressure. The ship was ordered to continue its course to the assigned anchorage position and at 1156 anchored southwest of Lujor Island (Reference 190). The following summarizes contamination reports (Reference 17, p. B-7; Reference 214, p. 34):

Day	Time	Readings (R/hr)
D-day	0820-0857	0.025 (on LCM-20)
	0835	0.100 on LST-859's fantail
	1130	Half the interior reduced
	1325	0.050
	1400	0.050 mean; 0.380, maximum; majority of personnel exceeded 0.100 on deck
	1630	0.004

Day	Time	Readings (R/hr)
D+1	0730	All readings removed
	1757	0.003.

- EASY (Enjebi Island, Enewetak Atoll, 21 April, 0627)

  On 20 April at 1500 commenced embarking Holmes & Narver Inc. (H&N) and Robertson employees and 43 TU 3.3.1 personnel. At 1530 completed embarkation. At 1649 underway to new anchorage. At 1820 anchored at berth C-2. On 21 April at 0545 went to general quarters. At 0704 secured from general quarters. On 22 April at 0620 underway for new anchorage. At 0802 anchored southwest of Lujor Island. On 23 April at 1418 commenced disembarking H&N and Robertson employees and 43 TU 3.3.1 personnel. Fallout occurring on board LST-859 is not mentioned. However, 3,000 yards (3.1 km) east, Parry Island recorded a small amount of fallout. If LST-859 received the same fallout, the average peak intensity would have been approximately 0.0015 R/hr.

- GEORGE (Aomon Island, Enewetak Atoll, 9 May, 0930)

  On 3 and 7 May around 0900 conducted radsafe drills. On 8 May at 1500 commenced embarking H&N employees. At 2002 anchored at berth P-2 off Enewetak Island. On 9 May at 0903 went to general quarters. At 1013 secured from general quarters. On 10 May at 1105 commenced disembarking H&N employees and offloading personnel gear and miscellaneous items. At 1455 underway to new berth. At 1527 anchored at berth B-2 off Parry Island. Ship received no GEORGE fallout.

- ITEM (Enjebi Island, Enewetak Atoll, 25 May, 0617)

  On 13 May at 1355 underway for Ponape Island, Caroline Islands, to retrieve a PBM-5A that had grounded on a coral head. On 15 May at 0851 moored in Ponape Island harbor. On 19 May at 1202 underway for Enewetak Atoll. On 21 May at 1241 anchored in berth K-3, Enewetak Lagoon. On 23 May at 0745 underway for Bikini Atoll. On 24 May at 1346 anchored in Bikini Lagoon. At 1730 underway for Kwajalein Atoll. On 25 May at 1748 anchored at berth K-15 at Kwajalein Atoll. On 27 May at 1453 underway for Enewetak Atoll. On 29 May at 0208 anchored at Q-4, Enewetak Lagoon. At 0812 beached at Enewetak Island to unload cargo then at 1253 anchored at berth R-3 off Enewetak Island. At 2055 underway for Kusaie Island, Caroline Islands. On 31 May at 1133 beached at Lele Island in Kusaie Harbor to unload cargo. Stayed in the area until 12 June to disestablish the Air Force special project and weather stations. On 12 June departed for Pearl Harbor. The ship received no ITEM fallout.

NAVY PERSONNEL IN OTHER ORGANIZATIONS

Navy personnel also served in elements of the task force other than the Navy task group. These other elements included Headquarters, TG 3.1 (Scientific), TG 3.2 (Army), and TG 3.4 (Air Force). In addition, there were Navy observers and ship units that visited Enewetak during the series on support missions.

Headquarters Joint Task Force 3

According to planning documents, 36 Navy personnel were assigned to this unit. They were distributed as follows:

	Officers	Enlisted Men	Total	Badged
Command	2	2	4	1
Administration (J-1)	4	4	8	1
Intelligence (J-2)	4	2	6	1
Operations (J-3)	5	4	9	4
Logistics (J-4)	4	4	8	3
Comptroller	1		1	1

The personnel from the organizations listed above participated in the experimental program as part of TU 3.1.3, except those from Naval Medical Records Institute (NMRI) in the biomedical program (TU 3.1.2) and those from Naval Ordnance Laboratory (NOL) and Naval Research Laboratory (NRL). The NOL and NRL personnel participated as part of TU 3.1.1.

Task Group 3.1 (Scientific)

Bureau of Aeronautics (BuAer). Two personnel, a civilian and a Navy officer, were involved (Reference 153). Both were badged. BuAer participated in Project 5.2.

Bureau of Medicine and Surgery (BuMed). BuMed personnel were involved in conducting biological experiments. Seventy personnel are listed, including one as an observer. Forty-eight of these personnel were badged, with the highest reading 4.93 R (References 213 and 58).

Bureau of Yards and Docks (BuDocks). Four BuDocks personnel participated in Project 3.2. One of them appears to have been a consultant to BuDocks. Three personnel were badged.

Naval Air Development Center (NADC). Six personnel from NADC participated in Project 5.2 at Enewetak Atoll; all were badged.

Naval Materials Laboratory (NML). Two civilian NML personnel participated in Project 6.2. Both were badged.

Naval Medical Research Institute (NMRI). Seventeen military and civilian personnel from NMRI participated in the biomedical program and Project 3.1.2, Project 3.1.5, and Project 5.2. Fourteen were badged, and two had readings of over 5 R.

Naval Ordnance Laboratory (NOL). Twenty-two military and civilian personnel from NOL have been identified. Most of these were involved in Project 1.6. Sixteen NOL personnel were badged.

Naval Radiological Defense Laboratory (NRDL). The NRDL team had 55 civilian and military personnel working in Program 6. Thirty-five were badged.

Naval Research Laboratory (NRL). One hundred ten military and civilian personnel from NRL or assigned to NRL (four Army and one Air Force) participated in Program 1. Of the 110, 82 were badged. The highest reading was 3.970 R.

Air Transport Squadron 3 (VR-3). VR-3, based at NAS Moffett Field, California, was part of the Military Air Transport Service (MATS). VR-3 provided three or four aircraft for each of the four tests, and the aircraft arrived at Enewetak Island before shot day. Their function was to carry the radioactive samples collected by the B-17 drones to the United States so that they could be analyzed at Los Alamos Scientific Laboratory (LASL) and other U.S. laboratories.

Immediately after filter papers were removed from the B-17 drone cloud samplers, they were transferred to two of the VR-3 aircraft. These would carry the duplicate radioactive samples retrieved from the drones to Hickam AFB, Hawaii, where the samples were transferred to waiting aircraft. The samples were then flown nonstop to Albuquerque, New Mexico.

The remaining aircraft would depart Enewetak 3 to 4 days later with radioactive samples that had been obtained from the ground. Since there was less time sensitivity with these samples, the original aircraft would normally take the samples to the final destination, with crew rest stops en route.

VR-3 had 119 men badged, which includes all flight crewmembers. It appears that film badges were issued upon arrival at Enewetak and then turned in at Hickam AFB or the final destination. The two highest VR-3 exposures, 1.679 R gamma and 3.150 R gamma, were for two radio operators. These exposures appear to include exposures while these radiomen were flying with VP-931 acting as TU 3.3.3. Excluding these two individuals, the next highest exposure was 1.490 R gamma.

Other Naval Personnel Participating in TG 3.1. Fifteen naval personnel were badged as part of TG 3.1 projects. These were as follows:

Project	Naval Personnel Badged	Indicated Affiliation
1.1	1	Amphibious Base, Coronado, California
1.5	1	USS *Amphion* (AR-13)
1.5	1	USS *Roanoke* (CL-145)
1.5	3	Naval Base, Norfolk, Virginia
1.5	2	Naval Base, Treasure Island, California
1.5	1	Naval Base, San Juan, Puerto Rico
1.5	2	Naval Receiving Station, San Francisco
1.5	1	Reserve Fleet PAC, San Francisco
1.6	1	"APO 187 (HOW)"
D-3	1	"Representative from AEC"

An additional 14 Navy personnel with unknown affiliation appear in a LASL document (Reference 58). However, their names, ranks, and project numbers are listed. Only two of these were badged.

Task Group 3.2 (Army)

One Navy officer was assigned to TG 3.2 in the Property Accounting Branch. He was not badged (Reference 191, Navy).

Task Group 3.4 (Air Force)

Twenty Navy personnel were assigned to TU 3.4.5 (Weather Squadron). None were badged (Reference 192, p. B-4; Reference 193).

Naval Observers

Observer lists are available for the first three shots of the series. DOG had 13 naval officer observers. Two of these were from the AEC Military Liaison Committee. No organizational affiliation is shown for the remaining eleven. One of the latter was badged.

Shot EASY had nine naval officer observers. Seven were badged. There are no organizational affiliations noted.

GEORGE had two naval officer observers. One was from the AEC Division of Military Applications. Neither was badged.

Transient Ships

Twenty transients appeared at Enewetak Atoll during GREENHOUSE. These ships were not a part of TG 3.3. Their mission was to bring food, fuel and other supplies to the atoll or in other ways support the operation (References 181 through 185 and 194). They were:

<u>USNS Bald Eagle</u> (T-AF-50)	<u>USS Nemasket</u> (AOG-10)
<u>USCGC Planetree</u> (WAGL-307)	PC-1546
<u>USS Cimarron</u> (AO-22)	<u>USNS Pvt. F.J. Petrarca</u> (T-AK-250)
<u>USS Faribault</u> (AK-179)	<u>USS Pictor</u> (AF-54)
<u>USNS Fred C. Ainsworth</u> (T-AP-181)	<u>USNS Pvt. Joe E. Mann</u> (T-AK-253)
<u>USNS General D.E. Aultman</u> (T-AP-156)	<u>USS Rio Grande</u> (AOG-3)
<u>USS General Daniel I. Sultan</u> (AP-120)	<u>USNS Sgt. Truman Kimbro</u> (T-AK-254)
<u>USNS General Edwin D. Patrick</u> (T-AP-124)	<u>USS Sussex</u> (AK-213)
<u>USS Genesee</u> (AOG-8)	<u>USS Warrick</u> (AKA-89)
<u>USNS Lt. Robert Craig</u> (T-AK-252)	<u>USS Zelima</u> (AF-49)

Table 22 shows transient arrival and departure dates from Enewetak Atoll. The information was extracted from other ships' logs and some data are missing.

Table 22. Transient ship arrivals, departures, and sightings during GREENHOUSE.

Date	Remarks
1 April	USS Warrick (AKA-89) stood in harbor, USNS Gen. Edwin D. Patrick (T-AP-124) stood in and out of harbor, USS Gennessee (AOG-8) stood out of harbor
5 April	Japanese ship Kuroshio Maru No. 7 was sighted in danger area and escorted out of area
6 April	Warrick stood out of harbor
8 April	Shot DOG: USNS Lt. Robert Craig (T-AK-252) stood in harbor at 1214
10 April	USCGC Planetree was identified steaming outside the harbor
11 April	USNS Pvt. F.J. Petrarca (T-AK-250) stood out of harbor
12 April	Planetree stood in harbor, USNS Fred C. Ainsworth (T-AP-181) stood in and out of harbor, Craig stood out of harbor at 1816
14 April	USNS Gen. Daniel Sultan (T-AP-124) stood in harbor
16 April	USS Nemasket (AOG-10) stood in harbor, USS Zelima (AF-49) stood in harbor
17 April	Nemasket and USS Cimarron (AO-22) stood out of harbor, Zelima stood out of harbor
24 April	USNS Gen. D.E. Aultman (T-AP-156) stood in harbor
26 April	Cimarron stood in harbor
27 April	Cimmarron stood out of harbor, Eugenia M. Moran was sighted in danger area
29 April	USNS Bald Eagle (T-AF-50) stood in harbor, Ainsworth stood in and out of harbor
30 April	Nemasket stood in harbor
1 May	Bald Eagle and Nemasket stood out of harbor
13 May	Aultman stood in and out of harbor, USS Rio Grande (AGO-3) stood in harbor
14 May	USNS Pvt Joe E. Mann (T-AK-253) stood in harbor
16 May	USS Sussex (AK-213) stood in harbor
19 May	Gennessee stood in harbor
20 May	USS Pictor (AF-54) stood in harbor, Mann stood out of harbor
21 May	USS Faribault (AK-179) stood in harbor, Pictor stood out of harbor
22 May	Faribault stood out of harbor

There is no information on whether these ships received radiological contamination. Due to the scheduled arrivals and departures, the likelihood of any exposure is small.

Two ships were sighted in the danger area during GREENHOUSE. One was the Japanese ship, Kuroshio Maru, sighted on 5 April then later escorted out of the area on the same day (Reference 184). The other was Eugenia M. Moran, a tug, sighted on 27 April (Reference 183). There is no information concerning escort of this ship out of the danger area.

CHAPTER 7

U.S. AIR FORCE PARTICIPATION IN OPERATION GREENHOUSE

The Air Force played a major role in Operation GREENHOUSE, performing radiological cloud sampling, weather reconnaissance, air control, weather reporting, radiological exlusion (radex) area plotting, and search and rescue (SAR) operations. Peak strength of Air Force personnel, both military and civilian, was over 2,600. This included 2,436 in Task Group (TG) 3.4, 126 in TG 3.1, the scientific task group (Reference 8, p. 1-32), and 59 in Headquarters, Joint Task Force 3 (JTF 3).

This chapter summarizes the number and sources of the Air Force personnel and their activities. Where available, radiation exposures for these men, recorded by their film badges, are also summarized (see Table 23). The exposures in Table 23 do not include a fallout component. Such assignments can be made using both generalized graphs developed by the JTF 3 radiological safety (radsafe) personnel and more recent work. These general approaches are further discussed in Chapter 10, Personnel Exposures.

Air Force personnel badged during GREENHOUSE included scientific personnel in TG 3.1 who performed missions where exposures were possible. Within TG 3.4, badged personnel included aircrews, decontamination crews, radiation monitors, runway crash crews, and photographers who accompanied scientific recovery missions to contaminated islands. About one-third of TG 3.4 was badged at one time or another during GREENHOUSE.

HEADQUARTERS JOINT TASK FORCE 3

Fifty-nine Air Force personnel were assigned to Hq JTF 3, including Commander JTF 3, an Air Force officer. They worked in all areas of the JTF 3 staff (References 191 and 195 through 197). Eleven of these fifty-nine men had one or more film badges (Reference 59). One person received more than 3 R. His specific duties are unknown, but almost all of of his exposure was accrued on 29 May 1951 (Reference 59, p. 733).

Almost all personnel assigned to JTF 3 Headquarters lived and worked on Parry Island and thus were subject to the fallout from shots DOG, EASY, and ITEM.

TASK GROUP 3.1 (SCIENTIFIC)

One hundred twenty-six Air Force men who were assigned to TG 3.1 have been identified (Reference 8). Most TG 3.1 personnel were from Los Alamos Scientific Laboratory (LASL); however, Army, Navy, Air Force, and Marine Corps personnel were assigned within TG 3.1 as well. TG 3.1 had several major responsibilities including nuclear device preparation, all experimental programs except Program 7, photography, radiological safety, and operating the base facilities. Of the 126 Air Force men in TG 3.1, 94 were badged at one time or another

Table 23. GREENHOUSE personnel exposures, U.S. Air Force organizations.

Element	No. of Air Force Persons in Element	No. of Persons Badged	Exposure Ranges (roentgens)										High (R)
			0	0.0001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	5-10	
Hq, Joint Task Force 3	59	11	2	8						1			3.220
Task Group 3.1	126	94	13	41	13	8	4	2	4	2	4	3	7.570
Task Group 3.4													
Task Unit 3.4.1	660	60	2	32	1	24	1						1.526
Task Detachment 3.4.1.1	232	0											0
Task Unit 3.4.2	649	421	23	194	62	21	19	13	20	30	20	19	8.475
Task Detachment 3.4.2.1	98	23	5	16	1				1				2.970
Task Unit 3.4.3	139	0											0
Task Unit 3.4.4	323	162	28	72	16	13	9	3	1		5	15	7.030
Task Unit 3.4.5	105	0											0
Task Unit 3.4.6	107	8	1	4	2					1			3.160
Task Unit 3.4.7	52	26	4	21	1								0.540
Task Unit 3.4.8	30	3		2			1						1.750
Other Task Unit 3.4	41	41	8	28	2			2		1			3.150
Total Task Group 3.4	2,436	744	71	369	85	58	30	18	22	32	25	34	8.475
Total Air Force	2,621	849	86	418	98	66	34	20	26	35	29	37	8.475

Note:

[a]Raw badge data; calculated assigned fallout exposures not included.

Sources: References 8 and 59.

during GREENHOUSE. Nine of these badged Air Force personnel received more than 3 R. The highest exposure was recorded by an officer working in Task Unit (TU) 3.1.5 (Radsafe) who accumulated 7.570 R (Reference 59). He may have been a monitor accompanying reentry parties. He was badged for eight different days and on four occasions had two badges in 1 day; no single badge reading exceeded 1 R. Of the other eight Air Force personnel whose exposures exceeded 3 R, all but one were in the radsafe unit. The exception was in TU 3.1.1, the LASL unit working with Program 1 experiments (Reference 8). Since all these TG 3.1 personnel were stationed on Parry Island, they were exposed to fallout from shots DOG, EASY, and ITEM. Most of the TG 3.1 personnel left the test area between 26 May and 2 June.

TASK GROUP 3.4 (AIR FORCE)

Table 24 shows the various Air Force units that sent personnel to the test area for GREENHOUSE TG 3.4 operations (Reference 178). The 5x8 exposure cards maintained for GREENHOUSE personnel only identified the individual with his task unit, not with his home organization or station. Thus, it is not possible to relate exposures of personnel to their home organizations from that source.

Task Unit 3.4.1 (Headquarters and Headquarters Squadron)

TU 3.4.1 was made up of persons from a variety of Aircraft Control and Warning (AC&W) squadrons, the 158th Fighter Bomber Squadron, the 3204th Medical Group, and the 3200th Drone Squadron. The task unit personnel operated the airbase at Enewetak, which included the base operations facilities and maintenance and supply support for aircraft and aircraft-related equipment (Reference 7, p. 2). The 158th Fighter Bomber Squadron consisted of six F-80C fighter interceptors with 28 crewmembers and supporting personnel whose function was air defense of the Pacific Proving Ground (PPG) if required (Reference 198, p. 6). The 3204th Medical Group provided medical personnel for the task group. The 3200th Drone Squadron formed the experimental aircraft unit (TU 3.4.2), but a few of these men worked in Hq TG 3.4, probably in staff duties. Of the 892 persons in TU 3.4.1, only 60 were badged during GREENHOUSE (Reference 59), 25 of whom received between 1 and 1.53 R. For these 25 personnel almost all exposures were received on 26 May, the day after shot ITEM (Reference 59).

TU 3.4.1 had approximately 495 personnel stationed on Enewetak Island as of 26 May (Reference 199, p. 8). Four in the unit had departed for the United States between 20 and 26 May 1951 (Reference 19, p. 1; Reference 200). Of the 495, 34 were scheduled to depart by 2 June, another 117 were scheduled to depart by 9 June, and another 20 by 16 June 1951.

Task Detachment (TD) 3.4.1.1 was formed on Kwajalein to provide maintenance and supply support to TG 3.4 elements on that island. This detachment had 232 persons assigned to it as of 31 March, 1951 (Reference 27, p. 40), none of whom was subjected to the fallout from shots DOG, EASY, and ITEM. Apparently everyone in TD 3.4.1.1 left Kwajalein by 2 June (Reference 200).

Table 24. Task Group 3.4 home organizations, GREENHOUSE.

Element	Home Organizations	Home Station
TU 3.4.1	158th Fighter Bomber Squadron	George AFB, CA
	634th AC&W Squadron	Everett, WA
	645th AC&W Squadron	Roslyn, NY
	646th AC&W Squadron	Twin Lights, NJ
	647th AC&W Squadron	Ft. George G. Meade, MD
	648th AC&W Squadron	Indiantown Gap, PA
	653th AC&W Squadron	Stewart AFB, NY
	654th AC&W Squadron	Grenier AFB, NH
	654th AC&W Squadron (Det. 1)	Otis AFB, MD
	655th AC&W Squadron	Seneca Ord Depot, NY
	656th AC&W Squadron	Ft. Ethan Allen, VT
	658th AC&W Squadron	Michel AFB, NY
	660th AC&W Squadron	Selfridge AFB, MI
	661th AC&W Squadron	Selfridge AFB, MI
	667th AC&W Squadron	Hamilton AFB, CA
	669th AC&W Squadron	Ft. MacArthur, CA
	670th AC&W Squadron	Camp Cook, CA
	677th AC&W Squadron	Hamilton AFB, CA
	3204th Medical Group	Eglin AFB, FL
	3200th Drone Squadron	Eglin AFB, FL
TU 3.4.2	3200th Drone Squadron	Eglin AFB, FL
TD 3.4.2.1	3151st Electronics Group	Griffiss AFB, NY
	3171st Electronics R&D Group	Griffiss AFB, NY
TU 3.4.3	1810th AACS Group	Hickam AB, HI
	1909th AACS Squadron	Andrews AFB, MD
	1960th AACS Squadron	Kwajalein, MI
TU 3.4.4	57th Strat. Recon Squadron	Hickam AB, HI

(continued)

Table 24. Task Group 3.4 home organizations, GREENHOUSE (continued).

Element	Home Organizations	Home Station
TU 3.4.5	26th Weather Squadron	Brookley AFB, AL
	2060th Mobile Weather Squadron	Tinker AFB, OK
	1600th Food Service Squadron	Westover AFB, MA
	1701st Food Service Squadron	Great Falls AFB, MT
	1801st AACS Group	Hamilton AFB, CA
	1814st AACS Group	Robins AFB, GA
	1901st AACS Squadron	Travis AFB, CA
	1905st AACS Squadron	McChord AFB, WA
	1907st AACS Sqaudron	March AFB, CA
	1909st AACS Squadron	Andrews AFB, MD
	1922nd AACS Squadron	Maxwell AFB, AL
	1923rd AACS Squadron	Kelly AFB, TX
	1928th AACS Squadron	MacDill AFB, FL
	1921-1 AACS Detachment	Perrin AFB, TX
	1921-2 AACS Detachment	Goodfellow AFB, TX
	1921-4 AACS Detachment	Tinker AFB, OK
	1921-6 AACS Detachment	Vance AFB, OK
	1921-9 AACS Detachment	Lowry AFB, CO
TU 3.4.6	2600th Air Base Squadron	Pope AFB, NC
	4415th Air Base Group	Pope AFB, NC
	4910th Air Base Group	Kirtland AFB, NM
	4th Liaison Flight	Pope AFB, NC
	5th Helicopter Flight	Pope AFB, NC
TU 3.4.7	4th Air Rescue Squadron, Flt A	Hamilton AFB, CA
	4th Air Rescue Squadron, Flt D	Lowry AFB, CO
	5th Air Rescue Squadron	Westover AFB, MA
	5th Air Rescue Squadron, Flt B	Ellington AFB, TX
	5th Air Rescue Squadron, Flt C	Maxwell AFB, AL
	5th Air Rescue Squadron, Flt D	Selfridge AFB, MI
	11th Air Rescue Squadron, Flt A	Hickam AB, HI
TU 3.4.8	Lookout Mountain Laboratory	Los Angeles, CA

Source: Reference 178.

Task Unit 3.4.2 (Experimental Aircraft)

This task unit, comprised of the 3200th Drone Squadron, was organized and trained at Eglin AFB, Florida, before deploying to Enewetak Island. Its primary function was to control the drone B-17s and T-33s used for nuclear cloud sampling and nuclear effects testing. At peak strength this task unit had 649 men, all of whom were stationed on Enewetak Island. Of these 649, 421 were issued one or more film badges during the test series. Sixty-nine persons in TU 3.4.2 received over 3 R from badge totals. Most of this exposure was received between 25 and 29 May, just after shot ITEM (Reference 59). TU 3.4.2 had 415 men left on Enewetak as of 26 May and 98 as of 2 June 1951.

A Strategic Air Command (SAC) RB-29, under the operational control of TU 3.4.2, flew to Enewetak just before shot GEORGE and departed 11 May, just after shot GEORGE. It conducted film-fogging tests during GEORGE, so the crew should have been badged; however, they were not on Enewetak long enough to accumulate any exposure from fallout (Reference 26, p. 25).

TD 3.4.2.1 was part of the Experimental Aircraft Unit and was located on Kwajalein. This task detachment was composed of elements of the 3151st Electronics Group and the 3171st Electronics R&D Group, both assigned to the Air Materiel Command. Personnel from this task detachment flew the two B-50As, the two B-50Ds, and the B-47. Since crews of the B-50As and B-50Ds tracked and sampled the nuclear cloud, they should have been badged for their missions. The pilot of a B-50A on 8 April and 10 April in connection with shot DOG mission activities (Reference 24, pp. 32 and 33) is not listed in film badge records at all, but his radsafe monitor for 8 April is; he received 0.060 R on that date (Reference 59). The two B-50Ds with crews and supporting personnel were moved from Kwajalein to Enewetak Island on 27 March and remained there through GEORGE (Reference 27, p. 47). After GEORGE all but five unit members departed the test area. These five (three were civilians) were evidently stationed at Enewetak and did not depart there until sometime between 3 and 9 June 1951 (Reference 200). Maximum strength of TD 3.4.2.1 was 98, of whom only 23 were badged (Reference 18, p. 2; Reference 44). All but one exposure from mission work (badge readings) were less than 1 R. One person who was badged on 29 May received 2.5 R that day (Reference 59). This 29 May badge reading could include a fallout contribution. The only men in this task detachment subjected to fallout were the crews and support personnel of the two B-50Ds that were moved to Enewetak for DOG, EASY, and GEORGE and the five persons who were stationed on Enewetak until early June.

Task Unit 3.4.3 (Communications)

This unit was made up of personnel from the 1810th Airways and Air Communications Service (AACS) Group, the 1909th AACS Squadron, and the 1960th AACS Squadron. The task unit was organized in September 1950 at Kwajalein (Reference 63, p. 10) to operate communications facilities and networks for aircraft, weather, and point-to-point communications. They also operated homing beacons and ground-controlled approach (GCA) equipment at Enewetak. This task unit had a detachment on Kwajalein of unknown strength (Reference 7, p. 6). TU 3.4.3 totalled 139 men at peak strength; none was ever badged (Reference 18, p. 3; Reference 59). On 26 May 1951, 135 persons in this task unit remained in the test area, some possibly still on Kwajalein (Reference 19, p. 2). Fifty-one left between 27 May and 2 June and fifty-one more left between 10 and 16 June.

Task Unit 3.4.4 (Weather Reconnaissance)

This unit was made up of personnel from the 57th Strategic Reconnaissance Squadron who flew the WB-29s that supported weather reconnaissance, cloud tracking, and cloud sampling. TU 3.4.4 also operated a personnel decontamination facility for TG 3.4 personnel on Kwajalein. At peak strength this unit had 323 persons, 162 of whom were issued one or more film badges. This task unit was stationed on Kwajalein for the duration of GREENHOUSE. Personnel of the unit who did not leave Kwajalein should have had no fallout contribution included in total GREENHOUSE exposure. Twenty men in TU 3.4.4 had badge readings exceeding 3 R, some as high as 7 R. All 20 were badged more than once. All were badged on 26 May and all received most of their exposure (ranging from 2 to over 5 R) on that date (Reference 59). Since ITEM was detonated on 25 May and personnel in this task unit flew cloud-tracking and -sampling missions lasting from 6 to 12 hours, most of the radiation probably was received on shot day (25 May); the badges were turned in for processing the following day.

Six men in this unit were stationed on Enewetak. Three noncommissioned officers were placed on temporary duty at JTF 3 Weather Central on Enewetak on 15 March 1951 (Reference 21, p. 31), and three officers were placed on temporary duty to TG 3.4 the first week of April (Reference 24, p. 2). These six would have been exposed to fallout radioactivity as long as they remained on Enewetak.

Apparently all TU 3.4.4 personnel left the test area by 2 June 1951 as forecast departures after 2 June 1951 did not include any personnel from this task unit (Reference 200).

Task Unit 3.4.5 (Weather)

The mission of the weather unit was to operate the JTF 3 Weather Central and to operate remote weather stations on the islands of Kusaie, Nauru, Bikati, and Majuro. This unit contained personnel from a variety of U.S.-based units (see Table 24). However, the majority were from the 2060th Mobile Weather Squadron, Tinker AFB, Oklahoma. Personnel from the food service and AACS units provided food service and communications support to the remote weather sites. The strength of TU 3.4.5 averaged 105 Air Force personnel in April and May 1951. Twelve Navy personnel from TG 3.3 and three Air Force personnel from TU 3.4.4 were also attached to TU 3.4.5 for duty at JTF 3 Weather Central (Reference 65, p. 1). Seventy TU 3.4.5 men were located on the four remote weather islands, which had no significant fallout during GREENHOUSE (Reference 64, p. 12). Three from this task unit prepared radex plots on Kwajalein for TU 3.4.4 aircrews, again in an area where no fallout occurred (Reference 64, App. 14). The remainder of TU 3.4.5, about 32 Air Force personnel, was located on Enewetak Island; these men were exposed to GREENHOUSE fallout.

Task Unit 3.4.6 (Liaison)

TU 3.4.6 personnel were from the 4910th Air Base Group at Kirtland AFB, New Mexico, the 4th Liaison Flight and 5th Helicopter Flight at Pope AFB, North Carolina. Very few were sent by the 4910th Air Base Group at Kirtland AFB; TU 3.4.6 was made up almost entirely of personnel from Pope AFB. Duties of this task unit included air transport of personnel to the various islands at Enewetak Atoll, close-in air search and rescue (SAR), aerial insecticide spraying, and participation in atmospheric conductivity tests for Program 7 using 22 light planes and 4 helicopters. Of the 107 persons in this unit at peak strength, only 8 had one or more badges during the period of testing. Only one man, an L-13 pilot, received more than 1 R. He accummulated 3.16 R, most of which was received on 25 and 27 May 1951, just after shot ITEM (Reference 59). No one else in this task unit was badged during or after ITEM. Everyone in this task unit was stationed on Enewetak Island and thus exposed to GREENHOUSE fallout radioactivity. On 12 May, 35 men from TU 3.4.6 returned to Pope AFB (Reference 26, p. 30). By 26 May 1951 (1 day after ITEM), the strength of this task unit was down to 73 personnel (Reference 19, p. 3). By 2 June 55 persons were left and by 9 June only 21 remained (Reference 200, pp. 1 through 3).

Task Unit 3.4.7 (Rescue)

This unit was made up of personnel from two U.S.-based units: the 4th Air Rescue Squadron, which provided two B-17s modified for SAR and 27 men, and the 5th Air Rescue Squadron, which provided two SA-16 aircraft and 25 men, and at least 1 individual from the 11th Air Rescue Squadron, Hickam AFB, Hawaii. By 18 March 1951 all 52 personnel were present in the test area (Reference 27, p. 73). The mission of TU 3.4.7 during GREENHOUSE was to provide SAR coverage within 300 nmi (556 km) of Enewetak (Reference 7, p. 8). Initially, TU 3.4.7 was based entirely on Kwajalein; however, in March 1951 an SA-16 and a B-17 were placed on Enewetak for better SAR response. Crews and aircraft were to rotate every 15 days. During rehearsals and on shot days, two SA-16s and one B-17 were positioned at Enewetak (Reference 27, p. 74). Both B-17s (one from Enewetak and one from Kwajalein) were airborne for all four shots while both SA-16s were on ground alert at Enewetak (Reference 20, p. 1). The 20 maintenance and administrative personnel in this task unit remained on Kwajalein for the duration of the test series (Reference 27, p. 75; Reference 201, p. 1; Reference 202, p. B13). The four 8-man aircrews alternately stood alert on Enewetak. At times two crews were on Enewetak and at other times three. For example, the following schedule was maintained between shots DOG and EASY (Reference 203, p. 31; Reference 201, p. 2):

7 - 9 April	Both SA-16s and one B-17 on Enewetak
10 April	SA-16 #9091 departed for Kwajalein
10 April	SB-17 crews traded locations
16 April	SA-16 #9091 returned to Enewetak
16 April	Rehearsal for EASY shot
17 - 22 April	Both SA-16s and one B-17 on Enewetak.

Twenty-six of the fifty-two men in this task unit were badged at least once during GREENHOUSE (Reference 60, p. 841), and all twenty-six received less than 1 R (Reference 59). The 32 crewmembers who flew the two SA-16s and the two B-17s, however, spent roughly 65 percent of their time on Enewetak and thus were subjected to DOG, EASY, and ITEM fallout (Reference 201, p. 2). On 26 May, 41 men from TU 3.4.7 were still in the test area. Since the two SA-16 aircraft at Enewetak were on alert for ITEM shot through 1800, 25 May (local time), they probably did not return to Kwajalein until the next day. The B-17 that flew from Enewetak during shot ITEM on 25 May may have returned to Enewetak or may have returned to Kwajalein after its orbiting mission. In any event, it is probable that by the evening of 26 May all remaining rescue unit personnel were back on Kwajalein, where they remained until they left the test area.

Only one person in TU 3.4.7 is shown in film-badge records as being badged on or after 25 May. He was issued one badge on 9 April (0.180 R) and a second on 26 May (0.360 R) (Reference 59). Not listed on 25 and 26 May are the crewmembers of the SA-16s and B-17s. In fact, only 12 TU 3.4.7 personnel who were not B-17 crewmembers were badged during GREENHOUSE, and 10 of these had only one badge; issued on 9 April 1951 (Reference 60, p. 841). This seems to indicate that SA-16 crewmembers were not badged, except possibly for shot DOG.

Task Unit 3.4.8 (Documentary Photo)

This unit contained personnel from the U.S. Air Force Lookout Mountain Laboratory at Los Angeles, California. Its mission was documentary motion picture and still photographic coverage of the series (Reference 7, p. 8). At peak strength TU 3.4.8 had 30 men in the test area (Reference 20, p. 69). All 30 were billeted on Enewetak Island; however, four unit writers and animators commuted daily to Parry Island where a trailer had been set up. Cameras were installed in several different locations: emplaced on the water towers on Parry and Enewetak islands, on the island of Ananij, and onboard a C-47 aircraft (Reference 204, pp. 2 and 3). Personnel from the unit also accompanied experimenters to islands near the surface zeroes to photograph experiment recovery operations (Reference 205, p. 3.23). For GEORGE, cameras were mounted in a manned B-17 drone aircraft (Reference 26, p. 34). Much of the documentary photography was done before the first shot (DOG), and the unit strength was down to 26 by 8 April. By 23 April strength was down to 23 where it remained through GEORGE on 9 May 1951. By ITEM on 25 May, however, task unit strength had declined to one officer, two enlisted men, and eight civilians (Reference 18, p. 3; Reference 19, p. 2) who departed by 2 June 1951 (Reference 200, p. 2).

On 8 April a photo crew went ashore on Runit Island 6 hours after DOG was detonated there to photograph a radiation survey crew (Reference 206, p. 32). Film-badge records indicate that three persons from TU 3.4.8 were badged on 8 April and that their exposures were less than 0.5 R (Reference 59). On EASY D-day, a camera crew went to Enjebi with biomedical personnel from Program 2 to film the removal of experimental animals. After 6 hours their jeep was too radioactive to use and it was left on the island (Reference 203, p. 33). Only one person from TU 3.4.8 was badged during this time period; his badge read less than 0.5 R. He wore a total of seven badges during GREENHOUSE and accumulated a total exposure of 1.745 R. His largest single exposure, 0.87 R, was received on 3 May (Reference 59). No other personnel were badged in this task unit.

OTHER AIR FORCE

No task unit assignment is known for 41 Air Force personnel who were badged one or more times because their 5x8 exposure cards do not show this information. Three people in this group recorded more than 1 R on their badges. One had three badges and recorded 2.2 R on 27 May; one of his other badges read 0.159 R. One had two badges and recorded almost all of his exposure on 27 May as well. The other badged person had only one badge, which showed an exposure of 3.15 R for 29 May 1951 (Reference 59). Table 23 presents exposure information for all Air Force personnel.

CHAPTER 8

U.S. MARINE CORPS PARTICIPATION IN GREENHOUSE

Participation of U.S. Marine Corps personnel in GREENHOUSE primarily involved security. Marine Corps units were assigned to both the flagship USS Curtiss (AV-4), and U.S. Naval Operating Base Kwajalein. Several of the Marine Corps members present at Enewetak were badged during GREENHOUSE.

Exposure data are available for the detachment on board the flagship but none, as expected, are available for the unit at Kwajalein Atoll. Marines at Kwajalein are assumed to have been unbadged. Radioactive fallout was not received at Kwajalein. Table 25 provides exposure data for U.S. Marine Corps personnel.

Table 25. GREENHOUSE personnel exposures, U.S. Marine Corps organizations.

Organization	No. of Persons In Unit	No. of Persons Badged	Exposure Ranges (R)				High (R)
			0	0-0.5	0.5-1	Over 1	
USS Curtiss (AV-4)	68	5	3	1	1		0.670
Task Unit 3.1.2	1	1			1		0.670
Task Unit 3.1.5	2	2				2	3.805
Total	71	8	3	1	2	2	3.805

TASK UNIT 3.3.1 -- USS CURTISS (AV-4)

Sixty-eight Marine officers and enlisted men were assigned to the Marine detachment aboard Curtiss, flagship of Task Group (TG) 3.3. The ship transported device elements from the United States to the operational area of Enewetak Atoll. Security for weapon elements was an important responsibility of the Marine detachment and was headed by a Marine Security Officer (Reference 207). Forty Marines aboard Curtiss were given security clearances while at Enewetak Atoll (Reference 208). Their clearances allowed these personnel access to restricted or exclusion areas on the atoll (Reference 16, E). Six other Marines were also given such clearances; however, their task units and assignments have not been identified (Reference 208). Five Curtiss Marines were badged. Three had zero exposures, one had 0.670 R, and the fifth had 0.050 R. A Marine officer from Curtiss was badged with TU 3.1.5; his exposure is discussed below. Other functions of the Marine detachment aboard Curtiss included orderly and housekeeping details (Reference 207). Chapter 6 contains further information about Curtiss' functions.

TASK UNIT 3.1.2 -- BIOMEDICAL PROGRAM

One Marine Corps enlisted man participated in the Biomedical Program under TG 3.1 (Scientific) (Reference 98). His activity with this program has not been identified, but he was badged between 23 April and May 10; his exposure recorded by the badges was 0.670 R (Reference 59). See Chapter 4 for information on the Biomedical Program and its activities.

TASK UNIT 3.1.5 -- RADIOLOGICAL SAFETY PROGRAM

One Marine Corps officer from Curtiss participated in this program. He was badged from 9 April until 9 May; his badge read 3.805 R. Another Marine Corps officer from Los Alamos Scientific Laboratory (LASL) was involved in the Task Unit (TU) 3.1.5 Radiological Safety Program under TG 3.1. He was badged from 8 April to 10 May; his badge read 3.043 R (References 59 and 209).

KWAJALEIN ATOLL

U.S. Naval Operating Base Kwajalein was the duty station of 61 Marine Corps officers and enlisted men. Their specific duties are unknown; however, their mission is assumed to have been security. There is no record of this group being badged.

JOINT TASK FORCE 3 -- INTELLIGENCE AND SECURITY

A Marine Corps major in J-2 (Intelligence Division) of JTF 3 was head of the Photographic, Information and Control Division for Operation GREENHOUSE (Reference 210). He does not appear to have been badged.

OBSERVERS AT ENEWETAK ATOLL

Two lists name three Marine Corps officers on flights that took them to Enewetak to observe shot GEORGE (Reference 210). Two officers, a lieutenant colonel and a brigadier general, were listed under Navy observers. One officer, a colonel, was listed under Secretary of Defense observers. A fourth observer for shot GEORGE, a lieutenant colonel from Headquarters, U.S. Marine Corps, has been identified. None of these observers appear to have been badged.

CHAPTER 9

JOINT DEFENSE, ATOMIC ENERGY COMMISSION, OTHER GOVERNMENT AGENCIES AND CONTRACTOR PARTICIPATION IN GREENHOUSE

The following groups participated in various ways in GREENHOUSE. Personnel exposures from film badges for this group are summed in Table 26.

JOINT DEPARTMENT OF DEFENSE AGENCIES

Armed Forces Institute of Pathology, Washington, D.C. Four persons participated at GREENHOUSE from this institute in Project 2.2. They were also involved in studies of dogs at GREENHOUSE. One person was an observer and was badged along with two others. The observer was a Navy captain. The other two were an Air Force colonel and an Army major.

Armed Forces Special Weapons Project. Armed Forces Special Weapon Project (AFSWP) was a joint defense organization consisting of civilian and military personnel. At GREENHOUSE its primary function was the sponsorship of Program 3, Structures. Civilian and military structures were built on the test islands to test nuclear blast effects. (Chapter 4 contains a detailed description of Program 3.) Two AFSWP personnel were involved in this program, a military officer and a badged civilian who was the program leader. Four officers, two Army, one Navy, and one Air Force, from AFSWP were assigned to the Radsafe Unit, Task Unit (TU) 3.1.5. Two were badged. One of the Army officers had a reading of over 4 R (References 152 and 153).

ATOMIC ENERGY COMMISSION

The Atomic Energy Commission (AEC), an executive agency established by the Atomic Energy Act of 1946, was charged with the development of nuclear weapons. Several military personnel in this agency participated at GREENHOUSE in various experiments.

One representative from headquarters, seven civilians from the Finance, Intelligence, and Production offices, three from the Division of Military Applications (DMA), and sixteen from the Santa Fe Operations Office (SFOO) were noted as VIP visitors. Universities and corporations operated laboratories under AEC contract and these contributed to GREENHOUSE. Sixteen personnel were listed as AEC with a laboratory notation. Whether they were part of the AEC or employees of the laboratory they represented is unclear. Ten AEC were badged. AEC laboratories represented follow.

Argonne National Laboratory, Chicago, Illinois. One badged civilian worked in Project 1.10.

Brookhaven National Laboratory. This AEC laboratory sent one civilian to participate in the Biomedical Program (Program 2). He was not badged.

Table 26. GREENHOUSE personnel exposures, for joint defense agencies, Atomic Energy Commission, other government, and contractor organizations.

Organization	No. of Persons in Unit	No. of Persons Badged	Exposure Ranges (roentgens)										High (R)
			0	0.0001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	5-10	
Joint Department of Defense													
Armed Forces Institute of Pathology	4	3		2	1								0.520
Armed Forces Special Weapons Project	6	3		1	1						1		4.872
Atomic Energy Commission													
Atomic Energy Commission	43	10	3	4		2	1						1.525
Argonne National Laboratory	1	1		1									0.360
Los Alamos Scientific Laboratory	163	136	50	30	15	5	8	5	4	6	5	8	7.710
Oak Ridge National Laboratory	2	2					1	1					2.105
Sandia Corporation	78	46	14	30	2								0.500
Univ. of California Radiation Lab	47	37	9	10	8	6	1	1	1	1			3.330
Other Government													
Central Intelligence Agency	2	1		1									0.305
U.S. Coast & Geodetic Survey	2	2		2									0.420
National Bureau of Standards	33	17	2	4	4	3	2		1			1	5.600
U.S. Public Health Service	1	1				1							1.115
Contractors													
Ammen & Whitney	1	1				1							1.027
Armour Research Foundation	11	9	2	3	4								0.910
Bell Telephone Laboratories	2	1					1						1.590
Bendix-Friez	1	1		1									0.270
Carnegie Institute	1	1	1										0
Edgerton, Germeshausen & Grier	40	30	6	12	7	2	1	1		1			3.810
Holmes & Narver		207	14	76	86	9	4	3	6	4	1	4	8.575
Massachusetts Institute of Technology	8	7		2	4		1						1.950
Melpar Inc.	1	1		1									1.00
Ohio State University	1	1	1										0
Princeton University	1	1			1								0.640
Stanford University	1	1			1								0.550
TracerLab	2	1			1								0.990
University of California	25	17	6	6	1	1	1	1			1		4.215
University of Illinois	1	1			1								0.600
University of Iowa	1	1				1							1.385
University of Rochester	9	7			1	4	1		1				2.650
Incomplete Identification	4	4	2		1							1	8.425

Note:

[a] Raw badge data; calculated assigned fallout exposures not included.

Source: Reference 59.

Los Alamos Scientific Laboratory (LASL), Los Alamos, New Mexico. LASL was operated by the University of California for the AEC and had both university employees and military personnel. Nuclear devices for GREENHOUSE were developed at LASL. This laboratory also conducted many scientific experiments at Enewetak Island as Task Group (TG) 3.1. Of the 163 personnel found on a TG 3.1 roster, there were 16 Navy, 19 Army, 21 Air Force, 1 major from "AEC MC," and 106 civilians. Of these 136 were badged: 14 Navy, 17 Army, 17 Air Force, and 84 civilians. One major in TG 3.1 cannot be identified by service.

Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee. ORNL was operated by Union Carbide for the AEC, had two civilians in Operation GREENHOUSE in Program 3 (Structures) and Program 2 biological dosimetry experiments involving tests of cataracts and Tradescantia. Both were badged.

Sandia Corporation, Albuquerque, New Mexico. Sandia was another AEC laboratory operated under contract by the Sandia Corporation, a nonprofit subsidiary of Western Electric Company. A roster of TG 3.1 personnel from Sandia shows 78 participants at GREENHOUSE. This included 11 Navy, 6 Army, 10 Air Force, and 51 civilians. Forty-six personnel were badged: five Army, ten Navy, nine Air Force, and twenty-two civilians.

University of California Radiation Laboratory, Berkeley, California. This AEC laboratory was represented by 47 personnel: 42 civilians, 1 Army, 1 Air Force, and 3 Navy. They participated in Project 1.8 and Project 1.12. Thirty-three civilians, one Army, and three Navy personnel were badged.

OTHER GOVERNMENT ORGANIZATIONS

Central Intelligence Agency (CIA), Washington, D.C. One person, a military officer was on the official observer list. A second person, an Army lieutenant colonel from CIA, was on a TG 3.1 roster and was badged.

U.S. Coast and Geodetic Survey (USC&GS). The roster for TG 3.1 shows two persons from this agency, a civilian and a Navy lieutenant commander. Both were badged with this organizational affiliation. USC&GS took part in Project 7.7 under Hq, U.S. Air Force.

National Bureau of Standards (NBS). The Radiation Physics Laboratory of NBS was involved in Project 1.2 at GREENHOUSE. Seventeen of the thirty-three NBS civilians on the TG 3.1 roster were badged.

National Security Resources Board. This organization took part in the test of windows for Program 3. Numbers of personnel are not available.

Public Building Service of the General Services Administration. This organization took part in the test of windows for Program 3 during the nuclear blasts. No individuals are identified.

U.S. Public Health Service (USPHS). A badged USPHS officer served in TU 3.1.5, the Radsafe Unit.

Public Works Division. During the construction phase at Enewetak Island, this group cooperated with Holmes & Narver, Inc., in building the structures necessary for Operation GREENHOUSE. No individuals are identified.

CONTRACTORS AND OTHERS

Andrew Corporation. Two civilians from this company participated in Project 1.8 and Project 3.1.1. Neither was badged.

Amman and Whitney, Consulting Engineers of New York. One badged civilian from this firm was involved in construction of the Army structures.

Applied Physics Laboratory, John Hopkins University, Silver Spring, Maryland. One civilian participated in Project 1.6.1.2. He was not badged.

Armour Research Foundation, Illinois Institute of Technology, Technical Center, Chicago, Illinois. Program 3 had 11 civilian personnel from this institute in the experiment on Blast Loading and Structural Response. Nine were badged.

Bell Telephone Laboratories. Two civilians are on the TG 3.1 roster under Projects 3.1.4 and 3.4. Only one was badged.

Bendix-Friez Corporation. One badged civilian was involved in Project 4.2.

Carnegie Institute. One Navy man, an observer, represented this institute at GREENHOUSE. He was badged as a member of Project 4.6 (Atmospheric Conductivity Test).

Chicago, University of, Chicago, Illinois. One source cites involvement of this university under the Miscellaneous Studies of Dosimeters (Reference 149). It is not known how many personnel were involved. None was badged.

Edgerton, Germeshausen & Grier (EG&G), Boston, Massachusetts. According to the TG 3.1 roster, 30 civilians, 2 Army, and 8 Air Force personnel were affiliated with EG&G. Twenty-three civilians, two Army, and five Air Force personnel were badged. This organization took part in various projects: 1.6.3.4, 1.9, 1.9.2, 1.11 and 4.1. See Chapter 4 for further details on these undertakings.

Holmes & Narver, Inc. (H&N), Los Angeles, California. This architect and engineering firm designed and constructed the scientific and support facilities at Enewetak Atoll under AEC contract.

Howard T. Fisher & Associates, Inc., Chicago, Illinois. This corporation was involved in the Air Force Structures project. Numbers of participants are unknown.

Kollsman Instrument Corporation. This company is mentioned in its role of maintaining instruments for Project 4, Cloud Physics. Numbers of participants are unknown.

Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts. MIT took part in the Army Structures and Blast Studies on Aircraft under Program 3. Seven of the eight identified men were badged.

Melpar, Inc. One badged employee of this company took part in Project 6.3 (Combat Vehicle Exposure).

Northwestern University, Evanston, Illinois. The Biomedical Program had one civilian from this university. He does not appear to have been badged.

Ohio State University, Department of Physics, Columbus, Ohio. A member of the department participated in Project 6.3. He was badged, but with no exposure.

Princeton University, Princeton, New Jersey. One civilian from this university was badged. He took part in Project 3.4 in the Structures Program.

Robertson Construction Company. This company erected vacuum pipes for Project 1.8.

Stanford University, Palo Alto, California. One civilian from Stanford took part in Project 3.4. He was badged with a reading of 0.550 R.

TracerLab, Boston, Massachusetts. Two civilians working in Project 6.1 appear on the TG 3.1 roster. One was badged.

University of California, Los Angeles. The TG 3.1 roster shows 23 civilians and 2 Air Force personnel participating in Program 4, Cloud Studies. Seventeen civilians were badged.

University of Illinois, Urbana, Illinois. One badged civilian was involved in the structures program.

University of Iowa, Iowa City, Iowa. One civilian represented this university in the Radsafe Unit. He was badged.

University of Rochester, New York. The thermal radiation injury project under the Biomedical Program involved nine personnel. The TG 3.1 roster shows six civilians, two Navy officers, and one Air Force officer assigned to TU 3.1.2. Of this group, five civilians, one Navy and the Air Force major were badged.

INCOMPLETELY IDENTIFIED

Berkeley, California. One badged civilian is listed under this heading. He participated in Project 4.5 and probably was affiliated with the University of California.

Bloomington, Indiana. One civilian was badged under this heading. He participated in Project 1.1. He was probably affiliated with the University of Indiana.

H&H Site. Two civilians were badged in TG 3.4 with this designation.

Medical Center, Los Angeles, California. One civilian from this organization is listed in the TG 3.1 roster. He was not badged.

CHAPTER 10

PERSONNEL EXPOSURES

Exposure to ionizing radiation during atmospheric nuclear testing was the sum of exposures resulting from activities that required personnel to undertake missions in radioactive areas or to deal with radioactive materials, and of exposures resulting from increased background radiation in normally nonradioactive areas that might be caused, for example, by fallout. All nuclear testing had some exposures of the first type, but GREENHOUSE also had fallout exposures. Three shots of the series deposited radioactive fallout over the base islands at Enewetak and six nearby ships, exposing personnel to radiation.

FALLOUT CONTRIBUTION TO EXPOSURES

The device normally used to record individual exposures, the film badge, was almost exclusively used for personnel involved in missions that had radiation exposure potential. Only a portion of the personnel in areas where exposure was not expected were badged. Radiation from the unexpected fallout, therefore, was unrecorded for the large majority of GREENHOUSE participants. Fallout radiation, however, was recorded by instruments used to monitor background radiation, on film badges staked outside of buildings on Parry Island, as well as by sample badges issued to selected personnel working in the areas affected by fallout.

These basic background measurements and sample badges were used by radsafe personnel at the time of GREENHOUSE to estimate the maximum possible exposures resulting from fallout. Estimates were made for personnel staying on the base islands -- Enewetak, Parry, and Japtan -- as well as the ships. An estimated maximum possible exposure for the week following shot DOG for Parry Island is shown in Figure 29. Chapter 3 also discusses methods used by Task Unit (TU) 3.1.5 to check its validity and applicability to other sites.

TU 3.1.5 continued monitoring the background and Figure 52 shows the result for Parry Island for the period of 8 April through 14 May, when residual radiation of the fallout from shots DOG and EASY had decayed so that it no longer measurably contributed to the personnel exposures. Figure 53 shows TU 3.1.5 estimates of the maximum possible exposure resulting from shot ITEM fallout from 25 May through the end of the month when significant rainfall effectively decontaminated the islands and ended the exposure buildup.

A 1981 analysis of the measurements (Reference 211) produced data for each island and matrix presentations of the estimated doses in rem for the whole test period (or any part of it), which are presented in Figures 54, 55, and 56 for Parry, Enewetak, and Japtan islands, respectively. The values in these three figures have been developed from the integrated intensity readings (Figures 29, 52, and 53) by adjusting for body shielding. This results in a dose that would have been recorded by a properly worn film badge. The factor used to make this adjustment is approximately 0.7. The recent analysis does confirm

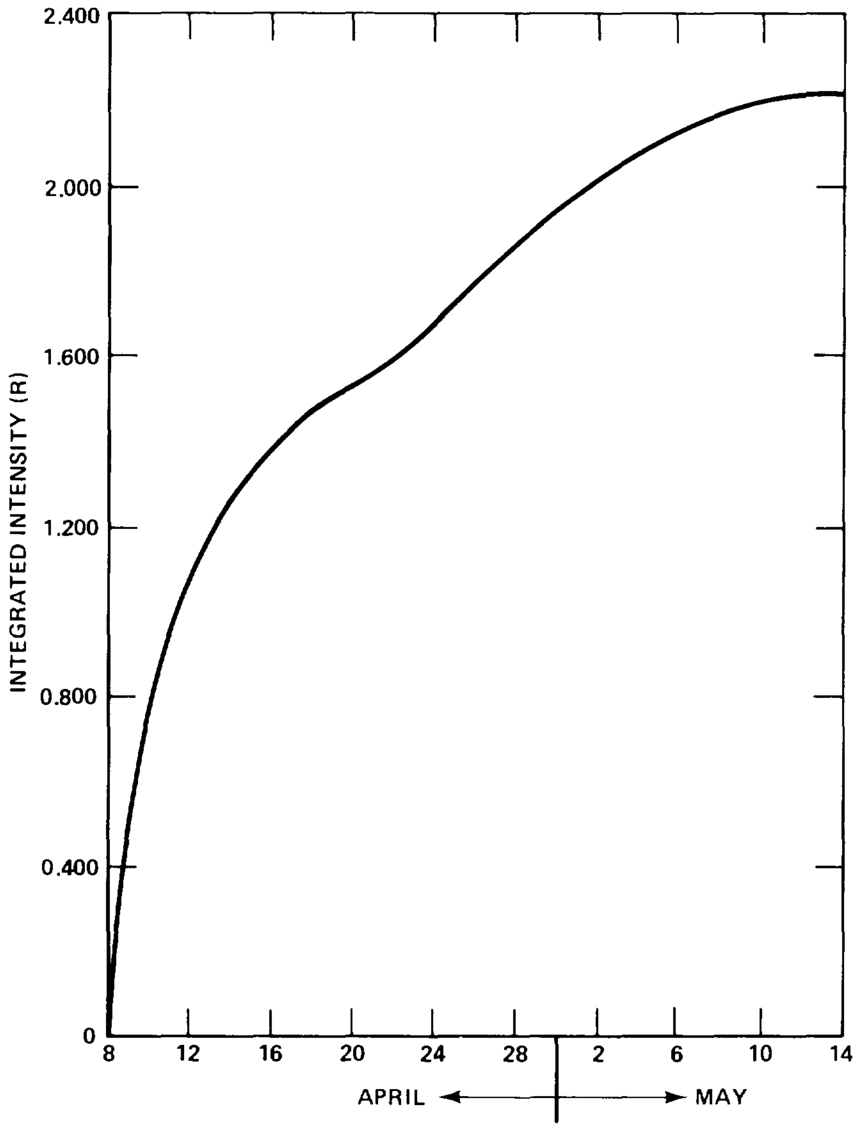

Figure 52. Cumulative gamma exposure -- Parry Island, maximum possible GREENHOUSE, DOG and EASY (source: Reference 38).

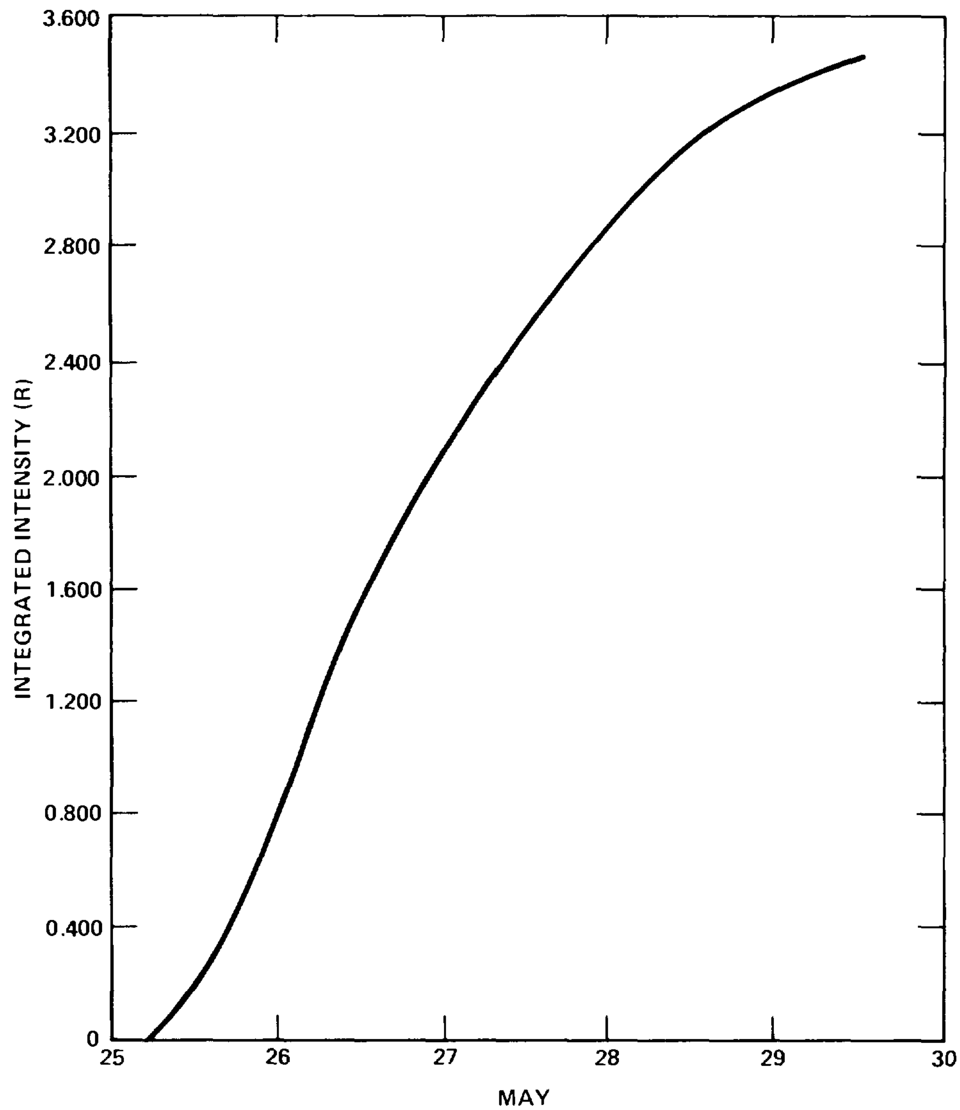

Figure 53. Cumulative gamma exposure -- Parry Island, maximum possible GREENHOUSE, ITEM (source: Reference 38).

Arrival date Parry Island	Apr 16	Apr 18	Apr 20	Apr 22	Apr 24	Apr 26	Apr 28	Apr 30	May 2	May 4	May 6	May 8	May 10	May 12	May 14	May 16	May 18	May 20	May 22	May 24	May 26	May 28	May 30	Jun 1
June 1																								0.08
May 30																							0.14	0.33
May 28																						0.53	0.93	1.12
May 26																					0.60	2.13	2.53	2.72
May 24																				0	0.60	2.13	2.53	2.72
May 22																			0	0	0.60	2.13	2.53	2.72
May 20																		0	0	0	0.60	2.13	2.53	2.72
May 18																	0	0	0	0	0.60	2.13	2.53	2.72
May 16																0	0	0	0	0	0.60	2.13	2.53	2.72
May 14															0	0.01	0.01	0.01	0.01	0.01	0.61	2.14	2.54	2.73
May 12														0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.62	2.15	2.55	2.74
May 10													0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.63	2.16	2.56	2.75
May 8												0.02	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.65	2.18	2.58	2.77
May 6											0.02	0.06	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.69	2.22	2.62	2.81
May 4										0.02	0.06	0.10	0.11	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.73	2.26	2.66	2.85
May 2									0.03	0.07	0.11	0.15	0.16	0.17	0.17	0.18	0.18	0.18	0.18	0.18	0.78	2.31	2.71	2.90
April 30								0.03	0.08	0.12	0.16	0.20	0.21	0.22	0.22	0.23	0.23	0.23	0.23	0.23	0.83	2.36	2.76	2.95
April 28							0.02	0.08	0.13	0.17	0.21	0.25	0.26	0.27	0.27	0.28	0.28	0.28	0.28	0.28	0.88	2.41	2.81	3.00
April 26						**0.02**	**0.08**	**0.14**	**0.19**	**0.23**	**0.27**	**0.31**	**0.32**	**0.34**	**0.33**	**0.33**	**0.34**	**0.34**	**0.34**	**0.34**	0.94	2.47	2.87	3.06
April 24					0.04	0.10	0.16	0.22	0.27	0.31	0.35	0.39	0.40	0.42	0.41	0.41	0.42	0.42	0.42	0.42	**1.02**	2.55	2.95	3.14
April 22				0.03	0.09	0.15	0.21	0.27	0.32	0.36	0.40	0.44	0.45	0.46	0.46	0.47	0.47	0.47	0.47	0.47	**1.07**	2.60	3.00	3.19
April 20			0.01	0.08	0.14	0.20	0.26	0.32	0.37	0.41	0.45	0.49	0.50	0.51	0.51	0.52	0.52	0.52	0.52	0.52	**1.12**	2.65	3.05	3.24
April 18		0.01	0.04	0.11	0.17	0.23	0.29	0.35	0.40	0.44	0.48	0.52	0.53	0.54	0.54	0.55	0.55	0.55	0.55	0.55	**1.15**	2.68	3.08	3.27
April 16	0.03	0.07	0.10	0.17	0.23	0.29	0.35	0.41	0.46	0.50	0.54	0.58	0.59	0.60	0.60	0.61	0.61	0.61	0.61	0.61	**1.21**	2.74	3.14	3.33
April 14	0.14	0.18	0.21	0.28	0.34	0.40	0.46	0.52	0.57	0.61	0.65	0.69	0.70	0.71	0.71	0.72	0.72	0.72	0.72	0.72	**1.32**	2.85	3.25	3.44
April 12	0.35	0.39	0.42	0.49	0.55	0.61	0.67	0.73	0.78	0.82	0.86	0.90	0.91	0.92	0.92	0.93	0.93	0.93	0.93	0.93	**1.53**	3.06	3.46	3.65
April 10	0.75	0.79	0.82	0.89	0.95	1.01	1.07	1.13	1.18	1.22	1.26	1.30	1.31	1.32	1.32	1.33	1.33	1.33	1.33	1.33	**1.93**	3.46	3.86	4.05
April 8	0.98	1.02	1.05	1.12	1.18	1.24	1.30	1.36	1.41	1.45	1.49	1.53	1.55	1.55	1.56	1.56	1.56	1.56	1.56	1.56	**2.16**	3.69	4.09	4.28

DEPARTURE DATE

Figure 54. Cumulative dose (rem) for personnel on Parry Island due to GREENHOUSE fallout (example: personnel arriving 26 April and departing 26 May receive dose of 0.94 rem).

ARRIVAL DATE ENEWETAK ISLAND

	APRIL								MAY														JUNE
	16	18	20	22	24	26	28	30	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	1
1																								0.11
30																							0.17	0.42
28																						0.66	1.17	1.42
26																					0.84	2.80	3.31	3.56
24																				0	0.84	2.80	3.31	3.56
22																			0	0	0.84	2.80	3.31	3.56
20																		0	0	0	0.84	2.80	3.31	3.56
18																	0	0	0	0	0.84	2.80	3.31	3.56
16																0	0	0	0	0	0.84	2.80	3.31	3.56
14															0	0	0	0	0	0	0.84	2.80	3.31	3.56
12														0	0	0	0	0	0	0	0.84	2.80	3.31	3.56
10													0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.85	2.81	3.32	3.57
8												0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.86	2.82	3.33	3.58
6											0.01	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.88	2.84	3.35	3.60
4										0.01	0.03	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.90	2.86	3.37	3.62
2									0.01	0.03	0.05	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.92	2.88	3.39	3.64
30								0.01	0.03	0.05	0.07	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.94	2.90	3.41	3.66
28							0.02	0.04	0.06	0.08	0.10	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.97	2.93	3.44	3.69
26						0.02	0.05	0.07	0.09	0.11	0.13	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	1.00	2.96	3.47	3.72
24					0.01	0.05	0.08	0.10	0.12	0.14	0.16	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	1.03	2.99	3.50	3.75
22				0.01	0.03	0.07	0.10	0.12	0.14	0.16	0.18	0.20	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	1.05	3.01	3.52	3.77
20			0.01	0.03	0.05	0.09	0.12	0.14	0.16	0.18	0.20	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	1.07	3.03	3.54	3.79
18		0.01	0.03	0.05	0.07	0.11	0.14	0.16	0.18	0.20	0.22	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	1.09	3.05	3.56	3.81
16	0.02	0.04	0.06	0.08	0.10	0.14	0.17	0.19	0.21	0.23	0.25	0.27	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	1.12	3.08	3.59	3.84
14	0.06	0.08	0.10	0.12	0.14	0.18	0.21	0.23	0.25	0.27	0.29	0.31	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	1.16	3.12	3.63	3.88
12	0.15	0.17	0.19	0.21	0.23	0.27	0.30	0.32	0.34	0.36	0.38	0.40	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	1.25	3.21	3.72	3.97
10	0.33	0.35	0.37	0.39	0.41	0.45	0.48	0.50	0.52	0.54	0.56	0.58	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.59	1.43	3.39	3.90	4.15
8	0.41	0.43	0.45	0.47	0.49	0.53	0.56	0.58	0.60	0.62	0.64	0.66	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	1.51	3.47	3.98	4.23

APRIL — MAY — JUNE

DEPARTURE DATE

Figure 55. Cumulative dose (rem) for personnel on Enewetak Island due to GREENHOUSE fallout (example: personnel arriving 28 April and departing 26 May receive dose of 0.97 rem).

Arrival date Japtan Island		16	18	20	22	24	26	28	30	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	1
Departure date →		APRIL								MAY															JUNE
JUNE	1																								0.08
MAY	30																							0.14	0.33
	28																						0.53	0.93	1.12
	26																					0.60	2.13	2.53	2.72
	24																				0	0.60	2.13	2.53	2.72
	22																			0	0	0.60	2.13	2.53	2.72
	20																		0	0	0	0.60	2.13	2.53	2.72
	18																	0	0	0	0	0.60	2.13	2.53	2.72
	16																0	0	0	0	0	0.60	2.13	2.53	2.72
	14															0	0	0	0	0	0	0.60	2.13	2.53	2.72
	12														0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.61	2.14	2.54	2.73
	10													0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.62	2.15	2.55	2.74
	8												0.02	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.65	2.18	2.58	2.77
	6											0.02	0.05	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.68	2.21	2.61	2.80
	4										0.02	0.06	0.09	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.72	2.25	2.65	2.84
	2									0.03	0.08	0.12	0.15	0.17	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.78	2.31	2.71	2.90
APRIL	30								0.03	0.08	0.13	0.17	0.20	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.83	2.36	2.76	2.95
	28							0.03	0.09	0.14	0.19	0.23	0.26	0.28	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.89	2.42	2.82	3.01
	26						0.03	0.10	0.16	0.21	0.26	0.30	0.33	0.35	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.96	2.49	2.89	3.08
	24					0.04	0.10	0.17	0.23	0.28	0.33	0.37	0.40	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43	1.03	2.56	2.96	3.15
	22				0.03	0.10	0.16	0.23	0.29	0.34	0.39	0.43	0.46	0.48	0.49	0.49	0.49	0.49	0.49	0.49	0.49	1.09	2.62	3.02	3.21
	20			0.02	0.08	0.15	0.21	0.28	0.34	0.39	0.44	0.48	0.51	0.53	0.54	0.54	0.54	0.54	0.54	0.54	0.54	1.14	2.67	3.07	3.26
	18		0.02	0.07	0.13	0.20	0.26	0.33	0.39	0.44	0.49	0.53	0.56	0.58	0.59	0.59	0.59	0.59	0.59	0.59	0.59	1.19	2.72	3.12	3.31
	16	0.03	0.08	0.13	0.19	0.26	0.32	0.39	0.45	0.50	0.55	0.59	0.62	0.64	0.65	0.65	0.65	0.65	0.65	0.65	0.65	1.25	2.78	3.18	3.37
	14	0.16	0.21	0.26	0.32	0.39	0.45	0.52	0.58	0.63	0.68	0.72	0.75	0.77	0.78	0.78	0.78	0.78	0.78	0.78	0.78	1.38	2.91	3.31	3.50
	12	0.39	0.44	0.49	0.55	0.62	0.68	0.75	0.81	0.86	0.91	0.95	0.98	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.61	3.14	3.54	3.73
	10	0.91	0.96	1.01	1.07	1.14	1.20	1.27	1.33	1.38	1.43	1.47	1.50	1.52	1.53	1.53	1.53	1.53	1.53	1.53	1.53	2.13	3.66	4.06	4.25
	8	1.14	1.19	1.24	1.30	1.37	1.43	1.50	1.56	1.61	1.66	1.70	1.73	1.75	1.76	1.76	1.76	1.76	1.76	1.76	1.76	2.36	3.89	4.29	4.48

DEPARTURE DATE

Figure 56. Cumulative dose (rem) for personnel on Japtan Island due to GREENHOUSE fallout (example: personnel arriving 28 April and departing 26 May receive dose of 0.89 rem).

that all personnel living on these three islands of Enewetak Atoll through the entire series probably exceeded the task force's maximum permissible exposure (MPE) due to the fallout alone. Any additional exposures on missions would add to this overexposure.

About 70 percent of the 2,952 Navy personnel at GREENHOUSE were badged. Among those badged were the boat pool personnel, who were expected to enter radioactive areas as they ferried scientific parties to the shot islands. Also badged were the air patrol squadron personnel who could have flown in the vicinity of the radioactive clouds, air transport personnel who flew radioactive samples to Hawaii and the United States, Navy laboratory personnel attached to TG 3.1, and a portion of crews aboard ships listed in Appendix A.

A search of Navy medical records indicates that 1,609 doses also were assigned immediately following the tests to nearly all personnel aboard USS Curtiss (AV-4), USS Sproston (DDE-577), USS Walker (DDE-517), USS Cabildo (LSD-16), the boat pool, and USS LST-859 for the period they were not badged. These doses accounted for fallout exposure. The documentation for these calculations has not been located. However, a 1981 scientific reconstruction of the probable fallout exposures for these ships is consistent with the assigned levels (Reference 211). Assignments for Cabildo and the boat pool appear to have considered individual assignment or work area and the number of days not badged since the same assignment was not made for all crewmembers of these units.

The fallout exposure of personnel aboard ships should, of course, be considerably lower than that for land-based personnel. Not only were ship structures more effective radiation shields than the light aluminum and canvas shelters on the islands, but decontamination of the ships during and after fallout moved radiating particles from the ships. Unless particles on the islands were covered, leached into the soil, or blown away, they continued to radiate until completely decayed.

The assigned fallout exposures contained in Navy medical records for personnel who were aboard ships for the entire test period are:

USS Curtiss (AV-4)	1.043 R
CTG 3.3 Staff (Curtiss)	1.043 R
USS Cabildo (LSD-16)	0.7 to 1.100 R
USS Sproston (DDE-577)	1.0 R
USS Walker (DDE-517)	0.433 R
USS LST-859	0.334 R
Boat Pool	0.700 - 2.100 R

MISSION CONTRIBUTION TO EXPOSURES

Although no explicit statement of policy has been located, it appears that the majority of film badges were issued to personnel to record their exposures while on the shot islands to recover data, test animals, and instrumentation; while decontaminating aircraft and removing radioactive cloud samples; were part of the boat pool; or flew aircraft during and after each shot. Since these personnel were not badged all the time, the exposures recorded by the badges should be considered as an increment to be added to the assessed fallout contribution.

The exposures as recorded by the badges alone (no fallout assessment) are listed in Table 27 and other portions of this report that discuss personnel exposures, including the summary table in the Fact Sheet of this report (p. 1 et seq.).

Table 27. GREENHOUSE personnel exposures by service.[a]

Element	No. of Persons Badged	Exposure Ranges (roentgens)										High (R)	Mean (R)
		0	0.0001-0.5	0.5-1	1-1.5	1.5-2	2-2.5	2.5-3	3-4	4-5	5-10		
U.S. Army	195	6	99	44	8	8	5	14	9	1	1	5.430	0.887
U.S. Navy	813	134	319	139	90	52	31	14	19	8	7[b]	8.080	0.800
U.S. Air Force	849	86	418	98	66	34	20	26	35	29	37	8.475	1.139
U.S. Marine Corps	8	3	1	2	0	0	0	0	2	0	0	3.805	1.094
Atomic Energy Commission organizations	232	76	75	25	14	10	7	5	7	5	8	7.710	0.864
Other government agencies	27	2	10	6	4	2	0	1	0	1	1	5.600	1.05
Contractors	292	32	101	108	18	9	5	7	5	2	5	8.575	0.823
Totals	2,416	339	1,023	422	200	116	67	67	77	46	59	8.575	0.944

Notes:

[a] Exposure values in this table were taken from personnel badges and do not include a fallout contribution.

[b] The three highest exposures include readings of 15 R, 15 R, and 20 R from film badges that were apparently left on a contaminated island and are not considered valid. The highest valid exposure was 8.080 R.

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Additional ordering information or assistance may be obtained by writing to the NTIS, Attention: Customer Service, or by calling (703) 487-4660.

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J.J. Knopow, J.H. Terry
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E.Tochilin, P. Howard
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Los Alamos Scientific Laboratory
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L.B. Werner, S.R. Sinnreich
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APPENDIX A

RADIOLOGICAL SAFETY RELATED DOCUMENTS

Annex D to Field Order No. 2 (Revised)

Appendix I to Annex D to Field Order No. 2 (Revised)
(Hazards Resulting from Atomic Bomb Explosions)

Annex G to Task Group Operation Plan No. 1-50
(Radiation Safety)

Operation Plan No. 1-51, Task Unit 3.1.5

Annex D to Task Unit 3.1.5 Operation Plan No. 1-51
(Laboratory Unit)

Annex E to Task Unit 3.1.5 Operation Plan No. 1-51
(Operations, DOG Shot)
(Operations, EASY Shot)

Annex F to Task Unit 3.1.5 Operation Plan No. 1-51
(Communications)

Commander Task Group 3.3 to Task Group 3.3
(Film Badges, Procurement, Distribution,
and Processing; Information Concerning)

Enclosure 1 to Commander Task Group 3.3 to Task Group 3.3
(Film Badge Data Sheet)

Task Group 3.3 Training Syllabus

Headquarters, Joint Task Force Three
Washington, 25, D.C.
1 December 1950

Annex D to Field Order No. 2 (Revised)

1. RADIOLOGICAL SAFETY of all military and civilian personnel is a command responsibility.

2. The SPECIAL ASSISTANT FOR RADIOLOGICAL SAFETY (also CTU 3.1.5) has the responsibility for advising the CJTF 3 on measures necessary to insure the radiological safety of all personnel. In the fulfillment of this responsibility he will supervise the issuance of appropriate instructions and information by the ASSISTANT CHIEF OF STAFF, J-3, JTF 3. These instructions and information will cover:

a. Collection and dissemination of information on radiological hazards which may cause injury or sickness to personnel.

b. Advice on the safe employment of personnel in radioactive areas.

c. Precautions necessary for protection of personnel against such hazards.

d. Reevaluation of the hazards of radioactive areas as radiological survey work progresses.

e. Advice to the TASK FORCE SURGEON in providing such necessary data as may be requested pertaining to the effects of ionizing radiation on personnel.

3. REGULATIONS: All personnel who will work in areas containing radioactivity and/or who will work with radioactive materials will be governed by the following regulations:

a. Prior to departure from the U.S., these persons will receive a complete physical examination, including chest X-ray, complete blood count (RBC, WBC, differential and hemoglobin) and urinalysis. Prior to departure from the U.S. authenticated copies of these physical reports will be reported to the following:

(1) One (1) copy to the appropriate task group commander (for use of TG Rad-Safe Officer).
(2) One (1) copy to CJTF 3.

b. Upon termination of services and prior to release from JTF 3, personnel will undergo further examinations if prescribed to Radiological Safety Officers.

c. The permissible radiological exposure is established at 0.7 roentgens per calendar week. Under unusual circumstances, the CTG 3.1 may recommend that CJTF 3 authorize an additional accumulated exposure up to three (3) roentgens in specific cases where required for a limited number of individuals.

d. Work in contaminated areas is divided into two general classifications, urgent work and routine work. All work on test islands on shot day must be authorized by CJTF 3 on request of CTG 3.1. Upon accomplishment of the special missions required by this work, further entry into contaminated areas will be discontinued until a comprehensive radiological survey has been made by TG 3.1 (TU 3.1.5).

e. Names of all individuals who are expected to enter radioactive areas will be submitted to CTG 3.1 in the form of an eligibility list two (2) weeks prior to the first test. Subsequent changes to the original list will be submitted as they occur.

f. Individuals or parties entering contaminated areas will in every instance check through the Radiological Safety Unit of TG 3.1 and will be accompanied by a monitor if considered necessary by this unit. In all instances in which monitors accompany persons entering contaminated areas the monitors will inform persons in charge of parties of the radiological hazards involved and when the predetermined permissible exposure has been reached, making due allowance for the exposure anticipated during withdrawal from the areas. Findings of the radiological monitor relative to radiological hazards <u>will be accepted</u>.

g. Prior to entering a contaminated area, the monitor will issue appropriate equipment. This equipment will consist of film badges, dosimeters and such protective clothing as may be required. Work parties on islands will wear gas masks if deemed necessary by the radiological monitor. Upon the completion of work in the contaminated zone, all persons will return film badges and dosimeters to the monitors and will dispose of booties and gloves upon leaving the area. The monitor will check clothing of all personnel and require those who are contaminated to report to the Radiological Safety Unit of TG 3.1 or to their Radiological Safety Officer as conditions warrant.

h. Persons eating, drinking, or smoking in any radioactive area will follow the usual sanitary precautions necessary to prevent ingestion of contaminated material.

i. Upon completion of work in radioactive areas, or with radioactive materials, all dosimeters and film badges will be forwarded to the laboratory of TG 3.1 where all processing and recording will be accomplished. A report of results will be sent appropriate commanders.

j. All islands in the Atoll will be considered contaminated after each test until reported clear by CJTF 3.

4. <u>OPERATIONS</u>: Radiological monitor units from TG 3.1 will be established at ENIWETOK, PARRY and JAPTAN Islands to monitor the handling of test materials. Monitoring of contaminated drone aircraft will be a responsibility of TU 3.1.5 until they are released to CTG 3.4. Monitors for aircraft operating near the radioactive cloud or over radioactive areas will be furnished by Task Group 3.4. The SPECIAL ASSISTANT FOR RADIOLOGICAL SAFETY will assist Task Group Radiological Officers in preparing special instructions for work of this nature.

5. <u>RADIOACTIVE MATERIALS</u>: Transportation of radioactive test materials (from the forward area) will be accordance with AEC regulations for escorted shipment of such material. Prior to transportation, all such materials shall be monitored by representatives of TG 3.1. Authority to remove samples of radioactive material from the forward areas which resulted from or were exposed

to detonation will be obtained from the CTG 3.1. Monitoring of radioactive test materials en route will be the responsibility of the escorting scientific personnel.

6. RADIOLOGICAL SAFETY RESPONSIBILITIES:

a. Radiological Safety functions will be performed through normal command channels. Each Task Group will provide spare parts for its own instruments. Facilities for storage of these spare parts will be available at Task Unit 3.1.5 (TG 3.1) on PARRY Island, if desired by the Task Groups.

b. CTG 3.1 will perform the following radiological safety services:

(1) Perform all ground monitoring services associated with experimental projects.

(2) Furnish laboratory services and technical advice for TG 3.1, TG 3.2, TG 3.3, and TG 3.4 associated with radiological safety to include:

(a) Procurement of film badges and other personnel protective devices

(b) Laboratory services to develop and interpret film badges.

(c) Records of exposures. Furnish duplicates to task groups.

(d) Calibration, repair and maintenance of instruments.

(e) Monitoring the removal and packaging of samples.

(3) Prepare surface RADEX plots.

(4) Procure protective clothing as necessary for TG 3.1 and for TG 3.2

(5) Be prepared to monitor the water supply on outlying inhabited islands.

(6) Procure and issue special goggles to all personnel of JTF 3 requiring same.

(7) Provide technical personnel to inspect radiologically contaminated items for all Task Groups and certify destruction, disposal or unserviceability of such items.

c. CTG 3.2 will be responsible for radiological safety of the base facilities on ENIWETOK Island, excluding activities relating to air operation. CTG 3.2 may call upon CTG 3.1 for radiological safety information and services as required.

d. CTG 3.3 will be responsible for the following radiological safety functions:

(1) Procuring the necessary radiological safety instruments and equipment.

(2) Procuring and issuing necessary protective clothing.

(3) Providing monitors and decontamination crews aboard each ship within the Task Group.

(4) Providing aircraft monitors for aircraft assigned to TG 3.3.

e. CTG 3.4 will be responsible for the following radiological safety functions:

(1) Procuring the necessary radiological safety instruments and equipment.

(2) Procuring and issuing necessary protective clothing.

(3) Providing radiological safety monitors for each manned aircraft actively participating in the test and for each aircraft collectting radiological information after detonation (for aircraft assigned to TG 3.4).

(4) Providing ground monitors to supervise decontamination of aircraft on the ground.

(5) Providing decontamination crews for handling and washing aircraft of TG 3.4 and assisting TG 3.3 if required.

(6) Plotting the Air RADEX and issuing instructions for aircraft operating in the vicinity.

f. Task Group Commanders will insure that all personnel are instructed in the radiological safety problems involved in conducting the test.

Headquarters, Joint Task Force Three
Washington, 25, D.C.
1 December 1950

Appendix I to Annex D to Field Order No. 2 (Revised)

HAZARDS RESULTING FROM ATOMIC BOMB EXPLOSIONS

1. NATURE OF HAZARDS

a. When an atomic bomb explosion occurs, a tremendous quantity of energy in a variety of forms is released. This energy is propagated outward in all directions.

b. When fission occurs, the immediate reaction is intense emission of ultra-violet visible and infrared (heat) radiation, gamma rays and neutrons. This is accompanied by the formation of a large ball of fire. The largest part of the energy from the explosion is emitted as a shock wave. The ball of fire produces a mushroom-shaped mass of hot gases, the top of which rises to about 10,000 feet in the first minute and about 30,000 feet in five minutes. In the trail below the mushroom cap, a thin column is left. The cloud and column are then carried downwind, the direction and speed being determined by the direction and speed of the wind at the various levels of air from the surface to 50,000 feet (or higher) altitude.

c. All personnel of the Task Force will be well outside of the range of all hazards at the time of detonation, except from the intense light from the fire ball.

d. Following the detonation, personnel entering shot areas will be exposed to beta particles and gamma rays coming from induced neutron activity in the soil and any fission products which might have been deposited on the ground. There may also be a potential alpha particle hazard from the unfissioned fissionable materials which may be deposited on the ground.

e. The light of explosion is so intense that temporary blindness may occur through facing the ball of fire, unless the eyes are protected by dark glasses.

f. The emission of dangerous nuclear radiation can be separated into two time periods. The primary radiation which occurs at the time of the flash is composed of gamma rays and neutrons. Casualties may result from this primary radiation if the exposure occurs within 2,000 yards of zero.

2. PROTECTION

a. Against the primary radiological effects, distance will provide protection.

b. Against the secondary radioactivity hazards from radioactive fission products, induced radioactivity and unfissioned residue, detection and avoidance provide the best protection. Suitable instruments indicate directly both the presence and intensity of radioactivity at a given place. Area reconnaissance, the maintenance of contamination situation maps, the posting of areas of hazard and minimizing the spread of contaminated material into uncontaminated areas constitute the active measures for reducing the radiological hazard.

c. Personnel within fifteen (15) nautical miles and who are to be facing in the direction of the flash will be required to wear special goggles to protect their eyes against excessive light. Personnel within fifteen (15) nautical miles who are not provided goggles will face in the opposite direction from the flash.

3. ANTICIPATED HAZARD AREAS

a. Immediately under the bomb burst there will be an area of intense radioactivity roughly 500 yards in radius.

b. Extending downwind, an airborne radioactive hazard will exist. Its characteristics will depend on the meteorological influences such as wind speed and direction at various altitudes up to the maximum height reached by the cloud.

c. Contaminated water in the lagoon adjacent to the shot island should be of no consequence, but will be checked by the Radiological Safety Unit of TG 3.1.

d. All individuals or objects leaving contaminated areas may transfer radioactivity to clean areas.

e. By means of instruments, such as Geiger-Mueller counters and ion chambers, it is possible to detect the area of contamination and to measure the intensity of the radioactivity. Radiation intensity will be measured and reported in roentgens per hour. Besides these instruments, dosimeters and film badges will be used as indicators of the accumulated exposure to radioactivity. Personnel will wear film badges to provide a permanent record of exposure.

f. The intensity of the radioactive hazard tends to decrease with time due to:

(1) Decay of radioactive materials

(2) Dispersion and dilution depending on climatic conditions.

As an approximation, the intensity of the radiation from the fission products decreases by radioactive decay inversely with the time after the detonation. An area which had 15 roentgens per hour at one (1) hour after detonation would have an intensity of 7.5 roentgens at two (2) hours after detonation and five (5) roentgens at three (3) hours.

Headquarters
Task Group 3.3
APO 187
30 Jauuary 1951

<u>Annex G to Task Group Operation Plan No. 1-50</u>

RADIOLOGICAL SAFETY

1. Responsibility for Radiological Safety is a command function. The Commanding General, Task Group 3.2, is responsible for Radiological Safety on Eniwetok Island less those activities involving Task Groups 3.1 and 3.4.

2. The Commanding General, Task Group 3.2, will appoint a qualified Radiological Safety Officer.

3. The responsibilities of the Radiological Safety Officer are:

a. Advising the Commanding General on:

(1) Presence and location of radiological hazards on Eniwetok Island. Such hazards will be conspicuously marked and placed "Off Limits" to all personnel not authorized to enter the area. The Radiological Safety Officer is charged with delineating such areas.

(2) Safe employment of personnel in radioactive areas.

(3) Precautions necessary for protection of personnel against radiological hazards.

b. Constant rechecking of known radioactive areas and submitting reports on their change of radioactivity to the Commanding General.

c. Advising the Task Group Surgeon of necessary data pertaining to the effects on ionizing radiation on personnel.

d. Receiving medical reports from the Task Group Surgeon on those personnel whose duties require them to work in a radioactive area.

(1) Supervising all Task Group 3.2 personnel entering a radioactive area and preventing those not physically qualified from entering such areas by notifying Unit Commanders of personnel disqualified by the Surgeon by Radsafe physical examinations.

e. Receiving and properly utilizing information and radiological safety equipment from the Special Assistant for Radiological Safety, Joint Task Force THREE.

f. Constant monitoring of radioactive areas in which personnel of Task Group 3.2 are working and rendering daily reports to the Surgeon, Task Group 3.2, on the total daily amount of radiation received by each such individual.

(1) Forwarding of individual dosimeters and film badges to the Radsafe Officer, Task Group 3.1.

4. The Commanding General, Task Group 3.2, will notify the Task Group Surgeon of the names of al personnel who are likely to be exposed to a radiological hazard.

5. Physical Qualifications:

a. The Surgeon of Task Group 3.2 will insure that all such individuals mentioned in par 3 are physically qualified for duty in a radioactive area. Such qualification will be determined by physical examination as prescribed in Joint Task Force THREE Letter AG 702 dated 31 March 1950. In addition he will perform necessary repeated physical examination on all personnel who have received in excess of 0.1 Roentgen of radiation in 24 hours. He will immediately notify the Radiological Safety Officer of those personnel who have been physically disqualified from reentry into a radioactive area.

b. Upon termination of duty with Joint Task Force THREE, all personnel of Task Group 3.2 who have been exposed to a radiological hazard will undergo a physical examination as prescribed by Joint Task Force THREE.

6. The Radsafe Officer will submit to Commander, Task Group 3.1, two weeks prior to their entry into a radiologically hazardous area, the names of all individuals assigned to Task Group 3.2 who are physically qualified to enter such areas.

Headquarters
Headquarters, Task Unit 3.1.5
Los Alamos, New Mexico
21 February 1951

Operation Plan No. 1-51

Task Unit 3.1.5

TASK ORGANIZATION

3.1.5 Radiological Safety Unit

A. Staff

Technical Deputy

Liaison Officer to Task Group 3.3 (Navy)

Liaison Officer to Task Group 3.4 (Air Force)

Operations Officer

Communications Officer

Supply Officer

B. Laboratory and Instrumentation Section

C. Monitoring Section

I. This plan is derived from Commander Joint Task Force THREE Field Order No. 2.

II. This Radiological Safety Unit will support Operation GREENHOUSE by effecting radiological safety of personnel of Task Group 3.1. In accomplishment of this mission, Commander Task Unit 3.1.5 will:

A. Organize and command a Radiological Safety Unit composed of radiological monitors, technical advisors, and supporting personnel.

B. Support operations in radioactive areas and for personnel working with radioactive materials by providing radiological monitors, equipment, services, and information.

C. Organize and maintain a radiological safety center at Parry Island.

D. Effect compliance with radiological safety regulations as indicated in ANNEX "D", Field Order No. 2, Joint Task Force THREE.

E. Maintain necessary records pertaining to personnel exposure.

F. Advise Task Force Surgeon, Joint Task Force THREE, regarding the nature of any injuries involving radiation which might occur.

III. Radiological monitors will be provided for authorized missions in radioactive areas and for personnel working with radioactive materials by the Operations Officer, Task Unit 3.1.5. All operations will be considered as routine, and will comply with permissible radiological exposures for routine work, except "special" operations which must be specifically designated by Commander, Joint Task Force THREE (see Annex "D").

IV. No radioactive material will be removed from the test site except as authorized in experimental programs. Unauthorized entry into and souvenir collecting in radioactive areas are prohibited.

Laboratory Unit

A. Mission

1. The laboratory unit, termed RadSafe Laboratory, is responsible for the procurement and maintenance of an adequate stock of radiological safety instruments, and for the repair, servicing, and calibration of the instruments to be used by Task Unit 3.1.5. All other groups of Joint Task Force THREE will procure radiological safety instruments and appropriate spare parts to be used in operations of those groups. The laboratory unit, TU 3.1.5, is responsible for the maintenance, repair, and servicing of all radiological safety instruments to be used by Joint Task Force THREE.

2. This unit is responsible for the processing of and measurements on photographic film badges for personnel monitoring of Joint Task Force THREE.

3. This unit will maintain adequate personnel exposure records of all personnel of Joint Task Force THREE.

B. Operations

1. Task Unit 3.1.5 will maintain a stock of ionization chambers, G-M counter survey instruments, personnel dosimeters, and pocket ionization chambers at the RadSafe Laboratory on Parry Island.

2. Survey instruments will be issued to the monitors, and these will be retained by the monitors throughout the operation as long as the instrument is in proper working order and it is of adequate range for the missions in which the monitor is engaged.

3. Photographic film badges and personnel dosimeters sufficient for the party will be issued to each monitor before each mission. All of those films and meters will be returned to the RadSafe Laboratory at the end of the mission.

4. Suitable sources of radiation for instrument calibration will be maintained by the RadSafe Laboratory. Each monitor will be responsible for the proper calibration of his survey instruments. The Laboratory will be responsible for the calibration of personnel dosimetry instruments and photographic film badges.

5. The RadSafe Laboratory will repair and check any survey instrument used by personnel of JTF-THREE returned because of improper operation.

6. The RadSafe Laboratory will process and read all photographic film badges and pocket chambers. Records of exposures will be maintained which will be available to proper authority.

7. The Laboratory will determine decay curves on crater material and other pertinent samples. Measurements of gamma, beta and alpha activity will be made on liquid and solid samples as required.

8. Vacuum-cleaner type air filters will be supplied as required. They will be supplied with filter papers and measurements will be made on the exposed papers by the RadSafe Laboratory.

Decontamination

I. All personnel working with radioactive materials will utilize protective clothing and/or gloves as indicated by ANNEX A. Safe handling of radioactive materials wil be insured by the proper utilization of additional protective equipment, such as tongs and remote handling devices.

II. Upon completion of each operation in a radioactive area, personnel will discard cloth booties and gloves at a designated location. Before returning to a non-contaminated area or living quarters, personnel will discard protective clothing at the appropriate radiological control point and submit to the prescribed decontamination procedure.

III. If clothing is contaminated, advice regarding the procedure of handling radioactively contaminated clothing will be given by the monitors. This clothing may require laundering, or as a result of decay, it may be possible to re-use it after a period of time without laundering.

Operations, DOG Shot

I. Composition of Operations Section

3 Officers

6 Enlisted Men

II. General Duties

A. Radiological Safety Center (RadSafe Center)

A Radiological Safety Center will be established on Parry Island which will serve as operations headquarters for all radiological safety activities. All radsafe data will be gathered at this headquarters, and information required by other groups will be distributed from this Center in the form of memoranda or situation maps.

This Center will provide information to Commander Task Unit 3.1.5 for planning radsafe operations, and will maintain current information on location of all monitors engaged in operation. It will maintain an operations table giving details on all missions into contaminated areas scheduled for each day, including name of monitors, destination, general type of mission (Program Number), and time of departure and arrival.

It will act as the receiving center for requests for radsafe services not previously anticipated.

B. Radsafe control points will be established as required.

C. After operational assignment, the radiological safety monitors will familiarize themselves with all pertinent phases of the experimental work.

III. Operation Plan, DOG Shot

A. Eniwetok - Drone Squadron

1. D-Day

Program	Number of Monitors	Remarks	Time of Operation
All	1 Senior Monitor		
1.7	4 + 1 Supervisor	Filter Recovery	H+2 to H+4
5 and 6	4 + 1 Supervisor (4 from Prog. 1.7)	Outside Gadgets Inside Gadgets	H+5 to H+8
5 and 6	2	Packing samples in 117 compound	H+6 to H+10

Total 13 Monitors

Task Unit 3.1.5 is responsible for the radiological safety of all personnel working in connection with removal of experimental material from drone aircraft until aircraft are released to Task Group 3.4.

Operations, Shot DOG

Upon arrival of all potentially contaminated aircraft on Eniwetok Island, a monitor will be supplied until such times as the aircraft have been parked. Monitors will accompany all recovery teams. They will be responsible for the monitoring of the packing, loading and for the release for shipment of all materials returning to the Z.I. Monitors will check out all recovery, packing, and loading personnel, after which time the drone planes will be released to Task Group 3.4.

All monitors with this assignment leave Parry Island 0900 D-1 and return to Parry Island on completion of their work, or approximately 1700 D Day. Upon arrival at Eniwetok they will report to the RadSafety Senior Monitor of Task Unit 3.1.5 and remain under his supervision until their return to Parry Island.

2. D+1 and following

There are no scheduled monitoring activities on Eniwetok Island by Task Unit 3.1.5 until next Shot Day unless indicated by Commander TU 3.1.5 as a result of situation analysis.

B. Runit Island

1. D-Day

Monitors will be assigned by Commander TU 3.1.5 when operations plans have been formulated by the various scientific groups.

2. D+1 Day

Thirty-five monitors proceed from Parry Island at 0700 by water taxi, arriving Runit Island at 0800. These monitors will make a radiological survey of Runit Island under the direction of the Senior Monitor present. Upon completion of monitoring activities, they will return to Parry Island with data obtained.

3. D+2 to D+15 Days

Monitors will be provided for all recovery party personnel as indicated by the radiological situation on Runit Island.

C. Non-Shot Island

1. D-Day

a. RadSafety Clearances Non-Shot Islands

One monitor in an L-5 aircraft and one monitor in a helicopter will proceed at H+1 hour to monitor Non-Shot Islands of the atoll to provide necessary Rad-Safety clearance for working parties.

b. Fall-out Distribution, Program 6.4

Monitoring for this activity will be provided by Task Group 3.1.

2. D+1 Day

   a. There will be no entry into radioactive areas of the Atoll until the completion of the radiological survey

   b. General Survey of non-shot islands will be continued by monitor in an L-5 aircraft.

3. D+2 to D+15 Days

   a. General survey of Atoll by monitor in L-5 aircraft will be continued as indicated.

   b. Programmatic activities on non-shot islands will be provided with monitors as indicated by the radiological situation.

   c. PBM aircraft will be dispatched to obtain water samples from various areas in Marshall Islands group as indicated by the radiological situation.

   d. Radiological Situation Plots

      (1) The RadSafe Center will maintain radiological situation data on all islands of the Atoll based upon monitor data and survey data obtained by specific monitoring missions. This information will be the basis of periodic situation reports or maps and briefing information for monitors entering radioactive areas.

      (2) The RadSafe Center will make surface radex plots.

Operations, EASY Shot

I. Composition of Operations Section

3 Officers

6 Enlisted Men

II. General Duties

A. Radiological Safety Center (RadSafe Center)

A Radiological Safety Center will be established on Parry Island which will serve as operations headquarters for all radiological safety activities. All radsafe data will be gathered at this headquarters, and information required by other groups will be distributed from this Center in the form of memoranda or situation maps.

This Center will provide information to Commander Task Unit 3.1.5 for planning radsafe operations, and will maintain current information on location of all monitors engaged in operation. It will maintain an operations table giving details on all missions into contaminated areas scheduled for each day, including name of monitors, destination, general type of mission (Program Number), and time of departure and arrival.

It will act as the receiving center for requests for radsafe services not previously anticipated.

B. Radsafe control points will be established as required.

C. After operational assignment, the radiological safety monitors will familiarize themselves with all pertinent phases of the experimental work.

III. Operation Plan, EASY Shot

A. Eniwetok - Drone Operation

1. D-Day

Program	Number of Monitors	Remarks	Time of Operation
All	1 Senior Monitor		
1.7	4 + 1 Supervisor	Filter Recovery	H+2 to H+4
2.54		Mouse Cages	H+3, H+6, H+10
5 and 6	4 + 1 Supervisor (4 from Prog. 1.7)	Outside Gadgets Inside Gadgets	H+5 to H+8
5 and 6	2	Packing samples in 117 compound	H+6 to H+10

Total 13 Monitors

Task Unit 3.1.5 is responsible for the radiological safety of all personnel working in connection with removal of experimental material from drone aircraft until aircraft are released to Task Group 3.4.

Operations, Shot EASY

Upon arrival of all potentially contaminated aircraft on Eniwetok Island, a monitor will be supplied until such times as the aircraft have been parked. Monitors will accompany all recovery teams. They will be responsible for the monitoring of the packing, loading and for the release for shipment of all materials returning to the Z.I. Monitors will check out all recovery, packing, and loading personnel after which time the drone planes will be rleased to Task Group 3.4.

2. D+1 and following.

There are no scheduled monitoring activities on Eniwetok Island by Task Unit 3.1.5 until next Shot Day unless indicated by Commander TU 3.1.5 as a result of situation analysis.

B. Engebi Island

1. D-Day

Program	Number of Monitors	Method of Travel	Time of Operation
All	1 Senior Monitor		
2	1 + 1 Supervisor	Helicopter	H + 30 min
2.4.1.2 2.4.1.3	(1 from Helicopter)	Speedboat	H+1 to H+2
1.5.1	(1 Senior Monitor) 4 + 1 Supervisor	Speedboat, Neutron Cable Speedboat, Neutron Camera	H+1 to H+4
6.3	4	Water Taxi	H+8+
1.8, 1.5.3	1	X-Ray party travel	H+8+
1.3, 1.1	1	NRL party travel	H+8+
1.6	1	Blast party travel	H+8+
3	5	M-Boat (6.10 & EGG)	H+8+
5.1	1	M-Boat	H+8+
8.2	1	M-Boat	H+8+

Total 27 Monitors

All Rad-Safety monitoring operations on Engebi will be under the control of the Rad-Safety Senior Monitor. All Program Two work will be under the supervision of a Rad-Safety Supervisor, who will coordinate with the Beachmaster who controls all Program Two operations on this island. The remaining operations will be under the control of the Senior Monitor, with the assistance of one supervisor.

a. Helicopter Mission

Helicopter will leave Parry Island at H+5 min., with the supervisor monitor for program Two and an additional monitor to accompany Program Two container inspector, loading on Engebi at H+30 min. The supervisor monitor will make a spot radiological survey check. The other monitor will accompany the Program Two container inspector and at the completion of this, will board the helicopter and survey Muzin, Kirinian, and Bokon Islands and return to Parry Island.

b. Speedboat Mission - Program Two

Monitor requirement satisfied by Supervisor monitor on Engebi who arrived by helicopter at H+30 min.

c. Neutron Cable and Camera Mission

Four monitors and one supervisor proceed to Parry Island to Engebi Island, H+5 min., by speedboat, arriving Engebi H+1 hr. They will monitor operation of recovery of neutron samples and neutron cameras. At the completion of the operation, monitors will report to the Senior Monitor on Engebi Island.

d. Program Two - T-Boat

Six monitors will be dispatched from Parry to Japtan, 0800 D-2, where they will report to the Director of Program Two. One monitor will remain on Japtan Island to monitor returning personnel and material of Program Two. Five monitors will accompany T-boat from Japtan to Engebi and report to supervisor monitor on Engebi Island at H+2. Upon completion of monitoring of recovery of Program Two material, they will report to the supervisor monitor.

Contingent upon reports received at the RadSafe Center on Parry Island from the Senior Monitor on Engebi Island, the following missions will be executed:

e. Program Two - M-Boats

These recovery parties to go to islands which have previously been cleared by monitor on Helicopter mission.

f. Tank Mission

Four monitors will proceed Parry Island by water taxi with Program 6.3 group at H+6. Upon completion of this mission they will report to the Senior Monitor on Engebi.

g. UCRL and NLRK Mission

One monitor will proceed from Parry Island at H+6, with personnel of Programs 1.8 and 1.5.3 recovery party. Upon completion of monitoring activity, monitor will report to the Senior monitor on Engebi Island.

h. NRL Mission

One monitor will proceed from Parry Island at H+6, with personnel of Programs 1.3 and 1.1 recovery party. Upon completion of monitoring activities, the monitor will report to the Senior Monitor on Engebi Island.

i. NOBL Mission

One monitor will proceed from Parry Island at H+6, with recovery personnel of Program 1.6. Upon completion of monitoring activities, the monitor will report to the Senior Monitor on Engebi Island.

j. Structures Program (Damage Survey and Recovery Teams)

Five monitors will proceed from Parry Island at H+6, with personnel of Program Three recovery and damage survey parties. Upon completion of monitoring activities, monitor will return to Parry Island. (Project 6.10 and EGG recovery parties may accompany this group.)

k. Dosimetry Recovery Mission

One monitor will proceed from Parry Island at H+6, with recovery personnel of Program 5.1. Upon completion of monitoring activities, monitor will report to the Senior Monitor in Engebi Island.

l. AMC Mission

One monitor will proceed from Parry Island at H+6, with personnel from Program 8.2. Upon completion of monitoring activities, monitor will report to the Senior Monitor on Engebi Island.

2. D+1 Day

Thirty-five monitors proceed from Parry Island at 0700 by water taxi, arriving Engebi Island at 0830. These monitors will make a radiological survey of Engebi Island under the direction of the Senior Monitor present. Upon completion of monitoring activities, they will return to Parry Island with data obtained.

3. D+2 to D+15 Days

Monitors will be provided for all recovery party personnel as indicated by the radiological situation on Enjebi Island.

C. Non-Shot Island

1. D-Day

a. Photographic Mission, Program 1.4

One monitor will accompany photographic recovery party of Program 1.4 to photographic installations on (Up-wind) [sic] and on Bogallua (down-wind). Upon completion of monitoring activities, return to Parry Island.

b. Static Panel Recovery, Program 8.2

One monitor will accompany static panel recovery party to Teiteiripucchi Island. Upon completion of monitoring activities, return to Parry Island.

c. Structures Program, Muzin Island

This island will have been cleared by Helicopter Monitor at H+2 hrs, and it is not felt that a monitor is required for this operation.

d. Fall-out Distribution, Program 6.4

Monitoring for this activity will be provided by Task Group 3.1.

e. Atoll Survey

One monitor leaves Parry Island at H+5 min. in an L-5 aircraft, landing at all Atoll islands which have airstrips, and making spot radiological survey checks. Upon completion, returns to Parry Island.

2. D+1 Day

a. There will be no entry into radioactive areas of the Atoll until the completion of the radiological survey.

b. General Survey of non-shot islands will be continued by monitor in an L-5 aircraft.

3. D+2 to D+15 Days

a. General survey of Atoll by monitor in L-5 aircraft will be continued as indicated.

b. Programatic activities on non-shot islands will be provided with monitors as indicated by the radiological situation.

c. PBM aircraft will be dispatched to obtain water samples from various areas in Marshall Islands group as indicated by the radiological situation.

d. Radiological Situation Plots

(1) The RadSafe Center will maintain radiological situation data on all islands of the Atoll based upon monitor data and survey data obtained by specific monitoring missions. This information will be the basis of periodic situation reports or maps and briefing information for monitors entering radioactive areas.

(2) The RadSafe Center will make surface radex plots.

Communications

Telephone and radio communications will be provided by Commander, Task Group 3.1. Details are covered in Annex "B" of CTG 3.1 OPERATION ORDER 1-51 and APPENDIX IV-8 thereto.

Commander Task Group 3.3
Fleet Post Office
San Francisco, California
22 March 1951

From: Commander Task Group 3.3

To: Task Group 3.3

Subj: Film badges, procurement, distribution, and processing; information concerning

Encl: (1) Film Badge Data Sheet

1. Commander Task Unit 3.1.5 has been requested to furnish film badges to the units of Task Group 3.3 for each shot during OPERATION GREENHOUSE in the following quantities:

USS CURTIS (AV-4)	20
USS WALKER (DDE-517)	10
USS SPROSTON (DDE-577)	10
USS CABILDO (LSD-16)	10
Boat Pool (aboard USS CABILDO -- to include 5 film badges for each of 3 LSUs)	215
USS LST-859	5
USNS SGT C.E. MOWER (T-AP-186)	10
Task Unit 3.3.3 (VP-931)	150
Total film badge requirements for each shot	430

2. Commander Task Unit 3.1.5 has been further requested to forward the prescribed number of film badges to Task Unit 3.3.3 (VP-931) so that these are received by them on or before D-minus-two days for each shot of the operation. All members of the crews of the aircraft which will be airborne from D-Day to D-plus-seven days will wear film badges.

3. The Radiological Safety Officer of the USS CABILDO (LSD-16) will procure and distribute the film badges for the USS CABILDO (LSD-16) and the Boat Pool. All members of the boat crews who will be operating on D-Day to D-plus-seven days will wear film badges, if practicable.

4. Radiological Safety Officers of all units of Task Group 3.3, except Task Unit 3.3.3, will procure the necessary number of film badges from Commander Task Unit 3.1.5 on Parry Island on D-minus-two days, prior to each shot. These film badges are to be worn by selected personnel in order to obtain a recording of exposure to radiation in various parts of the ship at the time of, and subsequent to, the detonations. These film badges are to be worn by these individuals continuously from just prior to H-Hour until D-plus-seven days after each shot, unless the exposure to radiation exceeds the maximum permissible exposure, as indicated by the pocket dosimeters. In the event that the maximum permissible exposure is exceeded, these badges are to be returned to Commander Task Unit 3.1.5 on Parry Island for

processing and reporting and new film badges will be issued at that time. After each shot on D-plus-seven days all film badges will be returned by each Radiological safety Officer to Commander Task Unit 3.1.5 on Parry Island for processing and reporting with the Film Badge Data Sheet (enclosure [1]) completely filled in.

5. The Film Badge Data Sheet (enclosure [1]) will be made out in triplicate for each film badge used, the original being forwarded to Commander Task Unit 3.1.5 with the film badge, one copy to Commander Task Group 3.3, and one copy retained in your files.

6. Transmission by United States registered mail or registered guard mail is authorized in accordance with Article 7-5, United States Navy Security Manual for Classified matter.

FILM BADGE DATA SHEET

COMMANDER TASK GROUP 3.3

NAME OF PERSON WEARING BADGE ______________________________

(Last) (First) (Middle)

FILE/SERVICE NO. __________ RANK/RATE ________ BRANCH OF SERVICE ________

FILM BADGE NO. ______________

DATES FILM BADGE WORN OR EXPOSED: FROM __________ TO ______________ 1951

SHIP OR STATION ______________________________

LOCATION ON SHIP OR STATION (DUTY STATION) ______________________

____

ACCUMULATED DOSAGE AS INDICATED BY DOSIMETER READINGS DURING EXPOSURE PERIOD:

______________ ROENTGENS

ADDITIONAL REMARKS ______________________________

____

____

____

(RADIOLOGICAL SAFETY OFFICER)

U.S.S. ______________________

NOTE: Film badges will be worn by designated personnel from D-Day (prior to H-Hour) until D-plus-seven days, for each shot. In the event that exposures, as recorded on the pocket dosimeters, are exceeding the maximum permissible exposure, film badges will be turned in to CTU 3.1.5 on Parry Island for development and interpretation and new badges will be issued at that time by CTU 3.1.5 for the remainder of the D-plus-seven period.

This form is to be filled out in triplicate. Forward the original with the film badge to CTU 3.1.5, one copy to CTG 3.3, and retain one copy on file.

TASK GROUP 3.3 TRAINING SYLLABUS

I. General Indoctrination

A. Background and nature of hazards

1. Historical

a. Early developments

b. Hiroshima, Nagasaki, SANDSTONE, RANGER

2. The Nuclear Bomb

a. Introduction

b. Fission and chain reaction

c. Explosion phenomena

(1) Instantaneous radiation

(a) Blast -- position and negative phases

(b) Thermal or non-ionizing radiation -- infrared, ultraviolet, visible light

(c) Penetrating or non-ionizing radiation -- gamma and neutrons

(2) Residual radiation

(a) Fission products

(b) Unfissioned bomb material -- alpha emitters

II. Detection and measurement of nuclear radiation

A. Introduction

1. General classes

a. Rate meters

b. Accumulative devices

2. Operating principles

a. Ionization

3. The Roentgen Unit

a. Definition

b. Maximum permissible exposure

4. Specific Instrument Types

a. Rate meters

(1) AN/PDR-5 Geiger counter -- beta gamma

(2) AN/PDR-8B Geiger counter -- beta gamma

(3) IM-3/PD Ion chamber -- gamma

(4) IM-4/PD Ion chamber -- alpha

(5) AN/PDR-T1B Ion chamber -- gamma

b. Accumulative devices

(1) Film badges

(2) Pocket dosimeters and chargers

III. Monitoring

A. Reasons for monitoring

B. Shipboard monitoring

1. Three phases

a. Setting up a radsafe organization

(1) Organization

(a) Radsafe bill

2. Communication

3. Radsafe Drill (based on USF 85)

4. Radiac instrument storage

5. Protective clothing

a. Preparation prior to detonation

(1) Condition Able

(2) Water film over all topside areas (if directed)

b. Post-detonation procedures

C. Safe working time

1. Introduction (a monograph dealing with safe working time in a contaminated area was distributed to all TG 3.3 units)

2. Formulas

IV. Decontamination

A. Introduction

B. Personnel decontamination

1. Personnel returning from contamination areas

2. Personnel requirements for decontamination center

3. Supervision

C. Material decontamination

1. Procedures for decontaminating ships and aircraft found in USF 85 and USF 82

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).

AC&W. 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.

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.

AN/PDR-39. An ion-chamber-type survey meter; this was the standard radsafe meter. Others in use included the Navy version, the AN/PDR-T1B, the AN/PDR-18A and -18B, and lower range Geiger-Mueller instruments (AN/PDR-27, Beckman MX-5, and Nuclear Corporation 2610).

AO. Oiler (Navy).

AOC. Air Operations Center.

AOG. Gasoline tanker (Navy).

AP. Transport ship (Navy).

APG. Aberdeen Proving Ground, Maryland.

APO. Army Post Office.

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).

ATF. Fleet ocean tug (Navy).

atoll. A ring of coral reefs, usually with small islets, that surrounds a lagoon. Most are isolated reefs rising from the deep sea that have built up on submerged volcanoes. They vary considerably in size; the largest atoll, Kwajalein in the Marshall Islands, has an irregular shape that extends for 84 miles (135 km). See also coral reef.

atomic bomb (or weapon). A term sometimes applied to a nuclear weapon utilizing fission energy only. See also fission, nuclear device.

atomic explosion. See nuclear explosion.

attenuation. The process by which radiation is reduced in intensity when passing through some material. It is due to absorption or scattering or both, but it excludes the decrease of intensity with distance from the source (inverse square law, which see).

AU. Army Unit.

AV. Seaplane tender (Navy).

AVR. Aircraft rescue vessel (Navy).

AW. Distilling ship (Navy).

B-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.

B-47. A 6-jet-engine bomber with sweptback wings and a double-wheel bicycle landing gear, developed by Boeing. Used as the subject of effects experiments.

B-50. A 4-engine bomber developed by Boeing, with some features like those of the B-29, but having a taller tail fin and larger engines and nacelles.

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 airburst, high-altitude burst, surface burst.

BuShips. Bureau of Ships (Navy).

C-47. A twin-engine transport aircraft manufactured by Douglas Aircraft Company (Air Force version of the DC-3).

C-54. A 4-engine military cargo and personnel transport manufactured by Douglas Aircraft Company (Air Force version of the DC-4).

cab. The shelter that covers a nuclear device being prepared for test. May be located on a tower, on the Earth's surface, or on a barge.

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 3. Commander, Joint Task Force 3.

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 Force Pacific (Navy).

ComServPac. Commander Service Forces Pacific (Navy).

Condition "Purple". See Purple conditions.

contamination. The deposit of radioactive material on the surfaces of structures, areas, objects, and personnel following a nuclear detonation. This material generally consists of fallout in which fission products and other device debris have become incorporated with particles of dust, vaporized components of device platforms, etc. Contamination can also arise from the radioactivity induced in certain substances by the action of neutrons from a nuclear explosion. See also decontamination, fallout, weapon debris.

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. Carrier 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).

DM. Minelayer destroyer (Navy). Converted destroyers designed to conduct high-speed minelaying 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 radionuclides.

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 and technical film coverage.

electromagnetic radiation. Electromagnetic radiations range from X-rays and gamma rays of short wavelength (high frequency), through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength.

electron. A particle of very small mass and electrically charged. As usually defined, the electron's charge is negative. The term negatron is also used for the negative electron and the positively charged form is called a positron. See also beta particles.

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.

F-80. Single-place jet fighter developed by Lockheed Aircraft in the last years of World War II. A radio-controlled drone version was used in nuclear testing.

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-cm^2 area.

fluorescence. The emission of light (electromagnetic radiation) by a material as a result of the absorption of energy from radiation. The term may refer to the radiation emitted, as well as to the emission process.

forward area. The 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 AN/PDR-39 and ion-chamber-type survey meter.

GMT. Greenwich Mean Time.

gray (Gy). A recently introduced ICRP term; 1 Gy equals 100 rad.

ground zero (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-5. Helicopter developed by Sikorsky Aircraft Division of United Aircraft Corporation.

H-hour. Time zero, or time of detonation. When used in connection with planning operations it is the specific 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 relatively more radioactive than some adjacent area.

IBDA. Indirect Bomb Damage Assessment. A revised target analysis based on new data such as actual weapon yield, burst height, and ground zero obtained by means other than direct assessment.

ICRP. International Commission on Radiological Protection.

initial radiation. Electromagnetic radiations of high energy emitted from both the fireball and the radioactive cloud within the first minute after a detonation. It includes neutrons and gamma rays given off almost instantaneously (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 3. Joint Task Force 3 was a combined force of personnel of the Department of Defense (Air Force, Army, Marine Corps, Navy), the AEC, and their contractors. JTF 3 was responsible for all aspects of nuclear weapon tests in the Pacific during 1951.

kiloton convention. Relates nuclear explosion energy to TNT explosion energy by using the approximate energy releast 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.

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.

MATS. Military Air Transport Service; later, Military Airlift Command.

megaton (energy). Approximately the amount of energy that would be released by the explosion of one million tons of TNT.

microcurie. One-millionth of a curie.

micron. One-millionth of a meter (i.e., 10^{-6} meter or 10^{-4} centimeter); it is roughly four one-hundred-thousandths (4×10^{-5}) of an inch.

milliroentgen. One-thousandth of a roentgen.

MPL. Maximum Permissible Limit. That amount of radioactive material in air, water, foodstuffs, etc. that is established by authorities as the maximum that would not create undue risk to human health.

mR; mr. Abbreviation for milliroentgen.

MSTS. Military Sea Transportation Service, (Navy).

mushroom cap. Top of the cloud formed from the fireball of a nuclear detonation.

MV. Motor vessel.

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.

P2V. Twin-engine patrol bomber used for maritime patrol and antisubmarine warfare. Developed by Lockheed for the U.S. Navy. Used in nuclear tests as controller and transient ship search.

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.

pig. A heavily shielded container (usually lead) used to ship or store radioactive materials.

POL. Petroleum, oil, and lubricants. The storage area for these products is referred to as a POL farm.

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.

QT-33. Radio-controlled version of the F-80.

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 x 10^{-4} coulomb in 1 kilogram of dry air under standard conditions. An exposure of 1 roentgen results in the deposition of about 94 ergs of energy in 1 gram of soft body tissue. Hence, an exposure of 1 roentgen is approximately equivalent to an absorbed dose of 1 rad in soft tissue.

roll-up. The process for orderly dismantling of facilities no longer required for nuclear test operations and their transfer to other areas.

SA-16. Air Force general purpose amphibian for air-sea rescue work. Manufactured by Grumman Aircraft Engineering Corporation, New York.

SAC. Strategic Air Command (Air Force).

sampler aircraft. Aircraft used for collection of gaseous and particulate samples from nuclear clouds to determine the level of radioactivity or the presence of radioactive substances.

SAR. Search and rescue operations.

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 AN/PDR-36, Geiger-Mueller counter, and ion-chamber-type survey meter.

survey, radiation. Evaluation of the radiation levels associated with radioactive materials or areas.

T-33. Two-place trainer version of the F-80.

T-AP. Personnel transport (Military Sea Transportion Service).

TDY. Temporary duty assignment.

TG. Task Group. Subordinate element of the Joint 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 artifical, resulting from high-altitude nuclear detonations.

tropopause. The boundary dividing the stratosphere from the lower part of the atmosphere, the troposphere. The tropopause normally occurs at an altitude of about 25,000 to 45,000 feet (7.6 to 13.7 km) in polar and temperate zones, and at 55,000 feet (16.8 km) in the tropics. See also stratosphere, troposphere.

troposphere. The region of the atmosphere, immediately above the Earth's surface and up to the tropopause, in which the temperature falls fairly regularly with increasing altitude, clouds form, convection is active, and mixing is continuous and more or less complete.

Trust Territory. The Marshall Islands were included in the Trust Territory of the Pacific Islands under the jurisdiction of the United Nations. Assigned by the United Nations to the United States in trust for administration, development, and training.

TU. Task Unit.

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.

UF-1. The Navy designation for the SA-16A.

UK. United Kingdom.

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 exposure. Thus, the entire body need not be exposed to be classed as a whole-body exposure.

Wilson cloud. A mist or fog of minute water droplets that temporarily surrounds a fireball following a nuclear detonation in a humid atmosphere. This is caused by a sudden lowering of the pressure (and temperature) after the passing of the shock wave (cloud chamber effect) and quickly dissipates as temperatures and pressures return to normal.

worldwide fallout. Consists of the smaller radioactive nuclear detonation particles that ascend into the upper troposphere and the stratosphere and are carried by winds to all parts of the Earth. The delayed (or worldwide) fallout is brought to Earth, mainly by rain and snow, over extended periods ranging from months to years.

WT. Prefix of Weapon Test (WT) report identification numbers. These reports were prepared to record the results of scientific experiments.

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.

YO. Fuel oil barge; self-propelled (Navy).

YOG. Gasoline barge; self-propelled (Navy).

YOGN. Gasoline barge; nonself-propelled (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 - Alembel - Arambiru
Aej	OLIVE - Aitsu
Aitsu	OLIVE - Aej
Alembel	VERA - Aaraanbiru - Arambiru
ALICE	Bokoluo - Bogallua
ALVIN	Jinedrol - Chinieero
Ananij	BRUCE - Aniyaanii
Anerowij	TOM - Munjor - Munjur
Aniyaanii	BRUCE - Ananij
Aomon	SALLY
Arambiru	VERA - Alembel - Aaraanbiru
BELLE	Bokombako - Bogombogo
Biijiri	TILDA - Bijire - Bijile - Bikile
Bijile	TILDA - Bijire - Biijiri - Bikile
Bijire	TILDA - Bijile - Biijiri - Bikile
Biken	LEROY - Rigile - Rigili
Bikile	TILDA - Bijire - Bijile - Biijiri
Billae	WILMA - Piiraai - Piirai
Billee	LUCY - Kidrinen - Kirinian
Bogairikk	HELEN - Bokaidrikdrik - Bogeirik - Bokaidrik
Bogallua	ALICE - Bokoluo
Bogan	IRWIN - Boken - Pokon
Bogeirik	HELEN - Bokaidrikdrik - Bogairikk - Bokaidrik
Bogen	REX - Jedrol - Jieroru
Bogombogo	BELLE - Bokombako
Bogon	IRENE - Boken
Bokaidrik	HELEN - Bokaidrikdrik - Bogairikk - Bogeirik
Bokaidrikdrik	HELEN - Bogairikk - Bogeirik - Bokaidrik
Bokandretok	WALT
Boken	IRENE - Bogon
Boken	IRWIN - Pokon - Bogan
Bokenelab	MARY - Bokonaarappu - Bokonarppu
Bokinwotme	EDNA - Sanildefonso
Boko	SAM
Bokoluo	ALICE - Bogallua
Bokombako	BELLE - Bogombogo
Bokonaarappu	MARY - Bokenelab - Bokonarppu
Bokonarppu	MARY - Bokenelab - Bokonaarappu
BRUCE	Ananij - Aniyaanii
Buganegan	HENRY - Mut - Mui

Chinieero	ALVIN - Jinedrol
Chinimi	CLYDE - Jinimi
CLARA	Kirunu - Eybbiyae - Ruchi
CLYDE	Jinimi - Chinimi
Cochita	DAISY - Louj - Lidilbut
DAISY	Louj - Cochita - Lidilbut
DAVID	Japtan - Muti
Drekatimon	OSCAR
Dridrilbwij	GENE - Teiteiripucchi
Eberiru	RUBY - Eleleron
EDNA	Bokinwotme - Sanildefonso
Eleleron	RUBY - Eberiru
Elle	NANCY - Yeiri
ELMER	Parry - Medren
Elugelab	FLORA - Eluklab
Eluklab	FLORA - Elugelab
Enewetak	FRED - Eniwetok
Engebi	JANET - Enjebi
Eniwetok	FRED - Enewetak
Enjebi	JANET - Engebi
Eybbiyae	CLARA - Kirunu - Ruchi
FLORA	Eluklab - Elugelab
FRED	Enewetak - Eniwetok
GENE	Dridrilbwij - Teiteiripucchi
Giriinien	KEITH - Kidrenen - Grinem
GLENN	Ikuren - Igurin
Grinem	KEITH - Kidrenen - Giriinien
HELEN	Bokaidrikdrik - Bogairikk - Bogeirik - Bokaidrik
HENRY	Mut - Buganegan - Mui
Igurin	GLENN - Ikuren
Ikuren	GLENN - Igurin
Inedral	URIAH
IRENE	Boken - Bogon
IRWIN	Boken - Bogan - Pokon
JAMES	Ribewon - Libiron - Ribaion
JANET	Enjebi - Engebi
Japtan	DAVID - Muti
Jedrol	REX - Jieroru - Bogen
Jieroru	REX - Jedrol - Bogen
Jinedrol	ALVIN - Chinieero
Jinimi	CLYDE - Chinimi
KATE	Mijikadrek - Mujinkarikku - Muzinbaarikku
KEITH	Kidrenen - Giriinien - Grinem
Kidrenen	KEITH - Giriinien - Grinem

Kidrinen	LUCY - Billee - Kirinian
Kirinian	LUCY - Kidrinen - Billee
Kirunu	CLARA - Eybbiyae - Ruchi
LEROY	Biken - Rigile - Rigili
Libiron	JAMES - Ribewon - Ribaion
Lidilbut	DAISY - Louj - Cochita
Lojwa	URSULA - Rojoa
Louj	DAISY - Cochita - Lidilbut
LUCY	Kidrinen - Billee - Kirinian
Lujor	PEARL - Rujiyoru - Rujoru
MACK	Unibor
MARY	Bokenelab - Bokonaarappu - Bokonarppu
Medren	ELMER - Parry
Mijikadrek	KATE - Mujinkarikku - Muzinbaarikku
Mui	HENRY - Mut - Buganegan
Mujinkarikku	KATE - Mijikadrek - Muzinbaarikku
Munjor	TOM - Anerowij - Munjur
Munjur	TOM - Munjor - Anerowij
Mut	HENRY - Buganegan - Mui
Muti	DAVID - Japtan
Muzinbaarikku	KATE - Mijikadrek - Mujinkarikku
NANCY	Elle - Yeiri
OLIVE	Aej - Aitsu
OSCAR	Drekatimon
Parry	ELMER - Medren
PEARL	Lujor - Rujiyoru - Rujoru
PERCY	Taiwel
Piiraai	WILMA - Billae - Piirai
Piirai	WILMA - Billae - Piiraai
Pokon	IRWIN - Boken - Bogan
REX	Jedrol - Bogen - Jieroru
Ribaion	JAMES - Ribewon - Libiron
Ribewon	JAMES - Libiron - Ribaion
Rigile	LEROY - Biken - Rigili
Rigili	LEROY - Biken - Rigile
Rojoa	URSULA - Lojwa
RUBY	Eleleron - Eberiru
Ruchi	CLARA - Kirunu - Eybbiyae
Rujiyoru	PEARL - Lujor - Rojoru
Rujoru	PEARL - Lujor - Rujiyoru
Runit	YVONNE
SALLY	Aomon
SAM	Boko
Sanildefonso	EDNA - Bokinwotme

Taiwel	PERCY
Teiteiripucchi	GENE - Dridrilbwij
TILDA	Bijire - Bijile - Biijiri - Bikile
TOM	Munjor - Anerowij - Munjur
Unibor	MACK
URIAH	Inedral
URSULA	Lojwa - Rojoa
VAN	Enewetak Atoll
VERA	Alembel - Aaraanbiru - Arambiru
WALT	Bokandretok
WILMA	Billae - Piirai - Piiraai
Yeiri	NANCY - Elle
YVONNE	Runit

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Kaman Tempo
ATTN: R. Miller

Kaman Tempo
ATTN: DASIAC
10 cy ATTN: C. Jones

National Academy of Sciences
ATTN: C. Robinette
ATTN: Medical Follow-up Agency
ATTN: National Materials Advisory Board

Pacific-Sierra Research Corp
ATTN: H. Brode, Chairman SAGE

R & D Associates
ATTN: P. Haas

Science Applications, Inc
ATTN: Tech Library

Science Applications, Inc
10 cy ATTN: L. Novotney

OTHER

Adams State College
ATTN: Govt Publication Lib

Akron Public Library
ATTN: Govt Publication Librarian

Alabama St Dept of Archives & History
ATTN: Military Records Division

University of Alabama
ATTN: Reference Dept/Documents

University of Alaska
ATTN: Director of Libraries

University of Alaska
ATTN: Govt Publication Librarian

OTHER (Continued)

Albany Public Library
ATTN: Librarian

Alexander City State Jr College
ATTN: Librarian

Allegheny College
ATTN: Librarian

Allen County Public Library
ATTN: Librarian

Altoona Area Public Library
ATTN: Librarian

American Statistics Index
ATTN: Cathy Jarvey

Anaheim Public Library
ATTN: Librarian

Andrews Library, College of Wooster
ATTN: Government Documents

Angelo State University Library
ATTN: Librarian

Angelo Iacoboni Pub Lib
ATTN: Librarian

Anoka County Library
ATTN: Librarian

Appalachian State University
ATTN: Library Documents

Arizona State University Library
ATTN: Librarian

University of Arizona
ATTN: Gov Doc Dept, C. Bower

Arkansas College Library
ATTN: Library

Arkansas Library Comm
ATTN: Library

Arkansas State University
ATTN: Library

University of Arkansas
ATTN: Government Documents Div

Austin College
Arthur Hopkins Library
ATTN: Librarian

Atlanta Public Library
ATTN: Ivan Allen Dept

Atlanta University Center
ATTN: Librarian

OTHER (Continued)

Auburn Univ at Montgomery Lib
ATTN: Librarian

B. Davis Schwartz Mem Lib
ATTN: Librarian

Bangor Public Library
ATTN: Librarian

Bates College Library
ATTN: Librarian

Baylor University Library
ATTN: Docs Dept

Beloit College Libraries
ATTN: Serials Docs Dept

Bemidji State College
ATTN: Library

Benjamin F. Feinberg Library
State University College
ATTN: Government Documents

Bierce Library, Akron University
ATTN: Government Documents

Boston Public Library
ATTN: Documents Department

Bowdoin College
ATTN: Librarian

Bowling Green State Univ
ATTN: Govt Docs Services

Bradley University
ATTN: Govt Publication Librarian

Brandeis University Lib
ATTN: Documents Section

Brigham Young University
ATTN: Librarian

Brigham Young University
ATTN: Documents Collection

Brookhaven National Laboratory
ATTN: Technical Library

Brooklyn College
ATTN: Documents Division

Broward County Library Sys
ATTN: Librarian

Brown University
ATTN: Librarian

Bucknell University
ATTN: Reference Dept

OTHER (Continued)

Buffalo & Erie Co Pub Lib
ATTN: Librarian

Burlington Library
ATTN: Librarian

California at Fresno State Univ Lib
ATTN: Library

California at San Diego University
ATTN: Documents Department

California at Stanislavs St Clg Lib
ATTN: Library

California St Polytechnic Univ Lib
ATTN: Librarian

California St Univ at Northridge
ATTN: [illegible]

California State Library
ATTN: Librarian

California State Univ at Long Beach Lib
ATTN: Librarian

California State University
ATTN: Librarian

California State University
ATTN: Librarian

California Univ Library
ATTN: Govt Publications Dept

California Univ Library
ATTN: Librarian

California University Library
ATTN: Govt Documents Dept

California University Library
ATTN: Documents Sec

California University
ATTN: Government Documents Dept

Calvin College Library
ATTN: Librarian

Calvin T. Ryan Library
Kearney State College
ATTN: Govt Documents Dept

Carleton College Library
ATTN: Librarian

Carnegie Library of Pittsburgh
ATTN: Librarian

Carnegie Mellon University
ATTN: Director of Libraries

OTHER (Continued)

Carson Regional Library
ATTN: Gov Publications Unit

Case Western Reserve University
ATTN: Librarian

University of Central Florida
ATTN: Library Docs Dept

Central Michigan University
ATTN: Library Documents Section

Central Missouri State Univ
ATTN: Government Documents

Central State University
ATTN: Library Documents Dept

Central Washington University
ATTN: Library Docs Section

Central Wyoming College Library
ATTN: Librarian

Charleston County Library
ATTN: Librarian

Charlotte & Mechlenburg County Pub Lib
ATTN: E. Correll

Chattanooga Hamilton Co
ATTN: Librarian

Chesapeake Pub Lib System
ATTN: Librarian

Chicago Public Library
ATTN: Governments Publications Dept

State University of Chicago
ATTN: Librarian

Chicago University Library
ATTN: Director of Libraries
ATTN: Documents Processing

Cincinnati University Library
ATTN: Librarian

Claremont Colleges Libs
ATTN: Doc Collection

Clemson University
ATTN: Director of Libraries

Cleveland Public Library
ATTN: Documents Collection

Cleveland State Univ Lib
ATTN: Librarian

Coe Library
ATTN: Documents Division

OTHER (Continued)

Colgate Univ Library
ATTN: Reference Library

Colorado State Univ Libs
ATTN: Librarian

Colorado University Libraries
ATTN: Director of Libraries

Columbia University Library
ATTN: Documents Service Center

Columbus & Franklin Cty Public Lib
ATTN: Gen Rec Div

Compton Library
ATTN: Librarian

Connecticut State Library
ATTN: Librarian

University of Connecticut
ATTN: Govt of Connecticut

Connecticut University
ATTN: Director of Libraries

Cornell University Lib
ATTN: Librarian

Corpus Christi State University Lib
ATTN: Librarian

CSIA Library
ATTN: Librarian

Culver City Library
ATTN: Librarian

Curry College Library
ATTN: Librarian

Dallas County Public Library
ATTN: Librarian

Dallas Public Library
ATTN: Librarian

Dalton Jr College Library
ATTN: Librarian

Dartmouth College
ATTN: Librarian

Davenport Public Library
ATTN: Librarian

Davidson College
ATTN: Librarian

Dayton & Montgomery City Pub Lib
ATTN: Librarian

University of Dayton
ATTN: Librarian

OTHER (Continued

Decatur Public Library
ATTN: Librarian

Dekalb Comm Coll So Cpus
ATTN: Librarian

Delaware Pauw University
ATTN: Librarian

University of Delaware
ATTN: Librarian

Delta College Library
ATTN: Librarian

Delta State University
ATTN: Librarian

Denison Univ Library
ATTN: Librarian

Denver Public Library
ATTN: Documents Div

Dept of Lib & Archives
ATTN: Librarian

Detroit Public Library
ATTN: Librarian

Dickinson State College
ATTN: Librarian

Drake Memorial Learning Resource Ctr
ATTN: Librarian

Drake University
ATTN: Cowles Library

Drew University
ATTN: Librarian

Duke University
ATTN: Public Docs Dept

Duluth Public Library
ATTN: Documents Section

Earlham College
ATTN: Librarian

East Carolina University
ATTN: Library Docs Dept

East Central University
ATTN: Librarian

East Islip Public Library
ATTN: Librarian

East Orange Public Lib
ATTN: Librarian

East Tennessee State Univ Sherrod Lib
ATTN: Documents Dept

OTHER (Continued)

East Texas State University
ATTN: Library

Eastern Branch
ATTN: Librarian

Eastern Illinois University
ATTN: Librarian

Eastern Kentucky University
ATTN: Librarian

Eastern Michigan University Lib
ATTN: Documents Libn

Eastern Montana College Library
ATTN: Documents Dept

Eastern New Mexico Univ
ATTN: Librarian

Eastern Oregon College Library
ATTN: Librarian

Eastern Washington Univ
ATTN: Librarian

El Paso Public Library
ATTN: Documents & Geneology Dept

Elko County Library
ATTN: Librarian

Elmira College
ATTN: Librarian

Elon College Library
ATTN: Librarian

Enoch Pratt Free Library
ATTN: Documents Office

Emory University
ATTN: Librarian

Evansville & Vanderburgh County Pub Lib
ATTN: Librarian

Everett Public Library
ATTN: Librarian

Fairleigh Dickinson Univ
ATTN: Depository Dept

Florida A & M Univ
ATTN: Librarian

Florida Atlantic Univ Lib
ATTN: Div of Public Documents

Florida Institute of Tech Lib
ATTN: Federal Documents Dept

Florida Intl Univ Library
ATTN: Docs Section

OTHER (Continued)

Florida State Library
ATTN: Documents Section

Florida State University
ATTN: Librarian

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 Delgado 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 Coll
ATTN: Librarian

Johnson Free Public Lib
ATTN: Librarian

Kahului Library
ATTN: Librarian

Kalamazoo Public Library
ATTN: Librarian

Kansas City Public Library
ATTN: Documents Div

Kansas State Library
ATTN: Librarian

Kansas State Univ Library
ATTN: Documents Dept

University of Kansas
ATTN: Director of Libraries

Kent State University Library
ATTN: Documents Div

Kentucky Dept of Library & Archives
ATTN: Documents Section

University of Kentucky
ATTN: Governments Publication Dept
ATTN: Director of Libraries

Kenyon College Library
ATTN: Librarian

Lake Forest College
ATTN: Librarian

Lake Sumter Comm Coll Lib
ATTN: Librarian

Lakeland Public Library
ATTN: Librarian

OTHER (Continued)

Lancaster Regional Library
ATTN: Librarian

Lawrence University
ATTN: Documents Dept

Lee Library, Brigham Young University
ATTN: Documents & Map Section

Library & Statutory Distribution & Svc
2 cy ATTN: Librarian

Little Rock Public Library
ATTN: Librarian

Long Beach Publ Library
ATTN: Librarian

Los Angeles Public Library
ATTN: Serials Div U.S. Documents

Louisiana State University
ATTN: Government Doc Dept
ATTN: Director of Libraries

Louisville Free Pub Lib
ATTN: Librarian

Louisville Univ Library
ATTN: Librarian

Lyndon B. Johnson Sch of Pub Affairs Lib
ATTN: Librarian

Maine Maritime Academy
ATTN: Librarian

Maine University at Oreno
ATTN: Librarian

University of Maine
ATTN: Librarian

Manchester City Library
ATTN: Librarian

Mankato State College
ATTN: Govt Publications

Mantor Library
Univ of Maine at Farmington
ATTN: Director of Libraries

Marathon County Public Library
ATTN: Librarian

Marshall Brooks Library
ATTN: Librarian

University of Maryland
ATTN: McKeldin Libr Docs Div

University of Maryland
ATTN: Librarian

OTHER (Continued)

University of Massachusetts
ATTN: Government Docs College

McNeese State Univ
ATTN: Librarian

Memphis Shelby County Pub Lib & Info Ctr
ATTN: Librarian

Memphis State University
ATTN: Librarian

Mercer University
ATTN: Librarian

Mesa County Public Library
ATTN: Librarian

University of Miami, Library
ATTN: Government Publications

Miami Public Library
ATTN: Documents Division

Miami Univ Library
ATTN: Documents Dept

Michel Orradre Library
University of Santa Clara
ATTN: Documents Div

Michigan State Library
ATTN: Librarian

Michigan State University Library
ATTN: Librarian

Michigan Tech University
ATTN: Library Documents Dept

University of Michigan
ATTN: Acq Sec Documents Unit

Middlebury College Library
ATTN: Librarian

Millersville State Coll
ATTN: Librarian

Milne Library
State University of New York
ATTN: Docs Librn

Milwaukee Pub Lib
ATTN: Librarian

Minneapolis Public Lib
ATTN: Librarian

Minnesota Div of Emergency Svcs
ATTN: Librarian

Minot State College
ATTN: Librarian

Mississippi State University
ATTN: Librarian

OTHER (Continued)

University of Mississippi
ATTN: Director of Libraries

Missouri Univ at Kansas City Gen
ATTN: Librarian

Missouri University Library
ATTN: Government Documents

M.I.T. Libraries
ATTN: Librarian

Mobile Public Library
ATTN: Governmental Info Division

Moffett Library
ATTN: Librarian

Montana State Library
ATTN: Librarian

Montana State University, Library
ATTN: Librarian

University of Montana
ATTN: Documents Div

Moorhead State College
ATTN: Library

Mt Prospect Public Lib
ATTN: Librarian

Murray State Univ Lib
ATTN: Library

Nassau Library System
ATTN: Librarian

Natrona County Public Library
ATTN: Librarian

Nebraska Library Comm
ATTN: Librarian

Univ of Nebraska at Omaha
ATTN: Librarian

Nebraska Western College Library
ATTN: Librarian

Univ of Nebraska at Lincoln
ATTN: Director of Libraries

Univ of Nevada at Reno
ATTN: Governments Pub Dept

Univ of Nevada at Las Vegas
ATTN: Director of Libraries

New Hampshire University Lib
ATTN: Librarian

New Hanover County Public Library
ATTN: Librarian

Nebraska Univ Lib
ATTN: Acquisitions Dept

OTHER (Continued)

New Mexico State Library
ATTN: Librarian

New Mexico State University [illegible]
ATTN: Lib Documents [illegible]

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 Con, 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

Oklahoma University Library
ATTN: Government 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: Library

Phoenix Public Library
ATTN: Librarian

University of Pittsburg
ATTN: Documents Office G 8

Plainfield Public Library
ATTN: Librarian

Popular Creek Public Lib District
ATTN: Librarian

Association of Portland Lib
ATTN: Librarian

Portland Public Library
ATTN: Librarian

Portland State University Library
ATTN: Librarian

Prescott Memorial Lib
Louisiana Tech Univ
ATTN: Librarian

Princeton University Library
ATTN: Documents Division

Providence College
ATTN: Librarian

Providence Public Library
ATTN: Librarian

Cincinnati & Hamilton County Public Library
ATTN: Librarian

Public Library of Nashville and Davidson County
ATTN: Library

University of Puerto Rico
ATTN: Doc & Maps Room

Purdue University Library
ATTN: Librarian

OTHER (Continued)

Quinebaug Valley Community Col
ATTN: Librarian

Ralph Brown Draughon Lib
Auburn University
ATTN: Microforms & Documents Dept

Rapid City Public Library
ATTN: Librarian

Reading Public Library
ATTN: Librarian

Reed College Library
ATTN: Librarian

Reese Library
Augusta College
ATTN: Librarian

University of Rhode Island Library
ATTN: Govt Publications Office

University of Rhode Island
ATTN: Director of Libraries

Rice University
ATTN: Director of Libraries

Richard W. Norton Mem Lib
Louisiana College
ATTN: Librarian

Richland County Pub Lib
ATTN: Librarian

University of Richmond
ATTN: Library

Riverside Public Library
ATTN: Librarian

University of Rochester Library
ATTN: Documents Section

Rutgers University, Camden Library
ATTN: Librarian

Rutgers State University
ATTN: Librarian

Rutgers University
ATTN: Government Doc Dep

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 Library of Ohio
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

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

Tennessee Technological University
ATTN: Librarian

OTHER (Continued)

Uniformed Svcs Univ of the Hlth Sci
ATTN: LRC Library

University Libraries
ATTN: Dir of Libraries

Upper Iowa College
ATTN: Documents Collection

Utah State University
ATTN: Librarian

University of Utah
ATTN: Special Collections

University of Utah
ATTN: Dept of Pharmacology
ATTN: Director of Libraries

Valencia Library
ATTN: Librarian

Vanderbilt University Library
ATTN: Govt Docs Sect

University of Vermont
ATTN: Director of Libraries

Virginia Commonwealth University
ATTN: Librarian

Virginia Military Institute
ATTN: Librarian

Virginia Polytechnic Inst Lib
ATTN: Docs Dept

Virginia State Library
ATTN: Serials Section

University of Virginia
ATTN: Public Documents

Volusia County Public Libraries
ATTN: Librarian

Washington State Library
ATTN: Documents Section

Washington State University
ATTN: Lib Documents Section

Washington University Libraries
ATTN: Dir of Libraries

University of Washington
ATTN: Documents Div

Wayne State University Library
ATTN: Librarian

Wayne State University Law Library
ATTN: Documents Dept

Weber State College Library
ATTN: Librarian

Wagner College
ATTN: Librarian

OTHER (Continued)

Wesleyan University
ATTN: Documents Librarian

West Chester State Coll
ATTN: Documents Dept

West Covina Library
ATTN: Librarian

University of West Florida
ATTN: Librarian

West Hills Community Coll
ATTN: Library

West Texas State University
ATTN: Library

West Virginia Coll of Grad Studies Lib
ATTN: Librarian

University of West Virginia
ATTN: Dir of Libraries

Westerly Public Library
ATTN: Librarian

Western Carolina University
ATTN: Librarian

Western Illinois University Lib
ATTN: Librarian

Western Washington Univ
ATTN: Librarian

Western Wyoming Community College Lib
ATTN: Librarian

Westmoreland Cty Comm Coll
ATTN: Learning Resource Ctr

Whitman College
ATTN: Librarian

Wichita State Univ Library
ATTN: Librarian

William & Mary College
ATTN: Docs Dept

William Allen White Library
Emporia Kansas State College
ATTN: Govt Documents Div

William College Library
ATTN: Librarian

Willimantic Public Library
ATTN: Librarian

Winthrop College
ATTN: Documents Dept

University of Wisconsin at Whitewater
ATTN: Governments Documents Library

OTHER (Continued)

Wisconsin Milwaukee University
ATTN: Librarian

Wisconsin Oshkosh University
ATTN: Librarian

Wisconsin Platteville University
ATTN: Librarian

Wisconsin University at Stevens Point
ATTN: Docs Section

University of Wisconsin
ATTN: Govt Pubs Dept

University of Wisconsin
ATTN: Acquisitions Dept

Worcester Public Library
ATTN: Librarian

OTHER (Continued)

Yale University
ATTN: Director of Libraries

Yeshiva University
ATTN: Librarian

Yuma City County Library
ATTN: Librarian

Wright State Univ Library
ATTN: Govt Documents Dept

Wyoming State Library
ATTN: Librarian

University of Wyoming
ATTN: Documents Div