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EXTRACTED VERSION

OPERATION HARDTACK

Report to the Scientific Director
Report of the Commander, Task Group 7.1

Joint Task Force Seven
Task Group 7.1

1 August 1958

NOTICE:
This is an extract of WT-1682, Operation HARDTACK.

Extracted version prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, DC 20305-1000

1 September 1985

Report to the Scientific Director

REPORT OF THE COMMANDER TASK GROUP 7.1

Joint Task Force Seven
Task Group 7.1
August 1958

ACKNOWLEDGMENTS

This report, like Operation Hardtack, was the work of many people. It was compiled by the Task Group staff under the direction of Duncan Curry, Jr., Deputy for Administration, Task Group 7.1, from the data provided by Programs, Projects, Task Units, and Staff Sections and produced by the technical reports office of the Task Group.

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HARDTACK FIRING SCHEDULE

Shot	Location	Date Fired[1]	Time Fired[2]	Delay, days: Weather	Technical	Change in Design	Other	Remarks
Yucca	N12°17', E163°21' (approx.)	4/28	1440:00.256±2N	0	0	0	0	Free balloon, 90,000 ft (from USS Boxer)
Cactus	Runit (E), surface	5/6	0615:00.142±1W	5	2	0	0	
Fir	Namu (B) crater, barge	5/12	0550:00.148W	19	2	0	0	
Butternut	Runit (E), barge	5/12	0615:00.113±1N	3	0	0	0	
Koa	Teiteiripucchi (E), tank	5/13	0630:00.145±1W	1	1	0	0	
Wahoo	8500 ft SW of Pokon (E)	5/16	1330:00.5±1W	0	1	0	0	500 ft deep in 3200 ft of water
Holly	Runit (E), barge	5/21	0630:00.145±1J	2	0	0	0	
Nutmeg	Eninman (B) Zuni crater, barge	5/22	0920:00.151±1W	1	0	0	0	
Yellowwood	Engebi (E), barge	5/26	1400:00.1345J	3	0	0	0	
Magnolia	Runit (E), barge	5/27	0600:00.1096J	2	0	0	0	
Tobacco	Engebi (E), barge	5/30	1415:00.1507J	0	0	0	0	
Sycamore	Namu (B) crater, barge	5/31	1500:00.1457±1W	8	0	0	5	
Rose	Runit (E), barge	6/3	0645:00.1123J	0	0	0	0	
Umbrella	10,000 ft NE of Mui (E)	6/9	1115:00.244±1J	0	0	0	0	On lagoon bottom, 150 ft deep
Maple	Romurikku (B) 1200 ft offshore, barge	6/11	0530:00.1417W	2	0	0	0	
Aspen[3]	Namu (B) crater, barge	6/15	0530:00.1361W	0	0	11	0	
Walnut[3]	Engebi (E), barge	6/15	0630:00.1401J	2	0	7	0	
Linden[4]	Runit (E), barge	6/18	1500:00.116J	0	0	0	3	
Redwood	Romurikku (B), barge	6/28	0530:00.1373W	8	0	0	0	
Elder	Engebi (E), barge	6/28	0630:00.130±20W	8	0	0	1	Delayed 1 day by radiation level
Oak	4 mi SW of Bogallua (E), LCU hull	6/29	0730:00.1467J	0	0	0	0	
Hickory	Eninman (B) Zuni crater, barge	6/29	1200:00.1455J	1	1	0	0	
Sequoia[4]	Runit (E), LCU hull	7/2	0630:00.1320J	0	0	0	0	
Cedar	Namu (B), barge	7/3	0530:00.1369W	7	1	0	1	Shot barge contaminated by Redwood
Dogwood[4]	Engebi (E), LCU hull	7/6	0630:00.2445J	0	0	0	0	
Poplar[3]	Namu (B), crater, barge	7/12	1530:00.141J	3	0	32	0	
Scaevola[4]	Runit (E), barge	7/14	1600:00.130J	0	0	0	0	
Pisonia[4]	12,000 ft off Runit (E), LCU hull	7/18	1100:00.123W	0	0	0	0	
Juniper	Eninman (B), Zuni crater, barge	7/22	1600:00.139W	3	1	0	0	
Olive[4]	Engebi (E), LCU hull	7/23	0830:00.224J	0	0	0	0	
Pine[4]	Engebi (E), LCU hull	7/26	0830:00.232W	0	0	0	0	
Teak	16°30'N, 170°60'W (approx.) (J)	7/31	2350:05.597	0	0	0	100	Redstone, 250,000 ft
Quince[4]	Runit (E), surface	8/6	1415:00.180±25	0	1	7	0	
Orange	16°23'N, 169°32'W (approx.) (J)	8/11	2330:08.607	1	0	0	100	Redstone, 141,000 ft
Fig[4]	Runit (E), surface	8/18	1600	3½	0	0	0	

[1]Date at shot site.
[2]Time at shot site. W, time from WWVH; J, time from JJY Japan uncorrected for transit time; N, corrected time by NBS. Time errors are in milliseconds.
[3]Device returned to U.S. for design modification.
[4]Shot added after beginning of operational period.

HARDTACK DEVICES AND YIELDS

Shot	Device	Sponsor	Expected Yield	Actual Yield[1]
Yucca		DOD		
Cactus		LASL	13 to 14 kt	17.5 ± 1.5 kt
Fir		UCRL		
Butternut		LASL		
Koa		LASL	1.75 Mt	1.30 ± 0.08 Mt
Wahoo		DOD		
Holly		LASL		
Nutmeg		UCRL		
Yellowwoo		LASL		
Magnolia		LASL		
Tobacco		LASL		
Sycamore		UCRL		
Rose		LASL		
Umbrella		DOD		
Maple		UCRL		
Aspen		UCRL		
Walnut		LASL		
Linden		LASL		
Redwood		UCRL		
Elder		LASL		
Oak		LASL	7.5 Mt	8.9 ± 0.6 Mt
Hickory		UCRL		
Sequoia		LASL		
Cedar		UCRL		
Dogwood		UCRL		
Poplar		UCRL		
Scaevola		LASL		
Pisonia		LASL		
Juniper		UCRL		
Olive		UCRL		
Pine		UCRL		
Teak		DOD		
Quince		UCRL		
Orange		DOD		
Fig		UCRL		

[1]Corrected to Februarv 1959.

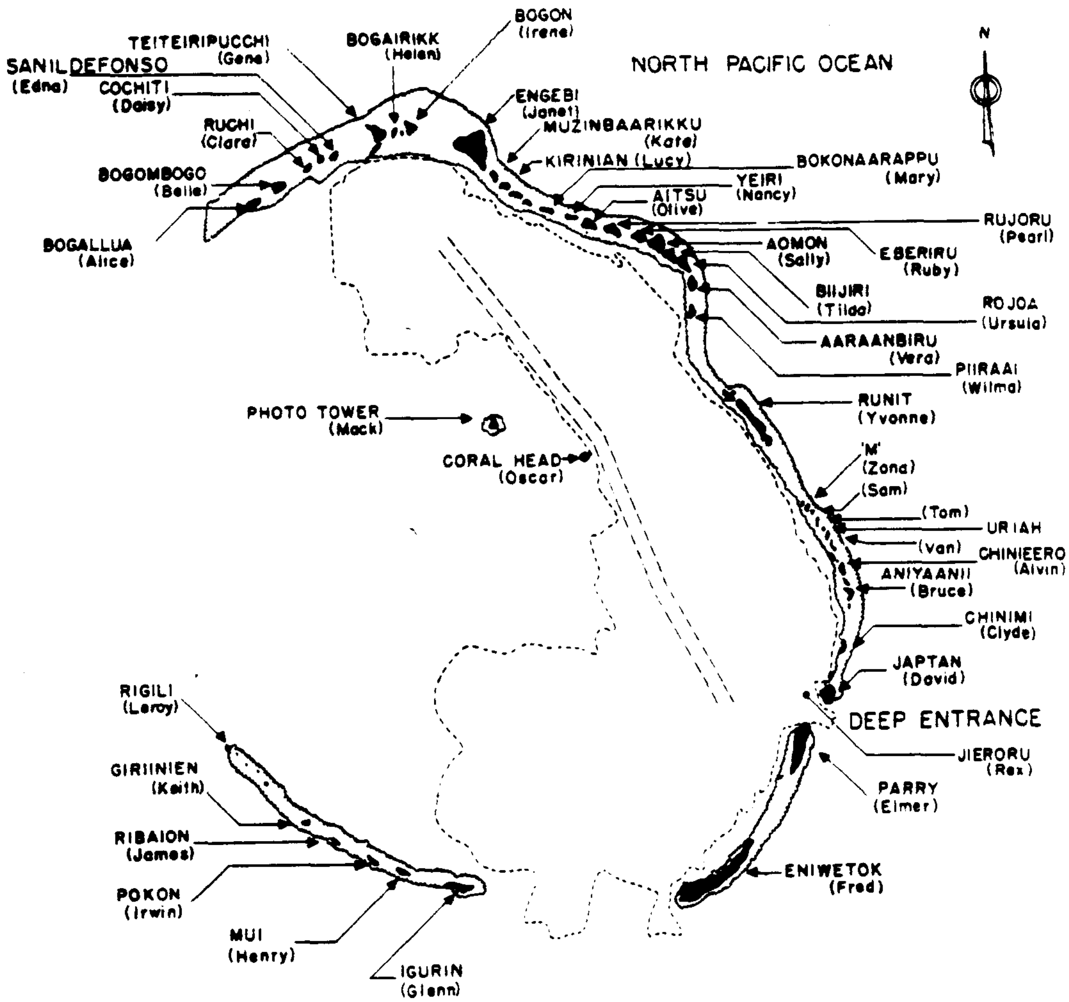
HARDTACK PROJECT PARTICIPATION SCHEDULE

Prog. and Proj. No.		Sponsor and Agency
1	BLAST AND SHOCK MEASUREMENTS	AFSWP
1.1	Underwater Pressure Measurements	NOL
1.2	Air Blast Measurements	NOL
1.3	Surface Phenomena Measurements	NOL
1.4	Land Crater Measurements	ERDL
1.5	Free Field Pressure Measurements	NEL
1.6	Water Wave Measurements	SIO
1.7	Air Blast and Structures Instrumentation	BRL
1.8	Structural & Ground Motion	SRI
1.9	Underground Loading under High Yields	AFSWC
1.10	Blast Overpressure Measurements	AFCRC
1.11	Early Hydrodynamics	ONR/ARF
1.12	Shock Spectra Studies	AFBMD
1.13	Bathimetry Measurements	ONR
2	NUCLEAR RADIATION AND EFFECTS	AFSWP
2.1	Shipboard Radiation Vulnerability	NRDL
2.2	Shipboard Contamination Ingress	NRDL
2.3	Characteristics of the Radiological Environment	NRDL
2.4	Neutron Flux Measurements	CWL
2.4a	Neutron Flux from a Very Low Yield Burst	CWL
2.6	Neutron Measurements from Very High Altitude Bursts	NRL
2.7	Prompt Nuclear Radiation Measurements	NRL
2.8a	Rocket Fallout Sampling	NRDL
2.8b	Aircraft Fallout Sampling	NRDL
3	STRUCTURES AND EQUIPMENT	AFSWP
3.1	Tapered Charge Testing of the DD-592	UERD
3.2	Test of Flexible Arches	BUDOCKS NCERL
3.3	Shock Studies of Naval Equipment	DTMB
3.4	Loading and Basic Target Response for Surface Ships	UERD
3.5	Submarine Hull Response	DTMB
3.6	Behavior of Deep Reinforced Concrete Slabs	AFSWC
3.7	Miscellaneous Structural Damage	WES
3.8	Technical and Engineering Services for Target Ships	BUSHIPS

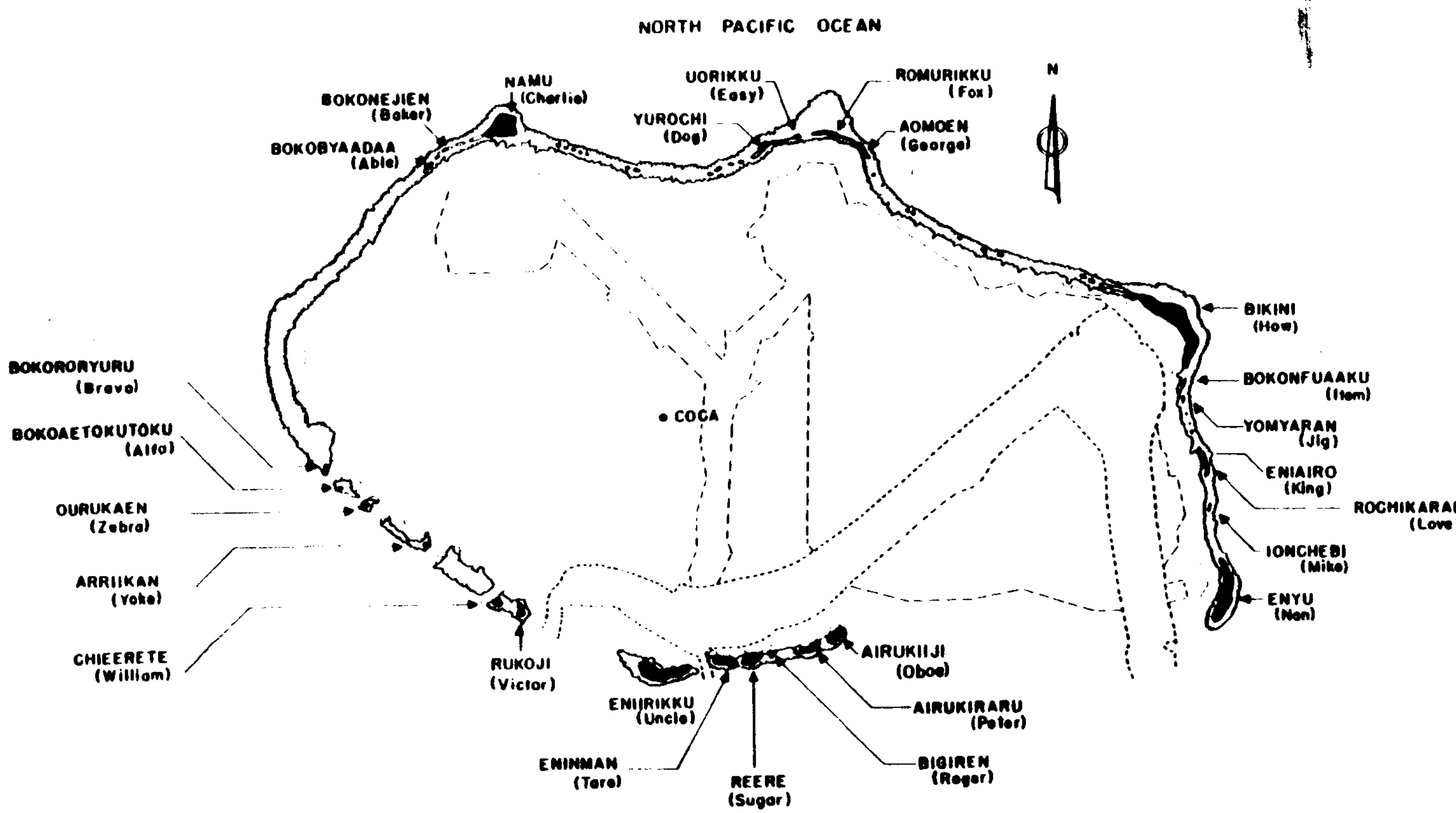
Prog. and Proj. No.		Sponsor and Agency
4	BIOMEDICAL STUDIES	
4.1	Effects on Eyes from Exposure to Very High Altitude Bursts	AFSAM
5	AIRCRAFT STRUCTURES	AFSWP
5.1	In-Flight Participation of B-52D	WADC
5.2	Weapon Effects on A4D-1 Aircraft	BUAER
5.3	Weapon Effects on FJ-4 Aircraft	BUAER
5.4	Aircraft Tracking and Positioning	FC/AFSWP
6	TEST OF SERVICE EQUIPMENT AND MATERIALS	AFSWP
6.3	Radiation Effects on Electronic Fuze Components and Anti-Countermeasure Devices	DOFL
6.4	Electromagnetic Pulse Measurements	USASIGRDLAB
6.5	Radar Fireball Observation	USASIGRDLAB
6.6	Radar Cloud Size Determination	USASIGRDLAB
6.7	Mine Clearance Studies	NOL
6.8	Underwater Influence and Mine Reaction Measurements	MDL
6.9	Ionospheric Effects of High Altitude Nuclear Detonations	USASIGRDLAB
6.10	Ionospheric Effects in the Operational Zone	AFCRC
6.11	HF and VHF Attenuation and Reflection Phenomena	AFCRC
6.12	Effects of Very High Altitude Atomic Detonations on S and L Band Transmission	USASIGRDLAB
6.13	Effects of Very High Altitude Bursts on Airborne Radar	MIT
8	THERMAL RADIATION AND EFFECTS	AFSWP
8.1	Effects of Thermal Radiation on Materials	NML
8.2	Thermal Radiation Measurements	AFCRC
8.3	Early Fireball Photography	EG&G
8.4	Thermal Radiation Spectrum Measurements	NRDL
8.5	Airborne Infra-Red Measurements	BUAER
8.6	Structural Effects Measurements on UHA and VHA'	WADC
8.7	Thermal Radiation from a Very Low Yield Burst	CWL
9	GENERAL SUPPORT	AFSWP
9.1a	General Support for Programs 1 to 9	
9.1d	High Altitude Density, Temperature, and Pressure Measurements	
9.2a, b, c	Balloon Carrier for VHA	AFCRC
9.3a, b	Support for UHA and VHA	ABMA
9.4	Support for Wahoo and Umbrella	ONR

Prog. and Proj. No.		Sponsor and Agency
10	FIREBALL PHYSICS	LASL J-10
10.1	Fireball Hydrodynamics	J-10
10.2	Time Interval Measurements	J-10
10.3	Photoelectric Measurements on High Altitude Shots	J-10
11	RADIOCHEMISTRY	LASL J-11
11.1	Radiochemical Analysis	J-11
11.2	Cloud Sampling	J-11
11.3	Heavy Element and Neutron Wheel Field Experiments	J-11
12	EXTERNAL NEUTRON MEASUREMENTS	LASL J-12
12.1	Pinex	J-12
13	REACTION HISTORY	LASL J-13
13.1	Alpha Measurements	EG&G
13.2	High Resolution Telemetry	SC
13.3	Development of Techniques for Diagnostic Measurements	J-13
14	PHONEX-PINEX	LASL P-Div.
14.1	Phonex-Pinex	P-Div.
15	PHOTO-PHYSICS	LASL J-15, J-10
15.1	EG&G Photography	EG&G
15.2	High Speed Photography	J-15
16	TEMPERATURE MEASUREMENTS	LASL J-16
16.1	Tritex	J-16
17	ELECTROMAGNETIC MEASUREMENTS	LASL J-16
17.1	Bikini Electromagnetic Measurements	J-16
17.2	Eniwetok Electromagnetic Measurements	J-16
17.3	Eniwetok Electromagnetic Measurements	J-16
18	THERMAL SPECTROSCOPY	LASL J-10
18.1	High Altitude Thermal Measurements	NRL
21	RADIOCHEMISTRY	UCRL
21.1	Radiochemical Analysis	UCRL
21.2	Sample Collection - Aircraft	UCRL
21.3a	Sample Collection - Rockets	UCRL

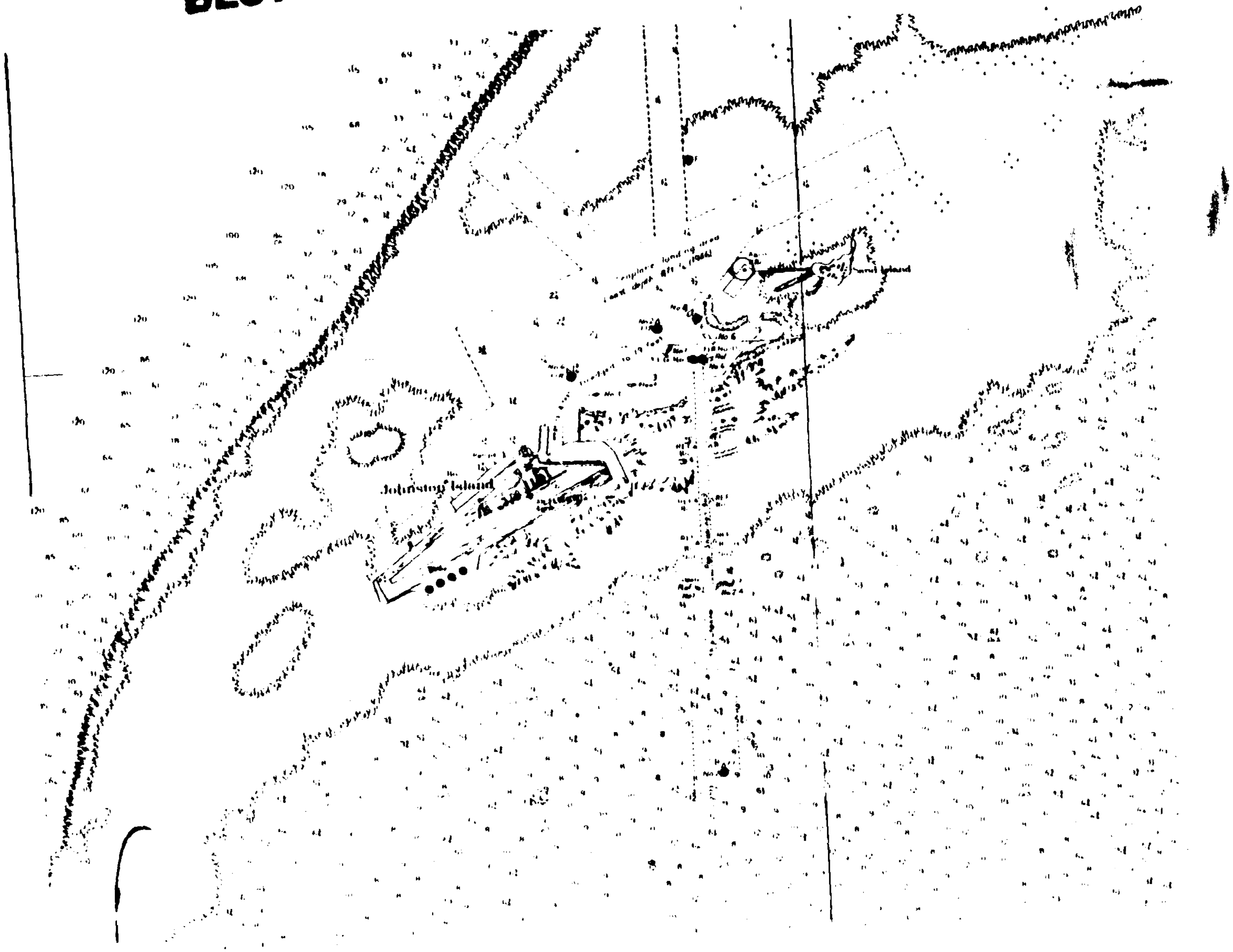
Prog. and Proj. No.		Sponsor and Agency
21.3b	Sample Collection - Rockets	UCRL
21.4	Gas Analysis	UCRL
21.5	External Neutron Flux Measurements	UCRL
22	REACTION HISTORY	UCRL
22.1	Nuclear Techniques	UCRL
22.2	Optical Techniques	UCRL
22.3	Pinex	UCRL
24	PHONEX	UCRL
24.1	Phonex	UCRL
A	WEAPON ASSEMBLY	UCRL
B	WEAPON ASSEMBLY	UCRL
32	DOORKNOB	SC
32.1	in Teak and Orange	SC
32.2	Instrument Systems	SC
32.3	RF Effects	SC
32.4	RF Systems	SC
32.5	Radchemical Sampler	SC
32.6	Companion Rockets	SC
34	SANDIA SUPPORT	SC
34.1	Diagnostic Telemetry	SC
34.2	Yucca Warhead System	SC
34.3	Electrical and Mechanical Assembly	SC
34.4	Microbarograph	SC
34.5	Zippers	SC
34.6	Assembly	SC
34.7	Nuclear Dose Rate Effects on Weapon Components and Materials	SC
34.8/2.14a	Fallout Measurements on Quince and Fig	SC
34.9/2.14b	Cloud Photography on Quince and Fig	SC
34.10/2.14c	Pre- and Postshot Wind Conditions on Quince and Fig	SC
40	RADIOBIOLOGICAL SURVEY	AEC DBM UWAFL



Map of Eniwetok Atoll



Map of Bikini Atoll



Map of Johnston Island

ABBREVIATIONS

ABMA	Army Ballistic Missile Agency
AEC	Atomic Energy Commission
AFB	Air Force Base
AFBMD	Air Force Ballistic Missiles Division
AFCRC	Air Force Cambridge Research Center
AFDL	Floating Drydock
AFSAM	Air Force School of Aviation Medicine
AFSWC	Air Force Special Weapons Center
AFSWP	Armed Forces Special Weapons Project
AGC	Amphibious Force Flagship
AICBM	Anti-Intercontinental Ballistic Missile
AOC-CIC	Air Operation Center - Combat Intelligence Center
APA	Air Priorities Agent, Attack Transport
APD	High Speed Transport
ARF	Armour Research Foundation
ARS	Air Rescue Service
ASR	Submarine Rescue Vessel
ATF	Ocean Tug, Fleet
AV	Seaplane Tender
BC	Army Floating Barge
BRL	Ballistic Research Laboratories
BUAER	Bureau of Aeronautics, USN
BUDOCKS	Bureau of Yards and Docks, USN
BUSHIPS	Bureau of Ships, USN
CJTF	Commander, Joint Task Force
CMLC	Chemical Corps
CTG	Commander, Task Group
CTU	Commander, Task Unit
CVA	Attack Aircraft Carrier
CVHA	Assault Helicopter Aircraft Carrier
CWL	Chemical Warfare Laboratories
DBM	Division of Biology and Medicine, AEC
DD	Destroyer
DDR	Radar Picket Destroyer
DE	Escort Vessel
DOD	Department of Defense
DOFL	Diamond Ordnance Fuze Laboratories
DTMB	David Taylor Model Basin
DUKW	Amphibious Truck - 2½-ton capacity
EAO	Eniwetok Airlift Office
EG&G	Edgerton, Germeshausen and Grier, Inc.
EPG	Eniwetok Proving Ground
ERDL	Engineer Research and Development Laboratory
FA	Forward Area
FC, AFSWP	Field Command, Armed Forces Special Weapons Project
FOPU	Fallout Prediction Unit
HE	High Explosive
H&N	Holmes and Narver

ICBM	Intercontinental Ballistic Missile
IRBM	Intermediate Range Ballistic Missile
JTF	Joint Task Force
LASL	Los Alamos Scientific Laboratory
LCM	Landing Craft, 30-ton capacity
LCPL	Personnel Craft, 36-passenger
LCPR	Personnel Craft with Ramp, 36-passenger
LCU	Landing Craft, Utility, 150-ton capacity
LSD	Landing Ship, Dock
LST	Landing Ship, Tank
MATS	Military Air Transport Service
MDL	Mine Defense Laboratory
MIT	Massachusetts Institute of Technology
MSTS	Military Sea Transport Service
M/T	Measurement Ton
NEL	Naval Electronics Laboratory
NML	Naval Materiel Laboratory
NOL	Naval Ordnance Laboratory
NRL	Naval Research Laboratory
NRDL	Naval Radiological Defense Laboratory
NTS	Nevada Test Site
ONR	Office of Naval Research
RSSU	Radiological Safety Support Unit
SC	Sandia Corporation
SIO	Scripps Institution of Oceanography
SRI	Stanford Research Institute
TAP	Transport (MSTS)
TCA	Transportation Control Agent
TG	Task Group
TU	Task Unit
UCRL	University of California Radiation Laboratory, Livermore
UERD	Underwater Explosions Research Division
UHA	Ultra High Altitude
USAF	United States Air Force
USASIGRDLAB	U. S. Army Signal Research and Development Laboratory
UWFL	University of Washington Applied Fisheries Laboratory
VHA	Very High Altitude
WADC	Wright Air Development Center
WES	Waterways Experiment Station
WET	Weapon Effects Test
YAG	Auxiliary, miscellaneous (Liberty Ship)
YC	Open Lighter
YCV	Aircraft Transportation Lighter
YFNB	Covered Lighter, large
YTB	Large Harbor Tug
ZI	Zone of the Interior

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Chapter 1

OBJECTIVES, DEVICES. AND WEAPONS

1.1 LOS ALAMOS SCIENTIFIC LABORATORY

A total of 14 full scale tests and one safety test were carried out by LASL in Operation Hardtack. Two of the tests were heavily instrumented and for this reason were fired on land. The other 13 were fired on barges to facilitate readiness and minimize contamination problems. The devices and yields are given on page 9.

1.2 UNIVERSITY OF CALIFORNIA RADIATION LABORATORY

During the course of Operation Hardtack, 15 devices designed by UCRL were tested. Diagnostic measurements were obtained in all cases. Of this total. two were tests of small devices with yields of three· were and the remainder varied Measured yields are given on page 9.

1.3 DEPARTMENT OF DEFENSE

Under the authority of letter, file SWPWT/960, Chief, Armed Forces Special Weapons Project, dated 2 June 1953, Subject: "Tests Involving Nuclear Detonations Participated in or Conducted by Agencies of the Government of the United States Outside the Continental United States," the AFSWP responsibility for the preparation, operation, and post-operation phases of Operation Hardtack was assigned to the Commander, Field Command, AFSWP.

The Joint Chiefs of Staff authorized AFSWP to plan and implement, in coordination with the various services and the AEC, the following:

1. Appropriate test programs to be conducted in conjunction with the following detonations:
   a. VHA balloon-borne -
   b. UHA (250,000 ft) missile-borne -
   c. VHA (125,000 ft) missile-borne -
   d. Deep underwater -
   e. Shallow underwater
   f.
2. The selection of the appropriate nuclear devices.

The Chief, AFSWP, formulated these plans and also a number of separate projects to be conducted on selected development detonations.

The Director, Test Division, WET, a staff agency under the Commander, Field Command, AFSWP, was assigned the functions of detailed planning and field implementation of the DOD Weapons Effects Program, Operation Hardtack. The approved military weapon effects test projects in Programs 1 through 6, and 8 and 9 are outlined below and discussed in Chap. 2.

Colonel E. K. Pinson, USAF, was assigned as the Technical Director to the DCS/WET, FC, AFSWP, and acted as Deputy Commander, Task Group 7.1, during the operation. The DOD Weapons Effects Programs were organized as Task Unit 3 of Task Group 7.1 and commanded by Col K. D. Coleman, USAF.

The DOD program participation in Hardtack was of greater magnitude than in any other Pacific Operation.

Program 1. This program was designed to determine air blast, underground shock, and underwater shock parameters and effects. Primary participation included the underwater shots, Wahoo and Umbrella; three surface shots, Koa, Cactus, and Fig; and the VHA shot, Yucca. Underwater and air blast pressures from the underwater events will be used as input data to determine safe delivery ranges for ships and aircraft, and to support the target response projects of Program 3. Ground shock measurements from the surface bursts will determine design criteria for "hard" underground structures and missile sites. Air blast data from the VHA shot will provide data to check theoretical estimates of energy partition at high altitudes.

Program 2. The objectives of this program were:

1. To determine the gross radiological hazards resulting from underwater bursts. Included were free-field measurements, deck and selected compartment contamination measurements, and measurements of ingestion and inhalation of contamination entering the ship via ventilation and combustion air systems.

2. To collect neutron energy spectrum data to supplement the presently inadequate knowledge of neutron energy spectra from thermonuclear weapons. Prompt neutron measurements were to be determined from a VHA small yield weapon and from two UHA large yield devices.

3. To measure radiation in the nuclear cloud from selected large yield detonations to obtain better data concerning the contribution of radioactive debris to worldwide contamination.

4. To determine prompt neutron and gamma radiation and fallout contamination from a subkiloton device.

Program 3. This program was designed for determination of the effects of underwater bursts on surface and subsurface vessels, and for the study of different types of land structures under various loading conditions. The information obtained by Programs 1 and 3 will be used to aid in formulation of operational doctrine, particularly insofar as delivery ranges and tactics for both surface and subsurface vessels are concerned. The information obtained on the response of ship structures will be used to provide criteria for future designs. Data obtained from various earth-covered flexible arches tested under both long and short duration air blasts, and deep reinforced concrete slabs tested under blast loading, will be used to determine construction criteria for future underground structures and for the study of the response of various types of land structures to air blast from surface detonations.

Program 4. The objective of this program was to determine the extent of chorioretinal damage caused by exposure to a high altitude, high yield nuclear detonation at distances from zero to 300 nautical miles from ground zero.

Program 5. This program was designed to determine the effects of nuclear weapons on aircraft structures. Nuclear weapon delivery by manned aircraft is often affected by the weapon's blast and thermal effects on the delivery aircraft and by nuclear radiation on the crew. Test data have indicated that blast input and skin temperature rise can be predicted within satisfactory limits, but that predictions of aircraft response to the blast and computation of thermal input is much less reliable. In order to perfect delivery tactics where safety margins are critical, manned B-52D, A4D-1, and FJ-4 aircraft were to fly several missions each, collecting data on the results of various inputs.

Program 6. This program was to study effects in four categories:

1. Electronic equipment located at various distances from the zero point was to collect data to determine the feasibility of using the electromagnetic pulse from a nuclear burst for long and short range detection, and to study the fireball and nuclear cloud with radar for determining ground zero and yield.

2. Investigations were to be undertaken of the ionization effects of high altitude detonations, particularly as they might effect communication systems dependent on the ionosphere for propagation.

3. Investigations were to be made of the deleterious effects on fuzes and their components of gamma rays and neutrons from nuclear explosions.

4. On the underwater shots, experiments were to be made to determine the feasibility of using nuclear explosions for clearing of mine fields.

Program 8. This program included the evaluation of laboratory methods of scaling thermal effects with weapon yield. Probably the most important part of the program participation was the investigation of the little known thermal phenomena and the parameters which have a direct relationship on the damage-producing thermal effects from the fireball of high altitude detonations and the prediction of those parameters for other heights and yields. Included was to be the photographic measurement of the fireball radius vs time history of high altitude detonations. Also, thermal measurements were to be made from a subkiloton device.

Program 9. This was a general support program designed primarily to provide photographic coverage for all interested TU-3 projects. Two numbered projects, 9.2 and 9.3, were assigned the mission of providing balloon and missile carriers, respectively, for the three high altitude events.

1.4 SANDIA CORPORATION

Program 32. The mission and designed purpose of Program 32 of Operation Hardtack for the Teak and Orange events was to measure phenomena of interest to the Atomic Energy Commission, to develop and test instrumentation techniques compatible with phenomena associated with large nuclear bursts at very high altitudes, and to measure effects of interest to the Department of Defense.

The measurements of particular interest to the Atomic Energy Commission pertained to the phenomenology of the warhead.

The study of instrumentation techniques consisted in determining how best to gather these data in addition to diagnostic measurements of device performance.

Of particular interest to the Department of Defense were the RF attenuation studies, which consisted mainly in recording signal strength from transmitters carried aloft by rockets to various position in time and space around the burst points.

Most of the instrumentation was in stations positioned by rockets. Radiofrequency telemetry and recovery systems were used as means for gathering data.

In addition, Program 32 provided the warheads and assisted in evaluating the fuzing and firing system.

Program 34. Program 34 included ten Sandia service projects, which were performed primarily for elements of Task Group 7.1.

Project 34.1 measured the functioning of Zippers and HE transit time on 29 shots. Also, it tried an experimental early alpha system on 15 LASL shots.

Project 34.2 supplied the device, fuze, and auxiliary systems used to detonate the DOD-sponsored, balloon-carried Yucca shot.

Project 34.3 procured, assembled, and checked out the devices used in the underwater DOD shots, Umbrella and Wahoo.

Project 34.4 measured microbarographic blast waves, primarily on Teak and Orange, but also on most of the other Hardtack shots.

Project 34.5 provided the Zippers and auxiliary system for LASL and UCRL on 28 shots.

Project 34.6 provided systematic support to UCRL.

Project 34.7 studied the prompt nuclear radiation rate effects on weapon materials and components exposed on the Quince and Fig events.

Project 34.8, 34.9, and 34.10 made measurements on the Quince and Fig events sufficient to delineate the gamma radiation fallout and to define a fallout model associated with a for use with any wind pattern. This permitted evaluation of militarily significant intensities and their limits.

Chapter 2

SUMMARY OF EXPERIMENTAL PROGRAMS

2.1 TASK UNIT 3, DOD PROGRAMS

Program 1, Blast and Shock Measurements

The thirteen projects of Program 1 investigated blast and shock parameters and effects produced by two underwater shots, two surface shots, and the VHA shot. The general objective was to define the environments produced by blast waves from nuclear detonations, both to increase our understanding of basic phenomena, and to support projects measuring effects produced by blast waves.

Areas of particular interest were underwater and air blast pressures produced by shots Wahoo and Umbrella, underground shock phenomena produced by shots Koa and Cactus, and blast wave characteristics (including energy partition) of shot Yucca.

Ground Shock

The entire DOD effort on study of ground shock phenomena was concentrated on two surface shots, Cactus and Koa. Complete air blast lines were installed on these shots also so that the air blast input contributing to underground effects would be known. Shot Cactus was chosen to provide a low yield tie-in of underground data with similar data obtained on Operation Plumbbob at NTS. Shot Koa was instrumented so that comparisons (Cactus vs Koa) could be made between data from low and high yield shots under similar soil conditions.

All five projects participating on shots Cactus and Koa successfully obtained the larger part of desired data. Results of individual projects are summarized below.

Air Blast. Complete air blast data were obtained on both shots. Overpressures ranged from psi at 470 ft to psi at 7868 ft ground range on shot Cactus and from psi at 1830 ft to psi at 6024 ft on shot Koa. Dynamic pressure data at 3-ft heights require further data reduction before results can be reported. Maximum overpressures from both shots when scaled to 1 kt at standard sea level conditions agreed well with a 1.6-kt free air pressure curve. Neither shot showed any evidence of a precursor; in the case of Koa, this was contrary to predictions. Cactus overpressures show an unusually slow and as yet unexplained decay for the first 25 to 40 msec.

Free-field Ground Accelerations and Relative Displacements. Instrumentation to measure accelerations at various depths to 100 ft and relative displacement between the ground surface and the 50- and 100-ft depths was installed on both shots at ranges corresponding to predicted pressures of 600, 200, and 100 psi. Ground accelerations up to 1120 g on Koa and 616 g on Cactus were recorded. Acceleration wave forms were more complex than those obtained at NTS; wave forms were influenced considerably by energy transmitted through the earth from ranges closer to the burst. Horizontal accelerations were higher than expected. Peak vertical accelerations showed a more rapid decay with depth than at NTS at similar pressure levels. Relative displacements were smaller than those observed at NTS, largest being less than 5 in.

Craters. Cactus crater dimensions of 180 ft radius and 36 ft depth agreed well with predictions. Koa crater dimensions of 1825 ft radius and 160 ft depth were significantly larger than predictions; it is believed the large water tank surrounding the Koa device may have increased the energy coupling with the ground.

Simulated Structures. Twenty steel drums with aluminum drumheads were buried at depths down to 20 ft at the 200-psi level on both Koa and Cactus. Results from the few drums recovered at this writing and from limited electronic data available indicate soil pressure decreased with depth to 10 ft and then rose to surface level values at 20-ft depths. As at NTS, the more flexible drums sensed the least pressure.

Shock Spectra. Gages consisting of cantilever springs (called "reed gages") were buried at expected ground surface pressure levels of 75 to 200 psi. Each gage recorded the response (displacement) of reeds having resonant frequencies of 3 to 300 cps. Results indicate that soil characteristics have a significant effect on shock spectra. Cactus results appeared to be similar to those obtained during Operation Plumbbob, but response of gages on Koa was generally lower than expected.

Air Shock at High Altitudes

Theory indicates that the effect of increasing the burst altitude reduces the energy appearing as air blast. On shot Yucca, the objective was to determine the characteristics of a blast wave at altitudes of about 90,000 ft in order to provide an accurate basis for scaling to higher and lower altitudes. Five canisters containing gages were to be suspended by a nylon line at ranges of 750 to 3000 ft from the device. Blackout of telemetering due to ionization was expected at zero time, but data were to be recorded and transmitted continuously for several minutes after the burst. Canister functions, including turning on the recorders, were to be controlled by a command transmitter aboard the USS Boxer. This project did not attain its objective because of failure of the transmitter about 2 min before shot time. One pressure record from the 3000-ft canister was obtained from the direct transmission but appeared to be spurious.

Blast and Shock Phenomena from Underwater Shots

Seven projects investigated free-field blast and shock phenomena on underwater shots Wahoo and Umbrella. Their primary objective was to obtain the free-field input data needed for determination of safe delivery and critical damage ranges for submarines, aircraft, and surface vessels operating in the vicinity of underwater nuclear detonations. In general, there was a rather thorough amount of information available on free-field blast and shock phenomena from HE tests. The only two nuclear underwater tests, Crossroads Baker and Wigwam, however, had left many basic questions unanswered. The blast and shock projects therefore were generally aimed at confirming and expanding Crossroads Baker and Wigwam results, providing a tie-in between data from nuclear and HE tests, providing input data for ships' damage projects, and generally increasing knowledge of underwater explosion effects.

Deep Water Shot, Wahoo. Underwater Pressures - The Naval Ordnance Laboratory and Naval Electronics Laboratory collaborated in measuring underwater pressures. Their main objectives were to confirm Wigwam results on scaling for isovelocity conditions and to study the effects of refraction. Pressure data were obtained at five to nine instrumented stations; peak pressures ranged from 100 to 1800 psi. There were four target ship stations; an adequate number of pressure-time histories (at various depths to 1850 ft) were obtained at the EC-2 (2346 ft) and the DD-593 (8887 ft). Only a few peak pressures were recorded at the DD-474, while at the DD-592 no data were obtained. The data generally confirmed Wigwam results. Thermal gradients showed considerable effect on the pressure field at the 8887-ft range and also influenced peak pressures at depths less than 300 ft at the range of the EC-2. The pressure-time data will be thoroughly analyzed, primarily by NEL, for refraction effects, using the shot time underwater temperature field provided by ONR-Hydrographic Office personnel. ONR-HO obtained its estimate of shot time underwater temperatures on the basis of bathythermograph (bt) readings from the DD-593 at H−15, H−5, and H−1 min and pre-shot bt data taken from three points in the array starting on D-7 day.

Air Overpressure - The NOL installed three near-surface gages on vessels in the array and self-recording gages on two balloons at heights of 500 and 1000 ft. Records were obtained from two gages from the balloon station at 3413-ft range and two surface gages at 2346-ft range. Records showed two distinct pulses; it is believed the first pulse resulted from underwater shock transmitted across the water-air interface and the second from bubble effects. Maximum pressure recorded was 0.21 psi at 30-ft elevation, 2346-ft range. Peak pressures showed general agreement with predictions based on HE results.

Surface Phenomena - The Scripps Institute of Oceanography measured water waves and NOL studied all other surface phenomena, i.e., spray domes, plumes, base surge, etc. Photography from four aircraft and several surface stations was the principal means of data collection. With the clear weather, photographic coverage was excellent. Film analysis in progress at this writing is expected to provide thorough documentation of the phenomena of interest. Surface phenomena bore a marked resemblance to Wigwam. Water waves containing approximately 4% of the weapon energy were observed.

Hydrodynamic Yield - The Armour Research Foundation failed in its attempt to measure the close-in propagation of the shock front. The technique used by Armour was the previously successful Wigwam method. The lack of a stable platform was the principal cause of failure.

Shallow Lagoon Shot, Umbrella. Underwater Pressures - NOL successfully measured underwater pressures at 16 stations. Records obtained at distances of 500 to 8000 ft from surface zero, at depths from 10 ft down to 130 ft, covered the pressure range between psi. Peak pressures were in agreement with theoretical predictions and HE results. Peak pressures decayed with distance at a significantly higher rate than would occur in free water. The main shock was preceded by a small gradual increase in pressure which was induced by ground shock. At close-in stations, near-ideal wave forms were observed; at 3000-ft range and beyond, wave forms were complex. A cavitation pulse was observed at all stations at 750-ft range and beyond; maximum cavitation pressure measured was psi at 1884-ft range.

Air Overpressures - NOL used a combination of 32 rockets, five balloon stations, and seven surface stations to document the air overpressure-time field at ranges up to 8000 ft from surface zero and altitudes up to 15,000 ft. Nine of 20 rockets recovered yielded usable data; eight additional rocket records may yield usable data after further evaluation. Five of the seven surface stations and one balloon station produced good records. Surface data showed good agreement with predictions based on HE results and indicate the use of 100% efficiency in scaling HE data to the nuclear case is reasonable. Peak pressures from rocket records were low compared with HE predictions. Maximum pressure recorded. 1.88 psi, was at 2500 ft altitude at a range of 2000 ft from surface zero.

Surface Phenomena - NOL investigated surface phenomena in general while SIO concentrated on water waves. EG&G provided excellent photographic coverage of surface phenomena from four aircraft and several surface stations. NOL obtained good records of temperature and humidity changes at five stations within the base surge. These records show well-defined temperature changes which correlate well with arrival of base surge as visually observed. SIO successfully measured the waterwaves from a number of stations and by a variety of means. The most interesting of these measurements came from three stations about 1700 ft from surface zero. They indicated that the highest wave was the first of the wave train. It was steep fronted and had a 22-ft span from crest to trough.

Hydrodynamic Yields - ARF attached two strings of blast switches and one doppler system to a taut cable running outward from the Umbrella device with the aim of measuring the time interval between closures of the blast switches and the rate of phase change of an rf signal fed into the doppler cable. Data were received in the zero LCU and telemetered to a remote location. Records were obtained for the blast switches only as the doppler cable was crimped during installation. Preliminary data analysis yielded an effective hydrodynamic yield pressure-distance curves from which hydrodynamic yields are determined, however, showed an as-yet unexplained deviation from the slope expected on the basis of Wigwam results.

Crater Dimensions - ONR and HO measured the Umbrella crater by means of preshot fathometer survey and a postshot lead-line and fathometer survey. A crater of about depth and diameter was found.

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Program 2, Nuclear Radiation and Effects

Program 2 included ten projects, which could be grouped into four categories: (1) underwater detonations, (2) high altitude detonations, (3) developmental shots, and (4) nuclear radiation from a very low yield device of particular interest to the Army, (discussed under Quince and Fig Results).

Underwater Shots, Wahoo and Umbrella

Shipboard Radiation Vulnerability. It was the object of this study to document the gamma radiation phenomena generated aboard three target destroyers by shots Wahoo and Umbrella. Both total gamma dose and gamma dose rate histories were measured by film badge dosimetry and gamma intensity time recorders (GITR's), respectively. Unshielded GITR stations and film badges supplied data on radiation at locations representing major battle stations; underwater GITR instrumentation supplied data on radiation in the water; and directionally shielded GITR stations mounted on deck supplied information on radiation from remote sources.

Radiation histories were obtained on only one destroyer during shot Wahoo because of ship's power failures on the two other destroyers. Radiation histories were obtained on all three ships during shot Umbrella, although some data were lost because of shock damage. Preliminary results indicate that weather-deck dose buildup ranged between 600 r received within 0.5 min at 2,000 ft from surface zero and 45 r received within 2 min at 8,000 ft. Dose reductions by factors less than 6 were obtained for all compartments above the waterline, and dose reduction factors greater than 9 were obtained only in machinery spaces below the waterline. Transit radiation appeared to represent a high percentage of the total radiation observed aboard the ships. In the one case where data were obtained, the underwater radiation did not contribute to the total radiation measured aboard ship. Data on gamma ionization decay was obtained for the period from 0.1 to 34.8 hr after Umbrella.

Shipboard Contamination Ingress. This was a study of the external and internal radiation hazards existing within typical interior compartments of a destroyer-type vessel as the result of the ingress of contaminant from nearby underwater nuclear detonations. Four compartments of the DD-592 were instrumented with total and time-incremental air samplers, surface samplers, animals (mice and guinea pigs), and GITR's. Rates of air flow for ventilation and boiler combustion for the instrumented compartments were controlled so as to be representative of those expected under nuclear-attack conditions.

Due to the failure of ship's power on the DD-592 during shot Wahoo, only surface sampler and animal data were obtained. The failure of a project timing circuit during shot Umbrella resulted in loss of time-dependent air sampler data although total air samples were obtained.

Estimates of the internal dose due to inhalation in the test compartments during Wahoo indicated that the doses were below the threshold for acute exposure but that possible chronic effects might be produced. Similar estimates for Umbrella indicated that doses were below the threshold for chronic effects, with the possible exception of the internal dose received in the engine room.

Umbrella estimates of the external dose rates in the test compartments due to ingress of contaminants showed them to be a small fraction of the compartment's total dose rate.

Radiological Environment. This study was to document the radiological environment resulting from underwater nuclear detonations. The gross gamma fields from shots Wahoo and Umbrella were defined by means of GITR instrumentation located on coracle platforms, as well as on the major target ships. These measurements were supplemented by those of total gamma dose made with floating film packs located throughout the target array. Incremental collections of radioactive material deposited from the resultant base surge and cloud permitted resolution of the gross gamma fields into initial, free-field, and residual doses and dose rates. Underwater probes were used to obtain information on radiation from radioactive materials suspended in the water.

For Wahoo and Umbrella, it was found that nearly all the total gamma dose occurred within 15 min after zero time and was due to the passage of air-borne radioactive material. However, the records of gamma dose rate versus time obtained from the two shots show pronounced and characteristic differences in the transiting gamma fields. Gamma doses in excess of 100 r occurred within the first 15 min at downwind distances of less than 16,500 ft for Wahoo and 11,000 ft for Umbrella. On both shots the dosage due to deposited radioactive material on the ships and coracles was from light to insignificant. A study of the downwind gamma data showed that a distance of approximately 23,000 to 28,000 ft from surface zero should be maintained in order to assure a total free-field dose of less than 25 r.

High Altitude Shot, Yucca

Neutron flux and gamma radiation measurements for the Johnston Island part of the Operation are covered in the summary pertaining to Teak and Orange.

Measurements of the neutron flux spectrum and total prompt gamma ray flux resulting from the detonation of shot Yucca, a burst at an altitude of approximately 90,000 ft were planned.

All data were to have been recorded and subsequently telemetered to a recording ground station. The instrumentation was contained in a canister suspended 2,750 ft below the nuclear device by means of a nylon line. Due to failure of the command transmitter, which controlled the canister operational functions, the instrumentation was inactive at zero time, and no data were obtained.

Projects Participating during Developmental Shots

Neutron Flux Measurements. This was a program to document the neutron flux and spectrum as a function of distance for two shots in the To achieve this objective, the project participated during shots Yellowwood and Walnut. The measurements were extended during the field phase of the operation to include shot Quince, and this participation is covered in the portion of this report relating to that detonation. To make the necessary measurements, threshold activation and fission detectors were exposed at various distances from the Yellowwood and Walnut zero points. These detectors included gold, cadmium-plated gold, plutonium, neptunium, uranium, sulfur, and zirconium. Since land masses of sufficient size were not available for displaying the detectors at desired distances, a buoy line was used. The line extended from 917 to 4100 yd from Ground Zero for both shots. Due to the radiological situation that existed after these detonations, recovery could not be effected until D+1 day. As a result, only limited neutron flux and dose data were obtained. Early results indicate that the neutron dose for shot Yellowwood was lower than predicted by a factor of 2.3 and the Walnut dose was low by a factor of 2.0.

Fallout Sampling. The objectives were to determine the relative contribution of certain isotopes to both local and world-wide fallout and to use this information, if possible, to determine the fraction of total bomb debris deposited in the local area. The project was divided into two separate efforts: (1) the collection of early cloud samples by means of newly developed rocket samplers, and (2) the collection of residual cloud samples and fallout debris by aircraft.

The rocket sampling was to have been accomplished with rockets developed by UCRL Project 21.3. Gas and particulate sampling of the residual cloud was accomplished by B-57D aircraft under the technical supervision of LASL personnel. Fallout samples were collected at various times after the detonation, based on predictions furnished by the Fallout Prediction Unit. These collections were made at an altitude of 1000 ft by WB-50 aircraft. The fallout collection was supervised by personnel of the U.S. Naval Radiological Defense Laboratory.

The project participated during shots Koa, Walnut, and Oak, as it was desired to obtain a comparison between the fallout from land surface and water surface detonations Because of various technical problems, satisfactory rocket samples were not collected from shots Koa and Walnut, and this portion of the project was canceled prior to Oak. Successful B-57D and WB-50 samplings of the Koa fallout were made; however, early analysis of the samples indicated they had been contaminated by debris from shot Fir, fired the previous day at Bikini. For this reason, project participation was extended to include Oak. Successful sampling was accomplished during Walnut and Oak. Collected samples were returned to the continental laboratories for analysis, and the resultant data were not available at the time this report was written.

Program 3. Structures and Equipment

The objective of this program was to provide information on the effects of nuclear bursts on ship structures and equipment, and on various land structures, under certain conditions that had not been heretofore investigated. Five of the eight projects were concerned with the response of ship structures and equipment to underwater bursts, and three were concerned with the response of land structures to air blast.

Prior to Operation Hardtack a series of tests was run employing HE charges against the destroyer DD-592 off Santa Cruz Island, Calif., in January 1958. A series of four large, specially shaped (tapered) HE charges weighing from 1400 to 4400 lb was planned to simulate underwater nuclear attack against the DD-592. The tests were carried up to the threshold of shock damage, but stopped after detonation of the third charge to avoid the probability of serious damage to the DD-592 prior to the Hardtack full scale nuclear tests. The results indicated that the shock wave pressure satisfactorily simulated the initial shock waves from a nuclear detonation.

Four unmanned major target ships, three destroyers, and an EC-2 merchant ship were instrumented and exposed to the Wahoo and Umbrella underwater detonations. In addition, three manned fleet operating ships, submarine SSK-3, and destroyers DD-728 and DD-826 had a small amount of instrumentation aboard and were also exposed to Wahoo. The SSK-3, unmanned, and a four-fifths scale submarine model, Squaw 29, were also exposed in Umbrella. The shock response of equipment as well as equipment foundations (which included hulls, bulkheads, decks, and superstructures) was recorded by 325 velocity-time meters and self-recording shock-spectrum gages and 40 high speed motion picture cameras. The following tentative conclusions with respect to damage to machinery and equipment may be made.

1. The minimum safe range for delivery of an antisubmarine weapon by destroyers is 3000 ft for Wahoo conditions and 2400 ft for Umbrella conditions. Damage or malfunction of particularly delicate equipment, e.g., some types of electronic equipment, may occur at even larger ranges.

2. The range for moderate damage for delivery of an antisubmarine weapon by destroyers is between 2300 and 3000 ft for Wahoo conditions, and less than 2400 ft for Umbrella conditions.

3. The minimum safe range for a submarine is 2500 ft for Umbrella conditions. For Wahoo conditions, 10,000 ft is conservatively safe; later analysis will permit determination of the minimum safe range.

4. The safe range and moderate damage range for submarine and surface targets is determined by shock damage to ship's equipment rather than by hull damage for both Umbrella and Wahoo conditions.

Gages and recording centers were installed on the three target destroyers and the EC-2 merchant ship in order to document the basic hull response of these surface ships. A total of approximately 170 gages recorded velocities, displacements, deflections, pressure, strains, rolling, and pitching. The hull damage was significant but less than expected on the attacked side of the EC-2 and negligible on the target destroyers. The following tentative conclusions were reached:

1. From the standpoint of hull deflection the following safe delivery ranges for destroyers have been demonstrated: 2900 ft under Wahoo conditions and 1900 ft under Umbrella conditions. No statement can be made at this time, from the viewpoint of hull deflections, concerning the minimum safe delivery ranges except that they must be considerably smaller than the above values.

2. The estimated horizontal lethal ranges for the EC-2 from the standpoint of hull deflections are 1700 ft for Wahoo conditions and 1300 ft for Umbrella conditions.

3. Check points for small scale UERD model experiments were obtained from both Wahoo and Umbrella.

For Umbrella, the submerged four-fifths scale submarine model, Squaw 29, at a range of 1600 ft was instrumented with strain gages; pressure gages; deflection gages; high-speed cameras; and roll, depth, and flooding indicators. The hull was plastically deformed but did not rupture. Four of the ten external ballast tanks ruptured and all were seriously dished, resulting in some loss of buoyancy. The SSK-3 was submerged at periscope depth and operated by its crew at 18,000 ft from Wahoo surface zero. In Umbrella, the SSK-3 was unmanned and located bow-on at a range of 2900 ft. No permanent hull deformations occurred from either shot. The following preliminary conclusions may be made:

1. A range for moderate hull damage to a submarine-like Squaw under Umbrella conditions is 1600 ft at a depth of 50 ft.

2. A conservatively safe range for the SSK-3 hull under Wahoo conditions is 7000 ft at a depth of 50 ft; later analysis will permit determination of the minimum safe range.

3. The SSK-3 under Umbrella conditions at 2900 ft range and at a depth of 50 feet was shown to be well beyond the minimum safe range for hull damage.

Failure criteria for prefabricated, corrugated steel, flexible arch-shell structures confined within non-drag-sensitive earthwork configurations of coral sand simulating partially underground structures was studied. Three structures were tested in the 80- to 180-psi peak overpressure region from a 1.4 Mt surface shot to determine empirically the response of such structures. A fourth structure was tested in the 90-psi peak overpressure region from a 17-kt surface shot to determine the effects of short-duration blast loading on a similar structure and environment. The 25-ft span by 48-ft 10-gage arch-shell structure subjected to 90 psi peak overpressure partially collapsed on the side away from ground zero. The collapse apparently was initiated by bearing failure of the shell plates at a bolted horizontal seam approximately 5 ft above floor level on the collapsed side of the structure. The following results were noted on the other three structures:

1. A 25-ft span structure and the 38-ft span by 40-ft 1-gage arch-shell structure, subjected, respectively, to 78 and 100 psi peak overpressure from shot Koa suffered a complete collapse symmetrically about the crown. A third 25-ft span structure subjected to 180 psi peak overpressure collapsed completely.

The dynamic behavior of deep (thick) reinforced concrete slabs in the high overpressure regions of 175 to 600 psi was studied to provide the basis for establishing design criteria for massive reinforced concrete structures under blast loads. Thirty one-way and 15 two-way slabs mounted flush with the ground surface were tested. The clear span was 6 feet and the ratios of depth to span varied from 0.15 to 0.78. Because of excessive postshot radiation at the slab locations, data recovery has not been completed. However, preliminary results indicate that the resistance of the slabs to high blast pressures was considerably greater than expected.

Program 5, Aircraft Structures

The Air Force was concerned with determining the structural response of a B-52D aircraft subjected to side loads. This determination had as an ultimate objective the definition of the delivery capability of the aircraft for multiple delivery tactics. A range of angles with respect to ground zero from 35° head-on to 180° tail-to in azimuth, including three different elevation angles, were utilized in verifying the analysis and predictions. It was concluded that the data obtained were sufficient to verify the method of analysis used to predict structural side loads from which the nuclear weapon delivery capability for multiple delivery tactics could be defined.

The Navy sponsored a project in which two A4D-1 aircraft participated jointly in several shots in order to measure weapon in-puts and structural responses to high yield weapons. The final objective was the correlation of the data with that of the Plumbbob tests in order to define the high yield (megaton range) weapon delivery capability of the A4D-1. From the preliminary data obtained it was determined that measured stresses were consistent with predictions obtained from the analytical techniques employed. It is anticipated that additional data obtained from wing pressure instrumentation will assist in further refining the dynamic analysis. Thermal inputs were generally substantially lower than predicted, although the temperature response calculations based upon measured inputs in general showed good correlation. It was concluded that the data obtained, when combined with that obtained from Operation Plumbbob and the aircraft performance characteristics, will permit the definition of the nuclear weapon delivery capability of the A4D-1 aircraft.

Effects input and structural response of two FJ-4 aircraft were measured. The information obtained was concentrated in inputs and effects from higher yields in order to correlate with data obtained from the lower yields of Plumbbob and confirm the Class D delivery capability of the aircraft. In general, excellent correlation of blast response data was obtained, verifying the dynamic analysis techniques used for predicting structural responses. It was concluded that response data have been obtained over a sufficiently wide range of yields and incidence angles to permit subsequent definition of the Class D delivery capability of the FJ-4B aircraft.

Program 6, Test of Service Equipment and Materials

This program had a wide range of project station locations: Wake Island and Eniwetok, Bikini, Kwajalein, Kusaie, Wotho, and Rongelap Atolls.

One project to study the wave form of electromagnetic pulse from a nuclear detonation used two sites: Kusaie, 420 miles from Eniwetok, and Wotho, 240 miles from Eniwetok. The objective was to make broad-band measurements from 0 to 10 Mc at ranges up to 460 miles. The measurements were not expected to be radically new. Although improvements in equipment were incorporated, the primary concern of this project was to increase the cataloging of wave forms. The data, which are in good agreement with those obtained during Operation Redwing, indicate that device yield and range and the presence of a second stage can be determined from wave-form parameters.

Another project, with stations at Wake Island and Kusaie, studied ionospheric effects of large-yield surface detonations. In agreement with results of Operation Redwing Project 6.3, the energy responsible for the first disturbance in the ionosphere above Kusaie was propagated with a mean velocity of 20 km/min. Also corroborating previous results, the second disturbance resulted from energy propagated with a mean velocity of about 13 km/min. The first effect has been postulated to be due to a compressional wave and the second to a hydromagnetic wave. The fact that the first effect was seen approaching but not receding is indicative of the shape of the ion-density variation associated with the disturbance.

Two projects participated during shot Umbrella to obtain effects data on feasibility of using nuclear weapons as a naval-mine countermeasure. One of them, sponsored by the Naval Ordnance Laboratory was to determine the ranges at which typical stockpile bottom mines would be neutralized by a shallow-water burst. To set up the experiment, a total of 120 mines, consisting of mines MK-25-2, MK-39-0, MK-50-0, MK-52-1, MK-52-2, MK-52-3, and MK-52-6 were laid in the Eniwetok Lagoon, north of ground zero, at distances of 1400 to 8100 ft. The operation of 23 of the mines (planted at distances greater than those at which damage was expected) was monitored during the shot by means of a system of internal recorders designed to begin recording when the mines were armed and to continue recording until the mines were recovered. The depth of water at the mine field varied between 120 and 150 ft. The results of the test indicate that:

1. At distances of less than 1600 ft from ground zero for weapons comparable in yield to that of shot Umbrella, 100 per cent clearance of mines may be expected.

2. At distances between 1600 and 2000 ft, 67 per cent of the MK-25-2's suffered component damage sufficient to render the mines inoperative.

3. At distances between 2000 and 2800 ft, 43 per cent of the MK-25-2's suffered component damage sufficient to render the mines inoperative.

The Navy Mine Defense Laboratory was the sponsoring agency of the other project participating in underwater experimentation. The over-all objective of the project was to determine the feasibility of employing nuclear weapons for wide area mine clearance by influence means. The specific objectives of this project were to (1) measure and record the amplitude, duration, and extent of mine actuating influences (pressure, acoustic, and magnetic) that may be generated at the sea bottom by the explosion of a low yield nuclear weapon in shallow water (approximately 150 ft depth); and (2) determine the reaction of certain instrumented naval mines to the influences generated.

Three LCU instrumentation platforms were located at distances of 8300, 20,150, and 44,750 ft from the Umbrella surface zero. Instrumentation was provided to obtain the time-pressure history resulting from the shot, including pressure changes due to waves, swells, and the shock wave; the time history of the magnetic field changes; the time history of the sound pressure level, 2 cps to 40 kc; the time history of displacement of the bottom; the mine reaction, including such items as search coil output, plate voltage rise, pressure switch opening, fires, and "looks"; and correlation of all influence measurements and mine reactions with respect to time.

From the Umbrella shot the following tentative conclusions were made:

1. The shot was not significantly effective in causing MK-25-0, MK-25-2, MK-50-0, and MK-36-2 mines planted at the three instrumentation platforms to register fire actuations.

2. One magnetic look was received by each operative MK-25-0 and MK-25-2 mine at Platforms 1 and 2. Those at Platform 3 received none. The magnetic looks occurred at a time that would indicate that they probably resulted from ground motion or the effects of the water shock wave.

3. All MK-25-2 mines received looks as a result of pressure waves generated by the shot.

4. Anticountermine actuations were recorded for nine acoustic mines. A fire actuation was recorded for one. Based on the time of occurrence, it is probable that the ground-transmitted pressure waves were responsible for some, or all, of the actuations.

A fifth project, sponsored by the Diamond Ordnance Fuze Laboratory, studied the effects of nuclear radiation on electronic fuze components and materials. Electronic components were placed in special test circuits to emphasize the property to be measured. The signals were fed into a magnetic-tape recorder, which recorded the performance of the components during the detonation. In addition, the telemetering points of a Corporal fuze system were monitored, and departure from normal operating level was recorded on the tape.

Neutron dosages of

r were recorded at experimental stations. As a result, some noteworthy changes in electronic gear were observed:

It may be tentatively concluded that:

1. Almost all electronic components may suffer deleterious effects after a nuclear detonation which cannot be detected by simple measurements.

2. Many transient effects would not have been noted in reactor experiments.

3. Transient susceptibility was directly dependent on the degree of exposure.

4. Data from a number of diodes shows that they may be reliably employed to discharge a firing capacitor at the time of a nuclear detonation.

5. A Corporal fuze system would be highly suspect in a nuclear environment.

<u>Program 8, Thermal Radiation and Effects</u>

It was the purpose of the program to (1) study the effects of megaton range atomic weapons on materials and to evaluate a skin simulant as a substitute for animate skin in these studies; (2) obtain spectroscopic measurements of thermal irradiance as a function of time on a high altitude burst; (3) measure the fireball size of a high altitude burst as a function of time by photographic means; (4) obtain a photographic record of the early time spectra of a high altitude burst with high time and spectral resolution; (5) make measurements of the size, persistence, and spectral irradiance of the fireball in the infra-red from a high altitude burst; and (6) study material ablation from specimens inside the fireball, and test the neutron vulnerability of various materials to be used in the Teak and Orange experiments.

For the very high altitude event, shot Yucca, two RB-36's were modified to serve as instrumentation platforms. Special windows and shelves were provided for the instrumentation and special wiring was installed. The aircraft were provided with special radar equipment to track the balloon assembly and position themselves. The AOC-CIC aboard the USS Boxer, which also served as the balloon launching platform, was utilized for control and as a back-up positioning system. Both aircraft were well positioned so that all instruments had the burst in their fields of view. Excellent records were obtained by all projects whose instrumentation was aboard.

In addition to its participation on shot Yucca, Project 8.5 also made infra-red measurements on shots Butternut and Koa as instrument checks and to obtain correlation data. A P2V also participated on events Butternut and Koa for instrumentation checks and to obtain data for correlation of data from a surface detonation with those from shots Teak and Orange. On Butternut the monochromator failed to function properly, but the mapper functioned satisfactorily. On Koa both instruments operated well. No data were received from the canister instruments on the drag line.

Tentative conclusions which can be made at this time are:

1. The Yucca shot appeared timewise as a detonation of one-tenth its actual yield.

2. The time to normal second maximum scales directly as the relative density to the one-third power.

3. The apparent yield scales directly as the relative density to the two-thirds power.

4. The radius of the fireball at time to second maximum scales inversely as the relative density to the one-sixth power.

5. No definite indication was received of a change in partition of energy since the apparent change was not sufficient to be conclusive. If there is a change, it would appear to scale inversely as the relative density to the 0.031 power.

The experiments on effects of atomic weapons on materials and evaluation of a skin simulant were carried out on shots Yellowwood and Walnut. Approximately 30 skin simulant specimens in various configurations, including bare and blackened unclothed samples, samples clothed with contact and spaced fabrics, and samples with various apertures were exposed. Time-temperature histories of the specimens were recorded. In addition, recording calorimeters and radiometers were used to measure the thermal radiation incident at the station.

Ablation and neutron vulnerability studies were carried out on shot Cactus. For the experiments on ablation of material, two specimens designed to determine the rate and depth of melting of a spherical surface were exposed on a 100-ft tower so as to be within the fireball. These specimens contained instruments for measuring and recording the time history of the temperature of unprotected metal at various depths, specimen acceleration, late fireball overpressure, and shock arrival time. Two additional specimens spaced 10 ft apart and rigidly connected were placed on the ground at a distance of 250 ft to measure the speed of sound inside the fireball. These specimens contained transducers and recorders for measuring the time of arrival of weak shocks from a series of small explosions set off at successive times after zero time. From these measurements it was hoped to calculate a time history of the gas temperature of the fireball.

As yet, no results are available from these studies. In the case of the neutron bombardment experiment, the radiation level in the area precluded immediate recovery. When the level of activity diminished, a search of the area was made, but the instrument carrier could not be located.

Program 9, General Support

The mission of Program 9 was to provide documentary and technical photographic support to participating DOD agencies. The documentary support consisted of both still and motion picture coverage of project activities to depict the scope of the project's effort and to show significant results of their effort for historical and report purposes. Still photography for illustrating preliminary and final reports was conducted by TG 7.1, TU-1. Motion picture coverage to be used in the production of a weapon effects film was provided by JTF 7. Technical photography, such as high-speed, time-lapse, and function-of-time photography, was furnished by TU-5 (EG&G).

During the planning phase of Operation Hardtack, it became evident that the needs of the various projects for photographically collected data would fall on the five military effects events: two high altitude rocket detonations, one high altitude balloon detonation, and two underwater detonations. Because of the varied nature and location of the detonations, more extensive and sophisticated camera installations were needed than on any prior operation. As the test series proceeded, additional shots of military interest were added, which further increased the complexity and number of camera stations.

For the high altitude balloon detonation, RB-36's were used with backup camera installation mounted on the USS Boxer. For the Teak and Orange shots, the RB-36's were used with backup surface and ground stations.

The photographic equipment used for all three high altitude detonations consisted of streak, high and medium speed motion picture, rapid sequence still, and Zenith cameras, utilizing both color and black and white film.

The photographic instrumentation for the two underwater shots was basically the same for each shot. The stations common to both shots consisted of a camera station on Parry Island, and one on Igurin Island; an LCU camera station anchored in the lagoon; an RB-50 aircraft directly over surface zero at 25,000 ft altitude; three C-54 aircraft orbiting at 20,000 ft range at altitudes of 1500 ft, 9000 ft, and 10,000 ft; and one RB-50 aircraft which provided vertical aerial photographic coverage of the target array before and after each shot.

For the Wahoo shot, an additional camera station was installed in the hold of the EC-2 to record effects of a deep-water detonation on the ship's structure.

For the Umbrella shot, in addition to the basic installations, a camera station was installed on a barge 20,000 ft from surface zero; another camera station was installed on Mui Island to photograph rocket firings, and a trimetrogon camera array was installed on an H-19 helicopter to photograph wave action at two surface instrument platforms.

In addition to the major portion of the photographic effort on the five military effects shots, a somewhat smaller effort was expended on some of the AEC diagnostic shots. A camera station was installed to record the effects of the thermal pulse on certain materials. Several aerial photographic surveys were accomplished of craters produced by land surface detonations; aerial surveys were accomplished to locate strings of gages placed in the water prior to several shots; and aerial mosaics were photographed of Johnston Island and all the islands of Bikini and Eniwetok Atolls for planning purposes.

Before the five original military effects shots had all been detonated, two additional shots of DOD interest were added to the program:
surface bursts on the island of Yvonne at Eniwetok Atoll. This necessitated the establishment of two camera stations to cover the events and the addition of some still and motion picture documentary coverage.

In all, about 66,000 ft of original 35-mm Eastman color negative film was exposed from which a military effects motion picture film report will be prepared after the operation. For historical and report purposes, approxi-[redacted] 3500 black and white still negatives were exposed during the operation.

Very High Altitude Carrier Systems

Program 9 also provided support for the three high altitude detonations on Hardtack: Yucca (Eniwetok-Bikini area, burst height about 90,000 ft), Teak (Johnston Island, burst height about 250,000 ft), and Orange (Johnston Island, burst height about 141,000 ft).

For Shot Yucca, Project 9.2a supplied the warhead, the fuzing and arming equipment, the radio-command system, and function monitoring for the Project 9.2b provided the carrier to deliver the device and associated instrumentation to altitude. This was a 128-ft, 2-mil, polyethylene balloon. Test flights from various launching sites conducted during the 18 months preceding the shot had shown that launch from an aircraft carrier, with a deck wind velocity of nearly zero, was the most reliable method.

The USS Boxer (CVS-21) departed Bikini Atoll at 1900 on April 27, and at 1125:05 on April 28 the balloon was launched. The total weight of the system was 1295.5 lb, including a payload The latter consisted of the device and five canisters containing instrumentation for measuring pressures, thermal and gamma radiation, neutron flux, and electromagnetic pulse. The device was suspended 568 ft below the balloon and the canisters from 750 to 3000 ft below the device. The device was detonated at 1440 on April 28.

Because of command transmitter failure prior to shot time, no effects data of significance was received from the suspended canisters; however, participating aircraft did obtain data for determining energy partition and extending scaling laws to include low yield detonations up to 100,000 ft.

For shots Teak and Orange, Project 9.3a was assigned the task of readying and firing the two Redstone missiles, each equipped with Each missile was also equipped with four instrumented pods mounted on the surface of the thrust unit; these were explosively expelled during the powered phase of the trajectory so as to be in pre-determined positions at burst times. The Redstone missiles were adapted specifically for these shots, and several flight tests of the modifications had been conducted.

On shot Teak, the burst did not occur where intended because of failure of the missile to program. From preliminary data, a vertical trajectory was assumed. Lift-off was at 2347:14.99 and burst occurred at 2350:05.597 LST on July 31.

On shot Orange, the missile programmed about as planned. Lift-off was at 2327:34.498, and burst occurred at 2330:08.607 LST on August 11.

On both shots, all except necessary key personnel were evacuated to ships during the morning and afternoon of shot day. Indications of missile performance were provided the Missile Flight Safety Officer, as well as means of taking corrective action in the event of malfunction, i.e., command destruction of the fuel tanks and, in the case of Orange, a means of preventing arming of the warhead.

Quince and Fig Results (Programs 1, 2, and 8)

The Quince event, planned as a ground surface burst, was added to the Hardtack schedule in June 1958. Because of its nature and possible tactical interest, three new Program 2 projects were created and an existing [redacted] extended in order to document the nuclear effects. Three projects of Program 34 (Projects 34.8, 34.9, and 34.10) were placed under the technical direction of Program 2. These are discussed in Sec. 2.4.

Quince As a result, the Fig event was added to the schedule and detonated on August 18, 1958. The yield was

Project 1.4, Crater Measurements, measured the size of the crater produced by the There were no project personnel in the EPG, as only a contractor survey was required. It was found that the crater produced was elliptical in shape, with the long axis roughly corresponding to that of the device. The diameters were respectively, measured from lip to lip. The depth was below grade with a lip above grade. At the time of measurement, D + 3 days, there was evidence of earth slides which resulted from severe rains that had occurred since the detonation. The crater was briefly observed on D + 1 day, prior to the slides. Based upon this observation and the measurements made a day later, it is estimated that the original crater was deeper and smaller in diameter from lip to lip immediately following the detonation.

The objectives of Project 1.7, Overpressure Measurements, were to document the overpressure measurements resulting from a and verify or extend existing scaling laws. The instrumentation consisted of 36 standard PT and Q gages containing pressure capsules located at ranges from 40 to 700 ft from ground zero. As the yield of the device was uncertain, it was necessary to provide the above instrumentation to accomodate a wide range of pressures.

The Fig device produced a nuclear yield of as measured by radiochemistry. Twenty-eight of the 36 instruments provided good records. Some failures were experienced due to undetermined causes at the close-in ranges. It is felt that these could be the result of heavy ground shock and motion, which in some instances shattered the glass recording discs. Pressures recorded varied from

The points plotted against curves scaled up from high explosive and down of nuclear yield showed a reasonably close fit. There was, however, a minor deviation in the slope of the recorded curve which cannot be explained without further study of the records and investigation of possible sources of experimental error due to the closeness of the instruments to the detonation. Preliminary field analysis of the data indicates that, using existing scaling laws, pressures can be predicted for detonations with reasonable accuracy.

Neutron flux measurements made by Project 2.4 were discussed in some detail in the Program 2 portion of this report. During the field phase of the operation, project participation was extended to include the Quince and Fig events and had as its objective the documenting of the neutron flux and spectra for the Two neutron lines were established to obtain the desired data. One was in the direction of the extended long axis of the device and ran out to a distance of 1039 yd, and the other was perpendicular to the device's long axis and extended for a distance of 900 yd.

Project 2.9, Gamma Dose Measurements, was a new project approved for the shot. Its objective was to measure gamma dose as a function of time and distance from the device. The basic type of instrument was the NBS film badge. The film badges were displayed along ground lines to give total gamma dose versus distance. Also, they were used in film dosimeter transport devices which exposed individual film badges for known time periods. The periodic exposure of film badges over an extended time interval permitted a determination of the initial and residual dose rates. Film badges are being processed and data are not available at this time.

Project 2.10, Residual Radiation, was also created specifically for participation on Quince and Fig and had the objective of documenting the residual gamma field intensities produced by the surface detonation of the device. The required data were obtained by means of radiological surveys conducted both on the ground by monitoring teams and from the air by means of a probe lowered to a 3-ft height from a helicopter. The results indicate the radiation intensities at the lip and crater of shot Fig were above 10,000 r/hr at H + 30 min, which would necessitate avoidance of this area by troops advancing at an early time. The area contaminated by fallout to levels of military significance was less than expected by a factor of 2.5 according to the present scaling laws.

The early decay measurements show that the normal fission product decay rate, $t^{-1.2}$, is not applicable for a period from H + 1 to H + 3 hr. Instead, the decay rate is $t^{-1.35}$, which is faster. However between H + 3 and H + 24 hr, the decay rate was only $t^{-0.84}$, which is slower than the normal fission product decay rate.

The third newly approved project, Project 2.11, had the mission of making gamma, neutron, and thermal measurements as a function of altitude for this event. A polyethylene balloon was moored 300 ft from ground zero, and appropriate instrumentation was exposed at various altitudes up to 1500 ft by attachment to the balloon mooring cable. Fission foils were too active to count at the EPG and will be counted in the ZI. Film for gamma dose measurements is being developed. Due to mechanical difficulties caused by adverse weather conditions, no thermal measurements were made.

Project 8.7, Thermal Measurements, measured the radiant exposure in cal/cm^2 and the thermal irradiance in $cal/cm^2/sec$ at various distances from surface zero for the subkiloton device. Instrumentation consisted of seven CWL Thermistor Calorimeters located from 150 to 600 ft from surface zero; two NRDL Disk Calorimeters located at 450 and 900 ft from surface zero; and four NML Radiant Exposure Meters located at 350, 450, 600, and 750 ft, respectively. The CWL instrument data were recorded in an instrument shelter 1200 ft from surface zero; the NRDL instruments were self-contained. No data are presently available from the NML meters, which have been forwarded to NML for reading and calibration. The CWL Thermistor Calorimeters recorded radiant exposures from The NRDL thermal data agreed with those taken by CWL.

Teak and Orange Results (Programs 1, 2, 4, 6, 8, and 9)

Program A: Blast and Atmospheric Measurements and Vulnerability Studies

This program was divided into four distinct projects and each will be discussed separately.

Project 1.7 had as its objective the documenting of surface and near-surface air blast, pressure-time measurements. Standard PT and VLP self-recording pressure gauges were employed, and electronic recording gages utilizing a strain-type pressure transducer provided back-up detection. Stations were located on Johnston Island, and aboard ships. Ground level pressures varied from about from Teak at a slant range of to from Orange at a slant range of The pressure values measured at the surface and near surface were considerably lower than were predicted. Assuming a yield for both shots, the pressure measurements indicated per cent blast efficiency at these altitudes in comparison to the standard 45 to 50 per cent for surface or near-surface detonations. These percentages, based on the modified Sachs scaling laws, indicate quite a reduction in blast efficiency for high altitude detonations. Lack of verified scaling procedures for these very high altitudes precludes the possibility of drawing firm conclusions at this time.

The objective of Project 9.1d was to obtain supporting atmospheric data for shot Teak. Instrumented Nike-Asp sounding rockets were fired, and the falling sphere technique was used to determine density, pressure, and temperature as a function of altitude between 200,000 and 300,000 ft.

The sphere contained a transit time accelerometer to measure drag acceleration, a telemetry system to relay accelerometer transit times to a ground station, and a DPN-19 beacon to provide, in conjunction with a MSQ-1A tracking radar, space position data. An IBM 650 computer was available to resolve the raw data to solutions for density, temperature, and pressure.

All four soundings were unsuccessful, and firing of subsequent rounds was canceled. Component failures within the sphere were the primary reason that upper atmosphere data were not obtained.

Project 8.6 had as its objective the obtaining of information concerning weapon inputs and corresponding structural effects during high altitude detonations of nuclear weapons. The data would be useful in evaluating the effectiveness of nuclear warheads as the energy source for destruction of an incoming ICBM. A jettisonable instrumented pod was affixed to each of the Teak and Orange Redstone missiles. The pods, ejected prior to burnout, were placed in close proximity to the device at burst time and were designed to be recovered. A two-stage parachute system slowed water entry to preclude hydrodynamic impact damage, and varied devices were installed on the pod to facilitate its location. After a 10-hr daylight search by air and surface craft the hunt for the Orange pod was abandoned. and no data were recovered. Recovery was successful on Teak, however, The objective of Project 2.6 was to provide data on neutron flux (primarily 14 Mev neutrons) versus range from a megaton weapon detonated at a very high altitude. The instrumentation, in three pods for each shot, was carried aloft by the Redstone missile and ejected ballistically at predetermined ranges. The neutron spectrum was measured by the time-of-flight method with special attention being given to the 14.2 Mev neutron group. Various types of detectors measured fast and slow ~~fission neutrons~~, background and prompt gamma rays, gamma ray dose, and interference effects, such as electromagnetic disturbances. The detector outputs were electronically encoded, commutated, and recorded on a magnetic tape recorder. The latter was programmed to record for 120 msec after the prompt gamma ray pulse and to switch repeatedly to a playback condition to telemeter the recorded information to a telemetry station in the missile control bunker. The objectives of this project were apparently accomplished. Gamma ray measurements were consistent from pod to pod.

The observed fluxes were within less than one order of magnitude of expected values. The extraction of further data (including all that on the 14.2 Mev neutrons) required oscilloscope camera methods and film processing facilities not available in the field.

Program B: Ground Studies of Thermal and Electromagnetic Phenomena

The work of Program B during shots Teak and Orange involved six projects.

Project 4.1, supported by thermal measurements from Project 8.1, studied the limiting distances at which chorioretinal burns might be caused by very high altitude detonations. Rabbits were exposed to shots Teak and Orange at stations located on Johnston Island, aboard ships, and in aircraft.

It was found that a very high altitude burst is particularly effective in producing chorioretinal burns because of the rapidity with which thermal energy is delivered to the eye before it can be protected by blinking. This is in contrast to low altitude detonations, where the delivery of thermal energy is slower and the attenuation greater. The limiting horizontal distance at ground level for minimal burns was found to be 300 nautical miles for at 250,000 ft altitude and 225 nautical miles for at 140,000 ft. The size and severity of the lesion correlated with distance. Correspondingly greater limiting distances would apply if the exposure was at altitudes where there would be proportionally less atmospheric attenuation All burns produced within 160 nautical miles would have produced permanent injury or at least a segmented visual defect in man. Visual acuity would have been reduced to from 20/100 to 20/200 if the lesion should occur on the macula.

Projects 6.5 and 6.6 utilized ground based service radars to study the feasibility of determining fireball and cloud parameters, respectively, for very high altitude shots. Both had pursued similar objectives during earlier surface shots at Eniwetok.

The returns from shot Teak were of short duration and did not appear until about H + 1 min, indicating initial absorption followed by reflection from the region of high electron density caused by the fireball. Although there are still attendant problems, location and yield determination for surface bursts using ground radars appears feasible; however, insufficient data were obtained to determine whether such detection is practical for very high altitude bursts.

The cloud detection experiment during the earlier surface bursts was a continuation of work done on Operations Greenhouse, Redwing, and Plumbbob. It appeared that X-band radar was applicable to cloud detection for surface or near-surface bursts. For these, the range of detection is the line-of-sight distance, the detection duration is four to six times longer in humid (EPG) areas than in arid (NTS) areas, and cloud parameters can be measured within the accuracies of the equipment. For bursts above a 90,000-ft altitude, the lack of sufficient moisture or particle density and the level of electron density precludes detection of the cloud by X-band, ground based radars.

Project 6.11 measured the absorption and induced ionization effects of very high altitude detonations with an aim toward resolving anticipated problems of high powered ICBM detection radars. Five discrete frequencies from 10 to 1000 Mc were utilized in specially constructed radars. Riometers were used to detect absorption by measuring any depressions in the integrated cosmic noise; with these, 30-, 60-, and 120-Mc frequencies were used.

It was found that increasing the altitude of the shot radically increases the ionization and absorption effects in the region of 10 to 1000 Mc. Shot Teak, and to a lesser extent shot Orange, strikingly resembled a man-made auroral display observable both visually and with radio equipment, similar to the natural aurora that has been studied with the same techniques in Alaska. At altitudes such as that of shot Teak, considerable high frequency communication blackout occurs, and absorption on the order of minutes occurs near the shot even at ultra-high frequencies. Clutter from the shot-caused aurora would be of concern to a radar operating in the vicinity.

Project 6.12 investigated the nature of radio frequency attenuation through the ionized region produced by very high altitude detonations. Rockets carried L- and S-band pulse carrier radio transmitters to above burst altitudes. Definite changes in signal were noted as the transmitters entered the region of the burst, although the signals were not completely lost. It was concluded that such signals are attenuated, but not to the extent that prior theoretical calculations had predicted.

Program C: Airborne Measurements of Thermal and Electromagnetic Phenomena

There were six projects in Program C: four investigating thermal phenomena (Projects 8.2, 8.3, 8.4, and 8.5) and two studying electromagnetic effects (Projects 6.10 and 6.13). Six aircraft were used, three equipped with thermal instrumentation and three with electromagnetic equipment. All projects were successful on both shots.

For shot Teak there was a single thermal pulse lasting Most of this energy came from molecular emission bands rather than from the blackbody radiation common to surface or near-surface bursts. The infrared radiation was intense but brief--about in duration. The maximum radius of the infrared fireball was almost The thermal pulse from shot Orange showed some of the characteristics of a sea-level shot. There was some evidence of a minimum and a second maximum. Some of the energy was radiated in a continuous spectrum, in addition to spectral bands similar to those from Teak. The infrared emission lasted about and the infrared fireball radius reached a maximum of about

Radar echoes from the ionized cloud were received by two of the aircraft. Returns were observed on UHF band radars for a period of about an hour for both Teak and Orange.

One of the aircraft also carried atmospheric sounding equipment and measured disturbances of the ionosphere produced during both shots. It was found that the electrical properties of the ionosphere were disturbed in excess of 4 hr out to distances of several hundred miles.

2.2 TASK UNIT 1, LASL PROGRAMS

Task Unit 1 carried out experiments to determine device performance, to measure physical quantities of interest in weapon design, and to understand the mechanisms by which the various effects of the devices are produced. In Operation Hardtack new methods were used to determine the configuration of the active material during the reaction period.

Programs 10 and 18, Fireball Physics and Thermal Radiation

The objectives of these programs were: (1) to determine the yields of the devices by observation of the various parameters associated with fireball hydrodynamics; (2) to measure the time interval between primary and secondary reactions in two-stage devices by optical means; (3) to study the phenomena taking place in the rarified air on two high altitude shots of about yield; and (4) to measure total thermal radiation and thermal power on the two very high altitude detonations.

Oscilloscopes and photomultipliers with optical narrow pass filters were used to record gamma-induced light from the air about two-stage devices. Photomultipliers and oscilloscopes with high time resolution were used for observations of narrow bands of the optical spectrum.

Table 2.1 lists yields obtained by Program 10 for shots fired in the EPG.

Total thermal radiation measured on Teak.

Although time interval was measured, the value obtained is probably low by about 10 per cent. The Teller light which provides time interval information originates at approximately 25 to 30 km above sea level, where the main gamma ray flux is stopped. The slow apparent rise time of the rather weak primary signal and unfavorable geometry related to the error in burst position may have caused a delay in the recording of the first signal. It is expected that a correction can be applied after further analysis.

The results of the experiments designed to attain the third and main objective of the two programs were unfavorably affected by the burst location error. Specifically, information on the very early development of the fireball could not be obtained, since none of the collimated instrument channels covered the true burst location. However the limb and so-called "envelope spaces" between radii of 4 and 12 km yielded interesting time-resolved spectroscopic data for times up to 5 min after the burst. They require much specific attention and analysis. Generally one can say that the records will provide information on the fluorescent yield of gamma ray and x-ray excited air, on the energy deposition in the air versus distance from source and thus indirectly on source strength, on transition processes in the medium and low energy deposition range, on gas temperatures and cooling rates, and about early recombination processes. One record shows neutron flux effects on air. Cursory inspection of the spectrograms and oscilloscope traces indicates higher temperatures and a greater degree of ionization at a given radius than expected and thus larger dimensions of the luminous fireball. This is borne out by the observation that the emission by molecular species at 12 km from burst center was of almost equal magnitude as the originally expected signal from the 6-km location. Closer in, singly and doubly ionized atomic species show up where the appearance of molecular species was expected. On the other hand there are indications that the core area of the fireball was less bright than predicted, indicating a higher rate of cooling by radiation flow towards the edges.

The project plans to analyze high speed photographic data for radius versus time and brightness versus time information. The combined information may suffice to check and revise current theory and provide a reasonably comprehensive understanding of high altitude fireball phenomenology.

After failure to obtain early fireball core data from Teak shot, an attempt was made to obtain such data from Orange, although one had to expect very high reaction rates, namely of the order of at least per second. Many instruments were therefore pointed at the burst location and set for highest possible time resolution. Unfortunately the shot was fired under deteriorating weather conditions, resulting in a mean diffuse optical transmission of only 6 per cent; the transmission for the collimated observation channels was even less. Instrument and station performance was

TABLE 2.1

YIELDS OF DEVICES FIRED BY LASL
(Values are in kilotons unless designated Mt)

Shot	Device	Radiochemical Yields: Fission Yield	Radiochemical Yields: Total Yield	Hydrodynamic Yield	Recommended Yield
Cactus			18.2 ± 1.8	16.9 ± 1.6	17.5 ± 1.5
Koa				1.30 ± 0.08 Mt	1.30 ± 0.08 Mt
Butternut					
Holly					
Yellowwood					
Magnolia					
Tobacco					
Rose					
Walnut					
Linden					
Elder					
Oak				8.9 ± 0.6 Mt	8.9 ± 0.6 Mt
Sequoia					
Scaevola					
Pisonia					
Wahoo					
Umbrella					

good. Not one NRL-operated instrument failed; at the LASL end 57 oscilloscope channels recorded out of a possible 61, and Bowen spectrograph channels operated.

The total thermal radiation recorded on Orange was

The time-interval measurement encountered similar difficulties as on Teak, except that they were more severe. Both primary and secondary signals were recorded, but because of scattering in the deep cloud layer the time smear of the primary light prevented the initial sharp rise required for a valid measurement. However unfolding of the otherwise well-written records should yield a useful number.

The majority of the spectrographs and cameras registered either weak signals or none. However, three instruments (two NRL, one LASL) recorded relatively late time information which appears valuable. Also many photoelectric channels wrote a readable signal. These data describe qualitatively the fireball behavior from approximately 1 msec on. Although information for earlier times is not entirely absent, it is very sketchy. Nevertheless there is a fair chance that one will arrive at a useful qualitative picture of Orange fireball development, especially if the spectroscopic data analysis can be supplemented by analysis of the EG&G high speed photographic records taken from airplanes.

Program 11, Radiochemistry

The objectives of Program 11 were (1) to determine the fission yield of the device, (2) to ascertain when possible what nuclear reactions take place in the device, (3) to study specific aspects of the reactions by radiochemical tracers placed within the device, and (4) to determine the production of specific activities in certain areas of the devices arising from materials included in them by design necessity or by intent.

Samples of radioactive material from the cloud were obtained by manned aircraft equipped with specially designed sampling tanks. Radiochemical analyses were made at LASL to determine the fraction of the bomb included in the sample and the number of fission events. The fission yield was determined from these data. Analyses were made to determine the production of various radioisotopes of interest from the bomb materials or from detector samples placed in or near the device.

The results of measurements of fission yields by various methods are included in Table 2.1. An investigation of water samples taken from the lagoon shortly after Walnut shot showed marked fractionation, indicating that such samples were not an adequate replacement for aircraft sampling.

Program 12, External Neutron Measurements

Program 12 was designed to determine the configuration of the active material of certain devices during the nuclear reactions by the Pinex technique, whereby a neutron collimating "pinhole" is placed between the device and detector. A pinhole camera image of the device is formed on the detector, which is a sandwich of various materials to be activated by the neutrons. The sample may be cut into segments and counted on a scintillation counter or placed against a photographic film to produce an autoradiographic image.

Pictures were obtained showing configuration of active materials on four primaries and two secondaries. Further details will be given in the project report.

Program 13, Reaction History

Program 13 measured alpha as a function of time for the fission devices and primaries in order to determine whether they worked properly, and in case they did not, to aide in diagnosing the trouble. It also made measurements indicating the "transit time" for the HE implosion and time from load ring pulse to very early gamma levels in the device.

Alpha detectors, each consisting of a plastic fluor and photocell or photomultiplier combination in a light-tight can, were mounted at appropriate distances from the devices to give a wide range in sensitivity. The signals were conducted over coaxial cables, which were shielded against gamma, neutron, and electromagnetic radiation, to concrete bunkers. These signals then were displayed on a series of high speed oscilloscopes together with timing frequencies and were recorded by cameras. Similar detectors, very near the device, gave signals which were telemetered by a wide band ultra high frequency transmitter-receiver combination and recorded on oscilloscopes.

For details on results of the alpha measurements the reader is referred to the project reports.

Program 14, Phonex-Pinex

The objective of Program 14 was to obtain neutron spectra at a number of positions on the secondary of a two-stage device. Neutrons were allowed to form an image of the source on a hydrogen-containing thin plastic foil by means of a pinhole placed in a mile-long vacuum pipe. Recoil protons from this foil passed through a collimating system and were recorded on nuclear emulsion plates. Tracks were counted and measured to determine the spectrum of the incident neutrons.

Program 15, Photo-Physics

Program 15 was conducted to obtain radius versus time data for hydrodynamic yield determinations, to determine the nature and behavior of a nuclear detonation by photographing the light produced during the initial stages of the detonation, and to study the reaction rate in the secondary of a two-stage device of megaton yield by means of gammas and neutrons emitted from the secondary at various positions.

Framing cameras were operated from several photo stations on each shot to record the growth of the fireball. Very high speed streak cameras were used to record the history of the light arising near the bomb in the first few microseconds. A pinhole in a mile-long vacuum pipe was used to collimate gamma rays and neutrons onto a plastic fluor. Light from the fluor was photographed with high speed streak cameras to record the gamma versus time history and the arrival rate of the neutrons. The latter makes possible the determination of the neutron spectrum at various places.

Program [redacted] Temperature Measurements

The purpose of Program 16 was to determine the temperature induced in a two-stage device by the explosion of the primary.

Program 17, Electromagnetic Measurements

This program measured the time interval between primary and secondary reactions of two-stage devices by electromagnetic signals and studied the signals in order to determine the mechanisms by which the various stages of the signal are produced. The electromagnetic signals accompanying nuclear detonations were picked up by an antenna and recorded on fast oscilloscopes.

2.3 TASK UNIT 2, UCRL PROGRAMS

Program 21, Radiochemistry

The main objectives of Program 21 were to determine the fission yields and the relative thermonuclear and fission efficiencies in different regions of the UCRL devices. Samples of the particulate debris were collected after each test and analyzed in the ZI. Gaseous samples were collected on selected shots and were analyzed for short-lived products in the FA where necessary; the rest were sent to Livermore for analysis.

Airplane sampling was used on all tests; rocket sampling was attempted on several. It was hoped that rockets could be used to supplement and perhaps later obviate the need for manned aircraft. For the present, at least, sampling aircraft seem to be here to stay.

Results are shown in Table 2.2.

Program 22, Reaction History

Program 22 had the responsibility for Pinex as well as the reaction history measurements on all UCRL events. Devices were fired from four different locations with measurements as follows:

1. Tare, Bikini. The three events (Nutmeg, Hickory, and Juniper) fired in the Zuni crater were extensively diagnosed. Coverage included measurements of high explosive transit time, high explosive pins, alpha versus time, boost time, boost temperature and yield from Koala, Pinex, and secondary interval time, where applicable. Pinex was the only entirely new technique employed although several new problems arose from the use of barges, e.g., effects of barge motion on collimation and the effect of water shine on neutron measurements.

2. Charlie and Fox, Bikini. Seven events (Fir, Sycamore, Maple, Aspen, Redwood, Cedar, and Poplar) were fired from various north Bikini locations. Several remote diagnostic schemes were developed for these shots: (1) alpha was measured by a photoelectric telescope which picked up light from a fluor wall mounted on the shot barge, (2) high explosive transit time

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and pin [redacted] were obtained by a pulse telemetry system, (3) stage interval times were measured from Teller light by sweeping cameras and a photoelectric telescope, and (4) interval times were measured by an electromagnetic pickup station.

3. Janet, Eniwetok. Three UCRL events (Dogwood, Olive, and Pine) were fired off Janet. Edgerton, Germeshausen & Grier, Inc., provided the electronic support for the following diagnostic measurements: (1) peak primary alpha on Dogwood and Olive, (2) secondary alpha on Dogwood, (3) time interval between the two primaries on Pine, and (4) secondary interval time on all three.

4. Yvonne, Eniwetok. The last two UCRL shots (Quince and Fig) were fired on Yvonne. EG&G operated the diagnostic station. Complete alpha versus time curves and high explosive transit time data were obtained.

The results of these experiments are contained in the preliminary shot reports and in the various technical reports written by the groups involved.

Program 24, Phonex

Program 24 was conducted to measure the number and energy distribution of the neutrons leaving the surfaces of devices on the Maple and Hickory events. The neutrons were detected by observing proton tracks left in nuclear track emulsions by protons ejected from a thin polyethylene radiator. The number of neutrons was determined from the density of proton tracks in the emulsion coupled with the known geometry of the experiment. The energies of the neutrons were determined from the ranges of the protons in the emulsion. In order to protect the emulsions from blast and radiation, the cameras were placed in heavily shielded collimators. For the Maple event, three such collimators were placed on Fox at distances of 500, 700, and 900 yd from the device. For the Hickory event two collimators were placed on Tare at distances of 240 and 400 yd. The emulsions were successfully recovered from all stations and will be processed and scanned at Livermore.

2.4 TASK UNIT 4, SC PROGRAMS

Program 32, Doorknob

The original intent of Program 32 was to measure the neutron, x-ray, total thermal, and gamma ray emission from a nuclear device burst at an altitude of 250,000 ft. Additional measurements were incorporated in the program as techniques became available for attempting them. These were a sampling of the radioactive debris, optical coverage of the burst, and a measurement of RF attenuation and refraction caused by the ionization of the atmosphere.

The techniques designed to accomplish the mission of the program and the specific measurements and instrumentation involved are as follows:

1. Stations for measuring the neutron, gamma ray, x-ray, and total thermal emissions were put at specified locations by one- and two-stage rocket-propelled instrument carriers. The propulsion units were modified LaCrosse solid propellant motors. The auxiliary hardware was designed specifically for these tests. The carriers were unguided, rail launched bal-

listic rockets with variations in weight and drag for altitude control.

Six stations were located at 40,000, 50,000, 60,000, and 80,000 ft altitude directly beneath the burst, and at 30,000 ft from the burst along the bomb axis and perpendicular to it.

Each carrier had a 226 to 235 Mc band telemetering system aboard with from four to eight subcarriers. The FM-FM receiving and recording station was located near the launch site on Johnston Island.

All six carriers contained transducers for measuring neutron and gamma ray fluxes. The neutron transducer consisted of activation foils that were counted by a scintillometer circuit during the fall time of the nose. Gamma rays were measured as dose rate by scintillometers and as total dose by silver-activated phosphorglass and a densitometer.

In addition, the two stations 30,000 ft from the burst measured x-ray and total thermal inputs at their locations. Both transducers utilized ballistic calorimeters containing resistance wires connected in a four-arm bridge. The total thermal was absorbed by a polished aluminum cone mounted inside a truncated cone. The x rays were filtered through beryllium discs of 50 and 70 mil thickness. The remaining energy impinged upon the calorimeter.

These six carriers also contained film packs for measuring high gamma flux and material samples for effects evaluation. The noses were designed for parachute retardation and for recovery from the ocean.

2. The Redstone carried two 4 KMc diagnostic systems for measuring HE transit time and early alpha of the primary bomb. This system and the WH fuzing system was monitored by 226 Mc telemetry equipment.

All six instrument carriers and the Redstone were tracked by two MIDOT (radio interferometer positioning system) stations for relative positioning of transducers and the burst. The transmitters aboard each carrier served as the beacon.

3. Two radiochemical sampling noses were to be carried through the Teak debris by two stages of the modified LaCrosse motors. These sampled, sealed, and lowered to the water a collection of the burst residue for laboratory analysis.

4. A system for measuring wind velocity at 250,000 ft altitude was designed to permit adjustment of the radchem sampler trajectories to increase the likelihood of sending the sampler through the densest debris. This measurement was made by carrying 5 cm chaff to altitude on a Deacon-Arrow II rocket, ejecting the chaff, and tracking it with a MSQ Radar.

5. The RF attenuation measurements were made by carrying eight transmitters (four operating near 225 Mc and four near 1500 Mc) aloft on eight two-stage rockets and recording received signal strength at two separate locations. Six of these carriers were Deacon-Arrow II combinations and two were Viper II-Arrow II combinations.

6. Optical instrumentation included high speed and longer time photography through three different narrow band filters, a high resolution spectral record, plate cameras located at each MIDOT station for location of burst position, and black and white and color documentary photography.

7. The warheads used on the high altitude shots were modified, installed, checked out, and armed by Program 32.

All equipment used on Teak operated as designed with the following exceptions:

1. The two radchem samplers appeared to suffer structural damage at the time of second-stage burning, became unstable, and fell back to the

reef near Johnston Island. Many of the parts were recovered by skin diving and the type of failure was deduced, if not the primary cause.

2. The two Viper II-Arrow II beacon carrying rockets failed at first-stage burnout and fell back onto the western half of Johnston Island. A subsequent test firing verified this failure.

3. The displaced burst point was outside the beam of the antenna receiving the 4 KMc diagnostic signal and no information was received. The signal, though weak, was seen at the receiving station, and operation of this system was verified by the 200 Mc monitor telemetry.

4. Two of the instrument carriers, the 50,000- and 80,000-ft stations were not recovered. The RF signals indicated the chutes operated satisfactorily, but the long time spent in searching for other nose cones and pods may have allowed these two noses to take on water and sink.

The displaced burst caused the stations to be considerably outside of the intended interest areas, but it appears that most of the desired data will be forthcoming from the records and the four recovered noses. The amount of optical data lost has not been determined at this time.

After Teak, Program 32 was asked to participate in the Orange shot to a larger extent than was originally intended. No attenuation measurements or instrument carriers were originally scheduled for Orange.

The measurements and instrumentation actually attempted on Orange test are as follows:

1. Four radchem samplers.

2. Three instrument carriers, one at 80,000 ft altitude and 95,000 ft horizontally displaced from the burst, and two at burst altitude, one 40,000 ft north and one 40,000 ft west of air zero.

3. Eight Deacon-Arrow II RF attenuation rockets.

4. MIDOT tracking of the three instrument carriers, two of the beacon carriers, and the Redstone.

5. The 4 KMc diagnostic measurement.

6. Photo coverage as on Teak plus documentary coverage from French Frigate Shoals.

7. Warhead.

Equipment operated and results were obtained as follows:

1. The four samplers were recovered, but only the sample collected 40 sec after burst contained any activity. Analysis by LASL will determine if this was adequate.

2. Telemetered data from the three instrument carriers appears satisfactory. The station 40,000 ft north of the burst was not recovered.

3. Only seven RF attenuation rockets were fired. Three 225 Mc systems recorded good data. The 1500 Mc results are not yet known.

4. MIDOT tracking was good.

5. The 4 KMc diagnostic measurements gave transit time and may give a figure for early alpha.

6. The photo coverage was lost because of cloud coverage.

7. The warhead apparently operated as expected.

Program 34, Sandia Support

Project 34.1 was responsible for the telemetry of high-time-resolution data relative to several areas of interest. Of primary importance among these were data on the functioning of Zippers and included: (1) time from X-unit pulse to a known rate of neutron production

and (2) the duration of the neutron pulse at this or a higher rate and the total number of neutrons produced. Coincidental with the Zipper monitoring was a measurement of HE transit time, or time from X-unit pulse to a known point in the period of the nuclear detonation. The Zipper measurements were made on 29 shots with one failure due to unknown causes.

was monitored on two shots using detectors supplied by LASL. On two shots for UCRL, simultaneity measurements between the firings of two primaries were successfully made. On two shots data on pin switch closures were telemetered and turned over to the interested people. On a third shot, Quince, the raster oscilloscopes failed; therefore, no pin switch information was obtained. The Zipper information was obtained from 517 oscilloscopes.

An experimental early alpha system was tried out on 15 LASL shots with at least partial success. The interpretation of these data is not yet complete. The system operates by telemetry of two narrow pulses corresponding to two known gamma levels or generations. The time between the pulses divided by the delta is an average alpha for that period. The making of these measurements and interpretation of the data was complicated considerably by their transmission over channels already crowded with other data.

The responsibility of Project 34.2 was to apply the device fuze and fire

in support of the DOD-sponsored very high altitude balloon test, Yucca. This test device consisted of a

pressurized and hermatically sealed, and fuzed with a radio command system backed up with a baro-controlled timer. The radio command system also supplied signals to actuate the canister deployment, weapon reel out, and emergency cutdown. Cutdown signals were also supplied by the fuze backup time and two clock timers.

Radio command and monitoring of the system was accomplished from a trailer van control station located aboard the USS Boxer. The EG&G timing system was utilized to initiate the arm and fire sequence. After five proof-test flights during Hardtack, the Yucca system was launched on April 28, 1958 at 1125 hr from the flight deck of the USS Boxer at 164°30'E longitude and 11°45'N latitude. At launch plus 8 min, altitude 7000 ft, the five instrument canisters were deployed by radio command, and at launch plus 13 min, 12,000 ft, the Yucca device was reel-deployed by radio command. The balloon-borne system reached a floating altitude of 86,000 ft at launch plus 88 min. Later a delay was requested by TG 7.4. Yucca was detonated by radio command at H-hour prime, 1440 hr, at 12°37'N latitude and 163°01.5'E longitude.

The yield for Yucca, estimated from the history of firings, was given by B. E. Watt, LASL, as The only major operational problem encountered during the test was caused by radio interference with the fuzing command system. After all unnecessary radio circuits below 300 Mc were closed down, all interference disappeared.

The objective of Project 34.3 was to procure, assemble, and check out the devices for the two underwater detonations, Wahoo and Umbrella, sponsored by the DOD.

Procurement of the needed parts included the design and purchase of the watertight device cases, the underwater signal cables, and the necessary firing and assembly equipment. Electrical equipment for both checkout and firing was purchased as regular device components or designed and fabricated by project personnel. Nuclear components were obtained from standard production through the AEC.

One of the major phases of the project's activities was coordination with DOD agencies and other support groups to devise a workable emplacement and firing system. This included taking part in various conferences and tests from the initial planning stages through preliminary sea trials of the suspension system and dry run activities prior to detonation. Checkout and assembly were completed prior to placing the devices in firing position. The device case and underwater signal cables were water-pressure tested before acceptance from the manufacturer. The electrical equipment for firing was tested on numerous dry runs for satisfactory operation. The two devices were detonated satisfactorily without any major difficulties or delays. Some trouble was encountered on the Wahoo event from fairly rough seas which made the zero instrument platform (LCM hull) very unstable. This was not only uncomfortable for personnel but created very unfavorable working conditions and caused deterioration of equipment. These conditions were corrected on the Umbrella event through the use of a larger platform (LCU hull) in an anchored position.

A few trouble spots developed in the fabrication of equipment such as the zero instrument platform, which was to be used by several agencies. These conditions were brought about by poor coordination between the users and fabrication agencies.

For any future test of a similar nature, the following recommendations are offered concerning the activities of Project 34.3:

1. Although the emplacement, suspension, and firing system as used during Operation Hardtack was employed successfully on the two underwater events, a different system, which should include a more stable platform for the zero firing and instrumentation system, would be desired.

2. More time should be allowed for the various support groups to determine their requirements and procure and fabricate special equipment. This action would permit better coordination for preparation of facilities.

The primary purpose of Project 34.4 was to measure blast waves from the Teak and Orange events. High temperatures or wind speeds in the upper atmosphere may cause portions of a blast wave to be returned to the ground at great distances. Microbarograph stations at Johnston Island; Lualualei, Oahu; and French Frigate Shoals were to record these refracted sounds, arrival time, and incidence angles. From these records it is anticipated that winds and temperatures at 100,000 to 180,000 ft, where the blast waves were returned to the ground, may be interpreted.

The secondary purpose of Project 34.4 was to measure blast waves generated near the ground at the Eniwetok Proving Ground. These waves are bent by refraction as they propagate through the upper atmosphere and were recorded at microbarograph stations located at Eniwetok, Bikini, Kwajalein, Utirik, Wotho, and Ujelang.

The microbarograph station at Johnston Island recorded an overpressure of Arrival time for the blast wave at the recording instrument was approximately 193 sec. These data were obtained for the Teak event and together with the Orange data will be evaluated in terms of wind speed and temperature. The same will apply to the recorded data from Lualualei and French Frigate Shoals. The microbarograph data from Eniwetok are being forwarded to Sandia Corporation for evaluation.

Project 34.5 was responsible for supplying Zippers, an external initiation device, to the LASL and UCRL weapon assembly groups. The Zippers were operated successfully on 27 nuclear shots and one safety test.

A new Zipper, S 102, was used for the first time on Operation Hardtack. It proved to be a reliable and versatile unit well suited for field use. Specific details and operating characteristics for the S 102 Zipper can be obtained by referring to the Sandia Corporation Publication, "Operating Manual for the S 102," 1411-186.

Trailers at Eniwetok and Bikini that contained test equipment were used to prepare the Zippers prior to installation at the zero site.
interval generator with an accuracy of 5 mμsec was used as a time standard
A silver counter was used to measure total neutron output. Oscilloscope pictures were taken of the output of a scintillator-photomultiplier tube in order to provide neutron pulse shapes for evaluation.

At the zero site the Zippers were installed in mounts provided by the weapon assembly group. After installation the Zippers were checked on dry runs, at which time the neutron output was monitored by portable scintillators and by Project 34.1 using high time resolution telemetry.

Individual Zipper books containing specific information on each shot have been completed. These books will be available for reference at Sandia Corporation, 5231.

Project 34.6 had responsibilities in three distinct and unrelated areas as follows: (1) systematics, which consisted generally of an intimate and current knowledge of the complete device firing systems, with staff advisory responsibilities to the Commander, Task Unit 2; (2) procurement, test, and field support for X-unit cables for all UCRL events; and (3) detonator electrical test prior to, during, and after assembly of the complete device.

The systematics function was a "first time" venture and was conceived by CTU-2. Sandia furnished this support at the request of UCRL. This function was particularly valuable in the preoperational period and was chiefly one of coordination between various "interconnected" agencies during the planning phase. In the operational period this function, although still valuable, suffered somewhat from manpower shortages, inasmuch as the other two functions are absolutely necessary to a shot and systematics is not.

For future operations it seems that the Arming and Firing Coordinator would be in a better position to handle the function with a minimum of duplication of effort. It was valuable, however, for the systematics coordinator to be located physically near UCRL in order to better handle the valuable preoperational phases.

The detonator test function is self-explanatory. Electrical tests were made on loose detonators or detonator cable assemblies at the request of any of the device field teams, and generally at four steps in the history of the device as follows: (1) prior to device assembly, (2) after device assembly and prior to transfer to zero site, (3) after transporting to zero site, and (4) at pre-arm.

The X-units used on this operation were MC-530 or MC-462 war-reserve quality. The stock units were slightly modified, tested by SCLB and UCRL for simultaneity, and then forwarded to EPG for use. All X-units performed as expected; there were no failures. On one particular shot, Juniper, Project 34.6 designed, built, tested, and fielded a hydrogen-thyratronfired X-unit, which, when coupled with equipment from Project 34.5, provided a precision-delayed firing signal for the Raynex experiment. The Raynex device was successfully detonated with the requested degree of time accuracy.

The objective of Project 34.7 participation on the Quince event was to study prompt nuclear dose rate effects on weapon materials and components. This interest stems from the need to reduce the vulnerability of nuclear weapons to other nuclear bursts and environments, and from observed instances of variation in radiation damage criteria between in-reactor exposures as compared with prompt nuclear bursts.

Specimens of transistors, diodes, capacitors, resistors, plastics, semiconducting materials, detonators, and high explosive materials were exposed to prompt nuclear dose rates in the range from The effect produced in these specimens will be compared to effects produced in similar specimens exposed in reactors to the same total neutron dose at much lower rates.

The aims of Project 34.8/2.14a were: (1) to make the necessary measurements on Quince event to delineate the fallout gamma radiation yield produced by a land surface detonation of a fission weapon with a yield between (2) using data collected by this project and by Projects 34.9 and 34.10, to construct a fallout model for use with any wind pattern and evaluate extremes in militarily significant intensities for the same yield range; and (3) to define the attendant plutonium contamination problem.

The site for Quince event was Runit (Yvonne) Island of Eniwetok Atoll. Only about 400 ft of land in the prevailing downwind direction was available for radiation monitoring, necessitating placement of bulk of the instrumentation in the lagoon. There were 92 lagoon stations, 46 land stations, and 8 reef stations. The bulk of the fallout instrumentation consisted of sticky pan fallout collectors. These were mounted on small buoys in the lagoon and on steel pipes in the reef area. After exposure, the pans were counted in a fixed geometry. Lagoon and reef pan readings were calibrated in terms of full yield intensities by dose rate measurements over the available land and flat-topped barges which were anchored in the lagoon. Dose rate readings on land and on the barges were made by hand-monitoring and by automatic recording instruments.

Since Quince it was decided to measure fallout from Fig, using the same array of instrumentation. Fig event produced fallout intensities greater than 100 r/hr at H + 1 hr, covering an area which extended 100 ft upwind to less than 1000 ft downwind and 150 ft crosswind. Beyond 400 ft upwind and 2600 ft downwind, intensities were less than 1 r/hr at H + 1 hr.

Project 34.9/2.14b was responsible for photographing the cloud produced by the Quince and Fig events. The main objective was to determine the cloud dimensions as a function of time. These measurements were necessary to assist Project 34.8 in constructing a fallout model.

That produced by Fig stabilized at 5400 ft approximately 6 min after zero time. Maximum diameter was 1900 ft, stem height was 75 per cent of the total height, and the puff diameter was 1.35 times that of the stem.

One of the objectives of Project 34.10/2.14c was to measure the preshot wind conditions over expected cloud heights for Quince and Fig so that shot time could be set to assure that expected fallout would be adequately sampled by the instrument array of Project 34.8. A second objective was to measure the postshot wind conditions to aid in construction of a fallout model by Project 34.8. Both objectives were completed satisfactorily.

2.5 PROGRAM 40, RADIOBIOLOGICAL SURVEY

The objectives of Program 40 were to determine the amounts and distribution of radioisotopes in the sea water, soil, and biological material at the test site, in the northern Marshalls, eastern Carolines, and other islands westward to the Palaus.

Pretest surveys were conducted at Eniwetok and Rongelap Atolls to determine the isotope content and the amounts of residual radioactivity from the previous test programs.

During the operation, soil, plants, and animals were collected from the islands of Eniwetok and Bikini Atolls and from the reefs and lagoons for measurement of radioactivity. Emphasis was placed on samples of food, water, plankton, and soil. Selected samples were analyzed for isotopic content. Observations on the rat population at Janet Island, Eniwetok, were continued to evaluate the soil-plant-rat relationship.

Tungsten-185, an isotope not previously detected at Eniwetok Atoll, was found on plant leaves (7.9×10^6 d/m/g dry weight) and soil (13×10^6 d/m/in.^{2}) samples from Belle Island, and lower levels were detected at Janet, Vera, Keith, and Henry. The isotope was also present on samples from Bikini, Ujelang, and Rongelap Atolls and on plankton collected nearby (Report UWFL-57, 1959). The levels of the other radioisotopes in the same samples were also determined.

The U.S. Hydrographic Office, Office of Naval Research, Naval Medical Research Institute, and the Laboratory of Radiation Biology, University of Washington, undertook a cooperative program on shot Wahoo aboard the USS Rehoboth (AGS-50) to measure the amount, kinds, and movement of radioactive materials. The methods used included survey readings, automatic monitoring gear installed on the ship's water systems, a deep water scintillation probe, and radiochemical separations on samples of water, plankton, and fish.

The initial survey showed that the major radioactivity in the water extended one mile southeast from target zero 80 min post shot (500 mr/hr) and about 3 miles west within 2 hr. In this area the radioactivity was mostly above the thermocline (100 m). At 48 hr post detonation, the major part of the radioactivity at target zero was below the thermocline. After 3½ days the detectable boundaries of the radioactive water mass extended west from target zero at least 50 miles and to a depth of 300 meters. The plankton contained principally Np^{239}, Mo^{99}-Tc^{99m}, Te^{132}-I^{132}, and U^{237}. Present in lesser amounts were Ce^{141}-Pr^{141}, Ru^{103}-Rh^{103}, Ba^{140}-La^{140}, and Zr^{95}-Nb^{95}. Fish had essentially the same radioisotope content as the plankton. Shrimp and squid contained Np^{239} and Te^{132}-I^{132} but no detectable Mo^{99}-Tc^{99m} (UWFL-58, 1959).

In order to evaluate the distribution of fallout outside the area of the EPG, measurements were made and samples collected at the weather stations on Ponape, Kusaie, Tarawa, Ujelang, Utirik, Kapingamarangi, and Wotho Atolls. The highest levels of activity were found in samples from Ujelang, Utirik, Wotho, and Rongelap Atolls. The radioactivity at the other sites was not appreciably above background.

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Because of the economic importance of tuna fishing in the Western Pacific, a project was undertaken to sample commercial fishery catches landed in Japan, since this appeared to be the best means of obtaining the coverage required to sample the area. From a total of 572 fish, 2722 samples were taken, including specimens of dark and light muscle, skin, liver, heart, kidney, spleen, stomach, stomach content, intestine, gonad, gill, and bone. In those samples containing radioactivity, Zn^{65} contributed 75 to 92 per cent of the total, with Fe^{55}, Fe^{59}, Co^{57}, Co^{58}, Co^{60}, and Mn^{54} accounting for most of the remainder. In no case were the levels of radioactivity greater than the maximum permissible concentration for drinking water.

Following the completion of the testing program, the region including the EPG and the area westward to Guam was surveyed to determine the amount, kinds, and extent of radiological contamination of the western Pacific Ocean. The survey was conducted in two sections: The USS Collett (DD-730) was used to survey the restricted area in August 1958, and the USS Silverstein (DE-534) was used for the survey in September extending to Guam. The The latter survey included an area bounded by 10°20' and 17°00'N and 144°50' and 161°51'E.

The upper, mixed layer of the ocean was sampled at stations on a grid at about 50-mile intervals. Samples included water, plankton, and fish at depths to 300 meters.

During the August trip W^{185} was found on plankton (19×10^6 d/m/g dry weight) collected 155 miles northwest of Eniwetok Atoll. This center of radioactivity had shifted 150 miles westward by the time of the second survey, and all the W^{185} had been lost from the plankton. The major remaining radioisotopes were Co^{58}, Ba^{140}-La^{140}, Zn^{65}, Co^{57}, Co^{60}, and Zr^{95}-Nb^{95}. The leading edge of the radioactive body of water was 200 miles east of Guam Island by September 1958.

Samples of crater material and sea water were collected in the target area of the Umbrella detonation and analyzed for radioisotope content. The anions Np^{239}, U^{237}, Te^{132}-I^{132}, Mo^{99}-Tc^{99m} accounted for 90 to 98 per cent of the total radioactivity in the samples. The isotope content of particles greater than 0.5 micron from the sea water was different from that in the fraction smaller than 0.5 micron.

The long range radiation ecology study at Rongelap was continued. Major emphasis was placed on studies of the soil-plant relationship, aquatic bird populations, and mineral transport, as well as evaluations of the uptake of specific isotopes by plants and animals used as food by the natives.

Chapter 3

GENERAL ACTIVITIES OF TASK GROUP 7.1

3.1 MISSION

Parts of the mission assigned to JTF 7 by agreement between AEC and DOD were:

1. Prepare for and conduct in the spring and summer of 1958 tests of such experimental devices as may be approved by the DOD or AEC.
2. Prepare for and conduct in association with the above tests experimental measurements necessary for the successful completion of the tests as approved by the DOD or the AEC and such weapon effects programs as may be approved by the DOD or the AEC.
3. Maintain the EPG as a closed area within the capability of forces available.
4. Assume responsibility for safety of populated islands relative to hazards introduced by the operation.

In order to accomplish their mission, JTF 7 assigned the following responsibilities to TG 7.1:

1. Position, arm, and detonate the nuclear test devices as authorized by CJTF 7.
2. Conduct such experiments on each nuclear explosion as are needed to fulfill the technical requirements determined by appropriate authority within the AEC and/or DOD and are in addition operationally feasible.
3. Provide such technical information, guidance, and services to all participating elements of the Joint Task Force as may be required for the conduct of their respective missions.
4. Ascertain and transmit to the appropriate headquarters the requirements for services to be furnished to TG 7.1 by other participating elements of the Joint Task Force.
5. Submit check lists of tasks to be accomplished prior to, during, and after each detonation.
6. Submit a written final report no later than 15 days subsequent to the last detonation of the Hardtack test series.

3.2 ORGANIZATION AND COMMAND RELATIONSHIPS

The organization chart of JTF 7, shown in Fig. 3.1, differed from the

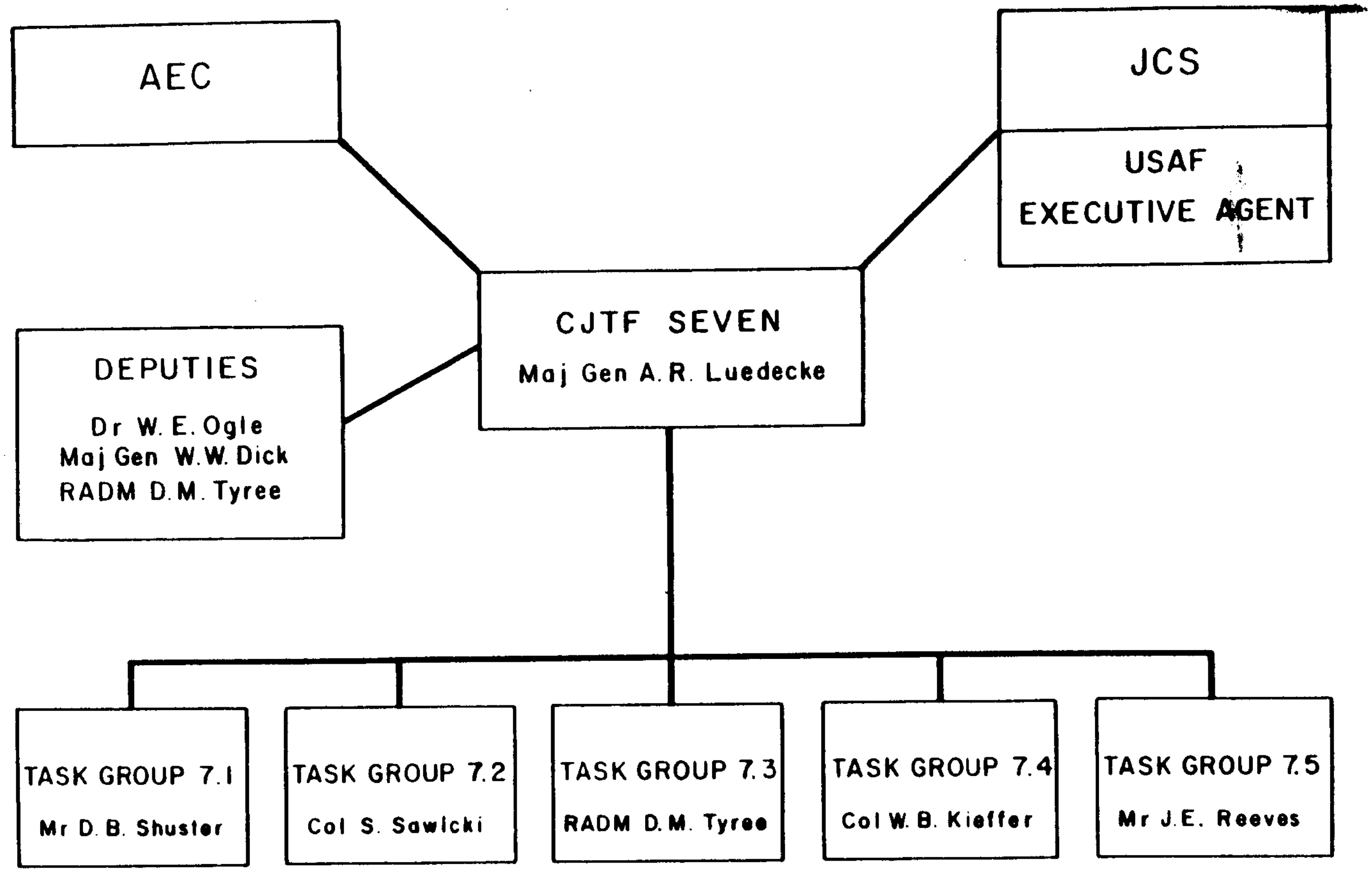

Fig. 3.1 Organization Chart - Joint Task Force 7.

Redwing chart by the omission of a dotted line called "Scientific Supervision" from the AEC to the Deputy Commander for Scientific Matters to Task Groups 7.1 and 7.5.

The TG 7.1 organization for Hardtack, shown in Fig. 3.2, represented a change from the Redwing organization in the following respects:

1. Task Units were reduced from twelve to six by absorbtion of the assembly and documentary photography functions within the major Task Units and by establishing Arming and Firing as a special staff office instead of a Task Unit. Task Units 1 to 4 remained major programmatic Task Units; Task Unit 5 continued to provide all timing and firing and to do some experimental work for Task Units 1, 2 and 3; and Task Unit 6 provided the usual rad-safe services.

2. Additional Deputy Commanders were provided, which somewhat facilitated independent operations in two locations, and later three, when Johnston Island was added.

3. On October 1, 1957, Gaelen L. Felt, CTG 7.1, terminated his employment at LASL. Don B. Shuster, of the Sandia Corporation, replaced him as Task Group Commander. As a result, each of the five major Task Units was represented in the Command Section. Neither the Commander nor any of the deputies performed any special Task Group functions for their parent organizations.

4. During the operational phase, Task Unit 7 was added to take care of a UN shot, which failed to materialize. Because of the purpose and nature of the shot, the limited amount of data to be acquired, and the fact that much of the preparation was outside the Task Force organization, Task Unit 7 bore little resemblance to any of the others.

Command relationships were closer to the military pattern than they were to those for operations at the Nevada Test Site. However, one important difference from normal military command relationships was that the TG 7.1 concept of operations and operation plans stemmed from the device and weapon programs and experimental programs of the Laboratories and the DOD, over the composition and extent of which the Task Group and Task Force had little or no control. In the normal military operation the commander formulates plans from the very beginning of the operation; the plans of subordinates stem from these. Because of these differences and since support of the TG 7.1 effort was among the principal functions of the Task Force and other Task Groups, their plans and operations depended in many ways on those of 7.1.

The Commander, JTF 7, authorized direct relationships among the various Task Groups once he had established policy and major items of support. Relationships of TG 7.1 with the Joint Task Force and with the other Task Groups were good and resulted in generally excellent support for the accomplishment of 7.1 missions.

Relationships within TG 7.1 were close and cordial. During the planning stage the Task Group Commander and members of his staff made frequent visits to the Field Command, AFSWP, and UCRL, and to Program and Project sites as necessary, to get first-hand information cn plans and requirements and to ensure operational feasibility, safety, coordination, and adequate support. Many visitors were received from the Task Units, Programs and Projects. Necessary meetings were held at locations most convenient for the bulk of the participants — Los Alamos, Albuquerque, Liver-

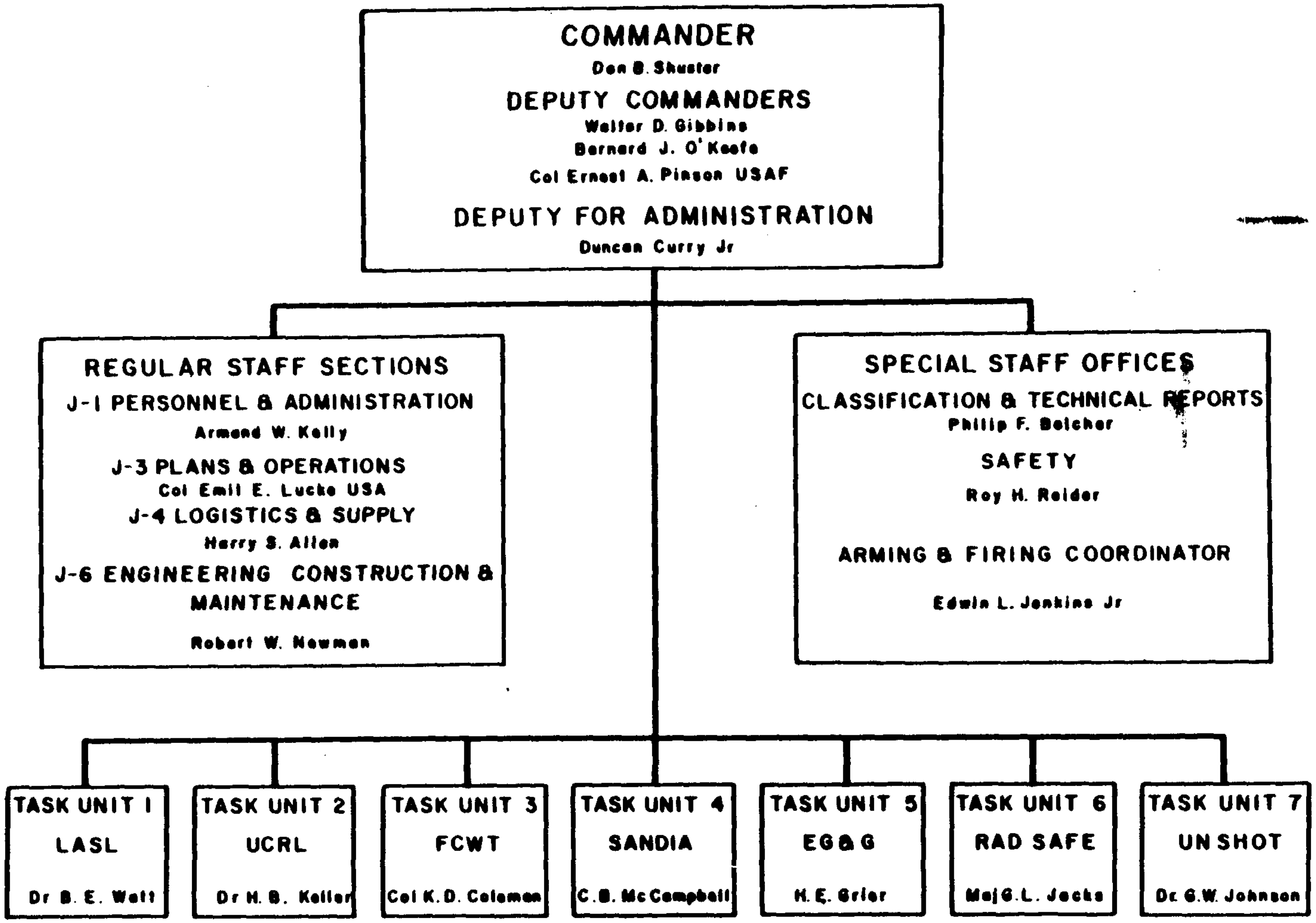

Fig. 3.2 Organization Chart - Task Group 7.1.

more, Travis AFB, Cape Canaveral, and San Diego, to name a few. Table 3.1 lists the key personnel of TG 7.1.

3.3 PLANNING AND TRAINING

Programs, Schedules, and Concepts. Planning for Operation Hardtack essentially started during Operation Redwing as ideas for improvement of operations were generated by the participants in the test area. These ideas, for example, involved the use of Taongi to offset delays caused by weather and fallout problems, and use of separate atolls by the two weapon laboratories to improve the continuity of effort and reduce the excessive commuting between Bikini and Eniwetok.

By the fall of 1956, the DOD had decided on five shots it planned to sponsor and on the major effects projects it proposed to carry out on Hardtack. At the end of January 1957, the Eniwetok Planning Board considered those 5 shots plus 12 sponsored by LASL and 14 by UCRL as the total program for the 1958 EPG operation. By June of 1957, the general concept of the operation had been evolved and was published for planning guidance, listing a total of 27 shots. This initial shot schedule was revised three times before publication of the Task Group's Operation Plan in January 1958 and, prior to the first detonation of Hardtack, two more changes to the shot schedule were issued. During the entire period 10 revised shot schedules were published, listing the latest available information on ready dates and expected yields, with pertinent remarks as to zero locations and shielding for the different devices and weapons.

Detailed planning for diagnostic and effects programs was, of course, slowed down as a consequence of the constantly changing shot schedule. It was further complicated by the competition for the experimenter's time when he was deeply involved in the Plumbbob operation in Nevada. Late decisions on whether or not to use Taongi, and on establishing the starting date for the operation as either April 1 or May 1 also served to hinder planning.

By the start of the operation, however, there had evolved the following more important concepts affecting operational planning and determination of requirements:

1. Both Bikini and Eniwetok Atolls would be used as shot sites for megaton as well as smaller yield shots. UCRL would conduct its tests on Bikini, while LASL would operate on Eniwetok - each independent of the other.

2. The DOD high altitude missile shots would be launched from Bikini Island, and the high altitude balloon shot would be fired from the USS Boxer between the two atolls. The two underwater shots would be detonated in the vicinity of the southern islands of Eniwetok.

3. General evacuation of Bikini Atoll would take place for four shots, the UCRL Sycamore and Poplar devices, and the two high altitude missile weapons.

4. A capability of conducting limited operations afloat while Bikini was evacuated would be maintained, as would an emergency evacuation capability for both atolls.

Two major changes in these concepts occurred after the operational phase started. Most drastic was the decision to transfer the Redstone missile shots to Johnston Island in order to reduce the flash blindness problem. Later in the operation it also became necessary to transfer some of the

TABLE 3.1

KEY PERSONNEL OF TASK GROUP 7.1

Unit or Section	Name	Organization
Commander	Don B. Shuster	SC
Deputy Commanders	Walter D. Gibbins	UCRL
	Bernard J. O'Keefe	EG&G
	Ernest A. Pinson, Col, USAF	FC, AFSWP
Deputy for Administration	Duncan Curry, Jr.	LASL
Classification, Security Liaison	Philip F. Belcher	LASL
and Technical Reports	Lucie D. Connolly	LASL
	John M. Harding	LASL
	Robert D. Krohn	LASL
	Willie V. Ortiz	LASL
	Leslie M. Redman	LASL
Arming & Firing Coordinator	Edwin L. Jenkins, Jr.	SC
	Robert Burton	SC
	Charles H. Stockley	SC
	John P. Johnson	SC
Safety	Roy Reider	LASL
J-1, Personnel and Admin-	Armand W. Kelly	LASL
istration	Samuel R. Whitaker	LASL
	Robert C. Beiler	LASL
Military Executive	Kenneth A. Noseck, LtCol, USA	LASL
J-3, Plans and Operations	Emil A. Lucke, Col, USA	LASL
Assistant J-3	James T. Avery, Jr., Col, USA	LASL
	Robert H. Gattis, Col, USAF	LASL
	John H. Wendell, CDR, USN	LASL
J-4, Logistics and Supply	Harry S. Allen	LASL
	Robert J. Van Gemert	LASL
	John W. Lipp	LASL
J-6, Engineering, Construction,	Robert W. Newman	LASL
and Maintenance	Rea Blossom	LASL
TU-1 - LASL Programs	Bob E. Watt	LASL
	R. Lee Aamodt	LASL
	Herman Hoerlin	LASL
Advisory Group	Keith Boyer	LASL
	Alfred T. Peaslee, Jr.	LASL
	David A. Liberman	LASL
Technical Assistants	Andrew M. Koonce	LASL
	Alvin L. Embry	LASL
J-1	William B. Sayer, LTJG, USN	LASL
J-3	Santo Italia, Maj, USAF	LASL
J-4	John W. Lipp	LASL
J-6	Rea Blossom	LASL
J-7, Design	James H. Hill	LASL
Photography	Robert C. Crook	LASL
	Robert Perlee	LASL
Computers	Paul E. Harper	LASL
	Reginald E. Martin	LASL

Weapon Assembly	R. Keith Young	LASL
Program 10	Herman Hoerlin	LASL
Project 10.1	Joseph F. Mullaney	LASL
Project 10.2, 10.3	Donald Westervelt	LASL
Program 11	George A. Cowan	LASL
Project 11.1	George A. Cowan	LASL
Project 11.2	Paul R. Guthals	LASL
Project 11.3	Phillip F. Moore	LASL
	Charles I. Browne	LASL
Program 12	R. Lee Aamodt	LASL
Project 12.1	Wendell A. Biggers	LASL
Program 13	John S. Malik	LASL
Project 13.1	Robert B. Patten	EG&G
Project 13.2	Robert G. Scharrer	SC
Project 13.3	Sidney N. Singer	LASL
	Leland K. Neher	LASL
Program 14	John Brolley, Jr.	LASL
Program 15	Arthur N. Cox	LASL
Project 15.1	Herbert E. Grier	EG&G
Project 15.2	Robert S. Fitzhugh	LASL
Program 16	Neel W. Glass	LASL
Program 17	Ralph E. Partridge	LASL
Project 17.1	Ralph E. Partridge	LASL
Project 17.2	Maurice Janco	LASL
Project 17.3	Ralph E. Partridge	LASL
Program 18	Herman Hoerlin	LASL
Project 18.1	Harold S. Stewart	NRL
	Frank Harrington	NRL
TU-2 - UCRL Programs	Harry B. Keller	UCRL
Alternate	Charles E. Violet	UCRL
Assistant to Commander	Jerry Zenger	UCRL
Advisory Group	Harold Brown	UCRL
	John S. Foster	UCRL
	Kenneth Street	UCRL
	Louis F. Wouters	UCRL
Rad-Safe	William E. Nolan	UCRL
Safety	John O. Vineyard	UCRL
	Bruce E. Linkous	UCRL
Electrical Systems	Walter Maupin	SC
	Robert Tockey	SC
Device Systems Coordinator	Walter F. Arnold	UCRL
Assembly Facility Coordinator	Wallace Decker	UCRL
	Arthur Werner, Jr.	UCRL
	Kenneth W. Copenhagen	UCRL
Support Staff Sections		
Coordinator	Vernon Denton	UCRL
Alternate	Clifford M. Bacigalupi	UCRL
Field Services	Roland W. Wallstedt	UCRL
L-4	Daniel J. Murphy	UCRL
L-6	Robert B. Petrie	UCRL
Documentary Photography	Raymond H. Jaeger	UCRL

Program 21	Robert H. Goeckermann	UCRL
Project 21.1	Robert H. Goeckermann	UCRL
Project 21.2	Roger E. Batzel	UCRL
Project 21.3a	Edward H. Fleming, Jr.	UCRL
Project 21.3b	Edward H. Fleming, Jr.	UCRL
Project 21.4	Floyd F. Momyer, Jr.	UCRL
Project 21.5	Norman A. Bonner	UCRL
Program 22	Myron W. Knapp	UCRL
Project 22.1	William H. McMaster	UCRL
	Arnold F. Clark	UCRL
Project 22.2	Ervin C. Woodward, Jr.	UCRL
	Jack N. Shearer	UCRL
Program 24	Francis C. Gilbert	UCRL
TU-3 - DOD Programs	Kenneth D. Coleman, Col, USAF	FC/AFSWP
Technical Assistant	William R. Hammond, Maj, USAF	FC/AFSWP
Operations	John C. McClure, LtCol, USAF	FC/AFSWP
	John Tyson, LtCol, USAF	FC/AFSWP
Requirements Branch	William A. Mowery, LtCol, USA	FC/AFSWP
Administrative Office	Charles A. Swartzell, Capt, USA	FC/AFSWP
Reports Branch	Walter J. Miller	FC/AFSWP
Logistics	George P. Forsyth, Maj, USAF	FC/AFSWP
Communications	George M. Adams, LtCol, USAF	FC/AFSWP
	Edward M. Thornbury, Maj, USAF	FC/AFSWP
Timing	Thomas B. Windsor, Maj, USA	FC/AFSWP
Classification	Charles R. Moorhead, Jr., LtCol, USA	FC/AFSWP
	Frederick A. DePalma, Maj, USAF	FC/AFSWP
Deputy Commander, Eniwetok	Alfred H. Higgs, CAPT, USN	FC/AFSWP
Special Assistant, Navy	Corwin G. Mendenhall, CAPT, USN	FC/AFSWP
Special Assistant, A/C Mod	Jack G. James, LtCol, USAF	FC/AFSWP
Deputy Commander, Bikini	Harold Black, LtCol, USA	FC/AFSWP
Dir. for Delivery System	Roger Ray, Maj, USA	FC/AFSWP
Special Assistant, VHA	Harry C. Henry, LtCol, USAF	FC/AFSWP
Program 1	John W. Kodis, LtCol, USAF	FC/AFSWP
	Francis E. Shoup, 1/Lt, USAF	FC/AFSWP
Project 1.1	Elijah Swift, Jr.	NOL
Project 1.2	Peter Hanlon	NOL
Project 1.3	Elijah Swift, Jr.	NOL
Project 1.4	Andrew W. Patteson	ERDL
Project 1.5	Tom McMillian	NEL
Project 1.6	Lewis W. Kidd	SIO
Project 1.7	Julius J. Meszaros	BRL
Project 1.8	Lawrence M. Swift	SRI
Project 1.9	Edward H. Bultmann, Capt, USAF	AFSWC
Project 1.10	Jack T. Pantall, Jr., Capt, USAF	AFCRC
Project 1.11	Francis B. Porzel	ONR/ARF
Project 1.12	James F. Halsey	AFBMD
Project 1.13	James W. Winchester	ONR
Program 2	Gordon C. Facer, CDR, USN	FC/AFSWP
	John A. Chiment, Maj, USA	FC/AFSWP
Project 2.1	Michael M. Bigger	NRDL
Project 2.2	Michael M. Bigger	NRDL
Project 2.3	Evan C. Evans III	NRDL

Project 2.4	John W. Kinch	CWL
Project [redacted]	David L. Rigotti	CWL
Project 2.6	Thomas D. Hanscome	NRL
Project 2.7	Paul A. Caldwell	NRL
Project 2.8a, b	Richard R. Soule	NRDL
Program 3	John F. Clarke, LCDR, USN	FC/AFSWP
	Charles W. Gulick, Jr., LT, USN	FC/AFSWP
Project 3.1	Heinrich M. Shauer	UERD
Project 3.2	Gifford H. Albright, LTJG, USN	NCEL
Project 3.3	Harry L. Rich	DTMB
Project 3.4	William W. Murray	UERD
Project 3.5	Harry L. Rich	DTMB
Project 3.6	Edward H. Bultmann, Capt, USAF	AFSWC
Project 3.7	William J. Flathau	WES
Project 3.8	James J. Kearns	BUSHIPS
Program 5	Frank E. O'Brien, LtCol, USAF	FC/AFSWP
Project 5.1	William R. Lounsberry, Capt, USAF	WADC
Project 5.2	Paul A. Anderson, LCDR, USN	BUAER
Project 5.3	Morris A. Esmiol, Jr., LCDR, USN	BUAER
Project 5.4	Frank E. O'Brien, LtCol, USAF	FC/AFSWP
Program 6	Edward G. Halligan, LtCol, USA	FC/AFSWP
	Severino Martinez, LtCol, USA	FC/AFSWP
Project 6.3	Edward E. Conrad	DOFL
Project 6.4	Felix J. Lavicka	USASIGRDLAB
Project 6.5	Gerald Carp	USASIGRDLAB
Project 6.6	Cecil W. Bastian	USASIGRDLAB
Project 6.7	Glenn M. Davidson	NOL
Project 6.8	Robert E. Lee, LCDR, USN	MDL
Project 6.9	Burton D. Jones, 1/Lt, USA	USASIGRDLAB
Project 6.10	George J. Gassman	AFCRC
Project 6.11	Lambert T. Dolphin	SRI
Project 6.12	Gerald Carp	USASIGRDLAB
Project 6.13	Verne L. Lynn	MIT, Lincoln
Program 8	William C. Linton, Jr., Maj, USA	FC/AFSWP
Project 8.1	Willard L. Derkson	NML
Project 8.2	Richard M. Brubaker, Maj, USAF	AFCRC
Project 8.3	Lewis Fussell, Jr.	EG&G
Project 8.4	William B. Plum	NRDL
Project 8.5	Ralph Zirkind	BUAER
Project 8.6	Charles J. Cosenza	WADC
Program 9	William M. Sheehan, LtCol, USA	FC/AFSWP
	William S. Isengard, Maj, USAF	FC/AFSWP
Project 9.2a, b, c	Arlo E. Gilpatrick, Maj, USAF	AFCRC
Deputy Commander, Subkiloton		
Event	Corwin G. Mendenhall, CAPT, USN	FC/AFSWP
Operations	Robert L. Dickenson, LtCol, USA	FC/AFSWP
Requirements and Construction	John E. Thomas, Capt, USA	FC/AFSWP
Administration	George R. Osbourn, CWO, USA	FC/AFSWP
Program A	William S. Isengard, Maj. USAF	FC/AFSWP
Project 1.7	Daniel P. Lefevre	APG
Project 8.7	Jerry J. Mahoney	CWL

Program B	William G. Sheehan, Capt, USA	Hq/AFSWP
Project 2.4	David L. Rigotti	CWL
Project 2.9	Manfred Morgenthau	CWL
Project 2.10	Manfred Morgenthau	CWL
Project 2.11	David L. Rigotti	CWL
Deputy Commander, Johnston	Harold Black, LtCol, USA	FC/AFSWP
Operations	Richard M. Elliott, LtCol, USMC	FC/AFSWP
Director for Delivery System	Roger Ray, Maj, USA	FC/AFSWP
Project 9.3a, b	Glenn P. Elliott, Col, USA	ABMA
Requirements	Robert C. Vance, LT, USN	FC/AFSWP
Logistics	Bill M. Saye, Capt, USA	FC/AFSWP
Communications	George M. Adams, LtCol, USAF	FC/AFSWP
Classification	Louis J. Cloutier, Capt, USAF	FC/AFSWP
Photography	Charles E. Campbell, Maj, USA	FC/AFSWP
Administration	Leroy A. Snodgrass, CWO, USA	FC/AFSWP
Program A	Joseph L. Delaware, LCDR, USN	FC/AFSWP
Project 1.7	Julius J. Meszaros	BRL
Project 2.6	Thomas D. Hanscome	NRL
Project 8.6	Charles J. Cosenza	WADC
Project 9.1d	Russell E. Loftman	CDC
Program B	Edward G. Halligan, LtCol, USA	FC/AFSWP
	C. Edward Lindberg, 2/Lt, USA	FC/AFSWP
Project 4.1	John E. Pickering, Col, USAF	Sch. of Av. Med.
Project 6.5	Theodore C. Viars	USASIGRDLAB
Project 6.6	Cecil W. Bastian	USASIGRDLAB
Project 6.10	George J. Gassman	AFCRC
Project 6.11	Lambert T. Dolphin, Jr.	SRI
Project 6.12	Stanley E. Bania	USASIGRDLAB
Project 8.1	Harold Korbel	NML
Program C	Jack G. James, LtCol, USAF	FC/AFSWP
	Harry W. Jones, Capt, USAF	FC/AFSWP
	Francis E. Shoup, 1/Lt, USAF	FC/AFSWP
Project 8.2	Richard M. Brubaker, Maj, USAF	AFCRC
Project 8.3	Jack H. Knight	EG&G
Project 8.4	Edd C. Y. Inn	NRDL
Project 8.5	Ralph Zirkind	BUAER
Project 6.13	Verne L. Lynn	MIT, Lincoln
TU-4 - Sandia Programs	Carroll B. McCampbell, Jr.	SC
Deputy Commanders	George P. Stobie	SC
	Clarence E. Ingersoll	SC
Scientific Advisor	Melvin L. Merritt	SC
Administrative Support		
A-1, 3, 4	Clifford A. Blossom	SC
A-6	Hugh R. MacDougall	SC
Photography	Henry G. Sweeney	SC
Program 32	Morgan L. Kramm	SC
	Charles G. Scott	SC
Scientific Advisor	Thomas B. Cook, Jr.	SC
Project 32.1	Richard L. Eno	SC
Project 32.2	John A. Beyeler	SC
Project 32.3	James L. Dossey	SC
Project 32.4	Charles G. Scott	SC

Project 32.5	David E. Henry	SC
Scientific Advisor	John R. Banister	SC
Project 32.6	Vincent G. Redmond	SC
	Theodore P. Krein	SC
Scientific Advisor	Harold R. Vaughn	SC
Program 34	Hans E. Hansen	SC
	A. Dean Thornbrough	SC
Scientific Advisor	Maynard Cowan, Jr.	SC
Rad-Safe Support	Harold L. Rarrick	SC
Project 34.1	Robert G. Scharrer	SC
Project 34.2	Tom H. Takahashi	SC
Project 34.3	Ira D. Hamilton	SC
Project 34.4	Robert A. Jeffrey	SC
Project 34.5	Edwin L. Jenkins	SC
Project 34.6	Walter A. Maupin	SC
	Robert A. Tockey	SC
Project 34.8	Raymond E. Butler	SC
Project 34.9	Henry G. Sweeney	SC
Project 34.10	Deacon G. Palmer	SC
TU-5 - EG&G Programs	Herbert E. Grier	EG&G
Deputy Commander	Lewis Fussell, Jr.	EG&G
	Francis I. Strabala	EG&G
Technical Administration-Bikini	Donald F. McClellan	EG&G
	Roderick G. Morrison	EG&G
	Ralph L. Cadwallader	EG&G
Timing & Firing	Michael F. Warchol	EG&G
Radar & Weather	Ernest F. Wilson	EG&G
Photography	Frederick E. Barstow	EG&G
Photo Processing	Charles W. Wyckoff	EG&G
Alpha	Robert B. Patten	EG&G
	William R. Poe	EG&G
Communications	Joseph B. Shrock	EG&G
	F. Glenn Wilhelm	EG&G
Analysis	Daniel F. Seacord	EG&G
	Bruce M. Carder	EG&G
	Donald J. Barnes	EG&G
Construction Administration	Erick R. Spiess	EG&G
	Jess C. Cauble	EG&G
Office & Security Administration	M. Boyd Carpenter	EG&G
	Frank E. James	EG&G
	Edward J. Finn	EG&G
	Edward K. Raschke	EG&G
TU-6 - Rad-Safe	Gordon L. Jacks, Maj, USA	LASL
Deputy, Eniwetok	Fred E. Rosell, Maj, USA	1st RSSU
	Rudolph S. Buddee, Capt, USA	CMLC
Deputy, Bikini	Robert L. Harvey, LCDR, USN	LASL
	Ralph N. Whistler, LT, USN	LASL
Instrument Repair	Robert D. Higgins, 2/Lt, USA	1st RSSU
Photo Dosimetry	George Zimmerman, SFC, USA	LASL
Program 40	Allyn H. Seymour	AEC DBM
	Lauren R. Donaldson	UWAFL

UCRL shots to Eniwetok to take advantage of its better weather conditions.

To provide a method of compiling detailed requirements, determining project plans, and resolving the conflicting demands of participating diagnostic and effects programs, the Task Group obtained monthly status (progress) reports starting on June 30, 1957, from the 90-odd projects. Following receipt of the first report, the Task Group Commander held a meeting of Project Officers at Sandia Base late in July. Representatives from the Task Force and the other Task Groups also attended the three day conference and heard each project announce its plan of operation and major problems foreseen at that time.

This conference helped to crystallize the over-all program and, with the subsequent written monthly reports, planning progressed on a realistic basis and firm requirements were placed on the Task Force and supporting Task Groups.

Determination of Requirements. Information regarding the expected number of personnel to be present in the FA during Operation Hardtack was obtained from the monthly status reports submitted by the various units of the Task Group prior to forward movement. In April, when the decision to move Teak and Orange to Johnston Island was made, Task Units submitted new status reports, which reflected their personnel requirements for that location. This decision radically changed the personnel phasing and peak populations at EPG.

The population figures were subdivided by location in the following general categories: sites at Bikini Atoll, sites at Eniwetok Atoll, and shipboard space. Detailed compilations were prepared showing the estimated weekly population at each location at the EPG. These estimates were useful in determining such things as camp locations, camp size, and over-all camp support required of Holmes and Narver. Population estimates were based on shot schedules, construction schedules, program participation, and organization participation. Changes in any of the above items caused variances between population estimates and the actual operational population. This was particularly true when shots were delayed or fired ahead of schedule.

The total number of quarters requested in all camps except Parry and Enyu exceeded the total estimated population by about 10 per cent. The excess was required to permit a few personnel who moved frequently between these locations to have permanent quarters in two camps.

Parry and Enyu Islands were considered base camps for their respective atolls, and accordingly, permanent space at these camps was requested for all personnel living temporarily at camps on other islands (except Eniwetok Island). As in Operation Redwing, this proved especially beneficial when the temporary camps were no longer habitable.

Eniwetok Atoll was considered the base of operations for the entire EPG, and the largest portion of the Task Group personnel was located there. Bikini Atoll and Johnston Island were used as forward working areas for those units participating in shots fired at those locations. A maximum population of 1351 was attained at the EPG on April 24, 1958, when 964 persons were at Eniwetok Atoll and 387 were at Bikini. A total of 2665 individuals participated in the operation. A chart showing the total personnel present by week is shown in Fig. 3.3.

Although the majority of personnel were present at Eniwetok and Bikini Atolls and Johnston Island, a few of the project personnel of TU-3 and TU-4 were based at Rongelap, Kwajalein, Kusaie, Wotho, and Wake Island. These

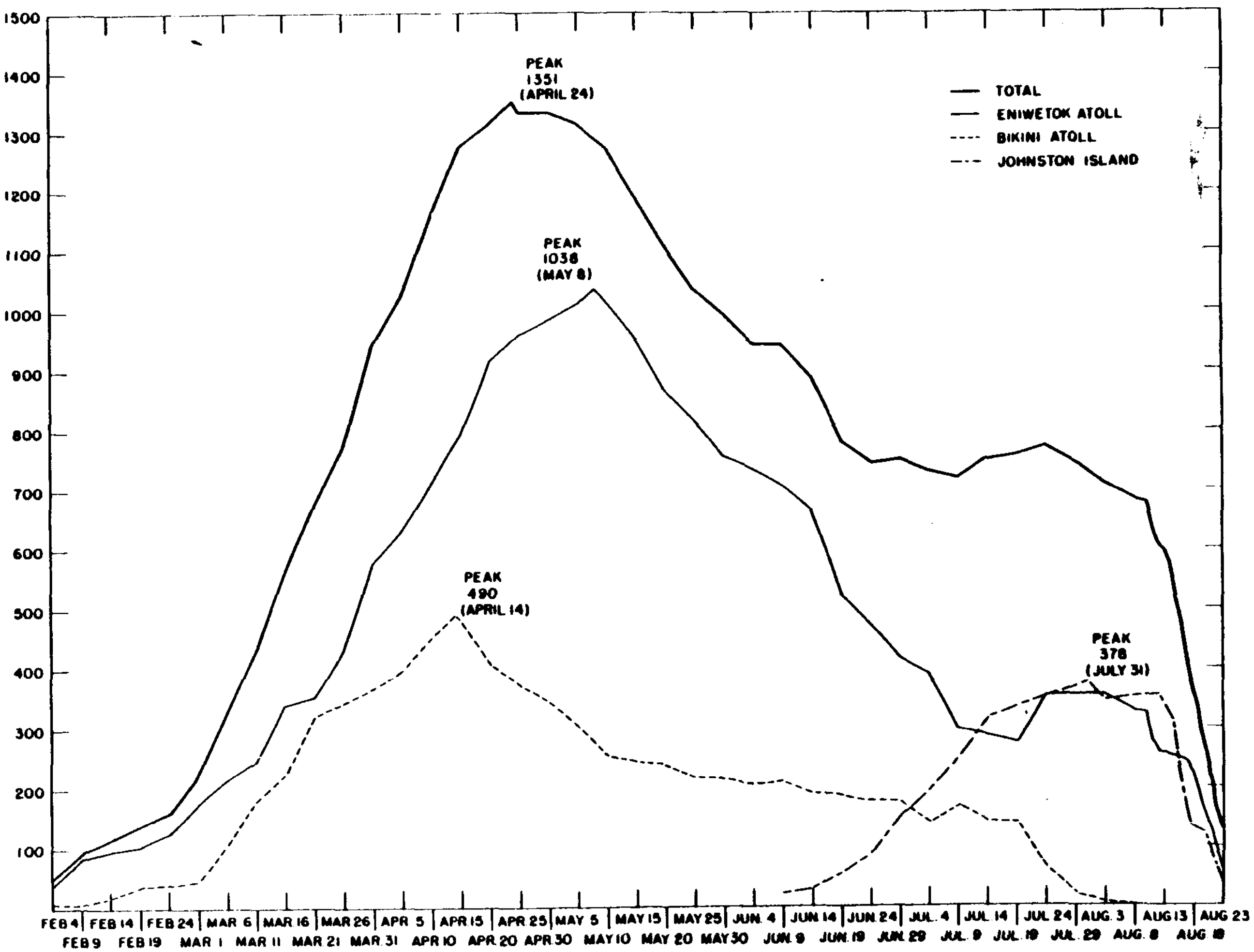

Fig. 3.3 Task Group 7.1 Population at the Eniwetok Proving Ground and Johnston Island, February 4, 1958, to August 23, 1958.

projects were primarily concerned with long-range fallout, ionosphere recordings, microbarograph, and electromagnetic studies.

Inasmuch as the DOD system for planning support for overseas nuclear tests requires that needs be estimated long before the shot schedule is in any way firm, preliminary estimates of requirements must be based to a degree on the preceding operation; as expected, they change substantially as planning progresses.

Table 3.2 lists the initial estimates of military support items required, those actually supplied, and the purpose for which they were used, except for motor vehicles, which are discussed in a separate section.

Training and Rehearsals. Training and rehearsals for Hardtack began in the United States and continued overseas throughout the operational period. The training programs were designed to meet Task Group scientific, operational, technical, and safety requirements and, insofar as possible, to allow rotation of individuals without jeopardizing the programs.

In order to make the maximum use of project Rad-Safe monitors, approximately 250 were trained at the EPG. Training courses were conducted at Parry, Eniwetok, and Enyu Islands beginning March 17, 1958. Courses were either 4 days or 1 day in duration. The training period lasted for 9 weeks. Four chemical laboratory technicians were trained in basic radiochemistry techniques at LASL. Seven instrument repair technicians were trained at the U.S. Naval Schools Command, Treasure Island, and at LASL. In addition, 39 men participated in the Rad-Safe program at NTS during Operation Plumbbob on a training basis. Other training was provided by the U.S. Army First Radiological Safety Support Unit in the normal unit training program.

In preparation for Hardtack, there were several firings of Redstone missiles at Cape Canaveral beginning in the summer of 1957.

Practice launchings of the Yucca type balloon from the ground were conducted at Eniwetok during July 1957. When these proved unsuccessful because of the surface wind velocities normally experienced at Eniwetok, practice launchings were made from the USS Boxer off San Diego from September 9 to 11, 1957. With the Boxer steaming down wind at the surface wind speed, launchings were consistently successful and this was the method used during Hardtack. There were 11 rehearsal launchings of the Yucca type balloon from the Boxer at the EPG, including one with a dummy weapon and high explosive, before the Yucca shot.

During the period from November 9 to 16, 1957, the USS Grasp (ARS-24) conducted two positioning tests for underwater devices off Oahu, T.H., in preparation for, and as feasibility studies of her Hardtack mission.

Associated with the Teak and Orange missiles were pods, some of which had to be located and recovered from the ocean after the shots. In addition, there were several rocket programs, including sampling rockets, which required postshot location and recovery of nose cones and other parts. Preliminary location and recovery tests were held at Salton Sea, Calif., on December 6 and 7, 1957, and off Point Mugu, Calif., between January 20 and 23, 1958.

A full scale Task Force rehearsal of the Teak event, to include token evacuation of the Bikini Atoll, was canceled when Teak was moved to Johnston Island. The Commander, Joint Task Force Seven, then decided to hold a full scale rehearsal of the Fir event, to include those parts of Poplar and Sycamore which required virtually complete evacuation of Bikini. The

TABLE 3.2

MAJOR ITEMS OF MILITARY SUPPORT

Type of Aircraft, Ship, or Surface Craft	Recommended by CTG 7.1 Oct. 1956	Recommended by CJTF 7 Feb. 1957	On Hand during Hardtack	Purpose and Remarks
DD	?	4	4	Security patrol, weather observations, recovery operations
DDR	-	?	1	Security patrol, weather observations, recovery operations
DE	?	1	1	Program 40
ATF	4	5	5	General towing and mooring
ATF	?	1 AR	1	Support for underwater shot programs
ARS	?	1	2	Support for underwater shot programs
ASR	?	?	1	Support for underwater shot programs
APD	1	0	0	Transport, telemetering station
SERVICE AND HARBOR CRAFT, LANDING CRAFT, AND BOATS				
AFDL	-	1	2	Support TG 7.5 marine operations
YTB	?	2	2	Target array mooring, TG 7.3
YTL	-	2	2	TG 7.5 port operations, Eniwetok
YFNB	-	1	1	Support TG 7.3 boat pool
YCV	2	2	2	Helicopter landing barges
BC	?	?	6	TG 7.5 - 3 helicopter barges, 1 cargo barge, 1 fuel barge, 1 unassigned
YC	-	?	2	TG 7.5 - 1 dredge, 1 unassigned
YOS	-	1 YON	1	Fueling smaller units at Eniwetok
LCU	8	10	4	TG 7.5 houseboats for TG 7.1 scientific projects
LCU	9	23	23	TG 7.5 boat pool. TG 7.1 recommendation based only on 7.1 needs

TABLE 3.2 (Continued)

Type of Aircraft, Ship, or Surface Craft	Recommended by CTG 7.1 Oct. 1956	Recommended by CJTF 7 Feb. 1957	On Hand during Hardtack	Purpose and Remarks
LCU	5	4	3	TG 7.3 boat pools
LCM	29	31	28	TG 7.5 boat pools. 2 LCM on loan from Army for trial purposes. Excellent fast support for Arming Party
LCM	19	21	19	TG 7.3 boat pools
LCM	?	12	12	Target array support, TG 7.3
Water Taxis	3		3	TG 7.5 boat pool, Eniwetok; arming party support
DUKW	45	50	46	TG 7.5 boat pools
LCPL	-	6	4	1 CJTF 7 barge, 1 CTG 7.3 barge, 2 SOPA Bikini
SAMPLING, EFFECTS, AND SCIENTIFIC PROGRAM AIRCRAFT				
B-57B (AF)	9+1 B-57C	10	10	Sampling - Programs 11 & 21, Project 2.8
B-57D (AF)	2	6	6	Sampling - Programs 11 & 21, Project 2.8
B-52 (AF)	?	1	1	Effects - Project 5.1
A4D-1 (Navy)	?	1	2	Effects - Project 5.2
FJ-4 (Navy)	?	1	2	Effects - Project 5.3
C-54 (AF)	?	3	3	Program photography
RB-36 (AF)	?	2	2	Technical photography, Project 8.4
C-97 (AF)	?	?	1	Project 6.10
P2V-5F (Navy)	?	?	1	Project 8.5
RB-50E (AF)	?	?	2	Wahoo and Umbrella photography and land crater mapping

TABLE 3.2 (Continued)

Type of Aircraft, Ship, or Surface Craft	Recommended by CTG 7.1 Oct. 1956	Recommended by CJTF 7 Feb. 1957	On Hand during Hardtack	Purpose and Remarks
B-47 (AF)	?	?	3	Indirect Bomb Damage Assessment (based on Guam)
		SUPPORT AIRCRAFT		
H-19 (AF) helicopters	12		6	Eniwetok inter-island airlift - Also Bikini until arrival of USMC helicopters
H-21 (AF) helicopters		10	9	Eniwetok inter-island airlift
HR5-3 (USMC) helicopters	20	15	15	Bikini inter-island airlift
L-20 (AF)	12	8	8	Inter-island airlift - 5 Eniwetok, 3 Bikini
C-54 (AF)	5 C-131A	2+4 C-123	5	Inter-atoll airlift
WB-50 (AF)	-	10	10	Weather reconnaissance (Special sampling Project 2.8)
SA-16 (AF)	7	7	7	Search and rescue, off-atoll support
UF-1 (Navy)	-	8	7	Augment SA-16 service, proficiency flying
L-19 (AF)	-	2 L-21	3	VIP and proficiency flying for General Officers
P2V-5F (Navy)	-	16	16	Air surveillance, danger area
	SCIENTIFIC PROGRAM SHIPS AND SURFACE CRAFT			
LST #511 & 2 YAG	1	0	0	Recommended BuShips leave instrumented after Redwing for possible Hardtack use. Not used.
DD	?	?	3	#474, 592, 593, Target array, instrumented, not manned

TABLE 3.2 (Continued)

Type of Aircraft, Ship, or Surface Craft	Recommended by CTG 7.1 Oct. 1956	Recommended by CJTF 7 Feb. 1957	On Hand during Hardtack	Purpose and Remarks
EC	?	?	1	#2, SS Michael Moran. Target array, instrumented, not manned
SSK	?	?	1	#3, USS Bonita. Target array, instrumented and manned
SQUAW	?	?	1	#29. Target array, instrumented, not manned
YFNB	2	2	1	#12. Target array, instrumented, not manned
YC	?	18	8	Target array, instrumented, not manned
BC	?	?	23	Shot barges (22 actually used)
BC	1	1	1	Rad-Safe barge
LCU hulls	?	?	10	6 shot barges, 3 Project 6.8, 1 photo barge
LCM hulls	?	?	2	Zero site instrumentation, Wahoo and Umbrella
		SUPPORT SHIPS		
CVS (USS Boxer, #21)	1 CVA	1 CVHA	1	Afloat command post for CJTF 7, CTG 7.3, and 7.4; command and firing post for CTG 7.1; launcher for Yucca balloon; helicopter base
AGC	-	1	0	Command ship CJTF 7 and CTG 7.3. Functions Combined on Boxer when it was decided not to provide continuing afloat capability at Bikini
AV	0	1	0	Command and firing ship CTG 7.1. Functions combined on Boxer when it was decided not to provide continuing afloat capability at Bikini

TABLE 3.2 (Continued)

Type of Aircraft, Ship, or Surface Craft	Recommended by CTG 7.1 Oct. 1956	Recommended by CJTF 7 Feb. 1957	On Hand during Hardtack	Purpose and Remarks
TAP (USNS Ainsworth)	1	1	1	Housing afloat at Bikini; CTG 7.5 afloat Command Post
APA (USS Renville, #227)	-	1	1	Emergency evacuation Eniwetok; housing for 7.3 personnel working on target array
LSD	1	2	2	Inter-atoll shot barge and other movements; support for underwater shots, Bikini boat pools, off atoll. Ships rotated to provide 2 in EPG at all times
LST	3	3	3	Inter-atoll and off-atoll support
LST 887	?	?	1	Support Project 6.7, mine clearance
LSM	?	?	1	ALOTO #444. Inter-atoll cargo service. On long term loan to AEC (H&N)
LCPR	-	2	2	TG 7.3 boat pool
40' utility launches	-	?	2	TG 7.3 boat pool

?, Requirement not known at the time.
-, Requirement of indirect or no interest to TG 7.1 at the time.

USS Boxer and USNS Ainsworth proceeded to their assigned areas of operation approximately 30 miles south of Enyu. Communications were thoroughly tested, ~~but only~~ token evacuation of personnel was directed and carried out.

On −4 day, Joint Task Force Seven held a rehearsal of Umbrella, including positioning of ships, lowering the dummy device, token evacuation from ships of the target array, and a complete test of communications. This was the last full scale rehearsal at the EPG.

In preparation for each shot, Task Group 7.1 held numerous dry runs of the timing and firing systems. The runs were normally conducted twice a day or more often until results were satisfactory, then once a day through shot time or postponement. At least one full power dry run and one "hot" dry run, when appropriate, were conducted prior to each shot. At Eniwetok, there were 88 such runs during a typical month of the firing period.

In addition, projects, programs, and task units conducted many rehearsals of operations of particular importance to them, especially where there was some question of safety, feasibility, best technique, stand-by methods, and length of time required if time was critical. The Commander, TG 7.1, also held many communications and frequency interference checks.

These signal runs, project rehearsals, and communications checks were of the utmost importance to CTG 7.1 and to the successful completion of the scientific missions.

3.4 MOVEMENT TO THE FORWARD AREA

Personnel. The major portion of the administration and coordination for orderly movement of individuals from the numerous duty stations and places of employment to the EPG was accomplished by the Adjutant General's Section and the liaison officers at Travis and Hickam Air Force Bases.

All military and Department of Defense civilian personnel (except DOD contract civilians) were moved commercially to Travis Air Force Base, and by Military Air Transport Service from Travis through Hickam to Eniwetok. Exceptions to this were the movement of a few of these individuals by Military Sea Transport vessels and the authorization for use of commercial air to Hawaii by Naval Research Laboratory DOD civilians. All AEC and DOD contract civilians normally traveled commercially to Hawaii and entered the MATS or MSTS system at that point.

During Operation Hardtack, a portion of the travel order issuing responsibility was separated from the Adjutant General at the Headquarters, Task Group 7.1, and delegated to Assistant Adjutants at the University of California Radiation Laboratory (TU-2) and the Weapons Effects Test Division, Sandia Base (TU-3). These assistant adjutants were responsible for writing orders and making necessary arrangements for the movement overseas of the personnel of these two major Task Units. This decreased considerably the work load at the headquarters, where the Adjutant General continued the order-issuing support of Task Units 1, 4, 5, and 6 and the Headquarters.

The number of travel orders issued during the operation is as follows:

Issuing Office	Number
Adjutant General Headquarters Task Group 7.1 Los Alamos, N. M.	543

Adjutant General Task Unit 2 (UCRL, Livermore, Calif.)	230	
Adjutant General Task Unit 3 (WETD, Sandia Base) Albuquerque, New Mexico	542	
Adjutant Generals Forward Areas (APO's 105 and 437)	190	
Total travel orders issued	1505	(covering 2665 individuals)

A new system for MATS "reservations" was initiated during Hardtack which greatly simplified the flow of personnel through the ports of embarkation (Travis and Hickam) and decreased the time losses experienced during past operations. Individual reservations were made by telephone to the liaison officer at Travis, or by wire message to the liaison officer at Hickam, and each individual was given the reporting time and departure schedule with his travel order brochure.

Task Group 7.1 Administrative Plan No. 1-57 was published on November 1, 1957, and its subsequent distribution to all AEC, Contractor, and DOD agencies who were to participate in Hardtack provided the necessary administrative procedures required of the individual and the organization for movement into the Forward Area. In addition, a pamphlet titled "Instructions and Information for Personnel departing for the EPG" was published and attached to each set of travel orders. Several of the participating agencies published additional instructions which covered their own institutional procedures.

Organizationally, the participating units, in compliance with procedures outlined in the Administrative Plan, submitted to the appropriate Adjutant General for each individual a Request for Civilian Travel Orders, or a Request for Overseas Travel Orders, a Badge Request Form, an Identification Card Request Form, and a certificate of personnel clearance under the provisions of CinCPac Serial 020. The complete packet of orders and allied papers was duplicated and distributed by the cognizant adjutant and returned to the individual or agency.

All arrivals at Eniwetok Atoll (Eniwetok Island for air passengers, individual ships for surface passengers) were met by J-1 representatives. Security badges, liquor ration cards, and radiological safety film badges were issued at those points, and contraband certificates were signed.

Efficiency of the Task Group 7.1 port of embarkation operation at Eniwetok Island was greatly improved during Hardtack. Incoming passengers were processed expeditiously and were on site within Eniwetok Atoll, enroute to Bikini, or billeted overnight, if necessary, for further transportation to Bikini Atoll within 2 hours. This one element of the operation, previously marred by lengthy, repetitious security briefings and baggage checks for contraband, considerably eased inter-Task Group relations after the long and exhausting trip from the home station.

Equipment. The movement of Task Group 7.1 equipment from continental United States was accomplished through the facilities of MSTS, the U.S. Navy, and MATS.

As the monthly progress reports were received from the various projects, the shipping requirements were projected and submitted to the Task Force. Projects were kept advised when ships would be on berth at Oakland, enabling the project people to move their equipment to the port in time to meet sailing dates with a minimum waiting period. The J-4 liaison officer at Oakland kept the J-4 office informed regarding the receipt and movement of cargo at the port.

Equipment began arriving at the Naval Supply Center, Oakland, in November 1957. Approximately 18,300 measurement tons of cargo were moved to the Eniwetok Proving Ground by MSTS vessels. All cargo vessels were discharged and loaded at the deep water pier at Parry Island. Cargo was lifted on reefers, regular cargo vessels, and in one instance a commercial cargo ship. Three trips were made by the Brostrom, a C-4 type cargo ship which is ideally suited for the type of cargo that Task Group 7.1 ships, which consists primarily of large scientific trailer vans. The Brostrom arrived at the EPG as follows: January 23, February 25, and April 2, 1958. Over 170 heavy lifts were made to the Proving Ground, of which there were 117 vans of over 2000 cu ft each. In addition there were approximately 46 smaller trailers and truck vans that did not meet the 2000-cu ft criterion of a large van. The peak of water shipments was during the months of February and March 1958.

WATER SHIPMENTS - ZI TO EPG

	Vans		General Cargo
Month	Number	M/T	M/T
November	0	0	80
December	2	2	366
January	38	2273	945
February	72	4809	2578
March	49	4427	2280
April	1	62	83
May	0	0	60
June	1	94	66
July	0	0	176
Total	163	11,667	6634

In addition to trailers lifted to the EPG by MSTS vessels, there were 2 vans and 11 helium tube bank trailers lifted on the USS Boxer in February 1958.

In order to support the Newsreel phase of Hardtack, the bulk of the equipment involved was shipped from the EPG to Johnston Island by means of LST and LSD, since facilities for unloading heavy lifts from regular cargo ships do not exist at Johnston Island.

WATER SHIPMENTS - EPG TO JOHNSTON ISLAND

		Vans		General Cargo
Month		Number	M/T	M/T
May		50	3386	2164
June		8	533	518
July		0	0	40
	Total	58	3919	2722

In addition, equipment was shipped from continental United States to Honolulu for trans-shipment by LST and barge to Johnston Island as well as for use by projects at Honolulu and Maui. The total tonnage was small but is reported to complete the shipping picture.

WATER SHIPMENTS - ZI TO HONOLULU FOR JOHNSTON ISLAND

Oakland to Honolulu, trans-shipped to Johnston - 554 M/T

Oakland to Honolulu, used at Honolulu - 85 M/T

Oakland to Honolulu, trans-shipped to Maui - 10 M/T

Air shipments of cargo for the EPG were all consigned to Eniwetok and, if necessary, forwarded to Bikini on C-54 "reflector" flights. Air cargo for Johnston Island was usually scheduled on MATS flights stopping there enroute from Honolulu to Eniwetok or vice versa. On April 1 a weekly C-54 flight was established between Eniwetok and Johnston. On July 12 a C-54 shuttle was established between Johnston and Hickam and operated on an as-needed basis. Both of these flights carried cargo and personnel.

Following is a tabulation of MATS cargo shipments, excluding weapons, lifted on SAM flights:

AIR SHIPMENTS (MATS) - ZI TO EPG

January		7,963
February		41,758
March		171,772
April		135,110
May		32,975
June		43,747
July		69,120
	Total	502,445 lb

AIR SHIPMENTS (MATS) - EPG TO ZI

April		21,572
May		40,316
June		52,337
July		105,550
August		38,000 (est.)
	Total	257,775 lb

AIR SHIPMENTS (MATS) -- EPG TO JOHNSTON ISLAND

May		329
June		31,995
July		17,664
	Total	49,988 lb

In addition two special MATS flights were completed between Newburgh, New York, and EPG carrying 46,000 lb of IBM equipment. This equipment was returned from EPG to Albuquerque, New Mexico, in the same manner.

It was ascertained that it would be too expensive to rehabilitate the liquid nitrogen plant in the CMR Compound and hire trained personnel to operate it, so in order to supply liquid nitrogen to the scientific groups using this item, a 6000-liter dewar trailer partly filled was shipped on the Brostom to Parry. This large storage dewar was kept filled by semiweekly shipments from Honolulu by air in 500-liter dewar trailers. Thirteen thousand liters of liquid nitrogen were purchased by LASL from Gaspro in Honolulu for air shipment to Parry.

The liquid hydrogen plant was not put into operation for the same reasons. To meet the requirement for this item one 6000-liter dewar trailer of liquid hydrogen was shipped by water to Eniwetok just before it was needed. Resupply of this item was not required.

3.5 MOVEMENT OF DEVICES AND COMPONENTS

Devices and components were moved to the Forward Area by MATS special air missions, with the exception of which were shipped on the USS Boxer.

The were shipped by Task Unit 4 and the AEC to San Diego for loading on the USS Boxer in mid-February 1958. The weapons were stowed in a hangar deck shop and in the ship's weapon magazines. Stowage space was guarded by USMC guards. The USS Boxer arrived at the Eniwetok Proving Ground on March 3, 1958. An additional were flown to the EPG on a SAM C-124 which arrived at the EPG March 13, 1958.

For Operation Newsreel it was necessary to fly the from Eniwetok to the Waikele branch of NAD, Oahu, by SAM C-124's as follows: June 15, 1958, units 1 and 4; June 20, 1958, units 2 and 5; June 25, 1958, unit 3, plus 5000 lb of gear.

The experimental devices from LASL were moved in several ways from the Laboratory to Travis AFB, which was the aerial port for shipment of weapons. As a rule small weapons were moved bv Carco C-54 from the Santa Fe Airport, but if total load did not exceed they were flown from the Los Alamos airstrip by C-47. Weapons exceeding the capability of the C-54 were flown out of Santa Fe by C-124 and in the case of Pinon (UN shot never fired), from Kirtland, on the SAM C-124 which flew the weapon to the EPG via Travis and Hickam.

Experimental devices from UCRL were moved from Livermore to Travis by truck, with the exception of Poplar, Sycamore, and Pine, which were picked up at Knoxville, Tenn., by SAM C-124's. UCRL preferred to have its smaller devices moved on C-97 aircraft.

In several instances small shipments of device components such as M-103 carrying cases were made on regularly scheduled MATS cargo flights under the surveillance of an armed courier.

Special Air Missions for Laboratory devices were as follows.

Shot	Departure Date	Point of Origin	Cargo Weight, lb	Aircraft
Fir	April 12	Travis		C-97
Butternut	April 14	Santa Fe		C-124
Cactus	April 17	Travis		C-97
Koa	April 17	Travis		C-97
Sycamore	April 18	Travis		C-124
Poplar	April 18	Travis		C-124
Magnolia	April 22	Travis		C-124
Holly	April 22	Travis		C-124
Elder	May 1	Santa Fe		C-124
Yellowwood	May 1	Santa Fe		C-124
Nutmeg	May 15	Travis		C-97
Rose	May 15	Travis		C-124
Tobacco	May 15	Travis		C-124
Walnut	May 16	Travis		C-124
Aspen	May 22	Travis		C-97
Maple	May 28	Travis		C-97
Linden	June 3	Travis		C-97
Aspen[1]	June 4	Eniwetok		C-97
Walnut[1]	June 5	Eniwetok		C-97
Poplar[1]	June 7	Eniwetok		C-124
Walnut[2]	June 8	Travis		C-97
Aspen[2]	June 11	Travis		C-124
Buckeye	June 13	Travis		C-97
Redwood	June 14	Travis		C-97
Cedar	June 19	Travis		C-97
Hickory	June 20	Travis		C-97
Sequoia	June 20	Travis		C-124
Oak	June 20	Travis		C-124
Dogwood	June 26	Travis		C-97
Juniper	July 2	Travis		C-97
Poplar[2]	July 3	Knoxville		C-124
Pinon	July 4	Kirtland		C-124
Buckeye[3]	July 8	Eniwetok		C-97
Scaevola	July 10	Kirtland		C-97
Pisonia	July 14	Travis		C-97
Olive	July 18	Travis		C-97
Pine	July 22	Travis		C-124
Quince	August 2	Travis		C-124/C-97
Pinon[3]	August 5	Eniwetok		C-124
Fig	August 12	Travis		C-97

[1]Returned to ZI for modification.
[2]Returned to EPG following modification.
[3]Returned to ZI, canceled.

The Redstone missiles were originally scheduled to be shipped from Huntsville, Ala., to Eniwetok on seven SAM C-124's between March 4 and April 4 but were rescheduled when the Teak and Orange firing site was changed to Johnston Island. Movement of the Redstone gear to the Forward Area and return of unused components was accomplished by C-124 flights from June to September.

There were no unsolvable problems connected with the movement of the weapons or devices, and it is believed that MATS provided outstanding service in this respect when called upon to move this most sensitive cargo.

3.6 FORWARD AREA OPERATIONS

General. During Operation Hardtack, as in Operation Redwing, Task Group 7.1 had its main base of operations on Parry Island at Eniwetok Atoll. Command and Staff Sections, Task Units, Programs, and Projects again provided sufficient qualified personnel to man offices at both atolls, Eniwetok and Bikini, and later at Johnston Island. Each atoll maintained an independent firing capability.

This operation found LASL devices detonated at Eniwetok Atoll and most of the UCRL devices detonated at Bikini. Some UCRL devices were detonated at Eniwetok later in the operation. This was done principally because of the more favorable firing weather at that atoll.

The Task Group Staff Sections moved to the EPG well in advance of the first planned ready date in order to orient new staff personnel, to become acquainted with their counterparts in the other Task Groups, to work out the final details of the plan of operations, and to expedite all matters of construction, transportation, and services which would enable the Laboratories to meet the first ready dates.

In coordination with the other Task Groups present, standing operating procedures and schedules were drawn up for the different modes of transportation. The principal change from the original concept of transportation control was the delegation to J-1 of the staff responsibility for booking passengers on reflector flights between Eniwetok and Bikini and to the off-atoll sites.

Of all of the scheduled events for Hardtack, Teak and Orange had the greatest impact on operations in the EPG. To meet advanced ready dates for the launching of the Redstone missiles from Bikini Island, priorities on construction, transportation, and communications were given to this effort. When the decision was made to transfer these two shots to Johnston Island, an evaluation was made of the capabilities to support both operations with personnel and equipment from resources available in the EPG. In addition, an all-out effort was directed towards the dismantling of the launch tower and other ABMA facilities on Bikini Island for shipment to Johnston Island prior to the first large UCRL shot. Prolonged bad weather delayed this first shot, and the island was evacuated completely without difficulty. Johnston Island operations will be discussed later.

Experience in the evacuation of Bikini Atoll gained from previous operations was put to good use during this operation. The evacuations conducted were all accomplished with no serious delays.

The TG 7.1 J-3 Section published Operational Letters for each shot outlining prediction of effects and operational planning factors, ready date and shot times, evacuation and re-entry check list, and organization and movement of the arming team. In addition, many of the early events which had heavy participation by the scientific projects required operational letters outlining the scientific frequency allocation and the plan for the movement and positioning of the device from the weapon compound to the zero site area.

It was originally intended that the calculations for blast and thermal effects would be performed by a staff section of JTF 7 (the Fallout Prediction Unit). However, it did not arrive in the area until around April 10, and it became operational several days after that date. In view of the early planned ready dates for some of the shots, it was necessary that computations be performed for Teak, Orange, and other events. These were performed by the J-3 Section. After FOPU became operational, assistance in determining blast and thermal data for several shots was provided the J-3 Section, but for the most part it was a case of verification of the compilation of predictions. In future operations it would be well to define clearly who or what agency is responsible for the calculating of predictions. If it is to be the J-3 Section, assurance must be had that a qualified atomic weapon staff officer be included in the section.

Operations at Johnston Island differed from those at Eniwetok and Bikini in that Task Force headquarters assumed more detailed control of all facets of the operation. Although this phase of the operation was successful and most of the objectives were achieved, technical participants questioned the need for such detailed control.

Additional problems arose early in the operational phase because of a division of the final planning effort, part being done at Eniwetok, while the major part was being undertaken at Johnston. Once the entire Task Force closed in, this problem ceased to exist and important decisions were more readily available.

Test Facilities. Criteria for the design and construction of test facilities and estimates of labor and equipment support required by TG 7.1 were collected from the various Task Unit Commanders, Program Directors, and Project Officers by the J-6 Section. Conflicts were resolved, locations assigned, completion dates established, and the total requirement passed to TG 7.5 for execution. In addition to the foregoing basic responsibility, J-6 also prepared the work orders necessary for the actual support of the various projects; operated a machine shop for the convenience of the experimenters; and assigned tent, trailer, and laboratory space as required.

J-6 was basically composed of 7 men augmented locally by 4 men from TU-1, 6 from TU-2, 6 from TU-3, 4 from TU-4, and 3 from TU-5. At times, personnel from the Task Units were designated to officially represent J-6 at Bikini, Johnston Island, and Hawaii.

From February 1958 until the close of the operation, J-6 personnel from Task Units 1, 2, and 3 were present at every camp site and zero area continuously. On islands other than Elmer and Nan, the J-6 representatives frequently assisted other agencies in accomplishing the over-all mission of the Task Group.

During the summer and fall of 1957, the basic pattern of operations was established and some firm criteria furnished to the AEC. Unfortunately, the AEC did not receive its FY 58 budget money until late October. As a consequence, much permanent accountable construction was delayed until it interfered with some of the scientific construction. However, most of the scientific requirements were submitted late also. Construction lagged considerably behind planned dates, this being mainly the effect of nondelivery of necessary materials to the jobsite. The final result of the delay in receipt of money, the late submission of criteria, and the late construction was that, again, experimenters were pressed for time to prepare their stations. The early shots, however, were delayed only briefly by the construction delays.

The construction required by revisions to the firing schedule, starting with the Teak and Orange move and ending with the Quince move from Bikini to Eniwetok, was handled entirely in the field. Its accomplishment was made possible by the initial overstocking of equipment for shot barges and "T" boat hulls and by the great cooperation of the contractor's construction forces. On April 1 the contractor estimated that to move Teak and Orange and supporting experimentation to Johnston Island would require over 6 months. Three months later, on July 7, all Johnston Island construction had been completed. After the operation was well under way, construction for 13 new shot sites, including 5 BC type barges, 5 T boat hulls (one a Pinex type), Fig and Quince ground shots, and a new Teak/Orange site, was initiated. Construction on each of these was accomplished within the time set when it began.

The work order system in effect during Hardtack makes it impossible to estimate the number of work orders and specific tasks laid upon the contractors. The operation required the construction and support of a total of 1155 stations. Nearly 5500 man-hours of machinist time were expended in the J-6 shop in support of the TG mission.

Intra-atoll Airlift. Intra-atoll airlift at Eniwetok was provided by CTG 7.4 using 9 H-21 and 6 H-19 helicopters augmented by 6 L-20 liaison aircraft. At Bikini CTG 7.3 provided 15 USMC H-19 type helicopters augmented by 3 of CTG 7.4's liaison aircraft.

At Eniwetok, the airlift requirement was at a sustained maximum from the beginning of the operational period in March through the month of June. Helicopters flew an average of 760 hr per month, carrying almost 6000 passengers and 70,000 lb of cargo each month. The L-20's averaged 350 flying hours, carrying 2200 passengers and 10,000 lb of cargo each month. Shipments of small, urgently needed pieces of equipment on J-4 manifest totaled 2106 lb for the operation.

The basic 7.1 evacuation and recovery requirement involving intra-atoll flights at Eniwetok was to obtain immediate support of emergency scientific needs created during dry runs and postshot surveys. On the first -1 day, it became evident that the reaction time for laying on support missions was excessive when the aircraft and the Transport Control Agent were on Fred while the users were on Elmer. Thereafter, it became the practice that, at least on -1 and D-days, the aircraft and a 7.4 Operations Officer were stationed on Elmer. This, combined with maximum utilization of fixed schedule airlift, ultimately led to an optimized arrangement which culminated on the last D-day in 23 precisely timed takeoffs on very critical recovery missions, all of which were completed in less than the allotted time.

Since there may be an extended interval before the next operation, it should be recorded that H-21 aircraft, because of their ability to carry greater loads, were used to sustain the scheduled airlift, while the H-19's were used for photo missions because of their greater stability, and for radsafe and sample recovery missions because their engine position reduced the radiation hazard to the pilots.

At Bikini, the total traffic was considerably less than at Eniwetok, thus aircraft utilization was far below the programmed capability. This should not be used as a basis for reducing air support in subsequent Bikini tests, however, since movement of the Teak and Orange events to Johnston Island greatly reduced the number of personnel the airlift had been committed to support. Cargo carried for J-4 totaled 986 lb.

The major recurring problems that arose resulted from the night and over-water flying restrictions which applied to Task Group 7.4 helicopters. Although these problems were never satisfactorily resolved, they were avoided on the second underwater shot by using USMC helicopters from Bikini, which did not have the same operational limitations.

Inter-atoll Airlift. Cargo lift from Eniwetok to Bikini was accomplished by means of a morning and afternoon C-54 flight from Fred to Nan. Cargo arriving at Fred via MATS marked for Bikini was segregated and booked on the C-54 reflector flight, without being first sent to Parry as on previous operations. This procedure saved valuable time and cut down on the wear and tear on cargo due to additional handling. This service was performed by a H&N air cargo man stationed permanently at Fred.

Air cargo for Bikini originating at Parry was documented by J-4 for movement through the H&N Shipping Section. This system worked quite well, with very little time lost in movement of this type of air cargo.

Air cargo excluding weapon movements was as follows:

CARGO AIRLIFT, ENIWETOK TO BIKINI, EXCLUDING DEVICES

February	3,170
March	40,318
April	45,536
May	30,275
June	32,283
July	8,151
Total	159,733 lb

Cargo airlifted from Bikini to Eniwetok during the entire operation amounted to 102,306 pounds.

Initial planning implemented at the start of the operation was based on the Eniwetok Airlift Office - Transportation Control Agent concept. This required each Task Group to designate a TCA, who was responsible for consolidating all requirements for airlift for his Task Group and forwarding the total requirement to the JTF 7 Air Priorities Agent, who was located in the EAO. The APA consolidated the requirements of all the Task Groups and made the necessary arrangements for adquate airlift support with TG 7.4. Task Group 7.1 appointed two TCA's: one from J-1 to handle all passenger requirements and one from J-4 to handle cargo requirements.

During the early stage of the operation, one flight daily was made between Eniwetok and Bikini Atolls. This was later increased to three flights daily (except for Sundays, when there was only one flight) during the peak period of the build-up phase, April 8 through May 7.

C-54 aircraft were utilized on the Eniwetok-Bikini shuttle. These aircraft replaced the twin-engine C-47 transports used on Redwing and immensely improved the shuttle service, since they could carry more passengers and were more comfortable.

Task Group 7.1 utilization of passenger airlift between Eniwetok and Bikini was as follows:

February	131	June	458
March	614	July	431
April	932	August 1-11	15
May	662		

Off-atoll Airlift. Procedures used in booking passengers for off-atoll transportation were the same as those used on the Eniwetok-Bikini shuttle. Generally, SA-16 aircraft were used in off-atoll flights, except that C-54's were used at locations that had air strips large enough to handle this type of aircraft.

Task Group 7.1 utilization of off-atoll flights during the operation was as follows:

Site	March	April	May	June	July	August
Wotho	4	14	22	0	2	0
Kapingamarangi	0	0	5	1	1	0
Nauru[1]	0	4	8	0	0	0
Utirik	7	2	0	0	0	0
Kusaie	4	6	19	0	2	0
Rongelap	9	21	10	0	3	0
Tarawa[1]	0	0	7	0	0	0
Ujelang	4	2	0	0	0	0
Johnston Island[1]	0	7	8	16	8	6
Kwajalein	0	8	3	13	5	0
Wake	0	3	2	0	0	0
Guam[1]	0	2	1	3	6	0

[1]Locations where C-54 aircraft were used.

Because of operational requirements it was occasionally necessary to set up special flights between Eniwetok and Bikini or to off-atoll locations. These flights were handled on an individual basis and generally did not cause any serious problems.

Intra-atoll Boat Service. Task Group 7.5 did an outstanding job of supporting Operation Hardtack by surface craft. Throughout the entire period they satisfied requirements as they arose. During the early part of the operation regularly scheduled boat runs were made to up-island sites at both atolls. Later, as the need for up-island traffic diminished, the trips were made on an as-needed basis. The J-3 Section of TG 7.1 controlled all special trips made for 7.1 by TG 7.5 boats. All trips were dispatched by the H&N Marine Dispatcher, with requirements made through the J-3. This system greatly facilitated control, and expeditious use of the boats.

Equipment was shuttled between the islands of the two atolls on LCU's. The J-4 Section booked the cargo with H&N, which actually moved the tonnage. During the operation 8907 M/T were carried at Eniwetok and 3320 M/T at Bikini.

During Wahoo and Umbrella events the TG 7.5 boats were augmented by use of the TG 7.3 Boat Pool Detachment, which made scheduled runs to the target arrays.

As of July 1, TG 7.5 boats were assigned as follows:

Eniwetok		Bikini
16 - LCM	9 - LCU	12 - LCM
12 - DUKW	3 - Houseboats (LCU)	12 - DUKW
3 - Water Taxis	2 - YTL (Tugs)	8 - LCU
1 - LCM Pusher		1 - Houseboat

Houseboats were LCU's that were especially configured to supply messing and sleeping facilities for arming team members and other project personnel who were working at or in the vicinity of the barge zero sites. Having such facilities immediately available at the zero site often expedited work that had to be done on a crash basis. Continued use of these boats in future operations is strongly recommended.

Water taxis were again available at Eniwetok Atoll. This greatly eased the up-island travel problem, particularly when the temporary camps at Yvonne and Janet were in operation. The Arming and Firing Coordinator made good use of the water taxis by utilizing them for transportation to the zero sites in the event of marginal weather. He would wait until the 2200 weather briefing, and then proceed to the zero site if the shot was still scheduled. Regular scheduled water taxi service between Parry and Eniwetok was maintained throughout the operation.

The complete cooperation afforded TG 7.1 by the TG 7.5 Marine Department ensured that there never were any problems in obtaining boat service. There were few days when all boats were not in operation.

Especially good use was made of the MK-8 LCM in cases of quick movement or evacuation. More use of this type craft is definitely recommended for future operations because of its size and speed.

Inter-atoll Water Lift. As in the last operation, surface lift between the two atolls was normally accomplished by two MSTS LST's. In addition, the M.V. Aloto was under the operational control of the TG 7.5 Supply Department.

Water cargo for TG 7.1 destined for Bikini Atoll was trans-shipped from Parry Island utilizing the following craft: LSM, LSD, and LST. Cargo for TG 7.1 was handled through the J-4 Shipping and Receiving Section, which arranged for the actual movement by the H&N Supply Department. Passengers by water were few in number and were booked by J-1. The total amount trans-shipped to Bikini, including trailers and general cargo, was as follows:

WATER LIFT FROM ENIWETOK TO BIKINI

January		1,132
February		4,942
March		4,279
April		837
May		206
June		48
July		121
	Total	11,565 M/T

Water lift from Bikini to Eniwetok for the entire operation totaled 8355 M/T.

Motor Vehicle Transportation. Motor vehicles for Task Group 7.1 arrived at the EPG on January 28 and February 7, 1958, in time for processing and issue. Processing required approximately 2 weeks; all requested vehicles except 35 weapons carriers were issued to Task Units by March 1.

In January 1958 the Task Force allocated 305 vehicles for TG 7.1 use. These were drawn from TG 7.2 by J-4 on memorandum receipt. Following is a breakdown of vehicles issued by type and number. Table 3.3 indicates their assignment and location on June 1, 1958.

Truck, utility, ¼-ton, M38A1	145
Truck, pickup, ½-ton	53
Truck, cargo, ¾-ton, M-37	70
Truck, stake body, 1½-ton	4
Truck, cargo, 2½-ton, M-35	17
Truck, tractor, 5-ton, M-52	3
Truck, decontamination, 2½-ton	4
Trailer, cargo, ¼-ton, M-100	3
Trailer, water tank, 1½-ton, M107A2	6

The following vehicles were shipped from Eniwetok to Johnston Island for use during Newsreel:

Truck, cargo, 2½-ton	5
Truck, stake body, 1½-ton	2
Truck, pickup, ½-ton	21
Truck, utility, ¼-ton	2

Between June 11, 1958, and July 31, as vehicles became excess they were turned back to J-4 for processing and return to Task Group 7.2. They were as follows:

Truck, utility, ¼-ton	50
Truck, pickup, ½-ton	17
Truck, cargo, ¾-ton	35
Trailer, water tank, 1½-ton	5

On final roll-up all vehicles still in the possession of Task Group 7.1 were turned over to H&N for processing and shipment as directed by the Task Group 7.2 Ordnance Officer.

Maintenance of TG 7.1 vehicles was in accordance with a maintenance agreement executed on June 11, 1958, between TG 7.2 and TG 7.5. This agreement did not outline in sufficient detail the responsibilities of TG 7.5. The term "organizational maintenance" was not clear to TG 7.5 and should have been spelled out in detail. This resulted in vehicles being scheduled through TG 7.5 shops every 2 weeks for what amounted to a lubrication job. No system was employed at this time.

Vehicles on various islands of Bikini and Eniwetok were maintained in similar manner by portable units. Temporary camp sites were in existence at Yvonne and Janet at Eniwetok Atoll, and Oboe and How at Bikini Atoll.

Some problems in the maintenance of vehicles developed when it became difficult to get project personnel to bring vehicles to the maintenance

TABLE 3.3

VEHICLE BREAKDOWN BY LOCATION, JUNE 1958

Vehicle	TU-1		TU-2		TU-3		TU-4		TU-5		TU-6		Staff		Pool		Total	
	E	B	E	B	E	B	E	B	E	B	E	B	E	B	E	B	E	B
¼-ton utility truck	22	1	4	31	27	3	6	4	10	6	-	-	12	7	9	2	90	54
½-ton pickup truck	7	-	3	8	5	-	-	1	3	3	3	3	4	1	6	4	31	20
¾-ton weapons carrier	8	-	3	9	22	2	4	3	6	1	-	-	-	1	11	-	54	16
1½-ton truck	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	2	1
2½-ton truck (6x6)	-	-	-	-	2	-	-	-	-	-	1	-	2	-	3	4	8	4
5-ton tractor	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	2	1
500-gal water trailer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1	5	1
¼-ton trailer	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	3	-
2½-ton decontamination trucks	-	-	-	-	-	-	-	-	-	-	2	2	-	-	-	-	2	2
Total[1]																	197	99

[1]Nine vehicles of the 305 allocated were under repair or in transit.

facilities as requested. A tighter control of vehicles should be exercised in order to get the maximum utilization out of all vehicles.

Although the Task Group requested 47 vehicles for use on Johnston, only 8 were assigned full time. A few more were available from a TG 7.5 central motor pool on a daily first-come-first-serve basis. A bus line using two 12-passenger "Toonerville" units circled the small island on a 15 round trip schedule. This system fell far short of meeting vehicle transportation requirements.

As the build-up increased, the inadequacy of this transportation system became more apparent. A request for more bus service was disapproved because of the inability to get full utilization at all hours of the day of the vehicles that were dispatched from the pool. The problem was finally overcome by having H&N hire additional drivers to operate a taxi system.

A somewhat similar problem occured at Hickam Air Force Base when vehicles promised to the TG 7.1 projects were not provided. That problem was solved by task units renting cars from the Hertz system.

Although the Johnston Island phase of the operation was successfully accomplished with a drastically reduced number of vehicles, the administrative attention required as well as frustrations of and harassments to both staff and technical personnel seemed to outweigh any of the hoped-for advantages.

Off-atoll Operations. Although the CTG 7.1 report for Operation Redwing recommended that plans for off-atoll stations in future operations be finalized prior to movement to the EPG, this was still not accomplished in some instances in this operation.

Off-atoll sites were operated at Wake Island, Rongelap, Utirik, Ujelang and Wotho Atolls, and Kwajalein Island. They were serviced by SA-16 aircraft and surface runs by the M.V. Aloto.

For the Newsreel events there were 11 manned stations located on Johnston and Sand Islands, 10 for scientific purposes and 1 for support needs (firefighting crews, etc.). Outlying TG 7.1 scientific stations included a maximum of five stations afloat (USS Boxer and Belle Grove, and the Dehaven, and Cogswell until replaced by the Epperson, Lansing, and Hitchiti), 10 airborne scientific stations, and units on top of Mount Haleakala on Maui, Wheeler Field and Lualualei on Oahu, and French Frigate Shoals.

Test Rockets. Extensive rocket firing tests were characteristic of the Teak and Orange operation at Johnston Island. A total of 37 firings were accomplished between July 10 and August 12, 1958. These included five types of rockets: The Nike-Cajun, Nike-Asp, Deacon-Arrow, Viper-Arrow, and the Modified Lacrosse.

The operation at Johnston Island was basically affected by: (1) the proximity of the inhabited area to the launchers, (2) the air traffic congestion through the Johnston Island air space, and (3) the location of the Navy ship support anchorage in the firing lanes. These features were in wide variance with the conditions that existed at Bikini Atoll.

Joint Task Force Seven decided that the firing conditions at Johnston Island required a central control agency for firings which had the authority to:

1. Dispatch CAA "Notices to Airmen" (NOTAMS) to air traffic influencing the complete Pacific air traffic system throughout the Hawaiian/Johnston airways system.

2. Dispatch orders to the TG 7.3 ships requiring boat movement at designated times.

3. Request security personnel and material for zoning danger areas and maintaining them over extended periods of time.

4. Install a system of communications with count-down interconnecting firing bunkers, control tower, MP roving stations, instrumented MIDOT stations, MSQ stations and others into a centralized control agency of JTF 7, with the code name "Alaska," all of which was not required for the operation at Bikini.

Detailed control of the arming and firing was exercised by JTF 7, Alaska.

The J-3 Section, TG 7.1, published weekly schedules which were forwarded to JTF 7 for approval and necessary support action. This action consisted of: (1) NOTAM safety notices, (2) air traffic control alerts, (3) Navy boat movement from the anchorage, (4) MP stations being manned for local safety precautions, and (5) siren alert signals to the local population that a firing was about to be conducted.

3.7 EVACUATION, RECOVERY, AND RE-ENTRY PLANNING

Planning for this aspect of the operation took place in three phases.

1. Early in 1957 the basic concepts and general plans of evacuation were determined. Based upon this, requirements for ships, boats, and aircraft were determined and submitted to JTF 7.

2. Later, as projects began to submit their monthly status reports, more detailed information was compiled in the J-3 Section of the Task Group. This was published early in February 1958 in an abbreviated form in the two atoll event booklets as appendixes to the Task Group Operation Plan 1-58.

3. Final detailed planning took place at the Proving Ground, when each task unit, one to two weeks before each shot, submitted its project's evacuation and re-entry cards to the J-3 Section on Bikini and Eniwetok Atolls. With these data a detailed check list, arranged chronologically, was prepared for each shot and given wide distribution to other Task Groups so that adequate support could be scheduled.

Although evacuation and re-entry problems for Hardtack were similar to those encountered during Redwing, rocket sampling of the radioactive clouds added a new recovery problem. Nose cones were designed to pass through the clouds and parachute to earth. Their points of impact varied with their trajectories, so that sometimes they landed in the lagoons, but more often several miles at sea.

Two nose cone recovery tests were conducted: one at Salton Sea and the other off the Southern California coast.

The evacuation and re-entry operation at Johnston Island had none of the complexities that were present at Bikini Atoll, since it involved a simple direct evacuation and re-entry from a single camp to the ships at anchorage.

A most important problem arose, however, in determining the loading technique to be used in rough waters at the ship's anchorage. Prior to the Teak event various methods such as loading platforms and loading nets were tried, all of which proved unsatisfactory. Finally, it was decided to build a loading cage. This railed platform was approximately 10 by 10 ft with a protective roof. It was capable of lifting 40 to 50 people at one time, but was limited to 35 for safety reasons. A single lifting lug was welded at the center point to receive the snatch block hook from the ship's boom. Four ropes were tied to the corners and used to steady the cage during lifting and lowering operations. On the whole, the technique worked quite satisfactorily.

The primary evacuation and re-entry vehicles were LCU's, which were scheduled at various times. Helicopters (H-19's) were used to load priority personnel, late evacuees, and early re-entry personnel.

Joint Task Force Seven appointed an Evacuation Officer for this operation, through whom the task groups coordinated their requirements. Muster, manned stations, boat loading, helicopter, and priority re-entry personnel lists were published as a basis for Task Group transportation requirements and forwarded to JTF 7 for coordination and necessary action.

The inflexibility of the personnel movement schedule made changes for technical reasons very difficult to accomplish. During the re-entry phase, the lack of command control and coordination of movement of priority personnel, helicopters, and ships caused abnormal delays and loss of some data. The loss of neutron data from a rocket nose cone was the direct result of VIP's receiving helicopter priority over the objects to be recovered.

This underlines the importance of recovery operations to the complete success of a nuclear experiment, which is such that all actions and movements not directly connected with data recovery must receive low priority.

The need for one person with command authority to move ships, aircraft, and people in the recovery operations again became apparent during the Orange event. This individual must have complete appreciation of the type of data to be recovered and its importance relative to other, similar, data.

3.8 PERSONNEL MUSTER AND EVACUATION

Musters. On April 8, 1958, the TG 7.1 plan for the conduct of sight-musters in the EPG was published. This plan established a Task Group Muster Officer, and two Atoll Muster Officers, for Eniwetok and Bikini Atolls, respectively. The plan also provided Muster Officers to represent Headquarters and each of the various Task Units.

Muster rosters were prepared by J-1, TG 7.1, at varying times, depending upon the number of changes occasioned by arrivals and departures from the EPG.. During Hardtack a new system was initiated for compiling these muster rosters. An IBM card was punched for each individual in TG 7.1 participating in the operation. When an individual arrived at the EPG, his card was placed in the active file; cards of departed personnel were held in an inactive file. The active file, which included anticipated arrivals, was used by the IBM 704 Computing Section to prepare the rosters on IBM equipment. This new method of preparing rosters saved many man-hours of work previously required to type dittos and assembly rosters.

The first muster was conducted on April 11 and 12, 1958, as a Teak rehearsal, and the last one on August 18, 1958, for Fig. Musters were normally conducted on D-1 or D-day in order to minimize false starts. The shot site and the time of H-hour determined the commencement time of the muster and the details of operation. Therefore, the following is a discussion of only the most commonly used procedures.

a. Shots at Eniwetok and/or Bikini Atoll

1. Muster of personnel at both Eniwetok and Bikini commenced at 1800 on D-1.

2. Task Unit Muster Officers mustered all personnel of their units present in the EPG at either Eniwetok or Bikini Atolls, resolved any discrepancies in reported locations, and reported by name to the Atoll Muster Officer only those personnel of their organizations who were in the danger area (normally all islands in Eniwetok Atoll except Parry and Eniwetok and all islands in Bikini Atoll except Enyu). In addition, Task Unit Muster Officers reported the movements of all of their personnel who moved either into or out of the danger area. When all personnel of the Task Group were out of the danger area, a report of the completion of the muster was submitted to CJTF 7 by the TG Muster Officer.

b. Shots at Bikini Atoll Requiring Evacuation to Ships

1. Muster at both atolls commenced at 1800 on D–1.

2. All personnel at Bikini Atoll were considered to be in the danger area; therefore, Task Units reported all of their personnel at Bikini Atoll by name to the Atoll Muster Officer. This muster was conducted and completed prior to evacuation, and its purpose was to ensure that all persons listed on the J-1 records as being at Bikini Atoll were accounted for.

3. TG 7.1 had J-1 representatives aboard the USS Boxer, USS Monticello, and the USNS Ainsworth. Each member of TG 7.1 was mustered upon boarding. When all personnel listed on the pre-evacuation muster list were aboard a ship, the muster was completed, and the final muster report was then submitted by the Task Group Muster Officer to CJTF 7.

c. Shots at Johnston Island

1. Due to the limited ports of entry, the small land area, and the small number of TG personnel present, muster of personnel for shots at Johnston Island was a relatively simple matter and was handled differently from the muster of personnel at Eniwetok and Bikini Atolls. A muster plan for the conduct of sight-musters at Johnston Island was published July 20, 1958. This plan was very similar to the plan used in the EPG, in that it established a Task Group Muster Officer, Task Unit Muster Officers, etc.

2. A pre-evacuation muster of personnel at Johnston was made as described in b.1 and b.2 above, except that the muster commenced at 1300 on D–1 and was limited to only those personnel on Johnston Island. The muster was checked against the J-1 records and any discrepancies were resolved prior to evacuation.

3. Task Group 7.1 had J-1 representatives aboard the USS Boxer, and when all personnel to be evacuated were aboard ship the evacuation was complete and an evacuation report was submitted by the Task Group Muster Officer to CJTF 7. A Muster Officer was also appointed for each ship other than the Boxer. This Muster Officer reported all TG 7.1 personnel aboard a specific ship by radio to the TG 7.1 Muster Officer aboard the Boxer.

4. Since a large number of TG personnel remained at Johnston Island in manned stations, it was necessary to appoint a Muster Officer for each of these locations. A Manned Station Muster Officer located in the Command Post was responsible for coordinating the muster of all manned stations ashore and reporting to CTG 7.1 when all TG personnel were in safe locations.

d. Postponements

When a shot was postponed after the muster was completed, an attempt was made to retain the validity of the muster if the delay was for less than 12 hr. Generally if the delay was 12 hr or more a new muster was conducted.

From the experience gained during this operation it is believed that the complete sight-muster at both atolls is no longer an operational necessity. A muster at the atoll where a shot is scheduled is sufficient to assure safety of all personnel.

Evacuation. The extent of personnel evacuation at Eniwetok and Bikini Atolls depended on the magnitude of the shot. The maximum at Eniwetok Atoll involved withdrawal of all personnel from the upper islands to Japtan, Parry, and Eniwetok, with a limited number of project personnel permitted on Aniyaanii.

At Bikini personnel were generally evacuated to Enyu Island; however, on large shots all personnel (except the arming party, which was located in Station 70 on Enyu Island) were evacuated aboard ship. When in a D-1 status, the average evacuation time at Bikini, following the evening weather briefing, was 5 to 6 hr.

In general, afloat housing at Bikini was assigned as follows:

USS Boxer (CVS-21) - Joint Task Force Seven, TG 7.3, TG 7.4, and TG 7.5 Commanders and Staffs, TG 7.1 Command and Staff Sections, key scientific personnel, Rad-Safe team, and persons scheduled for early re-entry and recovery by helicopter. The USS Monticello (LSD-35) was substituted for the Boxer in July and August, when the Boxer was at Johnston Island.

USNS Ainsworth (TAP-181) - J-1 and J-3 representatives, project personnel, and Holmes and Narver.

Assignment of berthing space (cabin and troop) was as follows:

Ship	Agency Making Berthing Assignments	When Berthing Assignments Were Made
USS Boxer	J-1 Bikini	D-3
USNS Ainsworth	Same as above	Same as above
Other ships	Representative of Ship's Captain	Upon embarkation

For the Teak and Orange events at Johnston Island, all personnel except those required in manned stations ashore were evacuated aboard ship. The USS Boxer was the primary ship used for evacuation, but there were a small number of individuals on various project ships. The evacuation procedures used were the same as those at Bikini.

The number of personnel evacuated to ships at Bikini Atoll and Johnston Island varied with project participation. The peak number of personnel evacuated was 178 officer grade personnel and 67 enlisted grade personnel for the Teak event. Numbers evacuated to ships were substantially lower than would have been required if it had been necessary to operate from ship for prolonged periods. Except for the carrier, which was badly overcrowded, billeting facilities afloat were adequate. For Teak and Orange, cots were placed on the hangar deck of the carrier to handle the overflow of personnel when all cabin spaces were filled. Utilizing the hangar deck for this purpose is satisfactory for billeting personnel overnight, or for emergencies, but it would not have been satisfactory if it had been necessary to operate from afloat for an extended period of time.

Task Groups 7.3 and 7.5 maintained a capability to evacuate all personnel at Eniwetok, Bikini, and Johnston Island aboard vessels in event of

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severe fallout or other emergency. This capability provided standing room only and would be used only to protect life and health from extraordinary hazards.

3.9 PROPERTY EVACUATION

The J-4 Section made pre-shot surveys to ensure that all excess equipment and material had been evacuated from the shot island and those areas subject to significant effects. J-4 assisted H&N in lifting material to the beaches and in relocating it when it was received on the base islands.

Vehicles, trailers, and other equipment which were no longer required at Bikini after a particular shot were turned over to J-4 prior to the shot for return shipment to Eniwetok.

The shot phase evacuation of scientific trailers involved the regular users and in addition J-3, J-4, J-6, and H&N. In general, the procedure was for J-3 to determine when the scientific users could afford to release the trailers, particularly those aboard houseboats, and also to determine the facilities required during evacuation and re-entry, such as power for dehumidifiers and air conditioners, and water for Photo Lab tanks. The actual movement of the trailers were accomplished by H&N personnel under J-4 supervision.

3.10 OPERATIONS AFLOAT, RECOVERY, AND RE-ENTRY

Operations Afloat. Since the base camp at Enyu, Bikini Atoll, was not contaminated by any shot, sustained operations afloat were not necessary. Complete evacuation was made for the Sycamore and Poplar events.

For the Sycamore shot the USNS Ainsworth (TAP-181) and the USS Boxer (CVS-21) were utilized. In general, the majority of TG 7.1 personnel were evacuated to the Ainsworth, with personnel essential to maintaining the operational capability of the Task Group evacuating aboard the Boxer. All Bikini-based helicopters were also evacuated to the Boxer so that recovery missions could be initiated from afloat.

Evacuation to ship on -1 days was carried out on three occasions, because the shot was postponed twice after the Task Force had embarked. Embarkation proceeded smoothly on all occasions, but a minor delay was experienced during debarkation because of the time necessary to begin operation of the boat pool.

Task Group 7.1 communications aboard the Boxer, in addition to ship's telephones, consisted of Command Net and Administrative Net radios, ciphony telephone and AN/TRC telephone. Primary communications requirements were contact between the Task Force Headquarters afloat and CTG 7.1 at Station 70 on Enyu and CJTF 7 at Eniwetok. Communications were generally satisfactory.

For the Poplar event the USS Monticello (LSD) was substituted for the USS Boxer, since the Boxer had departed to participate in the Johnston Island Operation. Basically the evacuation and operations afloat were the same as for the Sycamore event. Helicopters were evacuated to the USS Monticello, but since it was a daylight shot L-20 aircraft were flown and orbited in an area approximately 20 miles south of Enyu for the detonation.

Eniwetok Recovery and Re-entry. The operational phase of Hardtack began with two temporary camps in operation: at Yvonne a camp was established in support of the Cactus event, and at Janet a camp was established and operated in support of the Koa event. The permanent base camp for scientific operations was established at Parry. Personnel having primary interest in the early Eniwetok events, particularly Cactus and Koa, lived at the temporary camp sites.

All recovery and re-entry operations were controlled from the base camp at Parry. The normal re-entry — recovery operation was as follows:

1. Requirements for re-entry — recovery operations were submitted by project personnel on special cards designed specifically for this purpose.

2. After cards were edited, they were published as an annex to the evacuation and re-entry letter which served as the Task Group operation order for the event.

3. After publishing the evacuation and re-entry letter, changes were posted to a master copy in the J-3 Office. On −2 day all project personnel who had established requirements for the event were queried to reaffirm the requirement. This procedure was repeated on −1 day to firm up the shot day requirements and thereafter as often as −1 days occurred.

4. Initially it was decided that the rad-safe survey would commence at H+3 hr with a survey of the critical recovery areas to be followed by a more detailed survey at H+5 hr to specifically delineate the Radex areas. However, it was determined after the first two events that a survey time of H+1 hr was more realistic and provided a much better working period for the early recovery operations. With the exception of Cactus and Koa, two surface bursts, radiation levels were seldom of an intensity to prevent early recovery of critical scientific data. Critical recoveries were normally completed on shot days, although the radiation levels did force a delay or postponement at times. A predawn detonation favors recovery operations, and, all other factors being equal, should be sought as the optimum condition.

5. Following the radiological survey of the contaminated areas, recovery teams were immediately dispatched to their respective stations to effect recovery if the radiation dose was suitable for the individual and the stay time involved.

Several unique recovery operations were undertaken during Operation Hardtack. These included the recovery of floating coracles, film packs, and activated Pinex samples. Another recovery method effectively employed on Hardtack was to effect early recovery of fallout by grappling containers from their location on the funnels of the YC's by helicopter. On Umbrella, radchem analysis was started on some samples at H+40 min.

ASP rockets were used to evaluate their effectiveness as cloud sampling vehicles. Despite the extensive efforts put forth in air-sea combined operations to effect their recovery, only a small percentage were located and retrieved. It was later determined that the rockets were not acting properly upon entry into the water and were sinking before recovery operations were organized. The most valuable experience gained from the rocket recovery was the requirement to have an organized sea-air team with common communications and centralized control.

The main camps at Elmer and Fred were not evacuated for any of the shots, although extensive shoring operations were performed on weaker structures prior to shot Oak. Helicopters and light aircraft were evacuated from Elmer to Fred on those events where overpressures were expected to be in the neighborhood of 0.3 psi. For shot Oak, helicopters and light aircraft were evacuated to sea by the USS Boxer.

Bikini Recovery and Re-entry. Basic precepts of recovery — re-entry were established as follows:

1. Recovery missions did not depart until after the initial rad-safe damage survey had determined the radiation levels.

2. Two rad-safe missions were flown concurrently - one to the northern islands and one to the southern islands.

3. Based on data radioed back by these survey parties, CTG 7.1 gave permission for recovery parties to proceed as he deemed appropriate.

On the Sycamore shot the rad-safe surveys and film recovery parties of TU-2 and TU-5 were launched by helicopter from the Boxer. Since Enyu was cleared for re-entry before recoveries were completed, the helicopters returned to Enyu upon completion of the missions.

Recovery operations for the other shots varied, depending on shot location and project participation. However, early recoveries were the same for all shots, being recovery of TU-2 film from Station 2200 on Reere and Station 2300 on Airukiraru, and recovery of TU-5 film from Chieerete and Bikini. No problems were encountered in making these recoveries during the first 2 to 3 hr after detonation.

Re-entry at Bikini was divided into two general categories: re-entry to the atoll when the Task Force was afloat, and re-entry to the Airukiiji camp when possible after the shots fired from Eninnan. For re-entry to the atoll the ships entered the lagoon after a P2V aircraft had made a radiological sweep of the area. As the ships entered, the rad-safe surveys were launched, and by the time the ships anchored Enyu was declared open to re-entry. The Airukiiji camp was re-entered by boat and aircraft from Enyu as the radiological situation permitted.

Johnston Island Nose Cone Recovery. Generally, the nose cone recovery operation was successful on both the Teak and Orange events. The majority of test vehicles were recovered.

The search plan utilized a P2V aircraft, the USS Lansing, the USS Safeguard, and the USS Belle Grove. The ships were stationed at an approximate distance of 25 to 30 miles from Johnston Island and directed to the search area immediately after the detonation. The P2V was airborne from Johnston Island at about H+30 min.

The following is a summary of recoveries for both events:

Event	Project	Lost	Recovered
Teak	8.6	0	1 pod
	32.5	0	2 rad-chem samplers
	32.6	2	4 instrumented rockets
Orange	8.6	1	0 pod
	32.5	0	4 rad-chem samplers
	32.6	1	6 instrumented rockets

Although the recoveries were generally successful, certain aspects of the operation can be improved upon. Principal problems were: (1) the difficulty in communications between the shore and search/recovery vessels; (2) the timely return of recovered nose cones from distant sea areas to Johnston Island; (3) insufficient coordination between the search vessels, the control ship, and the helicopters during the helicopter sweeps of the impact area.

On future operations it would appear that the use of an LSD with a helicopter platform working in conjunction with the DD's and a carrier would enable recovered nose cones to be rapidly returned to shore. As an alternate plan, the projects might well mount their counting trailers on recovery ships so that critical data can be analyzed promptly.

3.11 SAMPLE RETURNS

The sample return program was supported by MATS in an outstanding manner. The cooperation of all concerned enabled the flyaway missions on Hardtack to be accomplished faster than on any previous overseas operation.

Prior to the operation it was estimated that approximately two aircraft would be required on most shots, and a program was developed by the JTF 7 Sample Return Director in coordination with MATS and J-3 and J-4 of TG 7.1 which provided for three C-97's to support each shot as follows: one each for Flyaways 1 and 2, and a third aircraft for back-up. When two shots were scheduled for the same or consecutive days, a fourth C-97 was committed. These aircraft normally arrived at Fred 36 hr before scheduled shot time.

After shot dates were more firmly established, it became apparent that careful preplanning and proper positioning of flyaway aircraft would allow consolidation of samples and therefore reduce this requirement considerably, and it was possible to satisfy all requirements of a 32 shot schedule with 42 flyaway aircraft.

Flyaway 1 aircraft for UCRL shots were routed Eniwetok-Hickam-Alameda, and for LASL shots, Eniwetok-Hickam-Kirtland to minimize enroute time to the Laboratory having primary interest in the cloud samples aboard. Flyaway 2 requirements were combined with other flyaways whenever possible, and routing was determined on the basis of the relative urgency of the samples aboard. All flights terminated at Travis.

Under normal wind conditions the C-97 aircraft are capable of making the Eniwetok-Kirtland flight within 22 hr, and the flight to Alameda in 20 to 21 hr. Average flight time to Kirtland on Hardtack was 25 hr, and to Alameda, 21 hr. Routing through Alameda to Kirtland added less than 2 hr to total flight time. This excellent enroute time was, to a large extent, made possible through the efforts of the LNO personnel and MATS at Hickam AFB. On arrival of a flyaway from Eniwetok, a second C-97 was waiting with crew aboard and engines running. Samples were transferred to this aircraft, which completed the mission. In many instances ground time was reduced to 5 min. MATS also provided back-up aircraft at Travis to support flyaways routed to both Alameda and Kirtland.

The TG 7.1 Operation Plan, Annex G, placed responsibility for handling flyaways on J-4 in coordination with J-3 and J-1. The working arrangements which evolved were that J-3 determined which samples each Task Unit had to return, desired departure time, routing, and couriers, and informed J-4, which ordered sample return aircraft through JTF 7, operated the sample return compound on Fred, assured that samples were properly packed and marked, delivered them to the aircraft, and released it to the JTF 7 Sample Return Director. Although use of flyaways to move passengers was discouraged, J-1 handled any requests for transportation of personnel for urgent official or personal reasons.

Each flyaway aircraft was assigned a military courier by the J-4 Section of JTF 7 who was responsible for delivery of all samples to the appropriate laboratory or its representatives. All samples were manifested by the J-4 Sample Return Officer, who in turn provided the military courier with three copies of each manifest: one for U.S. Customs at Hickam, one to be mailed back to J-4, TG-7.1, after delivery of the samples, and one for the military courier's file. Besides receiving a copy of each manifest at Hickam, U.S. Customs cleared each flyaway aircraft at Eniwetok.

In addition to carrying samples to the ZI, flyaway aircraft returned one device (Buckeye) on Flyaway 2 for the Dogwood shot. Also, in one instance (Redwood and Elder) firing times enabled samples from two shots to be dispatched on one aircraft.

Because of the large number of flyaway aircraft provided to satisfy the shot schedule, the reduction in enroute time, and the adequate back-up support provided at all times by J-4, JTF 7, the combined flyaway program was considered one of the most successful ever conducted.

A requirement of three flyaway aircraft was scheduled for the Teak event. However, requirements did not materialize for Flyaway 1 to Hickam. The Flyaway 2 C-97 departed Johnston for Hickam at 020330Z August and terminated at Hickam AFB. A third flyaway C-54 for Eniwetok with film for TU-5 aborted. The film and its courier were placed aboard the Hickam flyaway and flew from Hickam to Eniwetok on a MATS scheduled flight on August 2.

This section does not include flyaways for the Fig and Orange events.

3.12 ARMING AND FIRING

The Arming and Firing Organization was concerned with the following responsibilities:

1. Supervision of tests to assure reliability and readiness of the complete arming and firing system.
2. Safety in relation to the firing system components during dry runs after installation at the zero areas.
3. Making final connections of the device to the firing system.
4. Performing disarm operations.

The arming and firing personnel worked closely with the LASL, UCRL, EG&G, SC, and DOD organizations that were connected with firing activities. All tests were conducted jointly with representatives of the agencies responsible for the components under test.

The arm and fire activities were conducted in steps as outlined:

1. Initial planning and study of the requirements for the individual shots was carried out with the organizations concerned, and further coordination to assure that components and circuitry were adequate to meet all requirements.
2. Compatibility checks were conducted on the firing equipment to assure an adequate and reliable system prior to installation at the zero site.
3. Manual runs were often held locally at the zero site for calibration and preparation of equipment for dry runs.
4. Dry runs were observed in order to ascertain that the fire components and associated monitors operated properly while connected in the shot arrangement.

5. The arming party made final preparations at the zero area and connected the device to the firing system when directed by the Task Group Commander.

6. Disarming was accomplished by disconnecting the device from the firing system and returning the zero area to normal dry run conditions. These functions were carried out whenever the event was delayed for periods requiring access to the danger areas by other personnel.

During the Hardtack operation all shots were armed and detonated successfully, although disarming was required many times when the weather forced delay of shot and one time due to a technical failure at −15 min to zero time.

Arming books were prepared on each shot and will be available for reference purposes in the Hardtack 7.1 files in the Records Management Section at LASL. These data books contain check sheets, pictures, and a dry run log.

1. The check sheets are for the compatability test, interlock test, and arming procedures.

2. The pictures show the layout at the zero site of the device and associated firing equipment immediately prior to the departure of the arming party.

3. The dry run log provides a record of the number of dry runs for each event and the checks, calibration, and repairs of the firing components through the final run.

Based on the experience during Hardtack, the following recommendations are worth noting:

1. The Pinex barge weapon cabs did not provide sufficient space to comfortably accommodate the shot components and the working personnel. If this type of barge is utilized in the future, it is suggested that more space be provided for working room and equipment installation.

2. In consideration of reliability and shot preparation time, an attempt should be made by the organizations concerned to further standardize the arming and firing components.

3. Every effort should be made to limit the number of personnel present at the zero sites, especially during initial setup and dry run periods.

4. Personnel were sometimes called upon to work long, exhausting hours under adverse conditions. The possible gain should be carefully weighed against personnel safety and well-being, and the use of such practices should be minimized.

3.13 COMMUNICATIONS

Task Group 7.1 was assigned the following communications responsibilities by CJTF 7 for Operation Hardtack.

1. Provide, operate, and maintain special communications - electronic equipment required for conduct of scientific test programs.

2. Initiate the voice time broadcasts for all elements of the Task Force.

3. Coordinate special communications requirements originating by subordinate task units.

4. Prepare a TG 7.1 telephone directory for the EPG and Johnston Island.

Teletype and Mail Service. On February 2, 1958, the Task Group 7.1 Mail and Records Section for Operation Hardtack opened at Parry Island, Eniwetok. On February 15, 1958, a branch office was opened at Enyu Island, Bikini. On June 15, 1958, another office was opened at Johnston Island. Civilian and military personnel were used to man the three offices. The maximum strength at Parry Island was nine; at Enyu Island it was two; and at Johnston Island it was five. The Parry Island office was open 24 hr a day, seven days a week throughout the operation, and the other two offices were open from 0700 until 2400 hr seven days a week.

Teletype service was furnished at all locations for the entire Task Group and accounted for the greatest portion of the total work load. During Hardtack, the following listed teletype traffic was processed by the three offices:

Classified Outgoing	1,261
Classified Incoming	3,293
Unclassified Outgoing	6,306
Unclassified Incoming	12,272
Total	23,132

The Task Group Mail and Records Section normally handled official correspondence only for LASL. However, service was provided for non-LASL units until these organizations had their mail system in operation. Personal mail was handled in a similar manner.

A daily pouch was sent between the mail rooms at Eniwetok and Bikini Atolls. This service was available to all units of the Task Group and provided an expeditious means of transmitting unclassified and classified (up to and including Secret RD) correspondence between sites. A similar service was provided between Eniwetok Atoll and Johnston Island on the weekly reflector flight and on the MATS flight which stopped there once a week.

A Task Group Reading File was maintained by the Parry Island office. This file consisted of copies of outgoing correspondence and teletypes and was circulated among the headquarters staff sections.

Communications at Eniwetok Proving Ground. The Commander of TG 7.5 provided TG 7.1 with all the long and short range communications including cryptographic service. The individual projects were responsible for installation, maintenance, and operation of all scientific electronic equipment.

Task Group 7.1 had approximately 13 voice nets including the Eniwetok-Bikini-Boxer ciphony system. The primary net was the Command Net, which was used by the Staff Sections and Task Unit Commanders. In addition, each Task Unit had its own individual net. Two nets were reserved for calibration purposes and proved to be of great value.

The major nets were serviced by a repeater station which was located on towers at 150-ft levels at each atoll. The installation of antennas began in early February 1958 and radio sets were installed upon the users' request after arrival in March 1958.

The JTF 7 Weather Detachment provided communications to the following off-atoll scientific sites: Kusaie, Kwajalein, Rongelap, Utirik, Ujelang, and Wotho. Wake Island was serviced by the CAA at Wake. In addition, the respective off-atoll projects provided their own communications links between their respective sites. Drill messages were sent in April 1958 to provide training to all off-atoll sites.

A radio silence requirement during all shot times was established by

CJTF 7 upon the request of CTG 7.1. This silence consisted of 5 min, from H-3 to H+2 min, and was enforced for the protection of scientific equipment and data during all events. In addition, a daily radio silence period was established at 100M and 1500M for the scheduled daily dry runs. The dry run schedule was not always consistent with the above mentioned plan; therefore, the requirement for daily radio silence was deleted during the middle of the operation.

The greatest problem that developed during the entire operation was that of interference to the diagnostic telemetering projects sponsored by UCRL and Project 34.1 (Sandia). Project 34.1 experienced serious interference by local radar radiation originating primarily from the U.S. Naval vessels present. JTF 7 directed TG 7.3 to observe complete radar silence on all vessels while at anchor in port. Close coordination between the respective TG communications officers was required in order to eliminate the electronic interference.

The installation of a 600 automatic dial telephone system by CTG 7.5 on Elmer with integration of the Fred system provided excellent telephone service at Eniwetok Atoll. The Eniwetok-Hawaii-Conus Radio Phone Circuit was considered satisfactory and a great improvement over the Redwing operation.

The installation of the TROPO system by CTG 7.5 between Eniwetok and Bikini was a great improvement. This system provided adequate voice telephone lines, hot lines, ciphony, and count-down requirements to this Task Group.

CJTF SEVEN provided CTG 7.1 one ciphony channel, which was maintained and operated by NSA trained enlisted personnel assigned to CTG 7.5. The KY-5 equipment selected was cleared for Secret RD. It provided excellent service and is recommended for future operations.

Approximately 135 frequencies were assigned to TG 7.1 for scientific use. Early assignments of the frequencies is highly desirable in order that participating activities can advise their respective contractors to purchase the required equipment.

Task Unit 5 (EG&G) provided the voice count-down broadcasts over 153.89 and 243.0 Mc for all elements of the Task Force. The voice count-down broadcast was capable of patching into the major nets, thereby reducing the requirement for additional voice count-down receivers. This proved to be very beneficial to all the Task Units and projects concerned.

The CJTF 7 originally ruled that additional amateur radio stations would not be authorized because of the five stations permanently operating in the EPG. However, during the middle of the operation this order was rescinded, thereby opening the door to all task units. Four additional stations were finally authorized by CJTF 7. The procedures for obtaining call signs and licenses from the High Commissioner of the Trust Territory conflicted on several occasions and created a large volume of unnecessary correspondence. The additional amateur radio stations were of great morale value and did not cause any interference problems.

The success of communications provided during operation Hardtack can in part be attributed to the frequent communications conferences between Task Force Communications Officers during the interim and build-up period. These conferences are deemed necessary in order to obtain close coordination and a working agreement between the respective Task Groups.

Communications at Johnston Island. Radio communications during Newsreel were held down to a bare minimum, with maximum utilization being placed on hard-wire circuits. At Johnston Island this was extremely practical because of its size and the concentration of the scientific stations. A special hard-wire circuit was established from the bunker (J-70) switchboard to all manned stations for muster and coordination of the scientific effort. This circuit proved to be an extremely valuable adjunct to the installed dial system.

Interference with scientific instruments from all sources was a continuing problem throughout Hardtack. Interference sources were determined by means of ECM equipment, logic, visual and audible recognition, and the "cut and try" method. The ECM solution, was of course, the most reliable in that, bearing could be determined and equipment identified by pulse analyzation, but was least effective either due to equipment malfunction or inherent equipment design limitations. As a rule normal ECM equipment sensitivity was far below that of the scientific receivers. The solution to this problem was to make the ECM center mobile and "sample" the interference with a probe from the scientific receivers themselves. This approach was tried during the Newsreel phase of the operation and proved to be a valid concept.

For future operations involving large scale radio telemetry, the mobile ECM concept should be continued, and the equipment should be of the latest design that can be procured on a loan basis. Further, spare parts should be available in advance to provide maximum flexibility. A source of independent power should also be provided on a mobile mount.

In order to transmit the count-down to all projects over long distances, it was necessary to install medium high frequency single side-band equipment for the Teak and Orange events. This communications system provided a more rapid means of notifying the distant stations of delays or holds using WWV time base.

The single-side band equipment was installed on Sand Island by Task Group 7.5 and operated by Task Unit 5 in the 7 and 14 Mc bands. These frequencies gave extremely good coverage throughout the Pacific, and unofficial reports from amateur operators in Honolulu indicate that the transmissions were received in Alaska, Australia, and throughout the U.S. Due to the variety and types of receivers being used by projects to copy the count-down it was found necessary to instigate a calibration count-down starting at H-4 hr to enable the users to have their receivers properly tuned. This requirement did not exist before with the VHF count-down equipment as these receivers were crystal-controlled and no calibration or tuning count-down was required.

3.14 SECURITY

As during previous operations, the security activities of Task Groups 7.1 and 7.5 were joint responsibilities. Within TG 7.1, coordination and establishment of security policies was effected by the Classification Officer, while personnel security functions were delegated to the Military Executive, J-1. Personnel security responsibilities were redelegated to cover the three major groups of participants: Los Alamos (LASL, Sandia, EG&G, and 1st RSSU), Livermore (UCRL), and Sandia Base (DWET).

Joint Task Force Seven SOP's 205-1 through 205-9, establishing the security policies for Hardtack, were published between October 14 and November 25, 1957. These nine documents were reproduced by J-1, TG 7.1, together with TG 7.1 implementing instructions and distributed to the staff and subordinate units on December 13, 1957. This file constituted the CTG 7.1 security policy for the operation.

Predeparture Security Indoctrination. A joint Security Indoctrination Letter for Task Groups 7.1 and 7.5 was published on December 23, 1957. This letter established the procedures to be used in the instruction of personnel planning to participate in the operation. It was issued with the concurrence of CJTF 7 and incorporated both the requirements of the AEC Security Manual, Vol. 2000, and JTF 7 SOP 205-2, "Basic Security Indoctrination."

Each Hardtack participant was required to acknowledge in writing that he had read the indoctrination letter. A certificate to this effect was forwarded with his request for travel orders, and the signed copy was required before travel orders were issued. All statements were filed in the cognizant Adjutant General's office.

Transmission of Classified Documents in Personal Custody of Individuals. With JTF Seven SOP 205-4, "Courier Instructions," as a guide, an appendix to an annex of the Administrative Plan No. 1-57 was published on November 1, 1957. This appendix incorporated all courier instructions for transmission of documents and material between EPG and other locations, and within the EPG. Although procedures were not always followed in that written authority was not always obtained prior to couriering classified documents, no security violations were observed.

The problems present during past operations in the shipment of bulky classified materials through the mail were not evident during Hardtack. This resulted from adequate planning and coordination with Customs by TG 7.5 prior to the operational period.

Access to Restricted Data. Joint Task Force Seven SOP 205-3, "Security Clearances," specified prerequisites for access to Restricted Data. The exchange of RD between military and civilian personnel of DOD and AEC personnel (including personnel of AEC contractors) required certification of each DOD individual possessing a military clearance. No travel orders were issued on these individuals until proper certification was on file with TG 7.5. Two certifying areas were established: Certifying officers at Los Alamos processed headquarters and Task Units 1, 2, 4, 5, and 6; certifying officers at FC, AFSWP, Sandia Base, processed TU-3. During Castle all TG 7.1 personnel requiring access had been certified, with the concurrence of CTG 7.1, by CJTF 7. During Redwing and Hardtack this responsibility was delegated to the Military Executive, J-1, and to FC, AFSWP, with a minimum number of alternates, which resulted in a vast improvement over the JTF 7 certification in efficiency, facility, and control.

Exclusion Areas. Joint Task Force Seven SOP 205-6 directed the establishment of policies and procedures on exclusion areas. Access was predicated on the Sigma category indicated on the security badge and on the "need to know." Access lists for each exclusion area were published, and exchange badges were maintained for each individual requiring continuing access. Certain individuals were authorized to grant temporary access.

The system utilized was generally satisfactory, except that it often became unwieldy because of numerous changes. Initially, task units submitted the names of their personnel who required access to exclusion areas. Operational and other requirements and frequent personnel substitutions increased the workload, and many exchange badges were prepared in advance which were never used.

Clearances. Joint Task Force Seven SOP 205-3, "Security Clearances," required each TG 7.1 participant to possess a Secret or Top Secret military clearance, or an active Q clearance. Verification of these clearances was required by J-1 before travel orders authorizing entry into the EPG could be issued. This verification was obtained from three areas:

1. AEC Contractor Personnel: Q-cleared personnel were indicated on the status reports emanating from the subordinate organizations. These lists were compiled at intervals and forwarded to TG 7.5 to be confirmed. Task Group 7.5 then notified the Military Executive, J-1, of the confirmation.

2. Military and DOD Civilian Personnel: The Military Executive, J-1, was responsible for the verification of clearances on all DOD personnel assigned to TG 7.1 except for those under the operational control of TU-3. This verification was obtained from the cognizant security officer. As a member of J-2 of JTF 7, the Military Executive, J-1, also had the authority to grant military clearances in certain instances. Clearances granted by the Military Executive totaled 37, two of them crypto clearances.

3. TU-3 Military, DOD Civilian, and DOD Contractor Personnel: Personnel under the operational control of Task Unit 3 were certified for access to RD by FC, AFSWP. Since this organization was responsible for the issuance of its own overseas travel orders, verification of clearances was accomplished by the unit.

Badge Requests. Joint Task Force Seven SOP 205-6 outlined procedures to be followed for badging. The processing of badges was a simple operation except for numerous changes and resubmissions, and no major problems were encountered. Occasionally an individual arrived at the EPG before his badge request did; in these cases an OUO message was sent and a badge request form was prepared on the site.

Photographs were provided by the subordinate units, and badges were fabricated at EPG from the badge request information.

Compliance with CINCPAC Serial 020. CINCPAC Serial 020, dated April 1, 1952, "Eniwetok Atoll; Security Instructions," defines the general security requirements for entry into the EPG. All TG 7.1 personnel had to be certified, under the provisions of paragraph 4, as "good security risks." This determination was based on certification that each individual was mentally and emotionally stable; that he possessed the integrity, discretion, and responsibility essential to the security of classified information; that his reputation and records revealed no information which tended to indicate any degree of disloyalty to the United States; and that he had been thoroughly indoctrinated in existing instructions for the security of classified military information.

Each individual was certified by immediate superiors to Los Alamos, to TU-3, or to Livermore under the provisions of the letter. Compiled lists were submitted periodically to JTF 7, CINCPAC, the TG 7.1 LNO's, and to TG 7.2. When the time element demanded, wire messages were sent. Each travel order published by TG 7.1 also certified each individual as required. During Hardtack a total of 2374 certifications were submitted by roster, and 340 by wire message.

Although the procedures in use during the operations were repetitious and frequently ponderous, no particular problems were posed, and in no case was entry denied as a result of a breakdown in the system.

Paragraph 4c of the letter defined items classified as contraband material. Each individual was thoroughly indoctrinated on the subject, and violations were limited to four in TU-2 and eleven in TU-3 The majority of violations resulted from misinterpretations about storage facilities in Hawaii.

Security Briefings. Security briefings held during past operations by TG 7.2 for all TG 7.1 personnel arriving in the EPG were eliminated at the insistence of CTG 7.1. The individual background of experience in stringent security environments at all operating locations in the United States and the Security Indoctrination letter were considered adequate. In March 1958 the baggage search for all officers and officer-grade civilians was also eliminated except for spot checks. A certificate was substituted.

Security Posters. Prior to Hardtack security posters were requested from JTF 7 by TG 7.1. These were placed at advantageous locations throughout sites and buildings utilized by TG 7.1. However, the system did not appear to be entirely satisfactory, and could be improved by giving this responsibility to TG 7.2 for Eniwetok Island, and to TG 7.5 for other locations.

Security Violations. Security violations were quite minor to the overall effort, the most serious having been safe files left open.

Violation	Hq.	TU-1	TU-2	TU-3	TU-4	TU-5	TU-6
File Safes Open	6	1	13	4	3	4	0
Documents Adrift	0	4	4	2	1	1	0
Contraband Offenses	0	0	4	11	0	0	0
Badge Offenses	7	11	9	9	3	12	4
Total	13	16	30	26	7	17	4

3.15 CLASSIFICATION

The Task Group Classification Office worked very closely with the Task Force Classification Officer. Except at the beginning of Operation Hardtack, however, there were not many problems for the Classification Office, which indicated that the guide was adequate and most personnel knew how to use it. Because of the reduced need for the services of classification people, it is suggested that on the next operation one person can handle both 7.1 and JTF 7 headquarters responsibilities.

There was very little in the present guide to find fault with. It is suggested, however, that operation plans (stating shot time) for the shots be permitted to be issued as unclassified at least 2 weeks before the shot instead of the present 3 days. There is nothing magic about 3 days, and from an operation point of view, 2 weeks is logical provided there is no other reason to classify the information. Also, it is suggested that a general classification policy be accepted that what is visible to the general population of an atoll be considered unclassified.

3.16 TECHNICAL REPORTS

Annex E to the Task Group 7.1 Administrative Order delineated the procedures and responsibilities for formal reporting of the experimental work of the scientific programs. Briefly, Task Unit Commanders are responsible for seeing that reports are prepared within a reasonable time, that they are technically competent, that they are reviewed for classification considerations, and that they are printed and distributed in accordance with existing AEC-DOD agreements.

3.17 SAFETY

Preparation. The Task Group 7.1 Administrative Plan for Operation Hardtack established safety as a command responsibility and assigned a Safety Advisor to Headquarters TG 7.1 for consultation on all matters pertaining to accident prevention.

The Safety Advisor spoke to the Project Officers at a meeting in Albuquerque in the fall of 1957 on the subject of "Safety Problems in the Forward Area." Individual Project meetings held in Los Alamos in December 1957 were attended by members of the safety group to acquaint personnel with the safety problems associated with the projects and recommend safe practices.

Two papers on health and safety considerations at the Eniwetok Proving Ground were distributed to all personnel before their arrival at the test site.

Close liaison was maintained with J-4 on the packaging, shipping, handling, and storage of hazardous materials and devices. Two members of the group attended a JTF 7 meeting held in San Diego in January 1958 on the problems associated with handling and shipping devices from their point of origin to the test site. The Safety Advisor prepared a paper on safety problems and emergency action connected with the test devices. This paper was made the Safety Annex to the JTF 7 Shipping Plan.

In consultation with J-6, plans and specifications for test site facilities and structures were examined for safety considerations.

Personnel. The staff function of Safety Advisor to the Commander, Task Group 7.1, was assigned to the Safety Director of the Los Alamos Scientific Laboratory. In addition, the post was filled by five Staff Members from LASL. Safety Advisors were present at Bikini and Eniwetok Atolls from February 16 to the end of the operation, and at Johnston Island from June 29 to August 19, 1958.

Operations. The movement of all hazardous materials, including test devices, into and out of the EPG and between and within atolls was carried out with procedures advised upon by the Safety Advisor, who was in attendance at one stage or another during such movements.

Project stations, towers, tower elevators and stations, zero point barges, facilities and equipment, boats and vehicles, and recreational activities were surveyed and examined for safety. Problems of mutual interest were coordinated with safety personnel of other Task Groups.

Accident reports and forms were completed on all disabling and serious injuries. Forms were distributed to the home offices of the employees involved and to the Bureau of Employee Compensation at its office in Honolulu, T. H.

Safety information was published in the Information Bulletins issued by the Adjutant General's office, J-1.

In connection with test rocket firings from Johnston Island, the Safety Officer was appointed Rocket Range Safety Officer to coordinate safety matters with the JTF 7 Control Point. Procedures were developed to assure the safety of personnel involved in test rocket firings; danger zones and water, air, and ground exclusion areas were established; and warning signals were installed to alert the general population. Routine inspections of scientific stations were carried out, and special attention was given to small boat activities and personnel evacuation.

Safety bulletins were issued for the guidance of personnel in viewing the Teak and Orange events. All stations were given a final check during a 5 day period after the last event.

Unusual Incidents and Special Problems. Several helicopter crashes occurred during the operation; one resulted in the death of a TG 7.1 scientist. That accident is discussed in the Accident Summary and a complete report is on file in the office of the Safety Advisor. Other crashes resulted in minor injuries.

Use of motor vehicles continued to be a problem. There were several instances of abuse to government vehicles, driving in an unsafe manner, too fast for road conditions and vehicle design, and overloading vehicles. (One observer reported 11 men riding in or on one jeep.) Greater disciplinary action appears to be indicated. Part of the problem lies in the difficulty of identifying the personnel involved. Several incidents occurred at night and the vehicles were damaged and abandoned.

At the request of JTF 7, shark nets were installed around the swimming areas at Parry, Eniwetok, and Japtan Islands at Eniwetok Atoll and at Enyu Island at Bikini Atoll. These were damaged by rough seas and by wave action following detonation of devices. They were intact less than 3 months. There were no reports during the operation of injury to personnel of TG 7.1 or other Task Groups from attacks by sea life. One TG 7.5 employee stepped on a stonefish in the swimming area off Eniwetok Island and was disabled for a few days.

Accident Summary. One fatality occurred to TG 7.1 personnel: Mark M. Mills, a UCRL senior scientist, was drowned when a helicopter went down in the water off Rojoa Island, Eniwetok Atoll, during a rain squall on a night flight on April 7, 1958. Harry B. Keller was a passenger in the same craft and was hospitalized for 3 days. Keller had stopped breathing and was revived by means of artificial respiration applied by Col. Ernest A. Pinson, another passenger, and the crew.

The ratio of disabling injuries and diseases to minor injuries appears to be high. Out of 77 injuries and diseases reported to the dispensaries, 19 resulted in time lost from work. Of the 19 disabling injuries, 9 originated in recreational activities and 9 were occupational. Other than the death of Mark Mills and the potentially serious injury of Harry Keller, none of the accidents were serious; none resulted in a time loss of more than 3 days.

Briefly, lost-time occupational injuries were as follows: two back injuries resulting from lifting cylinders and while working on a rocket launcher, tip of finger amputated while operating hoist, fragments from blasting cap imbedded in shoulder, injured thigh when equipment shifted on deck of ship, dislocated elbow when employee slipped on greasy deck of ship, fungus infection on leg.

The recreational accidents were as follows: fractured ankle while playing basketball, dislocated thumb while playing softball, dislocated knee cap while playing volleyball, infected eye when hit by coconut being tossed, probable insect bite while on beach, laceration from rusty metal on beach, injured back when employee slipped on rock on beach, 3 days lost due to sunburn, and broken ankle when employee slipped, probably while intoxicated. Another employee was disabled at Eniwetok from sunburn received in Honolulu prior to arrival at Eniwetok.

A preliminary examination shows the following injuries reported to dispensaries at Johnston Island: occupational, 16; recreational, 7. The recreational injuries were mainly from volleyball, tennis, and water sports. Occupational injuries were mostly from striking stationary objects, the use of hand tools, and falls.

Six men suffered minor injuries in four vehicle incidents. There were no fires in TG 7.1 facilities or equipment during the operation.

Special Comment. A recommendation from a previous report is repeated: In future operations consideration should be given to using safety personnel from major participating laboratories, integrating them with individuals who have had previous test operation experience. Such integration should be complete enough to function for the benefit of all elements of the Scientific Task Group without excessive duplication of personnel and efforts.

Participating organizations should select test personnel with the proper physical qualifications to meet the demands of the test site environment. The specifications of the Administrative Plan medical requirements are strict enough if interpreted properly.

New test personnel should be thoroughly indoctrinated and oriented with respect to the peculiar hazards and different environment of the test site.

A new magazine area should be built on the north end of Parry Island to accommodate the small quantities of hazardous materials and explosives used by TG 7.1. Separate buildings should be constructed in order to store incompatible materials properly. The area should be surrounded by a fence to enclose loaded trailers of hazardous materials.

All plans for new structures and facilities should be examined for personnel safety. Safety considerations have been particularly lacking in structures designed for housing personnel.

It should be realized by test site personnel that proper driving practices and reasonable care of Government motor vehicles are the responsibilities of the individual, and particularly of his supervisor. In the past these responsibilities have been taken lightly by some people. Disciplinary action should be instituted against those who drive in an unsafe manner and those who negligently abuse Government equipment.

Consideration should be given to assigning a Safety Advisor to the Staff of the Joint Task Force. This individual could coordinate the various safety activities and resolve the conflicts that sometime exist between regulations established by different organizations. This Safety Advisor should have a broad background in varied safety work, stature in the field, and previous test site experience.

The Safety Officers report a completely cooperative response in dealings with Task Group 7.1 personnel at Johnston Island.

3.18 DISPOSITION OF FORCES (ROLL-UP)

Personnel of the Task Group began to be gradually redeployed from the EPG to the ZI during the last 2 weeks of April. This redeployment followed the decision to move the Teak and Orange events to Johnston Island and continued through the middle of August 1958. Following the detonation of Fig (the last event) on August 18, 1958, the remaining personnel phased out rapidly.

Phase-out of Personnel. Personnel phase-out estimates were obtained from the status reports submitted by various elements of the Task Group during the planning phase of the operation, beginning in July of 1957 and ending in February 1958, with the submission of the last status report. However, it was necessary to revise these estimates continuously throughout the operational period because of changes in the schedule and postponements of shots.

As shown in Fig. 3.3, there were 1351 TG 7.1 personnel in the EPG on April 24, 1958. This figure dropped to 1300 shortly after the Yucca event (the first shot of the series) and had declined to 890 a few days after the Umbrella event. By the time the last event was fired there were only 350 TG 7.1 personnel left in the EPG. Most of the remaining personnel left during the last two weeks in August.

The J-1 Travel Section on Parry Island handled the necessary arrangements for each individual's departure. This Section took reservations, maintained the priority list for each MATS flight, made MATS reservations, notified Holmes and Narver in Honolulu about desired hotel reservations in Hawaii and commercial reservations for those personnel traveling to the mainland via commercial carrier, and accepted the clearance sheets from departing personnel.

Arrangements were made with JTF 7 for Task Group 7.1 to have an allocation of a specific number of seats on each scheduled MATS plane. Reservations from the EPG to Honolulu generally were available when desired. The JTF 7 Air Transportation Section provided excellent assistance in obtaining the required airlift to move personnel from the EPG to Honolulu.

Most Task Group personnel were airlifted by MATS to Hickam AFB. Military personnel and most government civilian employees proceeded on to Travis AFB by MATS, whereas most of the AEC and civilian contractor personnel traveled via commercial carrier from Honolulu. A few Task Group personnel returned to the United States by MSTS, commercial ship, or naval vessel.

Property Roll-Up. Property roll-up for Hardtack can be broken down into three phases as follows: Bikini roll-up, Eniwetok roll-up, and Johnston Island roll-up.

Bikini Roll-up -- Final roll-up took place after the detonation of Juniper on July 22. Prior to that date, however, a number of projects with no further participation, principally DOD, closed down their activities at Bikini and transferred their equipment to Parry for return to the ZI or use at Eniwetok or Johnston.

On July 23, roll-up began in earnest and was completed by September 4, 1958. In many instances final packing of trailers and crated cargo was accomplished at Bikini; however, a certain amount of equipment was returned to Eniwetok for processing and documentation for ZI shipment. The J-4 Section arranged with H&N for the usual carpentry and rigger service, and provided rubberized hair, kimpak, silica gel, etc., from J-4 stock for packing equipment for movement by water and air to Eniwetok.

Eniwetok Roll-up -- Partial roll-up was a continuing process that began early in June and continued at a varying pace up until final roll-up. On July 18, completion of TU-1 shots brought on a surge of roll-up activity and again another surge was brought about by the roll-up of activities at Bikini. Beginning with a shipment on the Haiti Victory, which sailed on June 12, 1958, J-4 shipped trailers and general cargo on all vessels returning to the ZI or Honolulu. Various weapon components, such as spare parts, HE, and gas bottles were returned on sample return flyaways to the appropriate Laboratory. The Brostrom was the final roll-up ship, which departed on September 3, 1958 with 2296 M/T of cargo for TG 7.1.

Because of the late closing date of Hardtack and the impending operation at the Nevada Test Site, it was necessary to return an unusually large amount of electronic gear by air for TU-2 and TU-5. Approximately 143 tons of cargo was shipped by air from Eniwetok to the ZI during the last half of August and early September.

The IBM 704 computer was shut down August 6, 1958 and returned to the ZI on two SAM C-124's on August 14, 1958.

Newsreel Roll-up -- Because of the uncertainty of whether there would be a third shot in this phase of the operation, roll-up got under way slowly. When it was determined that the second shot was the last, it progressed rapidly and smoothly. Air shipment of 56 tons of cargo and water lift on three ships, as listed below, completed the movement of retrograde cargo from Johnston Island to the ZI via Pearl Harbor.

August 19, LSD Belle Grove	1820 M/T
August 24, LSD Monticello	2964 M/T
August 26, LST 618	1624 M/T

Manifests were flown to the Task Group 7.1, J-4 Liaison Officer at Hickam, and he in turn prebooked this cargo for movement to the ZI on available MSTS or commercial vessels.

Arrangements were made for Task Group 7.2 to have an ordnance team at Johnston for receipt of Task Group 7.1 vehicles and to process them there for return to the appropriate ordnance depot.

J-4 provided the normal roll-up services of furnishing packing material from stock, carpenters, and labor, and either documented or assisted in documenting cargo.

Headquarters Roll-up. Forty-five boxes of classified records of the Task Group were returned to home stations by air on August 15, 1958. The Forward Area Headquarters of TG 7.1 closed as of 2400 hr, August 29, 1958 (Eniwetok time and date).

All AEC and DOD equipment was shipped to the appropriate locations in the United States. Furniture and other office equipment on loan from Holmes and Narver and TG 7.2 were returned to their warehouses or left in place.

3.19 CONCLUSIONS AND RECOMMENDATIONS

General. Sites and Scheduling - The separation of weapon laboratory activities into two sites as well as establishment of multiple capabilities at each site proved to be one of the primary means by which the operation was accomplished on a reasonable time scale. It is recommended that future operations follow the same pattern, although substitution of Taongi for Bikini could prove to be extremely advantageous due to the more favorable weather situation at Taongi. The development of techniques for conducting open sea firings for limited diagnostic proof tests should also be vigorously pursued because of their many operational advantages.

It appears that it would be advantageous to separate weapon development tests from effects tests in time and/or location. In general, effects tests require a great deal more support, have many more operational limitations, and interpose schedule interferences with development tests.

Organization — The fact that Hardtack, which was larger than all of the other Pacific operations combined, was conducted on virtually the same time scale as earlier tests indicates that despite problems the organization functioned efficiently.

Most of the problems which arose during the course of the operation originated because of the split responsibility status of Project Officers and senior Laboratory representatives (Task Unit Commanders). The Project Officer or Task Unit Commander is charged by his home organization with the responsibility of carrying out an assigned scientific task. This individual's career progression depends to some extent on how well this task is accomplished. On the other hand, the same individual is also a member of the Task Force, and therefore is subject to the direction of Task Group and Task Force command elements. These directions are not always compatible with those received from the Laboratory or home agency. Problems which arose from such causes were subjected to on-the-spot arbitrary solutions in the interest of "getting the job done." These solutions were not necessarily the most satisfactory from the standpoint of those concerned. It is recommended that prior to the field phase of future operations clear-cut understandings be reached between the Laboratory or agency management and Task Group or Task Force command elements regarding division of authority and channels of communication to field personnel. It is not entirely clear that the Hardtack organization offers the best possible solution to the conduct of a Pacific test operation. Prior to another operation the entire organization picture should be fully explored by all participating agencies.

Operational Limitations - Because of the fallout difficulty of firing shots of large yield, operational limitations imposed by experimental programs can seriously jeopardize an entire test schedule. Special attention should be devoted in technical planning to means for reducing or eliminating as many factors as possible which could impose limitations as to when, how, or where a shot can be fired.

Radiochemical sampling by aircraft imposes more non-fallout associated operational limitations on the firing of average developmental shots than does any other experiment or program. In addition, it imposes a heavy support load on Task Force or supporting elements. It is recommended that the development of a simple, reliable, inexpensive rocket or drone sampling system be vigorously pursued.

Personnel and Morale — Experienced and skilled scientific personnel are the most valuable single asset associated with the nuclear testing capability. In general, less money is spent for attention devoted to these personnel than is devoted to the maintenance, shipment, and protection of the equipment they design. A great many of these people have participated in many consecutive test series, and each participation involves a considerable sacrifice in personal comfort and family life. The skills and talents that these people possess are in considerable demand in other fields of endeavor, and the end of each operation finds a not insignificant number realizing that they can find an equally interesting and probably more lucrative job which does not require the personal sacrifices and discomfort of nuclear testing.

When compared to those available to most of these people in any part of the United States, quarters and recreational facilities at EPG are entirely substandard. Most personnel have no objections to living under such conditions for relatively short periods of time, but when this is stretched to several months or many consecutive operations, such facilities become unsatisfactory. It is recommended in future operations either that provisions be made to provide for frequent rotation of personnel at all levels to home laboratories or stations, or that a marked and extensive improvement be made in living and recreational facilities at EPG.

J-1 Section, Personnel and Administration. Security — The Joint Security Indoctrination Letter for Task Groups 7.1 and 7.5 was issued on December 23, 1957, for Hardtack. It is strongly recommended that such a document, as well as other security procedures, be issued no later than September 1 of the year preceding a spring operation to allow time for distribution and use of the letter before personnel depart for overseas.

As in previous operations, many military personnel assigned to Task Group 7.1 reported for duty without security clearances. Since these persons could not begin work without clearance, many man-days were wasted, and the over-all effort was retarded. Only personnel with current Secret or Top Secret military clearances should be assigned to TG 7.1.

For Redwing and Hardtack, the TG 7.1 Military Executive performed additional duty as Security Officer. It is recommended that a full-time Security Officer be assigned for future operations, preferably a civilian with experience in AEC security procedures.

CINCPAC Serial 020 continued to create confusion, delay, and irritation. It is strongly recommended that the need for this directive be reviewed on at least two counts: (1) Since TG 7.1 personnel have either military or AEC clearances before being ordered to EPG, it seems redundant to declare them "good security risks," and (2) the list of contraband items should be reviewed and either eliminated, or shortened and clarified.

Transportation - MATS performed its primary mission of moving personnel and cargo in a satisfactory manner. However, aborts and late departures of C-97 aircraft continued during Hardtack to the extent that the MATS flight to and from EPG was regarded by a number of people as the worst feature of the tour of duty. The use of C-118's during the later phases considerably alleviated this problem. It is recommended that efforts continue toward improving the convenience and reliability of MATS transportation.

The inter-atoll transportation by C-54 aircraft was an improvement over past operations and was appreciated by all personnel.

Morale - In general the small camps on shot islands were adequate in size and space was available upon arrival of personnel. The base camps on Eniwetok and Parry Islands, however, were inadequate in most respects. On Parry, quarters were still being constructed on a crash basis when the population neared its peak, and it was necessary to move some personnel several times as new buildings became available. It is again recommended that camp construction be accomplished between operations when it can be done conveniently and economically. Other facilities on Parry, such as the mess hall, camp store, and movie theatre, were also inadequate. All such facilities, which are important to comfort and morale, should be designed and constructed to take care of the operational population before another test series is undertaken.

The amateur radio station at EPG improved morale by facilitating frequent and inexpensive conversations between persons at Eniwetok and their families and friends in the United States. Although widespread use of radiotelephone for personal conversations presents a certain security hazard, expansion of amateur radio service at EPG should be encouraged for its obvious effect on morale. Instructions covering amateur station licensing, etc., similar to JTF 7 SCI 10-13, should be published several months prior to the overseas phase of the next operation.

The recreational facilities and supplies of recreational equipment such as fishing gear, equipment for tennis, handball, and water skiing, all appear inadequate during an operational period. If it is not possible to increase the supplies of such items maintained by TG 7.5, JTF 7 should allocate funds to augment the supply of recreational gear during operational periods or subordinate units should arrange to supply their own personnel.

During Redwing and Hardtack a few persons from TG 7.1 were permitted to visit other islands in the Marshall, Gilbert, and Caroline groups as passengers on official trips to project sites. These visits were highly regarded as a welcome change from life at the EPG. It is urged that in future operations the opportunities for such trips be expanded so that most persons on extended tours may be able to leave the site for a few days of recreation.

J-3 Section, Plans and Operations. Communications - For future operations, it is recommended that the base consoles (20-watt transceivers with line termination equipment) for the major nets be installed in one central location at each respective site. Increased usage of "remote" units from the base consoles should be made in lieu of base transceivers whenever possible. The consolidation of base console stations will assist the maintenance and security problems.

The switchboard operators at Eniwetok and Bikini Atolls controlled the ciphony calls satisfactorily during normal operations. However, it is recommended that an additional small switchboard be installed in Building 204 on Nan to handle the special ciphony calls during an evacuation phase.

The use of "mobile" radios was very slight. It is recommended for future operations that portable pack sets be used whenever the need arises instead of installing "mobile" in all vehicles.

In order to protect scientific electronic equipment, it is recommended that modern mobile electronic countermeasure equipment with specially trained operators be provided at each atoll of operation.

Air Operations

1. Conclusions:

a. The airlift provided was adequate to support the scientific mission.

b. Administrative devices such as the TCA imposed unwieldy procedures on a purely operational requirement for airlift between scientific stations.

c. Control and dispatch of aircraft supporting the scientific mission is most effectively executed at the place where the mission requirement is generated.

d. Maximum use of scheduled airlift provides the most satisfactory service.

2. Recommendations:

a. Inter-island airlift at Eniwetok should be considered as an operational matter and should be arranged by normal staff action between operating and using headquarters. The TCA should not be concerned with operational requirements for helicopter missions any more than he is with requirements for B-36 missions.

b. The TG 7.4 operations personnel and TG 7.5 dispatch personnel with proper facilities for control and dispatch of aircraft supporting inter-island airlift should be at Elmer. Since they are there on −1 and

D—days, using a different procedure by operating from Fred between shots is not practical.

c. Regularly scheduled flights to the scientific stations should be maintained through all −1 days and should be resumed again on shot days as soon as the Rad-Safe survey and recovery missions are completed.

d. The operational limitations of the agency providing light aircraft and helicopter support should be established prior to the operation. Then the operation should be planned within the limitations of the support agency or another agency should be selected which can provide the support required.

e. The using agency should not be required to justify its requirements to the supporting agency. If justification is required, then requests for support should be routed through JTF 7, which should make the approved requests directive on the supporting agency.

Motor Vehicles - All details on the maintenance of vehicles, including spare parts, should be worked out between TG 7.2 and TG 7.5 prior to the start of the operation. Spare parts should be on hand and available for use no later than the arrival of vehicles at the proving ground.

J-4 Section, Logistics and Supply. The following recommendations are made by J-4 as a result of occurrences in Operation Hardtack. Some attention and correction along the lines indicated would improve future operations.

It is felt that the appointment of an APA with contacts in each Task Group did not improve the system in effect on previous operations. Actually it placed one more layer of administration between the users of a necessary service and the operators of that service. It is strongly recommended that the APA office be eliminated entirely and that authorized people from 7.1 and other goups contact the Air Force directly for the services coordinated on Hardtack by the APA

The cargo service on MATS was very bad during the formative stage of the operation. It certainly improved after the incident of the C-124 that sat on Johnston Island for a week, but it should be possible to get better service throughout the operation without having to wait for a near calamity to occur before the necessary steps are taken to ensure the kind of service needed.

After the many difficulties encountered in connection with purchases through ship's stores made by individuals who expected to be in the Forward Area, it would appear that such purchasing practices should be discontinued. Furthermore, it is apparent that some of the people who expected to be at Eniwetok during the operation did not get there, yet took advantage of purchases through ship's stores even though they had not qualified themselves to make such imports. The actual cases of difficulty came about in receipt, storage, and disposition of the materials received with possible ensuing financial liabilities, also by obvious and flagrant disregard for customs regulations in having materials imported for people who had not been an integral part of the Pacific operation.

Chapter 4

SUMMARY OF TASK UNIT ACTIVITIES

4.1 TASK UNIT 1, LASL PROGRAMS

The function of TU-1 was to carry out experiments designed to measure certain properties of the LASL-designed weapons and nuclear devices, to measure certain physical quantities of fundamental importance to weapon design, and to study the physics underlying certain effects produced by nuclear weapons or devices. The techniques used to make the measurements are outlined briefly in Sec. 2.2. They are described in more detail in the pre-operational and technical reports of the various programs.

The use of barges as firing points for most of the LASL shots, together with the capability of using two firing sites concurrently, made possible a speed-up in the firing schedule over previous operations and greatly simplified operational problems.

For the more remote land sites and barge operations, the flexibility provided to experimental groups by the use of houseboats proved very advantageous. Helicopter and boat transportation were generally good.

The radiation safety problem was well handled and caused little inconvenience to the scientific personnel during the operation.

Radio and telephone communications were generally good, and service was very prompt when units became defective.

The high speed computing facility was very useful to TU-1 experimenters and theoreticians. It was a marked advantage to be able to reduce data promptly in the field without laborious hand calculations and to recompute problems as new data became available. Adequate time was available on the machine for TU-1 purposes.

It was very satisfactory to have an engineering group available in the field to reconcile and coordinate individual experimental construction requirements up to shot time. The J-7 unit was particularly useful when new shots were added during the series.

The photographic requirements of TU-1 were efficiently handled, and, in addition, Graphic Arts was able to assist other task units on special problems.

It is recommended that the J-1, J-3, J-4, and J-6 Sections of TG 7.1 continue to handle the requirements of TU-1 directly rather than duplicate their functions in the TU-1 organization.

A system to allow dry run tests of shot barge equipment at the Parry barge slip would allow still further acceleration of the shot schedules without decreasing the reliability of the firing system.

Separation of the LASL and Livermore laboratory efforts on two atolls made possible better coordination of the work at each site and should be retained in the future if possible.

In order to maintain morale and improve coordination with the home laboratory, it is desirable to rotate people between field and the ZI more frequently. This is especially important if it is desired to maintain the capacity to add new devices to the shot schedule during the operation.

4.2 TASK UNIT 2, UCRL PROGRAMS

Task Unit 2 was organized to field UCRL-designed weapons and nuclear devices and to carry out diagnostic experiments designed to measure certain of their properties. The techniques used to obtain the various measurements are outlined briefly in Sec. 2.3. They are also described in greater detail in the preoperational and technical reports of the various programs.

The concept of UCRL and LASL limiting their activities to separate atolls was introduced for the first time in Hardtack. It proved to be a very satisfactory arrangement for the major portion of the operation, although a combination of factors resulted in the necessity of shifting several UCRL shots to Eniwetok during the latter stages of the program. Chief among the factors requiring UCRL to shift devices to Eniwetok was the tight production schedules encountered in the fabrication of devices and the inherently poorer shooting weather encountered at Bikini when compared to Eniwetok. Much of the diagnostic support required at Eniwetok was provided by EG&G; without this support the two-atoll operation would not have been possible.

The operation was very successful on all counts. It is recommended that the policy of concentrating an individual laboratory's major effort on one atoll should be continued.

Multiple shot sites should be prepared at each atoll. This makes it possible to fire several devices during a short period of favorable weather.

A small number of the support craft should be equipped with radios which would permit personnel aboard to communicate directly with their Task Unit headquarters. This could be limited to one LCM, LCU, and helicopter.

Teletype and telephone service cleared through Secret Restricted Data should be available to any complex or island on the atoll that is the site of a major camp.

Each shot within an atoll should have a completely independent timing and firing system, making it possible to dry run one device while another is in a ready state.

The Task Unit Commander should have direct communications from the CP to the sample control aircraft at all times.

4.3 TASK UNIT 3, DOD PROGRAMS

Task Unit 3 was activated in the EPG on March 15, 1958, and was organized to conduct approved weapon effects tests under the operational control of CTG 7.1 and the technical direction of the Chief, Armed Forces Special Weapons Project. Since activities involved vast areas of the Pacific region, the organization was broken into three operating units with Task Unit 3 Headquarters and a Deputy for Eniwetok, where, until the 30th of June, the majority of projects were based, and Forward Area Commands at Bikini and Johnston Island. The Bikini staff was reduced to one officer and one enlisted man after shot Yucca, since only one active project remained there after removal of launch site for Teak and Orange to Johnston Island. Most of the personnel thus relieved, along with a small number of personnel from Eniwetok, formed the Johnston staff, which after July 1 became the principal scene of DOD operations.

The Commander, Task Unit 3, Eniwetok, supported by a small staff, supervised the activities of the directors of 7 programs and 51 projects grouped under them in the EPG. During this phase of the operation, approximately 80 Task Unit 3 staff personnel and 900 project personnel participated. The peak strength was reached on April 12, when 665 TU-3 personnel were present in the EPG. After July 1, the Eniwetok staff and project personnel were appreciably reduced, leaving only those participating in the subkiloton shots, Quince and Fig. These offices were closed on August 26 with the completion of the roll-up.

Task Unit 3 staff members began arriving at Johnston Island on June 1 for this phase of Hardtack. The largest build-up of personnel occurred in early July. Thirty-one TU-3 staff members and approximately 230 project personnel were involved for the two shots at Johnston. TU-3 offices were closed on August 23, 12 days after the final shot, Orange.

Staff personnel for both phases of Hardtack were furnished by Field Command, Armed Forces Special Weapons Project, with a small number of augmentation personnel furnished by Headquarters, AFSWP, and from the various Armed Services upon the request of the Chief, AFSWP. Project personnel came from the agencies listed in Table 3.1. The Programs undertaken were comprehensive, including maximum efforts on five DOD shots (Yucca, Wahoo, Umbrella, Teak, and Orange), extensive activities on four development shots and participation by one or more projects on

Unfortunately, command transmitter failure on shot Yucca caused loss of all significant data from the canister array. Aircraft instrumentation was very successful, however. Failure of ship's power on two target destroyers prior to the Wahoo event resulted in some data loss. Aside from these two failures, the objectives outlined in Sec. 1.3 were attained, although some projects participating on development shots had to repeat their experiments or change their activities to other shots due to schedule or yield changes of some devices.

The Task Unit 3 mission was accomplished with but one major operational difficulty. The move of the launch site for Teak and Orange from Bikini to Johnston after completion of construction and the arrival of most of the personnel and equipment presented a formidable problem. It was not insurmountable, however, and JTF 7, Holmes and Narver, and TU-3 agencies successfully met the first new ready date for firing on July 31. The shortage of real estate was a hindrance to some agencies.

Careful management of manpower was necessary to properly maintain Task Unit 3 staffs at all operating locations. Although minor problems were presented throughout the operation, satisfactory solutions were found for all, often with the assistance of Task Group 7.1 staff agencies. Special problems were presented by the projects, with 41 personnel, stationed at considerable distances from the principal sites. In many instances, the excellent cooperation of other governmental agencies, particularly the Air Weather Service and the CAA, made the final accomplishment of the mission possible.

4.4 TASK UNIT 4, SC ACTIVITIES

The mission of Task Unit 4 was to organize and field Programs 32 and 34, which performed tasks for and provided information of interest to the AEC and DOD. These programs were supported by TU-4 staff services, consisting of Photo Support, Construction Liaison personnel, and the Task Unit counterparts of J-1, J-3, and J-4.

All service projects being performed by Sandia Corporation for AFSWP, LASL, and UCRL were organized into a single program with Sandia project numbers and a Sandia Program Director. This method of organization proved to be highly effective, as it not only provided better service to the organization placing the requirement but allowed closer administrative control over Sandia personnel connected with these projects.

Staff elements of TU-4 arrived in the Forward Area in January and February, and personnel attached to Program 32 arrived in March. By April 1 most of the personnel attached to Program 34 had arrived. The first personnel peak was reached in April, when 111 SC men were present at EPG. The second peak occurred in July, when 123 SC personnel were present. Over all, a total of 200 SC personnel participated in Operation Hardtack in the Pacific area.

In early April the decision was made to fire Teak and Orange at Johnston Island. Although this put a considerable strain on supplying staff elements, technical equipment, and qualified personnel, readiness at Johnston was accomplished well ahead of schedule without interfering or delaying operations at Bikini and Eniwetok.

A major objective in TU-4 planning was to do all possible to keep the morale of the participating personnel high. This was accomplished by providing the following:

1. A firm date for departing for home. This was normally after a 2-month period.
2. Amateur radio "Phone Patch" service to the United States.
3. Boats and motors for water skiing and fishing.
4. Indoor and outdoor sport equipment such as table tennis, tennis, volleyball, and fishing poles.
5. Tape recorders. These were used for playing music and taped messages from home, and for sending taped messages home.

An evaluation of early test data shows that the technical phases of TU-4 participation in the Hardtack operation were highly successful. These successes were achieved, to a great extent, by action on the following recommendations made by Task Unit 4 on Operation Redwing: more extensive use of prefabrication and trailermounted instrumentation, use of ECM equipment to locate interference, better recreational facilities and equipment, better communication facilities.

The amateur radio phone patch service provided by TU-4 was by far the outstanding contributor to high morale in the Forward Area. Even with delays and extensions of the operation, Task Unit 4 morale remained high.

It is recommended that the organizing of all service projects performed by SC into a single program be continued on future operations.

Amateur radio stations should be encouraged to operate in the Forward Area. The decided improvement of morale due to phone patch service home cannot be ignored.

On future operations a real effort should be made in the early planning stage to provide a more realistic shot schedule and estimate of the length of the operation. If this could be done, it would permit greater economy in the preparation of components and utilization of manpower.

The shortage of vehicles on Johnston Island caused real delays and unnecessary hardships to TU-4 personnel.

4.5 TASK UNIT 5, EG&G ACTIVITIES

Timing and Firing, Communications. The timing and firing program conducted by TU-5 had two principal objectives: (1) to provide reliable systems for arming, monitoring, and firing the devices, and (2) to provide experimental users with a precise sequence of signals with respect to zero time in each event.

Associated with these prime objectives were the determination of zero time with respect to world time, provision of a voice count transmission net synchronized to the timing signals, and determination of preliminary yield, where applicable, by use of Bhangmeters.

Because of the complexity of the firing schedule, operation on two atolls, and removal of the missile shots to Johnston Island, a total of seven independent firing systems were required. The control point on Enyu was originally scheduled to house three systems; however, with the relocation of the DOD/ABMA effort to Johnston Island, one complete system was removed to that site, leaving two on Bikini Atoll. The control point on Parry Island consisted of three distinct systems: one for the DOD underwater program, one for the Los Alamos Scientific Laboratory large yield devices, and one for the Laboratory's low yield devices. The USS Boxer contained a timing system for coordination of experimental programs with the Sandia firing system on high altitude experiment Yucca. For distribution of signals at the individual sites, a total of 13 distribution stations were used.

The timing system requirements for Hardtack necessitated a revision of the standard system used on previous operations. To provide this, a coder-decoder system was employed which greatly increased the flexibility of the systems. All minus time signals were transmitted on a single pair of hardwires and interpreted by the decoder at the pertinent timing station. A patching system was used whereby a signal series would be selected for a specific shot. The signals available were at ½-min intervals from −60 min to −2 min, and at each half-second interval from −2 min to a desired plus time. Twenty-four independent times could be selected for any event.

To supplement the hardwire system, two radio tone timing signal systems were employed at each atoll. In addition to this, a radio controlled firing system was implemented on the two underwater events at Eniwetok, and the provision for a remote control capability of operation of the Enyu control point from the USS Boxer.

The voice count transmission was provided on two separate frequencies and the ability to patch in the broadcast to the various command nets through their base transmitters was maintained.

Zero racks were provided for each surface and underwater experiment. A total of 32 racks were used.

On four experiments, TU-5 installed and operated a recording system to monitor temperature and humidity at the zero point.

At the Parry and Enyu control points, TU-5 employed a new world time clock accurate to a 0.1 msec and a series of Bhangmeters to record preliminary yield information. These pieces of equipment were triggered by light from the explosion. At each control point a weather radar system was employed to assure good line of sight to the diagnostic stations.

The timing and firing systems successfully detonated 32 surface and underwater shots. The Bikini system was used on 10 UCRL shots. The Eniwetok systems were used to detonate 15 Los Alamos Scientific Laboratory experiments, 2 DOD underwater events, and 5 UCRL experiments. The Boxer system synchronized timing with the Sandia system. The Johnston system synchronized experimental signal requirements with the ABMA missile system.

World time was recorded on 29 surface shots. Light to minimum records, which gave an early approximation of yield, were obtained on 27 surface shots.

Approximately 4200 signals were transmitted. The timing system functioned properly on all events. Two postponements were experienced on Bikini Atoll due to signal cable failures. A ship's power failure on event Wahoo caused loss of some experimental data.

Technical Photography. TU-5 performed technical photography of the visible aspects of all detonations as a service to the Los Alamos Scientific Laboratory, the Livermore laboratory, and the Department of Defense. The major tasks on Laboratory events were to photograph fireball growth for determination of yield and to record cloud growth and motion. DOD projects entailed much more detailed photography of specific underwater and high altitude phenomena.

For the Laboratory shots, camera stations were located on Bikini and Eniwetok Atolls. A total of 10 stations were activated. At least two stations were used on each detonation to provide accurate determination of fireball growth and cloud formation. To maintain dual capability, the major stations were outfitted to cover at least two zero sites. This was attained by providing two independent systems of cameras at each of six locations. For AEC requirements Eastman High Speed, Mitchell High Speed, Triad, Fastax, and Rapatronic cameras were used.

Photographic commitments for the DOD necessitated the outfitting of 23 separate stations. These stations were on land, lagoon barges, shipboard, and in aircraft.

All photo stations were completely automatic, being initiated by hard-wire or radio signals and controlled discrete timers. Film recoveries were made as soon as possible after each event and processed in the trailer facilities on Parry Island.

Approximately 150,000 ft of photographic film was exposed in the course of Hardtack. Preliminary analysis was performed in the Forward Area on all fireball records. Reports on fireball yield calculations were issued in the field on all but the last shot, Fig.

Alpha Measurements. On Hardtack TU-5 was scheduled to perform reaction history measurements on all Los Alamos Scientific Laboratory experiments. These measurements included alpha vs time throughout the required portion of measurable history, boost measurements, and peak level and half width of peak measurements of secondary reactions. When required, both primary and secondary coverage was provided.

To accomplish this, four alpha stations were activated. The complexity of measuring systems varied from experiment to experiment, depending on specific requirements for a given device. Except for surface shots Cactus, Koa, Quince, and Fig, all devices on which alpha was measured were detonated from barge locations. On seven tests, detectors were mounted at zero site and recorded the complete reaction history. To obtain at the detectors a signal representative of the neutron signal, it was advisable to limit the emerging gammas by an aperture near the device.

In addition, collimation at the detectors was accomplished by means of pipes which extended through the thickness of the blockhouse wall at the alpha station. Inside the detector room were adjustable baffle walls containing collimating holes which were spaced for alignment. In some cases attenuators were provided to reduce the gamma signal.

Three basic oscilloscope systems were employed for recording the alpha signal: a 100-ohm three scope system, a 100-ohm two scope system, and a 120-ohm two scope system. Three types of presentation were recorded on the scope faces: Rossi, linear, and creep-Rossi.

Having initially planned on nine LASL experiments, TU-5 was hard pressed in extending coverage to the increased program. Reaction history measurements were made on a total of 19 shots, 14 LASL and 5 UCRL shots. Oscilloscope traces were analyzed by means of precision comparators on each shot. These data were then reported on an IBM 704 EDPM computer. A shot report was issued, usually within 3 days following the event.

General Administration. A total of 320 Edgerton, Germeshausen, & Grier employees contributed to the successful completion of TU-5's effort in the Forward Area. Equipment installation began in early February, and a peak working force of 149 men was in the field on about the first of May. The average stay in the Forward Area was 8 weeks. A total of 180 tons of equipment was shipped to the Forward Area. Central warehousing was maintained on Parry Island in approximately 1200 sq ft of existing buildings in the old CMR compound. The last TU-5 crews departed from the Forward Area on September 1.

Johnston Island Activities. The primary objective of TU-5 at Johnston Island was to supply experimenters with an accurate sequence of timing signals, related to burst time, for the purpose of starting and stopping their equipment on both the Teak and Orange events. Other objectives were (1) to determine the time of burst with respect to WWVH, and (2) to provide a system of radio links to experimental stations over which voice-time announcements synchronized to the timing system could be transmitted.

Early in 1957 preliminary planning for a timing system to meet the special requirements of Teak and Orange was begun. As planning progressed, it became apparent that the regular sequence timing system planned for the surface shots on Hardtack would not meet the special requirements of these shots. A new sequence timing system patterned after the air drop system used on Plumbbob for the John event was developed in the EG&G Boston laboratory. This system was integrated into the Bikini hardwire timing system for Hardtack.

The timing system was assembled and operationally tested under simulated field conditions in Boston prior to its shipment to the Forward Area. In February 1958 the equipment was shipped to the Forward Area and installed as an integral part of the Bikini timing system. The installation was completed and operationally checked out in preparation for the scheduled Teak and Orange events. With the cancellation of the Teak and Orange events from the Bikini schedule, it was necessary to remove that part of the timing system from the Bikini installation. A redesign of this equipment to provide for its independent operation was accomplished in the Forward Area, utilizing the spare components of the Bikini and Eniwetok timing systems. The system was operationally checked out at Eniwetok prior to its shipment to Johnston Island.

Late in June 1958 a group of field personnel was sent to Johnston Island to start field installation of the timing system, which was installed at Station 70 in Building 6002. Preliminary dry runs started on July 10. Dry runs and special rehearsal tests were continued throughout the Teak and Orange series.

A world time rack identical to that used at EPG on the Hardtack series was included in the design of the Johnston timing system to record actual zero time with respect to WWVH. This measurement was obtained through the use of a 10-kc oscillator, driving the world time clock, synchronized to WWVH and located in the control room. The initial flash of the detonation triggered a fiducial marker on the roof of the CP. This in turn stopped the clock and produced a photographic record of the clock face at zero time.

Voice-time announcements were made from a script by the timing system control operator, referencing the timing sequence indicators. These announcements were transmitted to the remote stations on 153.89 Mc, 243 Mc, 7411 kc, and 1468 kc.

In order to transmit timing signals to the two RB-36 experimenter stations, a radio timing system was provided. This system was synchronized to the master timing system and transmitted various tone frequencies to radio receivers located aboard the RB-36's, which in turn activated equipment at the station.

Both ac and dc type Blue Boxes were used on both events to provide experimenters with a zero signal of millisecond accuracy.

The following timing signal sequence was provided for the Task and Orange events:

Teak	Orange
−60 min	−60 min
−30 min	−30 min
−15 min	−15 min
−5 min	−5 min
−170.3 sec, lift off	−153.8 sec, lift off
−165.0 sec	−145.0 sec
−151.4 sec	−110.0 sec
−137.2 sec	−98.0 sec
−131.6 sec	−95.5 sec
−76.2 sec	−66.6 sec
−70.0 sec	−60.0 sec
−66.6 sec	−43.0 sec
−60.0 sec	−40.6 sec
−57.8 sec	−15.0 sec
−51.4 sec	−5.0 sec

−46.8 sec
−40.0 sec
−15.0 sec
−5.0 sec
−2.5 sec
−1.0 sec
0 Test
+12 sec, cutoff

−2.5 sec
−1.5 sec
−1.0 sec
0 Test
+12 sec, cutoff

The timing system provided by TU-5 proved, on the whole, to be both reliable and satisfactory. Approximately 150 hardwire timing signals were delivered on both the Teak and Orange events, and 14 radio tone signals were delivered to the two RB-36's.

4.6 TASK UNIT 6, RADIOLOGICAL SAFETY

The mission of TU-6 was as follows:

1. Perform all ground and aerial monitoring services associated with the scientific mission except those in conjunction with aircraft and airborne collection of scientific data; assist TG 7.5 rad-safe organization during the operational phase.
2. Provide laboratory and technical assistance to all task groups.
3. Provide all official dosimetry services for JTF-7.
4. Maintain and issue monitoring instruments and protective clothing as required.
5. Provide decontamination facilities for personnel, vehicles and equipment.

The necessity of maintaining a capability for firing at both Bikini and Eniwetok Atolls at the same time required that TU-6 provide two complete and independent rad-safe organizations. Over-all control over the two organizations was maintained by CTU-6. In addition, full rad-safe support was provided for the operations conducted at Johnston Island. Each organization contained the following sections:

1. Monitoring section for providing all monitoring services and manning checkpoints.
2. Plotting and briefing section for conducting all aerial surveys and briefing all personnel going into radiological exclusion areas.
3. Supply section for maintenance of rad-safe supplies, including laundry (facilities furnished by TG 7.5).
4. Instrument repair section for maintenance of rad-safe instruments.
5. Laboratory section for determining the amount of activity contained in soil, water and urine samples.
6. Decontamination section for operating facilities for personnel and equipment decontamination.
7. Photodosimetry section for providing personnel dosage information.

Control over the official dosimetry and records was maintained directly by CTU-6. All personnel in JTF 7 were issued film badges. Badges were exchanged after missions in radex areas; periodic exchange was effected at 60-day intervals. Badges were processed by photodosimetry sections located on both Bikini and Eniwetok Atolls, and complete current dosage record files were maintained on a daily basis. A master record file for all personnel in JTF 7 was maintained at Eniwetok.

Personnel for manning TU-6 were obtained from the Army, Navy, and Air Force. LASL Health Division personnel were utilized as advisors to CTU-6. The majority were obtained from the U.S. Army First Radiological Safety Support Unit, a Chemical Corps unit stationed at Ft. McClellan, Ala. The following is a breakdown of personnel attached to TU-6:

1. Army - 95 officers and enlisted men.
2. Navy - 8 officers and enlisted men.
3. Air Force - 12 officers and enlisted men.
4. LASL - 4 civilian health physicists as advisors.
5. UCRL - 3 civilian health physicists as advisors.

Scientific project personnel in TG 7.1 and contractor personnel in TG 7.5 were requested to provide their own monitors for recovery and construction missions. A 4-day school was operated at EPG specifically to train such monitors. The schooling was found to be a very satisfactory arrangement.

In support of TG 7.1 and 7.5 at both Bikini and Eniwetok, check points were established as required. Main check points utilized at all times at both atolls were located at the air dispatcher's office and the marine landing. All personnel entering or returning from a radex area were processed through the check points. An area was considered "full radex" if the gamma radiation field exceeded 100 mr/hr. Full protective clothing was required for entry into a full radex area. Limited radex areas were established when the gamma radiation field exceeded 10 mr/hr but was less than 100 mr/hr. Clothing requirements varied with the situation in the limited radex areas. An area in which the gamma radiation field was less than 10 mr/hr was considered non-radex.

The following is a summary of rad-safe processing:

1. A total of about 6200 persons were processed through the Eniwetok check points from May 1, 1958, to August 20, 1958; 2700 persons were processed at Bikini from May 13, 1958, to August 5, 1958.

2. The personnel decontamination station at Eniwetok handled a total of 860 individuals, and the facility at Bikini processed about 1200.

3. The following equipment was decontaminated:

	Eniwetok	Bikini
Vehicles	56	28
Pieces of equipment	611	193
Aircraft (including helicopters)	9	4
Heavy equipment	100	70

The majority of the rad-safe surveys of both atolls were conducted by helicopter. Normal operations included a pre-entry survey with CTG 7.1 at H + 1 to 4 hr, followed by detailed surveys at H + 6 to 8 hr, and mornings of D + 1, 2, and 3 days. Additional surveys were made as required. Instruments used in the surveys were AN/PDR-39's converted to read to 500 r/hr. Ground surveys of islands in the atolls were conducted when required.

Fallout from the Fir device was evident at both atolls. Peak activity at Eniwetok was 20 to 25 mr/hr, at Bikini 12 mr/hr. Minor activity was observed following other shots in the series but total dose received was insignificant. It is estimated that the average personnel dose due to fallout in the living areas at Eniwetok was 1200 to 1500 mr, that at Bikini 300 mr.

A total of approximately 765 soil, water, and food samples were taken by laboratory personnel. An arbitrary limit of 500,000 d/m per liter of water was established as the tolerance level for swimming.

A single film badge system was used during the operation, with exchanges scheduled each 60 days or when personnel returned from full radex areas. Total dosage records were kept current daily by the use of IBM equipment, which included a 704 EDPM, 526 Summary Punch, 082 Sorter, 519 Reproducer, 552 Interpreter, and 066 Data Transceiver. The Eberline FS-3 Film Badge Evaluation System, developed for JTF 7 and AEC use, was used for reading all film and automatically preparing IBM cards for the 704. The Data Transceivers were used for daily exchange of information between Bikini and Eniwetok as all data processing was done at the IBM center at Eniwetok.

TU-6 assumed responsibility for personnel dosimetry on April 1, 1958 and the program was continued until August 20, 1958. During this period approximately 62,000 badges were issued to approximately 18,000 individuals. The maximum permissible dosage was established as 3.75 r for any 13-week period, 5 r for the entire operation. As of August 20, 1958, only six people exceeded the 5-r maximum permissible dose.

The Eberline FS-3 Film Badge Evaluation System, in conjunction with the IBM installation, enabled the dosimetry section to operate efficiently with less than half the personnel required for previous operations. The rigid polyvinyl chloride encased film badges were highly successful because they were not affected by heat, moisture, or humidity. The ceresin wax coating on the film packet was extremely satisfactory and did not interfere with the film processing.

The use of barges as zero points reduced the on-site radiological contamination significantly over previous operations and enabled the operation to proceed without delay due to excessive contamination at key locations.

4.7 WEAPON ASSEMBLY

LASL. The weapon assembly group was responsible for preparation of the various devices for firing. They assembled and checked out all bomb components, installed the device at its firing site, and operated a system for telemetering information essential to the readiness of the device for firing.

The use of barges as zero sites plus the high degree of efficiency reached by the assembly personnel enabled two devices to be placed on shot barges and fired within 24 hr. In one instance an unassembled two-stage device was received at the site, assembled, and fired within a 48-hr period.

The weapon assembly group functioned on every LASL shot, and, in addition, assembled the LASL-furnished primary on one Livermore shot.

UCRL. Program A was responsible for the field assembly of the large devices. Each assembly team was headed by a Project Physicist and a Project Engineer thoroughly familiar with the theory, design, fabrication, and assembly of their device.

Prior to shipment each device was completely trial-assembled except that dummy primaries were used. All devices were

delivered to the shot site without incident.

The following devices were all assembled for testing at EPG:

Code	Remarks
Fir	Fired in Bikini lagoon
Sycamore	Fired in Bikini lagoon
Aspen	Fired in Bikini lagoon
Maple	Fired in Bikini lagoon
Buckeye	Not tested because the requirements
Redwood	Fired in Bikini lagoon
Cedar	Fired in Bikini lagoon
Dogwood	Fired in Eniwetok lagoon
Poplar	Fired in Bikini lagoon
Olive	Fired in Eniwetok lagoon
Pine	Fired in Eniwetok lagoon

The function of Program B was the field assembly of small devices. In general, personnel were organized and devices handled as described under Program A. Much advance experience in assembly was obtained during the extensive hydrodynamic program required to develop the designs fielded. Devices were never completely assembled prior to shipment because of safety limitations, but components and subassemblies were prefitted wherever possible.

In addition to the devices listed below, were provided for Aspen, Maple, Redwood, and Dogwood and for Fir. Accessories (e.g., milkweed) were fielded for all events.

Code	Device	Remarks
Nutmeg		Fired in Bikini lagoon
Hickory		Fired in Bikini lagoon
Juniper		Fired in Bikini lagoon
Quince		Fired on Runit
Fig		Fired on Runit

Sandia. Assembly of the devices for the DOD-sponsored shots (Yucca, Wahoo, Umbrella, Teak, and Orange) was the responsibility of Sandia Personnel. Activities for shots fired in the EPG are described in Chap. 2.

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